BULLETIN 54
AN ECOSYSTEMATIC STUDY OF THE SOUTH RIVER, VIRGINIA

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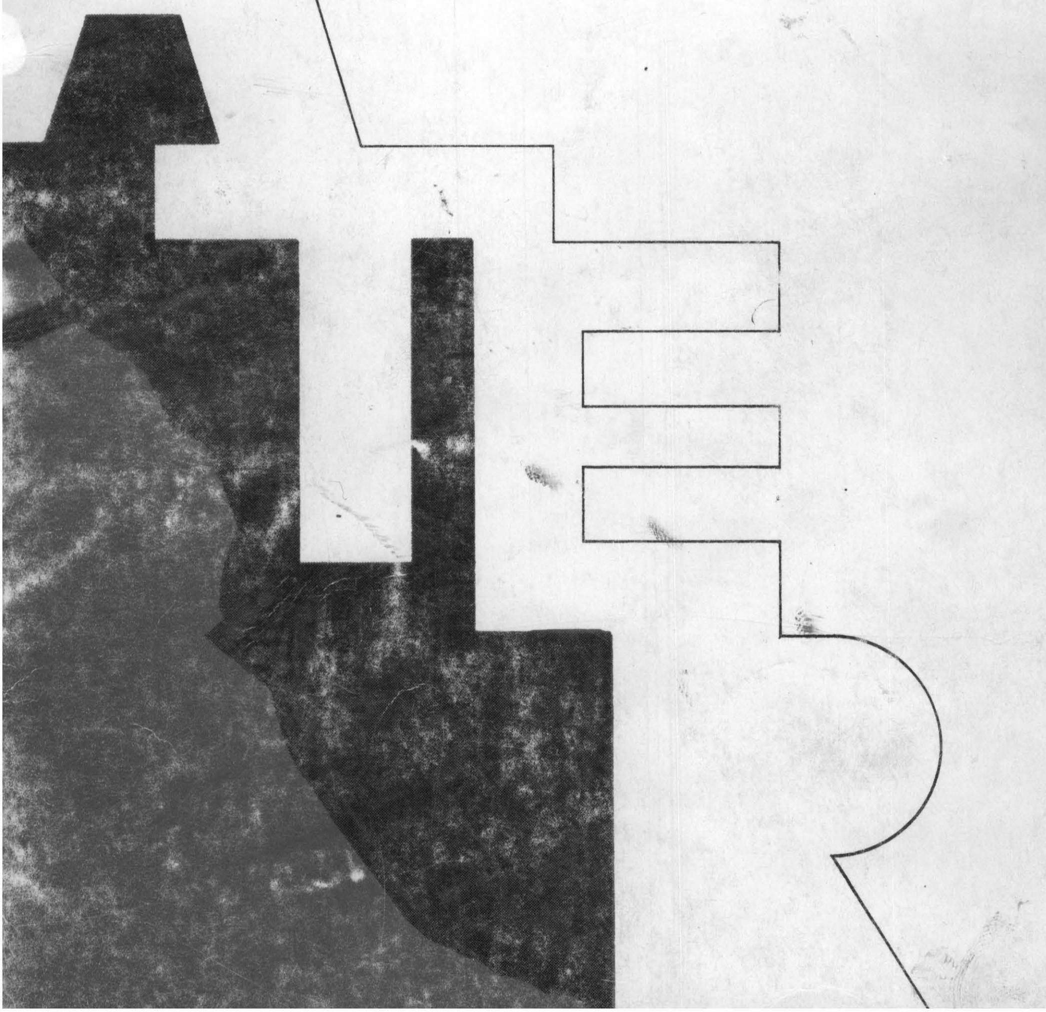

AN ECOSYSTEMATIC STUDY OF THE SOUTH RIVER, VIRGINIA

directed by

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PREFACE

This research effort was directed toward measuring the ecological condition of the South River, Virginia. These baseline data should make it possible to detect future degradation associated with continued municipal and industrial development in the area as well as improvements resulting from the installation of advanced waste treatment technology by industries and municipalities discharging into the South River. This study documents the biological condition of the South River in September 1970 in relation to the various waste discharges entering the system. By documenting the diversity, density, and distribution of aquatic life, we can identify problem situations, establish priorities, and thereby make maximum beneficial use of the South River.

John Cairns, Jr., and Kenneth L. Dickson were responsible for (1) location of stations (in consultation with the Virginia State Water Pollution Control Board and E. I. du Pont de Nemours and Co.), (2) the general type of data gathered – details were left to the individual investigators, (3) scheduling of field trips and completion of analysis of collections, (4) collection and delivery of water samples for physical-chemical determinations as well as certain analyses in the field, and (5) the general conclusions.

PREFACE

This research effort was directed toward measuring the ecological condition of the South River, Virginia. These baseline data should make it possible to detect further degradation associated with continued municipal and industrial development in the area as well as improvements resulting from the installation of advanced waste treatment facilities by industries and [illegible] discharging into the South River. This study documents the ecological condition of the South River in September 1970 in relation to the various waste discharges entering the system. By documenting the diversity, density and distribution of aquatic life we can identify problem situations, establish priorities, and thereby make maximum beneficial use of the South River.

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ABSTRACT

A biological survey of the fish, macroinvertebrates, algae, aquatic plants, protozoans, and bacteria was conducted on the South River, Virginia, in September 1970. The purpose of this survey was to measure the ecological condition of a system receiving agricultural, domestic, and industrial wastes. Eight sampling stations were located to determine the effects of various wastes on the biota of the South River. The fauna and flora at each station were examined to determine the diversity, density, and distribution of aquatic life in relation to physical and chemical water quality. Results of the study indicated that the discharge of domestic and industrial wastes in Waynesboro, Virginia: (1) exceeded the waste assimilative capacity of the river and caused the dissolved oxygen to be entirely depleted in certain reaches of the river at times of low flow and high temperature; (2) enriched the system by adding nutrients such as carbon, phosphorus, and nitrogen, causing a definite shift in the composition of the flora; and (3) decreased the diversity of fish and macroinvertebrates and caused qualitative shifts in algae, higher plants, bacteria, and protozoans when compared to areas of the South River upstream of Waynesboro. The study indicated that biological recovery was not complete fourteen miles downstream of Waynesboro at Harriston, Virginia.

Key Words: Organic enrichment, Biological survey, Nutrient enrichment, Diversity

INTRODUCTION

Our life support system has two components, one industrial and the other ecological. The survival of our present social system depends upon our ability to develop a harmonious relationship between these components. This relationship is dependent upon the development of a "use without abuse" philosophy by resource developers, industrialists, conservationists, ecologists, politicians, and others.

An ecological study of the South River in Virginia was conducted in September 1970 by the Biology Department of Virginia Polytechnic Institute and State University. This study represented one phase of E. I. du Pont de Nemours and Company's efforts at Waynesboro, Virginia, to make their manufacturing activities compatible with the local environment.

In order to properly evaluate the following ecological studies, it is necessary to "set the stage" so that the reader may fully understand the environmental factors affecting the ecology of the river. The South River is a small river consisting of a series of millponds and free flowing areas. It is not uncommon to have a flow rate as low as 25 cfs in the critical high-temperature time of the year. The river drains approximately 144 square miles of wooded mountainous terrain with agriculturally developed bottom lands. As it meanders to join the Middle and North Rivers to form the South Fork of the Shenandoah River, it passes through the City of Waynesboro where it receives domestic and industrial wastes.

Waste discharges entering the South River come from a variety of sources including industrial, agricultural, and domestic. The major discharges into the river include domestic waste from the Augusta County Service Authority – Stuarts Draft Plant (aerated lagoon) located upstream of Waynesboro; two industrial discharges – Crompton-Shenandoah, a textile plant (trickling filters), and the du Pont fibers plant (activated sludge); domestic waste from Skyline Incorporated (aerated lagoon); and domestic waste from the City of Waynesboro (high rate trickling filter).

The Virginia State Water Control Board developed a mathematical dissolved oxygen model of the South River Basin (Sutherland, 1970) showing that the maximum BOD_5 loading to meet the current 4.0 ppm dissolved oxygen standard on the river under low-flow, high-temperature conditions would be 1450 lb BOD_5/day. However, the BOD_5 loading from the combined sources approximated 3000 lb BOD_5/day in September 1970.

Although the waste assimilative capacity of the South River was still exceeded at low-flow, high-temperature conditions, the BOD_5 loading to the river has been drastically decreased over the last 26 years through a cooperative effort by the area's industries and communities. For example, in 1946 du Pont alone contributed an average of 13,300 lb BOD_5/day to the river. Through the installation of advanced waste treatment facilities, du Pont has decreased its BOD_5 discharge to 1500 lb/day, a reduction of 90%.

In order to determine the ecological condition of the South River, a survey was conducted at selected areas of the river. The survey included studies on the diversity, density, and distribution of fish, macroinvertebrates, algae, aquatic plants, protozoa, and bacteria in the system. Chemical water quality was determined at each of the sampling areas. Efforts were made throughout the study to integrate physical, chemical, and biological parameters to develop an understanding of the ecology of the South River.

A coordinated program utilizing a multidisciplinary team of investigators was set up to evaluate each of the sampling stations. Each team of investigators studied the same areas of the river, at approximately the same time (less than 5 days between various phases of the study). This assures the best possible correlation between the various components of the study.

In the sections that follow, each team of investigators has reported the results of its study. A section of general conclusions, which correlates and integrates the independent studies, is included.

SELECTION AND DESCRIPTION OF STATIONS

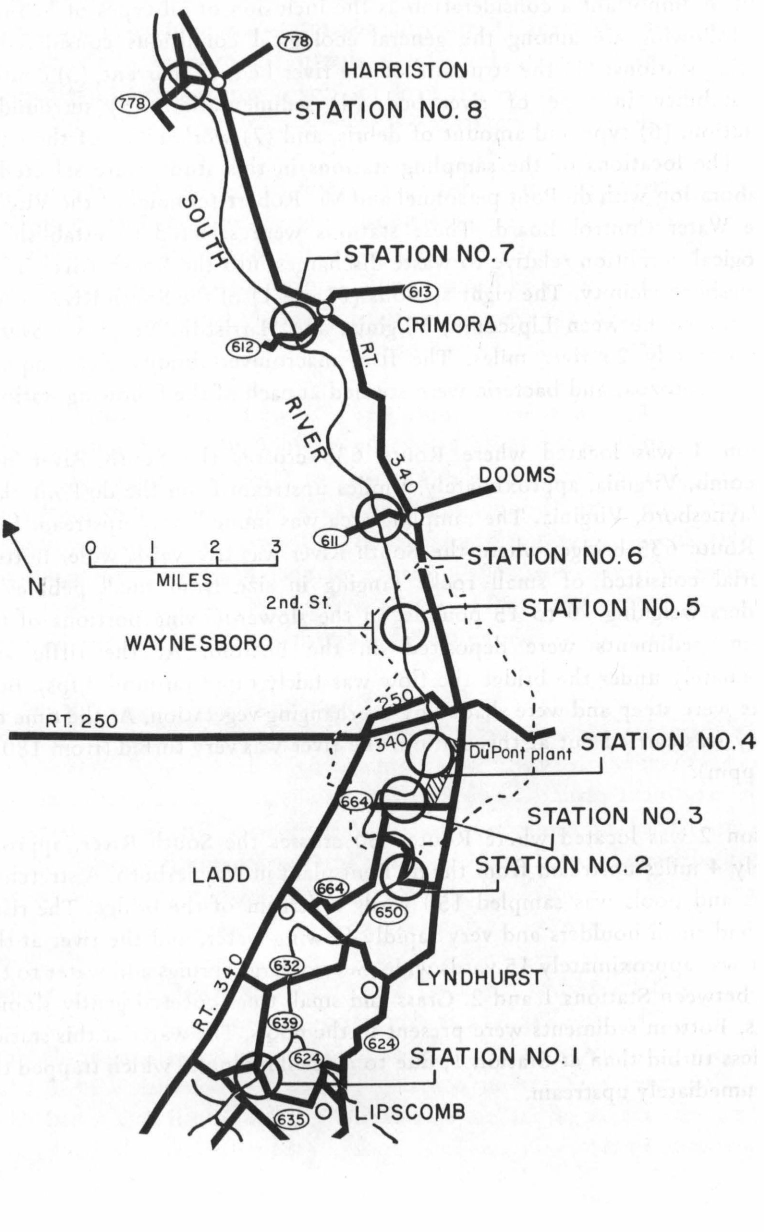
The areas of a river chosen for comparative study should include comparable ecological habitats whenever possible. This assures a given species equal opportunity to become established at all stations. The total area of a station is not as important a consideration as the inclusion of all types of habitats. The following are among the general ecological conditions considered in selecting stations: (1) the structure of the river bed, (2) current, (3) contour and stability in type of river bed, (4) sedimentation, (5) surrounding vegetation, (6) type and amount of debris, and (7) workability of the study area. The locations of the sampling stations in this study were selected in collaboration with du Pont personnel and Mr. Robert Jennings of the Virginia State Water Control Board. These stations were selected to establish the ecological condition relative to waste discharges into the South River in the Waynesboro vicinity. The eight stations (Figure 1) of the South River survey are situated between Lipscomb, Virginia, and Harriston, Virginia, covering approximately 23 river miles. The fish, macroinvertebrates, algae, aquatic plants, protozoa, and bacteria were studied at each of the following stations:

Station 1 was located where Route 635 crosses the South River near Lipscomb, Virginia, approximately 9 miles upstream from the du Pont plant at Waynesboro, Virginia. The sampling area was immediately upstream from the Route 635 bridge, where the South River was five yards wide. Bottom material consisted of small rocks ranging in size from small pebbles to boulders weighing 10 to 15 pounds. In the slower-moving portions of this station, sediments were deposited on the bottom. At the riffle area immediately under the bridge the flow was fairly rapid (around 3 fps). Both banks were steep and were shaded by overhanging vegetation. At the time the survey was carried out at this station, the river was very turbid (from 180 to 230 ppm).

Station 2 was located where Route 650 crosses the South River, approximately 4 miles upstream from the du Pont plant in Waynesboro. A stretch of riffles and pools was sampled 150 yards upstream of the bridge. The riffle area had small boulders and very rapidly flowing water, and the river at this point was approximately 15 yards wide. Several large springs add water to the river between Stations 1 and 2. Grass and small trees covered gently sloping banks. Bottom sediments were present in the pools. The water at this station was less turbid than at Station 1, due to a small millpond which trapped the silt immediately upstream.

FIGURE 1

Map of Study Area.



Station 3 was located on the du Pont property, but above all outfalls from the du Pont plant and Crompton-Shenandoah. The station consisted of a series of pools with a small riffle immediately above the waste discharge from du Pont's activated sludge treatment plant. The bottom consisted of large rocks and some small rocks in the riffle area, with riffles similar to the riffles at upstream stations. Flow velocity at this station was comparable to those of the upstream stations. Bottom sludge deposits and sediment deposits were apparent in the pool areas. Overhanging vegetation was minimal at this station on the right bank looking downstream due to the presence of the du Pont plant grounds. However, the left bank looking downstream had overhanging vegetation shading part of the river.

Station 4 was the stretch of the South River contiguous with the du Pont plant property and Crompton-Shenandoah property and extended to approximately 100 yards below the discharges from the two plants. This station was a series of shallow riffles with small pools. Bottom material consisted of small rocks similar to those at upstream stations. The right bank was steeply sloped and had very little overhanging vegetation.

Station 5 was located in Waynesboro where Second Street crosses the South River approximately 0.5 miles below the du Pont plant. This sampling area was 200 yards upstream of the Waynesboro sewage treatment plant, 100 yards upstream of the bridge, and bordered a Waynesboro municipal park. The river at this point was approximately 30 yards wide and consisted of shallow pools and riffles. The presence of rooted aquatic vegetation was pronounced at this station. The banks were steeply sloped with very little overhanging vegetation. Siltation and sediments were present in the weed beds.

Station 6 was located at Dooms, Virginia, where Route 611 crosses the South River, 5.5 miles below the du Pont plant and 5.0 miles below the Waynesboro sewage treatment plant. The river at this point consisted of a series of large pools and riffles and was approximately 25 yards wide. The bottom consisted of small rocks and rooted aquatic plants. Heavy sedimentation was present on the lee side of the rooted aquatic plants. Flow velocity at this station was increased in the riffle areas, as compared to the other stations.

Station 7 was located at Crimora, Virginia, where Route 640 crosses the South River. The sampling area at this station was approximately 300 yards upstream at the site of an old mill dam and 8.7 miles below the du Pont plant. The river at this point consisted of a large pool with a small riffle present in the center of the old mill dam. Substrate at this area consisted of sedimentation in the pools and small rocks in the riffle area. The banks were gently sloping, with large trees and overhanging vegetation shading the river.

Station 8 was located near Harriston, Virginia, where Route 778 crosses the South River, 14.0 miles below the du Pont plant. The sampling location was immediately upstream of the bridge. The South River at this point was approximately 30 yards wide and consisted of a series of riffles and pools. Riffles consisted of small rocks. Very little sediment was present at this station. Banks at this area were gently sloping, with trees and bushes shading the river.

MACROBENTHIC INVERTEBRATE STUDIES

by

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MACROBENTHIC INVERTEBRATE STUDIES

Introduction

Macrobenthic invertebrate communities in aquatic habitats are rather good yardsticks for measuring the biological impact of stresses upon streams. This is true because the number of species comprising these communities is rather stable from year to year although seasonal variations, due to birth, death, immigration, and emigration do occur. This means that the macrobenthic invertebrate community at a given location in a stream reflects not only habitat quality at the time of inspection, but the past habitat quality as well.

Communities respond to stresses by shifting in structure, i.e., changes in the kinds and numbers of species present and the numbers of individuals per species present. An unstressed community is likely to have a great number of species with relatively few individuals of each species. When a community is under stress, the number of species is likely to decrease and the number of individuals of the remaining species is likely to increase. Such changes in community structure are easy to measure when the stresses applied are severe. However, subtle stresses can result in subtle changes in community structure and such changes are masked by normal variations.

In fresh water, organic enrichment produces rather drastic alterations in the makeup of the benthic communities (Keup, 1966). This is due primarily to decreased dissolved oxygen, the presence of sludge deposits on the bottom, and the creation of an additional food supply for organisms adapted to the first two changes. Upstream of an organic waste discharge the number of species of macrobenthic invertebrates is usually high. The "pollution intolerant" forms such as the immatures of mayflies (Ephemeroptera), stoneflies (Plecoptera), certain caddisflies (Trichoptera), beetles (Coleoptera), and hellgrammites (Megaloptera) are normally present along with other invertebrates such as snails, clams, and limpets (Mollusca), and crayfish and their relatives (Crustacea). "Pollution tolerant organisms," such as sludgeworms (Annelida), certain types of caddisflies (Trichoptera), and true flies (Diptera) may be present, but usually in low density. Downstream of an organic waste discharge there is usually a zone of active decomposition in which wastes are being degraded and anaerobic conditions may prevail. The extent of the anaerobic zone depends upon the water temperature, degree of waste dilution, and the rate of stream flow. In this zone the number of species is generally drastically reduced, with sensitive species absent and tolerant species present in high numbers. A recovery zone can usually be found somewhere downstream of the zone of degradation. Recovery typically occurs slowly and is characterized by the reestablishment of the macrobenthic invertebrate community.

