ncasi technical bulletin

NATIONAL COUNCIL OF THE PAPER INDUSTRY FOR AIR AND STREAM IMPROVEMENT, INC., 260 MADISON AVENUE, NEW YORK, N.Y. 10016

EFFECTS OF BIOLOGICALLY STABILIZED BLEACHED KRAFT EFFLUENT ON WARM WATER STREAM PRODUCTIVITY IN EXPERIMENTAL STREAMS - THIRD PROGRESS REPORT

TECHNICAL BULLETIN NO. 414

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In early 1974 the National Council, in cooperation with the Weyerhaeuser Company and the North Carolina Department of Natural and Economic Resources, Office of Air and Water Resources, initiated the second in a series of major aquatic biology field investigative efforts. The objective of these efforts is to provide a basis for estimating the concentration of kraft mill effluents that would not be expected to directly or indirectly decrease the production of fish. The results of the first of these studies was distributed as NCASI Stream Improvement Technical Bulletin No. 290. The work reported in Technical Bulletin No. 290 covered a period of five years and during its course studied the effect of unbleached kraft mill effluent on salmonids, using specially constructed natural type streams.

The second in this series of studies described in NCASI Stream Improvement Technical Bulletins Nos. 292 and 301 dealt with work carried out at facilities located on property owned by the Weyerhaeuser Company at New Bern, North Carolina and are progress reports on the early years of the study. Here four specially constructed streams are supplied a source of receiving water and biologically treated bleached kraft effluent from the company raw process water supply and effluent treatment system, respectively.

The third in this series of studies pertains to work carried out at the National Council's Cold Water Fisheries Research Project. The facilities are located on property of the Potlatch Corporation in Lewiston, Idaho. Here water taken from the Clear Water River supplies four experimental streams which also receive biologically treated bleached kraft effluent. Technical Bulletins Nos. 368 and 413 describe the findings of the first and second year's study at this site.

The material reported in this bulletin is the third progress report on work underway at New Bern. It covers the work carried out over the first seven years of the study. The bulletin was prepared by Dr. Dennis L. Borton, Manager of the National Council's Southern Streams Warm Water Fisheries Research Project, who supervises the study, and is assisted by Mr. William R. Streblow and Mr. Richard E.

Rupp, Research Biologists. The analysis of effluent is carried out in part by Weyerhaeuser personnel, with chemical analysis requiring gas chromatographic and mass spectrophotometric analytical procedures conducted by National Council staff at the West Coast Regional Center. Earlier, the measurements were carried out under the direction of Dr. Robert R. Claeys, then Research Chemist. Mr. Lawrence E. La Fleur, Organic Analytical Laboratory Manager, has carried out this function in recent years.

The investigative techniques used are similar to those used in the study involving bleached kraft effluent and the cold water fishery. They provide for introduction of a biologically treated bleached kraft effluent at a controlled rate to specially constructed experimental streams. The effect of the effluent on a representative aquatic community of food organisms and warm water fish under conditions very close to those existing in nature can then be studied.

During the seven year period covered by the material in this technical bulletin, the amount of biologically treated bleached kraft mill effluent was increased incrementally on an annual basis, starting with 0.4 ppm BOD added to the experimental streams and finally reaching the level of 2.5 ppm BOD added, which was about 15 percent by volume. The greatest amount of total resin acids, chlorinated phenols, and color added was 200 ug/l, 30 ug/l, and 275 color units, respectively.

During the course of the study the macroinvertebrate biomass and numbers were equally as good or better in streams receiving effluent than the control streams. The total production and biomass of the three test species of fish, golden shiners, bluegill sunfish and bass, was equally as good and frequently better in streams receiving effluent than controls. At effluent concentrations of 1.7 ppm BOD added (9 percent by volume) and greater, the seasonal productivity during spring and early summer, of control streams for bass was slightly greater than those receiving effluent. The importance of this observation is limited since low stream flows in the South are seldom encountered during this season. The spawning success of all three species has not been impaired at the levels of effluent thus far tested.

This is the first of seven technical bulletins which will be issued in early 1984 covering investigations carried out at this study site during the past seven years. The others cover periphyton production, the histopathology of the test fish, early life stage egg-larval studies and observations regarding bioaccumulation in the test fish.

Your comments and questions on the content of this technical bulletin should be directed to me or to Dr. Borton at 911 Devers Avenue, New Bern, North Carolina 28560 (Telephone 919-637-4326).

Yours very truly,

Russell O. Blosser
Technical Director

ROB:gs
Attach.

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EFFECTS OF BIOLOGICALLY STABILIZED BLEACHED KRAFT EFFLUENT ON WARM WATER STREAM PRODUCTIVITY IN EXPERIMENTAL STREAMS - THIRD PROGRESS REPORT

I INTRODUCTION, OBJECTIVES AND BACKGROUND

Questions arising from an array of sources such as regulatory agencies, citizens groups, and the forest products industry indicate their concern about the effects of industrial or municipal effluents on aquatic communities inhabiting receiving waters. One primary question concerns the compatibility of these effluents with the continuous yield of valuable commercial or sport fish. Researchers have addressed this question using a variety of investigative techniques. NCASI (1, 2, 3), Leach (4, 5), and others have established that well treated pulp mill effluents of several types including bleached kraft effluent generate little, if any, response in static or flow through 96-hour short-term bioassays. These biologists and others realized that effects on the physiology, growth, and production of fish or other members of aquatic communities could occur at effluent levels below those likely to cause mortality during short-term tests. Several approaches have been used to study such effects during short and long-term sublethal testing. Walden and Howard (6) recently summarized the results of many such tests and again indicated the utility of biological treatment for the reduction of any direct toxic effects of the effluents on the parameters tested.

Many of the reported results reviewed by Walden deal with direct effects of effluents on a single physiological test parameter under laboratory conditions, the significance of which is frequently not understood. However, effluents entering receiving waters may affect the production of fish inhabiting those waters through either direct or indirect mechanisms. Direct mechanisms include activity or behavioral changes which alter the amount of food consumed and metabolic changes affecting the efficiency of food utilization. Changes in the abundance or availability of items in the food web are included in the indirect mechanisms. Also, fish in natural conditions may be exposed to effluent additions for a longer period of time than those exposed under laboratory conditions. It is desirable to take these factors into account when undertaking studies designed to determine the levels of effluents having no adverse effect on the production of fish in receiving waters.

For this reason, the NCASI aquatic biology program has focused on the effects of pulp mill effluent on the growth and production of important game fish species using experimental streams. In these streams, processes similar to those in natural streams occur, including direct effects of the effluents on the metabolism or behavior of the fish and indirect effects such as changes in the food web. The first such experimental stream program dealt with the effects of an unbleached kraft linerboard effluent on the production of salmonids. This study is reported in NCASI Stream Improvement Technical Bulletin No. 290. More recently, questions about the effects of chlorinated organic compounds on organisms inhabiting receiving waters have led to the current experimental streams study programs where the effects of bleached kraft pulp mill effluents on fish production have been studied. The study described in this bulletin was carried out at a site located at New Bern, North Carolina, and was designed to simulate conditions found in streams of the Southern United States. A second concurrently active site located at Lewiston, Idaho is designed to simulate the environment of cold water fish, and rainbow trout are used as a test species.

The primary parameter studied in this program and the subject of this technical bulletin was the production of fish, but other portions of the aquatic community, particularly those important in the food web, were not overlooked. The roles of the periphyton and macroinvertebrate communities of providing primary and secondary production are important study elements within the experimental streams program. Therefore, the biomass and community structure of the macroinvertebrate population as well as the biomass, chlorophyll content, and community structure of the periphyton are also studied.

This technical bulletin summarizes the results of the first seven years of effluent study in which two treatment streams received from 0.4 mg/l BOD of addition of mill effluent during the first year to over 2.5 mg/l of BOD during the most recently reported year. Separate reports are being completed concerning other aspects of the stream study to provide a comprehensive discussion of cumulative knowledge developed relative to fish production and other components of the food chain, such as periphyton production. Additionally, bulletins will be issued summarizing other aspects of the Southern Streams Program including acute, chronic and egg-larval bioassays with warm-water species, the extent of bioaccumulation observed, and histopathology studies of the fish exposed during the production studies reported here.

II TEST FACILITY AND EXPERIMENTAL METHODS

A. Facility Description

Four meandering streams, designed to create an environment similar to that of warm water streams in the Southern United States, and particularly the very productive backwater areas, were constructed on a site near the Weyerhaeuser Corporation bleached kraft pulp mill at New Bern, North Carolina. Each stream was approximately 350 feet long with square pools approximately 26 feet wide and 4 feet deep at the center alternating with 6 riffle areas which were 28 feet long, 5 to 6 feet wide and 1 foot deep at the center. The pools and riffles were constructed on a 3:1 slope and the sides were covered with a uniform marl gravel approximately 1-1/2 inches in diameter. The four streams each received 0.6 CFS of water pumped from the Neuse River. This water was taken from the main intake line of the Weyerhaeuser Corporation prior to any pretreatment for mill operations, and was delivered to the streams through approximately 500 feet of 12 inch asbestos cement (transite) pipe. The flow was split among the 4 streams by a cast iron splitter box and valved inflow lines to weir boxes at the head of each stream. The weir box at the head of each stream allowed the water flow to be continuously measured. Flows were adjusted when found to be outside the designated rate.

In addition to the river water, two of the streams hereafter termed treatment streams were designated to receive biologically stabilized effluent (BKME) from the nearby Weyerhaeuser Corporation aerated stabilization basins. Stabilized bleach kraft mill effluent (SBKME) was pumped from the final discharge canal of the mill's aerated stabilization basin and settling ponds to the NCASI stream site through 5,000 feet of 6 inch asbestos cement (transite) pipe. Effluent flow was introduced to two of the streams through headboxes with V-notch weirs for flow measurements. Flows to each headbox were controlled by valves on the effluent line. Two automatic shut-off valves eliminated the flow of effluent to the streams if the river water supply was interrupted.

Traps located immediately below each stream collected fish migrating from the streams and permitted their return to the test facility. Dilution water entering the streams also passed through a trap constructed of 0.039 square inch mesh openings. This allowed larger food organisms and small fish to be removed from the incoming water supply.

The stream site included a 50-foot laboratory trailer equipped for sample analysis and 4 fish holding tanks. The site is enclosed with a 5 foot high fence. A photograph of the experimental streams is shown in Figure 1.

B. Dilution Water Source and Characterization

The Neuse River Basin drains approximately 6,000 square miles of the piedmont (upper Neuse) and coastal (lower Neuse) physiographic regions of North Carolina. Approximately 750,000 people live within the basin, including 7 major municipalities. The basin is principally agricultural with approximately 65-79 percent of the total land area in farms. Over 50 percent of the

FIGURE 1 VIEWS OF SOUTHERN STREAMS

farmland is forested. At the point of intake of water for the controlled streams, the Neuse River is a sluggish coastal stream with very little gradient. The average slope of the entire system is nearly 1 foot per mile. The river is typical of Southeastern Coastal Streams, having a high nutrient content, and often relatively high color and turbidity and low pH as farmlands and backwater areas are flushed by rainfall (7).

The river water was characterized for BOD, COD, and pH by personnel of the Weyerhaeuser Environmental Laboratory according to methods described in Standard Methods (8). River water color and color in the experimental streams was determined by NCASI personnel (9). Analysis of nitrates and phosphates was available from the North Carolina Department of Natural Resources and Community Development Water Quality Section, and NCASI personnel conducted nutrient analyses in the streams during 1979-80 (7, 8). In addition to this information, the U.S. Geological Survey, in cooperation with the state agency, maintains a more complete sampling station at Kinston, North Carolina, approximately 25 miles upstream from the control water intake. Records of the heavy metal content of the water and sediments are available from this station as well as data on the levels of pesticides and herbicides often used for local agriculture (10).

The temperature of the water entering and exiting one of the experimental streams was continuously recorded on a Partlow spring-wound temperature recorder. Data from these charts could be taken as daily highs and lows, weekly means, or other periodic means as needed.

Prior to the spring of 1979, oxygen was measured by collecting samples in BOD bottles and transporting these to the laboratory for analysis by the Winkler method (8) or YSI Model 57 D.O. analyzer. After the spring of 1979, the oxygen was measured using a YSI Model 56 D.O.-temperature continuous recorder, and oxygen was monitored for daily periods in each stream following an alternating pattern.

C. Effluent Source and Characterization

Weyerhaeuser Corporation operates a non-integrated bleached market kraft pulp mill at New Bern, North Carolina producing approximately 725 to 750 tons per day from a furnish consisting of 15 to 25 percent hardwoods and 75 to 85 percent softwood species. Effluent from the CEHDED bleaching sequence combines with primary clarifier effluent consisting of the alkaline sewer from the kraft pulping process, before entering the first aerated stabilization basin for secondary treatment. This effluent then flows to polishing and settling basins for completion of the normal 12 to 14 day treatment. The effluent can be held up to 30 days, if necessary. The 28 to 32 mgd of biologically treated effluent then flows through an aeration canal before entering the river. The effluent used in these studies was pumped from the aeration canal to the stream site.

The effluent was usually characterized 4 to 5 times per week for BOD, suspended solids, and pH and weekly for total solids and COD by personnel of the Weyerhaeuser Environmental Laboratory using methods described in Standard Methods. The color of the effluent was also periodically characterized using NCASI methods. Samples were shipped to the NCASI West Coast Regional Center and examined there for the presence and levels of organic compounds in the effluent which have been shown to account for much of the biological effect on fish. These include resin acids and chlorinated compounds found in bleachery effluents (5). These procedures include GC-MS analysis. This analysis, as well as the number of samples analyzed has progressed over the years of this study, and details of the analytical techniques can be found in NCASI Stream Improvement Technical Bulletin No. 332 or 337 (11, 12).

D. Calculation of Effluent Characteristics Added to the Streams

The two designated treatment streams received effluent based on a desired incremental increase in BOD. The BOD was chosen as the basis for effluent introduction measurements because this parameter is often used for permit requirements and generally reflects the organic content, including an indication of the biologically active components of the effluent, if the level of treatment is known. Since the BOD of any effluent fluctuates somewhat because of treatment efficiency and measurement procedures, the BOD level was set for approximately one week based on the most recent measurement, and the percent by volume concentration entering the stream for that week was recorded. BOD's below 10 were considered to be 10 during these studies since percent by volume concentrations could otherwise reach excessively high levels. The actual BOD, TSS, and resin acid or other organic constituent concentrations added to the treatment streams were calculated by multiplying the single or mean value of each characteristic measured in the effluent during a given week by the percent by volume effluent concentration entering the stream during the same week. Effluent additions designated to increase the BOD of the treatment streams by 0.5 mg/l were added during the first year. The concentration of BOD was then increased by approximately 0.5 mg/l each succeeding year until approximately 1.5 mg/l of BOD was reached during the third year. At that time, the concentrations were increased only slightly to allow desired additions to the NCASI Aquatic Biology Program to be implemented before effluent concentrations in the experimental streams reached levels that would be rare in natural receiving water. The average concentration of effluent in these streams at 1.5 mg/l of BOD added was already greater than the

7Q10 concentration of effluent in the receiving water of 72% of Southern mills discharging into fresh water (13). Of the remaining 28%, 1/3 are on small creeks where the mill contributes 50% or more of the flow during low flow months. Sporadic increases in the content of organic components of the effluent and the desire to add more thorough chemical analysis, bioaccumulation studies, periphyton studies, and laboratory growth and full-life cycle studies all indicated a need to maintain the level of exposure near the previous levels during 1978 to 1979 and 1979 to 1980. During 1980 to 1981 and 1981 to 1982, the level of BOD added was increased to approximately 2.1 mg/l and 2.5 mg/l, respectively.

E. Experimental Methods for Macroinvertebrate Studies

Benthic organisms were sampled at approximately monthly intervals during each year of study because of their importance as a source of food for the fish. Three samples were collected each month from each stream. Riffles 1, 3 and 5, or 2, 4 and 6 were sampled on alternate months. A cylindrical sampler was pushed through the benthic gravel until a seal was formed in the sand beneath. The water inside the cylinder was then pumped through a U.S. Standard No. 35 seive net with a small hand operated diaphram pump or battery operated centrifugal pump. The gravel substrate within the cylinder was removed, placed in a screened container and sprayed with a high-pressure water hose until no attached organisms remained. The wash from the gravel was combined with the organisms found in the net after pumping to complete a riffle sample.

During the first 5 years of study, one half of each of the three samples from one stream were composited and preserved in a 10% formalin solution. One-half of the composite was then hand-picked without the aid of a microscope and separated into major taxonomic groups. The groups were counted and weighed to the nearest 0.1 mg. Excess moisture was removed by placing the organisms on an absorbent towel before weighing. Another 1/8 of the picked sample was hand-picked using a 10x binocular microscope. These organisms were also separated into taxonomic groups, counted and weighed. During the 1980 to 1981 and 1981 to 1982 years of the experimental stream studies, the samples were not composited, and 1/4 of each sample was initially picked without the aid of a microscope. One eighth of the picked sample was then picked again using a 10x binocular microscope. This procedure allowed sufficient samples for analysis of variance techniques to be applied to data.

Macroinvertebrates were identified to the lowest practical level using keys from several sources including Pennak (14), Ward and Whipple (15), Usinger (16), Merritt and Cummings (17), Holsinger (18), Brown (19), Williams (20), Kenk (21), and Beck

(22, 23, 24). Chironomids from the 1980 to 1981 and 1981 to 1982 study years were also identified using a more recent key from Brigham et al (25), and Mason (26).

Analysis of variance was applied to the 1980 to 1981 and 1981 to 1982 data to test the null hypotheses that mean monthly number and weights of the organisms were the same in streams receiving effluent and those without effluent addition. A logarithmic transformation was applied to normalize the data because the variances and means of the benthos counts were not independent (27, 28).

An intensive survey completed during April of 1980 was used to estimate the numbers of benthic samples necessary to achieve a given confidence interval about the mean. The coefficient of variation (SD/mean X 100%) of the log transformed counts of the major groups of organisms ranged from 15% for amphipods and chironomids to 42 and 43% for the isopods and snails, respectively. Organisms or groups having fewer numbers usually had higher coefficients of variation. Using the lower coefficients of variation, differences between control and treatment means of 30% would be expected to be detected 90 percent of the time with a 95% level of assurance (27) when 6 control and 6 treatment samples are taken (3 per stream). As the coefficient of variation increases to 42%, differences between means of 50% or more would be detected at frequencies of 60% or less when six samples of the control and treatment stream macroinvertebrates are taken.

Macroinvertebrate data from the 1980 to 1981 year was also used to calculate the Shannon-Weiner species diversity index (29), a biotic index based on Chutter's formula (30), and percentages of functional feeding groups (31).

The Shannon-Weiner index was calculated using the formula:

$$\bar{d} = \frac{C}{N} (N \, \text{Log}_{10} - \Sigma ni \, \text{Log}_{10} \, ni)$$ where C = 3.321928 (converts log base 10 to base 2); N = total number of individuals and ni = total number of individuals in the i^{th} species.

The biotic index was calculated using the formula:

$$BI = \frac{\Sigma ni \cdot Q}{N}$$

ni: = total number of individuals in the i^{th} species, N = total number of individuals, and Q = the quality number for that species.

The percent of each functional feeding group was calculated using the methods described by Cumming's (31). The biotic index number and functional feeding group number given to each species or genera was taken from a master list provided by the North Carolina Department of Natural Resources and Community Development-Division of Environmental Management-Biological Monitoring Group. These lists were the results of compilations by entomologists in the North Carolina area (32).

F. Experimental Methods for Fish Production Studies

Warm water streams in the Southeastern United States have natural populations of many game and forage fish species. In an experimental stream environment such as the system described previously, it would be very difficult, if not impossible, to follow the production of 25 to 30 species of fish. By selecting a single fish species such as the largemouth bass (Micropterus salmoides) to represent the carnivorous game fish and the bluegill sunfish (Lepomis macrochirus) to represent the sunfishes, the number of species stocked is greatly reduced but still represents some of the major game fish groups present in Southern rivers. Golden shiners (Notemigonus crysolucas) were selected to represent the abundant forage fish found in natural warm water streams.

All golden shiners stocked during each year were purchased from a local wholesale bait supplier. Largemouth bass and bluegill sunfish spawned in the experimental streams were distributed to the 4 streams and supplemented with fish from local farm ponds. The size and biomass at stocking varied somewhat during the experimental year because of differences in the stocking date and fish source.

Fish sampling was conducted at approximately monthly intervals during the first two years of the study. Since sampling during the first two years showed almost no production or growth to occur during the winter months, one winter sampling month was discontinued during later years. Also, sampling during late May and June was discontinued during 1980, 1981 and 1982 to avoid disturbing spawning fish. Fish were removed from the streams by seining with a 30 foot long, 6 foot deep bag seine. After removal from the streams, the fish of each species were counted and weighed in a tared container of water on a overhead balance to the nearest 0.1 gram. The fish were then returned to the stream from which they were seined.

Initial studies demonstrated that 95 to 100% of the golden shiners, 90 to 100% of the largemouth bass and 85 to 100% of the bluegill sunfish would be expected to be collected during each collection period. Inexperienced seine operators or macrophytes such as Elodea (sp) were found to reduce the seining efficiency somewhat. Also collection efficiency was somewhat reduced during winter months when fish apparently stayed very close to the stream bottom. If greater numbers of fish were collected during any month than the previous month the larger number was used for both sampling periods, and each additional fish was given the mean weight of fish collected during the earlier month.

Production and growth calculations were made according to the methods described by Allen (33) and later refined by Chapman (34). Production was calculated using the graphical method described there. The relative growth rates of each fish species is calculated using the following formula:

$$\text{Growth Rate mg/g/day} = \frac{Pn}{Bn \times Dn}$$

Pn = total production of a fish species during sampling period n

Bn = the mean biomass of that fish species during sampling period n

Dn = the number of days in sampling period n

Bn in the above formula is calculated using the following formula:

$$Bn = \bar{\bar{w}} \, (n_{\bar{\bar{w}}})$$

$\bar{\bar{w}}$ = median of the mean weights of fish during a sampling period =

$$\frac{(\bar{w}_n + \bar{w}_n + 1)}{2}$$

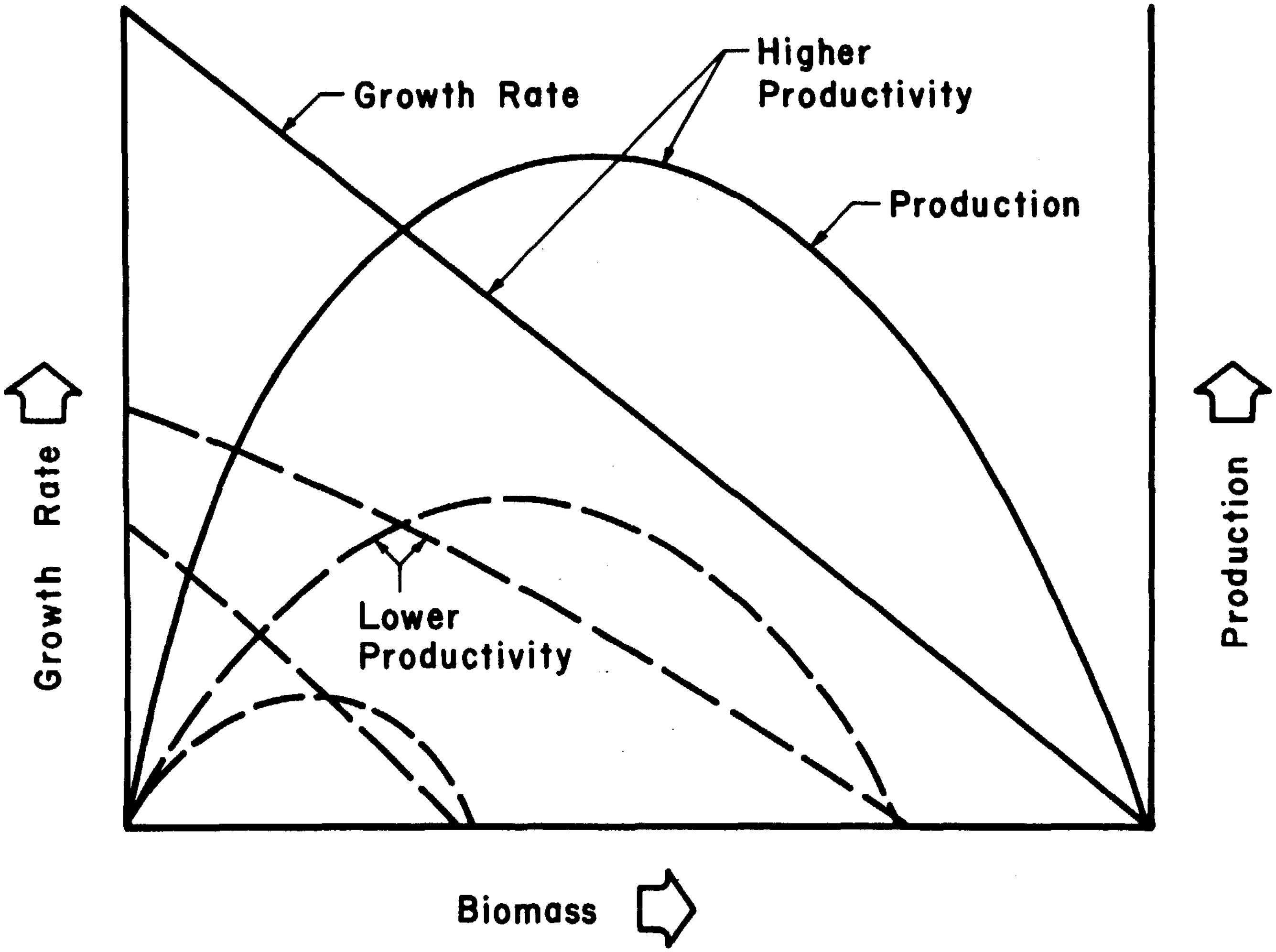
$\bar{w}_n$ = mean weight of fish at sampling date n

$\bar{w}_n + 1$ = mean weight of fish at sampling date n + 1

$n_{\bar{\bar{w}}}$ = number of fish in the stream at $\bar{\bar{w}}$ taken from the Allen curve

In analyzing the results of this study, the rationale first presented by Brockson, Davis and Warren (8, 9) and later further developed by Warren is used (10). Figure 2 shows theoretical relationships between fish production, growth rate, and biomass. The solid lines represent a system having a given productivity for fish. In a food-limited system having constant productivity as the biomass of fish increases the food available to a given weight of fish must decrease and, therefore, the growth rate

<u>FIGURE 2</u>



THEORETICAL RELATIONSHIP BETWEEN MEAN INDIVIDUAL GROWTH RATE AND MEAN POPULATION BIOMASS AND BETWEEN THE PRODUCTION AND BIOMASS OF THE POPULATION. CURVES ENCLOSING SMALLER AREAS INDICATE LOWER LEVELS OF STREAM PRODUCTIVITY FOR THE ANIMAL OF INTEREST.

must also decline during this time. The production is the product of the growth rate (mg/g/day), mean biomass (g/m^2), and time (days). Thus, initially, as the biomass increases from some low level, the production also increases. As the biomass continues to increase and the growth rate continues to decline, the production curve, after reaching a maximum, will begin to decline.

Were the productivity or capacity to produce fish to be greater in one experimental stream than another, two sets of production-biomass and growth rate-biomass relationships would be generated (Figure 2). The stream having the higher productivity will generate a production-biomass curve enclosing a greater area (solid line) than the stream having the lower productivity (dotted line). The more productive stream will also have a growth rate-biomass curve which is above and to the right of the growth rate-biomass curve of the less productive stream.

The relationships described above are for systems having constant productivity through time. In nature, however, the productivity of a system changes, within limits, over time. The productivity may be altered by changes in the temperature, nutrient levels, sunlight, insect life cycles, diseases, etc. These changes may partially obscure such theoretical relationships, but these relationships can be helpful in analyzing production studies such as this one.

Reproduction was observed in the experimental streams through observation and counting of the beds, or occurrence of spawning behavior. Streams were later observed for the occurrence in small fish. During the spring of 1980, 1981 and 1982, 6 round pans, 2 feet in diameter, filled 4 inches deep with gravel were placed in each stream and spawns having viable eggs were counted. Some of the spawns were used for egg hatchability testing and these data will be the subject of an upcoming technical bulletin.

G. Short Term Fish Bioassay Effluent Characterization

Fish were exposed for 96 hours to biologically treated BKME in static bioassay tests to determine the LC50 of fish to the effluent (8). Initially, the tests were performed at weekly intervals but, due to the total survival of the fish at 100% effluent concentrations, the bioassays were later performed at monthly intervals. Ten largemouth bass, bluegill sunfish, golden shiners, or mosquitofish were placed in plexiglass aquaria containing a series of effluent concentrations diluted to six litres with water from the Neuse River. Six litres of Neuse River water were placed in one of the aquaria as a control. The water temperature was held near 25°C during summer months and 20°C during winter months. After 96 hours of exposure to the effluent, the concentrations at which 50% of the fish survived was designated as the 96 hour LC50. In a test of this type, no fish may survive in one concentration but all of the fish might survive the next lower concentration. It is then necessary to extrapolate between these concentrations to determine the 96 hour LC50. After the 1978 to 1979 study year, these studies were replaced by continuous exposure, 30 day, early-life stage or full-life cycle studies with fathead minnows. These studies will be the subject of another technical bulletin.

III RESULTS AND DISCUSSIONS

A. Dilution Water Characteristics

Some characteristics of the incoming Neuse River water are shown in Table 1. At the time this bulletin was written, USGS data were not available for the 1981 to 1982 year and therefore only data through 1981 are reported. The mean BOD of the river water for the six years of testing was between 2.2 and 3.3 mg/l with individual low values near zero and a high value near 9.0 mg/l in April 1976. The mean COD ranged from 24 to 45 mg/l during the period with lows near zero and a high over 150 during July 1979. The water tended to be slightly acidic. The mean annual pH over four years ranged between 6.5 and 6.8, although lows of 5.3 and a high of 9.0 occurred. Drainage of acidic dark colored water from forested swamp areas probably affected the pH as well as the color. True color of the river water averaged between 53 and 70 mg/l and ranged between 30 and 120 mg/l during these 6 years. The lowest average river water true color occurred during the 1980 to 1981 year, which was a year of very low flow for the Neuse River. This may have affected the color because of low flushing and probably caused the incoming water temperature to increase as well. The water also tended to be nutrient rich with mean total phosphates ranging from 0.2 to 0.3 mg/l as P and mean nitrates plus nitrites between 0.5 and 0.9 mg/l as N during the six year of study reported. Low values of 0.1 mg/l and high of 1.6 mg/l of NO_3-N were recorded. Additional nitrogen was available as ammonia. Means ranging from 0.06 to 0.1 mg/l as N were recorded between July 1977 and July 1981. The incoming dissolved oxygen fluctuated with the temperature and season, being lower during the summer when a low of 3.4 mg/l was recorded in 1979. However, before entering the experimental streams, some oxygen was added to the water as it passed over the head box weir and cascaded through the screens of the front traps.

Figure 3 shows the temperature of the water entering the experimental streams during the studies described in this bulletin.

TABLE 1 PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE NEUSE RIVER ENTERING FOUR EXPERIMENTAL STREAMS

' INDICATES DATA OF USGS AT KINSTON, NC

	JUNE 1975 MAY 1976				JUNE 1976 JUNE 1977				JULY 1977 JUNE 1978			
	Mean	Max.	Min.	#OBS	Mean	Max.	Min.	#OBS	Mean	Max.	Min.	#OBS
BOD (mg/L)	3.3	8.9	0.1	47	3.4	7.9	0.5	53	2.2	6.6	0.3	47
COD (mg/L)	32.0	136	8	45	29	124	4	52	24	64	0	47
pH	6.8	8.4	5.3	47	6.8	9	5.7	53	6.5	7.4	5.7	48
Color (mg/L)	64	110	39	16	65	105	45	12	63	120	37	19
'Phosphates Total (mg/L as P)	0.2	0.3	0.1	7	0.3	0.4	0.1	13	0.2	0.4	0.1	13
'Nitrites + Nitrates (mg/L as N)	0.6	0.9	0.1	7	0.5	0.9	0	13	0.6	1.1	0.1	13
'Nitrogen Ammonia (mg/L as N)									0.1	0.1	0.01	10
Dissolved Oxygen (mg/L)	7.9	12.4	4.9	16	7.9	12.1	5.1	17	8.0	12.6	4.0	48

TABLE 1 (con't) PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE NEUSE RIVER ENTERING FOUR EXPERIMENTAL STREAMS
' INDICATES DATA OF USGS AT KINSTON, NC

	JULY 1978 AUG. 1979				SEPT. 1979 AUG. 1980				OCT. 1980 JULY 1981			
	Mean	Max.	Min.	#OBS	Mean	Max.	Min.	#OBS	Mean	Max.	Min.	#OBS
BOD (mg/L)	2.6	5.0	0.2	52	2.9	8.5	0.2	54	2.6	5.8	0.8	40
COD (mg/L)	29	152	0	43	41	80	8	54	47	118	7	41
pH	6.7	7.8	5.7	52	6.9	8.6	6	53	6.4	7.3	5.4	39
Color	70	118	30	17	78	130	35	23	53	105	30	21
'Phosphates Total (mg/L as P)	0.2	0.4	0.1	12	0.2	0.35	0.11	13	0.3	0.4	0.2	10
'Nitrites + Nitrates (mg/L as N)	0.6	1.0	0.1	12	0.6	1.1	0.01	13	0.9	1.2	0.6	10
Nitrogen Ammonia (mg/L as N)	0.1	0.2	0	12	0.06	0.13	0.01	13	0.07	0.11	0.04	10
Dissolved Oxygen (mg/L)	7.9	13.6	3.4	52	8.0	13.8	5.2	52	8.2	12.0	5.4	42

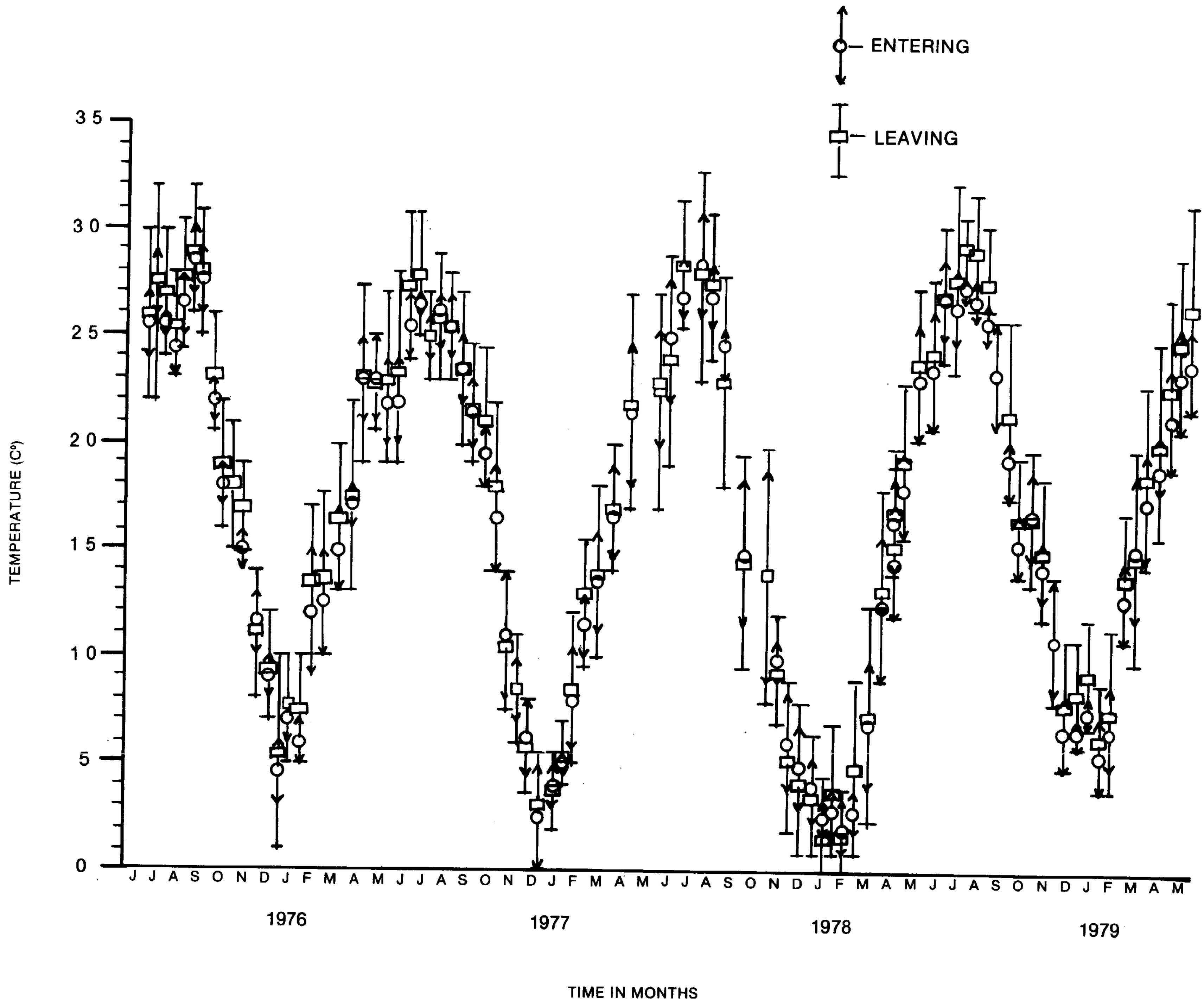


FIGURE 3 BIWEEKLY HIGH, LOW AND MEDIAN TEMPERATURE OF RIVER WATER ENTERING AND LEAVING STREAMS JUNE 1976 TO MAY 1979

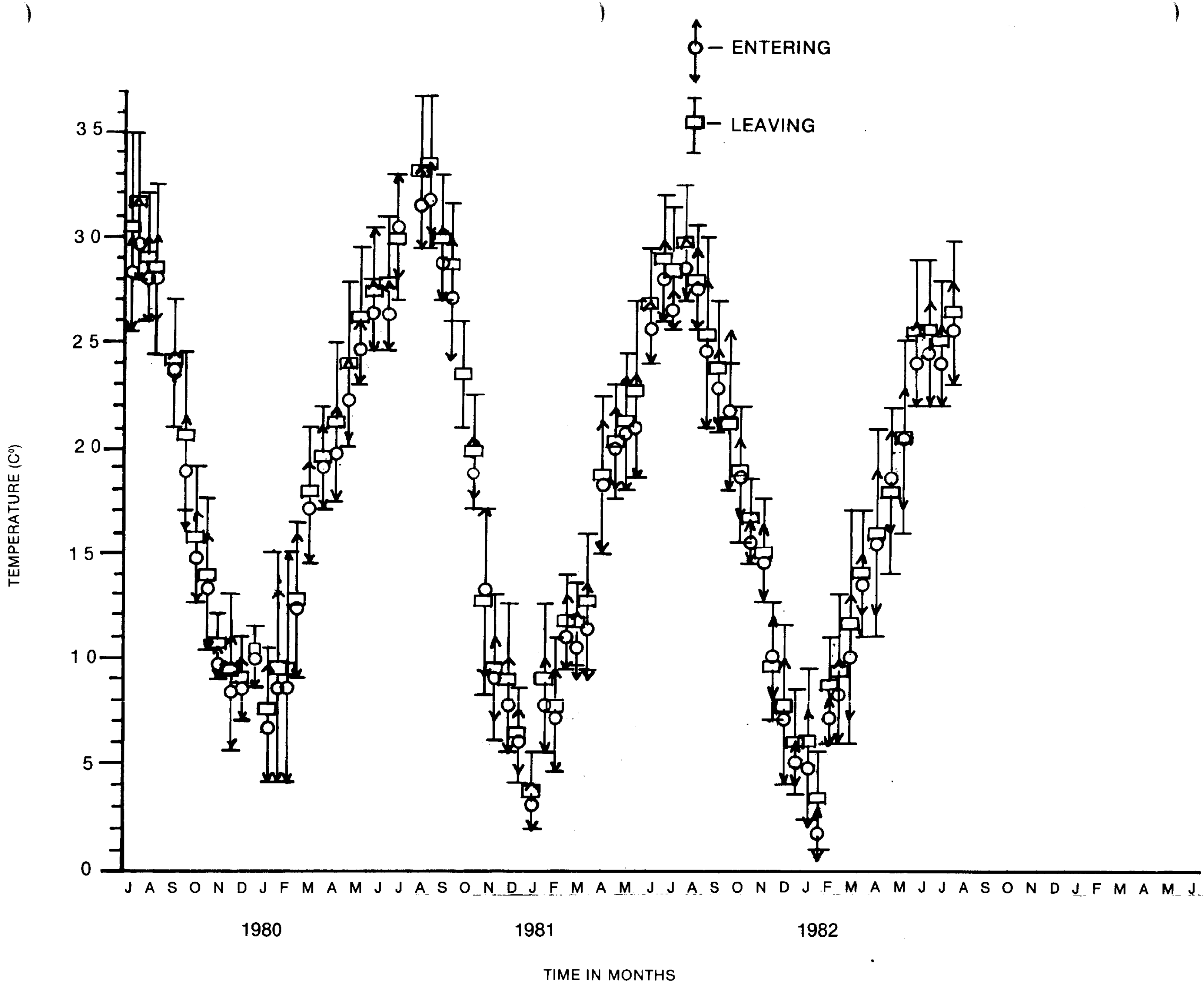


FIGURE 3 (Cont'd) BIWEEKLY HIGH, LOW AND MEDIAN TEMPERATURE OF RIVER WATER ENTERING AND LEAVING STREAMS JULY 1980 TO JUNE 1982

Usually, the incoming water ranged from near 0°C during the coldest winter months to highs near 32°C during the summer months. The water temperature increased a maximum of 2°C when passing through the streams during the summer and cooled by approximately the same amount during cooler nights. The temperature difference between effluent treated and control streams was never observed to be more than 1.0°C, and differences of 0.5°C were frequently detected only during the later years of these studies as the percent of effluent increased.

