THE EFFECTS OF WASTE DISCHARGES FROM RADFORD ARMY AMMUNITION PLANT ON THE BIOTA OF THE NEW RIVER, VIRGINIA

directed by

John Cairns, Jr.

and

Kenneth L. Dickson

Biology Department
and
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Virginia Polytechnic Institute and State University

The work upon which this publication is based was supported by a grant from Hercules Incorporated. Funds for the publication were provided by the Research Division, Virginia Polytechnic Institute and State University, and by the U.S. Department of the Interior, Office of Water Resources Research, as authorized under the Water Resources Act of 1964.

Virginia
Water Resources Research Center
Virginia Polytechnic Institute
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Blacksburg, Virginia
April 1973

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PREFACE

This investigation was designed to generate basic data regarding the effects of wastes from a munitions manufacturing plant on the fauna and flora of the receiving system. In the manufacture of munitions a variety of waste products are generated, including acids, nitro-bodies from the manufacture of TNT, solvents, thermal and ash discharges from power production, miscellaneous oils, and detergents. These wastes either independently or collectively may be detrimental to aquatic life if waste treatment facilities are not adequate and the assimilative capacity of the receiving system is exceeded. Baseline biological data enable one to identify toxic effluents, estimate the assimilative capacity of the receiving system, and assign priorities for the installation of additional waste treatment facilities when necessary. The information produced by these investigations should enable industry to use the receiving system without degrading it for other uses.

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ABSTRACT

The effects of waste discharges from Radford Army Ammunition Plant (RAAP), Radford, Virginia on fish, bottom fauna, algae, and higher aquatic plants in the New River were investigated in June 1971. Sampling stations were established upstream and downstream from the RAAP discharges. These stations were located to evaluate the individual effects of the various discharges (acid wastes, organic solvent wastes, thermal effluents, nitrogenous TNT wastes, and ash) on the fauna and flora. This was possible because there are a number of waste streams discharged at various points along the New River rather than a single combined waste discharge. An independent analysis of the data for each taxonomic group is presented along with general conclusions which integrate the findings of all the investigators. The waste discharges from the plant caused localized damage to the fauna and flora of the New River; however, the river had recovered in the five miles contained within the boundaries of the plant property.

Key Words: Stream survey, Biological survey, Munition wastes, TNT wastes, Nutrient Enrichment

INTRODUCTION

In order for an industry to effectively plan the implementation of new waste treatment technology, it must have a good baseline of chemical, physical, and biological data regarding the effects of its wastes on the receiving system. Once a baseline of data is established the industry can then design its waste treatment system to produce a waste within the assimilative capacity of the receiving system to obtain the maximum beneficial use without damage. Since each ecosystem has unique characteristics, the information generated in other areas can be used for general guidelines only - specific guidelines must be based on local data.

Radford Army Ammunition Plant (RAAP) is a government-owned, contractor-operated plant located on the New River near Radford, Virginia. The operating contractor, Hercules Incorporated, manufactures solid propellant for small arms, cannon and rockets, mortar increments and igniters, and assorted explosives, and also processes and assembles components and complete units of rocket motors. It utilizes large quantities of chemicals such as nitric and sulfuric acid which are used in manufacturing such basic explosives as nitrocellulose and nitroglycerin. Manufacturing wastes at the Radford Army Ammunition Plant include neutralized acids, nitro-bodies from the manufacturing of TNT, solvents such as ether and acetone, thermal discharges and ash from the power plant, and miscellaneous wastes such as oils, detergents (via runoff), and treated domestic wastes. Waste treatment operations at RAAP consist of acid neutralization using lime for waste from the nitro-cotton and acid manufacturing lines, acid neutralization of TNT wastes using soda ash, incineration of concentrated liquid TNT wastes, settling and recycling of wastes from the nitro-cotton manufacturing line, and secondary treatment (trickling filters) of domestic wastes.

At the time this study was conducted, June 1971, RAAP was in the first phase of a plan ultimately leading to the construction of advanced waste treatment facilities for all manufacturing wastes. The development of this plan was a cooperative activity involving the Hercules technical staff, consultants, and the Baltimore District of the U.S. Army Corps of Engineers. The first study phase included an evaluation of the existing waste treatment facilities plus physical, chemical, and biological information on the impact of wastes from RAAP on the New River, and treatability studies on the various wastes. These data would then be integrated to establish priorities for the implementation of additional waste treatment facilities.

It was the purpose of our investigations to establish a baseline of biological data for evaluating the effects of waste discharges from RAAP on the biota of the New River. These baseline data can also be used later to evaluate the beneficial effects on the biota of the river resulting from the installation of new or improved waste treatment facilities at RAAP. During June 1971 field crews from the Biology Department, Virginia Polytechnic Institute and State University, conducted a biological river survey at selected sampling stations upstream from all RAAP discharges, within RAAP property (i.e., the discharge area), and downstream of the plant (See foldout map - last page of the book). This survey consisted of a series of studies of the distribution of fish, algae, higher plants, and bottom fauna in relation to the various waste discharges from RAAP.

The following data were organized with a separate section of this Bulletin dealing with the major groups of aquatic life included within the study. This organization allows each team of investigators to present its interpretation of the data independently. However, a general summary is included which integrates the findings of the independent investigators.

The areas of a river chosen for comparative study should obviously include comparable ecological habitats whenever possible. This assures reasonably similar "niche" situations at all stations and presumably a comparable opportunity for a particular species to become established at each. The total area of the station is not as important a consideration as is the inclusion of all types of habitats for a survey based principally on the diversity of species present and only secondarily upon numbers of individuals per species. Among the general ecological conditions considered in selecting stations are: (1) structure of the river bed, (2) current, (3) contour, stability, and composition of the substrate, (4) sedimentation, (5) vegetation in the surrounding drainage area, (6) quality and quantity of debris, and (7) collectability of the study area.

The selection of stations and the general coordination of the survey were the responsibilities of Cairns and Dickson. The details of assessing the kinds and numbers of species in various groups were the responsibility of the specialists identified with each of the groups.

EFFECTS OF RADFORD ARMY AMMUNITION PLANT WASTES ON THE BOTTOM FAUNA IN THE NEW RIVER, VIRGINIA

by

Rhodes B. Holliman*

Lois I. Parsons**

*Professor of Zoology, Biology Department, Virginia Polytechnic Institute and State University, Blacksburg, Virginia

**Graduate Teaching Assistant, Biology Department, Virginia Polytechnic Institute and State University, Blacksburg, Virginia

EFFECTS OF RADFORD ARMY AMMUNITION PLANT WASTES ON THE BOTTOM FAUNA IN THE NEW RIVER, VIRGINIA

Introduction

Bottom fauna communities in aquatic habitats are relatively good yardsticks for measuring the impact of extraneous stresses impinging 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.

Communities respond to extraneous stresses by shifting in structure, i.e., changes in the number of species present, the numbers of individuals per species present, etc. 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 is likely to decrease and the number of individuals of the remaining species is likely to increase.

Bottom organisms, because they are relatively sessile animals which are associated with a substrate, act as effective "natural monitors" of water quality. These organisms are essential in the aquatic food web since they act as a primary source of fish food. A biological evaluation of water quality using bottom fauna presents a historical record of environmental conditions.

Between June 10 and 20, 1971, a bottom fauna survey was conducted on the New River in the vicinity of Radford Army Ammunition Plant (RAAP) to document the effects of waste discharges from RAAP upon the bottom fauna organisms of the New River.

Location of Sampling Sites

Sampling locations were strategically located to evaluate the effects of the major outfalls from RAAP.

Station 1B was upstream from the RAAP water intake point. This station consisted of a rocky riffle which supported a heavy growth of attached algae. Eight replicate bottom fauna samples were taken, equally spaced throughout the 150-yard width of the river (See map of the study area - last page of the book).

Station 2B was at the first riffle downstream of the entrance of Strouble's Creek to New River. This station was downstream from the oleum plant outfall, cooling water and ash outfall, and the neutralized acid discharge. The riffle at this station consisted of small rocks and gravel with some debris on the bottom. Eight replicate samples were taken.

Substation 1b was at the mouth of Strouble's Creek.

Substation 2b was on Strouble's Creek above and below the bridge over Highway 685.

Substation 3b was upstream of the TNT land fill near where Strouble's Creek enters RAAP property.

Station 4B was at riffles upstream from an island in the river. Nine replicate samples were taken across the river.

Station 5B was at the downstream plant boundary near Cowan, Virginia. This station was downstream of all discharges from RAAP. Eight replicate samples were taken at this station.

Materials and Methods

Bottom fauna were collected at each station, using a long-handled bottom net. This collecting technique produces qualitative and semiquantitative information. Each sample at each station was collected for a three-minute period during which the investigator kicked the loose riffle material, dislodging the organisms which then drifted into the collecting net positioned downstream. This technique has been shown to be superior to some of the routine sampling techniques commonly used (Frost, *et al*., 1971).

For the purpose of this survey the replicate samples were numbered, with Number 1 being on the left bank looking downstream, and additional samples numbered progressively and equally spaced across the river. Bottom fauna samples were preserved in the field with 70% ethanol and returned to Virginia Polytechnic Institute and State University laboratories where the organisms were separated from the debris by sugar flotation and later identified and counted.

Results and Discussion

All sampling stations in this survey showed a low diversity of bottom fauna organisms, (Tables 1, 2, 3, 4, and 5). Several factors probably influenced the results of the bottom fauna survey. The survey was conducted in early summer following the emergence of many aquatic insects from the water, thereby reducing the number and diversity of those remaining in the stream.

Another possible explanation of the depauperate bottom fauna may be due to the introduction of organic wastes upstream from RAAP. Associated with the low diversity of bottom fauna collected was the problem of poor substrate for optimal habitat. The New River in the RAAP boundary seemed to offer far from ideal substrate for a highly diverse and productive bottom fauna community due to the presence of large areas of bedrock and the absence of rubble.

The bottom fauna communities at each sampling station were similar, each having a low number of taxa and a relatively low density of organisms. (Reference) Station 1B had only nine genera of bottom fauna. Station 2B, located below all the major waste discharges from RAAP, supported 18 genera (Tables 1 and 2). Since most of the major discharges from RAAP enter the New River on the right bank (looking downstream) analyzing the data by subdividing each station into left bank, midchannel, and right bank should indicate whether or not the discharge is having an influence on a portion of the river. Figure 1 shows this type of analysis for the stations on the New River. The number of genera is greater at each of the substations at Station 2B when compared to (Reference) Station 1B.