The objective of this work was to assess the impact of treated effluents discharged by the Waynesboro, Virginia, du Pont plant upon the macrobenthic invertebrate community in the South River.

Materials and Methods

Both quantitative and qualitative sampling of the macroinvertebrate community was carried out. A Surber sampler was used to sample one square foot of bottom substrate. This sampler provided semi-qualitative data and was useful in the rapidly flowing, shallow stream areas with a rubble bottom characteristic of the South River sampling stations. At least four one-square-foot samples were taken at each of the eight sampling stations in this survey. A qualitative estimate of community diversity was obtained using a long handled bottom net. This net was effective in sampling many different habitats and provided very reliable qualitative data. Organisms were separated from debris in the field using a series of 35-, 10-, and 5-mesh Tyler sieves and were then preserved in 70% ethanol for subsequent identification and enumeration in the laboratory.

Results and Discussion

The following analyses were made on the pooled samples collected at each station: (1) community composition, by percent (Figure 2); (2) taxonomic diversity and density (Figure 3); and (3) community diversity index, $\overline{d}$, (Figure 4). Results of these analyses on a station-by-station basis are considered in the following paragraphs. Species lists by stations are in the Appendix.

Station 1

Station 1 was located above all known discharges from both the City of Waynesboro and the du Pont plant and was considered a reference station. This station, at the time of the survey, was receiving a high suspended solids load presumed to originate in agricultural runoff. Thirty-nine taxa of macrobenthic invertebrates were found at this station. There was a good balance among several groups of the macrobenthos – mayflies, caddisflies, beetles, mollusks, and true flies – indicating an acceptable water quality. An average of 120 organisms per square foot was collected at this station. This was the lowest number of organisms per square foot found at any station.

FIGURE 2

Macrobenthic Invertebrate Community at Selected Sites
in the South River Near Waynesboro, Virginia.

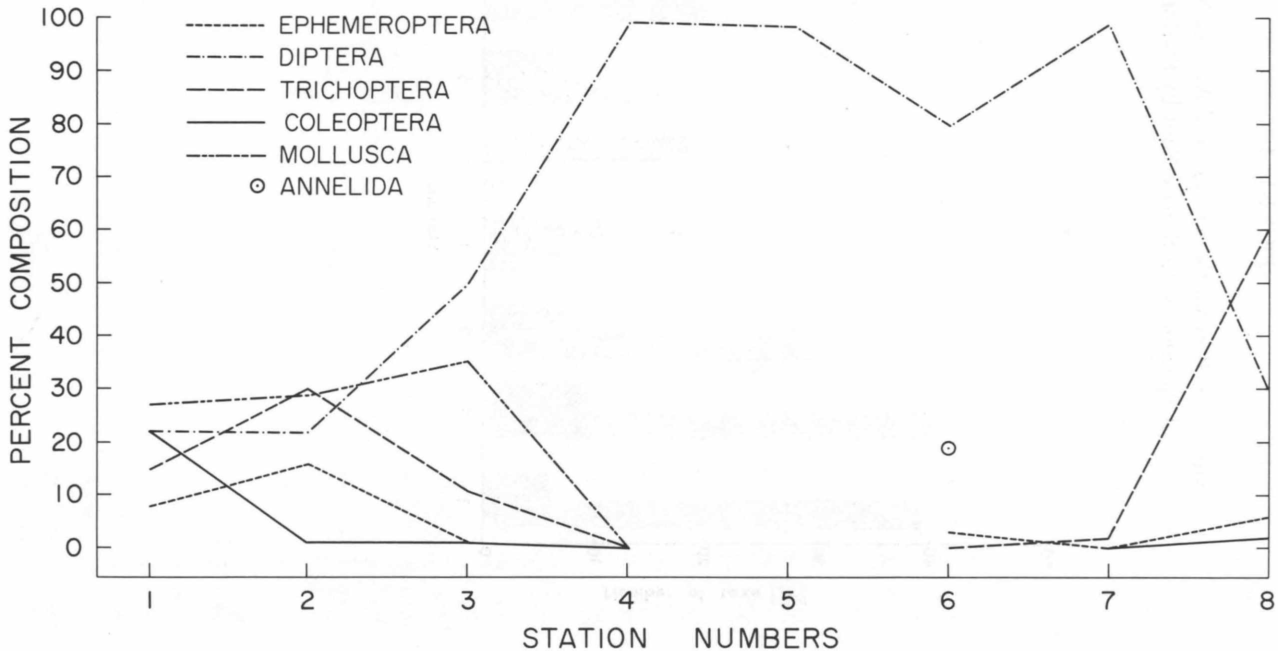


FIGURE 3

Number of Bottom Fauna Taxa and Average Number of Specimens Per Square Foot by Stations.

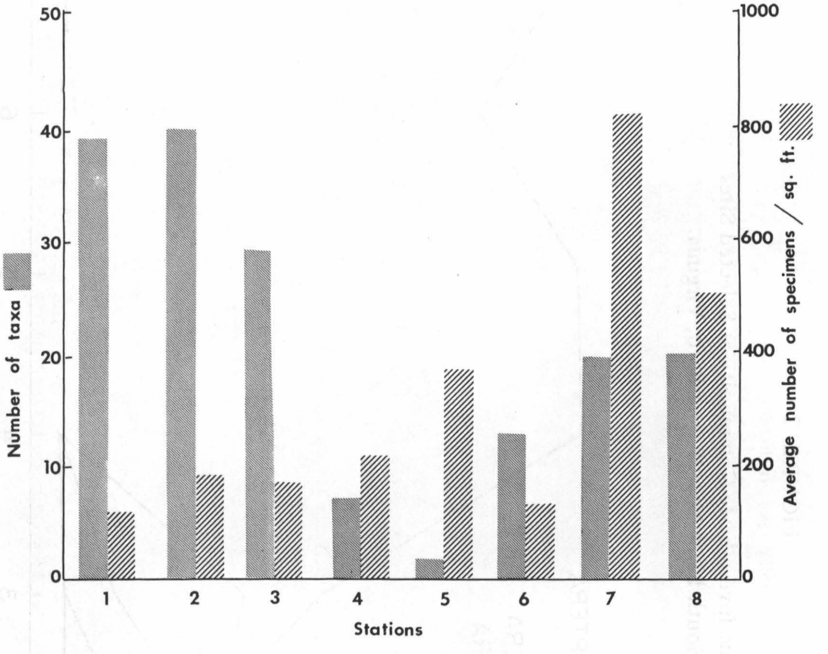
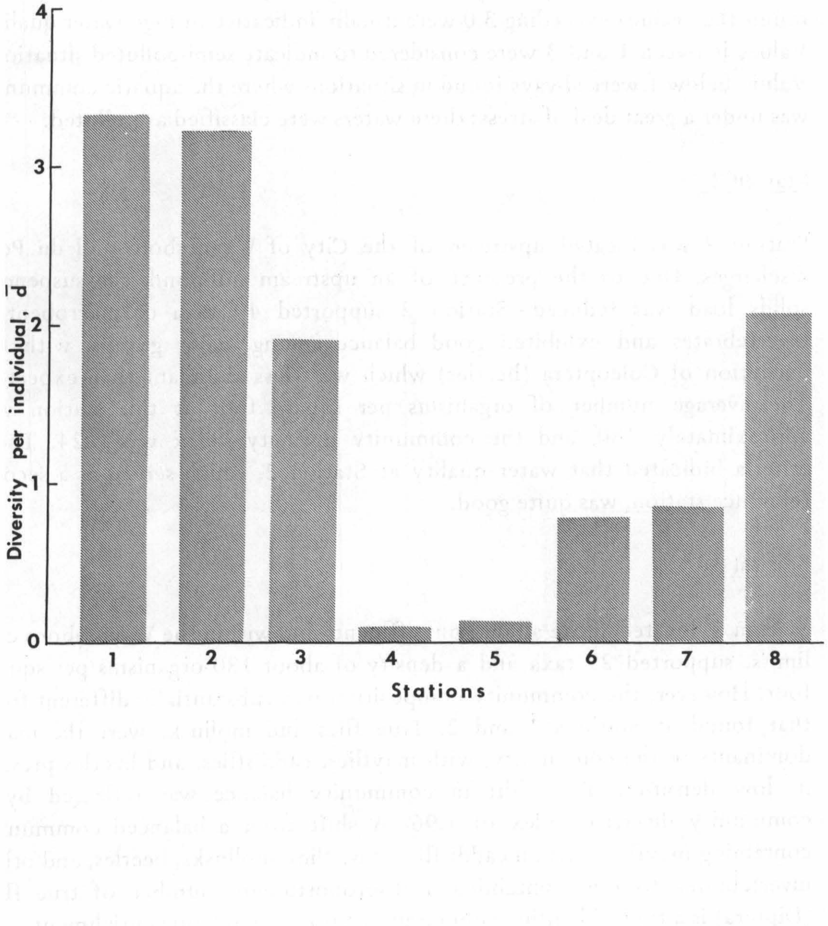


FIGURE 4

Bottom Fauna Community Structure
Evaluation ($\bar{d}$) by Stations.



The standing crop, or density, of macrobenthic invertebrates per unit area in a streambed is controlled by many factors, including food availability, space for colonization, predation rates, and other factors. Although it is generally true, in the case of organic enrichment in streams, that the standing crop of benthic organisms increases in density in response to the enrichment, very often in other types of stress, e.g., thermal or heavy metal, the density of macroinvertebrates may decrease at the stressed stations.

Station 1 had a diversity index of 3.34 (Figure 4). Wilhm and Dorris (1968) found that values exceeding 3.0 were usually indicative of high water quality. Values between 1 and 3 were considered to indicate semi-polluted situations. Values below 1 were always found in situations where the aquatic community was under a great deal of stress; these waters were classified as polluted.

Station 2

Station 2 was located upstream of the City of Waynesboro and du Pont discharges. Due to the presence of an upstream millpond, the suspended solids load was reduced. Station 2 supported 40 taxa of macrobenthic invertebrates and exhibited good balance among major groups, with the exception of Coleoptera (beetles) which were less abundant than expected. The average number of organisms per square foot at this station was approximately 180, and the community diversity index was 3.24. These criteria indicated that water quality at Station 2, which served as a second reference station, was quite good.

Station 3

Station 3, located above all du Pont effluents and within the Waynesboro city limits, supported 29 taxa and a density of about 180 organisms per square foot. However, the community composition was substantially different from that found at Stations 1 and 2. True flies and mollusks were the major dominants in the community, with mayflies, caddisflies, and beetles present in low densities. This shift in community balance was reflected by a community diversity index of 1.96. A shift from a balanced community containing mayflies, certain caddisflies, true flies, mollusks, beetles, and other invertebrates to one containing a disproportionate number of true flies (Diptera) is a typical benthic community response to organic enrichment.

There were several probable influences responsible for the apparent water quality degradation at Station 3. The station was located just downstream of a series of small impoundments which doubtless receive surface and storm runoff from Waynesboro. There may also be sewer intercepts and kitchen drains leaking into the impounded water. From whatever the source, there was obvious nutrient enrichment in the impounded water as evidenced by heavy algal growth in the water and on the dam spillway, and this enrichment probably had a somewhat degrading impact upon the invertebrate community at Station 3. Station 3 was not a typical riffle area in terms of flow and substrate type and this physiognomy may contribute somewhat to the apparently depressed benthic community.

Station 4

Station 4, located immediately below du Pont plant property and directly below the discharges from Crompton-Shenandoah, had a severely reduced macrobenthic invertebrate community. Eight taxa were collected at this station; 99% of the specimens collected were bloodworms (larvae of Chironomidae: Diptera). This community domination by bloodworms indicated a response to organic enrichment entering South River between Station 3 and Station 4. At Station 4 the average number of specimens per square foot was 220, which, coupled with the decrease in the number of taxa, was a community response characteristic of organic enrichment. A community diversity index of 0.08 at Station 4 indicated a grossly disturbed environment.

At Station 4 a transect of bottom fauna samples was taken in an attempt to separate the effects of du Pont's discharges, which channeled along the right bank, from Crompton-Shenandoah's effluents, which channeled on the left bank. However, no significant differences in the fauna between the left and right banks could be ascertained. Both sides of the river had a dramatically reduced faunal diversity, with bloodworms dominating the community. Based on these data, it appeared that the effluents from both du Pont and Crompton-Shenandoah were placing severe stress on the macrobenthic community at this station.

Station 5

Station 5, located at the Second Street Bridge below the du Pont and Crompton-Shenandoah discharges, but upstream from the City of Waynesboro sewage treatment plant, also supported a depressed macrobenthic invertebrate community. Two taxa were collected at this station (bloodworms and sludgeworms), both of which are considered to be highly tolerant to saprobic conditions. The average number of specimens per square foot at Station 5 increased to 370 and about 98% of these were bloodworms. The community diversity index was 0.08, indicating a highly stressed community.

Station 6

Station 6 was located downstream of the introduction of the City of Waynesboro waste treatment plant and 5.5 miles below du Pont. Thirteen macroinvertebrate taxa were collected at this station, indicating some recovery from conditions found upstream. However, over 99% of the specimens found belonged to two pollution-tolerant groups, bloodworms and sludgeworms. Pollution-intolerant organisms such as mayflies, caddisflies, and beetles were either absent or present only in very small numbers. The average number of specimens per square foot at Station 6 was 140. A community diversity value of 0.79 reflected a highly stressed community but demonstrated some evidence of recovery as compared to Station 5.

Station 7

Station 7, located at Crimora where Route 612 crosses the South River, had an increase in number of taxa to 20. Pollution-intolerant organisms such as mayflies, caddisflies, and beetles were found at this station but in exceedingly low numbers. Bloodworms and sludgeworms still made up over 99% of the community. The macroinvertebrate density at Station 7 was 820 per square foot, the highest encountered in the survey. A community diversity of 0.84 indicated a disturbed benthic community; however, some recovery from Station 6 was evident.

Station 8

Station 8, located at Harriston, Virginia, had 20 taxa of macrobenthic invertebrates. Community dominance shifted rather strikingly at Station 8 from bloodworms and sludgeworms to hydropsychid caddisflies; however, bloodworms were a close second in dominance. In our experience with various degrees of stress placed upon streams by organic enrichment, we have often observed a pattern of community dominance similar to that exhibited at Station 8. Slight-to-medium degrees of enrichment often result in a community dominated by hydropsychid caddisflies, with bloodworms or other dipteran larvae being subdominant. Mayflies and beetles were present at Station 8, but mollusks were absent.

The shift in community dominance and the beginnings of a relatively strong return of mayflies and beetles indicates a further recovery of the stream at Station 8 as compared with Station 7. Recovery is further substantiated by the community diversity index (2.1) and the macroinvertebrate density (500 per square foot).

Conclusions

1. Macrobenthic invertebrate community structure at Stations 1 and 2 indicated that water quality in the South River at these points was very good.

2. Indications were that water quality at Station 3 was somewhat degraded, probably due to some small impoundments upstream.

3. Stations 4 and 5 had severely depressed macrobenthic invertebrate communities indicating that water quality in these areas can be directly attributed to the combined effluent discharges from du Pont and Crompton-Shenandoah, and no separation of effects between the discharges of the two companies could be made.

4. Stations 6, 7, and 8 had low quality water as evidenced by the macrobenthic invertebrate communities inhabiting these sites. There were indications of the beginnings of a recovery gradient from Station 6 through Station 8; however, the macrobenthic community did not compare favorably with the communities at Stations 1 and 2.

5. South River appears to have typical organic enrichment with dissolved oxygen depletion and particulate deposition. These perturbations have seriously altered the macrobenthic invertebrate fauna in portions of the South River.

[illegible] at the [illegible]
good.

[illegible] water quality [illegible]
[illegible] generally [illegible]

[illegible]

Stations [illegible] and [illegible] considered [illegible] were indications of [illegible] the [illegible] Station [illegible] the [illegible] compare favorably with the [illegible]

5. North [illegible] to have [illegible] quality [illegible] [illegible] depositing [illegible]

FISH STUDIES

by

Robert D. Ross*

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FISH STUDIES

Introduction

The purpose of this study was to document the diversity, density, and distribution of fish throughout the South River system. Fish reflect water quality, directly and indirectly. Fish utilize other forms of aquatic life for food, thus the damaging or destruction of any lower trophic level has an effect on the fish community. Fish may be directly affected by toxic substances or severe reduction of dissolved oxygen. Therefore, fish communities reflect present and past conditions and are useful in the biological assessment of water quality. Since the economic value of fish is more generally accepted than that of other forms of aquatic life, the presence or absence, kind, and condition of the fish community is an important attribute of an aquatic system. This study was designed to determine if waste discharges entering the South River were damaging the fisheries at selected stations.

Jordan was the first to give records of fishes from South River (then called East River) at Waynesboro, Virginia. He probably fished within the present town limits and below a point where "a few large springs" enter the river and where the water temperature was 69°F on July 27, 1888 (Jordan, 1890). Ross (1959) published other records obtained during a biological survey conducted by the Virginia Commission of Game and Inland Fisheries on the South River. The Jordan and Ross records are compiled in Table 1 and are from the South River in and above Waynesboro. Ross found more species than did Jordan, but it should be kept in mind that Jordan worked at one place while Ross sampled several areas.

Materials and Methods

Fish were collected by both electroshocking and seining at each station. Pool and riffle areas were sampled at each station with approximately the same unit of effort in fish collection exerted at all stations. The fish were immediately preserved in the field with 4% formalin and returned to the Virginia Polytechnic Institute and State University fish museum, where they were identified and catalogued.

TABLE 1

Records of fishes from South River, Virginia, obtained by Jordan (1890) in Waynesboro and by Ross (1959) in and above Waynesboro and by Ross (1970) at Stations 1, 2, and 3.