Data of the U.S. Geological survey taken at Kinston, North Carolina approximately 25 river miles upstream are summarized in Tables 2 and 3, and show that the river is often turbid, particularly during high rainfall periods of the autumn and spring. This water is relatively soft, the hardness not usually over 20 mg/l of $CaCO_3$. The amounts of heavy metals in the water were, in nearly all cases, below the criteria reported in the EPA Red Book (38). Usually the mercury levels were below detectable limits, but 3 values reported during 1976 to 1977 year were above the recommendation for fresh water aquatic life of 0.05 µg/L. Cadmium levels of the water were slightly above the recommended 0.4 µg/L concentrations for sensitive fresh water organisms such as cladocerans, but with one exception were below the 4.0 µg/L recommended for more tolerant species. The levels of 22 pesticides and herbicides in the water column and river sediments were always below detectable limits (Table 3).

B. Description of Effluent Characteristics and Amounts of Effluent Entering the Experimental Streams

(1) Quality of the Effluent - The weekly BOD of the effluent and the effluent concentration added to the treatment streams is shown in Appendix B. The BOD of the effluent was usually between 7 to 50 mg/l and a high of 72 mg/l was recorded during June 1981 and a low of 3 mg/l was recorded during September 1975. The BOD's tended to be slightly higher during winter months when the cooler weather probably reduced treatment efficiency. Effluent TSS levels were usually between 5 and 40 mg/l with a high of 78 mg/l during February 1980 and lows of near 1 mg/l during August 1977. The TSS tended to fluctuate with the BOD level. The effluent color was usually between 1,800 and 2,500 mg/l and a range of 1,300 to 2,800 mg/l were recorded over the duration of these studies.

(2) Amounts of Effluent Characteristics Added to Treatment Streams - Table 4 shows the range and mean of the measured effluent characteristics which entered 2 of the experimental streams during each of the seven experimental periods. During

TABLE 2

WATER QUALITY OF THE NEUSE RIVER DILUTION WATER
AT KINSTON, NORTH CAROLINA
DATA OF THE U.S. GEOLOGICAL SURVEY

	SEPTEMBER 1975 TO 1976			SEPTEMBER 1976 TO 1977		
	Mean	Range	No.OBS	Mean	Range	No.OBS
Turbidity (JTU)	12.0	2 to 30	12	12.0	1 to 30	12
Hardness (mg/L)	21.0	13 to 27	12	24.0	16 to 31	11
Conductance (MHOS)	94.0	58 to 142	12	107.0	16 to 141	12
Alkalinity (mg/L as $CaCO_3$)	17.0	7 to 31	12	20.0	7 to 31	12
Total Organic Carbon (C) (mg/L)	8.3	4.1 to 11	4	7.4	4.6 to 12	5
Dissolved Arsenic (µg/L)	0.8	0 to 1	4	0.6	0 to 1	5
Dissolved Cadmium (µg/L)	0	0	4	0.75	0 to 3	5
Dissolved Chromium (µg/L)	0	0	4	1.6	0 to 7	5
Dissolved Cobalt (µg/L)	0	0	4	0	0	5
Dissolved Copper (µg/L)	3.5	3 to 5	4	3.0	0 to 6	5
Dissolved Iron (µg/L)	232.5	140 to 350	4	208.0	90 to 330	5
Dissolved Lead (µg/L)	3.25	4 to 5	4	7.0	0 to 12	4
Dissolved Manganese (µg/L)	10	10 to 10	4	78.0	10 to 260	5
Dissolved Mercury (µg/L)	0.03	0 to 0.1	4	0.12	0 to 0.5	5
Dissolved Selenium (µg/L)	0	0	4	0	0	5
Dissolved Zinc (µg/L)	2.5	0 to 10	4	8.0	0 to 20	5

TABLE 2 (Continued)

WATER QUALITY OF THE NEUSE RIVER DILUTION WATER
AT KINSTON, NORTH CAROLINA
DATA OF THE U.S. GEOLOGICAL SURVEY

	SEPTEMBER 1977 TO 1978			SEPTEMBER 1978 TO 1979		
	Mean	Range	No.OBS	Mean	Range	No.OBS
Turbidity (JTU)	21.0	6 to 50	12	19.0	3 to 40	11
Hardness (mg/L)	19.0	14 to 26	13	19.0	12 to 27	11
Conductance (MHOS)	82.0	52 to 123	13	87.0	50 to 142	11
Alkalinity (mg/L as $CaCO_3$)	13.0	3 to 27	13	15.0	6 to 32	11
Total Organic Carbon (C) (mg/L)	8.4	5.2 to 12	8	10.5	8.5 to 12	7
Dissolved Arsenic (µg/L)	0.8	0 to 1	5	1.0	1 to 2	5
Dissolved Cadmium (µg/L)	0.8	0 to 3	5	0.8	0 to 2	4
Dissolved Chromium (µg/L)	1.4	1 to 3	5	8.8	2 to 20	4
Dissolved Cobalt (µg/L)	2.2	0 to 6	5	0.3	0 to 1	4
Dissolved Copper (µg/L)	4.0	3 to 7	5	3.3	1 to 5	4
Dissolved Iron (µg/L)	420.0	240 to 640	5	242.5	60 to 310	4
Dissolved Lead (µg/L)	7.6	2 to 18	5	1.7	0 to 5	3
Dissolved Manganese (µg/L)	38.0	20 to 60	5	10.0	10 to 20	4
Dissolved Mercury (µg/L)	0.5	0.5	5	0.5	0.5	4
Dissolved Selenium (µg/L)	0	0	5	0.5	0 to 2	4
Dissolved Zinc (µg/L)	16.0	10 to 20	5	7.8	0 to 20	4

TABLE 2 (Continued)

WATER QUALITY OF THE NEUSE RIVER DILUTION WATER
AT KINSTON, NORTH CAROLINA
DATA OF THE U.S. GEOLOGICAL SURVEY

	SEPTEMBER 1979 TO 1980			SEPTEMBER 1980 TO 1981		
	Mean	Range	No.OBS	Mean	Range	No.OBS
Turbidity (JTU)	11	0.6 to 25	12	7	0.7 to 26	12
Hardness (mg/L)	20	16 to 25	12	22	17 to 27	12
Conductance (MHOS)	92	64 to 165	12	109	78 to 140	12
Alkalinity (mg/L as $CaCO_3$)	19	11 to 30	12	18	14 to 25	12
Total Organic Carbon (C) (mg/L)	10	4 to 20	8	8	5.1 to 13	8
Dissolved Arsenic (µg/L)	1.0	1	4	0.8	0 to 1	4
Dissolved Cadmium (µg/L)	2.0	0 to 5	4	0.9	<1 to 2	4
Dissolved Chromium (µg/L)	10.0	10	4	7.5	5 to 10	4
Dissolved Cobalt (µg/L)	0.8	0.1 to 2	4	0.8	0 to 2	4
Dissolved Copper (µg/L)	3.0	3	4	2.8	0 to 4	4
Dissolved Iron (µg/L)	365.0	100 to 660	4	385.0	170 to 600	4
Dissolved Lead (µg/L)	0.5	0 to 1	4	1.25	0 to 3	4
Dissolved Manganese (µg/L)	22.5	10 to 40	4	30.0	20 to 40	4
Dissolved Mercury (µg/L)	0.13	.1 to .2	4	0.2	<.1 to .4	4
Dissolved Selenium (µg/L)	0	0	4	0.01	0 to 1	4
Dissolved Zinc (µg/L)	7.0	4 to 10	4	3.8	0 to 8	4

TABLE 3 WATER AND SEDIMENT QUALITY OF NEUSE RIVER AT KINSTON, NORTH CAROLINA AS MEASURED BY THE LEVELS OF PESTICIDES AND HERBICIDES IN THE WATER AND SEDIMENT DATA OF THE U. S. GEOLOGICAL SURVEY

	SEPT. '75-81	
	NO. OF OBS.	RNG
Total Aldrin (μg/L)	15	ND
Total Chlordane (μg/L)	15	ND
Total DDD (μg/L)	15	ND
Total DDE (μg/L)	15	ND
Total DDT (μg/L)	14	ND
Total Diazinon (μg/L)	15	ND
Total Dieldrin (μg/L)	14	ND
Total Endrin (μg/L)	14	ND
Total Ethion (μg/L)	15	ND
Total Heptachlor (μg/L)	15	ND
Total Heptachlorepoxide (μg/L)	13	ND
Total Lindane (μg/L)	15	ND
Total Malathion (μg/L)	15	ND
Total Methoxychlor (μg/L)	15	ND
Total Methylparathion (μg/L)	15	ND
Ttoal Methyltrithion (μg/L)	15	ND
Total Parathion (μg/L)	15	ND
Total Toxaphene (μg/L)	15	ND
Total Trithion (μg/L)	15	ND
Total 2-4-D (μg/L)	10	ND
Total 2,4,5,T (μg/L)	10	ND
Total Silvex	10	ND

ND = Not Detectable
Total = Amount in water column and bottom material

TABLE 4 RANGE AND MEAN OF EFFLUENT CHARACTERISTICS ADDED TO EXPERIMENTAL STREAMS

EXPOSURE PERIOD OF FISH	EFFLUENT (%)			BOD (mg/L)			TSS (mg/L)			TOTAL RESIN* ACIDS (μg/L)			COLOR (mg/L) CoCU		
	MEAN	RNG.	#OBS	MEAN	RNG.	#OBS	MEAN	RNG.	#OBS	MEAN	RNG.	#OBS	MEAN	RNG.	#OBS
6-75 to 7-76	4.0	0.8 to 5.0	57	0.4	0.1 to 0.6	55	0.9	0.1 to 5.0	57	5	1 to 26	19	87	22 to 114	10
7-76 to 7-77	7.1	1.7 to 10.0	52	1.0	0.5 to 1.7	52	1.1	0.4 to 2.6	52	8	1 to 35	23	184	93 to 232	8
7-77 to 7-78	11.3	2.7 to 15.0	51	1.4	0.8 to 2.4	51	1.9	0.1 to 10.2	50	167	21 to 678	21	233	101 to 325	18
7-78 to 7-79	10.4	3.6 to 15.0	51	1.6	1.0 to 2.9	51	2.0	0.3 to 4.8	51	199	8 to 1035	40	196	64 to 334	18
7-79 to 7-80	9.0	4.3 to 15.0	55	1.7	0.7 to 3.1	55	2.1	0.5 to 4.9	55	91	6 to 456	52	187	89 to 360	23
9-80 to 7-81	12.2	4 to 20	42	2.1	0.4 to 7.9	42	2.8	0.9 to 9.8	42	38	4 to 344	41	274	76 to 480	21
7-81 to 7-82	15.3	7 to 21	50	2.5	0.5 to 6.1	50	4.2	1.2 to 9.5	50	95	7 to 380	49	270	103 to 390	9

*The total of Abietic, Dehydroabietic, Pimaric, and Isopimaric Acid.

1975 to 1976, the BOD was intended to be near 0.5 mg/l. However, effluent BOD's of less than 10 mg/l were considered to be 10 for the purpose of setting the volume of effluent. Thus, the effluent volume did not exceed 5% of the total water volume entering the stream during the year. The overall mean BOD calculated to have entered the streams during the first year was slightly lower than the target 0.5 mg/l of BOD figure and ranged from 0.1 to 0.6 mg/l. The BOD increased to a mean of 1.0 mg/l during 1976 to 1977, 1.4 mg/l during 1977 to 1978, 1.6 mg/l during 1978 to 1979, 1.7 mg/l during 1979 to 1980, 2.1 mg/l during 1980 to 1981 and 2.5 mg/l during 1981 to 1982. Corresponding increases in the percent of effluent added to the streams occurred during this time, rising from a mean of 4.0 percent by volume added during 1975 to 1976 to 7.1 percent in 1976 to 1977 and 11.3 percent during 1977 to 1978. The slightly lower average percent by volume in 1979 to 1980 is due to the generally higher BOD's observed in the effluent than the previous year and similar additions of BOD's to the streams during both years. The greatest mean addition of 15.3 percent by volume occurred during the 1981 to 1982 year. Highs of 21 percent by volume of effluent occurred in the treatment streams during this year. The amounts of total suspended solids (TSS) added to the streams increased from a mean of 0.9 mg/l added during 1975 to 1976, to 1.1 mg/l during 1976 to 1977 and approximately 2.0 mg/l added during 1977 to 1978 and 1978 to 1979. During the 1980 to 1981 and 1981 to 1982 experimental periods mean TSS concentrations of 2.8 and 4.2 mg/l, respectively, entered the treatment streams.

Color additions to the stream tended to follow the percent by volume addition of effluent. A mean color addition of 87 color units occurred during the 1975 to 1976 year and this increased to means of 184 and 233 color units during 1976 to 1977 and 1977 to 1978 as the BOD addition increased from 0.4 to 1.0 and 1.4 mg/l. The mean color added to the streams decreased slightly during the 1978 to 1979 and 1979 to 1980 study years because of the slightly reduced mean percent by volume additions of effluent. During the 1980 to 1981 and 1981 to 1982 years, the mean addition of color to the treatment streams by effluent was approximately 274 and 270 color units respectively. The number of samples was reduced during 1981 to 1982 from the previous 2 years because periphyton studies were reduced. However, the samples indicated the color of the effluent was slightly reduced between the 1980 to 1981 and 1981 to 1982 study years, particularly after January 1982. This allowed the color in the streams to be reduced slightly, even though the percent by volume concentration increased by nearly 3 percent.

(3) <u>Resin Acid and Chlorinated Compounds in the Effluent</u> - <u>Table 5</u> is a summation of the data concerning the amounts of several resin acid and chlorinated organic compounds detected

TABLE 5 SBKME CHEMICAL CHARACTERISTICS AND AMOUNTS ADDED TO TREATMENT STREAMS

Micrograms/Liter

	1975 to 1976								
	SBKME					ADDED TO TREATMENT STREAMS			
COMPOUND	No. of Samples Quantified	$\bar{x}$	S.D.	Max.	Min.	$\bar{x}$	S.D.	Max.	Min.
oleic acid	NA								
linoleic acid	NA								
9,10 dichlorostearic acid	NA								
pimaric acid	NA								
palustric acid	NA								
isopimaric acid	19	29	44	130	5	0.6	0.7	3	0.2
abietic acid	19	89	154	520	5	2.0	2.8	12	0.2
dehydroabietic acid	19	100	162	530	5	2.2	2.4	10	0.2
neoabietic acid	NA								
14 chlorodehydroabietic acid	NA								
12 chlorodehydroabietic acid	NA								
dichlorodehydroabietic acid	NA								
2,4 dichlorophenol	NA								
2,4,6 trichlorophenol	NA								
2,3,4,6 tetrachlorophenol	NA								
pentachlorophenol	NA								
4,5 dichloroguaiacol	NA								
4,5 dichlorocatechol	NA								
3,4,5 trichloroguaiacol (1)	16	23	26	90	5	0.9	0.8	2.5	0.2
4,5,6 trichloroguaiacol									
3,4,5 trichlorocatechol									
3,4,5,6 tetrachloroguaiacol	16	13	19	70	5	0.6	0.9	3.5	0.2
3,4,5,6 tetrachlorocatechol									
2,4,5 trichlorophenol	NA								

NA = Not Analyzed For

1. Procedure used included 3,4,5 and 4,5,6 trichloroguaiacol, 3,4,5 trichlorocatechol and trichloroveratrole.
2. Procedure used included 3,4,5,6 tetrachloroguiacol, 3,4,5,6 tetrachlorocatechol and tetrachloroveratrole.

TABLE 5 SBKME CHEMICAL CHARACTERISTICS AND AMOUNTS ADDED TO TREATMENT STREAMS (Continued)

Micrograms/Liter

	1976 to 1977								
	SBKME					ADDED TO TREATMENT STREAMS			
COMPOUND	No. of Samples Quantified	$\bar{x}$	S.D.	Max.	Min.	$\bar{x}$	S.D.	Max.	Min.
oleic acid	NA								
linoleic acid	NA								
9,10 dichlorostearic acid	23	ND							
pimaric acid	NA								
palustric acid	NA								
isopimaric acid	23	35	83	380	5	1.6	2.7	9.9	0.2
abietic acid	23	53	75	210	5	2.2	3.3	13.4	0.2
dehydroabietic acid	23	90	127	370	5	5.0	8.0	15.8	0.2
neoabietic acid	NA								
14 chlorodehydroabietic acid	NA								
12 chlorodehydroabietic acid	23	ND							
dichlorodehydroabietic acid	23	ND							
2,4 dichlorophenol	17	ND							
2,4,6 trichlorophenol	NA								
2,3,4,6 tetrachlorophenol	NA								
pentachlorophenol	NA								
4,5 dichloroguaiacol	NA								
4,5 dichlorocatechol	NA								
3,4,5 trichloroguaiacol (1)	17	26	33	110	5	1.7	2.1	6.2	0.2
4,5,6 trichloroguaiacol									
3,4,5 trichlorocatechol									
3,4,5,6 tetrachloroguaiacol (2)	17	13	13	40	5	0.9	0.9	2.7	0.1
3,4,5,6 tetrachlorocatechol									
2,4,5 trichlorophenol	NA								

ND = Not Detected NA = Not Analyzed For

1. Procedure used included 3,4,5 and 4,5,6 trichloroguaiacol, 3,4,5 trichlorocatechol and trichloroveratrole.
2. Procedure used included 3,4,5,6 tetrachloroguiacol, 3,4,5,6 tetrachlorocatechol and tetrachloroveratrole.

TABLE 5 SBKME CHEMICAL CHARACTERISTICS AND AMOUNTS ADDED TO TREATMENT STREAMS
(Continued)

Micrograms/Liter

	1977 to 1978								
	SBKME					ADDED TO TREATMENT STREAMS			
COMPOUND	No. of Samples Quantified	$\bar{x}$	S.D.	Max.	Min.	$\bar{x}$	S.D.	Max.	Min.
oleic acid	NA								
linoleic acid	NA								
9,10 dichlorostearic acid	21	3	8	25	0	0.3	0.5	1.6	0.0
pimaric acid	20	289	188	440	83	29	19.7	68.6	3.9
palustric acid	NA								
isopimaric acid	16	229	114	477	65	24.9	14.3	57	8.3
abietic acid	21	1,066	814	2,887	180	99.7	84.2	309	11.3
dehydroabietic acid	21	749	650	2,666	119	75.9	66.2	285	14.0
neoabietic acid	NA								
14 chlorodehydroabietic acid	NA								
12 chlorodehydroabietic acid	12	47	14	70	2.5	5.2	2.1	8.7	2.4
dichlorodehydroabietic acid	12	51	16	87	30	6.0	2.7	13.0	2.8
2,4 dichlorophenol	19	15	4	22	8	1.6	1.0	4.0	0.7
2,4,6 trichlorophenol	NA								
2,3,4,6 tetrachlorophenol	NA								
pentachlorophenol	17	3	4.4	14	ND	0.2	1.1	1.6	ND
4,5 dichloroguaiacol	ND								
4,5 dichlorocatechol	NA								
3,4,5 trichloroguaiacol									
4,5,6 trichloroguaiacol (2)	21	49	22	77	6	4.9	2.6	11	0.7
3,4,5 trichlorocatechol									
3,4,5,6 tetrachloroguaiacol									
3,4,5,6 tetrachlorocatechol (3)	19	32	17	70	11	3.3	1.6	4.7	1.0
2,4,5 trichlorophenol	NA								

ND = Not Detected NA = Not Analyzed For
1. Analysis began 9/11/77
2. Procedure used included 3,4,5 and 4,5,6 trichloroguaiacol, 3,4,5 trichlorocatechol and trichloroveratrole.
3. Procedure used included 3,4,5,6 tetrachloroguiacol, 3,4,5,6 tetrachlorocatechol and tetrachloroveratrole.

TABLE 5 SBKME CHEMICAL CHARACTERISTICS AND AMOUNTS ADDED TO TREATMENT STREAMS
(Continued)

Micrograms/Liter

	1978 to 1979								
	SBKME					ADDED TO TREATMENT STREAMS			
COMPOUND	No. of Samples Quantified	$\bar{x}$	S.D.	Max.	Min.	$\bar{x}$	S.D.	Max.	Min.
oleic acid	NA								
linoleic acid	NA								
9,10 dichlorostearic acid	51	6	16	83	0	0.4	0.4	5.6	0
pimaric acid	31	436	526	2,036	5	22.9	30.8	138.4	0.4
palustric acid	NA								
isopimaric acid	51	358	473	1,896	5	23.8	34.3	132.5	0.4
abietic acid	51	1,591	2,072	7,593	5	103.8	143.7	516	0.7
dehydroabietic acid	51	1,195	1,551	5,829	27	81.2	116.4	406.1	2.0
neoabietic acid	NA								
14 chlorodehydroabietic acid	NA								
12 chlorodehydroabietic acid	24	162	367	1,867	19	13.2	25.3	127	1.7
dichlorodehydroabietic acid	32	104	169	1,000	9	9.6	12.3	68	1.0
2,4 dichlorophenol	17	18	9	43	10	1.7	.8	3.2	0.4
2,4,6 trichlorophenol	NA								
2,3,4,6 tetrachlorophenol	NA								
pentachlorophenol	51	All below detection limits.							
4,5 dichloroguaiacol	NA								
4,5 dichlorocatechol	NA								
3,4,5 trichloroguaiacol									
4,5,6 trichloroguaiacol (1)	37	75	99	116	20	4.7	2.9	11	1.5
3,4,5 trichlorocatechol									
3,4,5,6 tetrachloroguaiacol									
3,4,5,6 tetrachlorocatechol (2)	35	34	14	70	10	3.1	1.6	7	1.0
2,4,5 trichlorophenol	NA								

NA = Not Analyzed For

1. Procedure used included 3,4,5 and 4,5,6 trichloroguaiacol, 3,4,5 trichlorocatechol and trichloroveratrole.
2. Procedure used included 3,4,5,6 tetrachloroguiacol, 3,4,5,6 tetrachlorocatechol and tetrachloroveratrole.

TABLE 5 SBKME CHEMICAL CHARACTERISTICS AND AMOUNTS ADDED TO TREATMENT STREAMS (Continued)

Micrograms/Liter

1979 to 1980

COMPOUND	SBKME: No. of Samples Quantified	SBKME: $\bar{x}$	SBKME: S.D.	SBKME: Max.	SBKME: Min.	ADDED TO TREATMENT STREAMS: $\bar{x}$	ADDED TO TREATMENT STREAMS: S.D.	ADDED TO TREATMENT STREAMS: Max.	ADDED TO TREATMENT STREAMS: Min.
oleic acid	67	76	81	330	8	6.9	8.1	35	ND
linoleic acid	67	6	8	34	ND	0.5	0.8	3	ND
9,10 dichlorostearic acid	67	14	19	62	ND	1.2	1.8	7	ND
pimaric acid	67	133	50	569	9	12.6	16.2	72	ND
palustric acid (1)	10	15	9	27	ND	2.1	1.2	4	ND
isopimaric acid	67	125	132	485	10	11.7	14.0	62	ND
abietic acid	67	408	420	1,655	34	38.3	48.5	248	ND
dehydroabietic acid	67	266	269	1,012	27	25.0	30.0	141	ND
neoabietic acid	10	13	5	21	8	1.5	0.8	3	ND
14 chlorodehydroabietic acid 12 chlorodehydroabietic acid (2)	67	53	25	122	9	4.9	2.9	13	ND
dichlorodehydroabietic acid	66	90	34	171	13	8.3	4.3	18	ND
2,4 dichlorophenol	67	10	6	24	ND	0.9	0.7	4	ND
2,4,6 trichlorophenol	67	6	8	24	ND	0.5	0.6	2	ND
pentachlorophenol	67			ND	ND			ND	ND
4,5 dichlorocatechol	5	5	12	26	ND	0.8	1.7	4	ND
3,4,5 trichloroguaiacol 3,4,6 trichloroguaiacol (4) 4,5,6 trichloroguaiacol	67	56	32	136	17	4.6	3.0	14	ND
3,4,5 trichlorocatechol (3)	5	4	5	11	ND	0.6	0.7	2	ND
3,4,6 trichlorocatecol (3)	5	35	6	41	27	5.4	1.2	7	ND
3,4,5,6 tetrachloroguaiacol 3,4,5,6 tetrachlorocatechol (5)	67	27	11	48	8	2.4	1.2	ND	ND

ND = Not Detected

1. Analysis began 6/6/80
2. 12 chlorodehydroabietic acid only until 4-28-79 when both 12 and 14 were included in analysis.
3. Separate analysis began 6-23-80 - prior to this, these were included with trichloroguaiacol.
4. Procedure used included 3,4,5 and 4,5,6 trichloroguaiacol, 3,4,5 trichlorocatechol and trichloroveratrole.
5. Procedure used included 3,4,5,6 tetrachloroguiacol, 3,4,5,6 tetrachlorocatechol and tetrachloroveratrole.

TABLE 5 SBKME CHEMICAL CHARACTERISTICS AND AMOUNTS ADDED TO TREATMENT STREAMS (Continued)

Micrograms/Liter

COMPOUND	1980 to 1981								
	SBKME					ADDED TO TREATMENT STREAMS			
	No. of Samples Quantified	$\bar{x}$	S.D.	Max.	Min.	$\bar{x}$	S.D.	Max.	Min.
oleic acid	90	150	174.3	828	ND	13.3	15.5	69	ND
linoleic acid	90	21	24.1	133	ND	2.0	2.3	12.0	ND
9,10 dichlorostearic acid	90	4	13.7	79	ND	0.3	0.9	5.1	ND
pimaric acid	90	58	92.7	543	ND	4.8	5.6	35.3	ND
palustric acid	90	57	125.4	803	ND	4.2	8.3	52.2	ND
isopimaric acid	90	59	88.4	450	ND	4.9	5.7	29.3	ND
abietic acid	90	174	301.2	1,396	ND	13.8	19.5	90.7	ND
dehydroabietic acid	90	115	190.2	1,166	10	9.5	11.0	75.8	ND
neoabietic acid	90	63	155.4	1,106	ND	4.7	10.7	71.9	ND
14 chlorodehydroabietic acid	90	5	4.6	27	ND	0.5	0.4	1.8	ND
12 chlorodehydroabietic acid	90	22	15.1	76	3	2.6	2.1	10.3	ND
dichlorodehydroabietic acid	90	51	33.6	156	6	6.2	5.1	24.0	ND
2,4 dichlorophenol	95	5	5.0	21	ND	0.5	0.6	3.0	ND
2,4,6 trichlorophenol	95	5	5.1	20	ND	0.5	0.6	3.3	ND
2,3,4,6 tetrachlorophenol	95	1	1.1	5	ND	0.1	0.2	0.8	ND
pentachlorophenol	95	0	0.5	1	ND	0.0	0.1	0.2	ND
4,5 dichloroguaiacol	95	0	0.7	3	ND	0.0	0.1	0.6	ND
4,5 dichlorocatechol	95	6	7.8	25	ND	0.5	0.8	4.8	ND
3,4,5 trichloroguaiacol	95	9	6.3	31	ND	1.2	1.0	3.6	ND
4,5,6 trichloroguaiacol	95	4	2.8	11	ND	0.5	0.4	1.8	ND
3,4,5 trichlorocatechol	95	16	14.8	46	ND	1.6	1.7	9.0	ND
3,4,5,6 tetrachloroguaiacol	95	4	3.4	12	ND	0.6	0.5	2.0	ND
3,4,5,6 tetrachlorocatechol	95	6	5.0	22	ND	0.6	0.5	2.4	ND
2,4,5 trichlorophenol	95	1	1.2	4	ND	0.1	0.1	0.7	ND

ND = Not Detected

TABLE 5 SBKME CHEMICAL CHARACTERISTICS AND AMOUNTS ADDED TO TREATMENT STREAMS (Continued)

Micrograms/Liter

	1981 to 1982								
	SBKME					ADDED TO TREATMENT STREAMS			
COMPOUND	No. of Samples Quantified	$\bar{x}$	S.D.	Max.	Min.	$\bar{x}$	S.D.	Max.	Min.
oleic acid	119	134	206	1,200	ND	12.7	12.7	60.3	ND
linoleic acid	119	26	40	233	ND	2.6	2.5	12.2	ND
9,10 dichlorostearic acid	118	18	3	100	ND	1.8	2.0	8.5	ND
pimaric acid	119	173	200	1,150	ND	17.6	13.9	58.9	1.1
palustric acid	119	149	291	1,320	ND	10.5	17.8	73.1	ND
isopimaric acid	119	155	189	878	5	14.9	12.5	53.1	1.5
abietic acid	119	363	591	2,750	2	30.1	37.6	147.0	0.8
dehydroabietic acid	119	336	437	2,170	8	32.2	28.3	121.1	2.8
neoabietic acid	118	91	178	852	ND	6.5	11.4	46.1	ND
14 chlorodehydroabietic acid	119	14	12	55	ND	1.6	1.0	4.3	0.1
12 chlorodehydroabietic acid	119	64	49	188	5	7.5	4.9	22.6	1.0
dichlorodehydroabietic acid	119	72	40	168	9	8.9	4.1	22.8	2.0
2,4 dichlorophenol	123	4	4	15	ND	0.4	0.5	1.8	ND
2,4,6 trichlorophenol	123	3	4	16	ND	0.4	0.4	1.8	ND
2,3,4,6 tetrachlorophenol	123	2	1	5	ND	0.3	0.2	1.4	ND
pentachlorophenol	123	0	1	2	ND	0.1	0.1	0.2	ND
4,5 dichloroguaiacol	123	1	3	15	ND	0.2	0.4	1.7	ND
4,5 dichlorocatechol	123	8	8	27	ND	0.9	0.9	4.3	ND
3,4,5 trichloroguaiacol	123	9	5	22	ND	1.2	0.7	3.1	ND
4,5,6 trichloroguaiacol	123	3	2	9	ND	0.4	0.3	1.6	ND
3,4,5 trichlorocatechol	123	16	18	87	ND	2.2	2.6	14.0	0.3
3,4,5,6 tetrachloroguaiacol	123	4	3	13	ND	0.5	0.4	1.7	ND
3,4,5,6 tetrachlorocatechol	123	5	5	26	ND	0.7	0.7	3.9	0.2
2,4,5 trichlorophenol	123	0	0	2	ND	0.0	0.1	0.3	ND

ND = Not Detected

during effluent characterization. Isopimaric, abeitic and dehydroabeitic acid were the resin acids commonly detected in the highest amounts. The total concentrations of these compounds in the effluent ranged from non-detectable to approximately 1.0 mg/l during 1975 to 1976 and 1976 to 1977 experimental periods. The mean levels of abeitic and dehydroabeitic acid were less than 0.1 mg/l each during the first two years. During 1977 to 1978 and 1978 to 1979, the totals of the resin acids detected in the effluent rose to levels higher than those of the two previous years and on one occasion during the year 1979, a high of approximately 13 mg/l of total resin acids in the effluent was reached. The mean concentration of abeitic acid was 1 mg/l and 1.6 mg/l during 1977 to 1978 and 1978 to 1979, respectively. During 1979 to 1980 and 1980 to 1981, the amounts were only slightly higher than the 1976 to 1977 levels.

The chlorinated resin acid compounds were first measured during the 1976 to 1977 study year, but were below detection limits of approximately 25 μg/l during that time (Table 5). The following study year, 12 monochlorodehydroabeitic and 12, 14 dichlorodehydroabeitic acids were above detection limits on 12 of 21 sampling dates. Mean concentrations of these 2 compounds in the effluent were 47 and 51 μg/l during the 1977 to 1978 study year. The mean amount of total chlorinated resin acids detected in the effluent was greatest during the 1978 to 1979 study year when 268 μg/l of these compounds were measured. During the 1979 to 1980, 1980 to 1981 and 1981 to 1982 study years, the mean concentrations of these compounds in the effluent were approximately 143, 78 and 136 μg/l.

Analysis of the chlorinated phenolic compounds was greatly expanded over the period of time these studies took place. During the 1975 to 1976 study period, the mean concentration of chloroguiacol and chlorocatechols measured in the effluent was approximately 39 μg/l. Similar amounts were detected in the effluent during the following year. The concentrations of chloroguiacols and chlorocatechols were higher than the previous two years, while the 1977 to 1978 study year was in progress. This increase and the additional analysis for di, tri and penta - chlorophenols boosted the chlorophenolic compounds detected in the effluent to a mean of 99 μg/l. The greatest mean concentrations of chlorophenols were detected during the 1978 to 1979 and 1979 to 1980 study years when 127 and 143 μg/l were measured in the effluent. During the 1980 to 1981 and 1981 to 1982 study years, the mean chlorophenol concentration detected in the effluent were 56 and 55 μg/l, respectively. The concentration of the most common chlorinated phenolic, trichloroguiacol was usually less than 0.1 mg/l in the effluent.

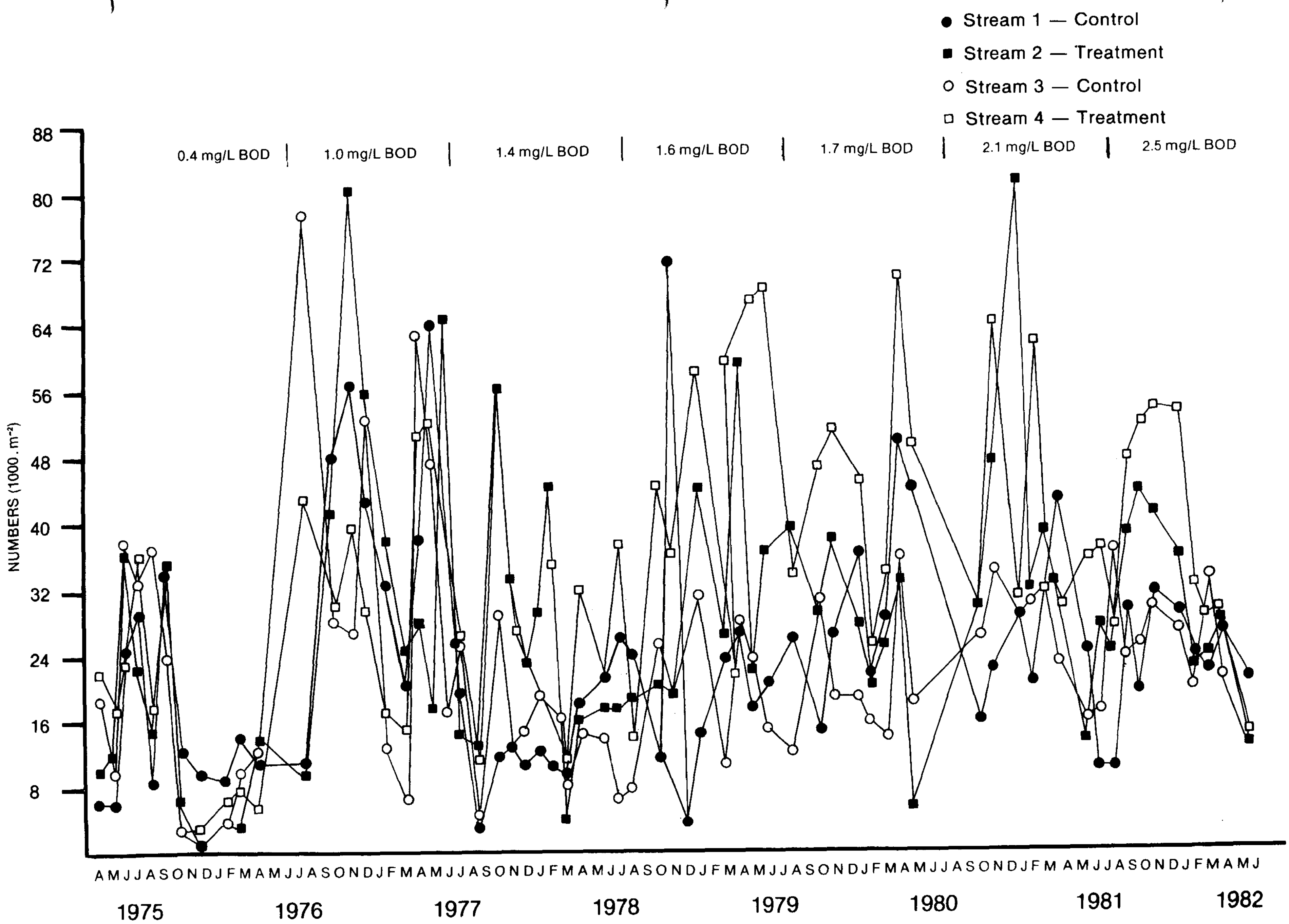
(4) Resin Acid and Chlorinated Compounds Added to Treatment Streams - The total amounts of resin acids entering the stream shown on Table 4 are the totals of abeitic, dehydroabeitic, pimaric and isopimaric acid. Individual compounds entering the streams are shown on Table 5. Pimaric acid was not assayed during 1975 and 1976. Also, when assays were performed but levels were below the limits of detection, a value equal to 1/2 of the detection limit was used to calculate the mean during the first 3 years and if interferences were noted in the analysis, the samples were not included in the calculation of compounds added to the streams. The amounts of resin acids entering the streams were very low during 1975 to 1976 and 1976 to 1977 with means of 5 and 8 µg/l and highs of 16 and 35 µg/l. An increase in resin acids entering the treatment streams occurred during 1977 to 1978, particularly during late spring months of 1978. This trend continued during 1978 to 1979 when mean total resin acid values of nearly 200 µg/l entered the treatment streams and on one occasion over 1,000 µg/l entered the streams. The concentrations of resin acids in the treatment streams were again lower during the 1979 to 1980, 1980 to 1981 and 1981 to 1982 years, when mean levels of 90, 38 and 95 µg/l of resin acids entered the streams. The concentrations of chlorinated resin acid compounds entering the two treatment streams are shown on Table 5. Additions of 5.2 and 6 µg/l were calculated to have entered the treatment streams during the 1977 to 1978 and 1978 to 1979 study years, when the chlorinated resin acids were first noted to be above detection limits. These concentrations should be considered as maximum amounts, since levels below detection were not used in these calculations. The mean amount of total chlorinated resin acids entering the treatment streams was greatest during the 1978 to 1979 study year, when a total mean concentration of 23 µg/l of chlorinated resin acid compounds were calculated to have been added to the treatment streams. During the 1979 to 1980, 1980 to 1981 and 1981 to 1982 study years, the mean concentrations of these compounds added to the treatment streams were 13, 9 and 16 µg/l, respectively.

The total concentrations of chloroguiacols and chlorocatechols added to the treatment streams during the 1975 to 1976 study period was less than 2 µg/l and less than 3 µg/l during the following year. During 1977 to 1978, analyses for di, tri and penta - chlorophenol were added to the compounds measured. This analysis and an increase in the amounts of chlorinated phenolic compounds in the effluent during the 1977 to 1978, 1978 to 1979 and 1979 to 1980 years increased the mean concentrations of chlorinated phenolic compounds added to the treatment streams to 10, 10 and 15 µg/l, respectively, for those three study years. During the 1980 to 1981 and 1981 to 1982 study periods, the concentrations of chlorinated phenolic compounds added to the treatment streams dropped to 6.2 and 7.3 µg/l.

