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Validity of Effluent and Ambient Toxicity Tests for Predicting Biological Impact, Naugatuck River, Waterbury, Connecticut

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Validity of Effluent and Ambient Toxicity Tests for Predicting Biological Impact, Naugatuck River, Waterbury, Connecticut

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Foreword

The Complex Effluent Toxicity Testing Program was initiated to support the developing trend toward water quality-based toxicity control in the National Pollutant Discharge Elimination System (NPDES) permit program. It is designed to investigate, under actual discharge situations, the appropriateness and utility of "whole effluent toxicity" testing in the identification, analysis, and control of adverse water quality impact caused by the discharge of toxic effluents.

The four objectives of the Complex Effluent Testing Program are:

1. To investigate the validity of effluent toxicity tests in predicting adverse impact on receiving waters caused by the discharge of toxic effluents.
2. To determine appropriate testing procedures which will support regulatory agencies as they begin to establish water quality-based toxicity control programs.
3. To provide practical case examples of how such testing procedures can be applied to effluents discharged into a receiving water.
4. To field test short-term chronic toxicity tests including the test organisms, *Ceriodaphnia* sp.[a] and *Pimephales promelas*.

Until recently, NPDES permitting has focused on achieving technology-based control levels for toxic and conventional pollutants in which regulatory authorities set permit limits on the basis of national guidelines. Control levels reflected the best treatment technology available, considering technical and economic achievability. Such limits did not, nor were they designed to protect water quality on a site-specific basis.

The NPDES permits program, in existence for over 10 years, has achieved the goal of implementing technology-based controls. With these controls largely in place, future controls for toxic pollutants will, of necessity, be based on site-specific water quality considerations.

Setting water quality-based controls for toxicity can be accomplished in two ways. The first is the pollutant-specific approach which involves setting limits for single chemicals, based on laboratory-derived no-effect levels. The second is the "whole effluent" approach which involves setting limits using effluent toxicity as a control parameter. There are advantages and disadvantages to both approaches.

The "whole effluent" approach eliminates the need to specify a limit for each of thousands of substances that may be found in an effluent. It also includes all interactions between constituents as well as biological availability.

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[a] The species of *Ceriodaphnia used for this study is not known with certainty The stocks were thought to be C* reticulata but, in November 1983, based on taxonomic verification by Dorothy Berner Ph D. (Temple University, Pa.), a second species, *C. dubia* was also discovered in the stock cultures The exact determination of the species tested is not critical to this study, and all reference is to the genus in this report

This report presents the site study on the Naugatuck River, Waterbury, Connecticut, which was conducted in August 1983. The Naugatuck River receives industrial discharges from tributaries and direct discharges from publicly owned treatment works.

To date, eight sites involving municipal and industrial dischargers have been investigated. They are, in order of investigation:

1. Scippo Creek, Circleville, Ohio
2. Ottawa River, Lima, Ohio
3. Five Mile Creek, Birmingham, Alabama
4. Skeleton Creek, Enid, Oklahoma
5. Naugatuck River, Waterbury, Connecticut
6. Back River, Baltimore Harbor, Maryland
7. Ohio River, Wheeling, West Virginia
8. Kanawha River, Charleston, West Virginia

This project is a research effort only and has not involved either NPDES permit issuance or enforcement activities.

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Acknowledgments

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COMPARISON OF LABORATORY TOXICITY DATA AND RECEIVING WATER BIOLOGICAL IMPACT
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Executive Summary

This report presents part of a larger study conducted on the Naugatuck River, Connecticut, August 1983. In addition to the studies described here, there is another report describing efforts to model the toxicity as BOD is modeled (DiToro and Hallden, 1985) and a site-specific single chemical criterion study (Carlson et al., 1986).

The major purpose of the study described here was to compare the relationship between measured toxicity of water samples collected from the Naugatuck River and the health of the aquatic community at the same locations where samples were collected. Because the river changed in size and character through the study area, habitat changes made the determination of toxicity effects on the stream community more difficult. Periphyton, benthos and fish species all showed a trend of reduced species richness from headwaters to mouth. The *Ceriodaphnia* and fathead minnow toxicity data show a similar trend. The zooplankton taxa did not follow an upstream downstream pattern. An impoundment and the large difference in stream size between N-1 and N-12 may account for part of the difference.

The effluent dilution tests were not performed in a manner that they could be used to predict impact because they were to be used for a mass balance model of toxicity and the needs for that purpose were different. When toxicity and species richness were converted to normalized percent values and compared at four levels of impairment, up to 85% correct predictions were achieved. Significant correlations ($P \leq 0.05$) were obtained with the *Ceriodaphnia* data and the periphyton, macroinvertebrate, and fish species richness.

Even though a number of factors such as stream size and gradient changed through the study area, there were significant correlations of the field impact and toxicity data.

Quality Assurance

Coordination of the various studies was completed by the principal investigator preceding and during the onsite work. A reconnaissance trip was made to the site before the study and necessary details regarding transfer of samples, specific sampling sites, dates of collections, and measurements to be made on each sample were delineated. The evening before the study began, a meeting was held onsite to clarify again specific responsibilities and make last minute adjustments in schedules and measurements. The mobile laboratory was established as the center for resolving problems and adjusting of work schedules as delays or weather affected the completion of the study plans. The prinicipal investigator was responsible for all Quality Assurance-related decisions onsite.

All instruments were calibrated by the methods specified by the manufacturers. For sampling and toxicity testing, the protocols described in the referenced published reports were followed. Where identical measurements were made in the field and laboratory, both instruments were cross-calibrated for consistency.

1. *Introduction*

The focus of water pollution control in the National Pollutant Discharge Elimination System (NPDES) permits program has been on the attainment of national technology requirements and the implementation of water quality criteria for the 129 priority pollutants. However, implementation of these standards and criteria does not always guarantee that certain dischargers will not cause adverse effects to receiving waters. Industrial and municipal effluents often contain large numbers of potentially toxic pollutants which can move through treatment systems virtually unaltered. Often these are pollutants for which little or no toxicity data exist. Further complications arise from the potential interaction of combinations of pollutants to increase or decrease toxicity.

Future activities in water pollution control will focus on the control of toxic pollutants which impact water quality. There are two methods used in controlling toxic impact: pollutant-specific controls and whole effluent toxicity-based controls. Because toxicity testing evaluates a living organism's response, it has an advantage over chemical-specific analyses which may not identify all pollutants in a wastewater sample and which cannot detect toxicity interactions. Toxicity information can indicate the need for additional characterization of an effluent and can also provide a basis for permit limits based on state water quality standards for toxicity- or technology-based requirements.

The primary purpose of this study is to investigate the relationship between ambient toxicity data and ecological response and to attempt a mass balance model of toxicity.

This report is organized into sections corresponding to the project tasks. An Executive Summary is presented after the Foreword as a brief overview of the major findings of this study. Following a description of the study design and a summary of the site, the chapters are arranged into toxicity testing, hydrology, ecological surveys for the study period, and an integration of the laboratory and field studies. Additional laboratory methods and support data are included in the appendixes.

2. *Study Design*

The primary purpose of this study was to investigate the ability of laboratory effluent toxicity tests to predict ambient stream toxicity impacts at a multiple discharge site on a medium-size river system. The site chosen for study was the Naugatuck River from Torrington to Ansonia, Connecticut. The study area included multiple discharges: several industrial dischargers on each of four tributaries and four major publicly owned treatment works (POTWs) located on the mainstem. A more complete description of the study area is in Chapter 3. This study required laboratory tests to measure expected effluent dilutions that would be safe for chronic exposure. In conjunction with these toxicity tests, ecological surveys of the Naugatuck River and its tributaries were conducted to identify structural effects to representative biotic communities and selected populations from point source discharges. Hydrological analyses included effluent configuration studies to define mixing characteristics of some of the effluents. Frequent flow measurements were taken at selected locations along the river to estimate effluent concentrations and to provide support data for mass balance calculations. The results from all of these study components were then integrated.

The study was conducted from 23 through 30 August 1983. The methods used in the study are detailed in Appendixes A, B, C, and D. Support toxicological and biological data are included in Appendixes E, F, and G.

2.1 Toxicity Tests

Toxicity tests were performed both onsite and at a remote laboratory. The objectives of these tests were to measure the Acceptable Effluent Concentration (AEC) of effluents or tributaries and the toxicity of undiluted ambient river samples.

For the onsite tests, both the 7-day fathead minnow larval growth test and the 7-day *Ceriodaphnia* reproduction test were used (Chapter 4). For the fathead minnow tests, 24-hour composite samples were taken of effluent and ambient samples and the test animals exposed for 24 hours. Then a new 24-hour composite was used for the renewal.

For the *Ceriodaphnia* tests, similar types of ambient tests were done using the same samples as for the fathead minnow tests. These were called "impact" type tests. In addition, another type, named "mass-balance" type tests, were done for a mass-balance toxicity model. In these tests, each sample was kept at 4°C and used to renew the test solutions which were changed only at the end of days 2 and 4 and were not changed daily. Thus, there were 7 separate chronic tests, each completed on a different 24-hour composite sample for each effluent or ambient station tested.

In the offsite testing, only *Ceriodaphnia* tests on effluents were done, i.e., no ambient tests were attempted (Chapter 5). An aliquot of the daily 24-hour composite effluent sample was shipped to the remote laboratory in Baltimore by air freight. Mass-balance type tests were done to establish the AEC for each effluent or tributary tested.

2.2 Field Survey

The field survey included quantitative assessment of the periphytic, zooplanktonic, benthic macroinvertebrate, and fish communities. The periphyton study measured chlorophyll *a* and biomass and estimated species composition and relative abundance (Chapter 7). The relatively short reproduction time and rapid seasonal fluctuations in growth make the periphytic algae community indicative of recent exposure conditions.

In contrast to the more sedentary periphytic and benthic communities, planktonic communities in lotic systems drift downstream and do not necessarily reflect exposure at the collection site. Crustacean zooplankton populations were measured and used as an indicator of planktonic community response (Chapter 8).

The benthic survey investigated ambient community response above and below the discharges (Chapter 9). The benthic community, measured by the methods used in this report, is less mobile than other community groups, such as fish, and is considered an indicator of longer term water quality trends.

The fish survey measured the fish species present and their relative abundance to discern any community changes from previous surveys or upstream and downstream of the discharges (Chapter 10).

Hydrological measurements were conducted using dye studies at each of three sites to identify the individual dilution characteristics of these effluents

(Chapter 6). By modeling downstream dilution contours for each discharge, the exposure concentrations at various ambient stations could then be established. Ancillary flow measurements were also taken to estimate the flow contribution of the discharges to the receiving waterbody.

2.3 Approach to Integration of Laboratory and Field Data

The data from the ambient toxicity tests is compared to the species richness at the ambient stations. Some rationale for selecting species richness as well as the comparisons is given.

3. *Site Description*

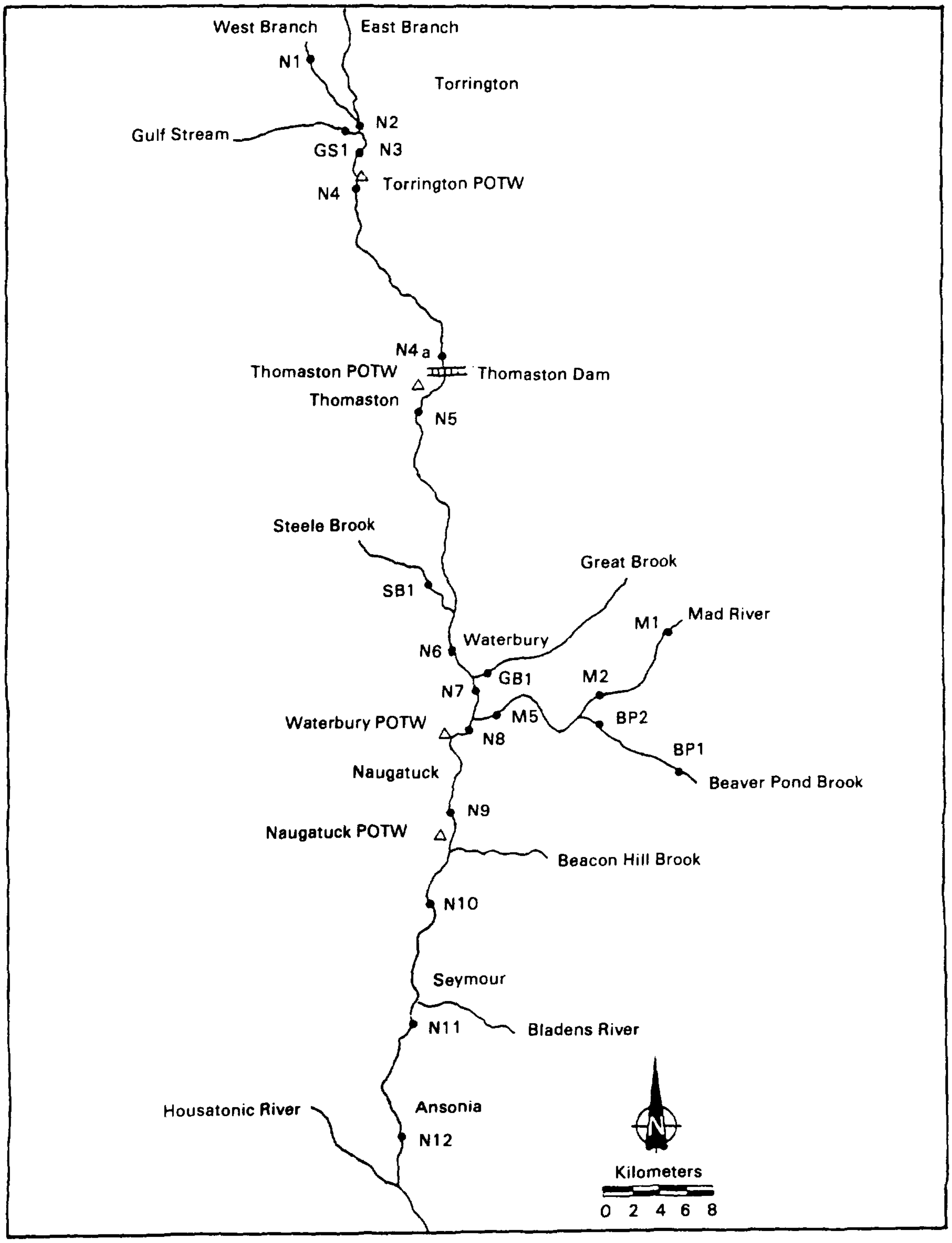
The study area on the Naugatuck River incorporated 60 km of the river and its tributaries extending from Torrington to Ansonia, Connecticut. Twelve main-stem river stations and eight tributary stations were established for sampling and testing (Table 3-1). The Naugatuck River above Torrington was approximately 15-20 m wide and less than 0.5 m deep during the study period. River flow measured in this area was approximately 0.05 m^3/sec. Downriver, near Ansonia, the Naugatuck River was approximately 100 m wide and 2-3 m deep. River flow in this area was 3-4 m^3/sec. The river was regulated in certain reaches near Thomaston, Seymour, and Ansonia (Figure 3-1). Water is impounded behind the Thomaston Dam only for flood control but there is no permanent pool maintained there.

Several publicly owned treatment works (POTWs) and privately owned industries discharge treated effluents to the Naugatuck River and its tributaries. Approximately 28 dischargers are within the study area extending from Torrington to Ansonia, Connecticut (Figure 3-1). The industries are mostly small metal refinishing facilites that discharge effluents into tributaries of the Naugatuck River (Gulf Stream, Steele Brook, Great Brook, and Mad River). Each of these tributaries was treated as a point source discharge to the Naugatuck River and samples were tested accordingly. Four major POTWs which discharge directly to the Naugatuck River were also studied. They are the Torrington, Thomaston, Waterbury, and Naugatuck POTWs. The waterbury POTW contributes the largest flow to the river, averaging 0.7 m^3/sec during the study period. The average discharges for the other POTWs were 0.2 m^3/sec for the Naugatuck POTW and less than 0.1 m^3/sec for the Torrington and Thomaston POTWs. The Mad River contributed the largest flow, averaging 0.3 m^3/sec for the study period. Steele Brook had a flow of 0.1-0.2 m^3/sec. The flows of both Gulf Stream and Great Brook were less than 0.1 m^3/sec. See Chapter 6 for a more detailed description of river flow.

Table 3-1. Naugatuck River and Tributary Station Descriptions

Station Number	River Kilometer	Station Location
N1	67.3	Rte. 4, West Fork of Naugatuck River, West of Torrington
N2	63.5	East Albert St. in Torrington, confluence of East and West Branch
N3	62.4	Palmer Bridge Rd. in Torrington
N4	59.0	Rte. 118, 0.8 to 1.6 km downstream from Torrington
N4A	50.1	0.1 km upstream from Thomaston Dam
N5	46.5	Frost Bridge in Thomaston (Benthos Station for State of Connecticut)
N6	32.5	W. Main St., 1.6 km downstream of Steel Brook (Benthos-State work)
N7	30.4	0.4 km upstream of Mad River; first bridge upstream of Washington St.
N8	28.3	0.8 km upstream of the Waterbury POTW. First bridge upstream on South Leonard St.
N9	21.9	1.6 km upstream from the Naugatuck POTW Rte. 63 bridge
N10	16.5	0.4 km upstream from USGS gauging station at Beacon Falls, Rte. 8 bridge
N11	9.5	Bridge immediately downstream from Rte. 8 in Seymour
N12	3.0	Railroad bridge 0.4 km upstream from Division St. in Ansonia (Benthos Station for State of Connecticut)
Tributaries		
GS1	62.8	Gulf Stream Bridge, 0.2 km upstream from confluence with Naugatuck River in Torrington
SB1	33.4	Steele Brook at East Aurora St. Bridge
GB1	32.9	Great Brook at confluence with Naugatuck River
M1	--	Upper reaches of Mad River at Frost Road Bridge
M2	--	Upstream of confluence of Mad River with Beaver Pond Brook at Main St. Bridge
BP1	--	Beaver Pond Brook upstream of confluence with Mad River
BP2	--	Near headwaters of Beaver Pond Brook
M5	29.9	Mad River at confluence with Naugatuck River
Location of POTWs		
Torrington	RK 61.2	
Thomaston	RK 47.5	
Waterbury	RK 27.2	
Naugatuck	RK 19.4	

Figure 3-1. Study area of the Naugatuck River.



4. Onsite Tests for Toxicity of Effluents and Receiving Water

As part of a large study to assess the biological impact of numerous discharges to the Naugatuck River, onsite toxicity tests were conducted in a mobile lab using samples collected from 23 to 30 August 1983. The major objective for the onsite testing was to measure ambient toxicity (the toxicity of water samples collected directly from the stream) to compare with the field biological test data. Effluent dilution tests require that the effluent concentrations in the stream be known in order to predict effects but this information is not necessary for the ambient tests. The sample collection and test methodologies used for both species are delineated in Appendix A.

A second major objective in this study was to gather information to enable construction of a mass balance toxicity model. Changes in the toxicity testing study design from previous sites (Mount et al. 1984, Mount et al. 1985) were required to facilitate the model. Complete 7-day chronic *Ceriodaphnia* tests on each of seven 24-hour composite samples were run rather than changing the animals into a new 24-hour composite sample every day. This procedure was defined as the "mass balance test" to distinguish it from another set of tests called the "impact tests." The latter test is when the *Ceriodaphnia* and fathead minnows are exposed to a different 24-hour composite sample each day for seven days. Thus, the mass balance tests generate seven estimates of chronic toxicity for each effluent or ambient station whereas the impact tests result in only one estimate of chronic toxicity. The mass balance tests are best used when the goal is to measure temporal variations in the toxicity of effluents and ambient stream stations, and the impact tests are best when simulating the exposure the organisms in the stream receive. There is no known way to match the results of the two tests to account for the different test exposures over their respective 7-day test periods.

Mass balance tests were conducted only with the *Ceriodaphnia*. Such tests are not very practical for fathead minnows because so many test-chambers and so much space would be required. The following summarizes the tests done:

	Ceriodaphnia		Fathead Minnow Impact
Sample	Mass Balance	Impact	
Torrington POTW	0	0	X
Waterbury POTW	0	0	X
Naugatuck POTW	0	0	X
Steele Brook	0	0	X
Mad River	0	0	X
N1	0	X	0
N2	X	0	X
N3	X	0	0
N4	X	X	X
N4A	0	X	0
N5	X	0	0
N6	X	0	X
N7	X	0	X
N8	X	0	X
N9	X	0	X
N10	X	X	X
N11	0	X	X
N12	0	X	X

Note: X = tests conducted
0 = no test conducted

All *Ceriodaphnia* effluent dilution toxicity tests were mass balance tests but were done on shipped samples by an environmental consulting laboratory offsite (Chapter 5). Aliquots of composite effluent samples were used to do impact tests (using a new composite sample each day) on the fathead minnows. The impact type fish tests were done onsite in the mobile laboratory. For the purpose of comparing the mass balance tests to biological impact in the field, the average of the seven *Ceriodaphnia* effluent tests was used but without any knowledge as to how the estimate compares to an impact-type test.

Two of the tributaries, i.e., Steele Brook and Mad River, had several dischargers on each. These tributary waters were treated as effluents to the Naugatuck River and dilutions were made in order to estimate an AEC.

4.1 Chemical/Physical Conditions

Temperatures were maintained between 22 and 28°C for the duration of the tests. The weather was very warm during the test period and the changes observed were a result of the effects of diurnal temperatures of the outside air on the mobile lab. The routine water quality measurements included pH, DO, and conductivity. Conductivity measurements ranged from 88 to 1,150 μmhos/cm. The Naugatuck POTW effluent exhibited the highest conductivity (1,150 μmhos/cm), whereas the other POTWs and ambient stations were mostly in the range of 153-484 μmhos/cm (Tables E-1 and E-2).

Other routine chemistries such as hardness, alkalinity, and turbidity were made on each ambient station, the tributaries, and the effluents. A summary of these mean measurements is given in Table E-3. Hardness ranged from 38 to 99 mg/L as $CaCO_3$ in the ambient stations, and 82 to 392 mg/L in the effluents and tributaries. A noticeable drop in hardness measurements was observed on day 6 (rainfall increased flow), where all values for the ambients were approximately half of their previous values. Alkalinity in the ambient stations ranged from 35 to 70 mg/L. The effluents and tributaries had alkalinity measurements of 46-151 mg/L. Turbidity measurements were made daily and ranged from 0.85 to 4.7 nephlometric turbidity units (NTU) for the ambients with the highest values of N7 and N8. Both Steele Brook and Mad River had turbidity measurements of about 6, whereas the effluents ranged from 4 to 6 NTU.

Prior to the test animals being placed into the test solutions, pH and DO measurements were taken, and again daily before the test water was renewed. Values observed for pH ranged from 6.9 to 8.2 for the fathead minnow and *Ceriodaphnia* tests (Tables E-1 and E-2). The initial DO values for both the minnow and *Ceriodaphnia* tests ranged from 8.1 to 8.8 mg/L. The final mean DO values taken early in the day, prior to test solution renewal, ranged from 5.0 to 7.0 mg/L; the means and ranges are given in Tables E-1 and E-2. Some individual values in fish tests were low, as low as 1.4 mg/L. However, experience by ERL-Duluth (Mount and Norberg-King, 1986) has shown that such values do not represent the oxygen concentrations the fish are actually exposed to. The fish move to the surface and the minnows grow at a normal rate even when the DO measured values are less than 1.0 mg/L. Tables E-4 and E-5 contain final DO values for the *Ceriodaphnia* tests. All values are in the acceptable range.

Effluent and ambient stream samples were composite samples with sampling done every 15 minutes. Stations N6 and N7 were composite samples collected manually every 4 hours. Due to vandalism, the following samples were collected as grab samples on the indicated sampling days: Station N1 was a daily grab, Station N3 on 23, 24, and 27 August, Station N4 on 28 August, Station N4A on 29 August, Station N9 on 24 August, and Station N10 on 23 August.

In the test on Steele Brook water, the fish weights for 1 percent are for six days of exposure. All fish died in the first 24-hour period, and another group was set up with the same lot of larval fish that were used to start the testing for the other concentrations.

4.2 Ambient Tests

Table 4-1 contains the growth and survival data for the fathead minnow ambient tests. The mortality at Stations N10 and N11 occurred on days 2 and 3, respectively, of the tests and corresponded to similarly timed mortalities of the *Ceriodaphnia*. In the Naugatuck POTW effluent dilution tests, all fish died on day 2 even at 1 percent. Dead fish were also observed downstream of Naugatuck POTW corroborating a slug of toxicity from that POTW. The *Ceriodaphnia* mass balance tests (Table 5-8) also show reasonably good survival and young production at Station N10 except on days 2 and 3. Stations N8, N10, N11 and N12 all had significantly lower survival and young production than Station N1. Station N9 was the only downstream station that had normal growth and survival. Station N7 growth was lower, but not significantly so, than Station N1. Survival and growth showed about the same toxicity.

Table 4-2 and 4-3 contain the mass balance and impact ambient toxicity data for the *Ceriodaphnia*. The sample collection day (Table 4-2) is the date the composite sample was ended. For the mass balance tests, Stations N7 through N9 were significantly lower than N4, the station with the highest young production and good survival. Station N10 might have been much higher if the slug of toxicity on days 2 and 3 had not occurred. Of the stations in the impact tests (Table 4-3), N10, N11, and N12 were significantly lower than N1, which was the water used for diluting effluents. The impact test at Station N11 was also affected by the slug of toxicity as were the mass balance tests; mortality occurred one day later, on day 3, as compared to Station N10 where it occurred on day 2. Both impact and mass balance tests were done using *Ceriodaphnia* on Stations N4 and N10. The slug of toxicity showed up at Station N10 in both tests but it made a comparison meaningless. The mean number of young per female for the seven mass balance tests at Station N4 is almost identical to the mean measured for the same station in the impact tests. Survival was similar also. Correspondence between the results of the two types of tests would be expected whenever variability from day to day is small.

Because the various industries discharge only on a 5-day per week schedule, the results of the *Ceriodaphnia* mass balance reproductivity tests were not expected to be the same over the duration of the tests at many stations. Such variation is inherent in effluent toxicity testing. If one uses the mean young/female of the seven mass balance tests as an estimate of an "impact" value that would have been obtained as well as the data in Table 4-3, the results

Table 4-1. **Mean Individual Weights (mg) and Survival of Larval Fathead Minnows Exposed to Impact Ambient Toxicity Tests, Naugatuck River, Waterbury, Connecticut**

Stream Station	Replicate A	B	C	D	Mean[a]	SE
			Weights (mg)			
N2	0.35	0.37	0.30	0.31	0.334	0.027
N4	0.47	0.40	0.44	0.39	0.424	0.025
N6	0.35	0.33	0.40	0.43	0.374	0.025
N7	0.31	0.29	0.26	0.29	0.289	0.025
N8	0.10	--	0.18	--	0.123[b]	0.041
N9	0.31	0.36	0.36	0.38	0.352	0.025
N10	--	--	--	--	--[b]	--
N11	--	--	--	--	--[b]	--
N12	0.13	0.17	0.17	0.15	0.157[b]	0.034
			Survival (%)			
N2	80	90	60	100	83	
N4	90	100	100	100	98	
N6	100	100	90	80	93	
N7	100	100	80	100	95	
N8	10	0	40	0	12[b]	
N9	100	80	100	90	93	
N10	0	0	0	0	0[b]	
N11	0	0	0	0	0[b]	
N12	60	70	60	20	53[b]	

[a] The mean weight of fish is given as a weighted mean and mean survival is expressed as mean percent.

[b] Significantly lower from N1 (Table 4-6) using the two-tailed Dunnett's test ($P \leq 0.05$).

Table 4-2. **Mass Balance *Ceriodaphnia* Toxicity Test Run with Ambient Samples Collected from the Naugatuck River, Waterbury, Connecticut**

Station Number	Sample Collection Day	Mean Number of Young per Female	Confidence Intervals	Mean Percent Survival
N2	23 Aug	15.0	12.3-17.7	60
	24 Aug	19.6	16.6-22.5	100
	25 Aug	17.1	13.3-20.9	90
	26 Aug	15.6	13.6-17.6	100
	27 Aug	21.9	19.5-24.2	90
	28 Aug	18.4	14.3-22.5	80
	29 Aug	17.8	16.1-19.5	100
Mean		17.9	(SD 2.4)[b]	87
N3	23 Aug	15.3	13.0-17.6	100
	24 Aug	16.5	13.3-19.8	80
	25 Aug	14.2	11.2-17.2	100
	26 Aug	16.7	12.2-21.2	90
	27 Aug	17.1	14.7-19.6	90
	28 Aug	7.2	5.5-8.9	50
	29 Aug	17.0	14.0-20.0	100
Mean		14.9	(SD 3.5)	87
N4	23 Aug	13.5	9.8-17.2	70
	24 Aug	17.0	14.9-19.2	90
	25 Aug	16.2	11.3-21.0	60
	26 Aug	20.9	18.2-23.6	90
	27 Aug	24.3	19.9-28.7	100
	28 Aug	25.0	20.7-29.3	100
	29 Aug	13.1	11.0-15.2	90
Mean		18.6	(SD 4.9)	86

Table 4-2 (Continued)

Station Number	Sample Collection Day	Mean Number of Young per Female	Confidence Intervals	Mean Percent Survival
N5	23 Aug	18.2	14.6-21.8	90
	24 Aug	17.6	15.2-20.1	80
	25 Aug	15.7	12.5-18.9	100
	26 Aug	17.3	14.9-19.7	90
	27 Aug	19.9	16.3-23.5	100
	28 Aug	17.4	15.3-19.6	90
	29 Aug	16.3	12.2-20.4	100
Mean		17.5	(SD 1.4)	93
N6	23 Aug	4.0	--	0
	24 Aug	7.0	3.3-10.6	80
	25 Aug	15.6	12.3-19.0	70
	26 Aug	15.3	12.5-18.0	70
	27 Aug	21.4	16.4-26.4	90
	28 Aug	18.1	15.7-20.5	100
	29 Aug	20.4	16.8-24.0	100
Mean		14.5	(SD 6.6)	73
N7	23 Aug	15.1	8.8-21.4	50
	24 Aug	0	--	10
	25 Aug	--	--	0
	26 Aug	--	--	0
	27 Aug	--	--	0
	28 Aug	21.0	16.9-25.1	70
	29 Aug	18.4	13.3-23.5	80
Mean		7.8[a]	(SD 9.9)	30
N8	23 Aug	--	--	0
	24 Aug	--	--	0
	25 Aug	--	--	0
	26 Aug	--	--	0
	27 Aug	--	--	0
	28 Aug	6.5	0-21.1	78
	29 Aug	--	--	0
Mean		1.2[a]	(SD 2.4)	11
N9	23 Aug	15.4	0-40.6	20
	24 Aug	9.2	5.5-12.8	70
	25 Aug	13.2	11.3-15.1	80
	26 Aug	5.9	3.2-8.5	30
	27 Aug	4.7	3.5-5.8	0
	28 Aug	4.5	2.8-6.3	50
	29 Aug	11.9	9.9-13.9	100
Mean		9.3[a]	(SD 4.4)	50
N10	23 Aug	10.0	5.6-14.4	67
	24 Aug	--	--	0
	25 Aug	--	--	0
	26 Aug	19.9	16.6-23.2	100
	27 Aug	21.5	18.9-24.1	100
	28 Aug	14.4	11.7-17.2	90
	29 Aug	12.9	9.8-16.1	89
Mean		11.3	(SD 8.6)	64

[a] Significantly lower than Station N4 ($P < 0.05$).

[b] Standard deviation.

Table 4-3. Mean Young Production and Percent Survival of *Ceriodaphnia* Impact Ambient Station Toxicity Test, Naugatuck River, Waterbury, Connecticut

Stream Station	Mean Number of Young per Female	Confidence Intervals	Day of Test						
			1	2	3	4	5	6	7
N1a[b]	19.1	14.3-24.0	100	100	90	90	90	90	90
N1b	12.6	8.4-16.8	90	90	90	90	90	90	90
N1c	17.2	13.0-21.4	100	100	90	90	90	90	90
N4	18.5	15.2-21.8	90	90	80	80	80	80	80
N4A	14.1	10.1-18.1	100	100	100	100	100	100	100
N10	--[a]	--	89	0	0	0	0	0	0[a]
N11	--[a]	--	80	80	0	0	0	0	0[a]
N12	--[a]	--	0	0	0	0	0	0	0[a]

[a] Significantly lower than Station N1 ($P \leq 0.05$).

[b] a, b, and c were replicates of Station N1 water.

show impact at Stations N7 through N12. The fathead minnow tests show toxicity at Stations N8, N10, N11, and N12. The *Ceriodaphnia* test results for Station N7 and N9 showed toxicity while no toxicity was observed in the fathead minnow tests for those stations.

4.3 Effluent Tests

The *Ceriodaphnia* effluent test data are found in Chapter 5 as they were conducted in a different location and manner (mass balance) than the fathead minnow effluent tests (impact tests).

The fathead minnow survival data for the effluent tests are given in Tables 4-4 and 4-5, and the weight data are given in Tables 4-6 and 4-7. The Torrington POTW gave an atypical dose response curve which has been seen on other occasions (Mount et al. 1984) but usually in the *Ceriodaphnia* tests rather than the fathead minnow tests. An AEC cannot be obtained from such data. The effect/no-effect levels were 100 and 30 percent, respectively, for the Waterbury POTW, and the AEC estimate (which is the geometric mean of the no observed effect concentration (NOEC) and lowest observed effect concentration [LOEC]) is 54.7 percent. The toxic concentration of the Naugatuck POTW effluent was determined by a toxic slug (within 48 hours) that put the AEC (attributed to the slug of toxicity) at less than 1 percent. The sample of the Naugatuck POTW was tested two days later at the 10 percent level using 3-day-old fathead minnows. All fish were dead in less than 24 hours. The AEC for Steele Brook is 1.7 percent and for Mad River it is less than 1 percent. From Tables 6-4, Steele Brook made up 15.7 percent of the flow in the Naugatuck at Station N6 and 14.8 percent at Station N7, but there was no ambient toxicity found even though the AEC was 10-fold less. The Mad River makes up over 20 percent of the flow at Station N8 (Figure 6-6) and the AEC for the Mad River was less than 1 percent. Toxicity was observed at Station N8 but not as dramatic as might be expected based on the Mad River dilution test. The explanation undoubtedly lies in the dilution water used for the effluent tests, i.e., Station N1 water. That dilution water does not contain effluents, especially POTW effluent, whereas the dilution water for the Steele Brook and Mad River does. In numerous other studies of receiving streams, we have observed mixtures of effluents which exhibit markedly less toxicity than would occur by simple addition of the effluents. Further evidence is provided by Carlson et al. (1986) in which they showed the toxicity of copper to be greatly reduced in Station N6 water as compared to Station N1 water. Likewise, below the Waterbury POTW at Station N9 where the Mad River still composes over 10 percent of the flow (Figure 6-6), no toxicity was evident. Based on experience at other locations and the copper toxicity data described by Carlson, et al., the lesser toxicity is to be expected.

Table 4-4. Seven-Day Percent Survival of Larval Fathead Minnows Exposed to Various Concentrations of Three POTW Effluents, Naugatuck River, Waterbury, Connecticut

Effluent by Replicate	Percent Effluent (v/v) 100	30	10	3	1	Dilution Water[a]
Torrington POTW						
A	90	100	30	60	30	--
B	100	100	70	90	10	--
C	60	100	20	70	0	--
D	80	90	30	40	20	--
Mean	83	98	38[b]	65[b]	15[b]	95[a]
Waterbury POTW						
A	80	100	90	100	90	100
B	60	90	90	80	100	90
C	80	90	90	100	90	100
D	10	100	100	90	100	90
Mean	58[b]	95	93	93	95	95[a]
Naugatuck POTW						
A	0	0	0	0	0	--
B	0	0	0	0	0	--
C	0	0	0	0	0	--
D	0	0	0	0	0	--
Mean	0[b]	0[b]	0[b]	0[b]	0[b]	95[b]

[a] N1 water was used as dilution water for each POTW effluent dilution test.

[b] Significantly lower from N1 using the two-tailed Dunnett's test ($P \leq 0.05$).

Table 4-5. Seven-Day Percent Survival of Larval Fathead Minnows Exposed to Various Concentrations of Two Tributary Water Dilution Tests, Naugatuck River, Waterbury, Connecticut

Sample by Replicate	Percent Tributary Water (v/v) 100	30	10	3	1	Dilution Water[a]
Steele Brook						
A	10	0	30	10	100	67
B	0	0	50	70	100	90
C	30	0	60	80	100	90
D	0	0	30	90	90	90
Mean	10[b]	0[b]	43[b]	63	98	84
Mad River						
A	10	40	70	60	60	80
B	30	30	70	10	40	90
C	0	0	90	60	70	100
D	30	0	90	40	30	100
Mean	18[b]	18[b]	80	43[b]	50[b]	93

[a] N1 water was used as dilution water for each test.

[b] Significantly lower from N1 using the two-tailed Dunnett's test ($P \leq 0.05$).

Table 4-6. Mean Individual Weights (mg) of Larval Fathead Minnows Exposed to Various Concentrations of Three POTW Effluents, Naugatuck River, Waterbury, Connecticut

Effluent by Replicate	Percent Effluent (v/v)					
	100	30	10	3	1	Dilution Water[a]
Torrington POTW						
A	0.29	0.34	0.17	0.23	0.13	--
B	0.33	0.34	0.20	0.26	0.30	--
C	0.27	0.38	0.20	0.26	--	--
D	0.30	0.38	0.17	0.23	0.25	--
Weighted Mean	0.307	0.360	0.188[c]	0.248[c]	0.198	0.341[b]
SE	0.027	0.025	0.040	0.030	0.063	0.016
Waterbury POTW						
A	0.18	0.38	0.32	0.36	0.36	0.38
B	0.20	0.31	0.30	0.33	0.46	0.40
C	0.20	0.30	0.33	0.32	0.33	0.40
D	0.20	0.31	0.31	0.37	0.32	0.47
Weighted Mean	0.193[c]	0.326	0.315	0.345	0.369	0.341[b]
SE	0.034	0.027	0.027	0.027	0.027	0.016
Naugatuck POTW[d]						
A	--	--	--	--	--	--
B	--	--	--	--	--	--
C	--	--	--	--	--	--
D	--	--	--	--	--	--
Weighted Mean	--[c]	--[c]	--[c]	--[c]	--[c]	0.341[b]
SE						0.016

[a] N1 water was used as dilution water for each POTW effluent dilution test.

[b] Value is a pooled weighted mean of all N1 dilution water weight data and used as basis for statistical comparisons.

[c] Significantly lower from N1 using the two-tailed Dunnett's test ($P \leq 0.05$).

[d] The fish died early in test and therefore no weight data were obtained.

Table 4-7. Mean Individual Weights (mg) of Larval Fathead Minnows Exposed to Various Concentrations of Two Tributary Water Dilution Tests, Naugatuck River, Waterbury, Connecticut

Sample by Replicate	Percent Effluent (v/v)					
	100	30	10	3	1	Dilution Water[a]
Steele Brook						
A	0.30	--	0.27	--	0.34	0.35
B	--	--	0.20	0.27	0.29	0.33
C	0.13	--	0.18	0.22	0.36	0.37
D	--	--	0.23	0.24	0.33	0.33
Weighted Mean	0.173[c]	--[c]	0.211[c]	0.242[c]	0.330	0.341[b]
SE	0.087	--	0.042	0.035	0.042	0.016
Mad River						
A	0.10	0.20	0.27	0.35	0.23	0.33
B	0.20	0.20	0.20	0.30	0.20	0.28
C	--	--	0.23	0.33	0.29	0.22
D	0.10	--	0.29	0.30	0.23	0.24
Weighted Mean	0.143[c]	0.200[c]	0.249[c]	0.328	0.245[c]	0.341[b]
SE	0.062	0.062	0.029	0.040	0.036	0.016

[a] N1 water was used as dilution water for each test.

[b] Value is a pooled weighted mean of three N1 dilution water replicates.

[c] Significantly lower from N1 using the two-tailed Dunnett's test ($P \leq 0.05$).

5. *Offsite Tests for Toxicity of Effluents and Receiving Water*

Toxicity tests offsite were conducted 24 August to 13 September using only *Ceriodaphnia*. The majority of the offsite tests were mass balance tests as described in Chapter 4, where seven estimates of chronic toxicity are generated. Testing was done on four POTWs, Station N8 and four tributary streams and some combinations of two. All these tests were run as effluent dilution tests in order to estimate an Acceptable Effluent Concentration (AEC). Effluent dilution tests were run on two POTWs which were mixed with the stream water from directly above the discharge. All other tests used N1 water as the diluent for purposes of the model. Ambient testing on Stations N9 and N10 were done during Phase I and Phase II, as were Station N8 dilution tests. A description of the testing program, sampling methods, and analytical methods is presented in Appendix B. Routine chemical data on the ambient stations and effluent dilution tests are in Appendix F, as well as preliminary methodological variability test results.

The overall objective of this part of the toxicity testing program was to investigate whether ambient toxicity can be predicted from the results of laboratory effluent toxicity tests used in conjunction with measured flow data in a mass balance model. The principle of mass balance required that effluents be diluted in N1 water. This, however, is not the same water quality in which the effluents are discharged in the stream and so this aspect could not be examined using the mass balance model approach. The model results are being published by DiToro and Hallden, 1985.

5.1 Chemical/Physical Conditions

Tables F-1 and F-2 contain the water quality measurement data for the tests. Conductivity, alkalinity, and hardness varied with station or effluent. All of these values and pH and D.O. are within acceptable limits for the test species. Temperatures were consistently *under* 25°C. Because of the large number of tests, constant temperature cabinets were not available. The lower temperature resulted in only two broods in many instances. Hamilton (1984) noted that the data he examined suggested that two broods were sufficient for test purposes, so that the data generated offsite may be adequate for purposes here.

5.2 Toxicity Test Results

The results of Phase I offsite *Ceriodaphnia* toxicity tests are given in Tables 5-1 to 5-7. Each test was run for seven days and the renewal of the test solutions were made with the same sample of effluent or tributary water used to start each test. Ambient station toxicity tests using Stations N9 and N10 are shown in Table 5-8. These tests were run without dilution and a new test was begun daily for both stream stations.

Tables 5-9 to 5-11 give the results of the effluent dilution tests using Station N1 water as the diluent during the Phase II offsite testing. The Waterbury POTW and Naugatuck POTW effluent tests diluted with the stream water directly above each discharge are shown on Tables 5-12 and 5-13. The results of ambient toxicity tests on Station N9 and N10 are given in Table 5-12. The tests were run in the identical manner as Phase I. The only tests run during both phases were the Station N8 dilution test and the ambient Stations N9 and N10.