Family and species	Jordan 1890	Ross 1959	Ross 1970
Suckers, family Catostomidae			
White sucker, *Catostomus c. commersoni*	x	x	x
Hog sucker, *Hypentelium nigricans*	x	x	x
Torrent sucker, *Thoburnia rhothoeca*	--	x	x
Minnows, family Cyprinidae			
Silvery minnow, *Hybognathus nuchalis*	x	--	--
Common shiner, *Notropis c. cornutus*	x	x	x
Satinfin shiner, *Notropis analostanus*	x	x	x
Rosyface shiner, *Notropis rubellus*	x	x	x
Swallowtail shiner, *Notropis p. procne*	x	x	x
Spottail shiner, *Notropis hudsonius*	--	x	x
River chub, *Nocomis micropogon*	--	x	x
Fallfish, *Semotilus corporalis*	--	x	x
Creek chub, *Semotilus a. atromaculatus*	x	x	x
Pearl dace, *Semotilus margarita*	--	x	x
Bluntnose minnow, *Pimephales notatus*	--	x	x
Cutlips minnow, *Exoglossum maxillingua*	x	x	x
Longnose dace, *Rhinichthys cataractae*	x	x	x
Blacknose dace, *Rhinichthys a. atratulus*	x	x	x
Redside dace, *Richardsonius funduloides*	--	x	--
Catfishes, family Ictaluridae			
Yellow bullhead, *Ictalurus n. natalis*	--	x	x
Killifishes, family Cyprinodontidae			
Banded killifish, *Fundulus d. diaphanus*	--	x	x

TABLE 1 (Continued)

Family and species	Jordan 1890	1959	1970
Sunfishes, family Centrarchidae			
Rock bass, *Ambloplites r. rupestris*	–	x	x
Pumpkinseed, *Lepomis gibbosus*	x	x	x
Redbreast sunfish, *Lepomis auritus*	x	x	x
Smallmouth bass, *Micropterus d. dolomieui*	x	x	x
Sculpins, family Cottidae			
Mottled sculpin, *Cottus bairdi*	x	x	x
Perches, family Percidae			
Fantail darter, *Etheostoma f. flabellare*	x	x	x
Johnny darter, *Etheostoma nigrum*	–	x	–

Results

South River Upstream of Waynesboro, Virginia

Station 1 at Route 635 bridge near Lipscomb had a small, turbid, sluggish, soft-bottom stream varying in width from 5 to 10 feet. The mud banks were low. There was little cover and only a moderate amount of shelter in the form of trash in the stream. The surrounding area was used primarily for agriculture. Most of the length of this station consisted of a long pool, but one riffle was below the Route 635 bridge. This part of South River abounds in fishes and several times large fish were observed avoiding the seine. Three large white suckers were captured and released but counted in the total entered in Table 2 for that species. The turbid water found at this station rendered the shocking gear ineffective, for the stunned fishes must be seen to be recovered.

It was gratifying to find the torrent sucker, *Thoburnia rhothoeca*, at this and other stations above Waynesboro (Stations 1 and 2). This is a relict species in the Shenandoah River system and is known elsewhere only from the James

River drainage. Another unusual find was the banded killifish, *Fundulus d. diaphanus*, which normally avoids running water. There is a large population of these killifishes in Spring Pond of Twin Ponds on Big Levels Game Preserve. The ponds drain into South River (Ross, 1959). The young killies have seven bars on the sides which meet on the mid-dorsal line. Adults usually have ten to twelve bars. This would indicate that the number of bars increases as the fish become mature.

Station 2 at Route 650 bridge north of Lyndhurst was below an impoundment. Much of the sediment load observed at Station 1 appeared to have settled out in the impoundment. The water was clear and cool, and the width of the stream was from 20 to 35 feet. Pools and riffles alternated more or less equally. There was considerable overhead shade, and a moderate amount of litter in the pools provided ample shelter. The bottom was hard, for the most part, and consisted of rubble in the riffles and sand and silt in the pools. The banks were low.

Game fishes were present and might have been more abundant if darters replaced the very large population of sculpins (Table 2) which dominated the riffles, since darters are much better as forage fishes for the smallmouth bass and other game fishes. The sculpin also competes with the game fishes for aquatic insects and other foods. Although conditions could improve for game fishes, Station 2 abounded in fishes and represented a healthy stream, since 20 species were collected at this station.

Station 3, just below the Waynesboro Y.M.C.A., was turbid and had been modified by a series of low dams and near the road many large rocks had been introduced as a part of the road bed. Much of the bottom was soft due to deposition of sediments. Most of the length of Station 3 consisted of a pool but a riffle was present at the lower end, immediately upstream of the first upstream discharge pipe from the du Pont plant. The stream width was from 30 to 45 feet. Some of the pools were too deep for wading. There was much litter on the stream bottom, some of it rubbish. Seining and shocking were difficult but both methods were used to collect fishes. In spite of artificial features and floating and sunken garbage, South River still supported a varied and abundant fish fauna (17 species) at this station along with frogs, turtles, and the water snake, *Natrix s. sipedon.*

A fish which might be expected to be collected at Station 1 or 2 was the redside dace, *Richardsonius funduloides*, which Ross (1959) reported from Back Creek, near Sherando Lake, one of the major tributaries to the upper South River. The redside dace may now be restricted to Back Creek near

TABLE 2

The species and numbers of fishes taken at 7 collecting stations on South River, Virginia, on September 4-6, 1970.

Families and species	Station Numbers 1	2	3	5	6	7	8	Totals
Suckers, family Catostomidae								
White sucker, *Catostomus c. commersoni*	17	2	4	0	1	0	0	24
Hog sucker, *Hypentelium nigricans*	3	1	0	0	0	0	0	4
Torrent sucker, *Thoburnia rhothoeca*	1	42	17	0	0	0	0	60
Minnows, family Cyprinidae								
Common shiner, *Notropis c. cornutus*	118	9	2	0	0	0	0	129
Satinfin shiner, *Notropis analostanus*	11	0	0	0	0	0	0	11
Rosyface shiner, *Notropis rubellus*	1	0	44	0	0	0	0	45
Swallowtail shiner, *Notropis p. procne*	0	23	7	0	0	0	0	30
Spottail shiner, *Notropis hudsonius*	0	3	0	0	0	0	0	3
River chub, *Nocomis micropogon*	1	2	0	0	0	0	0	3
Fallfish, *Semotilus corporalis*	47	13	4	0	0	0	0	64
Creek chub, *Semotilus a. atromaculatus*	0	1	2	0	0	0	0	3
Pearl dace, *Semotilus margarita*	5	2	2	0	0	0	0	9
Bluntnose minnow, *Pimephales notatus*	48	1	1	0	0	0	0	50
Cutlips minnow, *Exoglossum maxillingua*	0	4	0	0	0	0	0	4
Longnose dace, *Rhinichthys cataractae*	19	89	20	0	0	0	0	128
Blacknose dace, *Rhinichthys a. atratulus*	52	143	58	0	0	0	0	253
Carp, *Cyprinus carpio*	0	0	0	0	0	1	1	2
Catfishes, family Ictaluridae								
Yellow bullhead, *Ictalurus natalis*	2	3	2	0	0	0	0	7
Eels, family Anguillidae								
Common eel, *Anguilla rostrata*	0	0	0	0	0	0	1	1
Killifishes, family Cyrpinodontidae								
Banded killifish, *Fundulus d. diaphanus*	2	0	0	0	0	0	0	2
Perches, family Percidae								
Fantail darter, *Etheostoma f. flabellare*	13	19	32	0	0	0	0	64
Sunfishes, family Centrarchidae								
Rock bass, *Ambloplites r. rupestris*	1	5	2	0	0	0	0	8
Pumpkinseed, *Lepomis gibbosus*	0	0	0	0	0	1	0	1
Redbreast sunfish, *Lepomis auritus*	4	2	2	0	0	2	136	146
Green sunfish, *Lepomis cyanellus*	0	0	0	0	1	1	0	2
Bluegill, *Lepomis m. macrochirus*	0	0	0	0	0	0	5	5
Smallmouth bass, *Micropterus d. dolomieui*	1	1	1	0	0	0	0	3
Sculpins, family Cottidae								
Mottled sculpin, *Cottus bairdi*	55	86	21	0	0	0	0	162
Total number of species	19	20	17	0	2	4	4	

Sherando Lake since it ordinarily avoids turbid water. An excellent example of this is its disappearance during the past decade from the main North and South Forks of Roanoke River in Montgomery County, Virginia. Concurrent with the disappearance of this minnow, increased turbidities and siltation of the bottom were noted especially in the South Fork of the Roanoke River. Another species not found in the present survey or in Ross's 1959 survey was the silvery minnow, *Hybognathus nuchalis*, reported by Jordan (1890) from Waynesboro. Otherwise the upper South River seems to have changed very little in the past 80 years, as may be seen from Table 1.

South River Below Waynesboro, Virginia

South River at and below Second Street bridge in Waynesboro had a depauperate fish fauna. In Stations 5 through 8 there were only 7 species in 4 families among the 28 or more species in 8 families known to occur in South River. Table 2 shows very little difference between Stations 6, 7, and 8, although perhaps some recovery may be noted in the fact that a large school of young redbreast sunfishes was present at Station 8.

Station 5 just above Second Street bridge at a Waynesboro park yielded no fishes whatever. The water was darkly stained. The bottom was slippery due to the slime layer that had been formed by the extensive growth of microscopic organisms. The rubble riffles and pools both contained a black malodorous material which loaded each net haul.

Station 6 at Route 611 bridge at Dooms had dark water and the bottom was hidden by extensive beds of *Najas* and *Potomogeton* in which few fishes were found. Two specimens of two species were taken.

Station 7 had more lightly stained water and less *Najas* and *Potomogeton*. The varied bottom, the overhead cover, the shelter in the water, and the quality of the bottom provided appropriate habitats for many kinds of fishes, but six specimens of three species were all that could be found.

Station 8 at Route 778 bridge at Harriston yielded four species in three families among which was a school of 131 young redbreast sunfishes. Ross (1959) secured much better results on August 28, 1956, when he, David Robinson, and Charles Hanson shocked for about two hours at Harriston and obtained:

Family Catostomidae

White sucker, *Catostomus c. commersoni*, 6 specimens.
Hog sucker, *Hypentelium nigricans*, 5 specimens.

Family Cyprinidae

Spottail shiner, *Notropis hudsonius*, 18 specimens.

Family Ictaluridae

Yellow bullhead, *Ictalurus natalis*, 2 specimens.

Family Anguillidae

Common eel, *Anguilla rostrata*, 1 specimen.

Family Centrachidae

Smallmouth bass, *Micropterus d. dolomieui*, 2 specimens.
Largemouth bass, *Micropterus s. salmoides*, 1 specimen.
Redbreast sunfish, *Lepomis auritus*, 12 specimens.

The results of August 28, 1956, were not indicative of a very productive stream but they are significantly better than what was obtained with a larger crew which spent more time searching for fishes. It may be that the fauna at Harriston had actually deteriorated since 1956, but the evidence was not conclusive. Whatever may be the case, it was quite clear that South River at and below Second Street bridge in Waynesboro had a restricted fish fauna at least as far as Harriston, a total of 14 river miles.

Conclusions

1. A total of 1,233 fish were taken from the South River during the September 4-6, 1970, sampling period. These fish were distributed among 27 species.

2. A total of 1,083 fish were taken from the first 3 stations with 19, 20, and 17 species taken from Stations 1, 2, and 3, respectively.

3. A total of 150 fish were taken from Stations 5, 6, 7, and 8 and these were distributed among only 7 species. It should be added that 136 of the fish were taken at Station 8 when a school of sunfish was encountered.

4. It was quite obvious that definite differences existed in both numbers of individuals and species between the 3 upper stations and the 4 lower stations. These differences were probably due to an alteration of water quality between Station 3 and Station 6.

5. The fact that Ross found 8 species at Station 8 in 1956 and 4 species in 1970 suggests a slow but continuous deterioration of water quality at that station. However, the physical characteristics of this river have changed from a series of millponds to a fairly rapidly flowing stream so that basic habitat changes may be responsible for the reduced number of species.

PROTOZOAN STUDIES

by

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PROTOZOAN STUDIES

Introduction

Protozoa play a varied role in the food web in aquatic systems. Some Protozoa are capable of photosynthesis and thus are important in the primary production in aquatic systems. Perhaps a more important role is that of consumers of bacteria, detritus, and soluble organic material. In an organically enriched body of water it is not uncommon to find a high density of ciliated Protozoa harvesting the bacterial bloom. The density, diversity, and kinds of Protozoa present in water are all indicative of its quality. The purpose of this portion of the biological survey was to document the nature of the protozoan community of the South River at each of the eight sampling stations.

Methods

Samples from each station were taken from as many different substrates as possible (mud, rock, logs, algal mats, surface scum, aquatic vegetation, and floating debris) in both pool and riffle areas when both were included in a station. Sampling was done with a rubber suction bulb which was used to collect water and detritus from the substrate surface. The water was squeezed into 200 ml collecting jars. If the area being sampled included leaves, grass, or algae, some of this material was also added to the collection. Ten or eleven jars were filled to within ½ inch of the top at each station and taken immediately back to the field laboratory. Water samples to be examined were taken from the bottom of the jar, along the surface of leaves and debris, and from the meniscus. A brief examination was made as soon as possible after collection to get an idea of the kinds and numbers of species present; then a more thorough study was carried out by examining samples from each jar until the numbers of new species found decreased to two or fewer per slide. These species with only one individual recorded per station were not counted, except for the class Suctoria which were never present in large numbers.

The examination for each station usually was completed in about seven hours. It is possible that during this time there was a change in species diversity and density within the collecting jars. This was one reason for the brief examination right after collection – to see what species were there and if there was a considerable change in kinds of species present. More emphasis was placed on species diversity than density, but a rating system was used to estimate relative density.

Results

Table 3 lists those fresh-water Protozoa found at each station. Table 4 summarizes the numbers of species found at each station, with species grouped into classes.

The greatest number of species was found at Station 7, with more species and a greater density of flagellates than ciliates. Station 7, in an agricultural region, probably was rich in nutrients since cattle had free access to part of the river.

Station 5 had the lowest number of species, with high densities of ciliate bacterial feeders and some green flagellates. Since the number of species was still fairly high (not much lower than Station 1), conditions were evidently not toxic enough to drastically reduce the protozoan population. The change in quality and density of species does indicate a high organic enrichment.

Stations 4 and 5 were comparable in the kinds and density of ciliates, but Station 4 had more flagellates, most of them pigmented. Stations 1 and 4 had about the same number of species, but the kinds and densities differed. Percent overlap for flagellates was about 45%, and for ciliates only 17% of those at Station 4 were also at Station 1. Station 6 represented a recovery area. The number of species in all classes had increased from Station 5. The reduction in species at Station 8 may indicate less nutrients or some other difference in water chemistry between it and Station 6 and 7, since all three stations had similar habitats.

Conclusions

The first response of a protozoan community to organic enrichment is an increase in number of species. This is usually followed by a reduction in the number of species if further organic material is added. Overall, the number of protozoan species in the South River was high, reflecting the fact that this was an enriched situation even in the headwater area. There was a slight reduction in the total number of species at Stations 4 and 5 below the sewage treatment plant outfall, showing considerably higher numbers of species at Stations 6 and 7 than existed at Station 5. The highest number of species recorded was found at Station 7 and this was an unusually large number under any circumstances. This situation probably reflected the peak point of utilization of the organic material from the sewage plant insofar as the protozoan community was concerned. The rather substantial reduction in numbers which occurred at Station 8 reflected the restoration toward normal conditions and was not greatly different from the total number of species found at reference Station 1. The distribution among the various major groups of protozoans was not at all unusual, with the possible exception of the five species of suctorians found at Station 6.

TABLE 3

List of Protozoan Species Found in the
South River, Virginia, September 1970.

Taxa	Station 1	2	3	4	5	6	7	8
Phylum Protozoa								
Subphylum Plasmodroma								
Class Mastigophora								
Subclass Phytomastigia								
Order Chrysomonadida								
Family Chromulinidae								
Chromulina sp.	4*	3	3	–	–	–	3	4
Oikomonas termo (Ehrenberg)	4	3	2	–	–	–	2	–
O. socialis Moroff	2	2	–	–	–	4	–	–
Mallomonas sp.	–	1	–	1	–	–	–	–
Family Ochromonadidae								
Monas socialis Kent	2	–	–	5	–	3	2	–
Anthophysis vegetans Muller	–	–	–	1	–	–	–	1
Order Cryptomonadida								
Family Cryptomonadidae								
Cryptomonas erosa E.	5	6	6	2	–	–	5	3
Chilomonas paramecium E.	2	2	2	2	–	–	–	4
Cyathomonas truncata E.	4	2	2	–	–	2	2	2
Order Phytomonadida								
Family Chlamydomonadidae								
Chlamydomonas near *angulosa* Dill	–	–	–	2	–	–	–	–
C. globosa Snow	3	5	6	4	5	4	4	3
C. gracilis S.	3	3	2	5	4	4	3	3
C. monadina Stein	1	–	–	2	–	1	2	–
C. near *snowiae* Printz	3	5	3	–	–	–	3	–
C. sp.	–	–	–	–	2	–	–	–
Haematococcus pluvialis (Flotow)	–	–	2	–	–	–	2	–
Lobomonas rostrata Hanen	–	–	–	–	–	1	1	2
Chlorogonium tetragamum Bohlin	–	–	–	–	6	4	–	–
Family Carterlidae								
Carteria globulosa Pascher	–	–	2	–	–	–	–	–
Family Phacotidae								
Phacotus lenticularis (E.)	–	–	1	–	–	–	–	–
Family Volvocidae								
Spondylomorum quaternarium E.	–	–	–	2	–	–	–	–
Chlamydobotrys stellata Korschikoff	–	–	–	2	–	–	–	–

TABLE 3 (Continued)

Taxa	Station 1	2	3	4	5	6	7	8
Order Euglenoidida								
Family Euglenidae								
Euglena acus Ehrenberg	–	–	–	4	–	2	4	–
E. deses E.	–	–	–	–	–	–	1	–
E. gracilis Klebs	2	–	3	–	–	2	–	–
E. klebsi Mainx	–	1	–	–	–	–	–	–
E. pisciformis Klebs	5	3	–	2	4	4	5	3
E. rostrifera (Johnson)	–	–	–	3	–	3	2	–
E. spirogyra E.	–	–	–	1	–	–	–	–
E. terricola Dangeard	–	–	–	–	–	1	–	–
E. viridis E.	5	4	5	4	5	6	3	2
Phacus longicauda (E.)	–	–	–	–	–	–	1	–
P. pleuronectus Muller	1	–	–	1	–	–	4	–
P. pyrum (E.)	–	–	–	–	–	2	–	–
Trachelomonas near *ensifera* Daday	–	–	2	–	–	–	–	–
T. euchlora (E.)	–	–	–	–	–	–	1	–
T. hispida (Perty)	–	2	–	–	–	–	1	–
T. volvocina E.	–	1	–	–	–	–	–	–
Cryptoglena pigra E.	–	–	–	–	–	–	2	–
Family Astasiidae								
Petalomonas angusta (Klebs)	–	–	–	–	–	1	–	–
P. mediocanellata Stein	–	2	–	–	–	–	1	–
P. steinii Klebs	–	–	–	4	–	–	1	–
Menoidium tortuosum Stokes	–	1	–	–	–	–	–	–
Scytomonas pusilla Stein	–	–	–	–	–	–	–	1
Family Anisonemidae								
Anisonema acinus Dujardin	1	3	2	–	–	3	3	3
A. ovale Klebs	–	–	1	–	–	–	–	–
Peranema granulifera Penard	1	–	–	–	–	–	–	–
P. trichophorum (S.)	3	1	2	2	5	4	2	2
Heteronema sp.	–	2	1	–	3	1	1	1
Distigma proteus E.	–	–	–	–	1	–	–	–
Entosiphon obliquum Klebs	–	–	1	–	–	–	–	–
E. ovatum Stokes	–	–	–	–	–	–	2	–
E. sulcatum (Dujardin)	–	–	–	2	–	–	–	–
Notosolenus apocamptus Stokes	3	2	2	–	–	–	2	2
Order Dinoflagellida								
Family Gymnodiniidae								
Gymnodinium near *paradosum* Schill	–	1	2	–	–	–	–	–