Downstream Stations 4B and 5B also support a greater number of bottom fauna taxa than the Reference Station. Apparently the waste discharges from RAAP have only a localized effect on the bottom fauna, and this effect rapidly dissipated due to the dilution and waste assimilative capacity of the river.

A qualitative evaluation of the bottom fauna communities collected at each sampling station indicated that "pollution-intolerant" types, mayflies, caddis flies, and clams, were present at all of the New River stations, indicating acceptable water quality. These organisms were present at Stations 1B, 2B, 4B, and 5B.

Station 3B on Strouble's Creek, however, appeared to be degraded since it supported a "pollution-tolerant" community consisting primarily of midge larvae, isopods, and oligochaetes. It was felt, however, that Strouble's Creek was damaged before it entered the RAAP property since the "pollution-tolerant" community occurred at substation 3b. Strouble's Creek receives secondary treated sewage effluent from the Blacksburg-VPI treatment plant. Therefore, it is quite possible that it was damaged before reaching substation 3b.

Conclusions

1. There was little quantitative change in aquatic invertebrates from the four stations established in the main body of New River within the plant (Stations, 1B, 2B, 4B, and 5B).

2. Station 1B (reference) had abundant algae associated with the rocky bottom which might account for the abundance of Ephemeroptera and Trichoptera. This habitat provided proper substrate, protection, and food for these two major taxonomic groups.

3. There did not seem to be any clear-cut deficit of organisms in the direct paths of effluents discharged from the plant, with the exceptions of Strouble's Creek and the Power Plant effluent.

4. At Station 2B there was no significant difference in sample composition of nine samples, even though samples 5 through 9 were exposed to effluents containing, in part, nitro-bodies, ash, neutralized acids, inorganics, and heated water.

5. The total number of organisms at Station 1B was 384; at 2B, 427; at 4B, 311; and at 5B, 330. Thus, invertebrate numbers were essentially static throughout the river within the plant property, although the most abundant organisms (as major taxonomic groups) change between stations. Ephemeroptera were most abundant in the first two stations and the Mollusca were most abundant in Stations 4B and 5B. However, Ephemeroptera, Trichoptera, and Mollusca predominated throughout the survey.

6. Strouble's Creek appeared to suffer the most biological damage due to RAAP's effluents. At a point upstream from the TNT landfill, the creek supported 17 genera and 600 organisms in four samples (Substation 3b). Directly downstream from the TNT landfill, the productivity dropped to 12 genera and 333 organisms in four samples (Substation 2b). This loss in productivity was reflected in the mouth of Strouble's Creek with 13 genera and 244 organisms (Substation 1b).

TABLE 1

Number of Aquatic Invertebrates Collected at Station 1B

	Sample Number							
	1	2	3	4	5	6	7	8
Trichoptera								
Hydropsyche	19	19	26	9	28	34	9	4
Rhyacophila	1	1	--	--	--	--	--	--
Ephemeroptera								
Ephemerella	52	44	9	16	29	18	7	3
Isonychia	4	2	--	1	4	6	6	9
Plecoptera								
Perlesta	--	--	--	--	--	--	1	1
Megaloptera								
Corydalus	--	--	--	--	--	1	1	2
Gastropoda								
Viviparus	--	--	--	--	1	--	10	6
Campeloma	--	--	--	--	--	--	--	1
Pelecypoda								
Pisidium	--	--	--	--	--	--	1	--

TABLE 2

Number of Aquatic Invertebrates Collected at Station 2B

	Sample Number							
	1	2	3	4	5	6	7	8
Diptera								
Chironomus	--	--	2	1	--	--	--	--
Tipula	--	--	--	1	--	--	--	--
Trichoptera								
Hydropsyche	6	26	25	11	2	--	--	4
Limnephilus	--	--	3	--	--	--	--	--
Ephemeroptera								
Ephemerella	21	12	37	27	8	6	8	13
Isonychia	4	19	10	1	2	--	9	2
Pseudocloeon	--	--	2	--	--	--	--	--
Stenonema	--	--	--	--	--	--	1	--
Plecoptera								
Perlesta	--	--	1	--	--	--	--	--
Coleoptera								
Optioservus	--	--	1	--	--	--	--	--
Megaloptera								
Corydalus	--	1	--	--	1	--	--	--
Odonata								
Neurocordulia	--	--	--	--	--	--	1	--
Argia	--	--	--	--	--	--	1	--
Decapoda								
Cambarus	--	--	--	--	--	1	--	--
Gastropoda								
Viviparus	16	75	--	6	--	--	--	25
Helisoma	1	--	--	--	--	--	--	--
Pelecypoda								
Pisidium	9	7	1	3	--	--	--	13
Sphaerium	--	1	--	--	--	--	--	--

TABLE 3

Number of Aquatic Invertebrates Collected at Station 3B

	Substation											
	1b				2b				3b			
Sample Number	1	2	3	4	1	2	3	4	1	2	3	4
Diptera												
Chironomus	28	72	18	55	18	16	48	--	9	35	119	82
Pentaneura	--	--	--	--	--	--	2	--	3	--	--	--
Limnophora	--	--	--	--	--	1	--	--	--	1	6	1
Trichoptera												
Hydropsyche	--	--	--	--	--	1	--	--	--	--	--	--
Cheumatopsyche	--	1	--	--	--	--	--	--	4	--	--	--
Ephemeroptera												
Pseudocloeon	--	1	--	--	--	--	--	--	--	--	--	--
Baetis	15	18	6	--	6	--	--	--	5	--	7	--
Ephemera	1	--	--	--	--	--	--	--	2	--	--	--
Caenis	1	1	--	--	--	--	--	--	--	--	--	--
Plecoptera												
Acroneuria	--	--	--	--	--	--	1	--	--	--	--	--
Perlesta	--	--	--	--	--	--	--	--	--	1	--	--
Coleoptera												
Optioservus	--	--	--	--	--	--	--	--	--	--	1	--
Stenelmis	--	--	--	--	--	--	--	--	--	--	1	--
Helichus	--	4	--	2	1	3	--	--	--	1	--	--
Ectopria	--	--	--	--	--	--	--	--	--	--	1	--
Phanocercus	--	--	--	--	--	--	--	--	--	--	1	--
Isopoda												
Asellus	--	--	2	--	28	56	30	--	187	57	17	10
Porcellionides	1	--	1	--	--	--	--	--	--	--	--	--
Armadillidium	--	2	--	1	--	--	--	--	--	--	--	--
Decapoda												
Cambarus	--	--	--	--	1	--	--	--	--	--	--	--
Gastropoda												
Physa	--	--	--	--	1	--	--	--	--	--	--	1
Goniobasis	--	--	3	--	--	--	--	--	--	--	--	1
Oligochaeta	--	--	5	2	42	32	13	15	4	18	2	6
Hirudinea	1	--	--	2	--	9	--	--	3	14	--	--

TABLE 4

Number of Aquatic Invertebrates Collected at Station 4B

	Sample Number								
	1	2	3	4	5	6	7	8	9
Diptera									
Pentaneura	--	--	--	--	--	--	19	--	--
Trichoptera									
Hydropsyche	17	1	14	--	13	1	--	4	6
Ephemeroptera									
Ephemerella	7	--	1	--	12	4	--	1	7
Isonychia	--	--	--	--	1	2	5	--	2
Pseudocloeon	--	--	--	--	1	--	--	1	--
Stenonema	--	--	2	--	--	13	--	1	1
Cinygmula	--	--	--	--	--	--	--	1	--
Plecoptera									
Perlesta	--	--	1	--	--	--	--	--	--
Coleoptera									
Stenelmis	--	--	--	--	--	1	--	--	--
Helichus	--	--	--	--	--	1	--	--	--
Megaloptera									
Corydalus	--	--	--	--	--	--	1	--	--
Odonata									
Macromia	--	--	--	--	--	--	--	1	--
Dromogomphus	--	--	--	--	--	1	--	--	--
Chromagrion	--	--	--	--	--	--	--	--	1
Decapoda									
Cambarus	--	--	--	--	--	9	12	4	5
Gastropoda									
Viviparus	8	12	10	2	19	--	8	--	4
Physa	--	--	--	--	--	--	--	--	4
Helisoma	--	--	--	6	1	--	4	--	3
Campeloma	--	--	--	--	--	--	3	--	--
Pelecypoda									
Pisidium	--	19	2	7	2	--	--	--	1
Sphaerium	--	1	1	4	2	--	--	--	4
Oligochaeta	--	--	3	2	--	--	--	--	--
Hirudinea	--	--	--	2	--	2	--	--	--

TABLE 5

Number of Aquatic Invertebrates Collected at Station 5B

	Sample Number							
	1	2	3	4	5	6	7	8
Diptera								
Pentaneura	12	--	8	--	--	18	19	15
Trichoptera								
Hydropsyche	--	--	9	25	12	3	2	1
Cheumatopsyche	1	1	--	--	--	--	--	--
Ephemeroptera								
Ephemerella	--	4	8	16	--	--	7	--
Isonychia	--	1	4	5	--	--	1	--
Pseudocloeon	--	--	3	--	--	--	5	--
Stenonema	1	--	--	--	--	--	--	1
Coleoptera								
Promoresia	2	--	--	--	--	--	--	--
Megaloptera								
Corydalus	--	--	--	--	--	--	1	--
Chauloides	--	--	--	--	--	--	--	1
Odonata								
Chromagrion	2	--	--	--	--	--	--	3
Plathemis	2	--	--	--	--	--	--	--
Decapoda								
Cambarus	--	--	--	3	--	--	1	13
Gastropoda								
Viviparus	--	--	2	7	1	1	3	--
Physa	--	--	--	--	--	--	--	1
Helisoma	--	--	--	1	--	--	--	3
Pelecypoda								
Pisidium	--	19	5	23	4	2	14	24
Sphaerium	--	1	--	1	--	2	2	--
Oligochaeta	--	1	--	--	--	--	--	--
Hirudinea	--	--	--	--	--	--	--	3