Five of the values for the Mad River set are invalid and are not used in Table 5-15. There are five other values for different tests in which the control mortality exceeded 20%. Since in none of these cases was the effect concentration any higher than values for other days, the values were used in Table 5-15 even though such mortality would normally render the tests invalid.

Table 5-15 presents the Acceptable Effluent Concentration (AEC) for each dilution test. The AEC is calculated as the geometric mean of the mean no observed effect concentration (NOEC) and the mean of the lowest observed effect concentration (LOEC). During Phase I Gulf Stream dilution tests had a range of AECs from 1.7 to 54.7 percent. Torrington POTW AECs ranged from 5.5 to > 100 percent, but three out of seven AECs were > 100 percent. Thomaston POTW AECs were > 100 percent for two tests, 17.3 percent in two tests, 5.5 once, and 54.7 percent once. Steele Brook AECs were 5.5 percent for *five tests and* 1.7 percent for two tests. For four tests, Great Brook had an AEC of 1.7 percent, less than 1 percent for two tests and 17.3 for one test. Since only two tests on Mad River were valid, only two AECs are calculable. They were 5.5 and 54.7 percent. The AECs for the Station N8 dilution test were 17.3 percent for six tests and 54.7 percent for the other.

Table 5-1. Results of Offsite Phase I *Ceriodaphnia* Toxicity Tests with the Gulf Stream Sample, Naugatuck River

Sample or Effluent	Test Dates	Test Concentration Percent (v/v)	Mean Number of Young per Female	95% Confidence Interval	Percent Survival
Gulf Stream	24 Aug to 31 Aug	Dilution water	8.2	4.5-12.1	100
		1	9.8	6.8-12.8	100
		3	14.4[a]	10.8-18.1	100
		10	13.9[a]	10.4-17.4	100
		30	9.2	7.2-11.2	75
		100	--[a]	--	0[a]
	25 Aug to 1 Sept	Dilution water	17.3	13.1-21.5	100
		1	16.1	13.0-19.2	100
		3	10.0[a]	8.1-11.9	90
		10	4.5[a]	0.7- 8.3	0[a]
		30	--[a]	--	0[a]
		100	--[a]	--	0[a]
	26 Aug to 2 Sept	Dilution water	11.6	9.1-14.2	70
		1	12.8	12.1-13.5	90
		3	11.8	10.0-13.7	80
		10	11.2	8.8-13.6	80
		30	--[a]	--	0[a]
		100	--[a]	--	0[a]
	27 Aug to 3 Sept	Dilution water	10.3	8.6-12.0	78
		1	10.9	8.8-12.9	70
		3	11.6	9.6-13.6	90
		10	10.6	8.3-12.9	89
		30	5.5[a]	3.0- 8.0	33
		100	--[a]	--	0[a]
	28 Aug to 4 Sept	Dilution water	11.4	8.7-14.1	89
		1	15.1	12.4-17.8	100
		3	15.6[a]	13.1-18.1	100
		10	15.7	12.5-19.0	89
		30	19.2[a]	17.7-20.8	89
		100	--[a]	--	0[a]
	29 Aug to 5 Sept	Dilution water	12.4	9.8-14.9	60
		1	11.3	10.3-12.3	90
		3	11.2	10.0-12.3	90
		10	14.7	11.5-17.8	90
		30	12.7	11.2-14.2	100[a]
		100	--[a]	--	0[a]
	30 Aug to 6 Sept	Dilution water	16.7	13.0-20.4	100
		1	15.1	11.3-18.9	90
		3	14.6	11.5-17.7	100
		10	19.4	13.6-25.2	100
		30	16.6	12.5-20.7	100
		100	--[a]	--	0[a]

[a] Significantly different from the dilution water ($P \leq 0.05$)

The Phase II effluent dilution tests showed less variation in the range of AECs. The Waterbury POTW AECs were 17.3 percent for five tests and 5.5 percent for the remaining tests. Naugatuck POTW had an AEC of 54.7 percent for five tests and 17.3 percent for the other two tests. The AECs for Station N8 were 17.3 percent for three tests and 54.7 percent for four tests.

Day to day variability exceeds 20 times in several effluents indicating the need to properly sample effluents for any type of biological or chemical measurements. The toxic slug in the Naugatuck POTW discussed in Chapter 4 occurred before the tests described here were set up. The effect of dilution water on effluent toxicity can be seen in Table 5-15 for the Naugatuck POTW. The toxicity is more than 5 times less for some samples when the effluent is diluted with N9 water instead of N1 water. This agrees with the lesser toxicity observed at stations 6, 7, and 8 in the ambient tests compared to the toxicity at those stations that would be predicted from the effluent tests.

Further discussion of the effluent data can be found in the paper on the mass balance model (DiToro and Hallden, 1985).

Table 5-2. **Results of Offsite Phase I *Ceriodaphnia*** Effluent Dilution Toxicity Tests with the Torrington POTW, Naugatuck River

Sample or Effluent	Test Dates	Test Concentration Percent (v/v)	Mean Number of Young per Female	95% Confidence Interval	Percent Survival
Torrington POTW	24 Aug to 31 Aug	Dilution water	9.9	7.3-12.5	90
		1	13.1	9.8-16.5	80
		3	14.6	11.0-18.1	80
		10	18.8[a]	14.9-22.7	90
		30	20.1[a]	15.6-24.6	100
		100	12.2	7.2-17.1	90
	25 Aug to 1 Sept	Dilution water	15.1	9.9-20.3	90
		1	15.0	10.5-19.5	90
		3	14.7	11.0-18.3	100
		10	11.1	6.6-15.6	80
		30	18.0	13.7-22.3	100
		100	--[a]	-	0[a]
	26 Aug to 2 Sept	Dilution water	11.5	9.2-13.8	100
		1	9.7	8.3-11.1	50[a]
		3	10.7	8.5-12.9	100
		10	--[a]	-	0[a]
		30	--[a]	--	0[a]
		100	--[a]	--	0[a]
	27 Aug to 3 Sept	Dilution water	12.8	11.6-14.0	100
		1	11.7	10.9-12.5	100
		3	13.1	12.0-14.2	100
		10	8.9	5.6-12.2	100
		30	6.1[a]	3.5- 8.6	90
		100	8.3	1.5-15.2	60[a]
	28 Aug to 4 Sept	Dilution water	7.8	0-20.0	30
		1	18.1	15.0-21.2	70
		3	16.9	14.1-19.7	100[a]
		10	18.6	17.0-20.1	100[a]
		30	19.5	16.3-22.7	100[a]
		100	21.9	19.7-24.0	100[a]
	29 Aug to 5 Sept	Dilution water	15.1	11.1-19.1	100
		1	14.3	11.4-17.2	100
		3	12.8	9.8-15.7	78
		10	16.7	12.9-20.5	100
		30	18.7	14.5-22.9	90
		100	18.9	15.3-22.5	100
	30 Aug to 6 Sept	Dilution water	17.0	12.9-21.1	100
		1	16.5	11.5-21.5	88
		3	19.2	16.2-22.2	100
		10	16.6	12.4-20.9	89
		30	23.2[a]	21.7-24.7	100
		100	23.4[a]	20.6-26.2	100

[a] Significantly different from the dilution water ($P \leq 0.05$).

Table 5-3. **Results of Offsite Phase I *Ceriodaphnia* Effluent Dilution Toxicity Tests with the Thomaston POTW, Naugatuck River**

Sample or Effluent	Test Dates	Test Concentration Percent (v/v)	Mean Number of Young per Female	95% Confidence Interval	Percent Survival
Thomaston POTW	24 Aug to 31 Aug	Dilution water	16.1	11.2-21.0	70
		1	11.9	6.2-17.6	75
		3	12.7	9.2-16.2	67
		10	12.0	9.7-14.4	88
		30	6.1[a]	2.2-10.0	70
		100	--[a]	--	0[a]
	25 Aug to 1 Sept	Dilution water	12.4	9.1-15.6	70
		1	13.3	10.0-16.6	100
		3	14.7	11.4-18.0	90
		10	12.8	9.2-16.4	100
		30	2.1[a]	0.4- 3.8	80
		100	--[a]	--	0[a]
	26 Aug to 2 Sept	Dilution water	11.4	10.3-12.5	80
		1	11.6	8.2-15.0	78
		3	13.7	10.2-17.2	89
		10	13.8	10.0-17.5	90
		30	15.6	11.9-19.4	90
		100	10.6	7.1-14.0	100
	27 Aug to 3 Sept	Dilution water	10.9	9.2-12.5	80
		1	8.8	6.5-11.1	60
		3	9.8	8.9-10.8	70
		10	8.7	6.0-11.4	60
		30	10.0	8.0-12.0	90
		100	--[a]	--	0[a]
	28 Aug to 4 Sept	Dilution water	12.7	10.2-15.2	100
		1	14.4	11.2-17.5	80
		3	11.8	14.0	60
		10	--[a]	--	0[a]
		30	--[a]	--	0[a]
		100	--[a]	--	0[a]
	29 Aug to 5 Sept	Dilution water	11.9	8.0-15.9	100
		1	12.7	9.8-15.6	100
		3	15.7	11.8-19.6	100
		10	18.5[a]	14.3-22.7	100
		30	19.4[a]	15.9-22.9	100
		100	8.6	4.0-13.2	100
	30 Aug to 6 Sept	Dilution water	14.6	10.2-19.1	100
		1	13.2	8.8-17.8	100
		3	7.2[a]	3.23-11.1	63
		10	10.4	8.0-12.8	100
		30	--[a]	--	0[a]
		100	--[a]	--	0[a]

[a] Significantly different from the dilution water ($P \leq 0.05$).

Table 5-4. Results of Offsite Phase I *Ceriodaphnia* Toxicity Tests with the Steele Brook Sample, Naugatuck River

Sample or Effluent	Test Dates	Test Concentration Percent (v/v)	Mean Number of Young per Female	95% Confidence Interval	Percent Survival
Steele Brook	24 Aug to 31 Aug	Dilution water	14.8	11.1-18.5	90
		1	11.6	9.0-14.3	80
		3	5.1	2.7- 7.5	80
		10	8.7	2.1-15.2	40[a]
		30	9.2	7.2-11.2	0[a]
		100	--[a]	--	0[a]
	25 Aug to 1 Sept	Dilution water	11.8	9.5-14.1	100
		1	9.9	7.8-11.9	70
		3	8.3[a]	6.6-10.1	100
		10	--[a]	--	0[a]
		30	--[a]	--	0[a]
		100	--[a]	--	0[a]
	26 Aug to 2 Sept	Dilution Water	11.5	8.3-14.7	80
		1	10.0	8.2-11.7	70
		3	10.6	7.9-13.4	80
		10	--[a]	--	0[a]
		30	--[a]	--	0[a]
		100	--[a]	--	0[a]
	27 Aug to 3 Sept	Dilution water	11.9	10.1-13.7	80
		1	10.6	9.4-11.8	100
		3	12.0	10.5-13.4	80
		10	--[a]	--	0[a]
		30	--[a]	--	0[a]
		100	--[a]	--	0[a]
	28 Aug to 4 Sept	Dilution water	13.2	10.7-15.8	80
		1	13.3	11.4-15.2	100
		3	15.2	12.3-18.1	100
		10	--[a]	--	0[a]
		30	--[a]	--	0[a]
		100	--[a]	--	0[a]
	29 Aug to 5 Sept	Dilution water	15.1	11.9-18.3	100
		1	15.8	12.6-19.0	100
		3	16.5	11.6-21.4	100
		10	--[a]	--	0[a]
		30	--[a]	--	0[a]
		100	--[a]	--	0[a]
	30 Aug to 6 Sept	Dilution water	12.0	9.0-15.0	100
		1	14.5	10.9-18.1	100
		3	13.7	11.2-16.2	90
		10	--[a]	--	10[a]
		30	--[a]	--	0[a]
		100	--[a]	--	0[a]

[a] Significantly different from the dilution water ($P \leq 0.05$).

Table 5-5. **Results of Offsite Phase I *Ceriodaphnia* Toxicity Tests with the Great Brook Sample, Naugatuck River**

Sample or Effluent	Test Dates	Test Concentration Percent (v/v)	Mean Number of Young per Female	95% Confidence Interval	Percent Survival
Great Brook	24 Aug to 31 Aug	Dilution water	13.4	9.5-17.0	75
		1	15.2	9.5-20.9	63
		3	--[a]	--	0[a]
		10	--[a]	--	0[a]
		30	--[a]	--	0[a]
		100	--[a]	--	0[a]
	25 Aug to 1 Sept	Dilution water	8.5	5.1-12.0	90
		1	5.2	2.5- 8.0	80
		3	--[a]	--	0[a]
		10	--[a]	--	0[a]
		30	--[a]	--	0[a]
		100	--[a]	--	0[a]
	26 Aug to 2 Sept	Dilution water	8.9	7.1-10.8	30
		1	6.0[b]	--	0[a]
		3	--[a]	--	0[a]
		10	--[a]	--	0[a]
		30	--[a]	--	0[a]
		100	--[a]	--	0[a]
	27 Aug to 3 Sept	Dilution water	10.4	8.6-12.2	90
		1	12.7	10.9-14.5	100
		3	--[a]	--	0[a]
		10	--[a]	--	0[a]
		30	--[a]	--	0[a]
		100	--[a]	--	0[a]
	28 Aug to 4 Sept	Dilution water	13.8	10.8-16.8	89
		1	7.2[a]	3.7-10.7	67
		3	--[a]	--	0[a]
		10	--[a]	--	0[a]
		30	--[a]	--	0[a]
		100	--[a]	--	0[a]
	29 Aug to 5 Sept	Dilution water	15.3	11.6-19.1	90
		1	13.7	11.3-16.1	89
		3	18.0	14.3-21.7	100
		10	17.0	12.5-21.5	100
		30	--[a]	--	0[a]
		100	--[a]	--	0[a]
	30 Aug to 6 Sept	Dilution water	14.9	12.3-17.5	100
		1	16.8	12.7-20.9	100
		3	--[a]	--	0[a]
		10	--[a]	--	0[a]
		30	--[a]	--	0[a]
		100	--[a]	--	0[a]

[a] Significantly different from the dilution water ($P \leq 0.05$)

[b] This is a survivors only estimate. Value is mean young produced by one female.

Table 5-6. Results of Offsite Phase I *Ceriodaphnia* Toxicity Tests with the Mad River Samples, Naugatuck River

Sample or Effluent	Test Dates	Test Concentration Percent (v/v)	Mean Number of Young per Female	95% Confidence Interval	Percent Survival
Mad River	24 Aug to 31 Aug	Dilution water	12.2[b]	5.3-19.2	40[b]
		1	10.3	0-25.1	29
		3	16.5	12.4-20.5	89
		10	4.7	0.7- 8.8	67
		30	--	--	0
		200	--	--	0
	25 Aug to 1 Sept	Dilution water	12.7[b]	4.6-20.7	10[b]
		1	11.0	9.4-12.6	90
		3	11.2	7.8-14.7	100
		10	--	--	0
		30	--	--	0[a]
		100	--	--	0[a]
	26 Aug to 2 Sept	Dilution water	--[b]	--	0[b]
		1	1.7	0- 3.4	10
		3	2.9	0.9- 4.9	20
		10	--	--	0
		30	--	--	0
		100	--	--	0
	27 Aug to 3 Sept	Dilution water	--[b]	--	0[b]
		1	12.3	11.0-13.6	90
		3	12.5	9.8-15.1	90
		10	6.5	5.2- 7.8	60
		30	--	--	0
		100	--	--	0
	28 Aug to 4 Sept	Dilution water	13.2[b]	3.7-22.7	30[b]
		1	16.6	13.5-19.6	90
		3	13.8	10.6-16.9	70
		10	--	--	0
		30	--	--	0
		100	--	--	0
	29 Aug to 5 Sept	Dilution water	13.3	10.5-16.1	100
		1	16.5	13.2-19.7	92
		3	20.7[a]	15.2-26.2	100
		10	--[a]	--	0[a]
		30	--[a]	--	0[a]
		100	--[a]	--	0[a]
	30 Aug to 6 Sept	Dilution water	15.3	11.1-19.5	100
		1	16.6	12.1-21.1	100
		3	19.4	15.2-23.6	100
		10	22.3[a]	19.0-25.6	100
		30	10.4	0-32.3	20[a]
		100	--[a]	--	0[a]

[a] Significantly different from the dilution water ($P \leq 0.05$).

[b] Due to an error in test solution preparation these tests are invalid.

Table 5-7. **Results of Offsite Phase I *Ceriodaphnia* Toxicity Tests with Station N8 Sample, Naugatuck River**

Sample or Effluent	Test Dates	Test Concentration Percent (v/v)	Mean Number of Young per Female	95% Confidence Interval	Percent Survival
Station N8	24 Aug to 31 Aug	Dilution water	13.4	10.9-15.9	100
		1	11.8	8.7-14.9	100
		3	14.3	13.0-15.6	80
		10	10.9	7.4-14.4	78
		30	--[a]	--	0[a]
		100	--[a]	--	0[a]
	25 Aug to 1 Sept	Dilution water	11.3	10.6-12.1	80
		1	9.5	7.1-11.9	90
		3	9.6	7.0-12.1	90
		10	10.6	8.8-12.4	100
		30	--[a]	--	0[a]
		100	--[a]	--	0[a]
	26 Aug to 2 Sept	Dilution water	11.1	5.6-16.6	50
		1	11.9	10.1-13.7	90
		3	11.5	9.3-13.7	80
		10	12.0	6.9-17.1	50
		30	--[a]	--	0[a]
		100	--[a]	--	0[a]
	27 Aug to 3 Sept	Dilution water	12.0	9.3-14.7	100
		1	13.2	11.2-15.2	90
		3	13.6	12.6-14.6	100
		10	11.2	9.8-12.6	100
		30	--[a]	--	0[a]
		100	--[a]	--	0[a]
	28 Aug to 4 Sept	Dilution water	12.4	9.9-14.8	90
		1	10.1	7.3-13.0	100
		3	17.6	13.0-22.2	90
		10	13.5	8.8-18.1	67
		30	--[a]	--	0[a]
		100	--[a]	--	0[a]
	29 Aug to 5 Sept	Dilution water	17.1	13.7-20.5	90
		1	19.3	15.8-22.8	100
		3	22.1[a]	18.9-25.3	100
		10	25.2[a]	19.7-30.7	100
		30	20.2	17.2-23.0	90
		100	--[a]	--	0[a]
	30 Aug to 6 Sept	Dilution water	13.8	8.9-18.7	90
		1	14.8	10.5-19.1	90
		3	17.2	12.6-21.7	89
		10	15.4	13.1-17.6	100
		30	6.3[a]	4.6- 8.0	60
		100	--[a]	--	0[a]

[a] Significantly different from the dilution water ($P \leq 0.05$).

Table 5-8. Results of Offsite Phase I *Ceriodaphnia* Ambient Toxicity Tests at Stations N9 and N10, Naugatuck River

Ambient Station	Test Dates	Mean Number of Young per Female	95% Confidence Interval	Percent Survival
N9	24 Aug - 31 Aug	8.8	4.7-12.9	10
	25 Aug - 1 Sept	10.6	5.7-15.6	0
	26 Aug - 2 Sept	8.7	2.4-14.9	33
	27 Aug - 3 Sept	5.4	3.1- 7.6	40
	25 Aug - 4 Sept	--	--	0
	29 Aug - 5 Sept	8.3	6.6-10.0	10
	30 Aug - 6 Sept	17.7	14.2-21.1	70
N10	24 Aug - 31 Aug	11.9	9.5-14.2	90
	25 Aug - 1 Sept	--	--	0
	26 Aug - 2 Sept	--	--	0
	27 Aug - 3 Sept	12.6	10.2-15.0	100
	28 Aug - 4 Sept	20.2	14.6-25.8	100
	29 Aug - 5 Sept	20.7	18.0-23.5	90
	30 Aug - 6 Sept	19.3	15.0-23.6	100

Table 5-9. Results of Offsite Phase II *Ceriodaphnia* Effluent Dilution Toxicity Tests with the Naugatuck POTW, Naugatuck River

Sample or Effluent	Test Dates	Test Concentration Percent (v/v)	Mean Number of Young per Female	95% Confidence Interval	Percent Survival
Naugatuck POTW	31 Aug to 7 Sept	Dilution water	12.1	10.5-13.7	90
		1	11.7	9.5-13.8	100
		3	12.6	10.7-14.5	100
		10	14.5	11.5-17.5	100
		30	12.0	9.8-14.2	90
		100	--[a]	--	0[a]
	1 Sept to 8 Sept	Dilution water	10.7	8.2-13.2	100
		1	11.9	9.8-14.0	100
		3	14.5	11.1-17.9	100
		10	13.2	11.6-14.8	90
		30	14.1[a]	12.3-15.9	90
		100	1.3[a]	0- 2.6	50[a]
	2 Sept to 9 Sept	Dilution water	10.8	8.6-13.0	100
		1	11.5	10.5-12.5	100
		3	12.7	11.2-14.5	100
		10	12.3	10.5-14.1	100
		30	9.4	6.2-12.6	100
		100	3.0[a]	0.7- 5.2	75
	3 Sept to 10 Sept	Dilution water	12.7	9.5-16.0	90
		1	10.4	7.4-13.4	100
		3	13.7	12.2-15.2	100
		10	14.1	13.0-15.2	90
		30	7.0[a]	4.6- 9.5	80
		100	3.6[a]	2.3- 4.9	80
	4 Sept to 11 Sept	Dilution water	13.2	10.1-16.3	90
		1	12.2	10.2-14.2	100
		3	10.6	9.1-12.2	100
		10	13.4	11.1-15.7	100
		30	2.6[a]	0.6-4.65	80
		100	--[a]	--	0[a]
	5 Sept to 12 Sept	Dilution water	11.6	9.0-14.1	90
		1	10.5	9.4-11.6	100
		3	10.4	5.7-15.1	100
		10	10.8	9.2-12.4	100
		30	11.9	9.3-14.5	100
		100	3.0[a]	1.3- 4.7	80
	6 Sept to 13 Sept	Dilution water	9.0	7.0-11.1	100
		1	9.7	8.0-11.4	90
		3	9.7	8.2-11.2	100
		10	9.5	5.5-13.5	90
		30	14.0[a]	12.3-15.7	100
		100	2.2[a]	0- 4.5	60[a]

[a] Significantly different from the dilution water ($P \leq 0.05$).

Table 5-10. **Results of Offsite Phase II *Ceriodaphnia* Effluent Dilution Toxicity Tests with the Waterbury POTW, Naugatuck River**

Sample or Effluent	Test Dates	Test Concentration Percent (v/v)	Mean Number of Young per Female	95% Confidence Inteval	Percent Survival
Waterbury POTW	31 Aug to 7 Sept	Dilution water	11.2	8.8-13.7	100
		1	14.1	12.8-15.4	100
		3	14.0	13.0-15.1	80
		10	12.9	11.3-14.4	50
		30	--[a]	--	0[a]
		100	--[a]	--	0[a]
	1 Sept to 8 Sept	Dilution water	11.2	8.7-13.7	100
		1	13.1	12.2-14.0	100
		3	12.7	11.7-13.7	100
		10	9.0	7.0-11.0	20[a]
		30	--[a]	--	0[a]
		100	--[a]	--	0[a]
	2 Sept to 9 Sept	Dilution water	10.7	8.7-12.7	100
		1	12.2	10.6-13.8	100
		3	11.6	10.2-12.9	90
		10	11.8	9.9-13.7	67
		30	--[a]	--	0[a]
		100	--[a]	--	0[a]
	3 Sept to 10 Sept	Dilution water	11.5	8.2-14.7	70
		1	12.7	11.3-14.1	80
		3	12.7	11.2-14.2	100
		10	12.0	10.4-13.6	50
		30	--[a]	--	0[a]
		100	--[a]	--	0[a]
	4 Sept to 11 Sept	Dilution water	10.4	8.7-12.1	100
		1	11.0	9.6-12.4	100
		3	9.8	8.0-11.7	90
		10	9.0	7.1-10.9	30[a]
		30	--[a]	--[a]	0[a]
		100	--[a]	--[a]	0[a]
	5 Sept to 12 Sept	Dilution water	10.1	7.2-13.0	100
		1	8.9	7.5-10.3	100
		3	10.6	7.3-14.0	60
		10	10.7	8.0-13.4	70
		30	--[a]	--	0[a]
		100	--[a]	--	0[a]
	6 Sept to 13 Sept	Dilution water	8.0	6.4- 9.6	100
		1	8.4	6.5-10.3	100
		3	7.8	6.7- 9.0	90
		10	10.7	9.0-12.4	80
		30	7.4	5.3- 9.4	0[a]
		100	--[a]	--	0[a]

[a] Significantly different from the dilution water ($P \leq 0.05$).

Table 5-11. Results of Offsite Phase II *Ceriodaphnia* Ambient Station Dilution Toxicity Tests with Station N8 Samples, Naugatuck River

Sample or Effluent	Test Dates	Test Concentration Percent (v/v)	Mean Number of Young per Female	95% Confidence Interval	Percent Survival
N8	31 Aug to 7 Sept	Dilution water	13.4	12.4-14.4	90
		1	13.8	13.2-14.5	90
		3	13.9	11.9-15.9	100
		10	14.8	13.5-16.1	100
		30	9.7[a]	6.2-13.3	20[a]
		100	--[a]	--	0[a]
	1 Sept to 8 Sept	Dilution water	11.9	9.9-13.9	80
		1	12.0	10.9-13.1	100
		3	12.3	10.5-14.1	100
		10	13.8	12.5-15.1	100
		30	--[a]	--	0[a]
		100	--[a]	--	0[a]
	2 Sept to 9 Sept	Dilution water	10.5	8.3-12.7	100
		1	10.9	8.2-13.6	86
		3	10.6	9.2-11.9	100
		10	11.7	8.5-14.8	67
		30	11.6	9.8-13.4	80
		100	6.8[a]	4.8- 8.8	0[a]
	3 Sept to 10 Sept	Dilution water	13.1	11.7-14.6	100
		1	12.4	10.9-13.9	100
		3	12.7	11.5-13.9	80
		10	13.1	12.0-14.2	100
		30	10.7	7.3-14.1	50[a]
		100	--[a]	--	0[a]
	4 Sept to 11 Sept	Dilution water	11.6	9.3-13.8	90
		1	10.1	8.6-11.7	90
		3	11.1	8.9-13.3	100
		10	12.8	10.8-14.8	100
		30	10.9	9.3-12.5	100
		100	--[a]	--	0[a]
	5 Sept to 12 Sept	Dilution water	11.7	10.7-12.7	90
		1	10.3	7.9-12.7	90
		3	9.0	6.5-11.2	90
		10	13.8	10.7-16.9	100
		30	15.1	11.1-19.1	100
		100	--[a]	--	0[a]
	6 Sept to 13 Sept	Dilution water	9.7	8.0-11.4	100
		1	6.2	3.4- 9.0	80
		3	7.6	5.7- 9.4	90
		10	9.7	7.6-11.8	100
		30	13.3[a]	11.0-15.6	100
		100	--[a]	--	0[a]

[a] Significantly different from the dilution water ($P \leq 0.05$).

Table 5-12. Results of Offsite Phase II *Ceriodaphnia* Waterbury POTW and N8 Mixture Effluent Dilution Toxicity Tests, Naugatuck River

Sample or Effluent	Test Dates	Test Concentration Percent (v/v)	Mean Number of Young per Female	95% Confidence Interval	Percent Survival
Waterbury POTW and N8 Mixture	31 Aug to 7 Sept	Dilution water	13.5	9.8-17.2	100
		1	15.9	13.3-18.5	90
		3	16.7	12.2-21 1	70
		10	15.1	12.4-17.8	90
		30	18.5	15.4-21.6	80
		100	--[a]	--	0[a]
	1 Sept to 8 Sept	Dilution water	10.6	9.4-11.7	100
		1	11.8	10.4-13.1	80
		3	14.0[b]	13.0-15.0	90
		10	13.5[b]	12.5-14.5	100
		30	11.7	10.4-13.0	100
		100	--[a]	--	0[a]
	2 Sept to 9 Sept	Dilution water	11.2	9.4-13.1	100
		1	12.9	11.4-14.4	100
		3	11.4	10.0-12.8	100
		10	12.0	9.5-14 5	100
		30	12.7	11.6-13.8	100
		100	--[a]	--	0[a]
	3 Sept to 10 Sept	Dilution water	12.1	10.6-13.6	100
		1	12.3	11.4-13.2	100
		3	12.5	11.0-14.1	90
		10	11.1	9.6-12.6	90
		30	10.6	9.4-11.8	50
		100	--[a]	--	0[a]
	4 Sept to 11 Sept	Dilution water	11.0	8.0-14.0	100
		1	10.1	9.2-11.0	100
		3	11.0	10.0-12.0	100
		10	11.9	9.1-14.8	90
		30	12.8	9.7-15.8	70
		100	--[a]	--	0[a]
	5 Sept to 12 Sept	Dilution water	12.8	10.3-15.2	90
		1	7.5[a]	4.7-10.2	90
		3	12.2	10.9-13.5	100
		10	13.0	10.5-15.5	90
		30	13.4	12.5-14.3	80
		100	--[a]	--	0[a]
	6 Sept to 13 Sept	Dilution water	7.6	5.8- 9.4	100
		1	10.0	8.2-11.8	100
		3	10.3	7.8-12.7	90
		10	12.1[a]	11.0-13.2	100
		30	12.5[a]	9.4-15.7	90
		100	--[a]	--	0[a]

[a] Significantly different from the dilution water ($P \leq 0.05$).

Table 5-13. **Results of Offsite Phase II *Ceriodaphnia* Naugatuck POTW and N9 Mixture Effluent Dilution Toxicity Tests, Naugatuck River**

Sample or Effluent	Test Dates	Test Concentraiton Percent (v/v)	Mean Number of Young per Female	95% Confidence Interval	Percent Survival
Naugatuck POTW and N9 Mixture	31 Aug to 7 Sept	Dilution water	11.5	8.8-14.2	100
		1	11.5	9.2-13.8	90
		3	14.6	13.4-15.8	100
		10	15.7[a]	14.0-17.5	70
		30	15.9[a]	14.6-17.2	80
		100	14.8	13.4-16.2	60
	1 Sept to 8 Sept	Dilution water	11.6	10.0-13.2	100
		1	10.8	7.2-14.4	100
		3	15.3	11.1-19.4	90
		10	16.0[a]	12.6-19.4	100
		30	14.6[a]	12.9-16.3	100
		100	13.7	10.5-16.8	89
	2 Sept to 9 Sept	Dilution water	11.3	9.1-13.5	100
		1	12.7	11.4-13.9	100
		3	12.0	10.1-13.9	100
		10	14.2[a]	13.5-14.9	100
		30	14.9[a]	13.4-16.3	100
		100	10.7	8.8-12.6	70
	3 Sept to 10 Sept	Dilution water	10.2	8.3-12.1	90
		1	11.7	10.0-13.4	100
		3	12.1	10.3-14.0	100
		10	14.3[a]	12.8-15.8	100
		30	17.3[a]	13.1-21.5	80
		100	11.8	9.7-13.8	70
	4 Sept to 11 Sept	Dilution water	10.6	8.8-12.4	90
		1	10.3	8.7-12.0	100
		3	14.1	11.2-17.0	100
		10	14.5[a]	11.6-17.4	100
		30	14.9[a]	12.7-17.1	90
		100	8.0	5.0-11.0	40
	5 Sept to 12 Sept	Dilution water	5.3	0-12.1	50
		1	12.7	10.2-15.2	100[a]
		3	12.8	8.3-17.3	100[a]
		10	14.2[a]	11.4-17.0	100[a]
		30	14.0[a]	11.3-16.7	100[a]
		100	7.2	4.8- 9.6	30
	6 Sept to 13 Sept	Dilution water	7.9	4.8-10.9	90
		1	10.7	8.1-13.3	100
		3	11.7[a]	10.0-13.4	90
		10	15.2[a]	12.4-18.0	100
		30	16.3[a]	12.6-20.0	100
		100	15.8[a]	13.8-17.9	70

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[a] Significantly different from the dilution water ($P \leq 0.05$).

Table 5-14. **Results of Offsite Phase II *Ceriodaphnia* Ambient Station Toxicity Tests at Stations N9 and N10, Naugatuck River**

Sample or Effluent	Test Dates	Mean Number of Young per Female	95% Confidence Intervals	Percent Survival
N9	31 Aug to 7 Sept	13.5	12.8-14.2	20
	1 Sept to 8 Sept	11.9	10.8-12.9	50
	2 Sept to 9 Sept	8.1	5.9-10.4	50
	3 Sept to 10 Sept	12.4	10.8-14.1	67
	4 Sept to 11 Sept	10.0	8.3-11.8	20
	5 Sept to 12 Sept	6.1	2.5- 9.7	0
	6 Sept to 13 Sept	13.4	11.7-15.1	50
N10	31 Aug to 7 Sept	19.8	17.2-22.4	100
	1 Sept to 8 Sept	12.8	11.5-14.1	100
	2 Sept to 9 Sept	13.0	12.1-13.9	100
	3 Sept to 10 Sept	8.7	5.7-11.7	20
	4 Sept to 11 Sept	13.3	11.7-14.9	100
	5 Sept to 12 Sept	16.3	13.6-19.0	70
	6 Sept to 13 Sept	15.4	14.0-16.9	70

Table 5-15. **Summary of Offsite *Ceriodaphnia* Toxicity Tests Acceptable Effluent Concentrations (AEC's)**

Sample or Effluent	Test Phase	Diluent Water	Day Testing Began	(AEC[1]) Percent Effluent
Gulf Stream	I	N1	24 Aug	54.7
			25 Aug	1.7
			26 Aug	17.3
			27 Aug	17.3
			28 Aug	54.7
			29 Aug	54.7
			30 Aug	54.7
Torrington POTW	I	N1	24 Aug	>100
			25 Aug	54.7
			26 Aug	5.5
			27 Aug	17.3
			28 Aug	--[2]
			29 Aug	>100
			30 Aug	>100
Thomaston POTW	I	N1	24 Aug	17.3
			25 Aug	17.3
			26 Aug	100
			27 Aug	54.7
			28 Aug	5.5
			29 Aug	>100
			30 Aug	--[2]
Steele Brook	I	N1	24 Aug	1.7
			25 Aug	1.7
			26 Aug	5.5
			27 Aug	5.5
			28 Aug	5.5
			29 Aug	5.5
			30 Aug	5.5
Great Brook	I	N1	24 Aug	1.7
			25 Aug	1.7
			26 Aug	<1.0
			27 Aug	1.7
			28 Aug	<1.0
			29 Aug	17.3
			30 Aug	1.7
Mad River	I	N1	24 Aug	--[2]
			25 Aug	--[2]
			26 Aug	--[2]
			27 Aug	--[2]
			28 Aug	--[2]
			29 Aug	5.5
			30 Aug	54.7

Table 5-15 (Continued)

N8	I	N1	24 Aug	17.3
			25 Aug	17.3
			26 Aug	17.3
			27 Aug	17.3
			28 Aug	17.3
			29 Aug	54.7
			30 Aug	17.3
Waterbury POTW	II	N1	31 Aug	17.3
			1 Sept	5.5
			2 Sept	17.3
			3 Sept	17.3
			4 Sept	5.5
			5 Sept	17.3
			6 Sept	17.3
Naugatuck POTW	II	N1	31 Aug	54.7
			1 Sept	54.7
			2 Sept	54.7
			3 Sept	17.3
			4 Sept	17.3
			5 Sept	54.7
			6 Sept	54.7
N8	II	N1	31 Aug	17.3
			1 Sept	17.3
			2 Sept	54.7
			3 Sept	17.3
			4 Sept	54.7
			5 Sept	54.7
			6 Sept	54.7
Waterbury POTW	II	N8	31 Aug	54.7
			1 Sept	54.7
			2 Sept	54.7
			3 Sept	54.7
			4 Sept	54.7
			5 Sept	54.7
			6 Sept	54.7
Naugatuck POTW	II	N9	31 Aug	> 100
			1 Sept	> 100
			2 Sept	> 100
			3 Sept	> 100
			4 Sept	> 100
			5 Sept	> 100
			6 Sept	> 100

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[1] AEC (Acceptable Effluent Concentration) is the geometric mean of the no observed effect concentration (NOEC) and the lowest observed effect concentration (LOEC).

[2] Dash (--) indicates test was invalid, see Tables 5-1 through 5-14.

6. *Hydrological Survey*

Flow measurements were taken daily during the study period to calculate and monitor the effluent contribution to the receiving water at selected biological stations. A dye study was performed at three sites (Naugatuck POTW, Waterbury POTW, and Steele Brooke) to identify the individual dilution characteristics of each effluent. By modeling downstream dilution contours for each discharger, the exposure concentration pertinent to instream effects within the near field could then be quantified. See *Appendix C* for a presentation of the hydrological sampling methods.

6.1 Naugatuck River and Discharge Flow Measurements

Flows measured at the biological stations during the period 22 August to 4 September 1983 are shown in Table 6-1. The tidal influence of the Housatonic River extends to Station N12 during the high water portion of the cycle. As the river approaches high tide, the flow at Station N12 decreases due to water being impounded. As the water level recedes, the flow is greater than the base flow because of the excess storage released. The water level at Station N12 was recorded at the start and end of each set of velocity measurements once the tidal nature was observed.

Flow data available from four USGS stream gauging stations within the study area are also included in Table 6-1. These stations are located on the East and West Branch of the Naugatuck River just above their confluence near Torrington, at Thomaston, and at Beacon Falls. The reported flows on the East and West Branch were combined and treated as one source (Table 6-1). These combined USGS flows, which should coincide with the measured flows at Station N2, were typically 0.14 m^3/sec greater. Historical USGS data and field observation at the confluence during this study indicates that flows on the West Branch are typically larger than the East Branch. In the USGS data obtained for this study period, the flows of both branches were similar. The fact that the combined USGS flow exceeds the measured flow at Station N2 indicates that the East Branch USGS flows may be overestimated. The USGS flows at Beacon Falls were used in place of the measured flows at Station N10 since the two stations were within 0.4 km of each other.

The daily flow data indicate that the Naugatuck basin is undergoing a very gradual flow decrease from 22 to 27 August (Table 6-1). This is evidenced by a decrease from 0.59 to 0.54 m^3/sec at the USGS gauge at Thomaston and a decrease from 2.24 to 1.93 m^3/sec at Beacon Falls. Rain during the second half of 28 August greatly increased flows on 28 and 29 August. Flows receded during the remaining portion of the study and by 1 September had approached a base level similar to the previous week.

Historical yearly average flows for the Naugatuck River are substantially higher than the flows observed during the study period. Historical USGS flows average 0.69 m^3/sec and 1.61 m^3/sec for the East and West Branch, respectively, 5.66 m^3/sec at Thomaston, and 13.96 m^3/sec at Beacon Falls. The USGS records indicate that monthly flows during the late summer and the fall are usually significantly lower than the yearly average value. Reported 7Q10 flows for the Naugatuck River are 0.11 m^3/sec at the confluence of the East and West Branch, 0.35 m^3/sec at Thomaston, and 1.71 m^3/sec at Beacon Falls. The 7Q10 at Beacon Falls includes approximately 0.70 m^3/sec from the Waterbury POTW which originates from outside the Naugatuck basin. Examination of Table 6-1 for 22-26 August shows that the average USGS Thomaston flow of 0.57 m^3/sec was 63 percent (0.22 m^3/sec) higher and the USGS Beacon Falls flow of 2.22 m^3/sec was 30 percent (0.51 m^3/sec) higher than the 7Q10 values.

During the dye studies, and from 29 August to 4 September, hourly flows were tabulated from the plant operational strip charts of the Waterbury and Naugatuck POTWs. The resulting daily mean, minimum, and maximum discharges are presented in Table 6-2. The Waterbury POTW had an overall mean daily discharge of 0.78 m^3/sec with hourly flows varying from 0.33 to 1.25 m^3/sec over the study period. The Naugatuck POTW had an overall mean daily discharge of 0.19 m^3/sec with hourly flows varying from 0.11 to 0.32 m^3/sec. The Naugatuck POTW receives both domestic and pretreated industrial effluent. The industrial effluent, as reported by the Naugatuck POTW, showed little daily variations in flow and averaged 0.07 m^3/sec during this period. On Saturday, 3 September, no industrial effluent was discharged between 1000 and 2000 hours.

Table 6-1. **Flows Measured at Biological Sampling and USGS Stations in the Naugatuck River (m^3/sec)**[a]

	August										September			
Stations	22	23	24	25	26	27	28	29	30	31	1	2	3	4
N1	0.038	0.063		0.046		0.035			0.144		0.080		0.052	
N2	0.197	0.173	0.169	0.191	0.169	0.134	0.308	0.234	0.293	0.257	0.251	0.242	0.208	0.204
(USGS)[b]	0.314	0.309	0.306	0.303	0.297	0.295	0.524	0.419	0.411	0.396	0.382	0.368	0.357	0.348
N3	0.285	0.263		0.242		0.304			0.371		0.308			
N4	0.352	0.432		0.421		0.401		0.697	0.527		0.417		0.407	0.454
N4A	0.411		0.445		0.470		0.443			0.621		0.480		
(USGS)[c]	0.59	0.59	0.57	0.57	0.54	0.54	1.47	1.05	0.82	0.76	0.71	0.65	0.62	0.57
N5	0.528	0.611		0.543					0.941		0.675			
SB1	0.195		0.114		0.141	0.118	0.120	0.187		0.135		0.122		0.095
N6	0.88	1.16		0.82		0.76			1.30		1.04		0.96	
GB1	0.037		0.054		0.056			0.033		0.059		0.056		0.043
N7	0.824	0.98	0.78	0.80	0.91	0.83			1.21		1.05		0.82	
M5	0.317	0.327	0.343	0.393	0.316	0.294		0.344		0.398		0.347		0.291
N8	1.35	1.36	1.24	1.22	1.10	1.12	1.01	2.55	1.70	1.58	1.46	1.43	1.23	1.15
N9	2.17	1.88		2.43		1.65		3.61	2.51	2.10	1.99	2.13	1.67	1.48
N10 (USGS)[d]	2.24	2.66	2.10	2.07	2.04	1.93	3.65	4.28	3.23	2.52	2.35	2.18	1.95	1.73
N11	2.75		2.43		2.59		2.44	4.20		2.77		2.78		2.33
N12	4.47	3.90	3.64	2.69	3.16	3.11	2.86	5.32	7.23[e]	2.51	2.78[e]	2.48[e]	2.01	2.27

[a] USGS data are mean daily values.
[b] East and West Branch gauging station information combined. Data set intended to be comparable to Station N2 measured flows.
[c] Thomaston gauging station.
[d] Beacon Falls gauging station.
[e] Station N12 flow measurement performed at a varying water elevation.

