Evaluation of Monticello Nuclear Power Plant, Environmental Impact Prediction, Based on Monitoring Programs

by
K. L. Gore
J. M. Thomas
L. D. Kannberg
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November 1976

**Prepared for The Nuclear
Regulatory Commission**

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PACIFIC NORTHWEST LABORATORY
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BATTELLE
for the
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
Under Contract EY-76-C-06-1830

Printed in the United States of America
Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22151
Price: Printed Copy \$____*; Microfiche \$3.00

*Pages	NTIS Selling Price
001-025	\$4.50
026-050	\$5.00
051-075	\$5.50
076-100	\$6.00
101-125	\$6.50
126-150	\$7.00
151-175	\$7.75
176-200	\$8.50
201-225	\$8.75
226-250	\$9.00
251-275	\$10.00
276-300	\$10.25

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Richland, Washington 993532**

ACKNOWLEDGMENTS

We would like to extend our appreciation to Dave Heberling, Jim Bechthold and Larry Grotbeck of Northern States Power Company, Minneapolis, Minnesota for supplying us with pertinent information. Also, Dr. A. J. Hopwood and Dr. K. M. Knutson, Biology Department, St. Cloud St. College, Minnesota, were very helpful in gathering the data necessary for this report.

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PREFACE

In order to evaluate environmental programs conducted in conjunction with constructing and operating nuclear power plants, we selected three Environmental Impact Statements that we helped to prepare. The three plants selected, Monticello, Haddam Neck, and Millstone, represent those which we believe had the best environmental programs. Our choice was based, in large part, on monitoring programs covering the longest time span. Thus, while the state-of-the-art of power plant monitoring has improved since the 1960s to a point where these environmental programs may not appear to be "up-to-date," they were among the best of their period. We urge the reader to keep this in mind when reviewing this document.

I. INTRODUCTION

EVALUATION OF MONTICELLO NUCLEAR POWER PLANT ENVIRONMENTAL IMPACT PREDICTION, BASED ON MONITORING PROGRAMS

I. INTRODUCTION

This report evaluates quantitatively the nonradiological environmental monitoring programs at Monticello Nuclear Generating Plant. The general objective of the study is to assess the effectiveness of monitoring programs in the measurement of environmental impacts. Specific objectives include the following:

- Assess the validity of environmental impact predictions made in the Environmental Statement by analysis of nonradiological monitoring data.
- Evaluate the general adequacy of environmental monitoring programs for detecting impacts and their responsiveness to Technical Specifications objectives.
- Assess the adequacy of preoperational monitoring programs in providing a sufficient data base for evaluating operational impacts.
- Identify possible impacts that were not predicted in the environmental statement and identify monitoring activities that need to be added, modified or deleted.
- Assist in identifying environmental impacts, monitoring methods, and measurement problems that need additional research before quantitative predictions can be attempted.

In this report preoperational as well as operational monitoring data were examined to test the usefulness of baseline information in evaluating impacts. This included an examination of the analytical methods used to measure ecological and physical parameters, and an assessment of sampling periodicity and sensitivity where appropriate data were available.

This study is largely dependent on current statistical methodologies and new methods being developed at Battelle, Pacific Northwest Laboratories (PNL). A considerable amount of time was spent accumulating the basic data and preparing it for analyses.

In a final report that combines the results from three separate nuclear plants our efforts will be directed toward addressing the following questions: 1) are monitoring programs an effective way to assess environmental impacts, 2) can predicted impacts be verified by monitoring programs, and 3) do monitoring programs satisfy the requirements of the Technical Specifications? Answers to these questions should delineate deficiencies in preoperational and operational monitoring procedures and provide bases for improvements.

II. PLANT SITE AND HISTORY

II. PLANT SITE AND HISTORY

The Monticello Nuclear Generating Plant is located on the Mississippi River about 4.8 km northwest of the town of Monticello, Wright County, Minnesota. It is approximately 56 km northwest of St. Paul, Minneapolis, and about 40 km southeast of St. Cloud, Minnesota (Figure 1). The area around the site is mostly rural with the land used primarily for farming. The site lies on the outwash plain of the Mississippi River. Elk River, which flows parallel to the Mississippi River about 6 km north of the plant and connects with the Mississippi River about 24 km downstream, is the principal tributary nearest the site.

FIGURE 1. Monticello Nuclear Generating Plant and Environs to Approximately 50 Miles

Maximum and minimum flows for the river near the site are 54,000 cfs ($1,529 \text{ m}^3/\text{sec}$) and 240 cfs ($7 \text{ m}^3/\text{sec}$), respectively with average flow of 4,600 cfs ($130 \text{ m}^3/\text{sec}$). Based on flow duration data, the flow is expected to exceed 1,800 cfs ($51 \text{ m}^3/\text{sec}$) 90% of the time and 950 cfs ($72 \text{ m}^3/\text{sec}$) 99% of the time. Average flow velocities vary between 1.5 (0.15 m/sec) and 2.5 fps (0.8 m/sec) for flows below 10,000 cfs ($283 \text{ m}^3/\text{sec}$). Monthly river temperatures range between freezing and 85°F (29.5°C).

The aquatic biota near the Monticello Plant consists mainly of periphytic algae, benthic invertebrates and fish. Primary producers are mainly attached algae (diatoms, greens and blue-greens) with vascular plants being scarce. The invertebrates are characterized by caddisflies (Trichoptera) and mayflies (Ephemeroptera) which inhabit the flowing areas of the river. Dipterans, isopods and beetles are the dominant organisms found in the slack water areas of the river. The aquatic population is dominated by coarse fish. Carp and redhorse suckers were the most numerous fish captured by electrofishing methods with shiners dominating the seining collections. Game fish include: walleye, smallmouth bass, crappie, rock bass and northern pike.

In April 1966, Northern States Power Company (NSP) formally applied to the AEC (now Nuclear Regulatory Commission (NRC)) for permission to construct a nuclear power generating facility near Monticello, Minnesota, that would become operative in May 1970. After local hearings in the county seat, the AEC granted a construction permit to NSP on 19 June 1967. During the second half of the 1967 calendar year, the State of Minnesota raised questions concerning regulation of thermal and radioactive discharges to Minnesota water bodies and by May 1969 issued a permit to NSP with State regulatory statutes included. NSP questioned the authority of the State to regulate radioactive wastes and placed this matter before the Federal Courts. In August 1969, the Federal Courts ruled that only the Federal Government has the right to regulate radioactive releases from nuclear generating facilities.

In April 1970, AEC opened public hearings on NSP's application for an operating permit and in September 1970 issued a provisional low power operating license. On 18 February 1971, Monticello Plant received final authority from AEC to operate at full power. Since February 1971 the plant has been averaging better than 70% full power level, except for times when the plant was shut down for refueling. Figure 2 graphically depicts monthly power levels for years 1971 through 1974.

FIGURE 2. Gross Monthly Percent Power Generation

III. PLANT DESIGN AND CHARACTERISTICS

III. PLANT DESIGN AND CHARACTERISTICS

The Monticello Plant uses a single cycle, forced-circulation boiling water reactor designed for operation at power levels up to 1670 MWt and 545 MWe. The reactor core utilizes four modules assembled around a cruciform control rod. Enriched uranium dioxide pellets sealed in Zircaloy tubes serve as the fuel for the reactor. Water is both the moderator and coolant for the reactor core. Water enters the bottom of the core and flows upward through the fuel assemblies to produce steam from boiling. This mixture of water-steam is separated by steam separators and dryer assemblies within the reactor vessel. The steam is passed through the main steam lines to the turbine; whereas, the water is mixed with the incoming main feed-water line and recirculated (Figure 3). The condenser is a single pass, dual pressure, deaerating type with water supplied from the river to remove the excess heat.

FIGURE 3. Simplified Schematic of Plant Water Use

The circulating water system consists of an intake structure, circulating pumps, condenser-helper cooling towers and discharge structure. The intake structure is located inland from the bank of the Mississippi River at the end of a short (46 m) intake canal. The canal is about 19 m wide. Water is withdrawn from the river at approximately 645 cfs ($18 \text{ m}^3/\text{sec}$) passes through trash racks that retain large pieces of debris, and then through two traveling screens of 9.5 mm diameter. Water velocity in the intake canal is about 0.5 fps (0.15 m/sec), whereas, approach velocities to the traveling screens are less than 1 fps (0.3 m/sec). Water travels through the screens to the service water pump bays where the circulating water pumps (two half capacity pumps) circulate the water through the condensers. The service water pump bays are divided by a center wall to allow dewatering of either bay and provide dry access to the traveling screens independently of each other. At full plant design load, the water that passes through the main condensers is raised about 27°F (15°C) (ΔT) above the intake temperature but can vary up to 50°F (28°C). From the condensers, the water can be directed into the river via a discharge canal or diverted to the mechanical draft cooling towers for further cooling before being discharged to the river. Cooling water passes over two motor operated sluice gates and into a 305 m long discharge canal where the heated effluent is returned to the river downstream of the intake structure. Cooling tower blowdown enters the discharge canal just below the discharge structure. To control winter icing of the water intake, heated water from the condensers can be routed back to the intake.

The four modes of water circulation are as follows:

- Open Cycle

Water is withdrawn from the river at the rate of 645 cfs ($18 \text{ m}^3/\text{sec}$), passed through the condensers and returned to the river via the discharge canal. Total transit time through the plant and discharge canal is 15 minutes.

- Helper Cycle

This mode is essentially the same as open cycle except all or a portion of the cooling water effluent is diverted through mechanical cooling towers before being discharged back into the river. The same volume of water (645 cfs) is withdrawn and only the volume lost through evaporation in the cooling towers is not returned to the river. Total transit time through the plant cooling towers and discharge canal is about 18 minutes.

- Recirculation Cycle

In this mode only a portion of the total circulating water is withdrawn from the river. Most of the cooling water is recirculated and only the volume of water withdrawn is returned to the river minus cooling tower evaporative losses.

- Closed Cycle

This mode allows for a maximum quantity of water to be recirculated. About 54 cfs ($15 \text{ m}^3/\text{sec}$) is withdrawn and 36 cfs ($1 \text{ m}^3/\text{sec}$) is discharged and about 18 cfs ($0.5 \text{ m}^3/\text{sec}$) is lost to evaporation. Only the blowdown water is returned to the river.

The cooling tower operation is required only when the river flows are insufficient to supply adequate cooling water due to appropriation restrictions and/or to comply with regulations limiting the amount of heat discharged to the river. The State of Minnesota has set the following limitations on the discharge of heated water (State of Minnesota, 1969):

"Cooling facilities shall be provided and operated to insure that the heat content of the cooling water after reasonable dilution and mixing in the river does not raise the temperature of the river above limits specified below:

<u>Period</u>	<u>Maximum Temperature</u>	
July through August	86°F (30°C)	or 5°F (2.8°C) above the ambient temperature of the river whichever is greater, except that in no case shall the river temperature be raised above 90°F by the discharge of this effluent.
June through September	80°F (27°C)	
May through October	67°F (19.5°C)	
April through November	55°F (13°C)	
March through December	43°F (6°C)	
January through February	37°F (3°C)	

Although it is not necessary to operate the cooling towers much of the year, Northern States Power Company has been operating the towers to the maximum extent practicable. The cooling towers are not designed for winter-time operation.

IV. WATER QUALITY MONITORING

IV. WATER QUALITY MONITORING

River temperature information has been gathered by three separate measurement programs. The goals of each program were different and, hence, the type of information differs. Of these three sources of information, one is both preoperational and operational, the other two are operational.

TEMPERATURE MONITORING PROGRAM

PREOPERATIONAL

Both preoperational and operational temperature data were continuously collected at nine stations as part of the water quality monitoring. Two stations were established upstream of the plant and seven stations downstream (Figure 4). The temperature monitoring program began in July 1969 and continued until January 1973 (Station 9 was discontinued in 1971). Temperatures were measured with 7-day air temperature compensating Palmer® recording thermometers (accuracy $\pm 0.5^{\circ}\text{F}$) mounted on shore with the sensor lashed to a cement anchoring block positioned 18 to 27 m from the right side of the river. Weekly average maximum, average minimum, and the extreme temperatures encountered during each 7-day period were reported. The periods of operation for each station are given in Table 1. A sample of the reporting format is shown in Table 2.

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FIGURE 4. Position of Water Temperature Recorders (T) and Water Chemistry Stations (C) in 1968 (See Table 1 for locations of invertebrate sampling locations)

TABLE 1. Periods of Temperature Recording

Year	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8	Station 9
1969	7-5/12-31	7-5/12-31	7-5/12-31	7-12/12-31	7-12/11-15	7-5/12-31	7-5/12-5	7-5/7-25 8-3/12-31	7-5/12-
1970	4-30/12-31	2-20/12-31	2-26/4-23 5-7/12-31	1-29/8-19 8-27/9-2 9-10/11-25 12-31/	7-30/12-31	4-30/12-9 12-17/12-31	2-26/5-20 5-28/12-17	4-30/7-15 7-23/11-11 11-19/12-31	8-13/8-2 9-3/10- 12-10/12-
1971	1-1/2-3 2-11/3-24 6-17/12-31	1-1/12-31	1-1/4-8 8-26/12-31	1-1/7-22 8-26/11-25 12-16/12-31	1-1/1-20 2-28/12-31	1-1/12-31	Out all Year	1-1/1-20 1-28/4-7 7-22/9-8 9-23/11-3 12-2/12-23	Out all Year
1972	1-1/1-19 1-20/12-12	1-1/12-19	1-1/2-9 2-17/11-30	1-1/12-5	1-1/1-5 4-6/4-20 6-15/7-5 7-27/12-5	1-1/7-20	6-15/7-5 7-13/8-23 9-7/11-29	6-1/11-29	Out all Year

**TABLE 2. Temperature Reporting Format Employed
by NSP for Water Quality Monitoring**

Period		Average		Actual			Actual		
1971	1972	Max	Min	Max	Date	Hour	Min	Date	Hour
Dec. 30 -	Jan. 5	33.8	33.7	33.9	4	2400	33.6		
Jan. 6 -	12	33.7	33.7	34	6/7	1500/0001	33.4	12	2100
13 -	19	33.9	33.9	34	13/18		33.5	13	0300
20 -	26	34	34	34	20/26		34	20/26	
27 - Feb. 2		33.9	33.9	34	27/31		33.7	1/2	all day
Feb. 3 -	9	33.9	33.7	34	5/9		33.6	9	1300
10 -	16	33.8	33.6	34			33.6	12	1800
17 -	23	33.8	33.7	34	20/22	1500	33.5	23	2100
24 - Mar. 1		33.8	33.6	34	26/27	1200/0900	33.5	24/25	all day
Mar. 2 -	8	33.7	33.7	33.7	all week		33.7	all week	
9 -	15	33.6	33.6	33.7	9/11		33.5	12/15	
16 -	22	33.5	33.5	33.5	16/21		33.4	22	all day
23 -	29	32.3	31.8	33.4	23	1500	31.5		

OPERATIONAL

Two programs provided river temperature information; one to determine the thermal regimes downstream from the plant for different cooling modes and the other to support the periphyton monitoring program.

On 34 occasions during 1971 to 1973 thermal plume surveys were performed. Only results from the first 13 surveys were available for this review. The survey techniques are detailed in Supplement 1 to the Environmental Report. A summary of the essential elements of the program are given below.

Thermal plume temperatures were taken in a vertical and lateral cross-section grid at 19 locations (16 of which were downstream of the discharge). For each of these 19 transect points, 7 equally spaced lateral positions across the river were established where the temperature was measured at each 0.3 m depth interval from the water surface to 0.15 m from the bottom. Temperature measurements were made with thermistors (accuracy of final readings was estimated at $\pm 0.5^{\circ}\text{F}$). On each survey, data measurements began at a transect 91 m upstream from the intake structure, and proceeded to the transects downstream. The locations of the measurement transects are shown in Figure 5 and described in Table 3. During each survey, the plant operating load and cooling mode were kept constant, the intake and discharge temperatures were continuously monitored, and wet and dry bulb temperatures were taken hourly. Temperatures measured downstream of the discharge were corrected for variation in water temperature at the intake. Vertical, horizontal, and surface isotherm contours were then estimated and plotted for each transect.

Additional information reported for each of the first 13 surveys included:

- Average intake temperature at start of survey.
- Average intake temperature at end of survey.
- Median intake temperature.
- Average condenser intake temperature.
- Average condenser discharge temperature.

FIGURE 5. Thermal Plume Temperature Survey Measurement Transects and Stations

TABLE 3. Location of Thermal Survey Transect Sites

<u>Transect Designation</u>	<u>Location</u>
A	300 ft (91 m) upstream from intake
B	In discharge canal and river 50 ft (15 m) upstream from Station 1.
1	At discharge to river
2	200 ft (61 m) downstream from discharge
3	500 ft (152 m) downstream from discharge
4	900 ft (274 m) downstream from discharge
5	1,400 ft (426 m) downstream from discharge
6	2,000 ft (610 m) downstream from discharge
7	2,600 ft (792 m) downstream from discharge
8	3,200 ft (975 m) downstream from discharge
9	4,400 ft (1,341 m) downstream from discharge
10	5,450 ft (1,661 m) downstream from discharge
11	6,500 ft (1,981 m) downstream from discharge
12	7,700 ft (2,347 m) downstream from discharge
13	10,150 ft (3,094 m) downstream from discharge
14	12,350 ft (3,764 m) downstream from discharge
15	14,100 ft (4,298 m) downstream from discharge
16	16,400 ft (4,999 m) downstream from discharge
17	17,450 ft (5,319 m) downstream from discharge

- Average dry bulb temperature.
- Average wet bulb temperature.
- Average intake temperature.
- Average canal discharge temperature.
- Average plant load.
- Discharge flow to river.
- Average percent cloud cover.
- Average wind velocity.
- Average wind direction.
- River flow (or elevation at plant).
- Cooling mode characteristics (which tower is on, how many fans, etc.).