TABLE 3 (Continued)

Taxa	Station 1	2	3	4	5	6	7	8
Subclass Zoomastigia								
Order Protomonadida								
Family Codosigidae								
Codonosiga botrytis (E.)	–	–	–	–	–	2	2	–
Monosiga ovata Kent	–	–	1	–	–	–	–	–
M. robusta Stokes	–	–	–	–	–	1	–	–
Family Bodonidae								
Bodo caudatus Duj.	–	1	2	–	–	–	2	2
B. celer Klebs	–	2	–	–	–	3	–	3
B. edax Klebs	–	2	–	–	–	–	1	2
B. fusiformis (Stokes)	–	–	–	–	4	–	–	–
B. globosus Stein	2	–	–	–	–	–	–	–
B. minimus Klebs	2	3	2	–	3	3	2	3
B. putrinus (Stokes)	–	–	–	2	3	–	–	–
B. uncinatus Klebs	3	2	2	–	–	–	2	–
Pleuromonas jaculans Perty	–	–	–	–	–	–	–	3
Rhynchomonas nasuta (Stokes)	–	–	–	–	–	–	–	1
Class Sarocodina								
Subclass Rhizopoda								
Order Amoebida								
Family Naegleriidae								
Naegleria gruberi (Schardinger)	–	–	1	–	–	1	–	1
Family Amoebidae								
Amoeba gorgonia Penard	–	–	–	–	2	1	–	–
A. limicola Rhumbler	2	–	1	–	–	–	2	2
A. proteus (Pallas)	2	–	–	–	2	2	2	–
A. radiosa E.	1	–	2	2	–	2	2	1
A. striata Penard	–	–	–	–	1	–	–	1
A. verrucosa E.	–	–	–	–	–	3	–	–
A. vespertilio Penard	2	–	1	3	–	3	3	2
A. sp.	–	–	–	–	1	–	–	–
Flabellula velata	–	–	–	–	–	–	2	–
Vahlkampfia limax Duj.	2	–	–	2	–	1	2	2
Hartmanella sp.	2	–	–	–	2	–	–	–
Acanthamoeba sp.	–	–	–	–	1	2	–	–
Order Testacida								
Family Arsellidae								
Arcella discoides E.	–	–	–	–	–	–	1	–
A. vulgaris E.	–	–	–	–	–	2	–	–
Hyalosphenia sp.	1	–	–	–	–	–	–	–

TABLE 3 (Continued)

Taxa	Station 1	2	3	4	5	6	7	8
Family Difflugiidae								
Difflugia lobostoma Leidy	–	–	–	–	–	–	1	2
Clypeolina marginata Penard	–	1	1	–	–	–	–	–
Subclass Actinopoda								
Order Heliozoida								
Family Actinophryidae								
Actinophrys sol E.	1	–	2	–	–	1	1	1
Family Lithocollidae								
Astrodisculus sp.	1	–	–	–	–	1	–	1
Family Acanthocystidae								
Acanthocystis sp.	–	–	–	–	–	–	–	1
Subphylum Ciliophora								
Class Ciliata								
Subclass Holotricha								
Order Gymnostomatida								
Family Holophryidae								
Holophrya atra Svec.	–	–	3	–	–	–	–	–
H. simplex Schewiakoff	–	–	–	–	–	–	–	2
Prorodon near *nucleolatus* Penard	2	–	–	–	–	–	–	–
P. sp.	–	2	–	–	–	–	–	–
Placus sp.	–	–	–	–	–	–	–	2
Lacrymaria olor (Muller)	–	–	–	–	–	–	2	–
L. sp.	–	–	1	–	–	–	–	1
Enchelydon sp.	2	–	–	–	–	–	–	–
Trachelophyllum near *chillense* Burger	–	2	3	4	6	3	5	5
Trachelocerca sp.	–	1	–	–	–	–	–	–
Family Colepidae								
Coleps hirtus (Muller)	–	–	–	–	–	1	–	–
Family Didiniidae								
Mesodinium pulex (Claparede & Lachmann)	–	2	1	–	–	–	–	–
Family Amphileptidae								
Lionotus sp. 1	–	–	2	3	5	3	1	3
L. sp. 2	–	–	–	2	–	–	–	–
Hemiophrys sp.	–	–	–	–	–	–	–	1
Family Tracheliidae								
Dileptus anser Muller	1	–	2	–	–	–	–	–
D. monilatus (Stokes)	–	1	–	–	–	–	–	1
D. sp.	1	–	–	–	–	–	–	–
Paradileptus robustus Wenrich	–	–	–	–	–	–	–	1

TABLE 3 (Continued)

Taxa	Station 1	2	3	4	5	6	7	8
Family Loxodidae								
Loxodes vorax Stokes	–	–	–	–	–	–	–	5
Family Dysteriidae								
Trochilia sp.	2	–	–	–	–	–	3	4
Family Chlamydodontidae								
Chilodonella caudata (Stokes)	1	–	–	–	–	–	2	–
C. cucullulus (Muller)	4	3	2	–	–	–	2	2
C. fluviatilis (Stokes)	–	–	1	–	–	–	–	–
C. uncinata (E.)	5	3	3	2	2	5	4	4
Family Nassulidae								
Nassula aurea E.	–	–	1	–	–	–	–	–
Chilodontopsis depressa (Perty)	–	–	–	–	–	–	1	–
C. near *muscorum*	–	–	–	–	–	1	–	–
Order Trichostomatida								
Family Colpodidae								
Bresslaua vorax Kahl	–	–	–	–	2	–	–	–
Family Microthoracidae								
Leptopharynx sphagnetorum (Levander)	–	–	–	3	–	–	–	–
Order Hymenostomatida								
Family Tetrahymenidae								
Tetrahymena pyriformis (E.)	–	–	–	–	–	3	2	–
Colpidium campylum (Stokes)	–	1	–	5	4	2	2	3
C. striatum S.	–	–	–	–	3	–	–	–
Glaucoma scintillans E.	–	–	–	–	2	–	–	–
Monochilum frontatum Schewiakoff	–	–	2	–	–	–	–	2
Saprophilus muscorum Kahl	–	3	–	–	–	–	–	–
S. sp.	2	–	–	–	–	–	–	–
Family Philasteridae								
Philasterides armata (Kahl)	–	2	–	–	–	–	–	–
Family Parameciidae								
Paramecium aurelia E.	–	–	–	2	2	–	2	–
P. bursaria (E.)	–	–	–	5	–	–	–	–
P. caudatum E.	–	–	–	6	6	4	2	–
P. multimicronucleatum Powers & Mitchell	–	–	1	–	–	–	–	–

TABLE 3 (Continued)

Taxa	Station 1	2	3	4	5	6	7	8
Family Frontoniidae								
Frontonia leucas E.	–	–	1	2	3	3	1	–
Lembadion bullinum Perty	–	–	–	2	–	–	–	–
Cinetochilum margaritaceum P.	2	5	3	2	–	2	2	2
Urocentrum turbo (Muller)	–	–	–	1	–	3	–	–
Family Pleuronematidae								
Pleuronema sp.	–	1	–	–	–	–	–	–
Cyclidium elongatum Schew.	3	–	2	–	–	2	3	–
C. glaucoma Muller	–	2	–	5	–	–	2	2
C. litomesum Stokes	–	–	2	–	–	–	–	–
C. pellucidum	–	3	2	–	–	–	–	3
Subclass Spirotricha								
Order Heterotrichida								
Family Metopidae								
Metopus pulcher Kahl	–	–	–	–	2	–	–	–
Caenomorpha near *lauterborni* Kahl	–	–	–	–	2	–	–	–
Family Spirostomatidae								
Spirostomum intermedium Kahl	–	–	–	–	2	–	–	–
S. minus Roux	–	–	–	–	4	2	–	–
S. teres Claparede & Lachmann	–	–	–	3	–	–	–	–
Blepharisma near *steini* Kahl	–	–	–	2	–	–	–	–
B. sp.	–	–	–	–	1	–	–	–
Family Condylostomatidae								
Condylostoma near *arenarium* Spiegel	–	2	–	–	–	–	–	1
Family Stentoridae								
Stentor niger (Muller)	–	–	–	–	–	1	–	–
Order Oligotrichida								
Family Strobilidiidae								
Strobilidium gyrans (Stokes)	–	–	2	–	–	2	2	–
Order Hypotrichida								
Family Oxytrichidae								
Oxytricha sp. 1	–	2	2	–	–	2	1	1
O. sp. 2	–	–	3	–	–	–	–	–
Tachysoma parvistyla Stokes	–	–	1	–	–	–	1	1
Urosoma caudata (S.)	–	1	1	–	–	3	–	–
Keronopsis sp.	2	–	–	–	–	–	–	–
Holosticha near *scutellum* Cohn	2	–	–	–	–	–	–	–
H. vernalis Stokes	–	1	2	–	–	1	–	–

TABLE 3 (Continued)

Taxa	Station 1	2	3	4	5	6	7	8
Stylonychia mytilus (Muller)	1	–	2	–	–	2	–	1
S. pustulata E.	–	–	2	–	–	–	–	–
S. putrina Stokes	–	–	3	2	2	1	–	
Family Euplotidae								
Euplotes eurystomus Wryesniowski	1	2	3	5	5	3	–	–
E. sp. 1	–	–	–	2	2	–	–	1
E. sp. 2	–	–	–	–	–	–	2	–
Family Aspidiscidae								
Aspidisca costata (Duj.)	2	4	3	–	2	–	2	2
A. lynceus E.	–	2	–	2	1	3	1	–
Subclass Peritricha								
Order Peritrichida								
Family Vorticellidae								
Vorticella campanula E.	2	2	–	–	–	3	3	2
V. convallaria (Linnaeus)	–	3	–	3	6	4	2	2
V. microstoma E.	1	–	–	2	3	3	–	2
V. sp.	–	–	–	2	3	–	2	–
Family Epistylidae								
Epistylis plicatilis E.	–	–	–	–	–	3	–	–
Class Suctoria								
Order Suctorida								
Family Acinetidae								
Acineta sp. 1	–	–	–	–	–	2	–	–
A. sp. 2	–	–	–	–	–	2	–	–
Solenophrya inclusa Stokes	–	–	–	–	–	1	–	–
Family Podophryidae								
Podophrya sp.	–	–	–	2	–	–	2	–
Sphaerophrya soliformis Lauterborn	–	–	–	–	–	1	–	–
S. sp.	–	–	–	–	–	1	–	–

*Numbers indicate ratings given for relative density of a species per station.
Rating/Estimated number of individuals found in sampling.

1 — 2 individuals
2 — 3 - 8
3 — 9 - 16
4 — 17 - 32
5 — 32 - 64
6 — > 64

TABLE 4

Numbers of Species of Fresh-water Protozoa
Found in the South River, Virginia, September 1970.

	Station							
Taxa	1	2	3	4	5	6	7	8
Mastigophora								
Phytomastigia	19	22	21	20	9	19	29	14
Zoomastigia	3	5	4	1	3	4	5	6
Sarcodina	9	1	6	3	6	11	9	10
Ciliata	18	23	27	23	23	26	26	26
Suctoria	0	0	0	1	0	5	1	0
Totals	49	51	58	48	41	65	70	56

ALGAL AND OTHER AQUATIC PLANT STUDIES

by

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ALGAL AND OTHER AQUATIC PLANT STUDIES

Introduction

Algae are the major primary photosynthetic producers in most freshwater ecosystems. Consequently, algal community composition often is the first to exhibit dramatic change in response to changes in physical and chemical properties of aquatic environments. The use of natural algal community change as an assay of the degree of pollution of an aquatic environment is well established and has been discussed in numerous works (Fjerdingstad, 1964, 1965; Hynes, 1960; King, 1970; Palmer, 1962, 1967a, 1967b, 1969; Parker and Wodehouse, 1970; Patrick et al., 1954; and Wolman, 1971).

The primary objective of this study was to survey the distribution and approximate abundance of algal genera and species during the early fall of 1970 and to interpret these data, as completely as possible, in terms of the levels and types of possible waste discharges at eight stations along the South River near Waynesboro, Virginia. In addition, the higher aquatic plants were studied and some preliminary data relating to the rates of sedimentation of suspended particulates and light penetration were collected.

In the light of the data to be reported and discussed subsequently in this paper, several points should be considered:

1. A reduction in algal species and genus numbers frequently, but not without exception, indicates some form of heavy pollution stress.

2. Certain algal species and genera are tolerant of pollution, while others are good indicators of unpolluted streams.

3. Phytoplankton algae are less important as indicators of stream pollution stresses than are the attached algae like *Nitzschia palea, Stigeoclonium tenue*, and *Oscillatoria*, species.

4. The relative abundance of various algae is of considerable importance in assessing pollution, because the most reliable algal indicators of pollution are merely pollution-tolerant and also occur in small numbers in clean waters.

5. A valid interpretation of the degree of pollution in any aquatic environment should be based upon the data as a total entity; that is, the presence of numerous pollution-tolerant species constitutes superior

TABLE 5

List of Algae and Macrophytes Collected at
Stations 1 through 8, South River, Virginia, September 1970.

PLANT GENERA (OR SPECIES)	ESTIMATED RELATIVE ABUNDANCE*								RI VALUES**
	Stations								
	1	2	3	4	5	6	7	8	
Blue-green Algae:									
Chroococcus dispersus	1	–	–	2	–	2	–	3	GS-N
Merismopedia convoluta	4	–	–	–	–	–	–	–	G-36
M. glauca	3	3	3	3	–	–	–	–	S-37
Microcystis aeruginosa	–	–	–	–	3	–	–	–	G-19, S-65
Oscillatoria agardhii	–	4	4	4	–	–	–	–	G-2, S-N
O. limnetica	–	–	–	4	4	–	–	–	S-N
O. limnosa	2	–	4	–	–	–	–	–	S-3
O. nigra	–	–	–	–	4	–	–	–	S-N
O. obscura	1	3	3	3	1	1	3	–	S-N
Phormidium angustissimum	1	3	–	–	–	–	–	–	G-12, S-N
Spirulina major	–	–	–	4	–	–	–	–	G-37, S-N
Anabaena constricta	3	3	3	3	2	–	–	–	G-22, S-52
Rivularia globiceps	–	–	–	–	3	–	–	–	GS-N
Microcoleus subtorulosus	–	–	–	–	3	–	–	–	GS-N
Westielopsis	–	4	–	–	–	–	–	–	GS-N
Green Algae:									
Chlamydomonas sp.	–	–	–	–	2	3	–	–	G-3
C. sp. – palmelloid stage	3	3	3	3-2	3	–	4	–	–
Hydrodictyon reticulatum	–	–	1	2	–	–	–	3	–
Pediastrum boryanum	–	–	–	–	4	–	–	–	G-24, S-39
P. duplex	–	4	–	–	–	–	–	–	S-69
Scenedesmus abundans	–	4	4	–	4	–	–	–	G-4, S-N
S. bernardii	–	–	–	–	–	4	–	–	S-N
S. bijuga	–	–	–	3	3	2	1	3	S-N
S. seratus	4	–	–	–	–	–	–	–	S-N
Ulothrix sp.	–	–	–	–	–	–	3	3	G-30
Stigeoclonium tenue	3	–	–	3	2	–	–	–	G-8, S-6
S. farctum	–	–	4	–	–	–	–	–	–
Oedogonium microgonium	–	–	–	2-1	–	–	–	–	GS-N
Cladophora glomerata	2	1	1	3	–	–	–	–	G-42, S-72
Rhizoclonium heiroglyphicum	–	–	–	3-2	–	1	2	3	GS-N
Closterium lunaris	3	3	–	3	–	–	3	–	G-16, S-N
Cosmarium obtusatum	–	–	–	–	–	–	–	3	G-53, S-N
Cosmarium punctulatum	–	4	4	4	–	–	4	–	S-N
Cosmarium pyramidatum	4	–	–	–	–	–	–	–	S-N
Spirogyra sp. no. 1	–	3-2	3	–	3	3	3	3	G-21
S. sp. no. 2	–	3-2	3	3	–	–	3	3	–
S. sp. no. 3	–	–	3	–	–	–	–	–	–
Diatoms:									
Amphora	3	3	3	3	–	–	–	3	G-N
Anomoeneis	–	–	–	3	–	3	–	3	G-N
Cocconeis	3	2	3	3	2	2	2	3	G-52
*Cymatopleura solea** (or *Surirella*)	–	4	–	–	–	–	–	–	*G-59, S-62
Cymbella	3	–	–	3	3	3	–	–	G-39

TABLE 5 (Continued)

PLANT GENERA (OR SPECIES)	ESTIMATED RELATIVE ABUNDANCE*								RI VALUES**
	Stations								
	1	2	3	4	5	6	7	8	
C. prostrata	–	3-2	3	–	–	–	–	–	S-N
C. ventricosa	–	2	3	–	–	–	–	–	S-N
Diatoma vulgare	3	3	3	3	3	3	–	–	G-44, S-40
Fragilaria	3	3	3	3	2	1	3	–	GS-N
Frustulina	3	3	–	–	–	–	–	–	GS-N
Gomphonema sphaerophorum	–	3	3	3	3	2	–	1	G-14, S-N
Gyrosigma (or *Pleurosigma*)	4	–	3	3	–	3	1	–	G-N
Navicula	1	3	3-2	3	2	1	1	3	G-7
Nitzschia sp.	1	–	3	3	–	–	–	–	G-6
N. palea	–	3	–	3	1	2	–	–	S-2
Pinnularia	3	–	3-2	–	–	–	–	–	GS-N
Pleurosigma	–	–	4	–	–	–	–	–	G-N
Stauroneis	3	3	–	–	–	–	–	–	G-56
Surirella elegans	3	3	–	–	–	–	–	–	G-31, S-N
S. splendida	–	3	–	–	–	–	–	–	S-N
Synedra	3	–	3	3	–	2	4	3	G-9
Tabellaria fenestrata	–	3	–	2	–	–	–	–	GS-N
T. flocculosa	–	3-2	3	–	–	3	–	–	S-N
Terpsinoe	4	–	–	–	–	–	–	–	G-N
Cyclotella	–	–	–	–	–	–	2	2	G-15
Melosira varians	1	1	2	1	4	4	2	2	GS-13
Euglenoids:									
Euglena sp.	4	–	–	–	–	4	–	–	G-1
Red Algae:									
Audouinella violacea	–	–	–	–	–	–	–	3	GS-N
Total Algal Species Collected	30	30	29	31***	21	20	17	17	
Bryophytes:									
Hypnaceae	–	–	–	–	–	–	–	2	N/A
Ferns:									
Azolla rotundifolia	–	–	–	–	–	–	3	–	N/A
Salvinia	–	–	–	–	–	–	3	3	N/A
Flowering Plants:									
Anacharis canadensis (= *Elodea*)	–	2	3	3	–	4	–	–	N/A
Callitriche (?*C. heterophylla*)	–	–	–	–	–	3	–	–	N/A
Eichornia crassipes	–	–	–	–	–	4	–	–	N/A
Lemna minor	–	–	3	3	2	3	3	3	N/A
Najas sp. (broad leaves) (or *Potamogeton,* such as *P. foliosus* or *P. pusillus*)	–	–	–	–	–	3	1	1	N/A
Najas flexilis (thin leaves)	1	1	2	2	1	1	2	3	N/A
Nasturtium officianale	–	–	–	3	–	–	–	–	N/A

TABLE 5 (Continued)

PLANT GENERA (OR SPECIES)	ESTIMATED RELATIVE ABUNDANCE*								RI VALUES**
	Stations								
	1	2	3	4	5	6	7	8	
Polygonum opelousanum	–	–	–	–	–	4	–	–	N/A
Pontaderia cordata f. taenia	–	–	4	4	–	4	4	–	N/A
Potamogeton crispus	–	–	–	1	2-1	2-1	2	3	N/A
Vallisneria americana	–	–	–	–	–	4	4	2	N/A
Total Higher Aquatic Plants	1	2	4	6***	3	12	7	6	

*For station locations, see text; relative abundance estimates (as biomass):
1 = dominant or of primary importance,
2 = of considerable abundance but subdominant to those labeled 1,
3 = occasionally observed in collections, but probably not too important in biomass,
4 = of rare occurrence.