Table 6-2. **Daily Mean, Minimum, and Maximum Discharges at the Waterbury POTW and the Naugatuck POTW (m^3/*sec*)**

	August								September			
	22	23	24	25	26	29	30	31	1	2	3	4
Waterbury POTW												
Mean			0.90[a]	0.78	0.54[a]		0.91[a]	0.81	0.77	0.74	0.69	0.65
Minimum				0.44	0.44			0.43	0.35	0.39	0.34	0.33
Maximum			1.03	1.04			1.05	1.25	1.10	1.01	1.01	0.99
Naugatuck POTW												
Mean	0.18[a]	0.14[a]				0.21[a]	0.19	0.19	0.19	0.19	0.14	0.16
Minimum		0.11					0.14	0.13	0.13	0.13	0.11	0.11
Maximum	0.21	0.21				0.32	0.23	0.22	0.23	0.23	0.17	0.26

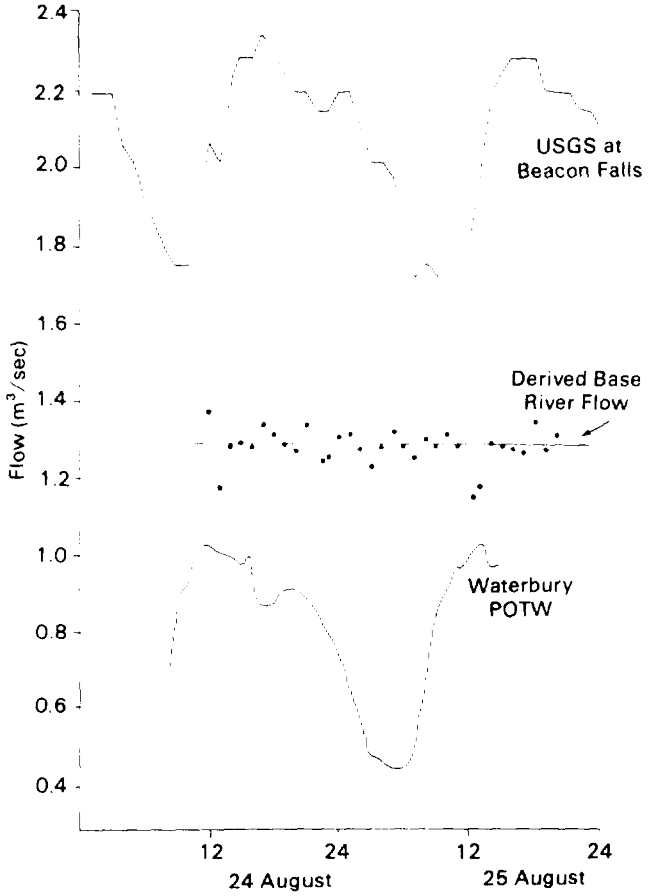
[a] Calculations based on a partial day.

Source. POTW plant records.

The hourly USGS flow data at Beacon Falls exhibits a 0.42-0.57 m^3/sec daily variation. This variation corresponds to the cyclic day/night flow pattern associated with the Waterbury POTW which is approximately 11 km upstream. On 24 and 25 August, the dates of the dye study, the hourly flows at the POTW and Beacon Falls are illustrated in Figure 6-1. The excellent agreement between the two curves is readily apparent and provides evidence of a 5-hour lag time between the two locations. This 5-hour shift represents a phase velocity for the propagation of a change in discharge downstream and does not represent a time-of-travel for a water parcel between the two stations: the parcel velocity would be several times slower. For 24-25 August the hourly POTW flows were subtracted from the flows at Beacon Falls taking into account the observed 5-hour shift. This removed the cyclic pattern resulting in a uniform flow at 1.30 m^3/sec for the two days (Figure 6-1). This flow is in reasonable agreement with the flows of 1.24 and 1.22 m^3/sec measured at Station N8 upstream of the Waterbury POTW, even including a nominal flow of 0.19 m^3/sec for the Naugatuck POTW.

Time-of-travel studies have been performed by the State of Connecticut several times between 1979 and 1982. The study in 1979 demonstrated that the tidal portion of the Naugatuck River which extends approximately 3 km upstream from the confluence of the Housatonic River and includes Station N12, has a

Figure 6-1. **Hourly USGS flows at Beacon Falls on the Naugatuck River and the discharge flow from the Waterbury POTW. Base river flow was derived by substracting hourly Waterbury POTW discharge from Beacon Falls flows.**



complete exchange of water in one tidal cycle (DEP 1980). During the 1980-1982 surveys, time-of-travel studies were performed at all reaches between the confluence of the East and West Branch at Torrington, upstream of Station N2, and the confluence with the Housatonic River (DEP 1982). These studies show a noticeable change in the velocity regime of the Naugatuck river at a point above the Waterbury POTW in the vicinity of the confluence with the Mad River (Table 6-3). In the upper portion of the river velocities are typically 0.06-0.08 m/sec except for velocities of less than 0.03 m/sec through the Summit Impoundment. Downstream of river kilometer (RK) 28.3, which is above the Waterbury POTW, velocities are greater than 0.19 m/sec.

The results of the time-of-travel studies performed by the State of Connecticut can be compared to the average velocity calculated downstream from each of the three dye study sites. These velocities were calculated at each transect by dividing the appropriate Naugatuck River flow by the cross-sectional area of the transect. The flow conditions during the dye studies were approximately half as large as those encountered by the State (Table 6-3). For the 1,219-m study area below Steele Brook (RK 33.4), the estimated velocity of 0.091 m/sec is 50 percent higher than the velocities reported in Table 6-3 for the RK 28.3-38.8 reach. Below the Waterbury POTW (RK 27.2) the estimated velocity of 0.101 m/sec for the 1,433-m reach was 50 percent less than the velocity reported in Table 6-3 for RK 20.4-27.2. This reduction may reflect both the reduced flows and the low velocities upstream of the dam (420 m downstream of the Waterbury POTW) which may not be representative of the larger area. For the 1,219-m study area below the Naugatuck POTW (RK 19.4), an estimated velocity of 0.210 m/sec compares favorably to the 0.265 m/sec value which was measured between RK 20.4 and 6.6 under higher flow conditions.

6.2 Dilution Analysis of Naugatuck POTW

The Naugatuck POTW is located on the west bank of the Naugatuck River at approximately RK 19.4. During the dye study, the plant operational data gave a 24-hour average discharge of 0.16 m^3/sec from noon 22 August to noon 23 August. The minimum flow of 0.11 m^3/sec occurred at 0400 hours and the maximum flow of 0.21 m^3/sec occurred at 1200 hours on 23 August.

The daily average USGS flow at Beacon Falls, 4.3 km downstream, was 2.24 and 2.66 m^3/sec on 22 and 23 August, respectively. The flow on 23 August was skewed by a sharp increase between 0100 and 0300 hours as a result of rain, which peaked at 4.67 m^3/sec. The flow quickly subsided reaching a more normal flow of 2.62 m^3/sec at 0700 hours and a minimum of 1.99 m^3/sec at 1200 hours. The following increase between 1200 and 1600 hours to 2.57 m^3/sec was typical in magnitude and phase with the flow variation imposed by the discharge of the Waterbury POTW.

A predicted discharge dye concentration was calculated at a 30-minute interval using the plant pumping data and the 3.15 g/min dye injection rate. Dye concentrations resulting from grab samples taken in the discharge were in better agreement with the predicted values than the measured values at the discharge fluorometer. This was attributed to poor electrical connections between the discharge fluorometer and the strip chart recorder. The average predicted discharge dye concentration was 73.0 ppb between 1800 hours on 22 August and 1200 hours on 23 August. A maximum value of 97.7 ppb occurred at 0400 hours and a minimum of 50.8 ppb occurred at 1200 hours on 23 August as a result of the varying plant flow. The instream water samples were collected on 23 August from 0910 to 1340 hours at the

Table 6-3. Results of Time-of-Travel Studies Performed by the State of Connecticut

	June-August 1980				July-August 1981, September 1982			
Station	River Kilometer	Travel Time (hr)	Average Velocity (m/sec)	Flow[a] (M^3/sec)	River Kilometer	Travel Time (hr)	Average Velocity (m/sec)	Flow[a] (m^3/sec)
N2-N5	63.5-41.4	75.5	0.082	0.51-1.27	61.2-55.1	19.7	0.085	0.59
N5	41.4-38.8[b]	35.0	0.021	1.27	41.4-38.8	37.0	0.018	1.13
N5-N8	38.8-28.5	48.0	0.061	1.27-2.12				
N5-N8	38.8-28.5	45.7	0.064	0.85-1.87				
N8-N11	28.5- 6.6	29.8	0.201	3.31-3.96	27.2-20.4	8.3	0.195	4.25-4.59
				20.4-6.6	15.5	0.265	4.81-5.24	
N12	4.7- 0.6	5.8	0.195	8.50				

River Kilometer	Feature
63.5	*Confluence of East and West Branch at Torrington (N_2)*
61.2	Torrington POTW
47.5	Thomaston POTW
38.8-41.5	Inclusive of Summit Impoundment
27.2	Waterbury POTW
19.4	Naugatuck POTW
3.0	RR Bridge at Ansonia (N12)

[a] Flow at beginning and end of reach.

[b] Summit Impoundment.

Source: DEP (1980, 1982).

12 transects described in Table C-1. The observed background fluorescence of 0.19 ppb was subtracted from all the instream data.

As an aid in determining the appropriate average discharge concentration to use in the downstream dilution ratios, the travel time for an "average" water parcel to reach each transect was considered. Based on each transect's cross-sectional area and a nominal flow of 2.2 m^3/sec, the resulting velocites ranged from 0.15 to 0.46 m/sec. The time for the average parcel to reach Transect T11 (1,219 m downstream) was 1.6 hours. Thus, while the transects were sampled between 0930 and 1340 hours, the corresponding water was leaving the discharge from 0930 to 1200 hours. This calculation, of course, does not account for individual pools which may exchange water at a slower rate. As a result of the above exercise, an average discharge dye concentration of 85.5 ppb, calculated between 0900 and 1000 hours, was used for the near-field Transects T1 to T4. At successive downstream transects the time interval was expanded such that, at Transects T10 and T11, a value of 67.3 ppb was used corresponding to the average discharge concentration from 0900 to 1200 hours. The instream samples had shown that the average dye concentration in the downstream transects was decreasing and this use of a variable discharge concentration was able to partially reduce the downstream variation in the dilution ratios. The resulting dilution contours are shown in Figure 6-2.

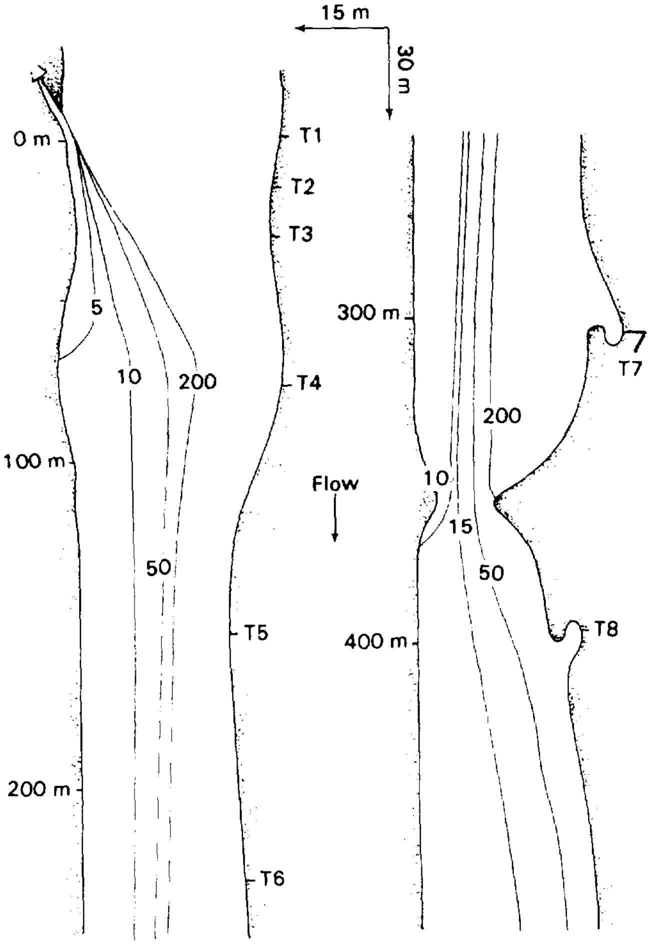
Only at Transect T6 and T8 was a major portion of the transect deeper than 0.5 m, resulting in the collection of surface and bottom samples. In these cases, the two depths gave very similar results.

The plume from the Naugatuck POTW remained along the right bank and did not mix past the midpoint of the river until after passing through a narrow constriction 365 m downstream. During this interval, a dilution ratio of 10 was located at approximately one-quarter of the river width. After the constriction, the plume mixed slowly across the river with a dilution ratio of 50 reaching the far bank of 610 m and a dilution ratio of 20 reaching the far bank of 1,200 m downstream. At 1,219 m (Transect T11), the river was approaching a fully-mixed condition. At this point, the remaining horizontal dilution gradient of 15-20 corresponds to the Naugatuck POTW comprising 6.7-5.0 percent of the Naugatuck River flow at the right and left bank, respectivley.

6.3 Dilution Analysis of the Waterbury POTW

The Waterbury POTW is located on the west bank of the Naugatuck River at approximately RK 27.2. The POTW has a maximum design flow of 1.1 m^3/sec (25 mgd). During the 24-hour period of the dye study extending from noon on 24 August to noon on 25 August, the average discharge flow was 0.79 m^3/sec according to the Waterbury POTW plant records. A

Figure 6-2. **Dilution contours in the Naugatuck River downstream from the Naugatuck POTW, 23 August 1983.**



minimum flow of 0.44 m^3/sec occurred at 0600 hours and a maximum flow of 1.04 m^3/sec occurred at 1200 hours on 25 August (Table 6-2). Flows of 1.24 and 1.22 m^3/sec were measured on 24 and 25 August at Station N8 located 1.1 km upstream from the POTW (Table 6-1).

Dye concentrations measured at the discharge fluorometer on 24 and 25 August were compared to dye concentrations calculated from the reported plant flows and the dye injection rate of 3.08 g/min. The measured dye concentrations averaged 0.37 ppb (3 percent) higher than the calculated concentrations. The instream water samples were collected on 25 August from 0915 to 1350 hours at the 12 transects described in Table C-1. The observed background was 0.12 ppb in the river and 0.42 ppb in the plant effluent. The background fluorescence applied to the transect data was extrapolated between these two values in proportion to the observed dye concentration in each sample.

On the morning of 25 August, the POTW flow increased from the observed minimum of 0.44 m^3/sec at 0600 hours to a flow of 0.91 m^3/sec at 0930 hours according to Waterbury POTW plant records. While the instream samples were being collected, the POTW flows were on a plateau and varied from 0.90 to 1.04 m^3/sec. The varying POTW flows and the resulting fluctuation in the discharge dye concentration, made it necessary to estimate a downstream travel time based upon a nominal river flow and each transect cross-sectional area. At Transects T1 to T6, 229 m downstream, which were sampled between 0930 and 1105 hours, the corresponding "average" water particles were leaving the discharge between 0930 and 1040 hours. Successively longer times were required to reach the farther downstream stations. At Transect T11 (1,433 m downstream) a 4-hour travel time was estimated such that the water sampled at 1350 hours left the discharge at 0950 hours. It was concluded that the increasing plant flows and correspondingly decreasing discharge dye concentrations between 0600 and 0930 hours prior to the instream samples being collected would not have a major influence on the observed downstream dye configuration.

A discharge dye concentration of 13.0 ppb, representative of conditions at the time the near-field

Figure 6-2. **(Continued)**

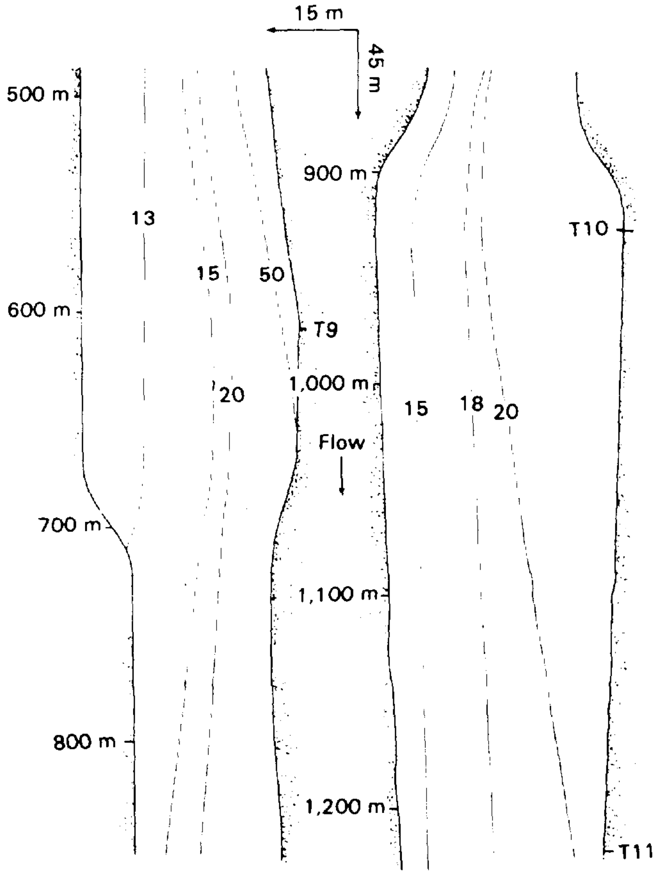
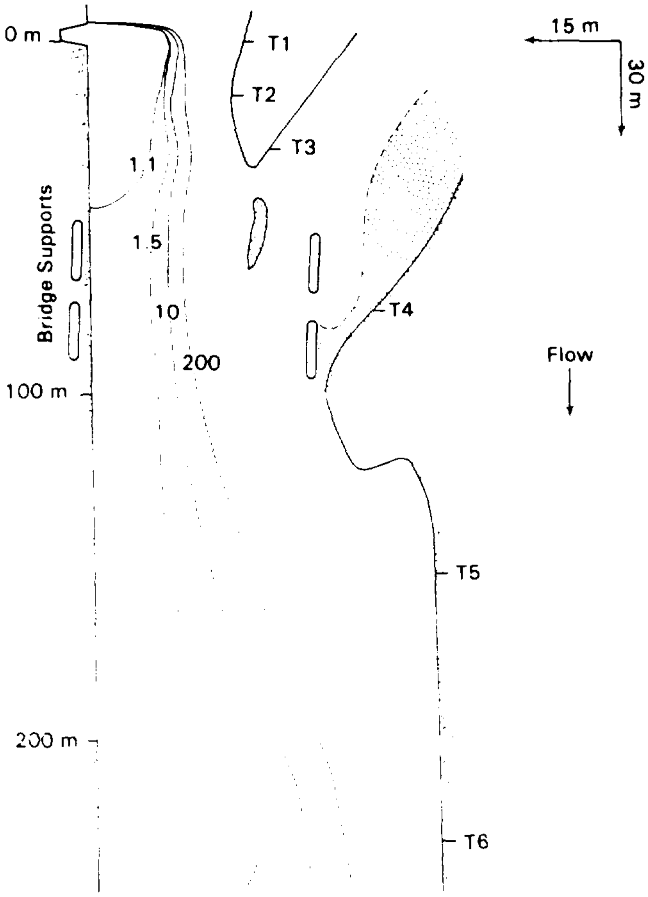


Figure 6-3. **Dilution contours in the Naugatuck River downstream from the Waterbury POTW, 25 August 1983.**

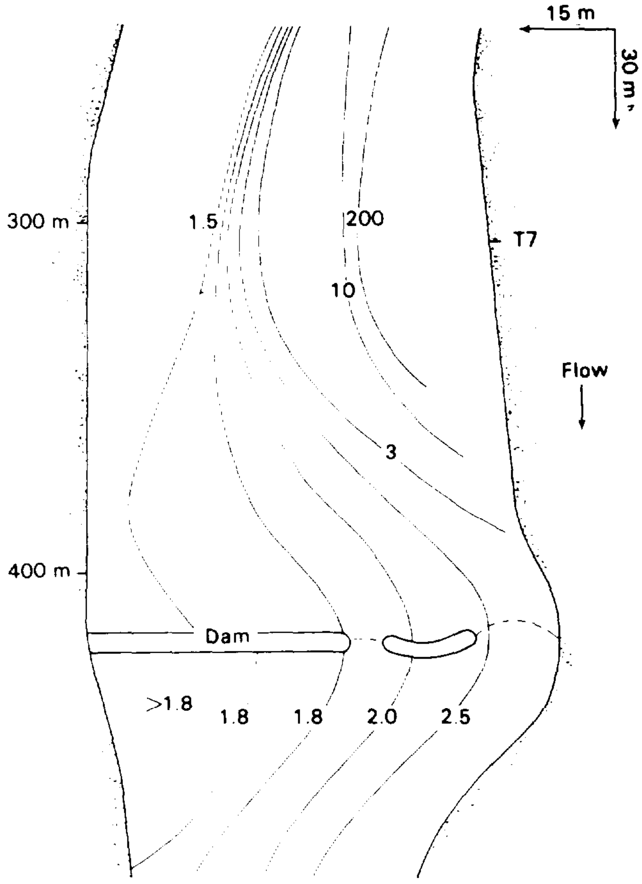


transects were being sampled, was used to calculate the dilution ratios. The resulting dilution contours are shown in Figure 6-3. At Transects T6 and T7 located in the pool above the dam and at Transect T9, a major portion of the transect was deeper than 0.5 m, resulting in the collection of surface and bottom samples. Dilution differences between the two depths were within the sampling variability. The plume from the Waterbury POTW remained along the right bank for the first 365 m downstream. Initially, the plume was kept to the right bank by the flow emerging from the left channel beyond the island in front of the discharge and by being pushed to the outside of the river bend that occurs at 240 m. The flow over the dam, 420 m downstream, takes place on the opposite side causing the river flow to transverse from right to left as it approaches. The resulting mixing reduces the 1.5-200 horizontal dilution gradient present 75 m above the dam to a 1.8-2.8 dilution gradient directly below the dam. The remaining mixing occurred more slowly achieving a dilution gradient of 2.4-2.6 at T10 (1,067 m). The Naugatuck River was observed to be fully mixed at T11 (1,433 m) with a dilution ratio of 2.5 which corresponds to the Waterbury POTW comprising 40 percent of the total flow.

6.4 Dilution Analysis of Steele Brook

Steele Brook is a tributary which flows into the Naugatuck River at approximately RK 33.4. During the dye study on 26 and 27 August, flows of 0.141 and 0.118 m^3/sec were measured at Station SB1. At the USGS gauging station near Thomaston, located approximately 12 km upstream of the confluence between Steele Brook and Naugatuck River, a daily average flow of 0.54 m^3/sec was reported on both days. Flow additions from the Thomaston POTW which has a reported nominal discharge of 0.06 m^3/sec (1 mgd) would result in an expected flow of 0.60 m^3/sec for the Naugatuck River above the confluence with Steele Brook. This value is consistent with the flows of 0.611 m^3/sec and 0.543 m^3/sec measured on 23 August and 25 August at Station N5 (Table 6-1). The combined upstream and Steele Brook flows are also consistent with the 0.76 m^3/sec value measured at Station N6 on 27 August when the day

Figure 6-3. **(Continued)**

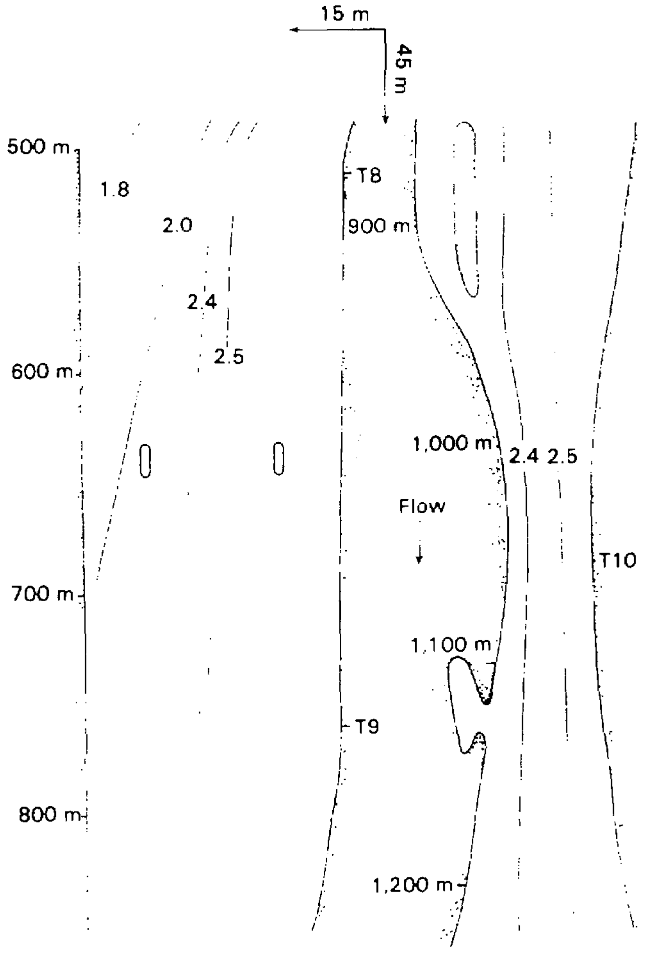


the instream samples were collected (Table 6-1). Station N6 corresponds to Transect T9 for the Steele Brook dye study.

The cross-sectionally averaged discharge dye concentration measured in Steele Brook at the transect 30 m above the confluence with the Naugatuck River was 64.0 ppb on 26 August (1650 hours) and 74.5 ppm on 27 August (0855 hours). In order for the dye injection rate of 2.21 g/min to result in these observed discharge concentrations, the flow from Steele Brook at the time of the dye measurement would have been 12-20 percent smaller than the flows of 0.141 and 0.118 m^3/sec which were measured on the corresponding days but at different times. An average discharge dye concentration for the two sets of measurements of 70.0 ppb was used to form the downstream dilution ratios.

The instream water samples were collected on 27 August from 0905 *to 1215 hours* at the 12 transects described in Table C-1. The observed background fluorescence was 0.07 ppb in Steele Brook and 0.19 ppb in the Naugatuck River above the confluence. The background fluorescence applied to the transect data was extrapolated between the two values in proportion to the observed dye concentration in each sample.

Figure 6-3. (Continued)



In the near field, depths exceeded 1 m at Transects T1 to T3 and exceeded 0.5 m at T4 such that surface and bottom samples were collected. The dilution contours for the near-field surface data are displayed in Figure 6-4. The dilution contours for the mid/bottom data are presented in Figure 6-5 for the near and far field. When only a mid-depth was sampled, the same value was used in both figures.

The surface and bottom data at transects T1 to T4 displayed a plume which emerged from Steele Brook, crossed the Naugatuck River on the bottom, and surfaced 50 m downstream on the far bank (Figures 6-4 and 6-5). The Steele Brook plume then proceeded to mix into the Naugatuck River from the far bank to the near bank as it traveled downstream. The 5.0 dilution contour crossed the Naugatuck River below the surface and then extended 230 m down the far bank. On the surface, a dilution contour of 50 extended 50 m downstream from the confluence over-riding the plume emerging from Steele Brook. At Transect T5, which extends from 122 to 194 m downstream, the flow passes over a wide shallow riffle in the middle of an "S" bend. Below Transect T5 there is no longer a distinct plume and the remaining mixing takes place slowly. At Transect T10, 1,067 m downstream, the river has approached the fully-mixed state at a dilution ratio of 7.2 (13.9 percent of the river flow).

6.5 Evaluation of Dilution Characteristics

The dye configuration studies showed that the effluent from Steele Brook was nearly fully mixed and from the Waterbury and Naugatuck POTWs was fully mixed before reaching the next downstream biological sampling station. The plume from Steele Brook crossed the Naugatuck River on the bottom, surfaced 50 m downstream on the far bank (left), and then mixed in from the far bank to the near bank as it traveled downstream. At Station N6 (corresponding to Transect T9, located 701 m downstream), the effluent comprised 17.9 percent of the flow on the left bank and 13.5 percent of the flow on the right bank. The river was fully mixed by Transect T10, 1,067 m downstream.

The plume from the Waterbury POTW remained along the right bank of the Naugatuck River until the flow traversed from right to left just above the dam, located 420 m downstream. Below the dam, the effluent comprised from 56 to 36 percent of the flow from right to left bank, respectively. The effluent was fully mixed at 1,430 m downstream with a 40 percent contribution to the flow.

Figure 6-4. Surface dilution contours in the Naugatuck River downstream from Steele Brook, 27 August 1983.

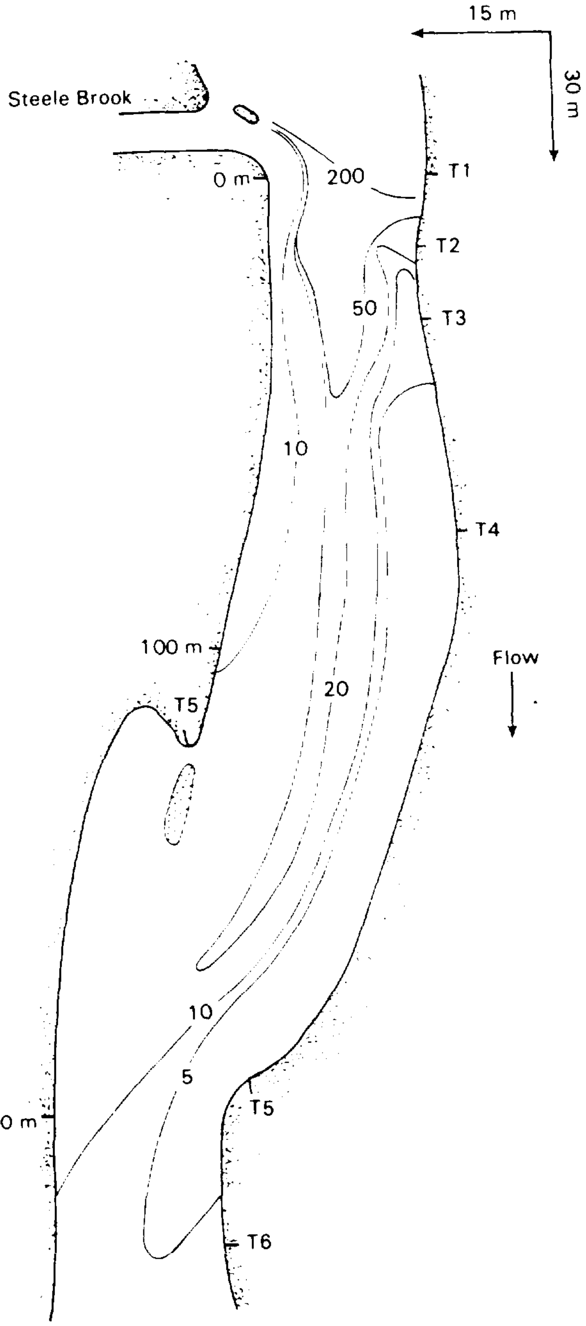
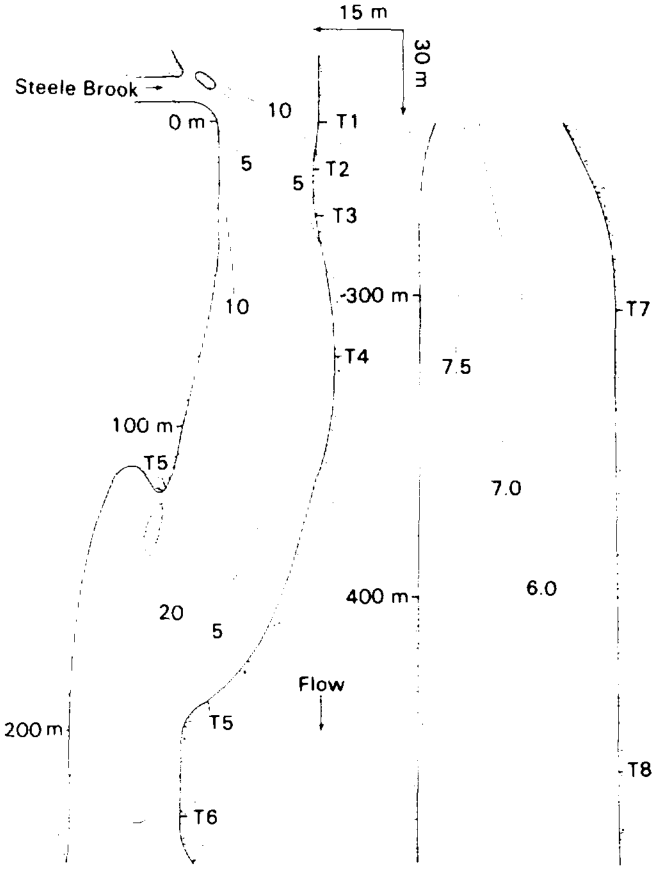


Figure 6-5. Mid/bottom dilution contours in the Naugatuck River downstream from the Steele Brook, 27 August 1983.



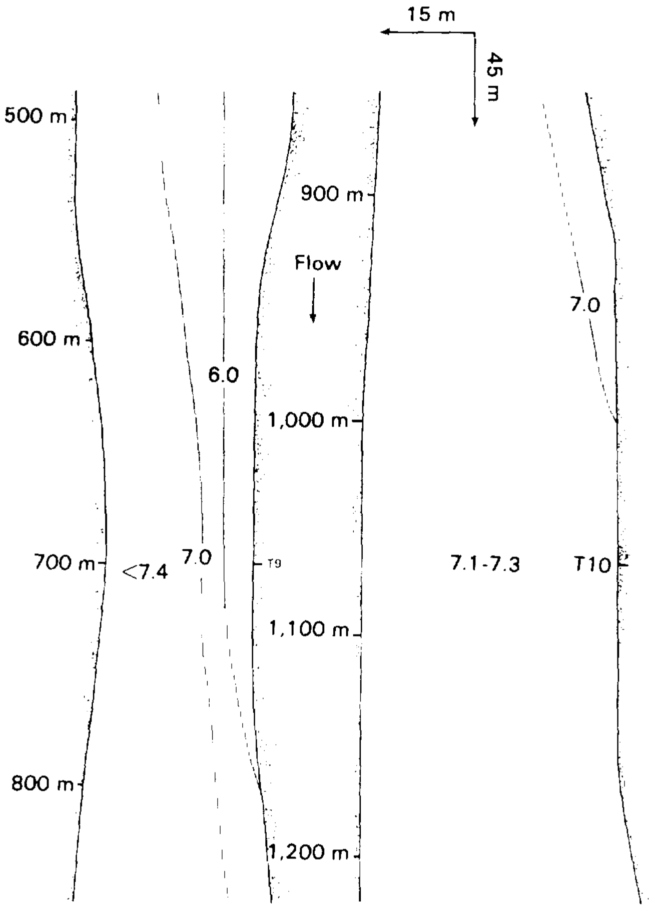
The plume from the Naugatuck POTW remained on the right bank of the Naugatuck River for the first 365 m and then mixed across after a narrow constriction. The river approached a fully mixed state 1,219 m downstream with a 5.7 percent effluent contribution.

The flow contributions of the three discharges addressed in the dilution analysis are illustrated in Figure 6-6 in relation to the total Naugatuck River flow between Station N2 and N12. The fully mixed (percent) flow contribution of the three discharges at each biological sampling station is summarized in Table 6-4. The mean flows used in Figure 6-6 and Table 6-4 were for the period 22-26 August 1983. At Station N12 the estimated flow of 3.0 m^3/sec was the average for the period 22-26 August and 31 August -4 September to reduce the irregular daily values due to tidal fluctuations and sampling variability. The flows used for the three discharges were 0.13 m^3/sec, 0.78 m^3/sec, and 0.19 m^3/sec for Steele Brook, Waterbury POTW, and Naugatuck POTW, respectively.

The flow contribution from Steele Brook decreased from 15.7 percent at Station N6 to 4.2 percent at Station N12 (Table 6-4). The Waterbury POTW contribution decreased from 38.4 to 25.9 percent from Station N9 to Station N12. Naugatuck POTW contribution decreased from 8.6 to 6.3 percent at Station N10 and Station N12.

The observed flows during the 22-26 August portion

Figure 6-5. (Continued)



of the study were 0.22 m^3/sec and 0.51 m^3/sec above a 7Q10 condition at the Thomaston and Beacon Falls USGS gauging stations, respectively. The flow contribution for the three discharges at Station N10, for a 17.1 m^3/sec 7Q10 flow condition is calculated assuming that the discharges remain at their current discharge rates. The resulting flow contributions are 7.4, 45.4, and 11.1 percent for Steele Brook, Waterbury POTW, and Naugatuck POTW, respectively (Table 6-4). It is likely that under 7Q10 conditions the discharge rates would decrease such that the above percent contributions would be an upper limit.

Figure 6-6. Flow contributions to the Naugatuck River from natural sources, POTWs, and other dischargers. Note: Rock Brook was not included in the study design but flow contribution was calculated for this figure.

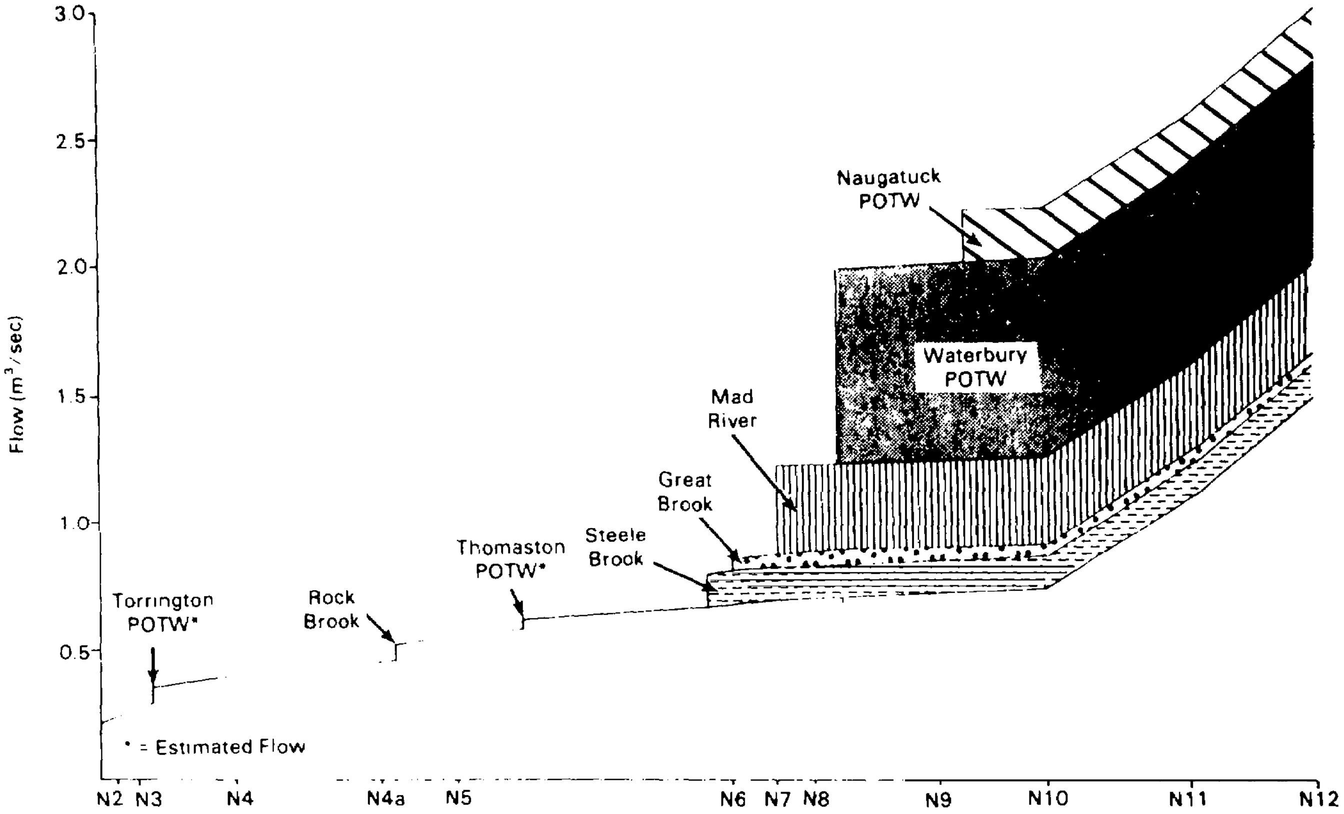


Table 6-4. Average Naugatuck River Flow and Percent Flow Contribution from Three Discharges for the Period 22-26 August 1983

Station	Total Flow (m^3/sec)	Percent Flow Contribution Upstream	 Steele Brook	 Waterbury POTW	 Naugatuck POTW
N2	0.20	100.0			
N3	0.26	100.0			
N4	0.40	100.0			
N4a	0.44	100.0			
N5	0.56	100.0			
N6	0.81	84.3	15.7		
N7	0.86	85.2	14.8		
N8	1.25	89.8	10.2		
N9	2.02	55.3	6.3	38.4	
N10	2.22	50.7	5.7	35.0	8.6
N11	2.59	57.8	4.9	30.0	7.3
N12	3.00	63.6	4.2	25.9	6.3
7Q10 Condition					
N10	1.71	36.1	7.4	45.4	11.1

7. *Periphytic Community*

The periphyton study investigated plant effects and the recovery of the periphytic community by measuring chlorophyll *a* and biomass and determining periphyton abundance and composition. The relatively short reproduction time and rapid seasonal fluctuation in growth of periphytic algae make that community a useful indicator of localized effects resulting from effluent toxicity. An effect on the periphytic community may be seen in either a reduction of an important habitat or food source for invertebrates and fish, or in the enhancement or dominance of nuisance species of algae that neither support other trophic levels nor are aesthetically pleasing. The methods used for periphyton collection and analysis are presented in Appendix D. Supporting biological data for periphyton are included in Appendix G.

7.1 Community Structure

Fifty-five algal taxa (51 genera) representing four major taxonomic divisions were identified in periphyton samples collected from 20 stations in the Naugatuck River and its tributaries. Forty-eight taxa were identified from the 13 stations in the river (Table G-1) and 36 taxa from the 7 stations in the tributaries (Table G-2). Diatoms and green algae comprised most of the taxa observed. Total periphyton densities ranged from 16,264 to 115,995 units/mm in the river and from 9,979 to 303,333 units/mm^2 in the tributaries (Tables G-1 and G-2). Diversity varied from 1.27 to 3.85 in the river and from 1.29 to 3.38 at tributary stations. Equitability ranges from 0.25 to greater than 1.00 in the Naugatuck river and from 0.27 to 0.81 in the tributaries.