The calendar dates, average intake and discharge canal temperature, average plant load, discharge flow, river flow, and cooling mode characteristics are given in Table 4 for the thermal plume surveys.

Other operational river temperature data were collected during the periphyton monitoring program from June 1971 through 1974. The period receiving the greatest attention was from April through November. During that time, river temperature was measured at varying numbers of stations (see Ecological Monitoring - Periphyton). There was at least one station upstream and one in the discharge canal, the rest being downstream of the discharge. The measurements were momentary temperatures taken with a mercury thermometer at a depth of 20 cm. There was no adjustment of downstream temperatures for diurnal temperature variation. The lateral position of the sampling points was described as either in the plume or out of it.

**TABLE 4. River and Plant Operating Characteristics
During Thermal Plume Surveys**

Survey Date	Average Intake (°F)	Average Canal Discharge (°F)	Average Plant Load, MW	Discharge Flow, cfs	River Flow, cfs	Cooling Operation During Survey
6/22/71	76.2	90.4	560	555	4,224	Both towers in service
7/1/71	73.3	87.9	567	565	6,234	Once through
7/6/71	76.8	99.3	552.4	561	4,533	Both towers in service
8/2/71	67.1	80.5	518.8	529	2,048	Both towers in service
8/3/71	68.2	92.1	521.3	606	2,048	Once through
8/13/71	74.3	85.6	510.0	509.8	1,140	Both towers in service one fan off
8/19/71	77.9	102.8	508.2	585	1,142	Once through
9/2/71	74.1	85.8	480	636	1,536	Both in service
9/20/71	60.8	74.2	508.6	633	1,215	Partial helper cycle
11/9/71	35.2	61.5	523.8	208	18,656	Partial recirculation
2/22/72	32.3	82.4	556.7	320	3,840	Once through
2/23/72	33.2	62.5	560.8	640	3,840	Once through
3/1/72	32.3	60.3	530	623.9	3,840	Once through
4/4/72	33.0	77.3	580	323.1	909 ⁽¹⁾	Once through
5/23/72	70.4	83.5	570	---	909 ⁽¹⁾	Once through
6/22/72	68.5	99.2	568.5	623.9	5,550	Once through
7/5/72	70.2	90.6	566.4	623.9	3,755	
8/3/72	---	80.1	455.8	---	18,901	Both towers in service
8/14/72	---	86.6	562.7	654.0	16,960	Both towers in service
8/18/72	---	88.8	563	623.9	14,450	Both towers in service
8/23/72	---	82.4	565.4	635	14,200	Both towers in service
8/30/72	---	86.5	566.8	630	14,976	Both towers in service
9/7/72	---	94.1	566.8	596	10,750	Once through
9/15/72	---	94.2	566.5	581.3	6,656	Once through
6/19/73	---	73.6	---	---	1,790	Shutdown
6/27/73	---	92.6	572.4	24.3	2,410	One tower bank now in service
7/2/73	---	85.8	543.7	375.5	1,790	Both towers in service
7/5/73	---	86.3	543.2	---	2,276	Both towers in service
7/12/73	---	89.6	538.1	581.0	2,155	Both towers in service
7/16/73	---	84.6	545.2	577.3	1,920	Both towers in service
7/19/73	---	86.8	498.3	551.5	2,219	Both towers in service
7/25/73	---	89.0	541.6	580	1,792	Both towers in service
7/30/73	---	82.1	544.1	577.7	2,410	Both towers in service
8/13/73	---	86.7	545.5	590.0	5,376	Partial tower service

(1)Flow not available; only water elevation.

WATER CHEMISTRY, PREOPERATIONAL
AND OPERATIONAL (1968-1974)

In 1968, water samples were taken at the same seven stations used for temperature data (Figure 4). Analyses were according to procedures found in Standard Methods (1960). Samples were collected biweekly throughout the year for 34 parameters; BOD and DOs were measured monthly. The parameters included total solids, dissolved solids, suspended solids, total hardness, Ca hardness, Mg hardness, bicarbonate, carbonate and hydroxide alkalinity, free CO_2 , H_2S , NH_4 , CO_3 , HCO_3 , OH , Cl , SO_4 , PO_4 , NO_3 , SiO_2 , Ca, Mg, Na, Fe, Al, Mn, Cu (ether soluble), detergents, turbidity, conductivity, pH, Rhyznar Index; dissolved oxygen, and BOD. In addition to water chemistry parameters, current velocities were measured with a Gurley current meter.

In 1969, only four stations were sampled for water chemistry. These corresponded with temperature and macroinvertebrate stations shown in Table 5. Approximately bimonthly analysis included alkalinity, BOD, phosphates and total, inorganic and organic solids. At the plant site the same 36 parameters were measured as in 1968 and at the same frequency. Water velocities and depth measurements were also taken concurrently with the macroinvertebrate sampling.

For the first half of 1970, sampling design and methodologies were the same as in 1969 for all physical parameters measured. However on 18 August 1970, all samples at the four stations were analyzed with a Hach water analysis kit.

During 1971, the first operational year for Monticello, the water chemistry monitoring procedures were the same as those used in the latter half of 1970, including the same stations, sampling frequencies and analytical methods. Water velocity and depth measurements were again taken in conjunction with the macroinvertebrate program. Thirty-six parameters were measured only during February, April, November, and December, at the plant site. The same parameters were measured approximately 0.2 km above the intake and below the discharge canal in November and December.

TABLE 5. Water Quality Monitoring Stations

<u>Temperature Station</u>	<u>Used for Measuring Other Parameters</u>	<u>Location*</u>
	Invertebrate C1-control	~5,500 ft (1676 m) upstream
1-control		~3,600 ft (1097 m) upstream
2-control	Water chemistry 1-control Invertebrate C2-control	~2,700 ft (823 m) upstream
3	Water chemistry-2 Invertebrate E-1	Near discharge
4	Invertebrate E-2	~1,500 ft (457 m) downstream
5	Invertebrate E-3	~3,600 ft (1097 m) downstream, above rapids
6	Invertebrate E-4	~6,500 ft (1981 m) downstream
	Invertebrate E-5	~8,100 ft (2469 m) downstream
7	Water chemistry-3	~10,400 ft (3170 m) downstream
8		~13,500 ft (4115 m) downstream
9	Water chemistry-4 Invertebrate E-6	~17,700 ft (5395 m) downstream

*Distance from discharge canal.

In 1972, water chemistry data were collected and analyzed the same way as in 1971 except Station 4 was dropped and only three stations were sampled. Water velocities and depth measurement were determined concurrently with the macroinvertebrate program as in previous years. Monthly measurements were made 0.2 km above plant intake, 0.2 km below the discharge canal, and a station was added in the discharge canal. Water chemistry methods for 1973 and 1974 were the same as those used in 1971 and 1972.

PREDICTION OF THE THERMAL REGIMES

An effort was made by NSP to mathematically model the thermal discharges to the river and predict surface isotherms downstream from the discharge. Several different heat dissipation operating modes, climatic, and river discharge conditions were modeled. The model employed in the simulations was a combination of the phenomenological correlations of Asbury and Frigo (1971), and observed thermal plume data obtained after operation began. The situation for prediction of the thermal regimes was unusual because the plant had already begun operation when the analysis was performed and some field isotherms had been defined.

The Asbury-Frigo (1971) treatment yields isotherm surface areas and enables one to employ previously obtained field data to tune the predicted isotherm areas to that field data. The great disadvantage is that the correlations by Asbury and Frigo are for surface discharges into the Great Lakes and their work was a simplification of the earlier work by Edinger and Polk (1969). Thus, the Asbury and Frigo (1971) approach is a poor one to use to predict the characteristics of the Monticello discharge plume. Since the methods of Edinger and Polk (1969) are also applicable to riverine environments, better agreement would probably be obtained by using their methods; certainly this is true once a small amount of field data became available. Another model available at the time of the analysis which might have been better to use was that of Koh and Fan (1970). Although the Koh and Fan model does not allow the inclusion of field data to as great a degree as either of the others, it is reasonably rigorous and would probably have predicted the discharge more accurately than the others, particularly for conditions different from those for which field data was available. The thermal surveys discussed earlier in this section were intended to offer verification for these modeling efforts. The comparison of the predicted cases and the thermal surveys are discussed further in Section VII.

V. ECOLOGICAL MONITORING

V. ECOLOGICAL MONITORING

PREOPERATIONAL AQUATIC ECOLOGY MONITORING

PERIPHYTON (1968-1970)

Due to the high current velocity in the Mississippi River near the site, true plankton, both phytoplankton and zooplankton, are absent and are so sparse that they do not contribute significantly to the aquatic ecosystem. The attached algae (periphyton) at the site are the important sources of primary production in the river and therefore, were chosen to be monitored for detection of potential power plant impacts.

The study began in May 1968, with 13 stations chosen as sampling sites (Figure 6). Stations 1 and 2 are upstream of the plant while Stations 3, 4, and 5 form a transect across the river near the end of the discharge canal. Stations 6, 7, and 8 form a transect about 1/4 mile (0.4 km) below the discharge canal with Stations 9 and 10 about another 1/2 mile (0.8 km) downstream near the lower end of an oxbow in the river. Stations 11, 12, and 13 are located 2-1/2 miles (4 km), 3-1/2 miles (5.6 km) and 5-1/2 miles (8.8 km) downstream from the discharge canal, respectively.

During 1968, very little sampling was accomplished because the sampling equipment initially used was not suitable for the fast-moving water near the site area and the abnormally high water runoff in 1968 also made sampling difficult. Periphyton were collected on artificial substrates (glass slides). Nine glass slides were placed in a holder and periphyton were allowed to colonize for approximately 2 weeks before it was removed for analysis. This method is uniform, nonselective, quantifiable and is useful for comparison of periphyton among several locations (Hopwood, 1969). It was not intended, however, to duplicate periphyton communities attached to the natural river bottom substrates. Samples that were collected showed large variances among the 9 slides per sampler, due most likely to large pieces of debris that clogged the sampler.

FIGURE 6. Position of Periphyton Artificial Substrates in 1968 and 1969

In 1969, sampler problems were largely overcome by adding a brushlike ring of stiff wires extending in front of the slide holders to entrap debris. Final design and testing began in April but it was not until July 9 that the program was in full operation. Due to human disturbances and high current flow, many samplers and slides were lost from July 9 through November 1969. The sampling stations remained as originally designed in 1968 with the exception of adding Station 14 (Figure 6), located just upstream from Highway #25 bridge at Monticello (approximately 6 km below the plant). Periphyton measurements included counts of the individual numbers per square centimeter by species, dry weight biomass by the tared slide technique, and chlorophyll-a concentrations by the trichromatic technique (Standard Methods, 1960).

Samples were collected in February, May, June, July, August, September, October, and November 1970; no collections were made in March, April, and December because the ice cover on the river made sample collection hazardous. Fourteen percent of the samples were lost during the year and cell counts were reported for only two time intervals. In addition to cell counts, and pigment and biomass analyses, the following additional analyses were performed: 1) chlorophyll-a and pheophytin-a measurements by the Lorenzen (1967) technique which differs from the previously used trichromatic technique; 2) biomass measurements were made by a modification of the Grzenda and Brehmer (1960) technique, and, 3) sample replication was increased from two to three. The sampling stations remained the same as in 1969. The 1971 periphyton sampling is considered operational monitoring and will be discussed later.

MACROINVERTEBRATES (1968-1970)

Since June 1968, two types of sampling techniques were employed. The first was a qualitative method that utilized hand netting and screening of bottom material among the grasses and sedges along the shoreline where the water was less than 2 ft deep. Exact locations could not be determined for the hand-netted samples. The organisms that were collected were classified to the lowest taxonomic level. A second method was quantitative, employing a stream bottom sampler consisting of a collapsible wire mesh bag surrounded by a nylon organdy bag (Bull, 1968). Inside the bag, clean rocks (surface area $\sim 22.5 \text{ m}^2$) were placed and allowed to colonize for 1 month. The bag was retrieved and the organisms separated from the rocks, identified, counted, and weighed. Samples were collected at seven stations (Figure 7).

In 1969 qualitative sampling was curtailed and a more intense quantitative study was initiated. The wire mesh, nylon bag sampler was replaced by a sampler more adaptable to water currents and depths near the site. The new artificial substrate sampler was designed by Britt (1955) and consisted of a concrete block with dimensions of 31.62 cm x 31.62 cm x 8.00 cm. The exposed surface of the block was roughened by sand blasting to provide a better surface for organism attachment. The block weighed about 18 kg and was self-anchoring. After the 1 month colonization time, the samplers were

FIGURE 7. Position of Macroinvertebrate Bull Samplers in 1968 and Fish Electroshocking Sectors (A-E)

retrieved and the organisms were removed by hand, preserved in a 10% formalin solution and brought back to the laboratory for analyses. Organisms were classified, counted, and then wet and dry weight determinations were made for each taxonomic group on each block. The study used a total of 88 blocks with 4 blocks per station during all four seasons. Sampling locations also changed from that used in 1968 to include 8 transects across the river with 2 above the plant as controls and 6 below as experimental transects, and, each station on each transect used four blocks as depicted in Figure 8. In 1970, the last year of preoperational monitoring, the macroinvertebrate sampling employed the same methodologies, stations and frequencies utilized in 1969 quantitative macroinvertebrate monitoring. The qualitative near-shore sampling (hand netting) was discontinued. However, due to the low number of stoneflies (Plecoptera) collected on the cement blocks in 1969, these organisms were collected separately with a Surber net (30.5 cm^2) at only 4 transects (C1, C2, E1 and E4). Sample collection and processing was the same as with the concrete block samples.

FIGURE 8. Position of Macroinvertebrate Concrete Block Samplers in 1969

FISH (1968-1970)

Fish studies were initiated in 1968 to determine the species composition and population density of the fish found in the vicinity of the site. Electrofishing was the primary tool used to collect fish in the river because stationary nets and traps could not be used in the swift currents. The electrofishing gear consisted of a 3,000 watt, 230 volt AC Homelite generator; control panel and switch box; a boom frame of galvanized steel tubing; and three electrodes hanging from the frame into the water off the bow of the boat. Fish were collected by orienting the boat parallel to the shore with the bow pointing downstream so that the shocked (stunned) fish would surface toward the bow for hand dip-netting. The dip-netted fish were placed in tubs of water and after completion of a shocking run, they were

counted, measured, weighed, tagged with monofilament spaghetti tags and released. Scale samples were taken from each fish for age analysis. Electro-fishing was conducted in five sectors (A-E) of the river (Figure 7) between predetermined landmarks.

The 1969 fish studies were essentially the same as in 1968 with electroshocking and tagging the principal field techniques used. It should be noted that the Schnabel Method was used to estimate population densities.

In 1970, seining replaced electrofishing as the method of fish collection. The seines were of a nonbag type, 20 ft (6.1 m) long, with either a 1/4 (6.4 mm) or 1/8 in. (3.2 mm) mesh. The seining stations were confined along the shoreline in areas of shallow slow moving water. Average current velocities about 1 fps (.3 m/sec) or less allowed operation of the seine from upstream to downstream direction. Six stations were established with two control stations located above the plant and four stations downstream of the plant (Figure 9). Seining was conducted 21 times between 26 May through 13 August 1970. Fish were classified and counted; however, if more than 100 fish were captured per haul, only an aliquot of 100 was counted and the rest returned immediately to the river.

FIGURE 9. Fish Seining Stations 1970-1971

OPERATIONAL AQUATIC ECOLOGY MONITORING

PERIPHYTON (1971-1974)

Operational monitoring began in 1971. Sampling techniques were the same as those used for preoperational periphyton monitoring. Three new stations were added; Station 3A, located in the discharge canal upstream from Station 3, and Station 4A, another control station located on the opposite side of the river from the discharge canal upstream from Station 4 (Figure 10). Station 14, which was located just upstream from Highway Bridge #25 in the town of Monticello, was deleted to reduce the number of analyses. A single winter sample was collected beneath the ice at 12 stations during February and March; during warmer months from 13 May to 18 October all stations were monitored biweekly.

FIGURE 10. Position of Periphyton Artificial Substrate Collectors - 1971

During 1972, the sampling techniques were identical to those used in 1971. Samplers underneath the ice were colonized for one month from 19 February to 16 March, biweekly during the warmer period from May through November. Station 13 was deleted because the data duplicated those of other stations.

In 1973, the third year of operational monitoring, sampling techniques were generally the same as those of previous years. However in 1973, no samplers were suspended beneath the ice in February because previous years' results showed essentially no growth beneath the ice. From 5 April to 23 November, floating open water samplers were exposed to biweekly colonization. Stations 1, 4, 5, 8, 10, and 12 were deleted due to duplication of other stations leaving only Stations 2, 3A, 3, 6, 7, 9, and 11.

Monitoring in 1974 included the same techniques and stations used in 1973. Sampling occurred only from 9 May to 3 November on a biweekly colonization schedule.