C. Benthos - Macroinvertebrate Levels Found in Experimental Streams

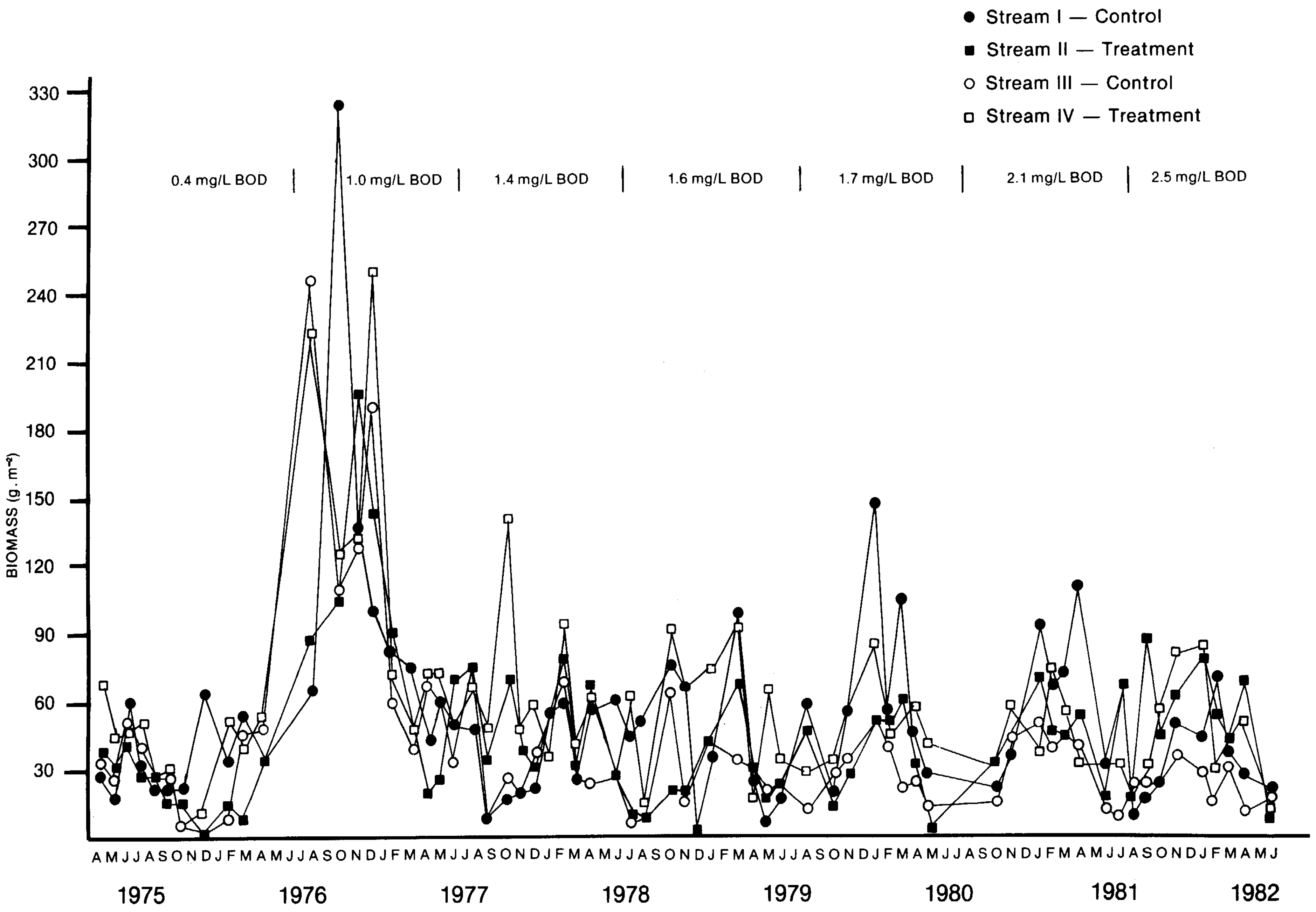
The total number (Figure 4) and biomass (Figure 5) of macroinvertebrates found during the monthly samples for benthos generally did not show any definite trend during the 1975 to 1976 and 1976 to 1977 exposure periods when mean effluent concentrations equivalent to 0.4 and 1.0 mg/l of BOD (4 and 7 percent by volume) entered the streams. During the following three years when 1.4 to 1.7 mg/l of BOD were added to the treatment streams, differences in the total number of organisms found in the control and treatment streams were not immediately evident. However, over this period of time, the total numbers of organisms found in combined treatment stream samples were greater than the combined control macroinvertebrate numbers during 23 of 28 monthly samples (Table 6). The total number of organisms were higher in control streams on the remaining sampling dates. This pattern was not observed when the biomass of the macroinvertebrates was studied. The biomass of the combined organisms from the two treatment streams was greater than the controls during only 16 of the 28 monthly samples, and during the 1978 to 1979 and 1979 to 1980 study years, the frequency that the biomasses of macroinvertebrates were greater in treatment or control streams was again nearly equal.

The amphipods *Gammarus faciatus* and later *Hyalella azteca* were the most abundant organisms found in most of the samples from all four streams during all exposure years. These organisms also appear to be major contributors to the patterns observed in the total numbers and biomasses of benthic organisms. Figures 6A and 6B show the number and biomass of amphipods found in each of the four streams on each sampling date. The numbers of *Gammarus* found in all experimental streams increased during the summer and fall of 1976, and in general, these numbers were maintained at slightly lower levels throughout the following years. The biomass of amphipods also increased during 1976, and was also maintained at a level slightly lower than the 1976 summer-fall highs. These patterns of abundance of amphipods were generally reflected in the total numbers and biomasses of organisms from the four streams, although other organisms demonstrated similar patterns of abundance. *Gammarus* and later (during 1978) *Hyalella* were abundant during all months of the year and females bearing developing eggs were frequently collected from all streams. The numbers and biomasses of amphipods found in the treatment streams resembled that of the total organisms in that no pattern of density was immediately evident during the first five years of the study. Once again, the numbers of amphipods collected from the two effluent treated streams were greater than those collected from control streams 23 of the 28 sampling periods. The biomass was greater in only 15 of the 28 combined samples (Table 6).



TOTAL BENTHIC MACROINVERTEBRATES

FIGURE 4 TOTAL NUMBER PER M^2 OF STREAM BOTTOM OF BENTHIC MACROINVERTEBRATES FROM FOUR EXPERIMENTAL STREAMS



TOTAL BENTHIC MACROINVERTEBRATES

FIGURE 5 TOTAL BIOMASS PER M^2 OF STREAM BOTTOM OF BENTHIC MACROINVERTEBRATES FROM FOUR EXPERIMENTAL STREAMS

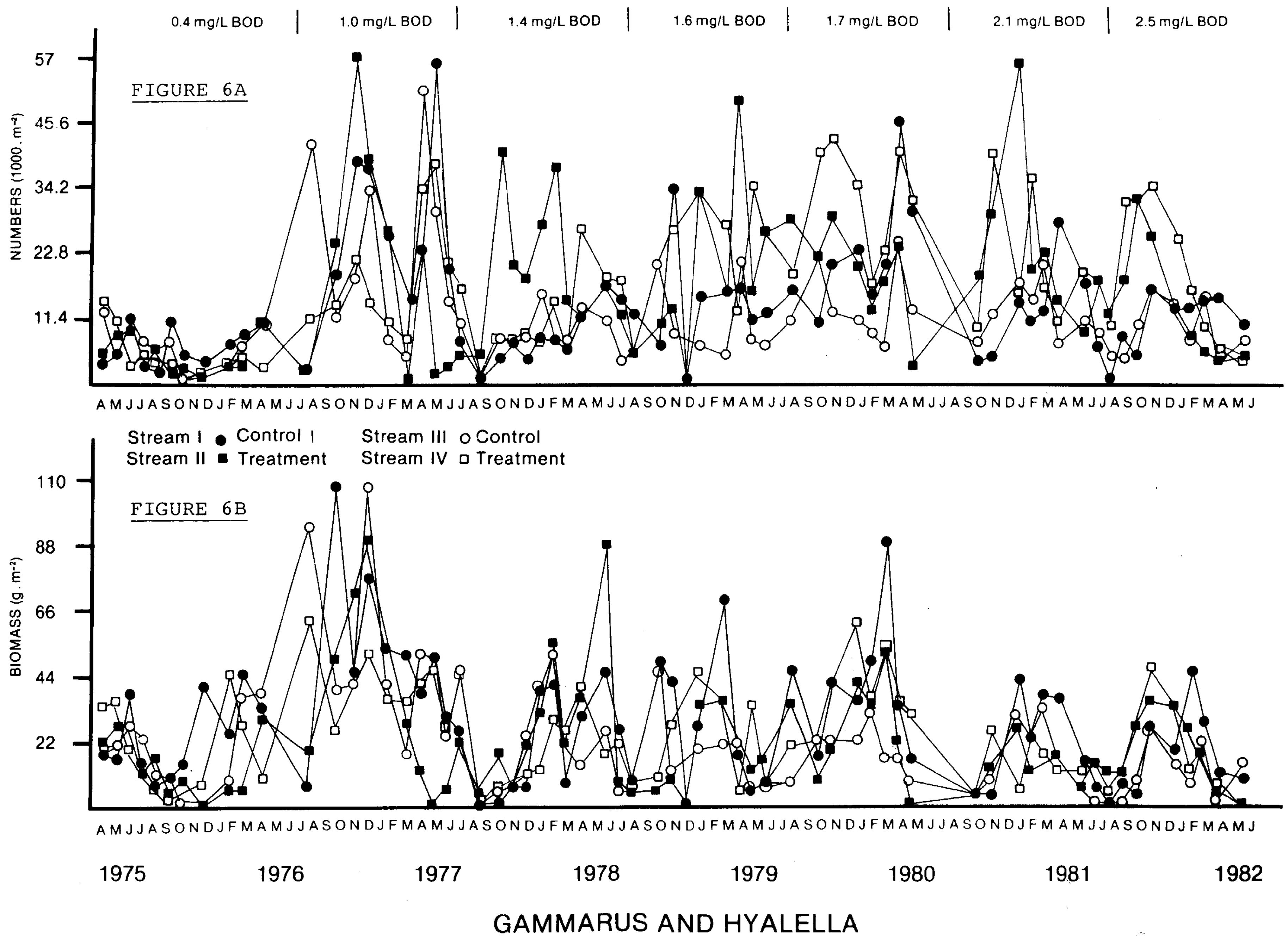


FIGURE 6A NUMBER OF GAMMARUS AND HYALELLA PER M^2 OF STREAM BOTTOM FROM FOUR EXPERIMENTAL STREAMS

FIGURE 6B BIOMASS OF GAMMARUS AND HYALLELLA PER M^2 OF STREAM BOTTOM FROM FOUR EXPERIMENTAL STREAMS

TABLE 6 FREQUENCY OF GREATER ABUNDANCE OF COMMON MACROINVERTEBRATE GROUPS IN CONTROL OR TREATMENT STREAM DURING EACH EXPOSURE YEAR. C=CONTROL, T=TREATMENT, N=NUMBER, B=BIOMASS

Exposure Year		Total		Amphipods		Isopods		Chironomids		Snails	
		C	T	C	T	C	T	C	T	C	T
1975-76	N	5	5	8	2	4	6	4	5	5	5
0.4 mg/L	B	5	5	5	5	3	6	5	5	5	5
1976-77	N	2	7	5	4	5	4	3	6	3	5
1.0 mg/L	B	3	6	8	1	5	4	5	4	3	5
1977-78	N	2	8	0	10	6	4	8	2	1	7
1.4 mg/L	B	2	8	3	7	9	1	8	2	1	7
1978-79	N	1	9	3	7	5	5	8	1	4	6
1.6 mg/L	B	5	5	7	3	6	4	7	2	4	6
1979-80	N	2	6	2	6	1	7	5	3	4	4
1.7 mg/L	B	5	3	3	5	0	8	4	4	7	1
1980-81	N	1	7	2	6	1	7	2	6	7	1
2.1 mg/L	B	3	5	4	4	1	7	1	7	6	2
1981-82	N	2	7	3	6	0	9	9	0	2	7
2.5 mg/L	B	2	7	4	5	1	8	5	4	8	1

The numbers of amphipods seemed to indicate a trend could have been occurring in the abundance of this and other organisms; for this reason more intensive sampling was undertaken during the 1980 to 1981 and 1981 to 1982 exposure years.

Another common organism was the isopod *Asellus* which generally had peaks of abundance during the spring and summer months. The numbers and biomasses of these organisms did not show any noticeable pattern of abundance during any experimental year prior to 1979 to 1980, 1980 to 1981 or 1981 to 1982 (Figures 7A and 7B) with the exception of the 1977 to 1978 year when 1.4 mg/l of BOD entered the effluent treated streams and the biomass of *Asellus* was higher in the two control streams on 9 of the 10 sampling dates. The frequency that the numbers or biomasses of *Asellus* were greater in control or effluent treatment streams during other years was approximately equal. During the 1979 to 1980, 1980 to 1981 and 1981 to 1982 years, when mean additions of 1.7, 2.1 and 2.5 mg/l BOD of SBKME were added to treatment streams, the total numbers of isopods found in the streams containing effluent were greater on 23 of 25 sampling dates. The biomass shows a similar increase in isopods in the treatment streams (Table 6).

As a group, the chironomids were often abundant organisms which made up a significant percentage of the total number of macroinvertebrates (Figures 8A and 8B). After the first year of colonization, these organisms tended to show peaks of abundance during the late summer and autumn, although they were present in all streams on nearly all sampling dates. During most months *Glyptotendepes* and *Chironomus* dominated these populations although many other genera were present. No consistent pattern of abundance was established in relation to the presence of effluent. During the first two years of exposure, when 0.4 mg/l and 1.0 mg/l of BOD entered the streams, numbers and biomass of the chironomids found in the combined samples from the two treatment streams were greater than those found in control streams on approximately 1/2 of the sampling dates (Table 6). During the following two years when 1.4 and 1.6 mg/l of effluent entered the treatment streams, the numbers of chironomids found in control streams were greater than the numbers found in treatment streams on 16 of 19 sampling dates. However, this was reversed the two following years when 1.7 and 2.1 mg/l of BOD entered the streams. During 1979 to 1980, the frequency that the numbers and biomass of chironomids were greater in treatment or control streams was again nearly equal. During 1980 to 1981, when 2.1 mg/l of BOD effluent entered the streams, the number of chironomids found in treatment streams was higher than the number found in control streams on 6 of 8 sampling dates and the biomass showed a similar pattern. During 1981 to 1982, when

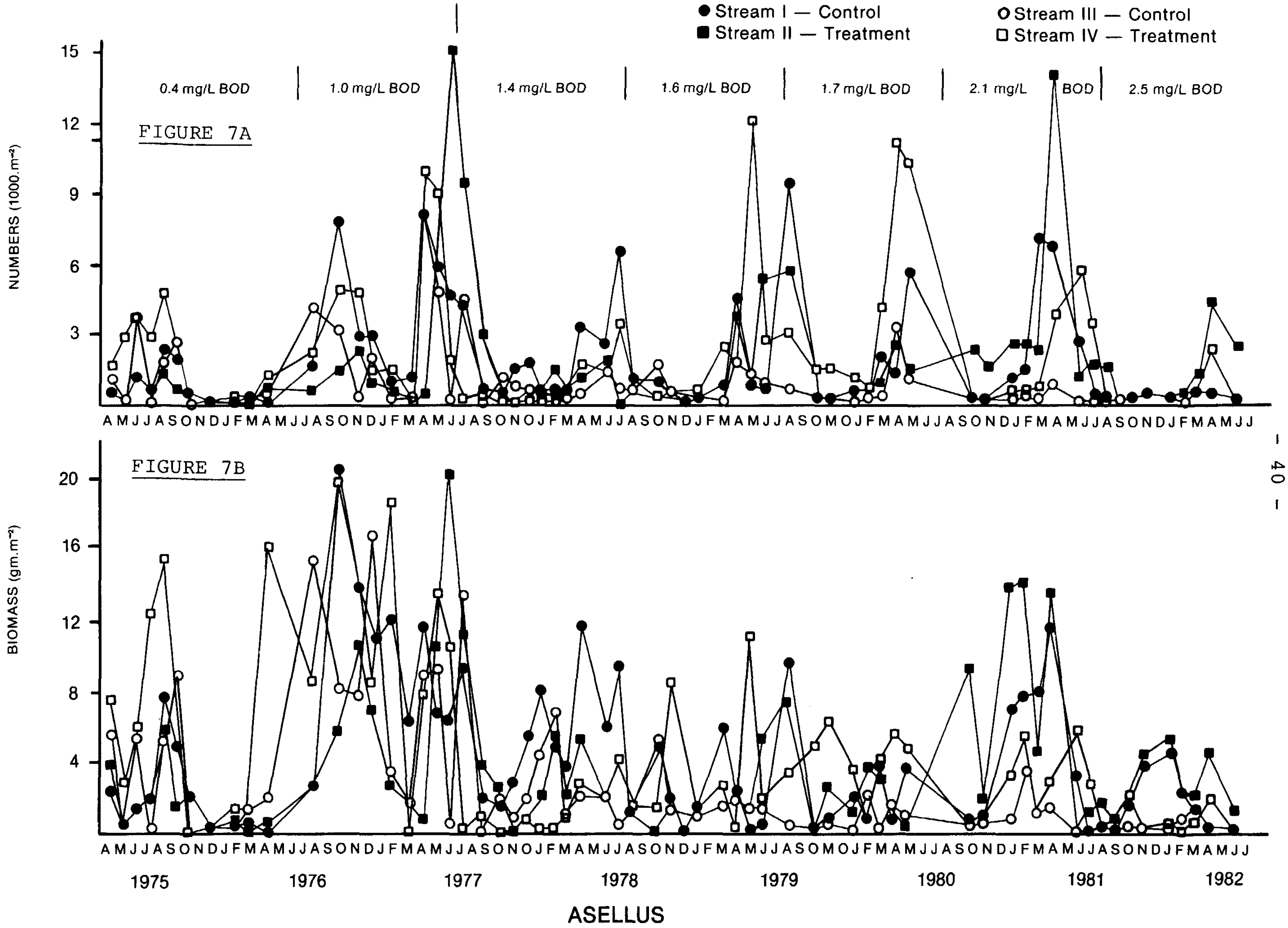
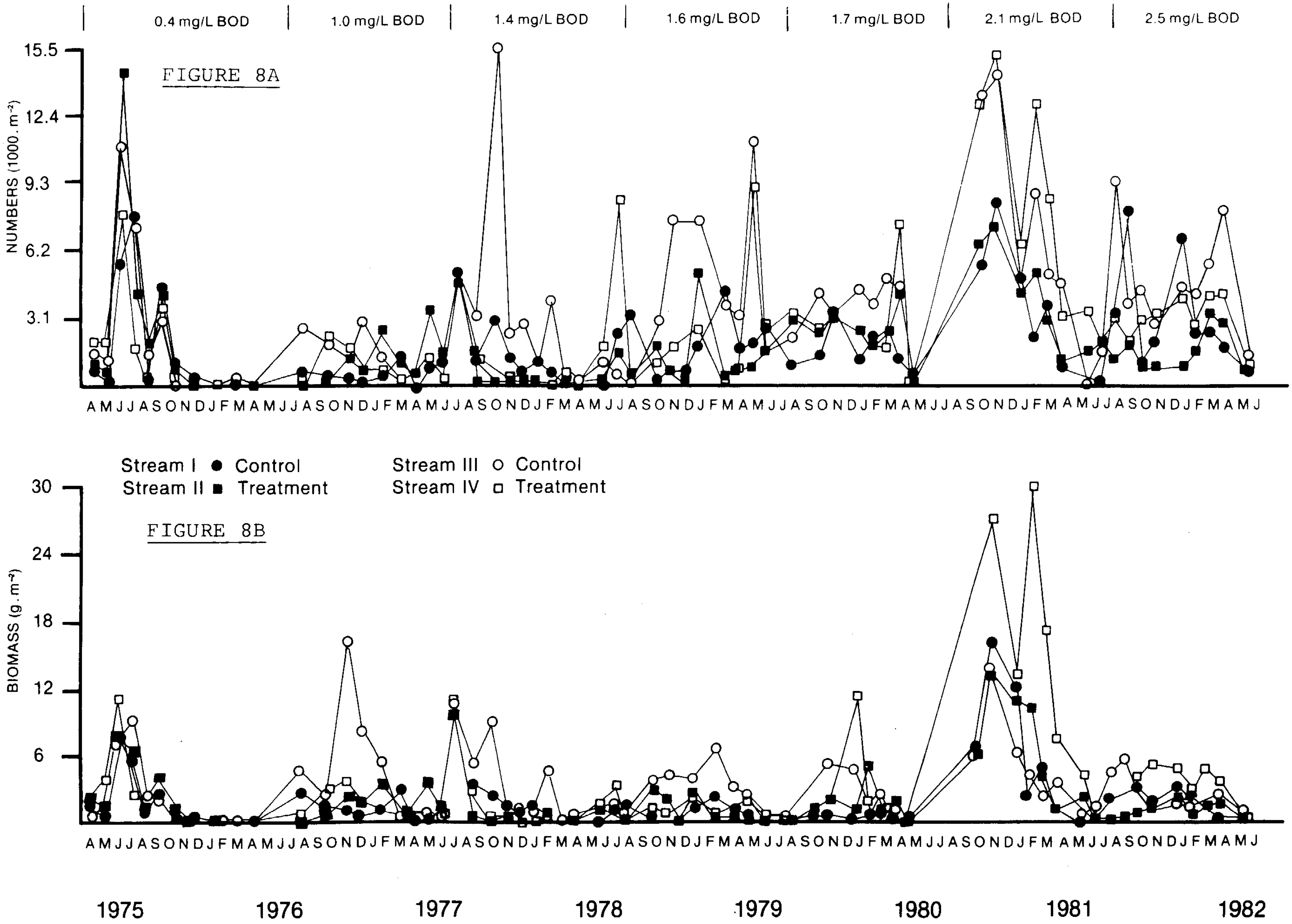


FIGURE 7A NUMBERS OF ASELLUS PER M^2 OF STREAM BOTTOM FROM FOUR EXPERIMENTAL STREAMS

FIGURE 7B BIOMASS OF ASELLUS PER M^2 OF STREAM BOTTOM FROM FOUR EXPERIMENTAL STREAMS



CHIRONOMIDAE

FIGURE 8A NUMBERS OF CHIRONOMIDAE PER M^2 OF STREAM BOTTOM FROM FOUR EXPERIMENTAL STREAMS

FIGURE 8B BIOMASS OF CHIRONOMIDAE PER M^2 OF STREAM BOTTOM FROM FOUR EXPERIMENTAL STREAMS

2.5 mg/l of BOD entered the streams, the number of chironomids were again greater in control streams on all 9 sampling dates, but the biomass was greater in control streams on only 5 of 9 sampling dates. Overall, no consistent pattern has yet been observed within the chironomid populations.

The snail Physa was present in all streams during the first year and after that time Heliosoma also occurred in the streams with an often equal or greater abundance than Physa (Figures 9A and 9B). During 1977 to 1978, when 1.4 mg/l of BOD was added to the treatment streams, the number or biomass of snails found in the streams receiving effluent was greater than control streams on 7 of 8 sampling dates. However, during most years, the frequency that the number or biomass of snails was greater in control streams approximately equaled the frequency that these parameters were greater in treatment streams. In 1980 to 1981, the numbers in the control streams were greater on 7 of 8 sampling dates, and the biomass was greater in control streams on 6 of 8 sampling dates (Table 6). The biomass of snails found in control streams was also greater than that found in treatment streams on 8 of 9 sampling dates during 1981 to 1982, when 2.5 mg/l BOD of SBKME was added to the treatment streams. However, the number of snails found in treatment streams was greater than those found in control streams on 7 of the 9 sampling dates. The differences noted in the ratio of the biomass to the number were due to the greater number of Physa in the treatment streams, whereas the control streams had a greater number of Heliosoma, a larger snail. Heliosoma tended to be associated with macrophytes such as Elodea which were more abundant in the control streams during this year.

Other organisms such as the fingernail clam Sphaerium, the mayfly Caenis, dragonflies or damsel flies, oligocaetes, beetles, etc. were either not found in abundance or so infrequently that they were difficult to analyze in this manner and were usually of little consequence as fish food organisms. The crayfish Procambarus sp. was seldom collected during bottom sampling, but was frequently observed during the seining of fish. This organism also appeared to be an important food source for bass (Table 10).

Because of the possible trends in macroinvertebrates observed during the 1978 to 1979 and 1979 to 1980 year, more intensive sample collection and analysis was undertaken during the 1980 to 1981 and 1981 to 1982 exposure years when mean concentrations of 2.1 and 2.5 mg/l of BOD (12.5% and 15% by volume) were added to the treatment streams. Table 7 lists the organisms found in all of the samples from control and treatment streams during the 1980 to 1981 exposure year. At the time of this writing, identification of all organisms for the 1981 to 1982 exposure year was incomplete and therefore not included with

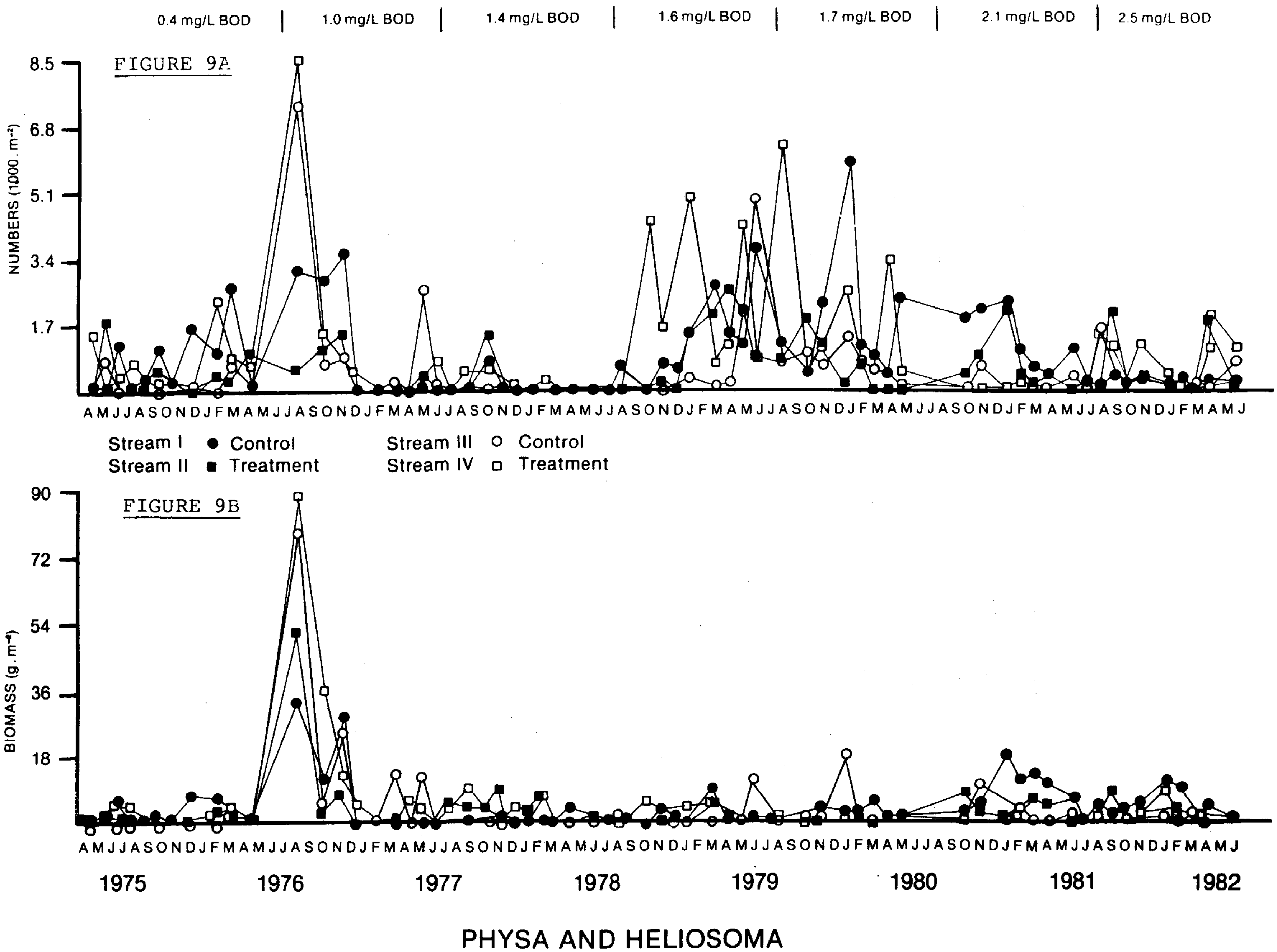


FIGURE 9A NUMBERS OF PHYSA AND HELIOSOMA PER M^2 OF STREAM BOTTOM FROM FOUR EXPERIMENTAL STREAMS

FIGURE 9B BIOMASS OF PHYSA AND HELIOSOMA PER M^2 OF STREAM BOTTOM FROM FOUR EXPERIMENTAL STREAMS

TABLE 7 MACROINVERTEBRATE TAXA COLLECTED IN CONTROL AND TREATED STREAMS DURING 1980 TO 1981 WHEN 2.1 MG/L OF BOD OF SBKME WERE ADDED TO THE TREATMENT STREAMS

TAXON	C*	T**
Isopoda		
Ascellus sp.	X	X
Cyathura politica	X	X
Amphipoda		
Gammaridae		
Gammarus fasciatus	X	X
Talitridae		
Hyalella azteca	X	X
Decapoda		
Astacidae		
Procambarus sp.	X	X
Plecoptera		
Perlidae		X
Ephemeroptera		
Baetidae		
Baetisca sp.	X	X
Caenis sp.	X	X
Odonata		
Zygoptera		
Enallagma sp.	X	X
Anisoptera		
Libellulidae		
Leucorrhina sp.	X	X
Erythrodiplax sp.	X	X
Erythemis sp.		X
Hemiptera		
Corixidae		X
Notonectidae		
Notonecta sp.		X
Megaloptera		
Sialidae		
Sialis		X
Trichoptera		
Hydropsychidae		
Cheumatopsyche sp.	X	X

TAXON	C	T
Leptoceridae		
Oecetis sp.	X	X
Lepidoptera		
Pyralidae		X
Coleoptera		
Elmidae		
Microcylloepus sp.	X	X
Hydrophilidae	X	
Haliplidae	X	X
Dytiscidae		
Hydroporinae		
Hydrovatus sp.		X
Diptera		
Chironomidae		
Chironominae		
Polypedilum sp.	X	X
Chironomus sp.	X	X
Glyptotendipes sp.	X	X
Rheotanytarsus sp.	X	X
Tanytarsus sp.	X	X
Zaurelia sp.	X	X
Stenochironomus sp.		X
Cryptochironomus sp.	X	X
Endochironomus sp.	X	
Pseudochironomus sp.	X	
Cladotanytarsus sp.	X	
Dicrotendipes sp.		X
Paratanytarsus sp.	X	
sp. 1	X	
Pagastiella sp.	X	
Omisus sp.		X
Parachironomus sp.		X
Tanypodinae		
Procladius spp. A&B	X	X
Clinotanypus sp.	X	X
Tanypus sp.	X	X
Ablabesmyia sp.	X	X
Coelotanypus sp.	X	X
Zaurelimyia sp.		X
Psectrotanypus sp.		X
Orthocladiinae		
Psectrocladius sp.	X	X

*Control
**Treatment

TABLE 7 (Cont'd) MACROINVERTEBRATE TAXA COLLECTED IN CONTROL AND TREATED STREAMS DURING 1980 TO 1981 WHEN 2.1 MG/L OF BOD OF SBKME WERE ADDED TO THE TREATMENT STREAMS

TAXON	C	T
Metriocnemus sp.	X	
Cricotopus sp.	X	
Cardiocladius sp.	X	X
Parakiefferiella		X
Bryophanocladius		X
Psuedosmittia spp. A&B		X
Orthocladius sp.		X
Cricotopus sp.		X
Eukiefferiella sp.		X
Paraphaenocladius sp.		X
Ceratopogonidae	X	X
Tabanidae	X	
Gastropoda		
Heliosoma sp.	X	X
Physa sp.	X	X
Pelecypoda		
Unionidae	X	X
Sphaeriidae	X	X
Turbellaria		
Planariidae		
Dugesia sp.	X	X
Annelida		
Oligochaeta	X	X
Hirudinea		
Dina sp.	X	X
Helobdella sp.	X	X

these analyses. During the entire year, 19 genera were found in the treatment streams which were not found in control streams and 9 genera were found in the control streams which were not found in the streams receiving effluent. In most of these cases a single organism from a genera of chironomidae or small numbers of such genera were collected on one occasion in a control or treatment stream. Overall, 38 of the more common genera or species were found in both control and effluent treated streams.

The species present in the experimental streams during 1980 to 1981 compare favorably with those found in the lower Neuse River during macroinvertebrate surveys by two groups of investigators. Of the approximately 18 freshwater genera or families found in a 1979 survey performed quarterly by the North Carolina Department of Natural Resources and Community Development, twelve were found in the experimental streams (7). Five of the other six species not found in the experimental streams were rare chironomids or *Chaoborus*. Of the approximately 54 families or genera found in the experimental streams but not in the Neuse River, 29 were chironomids. The 12 organisms found in both the Neuse River Surveys and the experimental streams are among the most common in both surveys. The number of organisms in common between the experimental streams and a 1978 survey of the lower Neuse River by Dr. Kirby-Smith was 14 and most of these organisms were the same genera reported in the NCDRCD survey (39). Dr. Kirby-Smith found four freshwater genera not found in the experimental streams. The large number of genera (51) found in the experimental streams, but not found in the Neuse River surveys is probably attributable to the greater number of samples taken and the habitat sampled. The Neuse River survey samples were taken primarily in the open rather uniform sections of the river, whereas much of the area sampled in the experimental streams was designed to resemble the more productive near shore or back water areas of warm water streams. If the shallower areas closer to shore were sampled in the Neuse River along with the more channelized area, the number of genera collected would probably increase greatly. The difference in productivity between the open uniform areas and near-shore areas is probably reflected in the total number of organisms as well as the total number of genera. The numbers of chironomids were at least 25 times greater in the experimental streams. Other organisms such as *Gammarus* were even more abundant in the experimental streams.

The hypothesis that the number and biomass of the most common macroinvertebrate groups were not significantly different between control and treatment streams were tested using analysis of variance performed on the 1980 to 1981 and 1981 to 1982 macroinvertebrate data. During 1980 to 1981, mean additions of 2.1 mg/l of BOD or approximately 12.5 percent by volume entered the two treatment streams and during 1981 to 1982, 2.5 mg/l of

BOD and 15% by volume were added to treatment streams. Table 8 summarizes the results of this statistical analysis performed on the total and most abundant organisms groups found in six samples (three from each stream) from treatment or control streams for each sampling date. The table also shows analysis of variance results when all of the samples for the year were combined. The means listed on Table 8 are from ln(x+1) transformations of the numbers/M^2 or biomass/M^2 expressed as mg of wet weight. Table 8 shows that significant differences between the number or biomass of total macroinvertebrates or dominant macroinvertebrate groups occurred infrequently when monthly samples were compared. During the 1980 to 1981 study year, only the numbers of amphipods and isopods and total macroinvertebrates found in July samples as well as the biomass of amphipods and isopods during the same month were significantly greater in treatment streams than control streams. When all control and treatment samples for the entire year were analyzed together, the number of total macroinvertebrates, amphipods, and chironomids and the biomass of amphipods were significantly greater in effluent treated streams than in control streams. Since these samples were taken during several months, the analysis of the totals for each group during the year can only be used to further indicate a trend toward greater numbers of macroinvertebrates in the treatment streams.

During the 1981 to 1982 study year, when 2.5 mg/l BOD of SBKME (15% by volume) were added to treatment streams, the number of times significant differences between control and treatment streams occurred increased somewhat. The total number and biomass of organisms found in treatment streams was significantly greater than control streams during October and January (Table 8). The number of amphipods was significantly greater in treatment streams during August, September and October of 1981 but were significantly greater in the control streams during March 1982. The biomass of amphipods was also significantly greater in treatment streams during August and October, although neither the number nor biomass was significantly different when all samples for the 1981 to 1982 study year were analyzed as a group.

The number and biomass of isopods were significantly greater in the treatment streams during September and over the entire year (Table 8). The number of chironomids was significantly greater in the control streams during September and October, while both the number and biomass were significantly greater over the entire study period.

Both the number and biomass of snails were significantly greater in the treatment streams during April and over the entire study period, the number of snails was significantly greater in the treatment streams.