7.1.1 Naugatuck River

Based on the periphyton data, the portion of Naugatuck River examined in this study was divided into three sections corresponding to similarities in periphyton community structure. The first section comprised stations N1 through N5 and was characterized by diversities in excess of 3.0, low to moderate densities of *Stigeoclonium*, and relatively diverse diatom flora (Table G-1). The lowest total density found in the Naugatuck River (16,264 units/mm^2)

Table 7-1. Chlorophyll *a* and Biomass Data and Statistical Results for Periphyton Collected from Natural Substrates in the Naugatuck River, August 1983

Parameter	N1	N2	N3	N4	N4A	N5	N6	N7	N8	N9	N10	N11	N12
Chlorophyll *a* (mg/m^2)													
Rep 1	134.2	117.7	195.7	123.8	165.4	132.8	132.8	95.2	237.8	111.1	42.8	53.0	254.7
Rep 2	32.2	84.8	151.9	208.7	188.4	171.0	341.6	102.0	592.7	135.5	51.2	103.0	586.7
Rep 3	38.1	133.8	268.2	150.6	111.1	57.1	51.6	77.8	168.9	115.8	64.2	133.7	149.0
Mean	68.2	112.1	205.3	161.0	155.0	120.3	175.3	91.7	333.0	120.8	52.7	96.6	330.1
Biomass (g/m^2)													
Rep 1	15.0	15.4	28.8	20.1	16.2	19.2	19.7	13.3	19.2	11.0	6.5	8.0	31.3
Rep 2	12.3	12.7	44.5	48.4	9.4	22.8	37.8	16.4	45.7	19.3	9.0	7.9	61.4
Rep 3	35.9	19.6	15.8	63.5	23.7	31.2	38.0	45.2	33.1	--	11.5	--	57.8
Mean	21.0	15.9	29.7	44.0	16.4	24.4	31.8	25.0	32.7	15.1	9.0	7.9	50.2
Autotrophic Index (Weber 1973)	309	142	145	273	106	203	181	272	98	125	171	82	152
Statistical Results[a]													
Chlorophyll *a*													
F=3.292 Station[b]	N10	N1	N11	N7	N5	N2	N9	N6	N4a	N4	N3	N12	N8
P=0.005 Mean[c]	3.97	4.02	4.51	4.52	4.70	4.71	4.80	4.90	5.03	5.06	5.30	5.64	5.67

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[a] Results based on analysis of variance and Tukey multiple comparison test procedure performed on data transformed with natural logarithms [ln(x+1)] Stations underscored by a continuous line were not significantly different ($P > 0.05$)

[b] Stations are listed in order of increasing mean values.

[c] Means of transformed data

occurred at Station N1 located west of Torrington (Table G-1). Station N5 was located downstream from both Thomaston Dam and Thomaston POTW, and the highest diversity observed in the Naugatuck River (3.85) occurred at Station N5.

The second section comprised Stations N6 through N11 and was characterized by diversities of ≤ 2.6, dominated by *Stigeoclonium, Scenedesmus,* and/or unidentified coccoid green algae, and usually less diverse diatom flora dominated by *Nitzschia*. A threefold increase in total periphyton density occurred between Station N5 and N6, the latter station being located downstream from the confluences with Steele Brook and Great Brook. The low diversity and equitability at Station N6 also indicated the occurrence of an environmental perturbation at this station. Evidence that conditions had improved at Station N7 was seen in diversity and equitability, both of which were considered moderate. These parameters fluctuated in this section according to station location with respect to discharges but generally suggested degraded conditions of the periphyton community.

The third section was near the confluence with the Housatonic River and included only Station N12 from this study. This section also exhibited moderately low diversity (2.1), but was dominated by unidentified naviculoid green algae (possibly *Oocystis*) and supported large periphyton standing crops (Tables 7-1 and G-1). Maximum periphyton density in the river (115,995 units/mm^2) occurred at Station N12.

7.1.2 Tributary Stations

Maximum periphyton density observed during this study (300,333 units/mm^2) occurred at a tributary station (SB1) located in Steele Brook (Table 7-2). The abundance of several taxa exceeded 20,000 units/mm^2 at this station. These taxa included the diatoms *Achnanthes* and *Navicula*, the green alga *Oocystis*, unidentified coccoid forms, unidentified naviculoid forms, and the blue-green alga *Phormidium* (Table G-2). The latter forms may indeed be isolated cells of *Oocystis*, a genus more commonly observed in plankton than periphyton (Prescott 1962). The occurrence of *Asterionella* also indicated there may be lentic habitats within the Steele Brook drainage. Diversity and equitability were moderately high at Station SB1 (3.05). The occurrence of potentially planktonic taxa complicted an evaluation of water quality at this station, but the pollution-tolerant organism, *Phormidium*, was very abundant.

With the exception of Gulf Stream, the remaining tributary stations were located within the Mad River drainage. Total density was 70,851 units/mm^2 at Station BP1 located in the upper reaches of Beaver Pond Brook and was reduced to 20,586 units/mm^2 at Station BP2 located upstream from the confluence with the Mad River (Table 7-2). Overall, the periphyton results indicated good water quality for Beaver Pond Brook (Figure 3-1).

Station M1 was located in the upper reaches of the Mad River, and total density at this station (70,433 units/mm^2) was very similar to that recorded at Station BP1 (Table 7-2). There were, however, distinct

Table 7-2. Chlorophyll *a* and Biomass Data and Statistical Results for Periphyton Collected from Natural Substrates in the Tributaries to the Naugatuck River, August 1983

Parameter	GS1	SB1	BP1	BP2	M1	M2	M5
Chlorophyll *a* (mg/m^2)							
Rep 1	66.3	164.5	132.6	31.7	99.7	50.3	229.6
Rep 2	32.0	214.5	119.5	48.0	94.7	53.3	135.6
Rep 3	46.2	193.5	75.9	41.8	137.8	66.3	87.7
Mean	48.2	190.8	109.3	40.5	110.7	56.6	151.0
Biomass (g/m^2)							
Rep 1	4.2	34.7	22.9	26.6	34.3	19.1	18.9
Rep 2	7.3	33.8	42.7	13.8	25.8	12.8	19.0
Rep 3	8.7	39.6	46.4	30.9	55.6	18.8	--
Mean	6.7	36.0	37.4	23.8	38.5	16.9	19.0
Autotroohic Index (Weber 1973)	140	189	342	587	348	298	126
Statistical results for[a] Mad River Drainage:							
F = 9.531 Station[b]	BP2	M2	BP1	M1	M5		
$P < 0.002$ Mean[c]	3.712	4.047	4.676	4.702	4.948		

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[a] Results based on analysis of variance and Tukey multiple comparison test procedure performed on data transformed with natural logarithms [ln(x+1)]. Stations underscored by a continuous line were not significantly different ($P > 0.05$).

[b] Stations are listed in order of increasing mean values.

[c] Means of transformed data.

differences in species composition between these two stations (Table G-2). Station M2 located upstream from the confluence with Beaver Pond Brook exhibited a total density of 9,979 units/mm^2. As with Beaver Pond Brook, the overall periphyton results suggest good water quality for this portion of the Mad River. Station M5 was located in the Mad River downstream from the confluence with Beaver Pond Brook and near the confluence with the Naugatuck River. Total density at Station M5 (224,883 units/mm^2) was the second highest recorded at any tributary station and twice as great as the highest density observed in Naugatuck River. The periphyton were heavily dominated by unidentified coccoid green algae although *Oocystis* was also a numerically important component of the community (Table 7-2). Diversity and equitability were low at Station M5, and indicated poorer water quality than at other stations within the Mad River drainage.

7.2 Chlorophyll *a* and Biomass

Average chlorophyll *a* standing crops in the Naugatuck River ranged from 52.7 to 333.0 mg/m^2; biomass standing crops varied from 7.9 to 50.2 g/m^2 (Table 7-1). Statistically, the only significant difference ($P \leq 0.05$) noted in the chlorophyll *a* data was that standing crops at Station N1 and N10 were less than those at Station N8 and N12. Spatial trends in the chlorophyll *a* and biomass data were similar to those described for total periphyton densities, except for the absence of a major peak in biomass at Station N8. Autotrophic Index (AI) values in the river ranged from 82 to 309 (Table 7-1), and values were less than 200 at most river stations. These values indicated that periphyton in the Naugatuck River were typically dominated by autotrophic (photosynthetic) rather than heterotrophic (nonalgal) taxa (APHA 1981). The higher AI value observed at Station N1 was similar to values recorded at several tributary stations, and may have reflected an increased importance of allochthonous material to benthic production in these areas (Cummins 1975). Relatively high AI values also occurred at Station N4 below the Torrington POTW and at Station N7.

Mean chlorophyll *a* and biomass standing crops at the tributary stations ranged from 40.5 to 190.8 mg/m^2 and from 6.7 to 38.5 g/m^2, respectively (Table 7-2). Except for a lower than expected biomass standing crop at Station M5, spatial trends in these data were similar to those noted for total periphyton density. The only statistically significant difference ($P \leq 0.05$) in chlorophyll *a* values within the Mad River drainage was that standing crop at Station BP2 was less than that at Station M5. In the tributaries, AI values varied from 126 to 587, with values greater than approximately 300 most frequent in the upper reaches, and lower values common near the confluences of tributaries with the Naugatuck River.

7.3 Evaluation of Periphytic Community Response

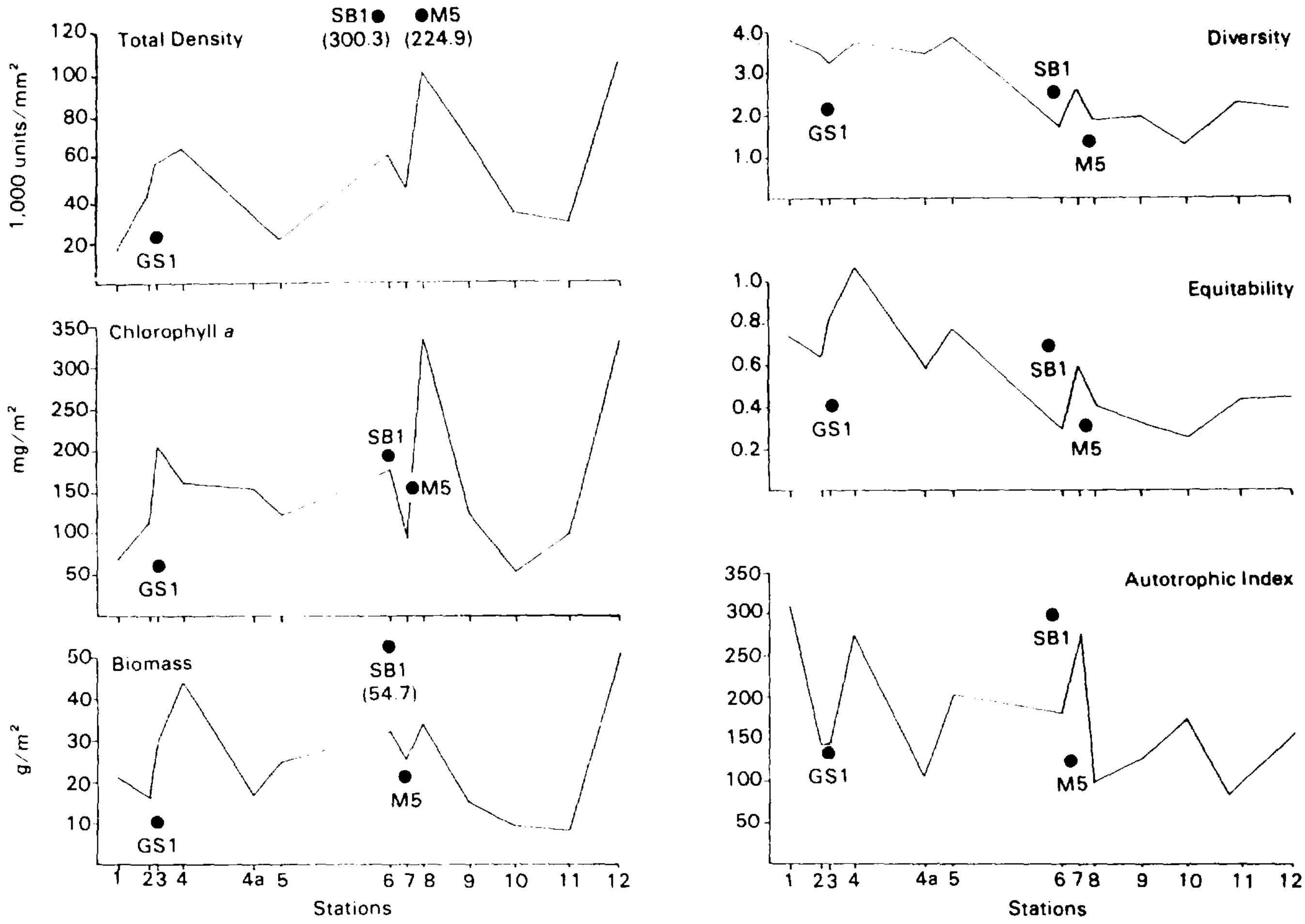
7.3.1 Naugatuck River

Although periphyton community structure in the first river section indicated relatively good water quality, there was evidence of some perturbations. The first instance of slightly reduced water quality occurred at Station N2 where, relative to Station N1, total density and chlorophyll *a* increased, while diversity, equitability, and AI values decreased (Figure 7-1). Other evidence of declining water quality was provided by the increased relative and absolute abundances of taxa such as *Nitzschia* (Palmer 1977) and *Scenedesmus* (Figure 7-2). In addition, *Achnanthes*, a genus more indicative of good water quality (Lowe 1974) decreased in abundance from Station N1 to Station N2. Although no specific dischargers were identified between the two stations, Station N2 was located in the City of Torrington and downstream from the confluence of a tributary that was not examined in this study.

Stations N3 and N4 were potentially affected by discharges from Gulf Stream and the Torrington POTW. Compared to Station N2, both stations supported greater periphyton standing crops, and exhibited similar or greater diversity and equitability (Figure 7-1). Stations N3 and N4 supported less *Stigeoclonium* and *Phormidium* but more *Scenedesmus* (Figure 7-2), as well as more typical periphytic genera such as *Achnanthes*, *Fragilaria*, and *Navicula* than Station N2. The abundance of *Scenedesmus* was higher at Station N3 than at either Station N2 or N4. These results indicate a recovery zone from the minor pollution effects observed at Station N2. The increased abundance of *Nitzschia* in this portion of the Naugatuck River was similar to the trend observed in the recovery zone downstream from a POTW in the Ottawa River, Ohio (Mount et al. 1984). It appeared that the green alga *Scenedesmus* also exhibited a similar response in the Naugatuck River. Although periphyton results indicated that Gulf Stream, which received effluents from several known industrial dischargers, probably had much poorer water quality than was generally characteristic of this portion of the river, there was little evidence that discharges from this tributary or from the Torrington POTW adversely affected periphyton communities in the Naugatuck River.

Stations N4A and N5 represented zones of downstream recovery from the effects noted near Torrington, although Station N6 was located downstream from both the Thomaston Dam and Thomaston POTW. Standing crop, diversity, and equitability at Station N5 returned or approached values observed at Station N1. The abundance of some genera, especially *Nitzschia*, also generally declined toward values at Station N1. It must be emphasized that this

Figure 7-1. Spatial variations in periphyton standing crop, diversity, and Autotrophic Index in the Naugatuck River and selected tributary stations (●), August 1983.

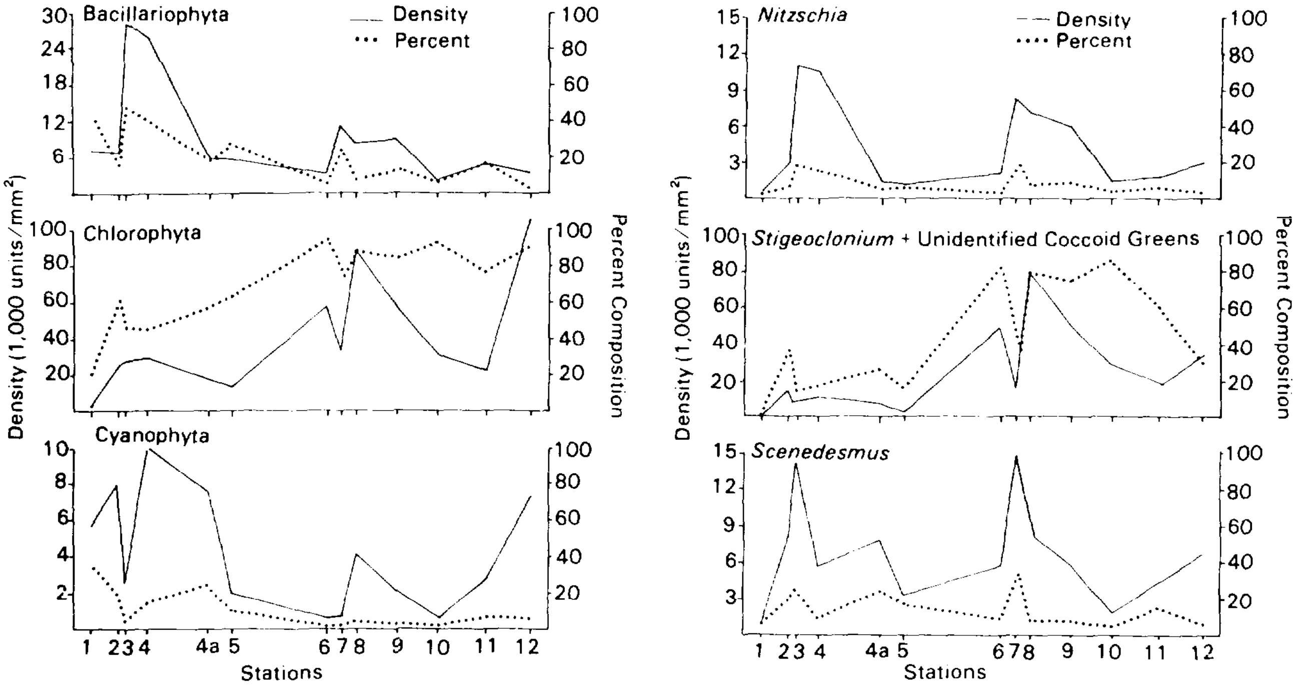


recovery was from minor pollution effects, compared to the more apparent perturbations evident further downstream, and that the upper section of the Naugatuck River was generally characterized by periphyton communities indicative of moderate to good water quality.

The second section of the Naugatuck River began with Station N6 located downstream from the confluence of Steele Brook and Great Brook. Relative to Station N5, this station exhibited greatly reduced periphyton diversity and equitability (Figure 7-1) resulting from dramatic increases in the relative and absolute abundance of *Stigeoclonium* and unidentified coccoid green algae (Figure 7-2). Although conditions in Great Brook were not studied because most of its flow was underground, it is very probable that discharges from Steele Brook, which receives effluents from several known industrial dischargers as well as the Waterbury POTW, were responsible for the changes in periphyton noted at Station N6. It is possible that the initial section of the Naugatuck River actually extended several miles downstream from Station N5, making the changes observed at Station N6 more abrupt, however, additional sampling stations located between the stations would be needed to document this hypothesis. Although the presence of typically planktonic forms in the periphyton of Steele Brook precluded using that data to predict composition at Station N6, the data for Station SB1 did suggest that an increase in periphyton standing crop was probable. An increase in standing crop was observed at Station N6.

Periphyton at Station N7 exhibited a recovery from the conditions observed at Station N6. Standing crop declined whereas diversity and equitability increased relative to values observed at Station N6 (Figure 7-1). The absolute and relative abundance of *Stigeoclonium* and unidentified coccoid greens decreased while that of *Nitzschia* and *Scenedesmus* increased (Figure 7-2). These results are consistent with the conclusion for the initial section of the river that *Nitzschia* and *Scenedesmus* are intermediate in their tolerance

Figure 7-2. **Spatial variations in absolute and relative abundance of major taxonomic groups and selected periphytic taxa in the Naugatuck River, August 1983.**



and, for the Naugatuck River, are characteristic of the moderate water quality conditions present in zones of recovery from pollution.

Periphyton at Station N8 again exhibited the effects of considerable environmental perturbation. Standing crops were at the maximum for this section of the river, diversity and equitability were lower than those observed at Station N7 (Figure 7-1), and the community was highly dominated by *Stigeoclonium* and unidentified coccoid green algae (Figure 7-2). Discharge from the Mad River drainage was probably responsible for the apparent decline in water quality at Station N8. Several industrial discharges are located within the Mad River drainage, and the periphyton results for Station M5 suggest that reduced diversity and equitability and increased abundance of unidentified coccoid green algae should be expected at Station N8.

With the possible exception of Station N11, little recovery was evident for periphyton at remaining stations in the second section of the river, which received discharges from the Waterbury and Naugatuck POTWs. Although the absolute abundance of *Stigeoclonium* and unidentified coccoid greens exhibited progressive declines at Stations N9, N10, and N11, these two taxonomic groups continued to dominate periphyton communities. The abundance of *Nitzschia* and *Scenedesmus*, which are associated with improving water quality conditions, also declined progressively, except for a modest increase in the latter genus at Station N11. Diversity and equitability remained low except for a modest improvement also noted at Station N11. Thus, discharges from the Waterbury and Naugatuck POTWs located upstream of Stations N9 and N10, respectively, may have favored the continued domination by *Stigeoclonium*. Progressive changes in flow or habitat conditions or progressive increases in dilution characteristics at Stations N9, N10, and N11 may have been factors affecting progressive declines in the absolute abundance of *Stigeoclonium*.

The third section of the Naugatuck River included only Station N12. Although this station was very similar to Station N11 in terms of diversity and equitability, Station N12 was sufficiently different in periphyton standing crop and composition to be considered a separate area of the river. Total density and biomass standing crops at Station N12 were greater than at any other river station, and chlorophyll *a* standing crop was near the river maximum (Figure 7-1). The periphyton community was dominated by unidentified naviculoid green algae (possibly *Oocystis*), although *Nitzschia, Scenedesmus,* and *Stigeoclonium* were present in numbers similar to those observed at Station N11 (Table G-1). The blue-green alga *Phormidium* was much more abundant at Station N12 than at Station N11 (6,688 units/mm^2 vs. 418 units/mm^2) (Table G-1). Overall periphyton results for Station N12 generally indicate poor water quality. Because there were no known discharges to the Naugatuck River between stations N11 and N12, and because Station N12 was less than 2 mi from the confluence with Housatonic River, tidal mixing of Naugatuck and Housatonic waters was considered the most probable explanation for sudden change in periphyton at Station N12. However, the results of the present study were insufficient to examine this factor.

7.4 Periphyton Community Summary

7.4.1 Naugatuck River

The Naugatuck River was divided into three sections based on the periphyton community results. Periphyton communities in the first section (Stations N1 through N5), generally were highly diverse, contained low to moderate densities of *Stigeoclonium* and unidentified coccoid green algae, and were represented by relatively diverse diatom flora. Although these results indicated good water quality within the section, minor pollution effects were evident at Stations N2, N3, and N4, with N3 and N4 appearing as zones of early recovery from effects at Station N2 in Torrington. There was no evidence of major adverse effects on periphyton due to discharges from Gulf Stream (even though its water quality appeared poor) or from the Torrington and Thomaston POTWs.

Periphyton in the second river section (Stations N6 through N11) was of low to moderate diversity, distinctly dominated by *Stigeoclonium* and/or unidentified coccoid green algae, and had diatom flora dominated by *Nitzschia*. Major effects were noted at Stations N6 and N8, downstream of discharges from Steele Brook and the Mad River respectively, both of which receive effluents from several industries. Some recovery downstream of the Steele Brook discharge was noted at Station N7, and this recovery was characterized by reduced abundance of *Stigeoclonium* and unidentified coccoid green algae, increased abundance of *Nitzschia* and *Scenedesmus*, and increased diversity and equitability. Little or no recovery downstream of the Mad River discharge was noted at Stations N9, N10, and N11. These results indicated poor to moderate water quality.

Periphyton in the third section of the Naugatuck River (Station N12) differed from the second river section in terms of standing crop and composition. Maximum or near maximum standing crop occurred at Station N12, and the community was numerically dominated by unidentified naviculoid green algae (possibly *Oocystis*). Results continued to indicate poor to moderate water quality, but influences from the Housatonic River, rather than direct discharges into the Naugatuck River, were suggested as the probable factor producing the observed results for periphyton.

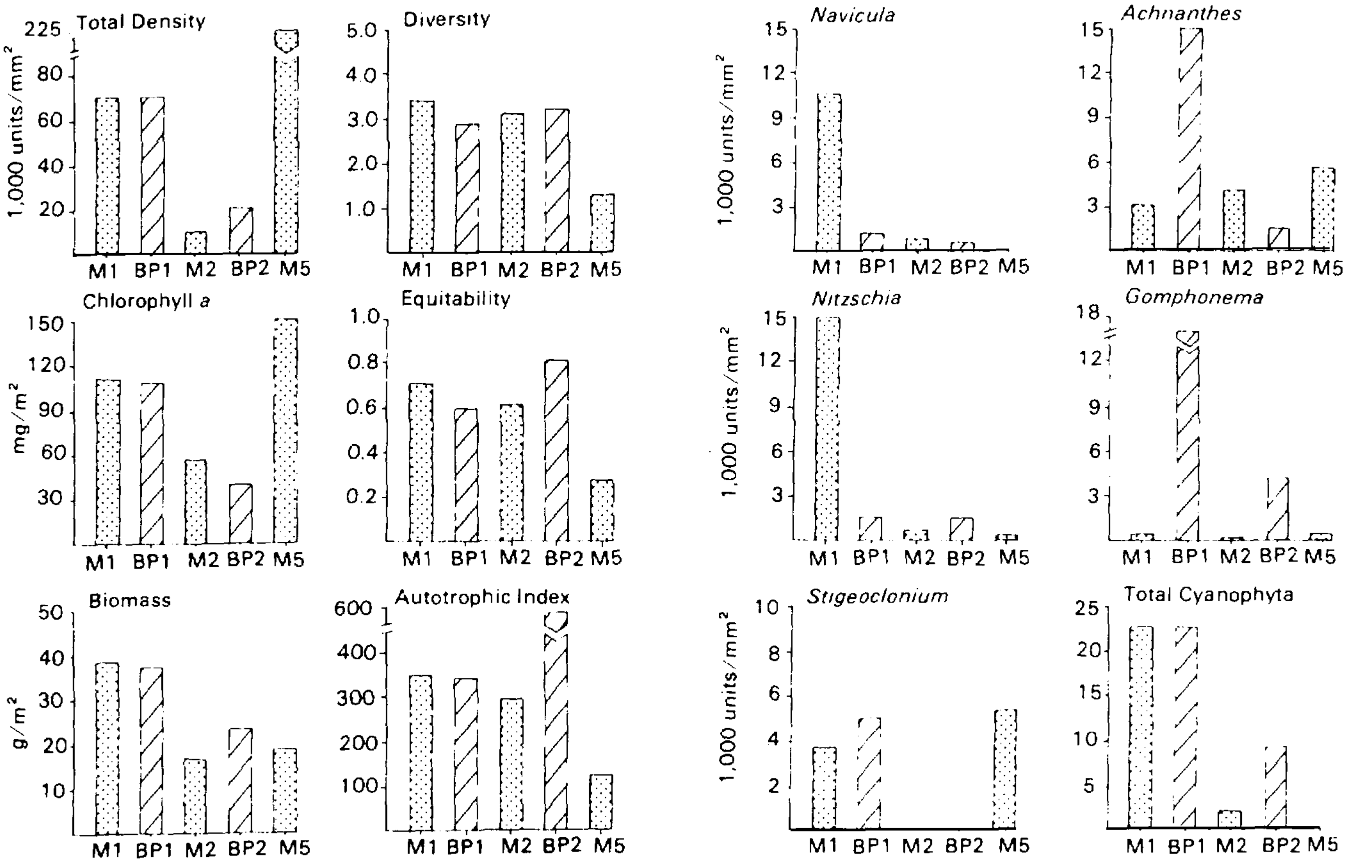
7.4.2 Tributary Stations

Periphyton standing crop and diversity was similar at Stations M1 and BP1 in the upper reaches of the Mad River drainage (Figure 7-3). The greatest difference noted in species composition between these upstream stations occurred in the dominant diatoms. Station M1 in the Mad River was dominated by *Navicula* and *Nitzschia*, whereas Station BP1 in Beaver Pond Brook was dominated by *Achnanthes* and *Gomphonema* (Table G-2).

Periphyton at Stations M2 and BP2 located near but upstream from the confluence of Beaver Pond Brook and the Mad River were also similar. Between the upper reaches and these stations, similar changes in standing crop and periphyton composition were noted in each of the tributaries (Figure 7-2). Although known dischargers existed in this portion of Beaver Pond Brook, none were evident in this portion of the Mad River. These results suggest that discharges into Beaver Pond Brook had little effect if any on periphyton at Station BP2 (with the possible exception of elevated AI values), and water quality remained moderate to good.

Additional industrial dischargers were known to be located on the Mad River between Beaver Pond Brook and the Naugatuck River. These discharges appeared to cause substantial increases in total periphyton density and chlorophyll *a* standing crop; marked declines in diversity, equitability, and AI values; and domination by unidentified coccoid green algae at Station M5. These results suggested poor water quality at Station M5. The observed effects of this environmental perturbation extended to Station N8 in the Naugatuck River.

Figure 7-3. **Spatial variations in periphyton standing crop, diversity, Autotrophic Index, and densities of selected taxa within the Mad River Drainage, August 1983. (BP1, BP2—Beaver Pond Brook stations; M1, M2, M5—Mad River stations).**



8. *Crustacean Zooplankton Community*

Planktonic communities in lotic systems are highly unstable, and subject to local flow conditions, in contrast to the more sedentary periphytic and benthic communities. Crustacean zooplankton in flowing waters almost always occur at low densities. Crustacean zooplankton community effects may be evident as a change in species composition or density, i.e., when impoundment of water behind a dam provides habitat more suitable to the production of limnetic zooplankton species. The methods used for zooplankton collections and data for taxonomic reference are included in Appendix G.

8.1 Community Composition

Eighty percent of all zooplankton species encountered were either daphnid (7 species) or chydorid cladocerans (5 species) or cyclopoid copepods (4 species). All of the species encountered are widely distributed in North America. Both *Ceriodaphnia reticulata*, and its smaller congener, *C. pulchella*, were encountered in Naugatuck River samples (Tables 8-1 and G-3).

The abundance and distribution of taxa encountered indicated that the majority of crustacean zooplankton in the Naugatuck River were subdominant to a few abundant taxa and were not widely distributed. The number of taxa ranged from 1 at Station N1 to 12 at Stations N6 and N7. Using 12 as representative of optimum conditions and therefore considered an "expected" value, a chi-square analysis was performed to detect spatial difference. Results indicated that Stations N4, N4A, N9, and N10 had significantly ($P \leq 0.05$) lower number of species than the optimum stations. Nearly three-fourths of the crustacean zooplankton collected were *Bosmina longirostris*; of the remaining taxa, only *Daphnia ambigua/parvula*, cyclopoid copepodites, nauplii, *C. pulchella*, and *Ilyocryptus spinifer* constituted more than one percent of the average abundance (Table 8-1).

The spatial distribution pattern of zooplankton abundance fluctuated greatly among locations and *was exemplified* by the fact that, while cyclopid copepodites were encountered at nearly every river station, only *Bosmina longirostris*, nauplii, and *Ilyocryptus spinifer* were encountered at half, or more, of the stations. *Ceriodaphnia* was the fifth most abundant taxa collected and was encountered at 30 percent of the locations sampled (Tables 8-1 and 8-2).

Bosmina longirostris, the most abundant zooplankter, dominated the community only at Station N5. This station provided more than 95 percent of the total zooplankton density collected and was probably a product of the impoundment behind Thomaston Dam which is located 1.5 miles upstream. Small impoundments upstream from Stations N11 and N12 produced similar effects at those two stations, where zooplankton densities were next highest. Species which were most favored by the presence of these impoundments were the limnetic cladocerans, *Bosmina longirostris* and *Daphnia* species; and the littoral cladocerans, *Ceriodaphnia pulchella, Diaphanosoma brachyurum*, and *Ilyocryptus spinifer*. Copepods exhibit similar habitat affinities, but taxonomic definition was limited in the present study by the preponderance of unidentifiable juveniles in the population.

The species with the widest distribution in the Naugatuck River was the littoral cladoceran, *Ilyocryptus spinifer*, a taxon favored by the weedy shallow-water habitat typical of flowing water; while the most abundant species was the limnetic cladoceran, *Bosmina longirostris*, a taxon favored by the open deeper-water habitat typical of the scattered impoundments along the river. *Ceriodaphnia* reached its maximum abundance at Station N5, but was also found upstream at Stations N2 and N3 and downstream at Stations N6 through N8.

8.2 Evaluation of Community Response

The most evident zooplankton community responses to perturbations in the Naugatuck River were apparent by increased density and decreased diversity at stations downstream from impoundments (Stations N5, N11, N12; Figure 8-1). Decreased diversity at these stations resulted from increased density of a few cladoceran species which dominated the zooplankton community at those stations (Table 8-2). Diversity at Stations N5 and N12 were among the lowest recorded along the river, while density was the highest (Table 8-2). In contrast, elevated density at Station N11 did not produce a correspondingly low diversity because the increase in density was distributed among more taxa. Density of *Ceriodaphnia* followed the overall trend for cladocerans within the limits of its distribution.

Table 8-1. **Percent Abundance and Occurrence of Crustacean Zooplankton Taxa Collected from the Naugatuck River and Tributaries, 25-27 August 1983**

Taxon	Percent Abundance	Percent Occurrence
Bosmina longirostris	73.587	50
Daphnia ambigua/parvula[a]	15.540	40
Cyclopoid copepodite	2.770	95
Nauplii	2.694	75
Ceriodaphnia pulchella[b]	1.790	30
Ilyocryptus spinifer	1.304	60
Diaphanosoma brachyurum	0.645	10
Chydorus sphaericus sphaericus	0.547	35
Paracyclops fimbriatus poppei	0.304	20
Simocephalus serrulatus	0.301	20
Pleuroxus denticulatus	0.181	20
Diaptomus pygmaeus	0.112	35
Calanoid copepodite	0.078	35
Alona rustica americana	0.056	25
Eucyclops agilis	0.031	40
Daphnia catawba	0.023	5
Mesocyclops edax	0.016	15
Scapholeberis aurita	0.010	15
Cyclops bicuspidatus thomasi	0.005	5
Leydigia leydigi	0.002	10
Harpacticoid copepodite	0.002	5
Acroperus harpae	0.001	5

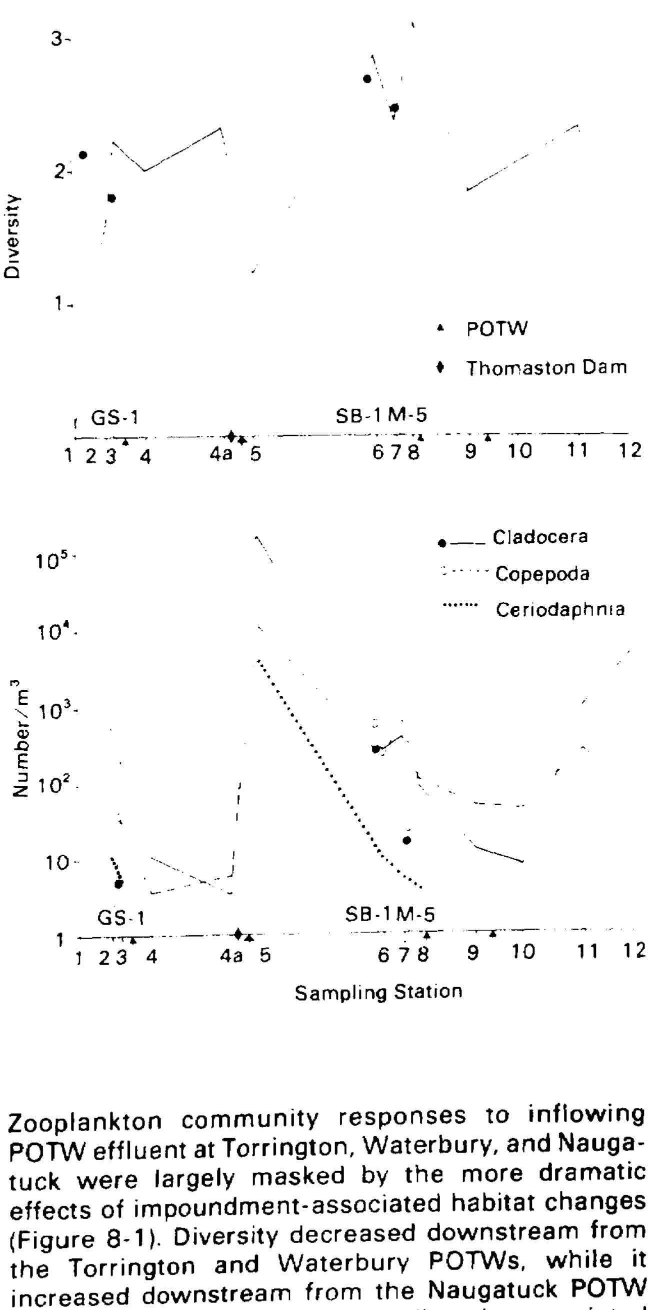
[a] Non-helmeted *D. ambigua* and *D. parvula* were not separable at 70X enumeration magnification.
[b] *C. reticulata* was also identified qualitatively at Station N5.

Table 8-2. **Density of Crustacean Zooplankton at Sampling Stations from the Naugatuck River, 25-27 August 1983**

Taxon	River Stations												
	N1	N2	N3	N4	N4A	N5	N6	N7	N8	N9	N10	N11	N12
Acroperus harpae	--	2,3	--	--	--	--	--	--	--	--	--	--	--
Alona rustica americana	--	23.0	36.8	--	--	--	46.0	10.5	3.9	--	--	--	--
Bosmina longirostris	--	6.9	--	--	2.0	156,619.1	105.3	215.8	27.6	--	--	252.6	14.7
Ceriodaphnia pulchella[a]	--	11.5	5.3	--	--	3,789.2	9.9	5.3	3.9	--	--	--	--
Chydorus sphaericus sphaericus	--	269.4	136.8	--	--	631.5	49.3	10.5	11.8	--	--	--	58.9
Daphnia ambigua/parvula[b]	--	--	--	3.9	--	29,681.8	9.9	10.5	--	--	--	536.8	2,762.9
Diaphanosoma brachyurum	--	--	--	--	--	1,263.1	--	--	--	--	--	115.8	--
Ilyocryptus spinifer	--	6.9	21.1	3.9	--	631.5	16.4	147.4	31.5	13.2	7.9	21.1	1,878.8
Leydigia leydigi	--	--	--	--	2.0	--	3.3	--	--	--	--	--	--
Pleuroxus denticulatus	--	324.6	36.8	3.9	--	--	--	--	--	--	--	--	22.1
Scapholeberis aurita	--	--	--	--	--	--	13.2	5.3	3.9	--	--	--	--
Simocephalus serrulatus	--	--	--	--	--	631.5	3.3	5.3	3.9	--	--	--	--
Total Cladocera	--	644.7	236.8	11.8	3.9	193,247.7	256.6	410.5	86.8	13.2	7.9	926.2	4,737.5
Nauplii	--	--	5.3	--	2.0	5,052.2	121.7	315.8	27.6	23.7	15.8	115.8	14.7
Calanoid copepodite	--	--	--	--	--	--	3.3	5.3	11.8	--	5.3	10.5	--
Cyclopoid copepodite	--	2.3	26.3	3.9	2.0	5,052.2	88.8	300.0	51.3	21.1	18.4	110.5	51.6
Diaptomus pygmaeus	2.3	--	--	--	--	--	3.3	--	11.8	--	--	21.1	--
Eucyclops agilis	--	--	5.3	--	--	--	--	10.5	15.8	5.3	2.6	10.5	7.4
Mesocyclops edax	--	--	--	--	2.0	--	--	--	--	--	--	5.3	--
Paracyclops fimbriatus poppei	--	--	--	--	--	631.5	--	5.3	--	--	--	--	7.4
Total Copepoda	2.3	2.3	36.8	3.9	5.9	10,736.0	217.1	636.8	118.4	50.0	42.1	273.7	81.0
Total Zooplankton	2.3	647.0	273.7	15.8	9.9	203,983.7	473.6	1,047.3	205.2	63.2	50.0	1,199.9	4,818.6
Diversity ($\bar{d}$)	0.0	1.50	2.22	2.00	2.32	1.22	2.84	2.36	3.13	1.83	2.04	2.32	1.25
No. of taxa	1	8	7	4	4	9	12	12	11	3	4	9	0
Chi square (X^2)[c]	9.19	1.02	1.69	4.69[d]	4.69[d]	0.52	0	0	0.02	6.02[d]	4.69[d]	0.52	1.02

[a] Non-helmeted *D. ambigua* and *D. parvula* were not separable at 70X enumeration magnification.
[b] *C. reticulata* was also identified qualitatively at Station N5.
[c] Expected value = 12 (maximum number).
[d] Significantly lower ($p \leq 0.05$) number of species.

Figure 8-1. **Spatial variation on crustacean zooplankton diversity and density in the Naugatuck River, August 1983. Individual data points are for the tributary stations.**



Zooplankton community responses to inflowing POTW effluent at Torrington, Waterbury, and Naugatuck were largely masked by the more dramatic effects of impoundment-associated habitat changes (Figure 8-1). Diversity decreased downstream from the Torrington and Waterbury POTWs, while it increased downstream from the Naugatuck POTW (*Table 8-2*). Neither decrease in diversity associated with POTWs were as low as those associated with impoundment effects at Stations N5 and N12. The increase in diversity noted downstream of the Naugatuck STP did not indicate recovery but was a result of a decrease in density distributed among relatively few taxa. Density decreased downstream from each of the three POTWs; however, each decrease appeared to be part of a larger decrease initiated further upstream.

Although *Ceriodaphnia* was not present at any of the stations immediately downstream of the POTWs (Stations N4, N9, and N10), it was present in generally low abundance at other stations, so that determination of effects upon *Ceriodaphnia* populations was not possible.

Likewise, tributary inflow had minimal apparent effect on the zooplankton community. Cladoceran densities in all three tributary systems were either less than or very similar to adjacent stations in the Naugatuck River (Figure 8-1). Copepod densities were similar between Gulf Stream (Station GS1) and the Naugatuck River Station N3. Yet copepod densities were less in Steele Brook (Station SB1) than in the river (N5), and less in the Mad River (M5) than on the Naugatuck River (N7) (Figures 8-1, 8-2, and 8-3). In no case, however, was there any detectable effect on Naugatuck River zooplankton densities from the tributaries; rather, densities were declining in the Naugatuck River from higher upstream densities to lower downstream densities irrespective of tributary inflow. *Ceriodaphnia* were not present at any tributary station but were present in the river downstream of where tributary inflow occurred. Diversity in tributaries was quite similar to adjacent river stations, also indicating no apparent effect (Table G-6). Density and diversity of two samples collected in the Mad River (Stations M1 and M2) and Beaver Pond Brook (Stations BP1 and BP2) were uniformly very low, precluding any evaluation of effects within that tributary system (Table 8-3 and G-5). In contrast, the number of species and zooplankton abundance was greater at Station M5 below sources of discharge within the Mad River compared to the upstream stations.