MACROINVERTEBRATES (1971-1974)

In 1971, two separate benthic monitoring studies were conducted. One was a continuation of the program conducted during 1969 and 1970, with methodologies and stations the same as in 1969 and 1970. The second study, initiated in July 1971, also used concrete cement blocks as artificial substrates but employed more of them at each station with the number of stations reduced to two (Figure 11). At each of the two stations, one above the plant (control) and one at the end of the discharge canal in the river proper (experimental), five sets of four blocks (20 blocks) each were set on the river bottom. After allowing the blocks to colonize for 1 week one set of four blocks was removed from each station and analyzed as in the other study. Each week, for five consecutive weeks, one set of four blocks was removed and not replaced until the end of five weeks when all blocks were replaced with new ones. This study was conducted between 19 July to 24 November 1971 to determine the growth and colonization rate of benthic organisms above and below the point of effluent discharge.

FIGURE 11. Position of Control and Experimental Stations for Benthic Colonization Study During 1971-1972

During 1972, benthic macroinvertebrate monitoring continued with the same two programs. The first, involving monthly colonization, was the same as in 1969, 1970, and 1971, and the same methodologies and techniques were employed. However, sampling transects were reduced to just one above the plant and four below (Figure 12); whereas in previous years there were two above and six below. The second study was concluded on 21 July 1972, after eight cycles of five weeks each were completed. Table 6 lists the eight sampling cycles and the substrate placement and recovery dates.

One benthic macroinvertebrate monitoring program was continued in 1973 and two new ones were initiated. Monthly samples were again collected, but at only three transects (C2, E1 and E2, Figure 12); in previous years up to eight transects were employed. Methodologies did not differ from the previous year.

FIGURE 12. Position of Macroinvertebrate Concrete Block Samplers in 1972

TABLE 6. A List of Macroinvertebrate Sampling Cycles and Substrate Placement and Recovery

Cycle	Dates
1	12 July - 16 August 1971
2	9 August - 13 September 1971
3	6 September - 14 October 1971
4	6 October - 10 November 1971 (Site E - 3 samples collected) 6 October - 27 October
5	2 November - 23 November 1971 (Site C only, 3 samples)
6	15 April - 19 May 1972 (Site E - collections on 29 April, 5 and 12 May)
7	19 May - 23 June 1972
8	23 June - 21 July 1972 (4 samples 1-4)

In July 1973, a 2-year study was begun to examine possible premature emergence and altered reproductive periodicity in aquatic insects exposed to heated plant effluents. Three stations were established on land about 2 m from the rivershore; one about a 1/2 km above the plant, the second by the discharge canal, and the last about 1/2 km below the discharge (Figure 13). Adult insects were collected nightly in a light trap consisting of a catch pan containing 50% isopropanol, illuminated with a 15 watt fluorescent lamp and supported on a wooden stand. Each sample was counted and weighed.

FIGURE 13. Position of Drift Insect Nets (•) and Insect Light Traps (Δ) in 1973-1974

The other new monitoring program, initiated in late July 1973, dealt with invertebrate drift organisms. Two stations were established and designated control and experimental (Figure 13). Samples were collected biweekly for 1 year with drift capture nets, 145 cm in length, with 15 cm square throats, constructed of 1/2-mm mesh netting. These nets were arranged

in a vertical array extending from the river bottom to the river surface, with the top net only half submerged in the water. Collected organisms were classified, counted, and weighed.

The studies conducted in 1973 were continued in 1974 with methodologies and techniques remaining the same. The concrete block artificial substrate samples were collected monthly throughout the entire year. However, three new stations were added in December of 1973 (E_{EI} , C_{EI} and C_{2I} , Figure 14). The insect trapping study was completed in July 1974 with methodologies and techniques identical to those used in 1973. The invertebrate drift study provided the basis for a masters thesis by Matter (1975), entitled "Invertebrate Drift in the Mississippi River Near Monticello, Minnesota." The technique and methodologies were the same as in the previous year (1973).

FIGURE 14. Position of Macroinvertebrate Concrete Block Samplers in 1974

FISH (1971-1974)

During 1971, the first operational year of fish studies, electrofishing methods, techniques and stations were the same as in the preoperational years (1968-1969). No seining was conducted in 1971.

In 1972, fish studies included electrofishing, seining and a creel survey. Electrofishing locations during 1972 were the same as in previous years with the exception of the discharge canal, which was sampled separately from Sector B (Figure 7). The seining study of 1970 was continued using the same methods. However, after capture the minnows were marked with a powdered nontoxic textile dye and released. The dye was applied with a 100 psi air compressor paint spray unit. Approximately 1 hour after the dyed (tagged) fish were released, the area was reseined, and the marked fish were identified in a light-tight box illuminated by a 40 watt ultraviolet light. A population estimate was then made using this data. This study differed slightly from the preoperational seining study in that eight stations were sampled instead of six. The two additional stations were located above the plant as extra controls. The third study conducted in 1972 was a stratified-random creel survey (Neuhold and Lu, 1957). This survey consisted of an instantaneous fish count and angler interviews. This method provides an unbiased estimate of the angler population and a qualitative procedure to estimate plant affects on sport fishing.

During 1973, the same three fish studies (electrofishing, seining, creel census) were continued. The electrofishing study was essentially the same except more emphasis was placed on delineating spawning areas in the vicinity of the plant by observing sex and breeding condition of the shocked fish. Electroshocking was conducted on 52 days between 26 March and 27 December 1973. The seining study was completed in 1973 and covered 1 year of plant operation (19 June 1972 to 25 July 1973). Methods and techniques employed were the same as those of 1972 and the creel census was identical to that carried out in 1972.

Fish sampling in 1974 included creel census, fish spawning, young-of-the-year seining, fish impingement, and cold shock studies. Also included

was a fish entrainment monitoring study. The creel census was the same as that conducted during the previous 2 years (a stratified-random creel survey). The fish spawning study (electrofishing) was essentially the same as that of 1973, except that sampling was conducted at weekly intervals from 6 April to 14 August 1974 in the section of river from 2 km upstream of the discharge to 10 km downstream of the city of Monticello. A master thesis by Eberley (1975) "Spawning Activities of Major Fish Species in the Monticello Area of the Mississippi River," evolved from the study. A new monitoring program initiated in 1973 and completed in 1974 investigated thermal influence on young-of-the-year fish (YOY). Previously employed seining techniques were used to make weekly collections of YOY from from mid-June through September for both years at four stations within each of three areas (Figure 15). The four stations represented two pool and two riffle habitats. The three areas included Section 1 above the plant, Section 2 below the plant on the opposite shore (out of influence of thermal plume) and Section 3 below the plant within the influence of the thermal plume.

FIGURE 15. Position of Young-of-the-Year Fish Seining Stations, 1973-1974

Fish impingement was measured 33 times between 11 July 1973, and 26 December 1974, at approximately 2-week intervals. Samples were collected in a framed net placed inside the sluice canal (Figure 16) for the entire screen rinse period. Screen wash is diverted from screens through a canal to the river downstream from the cooling water intake. Screens are washed approximately every 8 hours or more frequently if needed. Fish collected from the sluice canal were placed in a holding tank for 10 min to examine their physical conditions. Mortalities were described in terms of loss of equilibrium and weak or intermittent opercular movement.

FIGURE 16. Diagram of Intake Structure and Sluice Canal for Impingement Canal

A series of experiments were performed between 12 March to 18 March 1974, to determine the effects of winter plant shutdown (cold shock) on fish in the discharge canal. Six indigenous species including rock bass, walleye, black crappie, smallmouth bass and yellow and brown bullhead were tested. Duplicate tests were conducted. Fish were collected from the discharge canal 1 day prior to testing. If possible, all fish species were represented in the 0.9 x 1.2 x 1.2 m cages. At the rate of 5°F (2.8°C) every 12 min, the fish were subjected to an overall temperature decrease of 25°F (13.9°C), from 60°F (15.5°C) to 35°F (1.7°C), in 1 hour. In the final 2 min of each test, opercular dilations were counted and recorded along with general conditions of the fish. Fish were observed at 2, 12, 24, 36, and 48 min and 1, 2, 5, and 24 hours after reaching ambient temperature.

Entrainment Studies

Both laboratory and field fish entrainment studies were begun in 1972 under temperature conditions simulating those of passage through the plant cooling system. Test fish were the fathead minnow (Pimephales promelas), ranging between 30-60 mm in length. This fish is not indigenous to the Mississippi River near the Monticello Power Plant and was purposely chosen so there would be no problem in identifying the test fish. In the laboratory, oxygen consumption and response to thermal change was measured on animals acclimated to a wide range of temperature. Oxygen consumption was measured in fish acclimated to 1, 5, 10, 15, 20, 25 and 30°C, and compared to the consumption rate of fish acclimated to 1, 5, 10 and 15°C immediately after they had experienced a temperature increase of 15°C. In the temperature tests fish were exposed for 15 sec to a ΔT of 7.2°C, then for 74 sec at a ΔT of 15°C, and finally to a temperature decrease to river ambient over the next 10-15 min. These temperature changes represented those experienced by an entrained fish passing through the first condenser, second condenser, and discharge canal and mixing zone, respectively. After testing, fish were held at their original acclimation temperature for a 7-day observation period.

The field studies were conducted in June, September, November, December of 1972, and February 1973. Fathead minnows were introduced to the intake water between the circulating water pumps and the traveling screens. Fish were recaptured in the discharge canal by seining and dip netting from boats and shore. The recaptured fish were then held in live boxes at river ambient temperature for observation and examination.

In 1973, a fish entrainment study was begun to examine the number, kinds and seasonal occurrence of natural entrainment of fish and large invertebrates. The study began in September 1973, and continued through August 1974 and was designed to assess incidence, not survivorship. Biweekly samples were collected by a fish collection device (Figure 17) consisting of a net of 6.4 mm hardware cloth mounted on a 2.4 m wide 0.34 m high and 0.41 m deep frame. This net was lowered into the discharge canal and filtered about 7-10% of the total discharged water. All sampling times included 6, 15 min to 3 hour samples over a 24-hour period. After collection, the contents of the net were removed, preserved, weighed, identified, and enumerated.

Terrestrial ecology operational monitoring programs were not conducted at Monticello Nuclear Generating Plant. No impacts on the terrestrial biota were expected from plant operation.

FIGURE 17. Fish Entrainment Capturing Device and Placement in Discharge Canal

RATIONALE FOR DATA SYNTHESIS

Ecological monitoring programs have been conducted for approximately 8 years at Monticello. Some populations have been extensively monitored (from 1968-1974), thus data recording and synthesis for statistical analyses was a very important, and at times a cumbersome, aspect of this study. However, due to certain inconsistencies (e.g., additions and/or deletions of stations from year to year, changing sampling gear or methodologies, and reporting formats) not all data could be quantitatively evaluated (e.g., results section on fish). Thus, we present here the rationale for the choices we made whereby selected data sets were used for subsequent statistical analysis.

PERIPHYTON

Periphyton sampling was initiated in 1968 and has continued through 1975 (Table 7). During the first 2 years (1968 and 1969) sampling was conducted to improve and check sampling gear and field procedures. Limited results first appeared in the annual monitoring report in midyear 1969, but were reported in terms inconsistent with that of later reports. Therefore, only data from 1970 through 1974 were statistically and/or quantitatively analyzed by PNL. Thus, the results for 1 year of preoperation and 4 years of operation were available.

Since our analysis scheme required that samples be collected from the same stations in each collection period we deleted results from those stations which did not meet this criterion. For example, in 1968 thirteen stations were used as sampling sites, in 1969 one was added, in 1971 two new stations were added and one deleted, in 1972 three stations were deleted, and 1973-1974 only seven stations were monitored. Therefore, our final analyses incorporated data from these seven stations (2, 3, 3A, 6, 7, 9, and 11), (Figure 10) chosen because they were consistent throughout the sampling period 1970-1974.

Both temperature and current measurements made at these stations allowed us to analyze productivity based on concurrent values of these parameters. Stations 6 and 9, 2 and 11, and 3 and 7 were paired on the basis of slow,

TABLE 7. Summary of Periphyton Sampling and Analytical Methods

YEAR	COLLECTION METHOD	SAMPLING FREQUENCY	STATION LOCATION(S) AND NUMBER(S)	ANALYSIS	REMARKS
PREOPERATIONAL					
1968	ARTIFICIAL SUBSTRATES GLASS SLIDES	INCONSISTENT, WAS DESIGNED FOR BIWEEKLY COLLECTIONS	2 UPSTREAM (CONTROLS) 3 - JUST BELOW DISCHARGE 3 - 1/4 MILE BELOW DISCHARGE 2 - 1/2 MILE BELOW DISCHARGE 1 - 2 1/2 MILE BELOW DISCHARGE 1 - 3 1/2 MILE BELOW DISCHARGE 1 - 5 1/2 MILE BELOW DISCHARGE	CELL COUNTS EXPRESSED AS CELLS/cm ² PIGMENT ANALYSIS BY THE TRICHROMATIC TECHNIQUE FOR CHLOROPHYLL a, b, c AND CAROTENOIDS. DRY WEIGHT BIOMASS EXPRESSED AS gms / SLIDE	THIS SAMPLING GEAR WAS BASICALLY USED TO DEVELOP SAMPLING TECHNIQUES. VERY LITTLE DATA WERE COLLECTED
1969	ARTIFICIAL SUBSTRATES, GLASS SLIDES	INCONSISTENT FROM APR TO 9 JUL. 9 JUL THRU 30 OCT, BIWEEKLY	SAME AS 1968, EXCEPT ONE STATION ADDED 4 MILES BELOW DISCHARGE (14 TOTAL)	SAME AS IN 1968 FOR CELL COUNTS AND PIGMENT ANALYSIS. DRY WEIGHT BIOMASS EXPRESSED AS mg/cm ²	FINAL DESIGN OF SAMPLING GEAR WAS ACHIEVED BY ADDING A WIRE BRUSH RING ON UPSTREAM SIDE OF SAMPLER TO PREVENT DEBRIS CLOGGING
1970	ARTIFICIAL SUBSTRATES, GLASS SLIDES	ONE MONTHLY INCUBATION IN MAR UNDERNEATH ICE AND BIWEEKLY FROM 19 MAY THRU 7 NOV	SAME AS IN 1969	CELL COUNTS SAME AS IN 1969, CHLOROPHYLL a AND PHEOPHYTIN a BY TRICHROMATIC AND LORENZEN TECHNIQUES. DRY WEIGHT BIOMASS SAME AS 1969	LORENZEN TECHNIQUE INITIATED BECAUSE IT IS MORE ACCURATE AND FASTER THAN THE TRICHROMATIC TECHNIQUE. CELL COUNTS ONLY REPORTED FOR TWO TIME PERIODS
OPERATIONAL					
1971	ARTIFICIAL SUBSTRATES, GLASS SLIDES	MONTHLY IN FEB AND MAR UNDER ICE AND BIWEEKLY FROM 13 MAY THRU 28 OCT	13 STATIONS REMAINED THE SAME, DELETED ONE STATION BY HWY #25 BRIDGE AND ADDED 2 STATIONS (ONE IN DISCHARGE CANAL AND ONE ACROSS RIVER FROM IT)	CELL COUNTS AND DRY WEIGHT BIOMASS SAME AS IN 1970. CHLOROPHYLL a AND PHEOPHYTIN a BY THE LORENZEN TECHNIQUE ONLY	FIRST YEAR OF OPERATIONAL MONITORING. DROPPED THE TRICHROMATIC TECHNIQUE FOR PIGMENT ANALYSIS
1972	ARTIFICIAL SUBSTRATES, GLASS SLIDES	MONTHLY IN FEB AND MAR UNDER THE ICE BIWEEKLY FROM MAY THRU NOV	THE 3 FURTHEST DOWNSTREAM STATIONS DELETED (12 TOTAL STATIONS)	SAME AS IN 1971 EXCEPT ONLY CHLOROPHYLL a WAS ANALYZED FOR PIGMENT ANALYSIS	MADE RECOMMENDATIONS THAT DATA NEED NOT BE DUPLICATED AND SET GUIDELINES FOR STATISTICAL ANALYSES ON A REDUCED SCHEDULE
1973	ARTIFICIAL SUBSTRATES, GLASS SLIDES	BIWEEKLY FROM 5 APR THRU 3 NOV	REDUCED NUMBER OF STATIONS TO 7: ONE UPSTREAM CONTROL, ONE IN DISCHARGE, AND FIVE BELOW DISCHARGE	SAME AS IN 1972	NO WINTER SAMPLING BENEATH THE ICE BECAUSE PREVIOUS STUDIES SHOWED ESSENTIALLY NO GROWTH OR COLONIZATION
1974	ARTIFICIAL SUBSTRATES, GLASS SLIDES	BIWEEKLY FROM 9 MAY THRU 3 NOV	SAME AS IN 1973	SAME AS IN 1973	PERFORMED STATISTICAL ANALYSES ON THE DATA

medium, and fast currents, respectively. In addition, a thermal comparison was made since Stations 2, 7, and 9 were in water unaffected by the thermal plume while Stations 3, 6, and 11 were always in the plume (when the plant was operational).

BENTHIC MACROINVERTEBRATES

Benthic macroinvertebrates were sampled by NSP from 1968 through 1974 (Table 8) but we only evaluated data collected between 1969 through 1972 (two preoperational and two operational years). Usable data was obtained from annual monitoring reports, personal communication with NSP and their consultants, and a graduate dissertation. Data collected during 1968 were not used because sampling gear differed from that used in 1969-1974. In addition, data (percentages) reported in the 1973 and 1974 Annual Reports were inconsistent with those of 1969-1972 (numbers per station).