**Based on Palmer (1969). G = genus; S = species; GS = genus and species; N = not listed; number = numeric order of frequency of citation as a pollution indicator, no. 1 having been cited most frequently.

***Includes two longitudinal transects; thus, not comparable to other sampling stations.

evidence for pollution as compared with the presence of one or two such indicator species.

Materials and Methods

Algae were collected at each of the eight stations by running three shore-to-shore transects and sampling water, rocks, sediments, rooted plants, and all other substrates for attached algae. At Station 4, in addition, upstream-downstream transects were carried out along both shores and in midstream. Algal genera were identified tentatively while alive and during collection using a Nikon Field Microscope. Also, the relative abundances of the various genera and other taxonomic groups of algae were estimated visually during the transect samplings. All or part of each collection was preserved in 5% formalin. The preserved material was examined subsequently in detail in the laboratory. Algal species and genera were identified as completely as possible and their relative abundances at each sampling location were estimated. The relative abundances cited subsequently represent, therefore, an approximation of the relative biomasses of algae as seen both in the field and in the laboratory. In most instances the field and laboratory relative abundance estimates were in agreement with each other. However, in those several instances where the relative abundance estimates did not agree with each other, a second transect sampling was made during a revisit to each station approximately four weeks later.

The same general procedures were used in sampling and estimating relative abundances for the higher aquatic plants.

Results and Discussion

Table 5 summarizes the distribution and relative abundances of the algae and higher aquatic plants for the eight stations along the South River. Also, the last column in Table 5 indicates the relative importance of the genus and/or species as an indicator of organic pollution, based on Palmer's (1969) "Composite Rating" for algae.

Station 1, Rt. 635 Bridge

The total amount of algae at this site was lower than at Stations 2 and 3, perhaps because of the high turbidity. Generally, blue-green algae occurred more abundantly than the green algae and diatoms. The most abundant blue-greens, *Chroococcus dispersus, Oscillatoria obscura*, and *Phormidium angustissimum* were not listed in any of the references cited above as being pollution-tolerant. Of the green algae, *Cladophora glomerata* was plentiful. This species is widely distributed in clean and some polluted streams. While it may tolerate some types of pollution, such as high salinity (NaCl) (Fjerdingstad, 1965) and organic pollution (Palmer, 1969), the species is sensitive to heavy metals (Fjerdingstad, 1965). The diatoms *Navicula* sp., *Nitzschia* sp., and *Melosira varians* also are widespread geographically. Thus, the predominant members of the algal community at Station 1 gave no indication that it was seriously polluted. This interpretation could be reinforced by identifying the species of *Nitzschia* and *Navicula* and by re-examining the fairly abundant blue-green *Oscillatoria limosa* which is considered to be pollution-tolerant (Palmer, 1962, 1969; Fjerdingstad, 1965). A total of 30 algal species was collected at this station. This high number also supports the relatively clean-water interpretation.

Najas flexilis, the only higher aquatic plant at this site, occurred abundantly on the inside curves of the stream's meanderings where the flow rate was lowest. This species is reasonably tolerant to pollution and occurs widely in unpolluted streams.

Station 2, Rt. 650 Bridge

The total amount of algae at this site exceeded that observed at Station 1, perhaps due to lower turbidity, more open exposure to sunlight, and shallower and wider stream morphometry. Blue-green algae were relatively sparse at this site, while *Cladophora glomerata*, highly epiphytized with *Cocconeis*, and *Melosira varians* were very abundant. While these algae are considered somewhat pollution-tolerant, they are not certain indicators of pollution. Furthermore, their association with fairly substantial populations of the diatoms *Cymbella prostrata, C. ventricosa*, and *Tabellaria flocculosa*, none of which are pollution-tolerant, constituted reasonable evidence that the South River was clean at this location. As with Station 1, 30 algal species were collected at Station 2.

Anacharis canadensis joined *Najas flexilis* at this station, and neither of these higher plant species represents good pollution indicators, although they are probably quite pollution-tolerant.

Station 3, Above du Pont Plant

Samples from transects just above the dam provided evidence that blue-green algae represented a relatively insignificant part of the total algal biomass. The continued abundance of *Cladophora glomerata*, some *Melosira varians*, and lesser amounts of other algae constituted no basis for assuming severe pollution stress at this location. However, the first appearance of *Hydrodictyon reticulatum* could indicate high NH_4^+, NO_3^-, and organic matter of human origin. *Hydrodictyon* frequently thrives in sewage oxidation ponds in late summer (Fjerdingstad, 1965). A total of 29 algae were collected from this site.

Higher aquatic plants at Station 3 were not abundant in comparison with the algae, but the total number of species increased to four. These species are all fairly widespread in clean water and are pollution-tolerant as well.

Station 4, Throughout du Pont Property

Striking biological changes occurred throughout the length of this station. The previously abundant *Cladophora glomerata* disappeared altogether just below the du Pont sewage treatment plant outfall and *Rhizoclonium heiroglyphicum* made an appearance, especially along the left bank opposite Crompton-Shenandoah. Also, below the du Pont sewage treatment plant outfall, *Oedogonium microgonium* occurred for the first time and in considerable abundance, while *Stigeoclonium tenue* made a first appearance. Fjerdingstad (1965) notes that *Cladophora glomerata* is often replaced by *Stigeoclonium tenue* and other algae which are more pollution tolerant. *S. tenue*, for example, is tolerant to high organic matter, high phosphate, low pH, and toxic metals. More specifically it is more resistant to copper, chromium, phenol, and other metallic poisons than algae like *Cladophora*. Fjerdingstad (1965) quotes Islam (1963) as noting, "Occasionally, toxic ions may be present in sufficient concentration to kill or inhibit other great filamentous algae like *Cladophora, Oedogonium*, etc. whereas *Stigeoclonium* may survive and tolerate the toxicity fairly well." Also, it is possible that the high suspended solids in the South River aided in scouring out the *Cladophora glomerata*. *Rhizoclonium* is fairly tolerant of pollution but also occurs in clean water (Fjerdingstad, 1965; Palmer, 1962). Thus, the data at Station 4, especially for the green algae, suggested that an increase in pollution stress was taking place relative to Stations 1, 2, and 3. This interpretation is not obviously supported by the total of 31 algae collected. However, this figure is misleading because it represents the algae collected in both shore-to-shore and upstream-downstream transects. The center of the stream throughout most of the length of Station 4 contained the greatest number of algal species and resembled most closely the species composition of the Station 3 algal community. However, at no shore-to-shore transect at or below the organic solvent and thermal outfall were more than 10 algae collected. Thus, the total number of species relative to those collected in comparable transects was significantly lower at Station 4, which further indicates significant pollution stress.

A striking increase in abundance of higher aquatic plants also occurred at Station 4, especially on the left bank opposite du Pont. *Potamogeton crispus*, known to be highly tolerant of organic pollution, made its first appearance just below the du Pont sewage treatment plant outfall and rose to maximum abundance over all other higher aquatic plants approximately opposite the organic solvent and thermal outfall. In spite of the heavy sediment load and apparent high turbidity, all four higher aquatic plants appeared healthy along the left bank where noticeable dye from Crompton-Shenandoah seeped through the bank and colored the stream.

One possible explanation for the great biomass of higher aquatic plants at Station 4 and subsequently downstream was the increase in available CO_2 for photosynthesis. As King (1970) has noted, Wright and Mills (1967) reported changes in dominant macrophytes and decreased photosynthesis with downstream decrease in available CO_2 in the Madison River. Now, on the basis of pH and total hardness data collected by du Pont in the South River, one can calculate that a 5-fold or more increase in free CO_2 occurred between Stations 3 and 4, with further increases downstream as far as Station 7. There was thus an apparent positive correlation between available free CO_2 and the biomass of higher plants. This idea warrants further study.

Algae and higher aquatic plants were absent from all areas significantly warmed by du Pont's organic solvent and thermal outfall throughout Station 4. All data indicate this station was highly stressed from the various waste discharges at the time of the study.

Station 5, Second Street Bridge

The algae at this station were the most uniformly disturbed of the eight stations examined. A significant visible shift toward an abundance of blue-green algae occurred throughout the transects at this site. The considerable abundance of *Anabaena constricta* is noteworthy. This species commonly associated with organic pollution (Pamer, 1962), and is "a good indicator of heavy pollution" (Fjerdingstad, 1965). Fjerdingstad also notes that *A. constricta* often occurs in putrefying sludges and sediments and is insensitive to H_2S or anaerobic conditions. Other indications of organic enrichment at this site were the increased abundances of the green algae *Chlamydomonas* and *Stigeoclonium tenue* and the maximum abundance of

Nitzschia palea among the diatoms. The total number of 21 algal species collected further supports the interpretation that the aquatic environment at Station 5 was under severe stress.

A reduction in higher aquatic plant species also occurred at Station 5, but the pollution-tolerant *Potamogeton crispus, Najas flexilis,* and *Lemna* sustained considerable abundance as compared with Stations 1 to 3.

Station 6, Dooms, Virginia, Route 611 Bridge

In spite of the greater width of the South River at this location, transect sampling recovered only small quantities of algae. The reduction in numbers of blue-green algae, the absence of *Stigeoclonium tenue* and *Anabaena constricta*, and reappearance of *Rhizoclonium* along with several pollution-sensitive diatoms suggested a certain amount of stream recovery may have occurred at this station relative to Station 5. However, the total of 20 algal species still indicated an environmentally stressed situation.

The visible biomass of higher aquatic plants reached a maximum at this location. In addition, the number of higher plant species reached a maximum value of 12 here, which may also indicate the lack of severe stress but a gradual return to an oxidizing, nutrient-rich medium. Dissolved CO_2 also was high at this station based on King's (1970) monograph and du Pont chemical data.

Station 7, Crimora, Virginia, Route 612

The relative abundances of *Rhizoclonium* and the diatoms *Fragillaria* and *Gyrosigma* along with the absence of *Nitzschia palea* at this site suggest that the South River had recovered further from its polluted condition upstream. The total algal species numbers remained low at 17, however, which suggests that recovery was still incomplete.

The abundance and numbers of higher aquatic plant species exhibited marked decreases at this station compared with Station 6. Perhaps some nutrients had become more limiting at this station.

Station 8, Route 778 Bridge

Reappearance of *Chroococcus dispersus, Hydrodictyon reticulatum*, and *Amphora*; continued abundance of *Cyclotella* from Station 7; and the continued absence of such reliable indicators of pollution as *Nitzschia palea,* *Stigeoclonium tenue*, and *Anabaena constricta*, all suggest that the South River had appreciably recovered at this station.

A further reduction in total abundance of higher aquatic plants, along with a reduction in the amount of the pollution-tolerant *Potamogeton crispus*, probably supports the same conclusion based on the algal species, that the river was quite clean at this location. The first appearance of a moss at this station suggests the possibility of lower water temperature, perhaps from springs or tributary streams.

Conclusions

1. A natural change in algal and higher aquatic plant species occurred over the stretch of the South River from Stations 1 to 8. However, a pronounced change, possibly induced by the introduction of waste discharges, occurred in the algal and higher aquatic plant communities from Station 4 onwards.

2. Pollution stress appeared greatest at Stations 4 and 5 where the total numbers of algal species collected in shore-to-shore transects were markedly lower than at Stations 1, 2, and 3. Also, the more abundant algal species at Stations 4 and 5 (e.g., *Anabaena constricta, Stigeoclonium tenue*, and *Nitzschia palea*) coupled with apparent losses of species (e.g., *Cladophora glomerata*) support this conclusion.

3. The South River appears to recover progressively from Station 5 to Station 8, but complete recovery was not achieved, based on total algal species numbers and the algal composition.

BACTERIAL STUDIES

by

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BACTERIAL STUDIES

Introduction

The objectives of this phase of the study were to determine (1) the general bacterial quality of the South River and (2) the fecal coliform level as measured by the most probable number technique (MPN).

The bacterial quality at different points on the South River above and below Waynesboro should reflect the response of decomposers to organic materials from agricultural, industrial, and domestic sources. Bacteria utilize dissolved organic material as a source of energy and, therefore, play a vital role in the energy flow in an aquatic system. From a water quality viewpoint bacteria are important for two major reasons: (1) The presence of fecal coliforms indicates the potential presence of enteric bacteria and, therefore, possible pathogenic forms; (2) While using soluble organics as a source of food, bacteria consume oxygen and, therefore, are the major cause of the oxygen sag associated with organically enriched streams and rivers.

Based on information received from du Pont personnel, the Virginia State Water Control Board, and Federal Water Pollution Control Administration Technical Report No. 17, we predicted that the bacterial quantity should increase and species diversity decrease from Stations 3 through 5, and by Station 8 the bacterial quantity should decrease and species diversity increase.

The bacterial quality of the South River was studied primarily in the fall of 1970, corresponding with other phases of the biological study. However, additional studies were conducted in the spring of 1971 by the Aquatic Microbiology class at Virginia Polytechnic Institute and State University.

Materials and Methods

The South River was sampled six times in the fall of 1970 to determine bacterial quality. Grab samples of water were collected in sterile 200-ml bottles just below the surface at each station. The samples were kept refrigerated until processed at the Virginia Polytechnic Institute and State University laboratory. Samples were processed within 4 hours of the time of collection. The spread plate method was used to put 0.1 ml of the appropriate dilution on Yeast Extract (Difco) 0.1%, Peptone (Difco) 0.1%, Pond Sediment (10% by vol.) agar medium (YEPPS), and standard Plate Count Agar (Difco) to determine bacterial diversity and density. All plates were incubated for 5 days at 30°C. Bacteria were stained by the Kopeloff-Beerman method (Skerman, 1967). A replicate plate method was used to assay the gram-negative-to-positive ratio by using a velvet disc to transfer some cell material from each colony to the bottom of a glass petri plate which was then stained. Gram reaction was determined by scanning the plate with a dissecting microscope. Skerman's key was used to determine genera of the isolates (Skerman, 1967). A variety of growth media was used, since bacteria differ between genera in their growth requirements.

Fecal coliforms were determined by the high temperature method with EC medium and boric acid lactose broth according to the 12th edition of Standard Methods (1965).

Results and Discussion

Data are summarized in Tables 6, 7, 8, and 9; and data of September 18, 1970, are shown in Figure 5.

There were consistently more fecal coliforms and a higher bacterial count at Station 1 with respect to the next two downstream stations. These data suggest agricultural runoff has a significant effect on water quality. The water was turbid at Station 1 at all sampling times and was also turbid in Spring 1971 when the downstream stations were not.

Streptococcus bovis, a common species in cattle feces, was isolated at Station 1 in April and May 1971, whereas at Stations 2 and 8 *Streptococcus durans* was isolated. Animal contamination was suspected in both cases, since these stations were in a section of the river which passed through pasture areas. At Stations 4, 5, 6, and 7 the only fecal streptococcus which was isolated was *Streptococcus faecalis*. This bacterium is commonly isolated from human feces. There was a definite rise in fecal contamination as the South River passed through the city. The stream sediment at Station 5 contained a high concentration of enterobacteriaceae based upon recovery on Hektoen agar; the genera isolated included *Proteus vettgeri, Escherichia coli,* and strains of *Salmonella* which could not be identified. According to Virginia Streams Standards, no part of the study areas met Subclass C standards (water satisfactory for use as public or municipal water supply requiring disinfection only). The fecal coliform counts repeatedly were above Subclass B stream standards (primary contact recreation monthly average not more than 2400/100 ml coliform) at upstream and some downstream locations. At Stations 5 and 6 the coliform count exceeded limits for secondary contact recreation (monthly average value not more than 500/100 ml).

TABLE 6

Bacterial Data Summary, South River.

Stations	Bacterial Count*					Fecal Coliform**			(G—/G+)***
	18 Sept	1 Oct	12 Nov	4 Dec	Avg	2 Sept	10 Sept	18 Sept	Avg
1	1.3×10^5	6.3×10^4	--	2.0×10^4	7.0×10^4	>1609	2300	4900	5.8
2	4.0×10^4	6.3×10^3	2.0×10^4	8.0×10^3	1.8×10^4	>1609	1700	3300	7.9
3	2.5×10^4	8.0×10^3	5.0×10^4	2.0×10^4	1.6×10^4	>1609	500	1300	7.8
4a	8.0×10^5	2.0×10^5	--	6.3×10^5	5.0×10^5	>1609	800	1700	41.2
4b	2.0×10^6	5.0×10^5	--	8.0×10^5	1.0×10^6	--	--	--	30.3
5	1.6×10^6	3.2×10^5	2.0×10^5	6.3×10^5	8.1×10^5	>1609	4900	3300	54.6
6	1.3×10^6	2.0×10^6	2.0×10^5	2.0×10^5	1.2×10^6	>1609	54200	4900	65.0
7	1.6×10^5	6.3×10^4	2.0×10^5	6.3×10^4	9.0×10^4	221	200	1100	104.0
8	1.3×10^6	2.0×10^4	1.6×10^5	1.6×10^4	4.5×10^5	>1609	200	800	28.1

*Bacterial count of South River (Log_{10}/ml sample). Samples on Nov. 12 were taken after heavy rain the previous 24 hours and are not included in the average.

**MPN Index per 100 ml.

***Ratio of gram-negative colonies to gram-positive colonies. Data represent combined observations from Sept. 18, Oct. 1, and Dec. 4, 1970.

4a Right bank below du Pont outfall.

4b Left bank below Crompton-Shenandoah.

TABLE 7

Fecal Coliform and Fecal Streptococci Analysis, by Stations.