TABLE 8 MEAN AND STANDARD DEVIATION (IN PARENTHESIS) OF LN (X+1) TRANSFORMED NUMBERS AND BIOMASS OF TOTAL MACROINVERTEBRATES AND DOMINANT GROUPS FOUND IN BOTTOM SAMPLES DURING THE 1980 TO 1981 STUDY YEAR. C=CONTROL, T=TREATMENT, N=NUMBERS, B=BIOMASS, *INDICATES SIGNIFICANT DIFFERENCE AT P>95% USING ANALYSIS OF VARIANCE AND T-TEST

		TOTAL		AMPHIPODS		ISOPODS		CHIRONOMIDS		SNAILS	
MONTH	ST.	N	B	N	B	N	B	N	B	N	B
Oct.	C	8.69 (0.50)	8.67 (0.28)	7.16 (1.17)	7.10 (0.91)	2.67 (2.19)	3.52 (2.87)	7.80 (0.72)	7.59 (0.44)	4.03 (2.49)	4.74 (2.67)
	T	8.89 (0.90)	8.96 (0.94)	7.79 (1.44)	7.00 (1.27)	3.63 (3.16)	4.49 (3.80)	7.60 (1.20)	7.80 (1.30)	3.31 (1.96)	4.97 (3.02)
Nov.	C	9.06 (0.36)	9.44 (0.27)	7.84 (0.58)	7.72 (0.54)	3.48 (2.00)	4.14 (2.46)	8.14 (0.49)	8.32 (0.75)	5.48 (1.32)	6.64 (1.95)
	T	9.53 (0.82)	9.33 (0.96)	8.90 (1.05)	8.27 (1.19)	4.49 (2.41)	5.38 (2.94)	7.59 (0.93)	8.11 (1.46)	2.70 (3.04)	3.30 (3.66)
Jan.	C	9.14 (0.18)	10.02 (0.37)	8.58 (0.27)	9.41 (0.26)	4.53 (1.26)	6.47 (1.43)	6.94 (1.14)	7.63 (1.18)	3.47 (3.20)	4.14 (4.29)
	T	9.58 (0.72)	9.62 (0.53)	8.91 (1.14)	8.17 (1.04)	5.59 (1.55)	6.53 (2.62)	6.93 (1.34)	7.93 (1.09)	3.44 (3.14)	4.00 (3.22)
Feb.	C	8.90 (0.65)	9.62 (0.62)	8.07 (1.00)	8.42 (1.34)	4.98 (1.52)	5.96 (2.66)	6.48 (1.27)	6.64 (1.09)	4.43 (2.37)	5.95 (3.58)
	T	9.55 (0.47)	9.73 (0.60)	9.05 (0.49)	8.48 (0.61)	5.85 (1.17)	7.87 (0.82)	7.69 (0.91)	8.08 (1.35)	4.22 (1.07)	5.22 (1.85)
March	C	9.22 (0.32)	9.68 (0.68)	8.55 (0.47)	9.24 (0.70)	5.12 (3.17)	5.72 (3.18)	7.15 (0.54)	6.89 (0.62)	2.26 (2.76)	3.11 (4.05)
	T	9.20 (0.66)	9.57 (0.54)	8.58 (0.76)	8.51 (0.77)	5.83 (0.98)	6.31 (1.12)	7.14 (0.91)	7.39 (1.30)	3.26 (1.64)	5.75 (2.93)

TABLE 8 (Cont'd) MEAN AND STANDARD DEVIATION (IN PARENTHESIS) OF LN (X+1) TRANSFORMED NUMBERS AND BIOMASS OF TOTAL MACROINVERTEBRATES AND DOMINANT GROUPS FOUND IN BOTTOM SAMPLES DURING THE 1980 TO 1981 STUDY YEAR. C=CONTROL, T=TREATMENT, N=NUMBERS, B=BIOMASS, *INDICATES SIGNIFICANT DIFFERENCE AT P>95% USING ANALYSIS OF VARIANCE AND T-TEST

MONTH	ST.	TOTAL		AMPHIPODS		ISOPODS		CHIRONOMIDS		SNAILS	
		N	B	N	B	N	B	N	B	N	B
April	C	9.09 (0.70)	9.89 (0.75)	8.36 (0.89)	9.02 (0.54)	6.41 (1.43)	7.11 (1.12)	5.63 (2.85)	5.55 (2.83)	2.81 (2.29)	4.56 (3.76)
	T	9.19 (0.34)	9.53 (0.41)	8.29 (0.38)	8.50 (0.53)	7.68 (0.88)	7.62 (0.92)	6.11 (1.53)	6.60 (1.72)	3.16 (1.81)	5.22 (2.83)
June	C	8.73 (0.41)	8.70 (0.75)	8.38 (0.53)	8.12 (0.80)	4.06 (2.74)	3.98 (3.04)	3.41 (0.99)	3.65 (1.46)	4.45* (2.37)	5.83 (2.96)
	T	8.61 (0.93)	8.65 (0.84)	8.10 (0.95)	7.23 (1.50)	5.40 (2.42)	5.21 (2.91)	5.22 (2.85)	5.53 (2.95)	1.68 (1.94)	2.33 (3.40)
July	C	8.30 (0.49)	8.65 (1.20)	7.78 (0.49)	7.16 (0.92)	3.00 (1.92)	2.87 (1.71)	4.91 (1.59)	4.45 (2.13)	2.12 (1.88)	2.43 (2.06)
	T	9.24** (0.21)	9.26 (0.95)	8.71* (0.17)	8.47* (0.49)	6.13* (1.48)	8.95* (1.44)	5.91 (1.07)	4.73 (0.81)	3.02 (1.65)	3.23 (1.74)
Grand Totals	C	8.89 (0.53)	9.33 (0.83)	8.09 (0.82)	8.27 (1.14)	4.32 (2.30)	4.97 (2.67)	6.37 (1.99)	6.34 (2.09)	3.63 (2.47)	4.67 (3.31)
	T	9.22* (0.70)	9.34 (0.76)	8.54* (0.92)	8.08 (1.08)	5.57* (2.16)	6.17* (2.41)	6.81 (1.64)	7.04 (1.93)	3.10 (2.08)	4.25 (2.92)

TABLE 8 (Cont'd) MEAN AND STANDARD DEVIATION (IN PARENTHESIS) OF LN (X+1) TRANSFORMED NUMBERS AND BIOMASS OF TOTAL MACROINVERTEBRATES AND DOMINANT GROUPS FOUND IN BOTTOM SAMPLES DURING THE 1981 TO 1982 STUDY YEAR. C=CONTROL, T=TREATMENT, N=NUMBERS, B=BIOMASS, *INDICATES SIGNIFICANT DIFFERENCE AT P>95% USING ANALYSIS OF VARIANCE AND T-TEST

		TOTAL		AMPHIPODS		ISOPODS		CHIRONOMIDS		SNAILS	
MONTH	ST.	N	B	N	B	N	B	N	B	N	B
Aug.	C	8.62 (.93)	8.34 (.87)	5.49 (1.60)	5.47 (1.66)	2.51 (2.23)	2.67 (2.20)	7.34 (.80)	6.55 (.78)	3.38 (2.44)	4.37 (3.41)
	T	9.02 (.51)	8.46 (.64)	8.06* (.66)	7.73* (.78)	3.89 (2.56)	3.63 (2.63)	6.45 (.58)	5.57 (1.12)	4.74 (1.86)	5.52 (1.79)
Sept.	C	9.04 (.22)	8.75 (.40)	7.51 (.65)	7.17 (.94)	0.00 (0.00)	0.00 (0.00)	7.43* (.61)	6.84 (.80)	3.91 (1.48)	5.61 (1.04)
	T	9.45 (.57)	9.20 (1.13)	8.81* (.86)	7.91 (1.08)	3.99* (1.05)	4.64* (1.14)	6.14 (1.03)	5.54 (1.47)	3.29 (3.24)	3.69 (3.64)
Oct.	C	8.85 (.39)	8.91 (.32)	7.50 (1.10)	7.61 (.73)	1.83 (2.19)	2.74 (3.24)	7.48* (.48)	6.94 (.26)	3.46 (.98)	6.06 (1.26)
	T	9.56* (.58)	9.56* (.60)	9.19* (.55)	8.98* (.73)	3.07 (2.54)	3.73 (3.15)	6.21 (.80)	6.23 (1.24)	3.35 (1.18)	3.84 (2.34)
Nov.	C	9.20 (.25)	9.48 (.47)	8.52 (.50)	8.82 (.83)	2.42 (2.18)	4.12 (3.35)	6.24 (1.35)	5.96 (.94)	2.84 (2.30)	4.01 (3.40)
	T	9.59 (.42)	9.88 (.77)	9.13 (.47)	9.29 (.85)	4.08 (1.42)	5.42 (1.68)	6.05 (1.07)	6.18 (1.41)	3.34 (2.87)	4.43 (3.48)
Jan.	C	9.09 (.26)	9.32 (.49)	8.36 (.28)	8.57 (.60)	2.44 (2.01)	4.47 (3.57)	7.38 (.73)	6.62 (.60)	3.72 (1.28)	5.84 (2.05)
	T	9.53* (.39)	10.15* (.34)	8.60 (.56)	9.19 (.61)	2.88 (2.43)	4.35 (3.57)	6.40 (.87)	6.64 (.99)	4.24 (.88)	6.09 (2.15)

TABLE 8 (Cont'd) MEAN AND STANDARD DEVIATION (IN PARENTHESIS) OF LN (X+1) TRANSFORMED NUMBERS AND BIOMASS OF TOTAL MACROINVERTEBRATES AND DOMINANT GROUPS FOUND IN BOTTOM SAMPLES DURING THE 1981 TO 1982 STUDY YEAR. C=CONTROL, T=TREATMENT, N=NUMBERS, B=BIOMASS, *INDICATES SIGNIFICANT DIFFERENCE AT P>95% USING ANALYSIS OF VARIANCE AND T-TEST

		TOTAL		AMPHIPODS		ISOPODS		CHIRONOMIDS		SNAILS	
MONTH	ST.	N	B	N	B	N	B	N	B	N	B
Feb.	C	8.79 (.50)	9.21 (1.04)	8.05 (.53)	8.71 (1.08)	2.49 (2.09)	4.30 (4.37)	6.68 (.97)	6.09 (1.07)	2.11 (2.53)	3.18 (4.09)
	T	9.00 (.51)	9.34 (.68)	8.13 (.65)	8.69 (.66)	2.72 (2.19)	3.99 (3.24)	6.39 (.64)	5.57 (1.55)	1.82 (2.10)	2.39 (3.33)
March	C	9.06 (.33)	9.34 (.20)	8.43* (.38)	9.08 (.23)	2.77 (3.03)	3.31 (3.63)	7.03 (.63)	6.05 (.45)	3.31 (1.68)	4.67 (2.88)
	T	9.00 (.42)	9.34 (.61)	7.74 (.56)	8.64 (.47)	4.29 (2.43)	4.54 (2.54)	7.06 (.31)	6.62 (.86)	1.96 (2.30)	2.46 (3.03)
April	C	8.92 (.29)	8.60 (.63)	7.87 (.73)	7.68 (.78)	4.39 (1.37)	3.91 (1.39)	6.83 (1.48)	5.80 (1.19)	.80 (1.24)	1.84 (3.31)
	T	9.11 (.31)	9.79* (.56)	6.83 (1.38)	7.16 (1.63)	6.13 (1.77)	5.87 (2.12)	6.92 (.58)	6.75 (.53)	5.61* (1.48)	5.80* (.98)
June	C	7.99 (1.22)	8.25 (1.48)	7.10 (2.38)	6.51 (3.20)	2.20 (2.53)	2.11 (2.41)	5.16 (1.58)	4.30 (1.16)	4.09 (2.13)	4.57 (2.39)
	T	8.00 (1.04)	7.66 (.94)	5.47 (3.46)	4.69 (3.47)	4.25 (3.33)	4.09 (3.20)	3.67 (3.05)	2.96 (2.61)	4.04 (2.40)	3.05 (2.45)
Grand Totals	C	8.86 (.64)	8.91 (.82)	7.65 (1.36)	7.74 (1.71)	2.34 (2.23)	3.07 (2.92)	6.84* (1.19)	6.13* (1.10)	3.07 (1.98)	4.44 (2.89)
	T	9.14* (.70)	9.26 (.99)	8.00 (1.70)	8.03 (1.91)	3.92* (2.32)	4.47* (2.59)	6.14 (1.49)	5.78 (1.71)	3.60* (2.31)	4.14 (2.83)

Overall, at the highest concentrations tested of 2.1 and 2.5 mg/l BOD of SBKME (12.5 and 15% by volume), the benthic organisms have trended toward having greater numbers in the treatment streams, and particularly greater numbers of amphipods and isopods. The biomass has not shown this trend so clearly and organisms other than amphipods and isopods have not been consistently greater in either control or treatment streams over these study years.

Table 9 shows the month by month and yearly total analysis of the Biotic Index (BI) and trophic structure for feeding type during the 1980 to 1981 exposure year. The Biotic Index (Chutter's) is an indicator of the percentage of the organisms present which are tolerant of organic loading and low dissolved oxygen conditons. If the number is near 0 to 2, a large percentage of the organisms present are "intolerant". If the number is near 3, most of the organisms may be "facultative" or split between "tolerant" and "intolerant". If the number is 4 or above, more organisms are of the "tolerant" group. During all sampling periods, the BI was between 3 and 4 in both control and effluent treatment groups. Most of the organisms present were classified as "facultative" when using this system. This would be expected considering the water supply was from a large, slow moving river that has seasonal high temperatures over 30°C and dissolved oxygen at times below 5 mg/l.

The trophic index shows some diversity of feeding types although the majority of the organisms are considered to be collector-gatherers. Other feeding types were also found but not in abundance. Most of the remaining organisms were scavengers below the surface (worms). Although their numbers were sometimes great, the biomass of worms was never very large because of their relative size. Generally, changes in these functional groups due to the presence of effluent in treatment streams was not noted.

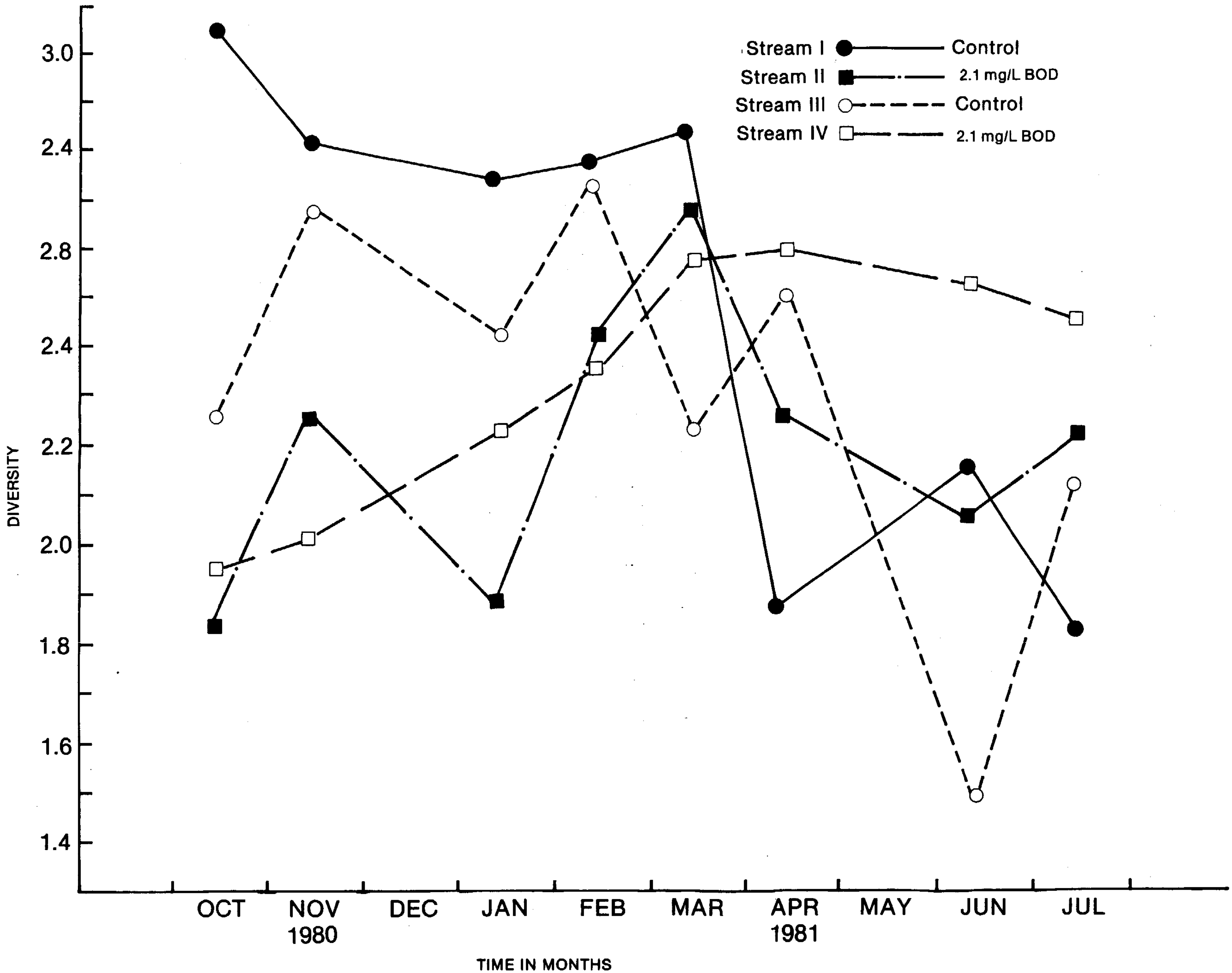
The Shannon-Weiner diversity index calculated for the control and treatment streams for each month during the 1980 to 1981 study year is shown on Figure 10. When 2.1 mg/l of BOD of SBKME (12.5% by volume) were added to the streams, the macroinvertebrate diversity was lower in the streams receiving effluent during the first four sampling periods, but was generally equal to or higher than the diversity index in control streams during the final four sampling periods of the study year. The initial lower diversity of macroinvertebrates in the effluent streams was primarily due to an increase in abundance of amphipods and isopods in those streams. The diversity index is usually lowered if 1 or 2 organisms become more dominant as occurred in the effluent treated streams. Since this lower

TABLE 9 THE BIOTIC INDEX (BI) OF THE TOTAL NUMBERS OF MACROINVERTEBRATES FOUND IN COMBINED CONTROL AND TREATMENT STREAMS AND THEIR PERCENT COMPOSITION AS CLASSIFIED BY FUNCTIONAL FEEDING GROUPS

DATE		BI	FTO %	FT1 %	FT2 %	FT3 %	FT4 %	FT5 %	FT6 %	FT7 %	FT8 %
Oct. 80	C	3.86	--	--	2	70	5	2	5	16	--
	T	3.65	--	--	<1	83	<1	1	3	12	--
Nov. 80	C	3.85	--	--	4	72	5	2	3	14	--
	T	3.36	<1	--	2	81	1	1	4	10	<1
Jan. 81	C	3.34	--	--	<1	74	4	1	4	15	2
	T	3.25	--	--	2	75	2	<1	2	15	4
Feb. 81	C	3.41	--	--	2	79	4	<1	2	13	<1
	T	3.28	--	<1	3	80	3	1	1	12	<1
Mar. 81	C	3.22	--	--	2	76	1	1	1	18	1
	T	3.29	<1	<1	3	74	<1	1	2	17	4
Apr. 81	C	3.06	--	--	<1	75	1	1	1	22	--
	T	3.08	--	--	2	73	<1	1	4	19	<1
Jun. 81	C	3.36	--	--	<1	68	18	<1	<1	12	1
	T	3.18	--	--	5	79	<1	<1	4	10	2
Jul. 81	C	3.13	<1	--	1	67	1	1	1	24	6
	T	3.04	<1	--	2	72	3	<1	1	22	--

FTO = Herbivores-feeding on living vascular hydrophyte, FT1 = Detritivores, FT2 = Filter Feeders, FT3 = Collectors-fine organic particles or on substrate surface-often on underside of rocks, FT4 = Scrapers-periphyton, FT5 = Predator, FT6 = Omnivore, FT7 = Scavenger-nutrients below substrate (worms), FT8 = Scavenger

FIGURE 10 SHANNON-WEINER DIVERSITY IN CONTROL AND TREATMENT STREAMS WHEN 2.1 MG/L OF BOD OF SBKME WERE ADDED TO STREAMS 2 AND 4



diversity is primarily due to greater numbers of organisms that are used as fish foods (Table 10), this would not be expected to result in any decrease in the productivity of these streams for fish. Most of the diversity numbers calculated for the experimental streams were between 2 and 3. These numbers were slightly higher than the diversity calculated during the two surveys of the Neuse River discussed earlier in this bulletin (7, 39). As stated earlier this is probably due to differences in the habitat sampled in the Neuse River and the experimental streams.

The diet of the bluegill sunfish from the experimental streams generally reflects the presence of organisms found in the benthic samples, although the damselfly larvae make up a higher percentage of the food than might be expected. A high percentage of the number of organisms found in the stomachs of bluegills were amphipods followed by chironomids and larvae of Odonata (primarily damselflies (Table 10). Occasionally, organisms from other groups were also found. These three groups not only made up a great deal of the total number of organisms found, but were also present in a high percentage of the stomachs examined.

The largemouth bass also consumed some amphipods and chironomids, but the overall importance of the amphipods as food items for the larger bass may be somewhat less than this percentage would indicate, since they were found in a relatively low percentage of the stomachs and the food value of a single amphipod is probably quite low compared to a crayfish, fish or adult dragonfly. As a percent of the total number of food organisms, the amount of crayfish found in the stomachs of bass appears to be low, but the percentage of bass stomachs which contained crayfish is in all cases greater than the number of stomachs containing amphipods. Since a single crayfish contains a great deal of food value compared to an amphipod, the relative contribution of crayfish to the food intake may be underestimated. The adult dragonflies are undoubtedly a seasonal food item, probably captured while depositing eggs in the streams. These are relatively large food items and their frequency of occurrence in the bass stomachs indicates they were an important food during the summer months when these samples were taken. Other food sources of the bass included fish, Odonata larvae and isopods. These samples, taken as fish were removed from the streams, do not indicate any particular difference in feeding patterns between fish from treatment streams and control streams.

D. Fish Production and Biomass

1. Total Fish Production and Biomass - The total production of the largemouth bass, bluegill sunfish, and golden shiners

TABLE 10 PERCENT COMPOSITION OF MACROINVERTEBRATES IN FISH STOMACH SAMPLES, DURING JULY 1980, AND JULY 1981 C=CONTROL STREAMS, T=TREATMENT STREAMS

TAXON	JULY 1980				JULY 1981			
	BASS[1]		BLUEGILL[1]		BASS[1]		BLUEGILL[1]	
	C	T	C	T	C	T	C	T
Amphipoda	20(21)[2]	24(7)	95(93)	66(100)	12(7)	27(7)	88(93)	67(79)
Isopoda		<1(7)	<1(7)			14(7)		12(14)
Decapoda	18(50)	2(36)		<1(7)	8(29)	14(43)		1(7)
Trichoptera		<1(7)						
Diptera								
Chironomidae		65(7)	<1(14)	27(36)	26(14)		6(14)	18(21)
Empididae	2(7)							
Odonata								
(Adults)	48(29)	4(43)	<1(7)	<1(7)	36(36)	36(43)		
(Larvae)	8(7)	1(21)	3(29)	6(57)		4(7)	5(36)	11(42)
Hemiptera								
Corixidae		2(21)		<1(14)				
Belostomatidae		<1(7)						
Gerridae		<1(7)						
Coleoptera			<1(14)					
Terrestrial Arthropoda	2(7)	<1(7)	<1(7)			2(7)		
Sphaeridae				<1(7)				
Hirudinea							<1(7)	
Oligochaeta								
Gastropoda								
Fish	2(7)				16(36)	2(7)		

[1] Fourteen fish were sampled for each group.
[2] The number in parentheses indicates the percent of total stomach samples in which this food item was present.

TABLE 10 (Cont'd) PERCENT COMPOSITION OF MACROINVERTEBRATES IN FISH STOMACH SAMPLES DURING JULY 1982
C=CONTROL STREAMS, T=TREATMENT STREAMS

	JULY 1982			
	BASS[1]		BLUEGILL[1]	
TAXON	C	T	C	T
Amphipoda	18(40)[2]	6(21)	44(65)	50(76)
Isopoda	1(5)		<1(5)	1(10)
Decapoda	39(85)	33(68)		<1(5)
Ephemeroptera		3(5)	2(15)	1(10)
Trichoptera		8(21)		10(33)
Diptera				
Chironomidae	9(35)	12(16)	47(65)	20(90)
Empididae				
Odonata				
(Adults)				
(Larvae)	18(45)	37(74)	3(15)	17(67)
Hemiptera				
Corixidae				
Belostomatidae			<1(5)	
Gerridae		1(5)		
Coleoptera	1(5)			1(14)
Terrestrial Arthropoda	2(10)		<1(5)	<1(5)
Sphaeridae				
Hirudinea				
Oligochaeta			<1(5)	1(14)
Gastropoda			2(15)	<1(5)
Fish	12(30)			

[1] Fourteen fish were sampled for each group.
[2] The number in parentheses indicates the percent of total stomach samples in which this food item was present.

stocked in the experimental streams is shown on Figure 11. Over the seven years of study shown on this figure, the total production ranged from a low of nearly 20 g/m^2 in control stream 1 during the 1979 to 1980 and 1981 to 1982 study years to a high of slightly over 40 g/m^2 in treatment stream 2 during the 1977 to 1978 production year. The production figures generally show the same trends during most years, in that the total production rate was high after initial stocking in the summer and fall, followed by almost no production or negative production (weight loss) during the winter months. The spring was again a period of high production although the rate of production was often less in late spring or early summer months than earlier spring months as the biomass of fish approached the carrying capacity of the streams (Figure 12). Total fish production and the accumulation of biomass of fish during 1980 to 1981 was an exception to this pattern. Fish were stocked in October rather than late June or July as in the previous years to allow time for repair of the effluent delivery system and use of the streams for a short-term bioaccumulation study. The later start during the 1980 to 1981 production year decreased the summer-fall production and biomass accumulation and the spring production was then slightly greater than earlier years, since the carrying capacity of the stream was probably not approached until late in the experimental year. During the first three years of study, the fish were stocked during June or early July and this tended to allow greater production prior to the winter months, as well as higher biomass during the winter months (Figure 12). During the last 4 years, the fish were removed and restocked somewhat later to allow more time for spawning and stream restoration. Because of the slightly later stocking dates, the total production during the initial summer months was lower during the last four years of study and the winter biomass was also lower than earlier years.

The total fish production shows some variability between the streams. During the first 3 years of study, when mean concentrations of 0.4, 1.0 and 1.4 mg/l of BOD entered the 2 treatment streams (means of 4, 7 and 11 percent by volume), the total production of fish in the treatment streams was similar to that of control streams and the total production values demonstrated no noticeable trends among control or treatment streams. During the 1978 to 1979 experimental year, when a mean concentration of 1.6 mg/l BOD (10.4 percent by volume) of SBKME was added to treatment streams, the total fish production was similar in control and treatment streams during the summer and winter months. During the spring months, the total production in each of the control streams was slightly higher than the production of fish in the treatment streams, and the cumulative total production

FIGURE 11 TOTAL CUMULATIVE PRODUCTION OF LARGEMOUTH BASS, BLUEGILL SUNFISH AND GOLDEN SHINERS DURING EACH STUDY YEAR. STREAMS 2 AND 4 RECEIVED STABILIZED BLEACHED KRAFT MILL EFFLUENT

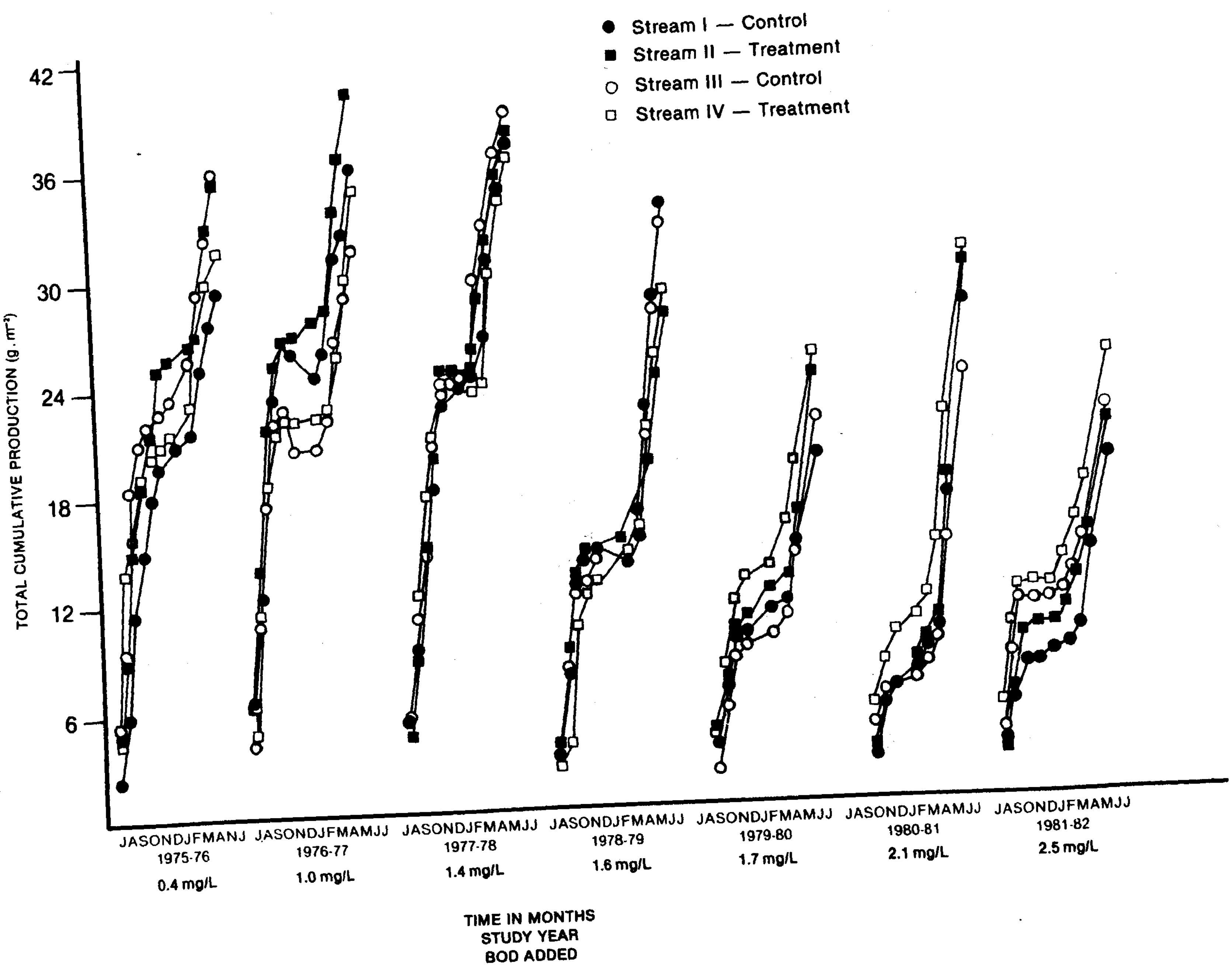
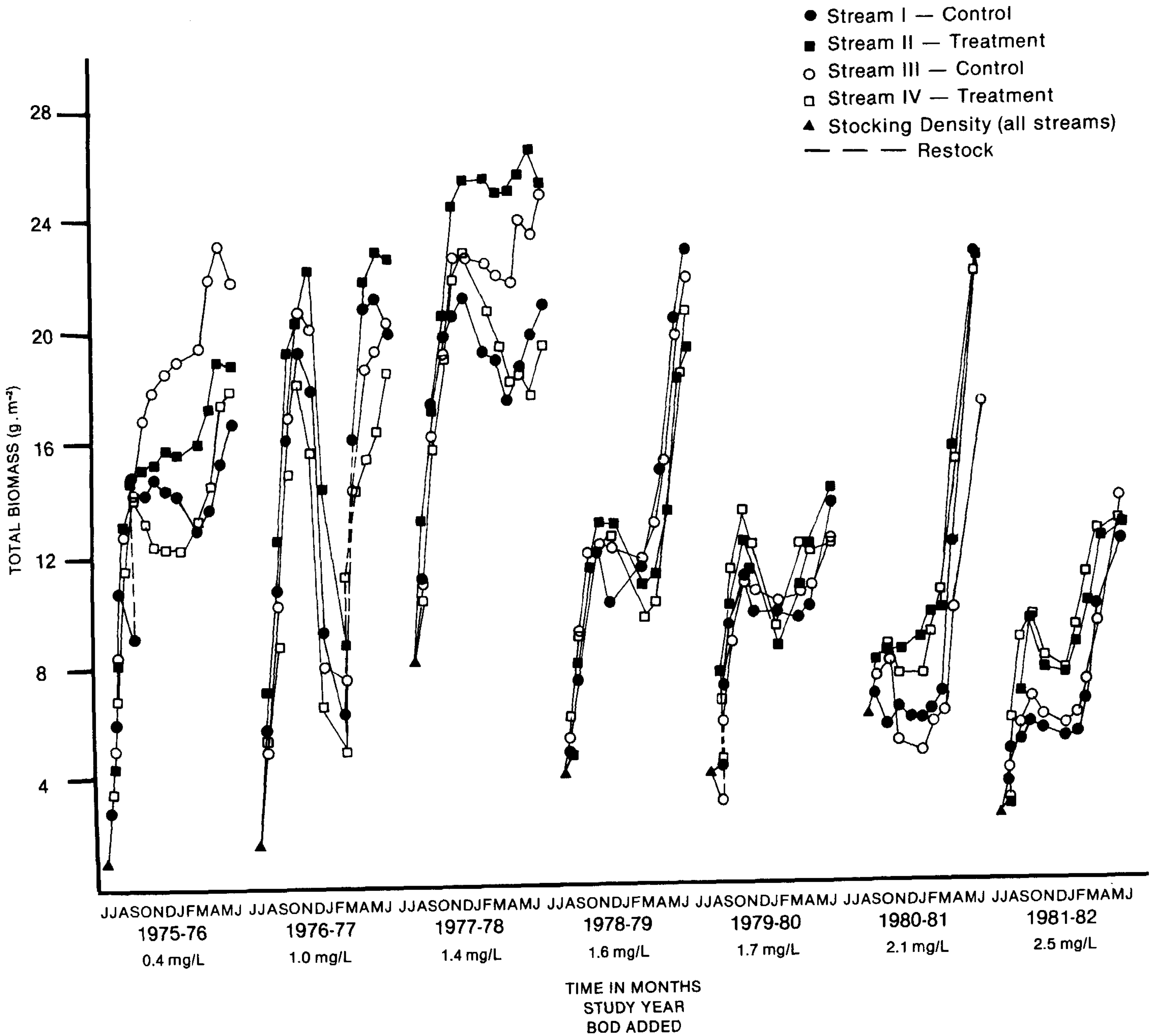


FIGURE 12 TOTAL CUMULATIVE BIOMASS OF LARGEMOUTH BASS, BLUEGILL SUNFISH AND GOLDEN SHINERS DURING EACH STUDY YEAR. STREAMS 2 AND 4 RECEIVED STABILIZED BLEACHED KRAFT MILL EFFLUENT



for the 1978 to 1979 year was approximately 14 percent higher in the control streams than in the treatment streams. The primary reason for this difference in production was the loss of bass biomass from both of the treatment streams during January, 1979 and subsequent low bass production because of their decreased numbers. Further elaboration of these production differences are given later in this section when the production of individual species is discussed.

During the 1979 to 1980 and 1980 to 1981 study years, mean additions of 1.7, and 2.1 mg/l of BOD of SBKME (9.0 and 12% by volume) entered the treatment streams compared to 1.6 mg/l BOD and 10.4 percent by volume during 1978 to 1979. The total production was either slightly greater in treatment streams or similar in control and treatment streams until the spring months when the total production of the three fish species was greater in streams receiving effluent than in control streams. The final total cumulated production was approximately 20 percent greater in the 2 effluent treated streams than in control streams during both of the study years. During the 1981 to 1982 study year, the mean BOD addition of SBKME to the treatment streams was approximately 2.5 mg/l (15% by volume). The total production of the three fish species in the treatment and control streams was similar for this study period; the combined total production from treatment streams 2 and 4 being about 12 percent greater than the combined production from control streams 1 and 3, with the total production of fish in control stream 3 being slightly greater than the total production in treatment stream 2. The increases of fish production in the treatment streams during the 1979 to 1980 and 1980 to 1981 study years were due to increased production of blue gill sunfish or golden shiners.

The total biomass of fish in the streams has usually followed the same trends as the production during the summer and fall months and into the winter. Since the stocking density of all of the fish was usually less than 6 g/m^2, the biomass usually increased steadily during the summer and fall months as the fish grew rapidly. One exception occurred during the 1980 to 1981 year when initial stocking occurred later in the fall and the temperatures were cool enough to prevent very rapid initial growth. During winter months, the biomass of fish in the experimental streams generally decreased slightly, since a few fish were usually lost from the stream systems due to natural mortality and production was very low or negative during the December to March time period of each study year. Biomass losses during the winter months of the 1976 to 1977 year were high in all streams. The large loss of biomass during that year was believed to be due to predation by herons and kingfishers. Areas to the immediate North and West of the streams were frozen during the winter of 1977 and more of these predators appeared to be present at the experimental streams than any other year. Fish of all species were restocked in all streams during the winter of 1977 to replace those lost due to predation, and production continued in the spring. The total biomass did not usually increase greatly during the spring of the first three years of these experiments (Figure 12) although the biomass of bass or bluegill sunfish usually continued to increase gradually (Figures 14 and 16). Increases of bass or bluegill biomass were usually offset by loss of golden shiner biomass. Apparently, the total biomass of fish in the streams was approaching the carrying capacity by the winter months and production of fish during the spring was nearly equaled by biomass losses during these years. During the 1978 to 1979 and 1980 to 1981 production years, the biomass was not as great as earlier years approaching the winter months and during the spring and early summer months, the biomass in the streams increased to levels approximating the final total biomass of earlier years which was usually between 18 to 25 g/m^2. Just as the total production was lower in all streams during the 1979 to 1980 and 1981 to 1982 production years, the total final biomass was also somewhat reduced in all streams compared to other years. The combined survival of all three species stocked in the streams was not as good during 1979 to 1980 as in other years and this appears to have been responsible for the lower production and biomass during that year. Poor survival of golden shiners in all streams during the 1981 to 1982 study year appears to be the primary reason for the lower biomass of fish in all streams during that year. Biomass losses of bass and bluegill sunfish from all streams during June of 1982 because of an intermittent water supply also contributed to the lower biomass during that year. No reason for the difference in survival in all streams between years could be determined, but such differences are not unusual in natural systems. For instance, Carlander (40) summarized several studies of bluegill sunfish populations and reported survivals of fingerlings in streams stocked with largemouth bass to be less than 25 percent in some studies while others reported survival of fingerlings to be 75 to 100 percent when stocked alone, or with other fish.

The total final biomass reported earlier in this section of 18 to 25 g/m^2 is not unusual for streams in Eastern North Carolina. Surveys of tributaries to several rivers in Eastern North Carolina found standing crops of all species present from 1 g/m^2 to 50 g/m^2 and standing crops from 10 to 30 g/m^2 were frequently found (41, 42, 43, 44 and 45).

Generally, the total final biomass was similar in both effluent and treatment streams and a trend related to the presence of effluent was not apparent. The total biomass was greater in both treatment streams until the final sampling period during the

1980 to 1981 and 1981 to 1982 study years when mean BOD additions of 2.1 and 2.5 mg/l (12.5 and 15 percent by volume) were added to the treatment streams. However, the total biomass of fish in at least one of the control streams was equal to or greater than the biomass in at least one of the treatment streams by the final sampling period.

2. Bass Production and Biomass - The production and biomass of largemouth bass have shown a greater variability among the 4 streams over the 7 years of these studies than the total fish production or biomass (Figures 13 and 14). Generally, if the production of bass has been greater in one stream, the production of one or both of the other 2 species has not been as great in that stream as in the other streams (Figures 21 and 29). The final cumulative production of bass was usually between 6 to 12 g/m^2 in all streams and the biomass between 4 to 9 g/m^2. As shown in the total production and biomass figures discussed previously, the bass production and biomass were lowest in all streams during the 1979 to 1980 study year and the lowest bass production of approximately 3 g/m^2 occurred in treatment stream 2 during the 1981 to 1982 study year. The highest production of bass was near 13 g/m^2 and occurred in control stream 3 during the 1976 to 1977 study year.

No consistent differences of bass production and biomass were noticeable between effluent and treatment streams during the first 3 years of study when mean concentrations of 0.4, 1.0, and 1.4 mg/l BOD of SBKME were added to the treatment streams (4, 7, and 11 percent by volume concentrations). During the 1975 to 1976 study year when 0.4 mg/l BOD of SBKME entered the two treatment streams, the production and biomass of bass in these streams was intermediate to the two control streams. Control stream 1 had the greatest bass production, particularly in the early summer and fall months. As noted earlier, when bass production was high in one stream, golden shiner or bluegill sunfish production was usually low in that stream. In this case, golden shiner production and biomass were very low (Figures 29 and 30) in stream 1. Bass production was slightly greater in both control streams during 1976 to 1977 when 1.0 mg/l of BOD was added to the treatment streams, but this appears to be an exception since the following year when 1.4 mg/l entered the treatment streams, the cumulative bass production in the 2 treatment streams was again intermediate to the two controls.

The pattern of increased golden shiner production and biomass during the summer and autumn months in streams when bass production was low, was again evident during the 1976 to 1977 study year. The production and biomass of golden shiners were greater in both effluent treatment streams during the summer and

FIGURE 13 CUMULATIVE PRODUCTION OF LARGEMOUTH BASS DURING EACH STUDY YEAR. STREAMS 2 AND 4 RECEIVED STABILIZED BLEACHED KRAFT MILL EFFLUENT.