Similar stations and/or transects were not always given in each year. However, four transects were consistent in the years defined above (1969 to 1974). These included C1, C2, E1 and E2 even though up to eight transects were sampled at one time, or in one year.

In 1970, both a Surber net and concrete blocks were used because of the low numbers of stoneflies collected by the concrete blocks. We did not analyze this data because it was not consistent with the data reported from the other years.

Three other short-term (1 year) studies were not examined. These studies included: 1) a recolonization study to assess the effect of heat on growth rates, 2) an invertebrate drift study to determine both drift composition and vertical distribution, and 3) flying insect collection to determine if thermal gradients influence emergence or seasonality of these insects.

Since each study lasted 1 year, their utility lies in a supportive role to the long-term macroinvertebrate monitoring program. For example, the weekly recolonization study verified that monthly collections (in the monitoring program) were adequate to determine benthic colonizations in terms

TABLE 8. Summary of Macroinvertebrates Sampling and Analytical Methods

YEAR	COLLECTION METHOD	SAMPLING FREQUENCY	STATION LOCATION AND NUMBER	ANALYSIS PERFORMED	REMARKS
PREOPERATIONAL					
1968	HAND-NETTING ALONG SHORELINE	NOT KNOWN	5 RIVER SECTORS, 1 ABOVE AND 4 BELOW	CLASSIFICATION TO LOWEST TAXONOMIC LEVEL	QUALITATIVE STUDY PERFORMED FOR ONE YEAR ONLY
	STREAM BOTTOM SAMPLES (BULL (1968))	MONTHLY COLONIZATIONS JUL THRU NOV	7 STATIONS - 2 ABOVE AS CONTROLS AND 5 DOWNSTREAM FROM DISCHARGE AREA TO HIWAY #25 BRIDGE	SAMPLES WERE RETRIEVED, WASHED AND SEPARATED FROM ~22.5 m ² OF ROCKS / SAMPLE. ORGANISMS WERE THEN CLASSIFIED, COUNTED AND DRY AND WET WEIGHTS WERE MEASURED	SAMPLING GEAR WAS DETERMINED TO BE INADEQUATE DUE TO VARIABLE DEPTH AND CURRENT SPEED IN THE RIVER
1969	CONCRETE BLOCKS HAVING DIMENSIONS OF 31.6 x 31.6 x 8 cm WEIGHING ~18 kg BRITT (1955)	MONTHLY COLONIZATIONS IN FEB, MAY, JUN, JUL, AUG, SEP, OCT AND NOV	8 TRANSECTS WITH 1 - 4 STATIONS / TRANSECT AND 4 SAMPLES / STATION; 2 TRANSECTS ABOVE PLANT AS CONTROLS AND 6 BELOW	SAMPLES WERE RETRIEVED, WASHED AND SEPARATED FROM BLOCK IN THE FIELD. LABORATORY ANALYSES INCLUDED CLASSIFYING, COUNTING AND WEIGHING ORGANISMS BY AVERAGING 4 BLOCK DATA FOR WET AND DRY WEIGHT/ORGANISM AND TAXONOMIC GROUP	ADDED NEW STATIONS FROM 1968 (8 VERSUS 32) AND ELIMINATED THE QUALITATIVE HAND-NETTING
1970	CONCRETE BLOCKS	MONTHLY COLONIZATIONS AS IN 1969	SAME AS IN 1969	SAME AS IN 1969	LAST YEAR OF PREOPERATIONAL MONITORING
	SURBER NET	MONTHLY	SAME AS ABOVE EXCEPT 2 INTERMEDIATE DOWNSTREAM TRANSECTS DELETED	SAME AS ABOVE	DUE TO LOW NUMBER OF STONEFLIES COLLECTED BY CONCRETE BLOCKS, A SURBER NET WAS ALSO USED
OPERATIONAL					
1971	CONCRETE BLOCKS	MONTHLY COLONIZATIONS AS IN 1970	SAME AS IN 1970	SAME AS IN 1970	FIRST YEAR OF OPERATIONAL MONITORING. NO SURBER NET EMPLOYED
	CONCRETE BLOCKS	WEEKLY COLONIZATIONS FROM 19 JUL THRU 24 NOV	2 STATIONS - 1 CONTROL AND 1 EXPERIMENTAL. 5 SETS OF 4 BLOCKS / STATION AT EACH STATION. 1 SET OF 4 BLOCKS REMOVED WEEKLY	ORGANISMS WERE COUNTED, WEIGHED AND THEN GROWTH WAS DETERMINED FOR EACH WEEK	DESIGNED TO DETERMINE THE GROWTH AND RECOLONIZATION RATES FOR THE BENTHOS AT TWO STATIONS (ONE CONTROL AND ONE AT DOWNSTREAM END OF DISCHARGE CANAL)
1972	CONCRETE BLOCKS	MONTHLY COLONIZATIONS IN JUN, JUL, OCT AND NOV	DELETED 3 TRANSECTS (1 ABOVE AND 2 BELOW) LEAVING 1 ABOVE AND 4 BELOW	SAME AS IN 1971	REDUCE SAMPLING FREQUENCY AND INTENSITY
	CONCRETE BLOCKS	WEEKLY COLONIZATIONS FROM 15 APR THRU 21 JUL	SAME AS IN 1971	SAME AS IN 1971	COMPLETED 1 YEAR STUDY IN JUL ON GROWTH AND RECOLONIZATION RATES
1973	CONCRETE BLOCKS	MONTHLY COLONIZATIONS BEGINNING IN MAR	DELETED 2 MORE TRANSECTS BELOW DISCHARGE LEAVING 1 ABOVE AND 2 BELOW	SAME AS IN 1972	DELETED 2 MORE TRANSECTS LEAVING 3 WHEN 8 WERE PREOPERATIONALLY SAMPLED. ONLY ONE MONTH (MAR) DATA WAS REPORTED
	LIGHT TRAPS	DAILY COLLECTIONS	3 STATIONS, 1 ABOVE INTAKE, 1 ALONG DISCHARGE CANAL AND 1 BELOW DISCHARGE CANAL, ALL 3 ON SHORE	SAMPLES WERE CLASSIFIED, COUNTED AND WEIGHED. EACH MONTH OF DATA SEPARATELY. SUBSAMPLE WEIGHTS WERE PROJECTED TO REPRESENT THE WHOLE SAMPLE	STUDY CONTINUED FOR 1 YEAR TO DETERMINE REPRODUCTIVE PERIODICITY OF RIVER INSECTS AND POSSIBLE PREMATURE EMERGENCE. ONLY DATA FOR JUL AND AUG WERE REPORTED
	DRIFT CAPTURE NETS	BIWEEKLY FROM JUL THRU NOV WITH NETS SET FOR 24 HOURS	2 STATIONS, 1 ABOVE AND 1 BELOW PLANT	SAMPLES WERE CLASSIFIED, COUNTED AND WEIGHED AS TOTAL DRIFT/24 HOURS	NETS WERE STACKED VERTICALLY ON TOP OF EACH OTHER FROM BOTTOM TO SURFACE. DATA WERE REPORTED FROM ONLY 3 TIME PERIODS
1974	CONCRETE BLOCKS	MONTHLY COLONIZATIONS FROM FEB THRU JUL	SAME AS 1973 EXCEPT 3 NEW STATIONS ADDED IN DEC 1973	SAME AS IN 1973	ONLY DATA FROM FEB - JUL WERE REPORTED
	LIGHT TRAPS AND DRIFT NETS	SAME AS IN 1973 EXCEPT SAMPLED FROM FEB THRU JUL	SAME AS 1973	SAME AS IN 1973	COMPLETED BOTH ONE YEAR STUDIES

of adequate growth and colonization rates. The emergent insect survey confirmed a heat-induced seasonal shift in time hatch, but there was no apparent effect on insects after emergence.

IMPINGEMENT AND ENTRAINMENT

Studies of fish entrainment were conducted for approximately 1 full year during 2 calendar years (1973-1974) while impingement studies were begun in July of 1973 and data were available until December of 1974 (Table 10). We evaluated both sets of data as presented in NSP annual reports even though sampling periodicities were very uneven over the intervals of data collection and unusual patterns of "day of the week" data collections were made. Even though both factors might bias the data and our, or NSP's, subsequent estimates of daily mortality, the ultimate assertion of impact rests on information inherent in a population model of the species of interest. Thus, the population estimates made from electrofishing results (tag-recapture) would be of interest in this regard.

ELECTROFISHING

Results of these studies were reported in each of the years 1968-1969, 1971-1972 and 1973-1974 (Table 9). Unfortunately, the numbers of fish actually caught in each of five sectors were only reported in the first 2-year periods, while percentage distribution of the catch was reported in the second 2-year interval. In the 1973-1974 period, data were reported in graphic form by thermal zones and on a catch per effort basis. Thus, a statistical comparison among 2-year periods was not possible.

We were able to obtain the original electroshocking data sheets for all years from the applicant's consultant. The data could not be quantitatively evaluated because of the following reasons: 1) shocking times were not recorded for 1968, 2) no sector differentiation could be ascertained for 1969, 3) time intervals between sectors were inconsistent and varied (sometimes two-week differences), and, 4) inconsistent sector shocking pressure, i.e., some sectors had up to ten shocking runs, while others had as

TABLE 9. Summary of Fish Sampling and Analytical Methods

YEAR	COLLECTION METHOD	SAMPLING FREQUENCY	STATION LOCATION AND NUMBER	ANALYSIS PERFORMED	REMARKS
PREOPERATIONAL					
1968	ELECTROSHOCKING	INCONSISTENT - DATA COLLECTED IN AUG, SEP AND NOV	5 SECTORS WITH 1 ABOVE AND 4 BELOW PLANT SITE	CAPTURED FISH WERE MEASURED SOME WEIGHED AND SOME TAGGED. THOSE TAGGED FISH HAD SCALES REMOVED FOR AGE DETERMINATIONS	1800 FISH WERE TAGGED AND RELEASED. DATA REPORTED AS FISH/ELECTROFISHING HOUR
1969	ELECTROSHOCKING	INCONSISTENT BUT AT LEAST ONCE/MONTH FROM JUN THRU OCT	SAME AS IN 1968	SAME AS IN 1968, BUT USED SCHNABEL METHOD FOR POPULATION ESTIMATES	POPULATION ESTIMATES CALCULATED FOR ABUNDANT SPECIES
1970	SEINING	~BIWEEKLY FROM LATE MAY TO MID AUG	6 AREAS - 2 ABOVE AS CONTROLS AND 4 BELOW PLANT SITE	CAPTURED FISH ENUMERATED IN THE FIELD. LAB ANALYSIS INCLUDED: LENGTH, WEIGHT, AGE AND GENERAL CONDITION	NO ELECTROSHOCKING DATA REPORTED
OPERATIONAL					
1971	ELECTROSHOCKING	UNKNOWN DATA REPORTED FOR JUN AND SEP	SAME AS IN 1969	LENGTH AND WEIGHT MEASUREMENTS	LITTLE DATA REPORTED. NO SEINING DATA REPORTED
1972	ELECTROSHOCKING	AT LEAST ONCE/MONTH IN JUN, JUL AND AUG IN ALL SECTORS	5 SECTORS AS BEFORE BUT RUNS WERE OF EQUAL LENGTH ON RIGHT AND LEFT SIDES OF RIVER	FISH WERE ENUMERATED BY SPECIES. NO OTHER DATA REPORTED	DATA PRESENTED AS FISH CAPTURED/HOUR IN EACH SECTOR BY SAMPLING DATE
	SEINING	NOT REPORTED	8 STATIONS - 4 CONTROLS ABOVE AND 4 BELOW PLANTS	SEINED FISH WERE COUNTED SPRAYED WITH DYE FOR MARKING AND RELEASED. ONE HOUR AFTER RELEASE, STATIONS WERE RESEINED	NO DATA REPORTED IN 1972 ANNUAL REPORT
	STRATIFIED RANDOM CREEL CENSUS	RANDOM BETWEEN JUN-OCT	5 SECTORS AS IN ELECTROSHOCKING	A STRATIFIED-RANDOM CREEL CENSUS [NEUBOLD AND LEE (1957)] WITH STATISTICAL EVALUATION [ELLIOT (1971)]	DATA PRESENTED AS TOTALS OVER 4 MONTH TIME PERIOD. NO DATA BY SAMPLING DATES
1973	ELECTROSHOCKING	52 DATES BETWEEN 26 MAR AND 27 DEC	14 AREAS DEFINED AS SPAWNING LOCATIONS BOTH ABOVE AND BELOW PLANT	EACH FISH WAS MEASURED, WEIGHED AND TAGGED. SCALES REMOVED FOR AGE DETERMINATIONS AND VISUAL OBSERVATIONS ON SEX AND BREEDING CONDITION	DATA REPORTED AS MAPS OF SPAWNING AREAS AND TEMPERATURE PREFERENDAM CAPTURED FISH / SHOCKING HOUR NOT REPORTED
	SEINING	19 JUN, 1972 - 25 JUL, 1973	SAME AS IN 1972	SEINED FISH ENUMERATED AND CLASSIFIED. STATISTICAL ANALYSES REPORTED FOR PRE- AND OPERATIONAL DATA	DATA REPORTED AS TOTAL FISH / STATION FOR YEARLY TOTALS
	STRATIFIED RANDOM CREEL CENSUS	RANDOM BETWEEN 12 MAY-28 OCT	SAME AS IN 1972	SAME AS IN 1972	CONTINUATION OF 1972 STUDY
1974	ELECTROSHOCKING	WEEKLY FROM 6 APR TO 14 AUG	APPROXIMATELY 3 MILES ABOVE AND BELOW PLANT	SAME AS IN 1973. EXCEPT FISH WERE NOT TAGGED	DATA REPORTED IN A MASTERS THESIS
	STRATIFIED RANDOM CREEL CENSUS	RANDOM BETWEEN 1 JUN-3 NOV	SAME AS IN 1973	SAME AS IN 1973	CONTINUATION OF 1972-73 STUDY
	SEINING	WEEKLY FROM MID JUN THRU SEP IN BOTH 1973 AND 1974	3 SECTIONS WITH 4 STATIONS WITHIN EACH SECTION	SEINED FISH ENUMERATED AND CLASSIFIED WITH SUBSAMPLE BACK TO LAB FOR LENGTH, WEIGHT AND STOMACH ANALYSIS. MEASUREMENTS MADE ON SUB-SAMPLES GROWTH AND ABUNDANCE STATISTICS CALCULATED	A NEW YOUNG-OF-THE-YEAR STUDY INITIATED IN JUN 1973 AND TERMINATED IN SEP 1974
	IMPINGEMENT NET COLLECTION IN SLUICE CANAL	BIWEEKLY ON 33 DATES BETWEEN 11 JUL, 1973 AND 26 DEC, 1974	1 STATION IN SLUICE CANAL	ENUMERATED AND COUNTED IMPINGED FISH FOR 24 HOUR PERIODS ON SAMPLING DATES. CALCULATED SOME MORTALITY PERCENTAGES OF SLUICE CANAL VERSUS TRASH BASKET	NEW STUDY STARTED IN 1973 AND CONTINUED INTO 1974. PHYSICAL CONDITION BASED ON TEN MINUTE HOLDING PERIOD
	PENS (COLD SHOCK)	12-18 MAR 74. DUPLICATE EXPERIMENTS ON COLD SHOCK EFFECTS	NOT APPLICABLE	AT THE RATE OF 5°F EVERY 12 min., SIX INDIGENOUS FISH WERE SUBJECTED TO AN OVERALL DROP FROM 60°F TO 38°F IN ONE HOUR. FISH WERE OBSERVED AT 2, 12, 24, 36 AND 48 min. AND 1, 2, 5 AND 24 hr AFTER REACHING AMBIENT TEMPERATURE	A NEW STUDY INITIATED TO DETERMINE THE EFFECTS OF PLANT SHUTDOWN ON THE FISH POPULATION IN THE DISCHARGE CANAL DURING THE WINTER

TABLE 10. Summary of Entrainment Sampling and Analytical Methods

YEAR	COLLECTION METHOD	SAMPLING FREQUENCY	STATION LOCATION AND NUMBER	ANALYSIS PERFORMED	REMARKS
1972	LABORATORY-SIMULATION MODEL OF ENTRAINMENT	NOT APPLICABLE	4 TEST CHAMBERS TO SIMULATE CONDENSER TEMPERATURE RISES AND DISCHARGE CANAL DECREASES	FATHEAD MINNOWS WERE PASSED FROM ONE AQUARIUM TO ANOTHER FOR A PRESCRIBED TIME: 15 sec AT 7.2°C ΔT, 10-15 min. FOR A DROP IN TEMPERATURE. BACK TO ACCLIMATION TEMPERATURE AND THEN HELD FOR 7 DAYS AT ACCLIMATION TEMPERATURE FOR DELAYED MORTALITIES	TEMPERATURES AND HOLDING TIMES. SIMULATED PASSAGE THRU FIRST CONDENSER, SECOND CONDENSER, DISCHARGE CANAL AND RETURN TO AMBIENT CONDITIONS
	FIELD STUDY - DIP-NETTING AND SEINING	ONCE IN JUN, SEP, NOV, DEC AND FEB 1973	ENTIRE LENGTH OF DISCHARGE CANAL	INTRODUCED FATHEAD MINNOWS (36 - 60 mm) BETWEEN THE TRAVELLING SCREENS AND CIRCULATING WATER PUMPS AND RECAPTURED THEM IN THE DISCHARGE CANAL BY DIP NETTING AND SEINING. CAPTURED FISH WERE TRANSPORTED TO LIVE BOXES AT AMBIENT TEMPERATURE AND HELD FOR OBSERVATION AND EXAMINATION	FATHEAD MINNOW NOT INDIGENOUS TO STUDY AREA
1973-74	FISH COLLECTION NET	BIWEEKLY FROM SEP 73 - AUG 74	ONE STATION AT HEAD OF DISCHARGE CANAL	EACH SAMPLING TIME INCLUDED 6, 15 min. TO 3 hr FISHING TIME OVER A 24 hr PERIOD. FISH WERE PRESERVED, AND THEN WEIGHED, IDENTIFIED, ENUMERATED AND VISUALLY EXAMINED	THIS STUDY WAS DESIGNED TO EXAMINE NUMBER, KINDS AND SEASONAL OCCURRENCE OF NATURAL ENTRAINMENT. THE STUDY WAS NOT DESIGNED TO DETERMINE SURVIVORSHIP

few as two runs. We have again summarized these inconsistencies in the result section on fish and in a limited way in Table 9.