	Fecal Coliform, MPN/100 ml		Fecal Streptococci, MPN/100 ml	
Station	18 April 1971	17 May 1971	18 April 1971	17 May 1971
1	348	2,600	542	1,100
2	46	1,609	221	918
3	172	2,700	542	1,400
4a	7,900	7,000	1,700	1,700
4b	200	7,000	10,900	800
5	13,000	54,200	4,900	3,300
6	17,200	17,200	3,300	1,300
7	3,300	3,300	500	700
8	1,100	4,600	2,100	2,300

4a Right bank below du Pont outfall.
4b Left bank below Crompton-Shenandoah.

TABLE 8

Evaluation of Bacterial Communities at Station 4.

Relation of Bacteria in Each System

Relationship	Crompton Ecosystem	du Pont Ecosystem
Pseudomonas/Total Count	66.5/100	78/100
Pseudomonas/Other Bacteria Count	2.44/1.00	4.34/1.00
Other Bacteria/Total Count	26.1/100	19/100

Bacterial Population of Each System

Organism	Crompton Ecosystem ($x10^4$/ml)	du Pont Ecosystem ($x10^4$/ml)
Pseudomonas	304	173
Flavobacterium	30	21
Achromobacter	15	21
Vibrio	12	15
Bacillus	4	3
Aeromonas	5	3
Alcaligenes	4	3
Serratia	--	5
Total Plate Count/ml	$3.8x10^6$	$2.6x10^6$

TABLE 9

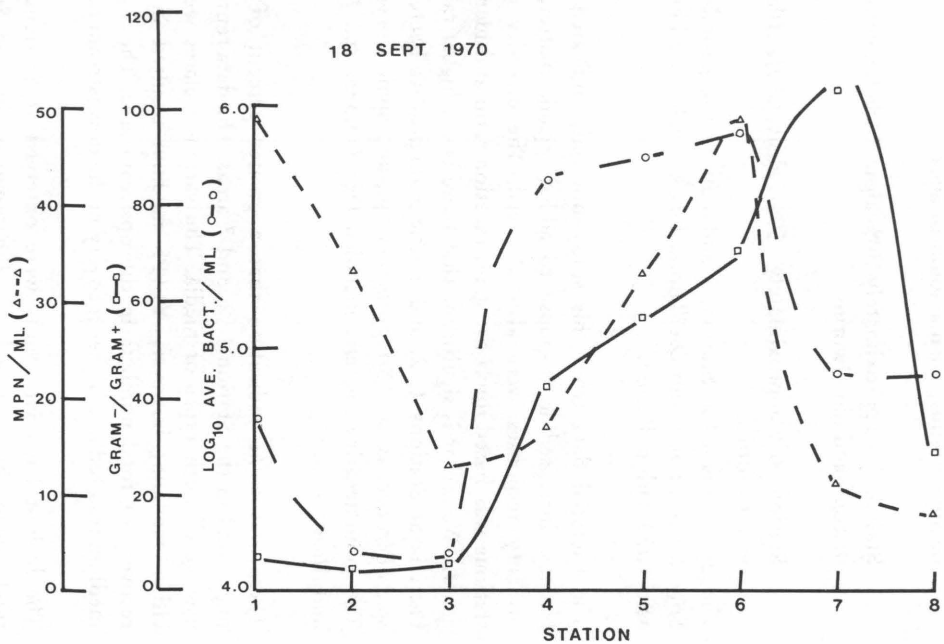
Filamentous Molds and Yeasts in South River, April 30, 1971.

Station	Yeasts	Molds
1	4,000*	20,500
2	2,000	11,500
3	3,000	11,500
4	250	5,250
5	5,000	7,666
6	1,250	6,250
7	2,500	25,500
8	--	--

*per ml

FIGURE 5

Fecal Coliforms, Gram-/Gram+ Ratio, and Bacterial Densities by Stations, September 18, 1970.



The total bacterial count data also reflected the agricultural waste added to Station 1. The maximum count was observed at Station 4. The streambed at Station 4 contained filamentous growth which appeared to be *Sphaerotilus*. On May 17, 1971, the microscopic examination of Surber samples produced the following results:

Station 4 – predominately filamentous forms (90%) which appeared to be *Sphaerotilus*, small amount of algae.

Station 5 – approximately 30% algae, 50% filamentous bacteria, many diatoms and bloodworms.

Station 6 – approximately 50% algae, 10% filamentous bacteria, various forms.

The algae observed at Stations 5 and 6 during this period were dominated by *Stigeclonium tenue* and *Oscillatoria limosa*, which are blue-green algae often associated with pollution.

The bacterial data from this study not only indicated that the bacterial biomass increased in response to added organic matter, but crude species diversity responses were also observed. The diversity difference between stations was based upon the gram reaction ratio and identification of major genera. We feel it is significant that there was a higher ratio of gram-positive bacteria at Stations 1, 2, and 3. The gram-positive bacteria include *Bacillus* sp., *Micrococcus* sp., *Streptomyces* sp., and some *Corynebacterium* types. The gram-negative bacteria included *Pseudomonas* sp., *Flavobacterium* sp., and *Alcaligenes* sp.

There was some indication that a greater percent of the colonies were pigmented in the Station 1, 2, and 3 areas. The data represent the combined average of both types of media. The various isolates were able to grow on either medium; however, YEPPS medium resulted in a slightly greater recovery of total numbers in the upstream area. The Standard Plate Count medium resulted in a higher recovery in the downstream region.

The highest bacterial counts were observed at Stations 4, 5, and 6. The predominant bacteria included *Pseudomonas* sp. and *Sphaerotilus* sp. The bacterial count decreased below Station 6, and there was a shift from *Pseudomonas* sp. toward *Flavobacterium* sp. At Station 7, the highest gram-negative/gram-positive ratio was observed; and at Station 8, the ratio was below the ratio observed from Stations 4 through 7. The bacterial data in this study fitted the diagrammatic presentation of organic material on stream ecology by Hynes (1960) very closely.

The comparison between the Crompton-Shenandoah and du Pont sides of the South River was of interest at Station 4. The total count was usually greater on the Crompton side. The data in Table 8 indicated that at Station 4 the bacterial populations were somewhat different on the left and right bank. There was a greater predominance of *Pseudomonas* sp. associated with du Pont waste, although *Pseudomonas* is one of the major genera in both systems. It should be pointed out that *Sphaerotilus* will not appear on the types of isolation media used in this study.

A preliminary study of filamentous molds and yeasts produced some interesting results (Table 9). The mold count decreased dramatically at Stations 5 through 7 in response to the waste discharges and recovered at Station 8. The yeasts showed a similar response except at Station 5 where there was a maximum count. These differences were confirmed on two subsequent sample dates.

Conclusions

1. A higher bacterial count and more fecal coliforms were recorded at Station 1 than at the other two reference stations (2 and 3). The presence of *Streptococcus bovis*, a common member in cattle feces, indicated this was probably due to agricultural runoff.

2. The presence of *Streptococcus faecalis*, a common isolate in human feces, at Stations 4, 5, 6, and 7 was correlated with the rise in fecal coliform MPN as the South River passed through the city. This indicated the presence of contamination of human origin.

3. No sampling station in the survey met the Virginia Stream Standard for fecal coliform Subclass C as it relates to public municipal water supply.

4. *Sphaerotilus* sp. dominated the bacterial community at Stations 4 and 5.

5. Gram-negative bacteria increased in dominance below Station 3 indicating a change in the bacterial community below the point of major waste discharges into the South River.

6. The highest bacterial counts were found at Stations 5 and 6; this correlated with the oxygen sag found in the field chemistry studies.

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[illegible] of [illegible] and [illegible] [illegible] Table 9). [illegible] stations [illegible] to the waste, the [illegible] Station 8 [illegible] a similar [illegible] (at Station 4) [illegible] these [illegible]

Conclusions

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[illegible] Streptococcus faecalis, [illegible] 4, 5, 6, and 7 was [illegible] South [illegible] [illegible] of [illegible] origin.

6. No sampling station in the survey met the Virginia Stream Standa[illegible] fecal coliforms. [illegible] public municipal sewerage

[illegible] bacterial community [illegible]

[illegible] bacteria [illegible] Station [illegible] a change in the bacterial community below the [illegible] [illegible] into the South River.

The highest bacterial counts were found at Stations 5 and 6 correlated with the oxygen [illegible] found in the field chemistry studies.

WATER CHEMISTRY

by

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WATER CHEMISTRY

Methods

Water samples for chemical analysis were collected at the time of the biological survey in order to correlate chemical water quality with biological water quality. Water samples were collected by Dr. Kenneth L. Dickson on September 1 (Stations 1 and 2), September 2 (Stations 3 and 4), September 3 (Stations 5 and 6), and September 4 (Stations 7 and 8). The analytical services group at the du Pont plant performed all the analyses shown in Table 10, with the exception of phosphate analyses which were carried out at Virginia Polytechnic Institute and State University, and mercury and pesticide analyses which were done by the Virginia State Water Control Board. Field determinations for dissolved oxygen concentration, temperature, hardness alkalinity, and pH were made at the time of the bottom fauna survey and are shown in Table 11.

All laboratory analyses (except mercury and pesticides) were conducted in accordance with the 12th edition of Standard Methods or by atomic absorption spectroscopy where applicable. Mercury and pesticides were analyzed by neutron activation and gas chromatography, respectively. Field determinations were made using a Hach field kit.

Results

The effects of waste discharges in the Waynesboro area on the chemical water quality of the South River seemed to be predominately associated with nutrient enrichment (carbon and phosphorus). The introduction of organic material via waste discharges was reflected in the BOD_5 and Loss-on-Ignition values in Table 11. At Stations 1, 2, and 3 the BOD_5 did not exceed 1.1 ppm. However, at Stations 4 and 5 the BOD_5 was 9.1 and 7.6, respectively. Loss on Ignition (an indirect measure of organic material) was 216.5 ppm and 226.4 ppm, respectively, compared to a maximum of 124.6 ppm at Reference Station 1. Soluble organic material can be utilized by bacteria and other microorganisms as a source of food. These organisms require oxygen in the biodegradation and respiration of organic material. The oxygen sag observed in the field determinations (Table 11) was probably a reflection of this phenomena. Phosphorus enrichment was most apparent between Stations 5 and 6, suggesting the Waynesboro sewage treatment plant as a possible source. However, phosphorus increased over Stations 1, 2, and 3 at Stations 4, 5, 6, 7, and 8, indicating general cultural enrichment from the Waynesboro area.

TABLE 10

Chemical Data – South River Survey.

Parameter	Stations 1	2	3	4	5	6	7	8
NO_3 Nitrogen, ppm	0.14	0.11	0.39	0.42	0.28	0.06	0.03	0.004
NO_2 Nitrogen, ppm	0.01	0.01	0.002	0.008	0.03	0.04	1.02	1.30
NH_3 Nitrogen, ppm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PO_4 – P (Total), ppm	0.194	0.143	0.115	0.2635	0.403	2.21	2.48	1.385
PO_4 – (Ortho), ppm	0.09	0.09	0.08	0.13	0.20	1.94	2.23	1.29
Loss on Ignition, ppm	124.6	83.0	69.4	216.5	226.4	218.5	214.9	169.3
BOD_5, ppm	1.1	0.7	1.1	9.1	7.6	2.3	2.7	1.3
Total Solids, ppm	175.8	112.1	92.9	281.1	329.1	310.6	300.5	235.1
Suspended Solids, ppm	52.5	26.0	14.0	35.6	12.0	4.0	1.1	0.8
Total Hardness, ppm	152.0	124.0	124.0	180.0	186.0	189.0	187.0	180.0
pH	8.00	8.10	8.20	7.90	7.60	7.60	7.50	7.90
Turbidity, ppm	213	66	93	56	57	45	27	29
Sulfates, ppm	12	8	9	102	103	103	102	78
Chlorides, ppm	3.87	2.93	1.76	9.16	34.83	34.29	27.95	16.67
Iron, ppm	0.40	0.19	0.25	0.94	0.35	0.20	0.115	0.09

TABLE 10 (Continued)

Parameter	Stations							
	1	2	3	4	5	6	7	8
Copper, ppm	0.063	0.023	0.008	0.143	0.063	0.046	0.030	0.021
Zinc, ppm	0.022	0.017	0.026	0.134	0.048	0.067	0.032	0.050
Chromium, ppm	0.008	0.007	0.007	0.096	0.111	0.036	0.034	0.025
Lead, ppm	0.009	0.007	0.008	0.012	0.011	0.017	0.018	0.018
Calcium, ppm	24.1	17.7	18.6	27.1	29.2	28.5	28.0	25.9
Magnesium, ppm	8.9	9.4	9.7	12.6	10.8	9.3	10.0	8.5
Sodium, ppm	2.7	1.4	1.6	20.8	44.6	44.8	41.0	29.0
Potassium, ppm	3.0	2.1	2.1	3.9	5.9	6.2	5.7	4.5
Mercury-Water, ppb	0.5	--	--	--	0.5	--	0.5	--
Pesticides-Water, ppm	ND	--	--	--	ND	--	ND	--

ND -- Not detectable

TABLE 11

Field Chemistry – South River Survey.

Parameter	Station Number 1	2	3	4		5		6		7	8
Sampling Location	M	M	M	R	L	R	L	R	L	M	M
Date	9-3-70	9-3-70	9-3-70		9-4-70		9-4-70		9-4-70	9-4-70	9-4-70
Dissolved Oxygen (ppm)	7.8	9.0	8.5	6.3	5.3	3.4	1.0	3.6	4.5	1.7	7.7
Temperature (°C)	23	23.5	23	26	26	26	24	24	23	24	25
Total Hardness (ppm)	188	137	137	188	154	135	188	188	188	188	188
Total Alkalinity (ppm)	171	136	171	154	256	171	171	171	171	171	153
pH	8.0	8.0	8.0	7.6	9.0	7.6	7.5	7.6	7.6	7.5	7.8

R = Right bank looking downstream.
L = Left bank looking downstream.
M = Middle of river.

The nitrogen regime of the South River, based on the data in Table 10, was rather confusing. Since anaerobic conditions were present in the bottom sediments at Stations 5, 6, and 7 (reducing conditions were apparent, with H_2S being present) ammonia nitrogen would be expected. However, none was present in the samples analyzed (Table 10). Studies on the South River in the spring of 1971 by the Aquatic Microbiology Class at Virginia Polytechnic Institute and State University showed ammonia to be present, suggesting that perhaps any ammonia in the samples during the fall of 1970 was lost before analysis. Samples taken in the fall of 1970 were not acidified and ammonia is somewhat transitory.

Total solids were higher at Stations 4, 5, 6, 7, and 8 than at the upstream stations. There was a general increase in the cations and anions at these stations. Perhaps the most dramatic increases were in sulfates and chlorides, which increased approximately ten-fold at Stations 4, 5, 6, 7, and 8 when compared to Stations 1, 2, and 3.

Another water quality change was a decrease in pH at Stations 4, 5, 6, 7, and 8. This could result from biological activity in the river and from waste discharges.

Concentrations of copper, zinc, chromium, and lead increased at Station 4 over Stations 1, 2, and 3. While none of the individual concentrations approached a level generally considered to be acutely toxic to blue-gill sunfish, they were in the range of levels reported to have chronic effects on some fish (Brungs, 1969).

A neutron activation analysis for mercury conducted by the Virginia State Water Control Board showed 0.5 ppb in the water at Stations 1, 5, and 7. Samples for pesticide analyses were also sent to the State Water Control Board at the time of the survey, but none were detected.

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Total solids were higher at Stations 4, 5, 6, 7, and 8 than at the upstream stations. There was a general increase in the [illegible] and anions at the stations. Relative [illegible] were [illegible] sulfates and chlorides which increased approximately ten-fold [illegible] Stations 4, 5, 6, 7, and 8 [illegible] compared to Stations 1, 2, and 3.

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A continuous [illegible] analysis for mercury conducted by the Virginia State Water Control Board [illegible] 0.5 ppb in the water at Stations 4, 5, and 7. Samples for pesticide analyses were also sent to the State Water Control Board at the time of the survey, but none were detected.

GENERAL CONCLUSIONS

by

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[illegible]AL CONCLUSIONS

by

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GENERAL CONCLUSIONS

1. Agricultural runoff and waste discharges from du Pont, Crompton-Shenandoah, the City of Waynesboro, and possible other diffuse or unidentifiable waste sources were adversely affecting biological and chemical water quality in the South River, Virginia, in September 1970.

2. The South River at Harriston, Virginia, 14.0 miles below Waynesboro, had not completely recovered biologically from the stress of the collective waste discharges from the Waynesboro area.

3. Stations 1, 2, and 3, located upstream from the major industrial and domestic waste discharges, supported a diverse and healthy fauna and flora of aquatic life.

4. Station 4, which was contiguous with the du Pont and Crompton-Shenandoah plants, had a drastically-reduced bottom fauna community composed primarily of pollution-tolerant midge larvae. A bank-to-bank transect revealed no significant differences in the bottom fauna community between the left and right banks.

5. The South River in and below Waynesboro, Virginia, to Harriston, Virginia, had a depauperate fish fauna when compared to areas of the river upstream of Waynesboro.

6. The algae decreased in diversity and exhibited a shift in species composition at Stations 4 and 5, which were exposed to the various waste discharges. However, the biomass of attached algae and higher plants increased at Stations 5, 6, and 7, possibly in response to nutrient enrichment.

7. The South River had high coliform counts at all stations. Fecal streptococci were present at Stations 4, 5, 6, and 7, indicating human fecal contamination. Bacterial density increased below Waynesboro, possibly in response to nutrient enrichment.

8. Chemical water quality of the South River between Stations 3 and 4 was characterized by an increase in organic material, phosphorus, heavy metals, total solids, sulfates, chlorides, and total hardness, and a decrease in pH.

[illegible] the City of [illegible] [illegible] [illegible] [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible] Station [illegible] and [illegible] plants [illegible] at Station [illegible] enrichment.

[illegible] had [illegible] possibly [illegible]

Chemical water quality of [illegible] was characterized by an increase [illegible] [illegible] total solids, sulfates, alkalinity [illegible] decrease in pH.

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... supported in part by E. I. du Pont de Nemours and Comp... Waynesboro, Virginia, through a grant to Virginia Polytechnic Institute ... State University. We appreciate the cooperation of du Pont personnel Mr. Roger Taylor, Mr. Jim McKenzie, and Mr. John Mays whose advice ... great support was invaluable. We are indebted to Mr. Robert Jennings ... the Virginia State Water Control Board for providing information a... technical assistance in this survey. We appreciate the cooperation of t... Virginia Water Resources Research Center in publishing the results of t... study.