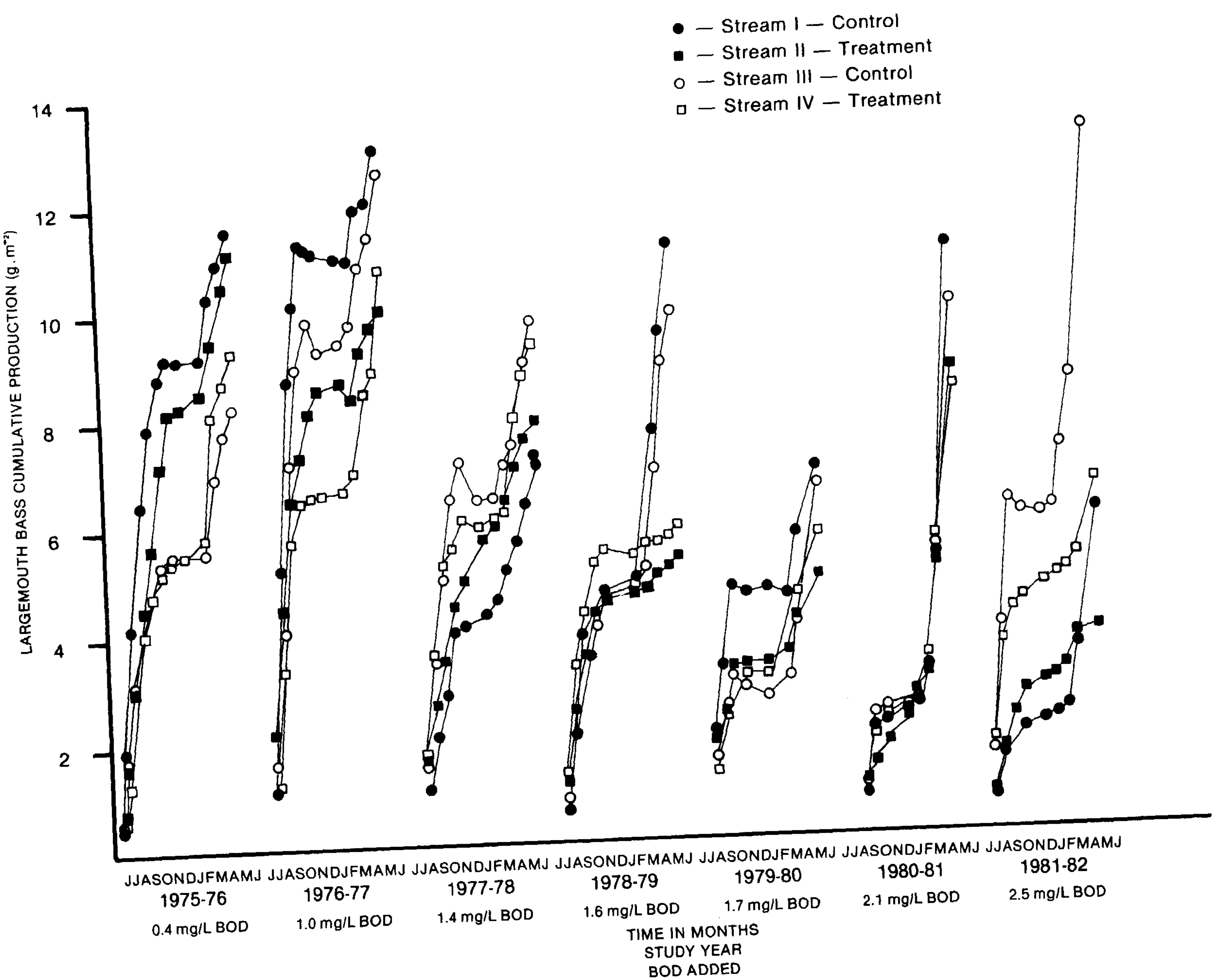
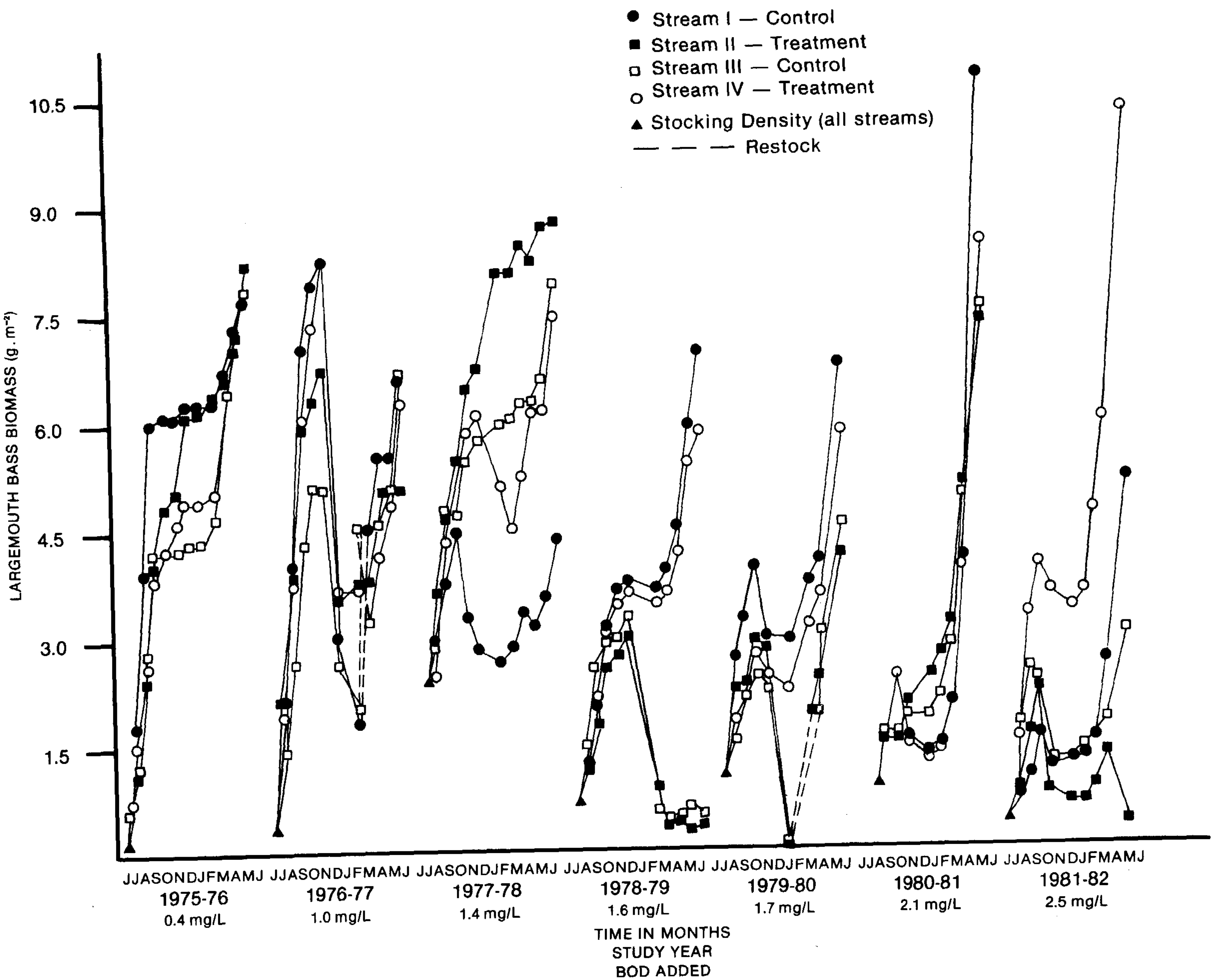


FIGURE 14 BIOMASS OF LARGEMOUTH BASS DURING EACH STUDY YEAR. STREAMS 2 AND 4 RECEIVED STABILIZED BLEACHED KRAFT MILL EFFLUENT.



fall months and the bass production was lower in treatment streams. The following study year when 1.4 mg/l of BOD entered the treatment streams, these results were reversed. The results indicate that although the reason for better survival and production of golden shiners or bass during these three years is not known, such differences do not appear to be related to the presence of effluent. During 1978 to 1979, when 1.6 mg/l BOD entered the treatment streams, the cumulative production of bass was nearly equal in all streams as the winter months approached. On January 9, 1979, nearly all of the bass from the two treatment streams were lost due to movement into the traps. This was attributed to a temporary abnormality in effluent quality (Tables B1 and C1). Bass of a suitable size for restocking could not be found, therefore, the low numbers of bass in the treatment streams caused the bass production and biomass to be so low in those streams during the spring of 1979 that bass production data was of no value. During the following 1979 to 1980 study year, the bass production and biomass were similar in treatment streams 2 and 4 and control stream 3. The production and biomass of bass in control stream 1 approaching the winter months was slightly higher than the 3 other streams. During January, most of the largemouth bass were again lost from the treatment streams. This occurred immediately after the effluent volume was increased from 7.5 to 15 percent. There was no indication of a change in the quality of effluent, as measured by BOD, TSS or concentrations of organic constituents (Table B1). It was later observed that rapid increases of the volume of effluent would flush low sections of the effluent delivery pipe and high concentrations of organic constituents as well as H_2S were flushed from the pipe. This flushing probably caused the bass to move from the streams during January 1980. Subsequently, the effluent was diverted from the stream and the pipe flushed at full volume flow before the effluent concentration was increased in the treatment streams. No further movement of the bass due to the presence of effluent was observed. Medium size bass were restocked in the treatment streams and production continued during the spring months.

The biomass, after restocking, was slightly lower than desired because of some mortality after introduction of the restocked fish. These fish did not grow as well as control fish during the spring months even though their biomass was somewhat reduced from controls. The combination of reduced biomass and reduced growth rates of these fish when compared to controls usually indicates the productivity of the system for that species has been lowered (35, 36, 37). Figure 18 shows the production-biomass relationship of bass during this study year. As mentioned in the methods section, the 2 curves in the upper portion of Figure 18 represent different levels of productivity of the streams for largemouth bass during the 1979 to 1980 study year. As referred to earlier, prior to spring months no difference in the production-biomass relationship due to the presence of effluent is noticeable (points 8, 9, 10, 11, 12, 1, 2 and 3). However, during the months of April, May and June, the production-biomass relationships of bass in the two control streams are at a higher level than those of the bass in the two streams receiving effluent (points 4, and 5, 6). This relationship indicates the level of productivity of the control streams for bass was slightly greater than that of the treatment streams during the late spring and early summer 1980 (35). As discussed later in this section, this increased level of productivity of the control streams for bass over the treatment streams during spring months may fit an emerging pattern. However, in this case, the lowered productivity may not have been caused by the presence of effluent, since other factors were involved. The introduction of unacclimated fish to the stream system may have reduced their ability to utilize that system when compared to control fish. More important, however, when these fish were sampled at the end of the study year for histopathological examination, they were heavily parasitied by trematodes in many internal organs. It appears that these parasites were present in the fish when they arrived which affected their overall health and growth. These factors probably resulted in reduced bass growth and production during the spring in the treatment streams during the 1979 to 1980 study year. The total bass production for the year was not as great in either treatment stream as in control streams due to the lowered late spring production.

During the 1980 to 1981 year, when a mean of 2.1 mg/l of BOD and 12.5 percent by volume entered treatment streams. The largemouth bass production and biomass were approximately equal in all streams during the fall and early spring months, but the total cumulative production was greater in both of the control streams because of increased production during the final 3 months in those streams.

The production and biomass of bass in streams 1 and 2 were lower than that of bass in streams 3 and 4 during the summer and fall months of the 1981 to 1982 study year. Streams 2 and 4 received additions of 2.5 mg/l BOD (15% by volume) of SBKME during this study year. Following some winter loss of biomass from all streams, the production of bass during late spring and summer months was greater in both control streams than in treatment streams and the total production of bass for the study year was much greater in control stream 3 than the other three streams. The production of bass in control stream 1 although less was nearly equal that of treatment stream 4. The total biomass of bass in the control streams was much greater than in treatment streams, but as mentioned earlier, some bass and bluegill sunfish mortality occurred in all streams during June when water was intermittently pumped to the streams for 2 days. Bass losses from treatment stream 2 were particularly great during that time. As in the previous two years, the production of bass during the late spring months was greater in the control streams than treatment streams.

In order to further illustrate the difference in the productivity of the streams for bass and separate productivity changes from biomass losses, production rate - mean biomass and growth rate - mean biomass relationships are shown for each study year on Figures 15 through 20. Figures 15, 16 and 17 show that during the first three study years when mean levels of 0.4, 1.0 and 1.4 mg/l of BOD of SBKME were added to the treatment streams (4, 7, and 11 percent by volume), the productivity of the control and treatment streams for bass were not noticeably different and no consistant trends developed at these concentrations. Individual streams may have had higher productivity for bass during a few months of one study year such as stream 1 during the fall of 1975 (Figure 15) or streams 1 and 2 during the fall of 1976, but such changes produced no consistent trends and overall the productivity of control and treatment streams for bass were similar. Growth rate - mean biomass curves also demonstrated that the productivity of the control and treatment streams for bass were not noticeably different and no consistent trend was evident.

The 1978 to 1979 study year is difficult to evaluate due to the low bass biomass in treatment streams during the spring months. However, during each of the latter three study years, when BOD additions of 1.7, 2.1 and 2.5 mg/l entered the treatment streams (9, 12.5 and 15 percent by volume), the productivity of control and treatment streams for bass was approximately equal during fall and winter months (Figures 18, 19 and 20, points 8, 9, 10, 11, 12, 1, 2 and 3). During each spring or early summer of these study years, the productivity of the control streams for bass was greater than that of the treatment streams (Figures 18, 19 and 20, points 4 and 5, 6). As was mentioned earlier, some of this trend may have been due to the stocking of bass during the winter of 1980 or high biomass losses due to intermittent water flow during the spring of 1982, but some effect of the effluent may also cause some of this change in productivity.

Differences in bass production between individual streams make a judgment as to the exact concentration of pulp mill effluent that affects the production of bass difficult to ascertain. However, differences in the production or biomass of this species between streams at mean effluent concentrations up to

FIGURE 15 RELATIONSHIP OF LARGEMOUTH BASS MEAN BIOMASS TO THE PRODUCTION RATE (UPPER FIGURE) OR GROWTH RATE (LOWER FIGURE) DURING THE 1975 TO 1976 STUDY YEAR. STREAMS 2 AND 4 RECEIVED 0.4 MG/L OF BOD OF SBKME.

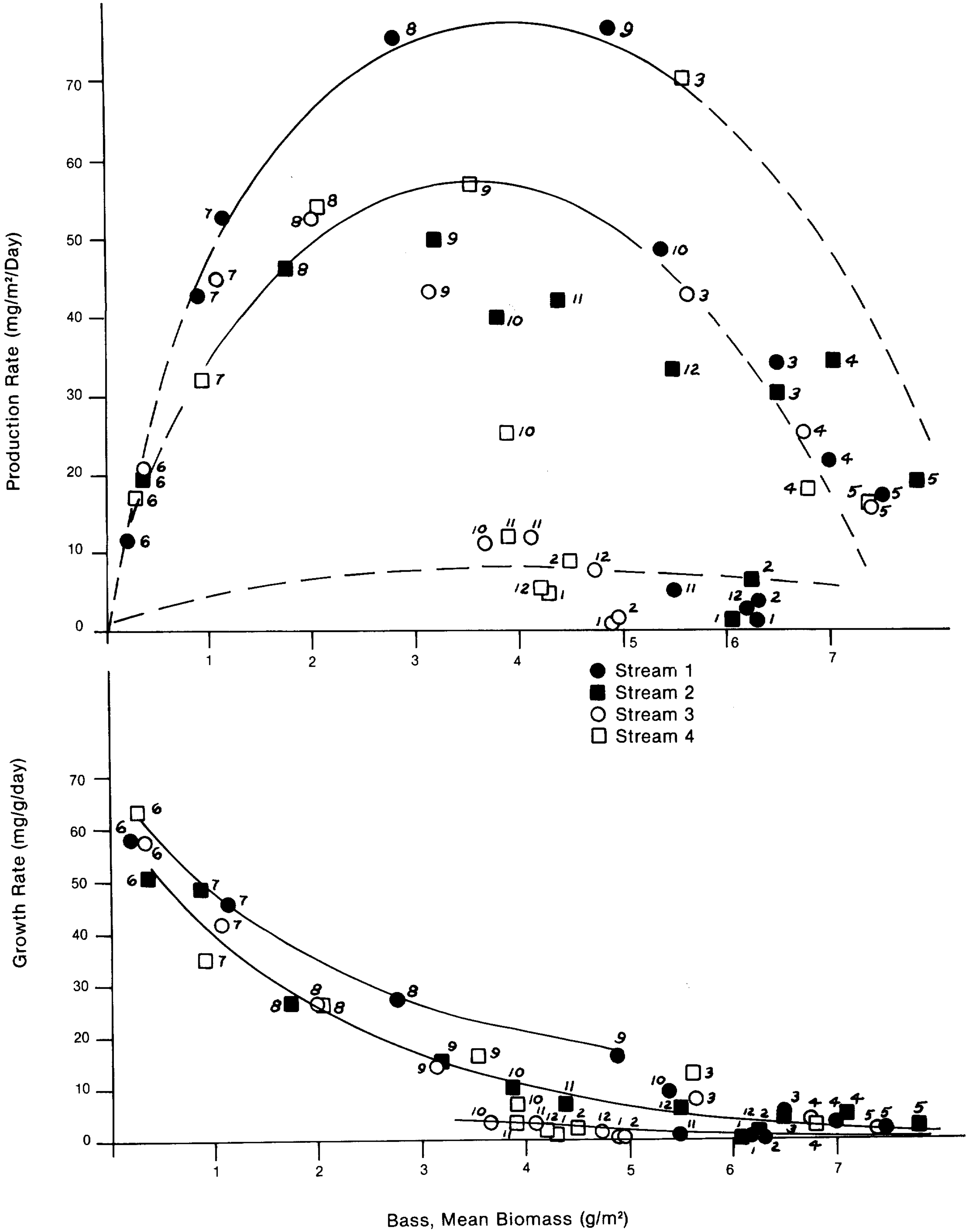


FIGURE 16 RELATIONSHIP OF LARGEMOUTH BASS MEAN BIOMASS TO THE PRODUCTION RATE (UPPER FIGURE) OR GROWTH RATE (LOWER FIGURE) DURING THE 1976 TO 1977 STUDY YEAR. STREAMS 2 AND 4 RECEIVED 1.0 MG/L OF BOD OF SBKME.

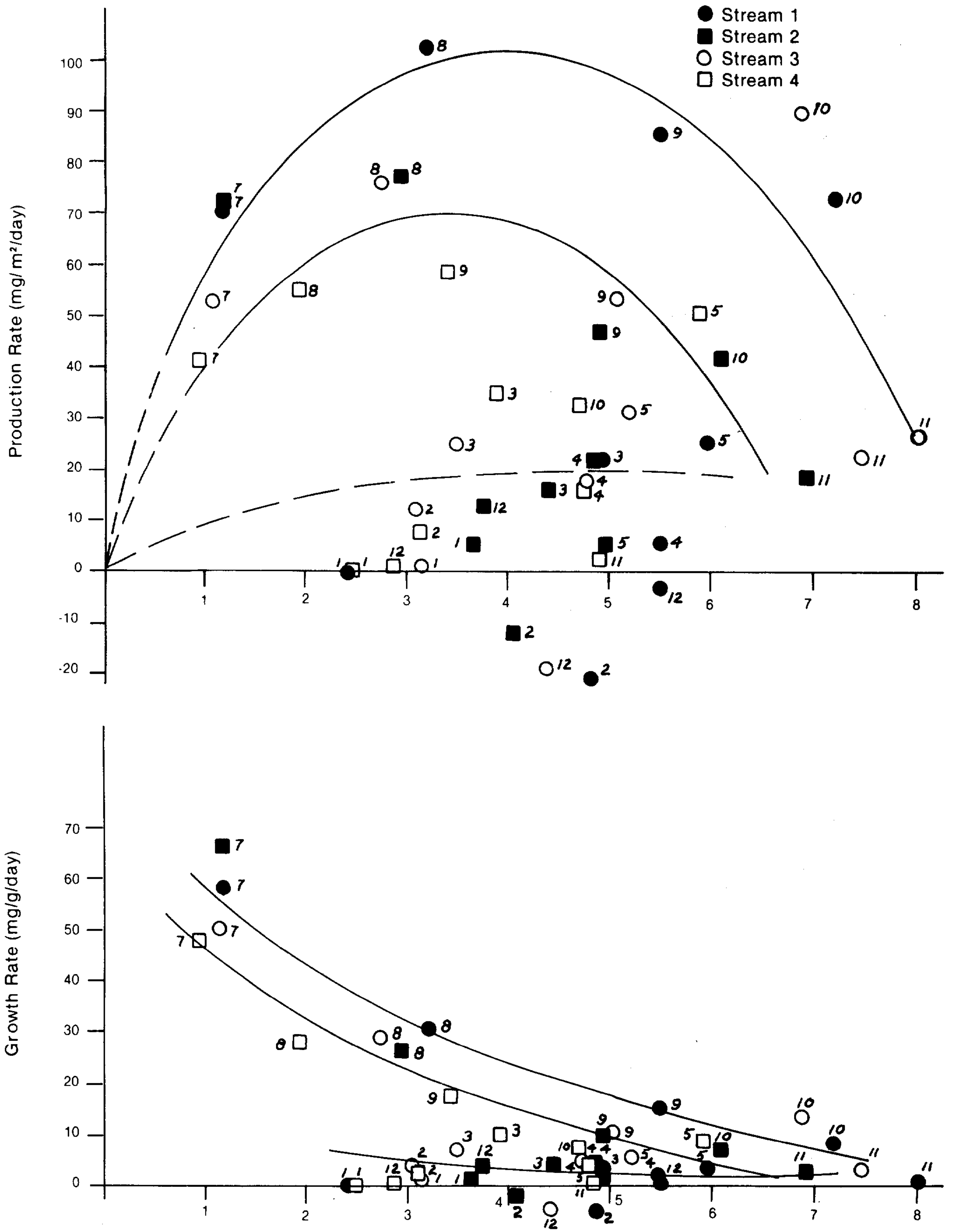


FIGURE 17 RELATIONSHIP OF LARGEMOUTH BASS MEAN BIOMASS TO THE PRODUCTION RATE (UPPER FIGURE) OR GROWTH RATE (LOWER FIGURE) DURING THE 1977 TO 1978 STUDY YEAR. STREAMS 2 AND 4 RECEIVED 1.4 MG/L OF BOD OF SBKME.

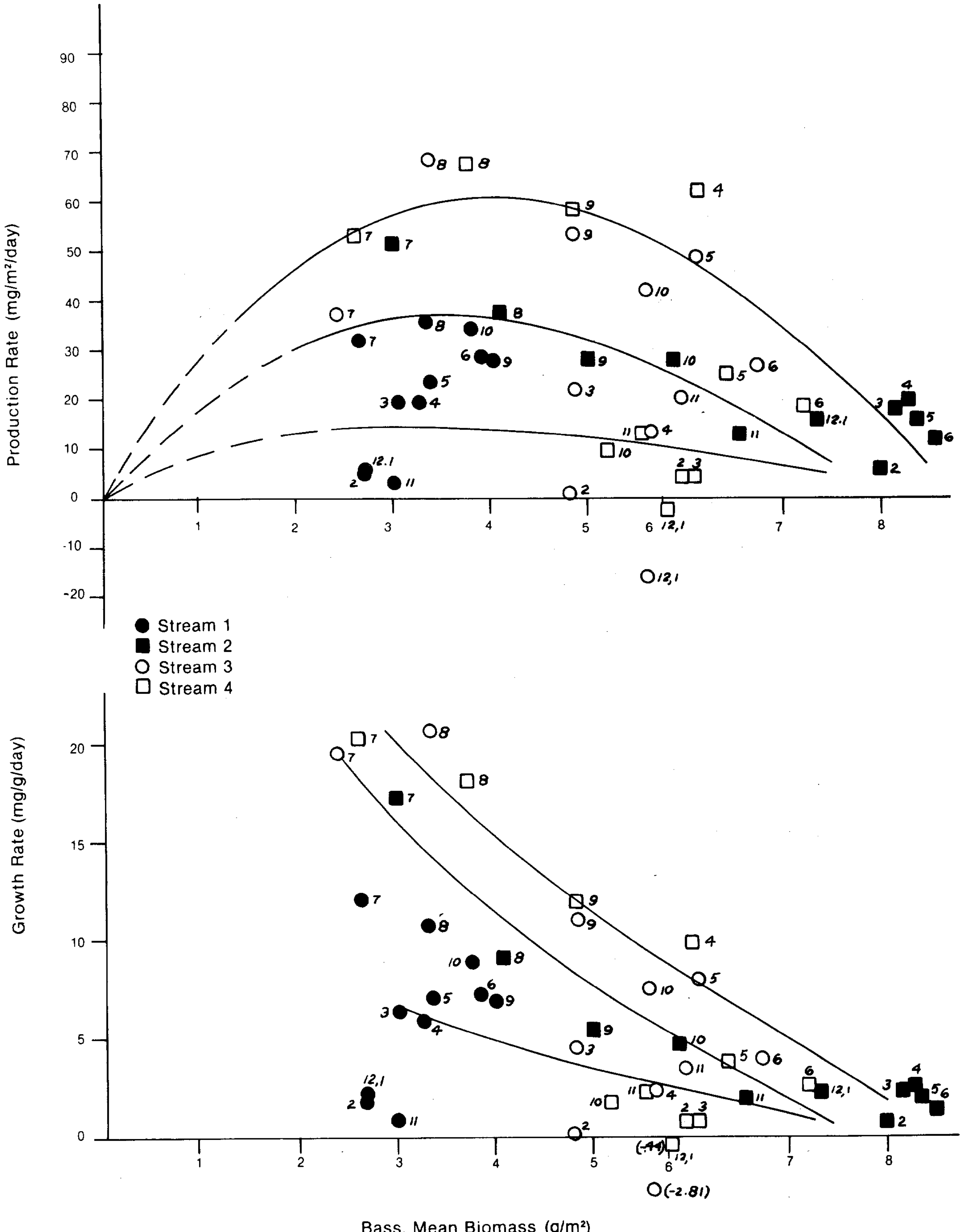


FIGURE 18 RELATIONSHIP OF LARGEMOUTH BASS MEAN BIOMASS TO THE PRODUCTION RATE (UPPER FIGURE) OR GROWTH RATE (LOWER FIGURE) DURING THE 1979 TO 1980 STUDY YEAR. STREAMS 2 AND 4 RECEIVED 1.7 MG/L OF BOD OF SBKME.

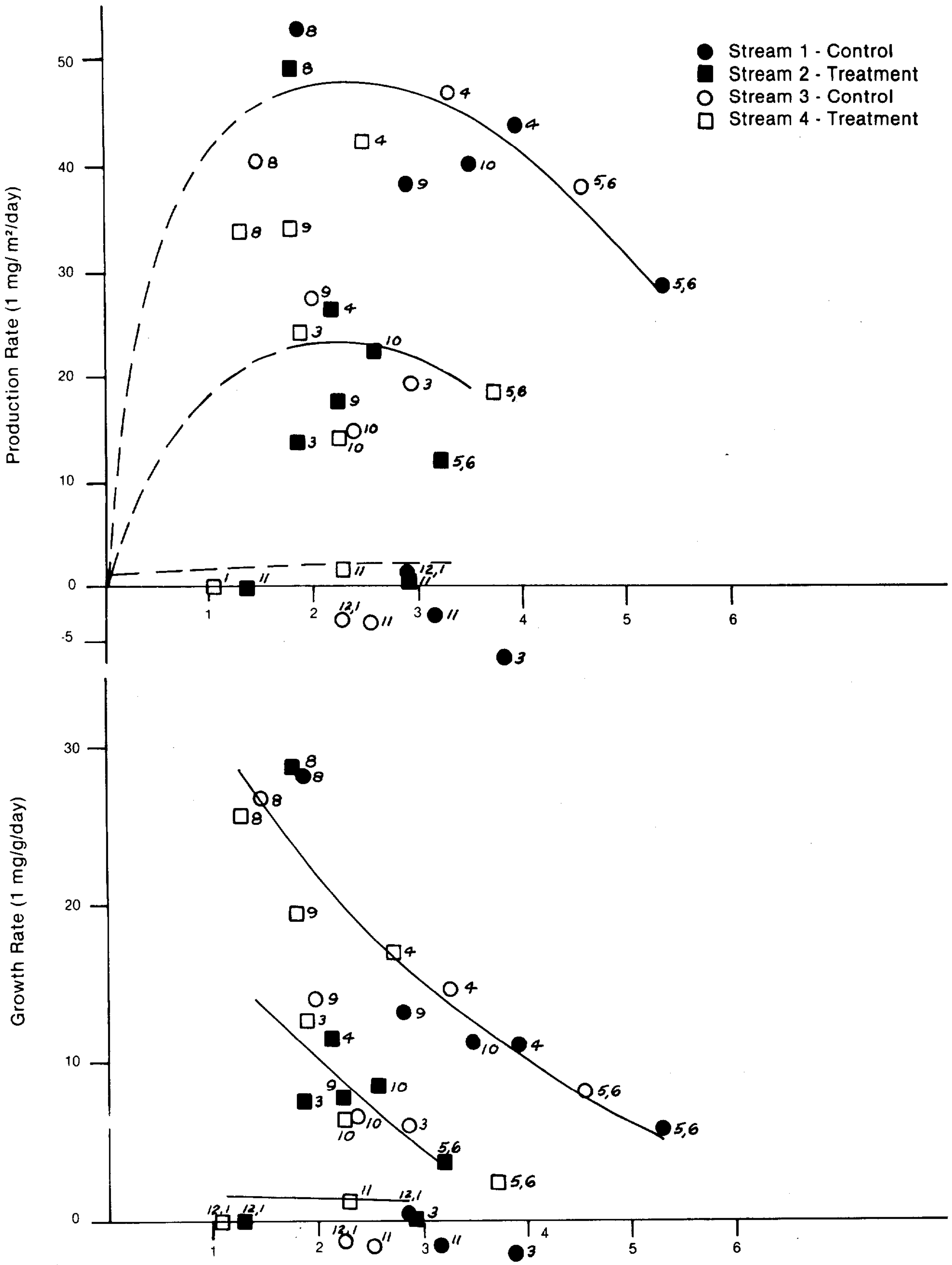


FIGURE 19 RELATIONSHIP OF LARGEMOUTH BASS MEAN BIOMASS TO THE PRODUCTION RATE (UPPER FIGURE) OR GROWTH RATE (LOWER FIGURE) DURING THE 1980 TO 1981 STUDY YEAR. STREAMS 2 AND 4 RECEIVED 2.1 MG/L OF BOD OF SBKME.

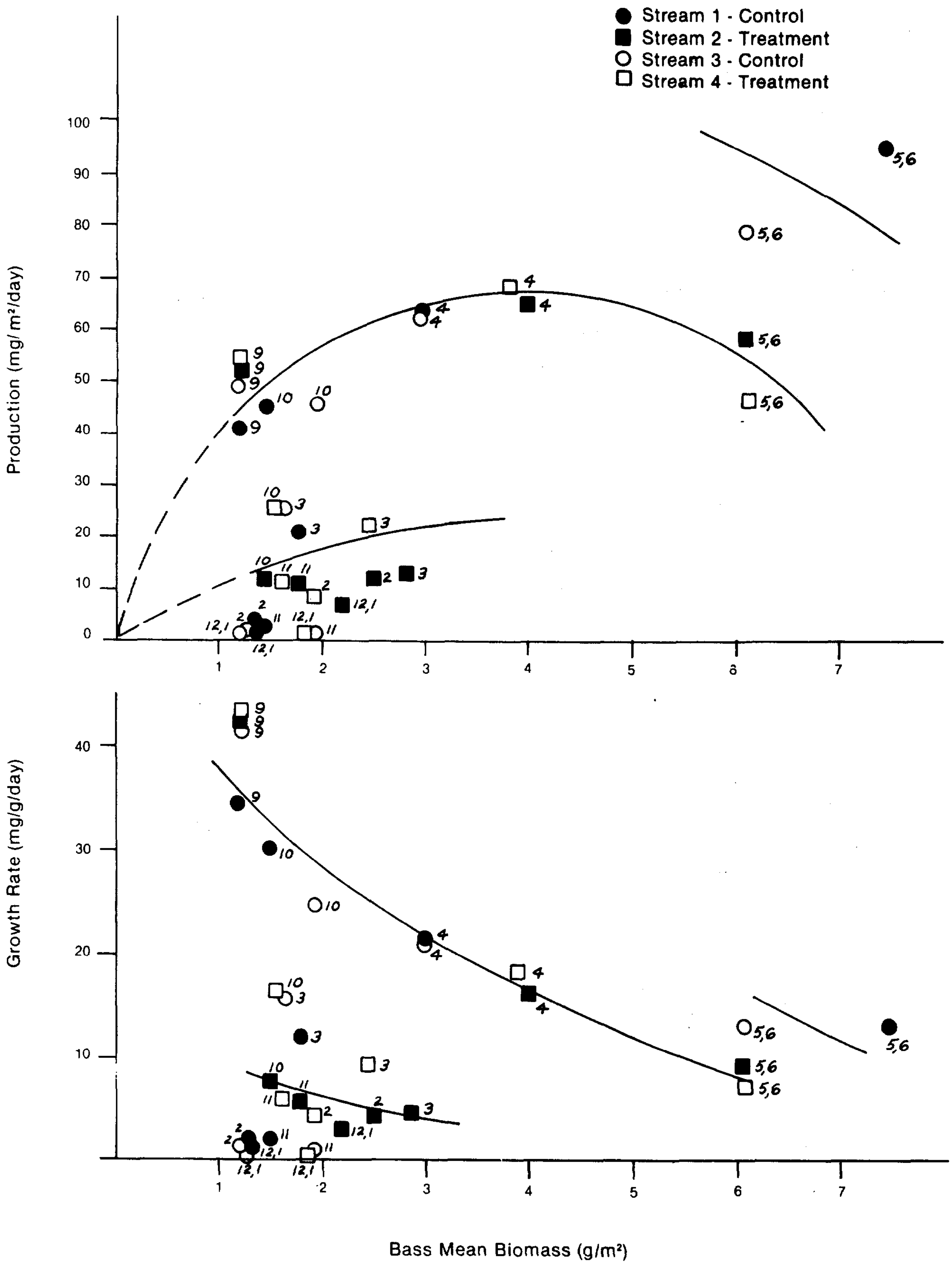
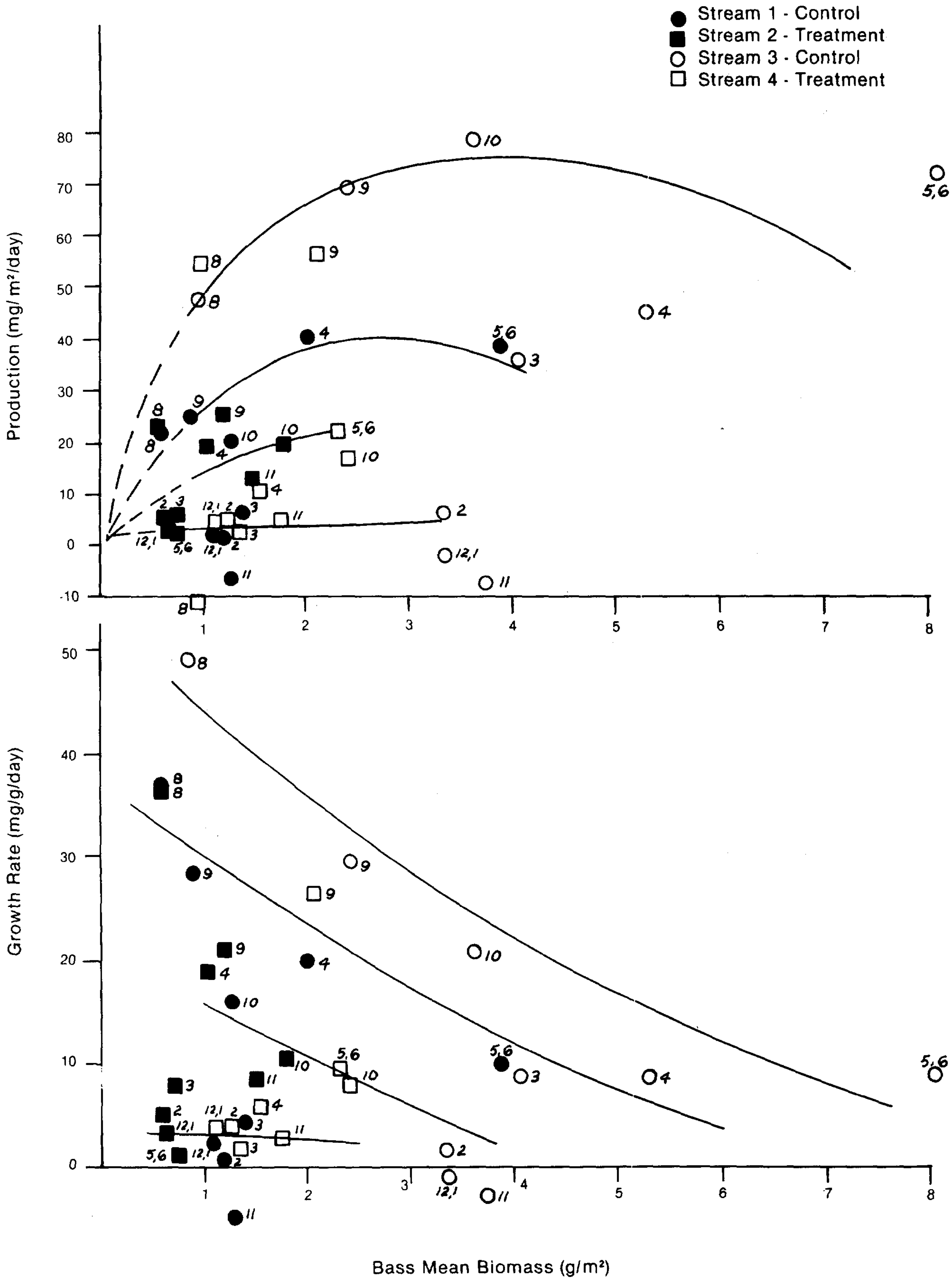


FIGURE 20 RELATIONSHIP OF LARGEMOUTH BASS MEAN BIOMASS TO THE PRODUCTION RATE (UPPER FIGURE) OR GROWTH RATE (LOWER FIGURE) DURING THE 1981 TO 1982 STUDY YEAR. STREAMS 2 AND 4 RECEIVED 2.5 MG/L OF BOD OF SBKME.



1.4 mg/l of BOD (mean of 11.5% by volume) appear to be due to stream or species variability which, although the causes are unknown, do not appear to be a result of the presence of pulp mill effluent. At concentrations of 1.6 and 1.7 mg/l of BOD added, the biomass and production of the bass have usually been approximately equal between treatment and control streams during the late summer and fall months. Winter losses of bass at the two test conditions when heavy winter losses occurred resulted in a situation where it was impossible to judge the effect of the effluent on the productivity of the stream for this species. During the 1980 to 1981 and 1981 to 1982 study years where 2.1 and 2.5 ppm BOD were added (12.5 and 15% by volume), the fall production and biomass of bass was similar in control and treatment streams but the production, biomass and growth of bass was greater in control than treatment streams during the late spring and summer months. Three study years are pertinent with regard to the productivity of the streams for bass during the late spring and early summer months. These are the 1977 to 1978 study year when 1.4 ppm BOD and 11.5% was added with no effect on the stream productivity for bass, and the study years 1980 to 1981 and 1981 to 1982 when BOD additions of 2.1 and 2.5 ppm (12.5 and 15% by volume) when some limiting capability of the treatment streams for bass production during the late spring and early summer months was observed.

Bass are sight feeders and it is possible that as the bass grow and shift from small food items taken frequently to larger food items such as fish or crayfish, the additions of color of 250 true color units or more affect their ability to find prey organisms. Although the amounts of macrophytes such as Elodea were not measured, they were present only near the sides of the pools in treatment streams during the latter 3 years of these studies and not as far toward the center of the pools as in control streams. Crayfish use such macrophytes as food and shelter and this may have influenced their abundance. Crayfish are an important food for bass and this may affect their production. These possible explanations are offered only as points of discussion, and are at least speculative even though they are based on observations made by personnel viewing the streams on a daily basis.

3. Bluegill Sunfish Production and Biomass - The cumulative production and final biomass of bluegill sunfish during the seven years reported here are shown on Figures 21 and 22. Similar to the largemouth bass, the variability between streams in any one year was greater than the variability of the total fish production. Also, similar to the largemouth bass, both biomass and production increased rapidly during the summer and fall months and leveled off during the winter. The production of

FIGURE 21 CUMULATIVE PRODUCTION OF BLUE GILL SUNFISH DURING EACH STUDY YEAR. STREAMS 2 AND 4 RECEIVED STABILIZED BLEACHED KRAFT MILL EFFLUENT.