As in the studies above, we did attempt an analysis of each 2-year data set.

SEINING

Two collection periods were available to us, a preoperational study conducted from 26 May 1970 to 20 November 1970 and operational study done between 19 June 1972 and 25 July 1973 (Table 10). Nonuniformity of sampling stations was again a problem because only three were surveyed both times. Further the considerable time between studies and lack of catch per unit effort data makes statistical analysis questionable. Nevertheless since a preoperational study was conducted, we attempted a statistical evaluation of the data.

CREEL CENSUS STUDY

We did not evaluate these data because data were only available for operational years and results from a creel census were used for fishing pressure and catch estimates.

COLD SHOCK STUDY

Our evaluation of this study was qualitative because adequate population size, and field mortality values were not available.

VI. PREDICTED IMPACTS AND TECHNICAL SPECIFICATIONS

VI. PREDICTED IMPACTS AND TECHNICAL SPECIFICATIONS

The Environmental Technical Specifications for the Monticello Nuclear Generating Plant have not been finally approved at this writing. A draft has been submitted by Northern States Power Company and is currently being studied by NRC. The draft is divided into five broad categories, which include sections on definitions, limiting conditions for operation, environmental surveillance, special surveillance programs, and administrative controls. Only a portion of Section 3, Nonradiological Surveillance, (Appendix A) is relevant to our study. This section gives the type, duration, methodologies and rationale for monitoring programs to be carried out at Monticello.

Since final Environmental Technical Specifications have not been issued, we used the draft document for the purposes of our study. The absence of final Technical Specifications did not interfere with the analysis of the extensive monitoring data base (3 years preoperational and 5 years operational). This long-term accumulation of monitoring information prior to Environmental Technical Specifications development was used as justification for a lesser required monitoring effort.

The objective stated in the draft of the Environmental Technical Specifications is the evaluation of impact of plant operation on the biotic community. Monitoring is required in 3 biotic communities: periphyton, benthic macroinvertebrates, and fish. Requirements for periphyton sampling call for one upstream control station and four stations below the plant outfall, one of which is located outside of the thermal plumes. Biweekly samples are to be collected unless hazardous ice or water conditions prevail. Benthic macroinvertebrates sampling calls for two transects to be investigated for potential effects, one upstream of the plant and one 75 m below the discharge canal. Each transect is to have at least three stations equidistant from each other with four concrete blocks comprising a station. Monthly sample collections are required. Fish populations are to be sampled primarily by electroshocking and seining with trapnetting augmenting these two methods.

A creel census is to be performed between May and November to determine the quality of fishing. In addition to the above programs a biweekly fish census is to be conducted to determine fish species distribution and abundance in the discharge canal during the winter months. This data is to be used to predict potential impacts from winter shutdowns (cold shock) and is to be conducted in accordance with Contention II-23 dated 23 October 1974.

In addition to studying effects on the three biological communities, impingement and entrainment programs are to be carried out for at least 2 years after the Technical Specifications are approved. Impingement studies are to be conducted every 2 weeks when the plant is operating and fish entrainment studies are to be conducted from May through August and aquatic insects from May through October. Mortality estimates are to be made on both fish and insects. These data are to be compared with an appropriate control station, to determine effects of impingement and entrainment.

Water quality is also to be studied at three locations on a quarterly basis to determine its effect on the aquatic communities. Sampling stations are situated 100 ft above and below the plant, with a third station in the discharge canal. The parameters to be monitored on a quarterly basis are as follows: dissolved oxygen, BOD, pH, conductivity, turbidity, current velocity, TDS, total phosphate, ortho-phosphate, nitrate-nitrogen, chlorides, iron and sulfates. Temperature at the intake and discharge is to be continually recorded by the plant computer system.

Predicted FES impacts for Monticello include: 1) alteration of the benthic macroinvertebrate populations in a 5-15 acre area on the plant side of the river, due to the thermal plume, 2) creation of a potential source for cold shock mortality for fish attracted to the discharge canal, and 3) potential mortalities of up to 15% for drifting organisms due to entrainment. These programs are addressed in the draft Technical Specifications, but since final Technical Specifications have not been approved or implemented we cannot determine whether these Technical Specifications will be responsive to the predicted impacts. However, based on our evaluation of the monitoring programs conducted at Monticello between 1968 and 1974, the draft Technical Specifications basically call for a continuation of those programs.

The question that needs answering then is: Have the impacts predicted in the Environmental Statement been verified by the data collected from the monitoring programs? Generally speaking the answer has to be no; however, each program should be evaluated separately. The benthic macroinvertebrate program could have detected large changes if they occurred because this program had reasonably good design and collected both preoperational and operational data sets. The periphyton chlorophyll-a analysis showed no statistically significant differences. However, qualitative examination of the data suggested some possible changes, but these had to be rejected on the basis of inconsistencies in the data. Regressions of periphyton count data on distance did show some significant relationships, but these were seasonally dependent on lower total periphyton in an area near the discharge. Without preoperational data sets for comparisons the meaning of these changes is difficult to interpret. Fish studies were evaluated for changes due to operation of the plant but could not be quantitatively assessed because of incomplete and apparently biased monitoring and poor population estimates. Reasons specific for individual fish studies can be found in the appropriate result section. While most of the monitoring programs were usually not designed to answer the question posed above, some programs (i.e., benthic macroinvertebrate) were well designed and more intensive sampling might have detected changes. If more consideration was given to a sampling design that is statistically oriented, which tries to differentiate between natural variation and plant induced effects, then answers to predicted FES impacts could possibly be attained through a highly quantitative Environmental Technical Specifications.

VII. ANALYSIS OF MONITORING DATA

VIII. ANALYSIS OF MONITORING DATA

THERMAL MONITORING

Three programs provided data for thermal analysis. Each was designed for different purposes and consequently these data must be evaluated separately. The first program, thermal survey, was used to evaluate the accuracy of model prediction (page 32). The second program, water quality temperature monitoring, was evaluated to determine: 1) distribution of excess heat downstream of the discharge, and 2) as support data to impact considerations. The periphyton temperature data (the third program) were examined for usefulness as a covariable to evaluate thermal effects on the biota.

THERMAL SURVEY RESULTS

Even though data from 13 of 34 runs were available for examination, only a few of these relate to thermal plume model predictions. For purposes of our evaluation the following cases were considered:

1. Summer, 4000 cfs river flow, cooling tower operation in the helper mode.
2. Summer, 1200 cfs river flow, cooling tower operation in the helper mode.
3. Summer, 1200 cfs river flow, once-through cooling.
4. Winter, 500 cfs river flow, once-through cooling.

For Case 1 the results of the model prediction are shown in Figure 18 [taken from the Environmental Report, Figure V-2, pg. V-5, employing the method of Asbury and Frigo (1971)]. Results from the thermal survey are shown in Figure 19 (taken from Supplement 1 to the Environmental Report). A constant value (11°F) was used for excess discharge temperature in all calculations with helper tower cooling. For once-through cooling, the excess discharge temperature employed for model calculations was 26.8°F.

Comparing Figure 18 and 19, one observes that the model predictions are considerably below the survey results for the far field. Even when adjusted for the difference in excess discharge temperature, the far field predictions are about 1/2 of the measured far field maximums (far field being considered as 3 miles downstream). It should be noted that the usual summer excess discharge temperature is closer to 13°F than the 11°F employed in the model. The areal extent of the surface excess temperature isotherms is also greater for the survey results than for the model predictions, particularly in the far field. This case is purported to be the usual summer case.

The model predictions for Case 2 are shown in Figure 20 (taken from the Environmental Report, Figure V-5, pg. V-8). Likewise the survey measurements for this case are shown in Figure 21 (taken from Supplement 1 to the Environmental Report). The conditions in Case 2 are supposedly an unusual summer condition because of the low river flow (1200 cfs). Comparison of the results illustrated in the two figures indicates that the far field maximum surface temperatures are underpredicted by the model, as are the areal extent of the isotherms. The "unusually" low summer flow (near 1140 cfs) persisted for nearly 2 months during the summer of 1971, so the results illustrated in Figure 21 are the rule for that summer rather than the exception.

The normal cooling mode for summer operation is with the cooling towers in operation. (An agreement between Northern States Power Company and the State of Minnesota requires the operation of the cooling towers whenever the ambient river temperature exceeds 68°F). However, should the cooling towers become inoperable during the summer, and the plant remains operating, the cooling mode would be once-through. The Environmental Report gave model predictions for a once-through cooling mode and a low summer river flow (1200 cfs). The predicted surface isotherms for this case (Case 3) are shown in Figure 22. A thermal survey made on 8/19/71 (Supplement 1 to the Environmental Report) gave temperature distributions for the conditions of Case 3; the results are shown in Figure 23. A comparison of the results shown in Figures 22 and 23 indicates good agreement, both in downstream maximum excess temperatures and in isotherm areal extent. This case, however, is considered unique because once-through cooling is unlikely to occur at unusually low river flow.

FIGURE 18. Surface Temperature Rise Predictions, August Average Flow, Helper Tower Operation

FIGURE 19. Thermal Survey Surface Temperature Rise of 6/22/71, A River Flow of 4224 cfs, and an Excess Discharge Temperature of 14.2°F

FIGURE 20. Surface Temperature Rise Predictions, August, Low Flow, Helper Tower Operation

FIGURE 21. Thermal Survey Surface Temperature Rise for 8/13/71, a River Flow of 1140 cfs, and an Excess Discharge Temperature of 11.3°F

FIGURE 22. Surface Temperature Rise Predictions, August, Low Flow, Open Cycle Operation

FIGURE 23. Thermal Survey Surface Temperature Rise for 8/19/71 a River Flow of 1142 cfs, and an Excess Discharge Temperature of 24.9°F

The final case, Case 4, is for normal winter operation, i.e., river flow about 3500 cfs, and once-through (open cycle) cooling. Unfortunately, the model predictions available were for a river flow of 2500 cfs, Figure 24. The nearest survey case is shown in Figure 25, and is for a river flow of 3840 cfs. The comparison should be fairly accurate, since the river velocities and mixing characteristics are not greatly different at these flows. A comparison of the model predictions (Environmental Report, Figure V-4, pg. V-7) to the survey results (Supplement 1 to the Environmental Report) shows that the predicted maximum far field excess temperatures are higher than those surveyed, as are the isotherm areas. This may be attributed to the containment of the effluent by the surface ice, to the difference in river flows noted above, or most likely to the lack of model consideration of heat transfer to the atmosphere.

In general, the model predictions are not representative of the river surface thermal distribution. The failure of observed and predicted data to agree indicates that the model was not sufficiently grounded in the physical principles to allow accurate prediction at conditions other than those for which phenomenological data already existed. Since little information is available concerning the manner in which the model was assembled, specific recommendations for model improvement cannot be made.

FIGURE 24. Surface Temperature Rise Predictions, January-February, Average Flow, Open Cycle Operation

FIGURE 25. Thermal Survey Surface Temperature Rise for 2/23/72, a River Flow of 3840 cfs, and an Excess Discharge Temperature of 29.3°F

WATER QUALITY TEMPERATURE MONITORING RESULTS

Weekly temperatures were measured at nine stations to characterize the preoperational and operational thermal nature of the river downstream of the discharge point. The stations were sited near the southwest shore where temperatures were likely to be the highest. Weekly reporting of data does not allow maximum use for model verification. However its principal purpose was in support of thermal impact predictions. The usefulness of the data is hindered by a considerable amount of missing measurements. As a tool for model verification, the data near the discharge are unacceptable because the temperatures were recorded near the bottom of the river rather than at the surface. Since there is significant stratification near the discharge, temperatures were not the maximum in the plume. The vertical temperature structure of the river at several close cross-sections is shown in Figure 26, taken from the thermal survey of August 13, 1971 (Supplement 1 to the Environmental Report). Considering these cross-sectional profiles one notes that the river remains somewhat stratified

FIGURE 26. Vertical Thermal Structure at Downstream Cross-Sections

until Transect 3, some 500 feet downstream from the discharge point. This means that the true maximum plume temperatures were not measured in the water quality program until at least Station 4. Even then, this is uncertain because the lateral positions of the temperature sensors (i.e., the distances from the shore) were not reported.

Because of the above factors, the water quality program temperatures were probably less than the maximum plume temperatures. For purposes of this analysis the reported water quality program temperature data have been averaged over each month and are presented in Appendix B for 9 months. The data for the preoperational years 1969 and 1970 are offered as control data and the ordinate temperatures are the differences between the reported values at Stations 3 through 9 and that of Station 2 (control station). When examining these data, note that the plant may not have been operating during certain periods. The data for March, August, and September are in Figures 27, 28 and 29. Since the plant did not begin operation until May of 1971, the 1971 data for March are actually preoperational values. The data shown in Figure 27 compare well with the data offered earlier for the winter condition, although there may be a small amount (1-2°F) of suppression from maximum plume temperatures since the sensors are located offshore by some unknown distance. Likewise, the data for August 1971 agree with the low flow thermal survey data presented in the prior section. The data offered in Figure 29 for September also support the survey results presented for summer 1971 conditions when the cooling towers were in full operation. The figure further suggests that the plant operated in open cycle in September of 1972. If temperatures at downstream Stations 6 through 9 are elevated more than 9° or 10°F above the Station 2 values, one may assume that the cooling mode is once-through with a reduced cooling water flow (less than 640 cfs). (Such cases seem to have occurred in October and November of 1972, see Appendix B). The data offered in Appendix B may be considered representative of the excess bottom temperatures likely to be encountered in future years provided the current cooling mode patterns are continued.

FIGURE 27. Excess Temperature Compared to Station 2 for March

FIGURE 28. Excess Temperature Compared to Station 2 for August

FIGURE 29. Excess Temperature Compared to Station 2 for September

PERIPHYTON TEMPERATURE MONITORING

The temperature data presented in the periphyton monitoring program are of limited value for model verification or thermal impact support. For the purposes of this study only the data from the upstream (control) Station 2, the canal Station 3A, and the downstream stations within the plume, 3, 6, and 11 are of concern. Temperature data collected in conjunction with the periphyton study are given in Table 11. Only cases when there are data for at least Stations 2 and 3A and when there was a near normal plant load are included in Table 11. This data is represented as dimensionless excess temperature ratios in Table 12. Although the sample size is small, thermal characteristics of the plume as it progresses downstream are readily evident. Taking averages at Stations 3, 6, and 11 for the summer (June, July, August), autumn (September, October), and winter [November, January (one record), February (one record)] may help to characterize the thermal plume; the averaged excess temperature ratios are as follows:

TABLE 11. Periphyton Monitoring Excess Temperature, °F
(Relative to Station 2)

<u>Date</u>	<u>Control</u>	<u>3A</u>	<u>Heated Stations</u>		
	<u>2</u>		<u>3</u>	<u>6</u>	<u>11</u>
7/09/71	73.9	11.0	8.1	6.1	3.1
8/05/71	68.0	12.1	5.0	4.0	3.1
9/30/71	59.9	19.8	6.3	6.1	5.4
10/14/71	53.2	14.8	2.2	7.2	---
10/28/71	51.4	13.0	0.0	1.8	---
5/09/72	53.6	30.6	3.6	2.7	3.2
5/22/72	68.0	13.0	2.3	2.3	3.2
6/05/72	70.0	11.0	2.5	3.2	3.2
6/19/72	67.6	16.6	5.8	3.8	5.6
7/04/72	69.6	12.8	5.2	5.4	4.7
8/15/72	75.6	14.9	3.1	5.4	4.7
9/01/72	69.8	11.7	0.9	2.7	2.7
9/18/72	63.5	29.7	---	7.2	8.1
10/03/72	53.6	32.4	---	---	7.2
10/16/72	43.7	40.5	5.4	10.8	7.2
11/01/72	39.2	30.6	4.5	8.1	7.2
11/28/72	32.0	38.0	3.1	12.1	4.1
1/16/73	32.0	36.0	---	14.9	---
2/16/73	32.0	39.6	---	15.3	---
5/22/73	63.3	22.9	7.4	8.3	8.5
6/05/73	68.9	20.7	8.1	6.3	6.3
7/02/73	75.2	11.2	6.3	4.5	5.4
7/17/73	75.2	10.8	4.5	3.6	4.5
8/14/73	73.8	10.1	4.1	2.5	3.2
8/28/73	72.5	14.8	5.9	2.9	3.6
9/11/73	65.7	26.1	9.5	8.6	7.7
9/24/73	62.8	21.8	6.1	5.2	5.4
10/09/73	63.5	11.3	5.4	5.4	5.4
11/09/73	33.8	35.1	6.5	13.0	8.1
11/23/73	37.4	30.6	11.2	10.4	7.2
5/23/74	57.2	16.2	7.2	3.6	3.6
6/25/74	70.7	9.9	2.7	2.7	2.7
7/09/74	80.6	8.1	1.8	1.8	3.6
7/23/74	78.8	9.0	3.6	3.6	4.5
8/05/74	72.1	10.3	2.7	3.1	3.1
8/20/74	77.0	9.9	4.5	4.5	3.6
9/04/74	62.6	23.2	7.0	6.3	6.3
9/19/74	64.9	27.4	6.7	6.7	6.7
10/16/74	46.4	28.4	7.2	---	---
10/31/74	51.8	28.8	9.0	7.2	7.2

Excess temperature ratio for:

Summer - Station 3 = 0.34

Station 6 = 0.34

Station 11 = 0.35

Autumn - Station 3 = 0.25

Station 6 = 0.30

Station 11 = 0.27

Winter - Station 3 = 0.19

Station 6 = 0.35

Station 11 = 0.21

The summer measurements show the plume excess temperature ratio is nearly constant over the three stations. The autumn measurements show the plume excess temperature ratio being reasonably constant although the possibility of stratification at Station 3 and the effects of increased atmospheric heat exchange between Station 6 and Station 11 are exhibited. Stratification or considerable lateral displacement off the plume center-line are indicated by the winter measurements. Similarly, increased winter atmospheric heat transfer may be indicated by the results for Station 11. The above results are considered preliminary and unsupportable since little is known concerning the distances from the shore to the measurement stations and because of the sparsity of data.