TABLE 6

Summary of Bottom Fauna Data for Each Station

Station Number	No. of Samples	Major* Groups	Genera**	Total Organisms	Most Abundant Genera	Most Abundant Group	Second Most Abundant Group	Third Most Abundant Group
1B	8	5	9	384	*Ephemerella* 178	Ephemeroptera 210	Trichoptera 150	Gastropoda 18
2B	8	10	18	427	*Ephemerella* 132	Ephemeroptera 182	Gastropoda 123	Trichoptera 77
3B sub. 1b	4	9	13	244	*Chironomus* 173	Diptera 173	Ephemeroptera 43	Isopoda 7
3B sub. 2b	4	11	12	333	*Asellus* 114	Isopoda 114	Oligochaeta 102	Diptera 85
3B sub. 3b	4	9	17	600	*Asellus* 271	Isopoda 271	Diptera 256	Oligochaeta 30
4B	9	12	23	311	*Viviparus* 63	Gastropoda 84	Ephemeroptera 62	Trichoptera 56
5B	8	11	18	330	*Pisidium* 91	Pelecypoda 97	Diptera 72	Ephemeroptera 56 Trichoptera 54

*Major taxonomic groups recovered in the entire project 13

TABLE 7

Number of Bottom Fauna Genera and Number of Specimens Per Replicate Sample by Stations

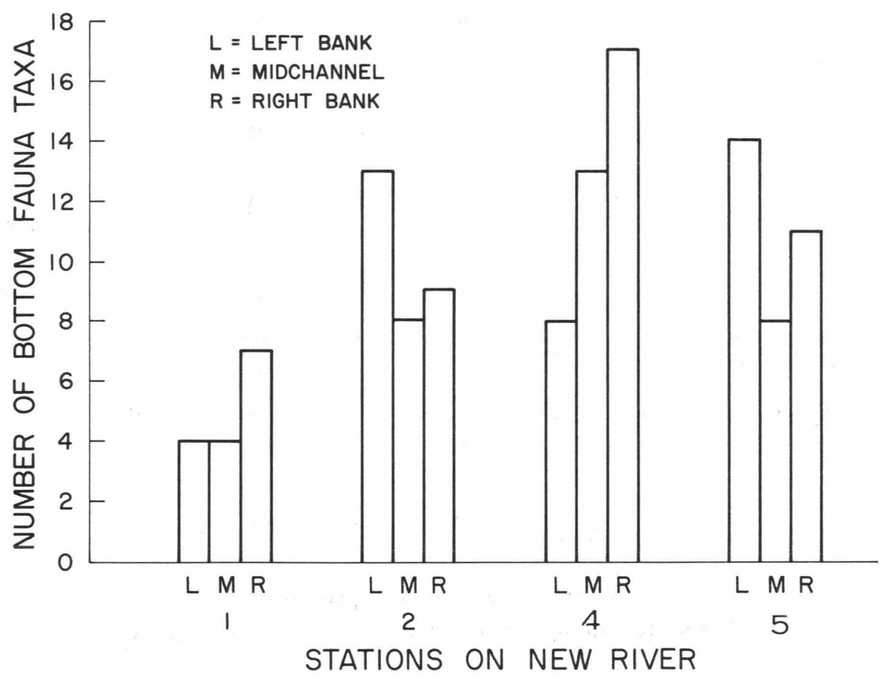
Station Number	Sample Number 1	2	3	4	5	6	7	8	9
1B	4*/76**	4/66	2/35	3/36	4/62	4/59	7/35	7/26	
2B	6/57	7/141	9/82	7/82	4/13	2/7	5/20	5/57	
3B sub. 1b	6/47	7/99	6/35	5/62					
3B sub. 2b	7/97	7/118	5/94	1/15					
3B sub. 3b	8/217	7/127	9/155	6/101					
4B	3/32	4/33	8/34	6/23	8/51	9/34	7/52	711/1338	
5B	6/20	6/27	7/39	8/81	3/17	5/26	10/45	10/65	

*Number of genera

**Number of specimens

FIGURE 1

Number of Bottom Fauna Taxa, by Stations



EFFECTS OF RADFORD ARMY AMMUNITION PLANT WASTES ON AQUATIC VEGETATION IN THE NEW RIVER, VIRGINIA

by

Richard S. Mitchell*

*Assistant Professor of Botany, Biology Department, Virginia Polytechnic Institute and State University, Blacksburg, Virginia

EFFECTS OF RADFORD ARMY AMMUNITION PLANT WASTES ON AQUATIC VEGETATION IN THE NEW RIVER, VIRGINIA

Introduction

Aquatic macrophytes make an important contribution to the ecological balance of any healthy boreal river. Not only do they act as producers, but they provide much surface area to which algae may attach. Their presence creates a labyrinth of microhabitats for invertebrates and minnows, and their root systems play a large role in the stabilization of banks and islands. The introduction of waste products into a river ecosystem can cause plant populations to decrease or increase, depending upon the nature of the effluents, but in either case it is important to assess the downstream effects on the ecosystem.

The primary concern of the botanical part of this study was to assess apparent effects of effluents on macrophytes in the New River, including aquatic flowering plants, mosses, and "stemmed" algae of the phylum Charophyta. Research was divided into two parts: (1) a floristic survey was carried out at ten sampling stations along a five-mile stretch of the river; (2) the same stations were used for ecological sampling of underwater communities to determine relative biomass. The two approaches combine to show the overall effects on both submerged and emergent vegetation.

Floristic Survey

Materials and Methods

Ten stations were chosen on the river banks, with Station 1, up-river from any chemical effect of plant effluents, designated the reference. (See map of the study area - last page of the book). Stations were chosen on the basis of ecological equivalence, related to the biomass study, and were also spaced so as to give a representative transect along the river study area. Sampling was carried out at low water in the mornings, since release of waters from Claytor Lake dam in the afternoon can raise the water level as much as four feet. Areas chosen were rich in small boulders, some of which protrude slightly above moderately flowing currents at low water. Heavily silted areas were avoided, due to erratic distribution patterns of vegetation which could be substrate-related.

For floristic purposes, a sampling area consisted of 300 yards of bank and river below the high-water mark. Samples of all plants rooted below the high-water mark were collected for identification. These were pressed and dried, and are now on deposit at the Virginia Tech herbarium. Species determinations were made in the herbarium using the latest available manuals (Radford, Ahles and Bell, 1968; Gleason and Cronquist, 1963), and specimens were compared with previously-collected plants from the herbarium.*

The species list (Table 8) comprises 68 flowering plants, one aquatic moss, and one macroscopic alga, *Chara*.

Results and Discussion

The number of species at Station 1P and at Station 10P was essentially the same (Figure 2). The most severe evidence of depletion of species was below the oleum plant outfall at Station 2P. At this point the number of taxa dropped from thirty-five (in the reference) to fifteen. Station 3P is down-river from the 48-in. pipe which dumps the power plant effluent containing cooling water, fly ash, and mixed waste products from the plant. This station also had fifteen species, as compared with thirty-five in the reference area. Station 4P was chosen specifically because of its location on the sheltered side of a small island opposite neutralized acid effluent. This station usually receives little of the waste which is channeled along the right bank on the opposite side of the island. These conditions, in combination with the fact that Station 4P is more heavily silted than the other stations, explain the larger number of species occurring at this point on the transect.

With the exception of the special case of Station 4P, the trend expressed in Figure 2 is an immediate drop by more than half the number of species below the first outfall, with a gradual increase toward Station lOP where recovery appears to be complete.

The number of weedy and introduced species showed no correlation with the position of the sampling station; certain native and introduced species, however, showed definite patterns of occurrence which indicated their elimination in areas receiving waste discharges. Three plants which were characteristically absent in the area of waste discharges were the submerged aquatics, *Potamogeton* and *Chara*, and the emergent, *Stellaria*. These were all present at the reference station, but only reappeared at Stations 7P through 10P. Apparently less susceptible, though reduced greatly in numbers, were the submerged aquatics, *Elodea* and *Fontinalis*. These were missing only from

*Special thanks to Leonard Uttal for help with some of the more difficult determinations.

the more severely affected stations (2P, 3P, 5P), and both were present at Station 4P, chosen for its sheltered location. *Podostemum*, which may be considered the major component of the submerged aquatic ecosystem of this river, was not totally eliminated at any sampling station, but its fluctuation in density made it ideal for use in the biomass studies described below.

Biomass Studies

Quantitative studies of productivity, growth, and seasonality of river plants have, in the past, utilized many different types of units to express the relative importance of aquatic macrophytes in an ecosystem. Problems of standardization of terminology are discussed in detail by Westlake (1963, 1965); however, the most frequently used measure of productivity appears to be biomass, expressed in grams (dry weight) per square meter. The following study was carried out to determine relative biomass at the ten sampling stations, and to correlate the figures obtained with occurence of effluent discharges from RAAP.

Materials and Methods

As indicated previously, sampling stations were chosen for relatively uniform depth and the presence of small boulders which effect reaeration during periods of low water. These areas have sandy bottoms with only moderate amounts of silt. Sand bars and heavily silted areas were avoided. Vegetation found in such areas was matted and attached to both rock and soil substrates. *Podostemum ceratophyllum* comprises up to 98% of the total biomass in these places whenever the current is sufficient for its growth. Due to the lack of aeration lacunae, *Podostemum* is known to be a sensitive indicator of oxygen deficiency (Willis, 1902); however, stations were chosen at which there is sufficient current and reaeration at low water period to sustain dense growth of *Podostemum* under normal river conditions.

Sampling was carried out during the second two weeks of July 1971. Each sample plot covered 100 square meters (20 x 50 m). The longer plot dimension was parallel with the river bank and three meters from the shoreline at the time of low water. Distances were measured with a meter tape, and a wooden frame was used to delimit each quadrant. Ten evenly-spaced quadrants of the standard size used to sample herbaceous vegetation (20 x 50 cm) were sampled within each plot. Depths were also measured at each quadrant location, but these were relatively uniform, and lack of vertical stratification of vegetation made volumetric correction factors unnecessary.

An attempt was made to collect all plant materials falling within each quadrant, including those attached to rocks, which were scraped uniformly. Specimens were labeled, placed in plastic sample bags and returned to the laboratory, where they were separated from pebbles and other inorganics and thoroughly heat-dried. Dry weight of the samples was obtained, using a Mettler balance, and figures were rounded off to the nearest one-hundredth gram.