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APPENDIX
BOTTOM FAUNA DATA SHEETS

du Pont Survey, South River
Station Number 1

	Bottom Net	S-1	S-2	S-3	S-4	S-5	Total
Ephemeroptera (mayflies)							
Centroptilium sp.	P	1	-	-	-	-	1
Ephemera sp.	-	6	3	7	-	-	16
Ephemerella sp.	P	3	-	1	-	-	4
Epheron sp.	P	-	-	-	-	-	-
Isonychia sp.	P	-	1	-	-	-	1
Siphlonurus sp.	-	-	-	-	-	-	-
Stenonema sp.	P	3	-	6	-	-	9
Pseudocloeon sp.	P	-	-	-	-	-	-
Odonata (dragonflies)							
Agrion sp.	-	-	-	-	-	-	-
Boyeri sp.	-	-	-	-	-	-	-
Macromia sp.	-	-	-	-	-	-	-
Droinogomphus sp.	-	-	-	-	-	-	-
Gomphaeschna sp.	-	-	-	-	-	-	-
Ophiogomphus sp.	-	-	-	1	-	-	1
Plecoptera (stoneflies)							
Acroneuria sp.	-	-	-	-	-	-	-
Diptera (true flies)							
Antocha sp.	P	4	1	-	-	-	5
Athrix varigata	-	-	-	3	-	-	3
CHIRONOMIDAE	P	56	-	20	-	-	76
EPHYDRIDAE	-	-	-	-	-	-	-
Hemerodromia sp.	-	-	-	-	-	-	-
Simulimum sp.	P	-	-	-	-	-	-
Tipula sp.	-	-	-	-	-	-	-
Megaloptera (hellgrammites)							
Sialis sp.	P	-	-	-	-	-	-
Corydauls sp.	P	-	1	-	-	-	1
Nigronia sp.	-	-	-	-	-	-	-
Trichoptera (caddisflies)							
Agraylea sp.	-	-	-	-	-	-	-
Brachycentrus sp.	-	-	-	-	-	-	-
Cheumatopsyche sp.	P	10	26	6	-	-	42
Chimarra sp.	P	-	-	-	-	-	-
Goera sp.	-	-	-	-	-	-	-
Helicopsyche sp.	-	-	-	-	-	-	-
Hydropsyche sp.	P	8	4	1	-	-	13
HYDROPTILIDAE	-	-	-	-	-	-	-
Leucotrichia sp.	-	-	-	-	-	-	-
Macronemum sp.	P	-	-	-	-	-	-
Neureclipsis sp.	-	1	-	1	-	-	2
Neophylax sp.	-	-	-	-	-	-	-
Orthotrichia sp.	-	-	-	-	-	-	-
Protoptilia sp.	-	-	-	-	-	-	-
Psychomyia sp.	-	-	1	-	-	-	1

Station Number 1 (Continued)

	Bottom Net	S-1	S-2	S-3	S-4	S-5	Total
Coleoptera (beetles)							
Berosus sp.	P	-	-	-	-	-	-
Dineutes sp.	P	-	-	-	-	-	-
Dubiraphia sp.	P	3	-	-	-	-	3
Helichus sp.	P	-	-	-	-	-	-
Hydrochus sp.	-	-	-	-	-	-	-
Hydrophilus sp.	-	-	-	-	-	-	-
Laccophilus sp.	-	-	-	-	-	-	-
Macronyshus sp.	P	-	-	-	-	-	-
Optioservus sp.	P	13	-	-	-	-	13
Pormoresia sp.	P	-	-	-	-	-	-
Psephenus herricki	P	9	1	1	-	-	11
Stenelmis sp.	P	8	27	20	-	-	55
Themonectus sp.	-	-	-	-	-	-	-
Triopsternus sp.	-	-	-	-	-	-	-
Hemiptera (true bugs)							
Trichocorixa sp.	-	7	-	-	-	-	7
Belastoma sp.	-	-	-	-	-	-	-
Ranatra sp.	-	-	-	-	-	-	-
Lepidoptera							
Cataclysta sp.	-	-	-	-	-	-	-
Annelida							
Oligochaeta	P	1	1	1	-	-	3
Hirundinea	-	-	-	-	-	-	-
Mollusca							
Ferrissia sp.	P	48	30	8	-	-	86
Gyraulus sp.	-	-	-	-	-	-	-
Lymnaea sp.	P	-	-	-	-	-	-
Musculium sp.	-	-	-	-	-	-	-
Physa sp.	P	-	-	-	-	-	-
Psidium sp.	P	-	-	-	-	-	-
Sphaerium sp.	-	12	-	3	-	-	15
Viviparus sp.	-	-	-	-	-	-	-
Snail sp. 1	-	-	-	-	-	-	-
Isopoda							
Licerus sp.	P	-	-	-	-	-	-
Decapoda							
CAMBARIDAE	P	-	-	-	-	-	-
Acari							
(Water-mite)	-	-	-	1	-	-	1
Platyhelminthes							
PLANARIDAE	-	-	-	-	-	-	-

du Pont Survey, South River
Station Number 2

	Bottom Net	S-1	S-2	S-3	S-4	S-5	Total
Ephemeroptera (mayflies)							
Centroptilium sp.	P	7	1	1	5	-	14
Ephemera sp.	-	1	-	-	-	-	1
Ephemerella sp.	P	10	11	12	38	-	71
Epheron sp.	-	-	-	-	-	-	-
Isonychia sp.	P	5	2	1	7	-	15
Siphlonurus sp.	-	-	-	-	-	-	-
Stenonema sp.	P	10	6	1	4	-	21
Pseudocloeon sp.	-	-	-	-	-	-	-
Odonata (dragonflies)							
Agrion sp.	-	-	-	-	-	-	-
Boyeri sp.	P	-	-	-	-	-	-
Macromia sp.	-	-	-	-	-	-	-
Droinogomphus sp.	-	-	-	-	-	-	-
Gomphaeschna sp.	-	-	-	-	-	-	-
Ophiogomphus sp.	-	-	-	-	-	-	-
Plecoptera (stoneflies)							
Acroneuria sp.	P	-	-	-	1	-	1
Diptera (true flies)							
Antocha sp.	P	33	10	14	18	-	75
Athrix varigata	-	-	-	-	-	-	-
CHIRONOMIDAE	P	44	32	9	6	-	91
EPHYDRIDAE	-	-	-	-	-	-	-
Hemerodromia sp.	-	-	-	-	-	-	-
Simulimum sp.	-	2	1	-	2	-	5
Tipula sp.	P	-	-	-	-	-	-
Megaloptera (hellgrammites)							
Sialis sp.	-	-	-	-	-	-	-
Corydauls sp.	P	-	-	-	-	-	-
Nigronia sp.	-	-	-	-	-	-	-
Trichoptera (caddisflies)							
Agraylea sp.	-	-	-	-	1	-	1
Brachycentrus sp.	P	2	4	5	5	-	16
Cheumatopsyche sp.	P	44	6	9	12	-	71
Chimarra sp.	P	2	-	-	-	-	2
Goera sp.	-	-	-	-	-	-	-
Helicopsyche sp.	-	2	-	-	-	-	2
Hydropsyche sp.	P	52	6	7	41	-	106
HYDROPTILIDAE	-	-	-	-	4	-	4
Leucotrichia sp.	-	-	-	-	-	-	-
Macronemum sp.	P	-	-	-	-	-	-
Neureclipsis sp.	-	-	-	-	-	-	-
Neophylax sp.	-	5	-	-	7	-	12
Orthotrichia sp.	-	-	-	1	-	-	1
Protoptilia sp.	-	3	1	2	2	-	8
Psychomyia sp.	-	1	-	1	-	-	2

Station Number 2 (Continued)

	Bottom Net	S-1	S-2	S-3	S-4	S-5	Total
Coleoptera (beetles)							
Berosus sp.	P	-	-	-	-	-	-
Dineutes sp.	-	-	-	-	-	-	-
Dubiraphia sp.	-	-	-	-	-	-	-
Helichus sp.	-	-	-	-	-	-	-
Hydrochus sp.	-	-	-	-	-	-	-
Hydrophilus sp.	-	-	-	-	-	-	-
Laccophilus sp.	-	-	-	-	-	-	-
Macronyshus sp.	-	-	-	-	-	-	-
Optioservus sp.	-	-	-	1	-	-	1
Pormoresia sp.	-	-	1	-	2	-	3
Psephenus herricki	P	-	-	1	-	-	1
Stenelmis sp.	-	-	-	-	-	-	-
Themonectus sp.	-	-	-	-	-	-	-
Triopsternus sp.	-	-	-	-	-	-	-
Hemiptera (true bugs)							
Trichocorixa sp.	-	-	-	-	-	-	-
Belastoma sp.	-	-	-	-	-	-	-
Ranatra sp.	-	-	-	-	-	-	-
Lepidoptera							
Cataclysta sp.	-	1	-	-	-	-	1
Annelida							
Oligochaeta	P	-	-	1	1	-	2
Hirundinea	P	-	-	-	-	-	-
Mollusca							
Ferrissia sp.	-	-	-	-	-	-	-
Gyraulus sp.	P	-	-	-	-	-	-
Lymnaea sp.	-	-	-	-	-	-	-
Musculium sp.	P	-	-	-	-	-	-
Physa sp.	P	-	-	-	-	-	-
Psidium sp.	P	1	-	-	-	-	1
Sphaerium sp.	-	-	-	-	-	-	-
Viviparus sp.	P	-	-	-	-	-	-
Snail sp. 1	P	220	-	-	-	-	220
Isopoda							
Licerus sp.	-	-	-	-	-	-	-
Decapoda							
CAMBARIDAE	P	-	-	-	-	-	-
Acari							
(Water-mite)	-	-	-	1	-	-	1
Platyhelminthes							
PLANARIDAE	P	1	-	-	-	-	1

du Pont Survey, South River
Station Number 3

	Bottom Net	S-1	S-2	S-3	S-4	S-5	Total
Ephemeroptera (mayflies)							
Centroptilium sp.	-	-	-	-	-	-	-
Ephemera sp.	-	-	-	-	-	-	-
Ephemerella sp.	-	-	-	-	-	-	-
Epheron sp.	-	-	-	-	-	-	-
Isonychia sp.	-	-	-	-	-	-	-
Siphlonurus sp.	-	-	-	-	-	-	-
Stenonema sp.	P	-	1	-	-	-	1
Pseudoclocon sp.	-	-	-	-	-	-	-
Odonata (dragonflies)							
Agrion sp.	-	-	-	-	-	-	-
Boyeri sp.	-	-	-	-	-	-	-
Macromia sp.	-	-	-	-	-	-	-
Droinogomphus sp.	-	-	-	-	-	-	-
Gomphaeschna sp.	-	-	-	-	-	-	-
Ophiogomphus sp.	-	-	-	-	-	-	-
Plecoptera (stoneflies)							
Acroneuria sp.	-	-	-	-	-	-	-
Diptera (true flies)							
Antocha sp.	P	-	-	-	1	-	1
Athrix varigata	-	-	-	-	-	-	-
CHIRONOMIDAE	P	60	50	138	106	-	354
EPHYDRIDAE	-	-	-	-	-	-	-
Hemerodromia sp.	-	1	-	-	-	-	1
Simulimum sp.	P	-	-	-	-	-	-
Tipula sp.	P	-	-	-	-	-	-
Megaloptera (hellgrammites)							
Sialis sp.	P	-	-	-	-	-	-
Corydauls sp.	P	-	-	-	-	-	-
Nigronia sp.	P	-	-	-	-	-	-
Trichoptera (caddisflies)							
Agraylea sp.	-	-	-	-	-	-	-
Brachycentrus sp.	P	1	1	22	-	-	24
Cheumatopsyche sp.	P	4	9	27	18	-	58
Chimarra sp.	-	-	-	-	-	-	-
Goera sp.	-	-	-	-	-	-	-
Helicopsyche sp.	-	-	-	-	-	-	-
Hydropsyche sp.	P	-	-	-	-	-	-
HYDROPTILIDAE	-	-	-	-	-	-	-
Leucotrichia sp.	P	-	-	-	-	-	-
Macronemum sp.	-	-	-	-	-	-	-
Neureclipsis sp.	-	-	-	-	-	-	-
Neophylax sp.	-	-	-	-	-	-	-
Orthotrichia sp.	-	-	-	-	-	-	-
Protoptilia sp.	-	-	-	-	-	-	-
Psychomyia sp.	-	-	-	-	-	-	-

Station Number 3 (Continued)

	Bottom Net	S-1	S-2	S-3	S-4	S-5	Total
Coleoptera (beetles)							
Berosus sp.	P	-	-	-	-	-	-
Dineutes sp.	-	-	-	-	-	-	-
Dubiraphia sp.	P	-	-	-	-	-	-
Helichus sp.	-	-	-	-	-	-	-
Hydrochus sp.	-	-	-	-	-	-	-
Hydrophilus sp.	P	-	-	-	-	-	-
Laccophilus sp.	-	-	-	-	-	-	-
Macronyshus sp.	-	-	-	-	-	-	-
Optioservus sp.	P	1	1	-	-	-	2
Pormoresia sp.	P	-	2	3	-	-	5
Psephenus herricki	-	-	1	1	-	-	2
Stenelmis sp.	P	-	-	-	-	-	-
Themonectus sp.	-	-	-	-	-	-	-
Triopsternus sp.	-	-	-	-	-	-	-
Hemiptera (true bugs)							
Trichocorixa sp.	-	-	-	-	-	-	-
Belastoma sp.	-	-	-	-	-	-	-
Ranatra sp.	P	-	-	-	-	-	-
Lepidoptera							
Cataclysta sp.	-	-	-	-	-	-	-
Annelida							
Oligochaeta	P	-	1	-	-	-	1
Hirundinea	-	-	-	-	-	-	-
Mollusca							
Ferrissia sp.	P	1	5	2	-	-	7
Gyraulus sp.	P	20	9	-	-	-	29
Lymnaea sp.	P	-	-	-	-	-	-
Musculium sp.	-	-	-	-	-	-	-
Physa sp.	P	1	-	-	-	-	1
Psidium sp.	-	-	-	-	-	-	-
Sphaerium sp.	P	-	1	2	-	-	3
Viviparus sp.	-	-	-	-	-	-	-
Snail sp. 1	P	35	103	64	8	-	210
Isopoda							
Licerus sp.	-	-	-	-	-	-	-
Decapoda							
CAMBARIDAE	P	-	1	-	-	-	1
Acari							
(Water-mite)	-	-	-	-	-	-	-
Platyhelminthes							
PLANARIDAE	-	-	-	-	-	-	-

du Pont Survey, South River
Station Number 4

	Bottom Net	S-1	S-2	S-3	S-4	S-5	Total
Ephemeroptera (mayflies)							
Centroptilium sp.	-	-	-	-	-	-	-
Ephemera sp.	-	-	-	-	-	-	-
Ephemerella sp.	-	-	-	-	-	-	-
Epheron sp.	-	-	-	-	-	-	-
Isonychia sp.	-	-	-	-	-	-	-
Siphlonurus sp.	-	-	-	-	-	-	-
Stenonema sp.	-	-	-	-	-	-	-
Pseudocloeon sp.	-	-	-	-	-	-	-
Odonata (dragonflies)							
Agrion sp.	-	-	-	-	1	-	1
Boyeri sp.	-	-	-	-	-	-	-
Macromia sp.	-	-	-	-	-	-	-
Droinogomphus sp.	-	-	-	-	-	-	-
Gomphaeschna sp.	-	-	-	-	-	-	-
Ophiogomphus sp.	-	-	-	-	-	-	-
Plecoptera (stoneflies)							
Acroneuria sp.	-	-	-	-	-	-	-
Diptera (true flies)							
Antocha sp.	-	-	-	-	-	-	-
Athrix varigata	-	-	-	-	-	-	-
CHIRONOMIDAE	P	62	225	397	38	18	1087
EPHYDRIDAE	P	-	-	-	-	-	-
Hemerodromia sp.	-	-	-	-	-	-	-
Simulimum sp.	-	-	-	-	-	-	-
Tipula sp.	-	-	-	-	-	-	-
Megaloptera (hellgrammites)							
Sialis sp.	-	-	-	-	-	-	-
Corydauls sp.	-	-	-	-	-	-	-
Nigronia sp.	-	-	-	-	-	-	-
Trichoptera (caddisflies)							
Agraylea sp.	-	-	-	-	-	-	-
Brachycentrus sp.	-	-	-	-	-	-	-
Cheumatopsyche sp.	-	-	-	-	-	-	-
Chimarra sp.	-	-	-	-	-	-	-
Goera sp.	-	-	-	-	-	-	-
Helicopsyche sp.	-	-	-	-	-	-	-
Hydropsyche sp.	-	-	-	-	-	-	-
HYDROPTILIDAE	-	-	-	-	-	-	-
Leucotrichia sp.	-	-	-	-	-	-	-
Macronemum sp.	-	-	-	-	-	-	-
Neureclipsis sp.	-	-	-	-	-	-	-
Neophylax sp.	-	-	-	-	-	-	-
Orthotrichia sp.	-	-	-	-	-	-	-
Protoptilia sp.	-	-	-	-	-	-	-
Psychomyia sp.	-	-	-	-	-	-	-

Station Number 4 (Continued)