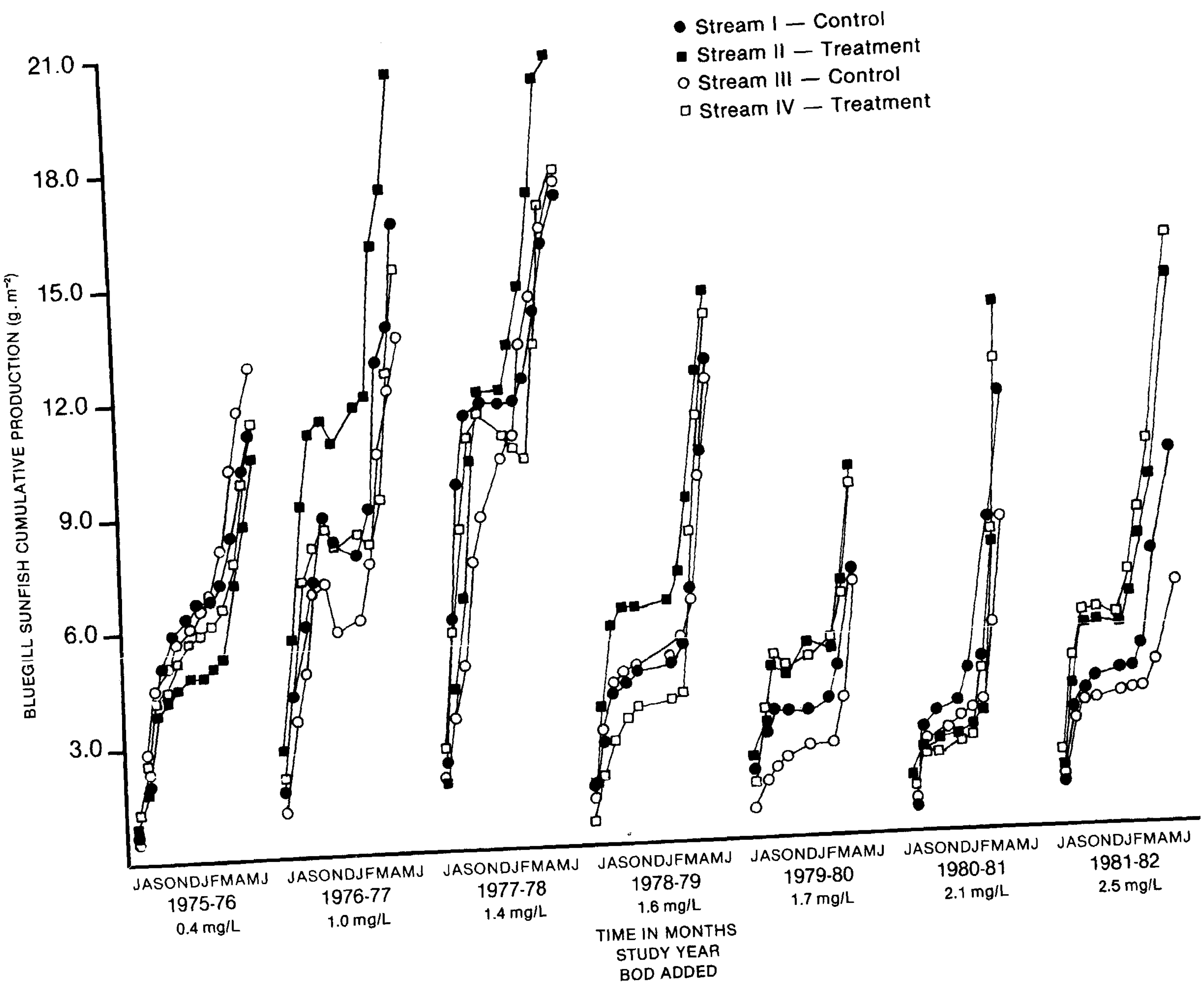
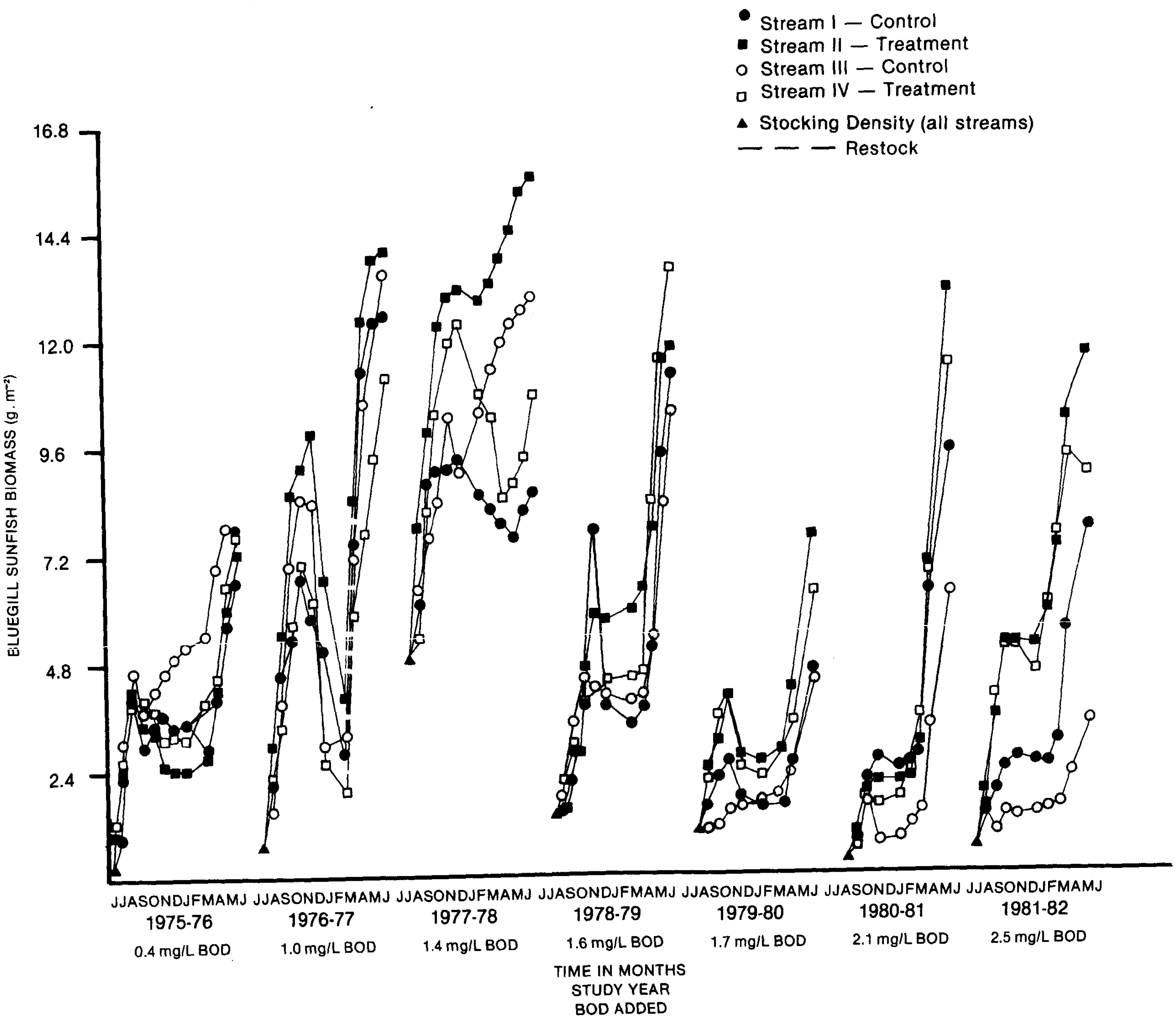


FIGURE 22 CUMULATIVE BIOMASS OF BLUEGILL SUNFISH DURING EACH STUDY YEAR. STREAMS 2 AND 4 RECEIVED STABILIZED BLEACHED KRAFT MILL EFFLUENT



bluegills tended to be the greatest during spring and early summer, and their biomass continued to increase, indicating that the carrying capacity of the streams for bluegills had not yet been reached. The greatest yearly production of nearly 21 g/m^2 occurred in treatment stream 2 during the 1977 to 1978 and 1978 to 1979 production years (Figure 22). The lowest totals of approximately 6 g/m^2 occurred in the two control streams during the 1979 to 1980 production year and in control stream 3 during the 1981 to 1982 production year. Generally, the total cumulative production of bluegill sunfish in each stream ranged from 9 to 19 g/m^2. The bluegill sunfish biomasses (Figure 22) showed peaks and lows similar to the production values and most final biomasses were between 7 and 13 g/m^2. The production of bluegill sunfish in the experimental streams falls within the wide range of values summarized by Carlander for bluegill sunfish raised in ponds or lakes in several areas of the United States (40). The range in those studies was from 1 g/m^2 to 33 g/m^2 and standing crops ranged from 1 to over 75 g/m^2. The biomass of all sunfish species in studies of North Carolina streams were also within this range and most standing crops of sunfish were found to be less than 10 g/m^2 (41, 42, 43, 44, 45).

Although some variabilty existed between streams, the production and biomass of bluegill sunfish did not appear to differ between control and treatment streams during the first two years of the controlled streams studies when mean concentrations of 0.4 and 1.0 mg/l BOD of SBKME (4 and 7 percent by volume) entered the two treatment streams. The production and biomass of bluegill sunfish in the 2 treatment streams was greater than the production of bluegills in the control streams during the 1977 to 1978, 1978 to 1979, 1979 to 1980, 1980 to 1981 and 1981 to 1982 years when mean effluent concentrations of 1.4, 1.6, 1.7, 2.1 and 2.5 mg/l of BOD were added to the treatment streams, and the mean by volume concentration ranged from 9 to 15.0 percent with concentrations up to 20 percent entering the treatment streams during the final two years. Production - biomass and growth rate biomass curves for the 1975 to 1976 and 1976 to 1977 study years also indicate that the productivity of the four streams for bluegill sunfish show no emerging pattern consistent with the presence of effluent (Figures 23 and 24). Also, the productivity of one of the treatment streams for bluegill sunfish may have been greater during the early spring months of the 1978 to 1979 production year, but a general emerging trend of changing stream productivity due to the presence of effluent could not be detected. This was the case despite the greater production of bluegill sunfish in the 2 treatment streams over the entire study year. The productivity of the two treatment streams for bluegill sunfish was greater than that of the control streams during the spring months of 1978 to 1979. However,

FIGURE 23 RELATIONSHIP OF BLUEGILL SUNFISH MEAN BIOMASS TO THE PRODUCTION RATE (UPPER FIGURE) OR GROWTH RATE (LOWER FIGURE) DURING THE 1975 TO 1976 STUDY YEAR. STREAMS 2 AND 4 RECEIVED 0.4 MG/L OF BOD OF SBKME.

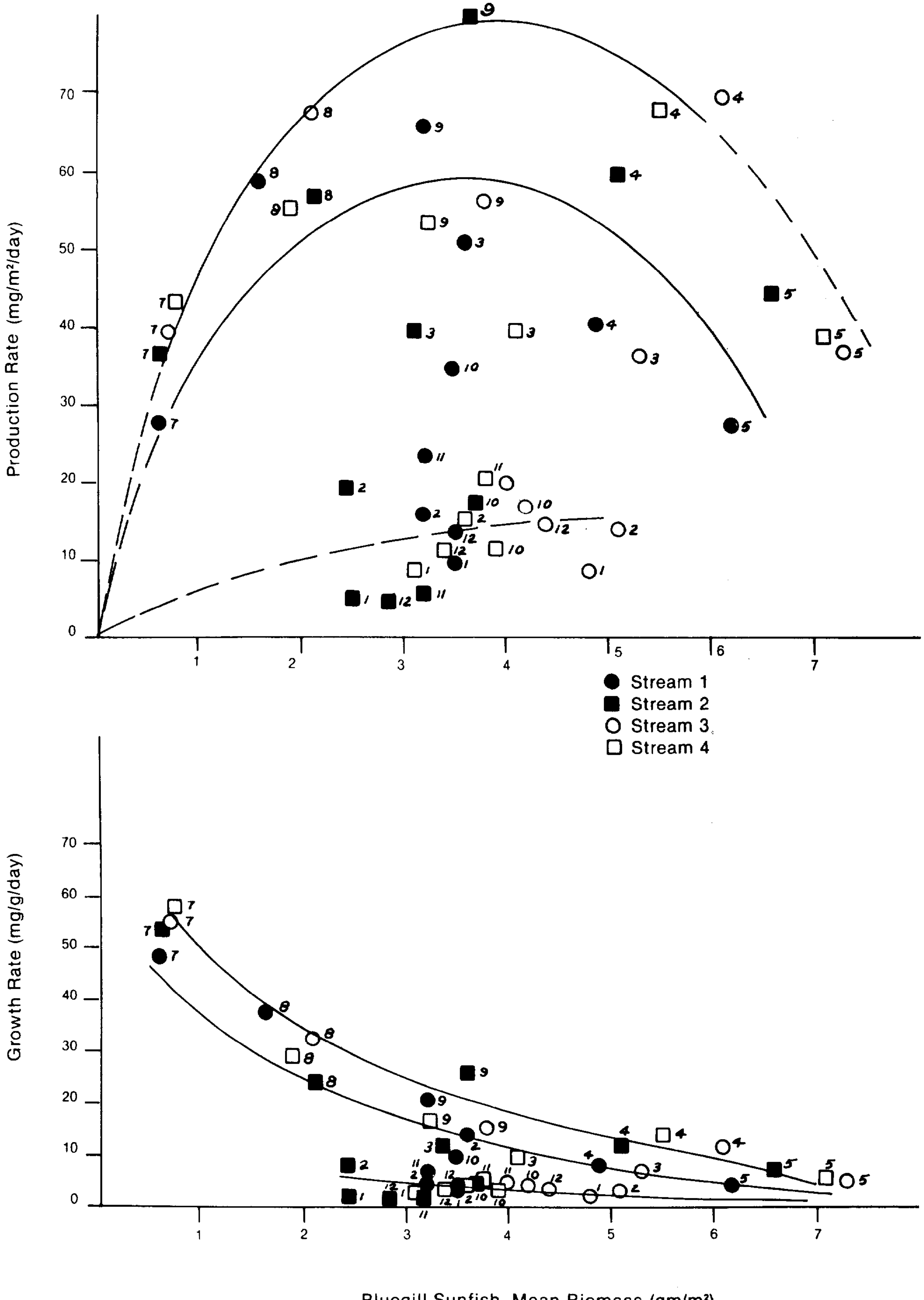


FIGURE 24 RELATIONSHIP OF BLUEGILL SUNFISH MEAN BIOMASS TO THE PRODUCTION RATE (UPPER FIGURE) OR GROWTH RATE (LOWER FIGURE) DURING THE 1976 TO 1977 STUDY YEAR. STREAMS 2 AND 4 RECEIVED 1.0 MG/L OF BOD OF SBKME.

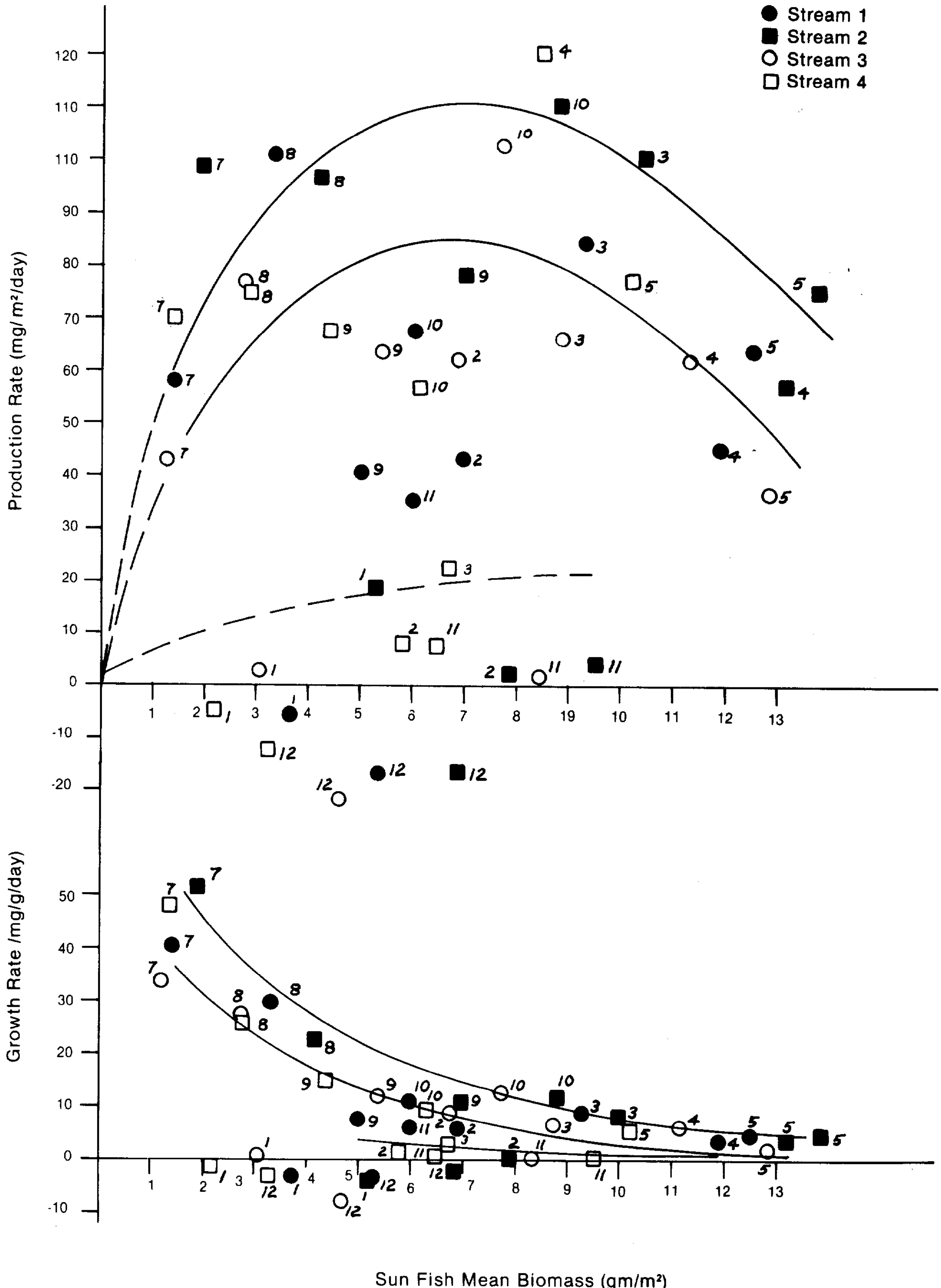
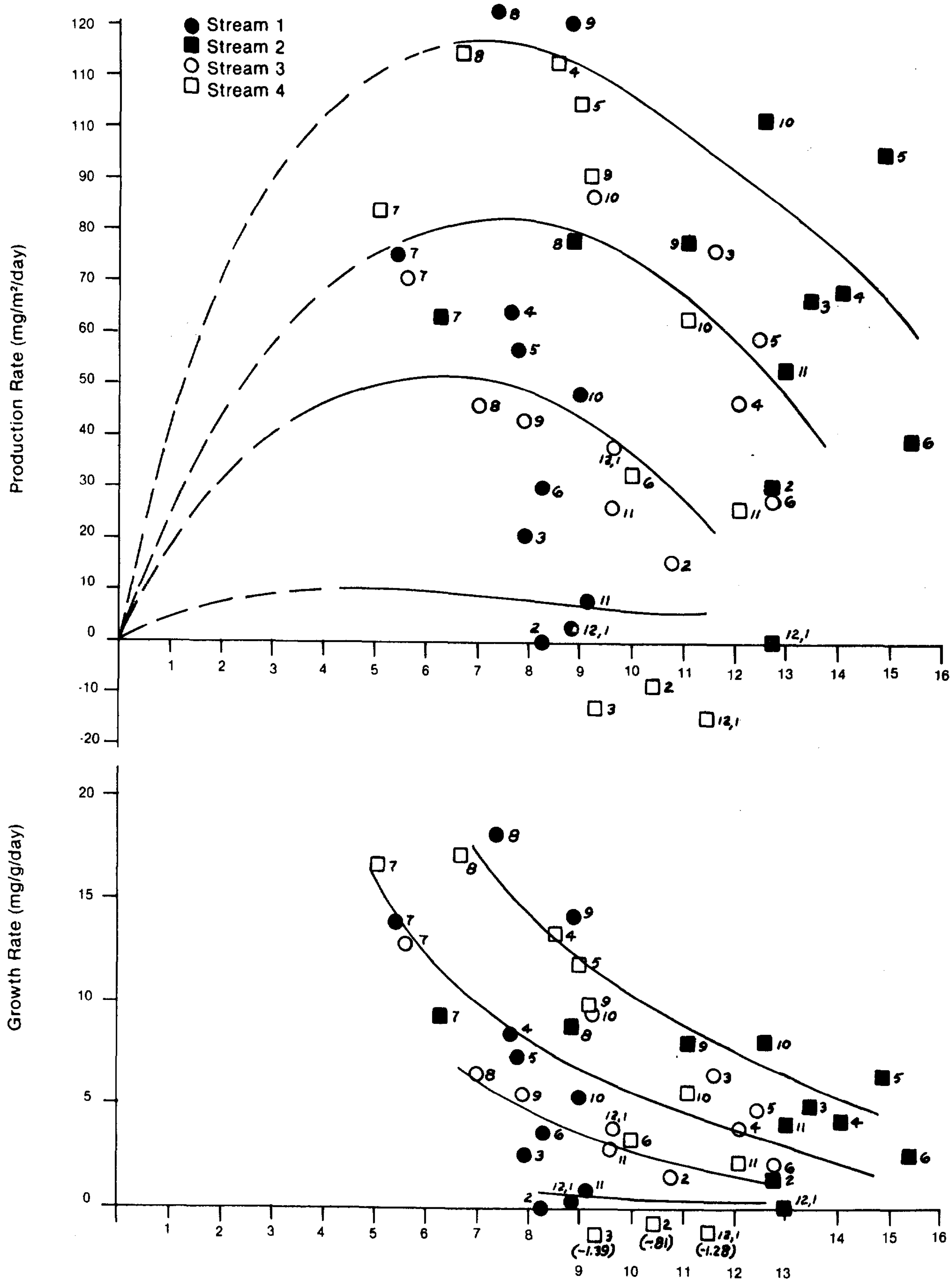


FIGURE 25 RELATIONSHIP OF BLUEGILL SUNFISH MEAN BIOMASS TO THE PRODUCTION RATE (UPPER FIGURE) OR GROWTH RATE (LOWER FIGURE) DURING THE 1977 TO 1978 STUDY YEAR. STREAMS 2 AND 4 RECEIVED 1.4 MG/L OF BOD OF SBKME.



since bass losses made the effect of the presence of effluent difficult to evaluate during this study year, such an analysis has not been included here. The productivity of the treatment streams for bluegill sunfish was particularly high during the late spring months or early summer months of 1980, 1981 and 1982 (Figures 26, 27 and 28, points 4 and 5, 6). Growth rates also indicated that productivity of the streams receiving effluent was greater for bluegill sunfish during the spring months of the latter four years of these studies, while during the first two years the productivity of the streams for bluegill sunfish did not appear to be affected by the presence of effluent. There appeared to be a general trend of increased production of the bluegill sunfish in the treatment streams when compared to control streams at mean effluent concentrations near 1.5 mg/l of BOD to 2.5 mg/l. During the 1978 to 1979 study year, increased bluegill sunfish production may have been influenced by the low biomass of largemouth bass since the larger bass may be sunfish predators and small bass may be competitors for food of the bluegill sunfish. Also, the generally lower production and biomass of juvenile largemouth bass during the spring of 1979 to 1980, 1980 to 1981 and 1981 to 1982 in the treatment streams may have had the same effect. The general trend of greater numbers of amphipods, isopods, and total benthic organisms in the treatment streams during the latter 5 years of the studies may also have caused an increased food supply to be present. As shown earlier on Table 10, amphipods were a major food item for bluegill sunfish in the experimental streams. If food availability were the cause of difference in bluegill production, a detectable increase of organisms in treatment streams during late spring or early summer months could be expected. This occurred only during July of 1982, and during other years any differences in macroinvertebrate populations between control and treatment streams were not consistent. Either reduced competition from largemouth bass or increased food supplies may have influenced the greater production of bluegill sunfish in the treatment streams during the last 5 years of these studies.

4. Golden Shiner Production and Biomass - The trend of golden shiner production was similar to the bluegill sunfish and largemouth bass, although the production during spring months tended to be less than that of the bass or sunfish (Figure 29). During the first 5 study years, the biomass of golden shiners tended to follow an entirely different pattern from the sunfish or bass in that the biomass usually increased rapidly during the summer and fall months as the fish grew and then declined during the spring and early summer months (Figure 30). During the 1980 to 1981 year, when stocking of larger golden shiners occurred later in the year than during previous years, almost no increase of golden shiner biomass was evident and the biomass generally declined after stocking. Both the biomass and production of

FIGURE 26 RELATIONSHIP OF BLUEGILL SUNFISH MEAN BIOMASS TO THE PRODUCTION RATE (UPPER FIGURE) OR GROWTH RATE (LOWER FIGURE) DURING THE 1979 TO 1980 STUDY YEAR. STREAMS 2 AND 4 RECEIVED 1.7 MG/L OF BOD OF SBKME.

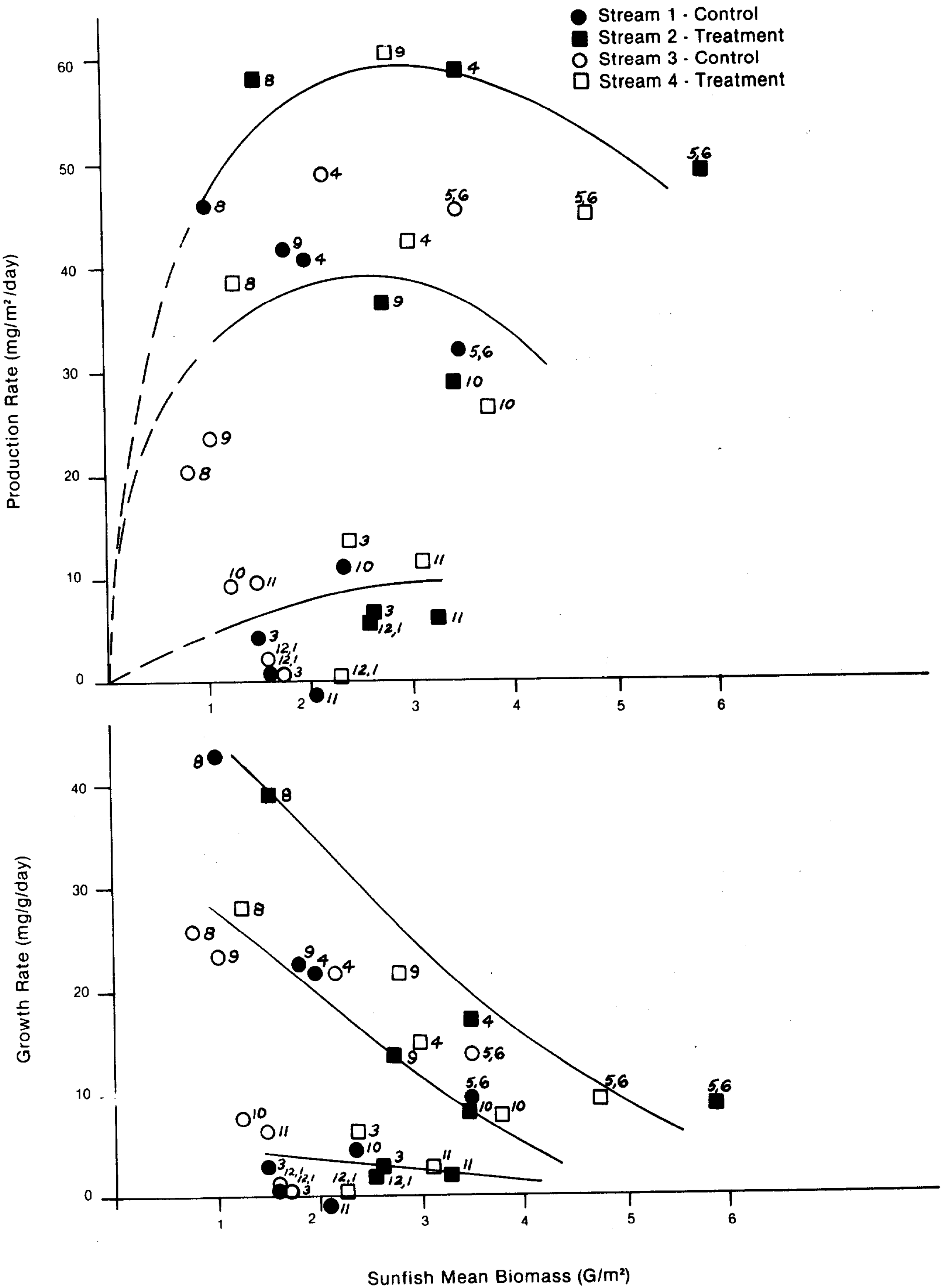


FIGURE 27 RELATIONSHIP OF BLUEGILL SUNFISH MEAN BIOMASS TO THE PRODUCTION RATE (UPPER FIGURE) OR GROWTH RATE (LOWER FIGURE) DURING THE 1980 TO 1981 STUDY YEAR. STREAMS 2 AND 4 RECEIVED 2.1 MG/L OF BOD OF SBKME.

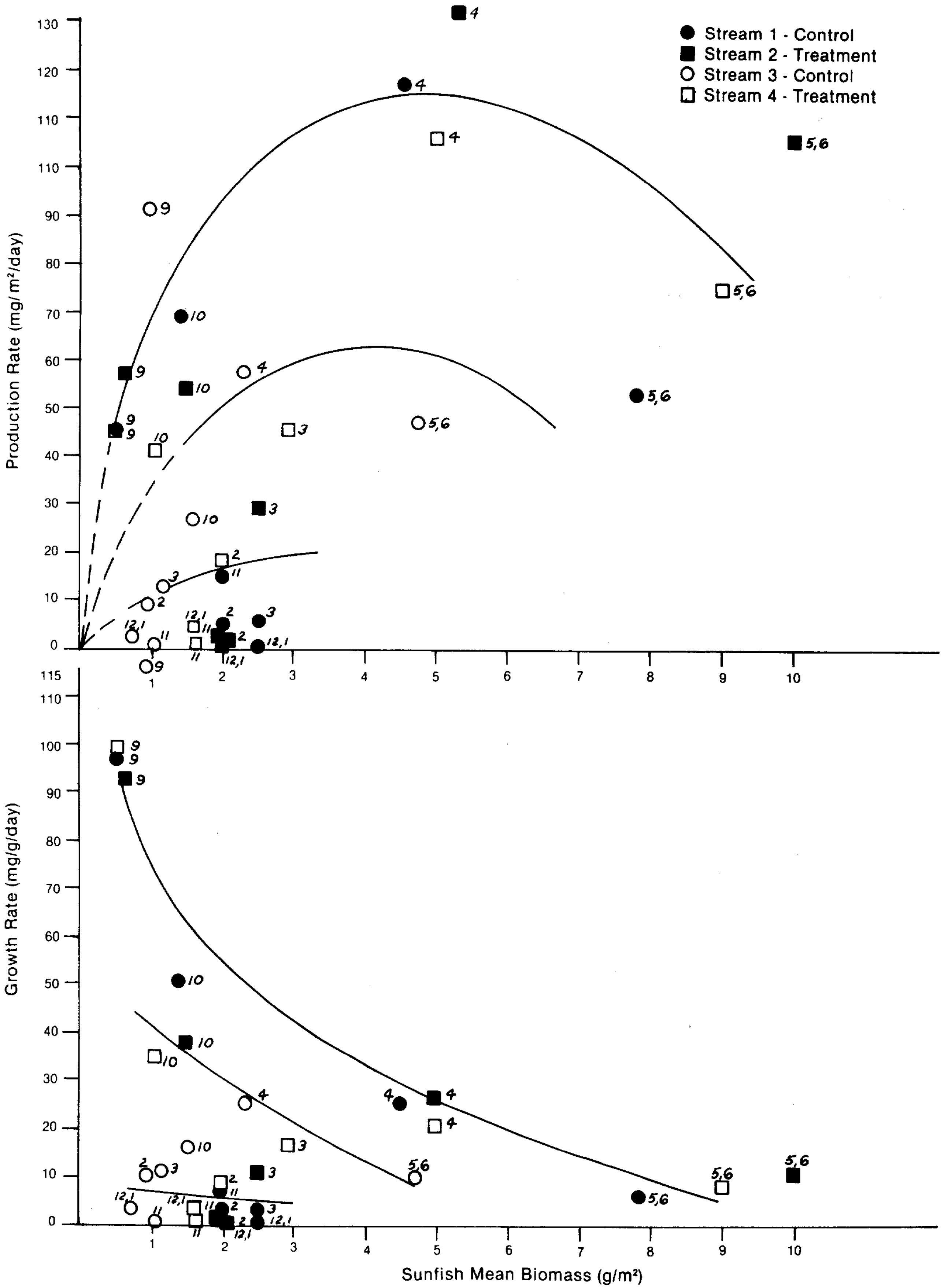


FIGURE 28 RELATIONSHIP OF BLUEGILL SUNFISH MEAN BIOMASS TO THE PRODUCTION RATE (UPPER FIGURE) OR GROWTH RATE (LOWER FIGURE) DURING THE 1981 TO 1982 STUDY YEAR. STREAMS 2 AND 4 RECEIVED 2.5 MG/L OF BOD OF SBKME.

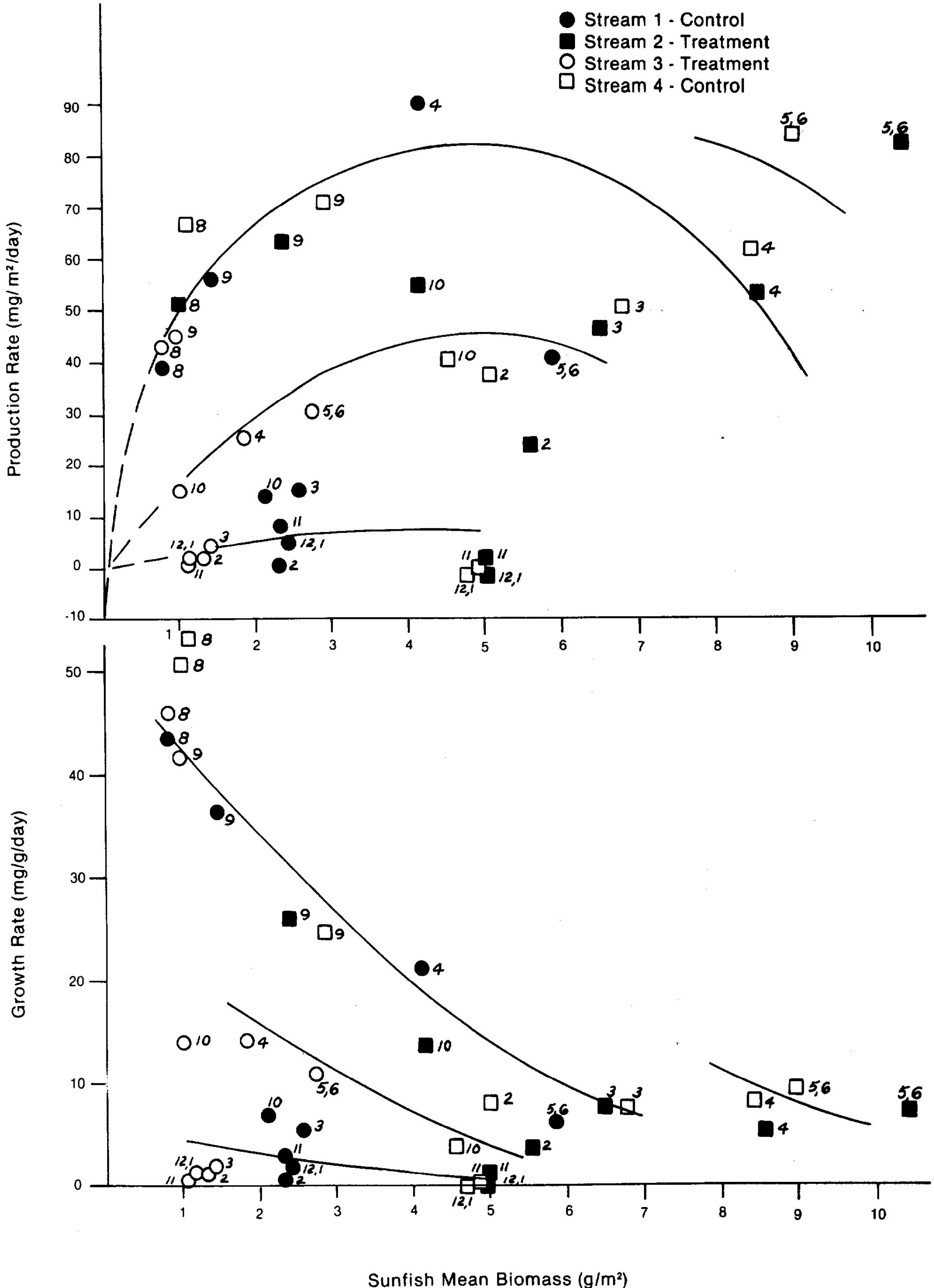


FIGURE 29 CUMULATIVE PRODUCTION OF GOLDEN SHINERS DURING EACH STUDY YEAR. STREAMS 2 AND 4 RECEIVED STABILIZED BLEACHED KRAFT MILL EFFLUENT.

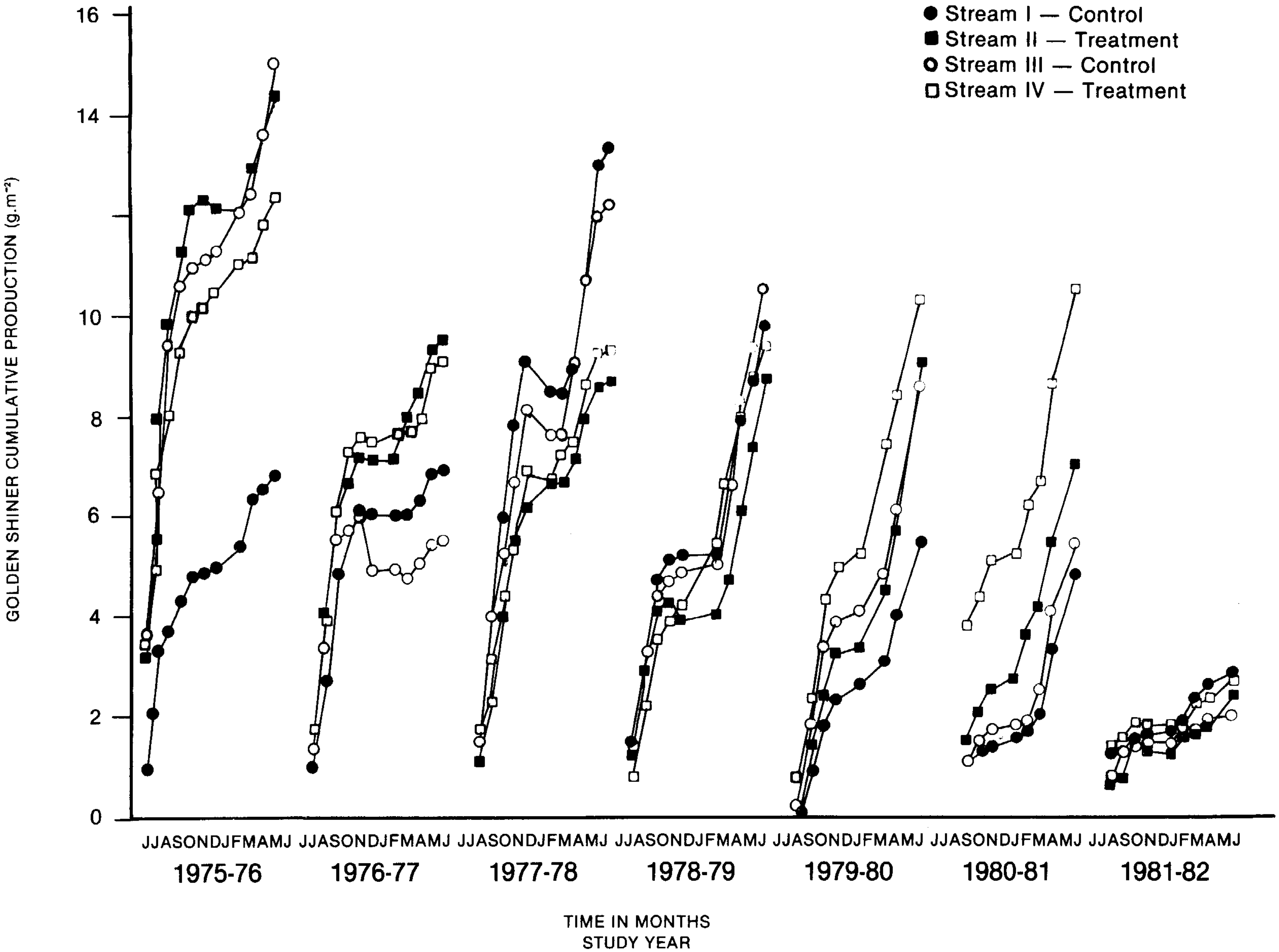
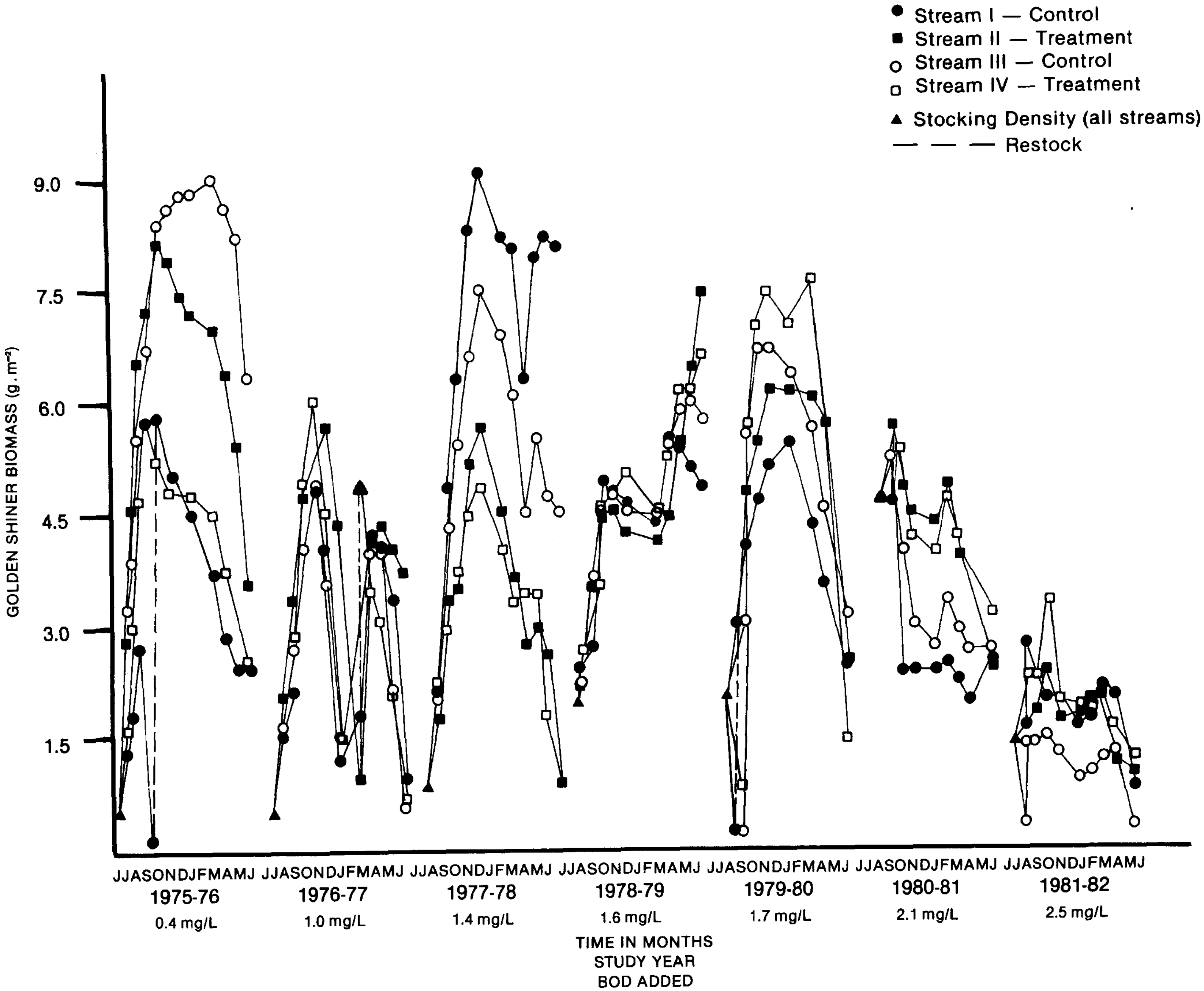


FIGURE 30 CUMULATIVE BIOMASS OF GOLDEN SHINERS DURING EACH STUDY YEAR. STREAMS 2 AND 4 RECEIVED STABILIZED BLEACHED KRAFT MILL EFFLUENT.



golden shiners was unusually low in all streams during the 1981 to 1982 study year. The initial stock of these fish had very high mortality in all streams and later restocking resulted in a gradual decrease in the numbers and biomass over the winter and spring months. The low biomass resulted in very low shiner production for the entire study year. Stream 3 which had the greatest biomass of bass had the lowest amount of golden shiner production and biomass for the year. The reason for the biomass decline during the spring of most years appears to be bass predation. By the late spring months, many of the bass were large enough to feed on the shiners and thus reduce their numbers. Competition from the increasing biomass of bluegill sunfish and smaller bass for food may also have affected the production of golden shiners during the spring, and thus the biomass lost due to predation was not replaced by growth. Perhaps the best evidence of the effect of predation was the increase in golden shiner biomass during the spring of 1979 in the treatment streams when the numbers of bass were very low in those streams. The lack of predation by bass appears to have allowed a greater number of shiners to survive and their growth increased the biomass of shiners in the treatment streams while the biomass of shiners was decreasing in the control streams.