Results and Discussion

Figure 3 illustrates the results of the biomass survey, and presents an almost "classic textbook" picture of the effects of pollutants upon biological organisms in a river or stream. Biomass in the reference station stood at 26.83 gm/m^2, and dropped to a low point of 0.6 gm/m^2 just below the main outfall at Station 3P. From this point there was a gradual increase in biomass up to the bend of the river at Station 7P. Then, there was an abrupt increase, and the figures greatly exceeded that of the reference area, from Stations 8P through 10P. The high point for biomass in the weedbeds down-river was at Station 9P where the figure reached 47.98 gm/m^2.

The sharp increase in biomass between Stations 7P and 8P might be explained in the following way: It is likely that at this point the toxic and deleterious effects of waste effluents were decreasing to levels where they become greatly overshadowed by the stimulatory effects of nutrient enrichment. Nitrate levels at the river's bend were calculated to be 13.90 ppm, as opposed to 1.69 ppm at the reference station.* Phosphate levels were also greater at Station 7P (0.135 versus 0.410 ppm). It should also be noted at this point that those species showing the greatest sensitivity to pollutants (*Potamogeton, Chara,* and *Stellaria*) were present at Stations 7P through 10P.

Conclusions

It may be generalized, then, that the apparent effects of effluents from RAAP on river vegetation are the following: (1) decrease in the number of species by over one half at the point of discharge of major effluents; (2) gradual increase toward the point where the river leaves RAAP property, at which time the number of species has returned to that of the reference; (3) drastic decrease in biomass of major vegetational components at the point of major effluent discharges; (4) increased biomass over that of the reference from the point of the river's bend at Station 7P and 8P, apparently due to nutrient enrichment of the water. This produces extensive weed beds, but the biomass figures from Station 10P indicated a possible decrease in this effect downstream.

*Chemical analyses were made following *Standard Methods* (6-23-71).

TABLE 8

Aquatic Macrophytes Collected at Stations 1P - 10P, New River, Virginia, June 1971

PLANT GENERA OR SPECIES	Station 1P	2P	3P	4P	5P	6P	7P	8P	9P	10P
Vascular Plants										
Acanthaceae										
Justicia americana L.	-	+	-	+	-	+	+	+	+	-*
Aceraceae										
Acer negundo L.	+	+	+	-	+	+	+	+	+	+
A. saccharinum L.	-	-	-	-	-	+	-	-	+	+
Araceae										
Sagittaria latifolia Willd.	+	-	-	-	-	-	-	-	+	+
Balsaminaceae										
Impatiens biflora Willd.	+	-	-	-	-	-	-	-	-	-
Caprifoliaceae										
Lonicera japonica Thunb.	+	-	-	-	-	-	-	-	-	-
Caryophyllaceae										
Stellaria aquatica L.	+	-	-	-	-	-	+	+	+	+
Commelinaceae										
Commelina communis L.	-	-	+	-	-	-	-	+	-	-
Compositae										
Bidens frondosa L.	-	-	-	+	-	-	-	+	-	+
Eupatorium perfoliatum L.	+	-	-	-	-	-	-	-	-	-
E. rugosum Houtt.	-	+	-	-	+	+	+	-	+	+
Galinsoga ciliata (Raf.) Blake	-	-	-	-	+	-	-	-	-	-
Helenium autumnale L.	+	-	-	-	+	+	+	-	+	+
Rudbeckia laciniata L.	+	-	+	+	-	-	-	-	-	+
Verbesina alternifolia (L.) Britt.	-	+	-	-	-	-	-	-	-	-
Convolvulaceae										
Convolvulus sepium L.	+	-	-	-	-	-	+	-	-	-
Cornaceae										
Cornus amomum L.	+	-	-	+	+	-	-	+	-	+
Cruciferae										
Arabis laevigata (Muhl.) Poir.	+	-	+	+	-	-	-	-	-	-
Cyperaceae										
Carex sp. (not flowering)	-	+	-	-	-	-	-	-	-	-
Eleocharis obtusa (Willd.) Schultes	-	-	-	+	-	-	-	-	+	+
Scirpus americanus Pers.	-	+	-	+	-	+	+	-	-	+
S. polyphyllus Vahl.	-	-	-	+	+	+	+	-	-	-
S. vallidus Vahl.	-	-	-	-	-	+	+	+	+	+

*Key: - indicates absence of taxa
+ indicates presence of taxa

TABLE 8 (Continued)

PLANT GENERA OR SPECIES	Station 1P	2P	3P	4P	5P	6P	7P	8P	9P	10P
Equisetaceae										
Equisetum arvense (L.)	-	-	+	+	-	-	-	+	-	-*
Euphorbiaceae										
Acalypha gracilens Gray	+	-	-	-	-	-	-	-	-	-
Gramineae										
Bromus purgans L.	+	-	-	-	-	-	-	-	-	-
Cinna arundinacea L.	-	-	+	-	-	-	-	-	-	+
Echinochloa crusgalli (L.) Beauv.	+	+	-	+	+	-	-	-	-	+
Leersia oryzoides (L.) Sw.	+	+	+	+	-	-	+	+	-	-
L. virginica Willd.	-	-	+	-	-	-	-	-	-	-
Muhlenbergia frondosa (Poir.) Gern.	-	-	+	-	-	-	+	-	-	+
Panicum sp. (not flowering)	+	-	-	+	+	-	-	-	-	-
Paspalum setaceum Michx.	+	+	-	-	-	-	-	-	-	-
Phalaris arundinacea L.	+	-	-	+	+	-	-	+	+	+
Haloragaceae										
Elodea nuttallii (Planch.) St. John	+	-	-	+	-	+	+	+	+	+
Hypericaceae										
Hypericum mutilum L.	-	-	-	+	-	-	-	-	-	-
Juncaceae										
Juncus effusus L.	-	-	-	-	-	-	-	-	-	+
Labiatae										
Lycopus virginicus L.	-	-	-	-	-	+	-	-	-	-
Mentha arvensis L.	-	-	-	+	-	-	-	-	-	-
Lauraceae										
Lindera benzoin (L.) Blume	+	-	-	-	-	-	-	-	-	-
Onagraceae										
Ludwigia palustris (L.) Ell.	-	-	-	+	-	-	-	-	-	+
Oenothera biennis L.	+	-	-	-	-	-	-	-	-	-
Potamogetonaceae										
Potamogeton crispus L.	+	-	-	-	-	-	+	+	+	+
Plantaginaceae										
Plantago major L.	-	-	-	-	+	-	-	-	-	-
Platanaceae										
Platanus occidentalis L.	-	-	-	+	+	+	+	+	+	+

*Key: - indicates absence of taxa
+ indicates presence of taxa

TABLE 8 (Continued)

PLANT GENERA OR SPECIES	Station 1P	2P	3P	4P	5P	6P	7P	8P	9P	10P
Podostemaceae										
Podostemum ceratophyllum Michx.	+	+	+	+	+	+	+	+	+	+*
Polygonaceae										
Polygonum cespitosum Blume	+	+	+	+	+	+	+	-	+	+
P. hydropiper L.	-	-	-	-	-	-	+	+	+	-
P. lapathifolium L.	-	-	+	-	-	-	-	-	-	-
P. pensylvanicum L.	-	-	-	+	+	-	-	+	-	-
P. punctatum Ell.	+	+	+	+	+	+	+	+	+	+
Rumex verticellatus L.	+	-	-	+	-	-	-	-	+	-
Rosaceae										
Agrimonia gryposepala Wallr.	-	-	-	+	-	-	-	-	-	-
Geum sp. (not flowering)	-	-	-	-	-	+	-	-	-	-
Salicaceae										
Salix nigra L.	+	+	+	+	+	+	+	+	+	+
Scrophulariaceae										
Scrophylaria lanceolata Pursh.	+	-	-	-	+	-	-	-	-	+
Lindernia dubia (L.) Penn.	+	-	-	-	-	-	-	-	-	+
Solanaceae										
Solanum carolinense L.	-	-	+	+	-	-	-	+	+	+
S. dulcamara L.	+	-	-	-	-	-	-	+	-	-
Typhaceae										
Typha latifolia L.	+	-	-	-	-	-	-	-	-	+
Ulmaceae										
Ulmus rubra Muhl.	-	-	-	-	-	-	+	-	-	+
Urticaceae										
Boehmeria cylindrica (L.) Sw.	+	+	+	-	+	+	-	-	+	+
Laportea canadensis (L.) Wedd.	+	-	-	+	-	-	-	-	+	-
Pilea pumila (L.) Gray	+	-	+	+	+	+	+	+	+	+
Umbelliferae										
Centella erecta (L.f.) Fern.	-	-	-	-	+	-	-	-	-	-
Osmorhiza claytonii (Michx.) Clarke	-	+	-	-	-	-	-	-	-	-
Vitaceae										
Vitis riparia Michx.	-	-	-	-	+	+	-	-	-	-
Mosses										
Fontinalaceae										
Fontinalis lescurii Sulliv.	+	-	-	+	+	+	+	+	-	+
Algae										
Characeae										
Chara sp.	+	-	-	-	-	-	+	+	+	+

*Key: - indicates absence of taxa
+ indicates presence of taxa

FIGURE 2

Histogram Representing the Number of Species of Aquatic Plants Present Below the High-Water Mark in Ten Samples Along the New River, June 1971