The excess temperature ratios offered above for each season may be used as gross approximations to the downstream temperatures, however the results from either two previously discussed monitoring programs are better suited to this purpose.

TABLE 12. Periphyton Excess Temperature Ratios,
($\Delta T_C / \Delta T$)

Date	Station		
	3	6	11
7/09/71	0.74	0.56	0.28
8/05/71	0.42	0.33	0.25
9/30/71	0.32	0.31	0.27
10/14/71	0.15	0.49	----
10/28/71	----	0.14	----
5/09/72	0.12	0.09	0.11
5/22/72	0.18	0.18	0.25
6/05/72	0.23	0.30	0.30
6/19/72	0.35	0.23	0.34
7/04/72	0.41	0.42	0.37
8/15/72	0.20	0.36	0.31
9/01/72	0.08	0.23	0.23
9/18/72	----	0.24	0.27
10/03/72	----	----	0.22
10/16/72	0.13	0.27	0.18
11/01/72	0.15	0.26	0.24
11/28/72	0.08	0.32	0.11
1/06/73	----	0.42	----
2/16/73	----	0.39	----
5/22/73	0.32	0.36	0.37
6/05/73	0.39	0.30	0.30
7/02/73	0.56	0.40	0.48
7/17/73	0.42	0.33	0.42
8/14/73	0.41	0.25	0.32
8/28/73	0.40	0.20	0.24
9/11/73	0.37	0.33	0.30
9/24/73	0.28	0.24	0.25
10/09/73	0.48	0.48	0.48
11/09/73	0.18	0.37	0.23
11/23/73	0.36	0.34	0.24
5/23/74	0.44	0.22	0.22
6/25/74	0.27	0.27	0.27
7/09/74	0.22	0.22	0.44
7/23/74	0.40	0.40	0.50
8/05/74	0.26	0.30	0.30
8/20/74	0.45	0.45	0.36
9/04/74	0.30	0.27	0.27
9/19/74	0.24	0.24	0.24
10/16/74	0.25	----	----
10/31/74	0.31	0.25	0.25

Note: $\Delta T_C = T_{3,6,11} - T_2$

$$\Delta T_O = T_{3A} - T_2$$

T_i = Temperature at Station i

Note: The 1974 average operating load was about 88% of the 1973 average operating load.

ECOLOGICAL PROGRAMS

BENTHOS

Introduction

Benthic data were evaluated using three different statistical approaches: 1) an "overview" of the entire data set via an analysis of variance, 2) a ratio approach suggested by Eberhardt (1976), and 3) a nonparametric procedure to test for statistically significant changes due to position (station) or time. The entire set of count data is listed by organism, station, and time in Appendix C. In addition, total counts and percentage of total accounted for by organism are also in Appendix C for the 2 years when total macroinvertebrates were reported. Appendix C also contains complete ratio data sets in both arithmetic and logarithmic units and the ratios are again listed by organism, station, and time. It should be noted that statistical tests were run on data sets when a large number of comparisons were made so that some of the significant results ($P < .05$) were to be expected.

Control-to-experimental station ratios were calculated based on what we believe would have been the a priori choices because of common position in the river (i.e., see sampling plan in Figure 8 and the associated discussion of Section V). Further, we did not use data from any station more than once, in an effort to approximate statistical "independence." In addition, one station ratio (E2L/E2E) was used in our analysis based on the report that heated water did not reach the left side of the river (Hopwood, 1975) and that the benthos therein were unaffected by reactor operations.

Overview (Analysis of Variance)

While missing data problems are not unusual in ecological field studies, reference to the original count data in Appendix C illustrates two additional complications. First, the number of sampling stations within a transect were unequal and data are missing in an irregular pattern. The second complication arose because certain downstream (within transect) stations were always in the thermal plume, some were in the plume only part of a year, while others were never in the plume (Table 13).

TABLE 13. Thermal Status of Stations Within Transects

(1) Even though Transect E1 is closer to the discharge canal than E2, E2 is in the intermediate discharge area. These descriptions of discharge are given in: Effects of a Heated Discharge on the Ecology of the Mississippi River, (316(a) Type I Demonstration on the Monticello Nuclear Generating Plant, Monticello, Minnesota) p 110. Prepared by NUS Corporation, Pittsburgh, PA.

Since some of the factors or effects were "nested" or observed within another effect, the analysis of variance used was a nested and crossed, model (Table 14) with the complications introduced as discussed above. Because of the extreme imbalance in the data, we were unable to apply any of the usually available computer programs (i.e., BMD, SPSS, STATPK, etc.) to this problem. However, a computer routine appropriately acronymed MAD (Modified Abbreviated Doolittle), was obtained from Brigham Young University, to compute the necessary analyses of variance. When large

TABLE 14. Statistical Model Used as an "Overview"
of Each Macroinvertebrate Group

Effect	Symbol	Range
Operational Status	A_i	$i = 1, 2$
Year Within {Preoperational Period Operational Period}	$B_{j(i)}$	$j = 1, 2, 3$
Months	C_k	$k = 1-8(2, 5, 6, 7, 8, 9, 10, 11)$
Transect Location {Upstream Downstream, In Plume Downstream, Not In Plume}	D_l	$l = 1, 2, 3$
Site Within {Upstream Downstream, In Plume Downstream, Not In Plume} Transect	$F_{m(l)}$	$m = 1, 2, 3, 4$
Two Factor Interactions	Symbol	
Operational Status x Months	$(AC)_{ik}$	
Operational Status x Transect Location	$(AD)_{il}$	
Operational Status x Site Within Transects	$(AF)_{im(l)}$	
Year Within Operational Status x Months	$(BC)_{jk(i)}$	
Year Within Operational Status x Transect Location	$(BD)_{jl(i)}$	
Year Within Operational Status x Site Within Transects	$(BF)_{jm(il)}$	
Months x Transect Location	$(CD)_{kl}$	
Months x Site Within Transects	$(CF)_{km(l)}$	
Error	All Other Interactions	

amounts of data are missing the magnitude of various effects is dependent on the order which variables are entered; significance may also be affected. Thus, in the results reported in Table 15, variable C (months) was forced to enter each analysis first because we found it consistently affected estimates of other effects. We used the common logarithm of the observed count data plus one to obtain the results shown in Table 15.

TABLE 15. Results of Analysis of Variance of Abundance
for Six Macroinvertebrate Groups Reported

Effect(1)	Organism					
	Caddisflies		Midges Chironomini	Black Flies Simuliidae	Mayflies	
	Hydropsyche and Cheumatopsyche	Macronemum			Stenonema	Baetis
A_i			?	*		
$B_{j(i)}$						*
C_k	*	*		*	*	*
D_l		?				*
$F_m(2)$	*	?	*	*	*	
$(AC)_{ik}$						
$(AD)_{il}$						
$(AF)_{im}(2)$				*		
$(BC)_{jk(i)}$	*	*	*	*	*	*
$(BD)_{jl(i)}$					*	
$(BF)_{jm(il)}$						
CD_{kl}		*				
$CF_{km}(2)$	*	*		*		*
Error Variance	0.51	0.89	0.53	2.07	0.77	0.37
Number of Observations	262	161	267	263	257	221

* Always significant ($P < 0.05$) regardless of the ordering of input variables

? Significance ($P < 0.05$) dependent on the ordering of input variables

(1) See Table 9 for the meaning of these symbols.

The datum of interest, used to detect changes in population numbers due to plant operation, is the operational status by transects interaction term (AD). However, this interaction was not significant ($P < 0.05$) for any of the organisms studied, while the operational status by site within transects interaction (AF) term was only statistically significant for Simuliidae. Reference to the calculated error variances shows that this organism exhibited a value not in accord with those for the other macroinvertebrates studied. One reason for this larger variance is suggested below.

Among the main effects studied, site within transects, F, and months, C, were often both statistically significant ($P < 0.05$) for each benthic organism. This result would have been predicted by most field ecologists as would the significant interactions observed for months by year within the operational or preoperational periods (BC). Thus, our statistical analysis was unable to detect a change due to plant operation but the statistically significant location and time differences one would normally expect were present. When interpreting the analysis above, several notes of caution seem advisable. First, the F-tests were calculated assuming a random effects model (even though all effects were not random) with expected mean squares and degrees of freedom approximated as shown by the example calculations in Tables 16 and 17 (Guenther, 1964). Secondly, reference to Appendix C shows that considerably fewer observations were available for most macroinvertebrates (particularly for control stations) during 1972-1973. Therefore, most of the statistical analysis was based on two preoperational (1969, 1970) and one operational year (1971). In some of the tables and figures which follow, we indicate specifically where the amount of operational data appeared to be inadequate.

TABLE 16. An Example of the Calculation of One Interaction F-Test

- TEST σ_{CF} (MONTHS x SITE WITHIN TRANSECTS)

$$^1_{EMS} \sigma_{CF} \sim \sigma_E^2 + 0.550 \sigma_{CF}^2 = 2.422$$

$$^2_{EMS} \sigma_E \sim \sigma_E^2 = 0.959$$

$$F(19, 177) \sim 2.422/0.959 = 2.526^{**}$$

- ESTIMATE σ_{CF} (NEEDED FOR THE CALCULATION OF OTHER TESTS)

$$0.959 + 0.550 \hat{\sigma}_{CF}^2 = 2.422$$

$$\hat{\sigma}_{CF}^2 = 2.66$$

** = SIGNIFICANT AT 0.01 LEVEL

$^1_{EMS}$ = EXPECTED MEAN SQUARE

2_E = ERROR

TABLE 17. Schematic Example Calculation of Degrees of Freedom for F-Tests

GIVEN M_i = INDIVIDUAL MEAN SQUARES

$$M' = \sum_i a_i M_i$$

WHERE M_i HAS n_i DF

a_i IS MULTIPLIER

$$M \sim \chi^2(n')$$

$$\text{WHERE } n' = \frac{(M')^2}{\sum_i \frac{(a_i M_i)^2}{n_i}}$$

Nonparametric Tests

Because of the skewed characteristics of benthos count distributions, we used the common logarithm plus one of the data in the analysis of variance previously discussed. In order to examine the data in the absence of a distributional assumption, Wilcoxon's Signed Rank Test was used to compare control and experimental stations for each macroinvertebrate reported. Our assumption that the various data sets are from the same unknown distribution seems reasonable, but we doubt that the serial observations in time (even though benthos colonized new concrete blocks each month) can be assumed to be uncorrelated random variables.

Results of our comparison of individual stations (Table 18 and Table 19) gives an overall summary of the findings. Reference to the column labeled P (Table 18), under the macroinvertebrate Baetis, shows that there were statistically significant ($P < 0.05$) differences among stations in the preoperational (C1C versus E1C and C2R versus E2R) and operational (C1L versus E1L and C2R versus E2R) periods. Further, the four associated rank sums were all positive (column labeled s) with respect to the control station, indicating that control numbers were significantly higher than numbers enumerated at the corresponding experimental stations. The summarized results for Baetis in Table 20 indicate that two control stations had significantly (probability for significance relaxed to 0.10, thus an increased Type II error) higher numbers of Baetis during the preoperational period compared to counterpart downstream stations and this difference remained unchanged during reactor operation. In contrast, numbers of Baetis observed at two other control stations were statistically indistinguishable from counterpart downstream stations during operation even though they had been significantly different during the preoperational period. The final station comparison (E2L versus E2E) showed no significant change during either period. Further, other statistically significant changes similar to those for Baetis occurred for other macroinvertebrates. However, the overall results in Table 19 show a nearly equal total number of significant changes during preoperational and operational periods and a predominance of no significant changes. This supports the conclusion that there is no demonstrable overall effect (or

impact) on the benthic community due to the operation of the Monticello Plant. However, we again were able to show statistically significant ($P < 0.05$) differences in numbers of benthic organisms between stations on both the same and different transects (Table 18). This latter point is illustrated graphically in Figure 30, using only the C1 transect data, where we show that counts for certain stations in the transect are consistently higher or lower during portions of the 3-year period depicted.

TABLE 18. Comparison of Station Macroinvertebrate Counts Using Wilcoxon's Signed-Ranks Test

Organism	Station Comparisons		Preoperational 1969-1970			Operational 1971-1973			Operational and Preoperational 1969-1973		
	Control	Plume	(n)	(P) ⁽²⁾	(s) ⁽¹⁾	(n)	(P)	(s)	(n)	(P)	(s)
Caddisfly	C1C vs. E1C		7	0.45	+	3	0.59	(3)	10	0.68	+
Macronemum	C1L vs. E1L		6	0.91	-	3	0.29	(3)	9	0.59	+
	C2R vs. E2R		9	0.01	+	3	1.00	(3)	12	0.01	+
	C1R vs. E1R		4	0.07	-	3	0.11	(3)	7	0.02	-
	E2L vs. E2E		6	0.05	+	3	0.11	(3)	9	0.01	+
Mayflies	C1C vs. E1C		12	0.03	+	5	0.23	+	17	0.02	+
Baetis	C1L vs. E1L		10	0.09	+	5	0.04	+	15	0.01	+
	C2R vs. E2R		11	0.01	+	7	0.02	+	18	0.0004	+
	C1R vs. E1R		10	0.06	+	5	0.89	+	15	0.08	+
	E2L vs. E2E		9	0.72	+	6	0.46	+	15	0.41	+
Stenonema	C1C vs. E1C		12	0.16	+	5	0.29	-	17	0.43	+
	C1L vs. E1L		11	0.37	-	5	0.36	+	16	0.69	-
	C2R vs. E2R		13	0.14	-	10	0.41	-	23	0.12	-
	C1R vs. E1R		11	0.01	+	5	0.18	+	16	0.003	+
	E2L vs. E2E		5	0.22	+	8	0.26	+	13	0.09	-
Blackflies	C1C vs. E1C		12	0.05	+	5	0.47	-	17	0.21	+
Simuliidae	C1L vs. E1L		11	0.72	-	5	0.42	-	16	0.52	-
	C2R vs. E2R		9	0.58	-	6	0.50	-	15	0.40	-
	C1R vs. E1R		9	0.11	-	5	0.72	-	14	0.13	-
	E2L vs. E2E		8	0.01	+	5	0.04	+	13	0.002	+
Midges	C1C vs. E1C		12	0.41	+	5	0.69	+	17	0.34	+
Chironomini	C1L vs. E1L		1	0.42	+	5	0.50	+	16	0.28	+
	C2R vs. E2R		7	0.13	+	11	0.72	-	18	0.41	+
	C1R vs. E1R		11	0.93	+	5	0.22	+	16	0.61	+
	E2L vs. E2E		10	0.11	+	9	0.16	+	19	0.03	+
Caddisflies	C1C vs. E1C		12	0.21	-	5	0.14	-	17	0.07	-
Hydropsyche and	C1L vs. E1L		11	0.05	-	5	0.08	-	16	0.01	-
Cheumatopsyche	C2R vs. E2R		13	0.81	-	7	0.74	-	20	0.74	-
	C1R vs. E1R		11	0.01	-	7	0.02	-	18	0.001	-
	E2L vs. E2E		10	0.01	+	8	0.01	+	18	0.0003	+

(1) "s" is the sign of the rank sum associated with the control group.

(2) "P" is the two tailed probability of the observed rank sum.

(3) Too few observations.