In summary, the zooplankton community in the Naugatuck River exhibited a greater response to the presence of impoundments than to either sewage treatment plant effluent or tributary stream inflow. Density of a few species of crustacean zooplankton generally increased dramatically in impounded river reaches, resulting in lower diversity index values. These effects masked any effects of POTW and tributary inflows, rendering their detection impossible. Both *Ceriodaphnia reticulata* and its smaller congener, *C. pulchella*, were present in the Naugatuck River, although abundances were generally low and distribution related mostly to impoundment.

Table 8-3. Density (No./m^3) of Crustacean Zooplankton Taxa at Sampling Stations Along Tributaries of the Naugatuck River, 25-27 August 1983

Taxon	Tributary Sampling Stations						
	GS1	SB1	BP1	BP2	M1	M2	M5
Bosmina longirostris	5.3	11.8	--	--	--	--	--
Daphnia ambigua/parvula[a]	--	197.4	--	--	--	--	7.9
Daphnia catawba	--	49.3	--	--	--	--	--
Ilyocryptus spinifer	--	--	--	--	--	--	7.9
Total Cladocera	5.3	258.5	--	--	--	--	15.8
Nauplii	15.8	25.7	--	3.9	13.2	--	3.9
Calanoid copepodite	--	128.3	2.6	--	--	--	--
Cyclopoid copepodite	15.8	152.0	2.6	3.9	10.5	2.6	3.9
Cyclops bicuspidatus thomasi	--	9.9	--	--	--	--	--
Diaptomus pygmaeus	--	185.5	2.6	--	--	--	11.8
Eucyclops agilis	--	7.9	--	--	--	--	--
Mesocyclops edax	--	27.6	--	--	--	--	--
Paracyclops fimbriatus poppei	5.3	--	--	--	--	--	--
Harpacticoid copepodite	--	--	--	--	--	--	3.9
Total Copepoda	36.8	536.8	7.9	7.9	23.7	2.6	23.7
Total Zooplankton	42.1	795.3	7.9	7.9	23.7	2.6	39.5
Diversity ($\bar{d}$)	1.81	2.68	1.58	1.00	0.99	0.0	2.45

[a] Non-helmeted *D. ambigua* and *D. parvula* were not separable at 70X enumeration magnification.

9. *Benthic Macroinvertebrate Community*

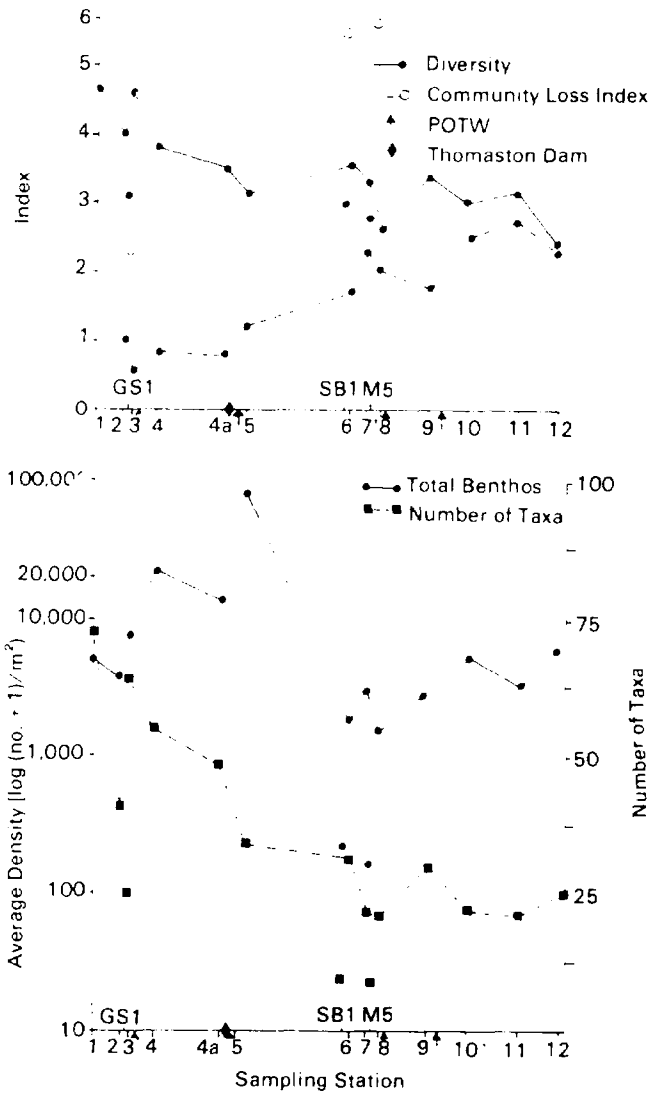
The benthic community is considered a good indicator of ambient response to adverse conditions because of their general lack of extensive mobility. The degree of community stability within affected areas can be measured by comparing composition and dominance to that of nonaffected areas. An effect on the benthos would be apparent as an alteration in community structure, standing crop, or species composition of the benthos beyond the limits of normal fluctuation within the receiving waterbody. The increased abundance of nuisance insect larvae or other benthic species also would be regarded as an effect. The following discussion is intended to present an overview of the response of the benthic community and selected populations to the discharges. Methods used for benthos sampling and analysis are discussed in Appendix D. Support benthic data on the composition, relative abundance, and community parameters are presented in Appendix G.

9.1 Community Structure

The abundance or density of the benthos fluctuated considerably over the study area. A taxonomic list of organisms collected by station is presented in Table G-4. The density ranged from approximately 1,500 organisms per m^2 at Station 8 to 81,000 organisms per m^2 at Station N5 (Table 9-1; Figure 9-1). The least dense populations were encountered from Stations N6 through N9. The most dense populations were at Stations N4, N4A, and N5. The number of taxa generally declined from the upstream stations to the downstream stations (Figure 9-1).

Composition and abundance of benthic invertebrates varied between stations as summarized in Table 9-2 (based on the 38 most abundant taxa [Table G-5]). The community in the study area was dominated by the trichopterans, *Cheumatopsyche*, and *Symphitopsyche*, which together comprised about 37 percent of individuals. However, with few exceptions, the benthos at most stations was dominated by midges within the genus *Cricotopus*.

Figure 9-1. **Spatial comparison of benthic community parameters. Individual data points are from tributary stations.**



Community response was examined using both an index of diversity and a community loss index described in D-5. The community indices supported the spatial trend of the number of species and indicated a general decline in the health of the benthic community associated with downstream distance compared to the upstream communities near Torrington (Table G-6; Figure 9-1). Although no statistical analyses were performed on the community parameters to detect significant differences, three general groupings of the Naugatuck River stations can be constructed. A general decline in community quality occurred from Station N1 to Station N5, a decline from Station N6 to Station N8,

Table 9-1. Average Density (No/m²) of the Most Abundant Benthic Taxa at Each Sampling Station, Naugatuck River and Tributaries, August 1983

Station	N1		N2		N3		N4	
Species	Number Indivs	PCT Comp	Number Indivs	PCT Comp	Number Indivs	PCT Comp	Number Indivs	PCT Comp
Cheumatopsyche l.	301.33	5.72	199.63	5.31	493.43	6.55	621.50	2.72
Symphitopsyche l.	613.97	11.66	124.30	3.31	105.47	1.40	184.57	0.81
Tricladida	3.77	0.07	0.00	0.00	3.77	0.05	0.00	0.00
Leucotrichia pictipes l.	158.20	3.00	7.53	0.20	233.53	3.10	0.00	0.00
Hydropsychidae l.	244.83	4.65	301.33	8.02	199.63	2.65	256.13	1.12
Cricot. bicinct. grp. l.	30.13	0.57	67.80	1.80	241.07	3.20	2,998.27	13.11
Nais communis	0.00	0.00	18.83	0.50	429.40	5.70	7,292.27	31.88
Chironomidae p.	143.13	2.72	316.40	8.42	316.40	4.20	527.33	2.31
Cladocera	0.00	0.00	0.00	0.00	203.40	2.70	0.00	0.00
Cricot tremulus grp. l.	*135.60*	*2.58*	*459.53*	*12.22*	*504.73*	*6.70*	2,049.07	8.96
Cricot. cylind. grp. l.	86.63	1.65	455.77	12.12	470.83	6.25	549.93	2.40
Acarina	131.83	2.50	632.80	16.83	794.77	10.56	305.10	1.33
Nematoda	26.37	0.50	146.90	3.91	429.40	5.70	259.90	1.14
Hydropsyche l.	131.83	2.50	90.40	2.40	210.93	2.80	1,389.90	6.08
Thienemannimyia ser. l.	3.77	0.07	0.00	0.00	26.37	0.35	425.63	1.86
Cardiocladius l.	199.63	3.79	154.43	4.11	161.97	2.15	489.67	2.14
Trichoptera l.	7.53	0.14	0.00	0.00	11.30	0.15	11.30	0.05
Baetis n.	60.27	1.14	0.00	0.00	0.00	0.00	11.30	0.05
Empididae l.	101.70	1.93	128.07	3.41	109.23	1.45	474.60	2.08
Nais bretscheri	0.00	0.00	214.70	5.71	346.53	4.60	1,243.00	5.43
Rheotanyhtarsus l.	354.07	6.72	3.77	0.10	0.00	0.00	0.00	0.00
Polypedilum scalaenum l.	3.77	0.07	33.90	0.90	135.60	1.80	519.80	2.27
Symphit. morosa l.	169.50	3.22	37.67	1.00	15.07	0.20	11.30	0.05
Nemertea	52.73	1.00	41.43	1.10	214.70	2.85	41.43	0.18
Ancylidae	380.43	7.22	11.30	0.30	45.20	0.60	384.20	1.68
Trichoptera p.	49.97	0.93	30.13	0.80	33.90	0.45	86.63	0.38
Polypedilum convictum l.	22.60	0.43	0.00	0.00	26.37	0.35	387.97	1.70
Nais variabilis	0.00	0.00	0.00	0.00	3.77	0.05	768.40	3.36
Hydroptilidae l.	3.77	0.07	3.77	0.10	662.93	8.80	0.00	0.00
Eukief. discoloripes grp.	37.67	0.72	0.00	0.00	0.00	0.00	0.00	0.00
Pristina sima	3.77	0.07	0.00	0.00	3.77	0.05	139.37	0.61
Empididae p.	15.07	0.29	37.67	1.00	33.90	0.45	3.77	0.02
Hydropsychidae p.	18.83	0.36	3.77	0.10	15.07	0.20	15.07	0.07
Antocha l.	45.20	0.86	64.03	1.70	67.80	0.90	3.77	0.02
Orthocladius l.	60.27	1.14	30.13	0.80	41.43	0.55	45.20	0.20
Isonychia n.	534.87	10.16	7.53	0.20	0.00	0.00	0.00	0.00
Bothrio. vejdovskyanum	0.00	0.00	3.77	0.10	433.17	5.75	97.93	0.43
Nanocladius l.	0.00	0.00	7.53	0.20	48.97	0.65	184.57	0.81
Other Species	1,133.77	21.53	124.30	3.31	455.77	6.05	1,092.33	4.78
Station Total	5,265.80		3,759.13		7,529.57		22,871.20	

Note: l. = larva
p. = pupa
n. = nymph

and a third decline in quality from Station N9 to Station N12. Information illustrated by diversity and community loss indices was generally consistent throughout the study area with the exception of four stations. Diversity at Stations N6, N8, and N11 declined from adjacent upstream stations due to a substantial drop in densities (Figure 9-1). However, at these three stations, the number of species was similar to the adjacent stations and thus community loss was not affected. Conversely, at Station N12, both benthic abundance and number of species increased from that observed at Station N11. Evenness was lowest at Station N12 (0.52), which accounted for the lowered diversity value (Table G-6).

The pattern of diversity is reflected strongly in the evenness component of the diversity index which considers the way individuals are distributed among taxa. Evenness and richness, or the relative number of taxa present, are the two primary components of diversity, while the community loss index is influenced solely by the number of taxa. The relationship in the spatial trend of these community parameters to the point source dischargers was fairly consistent. The quality of the community declines following the discharge of Gulf Stream and the Torrington POTW and after the Thomaston Dam in the upper reach, after the Mad River in the middle reach, and after the Naugatuck POTW in the lower reach. An improve-

Table 9-1. (Extended)

Station	N4A		N5		N6		N7	
Species	Number Indivs	PCT Comp	Number Indivs	PCT Comp	Number Indivs	PCT Comp	Number Indivs	PCT Comp
Cheumatopsyche l.	1,020.77	7.47	19,940.73	24.57	56.50	3.16	15.07	0.47
Symphitopsyche l.	3,292.07	24.09	12,859.40	15.85	15.07	0.84	18.83	0.59
Tricladida	0.00	0.00	13,770.93	16.97	18.83	1.05	308.87	9.64
Leucotrichia pictipes l.	3,035.93	22.22	8,885.57	10.95	11.30	0.63	0.00	0.00
Hydropsychidae l.	327.70	2.40	8,395.90	10.35	45.20	2.53	0.00	0.00
Cricot. bicinct. grp. l.	67.80	0.50	60.27	0.07	139.37	7.79	666.70	20.80
Nais communis	7.53	0.06	210.93	0.26	0.00	0.00	0.00	0.00
Chironomidae p.	109.23	0.80	60.27	0.07	90.40	5.05	94.17	2.94
Cladocera	0.00	0.00	5,936.27	7.32	3.77	0.21	15.07	0.47
Cricot tremulus grp. l.	64.03	0.47	120.53	0.15	71.57	4.00	361.60	11.28
Cricot. cylind. grp. l.	150.67	1.10	301.33	0.37	116.77	6.53	173.27	5.41
Acarina	135.60	0.99	482.13	0.59	372.90	20.84	158.20	4.94
Nematoda	177.03	1.30	361.60	0.45	320.17	17.89	723.20	22.56
Hydropsyche l.	3.77	0.03	1,408.73	1.74	33.90	1.89	11.30	0.35
Thienemannimyia ser. l.	15.07	0.11	30.13	0.04	56.50	3.16	312.63	9.75
Cardiocladius l.	1,401.20	10.25	64.03	0.08	120.53	6.74	0.00	0.00
Trichoptera l.	67.80	0.50	3,002.03	3.70	0.00	0.00	0.00	0.00
Baetis n.	165.73	1.21	0.00	0.00	3.77	0.21	3.77	0.12
Empididae l.	11.30	0.08	180.80	0.22	146.90	8.21	33.90	1.06
Nais bretscheri	120.53	0.88	0.00	0.00	0.00	0.00	0.00	0.00
Rheotanyhtarsus l.	1,318.33	9.65	30.13	0.04	3.77	0.21	11.30	0.35
Polypedilum scalaenum l.	15.07	0.11	0.00	0.00	0.00	0.00	0.00	0.00
Symphit. morosa l.	30.13	0.22	1,107.40	1.36	0.00	0.00	0.00	0.00
Nemertea	26.37	0.19	271.20	0.33	37.67	2.11	165.73	5.17
Ancylidae	322.93	2.37	0.00	0.00	0.00	0.00	0.00	0.00
Trichoptera p.	11.30	0.08	904.00	1.11	0.00	0.00	0.00	0.00
Polypedilum convictum l.	60.27	0.44	301.33	0.37	3.77	0.21	26.37	0.82
Nais variabilis	0.00	0.00	30.13	0.04	0.00	0.00	0.00	0.00
Hydroptilidae l.	0.00	0.00	120.53	0.15	0.00	0.00	0.00	0.00
Eukief. discoloripes grp.	376.67	2.76	361.60	0.45	3.77	0.21	0.00	0.00
Pristina sima	0.00	0.00	421.87	0.52	0.00	0.00	0.00	0.00
Empididae p.	11.30	0.08	30.13	0.04	67.80	3.79	33.90	1.06
Hydropsychidae p.	45.20	0.33	572.53	0.71	0.00	0.00	0.00	0.00
Antocha l.	339.00	2.48	120.53	0.15	3.77	0.21	0.00	0.00
Orthocladius l.	169.50	1.24	120.53	0.15	3.77	0.21	0.00	0.00
Isonychia n.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bothrio. vejdovskyanum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nanocladius l.	0.00	0.00	0.00	0.00	11.30	0.63	33.90	1.06
Other Species	764.63	5.60	685.53	0.84	30.13	1.68	37.67	1.18
Station Total	13,665.47		81,149.07		1,789.17		3,205.43	

Note: l. = larva
p. = pupa
n. = nymph

ment in the benthic community was obsered following the Waterbury POTW in the middle reach. Although these findings are not conclusive, they indicate the presence of both gross effects from individual dischargers and a degradation of the benthic community from upstream to downstream.

In comparison to the Naugatuck River stations, both the diversity and community loss indices for the tributaries indicated that tributaries had degraded communities compared to adjacent river stations (Table G-6; Figure 9-1). Densities and number of taxa were reduced in the tributaries from that observed at the Naugatuck River stations.

9.2 Differences Between Stations

An understanding of the abundance and distribution of major taxonomic groups of benthic organisms is important in interpreting the interaction among various components of the community and hence the spatial trends in dominance and composition. With one exception (Station N6) the trichopterans (caddisflies) and chironomids (midge larvae) constituted more than 50 percent of the benthos in the upper reach of the Naugatuck River (Table 9-2). However, the chironomids composed more than 60 percent of the benthos in the lower reach (Stations N9 through N12). The oligochaetes were abundant only at

Table 9-1. (Extended)

Station	N8		N9		N10		N11	
Species	Number Indivs	PCT Comp	Number Indivs	PCT Comp	Number Indivs	PCT Comp	Number Indivs	PCT Comp
Cheumatopsyche l.	3.77	0.25	11.30	0.43	15.07	0.28	3.77	0.13
Symphitopsyche l.	22.60	1.50	7.53	0.28	7.53	0.14	0.00	0.00
Tricladida	64.03	4.26	0.00	0.00	0.00	0.00	0.00	0.00
Leucotrichia pictipes l.	0.00	0.00	0.00	0.00	7.53	0.14	0.00	0.00
Hydropsychidae l.	0.00	0.00	3.77	0.14	0.00	0.00	3.77	0.13
Cricot. bicinct. grp L	161.97	10.78	214.70	8.10	406.80	7.49	497.20	17.72
Nais communis	0.00	0.00	0.00	0.00	0.00	0.00	15.07	0.54
Chironomidae p	82.87	5.51	519.80	19.60	1,310.80	24.13	248.60	8.86
Cladocera	0.00	0.00	0.00	0.00	3.77	0.07	0.00	0.00
Cricot tremulus grp. l	15.07	1.00	534.87	20.17	587.60	10.82	116.77	4.16
Cricot. cylind. grp. l.	30.13	2.01	376.67	14.20	113.00	2.08	135.60	4.83
Acarina	71.57	4.76	33.90	1.28	18.83	0.35	11.30	0.40
Nematoda	757.10	50.38	105.47	3.98	109.23	2.01	37.67	1.34
Hydropsyche l.	3.77	0.25	0.00	0.00	0.00	0.00	0.00	0.00
Thienemannimyia ser. l.	26.37	1.75	75.33	2.84	214.70	3.95	670.47	23.89
Cardiocladius l.	33.90	2.26	22.60	0.85	365.37	6.73	67.80	2.42
Trichoptera l.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Baetis n.	7.53	0.50	105.47	3.98	1,404.97	25.87	455.77	16.24
Empididae l.	173.27	11.53	203.40	7.67	372.90	6.87	165.73	5.91
Nais bretscheri	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rheotanyhtarsus l.	3.77	0.25	7.53	0.28	0.00	0.00	0.00	0.00
Polypedilum scalaenum l	0.00	0.00	135.60	5.11	180.80	3.33	109.23	3.89
Symphit. morosa l.	3.77	0.25	0.00	0.00	3.77	0.07	0.00	0.00
Nemertea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ancylidae	0.00	0.00	3.77	0.14	0.00	0.00	0.00	0.00
Trichoptera p.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Polypedilum convictum l.	3.77	0.25	33.90	1.28	0.00	0.00	67.80	2.42
Nais variabilis	0.00	0.00	3.77	0.14	0.00	0.00	0.00	0.00
Hydroptilidae l.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Eukief. discoloripes grp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pristina sima	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Empididae p.	3.77	0.25	64.03	2.41	192.10	3.54	82.87	2.95
Hydropsychidae p.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Antocha l.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Orthocladius l.	3.77	0.25	0.00	0.00	0.00	0.00	0.00	0.00
Isonychia n.	3.77	0.25	0.00	0.00	0.00	0.00	0.00	0.00
Bothrio. vejdovskyanum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nanocladius l.	18.83	1.25	15.07	0.57	15.07	0.28	0.00	0.00
Other Species	7.53	0.50	173.27	6.53	101.70	1.87	116.77	4.16
Station Total	1,502.90		2,651.73		5,431.53		2,806.17	

Note: l = larva
p. = pupa
n. = nymph

Stations N3 and N4. With the exception of the miscellaneous grouping which including various minor phyla such as nematodes and water mites, the other major groups did not constitute more than 12 percent of the benthos at the Naugatuck River stations. The chironomids and oligochaetes generally dominated the tributary stations (Table 9-2)..Only at Station M2 were the caddisflies the predominant group. The miscellaneous species group was numerically important at most tributary stations except in the upper Mad River tributary.

Certain key taxa represent the greatest contribution to total abundance of the benthic community evaluated under diversity and its components. The predominant trichopterans encountered in the Naugatuck River were species of *Cheumatopsyche* and *Symphitopsyche* (Table 9-1). The spatial trends of the abundance of these genera were similar and illustrated that of the total group (Figure 9-2). The peak densities of these genera occurred at Station N5 and composed the majority of the benthos at that station, hence increasing the redundancy value and decreasing diversity. For *Cheumotopsyche,* the abundance (P = 0.0001) was significantly greater than that at other stations (Table G-9). Although the density of *Symphitopsyche* was significantly (P = 0.0001) different among stations, the results of a Tukey's multiple-range test indicated the densities at Stations

Table 9-1. **(Extended)**

Station	N12		GS1		M1		M2	
Species	Number Indivs	PCT Comp	Number Indivs	PCT Comp	Number Indivs	PCT Comp	Number Indivs	PCT Comp
Cheumatopsyche l.	3.77	0.05	0.00	0.00	26.37	1.12	64.03	11.18
Symphitopsyche l.	3.77	0.05	0.00	0.00	7.53	0.32	33.90	5.92
Tricladida	7.53	0.11	0.00	0.00	0.00	0.00	0.00	0.00
Leucotrichia pictipes l.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydropsychidae l.	7.53	0.11	0.00	0.00	26.37	1.12	41.43	7.24
Cricot. bicinct. grp. l.	2,772.27	40.37	0.00	0.00	48.97	2.08	11.30	1.97
Nais communis	0.00	0.00	3.77	0.39	173.27	7.35	0.00	0.00
Chironomidae p.	2,015.17	29.35	37.67	3.88	226.00	9.58	15.07	2.63
Cladocera	22.60	0.33	0.00	0.00	0.00	0.00	0.00	0.00
Cricot tremulus grp. l.	116.77	1.70	82.87	8.53	22.60	0.96	7.53	1.32
Cricot. cylind. grp. l.	730.73	10.64	37.67	3.88	418.10	17.73	22.60	3.95
Acarina	226.00	3.29	365.37	37.60	361.60	15.34	7.53	1.32
Nematoda	37.67	0.55	48.97	5.04	237.30	10.06	7.53	1.32
Hydropsyche l.	0.00	0.00	0.00	0.00	75.33	3.19	259.90	45.39
Thienemannimyia ser. l.	523.57	7.62	18.83	1.94	3.77	0.16	7.53	1.32
Cardiocladius l.	0.00	0.00	11.30	1.16	0.00	0.00	3.77	0.66
Trichoptera l.	0.00	0.00	0.00	0.00	3.77	0.16	3.77	0.66
Baetis n.	22.60	0.33	0.00	0.00	0.00	0.00	3.77	0.66
Empididae l.	11.30	0.16	71.57	7.36	18.83	0.80	7.53	1.32
Nais bretscheri	0.00	0.00	0.00	0.00	0.00	0.00	7.53	1.32
Rheotanyhtarsus l.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Polypedilum scalaenum l.	0.00	0.00	30.13	3.10	0.00	0.00	0.00	0.00
Symphit. morosa l.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nemertea	0.00	0.00	0.00	0.00	263.67	11.18	22.60	3.95
Ancylidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Trichoptera p.	0.00	0.00	0.00	0.00	7.53	0.32	3.77	0.66
Polypedilum convictum l.	45.20	0.66	64.03	6.59	0.00	0.00	0.00	0.00
Nais variabilis	0.00	0.00	0.00	0.00	7.53	0.32	0.00	0.00
Hydroptilidae l.	3.77	0.05	0.00	0.00	26.37	1.12	0.00	0.00
Eukief. discoloripes grp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pristina sima	0.00	0.00	0.00	0.00	150.67	6.39	3.77	0.66
Empididae p.	7.53	0.11	105.47	10.85	3.77	0.16	0.00	0.00
Hydropsychidae p.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Antocha l.	0.00	0.00	0.00	0.00	0.00	0.00	7.53	1.32
Orthocladius l.	0.00	0.00	3.77	0.39	7.53	0.32	18.83	3.29
Isonychia n.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bothrio. vejdovskyanum	0.00	0.00	3.77	0.39	0.00	0.00	0.00	0.00
Nanocladius l.	82.87	1.21	0.00	0.00	33.90	1.44	0.00	0.00
Other Species	226.00	3.29	86.63	8.91	207.17	8.79	11.30	1.97
Station Total	6,866.63		971.80		2,357.93		572.53	

Note: l. = larva
p. = pupa
n. = nymph

N5, N4A, and N1 to be similar. Significant station differences (P = 0.0001) were obtained from ANOVA on total Trichoptera, but considerable overlap existed among stations (Table G-8). Some fluctuation in abundance among the two genera and early instars occurred at the upstream stations and may have had some influence on the fluctuations in diversity at these stations.

The ephemeropterans (mayflies) were not a numerically dominant benthic group, but did attain three major abundance peaks (Figure 9-2). In the upper reach where peaks in abundance occurred at Stations N1 and N4A, the genus *Isonychia* was responsible for major densities of mayflies at Station N1 and *Baetis* sp. at Station N4A (Table 9-1). The mayflies were not abundant in the middle reach of the Naugatuck River, but peaked at Station N10 in the lower reach which was due to a high density of *Baetis* sp. No direct effects from individual dischargers upon either the mayflies or caddisflies were readily apparent. Rather, effects were more generalized and appeared to be associated with degradation of reaches of the river.

The Chironomidae were relatively abundant at all Naugatuck River stations, fluctuating between a low density of 400/m^2 at station 8 to a peak density of 6,500/m^2 at Station N12 (Figure 9-3). The chironomids were generally less abundant in the middle reach. Although results of Tukey's multiple-range

Table 9-1. (Extended)

Station	M5		BP1		BP2		SB1			
Species	Number Indivs	PCT Comp	Number Indivs	PCT Comp	Number Indivs	PCT Comp	Number Indivs	PCT Comp	Total Number	Comp PCT
Cheumatopsyche l.	0.00	0.00	11.30	0.56	0.00	0.00	0.00	0.00	1,139.42	13.47
Symphitopsyche l.	0.00	0.00	0.00	0.00	56.50	1.27	0.00	0.01	867.65	10.26
Tricladida	3.77	2.44	0.00	0.00	0.00	0.00	0.00	0.00	709.08	8.38
Leucotrichia pictipes l.	0.00	0.00	3.77	0.19	0.00	0.00	0.00	0.00	617.17	7.29
Hydropsychidae l.	3.77	2.44	11.30	0.56	82.87	1.86	0.00	0.00	497.58	5.88
Cricot. bicinct. grp. l.	22.60	14.63	11.30	0.56	97.93	2.20	18.83	9.26	426.76	5.04
Nais communis	0.00	0.00	41.43	2.06	248.60	5.59	3.77	1.85	422.24	4.99
Chironomidae p.	3.77	2.44	37.67	1.88	331.47	7.46	7.53	3.70	324.69	3.84
Cladocera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	309.24	3.66
Cricot tremulus grp. l.	0.00	0.00	7.53	0.38	297.57	6.69	0.00	0.00	277.79	3.28
Cricot. cylind. grp. l.	*0.00*	*0.00*	*101.70*	5.07	527.33	*11.86*	*0.00*	*0.00*	239.94	2.84
Acarina	7.53	4.88	214.70	10.69	331.47	7.46	18.83	9.26	234.10	2.77
Nematoda	48.97	31.71	60.27	3.00	263.67	5.93	48.97	24.07	210.37	2.49
Hydropsyche l.	0.00	0.00	0.00	0.00	101.70	2.29	0.00	0.00	186.07	2.20
Thienemannimyia ser. l.	22.60	14.63	478.37	23.83	474.60	10.68	52.73	25.93	171.95	2.03
Cardiocladius l.	26.37	17.07	11.30	0.56	0.00	0.00	0.00	0.00	156.69	1.85
Trichoptera l.	0.00	0.00	0.00	0.00	3.77	0.08	0.00	0.00	155.56	1.84
Baetis n.	0.00	0.00	82.87	4.13	516.03	11.61	0.00	0.00	142.19	1.68
Empididae l.	0.00	0.00	18.83	0.94	177.03	3.98	18.83	9.26	121.29	1.43
Nais bretscheri	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	96.61	1.14
Rheotanyhtarsus l.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	86.63	1.02
Polypedilum scalaenum l.	0.00	0.00	203.40	10.13	252.37	5.68	0.00	0.00	80.98	0.96
Symphit. morosa l.	0.00	0.00	3.77	0.19	11.30	0.25	0.00	0.00	69.68	0.82
Nemertea	0.00	0.00	0.00	0.00	15.07	0.34	0.00	0.00	57.63	0.68
Ancylidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	57.44	0.68
Trichoptera p	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	56.31	0.67
Polypedilum convictum l.	0.00	0.00	11.30	0.56	67.80	1.53	0.00	0.00	56.12	0.66
Nais variabilis	0.00	0.00	18.83	0.94	26.37	0.59	0.00	0.00	42.94	0.51
Hydroptilidae l.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	41.06	0.49
Eukief. discoloripes grp.	0.00	0.00	3.77	0.19	0.00	0.00	0.00	0.00	39.17	0.46
Pristina sima	0.00	0.00	3.77	0.19	45.20	1.02	0.00	0.00	38.61	0.46
Empididae p.	0.00	0.00	11.30	0.56	60.27	1.36	0.00	0.00	38.23	0.45
Hydropsychidae p.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	33.52	0.40
Antocha l.	0.00	0.00	3.77	0.19	3.77	0.08	0.00	0.00	32.96	0.39
Orthocladius l.	0.00	0.00	3.77	0.19	105.47	2.37	0.00	0.00	30.70	0.36
Isonychia n.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.31	0.32
Bothrio. vejdovskyanum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	26.93	0.32
Nanocladius l.	0.00	0.00	7.53	0.38	0.00	0.00	3.77	1.85	23.17	0.27
Other Species	15.07	9.76	644.10	32.08	346.53	7.80	30.13	14.81	314.52	3.72
Station Total	154.43		2,007.63		4,444.67		203.40		8,460.36	

Note: l. = larva
p. = pupa
n. = nymph

test applied to the log transformed counts *a posterior* exhibited considerable overlap among stations. No consistent spatial trend in densities of the three principal species of *Cricotopus* could be discerned along the river gradient (Figure 9-3). However, station differences were significant ($P \leq 0.01$) for all three species (Table G-10). The densities of the three species were generally within an order of magnitude of each other and fluctuated in dominance between stations.

The oligochaetes fluctuated from less than 100 individuals/m^2 at several stations to a peak density of over 10,000/m^2 at Station N4. The oligochaete, *Nais communis*, peaked in abundance at Station N4 accounting for almost 72 percent of the oligochaetes at that station. Generally, *N. communis* had a highly variable spatial distribution increasing in abundance downstream of the Torrington, Thomaston, and Waterbury POTWs (Table 9-1). However, other species of oligochaetes such as *Nais bretscheri, Pristina sima,* and *Bothrioneurum vejdovskyanum* were predominant at stations other than at Station N4.

9.3 Station Comparisons of the Number of Benthic Taxa

Naugatuck River flows increased from 0.2 m^3/sec in the headwaters of the study area to 3 m^3/sec at the farthest downriver station (N12). Differences in benthic community structure among the stations may

Table 9-2. Density (No./m^2) and Percent Composition of Major Benthic Taxa Collected from the Naugatuck River and Tributaries, August 1983

	Station N1		Station N2		Station N3		Station N4		Station N5	
Species	Number Indivs	PCT Comp	Number Indivs	PCT Comp	Number Indivs	PCT Comp	Number Indivs	PCT Comp	Number Indivs	PCT Comp
Trichoptera	1,853.20	35.19	813.60	21.64	2,000.10	26.56	2,576.40	11.26	7,902.47	57.83
Chironomidae	1,367.30	25.97	1,589.53	42.28	2,188.43	29.06	8,463.70	37.01	4,015.27	29.38
Ephemeroptera	1,069.73	20.31	11.30	0.30	18.83	0.25	11.30	0.05	516.03	3.78
Oligochaeta	22.60	0.43	241.07	6.41	1,333.40	17.71	10,147.40	44.37	169.50	1.24
Mollusca	429.40	8.15	33.90	0.90	45.20	0.60	436.93	1.91	327.70	2.40
Other Diptera	161.97	3.08	233.54	6.21	222.23	2.95	512.26	2.24	391.74	2.87
Other Insects	143.14	2.72	15.07	0.40	52.73	0.70	30.13	0.13	3.77	0.03
Miscellaneous	218.47	4.15	821.13	21.84	1,668.63	22.16	693.07	3.03	339.00	2.48
Total	5,265.81		3,759.14		7,529.55		22,871.19		13,665.48	

Table 9-2. (Extended)

	Station N5		Station N6		Station N7		Station N8		Station N9	
Species	Number Indivs	PCT Comp	Number Indivs	PCT Comp	Number Indivs	PCT Comp	Number Indivs	PCT Comp	Number Indivs	PCT Comp
Trichoptera	57,637.53	71.03	161.97	9.05	45.20	1.41	33.90	2.26	26.37	0.99
Chironomidae	1,604.60	1.98	621.50	34.74	1,710.07	53.35	384.20	25.56	2,018.93	76.14
Ephemeroptera	30.13	0.04	3.77	0.21	3.77	0.12	11.30	0.75	105.47	3.98
Oligochaeta	693.07	0.85	11.30	0.63	0	0	0	0	79.10	2.98
Mollusca	0	0	0	0	0	0	0	0	3.77	0.14
Other Diptera	331.47	0.41	229.76	12.84	75.33	2.36	177.03	11.78	274.96	10.37
Other Insects	0	0	7.54	0.42	0	0	3.77	0.25	3.77	0.14
Miscellaneous	20,852.26	25.70	753.34	42.10	1,371.07	42.78	892.70	59.40	139.37	5.26
Total	81,149.06		1.789.18		3,205.44		1,502.90		2,651.74	

Table 9-2. (Extended)

	Station N10		Station N11		Station N12		Station GS1		Station M1	
Species	Number Indivs	PCT Comp	Number Indivs	PCT Comp	Number Indivs	PCT Comp	Number Indivs	PCT Comp	Number Indivs	PCT Comp
Trichoptera	33.90	0.62	7.53	0.27	18.83	0.27	0	0	184.57	7.83
Chironomidae	3,261.93	60.06	1,973.73	70.34	6,478.67	94.35	308.87	31.78	764.63	32.43
Ephemeroptera	1,412.50	26.01	455.77	16.24	22.60	0.33	0	0	30.13	1.28
Oligochaeta	0	0	30.13	1.07	3.77	0.05	7.53	0.78	369.13	15.65
Mollusca	0	0	0	0	0	0	0	0	0	0
Other Diptera	572.53	10.54	256.13	9.13	18.83	0.27	207.17	21.32	22.60	0.96
Other Insects	18.83	0.35	33.90	1.20	30.14	0.43	33.90	3.49	11.30	0.48
Miscellaneous	131.83	2.43	48.97	1.74	293.80	4.28	414.34	42.64	975.57	41.38
Total	5,431.52		2,806.16		6,866.64		971.81		2,357.93	

Table 9-2. (Extended)

	Station M2		Station M5		Station BP1		Station BP2		Station SP1	
Species	Number Indivs	PCT Comp	Number Indivs	PCT Comp	Number Indivs	PCT Comp	Number Indivs	PCT Comp	Number Indivs	PCT Comp
Trichoptera	406.80	71.05	3.77	2.44	33.90	1.69	256.13	5.76	0	0
Chironomidae	86.63	15.13	75.33	48.78	1,065.97	53.10	2,282.60	51.36	97.93	48.15
Ephemeroptera	11.30	1.97	0.00	0.00	86.63	4.32	523.57	11.78	0	0
Oligochaeta	11.30	1.97	3.77	2.44	455.77	22.70	463.30	10.42	7.53	3.70
Mollusca	0	0	0	0	11.30	0.56	26.37	0.59	0	0
Other Diptera	15.07	2.63	0	0	52.74	2.63	248.60	5.59	26.36	12.96
Other Insects	0	0	11.30	7.32	15.07	0.75	15.07	0.33	3.77	1.85
Miscellaneous	41.43	7.24	60.26	39.03	286.27	14.26	629.04	14.15	67.80	33.33
Total	572.53		154.43		2,007.65		4,444.68		203.39	

Figure 9-2. Spatial trend in abundance of Trichoptera and Ephemeroptera and predominant trichopteran genera in Naugatuck River.

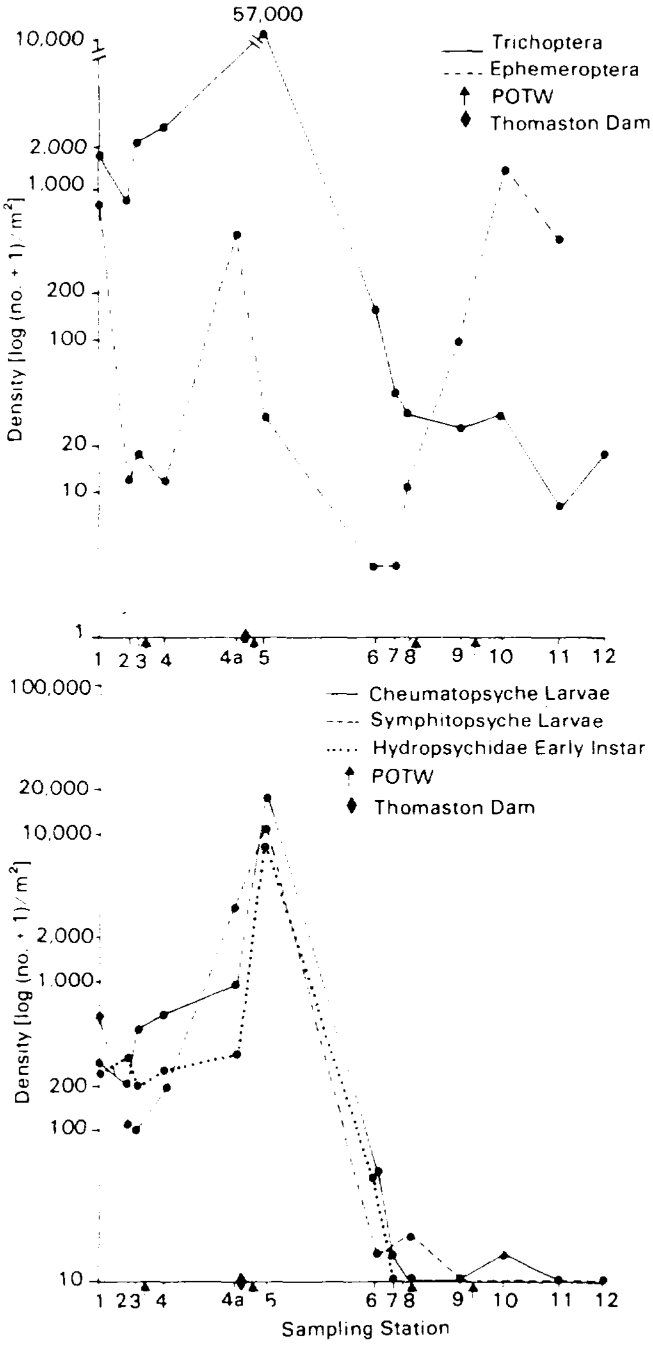
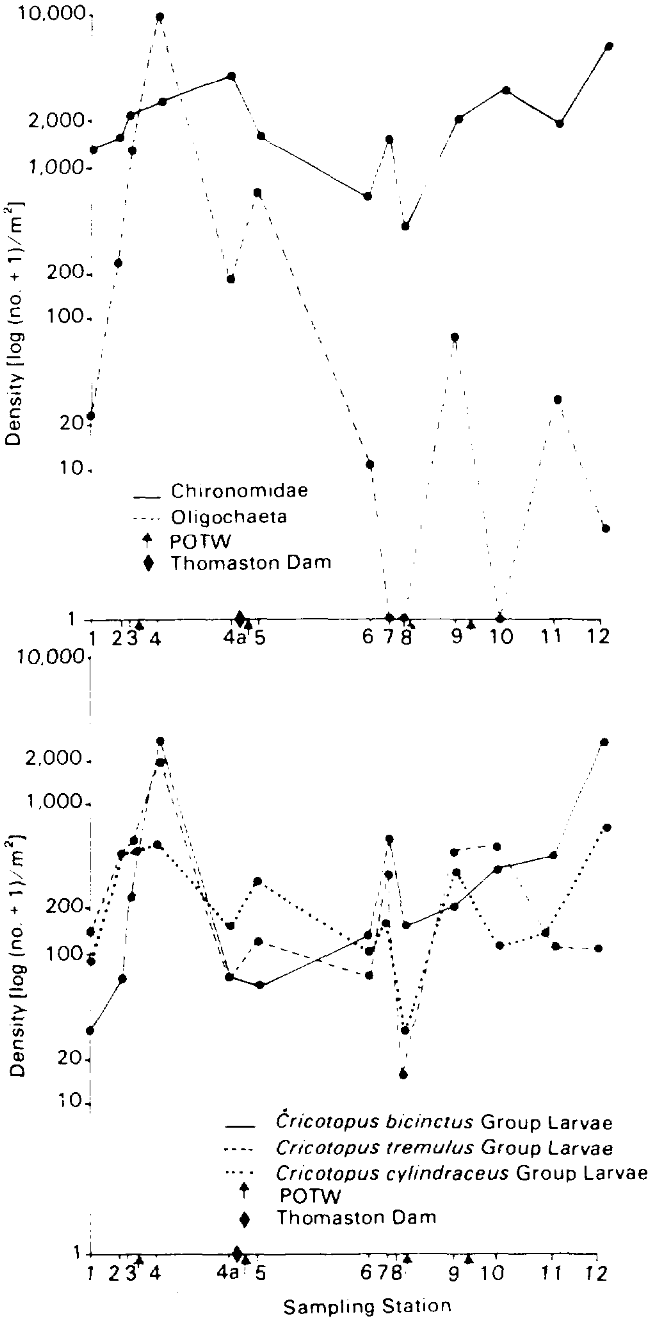
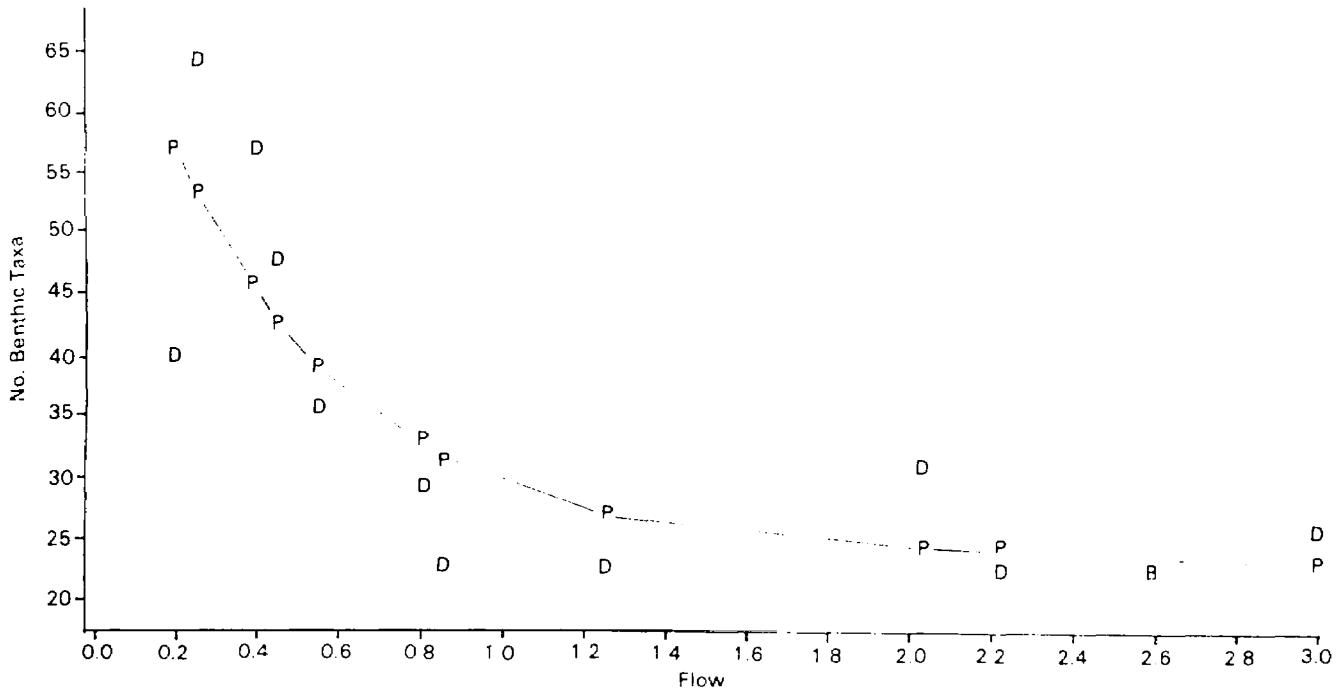


Figure 9-3. Spatial trends in abundance of Chironomidae and Oligochaeta and predominant chironomid species groups in the Naugatuck River.



be highly influenced by the differences in the flow regime along the river gradient. To test this relationship, a nonlinear regression was performed on the number of benthic taxa versus river flow (M^3/sec). The results indicated that variation in the number of taxa in the upper reach of the Naugatuck River (Stations N2 through N7) is related to flow differences as represented by the steep slope on Figure 9-4. However, the number of benthic taxa in the lower reach of the Naugatuck River (Stations N8 through N12) is not influenced to any great extent by flow (~horizontal slope).