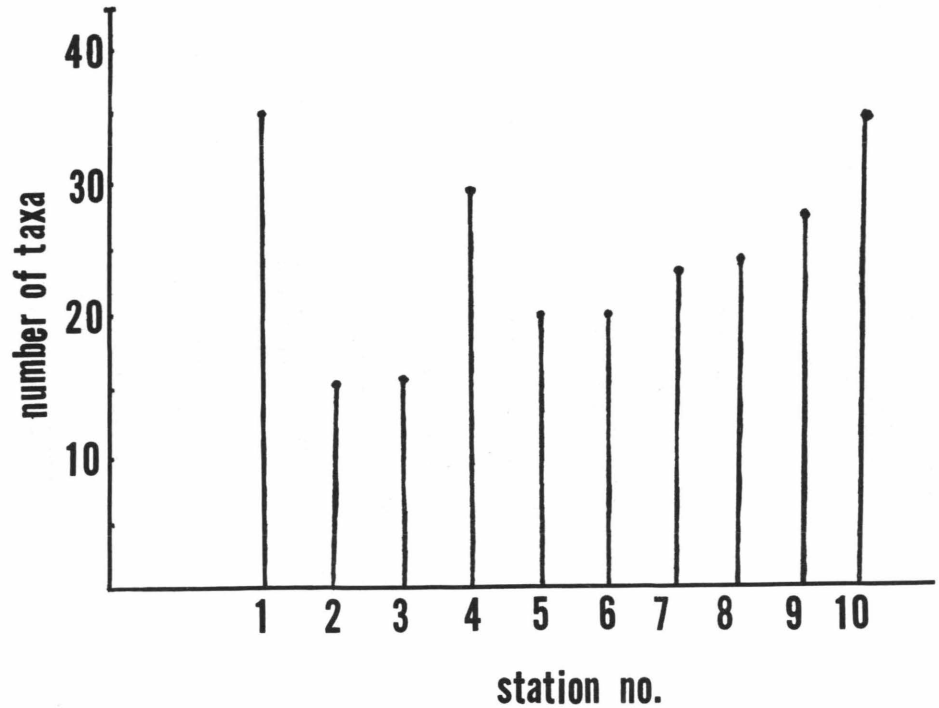
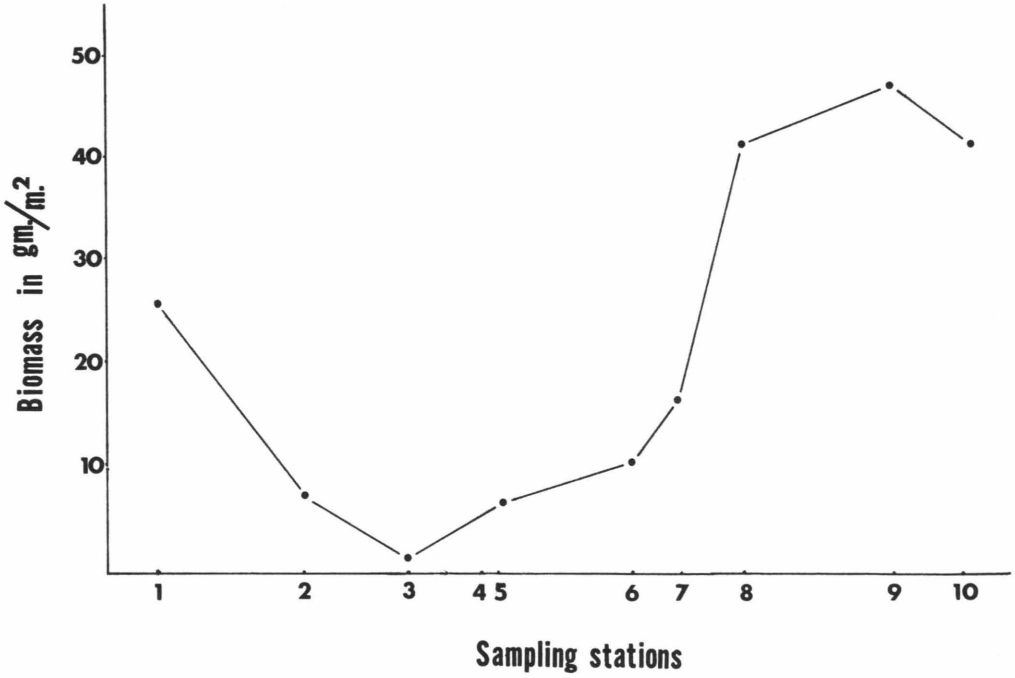


FIGURE 3

The Effect of Effluent Discharges on Biomass of Submerged, Attached Vegetation (Primarily *Podostemum*) in the New River



EFFECTS OF RADFORD ARMY AMMUNITION PLANT WASTES ON THE ALGAE IN THE NEW RIVER, VIRGINIA

by

Edmund B. Wodehouse*

Ebenezer K. Obeng-Asamoa**

Bruce C. Parker***

*Graduate Research Assistant, Department of Biology, Virginia Polytechnic Institute and State University, Blacksburg, Virginia

**Graduate Research Assistant, Department of Biology, Virginia Polytechnic Institute and State University, Blacksburg, Virginia. Present address - VBRP - University of Ghana, Legon, Ghana

***Professor of Botany, Department of Biology, Virginia Polytechnic Institute and State University, Blacksburg, Virginia

EFFECTS OF RADFORD ARMY AMMUNITION PLANT WASTES ON THE ALGAE IN THE NEW RIVER, VIRGINIA

Introduction

In a river such as the New River, attached algae (periphyton) act as primary producers, converting solar energy into cellular components. Thus, they are vital in the energy flow through the aquatic ecosystem. Waste effluents such as those produced by RAAP can cause profound effects on the complexity of the algal community from both a qualitative and quantitative standpoint. Toxic substances tend to reduce the number of algal species residing in the river, as well as to depress the biomass (Hynes, 1960). Suspended solids (such as fly ash) often smother the algae and/or scour the bottom substrates, making it difficult for all but the most tolerant species to survive (Blum, 1956). Sewage or other organically- and nutrient-rich effluents may initially reduce the number of algal species in the river by causing an oxygen deficiency (Hynes, 1960). However, the nutrients from these wastes ultimately increase the amount of algae downstream. Phosphorus, nitrogen, and carbon are especially important in this process (Wadleigh, 1968).

The purpose of the algal survey in the vicinity of RAAP was to study the algal communities to see if any apparent variations in the distribution of algae could be directly attributed to RAAP effluent discharges. For this study the algae were sampled from a qualitative or species distribution standpoint, and no quantitative or biomass measurements were made.

Materials and Methods

Algae were collected at 12 locations within the section of the New River under study. Collections were made on June 22 and 23, 1971. The algae were scraped from rocks or lifted directly from sandy areas at each station. Small stones were collected for more complete scraping and analysis in the laboratory. The collected algae were preserved in 3% formalin until they could be identified by microscopic analysis.

To facilitate identification of diatom species, organic material was removed from the frustules by an acid cleaning technique described by Patrick and Reimer (1966). In our preparations, however, nitric acid was substituted for sulfuric acid. Permanent microscope slides of the cleaned diatoms were prepared and are on file at Virginia Tech.

Sampling locations

Whenever possible, sampling sites were chosen in concordence with those studied in the aquatic vegetation section of this study, 1P-10P. The sites chosen were as nearly uniform as possible and constituted what might be called a matched set of sampling sites. Rocky areas with moderate flow near shore were selected. Brief descriptions of the 12 sites sampled for the algae are presented here.

Station 1A was on the right bank of the river at the RAAP water intake. This station can be considered a reference station as it is upstream from RAAP discharges, and therefore not under their influence. Algae were collected on the upstream and open-water sides of the small island near the intake lagoon.

Station 2A was on the right bank of the river under the bridge connecting the two parts of the plant. This site was characterized by slower-moving water than that at all the other sites sampled. Consequently, mud deposition was more pronounced.

Station 3A was on the left bank of the river under the bridge. A muddy bottom also characterized this site.

Station 4A was on the right bank of the river just downstream from the power plant outfall. Heavy deposits of fly ash had accumulated on all bottom surfaces. This site corresponded to Station 3P.

Station 5A was on the right bank of the river just downstream from the neutralized acid effluent discharge.

Station 6A was on the right bank just upstream from the mouth of Strouble's Creek. This site corresponded to Station 4P.

Station 7A was on the right bank just downstream from the mouth of Strouble's Creek, at the same location as Station 5P.

Station 8A was on the left bank at the burning grounds.

Station 9A was on the right bank at nearly the midpoint of the river's bend. This site corresponded to Station 6P.

Station 10A was on the left bank, at Station 7P.

Station 11A was at midstream on the upstream edge of an island. This site corresponded to Station 9P.

Station 12A was on the left bank of the river at the boat landing at the downstream end of RAAP property.

Results and Discussion

With only a few exceptions, the algal community appeared similar from station to station (Table 9). Table 10 shows the distribution of taxa within the major divisions of algae, by station, and illustrates that the diatoms were the most diverse group. At most stations the diatoms grew in a layer of silt and sand that coated the rocks and sedimented areas alike. This bottom layer, ranging from about 1 mm to 1 cm in thickness, was held together by mucilage secreted by the diatoms and by a network of blue-green algae filaments. At some stations the blue-green algae, *Oscillatoria, Phormidium,* and/or *Lyngbya*, gave a blue-green color to the river bottom. However, the diatom layer was usually invisible to the naked eye due to the accumulation of silt and sand.

A general trend could be seen (Table 10); the green algae tended to increase in both total number of taxa and in percent of the algal community at downstream Stations 8A, 9A, 10A, 11A, and 12A. However, it was noted that the green alga, *Stigeoclonium tenue*, was most abundant at the reference, Station 6A. This alga is an indicator of organic or nutrient enrichment and this abundance of *S. tenue* indicates that the waters of the New River were probably already relatively high in organic and nutrient content before they entered RAAP property.

At Station 6A, located immediately downstream from the 48-in. thermal and ash discharge from the power plant, only 23 taxa of algae were recorded, indicating that this discharge was having a detrimental effect on the algal community. (See Figure 4). It is likely that the coal-ash in the discharge was smothering the substrate, thus causing a reduction in the number of algae present. At Station 8A, immediately downstream from the burning ground, only 37 taxa of algae were recorded, indicating a possible toxic runoff. Apparently, other waste discharges from RAAP were having little effect on the algal community at the time of the survey.

Conclusions

The type of algal community recorded in this study is beneficial to the health of the river and at no point throughout the study area constituted what could be considered a nuisance situation. However, this study was carried out in late June during a relatively high-flow period; nuisance algal growths usually occur under low-flow and high-temperature conditions in later summer. In order to effectively evaluate the effects of waste discharges from RAAP on algal productivity, a summer-long study would be necessary.