	Bottom Net	S-1	S-2	S-3	S-4	S-5	Total
Coleoptera (beetles)							
Berosus sp.	-	-	-	-	-	-	-
Dineutes sp.	-	-	-	-	-	-	-
Dubiraphia sp.	-	-	-	-	1	-	1
Helichus sp.	-	-	-	-	-	-	-
Hydrochus sp.	-	1	-	-	-	-	1
Hydrophilus sp.	-	-	-	-	-	-	-
Laccophilus sp.	-	-	-	-	1	-	1
Macronyshus sp.	-	-	-	-	-	-	-
Optioservus sp.	-	-	-	-	-	-	-
Pormoresia sp.	-	-	-	-	-	-	-
Psephenus herricki	-	-	-	-	-	-	-
Stenelmis sp.	-	-	-	-	-	-	-
Themonectus sp.	-	-	-	-	-	-	-
Triopsternus sp.	-	-	-	-	-	-	
Hemiptera (true bugs)							
Trichocorixa sp.	-	-	-	-	-	-	-
Belastoma sp.	-	-	-	-	-	-	-
Ranatra sp.	-	-	-	-	-	-	-
Lepidoptera							
Cataclysta sp.	-	-	-	-	-	-	-
Annelida							
Oligochaeta	P	-	-	4	-	-	4
Hirundinea	-	-	-	-	-	-	-
Mollusca							
Ferrissia sp.	-	-	-	-	-	-	-
Gyraulus sp.	-	-	-	-	-	-	-
Lymnaea sp.	-	-	-	-	-	-	-
Musculium sp.	-	-	-	-	-	-	-
Physa sp.	P	-	-	-	1	-	1
Psidium sp.	-	-	-	-	-	-	-
Sphaerium sp.	-	-	-	-	-	-	-
Viviparus sp.	-	-	-	-	-	-	-
Snail sp. 1	-	-	-	-	-	-	-
Isopoda							
Licerus sp.	-	-	-	-	-	-	-
Decapoda							
CAMBARIDAE	-	-	-	-	-	-	-
Acari							
(Water-mite)	-	-	-	-	-	-	-
Platyhelminthes							
PLANARIDAE	-	-	-	-	-	-	-

du Pont Survey, South River
Station Number 5

	Bottom Net	S-1	S-2	S-3	S-4	S-5	Total
Ephemeroptera (mayflies)							
Centroptilium sp.	-	-	-	-	-	-	-
Ephemera sp.	-	-	-	-	-	-	-
Ephemerella sp.	-	-	-	-	-	-	-
Epheron sp.	-	-	-	-	-	-	-
Isonychia sp.	-	-	-	-	-	-	-
Siphlonurus sp.	-	-	-	-	-	-	-
Stenonema sp.	-	-	-	-	-	-	-
Pseudoclocon sp.	-	-	-	-	-	-	-
Odonata (dragonflies)							
Agrion sp.	-	-	-	-	-	-	-
Boyeri sp.	-	-	-	-	-	-	-
Macromia sp.	-	-	-	-	-	-	-
Droinogomphus sp.	-	-	-	-	-	-	-
Gomphaeschna sp.	-	-	-	-	-	-	-
Ophiogomphus sp.	-	-	-	-	-	-	-
Plecoptera (stoneflies)							
Acroneuria sp.	-	-	-	-	-	-	-
Diptera (true flies)							
Antocha sp.	-	-	-	-	-	-	-
Athrix varigata	-	-	-	-	-	-	-
CHIRONOMIDAE	P	114	24	-	89	1600	1827
EPHYDRIDAE	-	-	-	-	-	-	-
Hemerodromia sp.	-	-	-	-	-	-	-
Simulimum sp.	-	-	-	-	-	-	-
Tipula sp.	-	-	-	-	-	-	-
Megaloptera (hellgrammites)							
Sialis sp.	-	-	-	-	-	-	-
Corydauls sp.	-	-	-	-	-	-	-
Nigronia sp.	-	-	-	-	-	-	-
Trichoptera (caddisflies)							
Agraylea sp.	-	-	-	-	-	-	-
Brachycentrus sp.	-	-	-	-	-	-	-
Cheumatopsyche sp.	-	-	-	-	-	-	-
Chimarra sp.	-	-	-	-	-	-	-
Goera sp.	-	-	-	-	-	-	-
Helicopsyche sp.	-	-	-	-	-	-	-
Hydropsyche sp.	-	-	-	-	-	-	-
HYDROPTILIDAE	-	-	-	-	-	-	-
Leucotrichia sp.	-	-	-	-	-	-	-
Macronemum sp.	-	-	-	-	-	-	-
Neureclipsis sp.	-	-	-	-	-	-	-
Neophylax sp.	-	-	-	-	-	-	-
Orthotrichia sp.	-	-	-	-	-	-	-
Protoptilia sp.	-	-	-	-	-	-	-
Psychomyia sp.	-	-	-	-	-	-	-

Station Number 5 (Continued)

	Bottom Net	S-1	S-2	S-3	S-4	S-5	Total
Coleoptera (beetles)							
Berosus sp.	-	-	-	-	-	-	-
Dineutes sp.	-	-	-	-	-	-	-
Dubiraphia sp.	-	-	-	-	-	-	-
Helichus sp.	-	-	-	-	-	-	-
Hydrochus sp.	-	-	-	-	-	-	-
Hydrophilus sp.	-	-	-	-	-	-	-
Laccophilus sp.	-	-	-	-	-	-	-
Macronyshus sp.	-	-	-	-	-	-	-
Optioservus sp.	-	-	-	-	-	-	-
Pormoresia sp.	-	-	-	-	-	-	-
Psephenus herricki	-	-	-	-	-	-	-
Stenelmis sp.	-	-	-	-	-	-	-
Themonectus sp.	-	-	-	-	-	-	-
Triopsternus sp.	-	-	-	-	-	-	-
Hemiptera (true bugs)							
Trichocorixa sp.	-	-	-	-	-	-	-
Belastoma sp.	-	-	-	-	-	-	-
Ranatra sp.	-	-	-	-	-	-	-
Lepidoptera							
Cataclysta sp.	-	-	-	-	-	-	-
Annelida							
Oligochaeta	P	12	11	-	1	3	27
Hirundinea	-	-	-	-	-	-	-
Mollusca							
Ferrissia sp.	-	-	-	-	-	-	-
Gyraulus sp.	-	-	-	-	-	-	-
Lymnaea sp.	-	-	-	-	-	-	-
Musculium sp.	-	-	-	-	-	-	-
Physa sp.	-	-	-	-	-	-	-
Psidium sp.	-	-	-	-	-	-	-
Sphaerium sp.	-	-	-	-	-	-	-
Viviparus sp.	-	-	-	-	-	-	-
Snail sp. 1	-	-	-	-	-	-	-
Isopoda							
Licerus sp.	-	-	-	-	-	-	-
Decapoda							
CAMBARIDAE	-	-	-	-	-	-	-
Acari							
(Water-mite)	-	-	-	-	-	-	-
Platyhelminthes							
PLANARIDAE	-	-	-	-	-	-	-

du Pont Survey, South River
Station Number 6

	Bottom Net	S-1	S-2	S-3	S-4	S-5	Total
Ephemeroptera (mayflies)							
Centroptilium sp.	-	-	-	-	-	-	-
Ephemera sp.	-	-	-	-	-	-	-
Ephemerella sp.	-	-	-	-	-	-	-
Epheron sp.	-	-	-	-	-	-	-
Isonychia sp.	-	-	-	-	-	-	-
Siphlonurus sp.	-	-	-	-	-	-	-
Stenonema sp.	-	-	-	-	-	-	-
Pseudocloeon sp.	-	-	-	-	-	2	2
Odonata (dragonflies)							
Agrion sp.	P	1	-	-	-	-	1
Boyeri sp.	-	-	-	-	-	-	-
Macromia sp.	-	-	-	-	-	-	-
Droinogomphus sp.	-	-	-	-	-	-	-
Gomphaeschna sp.	-	-	-	-	-	-	-
Ophiogomphus sp.	-	-	-	-	-	-	-
Plecoptera (stoneflies)							
Acroneuria sp.	-	-	-	-	-	-	-
Diptera (true flies)							
Antocha sp.	-	-	-	-	-	-	-
Athrix varigata	-	-	-	-	-	-	-
CHIRONOMIDAE	P	70	40	60	102	190	462
EPHYDRIDAE	-	-	-	-	-	-	-
Hemerodromia sp.	-	-	-	-	-	1	1
Simulimum sp.	P	-	-	-	-	-	-
Tipula sp.	-	-	-	-	-	-	-
Megaloptera (hellgrammites)							
Sialis sp.	-	-	-	-	-	-	-
Corydauls sp.	-	-	-	-	-	-	-
Nigronia sp.	-	-	-	-	-	-	-
Trichoptera (caddisflies)							
Agraylea sp.	-	-	-	-	-	-	-
Brachycentrus sp.	-	-	-	-	-	-	-
Cheumatopsyche sp.	-	-	-	-	-	-	-
Chimarra sp.	-	-	-	-	-	-	-
Goera sp.	-	-	-	-	-	-	-
Helicopsyche sp.	-	-	-	-	-	-	-
Hydropsyche sp.	P	-	-	-	-	-	-
HYDROPTILIDAE	-	-	-	-	-	-	-
Leucotrichia sp.	-	-	-	-	-	-	-
Macronemum sp.	-	-	-	-	-	-	-
Neureclipsis sp.	-	-	-	-	-	-	-
Neophylax sp.	-	-	-	-	-	-	-
Orthotrichia sp.	-	-	-	-	-	-	-
Protoptilia sp.	-	-	-	-	-	-	-
Psychomyia sp.	-	-	-	-	-	-	-

Station Number 6 (Continued)

	Bottom Net	S-1	S-2	S-3	S-4	S-5	Total
Coleoptera (beetles)							
Berosus sp.	P	-	-	-	-	-	-
Dineutes sp.	-	-	-	-	-	-	-
Dubiraphia sp.	-	-	-	-	-	-	-
Helichus sp.	-	-	-	-	-	-	-
Hydrochus sp.	-	-	-	-	-	-	-
Hydrophilus sp.	-	-	-	-	-	-	-
Laccophilus sp.	P	-	-	-	-	1	1
Macronyshus sp.	-	-	-	-	-	-	-
Optioservus sp.	-	-	-	-	-	-	-
Pormoresia sp.	-	-	-	-	-	-	-
Psephenus herricki	-	-	-	-	-	-	-
Stenelmis sp.	-	-	-	-	-	-	-
Themonectus sp.	P	-	-	-	-	-	-
Triopsternus sp.	P	-	-	-	-	-	-
Hemiptera (true bugs)							
Trichocorixa sp.	-	-	-	-	-	-	-
Belastoma sp.	-	-	-	-	-	-	-
Ranatra sp.	-	-	-	-	-	-	-
Lepidoptera							
Cataclysta sp.	-	-	-	-	-	-	-
Annelida							
Oligochaeta	P	80	13	9	6	3	111
Hirundinea	-	-	-	-	-	-	-
Mollusca							
Ferrissia sp.	-	-	-	-	-	-	-
Gyraulus sp.	-	-	-	-	-	-	-
Lymnaea sp.	-	-	-	-	-	-	-
Musculium sp.	-	-	-	-	-	-	-
Physa sp.	P	-	-	-	-	-	-
Psidium sp.	-	-	-	-	-	-	-
Sphaerium sp.	-	-	-	-	-	-	-
Viviparus sp.	-	-	-	-	-	-	-
Snail sp. 1	-	-	-	-	-	-	-
Isopoda							
Licerus sp.	-	-	-	-	-	-	-
Decapoda							
CAMBARIDAE	P	-	-	-	-	-	-
Acari							
(Water-mite)	-	-	-	-	-	-	-
Platyhelminthes							
PLANARIDAE	-	-	-	-	-	-	-

du Pont Survey, South River
Station Number 7

	Bottom Net	S-1	S-2	S-3	S-4	S-5	Total
Ephemeroptera (mayflies)							
Centroptilium sp.	-	-	-	-	-	-	-
Ephemera sp.	-	-	-	-	-	-	-
Ephemerella sp.	-	-	-	-	-	-	-
Epheron sp.	-	-	-	-	-	-	-
Isonychia sp.	-	-	-	-	-	-	-
Siphlonurus sp.	P	-	-	-	-	-	-
Stenonema sp.	-	-	-	-	-	-	-
Pseudoclocon sp.	-	-	-	-	-	-	-
Odonata (dragonflies)							
Agrion sp.	P	2	2	1	2	0	7
Boyeri sp.	P	-	-	-	-	-	-
Macromia sp.	-	-	-	-	-	-	-
Droinogomphus sp.	-	-	-	-	-	-	-
Gomphaeschna sp.	P	-	-	-	-	-	-
Ophiogomphus sp.	-	-	-	-	-	-	-
Plecoptera (stoneflies)							
Acroneuria sp.	-	-	-	-	-	-	-
Diptera (true flies)							
Antocha sp.	-	-	-	-	-	-	-
Athrix varigata	-	1	1	-	-		2
CHIRONOMIDAE	P	1000	1500	343	173	115	3131
EPHYDRIDAE	-	-	-	-	-	-	-
Hemerodromia sp.	-	-	-	-	-	-	-
Simulimum sp.	P	346	464	86	73	17	986
Tipula sp.	-	-	-	-	-	-	-
Megaloptera (hellgrammites)							
Sialis sp.	-	-	-	-	-	-	-
Corydauls sp.	-	-	1	-	-	-	1
Nigronia sp.	-	-	-	-	-	-	-
Trichoptera (caddisflies)							
Agraylea sp.	-	-	-	1	-	-	1
Brachycentrus sp.	-	-	-	-	-	-	-
Cheumatopsyche sp.	P	-	-	-	-	-	-
Chimarra sp.	-	-	-	-	-	-	-
Goera sp.	-	-	-	-	-	-	-
Helicopsyche sp.	-	-	-	-	-	-	-
Hydropsyche sp.	P	-	-	-	-	-	-
HYDROPTILIDAE	-	-	-	-	-	-	-
Leucotrichia sp.	-	-	-	-	-	-	-
Macronemum sp.	-	-	-	-	-	-	-
Neureclipsis sp.	-	-	-	-	-	-	-
Neophylax sp.	-	-	-	-	-	-	-
Orthotrichia sp.	-	-	-	-	-	-	-
Protoptilia sp.	-	-	-	-	-	-	-
Psychomyia sp.	-	-	-	-	-	-	-

Station Number 7 (Continued)

	Bottom Net	S-1	S-2	S-3	S-4	S-5	Total
Coleoptera (beetles)							
Berosus sp.	-	-	-	-	-	-	-
Dineutes sp.	P	-	-	-	-	-	-
Dubiraphia sp.	-	-	2	-	-	-	2
Helichus sp.	-	-	-	-	-	-	-
Hydrochus sp.	-	-	-	-	-	-	-
Hydrophilus sp.	-	-	-	-	-	-	-
Laccophilus sp.	P	2	2	2	1	-	7
Macronyshus sp.	-	-	-	-	-	-	-
Optioservus sp.	-	-	-	-	-	-	-
Pormoresia sp.	-	-	-	-	-	-	-
Psephenus herricki	-	-	-	-	-	-	-
Stenelmis sp.	-	-	-	-	-	-	-
Themonectus sp.	P	-	-	-	-	-	-
Triopsternus sp.	-	-	-	-	-	-	-
Hemiptera (true bugs)							
Trichocorixa sp.	P	-	-	-	-	-	-
Belastoma sp.	P	-	-	-	-	-	-
Ranatra sp.	-	-	-	-	-	-	-
Lepidoptera							
Cataclysta sp.	-	-	-	-	-	-	-
Annelida							
Oligochaeta	P	10	1	-	8	-	19
Hirundinea	-	-	-	-	-	-	-
Mollusca							
Ferrissia sp.	-	-	-	-	-	-	-
Gyraulus sp.	-	-	-	-	-	-	-
Lymnaea sp.	-	-	-	-	-	-	-
Musculium sp.	-	-	-	-	-	-	-
Physa sp.	P	-	-	-	-	-	-
Psidium sp.	-	-	-	-	-	-	-
Sphaerium sp.	-	-	-	-	-	-	-
Viviparus sp.	-	-	-	-	-	-	-
Snail sp. 1	P	-	-	-	-	-	-
Isopoda							
Licerus sp.	-	-	-	-	-	-	-
Decapoda							
CAMBARIDAE	-	-	-	-	-	-	-
Acari							
(Water-mite)	-	-	-	-	-	-	-
Platyhelminthes							
PLANARIDAE	-	-	-	-	-	-	-

du Pont Survey, South River
Station Number 8

	Bottom Net	S-1	S-2	S-3	S-4	S-5	Total
Ephemeroptera (mayflies)							
Centroptilium sp.	P	15	17	14	29	28	103
Ephemera sp.	-	-	-	-	-	-	-
Ephemerella sp.	-	-	-	-	-	-	-
Epheron sp.	-	-	-	-	-	-	-
Isonychia sp.	P	-	-	-	-	-	-
Siphlonurus sp.	-	-	-	-	-	-	-
Stenonema sp.	-	2	-	5	11	3	21
Pseudocloeon sp.	-	-	-	1	12	-	13
Odonata (dragonflies)							
Agrion sp.	P	1	2	-	2	-	5
Boyeri sp.	P	-	-	-	-	-	-
Macromia sp.	P	-	-	-	-	-	-
Droinogomphus sp.	P	-	-	-	-	-	-
Gomphaeschna sp.	-	-	-	-	-	-	-
Ophiogomphus sp.	-	-	-	-	-	-	-
Plecoptera (stoneflies)							
Acroneuria sp.	-	-	-	-	-	-	-
Diptera (true flies)							
Antocha sp.	-	2	-	-	4	-	6
Athrix varigata	-	-	-	-	-	-	-
CHIRONOMIDAE	P	192	79	133	95	90	589
EPHYDRIDAE	-	-	-	-	-	-	-
Hemerodromia sp.	-	1	-	-	-	-	1
Simulimum sp.	-	9	1	-	3	18	31
Tipula sp.	-	-	-	-	-	-	-
Megaloptera (hellgrammites)							
Sialis sp.	P	-	-	-	-	1	1
Corydauls sp.	-	1	2	-	2	-	5
Nigronia sp.	-	-	-	-	-	-	-
Trichoptera (caddisflies)							
Agraylea sp.	P	3	-	4	7	3	17
Brachycentrus sp.	-	-	-	-	-	-	-
Cheumatopsyche sp.	P	61	33	63	46	76	279
Chimarra sp.	-	-	-	-	-	-	-
Goera sp.	-	-	-	-	-	-	-
Helicopsyche sp.	-	-	-	-	-	-	-
Hydropsyche sp.	P	206	40	237	175	284	942
HYDROPTILIDAE	-	-	-	-	-	-	-
Leucotrichia sp.	-	-	-	-	-	-	-
Macronemum sp.	-	-	-	-	-	-	-
Neureclipsis sp.	-	-	-	-	1	3	4
Neophylax sp.	-	-	-	-	-	-	-
Orthotrichia sp.	-	-	-	-	-	-	-
Protoptilia sp.	-	-	-	-	-	-	-
Psychomyia sp.	-	-	-	-	-	-	-

Station Number 8 (Continued)

	Bottom Net	S-1	S-2	S-3	S-4	S-5	Total
Coleoptera (beetles)							
Berosus sp.	-	4	1	-	5	28	38
Dineutes sp.	-	-	-	-	-	-	-
Dubiraphia sp.	-	-	-	-	-	-	-
Helichus sp.	-	-	-	-	-	-	-
Hydrochus sp.	-	-	-	-	-	-	-
Hydrophilus sp.	-	-	-	-	-	-	-
Laccophilus sp.	-	-	-	-	-	-	-
Macronyshus sp.	-	-	-	-	-	-	-
Optioservus sp.	-	-	-	-	-	-	-
Pormoresia sp.	-	-	-	-	-	-	-
Psephenus herricki	-	-	-	-	-	-	-
Stenelmis sp.	-	-	1	-	1	-	2
Themonectus sp.	-	-	-	-	-	-	-
Triopsternus sp.	-	-	-	-	-	-	-
Hemiptera (true bugs)							
Trichocorixa sp.	-	-	-	-	-	-	-
Belastoma sp.	-	-	-	-	-	-	-
Ranatra sp.	-	-	-	-	-	-	-
Lepidoptera							
Cataclysta sp.	-	-	-	-	-	-	-
Annelida							
Oligochaeta	-	-	-	-	-	-	-
Hirundinea	-	-	-	-	-	-	-
Mollusca							
Ferrissia sp.	-	-	-	-	-	-	-
Gyraulus sp.	-	-	-	-	-	-	-
Lymnaea sp.	-	-	-	-	-	-	-
Musculium sp.	-	-	-	-	-	-	-
Physa sp.	-	-	-	-	-	-	-
Psidium sp.	-	-	-	-	-	-	-
Sphaerium sp.	-	-	-	-	-	-	-
Viviparus sp.	-	-	-	-	-	-	-
Snail sp. 1	-	-	-	-	-	-	-
Isopoda							
Licerus sp.	-	-	-	-	-	-	-
Decapoda							
CAMBARIDAE	-	-	-	-	-	-	-
Acari							
(Water-mite)	-	-	-	-	-	-	-
Platyhelminthes							
PLANARIDAE	-	-	-	-	-	-	-

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