Figure 9-4. Nonlinear regression of the number of benthic taxa on flow.



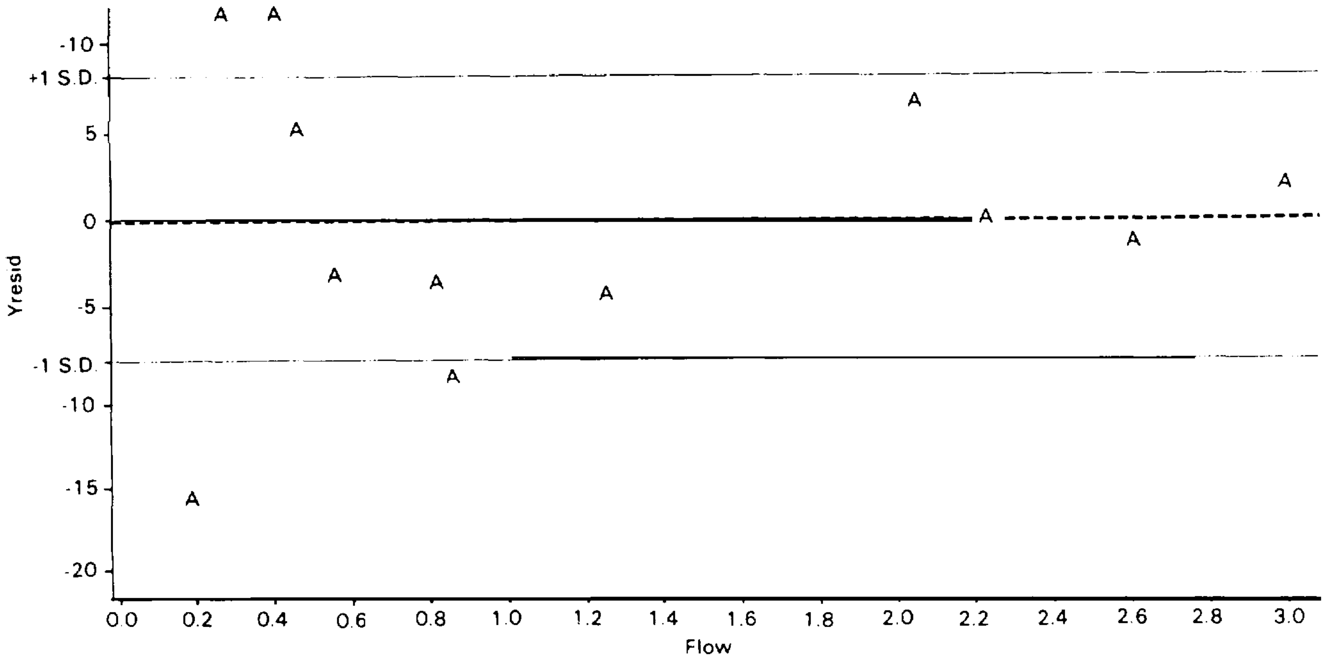
A plot of the residuals (actual minus predicted number of taxa) versus flows and associated standard deviations indicates that the greatest deviation from the predicted value occurs in the upper reach of the Naugatuck River (Figure 9-5). However, all data fall within ±2 standard deviations. Data from the lower reach (flow > 1 m^3/sec) are within ±1 standard devition. The residual number of taxa have a narrower range (28) among stations than do the original data set (range = 42 taxa). The implications of these findings are that variation in number of taxa in the upper reach is more related to river flows than that in the lower reach, and differences in number of taxa along the river gradient need to be interpreted in that context. However, a number of other changes are associated with increased flow, for example more habitat types, increased effluent concentrations, and higher dissolved solids. There are no data to indicate which of the many changes caused the effects on the macroinvertebrates and flow may or may not be among the causes.

9.4 Evaluation of the Macroinvertebrate Community

A general degradation of the benthic community along the river gradient from N2 to N12 was suggested by the spatial trend of the community parameters (diversity and community loss) and the distribution of certain benthic taxa. This downstream trend of decreasing health of the benthos could be attributed to the combination of two primary factors. First, the cumulative input of industrial effluent and serial positioning of the discharges has not only localized effects but prohibits effective recolonization downstream. Secondly, and perhaps more importantly, the flow regime of the river substantially increases from N2 to N12 causing shifts in habitat quality from upstream to downstream. The flow at N12 was more than 50 times greater than that measured at N2 (Table 6-3). These flow differences along with periodic regulation of the river, alters the habitat to which the organisms are exposed.

Results of the community parameters best reflected effects from individual discharges. Direct effects were attributed from these data to the Gulf Stream and Mad River tributaries, the Torrington and Naugatuck POTWs, and the Thomaston Dam. Direct discharge effects were not as apparent from the benthic population data. A degree of intermediate recovery of the benthos was noted along the river gradient from the community parameter data resulting in a division of the study area into "reaches." The upper reach contained the healthiest benthic community and extended from the N1 upstream of Torrington to Station N5 located downstream of the Thomaston POTW. The middle reach reflected a lower quality community and extended from Station N6 located downstream of Steele Brook to Station N8 downstream of the Mad River. The lower reach had the

Figure 9-5. **Residuals (actual minus predicted number of benthic taxa) versus river flow.**



poorest quality benthic community and extended from Station N9 downstream of the Waterbury POTW to Station N12.

Certain other factors such as predation and grazing pressure (competition) may have had some influence on the quality of the benthos. These factors were not investigated but are believed to have had little influence on the structure of the benthic community in comparison to the observed effects due to discharges and habitat.

10. Fish Community

Investigation of the fish community of the Naugatuck River was used as another measure of the community condition of the river. The objective of the fisheries investigation was to collect, identify, and count fishes from locations throughout the Naugatuck River watershed and examine the resulting data for evidence of response to known point-source discharges. The methods used for the fisheries survey are presented in Appendix D.

10.1 Community Structure

The fisheries survey of the Naugatuck River watershed yielded nearly 4,000 specimens from eight families and 22 species (Tables 10-1 and G-7). The minnow family was dominant with the blacknose dace as the most abundant species (Table 10-1). White sucker was the second most abundant species *collected, but was the only representative of the* sucker family. The third most abundant species was the tassellated darter of the perch family.

The distribution of the fish species among the *sampling stations exhibit three general trends.* Species distribution and abundance data indicate that different communities exist in the tributaries and in the upper and lower Naugatuck River. The species differences appear to be due to physical habitat changes as well as influences from effluent discharges. The differences between the three areas sampled are shown by examining the numbers of species and individuals collected (Table 10-1). Based *on a chi-square analysis, Stations N6, N8, N10, and* N12 were significantly ($P \leq 0.05$) lower than the maximum number of species found at Station N5. The maximum number of species was considered reflective of optimum conditions and therefore used as the expected value. The mean number of individuals collected at the upstream Naugatuck River stations was four times greater than at the tributary stations and 10 times greater than at the lower Naugatuck River stations (474 vs. 115 vs. 45). *In addition, the* mean number of fish species collected at the upper *Naugatuck* River stations was twice as high as either of the other two areas (11 vs. 5 vs. 6).

In the tributary stations, fewer species and numbers of individuals were collected. This occurrence may be due either to limited habitat or known point-source discharges. The Beaver Pond Brook Stations, BP1 and BP2, *produced relatively few species in low to* moderate numbers (Table 10-1). This appears to be a result of habitat limitation rather than upstream discharges. Beaver Pond Brook was shallow and narrow (5.2 m) and thus did not have the physical habitat available to hold a large number of fishes, despite apparent good water quality. Gulf stream and Steele Brook (Stations GS1 and SB1, respectively) were similar in habitat to Beaver Pond Brook, but no fish were collected at Station GS1 and only three were collected at Station SB1. This may be due to point-source discharges upstream. The Mad River tributary was larger and offered a greater diversity of habitat than the other tributaries. This was reflected in the greater number of species and specimens captured at Stations M1 and M2. Fishing efforts at Station M5, which contained good fish habitat, produced no fish. The water at Station M5 contains the combined effluents of several upstream industrial discharges. The upper Naugatuck River stations, from Station N1 at Torrington to Station N5 at Waterbury, represent a second type of habitat in terms of fish species composition and abundance (Table 10-1). The combination of greater amount of physical habitat (relative to tributaries) and fewer sources of polluted effluents accounts for the larger number of fish at these locations. Although there are differences in individual species among the upper Naugatuck River stations, they are largely attributable to microhabitat differences. Minnows, white sucker, and tessellated darter dominated catches. Sunfish occurred in very low numbers at these stations, except at Station N5. Stations N2 and N3 were wide and shallow and lacked the depth and cover necessary to support sunfish. The cutlips minnow occurred only at Stations N2 through N4A. Their absence downstream may be attributed to their sensitivity to turbidity and siltation (Scott and Crossman 1973; Cooper 1983); however, absence from the tributaries and at Station N1 is unexplained except that the average stream flow may have been too high for this reportedly sluggish minnow.

Other differences in catches of a species among the uypper Naugatuck River stations are evident. For *example, tessellated darters were uncommon at* Stations N1 through N3 relative to Stations N4 through N5. This may be explained at least in part by the poorly developed riffles at Stations N2 and N3

Table 10-1. Numbers of Fish Collected from the Naugatuck River and Tributaries in Connecticut, 1983

	Naugatuck Sampling Station													Tributaries Sampling Station						
Species	N1	N2	N3	N4	N4A	N5	N6	N7	N8	N9	N10	N11	N12	BP1	BP2	GS1	SB1	M1	M2	M5
American eel						1						2	1							
Brown trout																			1	
Chain pickerel	1				1		3											3		
Redfin pickerel						1								9	1				1	
Common shiner	5	67	15	2	15	3		1		5									35	
Spottail shiner						3		1		8								41		
Creek Club	1	32	19	58	42					2		5								
Fallfish	31	14	22			14		3							17		1	64	73	
Longnose dace	20	9	17	87	262	57		1		26					7			4	20	
Blacknose dace	9	677	49	25	119	9		2		62		3		8	35			3	36	
Cut lips minnow		71	43	1	14															
Golden shiner				1	6	4								1				1		
White sucker	19	38	24	50	96	174	6	2		24	2	7					1	254	17	
Brown bullhead	5					3		1	3									2		
Yellow bullhead																			1	
Bluegill	1				3	6		1		13		1	1							
Pumpkinseed				1	1	28	2	2					2							
Redbreast sunfish								1	1		1	1			1			41	30	
Rock bass	2			2	5	12	1					1								
Largemouth bass	7			1	7	58		11	2	8					3			6	4	
Sunfish sp			1								1									
Yellow perch						1														
Tessellated darter	6	18	8	40	252	152	5	15		69		9		15	55		1	12	1	
Crayfish	24	51	138	62	100	131	7	94	19	23	15	16	1	34	15		5	78	55	2
Total Number of Fish	107	926	198	268	823	526	17	41	6	217	4	29	4	33	119	0	3	431	219	0
Chi-square (X^2)[a]	0.76	3.52	3.52	1.27	0.39	0	6.89[b]	0.76	9.77[b]	2.64	9.77[b]	3.52	9.77	--	--	--	--	--	--	--
No. of Taxa	12	8	9	11	13	16	5	12	3	9	3	8	3	4	7	0	3	11	11	0

[a] Expected value = 16 (maximum number) X^2 not calculated for tributaries

[b] Significantly lower ($P \leq 0.05$) from Station N5

relative to N4A, and the consequent better darter habitat at Station N4A.

Beginning with Station N2 and extending downstream, there is a third change in the fish community. Although the number of species captured differed greatly among these downstream stations, the number of specimens captured was still markedly lower than at upper Naugatuck River stations. In addition, the number of different species collected at the downstream stations declined relative to those stations in the upper Naugatuck River. From Station N6 to N12, the number of species and individuals was lower than at upstream stations, with the exception of station N9.

10.2 Evaluation of Fish Community Response

The fish survey was conducted and the results were analyzed, independent of the effluent configuration and toxicity testing carried out concurrently and presented in this report. By excluding information on effluent concentrations and toxicities, the field data may serve as an independent confirmation test for the other studies. The catch from this study of 22 species is quite representative of the historically documented fish community in the Naugatuck River. Whitworth et al. (1968) reported less than 30 fish species in the Naugatuck watershed, based on a state-wide survey in 1965-1967 and other extant records. This is a rather low number of species, given the size of the stream, but is a result of the greater effect of glaciation in this area as well as the relatively poor productivity of New England streams in general (Gilbert 1980).

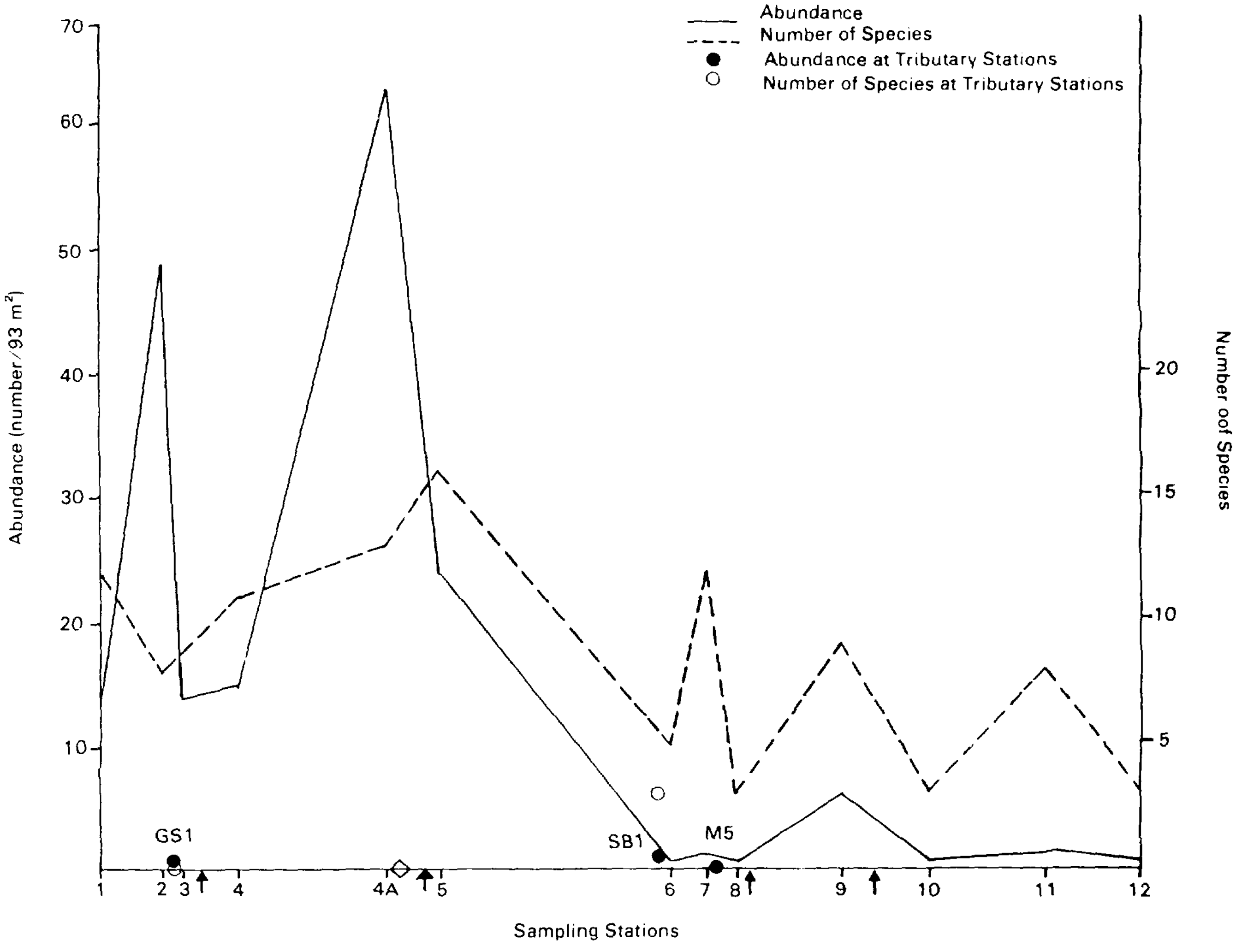
To provide the best comparison of the fish results among sampling stations, the catch data were converted to total number of fish per 93 m^2 (Figure 10-1). Although one 91.4-m length of stream was sampled in all but one case, the stream widths differed greatly (Table C-1) and consequently, the actual size of the areas sampled differed among stations—by an order of magnitude between Stations BP1 and N10. The calculation of fish per 93 m^2 provides a more precise comparison between stations when assuming that the carrying capacity of a stream section is directly proportional to its size.

The catches in the upper Naugatuck River, although variable, were indicative of an abundant, diverse fish community from Station N1 downstream through Station N5 (Figure 10-1). While the differences in catches among upper stations may be influenced by point-source effluents, it is probable that these differences are due primarily to variation in available microhabitat among the stations. After Station N5, the Naugatuck River fish community changes noticeably. These data suggest that the fish community in Steele Brook and in the Naugatuck River below the confluence with Steele Brook is stressed. This stress on the fish community does not dissipate for some distance downstream. The moderate recovery of the fish community at Station N9 may be a function of distant downstream from the major effluent sources. However, this recovery is short-lived, as fish were essentially absent at Stations N10 through N12.

The Gulf Stream tributary, which enters the Naugatuck River between Stations N2 and N3, was sampled in its lower reach and no fish were captured. This tributary is apparently greatly affected by upstream effluents. Similarly, Steele Brook produced only a few fish. In this tributary, a greenish deposit was noticed on the substrate that may have originated from any of several upstream dischargers.

Sampling in Beaver Pond (Stations BP1 and BP2) revealed a good fish community for the stream size (Figure 10-2). The community was not noticeably affected by known point-source effluents downstream of Station BP1. The upper Mad River (Stations M1 and M2) also produced good catches in terms of species and individuals. However, at Mad River Station M5 just prior to the juncture with the Naugatuck River, no fish and only two crayfish were captured. The most plausible explanation for this is the effect of industrial dischargers in the lower Mad River.

Figure 10-1. Abundance and number of species of fish captured from the Naugatuck River, Connecticut.



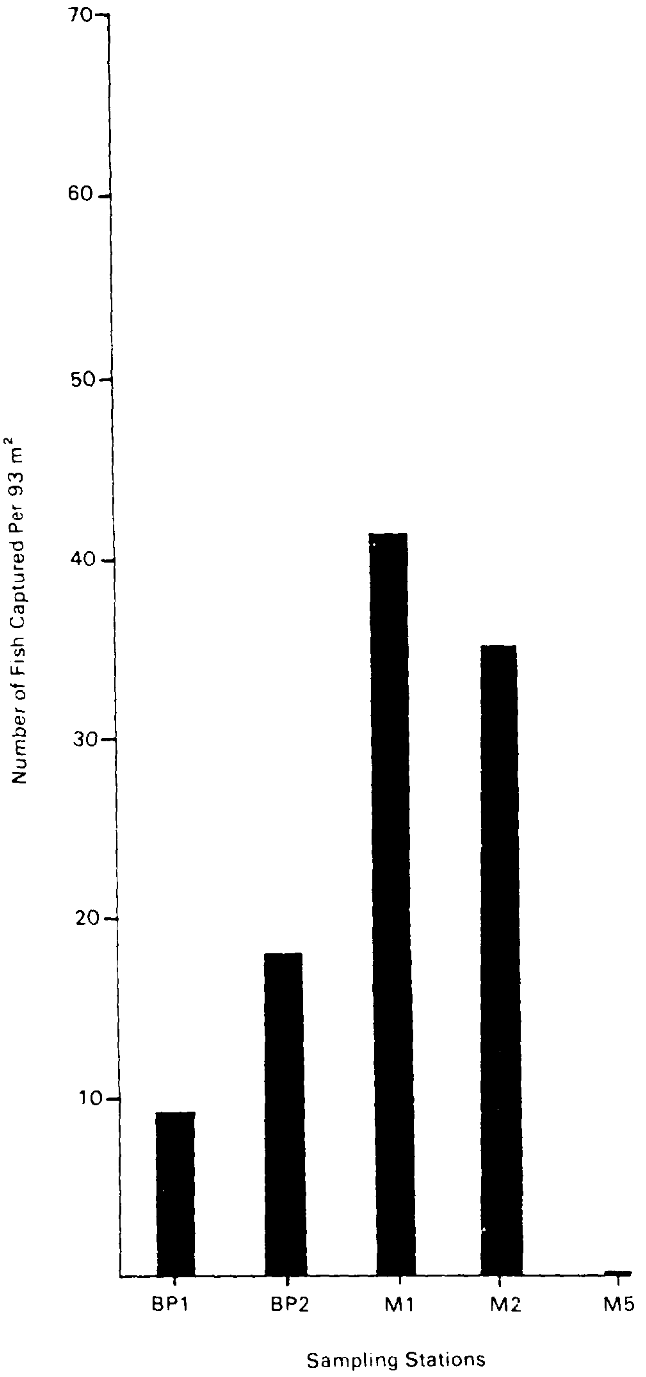


Figure 10-2. **Number of fish captured inthe Mad River, Connecticut.**

The presence of a relatively abundant and diverse fish community in the Naugatuck River between Torrington and Waterbury represents an improvement over recent historical conditions. In their state-wide sampling survey during 1965-1967, Whitworth et al. (1968) reported finding in the Naugatuck River, "a varied and large fish fauna..above Torrington and virtually no fishes...south of that city." They attributed this condition to the effect of domestic and industrial effluents. Judging by this fish community, the present survey demonstrates that river conditions have improved downstream at Torrington but that the effluent loading in the Waterbury area prohibits the recovery of the fish community from Waterbury downstream at least as far as Ansonia and perhaps as far as the juncture with the Housatonic River.

11. *Comparison Between Laboratory Toxicity Tests and Instream Biological Response*

11.1 Background

The comparison between toxicity measured in the laboratory on a few species and the impact occurring in the stream on whole communities must compensate for a very limited database from which to predict. The sensitivity of the test species relative to that of species in the community is almost never known and certainly not in these toxicity tests. Therefore, when toxicity is found, there is no method to predict whether many species in the community, or just a few, will be adversely affected at similar concentrations, since the sensitivity of the species in the community is not known. For example, at a given waste concentration, if the test species has a toxic response and if the test species is very sensitive, then only those species in the community of equal or greater sensitivity would be adversely affected by direct toxic effects. Conversely, if the test species is tolerant of the waste, then many more species in the community would be affected at the concentration which begins to cause toxic effects to the test species. It is possible that no species in the community is as sensitive as the most sensitive test species, but since there are so many species composing the community, this is unlikely. It is more likely that a number of species in the community will be more sensitive than the test species. The highest probability is that the test species will be near the mean sensitivity of organisms in the community if the test species is chosen without knowledge of its sensitivity (as was the case here).

In a special case, where toxicants remain the same and the species composing the community remain the same, the number of species in the community having a sensitvity equal to or greater than the test species also will remain the same. As a result, there should be a consistent relationship between the degree of toxicity as measured by the toxicity test and the reduction in the number of species in the community. In this special case, there should be a tight correlation between degree of toxicity and the number of species. If the toxic stress is great enough *to diminish* the production of offspring by a test species, it should also be severe enough to diminish the reproduction of some species within the community of equal or greater sensitivity. This should ultimately lead to elimination of the more sensitive species if the reduction is large enough. Therefore, a lower number of taxa should be a predictable response of the community. For example, there should be a relationship between the number of young per female *Ceriodaphnia* or the growth of fathead minnows (or other test species) and the number of species in the community. Obviously, the test species must have a sensitivity, such that at ambient concentrations to which the community has responded, a partial effect is produced in the toxicity test. However, unless the special case described above exists, the correlation between toxicity and species richness will not be a tight one.

Effluents differ from single chemicals in some important respects. We know from the literature on single chemicals that there usually are large differences in the relative sensitivity of species to a chemical and that the relative sensitivity changes with different chemicals. For exmaple the fathead may be more sensitive to effluent A and *Ceriodaphnia* more sensitive to effluent B. We also know that effluents vary in their composition from time to time and often within a few hours. We should not be surprised therefore to find fathead minnows being more sensitive to an effluent on one day and daphnids more sensitive on another day.

Effluents begin changing in composition as soon as they are discharged. Fate processes such as bacterial decomposition, oxidation, and many others change the composition. In addition, various components will change at different rates. For example, ammonia would be expected to disappear more rapidly than PCBs. If so, then the composition of the effluent is ever changing as it moves through the receiving water. Note that this change is not just a lessening concentration as a result of dilution but also a change in the relative concentrations of the components. In reality, the aquatic organisms at some distance from the outfall are exposed to a different toxicant than those near the discharge point! Therefore, it is logical to expect that sometimes one test species would be more sensitive to the effluent as it is discharged and another species more sensitive *after fate processes* begin altering the effluent. To be sure, the source of the effluent is the same but it is certainly not the same "effluent" in regard to its composition. If these statements are true then one should also expect that species in the community in the receiving water may be affected at one place near the discharge and a different group of species may be affected from the same effluent at another location.

An effluent cannot be viewed as just diluting as it moves away from the outfall. In fact, it is a "series of new effluents" with elapsed flow time. If so, there are important implications for interpretation of toxicity and community data. One should not expect the various test species to respond similarly to water collected from various ambient stations. We should expect one species to be more sensitive at one station and another species to be more sensitive at the next. The affected components of the community should vary in a like manner.

An even bigger implication is that the surrogate species concept is invalid in such a situation. As one examines the community data in the Lima report (Mount etal., 1984) and in subsequent studies in press, it is clear that there is no one community component that is consistently sensitive. Sometimes the benthic invertebrates and the periphyton have similar responses and both are different from the fish. Sometimes the fish and periphyton have similar responses and these are unlike the benthic invertebrates.

The same is true of the test species. Sometimes the *Ceriodaphnia* respond like the periphyton and other times like the fish. The important point is that a careful analysis of our knowledge of toxicology, effluent decay, and relative sensitivity tells us that we *cannot* expect:

1. *Ceriodaphnia* toxicity to always resemble toxicity to benthic invertebrates
2. Fathead minnow toxicity to always resemble toxicity to fish
3. Fathead minnows and other fish to display the same relative sensitivity to different effluents.

Any test species should have a sensitivity representative of some components of the community. The important distinction is that one never can be sure which components they will represent.

In comparing toxicity test results to community response, comparison must be made with the above in mind. Certainly those community components that are most sensitive will be most impacted and/or lost. The response of the most sensitive test species should therefore be used to compare to the response of the most sensitive of the community.

A weakness in using the number of species as the measure of community response is that species may be severely affected yet not be absent. The density of various species is greatly influenced by competition for available habitat, predation, grazing, and/or secondary effects which may result from changing species composition. Density is more subject to confounding causes, other than direct toxicity, and is not as useful as the species richness in the community to compare community response to measured toxicity.

Several measures of community structure are based on number of species, e.g., diversity and community loss index. Since diversity measures are little affected by changes in the number of species (or taxa) that are in very low densities in the community, diversity is an insensitive measure for some perturbations which can be measured by toxicity tests. The community loss index is based only on the presence or absence of specific species relative to a reference station and would be useful except that habitat differences between stations heavily affect this measure. There are several problems when using the number of (taxa) species measured. The foremost is that the mere presence or absence of species is not a comprehensive indicator of community health, especially if the species are ecologically unimportant. Secondly, a toxic stress may not eliminate species but yet have a severe effect on density; presence or absence does not consider such partial reductions. The presence or absence of species as the measure of community impact is influenced by the chance occurrence of one or a few individuals due to either drift, immigration, or some catastrophic event when in fact that species is not actually a part of the community where it is found. Effects other than toxicity, such as habitat, will always confuse such comparisons to toxicity data to some extent. Use of artificial substrates should reduce habitat effects compared to natural substrates. They cannot be eliminated. Identification of taxa to different levels can reduce the sensitivity of species richness.

Even though species richness has numerous sources of error as a representative measure of community health, it remains the best measure for comparison with toxicological data. Species sensitivity will respond in the most direct way to toxic response of the community with the least interference.

11.2 Comparison of toxicity and Field Data for Naugatuck River

11.2.1 Effluent Tests

The need to provide the data for the mass balance modeling efforts required that the effluent tests had to be performed using water from station N1 rather than immediately upstream of each outfall. In a complex situation such as this site with many discharges, the characteristics of the water quality change with additional dischargers. This is illustrated in two ways.

In the work for the site-specific criteria development, Carlson et al. (1986) found that copper was 3.2 and

7.1 times less toxic at Stations N4A, N5, N6, and N7 as compared to Station N1. In this report, for example, Steele Brook produces an instream waste concentration of 15.7% at Station N6 (Table 6-4). The AEC for daphnids of Steele Brook water is 1.7 and 5.5% (Table 5-15). The instream waste concentration exceeds the AEC by 3 to 8 times, yet the ambient toxicity at Station N6 was not measurable on 5 of 7 days of the testing period (Table 4-2).

Since metals, especially copper (Carlson et al., In preparation), were found to be important toxicants at this site, the addition of POTW effluent would be expected to reduce metal toxicity. Because the tests on effluents were not done on water immediately upstream of each discharge, the effluent test data are not useful for predicting effects downstream of the effluent discharge point. However, should the regulatory strategy be such that the safety of one discharge should *not* be dependent on the presence of another, then the effluents should be diluted with a water such as N1 to determine acceptable effluent concentrations.

11.2.2 Ambient Toxicity

Figure 11-1 is a plot of the ambient toxicity data for both test species. The data for daphnids and fatheads represent a different exposure condition. The fatheads were exposed to a different water sample for each 24-hour period whereas the daphnids were exposed to the same sample for the entire seven-day test period. The daphnid values plotted are the means of seven such tests using samples collected on seven successive days. The daphnids show a trend of declining young per female from upstream to downstream. The fatheads show a similar trend except at Station N9 where there was little toxicity to the fatheads. The total mortality of fatheads at Stations 10 and 11 resulted from a toxic slug from the Naugatuck POTW. Since the fatheads were exposed to a new sample every day, once killed by a single day's sample, the toxicity of succeeding day's samples could not be measured. Similar types of tests were done using *Ceriodaphnia* (Table 4-3) and they were also all killed at Stations N10 and N11. At Station N12 all daphnids were killed (Table 4-3) but mean survival of fatheads was 53% (Table 4-1) indicating the fatheads were less sensitive than daphnids to the toxic slug. The data points in Figure 11-1 for daphnids are derived as a mean of seven mass balance type tests (Table 4-2) and the toxic slug lowered the mean value, but after it passed, young per female was much *higher*. Considering the different exposure conditions, the two test species have the same trend except for Station N-9.

Figures 11-2 and 11-3 are plots of the number of taxa for periphyton, benthic macroinvertebrates, zooplankton, and fish. Except for zooplankton, there is a trend of decreasing taxa from upstream to downstream, trends that resemble the ambient toxicity data shown in Figure 11-1. The zooplankton data are different. The zooplankton investigators attribute the increased density and taxa at Stations N5, N6, N7, and N8 to the effects of the impoundment. One might expect, if so, that Station N5 would be the highest followed by a decline at downstream stations, which was not the case.

If toxicity occurs that takes time to be expressed, then one would expect the drifting zooplankters to show effects somewhat downstream of the point of discharge. This would explain the drop in taxa between stations N8 and N9. From Table 4-2, one can see that

Figure 11.1 **Toxicity of ambient station water to fathead minnows and *Ceriodaphnia*,** Naugatuck River.

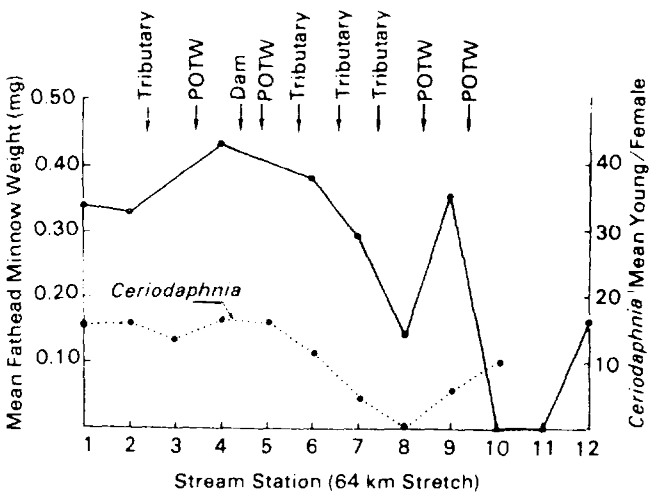


Figure 11.2. **Number of fish and periphyton taxa at the various stream stations, Naugatuck River.**

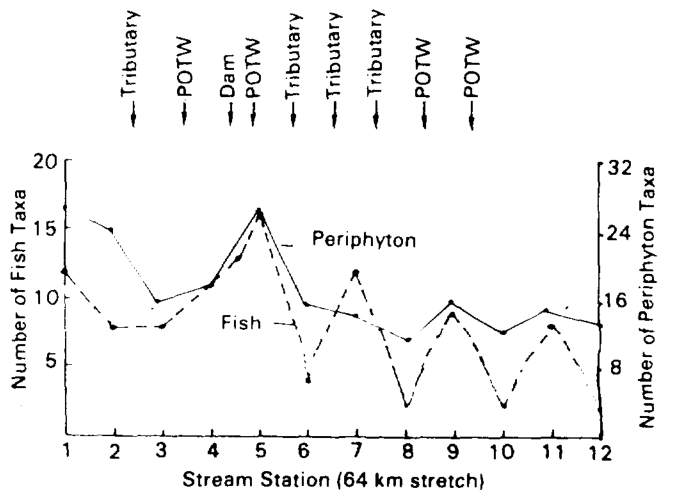
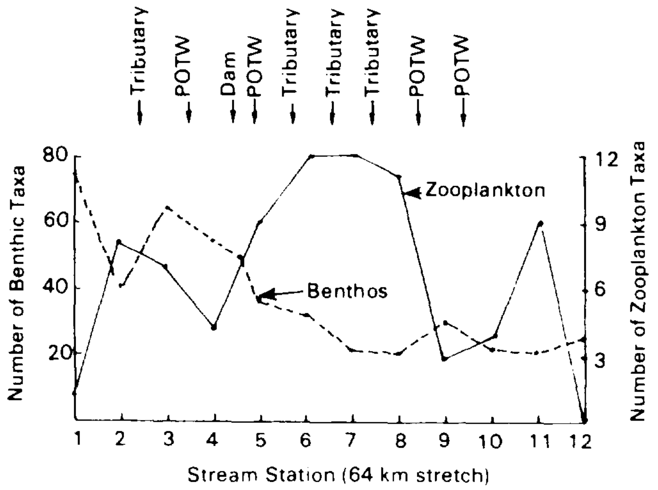


Figure 11.3. **Number of benthic and zooplankton taxa at various stream stations, Naugatuck River.**



Station 8 water was lethal every day but one whereas Station N9 water was less toxic. The populations enumerated at Station N9 may have been intoxicated at Station N8 and then disappeared as they drifted to Station N9. The absence of zooplankton at Station N12 agrees with observed toxicity. Although Station N12 was run as an impact test, new animals were set up in each day's samples and they were killed within 24 hours in every case. The ambient test data do not agree with the few species found at Station N1 but the stream was small at N1 and one would not expect zooplankton to be abundant as a result of habitat—not toxicity. The substantial increase at Station 2 may be a result of an impoundment on a tributary upstream of that station.

The data for the toxicity test and for the number of taxa show the same trends except for zooplankton. To make a more quantitative comparison, Table 11-1 was compiled by using the highest number of young per female or the largest weight as 0 toxicity for the daphnids and fatheads, respectively. Toxicity for other stations was then calculated as a percent of those reference values. The reduction in number of taxa was calculated in a similar way. Thus the reference stations were different among the various measures. Table 11-2 was then constructed from Table 11-1 in the following way. If both toxicity values for a station were below 20% and all four taxa values were below 20%, a correct prediction was registered. If one or more toxicity values and one or more taxa values were over 20%, a correct prediction was counted. This was done for all stations and the percent correct prediction placed in the upper left cell of Table 11-2. The same procedure was used for each cell only changing the percentage used to the appropriate value for that cell.

The highest percentage of correct predictions were obtained when 20 percent was used for toxicity and 20 or 40 percent for the field data. Eighty-five percent of the stations were correctly predicted. One can also see that the largest percentage of correct predictions were obtained when comparable percentages were compared, i.e., the highest values lie along a diagonal from upper left to lower right. This pattern is evidence that the degres of toxicity is related to the degree of taxa reduction. To verify this trend qualitatively, the degree of toxicity and reduction of taxa was subjected to a correlation analysis. The correlation was significant ($P \leq 0.05$) for daphnids with periphyton, macroinvertebrates, and fish but not zooplankton. Since there were no fathead minnow data at three stations, correlations were not done with that data.

11.3 Summary

The toxicity data reflected the same trend as the field data for three groups of organisms. The correlation of daphnid toxicity data with periphyton, macroinvertebrates, and fish species richness was significant ($P \leq 0.05$). When percent toxicity and taxa reduction were compared in a matrix, up to 85% of the stations were correctly predicted.

Table 11-1. Percent Increase in Toxicity and Reduction in Taxa for Each Ambient Station Using the Least Toxicity or Largest Number of Taxa as Zero Percent

Station	*Ceriodaphnia*	Fathead Minnows	Algae	Zooplankton	Benthic Macro-Invertebrate	Fish
1	12	20	0	92	0	25
2	4	21	11	33	44	50
3	20	--	41	42	10	44
4	0	0	33	67	21	31
4A	24	--	0	67	32	19
5	6	--	0	25	51	0
6	22	18	44	0	59	69
7	58	32	48	0	68	25
8	94	70	56	8	69	81
9	50	17	41	75	58	44
10	39	100	56	67	68	81
11	100	100	44	25	69	50
12	100	63	52	100	65	81

Source: Tables 4-1 to 4-3, 8-2, 10-1, G-1, G-6, and 10-1.

Table 11-2. Percent Correct Predictions of Impact Using Four Levels of Comparison

	Combined Field Data (Percent)			
Combined Toxicity Data	20-100	40-100	60-100	80-100
20-100	85	85	77	46
40-100	38	38	62	62
60-100	23	23	46	77
80-100	23	23	46	77

Source: Table 11-1

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Appendix A
Onsite Toxicity Test and Analytical Methods

Two types of effluent and ambient toxicity tests were conducted for the Naugatuck River study. One set of tests was termed the "impact tests" in which the test organisms were exposed to a new effluent or ambient stream station sample each day for seven days. The other set of tests was termed the "mass balance tests" (as the results were to be used in a mass balance model of toxicity) in which the entire test was completed on the same sample. In this test, the tests solutions were renewed only twice, in contrast to daily, and the sample was kept refrigerated for the duration of the test. Seven such tests were run on each of seven ambient station samples for each exposure condition. This type of exposure is less representative of the exposure of the organisms in the receiving water.