Before the 1981 to 1982 study year, when the total production of golden shiners in all streams was only 3 g/m^2, the total production of golden shiners had consistently ranged from 5 to 15 g/m^2 with most values between 6 and 10 g/m^2 over the first six years of study. No particular pattern with respect to the presence of effluent has emerged through the entire study period, although the greater production of shiners in the two treatment streams during the 1979 to 1980 and 1980 to 1981 years, when mean effluent concentration were 1.7 and 2.1 mg/l BOD of SBKME, respectively, indicates a trend may have been developing as the concentration of effluent in the treatment streams increased. The low production of shiners in all streams during the 1981 to 1982 study year did not allow such a trend to develop.

During the 1975 to 1976 year, when 0.4 mg/l BOD of SBKME entered the treatment streams, the shiner production was greater in control stream 1 than the other 3 streams. During 1976 to 1977, when 1.0 mg/l of BOD entered the treatment streams, the golden shiner production was greater in both treatment streams than in the two control streams. This was reversed the following two years when 1.4 and 1.6 mg/l of BOD entered the treatment streams, and the production of golden shiners was greater in the 2 control streams during those years.

As noted earlier, during the two of the three most recent years reported here when the effluent concentrations in the treatment streams were greatest, the production of golden shiners was higher in both treatment streams than control streams.

This lack of a consistent pattern over the years of study does not allow any conclusions about the effect of the effluent on golden shiner production other than no consistent adverse affects were apparent throughout these studies.

E. Fish Reproduction in the Experimental Streams

Largemouth bass have spawned sporadically in the experimental streams during the time these studies have occurred. During the spring of 1976, when 0.4 mg/l of BOD entered treatment streams, bass spawned in control stream three and treatment stream four. The following spring, bass did not spawn in any of the streams and during the spring of 1978, a single bass spawn occurred in control stream one. During the spring of 1979, one 24" diameter pan containing pea size gravel was placed in each pool of the streams to provide a better and more readily observable spawning area for fish. Bass did not spawn in the pans, however, spawns were observed to occur on the stream bed behind the obstruction provided by the pan. During 1979, one spawn was observed in control stream three, and during 1980, bass spawned in control streams one and three. During spring of 1981, when 2.1 mg/l of BOD entered the two treatment streams, at least one spawn occurred in control stream three and one occurred in treatment stream four based on the observed presence of juvenile bass. Bass spawned only in control stream 3 during the spring of 1982, and at least 3 spawns occurred in that stream. Spawning beds were difficult to see in the streams receiving effluent at the highest concentrations tested due to the color and only the observed presence of juvenile bass assured that spawning had taken place. The infrequent and sporadic nature of the bass spawning is probably due to the size and age of these fish. Infrequently, first year bass are known to spawn in the southern area of the United States, if they have grown to sufficient size (43). Pardue has discussed the variability of growth of largemouth bass in three North Carolina ponds and has pointed out that a few fish may reach sexual maturity at the end of one year but most will not (44).

Bluegill sunfish spawned in each of the four experimental streams after the first year. However, during the spring of both 1977 and 1978 when fish were removed in June, approximately 15 of the largest sunfish were allowed to remain in each stream for one month for spawning purposes.

During those two years, spawning had occurred in all four streams by July, and occurred somewhat earlier in the two control streams during the spring of 1978. Bluegill sunfish spawned in pans placed in all four streams during the spring of 1979, 1980, 1981 and 1982 when 1.6, 1.7, 2.1 and 2.5 mg/l BOD of SBKME, respectively, entered treatment streams two and four.

During 1979, seven bluegill spawns were found in the two control streams and six were found in the two treatment streams. During the spring of 1980, 1981 and 1982, 12, 15 and 17 spawns, respectively, were found in the two control streams, while 15, 18 and 29 spawns were found in the treatment streams. Bluegill sunfish mature more rapidly than bass and therefore would be expected to spawn by the end of their first year of growth (37). The spawns of both bluegill sunfish and bass when present routinely served as a partial restocking source for the subsequent study year.

Golden shiner juveniles were found in all four streams after the first year of study and thereafter spawning behavior and eggs attached to stream gravel or macrophytes were observed in each of the four streams during all years of exposure. Juvenile golden shiners were also frequently observed in all streams during each year.

The sporadic spawning of largemouth bass in all of the streams makes an evaluation of any effect of an effluent on this species difficult. However, the occurrence of at least one spawn during the spring of 1981 indicates spawning can occur at mean effluent concentrations over 2.0 mg/l BOD of SBKME added. This observation in addition to the frequent spawning of bluegill sunfish and golden shiners at mean effluent concentrations up to 2.5 mg/l indicates the reproductive success of these three fish species has not been noticeably impaired at the levels of effluent thus far tested in the experimental streams.

F. Short Term Bioassay Response

Appendix Table C1 shows the results of short term bioassay tests performed at approximately monthly intervals during the period of time from June 1975 to May 1979. Usually, all fish survived in 100% effluent for 96 hours under static conditions. One exception occurred during January 1979 when 96 hr LC_{50}'s of 50 and 33% by volume were recorded. The concentration of organic compounds measured at that time also reached concentrations higher than any detected previously. Total resin acid concentrations (Appendix Table B1) were over 11 mg/l. This appeared to be associated with soap losses within the mill after a seasonal closure for maintenance. When the concentration of total resin acids was 3 mg/l or less, mortality of fish within the effluent was not detected.

Leach (5) found that rainbow trout survived for 96 hours in all of the 13 secondary treated pulp mill effluents from the United States that he tested. He also found the 96 hr LC_{50}'s of abeitic acid and dehydroabeitic acid to be between 0.8 and 2.0 mg/l for this cold water species. The levels of individual resin acid compounds were within or below this range when fish survived in this effluent and fell outside this range during January 1979. Generally, Leach found that levels of the resin acids from 1 to 2 mg/l would be expected to cause mortality of rainbow trout during short term testing. It appears from this data that juveniles of warmwater fish may not be as sensitive to pulp mill effluents as coldwater species. During later years, the short-term tests were replaced by continuous exposure full life cycle or 30 day egg/larvae tests, and the results of those tests will be reported in an upcoming bulletin.

IV SUMMARY AND CONCLUSIONS

(1) This technical bulletin contains the findings of the first seven years of investigation which address portions of a study carried out in an experimental stream setting in the South. The subject matter covers the effect of biologically treated bleached kraft effluent on the productivity of the experimental streams for fish and benthic organisms. During the course of the study, nearly uniform exposure conditions were maintained during a one-year period. Effluent concentrations were then adjusted upward for each subsequent study year. Interpretation of the observations and findings must therefore be carried out within the framework of the occurrence of natural events. Probably most important of these events with regard to the portion of the study reported in this bulletin, should be recognition that maximum concentrations of effluent in receiving streams normally occur during the low flow months of the late summer and early fall in the South. Any seasonal aspects of the effect of effluent on stream productivity should therefore be judged within the confines of effluent concentrations likely to be present during the season of interest.

(2) The quality of the water fed the warmwater experimental streams was typically slightly acidic, highly colored, very soft, and at times, relatively turbid. The nutrients, phosphorous and nitrogen were nearly always abundant. Summer temperatures frequently reached 30°C or greater and the dissolved oxygen was at times below 4.0 mg/l. There was a nominal 5°C increase in temperature during passage through the experimental streams.

(3) Effluent additions to the streams were increased annually over the seven years of study reported in this bulletin. From 1975 through 1982, the average BOD of biologically treated bleached kraft effluent (SBKME) added to the streams increased incrementally from 0.4 to 2.5 mg/l and the percent by volume concentration increased from a mean of 4 to 15 percent. The mean total resin acid concentrations added to streams receiving

effluent ranged from a low of 5 μg/l during 1975 to 1976 to a high of 199 μg/l during 1978 to 1979. The addition of chlorinated phenolic compounds increased over the 7 years of study and mean additions ranged from approximately 8 to 30 μg/l. Mean additions of suspended solids ranged from 1 mg/l to 2.8 mg/l, and mean true color additions of 90 to 275 cu were also made to streams receiving effluent.

(4) The primary observable difference between streams receiving effluent and control streams was the presence of color. At mean true color additions of approximately 200 color units, an effect on the growth of the macrophyte *Elodea* because of light reduction was noticeable.

(5) The numerical and biomass density of macroinvertebrates was variable between streams and within streams through time, but no noticeable difference of these parameters between control and streams receiving effluent was noted until the BOD of SBKME added reached 1.4 mg/l (11 percent effluent by volume). Above this level, the number of the amphipods, isopods and total macroinvertebrates were frequently greater in the streams receiving effluent than the control streams. The biomass of these organisms did not demonstrate this trend to the extent that the numbers did. The numbers and biomass of chironomids and snails tended to be greater in control streams during one year, but greater in streams receiving effluent during other years. At the highest effluent concentrations tested of 2.5 mg/l of BOD added and 15 percent by volume, the numbers of amphipods, isopods and total macrobenthic organisms were greater in streams receiving effluent than control streams on more than 75% of the sampling dates and the biomass of macrobenthic organisms demonstrated this same trend. The number of organisms and macroinvertebrate species in the experimental streams was generally greater than the numbers reported in surveys of nearby rivers. This difference may have been influenced by the selection of sampling points in those river studies.

(6) Stomach analysis of fish sampled during the last three years of study indicated that crayfish, adult and larval dragonflies, fish, amphipods and chironomids were important food items for bass. Bluegill sunfish fed primarily on amphipods, chironomids and larval damselflies. No consistent differences in the feeding habits were noted between fish from streams receiving effluent and control streams.

(7) The total production and biomass of fish from all streams were nearly equal when 0.4, 1.0 and 1.4 mg/l (4, 7 and 11 percent by volume) of BOD of SBKME were added to treatment streams. The productivity of the streams for bass, bluegill sunfish, and golden shiners, although variable at these effluent concentrations was not found to be affected by the presence of effluent

although there was higher production of bluegill sunfish at 11% effluent added. Total production and biomass did not indicate any total yearly or seasonal effect due to the addition of effluent during this time period. During the study year that 1.6 mg/l of BOD entered the streams (10 percent by volume) winter losses of bass from streams receiving effluent made an evaluation of the productivity of the streams for fish of limited value. In subsequent years, when 1.7, 2.1 and 2.5 mg/l of BOD was added to the streams (9.0, 12 and 15 percent by volume), the total production and biomass of the three species of fish from streams receiving effluent was usually as great or greater than the total production or biomass of fish from control streams. The production and biomass of golden shiners did not demonstrate a clear continuing trend during these three latter study years although the shiner production and the productivity of the stream for shiners was greater in streams receiving effluent during the years of highest effluent additions when mean additions of 2.1 and 2.5 mg/l of BOD (12 and 15 percent by volume) occurred. Bluegill sunfish total production and biomass was greater in streams receiving effluent during the last three years when effluent concentrations were the greatest. The productivity of the streams receiving effluent for bluegill sunfish was also greater than control streams during these 3 years, particularly during the late spring months. Total yearly bass production and biomass during the last 3 years of study, when mean additions of BOD were 1.7, 2.1 and 2.5 mg/l (9.0, 12 and 15 percent by volume), was usually greater in control than in streams receiving effluent, primarily due to lower production of bass during the late spring to early summer months. The seasonal productivity of the control streams for bass was greater than that of streams receiving effluent during each spring and early summer of these three study years, but during late summer, fall and winter productivity differences due to the presence of effluent were not evident. Since stream flows during spring months are high in the South, this seasonal difference in stream productivity levels for bass is of limited importance since only a fraction of maximum effluent concentrations encountered during the low flow period occur during this season.

(8) Bluegill sunfish have spawned in the streams at all effluent concentrations tested. Bluegill sunfish and bass juveniles when spawning occurred served as a partial restocking source the subsequent study year. Numbers of bluegill spawns recorded during the spring of 1979, 1980, 1981 and 1982 indicated no noticeable trends in spawning activity between streams receiving effluent and control streams. Golden shiners were also observed spawning in the streams during all years and larval golden shiners were routinely observed in both control and treatment streams. Because of their youth, largemouth bass have reproduced only sporadically in the experimental streams. At the highest effluent

concentration tested, bass spawned in one control stream and one treatment stream. Based on these observations, the reproductive success of these three species has not been noticeably impaired at the levels of effluent thus far tested.

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APPENDIX A

PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE NEUSE RIVER WATER ENTERING FOUR EXPERIMENTAL STREAMS

TABLE A1 PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE NEUSE RIVER WATER ENTERING FOUR EXPERIMENTAL STREAMS

DATE		BOD mg/L	COD mg/L	AMMONIA[1] NITROGEN mg/L (N)	NITRITES[1] PLUS NITRATES mg/L (N)	PHOSPHATES[1] TOTAL mg/L (P)	pH	COLOR COBALT COLOR UNITS
1975								
Aug.	4	1.1	36				6.3	
	11	0.9	44				7.4	
	18	3.1	44				7.4	
	25	3.0	8				7.2	
Sept.	3	5.2	12				7.0	
	8	5.6	136				6.8	
	15	4.6	48				7.8	
	22	2.0	18				6.8	
	29	1.1	16				6.1	
Oct.	8	1.6	32				6.2	
	15	6.0	20		0.65	0.21	6.5	
	20	0.1	32				6.7	
	30	2.8	20				6.7	
Nov.	4	2.2	44				6.9	
	12	2.8	12				6.6	
	19	2.3	16		0.39	0.21	7.1	
	24	1.9	48				6.6	
Dec.	3	4.2	8				6.8	
	11	3.8	24		0.75	0.27	6.8	
	18	2.1	32				6.9	
	22	6.7	16				6.7	
	29	4.9	12				6.5	

1 = Data of U.S. Geological Survey at Kinston, NC

All color values in this table are true color.

TABLE A1 (con't) PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE NEUSE RIVER WATER ENTERING FOUR EXPERIMENTAL STREAMS

DATE		BOD mg/L	COD mg/L	AMMONIA[1] NITROGEN mg/L (N)	NITRITES[1] PLUS NITRATES mg/L (N)	PHOSPHATES[1] TOTAL mg/L (P)	pH	COLOR COBALT COLOR UNITS
1976								
Jan.	6	2.1	40				6.8	
	13	5.2	36				6.0	
	20	2.1	32				6.7	
	27	3.6	24				6.5	
Feb.	2	1.4	35		0.54	0.13	6.0	
	9	1.7	12				5.3	
	16	1.9	36				6.6	
	25	2.9			0.90	0.16	6.7	
Mar.	1	2.5	20				6.8	
	8	3.5	46				6.6	
	18	3.3	48				6.9	
	23	2.9	20		0.81	0.27	6.7	
Apr.	5	5.3	16				7.0	
	12	6.3	24		0.06	0.27	6.5	
	21	8.9	20				6.6	
	26	6.7	12				7.8	
June	1	4.1	24				6.9	
	7	4.3	72				6.3	
	15	3.5	20				6.7	
	22	3.2	56				6.7	
	28	4.8	20		0.70	0.28	6.4	60

1 = Data of U.S. Geological Survey at Kinston, NC

TABLE A1 (con't) PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE NEUSE RIVER WATER ENTERING FOUR EXPERIMENTAL STREAMS

DATE		BOD mg/L	COD mg/L	AMMONIA[1] NITROGEN mg/L (N)	NITRITES[1] PLUS NITRATES mg/L (N)	PHOSPHATES[1] TOTAL mg/L (P)	pH	COLOR COBALT COLOR UNITS
1976								
July	6	1.5	18				6.1	
	12	3.4	12				6.3	
	22	7.4	12				7.1	
	26	3.8	32		0.00	0.24	7.4	45
Aug.	2	2.1	40				6.8	
	9	3.9	32				6.6	
	16	3.1	4		0.00	0.22	6.5	
	23	3.8	4				6.7	65
	30	3.3	6				7.1	
Sept.	10	1.4	24				7.1	
	17	5.2	76				6.8	60
	20	3.0	76		0.72	0.36	7.6	
	28	3.3	24				7.1	
Oct.	5	4.9	64		0.80	0.26	7.0	
	13	2.7	36				7.1	
	18	4.4	40				7.3	
	28	1.6	28				6.8	75
Nov.	2	6.8	16				7.1	
	8	4.6	8		0.92	0.31	6.9	
	15	4.3	20				6.9	
	22	2.3	32				6.7	105
	29	3.7	32				5.7	

1 = Data of U.S. Geological Survey at Kinston, NC

TABLE A1 (con't) PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE NEUSE RIVER WATER ENTERING FOUR EXPERIMENTAL STREAMS

DATE		BOD mg/L	COD mg/L	AMMONIA[1] NITROGEN mg/L (N)	NITRITES[1] PLUS NITRATES mg/L (N)	PHOSPHATES[1] TOTAL mg/L (P)	pH	COLOR COBALT COLOR UNITS
1976								
Dec.	6	2.0	20		0.80	0.32	7.0	
	14	2.8	28				6.4	
	22	0.9	20		0.53	0.13	6.1	55
	28	0.8	12				7.2	
1977								
Jan.	3	2.3	20				6.7	
	10	3.1	36				6.7	
	17	4.0	40				6.0	85
							6.6	
Feb.	3	1.3	4				6.4	
	7	4.4	12				6.6	
	14	2.7	8				6.7	60
	23	2.0	12		0.51	0.07	6.4	
Mar.	1	0.5	28				6.4	
	8	3.0	21				6.1	
	14	5.3	32				6.3	60
	21	2.4	20		0.21	0.11	7.5	
	28	2.7	48				6.0	
Apr.	4	1.4	8				7.3	
	13	2.5	24				6.3	
	18	3.5	32				6.3	
	26	3.3	40		0.59	0.25	7.0	70

1 = Data of U.S. Geological Survey at Kinston, NC

TABLE A1 (con't) PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE NEUSE RIVER WATER ENTERING FOUR EXPERIMENTAL STREAMS

DATE		BOD mg/L	COD mg/L	AMMONIA NITROGEN[1] mg/L (N)	NITRITES PLUS NITRATES[1] mg/L (N)	PHOSPHATES TOTAL[1] mg/L (P)	pH	COLOR COBALT COLOR UNITS
1977								
May	2	4.7	20				7.3	
	9	4.2	12				7.4	
	17	7.9	124				9.0	
	24	2.5	20		0.12	0.36	7.1	45
June	8	3.0					6.3	
	15	5.1	24				7.9	
	22	3.1	40				8.0	
	29	4.0	16		0.00	0.36	7.2	95
July	5	6.6	20				7.1	
	11	1.1	8				7.4	
	18	4.0	8				7.1	67
	26	3.2	40		0.07	0.34	6.8	
Aug.	3	2.2	48				6.8	
	11	3.2					7.1	
	17	0.9	4		0.40	0.34	7.0	57
	25	1.8	32				6.2	40
Sept.	6	1.7	40				6.8	37
	14	1.6	12		0.32	0.22	5.9	60
	20	2.4	20				5.8	68
	25	2.8	28				6.6	40

1 = Data of U.S. Geological Survey at Kinston, NC

TABLE A1 (con't) PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE NEUSE RIVER WATER ENTERING FOUR EXPERIMENTAL STREAMS

DATE		BOD mg/L	COD mg/L	AMMONIA[1] NITROGEN mg/L (N)	NITRITES[1] PLUS NITRATES mg/L (N)	PHOSPHATES[1] TOTAL mg/L (P)	pH	COLOR COBALT COLOR UNITS
1977								
Oct.	3	1.0	56				6.5	
	10	.9	4				7.1	43
	20	3.9	16				7.0	
	30	3.4	12	0.10	1.10	0.35	6.2	57
Nov.	7	1.9	28				5.9	
	14	2.6	48	0.04	0.23	0.15	6.5	120
	22	0.5	8				6.0	87
	29	4.3	16				6.0	
Dec.	5	3.4	28				6.4	63
	12	4.0	48				6.1	70
	19	3.6	24	0.07	0.61	0.18	6.2	
	29	1.2	32				6.4	
1978								
Jan.	4	1.7	28				6.7	
	13	0.9	8				7.1	58
	18		32				6.3	
	23	3.0	64	0.04	0.64	0.10	6.5	
	30	2.0	16	0.01	0.62	0.05	6.0	
Feb.	8	1.1	16				6.6	
	13	1.3	4				6.4	67
	20	1.1	0	0.09	1.10	0.15	6.7	

1 = Data of U.S. Geological Survey at Kinston, NC

TABLE A1 (con't) PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE NEUSE RIVER WATER ENTERING FOUR EXPERIMENTAL STREAMS

DATE		BOD mg/L	COD mg/L	AMMONIA[1] NITROGEN mg/L (N)	NITRITES[1] PLUS NITRATES mg/L (N)	PHOSPHATES[1] TOTAL mg/L (P)	pH	COLOR COBALT COLOR UNITS
1978								
Mar.	6	0.3	20				7.0	
	13	1.3	36				6.2	48
	20	3.0	28				6.0	
	30	2.4	12	0.11	0.75	0.22	6.1	
Apr.	3	1.9	28				6.1	
	11	3.4	32				6.2	
	17	2.9	40				6.3	43
	24	1.7	28	0.08	0.57	0.16	5.8	
May	8	1.8	28				6.8	113
	15	0.4	24				5.7	
	25	2.0	20	0.04	0.43	0.14	6.0	
	31	0.4	20				7.2	
June	6	3.0	36				6.7	
	13	1.8	24	0.09	0.55	0.25	6.7	87
	19	0.3	12				6.5	
	27	1.6	4				6.6	
July	5	1.9					6.9	
	10	3.0					6.5	
	20	2.0		0.09	0.71	0.29	6.2	
	26	1.4					6.5	78
Aug.	3	1.6		0.07	0.66	0.27	6.5	
	10	1.3	36				6.7	
	21	3.0	32				6.7	57
	28	2.4	4				7.2	40

1 = Data of U.S. Geological Survey at Kinston, NC

TABLE A1 (con't) PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE NEUSE RIVER WATER ENTERING FOUR EXPERIMENTAL STREAMS

DATE		BOD mg/L	COD mg/L	AMMONIA[1] NITROGEN mg/L (N)	NITRITES[1] PLUS NITRATES mg/L (N)	PHOSPHATES[1] TOTAL mg/L (P)	pH	COLOR COBALT COLOR UNITS
1978								
Sept.	5	4.8		0.02	0.11	0.30	6.5	
	13	3.2					6.9	98
	20	1.8					7.0	
	29	1.9					7.0	32
Oct.	4	2.0	48	0.11	0.88	0.31	7.8	30
	10	3.0	16				7.3	
	16	3.3	24				7.4	30
	23	3.1	8				6.9	
Nov.	6	3.9	16				7.4	38
	13	3.1	8	0.17	0.95	0.36	7.3	
	21	3.0	0				7.2	50
	27	4.9	24				7.4	48
Dec.	5	1.7	12				7.7	68
	11	1.9	4	0.06	0.66	0.18	7.2	
	22	2.0	4				6.7	
	26	2.1	20				6.6	
1979								
Jan.	3	3.3	24				6.8	
	8	2.8	32				5.8	
	22	3.9	32				6.4	
	29	2.6	28				6.4	

1 = Data of U.S. Geological Survey at Kinston, NC

TABLE A1 (con't) PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE NEUSE RIVER WATER ENTERING FOUR EXPERIMENTAL STREAMS

DATE		BOD mg/L	COD mg/L	AMMONIA[1] NITROGEN mg/L (N)	NITRITES[1] PLUS NITRATES mg/L (N)	PHOSPHATES[1] TOTAL mg/L (P)	pH	COLOR COBALT COLOR UNITS
1979								
Feb.	5	2.6	36				6.3	
	12	4.3	8	0.10	0.87	0.12	6.8	
	20	3.7	12				6.6	
	26	2.8	8				6.6	
Mar.	6	4.6	20	0.08	0.63	0.11	6.4	
	13	2.2	8				6.5	
	20	1.7	12				7.4	
	30	3.1	24				6.5	
Apr.	5	1.6	12	0.05	0.36	0.09	6.8	
	10	2.7	20				7.2	
	18	1.1	24				5.7	
	30	3.2	72				6.1	
May	8	3.6	44				6.6	68
	17	2.1	32				6.1	
	21	.6	36	0.05	0.36	0.14	6.0	98
	31	1.8	8				6.0	118
June	5	1.9	76				6.0	110
	11	0.2	68	0.04	0.30	0.16	6.4	
	18	2.1	40				6.0	115
	25	.4	44				5.9	108
July	2	.4	44	0.00	0.21	0.24	6.5	
	9	2	48				7.6	
	17	4	8				6.8	
	24	5					6.8	

1 = Data of U.S. Geological Survey at Kinston, NC

TABLE A1 (con't) PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE NEUSE RIVER WATER ENTERING FOUR EXPERIMENTAL STREAMS

DATE		BOD mg/L	COD mg/L	AMMONIA[1] NITROGEN mg/L (N)	NITRITES[1] PLUS NITRATES mg/L (N)	PHOSPHATES[1] TOTAL mg/L (P)	pH	COLOR COBALT COLOR UNITS
1979								
Sept.	4	3.0	36				6.9	
	12	2.3	68	0.03	0.27	0.15	6.0	
	20	2.4	32				6.1	128
	28	2.9	64				6.5	
Oct.	1	2.8	32	0.07	0.77	0.24	6.3	85
	12	1.9	40				6.2	
	18	2.5	60				6.5	68
	24	0.2	60				6.7	
Nov.	5	2.4	20	0.06	0.93	0.35	6.6	60
	12	2.6	40				6.5	
	19	1.7	60				6.3	125
	28	4.3	80				6.4	
Dec.	3	3.3	40				6.2	130
	14	1.3	60	0.08	0.74	0.17	6.5	
	21	2.7	40				6.4	82
	27	2.1	38				6.8	
1980								
Jan.	3	1.3	54				7.0	70
	10	2.3	60				6.9	
	15	2.6	16				6.3	
	21	2.5	41	0.13	0.72	0.13	6.3	106

1 = Data of U.S. Geological Survey at Kinston, NC

TABLE A1 (con't) PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE NEUSE RIVER WATER ENTERING FOUR EXPERIMENTAL STREAMS

DATE		BOD mg/L	COD mg/L	AMMONIA[1] NITROGEN mg/L (N)	NITRITES[1] PLUS NITRATES mg/L (N)	PHOSPHATES[1] TOTAL mg/L (P)	pH	COLOR COBALT COLOR UNITS
1980								
Feb.	6	5.0	73				6.7	70
	14	6.2	28				6.5	72
	19	4.8	69	0.1	1.0	0.12	6.5	42
	26	0.6	63				6.5	
Mar.	3							62
	10	5.4	32				6.8	58
	17	3.7	28				6.7	
	24	3.7	24	0.05	0.56	0.11	7.0	90
	31	2.1	76				7.5	
Apr.	7	0.8	41				6.7	98
	14	1.5	18				7.0	
	21	2.4	24	0.08	0.49	0.17	6.5	95
	28	1.4	42				6.5	
May	5	2.2	38				7.3	
	12	1.3	64	0.02	1.10	0.22	6.7	
	19	2.6	18				7.0	58
	26	3.0	43				6.6	
June	2	1.6	36				6.4	78
	9	1.9	70				7.2	
	16	4.2	20	0.02	1.10	0.21	8.0	35
	23	4.0	31				7.1	35
	30							

1 = Data of U.S. Geological Survey at Kinston, NC

TABLE A1 (con't) PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE NEUSE RIVER WATER ENTERING FOUR EXPERIMENTAL STREAMS

DATE		BOD mg/L	COD mg/L	AMMONIA[1] NITROGEN mg/L (N)	NITRITES[1] PLUS NITRATES mg/L (N)	PHOSPHATES[1] TOTAL mg/L (P)	pH	COLOR COBALT COLOR UNITS
1980								
July	7	1.9	28.2				6.7	50
	14	3.5	28				8.5	
	21	4.9	37.2	0.01	0.01	0.25	7.3	
	28	3.4	8.0				2.4	
Aug.	4	3.2	7.7				8.2	
	11	8.5	36.0				8.6	
	18	5.2	40.0	0.09	0.07	0.14	7.3	
	25	2.2	20.0				7.9	
Sept.	1	3.0	47				7.3	
	8	3.1	51	0.06	0.31	0.27	7.1	
	15	4.2	34				7.5	
	22	2.6	39				7.4	
	29	2.3	34				6.6	
Oct.	6	1.9	29	0.07	1.10	0.38	7.3	
	13	2.3	38					30
	20	1.7	11				6.8	
	27	1.7	67					30
Nov.	3	.8	35	0.07	1.10	0.30	6.7	40
	10		67				6.8	38
	17	1.3	15				6.6	45
	24	1.1	36				6.6	42

1 = Data of U.S. Geological Survey at Kinston, NC

TABLE A1 (con't) PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE NEUSE RIVER WATER ENTERING FOUR EXPERIMENTAL STREAMS

DATE		BOD mg/L	COD mg/L	AMMONIA[1] NITROGEN mg/L (N)	NITRITES[1] PLUS NITRATES mg/L (N)	PHOSPHATES[1] TOTAL mg/L (P)	pH	COLOR COBALT COLOR UNITS
1980								
Dec.	1	1.0	35	0.06	0.67	0.26	6.3	
	8	.8	22				6.8	49
	15	.95	75				6.3	
	22	2.2	47				6.4	
	29	5.8	29				6.5	
1981								
Jan.	5	1.5	49				6.0	75
	12	2.5	22				5.6	
	19	4.0	24				6.5	35
	26	2.6	16	0.11	1.20	0.26	6.6	
Feb.	2	1.7	18				6.1	
	9	3.6	31	0.09	0.95	0.20	6.2	38
	16	3.3	34				5.9	
	23	2.8	48				6.1	55
Mar.	5	1.2	46				5.6	
	12	3.1	37				5.7	
	20	2.8	23				7.2	
	26	0.9	7	0.08	0.92	0.23	6.1	48
Apr.	6	3.5	38				6.1	62
	13	2.6	94				6.5	56
	20	5.1	80				6.6	47
	27	3.4	104	0.04	0.92	0.33	6.7	40

1 = Data of U.S. Geological Survey at Kinston, NC

TABLE A1 (con't) PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE NEUSE RIVER WATER ENTERING FOUR EXPERIMENTAL STREAMS

DATE		BOD mg/L	COD mg/L	AMMONIA[1] NITROGEN mg/L (N)	NITRITES[1] PLUS NITRATES mg/L (N)	PHOSPHATES[1] TOTAL mg/L (P)	pH	COLOR COBALT COLOR UNITS
1981								
May	4	2.8	95				6.5	34
	11	5.2	76				6.6	
	18		44					
	25	2.4	32	0.04	0.90	0.33	5.9	
June	1	5.3	47				6.7	78
	8	1.1	118	0.08	0.79	0.37	6.0	105
	15	3.1	109				7.3	80
	22	4.5	67				5.4	88
	29	3.5					6.3	
July	6	2.1	27				6.5	
	13	2.1	26				6.6	
	20	1.5	35				6.4	
	27	5.5	16	0.09	0.65	0.27	7.1	
							249.9	

1 = Data of U.S. Geological Survey at Kinston, NC

TABLE A1 (con't) PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE NEUSE RIVER WATER ENTERING FOUR EXPERIMENTAL STREAMS

DATE		BOD mg/L	COD mg/l	AMMONIA NITROGEN mg/L (N)	NITRITES PLUS NITRATES mg/L (N)	PHOSPHATES TOTAL mg/L (P)	pH	COLOR COBALT COLOR UNITS
1981								
Aug.	4	2.9	29				7.1	
	11	3.2	20				6.6	
	18	2.2	23				6.5	
	25	1.6	16				6.7	
Sept.	1	1.9	32				6.3	105
	8	4.4	26				6.6	
	15	4.8	27				6.3	70
	22	1.8	15				6.9	
	29	3.2	25				6.6	
Oct.	6	2.8	92				6.9	
	13	3.8	29				8.0	
	20	2.6	18				7.1	
	27	3.3	148				6.7	
Nov.	3	2.1	43					
	10	2.3	104					
	17	1.6	78					
	24	1.3	65					
Dec.	1							
	8	2.8	27				6.8	
	15	3.9	19				6.9	
	22	2.2	31				7.1	
	29	2.2	63				6.4	

1= Data of U. S. Geological Survey at Kinston, NC.