TABLE 19. Comparison of Preoperational and Operational Macroinvertebrate Counts Using Wilcoxon's Signed-Ranks Test

Macroinvertebrate Organism	Number of Station Comparisons Where Preoperational Controls Had				
	Significantly Greater Numbers ($P < 0.10$) and Remained so During Operation	Significantly Greater Numbers ($P < 0.10$) but Were Not so During Operation	Significantly Lower Numbers ($P < 0.10$) and Remained so During Operation	Significantly Lower Numbers ($P < 0.10$) but Were Not so During Operation	No Significant Change
Macronemum	(1)	(1)	(1)	(1)	(1)
Baetis	2	2	--	--	1
Stenonema	--	1	--	--	4
Simuliidae	1	1	--	--	3
Chironomini	--	--	--	--	5
Hydropsyche and Cheumatopsyche	<u>1</u>	--	<u>2</u>	--	<u>2</u>
TOTAL	4	4	2	0	15

(1) Not enough data during operation.

FIGURE 30. Illustration of Statistically Significant Differences Among Control Stations for Hydropsyche and Cheumatopsyche

Both because of limited numbers of observations available during the operational period (Table 18) and because we could not assess the magnitude of station differences by the Wilcoxon test used, the conclusion above is considered tentative. For example, even though we showed that the preoperational Baetis population was significantly ($P < 0.01$) higher at C2R compared to E2R (Table 18) and that it remained significantly higher during reactor operation, the counts from C2R might be for example, twice as numerous as those at E2R preoperationally, in contrast to say four times higher during operational periods.

Analysis of Benthos Station Ratios

Eberhardt (1976) has proposed a pseudodesign in which preoperational data on a site and a control area are compared to operational data on both areas, thus allowing replication in time to substitute for replication in space. In order to take advantage of such replication and to provide a means to circumvent the objection in the section above, we have calculated the ratios of stations (selected as discussed in the section above) where nonzero values occurred at both stations. The calculated ratios appear in Appendix D along with a stem and leaf display (Tukey, 1976) for each organism. A key to the nomenclature of stem and leaf displays is found on page 2 of Appendix D. Clearly, on the arithmetic scale observations are skewed toward the origin. Further, it appears that Hydropsyche and Cheumatopsyche exhibit the largest ratios. However, when the same data are presented as logarithms (Appendix D) the distributions become much more symmetric and seem to contain fewer "outliers". Thus, it appears that a logarithmic transformation of benthos count ratios can be supported visually as well as theoretically (i.e., the distribution of the ratio of two log-normally distributed random variables should also be lognormal). Some further discussion of ratios with reference to radionuclides is in Thomas, et al. (1976) while the book by Chayes (1971) offers some additional ideas when correlations are present.

The results of an individual one-way analysis of variance (ANOVA) for each control/site station ratio, where each year is considered a treatment, are in Table 20. The ratio of Simuliidae counted at stations E2L and E2E were significantly different ($P < 0.05$) in operational year 1971 compared to the two preoperational years (1969, 1970). We believe the wide difference in mean ratios for Simuliidae (Table 20) is reflected in the discrepant variance calculated for this organism in Table 15. No other statistically significant results are formed in Table 20 and thus no evidence for a change due to operation of Monticello is provided. Finally, we have plotted (Figure 31) the entire data set for all five station ratios by times observed using the family Simuliidae to assess possible seasonal (or monthly) effects and to visually appraise the possibility that we could increase the discriminatory ability (power) of our test by comparing all preoperational to operational station ratios. Even though nearly twice as many operational ratios are less than unity (8 versus 5) while the preoperational ratios are almost evenly divided (29 versus 22), it would require a large number of additional samples to discriminate between the two periods. Even if a statistically significant difference could be detected, it appears from the figure that the result would probably be ecologically meaningless because the prospective difference would be numerically very small.

Table 22 was prepared to circumvent any influence that season-of-the-year (month) might exert (by inflating estimates of error variance in the one-way ANOVAS above) and to avoid the problems inherent in an unbalanced analysis of variance generally. In Table 22, the mean of 1969 and 1970 preoperational ratios were compared to the mean of the 1971 and 1972 station operational ratio for each month (if one observation was available it was used as a mean value). We then calculated the algebraic sign of the mean preoperational-operational value and reported the summary in Table 22. There was a nearly equal distribution of positive and negative signs, again supporting the conclusion of no significant changes in the benthic community resulting from the operation of the Monticello plant.

TABLE 20. Results of Macroinvertebrate One-Way Analysis of Variance for Logarithms (Base 10) of Control/ Site Station Ratios Where Years are Treatments

Organism	Years Observed	Number of Ratios	F Value	Probability	Range of Yearly Means			
					Log 10		Antilog	
					Minimum	to Maximum	Minimum	to Maximum
<hr/> C1C/E1C <hr/>								
Macronemum	1969-1971	10	2.34	0.16	-0.463	0.316	0.344	2.070
Baetis	1969-1971	16	1.30	0.31	0.157	0.592	1.435	3.910
Stenonema	1969-1971	16	0.84	0.45	-0.005	0.302	0.989	2.000
Simuliidae	1969-1971	17	1.15	0.35	-0.214	0.392	0.611	2.470
Chironomini	1969-1971	17	0.76	0.93	0.079	0.147	1.198	1.401
Hydropsyche and Cheumatopsyche	1969-1971	17	0.81	0.46	-0.196	-0.031	0.637	0.932
<hr/> C1L/E1L <hr/>								
Macronemum	1969-1971	9	0.40	0.69	-0.280	0.163	0.524	1.040
Baetis	1969-1971	14	1.30	0.31	0.137	0.451	1.370	2.830
Stenonema	1969-1971	16	1.74	0.22	-0.330	0.258	0.468	1.810
Simuliidae	1969-1971	15	0.16	0.85	-0.209	-0.042	0.617	0.908
Chironomini	1969-1971	16	0.28	0.76	0.051	0.183	1.150	1.520
Hydropsyche and Cheumatopsyche	1969-1971	16	0.38	0.69	-0.346	-0.198	0.451	0.634
<hr/> C2R/E2R <hr/>								
Macronemum	1969-1971	11	1.72	0.24	-0.190	0.535	0.644	3.420
Baetis	1969-1972	17	0.90	0.47	0.310	0.764	2.040	5.800
Stenonema	1969-1972	21	1.08	0.39	-0.292	0.151	0.511	1.410
Simuliidae	1969-1971	12	0.03	0.97	-0.521	-0.205	0.301	0.624
Chironomini	1969-1972	17	0.26	0.85	-0.087	0.171	0.819	0.674
Hydropsyche and Cheumatopsyche	1969-1971	20	0.08	0.93	-0.166	-0.054	0.682	0.883
<hr/> C1R/E1R <hr/>								
Macronemum	1969-1971	7	0.15	0.86	-0.778	-0.583	0.166	0.279
Baetis	1969-1971	14	0.15	0.86	0.0846	0.212	1.215	1.639
Stenonema	1969-1971	15	0.04	0.97	0.3533	0.410	2.256	2.570
Simuliidae	1969-1971	12	1.73	0.23	-1.019	-0.098	0.096	0.798
Chironomini	1969-1971	16	1.04	0.38	-0.0515	0.198	0.888	1.576
Hydropsyche and Cheumatopsyche	1969-1972	18	0.70	0.57	-0.4856	-0.196	0.326	0.637
<hr/> E2L/E2E <hr/>								
Macronemum	1969-1972	9	0.19	0.90	0.439	0.802	2.750	6.310
Baetis	1969-1972	14	0.08	0.97	0.109	0.493	1.290	3.110
Stenonema	1970-1972	11	0.61	0.57	0.088	0.328	1.230	2.130
Simuliidae(1)	1969-1971	8	6.99	0.04	0.540	1.381	3.470	24.050
Chironomini	1969-1972	18	0.54	0.66	0.043	0.390	1.100	2.470
Hydropsyche and Cheumatopsyche	1969-1972	18	1.68	0.22	0.212	1.057	1.620	11.220

(1) Note the wide range of mean ratios on arithmetic scale. This may partially explain the large variance in Table 9.

FIGURE 31. Time Series of Station Ratios for Simuliidae

TABLE 21. Comparison of Station Logarithmic Count Ratios by Month for Preoperational and Operational Years

Station Ratio	Month	Macronemum				Average of 1971 and 1972 Relative to 1969 and 1970	Baetis				Average of 1971 and 1972 Relative to 1969 and 1970
		Preoperational		Operational			Preoperational		Operational		
		1969	1970	1971	1972		1969	1970	1971	1972	
C1C/E1C	5	0.12	-.385								
	6		-.602	-.778		-	.829	.257	1.501		+
	7						.240	.092	1.161		+
	8	.429	-.176	-.954		-	.239	-.129	-.078		-
	9	.506	.182	.342		-	.196	.448	.384		+
	10							.280	-.010		-
	11										
C1L/E1L	5										
	6	-1.494	-.602				.771	.407	.444		-
	7		-.176	-.398		-	.574	.358	.621		+
	8	.139		.410		+	.362		.402		+
	9	.514	-.041	.477		+		-.231	.488		+
	10						-.164	.012	.301		+
	11										
C2R/E2R	5	.439									
	6	.133	.342				.596	.580	.107	.368	-
	7	1.380	.301	.097		-	.114	-.170	.439		+
	8	.301	.114	-.477		-	.074	.536	.232		-
	9	.419	1.279				.378	.702	.597		+
	10						.449	2.170	.176	.903	-
	11										
C1R/E1R	5										
	6							.743	-.197		-
	7			-.176			.361	.359	.859		+
	8	-.504	-.267	-1.255		-	.274	.294	.044		-
	9	-.602	-.978	-.903		-	.275	-.102	-.232		-
	10						-.182	-.234	-.051		+
	11										
E2L/E2E	5										
	6		.348		.602	+		-.454	-.510	.109	+
	7		-.602	.903		+		-.331	-.557		-
	8	.359	.727	.681		+	-.101	.180	.646		+
	9	1.246	1.283				.496	1.437	.778		-
	10						.836	1.635	1.1969		-
	11										

TABLE 21. Continued

Station Ratio	Month	Stenonema				Simuliidae			
		Preoperational		Operational		Preoperational		Operational	
		1969	1970	1971	1972	1969	1970	1971	1972
					Average of 1971 and 1972 Relative to 1969 and 1970				Average of 1971 and 1972 Relative to 1969 and 1970
C1C/E1C	5								
	6	.778	-.243	.602	+	1.370	.529	.417	-
	7	.426	-.398		+	.027	-1.169	-.729	-
	8	.119	-.176	-.602	-	.084	-.267	-1.358	-
	9	.033	.138	-.022	-	.342	.434	.000	-
	10	.153	-.151		-	.574	.509	.602	+
	11		.954			-.043	.145		
C1L/E1L	5								
	6	1.279	-.602	.176	-	.848	.742	.219	-
	7	.929	-.564	.269	-	.080	-.079	-.360	-
	8	-.022			+	-.178		-.371	-
	9	-.071	-.417	-.084	+	.051	-.954		
	10	.036	.647	.301	-	-.398	-.278	.301	+
	11	-.602	-.653			-.653	-.477		
C2R/E2R	2		-.477	.349	+				
	5	.352		-.380	-	-4.000		-1.583	+
	6	.301	.331	.204	-	-.583	.410	.329	+
	7	-.041	-.028	-.222	-	.266	.000	-.903	-
	8	-.176	-.681	-.602	-	-.383		.073	+
	9	-.339	-.456	.439	+				
	10	-.176	-.439	-.067	+	1.398			
C1R/E1R	11					.467			
	5								
	6		.021	.439	+		-.298	.422	+
	7	.125	.760	.882	+	1.301	-1.176	-.283	-
	8	.176	.352	-.187	-	-.347	-.699	-.669	-
	9	.322	.347	.118	-	-1.000		-.505	+
	10	.865	.128	.769	+		-1.903		
E2L/E2E	11		.512			-.345			
	5		-.114	-.125	.090	+			
	6		.163	.255	+		.751	1.487	+
	7		-.090	-.021	+			1.276	
	8		.873	.150	-	.820	.301		
	9		.809	.182	-		.806		
	10								
	11					.336	.301		

TABLE 21. Continued

Station Ratio	Month	Chironomini				Hydropsyche and Cheumatopsyche			
		Preoperational		Operational		Preoperational		Operational	
		1969	1970	1971	1972	1969	1970	1971	1972
		Average of 1971 and 1972 Relative to 1969 and 1970						Average of 1971 and 1972 Relative to 1969 and 1970	
C1C/E1C	6	.655	.514	.453	-	-.040	-.395	-.044	+
	7	-.016	-.224	.193	+	-.060	-.214	.136	+
	8	.167	.161	-.295	-	.019	-.004	-.326	-
	9	.185	.388	-.038	-	-.178	.123	-.222	-
	10	-.064	.053	.080	+	-.133	.084	-.524	-
	11	-.267	-.013			-.528	.222		
C1L/E1L	6	.432	.336	.086	-	-.343	-.561	-.328	+
	7	.170	.043	.854	+	.123	-.142	.092	+
	8	.275	-.081	.284	+	.167		-.364	-
	9	-.043	.048	-.149	-	-.195	-.138	-.602	-
	10	-.218	.028	-.163	-	-.215	-.631	-.527	-
	11	-.311				-.727	-.062		
C2R/E2R	2		-.748	-.669	+		-1.843	-1.289	+
	5			.245		.403		-.144	-
	6	.171	.234	.253	.043	.185	.027	-.136	-
	7		.022	.029	+	-.235	-.197	-.160	+
	8		.294	-.052	-	.109	-.049	-.034	-
	9		.050	-.243	-	-.127	.469	.444	+
	10		.178	-.170	.092	-.233	.604	.157	-
	11				-.022	-.480			
C1R/E1R	6		.064	.315	+		-.378	-.613	-.261
	7	.569	.053	.611	+	.102	-.295	-.139	-
	8	-.267	.107	-.088	-	-.362	-.113	-.372	-
	9	.065	.138	-.044	-	-.276	-.529	-.925	-
	10	-.227	-.245	.194	+	-.345	-.498	-.378	-.131
	11	-.397	.062			-.823	-.012		
E2L/E2E	6		.240	.429	.481		-.015	.258	.373
	7		.151	.720			.290	.502	
	8	-.196	.453	.327		.519	.735	.758	
	9	.255	1.178	.270		1.272	1.598	1.853	
	10	.335	.451	-.314	-.008	1.367	1.224	1.454	.094
	11	.496	-.132		-.345	1.072	.785		.170

TABLE 22. Comparison of Preoperational and Operational
Logarithmic Macroinvertebrate Ratios

<u>Organism</u>	Number of Times the Average Logarithm of 1971 and 1972 (Operational) Ratios Compared to the Average of 1969 and 1970 (Preoperational) Ratios Were:	
	<u>Positive</u>	<u>Negative</u>
Macronemum	5	8
Baetis	11	13
Stenomena	13	14
Simuliidae	8	10
Chironomini	12	14
Hydropsyche	12	15
Cheumatopsyche		

Summary

We have subjected the benthic data available to us to statistical analysis from three separate perspectives. The results of an analysis of variance, Wilcoxon's Signed-Ranks Test, and a ratio evaluation indicate no significant changes in benthic fauna from the operation of the Monticello Power Station. If short-term changes, such as earlier emergence were present, our analysis did not detect these effects.

PERIPHYTON

Introduction

Unlike the benthic data, very little preoperational periphyton count data were available. Thus, our comparisons among various periphyton species were based on counts from heated and control stations only during periods of reactor operation. Three such control and heated "matched" stations were defined by Knutson (1973). Following his definitions, we refer, in this and the following section, to Stations 2, 7, and 9 as ambient or control stations and Stations 3, 11, and 6 as heated or plume stations. Further, in 1971 sampling was initiated at Station 3A, near the mouth of the discharge canal. Details of sampling station locations are in Figure 9. The complete data set for the stations discussed above, is listed by species, station, and time in Appendix E. In addition, a graphic depiction of total periphyton counts across time for each station is also in Appendix E.

Even though considerably more species were enumerated by the consultants for Northern States Power Company, counts were quantitatively evaluated for the 12 species listed in Appendix E because they usually constituted the majority of organisms enumerated. Table 23 illustrates the apparent exceptions by showing data for three stations where the 12 selected species represented less than 75% of the total count [26 sampling times (Table 23) of the possible 46 sampling periods shown for total periphyton in Appendix E]. However, only on 12 sampling dates of the 26 listed, denoted by an X in Table 23, were there large (arbitrarily greater than 15,000 organisms/cm²) numbers of periphyton counted. Thus, in a few cases large numbers of "seasonal" periphytic organisms were observed (cf. data of Stations 3 and 6, 10/2/74, Table 23) at times when the 12 selected species were not as abundant. Table 24 shows that of the 26 occurrences when less than 75% of the total count was analyzed, 24 were in March-May or the early fall. Therefore, it is possible that in the analyses which follow failure to detect effects on excluded organisms which were abundant only during cooler periods of the year may have occurred.