A.1 Sampling Preparation

Sampling of each effluent and ambient stream station was done using the ISCO samplers. An aliquot was collected every 15 minutes and composited into a 5-gal polyethylene container. About 18 L were collected every 24 hours and new samples were taken each day. However, aliquots of Stations N6 and N7 water were collected manually every 4 hours. The N1 water used for dilution was collected in 5-gal polyethylene containers as a daily grab. Due to collection difficulties, the following stations on the specified day were grab samples: Station N3 on 23, 24, and 27 August, Station N4 on 28 August, Station N4A on 29 August, Station N9 on 24 August, and Station N1A on 23 August.

A.2 Fathead Minnow Tests

Only impact tests were performed on the fathead minnows. Three POTW effluents were tested at concentrations of 1, 3, 10, 30, and 100 percent. Two tributary streams (Mad River and Steele Brook) that each had several discharges were tested as effluents, using water collected at the mouth of each tributary. The same dilution sequence was used. The source of dilution water was the most upstream ambient station, Station N1, which was upstream of all known dischargers.

For ambient toxicity tests, stations were established over the distance of the river from Station N1 to near the river mouth. Stations were selected to measure the impact, if any, of the various effluents and tributaries.

Larval fathead minnows were less than 24 hours old and were air-shipped from the Newtown Fish Toxicology Station. The fish were assigned one or two at a time to replicate test chambers until all replicates had 10 fish in each chamber or 40 fish per concentration. Test tempertures were 25 ± 2°C, and were maintained by control of the air conditioner and furnace. Newly hatched brine fish were fed to the fish twice per day. The uneaten shrimp were removed daily by siphoning the chambers during test renewal. At that time the test water was also drawn down to a depth of approximately 1 cm, and 2 L of new test solution were added. Effluent dilutions were made using polypropylene graduated cylinders of various sizes and mixing was done in 4-L polyethylene beakers. Initial dissolved oxygen (DO), pH, and conductivity measurements were taken before the test solutions were added to the test chambers. Prior to renewal, DO was measured again and recorded as the final value.

After seven days of exposure the fish were removed and preserved in 4 percent formalin. On returning to the laboratory, the fish were rinsed in distilled water, oven-dried for 18 hours in preweighed weighing pans, and weighed on a five-place analytical balance. The methods followed those described in Norberg and Mount (1985).

A.3 *Ceriodaphnia* Tests

Adult *Ceriodaphnia* sp. from the ERL-D culture were transported by air to the study site and transferred to Station N1 water. One adult each was placed in 15 ml of dilution water in a 1 oz clear plastic cup. Each day the adult was removed and transferred to new water. The young produced from these adults were used for the toxicity tests when they were 0-4 hours old. Since the mass balance tests were initiated daily (each day for 7 days), young animals were needed every day. Therefore, adults were maintained as described above to constantly provide new test organisms. Because the various industries discharge on a 5-day per week schedule, the results of the *Ceriodaphnia* mass balance tests were not expected to be the same over the seven day test period. Both mass balance and impact tests were conducted using *Ceriodaphnia*.

A drop (~ 0.05) of a yeast suspension containing 250 μg of yeast was fed to each adult daily. In the impact tests, the test animal was transferred to a new test solution on day 2 and 4 at which time any young present were counted and discarded. The effluent sample for the impact test was stored at < 4°C until each renewal. At that time the test cups were filled with 15 ml of test solution and slowly warmed to room temperature. Final DO was measured in one of the ten cups for each treatment at each renewal. The methods used generally followed those of Mount and Norberg (1984).

A.4 Quantitative Analyses

A.4.1 Ceriodaphnia

The statistical analyses of the data were performed using the procedure of Hamilton (1984) as modified by Rogers (personal communication). In this procedure the young production data were analyzed to obtain the mean number of young per female per treatment. Daily means were calculated and these means were summed to derive the 7-day mean young value. By this method, any young produced from females that die during the test are included in the mean daily estimate. Using this procedure, mortalities of the original females affect the estimate minimally, but the mortality of the adult is used along with the young production to determine overall toxicity effects. Confidence intervals are calculated for the mean reproductivity using a standard error estimate calculated by the bootstrap procedure. The bootstrap procedure subsamples the original data set ($n = 999$) by means of a computer to obtain a robust estimate of standard error.

A Dunnett's two-tailed t-test is performed with the effluent test data to compare each treatment to the control for significant differences. For the ambient station data, Tukey's Honestly Significant Difference Test is used to compare between stations.

A.4.2 Fathead Minnows

The four groups' mean weights are statistically analyzed with the assumption that the four test chamber compartments behave as replicates. The method of analysis assumes the variability in the mean treatment response is proportional to the number of fish per treatment. MINITAB (copyright Pennsylvania State University 1982) was used to estimated a t-statistic for comparing the mean treatment and control data using a weighted regression with weights equal to the number of measurements in the treatments. The t-statistic is then compared to the critical t-statistic for the standard two-tailed Dunnett's test (Steele and Torrie 1960). The survival data are arcsine-transformed prior to conducting the regression analyses to stabilize any variances in the percent data.

Appendix B
Offsite Toxicity Test and Analytical Methods

B.1 Test Program

Due to the number of tests involved, the laboratory testing program with *Ceriodaphnia* was divided into two phases: Phase I—upstream tributaries and effluents; Phase II—downstream effluents and effluent/receiving water mixtures. In addition, a methodological variability study was conducted just prior to Phase I to provide an estimate of inherent test variability which may be expected due to differences in organism sensitivity and/or handling of test organisms and performance. The methodological variability study consisted of seven replicate *Ceriodaphnia* tests conducted simultaneously using a single sample of the Waterbury POTW effluent. Water from Station N1 collected each day as a grab sample was used as the dilution water for preliminary, Phase I and Phase II, *Ceriodaphnia* tests. Newly released neonates (< 8 hours old) were used to initiate the tests.

For Phase I seven mass balance effluent dilution *Ceriodaphnia* toxicity tests (each with five concentrations and a dilution water control with ten replicates per treatment) and two mass balance ambient toxicity tests (see Appendix A for details of test methodology) were initiated daily for seven consecutive days (Days 1-7; 24-30 August). Twenty-four hour composite samples were collected daily and shipped air freight to the laboratory in Baltimore. A test was initiated with each fresh sample, which was then stored at 4°C for subsequent use in Day 2 and Day 5 solution renewals. Prior to use, all samples were passed through 100 mesh Nitex screen to remove planktonic organisms.

The Phase I mass balance effluent dilution *Ceriodaphnia* toxicity tests were initiated with Torrington and Thomaston POTWs, and five samples tested as effluents (Gulf Stream, Steele Brook, Great Brook, Mad River, and Station N8). Two mass balance ambient toxicity tests were run with daily samples of Stations N9 and N10. These tests corresponded to tests performed onsite (Chapter 4) and were intended to serve as internal calibration between tests conducted between onsite and offsite testing. Split samples for onsite and offsite testing were used during Phase I. Also, N9 was a grab sample on 24 August and N10 was a grab sample on 23 August.

During Phase II (Days 8-14, 31 August to 6 September) five mass balance effluent dilution toxicity tests and two mass balance ambient toxicity tests were initiated daily. Mass balance effluent dilution tests were conducted on the Waterbury POTW, the Naugatuck POTW, and Station N8 using N1 water as the diluent for all tests. In addition, tests were done on the Waterbury POTW mixed with Station N8 water and the Naugatuck POTW mixed with N9 water. Both of these tests were then diluted with N1. The 100 percent solutions of these latter tests were prepared on the proportional POTW/ stream flows measured on the day the sample was collected. The two mass balance ambient toxicity tests with Stations N9 and N10 were repeated during Phase II to continue the calibration during Phase I. The mass balance effluent dilution toxicity tests performed with Station N8 water performed during Phases I and II was done to provide information on whether there was a change in the stream toxicity over the two-week sampling and testing period.

B.2 Toxicity Test Data Analysis

The *Ceriodaphnia* 7-day test, which is primarily intended to assess the chronic toxicity of a test material by detecting differences in cumulative young production over the test period, also yields data on mortality caused by toxicant exposure.

In addition, the Acceptable Effluent Concentrations (AEC) was determined for each test based on the mean young production at each test concentration. Estimates of mean young production per treatment group were calculated using the procedure of Hamilton (1984 as modified by J. Rogers [personal communication, ERL-Duluth]). Details of this procedure are discussed in Appendix A (Section A.4.1). The AEC is determined by taking the geometric mean of the No Observed Effect Concentration (NOEC) with no adverse effect and the Lowest Observed Effect Concentration (LOEC) which has an adverse effect.

Conductivity, pH, hardness, and alkalinity were measured in each sample received. Table F-1 lists the ranges in those parameters for each of the sample points. Table F-2 contains the results of the routing water chemistry measurements taken during the tests. Measurements were taken on the dilution water control, low, medium, and high test concentration replicate at test initiation, each renewal and test termination. All dissolved oxygen (DO) measurements were ≥ 6.5 mg/liter. Some of the water quality measurements on freshly prepared solutions were taken before the beakers had equilibrated to test temperature and prior to the addition of test organisms. This results in some lower (e.g., 18°C) recorded temperatures and wider recorded temperature ranges (e.g., 22.4-28.3°C) than presumably occurred during the tests.

Appendix C
Hydrological Sampling and Analytical Methods

C.1 Flow Measurements

During the study period of 22 August to 4 September 1983, flows were measured at Naugatuck River Stations N1 through N12, as well as tributary Stations SB1, GB1, and M5. Flows were measured daily at Stations N2, N8, and N12. At the remaining stations the flows were measured approximately every other day. These measurements were performed using a Teledyne Gurley "pygmy" flowmeter. A minimum of 10 velocity measurements were made along a transect at each station unless measurements were limited by the narrowness of the cross section, such as at Station GB1. As many as 20 measurements were sometimes performed at the wider stations. The water depth was also recorded with each measurement. At stations with depths of less than 0.75 m, velocities were measured at a depth of 60 percent of the water column. At stations with depths greater than 0.75 m, velocities were measured at depths of 20 and 80 percent of the water column and the mean velocity was used in subsequent calculations. A volume discharge was calculated for each velocity measurement by multiplying the velocity times the cross-sectional area associated with the segment. The total flow through a transect is the summation of the flows through each segment along that transect.

As part of the hydrological analyses at the three dye study sites (Naugatuck POTW, Waterbury POTW, and Steele Brook), a travel time for an "average" water particle was estimated between the discharge and each downstream transect. This was accomplished by calculating an average cross-sectional velocity at each transect by dividing the appropriate Naugatuck River flow by the cross-sectional area of that transect. The resulting velocities were used in conjunction with the transect spacing in order to calculate travel time between each transect.

C.2 Effluent Configuration Dye Study

Dye was injected continuously for approximately 24 hours at each of the three sites to establish an equilibrium between the injection-point dye concentration and the downstream dye distribution. On the second day of each study, water samples were collected at 12 transects extending from 30 m above to approximately 1,400 m below the point of discharge. The transect locations with respect to the three discharges are illustrated in Table C-1. The ratio of the dye concentration at the point of discharge to the dye concentration in the water samples collected at the downstream transects represents the dilution undergone by the effluent. By conducting the studies from the downstream to the upstream site, contamination of dye from one study area to the next was avoided.

Rhodamine WT dye was injected at each site by a Fluid Metering, Inc., precision metering pump. The injection system was placed at a sufficient distance from the river to allow complete mixing of the dye and effluent prior to the point of discharge. The weight of the dye container was periodically recorded to monitor the dye injection rate. The Rhodamine WT dye used in the study will decay in the presence of chlorine. Sodium thiosulfate, $Na_2S_2O_3$, reduced the chlorine to chloride when present in a concentration approximately six times as great as the chlorine level. At the Naugatuck and Waterbury POTWs, a second Fluid Metering, Inc. precision metering pump injected an appropriate solution of $Na_2S_2O_3$. The line from the dye was inserted through the side wall of the larger line from the $Na_2S_2O_3$ such that both solutions were injected at the same point.

A flow-through Turner Designs fluorometer was set up where the discharge from the Naugatuck and Waterbury POTWs enters the Naugatuck River to provide a continuous record of discharge dye concentration. The fluorometer reading was recorded on a Russtrack strip chart recorder. The temperature at the discharge was recorded using a YSI probe and an Esterline Angus strip chart recorder because the fluorometer reading is temperature-dependent. Prior to the field survey, the two fluorometers used had been calibrated over a dye concentration range of 0-200 ppb.

During the instream survey on the second day of dye injection, water samples were collected in 200-ml bottles. A sample was taken and the water depth recorded every 3 m across the transect, except near a discharge or at a narrow transect where a 1.5-m interval was used for greater resolution. A manual sampler was set to take the water samples 0.2 m (8 in.) from the bottom. When the depth was less than 0.25 m, the sample was taken at middepth. If the water depth was greater than 0.5 m, a second sample was taken 0.1 m from the surface. Water samples were processed on the same day of the instream survey using a Turner Designs fluorometer in the discrete sample mode. The fluorometer calibration was checked with field standards each day it was used.

The fluorometer data was converted to dye concentration, C(ppb), using the relationship

$$C(ppb) = SR \exp(0.027)(T-25) \qquad \text{(Equation C-1)}$$

where

S = slope from the calibration regression for the appropriate sensitivity scale of the fluorometer

R = fluorometer reading

T = temperature of the grab sample at the time it was processed

exp(0.027(T-25)) = correction factor for the temperature dependence of fluorescence (25°C is the reference temperature)

In a similar fashion, the fluorometer readings from the discharge strip chart recorder were reduced every 30 minutes for the duration of the study. The background levels (equivalent dye concentration fluorescence) measured upstream of the discharge and in the effluent prior to dye injection were flow-weighted to determine a background level which was subtracted from the instream data.

On the first day of each of the three dye studies, a dye integrity study was performed. Rhodamine WT dye was added to effluent and upstream river water in order to make two 50 ppb dye solutions. The effluent solution for the two POTWs also contained sodium thiosulfate. Each solution was measured in the fluorometer immediately after mixing, periodically for several hours, and one day later. No noticeable decay was observed in any of the samples.

At the Naugatuck POTW, injection of Rhodamine WT dye started at 1330 hours on 22 August and continued until 1430 hours on 23 August. The two precision metering pumps were connected to a 200 gm/kg container of dye and a 400 g/liter solution of $Na_2S_2O_3$, respectively, and the combined line lead through a grate following the chlorine contact chamber. The resulting dye injection rate was calculated to be 3.15 g/min over the duration of the study. The $Na_2S_2O_3$ injection rate of 110 ml/min is equivalent to a 4.7 ppm concentration in a discharge flow of 0.16 m^3/sec, which would protect the dye from a chlorine residual of 0.8 ppm. The fluorometer monitoring the discharge dye concentration was set up at the flume approximately 30 m below the dye injection point.

At the Waterbury POTW, injection of Rhodamine WT dye started at 1350 hours on 24 August and continued to 1530 hours on 25 August. The two precision metering pumps were connected to a 200 g/kg container of dye and a 500 g/liter solution of $Na_2S_2O_3$, respectively. The solution was injected at the flume following the chlorine contact chamber. The resulting dye injection rate was calculated to be 3.08 g/min over the duration of the study. The $Na_2S_2O_3$ injection rate of 260 ml/min is equivalent to a 2.73 ppm concentration in a discharge flow of 0.79 m^3/sec, which would protect the dye from a chlorine residual of 0.46 ppm. The fluorometer monitoring the discharge dye concentration was set up at the point where the discharge pipe empties into the Naugatuck River, approximately 150 m from the point of injection.

At Steele Brook, injection of Rhodamine WT dye started at 1020 hours on 26 August and continued to 1230 hours on 27 August. The precision metering pump was connected to a 200 g/kg container of dye. The dye was injected into Steele Brook at a distance 82 m above its confluence with Naugatuck River. During the dye study, the injection rate appeared to increase uniformly from 2.07 g/min to 2.31 g/min. The average injection rate was 2.21 g/min. A fluorometer was not set up to continuously monitor the discharge dye concentration from Steele Brook due to the lack of 110 v power and the unsecured nature of the site. Instead, the discharge dye concentration was monitored by collecting grab samples along a transect 30 m before the confluence.

Table C-1. **Transect Locations for Dye Studies at Three Sites on the Naugatuck River in August 1983**[a]

Transect	Naugatuck POTW	Waterbury POTW	Steele Brook
T0	-30	-30	-30
T1	0	0	0
T2	15	15	15
T3	30	30	30
T4	76	76	76
T5	152	152	122-194
T6	229	229	229
T7	305	305	306
T8	396	503	457
T9	610	762	701
T10	914	1,067	1,067
T11	1,219	1,433	1,372

[a] Distance downstream from the discharge (meters).

Appendix D
Biological Sampling and Analytical Methods

D.1 Periphyton

Natural substrates (rocks) in the Naugatuck River (13 stations) and selected tributaries (7 stations) (Figure 2-1) were sampled quantitatively using an epilithic algal bar-clamp sampler. Samples were taken from the lower end of riffle areas and runs located at each station. Three replicate samples were taken at each station for chlorophyll *a* and biomass measurements. A volumetrically measured aliquot was removed from these samples and filtered using 0.45-μm filters. These filters were stored with desiccant on wet ice to await laboratory analysis for chlorophyll *a*. The remainder of each sample was stored in 4-oz. glass jars on ice to await laboratory analysis for biomass. One sample consisting of a single bar-clamp collection was taken from each station for cursory (genus level) identification and abundance estimates. These samples were stored in M3 preservative prior to analysis.

Samples were analyzed for ash-free dry weights (AFDW) and chlorophyll *a* concentration. For AFDW, samples were dried at 105°C to a constant weight and ashed at 500°C. Distilled water then was added to replace the water of hydration lost from clay and other minerals. Samples were redried at 105°C before final weighing, and standing crop (biomass) was expressed in grams per square meter (g/m^2). Filters for chlorophyll *a* analysis were macerated in a 90 percent acetone solution, then centrifuged and analyzed spectrophotometrically. A chlorophyll *a* standard (Sigma Chemicals) extracted in a 90 percent acetone solution was used for instrument calibration. Chlorophyll *a* standing crop was expressed as milligrams per square meter (mg/m^2). The biomass and chlorophyll *a* data were used to calculate the Autotrophic Index (Weber 1973), which indicates the relative proportion of heterotrophic and autotrophic (photosynthetic) components in the periphyton. The chlorophyll *a* data were also statistically examined by analysis of variance (Steel and Torrie 1960) and multiple comparison tests to detect significant differences ($P \leq 0.05$) between sampling locations.

For identification and enumeration, each periphyton sample was mixed for 30 seconds in a blender to disrupt algal clumps, and then the sample volume was increased to 100 or 250 ml. Ten percent of each thoroughly mixed sample was removed to prepare Hyrax slides, which were examined at 1,250X magnification to confirm the identity of diatoms encountered during the quantitative analyses. A 0.1-ml, 0.2-ml, or 0.5-ml aliquot from each quantitative sample was placed in a settling chamber designed for use on an inverted microscope. The chamber was then filled with deionized water, and periphytic forms were allowed to settle to the bottom of the chamber for 24 hours. Samples were examined at 1,000X magnification with an inverted microscope, and algae were identified to genus. For each sample, two or four diameters of the counting chamber were examined, and algae containing protoplasm were enumerated as units. These units were cells except for genera of filamentous blue-green algae and the large green algae *Cladophora* and *Oedogonium*, which were counted in 10-μm units of length. The actual number of units identified and counted in each sample ranged from 191 to 1,473 but was greater than 300 in all except two samples. Periphyton abundance was expressed as number of units per square millimeter ($units/mm^2$), and taxa diversity and equitability were calculated from raw counts by U.S. EPA Methods (EPA 1973).

D.2 Zooplankton

Zooplankton samples were collected by filtering 15-150 gallons of water through an 8-μm mesh Wisconsin plankton net at each of 13 Naugatuck River stations and 7 tributary stations. Sample concentrates were preserved in 10 percent formalin and returned to the laboratory for analysis. Three replicate samples were collected from each station. However, due to an accident during shipment, several samples were destroyed. Only one sample from each sample was analyzed in the laboratory. Water quality measurements consisting of depth, temperature, dissolved oxygen, conductivity, and pH were taken at every station using a Hydrolab water quality instrument.

Samples were enumerated by species or the lowest practical taxon with the aid of a Bausch and Lomb 10-70X dissecting microscope. Whole samples were analyzed at each station due to the low densities encountered except for those collected at Stations N5 and N12. A 10-ml subsample of a 400-ml sample concentrate was analyzed at Station N5, while a stratified count of Station N12 was utilized, whereby the first 10-ml aliquot of a 100-ml sample concentrate was scanned for all organisms and four subsequent 10-ml aliquots were scanned for the more uncommon organisms. Representatives of each species were permanently mounted on microscope slides in CMC-10 and identified at 200- or 500X with the aid of a Zeiss compound microscope and phase-contrast illumination. Zooplankton densities (No./m^3) were extrapolated from the subsample volume, sample concentrate volume, and the volume of water sampled. The volume of water sampled was estimated from flow velocity and sample time measurements. Diversity was measured using the machine calculation of the Shannon-Weaver function (EPA 1973).

D.3 Benthic Macroinvertebrates

Benthic samples were collected from nine stations with a Hess stream sampler (881 cm^2). Three replicate samples were collected from the riffle habitat at each station. The mesh size on the Hess sampler is 500 μm, thereby retaining those benthic organisms classified as macroinvertebrates. Samples were preserved in 10 percent buffered formalin and returned to the laboratory for analysis.

Water quality measurements consisting of temperature, dissolved oxygen, pH, and conductivity were taken at every station. The water quality for the biological field efforts are discussed in Section 4.1.

Qualitative samples were collected using a D-frame kick net. Habitats other than riffle areas were sampled in a standard unit of effort which consisted of two sweeps of the net for a distance which equaled length of the net pole. The habitats sampled were generally shorezone vegetated and non-vegetated areas, pools, submerged aquatic plants, and detritus packs. The samples were processed on-site by using white enamel pans and hand-picking techniques. The organisms were preserved in 10 percent formalin to await laboratory processing.

Some benthic samples contained large amounts of detritus and organisms and were subsampled to expedite organism sorting and identification. Subsampling was done using EA's penumatic rotational sample splitter (patent pending). Samples were sorted with the aid of a Wild M-5 dissecting microscope. Organisms were sorted into major taxonomic categories and preserved in 70 percent alcohol for later identification; organisms were identified to the lowest practical taxon using appropriate keys and references. Oligochaetes and chironomid larvae were mounted on microslides prior to identification.

D.4 Fish

Fish collections were made in premeasured sections at each of the 13 Naugatuck River stations and 7 tributary biological sampling stations. All but one fish sampling station were 91.4 m long and most of these were one-half riffle and one-half pool habitat (Table D-1). Stations M1 and N4 primarily contained pool habitat.

Table D-1. **Dimensions (m) of Pool and Riffle Habitat at Each Sampling Station**

Station	Pool Length	Riffle Length	Mean Width Entire Section
BP1	45.7	45.7	3.6
BP2	45.7	45.7	6.4
GS1	0	91.4	4.6[a]
SB1	54.9	36.6	5.2
M1	73.2	18.3	10.4
M2	45.7	45.7	6.4
M5	45.7	45.7	13.4
N1	45.7	45.7	8.2
N2	45.7	45.7	19.5
N3	45.7	45.7	14.9
N4	75.3	16.2	18.6
N4A	45.7	36.6	14.6[b]
N5	45.7	45.7	21.9
N6	61.0	30.5	32.0
N7	45.7	45.7	38.1
N8	45.7	45.7	28.6
N9	45.7	45.7	38.7
N10	45.7	45.7	39.6
N11	45.7	45.7	29.6
N12	45.7	45.7	19.8[b]

[a] Estimated.

[b] Stream bissected by island; only sampled one channel.

Most fish collections were made with a Coffelt VVP-2C electroshocker operated either from a towed pram or from the stream bank. Pulsed direct current was generated through two hand-held positive electrodes. Each section of stream was fished from bank-to-bank in the upstream direction. Captured fishes were held in buckets of stream water until an entire section was completed, and then they were identified and counted. Only those fish of questionable identify and requiring further examination were preserved and returned to the laboratory. Remaining fishes were either released alive or properly disposed of if dead.

D.5 Data Analysis

At tributary Stations BP1, BP2, GS1, and SB1, the habitat was small (average stream width of 5.2 m) and shallow and thus unsuitable for the electrofishing system. These sites were sampled by placing a 1.2 m by 3.4 m, 0.32-cm mesh seine in position and "kicking" the rocks and habitat above the seine to chase fish down into the seine. This was done throughout each 91.4-m section such that all available habitat was sampled.

In conjunction with fish sampling, stream widths were measured at four approximately equidistant points through the section. This was used in the computation of number of fish per 93 m^2.

Community response was examined using both an index of diversity and a community loss index. The Shannon-Wiener diversity index (Shannon and Weaver, 1963) is based on information theory, and incorporates both the number of taxa present (richness) and the distribution of individuals among taxa (evenness). Diversity and associated parameters of evenness and redundancy were calculated. The community loss index (Courtemarch 1982) which is based on the presence or absence of species emphasizes taxonomic differences between the reference station and the station of comparison. In this index, rarer species are given equal weight to the more abundant taxa. Therefore, an effect is measured as the elimination or replacement of entire species populations. The formula used to calculate community loss is:

$$I = \frac{A-C}{B} \qquad \text{(Equation D-1)}$$

where

A = number of species found at reference station
B = number of species found at station of comparison
C = number of species common to both stations

Appendix E
Onsite Toxicological Data

Table E-1. Routine Chemistry Data for Effluent Dilution Toxicty Tests, Naugatuck River, Waterbury, Connecticut

Sample	Percent Effluent (v/v)	pH Range	Initial DO (mg/L) $\bar{x}$	Initial DO (mg/L) Range	Final DO (mg/L) $\bar{x}$	Final DO (mg/L) Range	Conductivity
Torrington POTW	100	6.9-7.3	7.9	6.9-9.2	7.0	6.5-7.8	433
	30	7.2-7.3	8.3	8.1-8.5	6.3	4.3-7.7	192
	10	7.3-7.5	8.4	8.2-8.5	6.5	4.3-7.7	123
	3	7.4-7.5	8.4	8.2-8.5	6.2	2.7-7.6	100
	1	7.5	8.3	8.1-8.5	6.1	3.7-7.4	90
Waterbury POTW	100	7.0-7.2	7.7	7.0-8.4	6.2	3.9-7.3	518
	30	7.0-7.3	8.2	7.8-8.6	5.8	2.0-7.3	252
	10	7.1-7.4	8.3	8.1-8.6	6.1	1.9-7.7	128
	3	7.2-7.5	8.3	8.1-8.6	6.0	2.2-7.4	95
	1	7.2-7.6	8.2	8.1-8.6	6.0	3.8-7.2	80
	Dilution Water[a]	7.2-7.7	8.2	7.9-8.5	6.4	5.6-7.1	90
Naugatuck POTW	100	7.0-7.1	7.0	6.6-7.4	6.7	6.4-7.0	1,150
	30	7.3	8.2	7.9-8.5	6.8	6.6-7.0	375
	10	7.3-7.4	8.4	8.2-8.5	7.0	6.6-7.5	190
	3	7.4-7.5	8.4	8.2-8.6	6.9	6.4-7.3	120
	1	7.4-7.6	8.3	8.1-8.5	6.9	6.1-7.6	100
Steele Brook	100	7.0-7.2	8.3	8.1-8.4	6.2	2.3-7.8	382
	30	7.2-7.3	8.4	8.1-8.7	5.2	1.5-7.5	160
	10	7.3-7.5	8.4	8.0-8.8	6.2	1.5-7.8	122
	3	7.4-7.5	8.4	8.1-8.7	5.8	1.6-7.4	100
	1	7.4-7.6	8.4	8.1-8.9	6.2	4.2-7.2	93
	Dilution Water[a]	7.5-7.6	8.4	8.1-8.8	6.9	6.2-7.5	88
Mad River	100	7.1-7.3	8.3	7.6-8.8	6.6	5.4-7.4	253
	30	7.2-7.4	8.5	8.0-8.8	6.2	4.7-7.1	140
	10	7.3-7.4	8.6	8.2-8.9	6.4	4.8-7.2	107
	3	7.4-7.5	8.6	8.3-8.9	6.2	4.8-6.9	95
	1	7.4-7.7	8.8	8.2-9.8	6.5	5.2-7.1	88
	Dilution Water[a]	7.1-7.7	8.4	6.8-9.9	6.0	4.4-6.8	88

[a] N1 water was used as dilution water for each POTW effluent dilution test

Table E-2. **Routine Chemistry Data for Ambient Station Toxicity Tests, Naugatuck River, Waterbury, Connecticut**

Stations	pH Range	Initial DO (mg/L) $\bar{x}$	Initial DO (mg/L) Range	Final DO (mg/L) $\bar{x}$	Final DO (mg/L) Range	Conductivity (μmhos/cm^{2})
N2	7.5-7.8	8.3	7.7-8.8	7.0	5.7-8.2	153
N3	7.2-7.6	8.1	7.9-8.3	--	--	255
N4	7.0-7.5	8.1	7.5-8.7	6.8	4.9-7.8	285
N4A	7.4-7.6	8.3	8.0-8.7	--	--	258
N5	7.3-7.9	8.6	8.3-9.0	--	--	380
N6	7.1-7.5	8.3	7.6-9.5	5.6	2.8-7.4	308
N7	7.1-7.5	8.1	7.5-9.2	5.6	2.9-7.2	373
N8	7.1-7.4	8.6	7.7-9.0	6.3	3.1-7.6	434
N9	7.1-7.4	8.2	7.4-8.7	5.2	1.4-6.7	386
N10	7.3-7.6	8.4	7.8-9.8	6.6	6.1-7.1	484
N11	7.4-8.2	8.8	8.4-9.2	5.0	1.4-7.5	433
N12	7.1-7.5	8.0	7.6-8.4	6.7	5.7-7.8	440

Table E-3. **Hardness, Alkalinity, and Turbidity Measurements for the Ambient Stations, the Two Tributary Samples and the Three POTWs Tested, Naugatuck River, Waterbury, Connecticut**

Sample	Hardness (mg/L)	Alkalinity (mg/L)	Turbidity (NTU)
N1	38	38	0.85
N2	50	42	1.4
N3	59	47	1.7
N4	62	61	2.3
N4A	56	43	2.6
N5	73	38	2.0
N6	74	42	3.0
N7	84	45	4.0
N8	88	35	4.7
N9	83	70	3.4
N10	99	66	3.5
N11	99	55	2.7
N12	94	48	2.3
Steele Brook	133	61	5.7
Mad River	114	46	6.4
Torrington POTW	82	96	3.7
Waterbury POTW	115	151	5.5
Naugatuck POTW	392	145	5.9

Table E-4. **Final Dissolved Oxygen Measurements for *Ceriodaphnia* Impact Station Toxicity Tests, Naugatuck River, Waterbury, Connecticut**

Stream Station	Mean Final DO (mg/L)	Range
N1A	7.5	7.2-7.9
N1B	7.7	7.4-7.9
N1C	7.7	7.4-7.9
N4	7.5	7.3-7.9
N4A	7.7	7.4-7.9
N10	7.8	7.5-8.0
N11	7.7	7.5-7.9
N12	7.8	7.7-7.9

Table E-5. **Final Dissolved Oxygen Measurements for *Ceriodaphnia* Mass Balance Test, Run with Ambient Samples Collected from the Naugatuck River, Waterbury, Connecticut**

Station Number	Sample Collection Day	Final DO (mg/L) Range
N2	8/23	7.0-8.3
	8/24	7.0-7.2
	8/25	7.0
	8/26	7.0
	8/27	6.9-7.0
	8/28	7.2
	8/29	6.9-7.2
N3	8/23	7.1-7.3
	8/24	6.5-7.2
	8/25	7.4
	8/26	6.9-7.8
	8/27	6.9-7.0
	8/28	6.8-7.0
	8/29	7.0-7.4
N4	8/23	6.7-6.9
	8/24	6.8-7.1
	8/25	7.2-7.3
	8/26	6.9-7.3
	8/27	6.8-7.2
	8/28	7.0-7.2
	8/29	7.2-7.4
N5	8/23	6.4-7.2
	8/24	7.1-7.7
	8/25	7.2-7.3
	8/26	7.1-7.4
	8/27	7.3
	8/28	6.8-7.0
	8/29	7.5
N6	8/23	6.2-7.5
	8/24	7.0-7.4
	8/25	7.3-7.6
	8/26	7.0
	8/27	7.0
	8/28	7.2
	8/29	7.0
N7	8/23	6.7-7.0
	8/24	6.7-7.7
	8/25	7.0-7.2

Table E-5 (Continued)

	8/26	7.0-7.4
	8/27	7.0
	8/28	6.9-7.1
	8/29	7.1-7.4
N8	8/23	6.9
	8/24	7.3
	8/25	7.5
	8/26	7.4
	8/27	7.3
	8/28	6.9-7.2
	8/29	7.1-7.4
N9	8/23	6.2-6.6
	8/24	6.5
	8/25	7.2-7.9
	8/26	7.0-7.3
	8/27	7.4-7.3
	8/28	6.9
	8/29	7.3
N10	8/23	6.6-6.8
	8/24	7.4
	8/25	7.4
	8/26	7.0-7.3
	8/27	7.2
	8/28	6.9-7.3
	8/29	7.3-7.4

Appendix F
Offsite Toxicological Data

Table F-1. **Ranges in Water Quality Parameters for Ambient Stations, Tributaries and Effluent Samples, Naugatuck River**

Sample or Effluent	Conductivity (μmhos/cm^2)	pH	Alkalinity (mg/L as $CaCO_3$)	Hardness (mg/L as $CaCO_3$)
Phase I				
Gulf Stream	89-310	6.70-7.96	22-43	21-69
Torrington POTW	70-1,600	6.75-7.67	26-172	25-311
Thomaston POTW	70-3,300	6.68-7.88	32-204	25-1,419
Steele Brook	85-480	6.78-7.78	21-63	26-146
Great Brook	75-205	6.45-7.66	12-49	24-78
Mad River	40-355	6.80-8.16	25-49	24-123
Station N8	85-450	6.70-7.57	22-46	24-103
Station N9	60-480	6.95-7.92	38-76	28-119
Station N10	40-550	7.15-7.70	44-73	69-106
Phase II				
Station N8	300-500	6.21-8.30	31-47	69-97
Waterbury POTW	400-800	7.01-8.41	125-172	66-111
Naugatuck POTW	700-2,060	6.81-8.16	74-92	220-337
Naugatuck POTW and N9 mixture	300-700	7.01-7.93	53-65	87-173
Waterbury POTW and and N8 mixture	390-590	7.08-7.95	53-77	83-100
Station N9	190-480	7.03-8.03	47-65	67-100
Station N10	230-600	7.27-9.04	47-62	73-110

Table F-2. Measured Water Quality Parameters During Offsite *Ceriodaphnia* Toxicity Tests

		Dissolved Oxygen (mg/L)		pH		Temperature (C)	
Sample or Effluent	Test Dates	Mean	Range	Mean	Range	Mean	Range
Phase I							
Waterbury POTW	24 Aug-31 Aug	7.6	7.0-8.4	7.7	7.3-8.2	24.3	23.0-25.7
	25 Aug-1 Sept	7.5	6.8-8.4	7.7	7.6-7.9	23.9	22.5-24.9
	26 Aug-2 Sept	7.6	6.9-8.6	7.8	7.5-8.0	23.8	24.5-22.4
	27 Aug-3 Sept	7.7	6.9-8.6	7.9	7.5-8.1	23.9	22.2-24.9
	28 Aug-4 Sept	7.7	7.1-8.8	7.8	7.5-8.1	23.8	22.1-25.0
	29 Aug-5 Sept	7.7	7.0-8.8	7.9	7.6-8.1	23.8	22.1-24.7
	30 Aug-6 Sept	7.8	7.2-8.8	7.9	7.6-8.1	23.7	19.8-24.7
Gulf Stream	24 Aug-31 Aug	7.9	7.3-8.6	7.5	6.8-8.2	24.2	23.6-25.0
	25 Aug-1 Sept	7.6	7.2-8.2	7.4	7.2-7.7	24.2	23.4-25.4
	26 Aug-2 Sept	7.5	6.6-8.3	7.4	7.2-7.5	24.5	23.7-25.0
	27 Aug-3 Sept	7.9	7.4-8.2	7.1	6.9-7.3	23.8	22.8-24.8
	28 Aug-4 Sept	7.9	6.9-8.8	7.2	7.0-7.4	24.9	23.0-27.6
	29 Aug-5 Sept	7.9	7.5-8.2	7.3	7.1-7.4	23.9	22.6-25.0
	30 Aug-6 Sept	7.9	7.6-8.1	7.3	6.8-7.6	23.4	20.0-24.4
Torrington POTW	24 Aug-31 Aug	7.6	6.6-8.3	7.4	6.8-7.8	23.9	22.9-24.7
	25 Aug-1 Sept	7.6	7.1-8.1	7.5	7.4-7.8	23.8	23.0-25.1
	26 Aug-2 Sept	7.5	6.9-8.1	7.6	7.4-7.8	24.3	23.4-24.7
	27 Aug-3 Sept	7.9	7.7-8.1	7.2	6.9-7.6	23.7	23.0-24.5
	28 Aug-4 Sept	7.9	6.9-8.9	7.3	7.0-7.7	24.5	22.3-27.7
	29 Aug-5 Sept	7.6	6.6-8.5	7.6	7.4-7.8	23.7	22.8-25.1
	30 Aug-6 Sept	7.9	7.6-8.5	7.2	6.8-7.5	22.6	19.5-24.3
Thomaston POTW	24 Aug-31 Aug	8.0	7.3-8.6	7.4	6.8-7.8	23.9	22.6-24.9
	25 Aug-1 Sept	7.7	7.0-8.1	7.7	7.4-8.1	23.7	23.0-25.0
	26 Aug- 2 Sept	7.7	6.8-8.3	7.6	7.3-8.0	24.1	23.5-24.6
	27 Aug-3 Sept	7.9	7.6-8.3	7.3	7.0-7.9	23.7	22.6-24.5
	28 Aug-4 Sept	7.5	6.5-8.7	7.3	7.2-7.8	25.1	22.4-28.3
	29 Aug-5 Sept	7.7	7.1-8.4	7.7	7.5-7.9	23.7	22.8-25.1
	30 Aug-6 Sept	7.9	7.6-8.4	7.4	6.9-7.8	22.8	20.0-24.3
Steele Brook	24 Aug-31 Aug	7.7	6.6-8.3	7.6	7.0-8.1	23.6	22.2-24.7
	25 Aug-1 Sept	7.7	7.3-8.0	7.9	7.4-8.3	23.7	22.7-24.9
	26 Aug-2 Sept	7.6	7.0-8.3	7.5	7.3-7.7	24.1	23.4-24.5
	27 Aug-3 Sept	8.0	7.2-8.8	7.4	6.9-7.7	23.5	22.2-24.6
	28 Aug-4 Sept	7.6	6.6-8.9	7.4	7.1-8.0	25.1	22.4-28.1
	29 Aug-5 Sept	7.5	7.1-8.2	7.9	7.5-8.2	24.0	22.8-25.7
	30 Aug-6 Sept	7.9	7.7-8.5	7.4	6.9-7.8	22.9	18.0-24.3
Great Brook	24 Aug-31 Aug	7.9	7.2-8.5	7.5	7.0-7.8	23.5	22.0-25.0
	25 Aug-1 Sept	7.8	7.4-8.1	7.8	7.4-8.0	23.8	22.8-25.0
	26 Aug-2 Sept	7.6	7.1-8.2	7.5	6.8-7.8	24.2	23.5-24.5
	27 Aug-3 Sept	8.0	7.3-8.8	7.5	7.0-7.7	23.6	22.2-24.4
	28 Aug-4 Sept	7.7	6.9-8.9	7.3	6.9-7.5	24.8	22.4-27.7
	29 Aug-5 Sept	7.7	7.3-8.2	7.8	7.5-7.9	24.1	22.8-25.8
	30 Aug-6 Sept	7.9	7.6-8.4	7.3	6.9-7.7	23.1	20.0-24.3
Mad River	24 Aug-31 Aug	7.9	7.4-8.1	7.5	6.9-7.8	23.9	23.0-25.0
	25 Aug-1 Sept	7.8	7.4-8.1	7.6	7.3-7.9	23.7	22.6-24.8
	26 Aug-2 Sept	7.6	7.2-8.0	7.4	7.3-7.7	23.8	23.4-24.2
	27 Aug-3 Sept	8.1	7.6-8.8	7.4	6.9-7.7	23.4	22.2-24.4
	28 Aug-4 Sept	7.8	6.8-8.8	7.2	6.9-7.4	24.8	22.3-28.0
	29 Aug-5 Sept	7.8	7.5-8.3	7.6	7.5-7.9	24.1	22.5-25.7
	30 Aug-6 Sept	8.0	7.6-8.5	7.3	6.8-7.6	22.8	20.0-24.4
Station N8	24 Aug-31 Aug	7.9	7.5-8.3	7.7	6.9-8.3	23.7	22.5-24.7
	25 Aug-1 Sept	7.9	7.6-8.1	7.6	7.3-7.9	23.7	22.6-24.8
	26 Aug-2 Sept	7.8	7.5-8.2	7.6	7.1-7.8	23.9	23.3-24.5
	27 Aug-3 Sept	7.9	7.5-8.2	7.4	7.0-7.7	23.7	23.5-24.0
	28 Aug-4 Sept	7.9	7.1-8.9	7.2	7.0-7.4	24.4	22.1-27.2
	29 Aug-5 Sept	7.7	7.3-8.3	7.7	7.4-7.9	23.9	22.7-24.8
	30 Aug-6 Sept	7.9	7.6-8.3	7.2	6.6-7.6	23.0	20.1-24.4
Station N9	24 Aug-31 Aug	8.0	7.4-8.7	7.5	7.0-7.7	23.7	22.3-24.9
	25 Aug-1 Sept	8.0	7.6-8.2	7.6	7.3-7.8	23.4	22.4-24.2
	26 Aug-2 Sept	7.9	7.7-8.2	7.6	7.5-7.7	23.9	23.4-24.2
	27 Aug-3 Sept	7.8	7.4-8.0	7.4	7.0-7.6	23.4	22.8-23.9
	28 Aug-4 Sept	7.9	7.0-8.7	7.4	7.2-7.6	24.5	22.9-27.1
	29 Aug-5 Sept	7.7	7.4-8.3	7.7	7.5-7.9	23.6	22.8-24.4
	30 Aug-6 Sept	7.9	7.6-8.4	7.1	6.7-7.4	23.4	22.2-24.4