TABLE 9

Algae Collected at Stations 1A - 12A, New River, Virginia, June 1971

	Station											
	1A	2A	3A	4A	5A	6A	7A	8A	9A	10A	11A	12A
CYANOPHYTA (the blue-green algae)												
Lyngbya sp.	-	-	-	-	-	-	-	+	+	+	-	-*
Phormidium sp.	+	+	+	-	+	+	+	-	+	-	+	+
Oscillatoria sp.	+	+	+	-	+	+	+	+	+	+	+	+
CHLOROPHYTA (the green algae)												
Cladophora glomerata	+	+	-	-	-	-	-	+	+	+	+	+
Closterium ralfsil	-	+	+	-	-	-	-	+	-	-	+	+
Gongrosira DeBaryana	-	-	-	-	-	+	+	+	+	+	+	+
Oedogonium sp. 1	-	-	-	-	+	+	+	+	+	+	+	+
Oedogonium sp. 2	+	-	-	-	-	-	-	-	+	-	+	+
Rhizaclonium hieroglyphicum	-	-	-	+	+	+	-	-	+	+	+	+
Scenedesmus quadricauda	+	-	-	-	-	-	-	-	-	-	+	-
Spirogyra sp.	-	-	+	-	-	-	-	-	-	-	-	-
Stigeoclonium tenue	+	+	-	-	+	+	-	-	+	+	+	-
EUGLENOPHYTA (euglenoid flagellates)												
Phacus sp.	-	-	-	-	-	-	-	-	+	-	-	-
CHRYSOPHYTA (the yellow-green algae)												
Tribonema affine	-	-	-	-	-	-	-	-	-	+	+	+
T. bombycinum	+	+	-	-	-	+	+	-	-	-	+	+
Characiopsis spinifer	-	-	-	-	-	-	-	-	-	+	+	+
BACILLARIOPHYTA (diatoms)												
Achnanthes linearis	+	+	+	+	+	+	+	+	+	+	+	+
A. lancoolata	+	+	+	+	+	+	+	+	+	+	+	+
A. hauckiana	-	-	-	-	+	-	-	-	-	-	-	+
A. minutissima	-	-	-	-	-	-	-	+	-	-	-	-
Amphora ovalis	-	-	-	-	-	+	-	-	-	-	-	-
A. sp.	-	+	-	-	+	+	-	-	-	-	-	-
Asterionella bleakleyi	+	+	-	-	+	+	-	-	-	-	-	-
A. formosa	+	+	+	+	+	+	+	+	+	+	+	+
Caloneis ventricosa	-	-	-	-	+	-	-	-	-	-	-	-
Cocconeis pediculusa	-	-	-	-	-	-	-	-	-	+	+	+
C. placentula	+	+	+	+	+	+	+	+	+	+	+	+
Coscinodiscus sp.	-	+	-	-	-	-	-	-	-	-	-	-
Cymbolia affinis	+	+	+	-	+	-	-	-	+	-	-	-
C. gracilis	-	+	-	-	-	-	-	-	-	-	-	-
C. mexicana	+	-	-	-	-	-	-	-	-	-	-	-
C. prostrata	+	+	+	-	-	-	-	+	+	+	+	+
C. tumida	+	+	-	-	-	-	-	-	+	-	-	-
C. turgida	+	+	+	+	+	+	+	+	+	+	+	+
C. ventricosa	+	-	-	-	-	-	-	+	+	+	+	-
Cyclotella bodanica	-	-	-	+	-	-	-	-	-	-	-	-
C. meneghiniana	-	+	-	+	-	-	+	-	+	-	-	-
C. michigina	-	-	-	-	-	+	+	-	+	+	-	+
C. pseudstelligera	-	+	-	-	-	-	-	-	-	-	-	-
C. stelligera	+	+	-	-	-	+	-	-	+	-	-	-

*Key: - indicates absence of taxa
+ indicates presence of taxa

TABLE 9 (Continued)

	Station											
	1A	2A	3A	4A	5A	6A	7A	8A	9A	10A	11A	12A
Diatoma vulgare	+	+	+	+	+	+	+	+	+	+	+	+*
Diploneis puella	-	-	-	-	-	-	-	-	+	+	-	-
Epithemia turgida	-	+	-	-	-	-	-	-	-	-	-	-
E. zebra	-	+	-	-	-	-	-	-	-	-	-	-
Fragilaria brevistriata	-	-	-	-	+	-	-	-	-	-	-	-
F. capucina	+	-	+	-	+	+	+	+	+	+	+	-
F. construens	-	-	-	-	+	+	+	-	+	-	+	+
F. crotonensis	+	+	-	-	+	+	+	+	+	+	+	+
F. lapponica	-	-	-	-	-	-	-	-	-	+	-	-
F. pinnata	-	+	-	-	-	+	-	-	-	-	-	-
F. vaucheriae	+	-	-	-	+	+	+	-	+	-	+	+
F. virescens	-	+	-	+	-	-	-	-	-	-	-	-
F. sp. 1	+	+	+	+	+	+	+	-	+	-	-	-
F. sp. 2	+	+	-	+	-	+	+	-	-	-	-	-
F. sp. 3	-	+	-	-	-	-	-	-	-	-	-	-
Frustulia rhomboides	+	+	-	-	-	-	+	+	+	+	+	-
F. vulgaris	-	-	-	-	+	+	-	-	-	-	-	-
Gomphonema abbreviatum	-	-	-	-	+	+	+	-	-	-	-	-
G. acuminatum	-	-	-	-	-	+	-	-	-	-	-	-
G. olivaceum	+	+	+	+	+	+	+	+	+	+	+	-
G. angustatum	-	-	-	-	-	-	+	+	+	-	-	-
G. constrictum	-	+	+	-	-	-	-	-	-	-	-	-
G. parvulum	+	+	+	+	+	+	-	+	+	+	-	-
G. sp. 1	-	+	-	+	-	-	-	-	-	-	-	-
Gyrosigma acuminatum	-	-	-	-	+	+	-	-	-	-	-	-
G. obtusatum	+	+	+	-	-	-	+	+	-	+	-	+
G. scalproides	-	+	+	+	-	-	-	-	-	-	-	-
Melosira distans	-	-	-	-	-	-	-	-	+	-	-	-
M. granulata var. angustissima	+	+	+	-	+	+	+	+	+	+	+	+
M. varians	+	+	+	+	+	+	+	+	+	+	+	+
M. sp. 1	-	-	-	-	+	-	-	-	-	-	-	-
Meridion circulare	-	+	-	-	-	-	+	-	-	-	-	+
Navicula cryptocephala	+	+	+	+	+	+	+	+	+	+	+	+
N. cuspidata	-	+	-	-	-	-	-	-	-	-	-	-
N. elginensis	-	-	-	-	-	+	-	-	-	-	-	-
N. exiqua	-	-	-	-	+	+	-	+	-	+	-	+
N. gregaria	-	+	-	-	-	-	-	-	-	-	-	-
N. halophila	-	+	-	-	-	+	-	-	-	-	-	-
N. hungarica	-	-	-	-	-	-	-	-	-	-	-	+
N. mutica	+	+	+	-	-	+	+	-	+	+	+	-
N. peregrina	+	+	-	+	+	+	+	-	+	+	+	+
N. pupula	-	-	-	-	-	-	-	-	+	+	-	-
N. radiosa	-	-	+	+	+	+	+	-	+	+	+	-
N. salinarum	+	+	-	-	-	-	+	+	-	+	+	+
N. tripunctata	+	+	-	-	-	-	-	-	+	-	-	-
N. viridula	-	+	+	-	-	-	+	-	-	-	-	-
N. sp. 1	-	+	-	-	-	+	-	+	+	-	-	+
Neidium apiculatum	-	-	-	-	-	-	-	-	-	-	-	+

*Key: - indicates absence of taxa
+ indicates presence of taxa

TABLE 9 (Continued)

	Station											
	1A	2A	3A	4A	5A	6A	7A	8A	9A	10A	11A	12A
Nitzschia acicularia	-	-	-	-	+	-	-	-	-	-	-	-*
N. amphibia	+	+	-	+	+	+	+	+	+	+	+	+
N. dissipata	-	-	-	-	+	-	-	-	+	-	-	-
N. filiformis	-	-	+	-	-	-	-	-	-	-	-	-
N. fonticola	-	-	-	+	-	-	-	-	-	-	-	-
N. hungarica	-	-	-	-	-	-	+	-	-	-	-	-
N. palca	-	-	-	+	+	-	-	-	-	-	-	-
N. parvula	+	+	-	-	-	-	-	-	+	+	-	+
N. scalaris	-	+	-	-	-	-	-	-	-	-	-	-
N. sigma	+	-	+	-	+	-	-	-	-	-	-	-
N. sigmoidea	-	+	-	-	-	+	-	+	-	-	+	-
N. sinuata	-	-	-	-	-	-	-	+	-	+	-	-
N. sp. 1	+	+	+	-	+	+	+	+	+	+	+	+
N. sp. 2	+	+	+	-	+	+	+	+	-	+	-	+
N. sp. 3	-	-	+	-	-	+	+	-	-	-	-	-
N. sp. 4	-	+	-	-	-	-	+	-	-	-	-	-
Pinnularia biceps	-	-	-	-	-	+	+	-	-	-	-	-
P. brebissonii	-	-	-	-	+	-	-	-	-	-	-	-
P. divergens	-	-	-	-	+	-	-	-	-	-	-	-
P. subcapitata	-	-	+	-	+	-	-	-	-	-	-	-
P. sp. 1	-	+	-	-	-	-	-	-	-	-	-	-
Rhizolenia sp.	-	-	-	-	-	-	-	+	-	-	-	-
Rhoicosphenia curvata	+	+	+	+	+	+	-	+	-	+	+	+
Stauroneis obtusa	-	-	-	-	+	-	-	-	-	-	-	-
Stephanodiscus sp.	-	-	-	-	+	+	+	-	-	-	-	-
Surirella angustata	+	+	+	-	+	-	+	-	+	+	+	+
S. elegans	-	-	+	-	-	-	-	-	-	-	-	-
S. linearis	+	+	-	-	-	-	-	+	-	-	+	-
S. ovata	+	-	-	-	-	+	+	-	+	+	-	+
S. sp. 1	-	-	-	-	-	+	-	-	-	-	-	-
Synedra acus	+	+	-	+	-	+	+	-	-	-	+	-
S. actinastroides	-	-	-	-	-	-	+	-	-	-	-	-
S. delicatissima	-	-	-	-	-	-	+	-	-	-	-	-
S. faciculata	-	-	-	-	-	-	-	-	+	+	+	-
S. gaillonii	-	-	-	-	-	-	-	-	-	-	-	+
S. goulardi	-	+	-	-	-	-	-	-	-	-	-	-
S. parasitica	-	-	-	-	+	-	-	-	-	-	-	-
S. pulchella	-	-	-	-	-	-	+	-	-	-	-	-
S. rumpens	+	+	+	+	+	+	+	+	+	+	+	+
S. socia	+	+	-	-	-	-	-	-	-	-	-	-
S. ulna	+	+	-	-	+	+	+	+	+	-	+	-
Tetracyclus sp.	-	+	-	-	-	-	-	-	-	-	-	-