TABLE A1 (con't) PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE NEUSE RIVER WATER ENTERING FOUR EXPERIMENTAL STREAMS

DATE		BOD mg/L	COD mg/l	AMMONIA NITROGEN mg/L (N)	NITRITES PLUS NITRATES mg/L (N)	PHOSPHATES TOTAL mg/L (P)	pH	COLOR COBALT COLOR UNITS
1982								
Jan.	5	2.3	39				7.2	
	12	2.1					7.5	
	19	4.4	45				6.3	
	26	2.8	24				6.3	
Feb.	2	4.0	26				6.8	
	9	1.6	40				6.5	
	16	3.3	44				7.2	74
	23	1.4	27				6.7	
Mar.	2	1.9	38				6.7	
	9	1.8	26				6.7	
	16	1.6	24				6.7	
	23	1.3	35				6.4	
	30							
Apr.	6	1.8	18				6.7	
	13	2.9	4				7.0	
	20	3.9	69				6.7	62
	27	2.3	25				6.8	85
May	4	2.7	38				6.6	
	11	2.1	18				6.8	
	18	2.9	22				7.0	63
	25	2.6	7				7.1	

1= Data of U. S. Geological Survey at Kinston, NC

TABLE A1 (con't) PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE NEUSE RIVER WATER ENTERING FOUR EXPERIMENTAL STREAMS

DATE		BOD mg/L	COD mg/l	AMMONIA NITROGEN mg/L (N)	NITRITES PLUS NITRATES mg/L (N)	PHOSPHATES TOTAL mg/L (P)	pH	COLOR COBALT COLOR UNITS
1982								
June	1	0.4	18				6.7	100
	8	2.1	22				6.1	
	15	3.0	34				6.3	
	22	0.8	55				6.7	
	29	1.8	42				7.0	120
July	6	2.6	53				6.9	
	13	0.3					7.0	
	20	1.2	17				6.5	
	27	1.8	9				6.4	

1- Data of U. S. Geological Survey at Kinston, NC

APPENDIX B

EFFLUENT BOD, TSS, TOTAL RESIN ACIDS, AND TRUE COLOR - BOD VALUES USED TO SET THE PERCENT EFFLUENT ENTERING THE EXPERIMENTAL STREAMS AND PERCENT EFFLUENT, BOD, TSS, RESIN ACIDS AND COLOR ADDITIONS TO THE STREAMS RECEIVING EFFLUENT

TABLE B1 EFFLUENT BOD, TSS, TOTAL RESIN ACIDS, AND TRUE COLOR - BOD VALUES USED TO SET THE PERCENT EFFLUENT ENTERING THE EXPERIMENTAL STREAMS AND PERCENT EFFLUENT, BOD, TSS, RESIN ACIDS AND COLOR ADDITIONS TO THE STREAMS RECEIVING EFFLUENT

	Effl.BOD mg/L		Added		EFFLUENT TSS (mg/L)		EFFLUENT RESIN ACIDS (ug/L)		EFFLUENT COLOR ClPt (mg/L)	
DATE	Act. Range	Used to set	Prct. Effl.	BOD mg/L	Total	Added	Total	Added	Total	Added
1975										
SEPT.										
29	3-5	10	5.0	0.20	4	0.20				
OCT.										
8	4-5	10	5.0	0.23	5	0.25				
15	5-6	10	5.0	0.28	5	0.25				
23	5-8	10	5.0	0.33	7	0.35				
30	6-17	10	5.0	0.58	12	0.60				
NOV.										
4	19-23	17	2.9	0.61	28	0.81	200	5	2200	58
11	17-23	20	2.5	0.5	22	0.55				
18	14-23	17	2.9	0.54	23	0.67				
24	13-16	16	3.1	0.45	23	0.72				
DEC.										
3	19-23	16	3.1	0.65	35	1.09				
9	22-24	22	2.3	0.52	30	0.68			2060	54
18	14-20	22	2.3	0.39	32	0.74				
22	20-23	20	2.5	0.54	40	1.00				
30	23-24	23	2.2	0.50	37	0.81				
1976										
JAN.										
4	11-16	22	2.3	0.31	27	0.62			2250	102
13	13-26	11	4.6	0.90	37	1.71				

TABLE B1 (Cont'd) EFFLUENT BOD, TSS, TOTAL RESIN ACIDS, AND TRUE COLOR - BOD VALUES USED TO SET THE PERCENT EFFLUENT ENTERING THE EXPERIMENTAL STREAMS AND PERCENT EFFLUENT, BOD, TSS, RESIN ACIDS AND COLOR ADDITIONS TO THE STREAMS RECEIVING EFFLUENT

DATE	Effl.BOD mg/L Act. Range	Effl.BOD mg/L Used to set	Added Prct. Effl.	Added BOD mg/L	EFFLUENT TSS (mg/L) Total	EFFLUENT TSS (mg/L) Added	EFFLUENT RESIN ACIDS (ug/L) Total	EFFLUENT RESIN ACIDS (ug/L) Added	EFFLUENT COLOR ClPt (mg/L) Total	EFFLUENT COLOR ClPt (mg/L) Added
1976										
JAN.										
20	38-49	26	1.9	0.83	35	0.66				
25	54-62	48	1.0	0.58	42	0.42				
FEB.										
2	44-59	59	.8	0.43	63	0.84	980	8	2560	22
10	32-40	44	1.1	0.40	45	0.49	930	10		
16	17-24	34	1.5	0.31	15	0.23	1080	16		
25	11-16	21	2.4	0.32	11	0.26	78	2		
MAR.							140	3		
2	15-17	15	3.3	0.53	17	0.56	30	0.9	2325	77
7	11-12	15	3.3	0.38	9	0.30	200	7		
17	9-13	11	4.6	0.51	21	0.96	76	4		
23	7-10	10	5.0	0.43	13	5.00	56	3		
APR.							40	2		
4	5-13	10	5.0	0.45	12	0.60	150	8	2115	106
11	18-20	10	5.0	0.95	30	1.50	310	16		
21	13-17	20	2.5	0.37	19	0.48	56	1		
27	4-8	15	3.3	0.19	8	0.26	70	2		
MAY										
2	6-10	10	5.0	0.40	12	0.60	60	3	2253	113
10	5-14	10	5.0	0.48	4	0.20	-- No sample			
16	11-15	14	3.6	0.46	8	0.29	22	1		

TABLE B1 (Cont'd)

EFFLUENT BOD, TSS, TOTAL RESIN ACIDS, AND TRUE COLOR - BOD VALUES USED TO SET THE PERCENT EFFLUENT ENTERING THE EXPERIMENTAL STREAMS AND PERCENT EFFLUENT, BOD, TSS, RESIN ACIDS AND COLOR ADDITIONS TO THE STREAMS RECEIVING EFFLUENT

DATE	Effl.BOD mg/L Act. Range	Used to set	Added Prct. Effl.	BOD mg/L	EFFLUENT TSS (mg/L) Total	Added	EFFLUENT RESIN ACIDS (ug/L) Total	Added	EFFLUENT COLOR ClPt (mg/L) Total	Added
MAY										
23	9-15	11	4.6	0.55	19	0.87	30	1		
JUNE										
1	9-11	10	5.0	0.50	10	0.50	30	3	2250	112
7	8-8	10	5.0	0.40	3	0.15				
14	5-11	10	5.0	0.40	3	0.15				
23	8-10	10	5.0	0.45	5	0.25				
28	9	10	5.0	0.45	10	0.59				
JULY										
6	2-7	10	10.0	0.45	4	0.40	ND 15	1.5	1850	185
12	3-8	10	10.0	0.55	4	0.40				
22	7-9	10	10.0	0.80	11	1.10				
26	8-10	10	10.0	0.90	14	1.40	ND 15	1.5		
AUG.										
2	5-8	10	10.0	0.65	11	1.1	ND 15	1.5	2325	232
9	5-8	10	10.0	0.65	9	0.9				
16	7-11	10	10.0	0.90	7	0.7				
23	7-9	10	10.0	0.80	4	0.4				
30	10-12	10	10.0	1.10	4	0.4				
SEPT.										
7	10-12	10	10.0	1.10	11	1.10			2200	220
13	9-14	11	9.1	1.05	8	0.73	30	2.7		

TABLE B1 (Cont'd) EFFLUENT BOD, TSS, TOTAL RESIN ACIDS, AND TRUE COLOR - BOD VALUES USED TO SET THE PERCENT EFFLUENT ENTERING THE EXPERIMENTAL STREAMS AND PERCENT EFFLUENT, BOD, TSS, RESIN ACIDS AND COLOR ADDITIONS TO THE STREAMS RECEIVING EFFLUENT

DATE	Effl.BOD mg/L Act. Range	Effl.BOD mg/L Used to set	Added Prct. Effl.	Added BOD mg/L	EFFLUENT TSS (mg/L) Total	EFFLUENT TSS (mg/L) Added	EFFLUENT RESIN ACIDS (ug/L) Total	EFFLUENT RESIN ACIDS (ug/L) Added	EFFLUENT COLOR ClPt (mg/L) Total	EFFLUENT COLOR ClPt (mg/L) Added
1976										
SEPT.										
20	9-2	10	10.0	0.65	12	1.20	ND 15	1.5		
27	14	10	10.0	1.40	9	0.90	30	3.0		
OCT.										
4	10-12	12	8.3	0.92	10	0.83	ND 15	1.2	2150	179
11	11-13	12	8.3	1.00	16	1.33				
17	9-14	12	8.3	0.95	12	1.00	ND 15	1.0		
25	6-8	10	10.0	0.70	7	0.70				
NOV.										
1	7-14	10	10.0	1.1	10	1.00	ND 15		2025	202
8	14-22	14	7.1	1.3	10	0.71				
15	21-54	22	4.5	1.69	44	1.98	280	12.6		
21	52-58	54	1.8	0.99	77	1.39				
29	40-43	52	1.9	0.79	31	0.59	650	12.3		
DEC.										
5	29-44	40	2.5	0.91	40	1.00	680	0.2		
12	19-26	26	3.8	0.87	22	0.85				
19	22-25	23	4.4	1.0	27	1.17	ND 15	0.6		
27	22-29	24	4.2	1.1	36	1.50			2295	93
1977										
JAN.										
3	15-21	22	4.5	0.81	16	0.72				

TABLE B1 (Cont'd)

EFFLUENT BOD, TSS, TOTAL RESIN ACIDS, AND TRUE COLOR - BOD VALUES USED TO SET THE PERCENT EFFLUENT ENTERING THE EXPERIMENTAL STREAMS AND PERCENT EFFLUENT, BOD, TSS, RESIN ACIDS AND COLOR ADDITIONS TO THE STREAMS RECEIVING EFFLUENT

DATE	Effl. BOD mg/L		Added		EFFLUENT TSS (mg/L)		EFFLUENT RESIN ACIDS (ug/L)		EFFLUENT COLOR ClPt (mg/L)	
	Act. Range	Used to set	Prct. Effl.	BOD mg/L	Total	Added	Total	Added	Total	Added
1977										
JAN.										
10	12-29	20	5.0	1.92	15	1.25	310	25.8		
18	28-38	12	8.3	2.73	45	3.73				
24	23-38	35	2.9	0.87	40	1.14	470	13.4		
FEB.										
3	16-20	24	4.2	0,76	41	1.72			2425	102
7	11-20	16	6.2	0.96	19	1.18	450	27.9		
14	11-13	14	7.1	0.86	9	0.64				
23	10-31	13	7.7	1.66	30	2.31				
MAR.										
1	11-34	19	5.3	1.2	29	1.53				
7	24-32	28	3.6	1.00	28	1.00				
14	30-47	30	3.3	1.3	52	1.73				
21	24-47	39	2.6	0.91	44	1.13	850	21.8		
28	13-17	27	3.7	0.56	12	0.44				
APR.										
2	9-12	13	7.7	0.81	16	1.23	ND 15	1.15	2125	164
9	8-12	10	10.0	0.90	15	1.5				
16	12-14	10	10.0	1.30	17	1.70	ND 15	1.50		
23	8-17	12	8.3	1.04	13	1.08	ND 15	1.2		
MAY										
2	14-17	14	7.1	1.1	16	1.14				

TABLE B1 (Cont'd)

EFFLUENT BOD, TSS, TOTAL RESIN ACIDS, AND TRUE COLOR - BOD VALUES USED TO SET THE PERCENT EFFLUENT ENTERING THE EXPERIMENTAL STREAMS AND PERCENT EFFLUENT, BOD, TSS, RESIN ACIDS AND COLOR ADDITIONS TO THE STREAMS RECEIVING EFFLUENT

DATE	Effl.BOD mg/L Act. Range	Effl.BOD mg/L Used to set	Added Prct. Effl.	Added BOD mg/L	EFFLUENT TSS (mg/L) Total	EFFLUENT TSS (mg/L) Added	EFFLUENT RESIN ACIDS (ug/L) Total	EFFLUENT RESIN ACIDS (ug/L) Added	EFFLUENT COLOR ClPt (mg/L) Total	EFFLUENT COLOR ClPt (mg/L) Added
1977										
MAY										
9	13-18	16	6.3	0.97	14	0.88	ND 15	1.1		
16	12-20	14	7.1	1.14	20	1.42	130	4.1		
23	15-19	18	5.6	0.95	34	1.89				
JUNE										
1	11-11	15	6.7	0.73	12	0.80				
6	11-14	11	9.1	1.1	12	1.09	ND 15	1.4		
13	14-22	12	8.3	2.4	29	2.41				
19	15-18	18	5.6	0.9	32	1.78				
27	9-10	15	6.7	0.63	18	1.21				
JULY										
5	11-14	10	15.0	1.9	12	1.80				
12	5-27	11	13.6	2.2	2	0.27				
19	7-8	10	15.0	1.1	2	0.30			1928	289
26	11-13	10	15.0	1.6	10	1.50				
AUG.										
2	4-10	11	13.6	0.95	7	0.95				
9	5-9	10	15.0	1.1	3	0.45				
16	4-9	10	15,0	0.98	11	1.65	750	112	1833	275
23	3-9	10	15.0	0.9	1	0.15	622	92	2133	320
30	15-19	10	15.0	2.6	14	2.10				

TABLE B1 (Cont'd)

EFFLUENT BOD, TSS, TOTAL RESIN ACIDS, AND TRUE COLOR - BOD VALUES USED TO SET THE PERCENT EFFLUENT ENTERING THE EXPERIMENTAL STREAMS AND PERCENT EFFLUENT, BOD, TSS, RESIN ACIDS AND COLOR ADDITIONS TO THE STREAMS RECEIVING EFFLUENT

DATE	Effl.BOD mg/L Act. Range	Effl.BOD mg/L Used to set	Added Prct. Effl.	Added BOD mg/L	EFFLUENT TSS (mg/L) Total	EFFLUENT TSS (mg/L) Added	EFFLUENT RESIN ACIDS (ug/L) Total	EFFLUENT RESIN ACIDS (ug/L) Added	EFFLUENT COLOR ClPt (mg/L) Total	EFFLUENT COLOR ClPt (mg/L) Added
1977										
SEPT.										
6	14-30	15	6.0	1.3	17	1.02			2366	142
13	18-22	20	7.5	1.5	22	1.65	2065	124	2400	100
20	18-30	20	5.0	1.2	25	1.25	1825	138	2366	118
27	13-18	18	8.3	1.3	14	1.17	2259	186	2400	200
OCT.										
4	11-18	15	10.0	1.4	13	1.30	1718	172	2030	203
11	7-11	12	11.5	1.0	3	0.35	1801	207		
18	4-6	10	15.0	0.8	2	0.30	996	149		
25	6-18	10	15.0	1.8	5					
NOV.										
1	4-6	10	15.0	0.75	4	0.60			2033	305
8	7-10	10	15.0	1.3	2	0.30			1933	290
15	9-12	10	15.0	1.6	1	0.15	1164	175	1933	290
22	12-15	10	15.0	2.1	8	1.20				
29	12-17	15	10.0	1.4	10	1.00	3075	308		
DEC.										
6	10-12	15	10.0	1.1	18	1.80			2166	216
13	6-13	10	15.0	1.4	12	1.80	4302	645		
20	7	--	----	---	21	----	Pipe broken			
27	7-9	10	15.0	1.2	21	3.15				

TABLE B1 (Cont'd) EFFLUENT BOD, TSS, TOTAL RESIN ACIDS, AND TRUE COLOR - BOD VALUES USED TO SET THE PERCENT EFFLUENT ENTERING THE EXPERIMENTAL STREAMS AND PERCENT EFFLUENT, BOD, TSS, RESIN ACIDS AND COLOR ADDITIONS TO THE STREAMS RECEIVING EFFLUENT

DATE	Effl. BOD mg/L Act. Range	Effl. BOD mg/L Used to set	Added Prct. Effl.	Added BOD mg/L	EFFLUENT TSS (mg/L) Total	EFFLUENT TSS (mg/L) Added	EFFLUENT RESIN ACIDS (ug/L) Total	EFFLUENT RESIN ACIDS (ug/L) Added	EFFLUENT COLOR ClPt (mg/L) Total	EFFLUENT COLOR ClPt (mg/L) Added
1978										
JAN.										
3	5-7	10	15.0	0.9	5	0.75	1187	177	2020	303
10	5-8	10	15.0	1.0	68	10.20				
17	8-14	10	15.0	1.6	20	3.00				
24	17-22	13	11.5	2.2	26	2.99				
31	14-35	19	7.9	1.9	52	4.11				
FEB.										
7	19-21	19	7.9	1.6	47	3.71			2124	168
14	9-16	19	7.9	1.0	19	1.50				
21	8-9	10	15.0	1.3	35	5.25				
28	3-10	10	15.0	1.0	27	4.05				
MAR.										
7	6-8	10	15.0	1.0	12	1.8	778	116		
14	6-9	10	15.0	1.1	4	0.60			1983	297
21	12-16	10	15.0	2.1	28	4.20	1100	165		
28	14-18	16	8.3	1.3	45	3.65				
APR.										
4	22-27	18	8.3	2.4	41	3.40	443	37		
11	13-17	32	4.7	0.7	53	2.49			2151	101
18	17-23	13	11.5	2.3	42	4.83	868	100		

TABLE B1 (Cont'd)

EFFLUENT BOD, TSS, TOTAL RESIN ACIDS, AND TRUE COLOR - BOD VALUES USED TO SET THE PERCENT EFFLUENT ENTERING THE EXPERIMENTAL STREAMS AND PERCENT EFFLUENT, BOD, TSS, RESIN ACIDS AND COLOR ADDITIONS TO THE STREAMS RECEIVING EFFLUENT

	Effl.BOD mg/L		Added		EFFLUENT TSS (mg/L)		EFFLUENT RESIN ACIDS (ug/L)		EFFLUENT COLOR ClPt (mg/L)	
DATE	Act. Range	Used to set	Prct. Effl.	BOD mg/L	Total	Added	Total	Added	Total	Added
1978										
May										
2	12-30	23	6.5	1.4	60	3.90				
9	24-34	24	6.2	1.8	40	2.50	3363	161	2050	128
16	19-38	31	4.8	1.4	47	2.27				
23	16-28	26	5.8	1.3	18	1.04				
30	14-29	16	9.4	2.0	14	1.32				
June										
6	13-22	20	7.5	1.2	16	1.2	4119	309	2070	222
13	14-19	14	10.7	1.8	1	0.11	6335	678		
20	12-17	16	9.4	1.4	12	1.13	4269	401		
27	7-12	12	12.5	1.2	1	0.12	2339	292		
July										
4	10-12	12	12.5	1.4	3	0.38			1450	218
11	8-11	10	15.0	1.4	30	4.50				
18	6-8	10	15.0	1.1	3	0.45				
25	8-12	10	15.0	1.5	6	0.90				
Aug.										
1	9-13	10	15.0	1.7	9	0.90				
8	7-24	10	15.0	2.3	20	3.00				
15	14-18	16	9.4	1.5	21	1.97	3236	307	1933	182
22	20-24	16	9.4	3.5	6	0.56	1602	150		
29	12-34	20	7.5	1.7	36	2.70	8282	821	2033	152

TABLE B1 (Cont'd) EFFLUENT BOD, TSS, TOTAL RESIN ACIDS, AND TRUE COLOR - BOD VALUES USED TO SET THE PERCENT EFFLUENT ENTERING THE EXPERIMENTAL STREAMS AND PERCENT EFFLUENT, BOD, TSS, RESIN ACIDS AND COLOR ADDITIONS TO THE STREAMS RECEIVING EFFLUENT

DATE	Effl. BOD mg/L Act. Range	Effl. BOD mg/L Used to set	Added Prct. Effl.	Added BOD mg/L	EFFLUENT TSS (mg/L) Total	EFFLUENT TSS (mg/L) Added	EFFLUENT RESIN ACIDS (ug/L) Total	EFFLUENT RESIN ACIDS (ug/L) Added	EFFLUENT COLOR ClPt (mg/L) Total	EFFLUENT COLOR ClPt (mg/L) Added
1978										
Sept.										
5	13-23	13	11.5	2.1	18	2.08	8092	934		
12	11-19	15	10.0	1.5	3	0.30	8126	809	2125	212
19	8-2	18	8.3	1.2	28	2.30	3644	440		
26	13-18	13	11.5	1.8	15	1.73	5305	419	2025	234
Oct.										
3	11-13	15	10.0	1.2	25	2.50	1940	194		
10	12-17	11	13.6	2.0	17	2.31	713	97	1975	268
17	10-14	12	12.5	1.5	16	2.00				
24	9-21	12	12.5	2.2	7	0.88	382	48	2175	272
31	13-17	14	10.7	1.6	13	1.39	252	27		
Nov.										
7	15-20	16	9.4	1.6	17	1.59	251	23	1300	122
14	11-14	15	10.0	1.2	7	0.70	840	84	1875	216
21	10-13	13	11.5	1.3	3	0.35	606	70		
28	7-23	10	15.0	2.3	10	1.50	585	88	1925	289
Dec.										
5	12-18	14	10.7	1.6	16	1.71				
12	10-17	15	10.0	1.4	29	2.90	123	12	1875	188
19	12-29	Pump broken			42		Pump broken			
26	8-14	14	10.7	1.2	17	1.82	147	16		

TABLE B1 (Cont'd)

EFFLUENT BOD, TSS, TOTAL RESIN ACIDS, AND TRUE COLOR - BOD VALUES USED TO SET THE PERCENT EFFLUENT ENTERING THE EXPERIMENTAL STREAMS AND PERCENT EFFLUENT, BOD, TSS, RESIN ACIDS AND COLOR ADDITIONS TO THE STREAMS RECEIVING EFFLUENT

DATE	Effl.BOD mg/L Act. Range	Effl.BOD mg/L Used to set	Added Prct. Effl.	Added BOD mg/L	EFFLUENT TSS (mg/L) Total	EFFLUENT TSS (mg/L) Added	EFFLUENT RESIN ACIDS (µg/L) Total	EFFLUENT RESIN ACIDS (µg/L) Added	EFFLUENT COLOR ClPt (mg/L) Total	EFFLUENT COLOR ClPt (mg/L) Added
1979										
JANUARY										
2	10-12	10	15.0	1.7	27	4.05	1347	202		
9	18-24	12	12.5	1.6	20	2.50	100092	1262		
16	15-25	50	3.0	0.6	70	2.10	12631	378		
23	24-30	50	3.0	0.8	57	1.71	8092	240		
30	27-32	50	3.0	0.9	46	1.38	6174	185		
FEBRUARY										
6	22-29	50	3.0	0.8	49	1.47	2235	67		
13	13-26	50	3.0	0.8	26	0.78	1454	43		
20	13-18	13	11.5	1.8	23	2.65	994	114		
27	12-16	14	10.7	1.5	7	1.70	859	92		
MARCH										
6	8-11	10	15.0	1.6	10	1.5	333	50		
13	11	11	13.6	1.5	16	2.18	205	29		
20	11-13	12	12.5	1.5	24	3.00	163	21		

TABLE B1 (Cont'd)

EFFLUENT BOD, TSS, TOTAL RESIN ACIDS, AND TRUE COLOR - BOD VALUES USED TO SET THE PERCENT EFFLUENT ENTERING THE EXPERIMENTAL STREAMS AND PERCENT EFFLUENT, BOD, TSS, RESIN ACIDS AND COLOR ADDITIONS TO THE STREAMS RECEIVING EFFLUENT

DATE	Effl.BOD mg/L Act. Range	Effl.BOD mg/L Used to set	Added Prct. Effl.	Added BOD mg/L	EFFLUENT TSS (mg/L) Total	EFFLUENT TSS (mg/L) Added	EFFLUENT RESIN ACIDS (µg/L) Total	EFFLUENT RESIN ACIDS (µg/L) Added	EFFLUENT COLOR ClPt (mg/L) Total	EFFLUENT COLOR ClPt (mg/L) Added
1979										
MARCH										
27	10-12	11	13.6	1.5	28	3.82	111	15.6		
APRIL										
3	12-17	16	9.4	1.4	46	4.31	102	9.4		
10	12-15	12	12.5	1.7	24	3.00	99	11.6		
17	13-15	14	10.7	1.5	17	1.82	124	13.1		
							162	16	1950	209
24	10-21	18	8.3	1.3	21	1.75	158	12.9		
							71	5.2		
MAY										
1	10-15	11	13.6	1.7	6	0.82	57	7.9	1825	249
8	17-38	29	6.3	1.7	27	1.69	1086	68.2	1800	64
15	31-42	42	3.6	1.3	53	1.89				
22	21-46	34	4.4	1.5	61	2.69	376	16.4	1825	80
29	15-31	17	8.8	2.0	49	1.59				
JUNE										
5	6-12	10	15.0	1.4	2	0.30	300	44.9	1850	278
12	9-22	10	15.0	2.3	19	2.85	252	38	2225	334
19	20-27	20	7.5	1.8	35	2.63	1328	99.5		
26	26-32	26	5.8	1.7	14	0.81	1338	77.5	2175	126
							3043	178		

TABLE B1 (Cont'd)

EFFLUENT BOD, TSS, TOTAL RESIN ACIDS, AND TRUE COLOR - BOD VALUES USED TO SET THE PERCENT EFFLUENT ENTERING THE EXPERIMENTAL STREAMS AND PERCENT EFFLUENT, BOD, TSS, RESIN ACIDS AND COLOR ADDITIONS TO THE STREAMS RECEIVING EFFLUENT

DATE	Effl.BOD mg/L		Added		EFFLUENT TSS (mg/L)		EFFLUENT RESIN ACIDS (μg/L)		EFFLUENT COLOR ClPt (mg/L)	
	Act. Range	Used to set	Prct. Effl.	BOD mg/L	Total	Added	Total	Added	Total	Added
1979										
JULY										
2	18-35	30	5	1.32	28	1.4	3520	176.0		
11	11-30	35	4.3	1.88	31	1.33	2712	116.6		
18	19-28	30	5	1.17	37	1.8	2725	136.2		
25	17-25	28	7.5	1.58	30	2.3	No sample			
AUGUST										
1	11-19	15	10.8	1.5	17	1.7	1487	148.7		
7	10-17	12	12.5	1.69	34	4.3	1569	196.1		
14	7-37	12	12.5	2.75	17	2.1	1080	135.0		
21	8-13	15	10	1	17	1.7	1306	130.6		
28	7-27	10	15	2.55	33	4.9	929	139.3		
SEPTEMBER										
4	18-27	11	13.6	3.06	26	3.5	3353	456.0		
11	7-20	15	10.0	1.35	9	.9	1671	167.1		
18	18-24	20	7.5	1.57	25	1.8			2600	195
25	12-24	18	8.3	1.49	40	3.3	3490	289.6		
							2489			
OCTOBER										
2	18-26	17	8.8	1.93	20	1.7	2641	232.4	2300	202.4
9	14-23	20	7.5	1.39	21	1.6	2468	185.1		
16	17-23	14	10.7	2.14	21	2.2	2923	312.7	2075	222
23	16-26	20	7.5	1.58	29	2.2	3088	231.6		
30	21-36	22	6.8	1.94	31	2.1	2066	240.4		

TABLE B1 (Cont'd)

EFFLUENT BOD, TSS, TOTAL RESIN ACIDS, AND TRUE COLOR - BOD VALUES USED TO SET THE PERCENT EFFLUENT ENTERING THE EXPERIMENTAL STREAMS AND PERCENT EFFLUENT, BOD, TSS, RESIN ACIDS AND COLOR ADDITIONS TO THE STREAMS RECEIVING EFFLUENT

DATE	Effl.BOD mg/L Act. Range	Effl.BOD mg/L Used to set	Added Prct. Effl.	Added BOD mg/L	EFFLUENT TSS (mg/L) Total	EFFLUENT TSS (mg/L) Added	EFFLUENT RESIN ACIDS (μg/L) Total	EFFLUENT RESIN ACIDS (μg/L) Added	EFFLUENT COLOR ClPt (mg/L) Total	EFFLUENT COLOR ClPt (mg/L) Added
1979										
NOVEMBER										
6	19-36	22	6.8	1.87	29	1.9	1656	112.6	2070	140.7
13	10-17	25	7.1	.95	38	2.6	1139	80.8		
20	12-13	15	10	1.25	25	2.5	764	76.4	1850	185
27	9-21	12	13.8	1.95	23	2.9	451	58.6		
DECEMBER										
4	14-20	15	10	1.7	22	2.2	188	18.8	1825	182.5
11	16-21	17	8.8	1.63	31	2.7	186	16.3		
18	12-21	17	8.8	1.45	12	1.0	118	10.3	2025	178.2
25	15	15	10	1.5	22	2.0				
1980										
JANUARY										
1	5-12	11	13.6	1.16	9	1.2	134	18.2	2650	360.4
8	8-10	20	7.5	.68	44	3.3	209	15.6		
15	11-16	10	15.0	2.03	18	2.7	341	51.6		
22	17-21	20	7.5	1.43	23	1.7	661	49.5	1750	131.2
29	10-22	20	7.5	1.2	23	1.7	737	55.2	1725	129.3
FEBRUARY										
5	22-32	22	6.8	1.84	25	1.7	1208	82.1	1760	119.6
12	29-39	20	7.5	2.6	23	1.7	1254	94.0	1900	142.5
19	24-29	21	7.1	1.88	23	1.6	655	46.5	1850	131.3
26	29-37	28	5.4	1.78	78	4.2	527	28.4		

TABLE B1 (Cont'd)

EFFLUENT BOD, TSS, TOTAL RESIN ACIDS, AND TRUE COLOR - BOD VALUES USED TO SET THE PERCENT EFFLUENT ENTERING THE EXPERIMENTAL STREAMS AND PERCENT EFFLUENT, BOD, TSS, RESIN ACIDS AND COLOR ADDITIONS TO THE STREAMS RECEIVING EFFLUENT

DATE	Effl.BOD mg/L Act. Range	Effl.BOD mg/L Used to set	Added Prct. Effl.	Added BOD mg/L	EFFLUENT TSS (mg/L) Total	EFFLUENT TSS (mg/L) Added	EFFLUENT RESIN ACIDS (μg/L) Total	EFFLUENT RESIN ACIDS (μg/L) Added	EFFLUENT COLOR ClPt (mg/L) Total	EFFLUENT COLOR ClPt (mg/L) Added
1980										
MARCH										
5	31-35	30	5	1.65	55	2.7	586	29.3	2200	110.0
11	29-37	30	5	1.65	19	.95	289	14.4	2075	103.7
18	25-32	30	5	1.43	38	1.9	183	9.1		
25	28-33	30	5	1.53	29	1.4	215	10.7	2200	110.0
APRIL										
1	27-33	30	5.0	1.50	24	1.1	585	27.4		
8	28-45	30	5.0	1.82	59	2.9	817	40.8	1775	88.7
15	33-52	30	5.0	2.12	66	3.3	1135	56.7		
22	30-47	33	4.5	1.73	37	1.6	1005	45.2	2350	105.7
29	20-37	30	5.0	1.42	30	1.5	585	29.3		
MAY										
6	19-29	20	7.5	1.8	14	1.0	346	25.9		
13	16-26	19	7.9	1.66	13	1.0	200	15.8		
20	10-19	23	6.9	1.0	32	2.2	94	6.5	2350	162.1
27	10-16	16	9.4	1.22	11	1.0	299	28.1		
JUNE										
3	4-18	10	15.0	1.65	13	1.95	412	61.8	2300	345.0
10	6-23	11	13.6	1.97	23	3.1	293	39.8	2350	319.6
17	4-7	12	12.5	.69	4	.5	306	38.2		
24	4-8	10	15.0	.9	5	.8	268	40.2	2025	303.7
30	14-18	10	15.0	2.4	16	2.4	332	49.8	2175	326.0

TABLE B1 (Cont'd) EFFLUENT BOD, TSS, TOTAL RESIN ACIDS, AND TRUE COLOR - BOD VALUES USED TO SET THE PERCENT EFFLUENT ENTERING THE EXPERIMENTAL STREAMS AND PERCENT EFFLUENT, BOD, TSS, RESIN ACIDS AND COLOR ADDITIONS TO THE STREAMS RECEIVING EFFLUENT

DATE	Effl. BOD mg/L Act. Range	Effl. BOD mg/L Used to set	Added Prct. Effl.	Added BOD mg/L	EFFLUENT TSS (mg/L) Total	EFFLUENT TSS (mg/L) Added	EFFLUENT RESIN ACIDS (µg/L) Total	EFFLUENT RESIN ACIDS (µg/L) Added	EFFLUENT COLOR ClPt (mg/L) Total	EFFLUENT COLOR ClPt (mg/L) Added
1980										
JULY										
7	11-27	10	15.0	2.85	17	2.5	481	72.2		
14	10-17	10	15.0	2.1	18	2.7	412	61.8		
SEPTEMBER										
22	6-12	10	15	1.35	10	1.5	255	38.2		
29	7-10	10	15	1.28	14	2.1	224	33.6		
OCTOBER										
6	7-9	11	18	1.44	10	1.8	139	25.0		
13	8-14	11	18	1.98	9	1.7	134	24.1	2208	331.2
20	16-19	13	15	2.62	23	3.5	185	27.7		
27	15-19	15	13	2.21	24	3.1	199	25.8	2800	364
NOVEMBER										
3	11-16	20	10	1.35	26	2.6	189	18.9	2450	245
10	12-15	15	13	1.75	16	2.1	126	16.3	2275	295.8
17	5-11	15	13	1.04	17	2.2	68	8.8	2025	263.3
24	6-10	15	13	1.04	11	1.4	31	4.0	1950	253.5
DECEMBER										
1	9-11	15	13	1.3	20	2.6	32	4.1	2375	308.8
8	11-14	13	15	1.8	18	2.3	36	5.4		
15	9-15	14	17	2.04	13	1.8	62	10.5		
22	11-12	10	20	2.3	20	2	104	20.8		
29	7-11	10	20	1.8	29	3	112	22.4		

TABLE B1 (Cont'd)

EFFLUENT BOD, TSS, TOTAL RESIN ACIDS, AND TRUE COLOR - BOD VALUES USED TO SET THE PERCENT EFFLUENT ENTERING THE EXPERIMENTAL STREAMS AND PERCENT EFFLUENT, BOD, TSS, RESIN ACIDS AND COLOR ADDITIONS TO THE STREAMS RECEIVING EFFLUENT

DATE	Effl. BOD mg/L Act. Range	Effl. BOD mg/L Used to set	Added Prct. Effl.	Added BOD mg/L	EFFLUENT TSS (mg/L) Total	EFFLUENT TSS (mg/L) Added	EFFLUENT RESIN ACIDS (μg/L) Total	EFFLUENT RESIN ACIDS (μg/L) Added	EFFLUENT COLOR ClPt (mg/L) Total	EFFLUENT COLOR ClPt (mg/L) Added
1981										
JANUARY										
5	10-18	11	18	2.52	13	2.3	122	21.9	2175	391.5
12	22-31	11	18	4.77	34	6.1	282	50.7		
19	35-39	18	6	2.22	40	2.4	1885	113.1	2350	141
26	23-47	18	6	2.1	43	2.6	2395	143.7		
FEBRUARY										
2	16-29				22	Pipe broke				
9	16-18	16	12	2.04	27	3.2	416	49.9	1950	234
16	12-20	20	10	1.6	28	3.0	277	27.7		
23	19-26	5	4	0.9	22	0.9			2225	89
MARCH										
2	24-40	50	4	1.28	39	2.0	669	26.7		
9	32-44	50	4	1.52	27	2.0	883	35.3		
16	13-29	50	4	.84	57	2.3	920	36.8		
23	12-26	50	4	.76	19	1.0	517	20.7	1900	76
30	9-12	50	4	.42	13	1.0	174	6.9		
APRIL										
6	8-11	15	12.5	1.18	16	2.00	109	13.6	2200	275
13	9-12	10	20	2.1	25	5	123	24.6	1975	395
20	7-12	10	20	1.9	27	5.4	81	16.2	1575	315
27	10-30	10	20	4	17	3.4	91	18.2	1925	385

TABLE B1 (Cont'd) EFFLUENT BOD, TSS, TOTAL RESIN ACIDS, AND TRUE COLOR - BOD VALUES USED TO SET THE PERCENT EFFLUENT ENTERING THE EXPERIMENTAL STREAMS AND PERCENT EFFLUENT, BOD, TSS, RESIN ACIDS AND COLOR ADDITIONS TO THE STREAMS RECEIVING EFFLUENT

DATE	Effl. BOD mg/L Act. Range	Effl. BOD mg/L Used to set	Added Prct. Effl.	Added BOD mg/L	EFFLUENT TSS (mg/L) Total	EFFLUENT TSS (mg/L) Added	EFFLUENT RESIN ACIDS (µg/L) Total	EFFLUENT RESIN ACIDS (µg/L) Added	EFFLUENT COLOR ClPt (mg/L) Total	EFFLUENT COLOR ClPt (mg/L) Added
1981										
MAY										
4	31-48	10	20	7.9	49	9.8	158	31.6	2400	480
11	20-33	30	4	1.06	28	1.1	147	5.8		
18	29-32	23	8.4	2.6	24	2.02	101	8.5		
25	12-19	30	6.5	1.00	36	2.34	97	6.3		
JUNE										
1	13-14	14	14.3	1.93	32	4.58	108	15.4	2250	321.8
8	7-18	14	14	1.75	15	2.1	50	7	1750	245
15	20-72	14	14	6.44	38	5.3	167	23.4	1550	217
22	27-47	30	7	2.59	52	3.6	1541	107.8	1825	127.8
29	24-28	30	5	1.3	18	1.0	6885	344.3		
JULY										
6	12-21	40	5	1.83	26	1.3	924	46.2		
13	20-27	12	18	4.23	26	4.7	461	82.9		
20	9-18	Effluent Shut Off for Clean Up								
27	15-15									

TABLE B1 (Cont'd) EFFLUENT BOD, TSS, TOTAL RESIN ACIDS, AND TRUE COLOR - BOD VALUES USED TO SET THE PERCENT EFFLUENT ENTERING THE EXPERIMENTAL STREAMS AND PERCENT EFFLUENT, BOD, TSS, RESIN ACIDS AND COLOR ADDITIONS TO THE STREAMS RECEIVING EFFLUENT

DATE	Effl.BOD mg/L Act. Range	Effl.BOD mg/L Used to set	Added Prct. Effl.	Added BOD mg/L	EFFLUENT TSS (mg/L) Total	EFFLUENT TSS (mg/L) Added	EFFLUENT RESIN ACIDS (ug/L) Total	EFFLUENT RESIN ACIDS (ug/L) Added	EFFLUENT COLOR ClPt (mg/L) Total	EFFLUENT COLOR ClPt (mg/L) Added
1981										
Aug.										
4	14-20	15	17	2.9	24	4.1	88	14.9		
11	16-19	15	17	3.0	32	5.4	80	13.7		
18	16-19	15	17	3.0	35	6.0	68	11.5		
25	12-20	15	17	2.7	26	4.4	43	7.3		
Sept.										
1	6-10	15	17	1.4	18	3.1	51	8.7	1725	293
8	24-27	14	18	4.6	36	6.5	248	44.6		
15	15-24	25	10	2.0	29	2.9	155	15.5	2175	218
22	5-8	16	16	1.0	17	2.7	71	11.3		
29	15-30	16	16	3.6	26	4.2	351	56.2		
Oct.										
5	36-40	16	16	6.1	33	5.3	619	99.0		
12	31-43	30	8	3.0	32	2.6	828	66.2		
19	20-23	30	8	1.7	31	2.5	1351	108.1		
26	21-25	30	8	1.8	29	2.3	2341	187.3		
Nov.										
2	15-21	20	12.5	2.3	26	3.2	2257	282.1		
9	12-20	20	12.5	1.9	28	3.5	1646	205.8		
16	7-9	17	15	1.2	24	3.6	674	101.1		
23	10	12	20	2.0	28	5.6	196	39.1		
30	9-10	10	20	2.0	18	3.6	470	93.9		

TABLE B1 (Cont'd)

EFFLUENT BOD, TSS, TOTAL RESIN ACIDS, AND TRUE COLOR - BOD VALUES USED TO SET THE PERCENT EFFLUENT ENTERING THE EXPERIMENTAL STREAMS AND PERCENT EFFLUENT, BOD, TSS, RESIN ACIDS AND COLOR ADDITIONS TO THE STREAMS RECEIVING EFFLUENT

DATE	Effl. BOD mg/L Act. Range	Effl. BOD mg/L Used to set	Added Prct. Effl.	Added BOD mg/L	EFFLUENT TSS (mg/L) Total	EFFLUENT TSS (mg/L) Added	EFFLUENT RESIN ACIDS (ug/L) Total	EFFLUENT RESIN ACIDS (ug/L) Added	EFFLUENT COLOR ClPt (mg/L) Total	EFFLUENT COLOR ClPt (mg/L) Added
1981										
Dec.										
7	10-14	10	20	2.4	27	5.4	384	76.8		
14	10-16	10	20	2.6	36	7.2	546	109.2		
21	13-17	10	20	3.0	30	6.0	No sample			
28	10-13	12	20	2.3	34	6.8	656	131.2		
1982										
Jan.										
4	8-14	12	20	2.2	38	7.6	615	123.0		
11	19-34	12	20	5.3	39	7.8	736	147.1		
18	32-59	35	7	3.2	56	3.9	4666	326.6	1475	103
25	60-72	35	7	4.6	70	4.9	5430	380.1		
Feb.										
1	56-75	35	7	4.6	88	6.2	4540	317.8		
8	41-50	35	7	3.2	62	4.3	3286	230.0		
15	28-41	35	7	2.4	27	1.9	2033	142.3		
22	24-27	35	7	1.8	28	2.0	1784	124.9	1800	126
Mar.										
1	16-22	25	10	1.9	26	2.6	1568	156.8		
8	13-18	20	12.5	1.9	17	2.1	1158	144.7		
15	15-20	12	20	3.5	26	5.2	642	128.4		
22	21-23	20	12.5	2.8	34	4.2	525	65.6		
29	18-23	20	12.5	2.6	38	4.8	470	58.7		

TABLE B1 (Cont'd)

EFFLUENT BOD, TSS, TOTAL RESIN ACIDS, AND TRUE COLOR - BOD VALUES USED TO SET THE PERCENT EFFLUENT ENTERING THE EXPERIMENTAL STREAMS AND PERCENT EFFLUENT, BOD, TSS, RESIN ACIDS AND COLOR ADDITIONS TO THE STREAMS RECEIVING EFFLUENT

	Effl.BOD mg/L		Added		EFFLUENT TSS (mg/L)		EFFLUENT RESIN ACIDS (ug/L)		EFFLUENT COLOR ClPt (mg/L)	
DATE	Act. Range	Used to set	Prct. Effl.	BOD mg/L	Total	Added	Total	Added	Total	Added
1982										
APRIL										
5	21-26	20	12.5	2.9	76	9.5	535	66.9		
12	13-23	25	10	1.8	42	4.2	337	33.7		
19	9-13	15	17	1.9	28	4.8	296	50.3	1675	251
26	7-10	10	20	1.7	18	3.6	202	40.3	1600	320
MAY										
3	6-10	10	20	1.6	12	2.4	38	7.6		
10	6-9	10	20	1.5	14	2.8	230	46.0		
17	11-13	10	20	2.4	26	5.2	468	93.6	1775	355
24	8-11	10	20	1.9	24	4.8	326	65.1		
31	11-13	10	20	2.4	21	4.2	262	52.5	1950	390
JUNE										
7	15-27	10	20	4.2	22	4.4	309	61.8		
14	8-15	20	12.5	1.4	16	2.0	207	25.9		
21	6-18	12	20	2.4	18	3.6	122	24.4		
28	5-11	10	20	1.6	14	2.8	42	8.4	1875	375
JULY										
5	2-3	10	20	0.5	8	1.6	94	18.8		
12	7-12	10	20	1.9	6	1.2	117	23.4		

APPENDIX C

SHORT TERM BIOASSAY RESULTS

APPENDIX C

TABLE C1 96 HR STATIC BIOASSAY RESULTS OF FISH EXPOSED TO BIOLOGICAL STABILIZED EFFLUENT
LB = LARGEMOUTH BASS, BG = BLUEGILL SUNFISH, GS = GOLDEN SHINER, AND MF = MOSQUITO FISH

DATE	SPECIES	96 HR LC_{50} (% by volume)	DATE	SPECIES	96 HR LC_{50} (% by volume)
6/10/75	LB	100	7/18/77	LB	100
7/15/75	BG	100	8/15/77	BG	100
8/11/75	BG	100	9/19/77	BG	100
9/08/75	BG	100	10/17/77	BG	100
10/13/75	BG	100	11/14/77	GS	100
11/11/75	MF	100	12/19/77	GS	100
12/15/75	MF	100	1/16/78	GS	100
1/12/76	MF	100	2/20/78	GS	100
2/15/76	MF	100	3/20/78	GS	100
3/15/76	MF	100	4/17/78	GS	100
4/12/76	MF	100	5/13/78	GS	100
5/15/76	LB	100	8/08/78	LB	100
7/12/76	LB	100	9/14/78	GS	100
8/09/76	BG	100	10/30/78	GS	100
9/13/76	BG	100	11/14/78	LB	100
10/11/76	BG	100	12/15/78	LB	100
11/15/76	MS	100	1/09/79	LB	50
12/13/76	MS	100	1/24/79	GS	33
11/10/77	GS	100	2/19/79	GS	100
2/14/77	GS	100	3/12/79	GS	100
3/14/77	GS	100	4/16/79	GS	100
4/11/77	GS	100			
5/16/77	GS	100			