Table F-2. (Continued)

Station N10	24 Aug-31 Aug	7.9	7.5-8.2	7.5	7.0-7.9	23.7	22.6-24.6
	25 Aug-1 Sept	7.6	7.5-7.6	7.7	7.6-7.7	23.4	22.5-24.3
	26 Aug-2 Sept	7.7	7.7-7.8	7.6	7.5-7.6	24.0	23.8-24.2
	27 Aug-3 Sept	7.9	7.6-8.1	7.5	7.1-7.7	23.4	22.7-23.8
	28 Aug-4 Sept	7.9	7.0-8.8	7.5	7.4-7.5	24.6	23.0-27.3
	29 Aug-5 Sept	7.7	7.3-8.3	7.8	7.6-8.0	23.7	22.8-24.6
	30 Aug-6 Sept	7.9	7.4-8.4	7.2	6.9-7.5	23.3	22.2-24.3
Phase II							
Station N8	31 Aug-7 Sept	7.8	7.5-8.0	7.8	7.2-8.9	23.6	22.4-24.3
	1 Sept-8 Sept	8.0	7.7-8.5	7.5	7.1-7.8	23.6	22.6-24.2
	2 Sept-9 Sept	7.9	7.1-8.3	7.5	6.9-8.1	23.9	23.3-26.0
	3 Sept-10 Sept	8.0	7.8-8.6	7.3	6.8-8.0	23.2	22.6-23.6
	4 Sept-11 Sept	7.8	7.5-8.2	7.4	7.2-7.8	24.3	23.0-25.2
	5 Sept-12 Sept	8.1	7.6-8.6	7.6	7.1-7.8	23.0	20.9-24.2
	6 Sept-13 Sept	7.7	7.2-8.2	7.4	7.2-7.5	24.4	23.5-25.9
Waterbury POTW	31 Aug-7 Sept	7.7	7.4-8.0	7.5	6.9-8.1	23.4	22.4-24.0
	1 Sept-8 Sept	8.0	7.6-8.3	7.7	7.5-7.9	23.3	22.8-23.8
	2 Sept-9 Sept	7.9	7.4-8.3	7.6	7.1-8.1	24.1	23.5-26.0
	3 Sept-10 Sept	7.9	7.2-8.6	7.4	7.0-7.7	23.0	22.7-23.4
	4 Sept-11 Sept	7.7	7.0-8.3	7.7	7.4-8.1	24.2	22.6-25.7
	5 Sept-12 Sept	8.1	7.3-8.6	7.6	7.3-7.9	22.9	21.1-24.2
	6 Sept-13 Sept	7.8	7.4-8.2	7.5	7.0-7.7	24.2	23.2-25.9
Naugatuck POTW	24 Aug-31 Aug	7.7	7.4-8.0	7.5	6.8-7.9	23.5	22.4-24.0
	25 Aug-1 Sept	7.9	7.7-8.3	7.7	7.5-7.8	23.3	22.8-23.8
	26 Aug-2 Sept	7.9	7.4-8.2	7.6	7.2-8.1	24.3	23.2-26.0
	27 Aug-3 Sept	8.0	7.5-8.7	7.5	7.1-8.0	23.0	22.5-23.4
	28 Aug-4 Sept	7.4	7.4-8.7	7.7	7.5-8.0	23.8	22.5-25.2
	29 Aug-5 Sept	8.0	7.7-8.5	7.7	7.4-7.9	23.0	22.3-24.0
	30 Aug-6 Sept	7.8	7.4-8.4	7.6	7.1-7.9	24.4	23.0-26.0
Naugatuck POTW and N9 Mixture	24 Aug-31 Aug	7.7	7.4-7.9	7.5	6.9-8.1	23.3	22.8-23.7
	25 Aug-1 Sept	7.9	7.7-8.4	7.7	7.6-7.9	23.3	23.0-23.7
	26 Aug-2 Sept	7.9	7.6-8.2	7.8	7.4-8.3	25.0	23.5-29.0
	27 Aug-3 Sept	7.9	7.5-8.7	7.6	7.1-8.1	23.1	22.6-23.5
	28 Aug-4 Sept	7.9	7.2-8.3	7.7	7.6-8.0	23.8	22.3-25.7
	29 Aug-5 Sept	8.0	7.6-8.6	7.7	7.4-7.9	22.7	20.8-24.0
	30 Aug-6 Sept	7.8	7.4-8.3	7.6	7.1-7.9	24.5	27.1-26.1
Waterbury POTW and and N8 Mixture	24 Aug-31 Aug	7.7	7.4-7.9	7.5	7.0-8.1	23.6	23.3-24.0
	25 Aug-1 Sept	8.0	7.7-8.4	7.7	7.5-7.9	23.2	22.6-23.6
	26 Aug-2 Sept	7.9	7.5-8.2	7.8	7.6-8.3	24.7	23.4-28.0
	27 Aug-3 Sept	7.9	7.4-8.9	7.5	7.1-8.0	23.1	22.8-23.2
	28 Aug-4 Sept	7.7	7.4-8.2	7.8	7.6-8.1	24.3	22.9-25.8
	29 Aug-5 Sept	8.0	7.7-8.5	7.6	7.6-7.9	22.7	20.9-24.0
	30 Aug-6 Sept	7.8	7.5-8.4	7.6	7.1-7.9	24.6	23.2-26.4
Station N9	24 Aug-31 Aug	7.6	7.5-7.9	7.6	7.1-8.0	23.6	23.4-24.0
	25 Aug-1 Sept	7.8	7.7-8.0	7.7	7.6-7.8	23.4	23.1-23.8
	26 Aug-2 Sept	7.8	7.6-8.0	7.9	7.7-8.1	23.2	22.0-23.9
	27 Aug-3 Sept	7.9	7.4-8.5	7.7	7.5-8.1	23.4	23.3-23.5
	28 Aug-4 Sept	7.6	6.9-8.3	7.8	7.6-8.0	24.1	22.8-25.5
	29 Aug-5 Sept	7.9	7.5-8.5	7.8	7.7-7.9	22.9	21.2-23.8
	30 Aug-6 Sept	7.7	7.3-8.1	7.6	7.2-7.9	24.6	23.4-26.3
Station N10	24 Aug-31 Aug	7.7	7.6-7.9	7.7	7.3-8.1	23.5	22.8-24.0
	25 Aug-1 Sept	7.9	7.7-8.3	7.9	7.8-7.9	23.3	23.1-23.1
	26 Aug-2 Sept	7.8	7.6-8.0	8.5	8.4-8.7	23.8	23.4-24.0
	27 Aug-3 Sept	7.8	7.3-8.6	7.2	7.3-8.2	23.5	23.4-23.6
	28 Aug-4 Sept	7.7	7.3-8.4	8.4	8.2-8.6	24.1	22.7-25.7
	29 Aug-5 Sept	7.9	7.7-8.4	8.4	8.2-8.6	22.7	21.1-23.5
	30 Aug-6 Sept	7.6	7.3-8.0	7.7	7.3-7.9	24.7	23.5-26.4

Table F-3. Results of Preliminary Methodological Variability Tests With *Ceriodaphnia* and Waterbury POTW Effluent Dilution Tests

Sample or Effluent	Test Dates	Test Concentration Percent (v/v)	Mean Number of Young per Female	95% Confidence Interval	Percent Survival
Waterbury POTW	22-29 Aug	Dilution water	13.1	10.0-16.2	90
		1	13.8	11.3-16.3	90
Test 1		3	13.2	9.0-17.4	90
		10	11.0	7.5-14.5	40
		30	3.7[a]	0-11.2	20[a]
		100	--[a]	--	0[a]
Test 2	22-29 Aug	Dilution water	11.6	9.5-13.8	80
		1	13.2	10.5-15.9	90
		3	14.1	11.5-16.7	80
		10	11.5	8.7-14.3	70
		30	1.3[a]	0-2.6	10[a]
		100	--[a]	--	0[a]
Test 3	22-29 Aug	Dilution water	12.8	11.5-14.2	80
		1	14.2	12.0-16.4	100
		3	13.2	11.9-14.5	70
		10	11.7	9.6-13.8	40
		30	--[a]	--	0[a]
		100	--	--	0[a]
Test 4	22-29 Aug	Dilution water	11.6	9.9-13.3	100
		1	13.1	11.5-14.8	90
		3	15.2[a]	13.6-16.8	90
		10	12.9	11.0-14.9	30
		30	--[a]	--	0[a]
		100	--	--	0[a]
Test 5	22-29 Aug	Dilution water	13.4	12.0-14.8	100
		1	12.6	11.9-13.3	100
		3	11.8	10.6-13.0	100
		10	12.0	10.4-13.6	30
		30	--[a]	--	0[a]
		100	--[a]	--	0[a]
Test 6	22-29 Aug	Dilution water	12.5	10.1-14.9	80
		1	11.7	9.9-13.6	90
		3	12.2	9.3-15.1	80
		10	11.2	9.7-12.6	20
		30	--[a]	--	0[a]
		100	--[a]	--	0[a]
Test 7	22-29 Aug	Dilution water	12.4	10.4-14.4	90
		1	11.5	9.9-13.1	80
		3	14.0	12.4-15.6	100
		10	12.5	11.2-13.8	70
		30	--[a]	--	10[a]
		100	--[a]	--	0[a]

[a] Significantly different from dilution water ($P \le 0.05$)

Table F-4. Summary of Preliminary Methodological Variability Tests

Effluent	Phase	Test No	Test Dates	AEC[2] Percent Effluent
Waterbury POTW	Preliminary[1]	1	22-29 Aug	17.3
		2	22-29 Aug	17.3
		3	22-29 Aug	17.3
		4	22-29 Aug	17.3
		5	22-29 Aug	17.3
		6	22-29 Aug	17.3
		7	22-29 Aug	17.3

[1] Preliminary testing just prior to start of offsite tests

[2] AEC (Acceptable Effluent Concentration) is the geometric mean of the No Observed Effect Concentration (NOEC) and the Lowest Observed Effect Concentration (LOEC).

Appendix G
Biological Data

Table G-1. Abundance (units/mm^2) and Diversity of Periphytic Algae on Natural Substrates in the Naugatuck River, August 1983

Taxa	N1	N2	N3	N4	N4A	N5	N6	N7	N8	N9	N10	N11	N12
BACILLARIOPHYTA (Diatoms)													
Achnanthes	3.219	794	3,135	4,807	794	502	314	418	732	836	42	376	209
Amphipleura	42	0	0	0	0	0	0	0	0	0	0	0	0
Cocconeis	84	0	0	0	0	0	0	0	0	0	0	0	0
Cyclotella	42	0	0	0	84	84	104	0	0	0	0	0	0
Cymbella	460	84	209	0	42	0	0	0	104	0	0	0	0
Denticula	0	0	209	0	0	167	0	0	0	0	0	0	0
Fragilaria	84	543	7,315	2.299	1,588	1,338	104	522	0	0	0	0	209
Comphonema	209	84	0	418	84	125	104	0	0	209	0	0	0
Melosira	84	543	627	2,299	836	1,547	0	0	0	0	0	0	0
Navicula	2,257	1,714	5,643	5,016	711	669	209	836	209	1,672	376	2,633	0
Nitzschia	585	3,010	11,077	10,659	1,505	1,170	2.194	8,360	7,210	6,061	1 463	1,756	2,926
Pinnularia	0	0	0	0	0	0	104	732	0	104	0	42	0
Rhoicosphenia	0	0	0	418	0	0	0	0	0	0	0	0	0
Surirella	0	0	0	0	42	42	0	104	0	0	0	0	0
Synedra	42	125	209	0	209	0	0	0	0	0	0	0	0
Unidentified pennates	0	0	0	0	0	0	0	0	0	0	84	0	0
Total Bacillariophyta	7.108	6.897	28,424	25,916	5,895	5,644	3.133	10,972	8,255	8.882	1.965	4,807	3,344
CHLOROPHYTA (Green Algae)													
Ankistrodesmus	42	460	209	1,881	42	42	0	0	104	104	84	0	209
Chlamydomonas	0	0	0	0	0	167	104	0	0	209	0	0	0
Cladophora	0	293	2,299	0	0	0	0	0	0	0	0	0	0
Coelastrum	0	0	0	5,016	669	0	0	0	0	0	0	0	0
Cosmarium	84	42	0	0	42	42	104	104	418	0	0	84	209
Dictyosphaerium	836	0	0	0	0	334	0	0	0	0	167	0	0
Hydrodictyon	0	0	0	0	0	0	0	0	0	0	0	0	418
Micractinium	42	0	0	0	0	42	0	0	0	0	0	0	0
Oedogonium	209	418	0	1,672	0	794	0	0	0	0	0	0	0
Oocystis	376	0	0	0	167	167	104	1,045	418	209	251	167	1,672
Pediastrum	502	0	0	3,762	920	3,804	0	836	0	0	0	0	0
Quadrigula	0	0	836	0	334	0	0	0	0	0	0	0	0
Scenedesmus	836	8,067	14,212	5,643	7,775	3,428	5.748	14,839	7,942	5,748	1,797	4,347	6,688
Selenastrum	42	669	1,463	0	42	0	0	0	0	0	0	0	0
Sorastrum	0	0	0	0	0	752	0	0	0	0	0	0	0
Sphaerocystis	0	334	0	0	0	0	0	0	0	0	0	0	0
Staurastrum	42	0	0	0	0	0	0	0	0	0	0	0	0
Stigeoclonium	0	11,788	5,016	2,508	6,855	1,839	10,346	9,614	58,206	42,845	27,254	15.550	11,077
Tetraedron	0	0	0	0	42	125	0	0	0	0	0	42	0
Tetrastrum	0	167	0	0	0	0	0	0	0	0	0	0	0
Unidentified coccoid forms	460	3,302	2,926	8,360	1,338	1,505	39,814	6,479	21,318	8,256	2,132	2,048	23.408
Unidentified naviculoid forms	0	0	0	0	0	0	1,358	0	209	209	0	0	61,655
Total Chlorophyta	3,471	25,540	26,961	28,842	18,226	13,041	57,578	32,917	88,615	57,580	31,685	22,238	105,336
CHRYSOPHYTA (Yellow-green Algae)													
Characiopsis	0	1,547	0	0	0	0	0	0	0	0	0	0	0

Table G-1. (Continued)

CYANOPHYTA (Blue-green Algae)													
Aphanocapsa	836	0	0	0	0	0	0	0	0	0	0	0	0
Chroococcus	1,714	334	0	0	0	167	0	0	0	0	0	669	0
Lyngbya	1,965	1,463	0	1,672	3,010	1,087	0	209	0	836	376	125	0
Merismopedia	334	0	0	0	0	0	0	0	0	0	0	0	0
Oscillatoria	0	794	0	7,106	543	251	0	0	0	418	0	167	0
Phormidium	836	4,138	2,508	627	878	334	627	522	4,076	418	251	418	6,688
Unidentified coccoid forms	0	1,254	0	627	3,177	167	0	0	0	418	0	334	627
Total Cyanophyta	5,685	7,983	2,508	10,032	7,608	2,006	627	731	4,076	2,090	627	1,713	7,315
EUGLENOPHYTA (Euglenoids)													
Euglena	0	0	0	0	42	0	0	0	0	0	0	0	0
Trachelomonas	0	0	0	0	42	0	0	0	0	0	0	0	0
TOTAL PERIPHYTON DENSITY	16,264	41,967	57,893	64,790	31,813	20,691	61,338	44,620	100,946	68,552	34,277	28,758	115,995
Taxa Diversity ($\bar{d}$)	3.78	3.42	3.20	3.72	3.45	3.85	1.70	2.59	1.87	1.95	1.27	2.27	2.11
Taxa Equitability (e)	0.72	0.64	0.82	1.06	0.58	0.77	0.28	0.59	0.40	0.32	0.25	0.43	0.44
Total Taxa Identified	27	24	16	18	27	27	15	14	12	16	12	15	13

Table G-2. Abundance (units/mm²) and Diversity of Periphytic Algae on Natural Substrates in Gulf Stream, Steele Brook, Beaver Pond Brook, and Mad River, August 1983

	Sampling Station						
Taxa	GS1	SB1	BP1	BP2	M1	M2	M5
BACILLARIOPHYTA (Diatoms)							
Achnanthes	585	68,134	15,048	1,463	3,135	4,076	5,643
Anomoeoneis	0	0	209	0	209	0	0
Asterionella	0	418	0	0	0	0	0
Caloneis	42	0	0	0	0	0	0
Cyclotella	0	209	0	0	209	0	0
Cymbella	84	209	627	0	1,672	157	0
Eunotia	0	0	0	0	0	104	0
Fragilaria	42	1,672	418	1,463	4,807	104	418
Frustulia	0	0	0	0	0	52	0
Gomphonema	0	836	17,138	4,180	418	52	418
Melosira	0	0	0	0	1,045	52	209
Navicula	293	20,691	1,254	522	10,659	836	0
Neidium	0	209	0	0	0	0	0
Nitzschia	836	5,225	1,463	1,463	15,257	679	418
Pinnularia	0	418	0	104	0	0	0
Surirella	0	0	0	0	418	0	0
Synedra	0	209	1,881	314	836	157	0
Tabellaria	0	0	418	0	0	0	0
Unidentified pennates	0	0	0	104	0	0	0
Total Bacillariophyta	1,882	98,230	38,456	9,613	38,665	6,269	7,106
CHLOROPHYTA (Green Algae)							
Ankistrodesmus	0	418	209	104	418	52	0
Cosmarium	0	0	0	0	209	0	0
Dictyosphaerium	0	0	0	0	0	418	0
Oedogonium	0	0	2,508	0	0	0	0
Oocystis	293	21,318	0	0	209	0	38,874
Pediastrum	0	0	0	0	0	157	0
Scenedesmus	543	4,389	836	1,568	5,016	627	1,254
Selenastrum	0	0	209	732	0	52	0
Staurastrum	0	0	0	104	0	0	0
Stigeoclonium	3,219	6,897	5,016	0	2,717	0	5,434
Unidentified coccoid forms	11,370	33,649	836	209	418	314	165,318
Unidentified naviculoid forms	334	58,938	0	0	0	0	6,688
Total Chlorophyta	15,759	125,609	9,614	2,717	8,987	1,620	217,568

Table G-2. (Continued)

CYANOPHYTA (Blue-green Algae)							
Lyngbya	418	1,463	19,019	3,971	836	366	0
Oscillatoria	0	0	0	314	13,585	626	0
Phormidium	293	75,031	3,762	3,971	5,852	52	0
Unidentified coccoid forms	167	0	0	0	2,508	1,045	0
Total Cyanophyta	878	76,494	22,781	8,256	22,781	2,090	0
EUGLENOPHYTA (Euglenoids)							
Trachelomonas	0	0	0	0	0	0	209
TOTAL PERIPHYTON DENSITY	18,519	300,333	70,851	20,586	70,433	9,979	224,883
Taxa Diversity ($\bar{d}$)	2.03	3.05	2.88	3.19	3.38	3.12	1.29
Taxa Equitability (e)	0.39	0.61	0.60	0.81	0.71	0.61	0.27
Total Taxa Identified	14	19	17	16	21	20	11

Note: Station GS1 in Gulf Stream, Station SB1 in Steele Brook, Stations BP1 and BP2 in Beaver Pond Brook, and Stations M1, M2, and M5 in Mad River.

Table G-3. Crustacean Zooplankton Species Collected from the Naugatuck River, 25-27 August 1983

Cladocera
- Sididae
  - *Diaphanosoma brachyurum* (Lievan) 1848
- Daphnidae
  - *Ceriodaphnia pulchella* Sars 1862
  - *Ceriodaphnia reticulata* (Jurine) 1820
  - *Daphnia ambigua* Scourfield 1947
  - *Daphnia catawba* Coker 1926
  - *Daphnia parvula* Fordyce 1901
  - *Scapholeberis aurita* (Fischer) 1849
  - *Simocephalus serrulatus* (Koch) 1841
- Bosminidae
  - *Bosmina longirostris* (O. F. Muller) 1785
- Macrothricidae
  - Ilyocryptus spinifer Herrick 1884
- Chydoridae
  - *Acroperus harpae* (Baird) 1834
  - *Alona rustica americana* Flossner and Frey 1970
  - *Chydorus sphaericus sphaericus* (O. F. Muller) 1785
  - *Leydigia leydigi* (Schoedler) 1863
  - *Pleuroxus denticulatus* Birge 1879

Copepoda*
- *Calanoida*
  - Diaptomidae
    - *Diaptomus pygmaeus* Pearse 1906
- *Cyclopoida*
  - Cyclopidae
    - *Cyclops bicuspidatus thomasi* S. A. Forbes 1882
    - *Eucyclops agilis* (Koch) 1838
    - *Mesocyclops edax* (S. A. Forbes) 1891
    - *Paracyclops fimbriatus poppei* (Rehberg) 1880
- *Harpacticoida*

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*Adults only determined to species; copepodids determined to sub-order; nauplii determined to order.

Table G-4. **Taxonomic List of Benthic Macroinvertebrates Collected from a Qualitative Sampling Effort in the Naugatuck River and Tributaries, September 1983**

	Naugatuck River Stations													Tributary Stations						
	1	2	3	4	4A	5	6	7	8	9	10	11	12	GS1	SB1	M1	M2	M5	BP1	BP2
Platyhelminthes									X				X							
Turbellaria								X												
Tricladida																				
Mollusca																				
Gastropoda																				
Limnophila																				
Physidae																				
Physella		X	X	X	X								X							
Planorbidae (*a. anceps*)																				
Helisoma	X		X																	
Annelida																				
Oligochaeta		X	X	X	X		X		X	X										X
Arthropoda																				
Arachnida																				
Acarina													X							
Crustacea																				
Isopoda																				
Asellidae																				
Asellus																			X	
Amphipoda																				
Talitradae																				
Hyalella azteca																			X	
Decapoda																				
Astacidae																				
Occonectes rusticus															X	X			X	
Insecta																	X			
Ephemeroptera																				
Caenidae																				
Caenis N.		X																		
Baetidae		X																	X	
Baetis N.											X	X								X
Calibaetis N			X																	
Centroptilum N.						X														
Heptageniidae																				
Stenonema					X											X				
Anisoptera																				
Aeshnidae																				
Aeshna N.																X				
Boveria N.				X																
Zygoptera																				
Calopt erygidae																				
Calopteryx N.				X													X			
Coenagrionidae																				
Argia N.				X																
Enallagma N.				X	X			X	X											
Ischnura N.	X	X	X										X			X		X	X	
Coleptera																				
Hydrophilidae A.																			X	
Laccophilus A.			X								X		X							
Laccophilus L.		X	X	X									X							
Berosus A.							X					X	X							
Berosus L.											X	X								
Tropisternus A.					X															
Haliplidae																				
Peltodytes A.		X											X							
Peltodytes N.			X																	
Hemiptera																				
Belostomatidae A.					X															
Corixidae A.		X	X										X							
Corixidae N.	X																			
Nepidae A.																				
Ranatra A.			X	X																
Mesoveliidae																				
Mesovelia			X					X												

Table G-4. (Continued)

	Naugatuck River Stations													Tributary Stations						
	1	2	3	4	4A	5	6	7	8	9	10	11	12	GS1	SB1	M1	M2	M5	BP1	BP2
Megaloptera																				
Corydalidae																				
Nigronia														X						
Trichoptera						X														
Hydropsychidae																				
Hydropsyche l.												X								X
Cheumatopsyche l.				X																
Limnephiloidae																				
Phryganeinae																				
Oligostomia l.																			X	
Dipteria																				
Simulidae																				
Simulium l.						X														
Chironomidae p.				X					X	X										
Tanypodinae l.																				
Macropelopiini l.																				
Procladius l.			X				X		X		X							X	X	
Pentaneurini l.																				
Ablabesmyia l.	X																			
Thenemanninnyia grp.											X									
Orthocladiinae l.																				
Cardociadius l.											X									
Orthocladius l.																				
Eukieff discoloripes grp.																				
Chironomini l.																				
Chronomus l.		X			X		X				X						X			
Polypedilum l.		X			X					X	X						X			
Poly. illenoense l.				X				X												
Poly. tripodura l.																	X			
Poly. trip. scol.													X							
Poly. trip. grp.										X	X									
Xenochironomus l.																				
Phaenospectral		X																		
Tanytarsini																				
Cladotanytarsus l.					X															
Orthocladini																				
Cricotopus								X			X		X							
Cricotopus bicinctus				X							X		X							
Culicidae P.					X															
Culicidae L.																				
Anopheles l.					X															
No. of Taxa	4	10	12	12	11	2	4	5	5	4	11	5	12	1	1	4	5	2	8	2

Table G-5. Ranked Abundance Listing for all Macroinvertebrates Collected from Naugatuck River, August 1983

Taxa	Number	Percent	Cumulative Percent
Cheumatopsyche l.	1139.416	13.468	13.468
Symphitopsyche l.	867.652	10.256	23.723
Tricladida	709.075	8.381	32.105
Leucotrichia pictipes l.	617.168	7.295	39.399
Hydropsychidae l.	497.577	5.881	45.281
Cricot. bicinct. grp. l.	426.763	5.044	50.325
Nais communis	422.243	4.991	55.316
Chironomidae p.	324.687	3.838	59.154
Cladocera	309.243	3.655	62.809
Cricot. tremulus grp. l.	277.792	3.283	66.092
Cricot. cylind. grp. l.	239.937	2.836	68.928
Acarina	234.098	2.767	71.695

Table G-5. (Continued)

Nematoda	210.368	2.487	74.182
Hydropsyche l.	186.073	2.199	76.381
Thienemannimyia ser. l.	171.948	2.032	78.414
Cardiocladius l.	156.693	1.852	80.266
Trichoptera l.	155.563	1.839	82.105
Baetis n.	142.192	1.681	83.785
Empididae l.	121.287	1.434	85.219
Nais bretscheri	96.615	1.142	86.361
Rheotanytarsus l.	86.633	1.024	87.385
Polypedilum scalaenum l.	80.983	0.957	88.342
Symphit. morosa l.	69.683	0.824	89.166
Nemertea	57.630	0.681	89.847
Ancylidae	57.442	0.679	90.526
Trichoptera p.	56.312	0.666	91.191
Polypedilum convictum l.	56.123	0.663	91.855
Nais variabilis	42.940	0.508	92.362
Hydroptilidae l.	41.057	0.485	92.848
Eukief. discoloripes grp.	39.173	0.463	93.311
Pristina sima	38.608	0.456	93.767
Empididae p.	38.232	0.452	94.219
Hydropsychidae p.	33.523	0.396	94.615
Antocha l.	32.958	0.390	95.005
Orthocladius l.	30.698	0.363	95.368
Isonychia n.	27.308	0.323	95.690
Bothrio. vejdovskyanum	26.932	0.318	96.009
Nanocladius l.	23.165	0.274	96.282
Nais alpina	23.165	0.274	96.556
Stenonema n.	22.223	0.263	96.819
Leucotrichia sp. a l.	21.658	0.256	97.075
Pseudocloeon n.	20.905	0.247	97.322
Cric. intersect. grp.	16.762	0.198	97.520
Tanytarsus l.	14.878	0.176	97.696
Nais pardalis	13.937	0.165	97.861
Polyped. fallax grp. l.	10.923	0.129	97.990
Ablabesmyia l.	10.547	0.125	98.115
Enchytraeidae	8.852	0.105	98.219
Tanytarsus coffmani l.	7.345	0.087	98.306
Physella	6.592	0.078	98.384
Neureclipsis l.	5.650	0.067	98.451
Psectrocladius l.	5.273	0.062	98.513
Chaetogaster diastrophus	4.897	0.058	98.571
Branchiobdellida	4.897	0.058	98.629
Hydroptilidae p.	4.520	0.053	98.682
Aulodrilus limnobius	4.520	0.053	98.736
Limnodrilus udekemianus	4.520	0.053	98.789
Cladotanytarsus l.	4.143	0.049	98.838
Eukief. bavarica grp. l.	3.955	0.047	98.885
Diptera p.	3.578	0.042	98.927
Imm. tub. w/o cap. chaet	3.390	0.040	98.967
Cricot. trifasc. grp. l.	3.390	0.040	99.007
Phaenopsectra l.	3.390	0.040	99.047
Dicrotendipes l.	3.202	0.038	99.085
Parachironomus l.	3.013	0.036	99.121
Hydrozoa	2.825	0.033	99.154
Pristina foreli	2.825	0.033	99.187
Berosus l.	2.825	0.033	99.221
Pagastia l.	2.825	0.033	99.254
Harpacticoida	2.260	0.027	99.281
Corydalus cornutus l.	2.260	0.027	99.308
Ceratopogonidae l.	2.260	0.027	99.334
Hydroptila l.	1.883	0.022	99.357
Procladius l.	1.883	0.022	99.379
Oulimnius latiusculus a.	1.695	0.020	99.399
Nais simplex	1.507	0.018	99.417
Coenagrionidae n.	1.507	0.018	99.435
Aeolosoma	1.507	0.018	99.452
Synorthocladius l.	1.507	0.018	99.470
Lumbriculidae	1.318	0.016	99.486
Limnodrilus hoffmeisteri	1.318	0.016	99.501

Table G-5 (Continued)

Psephenus herricki l.	1.318	0.016	99.517
Chironomus l.	1.318	0.016	99.533
Dina parva	1.130	0.013	99.546
Eurylophella n.	1.130	0.013	99.559
Oulimnius latiusculus l.	1.130	0.013	99.573
Orconectes	0.942	0.011	99.584
Baetidae n.	0.942	0.011	99.595
Calopteryx n.	0.942	0.011	99.606
Argia n.	0.942	0.011	99.617
Elmidae l.	0.942	0.011	99.628
Larsia l.	0.942	0.011	99.639
Dero digitata	0.753	0.009	99.648
Telmat. vejdovskyi	0.753	0.009	99.657
Erpobdella punc. punc.	0.753	0.009	99.666
Ostracoda	0.753	0.009	99.675
Nigronia l.	0.753	0.009	99.684
Petrophila l.	0.753	0.009	99.693
Optioservus trivittatus	0.753	0.009	99.702
Chironomidae l.	0.753	0.009	99.711
Thienemanniella l.	0.753	0.009	99.720
Polypedilum scal. typ. l.	0.753	0.009	99.728
Paratanytarsus l.	0.753	0.009	99.737
Rheotanytarsus p.	0.753	0.009	99.746
Tipulidae l.	0.753	0.009	99.755
Antocha p.	0.753	0.009	99.764
Gastropoda	0.753	0.009	99.773
Slavina appendiculata	0.565	0.007	99.780
Stephensoniana tandyi	0.565	0.007	99.786
Ephemeroptera n.	0.565	0.007	99.793
Gomphidae n.	0.565	0.007	99.800
Hemiptera n.	0.565	0.007	99.806
Stenelmis a.	0.565	0.007	99.813
Thienemannimyia grp. l.	0.565	0.007	99.820
Brillia l.	0.565	0.007	99.826
Cricotopus p.	0.565	0.007	99.833
Cryptochironomus l.	0.565	0.007	99.840
Rhabdocoela	0.377	0.004	99.844
Nais	0.377	0.004	99.849
Plecoptera n.	0.377	0.004	99.853
Acroneuria n.	0.377	0.004	99.858
Gerris n.	0.377	0.004	99.862
Megaloptera l.	0.377	0.004	99.866
Corydalus l.	0.377	0.004	99.871
Psychomyia l.	0.377	0.004	99.875
Glossosomatidae p.	0.377	0.004	99.880
Glossosoma l.	0.377	0.004	99.884
Oecetis l.	0.377	0.004	99.889
Diptera l.	0.377	0.004	99.893
Microtendipes l.	0.377	0.004	99.898
Parachironomus freq. l.	0.377	0.004	99.902
Limonia l.	0.377	0.004	99.907
Lymnaeidae	0.377	0.004	99.911
Sphaerium	0.377	0.004	99.915
Turbellaria	0.188	0.002	99.918
Arcteonais lomondi	0.188	0.002	99.920
Aulodrilus pluriseta	0.188	0.002	99.922
Copepoda	0.188	0.002	99.924
Asellus	0.188	0.002	99.927
Heptageniidae n.	0.188	0.002	99.929
Heptageniinae n.	0.188	0.002	99.931
Epeorus n.	0.188	0.002	99.933
Serratella n.	0.188	0.002	99.935
Tricorythodes n.	0.188	0.002	99.938
Zygoptera n.	0.188	0.002	99.940
Boyeria n.	0.188	0.002	99.942
Paragnetina n.	0.188	0.002	99.944
Phasganophora n.	0.188	0.002	99.947
Rhagovelia a.	0.188	0.002	99.949
Rhagovelia n.	0.188	0.002	99.951
Corixidae n.	0.188	0.002	99.953

Table G-5 (Continued)

Polycentropodidae l.	0.188	0.002	99.956
Polycentropodidae p.	0.188	0.002	99.958
Leucotrichiinae l.	0.188	0.002	99.960
Coleoptera p.	0.188	0.002	99.962
Promoresia l.	0.188	0.002	99.964
Promoresia elegans l.	0.188	0.002	99.967
Hydrophilidae l.	0.188	0.002	99.969
Ectopria nervosa l.	0.188	0.002	99.971
Dolichopodidae p.	0.188	0.002	99.973
Ephydridae l.	0.188	0.002	99.976
Cricotopus l.	0.188	0.002	99.978
Heterotrissocladius l.	0.188	0.002	99.980
Parachaetocladius l.	0.188	0.002	99.982
Polypedilum l.	0.188	0.002	99.984
Polypedilum ophoides l.	0.188	0.002	99.987
Symposiolladium acutil.	0.188	0.002	99.989
Xenochir. xenolabis l.	0.188	0.002	99.991
Psychodidae p.	0.188	0.002	99.993
Tipulidae p.	0.188	0.002	99.996
Atherix Variegata l.	0.188	0.002	99.998
Pisidiidae	0.188	0.002	100.00

Note: *l* = larva
p = pupa
n = nymph
a = adult
grp = group

Table G-6. Shannon-Wiener Diversity Indices $\bar{d}$ and Associated Evenness and Redundancy Values for the Benthic Macroinvertebrates from the Naugatuck River and Tributaries, September 1983.

Station	Diversity[a]	Evenness	Redundancy	Maximum Diversity	Minimum Diversity	Number of Species	Mean Density (No./m^2)	Community Loss Index[b]
				Naugatuck River				
N1	4.7755	0.7765	0.2260	6.1498	0.0682	71	5,267	--
N2	4.0165	0.7547	0.2477	5.3219	0.0515	40	3,759	1.00
N3	4.6377	0.7729	0.2287	6.0000	0.0444	64	7,530	0.57
N4	3.8117	0.6563	0.3445	5.8074	0.0140	56	22,871	0.81
N4A	3.5951	0.6437	0.3575	5.5850	0.0192	48	13,665	0.79
N5	3.1770	0.6194	0.3808	5.1293	0.0027	35	81,149	1.23
N6	3.6509	0.7515	0.2522	4.8580	0.0721	29	1,789	1.71
N7	3.3000	0.7295	0.2725	4.5236	0.0336	23	3,205	2.30
N8	2.6480	0.5938	0.4120	4.4594	0.0633	22	1,503	2.05
N9	3.4889	0.7110	0.2921	4.9069	0.0525	30	2,652	1.76
N10	3.0631	0.6771	0.3244	4.5236	0.0208	23	5,432	2.56
N11	3.2932	0.7385	0.2637	4.4594	0.0361	22	2,806	2.76
N12	2.4384	0.5251	0.4768	4.6439	0.0184	25	6,867	2.29
				Tributaries[c]				
GS1	3.1610	0.6807	0.3268	4.6439	0.1066	25	972	2.33
M5	2.8449	0.8224	0.1898	3.4594	0.2221	11	154	7.71
SB1	3.0076	0.8389	0.1702	3.5850	0.1924	12	203	5.50

[a] Calculated on a logarithmic base 2.

[b] Calculated using Station N1 as reference station.

[c] Community parameters for upstream stations of Mad River tributary (Stations BP1, BP2, M1, M2) were not calculated.

Table G-7. List of Fish Species and Families Collected from the Naugatuck River and Tributaries, Connecticut

Family	Scientific Name	Common Name
Anguillidae (freshwater eels)	*Anguilla rostrata*	American eel
Salmonidae (trouts)	*Salmo trutta*	Brown trout
Esocidae (pikes)	*Esox niger*	Chain pickerel
	Esox a. americanus	Redfin pickerel
Cyprinidae (minnows)	*Notropis cornutus*	Common shiner
	Notropis hudsonius	Spottail shiner
	Semotilus atromaculatus	Creek chub
	Semotilus corporalis	Fallfish
	Rhinichthys cataractae	Longnose dace
	Rhinichthys atratulus	Blacknose dace
	Exoglossum maxillingua	Cutlips minnow
	Notemigonus crysoleucas	Golden shiner
Castostomidae (suckers)	*Castostomus commersoni*	White sucker
Ictaluridae (bullhead catfishes)	*Ictalurus nebulosus*	Brown bullhead
	Ictalurus natalis	Yellow bullhead
Centrarchidae (sunfishes)	*Lepomis macrochirus*	Bluegill
	Lepomis gibbosus	Pumpkinseed
	Lepomis auritus	Redbreast sunfish
	Ambloplites rupestris	Rock bass
	Micropturus salmoides	Largemouth bass
Percidae (perches)	*Perca flavescens*	Yellow perch
	Etheostoma olmstedi	Tessellated darter

Table G-8. Analysis of Variance and Tukey's Studentized Range Test Results for Major Benthic Groups, Naugatuck River, August 1983

Chironomidae

Dependent Variable: ln count

Source	df	Sum of Squares	Mean Square	F Value	PR > F
Model	12	23.27	1.94	3.26	0.0057
Error	26	15.47	0.60		
Corrected total	38	38.74			

Tukey's Studentized Range Test

Station	4	12	4A	10	3	9	5	2	11	1	7	6	8
mean in count	(6.3)	(6.2)	(5.8)	(5.5)	(5.2)	(5.2)	(5.0)	(4.9)	(4.9)	(4.7)	(4.3)	(4.0)	(3.5)

Oligochaeta

Dependent Variable: ln count

Source	df	Sum of Squares	Mean Square	F Value	PR > F
Model	12	126.81	10.57	7.79	0.0001
Error	26	35.29	1.36		
Corrected total	38	162.09			

Tukey's Studentized Range Test

Station	4	3	5	2	11	4A	9	1	6	12	10	7	8
mean in count	(6.0)	(4.6)	(2.9)	(2.7)	(2.6)	(2.3)	(1.7)	(1.1)	(0.7)	(0.2)	(0)	(0)	(0)

Table G-8 (Continued)

Ephemeroptera

Dependent Variable: ln count

Source	df	Sum of Squares	Mean Square	F Value	PR > F
Model	12	103.10	8.59	11.05	0.0001
Error	26	20.21	0.78		
Corrected total	38	123.32			

Tukey's Studentized Range Test

Station	10	1	4A	11	9	12	5	3	2	8	4	7	6
mean in count	(4.6)	(4.5)	(3.6)	(3.6)	(1.7)	(0.8)	(0.7)	(0.6)	(0.6)	(0.6)	(0.5)	(0.2)	(0.2)

Trichoptera

Dependent Variable: ln count

Source	df	Sum of Squares	Mean Square	F Value	PR > F
Model	12	226.10	18.84	17.04	0.0001
Error	26	28.75	1.11		
Corrected total	38	254.86			

Tukey's Studentized Range Test

Station	5	4A	4	1	2	3	6	7	10	8	9	12	11
mean in count	(8.4)	(6.4)	(5.3)	(5.0)	(3.9)	(3.6)	(2.6)	(1.3)	(1.2)	(1.1)	(1.0)	(1.0)	(0.4)

Table G-9. **Analysis of Variance and Tukey's Studentized Range Test Results for Genera of Hydropsychidae, Naugatuck River, August 1983**

Cheumatopsyche spp.

Dependent Variable: ln count

Source	df	Sum of Squares	Mean Square	F Value	PR > F
Model	12	158.45	13.20	13.76	0.0001
Error	26	24.95	0.96		
Corrected total	38	183.40			

Tukey's Studentized Range Test

Station	5	4A	4	1	2	3	6	7	10	9	12	8	11
mean in count	(7.2)	(4.2)	(3.9)	(3.2)	(2.6)	(2.3)	(1.6)	(0.7)	(0.7)	(0.5)	(0.2)	(0.2)	(0.2)

Symphitopsyche spp.

Dependent Variable ln count

Source	df	Sum of Squares	Mean Square	F Value	PR > F
Model	12	159.34	13.28	13.57	0.0001
Error	26	25.45	0.98		
Corrected total	38	184.79			

Tukey's Studentized Range Test

Station	5	4A	1	2	4	3	8	7	6	10	9	12	11
mean in count	(6.7)	(5.3)	(4.1)	(2.5)	(1.9)	(1.7)	(1.0)	(0.8)	(0.7)	(0.6)	(0.5)	(0.2)	(0)

Table G-10. **Analysis of Variance and Tukey's Studentized Range Test Results for Species of *Cricotopus*, Naugatuck River, August 1983**

C. bicinctus

Dependent Variable: ln count

Source	df	Sum of Squares	Mean Square	F Value	PR > F
Model	12	63.05	5.25	5.09	0.0003
Error	26	26.82	1.03		
Corrected total	38	89.87			

Tukey's Studentized Range Test

Station	12	4	10	11	7	3	9	8	6	2	4A	1	5
mean in count	(5.4)	(5.1)	(3.6)	(3.4)	(3.1)	(2.9)	(2.9)	(2.7)	(2.5)	(1.9)	(1.7)	(1.2)	(0.9)

C. cylindraceus

Dependent Variable: ln count

Source	df	Sum of Squares	Mean Square	F Value	PR > F
Model	12	22.29	1.86	2.61	0.0195
Error	26	18.47	0.71		
Corrected total	38	40.76			

Tukey's Studentized Range Test

Station	12	3	4	9	5	2	6	4A	11	7	10	1	8
mean in count	(4.0)	(3.7)	(3.5)	(3.5)	(3.3)	(3.2)	(2.4)	(2.4)	(2.4)	(2.2)	(2.2)	(2.1)	(1.3)

C. tremulus

Dependent Variable: ln count

Source	df	Sum of Squares	Mean Square	F Value	PR > F
Model	12	46.8	3.90	3.99	0.0015
Error	26	25.4	0.98		
Corrected total	38	72.2			

Tukey's Studentized Range Test

Station	4	10	9	3	2	7	12	1	6	5	11	4A	8
mean in count	(4.6)	(3.9)	(3.8)	(3.8)	(3.7)	(3.0)	(2.3)	(2.3)	(1.9)	(1.9)	(1.9)	(1.6)	(0.8)

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