*Key: - indicates absence of taxa
+ indicates the presence of taxa

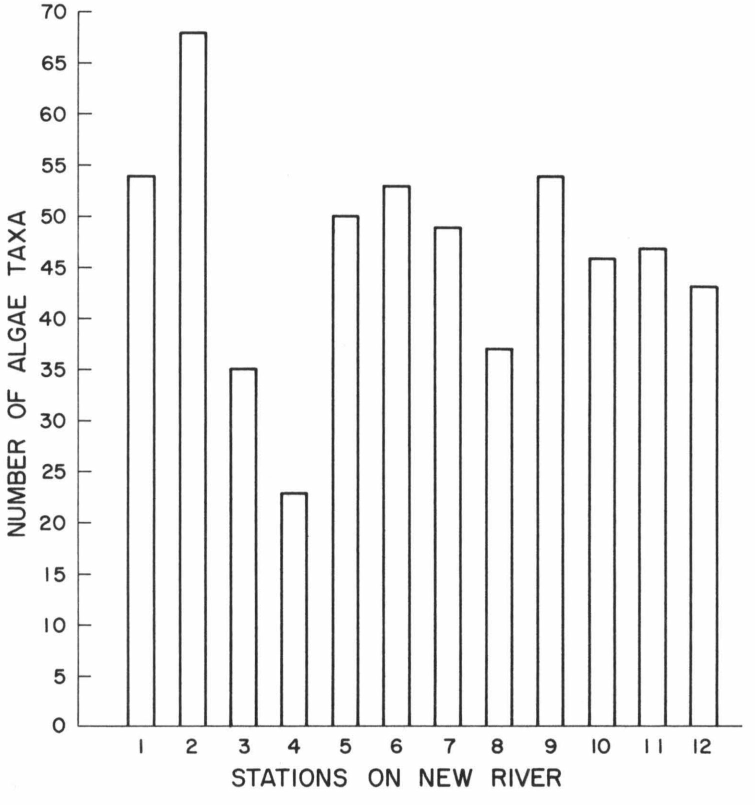
TABLE 10

Number of Algal Taxa Present in Each Major Division, by Stations

Division	Station											
	1A	2A	3A	4A	5A	6A	7A	8A	9A	10A	11A	12A
Cyanophyta (blue-green algae)	2	2	2	0	2	2	2	2	3	2	2	2
Chlorophyta (green algae)	4	3	2	1	3	4	2	4	6	5	8	6
Euglenophyta (euglenoids)	0	0	0	0	0	0	0	0	1	0	0	0
Chrysophyta (yellow-green algae)	1	1	0	0	0	1	1	0	0	2	3	3
Bacillariophyta (diatoms)	42	62	31	22	45	46	44	31	44	39	34	32
Total	49	68	35	23	50	53	49	37	54	48	47	43

FIGURE 4

Number of Algal Taxa, by Stations, June 1971



EFFECTS OF RADFORD ARMY AMMUNITION PLANT WASTES ON THE FISHES OF THE NEW RIVER, VIRGINIA

by

Robert D. Ross*

*Professor of Zoology, Department of Biology, Virginia Polytechnic Institute and State University, Blacksburg, Virginia

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Introduction

Fish occupy the apex of the aquatic trophic system utilizing directly or indirectly lower forms and are therefore dependent upon an adequately functioning aquatic community for their survival. Because of their direct economic value, they are extremely important in assessing the effects of waste discharges on the receiving system. However, unlike many lower forms of aquatic life which are relatively sessile, fish may avoid stress and therefore their absence may not necessarily indicate a lethal condition but merely that the fish have vacated the area of unacceptable water quality. By comparing ecologically similar areas above and below a waste outfall, it is often possible to evaluate the effects of a waste discharge since the effluent may preclude the use of an area as a feeding ground, nursery, spawning ground, etc.

It was the purpose of these studies to determine the effects of the waste discharges from Radford Army Ammunition Plant (RAAP) on the fishes of the New River.

Sampling Stations

Seven fish sampling stations (Stations $1F_1$, $1F_2$, 1F-5F) were established, located as shown on the map of the study area on the last page of this book. Station $1F_1$ was located at the Fairlawn Sewage Disposal Plant (but above its effluent) below Radford, Virginia, and just below the gaging station on New River at Fairlawn.

Station 1A was located at the water intake plant and this represented a station above all effluents from RAAP. Station $1F_2$ was just below the oleum plant discharge. Station 2F was above and below the bridge between the main manufacturing area and the magazine area but upstream from the power plant effluent. Station 3F was any point along Strouble's Creek within the plant area. Station 4F was at the head of two islands near Whitethorn, Virginia. Station 5F was just above the power plant in the cast propellant area and below the last major effluent from RAAP.

None of these stations was ecologically similar to any other in every respect, although similar features of one or more kinds were present at all stations. This contributes to unequal results as to the fauna from each station under ordinary circumstances and renders comparison of the results of the several stations difficult.

Station $1F_1$ was added in order to study an additional reference area upstream from RAAP. Station $1F_2$ was added because it became apparent that the effects of the oleum plant effluent might well become masked if the several collecting stations were spaced widely apart.

Materials and Methods

Rotenone proved to be the most satisfactory method of collecting, although it was difficult, if not impossible, to neutralize the rotenone slug below the collecting station. Electric shocking by alternating current was also very effective. When shocking was attempted, the results of the right and left banks were studied separately; the shocking period was 30 minutes of actual shocking time (when the current was operating in the water).

Seining was most effective over riffles and rubble bottoms and in creeks (Station 3F - Strouble's Creek). A trot line set at station 1F yielded no results. Hoop nets were set at Stations 1F, 2F, and 5F. A uniformity of fishing effort was made at each station.

Results and Discussion

The Upstream Stations

The results of fishing at the two upstream reference Stations $1F_1$ and 1F, neither of which were influenced by RAAP effluents, are listed in Table 11. Twenty-nine of the 31 species of fishes taken from all stations occurred at one or both of these stations. The species listed in Table 11 are by no means thought to represent all of the species present at these places, and several more species could most likely be added by more extensive collecting. This would only strengthen the impression already gained of the condition of New River above RAAP. Either station alone or both together show healthy stream conditions in so far as the fish fauna are concerned.

There are some conspicuous differences between the fishes obtained from Station $1F_1$ and 1F, especially with the bluntnose minnow and the Piedmont darter, both of which show populations apparently of high density at one, but not both, stations. This probably is due to ecological differences between these two stations. Station $1F_1$ is almost wholly rubbly or hard-bottomed, whereas at Station 1F there were large areas with a silty or softer bottom. The bluntnose minnow prefers soft bottoms, whereas the Piedmont darter favors hard bottoms.

The Piedmont darter apparently has been introduced into New River. In the summer of 1965, the writer took a single specimen from New River at the mouth of Spruce Run, in Giles County, Virginia. One or two specimens have been taken since then. On the present survey the Piedmont darter was found in considerable numbers, suggesting that this species is now enjoying a population explosion in New River. Other fishes apparently introduced in recent years, are the telescope shiner, *Notropis telescopus*, the whitetail shiner *Notropis galacturus*, the swallowtail shiner, *Notropis procne*, and the spottail shiner, *Notropis hudsonius*. The last two species have not previously been reported from New River, to the writer's knowledge. Both species seem to be well established.

Stations Showing A Damaged Fish Fauna

Stations $1F_2$, 2F, and 3F indicate the effects of waste discharges (Table 12; Figure 5). Station $1F_2$ was taken only on the right side of the river, below the outfall from the oleum plant. A large riffle was investigated here, one side of which (nearest the bank) was under the influence of the effluent, whereas the other side of the riffle was still untouched by any plant outfall. On the discharge side of the riffle all of the rocks were clean and bare of any algal growths. Few aquatic insects were observed here and only five species of fishes were collected. Below the riffle and also under the influence of the wastes from the oleum plant was a large pool which presumably would serve as a nursery ground for all kinds of fishes, both game and forage types. This pool was thoroughly poisoned with rotenone, but not a single fish was recovered.

Station 2F was found to be well below the standard of "health" for this portion of New River, as established at reference Stations $1F_1$ and 1F. Less than half of the expected number of fishes was present, and for almost all species the numbers of specimens of each species taken were minimal. The only exception to this was 41 common suckers (a number greater than was taken elsewhere for this species during this survey). Most of these were young-of-the-year which had just absorbed the yolk sac. Many of these were found drifting downstream along the right bank. Special efforts were made to secure these with a dip net for identification. More of this species were recovered by this method than would otherwise have been the case.

Station 3F - Strouble's Creek, was found to be devoid of fishes except for two specimens of the blacknose dace. These fish were sleek and in prime condition. They had doubtless entered from the main river as migrants and would not have remained long if they had not been captured. Almost any other species might be found in Strouble's Creek as transients. Waste discharges from both the Blacksburg-VPI Sewage Treatment Plant and RAAP seem to have reduced Strouble's Creek to almost zero productivity insofar as fish are concerned.

This creek once supported a varied fish fauna of about 20 species, as may be shown by Virginia Polytechnic Institute and State University collections 452, 477, and 503, taken in 1951 and 1952. In 1954 considerable damage had been done, and only seven species of fishes were found (collection 625).

Downstream Recovery

Table 13 shows the results of fishing at Station 4F and 5F. It should be clear that New River had recovered to a state of "health" at these places. There were 26 of the 31 species reported present here. This is three less than the number of species reported from the upstream Stations $1F_1$ and 1F, but the difference in quality of the upstream and downstream faunas was slight or nonexistent.

Some species in the samples taken at Stations 4F and 5F were much more numerous than others. If the sample figures truly reflect population numbers, it may be that the local ecological conditions favor these species more than conditions elsewhere. Additional surveying would doubtless increase the numbers reported from all stations.

Conclusions

The New River in Montgomery and Pulaski Counties, Virginia, is a large stream, wide and deep enough and sufficiently varied ecologically to support a fish fauna of more than 30 species. Waste discharges may reduce the fish fauna drastically, but the river is capable of absorbing a heavy and varied discharge and recovering from the deleterious effects of this load in a relatively short distance, as evidenced by the fish data in this report.

The principal effect of waste discharges from RAAP seems to be a localized decrease in the number of fish species present. The number of minnow species was drastically reduced below the oleum discharge and the 48-in. power plant effluent. The total number of fish collected at these stations was also reduced, even though the sampling efforts were equal. However, the fish fauna at Stations 4F and 5F seemed to be similar to the upstream reference areas, indicating a recovery from the localized damage.

TABLE 11

Numbers and Species of Fishes from New River at the Upstream Stations, June 1971

Families and Species	$1F_1$	Right 1F	Left 1F
Sucker family, Catostomidae			
Common sucker, *Catostomus commersoni*	3	1	2
Hog sucker, *Hypentelium nigricans*	1	--	--
Minnow family, Cyprinidae			
Stoneroller minnow, *Campostoma anomalum*	12	--	--
Mountain redbelly dace, *Phoxinus oreas*	1	--	--
Blacknose dace, *Rhinichthys atratulus*	2	--	--
Bluntnose minnow, *Pimephales notatus*	8	93	100
Bigmouth chub, *Nocomis platyrhynchus*	53	1	--
Bluehead chub, *Nocomis leptocephalus*	--	--	1
Rosefin shiner, *Notropis ardens*	--	--	1
White shiner, *Notropis albeolus*	--	2	5
Spottail shiner, *Notropis hudsonius**	93	1	1
Whitetail shiner, *Notropis galacturus**	--	7	5
Spotfin shiner, *Notropis spilopterus*	--	11	--
Swallowtail shiner, *Notropis procne**	14	6	7
Rosyface shiner, *Notropis rubellus*	--	22	30
Telescope shiner, *Notropis telescopus**	1	16	2
Mimic shiner, *Notropis volucellus*	--	18	10
Catfish family, Ictaluridae			
Margined madtom, *Noturus insignis*	1	--	--
Perch family, Percidae			
Greenside darter, *Etheostoma blennioides*	3	--	--
Fantail darter, *Etheostoma flabellare*	3	--	--
Yellow perch, *Perca flavescens*	--	6	3
Piedmont darter, *Percina crassa**	155	--	15
Sunfish family, Centrarchidae			
Smallmouth bass, *Micropterus dolomieui*	--	1	1
Spotted bass, *Micropterus punctulatus*	--	--	--
Rockbass, *Ambloplites rupestris*	17	2	4
Redbelly sunfish, *Lepomis auritus*	7	7	9
Green sunfish, *Lepomis cynellus*	--	--	1
Pumpkinseed, *Lepomis gibbosus*	--	1	--
Bluegill, *Lepomis macrochirus*	1	5	4

*New records for New River, or recent introductions
Right = Right Bank, facing downstream
Left = Left bank, facing downstream

TABLE 12

Numbers and Species of Fishes from New River at Some Stations, June 1971

Families and Species	$1F_2$	Right 2F	Left 2F	3F*
Sucker family, Catostomidae				
Common sucker, *Catostomus commersoni*	2	41	2	--
Minnow family, Cyprinidae				
Bluntnose minnow, *Pimephales notatus*	--	1	2	--
Blacknose dace, *Rhinichthys atratulus*	--	--	--	2
White shiner, *Notropis albeolus*	--	5	--	--
Spottail shiner, *Notropis hudsonius*	--	1	2	--
Spotfin shiner, *Notropis spilopterus*	--	3	--	--
Swallowtail shiner, *Notropis procne*	--	1	--	--
Rosyface shiner, *Notropis rubellus*	4	1	--	--
Perch family, Percidae				
Greenside darter, *Etheostoma blennioides*	2	--	--	--
Piedmont darter, *Percina crassa*	21	--	3	--
Sunfish family, Centrarchidae				
Smallmouth bass, *Micropterus dolomieui*	1	1	1	--
Rockbass, *Ambloplites rupestris*	--	5	--	--
Redbelly sunfish, *Lepomis auritus*	--	6	6	--
Bluegill, *Lepomis macrochirus*	--	--	3	--

*Sum of four collecting localities on Strouble's Creek
Right = Right Bank, facing downstream
Left = Left Bank, facing downstream

FIGURE 5

Number of Fish Taxa, by Stations, June 1971

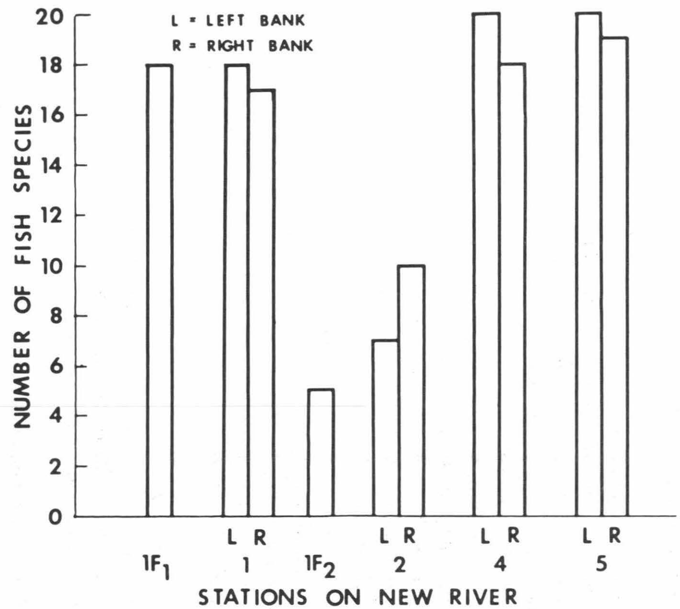

TABLE 13

Numbers and Species of Fishes Taken from New River at Two Stations Showing Recovery within the Radford Army Ammunition Plant, June 1971

Families and Species	4F Right	4F Left	5F Right	5F Left
Sucker family, Catostomidae				
Common sucker, *Catostomus commersoni*	7	7	5	2
Hog Sucker, *Hypentelium nigricans*	--	2	--	--
Minnow family, Cyprinidae				
Stoneroller minnow, *Campostoma anomalum*	24	44	11	--
Blacknose dace, *Rhinichyhys atratulus*	128	113	8	7
Bluntnose minnow, *Pimephales notatus*	8	2	345	235
Carp, *Cyprinus carpio*	--	--	1	--
Bigmouth chub, *Nocomis platyrhynchus*	--	18	--	--
White shiner, *Notropis albeolus*	16	--	2	12
Common shiner, *Notropis cornutus*	2	5	2	3
Spottail shiner, *Notropis hudsonius*	31	28	6	--
Whitetail shiner, *Notropis galacturus*	11	10	5	8
Spotfin shiner, *Notropis spilopterus*	6	1	14	--
Swallowtail shiner, *Notropis procne*	--	--	26	4
Rosyface shiner, *Notropis rubellus*	32	39	2	--
Telescope shiner, *Notropis telescopus*	--	--	1	8
Mimic shiner, *Notropis volucellus*	12	2	2	1
Perch family, Percidae				
Greenside darter, *Etheostoma blennioides*	--	2	--	2
Fantail darter, *Etheostoma flabellare*	--	--	--	1
Yellowtail perch, *Perca flavescens*	6	4	2	8
Sunfish family, Centrarchidae				
Smallmouth bass, *Micropterus dolomieui*	1	3	--	1
Spotted bass, *Micropterus punctulatus*	4	3	1	--
Rockbass, *Ambloplites rupestris*	18	12	5	13
Redbelly sunfish, *Lepomis auritus*	16	24	10	16
Green sunfish, *Lepomis cyanellus*	--	--	15	4
Pumpkinseed, *Lepomis gibbosus*	1	4	--	2
Bluegill, *Lepomis macrochirus*	2	3	--	2

Right = Right Bank, facing downstream
Left = Left Bank, facing downstream

GENERAL CONCLUSIONS

The purpose of the biological phase of this study was to determine the effects upon biological water quality of waste discharges from RAAP which might affect the aquatic biota. The results indicate that at the time the survey was conducted some waste discharges from RAAP were having a localized effect on the aquatic biota. However, principal damage seemed to be restricted to an area within the physical boundaries of RAAP. Specific conclusions follow:

1. The results of the biological survey indicated that major waste effluents, oleum plant discharge, heated water and ash, and TNT wastes via Strouble's Creek, were having a localized damaging effect on the biota of the New River. However, recovery was apparent downstream and by the time the river left the RAAP property the biota was similar to the upstream reference above any influence from RAAP.

2. The fish fauna below the oleum discharge, below the heated water and ash discharge, and in Strouble's Creek was drastically reduced in both species and number of individuals when compared to reference areas and historical data. Strouble's Creek had a depauperate fish fauna as it entered RAAP property before contact with any waste discharge from RAAP.

3. "Pollution-intolerant" bottom fauna organisms were present at all sampling stations on the New River. However, Strouble's Creek supports a "pollution-tolerant" community, indicating a stressed condition. In the New River a depauperate bottom fauna community was present above, in, and below RAAP.

4. The biomass of aquatic macrophytes was decreased immediately below the major waste discharges but increased downstream from the effluent from the TNT operations. A greater biomass was present at Stations 8P, 9P, and 10P than at the reference areas upstream from RAAP. Limited chemical data indicate that this may have been in response to nutrient enrichment (nitrogen) from RAAP. The diversity of aquatic macrophytes was reduced below the major discharges from RAAP but recovered as the river left the plant property.

5. The algal communities were similar at all of the sampling stations, with major changes being apparent only immediately below the

waste discharges. No algal blooms were apparent at the time of the survey.

Based on the biological survey data it appears that RAAP should consider corrective treatment action regarding the following waste discharges:

Oleum plant discharge. The biota immediately below this waste discharge appears to be under toxic stress. The fish fauna and aquatic plants were greatly reduced in diversity and number, indicating a toxic situation rather than an organic enrichment problem.

Heated water-ash discharge. The primary effects of this discharge seemed to be due to a siltation-sedimentation of ash materials. The ash appeared to be physically smothering the substrate material in the river and thereby altering the habitat. The attached algae downstream from this disc harge were greatly reduced. The influence of the heated water and other organic and inorganic waste components could not be separated from the effects of the ash.

TNT waste via Strouble's Creek. The entire stretch of Strouble's Creek was in a degraded state throughout RAAP property. Therefore, it was impossible to evaluate the effects of waste discharges on the biota in the creek. However, waste carried via Strouble's Creek either from RAAP or from domestic waste in Strouble's Creek through apparent nutrient enrichment were stimulating the growth of higher plants in the New River. It is possible that nitrogen-containing waste from the TNT process were contributing to this enriched condition.

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