TABLE 23. Times When Less than 75% of the Total Periphyton
Were Accounted for by the Twelve Species Considered

Station	Date	Total 12 Species	Total Species	Fraction Counted	Large ⁽¹⁾ Numbers
2	7/22/71	421,437	1,050,021	0.4014	X
	5/22/72	4,670	12,754	0.3662	
	10/26/73	2,800	3,760	0.7447	
	11/09/73	120	240	0.5000	
	5/22/74	694,535	1,031,978	0.6730	X
3	10/28/71	0	51,191	0	X
	5/22/72	640	2,080	0.3077	
	10/03/72	2,600	4,620	0.5628	
	10/17/72	5,220	12,630	0.4133	
	9/11/73	6,020	8,060	0.7469	
	9/25/73	35,458	71,580	0.4954	X
	10/09/73	11,120	18,080	0.6150	
	11/09/73	120	640	0.1875	
	5/22/73	355	533	0.6660	
	9/19/74	376,700	695,640	0.5415	X
	10/02/74	95,840	176,432	0.5432	X
6	10/28/71	1,988	18,886	0.1053	X
	5/22/72	300	1,200	0.2500	
	10/17/72	5,130	7,130	0.7195	
	3/03/73	867	1,467	0.5910	
	5/22/73	8,820	15,220	0.5795	X
	9/25/73	38,160,540	60,720,900	0.6285	X
	11/09/73	480	720	0.6667	
	5/22/74	1,106	1,636	0.6760	
	10/02/74	102,300	1,938,700	0.0528	X
	10/16/74	275,500	510,300	0.5399	X

⁽¹⁾ X = > 15,000 for all species

TABLE 24. Periods of the Year When 75% or Less of the Total Periphyton Were Accounted for by the Twelve Species Considered

MONTH	YEARS			
	1971	1972	1973	1974
MARCH			6	
MAY		2 3 6	6	2 3 6
JUNE				
JULY	2			
AUGUST				
SEPTEMBER			3 3 6	3
OCTOBER	6		2 3	3 6 6
NOVEMBER	3	3 3 6	2 3 6	

* VALUES ENCLOSED IN REPRESENT THE HIGHER TOTAL COUNTS.

Wilcoxon's Signed-Ranks Test was used to statistically assess the 12 species for differences due to plant operation even though a significant finding might not be interpretable because no preoperational data were available (i.e., a control station may have a greater abundance of periphyton preoperationally than a counterpart heated station. This difference measured during operation may be attributed to the plant.) In addition, regression analyses of total periphyton counts using distance downstream from the discharge canal [Station 3A; Knutson (1973)] as the dependent variable were used to evaluate the operational data. The bases for using gradients of environmental insult in the analysis of environmental stressors are found in Thomas and Eberhardt (1975) and Eberhardt (1976).

Wilcoxon's Signed-Ranks Test

The three available heated versus control "matched" station comparisons evaluated using Wilcoxon's Signed-Ranks Test are given in Table 25 for the 12 selected species and for total counts of periphyton. A summary of these detailed results is in Table 26; two species were eliminated due to too few observations. All but two of the significant differences ($P < 0.10$ was selected for exploratory purposes) involved the comparison of Stations 11 and 2. Control counts (Station 2) were higher in four of five cases illustrated (Table 26). In the absence of preoperational data we speculate that these results could be meaningless because the other two heated versus control comparisons did not exhibit similar significant effects. Further, Station 11 was located far downstream (5300 ft) from the discharge canal where diminished effects were anticipated. Thus, the results cannot be considered definitive in establishing any cause and effect relationship.

In order to evaluate the magnitude of the findings above, the time series of signed differences between numbers of periphyton enumerated at plume and control stations [where significant ($P < 0.10$) in Table 26] are tabulated in Table 27. In terms of large numbers of organisms counted, it appears that many more Cocconeis placentula were found at Station 2 than at Station 11 in the summer of 1973. Values for Chroococcus minimus at Station 9 exhibited a similar pattern but no other station's comparisons appeared as consistent or involved such large numbers of periphyton. In the absence of

TABLE 25. Results of Wilcoxon's Signed-Ranks Test for Periphyton Numbers where Stations 3, 6, and 11 were Subjected to Thermal Additions

Species	Station Comparisons	Total Cases	Negative Rank Number	Negative Rank Sum	Positive Rank Number	Positive Rank Sum	2-Tailed Probability
Total	3 vs. 7	38	12	348	23	393	0.74
All	6 vs. 9	37	20	382	17	321	0.64
Species	11 vs. 2	34	16	301	18	294	0.95
Chroococcus minimis	3 vs. 7	18	5	55	12	98	0.31
	6 vs. 9	22	12	148	7	43	0.04
	11 vs. 2	24	12	141	12	159	0.80
Chroococcus minor	3 vs. 7	3	-----Limited Data Precludes Analysis-----				
	6 vs. 9	1	-----Limited Data Precludes Analysis-----				
	11 vs. 2	3	-----Limited Data Precludes Analysis-----				
Cocconeis placentula	3 vs. 7	29	16	232	10	120	0.16
	6 vs. 9	27	9	129	17	222	0.24
	11 vs. 2	29	18	298	11	137	0.08
Achanthes exigua	3 vs. 7	2	-----Limited Data Precludes Analysis-----				
	6 vs. 9	1	-----Limited Data Precludes Analysis-----				
	11 vs. 2	0	-----Limited Data Precludes Analysis-----				
Gomphonema parvulum	3 vs. 7	17	8	60	7	60	1.00
	6 vs. 9	14	5	33	8	58	0.38
	11 vs. 2	14	5	16	9	62	0.07
Achanthes lanceolata	3 vs. 7	6	3	7	1	3	0.47
	6 vs. 9	12	7	43	5	35	0.75
	11 vs. 2	6	5	19	1	2	0.08
Cybella asinuata	3 vs. 7	31	-----Limited Data Precludes Analysis-----				
	6 vs. 9	8	3	7	4	21	0.24
	11 vs. 2	6	5	15	0	0	0.04
Diatoma vulgare	3 vs. 7	10	4	18	5	27	0.59
	6 vs. 9	13	9	50	3	28	0.39
	11 vs. 2	15	12	100	3	20	0.02
Gomphonema olivaceum	3 vs. 7	4	-----Limited Data Precludes Analysis-----				
	6 vs. 9	5	-----Limited Data Precludes Analysis-----				
	11 vs. 2	8	5	18	2	10	0.50
Navicula gracilis	3 vs. 7	9	6	28	3	17	0.52
	6 vs. 9	12	4	23	7	43	0.37
	11 vs. 2	17	9	83	7	53	0.44
Navicula Cf. rhynchocephala	3 vs. 7	11	7	39	2	6	0.05
	6 vs. 9	13	4	44	4	22	0.33
	11 vs. 2	14	7	40	4	26	0.53
Synedra ulna	3 vs. 7	7	4	15	3	13	0.87
	6 vs. 9	15	7	66	7	40	0.41
	11 vs. 2	11	7	40	3	15	0.20

preoperational data quantitative interpretation of the operational counts was not possible, and we were unable to qualitatively demonstrate any meaningful changes due to the operation of Monticello Power Plant (Table 27).

TABLE 26. Summary of Wilcoxon's Signed-Ranks Tests for Periphyton Numbers

<u>Species</u>	Station Comparisons (Plume vs. Control) ⁽¹⁾		
	<u>3 vs. 7</u>	<u>6 vs. 9</u>	<u>11 vs. 2</u>
Total all species	0.74	0.64	0.95
<u>Chroococcus minimus</u>	0.31	0.04 ⁽²⁾ C	0.80
<u>Cocconeis placentula</u>	0.16	0.24	0.08 ⁽²⁾ C
<u>Gomphonema parvulum</u>	1.00	0.38	0.07 ⁽²⁾ P
<u>Achanthes lanceolata</u>	0.47	0.75	0.08 ⁽²⁾ C
<u>Cybella asinuata</u>	—	0.24	0.04 ⁽²⁾ C
<u>Diatoma vulgare</u>	0.59	0.39	0.02 ⁽²⁾ C
<u>Gomphonema olivacum</u>	—	—	0.50
<u>Navicula gracilis</u>	0.52	0.37	0.44
<u>Navicula cf. rhynchocephala</u>	0.05 ⁽²⁾ C	0.33	0.50
<u>Synedra ulna</u>	0.87	0.41	0.20

(1) Stations were matched on the basis of current and depth. Table values are two tailed probabilities of observing the rank sums in Table 26.

(2) Significant changes ($P < 0.10$) observed between test and control stations during reactor operation. Letter indicates whether control (C) or plume (P) organisms were more numerous.

TABLE 27. Signed Differences in Periphyton Numbers (cells/cm²) Between Control and Heated Periphyton Stations Found Significantly (P<0.10) Different by Wilcoxon's Signed-Ranks Test

Data	[Station 11 - Station 2]					[Station 3 - Station 7]	[Station 6 - Station 9]
	Cocconeis placentula	Gomphonema parvulum	Achnanthes lanceolata	Cybellia asinuata	Diatoma vulgare	Navicula cf. rhynchocephala	Chroococcus minimus
7/28/70	+74,695						
7/22/71	+323,831						
8/19/71	+264,354						
5/22/72					-280		
6/05/72	-3,887,600	+5,600					
6/19/72	-5,630,452	+23,058					-521,740
7/04/72	+1,500,004	+58,791		-996			+70,678
7/17/72	-12,853,792	+610		-5,950			+200,912
7/31/72				-5,900			
8/15/72							
9/01/72	-7,534,880	-664					-2,831,524
9/18/72	-22,450	+21,208					+2,200
10/03/72	-14,900				+100		
10/17/72	+980				-14,300	-430	
11/01/72					-1,200		
4/24/73					-1,000		
5/09/73					-599,160		
5/22/73					-903,475		
6/05/73	+59,000	+35,000			-2,020	-1,280	+76,000
6/20/73	-5,000,000						-300,000
7/02/73	-7,500,000	-4,299,760		-6,180,000			-6,000,000
7/17/73	-7,000,000						+19,000,000
7/31/73	-7,000,000	-80				+120	-19,000,000
8/14/73	+8,000,000						-24,000,000
8/28/73	-2,000,000						
9/11/73	-3,000,000						
9/25/73	+20,600,000				-197,880	-4,591,330	
10/09/73	+20,000				+12,970	-3,180	
5/22/74	-18,488				-43,100		
6/10/74	-4,160,000		-41,430	-71,760			+63,360
6/25/74	-183,672	+343,536	+17,006				-2,877,520
7/09/74	-367,344	+292,518	-45,920				-688,770
7/23/74	-61,200						-12,478,000
8/05/74	+20,400		-20,300				-2,230,400
8/20/74							-455,600
9/04/74	-69,000		-60,000			+6,700	-2,040,000
9/19/74	+95,200	+142,800	-17,000		-54,300	-13,500	+764,900
10/02/74					-135,900	-26,500	
10/16/74					+206,040	-91,800	
11/03/74					-15,300		

Regression Analysis

The common logarithms of total periphyton are tabulated by year, season-of-the-year (an arbitrary choice using 3-month periods) and distance from the discharge canal station in Appendix F. Examination of the mean values for increasing distances (parenthetical entries across the top of the tables) for both the summers of 1973 and 1974 indicated that regression analysis was a plausible analytical approach. Further, the summary for each year (at the bottom of each page in Appendix F) shows that the seasons (as defined) markedly differ in periphyton productivity, as expected, supporting a separate analysis for each season. In addition, it should be noted that

the reactor was "off" prior to or during several sampling periods. Examination of the results from all stations during various on/off periods revealed no discernible effect which could be separated from natural variation and/or "real" changes on different sampling dates.

A summary of two regression models fitted to log transformed total counts using distance from the discharge canal station as the dependent variable, is shown in Table 28. As illustrated by the calculated F-values, it would be difficult to choose between the linear and quadratic regression models when a significant ($P < 0.05$) relationship was found. It is clear that the counts from Station 3A must be included for summer, fall and entire year regressions for 1974 to obtain significant model parameters ($P < 0.05$) because probabilities are no longer at the critical value when this data point is excluded. In contrast, the results for the summer and total year regressions in 1973 remained statistically significant ($P < 0.05$) when the results from 3A were excluded, although the calculated F-values were smaller. Examples of the significant regression models are presented graphically in Figures 32-34 where the mean values for each station are plotted (Appendix F) rather than the individual data points used to fit the regressions. The 1972 linear regression relationship (fall, Figure 32) was statistically significant because of consistently small increases in counts with increasing distance from Station 3A. Clearly, the regression using all the data for 1973 (Figure 33) is influenced mostly by summer and spring counts while the 1974 overall regression (Figure 34) is seemingly an average of all three seasons.

TABLE 28. Summary of Regression Analysis of Total
Periphyton (cells/cm²) with Distance (ft)
from Monticello Nuclear Power Plant

Season	Linear Model				Quadratic Model			
	Including Plume Station		Excluding Plume Station		Including Plume Station		Excluding Plume Station	
	F(1)	P(2)	F	P	F	P	F	P
1972								
Spring	0.03	0.88	0.21	0.66	0.03	0.96	0.12	0.89
Summer	0.23	0.63	0.04	0.85	0.63	0.54	0.59	0.57
Fall	4.31	0.05	2.67	0.12	2.07	0.15	1.25	0.32
Complete Year	0.33	0.57	0.02	0.88	0.45	0.64	0.17	0.85
1973								
Spring	0.99	0.33	0.85	0.37	0.75	0.48	0.59	0.57
Summer	19.13	0.001	7.09	0.01	16.10	0.001	5.68	0.008
Fall	0.07	0.79	1.22	0.31	0.34	0.72	0.51	0.63
Complete Year	11.71	0.001	6.02	0.02	5.83	0.004	2.97	0.06
1974								
Spring	0.01	0.91	0.21	0.65	0.01	0.99	0.35	0.71
Summer	6.26	0.02	0.46	0.50	7.36	0.002	1.27	0.30
Fall	9.47	0.01	1.75	0.21	13.13	0.001	1.90	0.19
Complete Year	4.91	0.03	0.71	0.40	5.13	0.008	1.50	0.23

(1) F-value from regression analysis.

(2) Probability of a larger value of F due to chance.

FIGURE 32. Total Periphyton (Log₁₀) with Distance from Canal Station 3A for 1972 (cells/cm²)

FIGURE 33. Total Periphyton (Log₁₀) with Distance from Canal Station 3A for 1973 (cells/cm²)

FIGURE 34. Total Periphyton (Log_{10}) with Distance from Canal Station 3A for 1974 (cells/cm^2)

In order to statistically evaluate some of the effects of Station 3A counts on the regression models above, a one-way analysis of variance on each seasonal data set within years was performed (i.e., stations were considered treatments). The analysis was conducted on logarithmically transformed values and Duncan's Multiple Range Test was used to test for significant station differences for each season within years. The results in Table 29 show that total periphyton counts for Station 3A were significantly lower ($P < 0.05$) than counts for all other stations in three of the four cases where seasonal regressions were significant (Figures 31-33). Moreover, the significant regression calculated for the summer of 1973, when Station 3A was excluded, was partially due to low counts at Station 3 the next "downriver" station). Station 3 counts were also significantly ($P < 0.05$) lower than found for all other downriver stations. Thus, it appears that a large portion of the relationship between distance (stressor) and total periphyton was associated with the area near the discharge canal.

TABLE 29. Results from One-Way Analyses of Variance of Log-Transformed (base 10) Total Periphyton (cells/cm²)

Year	Season	Calculated F	Probability	Stations Significantly Different	Comments
1972	Spring	0.16	0.97	none	Limited numbers of observations, Station 3A
	Summer	1.16	0.36	none	
	Fall	0.74	0.61	none	
1973	Spring	1.96	0.13	none	
	Summer	6.59	0.001	3A<3<Rest	s ² for Stations 3A and 3 are significantly larger ($P < 0.05$)
	Fall	(1)	(1)	(1)	
1974	Spring	0.64	0.67	none	Only 1 observation, Station 7
	Summer	3.56	0.01	3A<Rest	s ² for Station 3A is significantly larger ($P < 0.05$)
	Fall	12.37	0.001	3A<Rest	

(1) Limited number of observations.

Summary

Analysis of periphyton data by species where comparisons of heated and control stations using Wilcoxon's Signed-Ranks test were made, provided little evidence of changes due to operation of Monticello Power Plant. However, because preoperational data were not available this observation is tentative and should be considered qualitative. Regression analysis indicated significantly lower total periphyton in the area near the discharge canal in some seasons. In addition, a one-way analysis of variance indicated that counts taken in the summer of 1973, 550 ft from the canal, were significantly lower than other downriver stations. Linear and quadratic regressions were usually not statistically significant if the data from Station 3A (in the discharge canal) were excluded.

PERIPHYTON PRODUCTIVITY (CHLOROPHYLL-a)

Introduction

In contrast to the periphyton abundance data where little preoperational data was taken, a complete year of preoperational (1970) chlorophyll-a (productivity) measurements were obtained. Thus, we utilized the ratio procedure (pseudodesign), explained in the section on benthos analysis for our statistical evaluation. In addition, sample replicates obtained in 1972 and 1973 enabled us to check the distributional assumptions for our statistical analysis of chlorophyll-a data measurements. Station locations, rationale for selection of those to be used in the statistical analysis of station ratios, and appropriate references are on page 87. The complete individual sample data set and the calculated statistics for replicate measurements are in Appendix G. Concurrent data on temperature and current velocity data were obtained on each periphyton sampling date. These data sets were used in an attempt to construct a multiple regression model with productivity as the dependent variable.

Overview of the Data Set

Mean and standard deviations calculated for the three heated (Stations 3, 6, and 11) and three-control stations (Stations 2, 7, and 9) are presented in Table 30, as well as the single determination for the discharge canal station (3A). These data are also illustrated in Figure 35. No differences attributable to reactor operations are readily apparent unless the few values in May, where means from heated stations appear to be consistently lower than those of control stations, were substantiated by additional observations. It appears that mean chlorophyll-a values are generally lower in spring but rise to a level in late June which is maintained until October (an expected finding). There is some visual evidence that mean values become more erratic in late September and October, perhaps reflecting the appearance or disappearance of seasonal species (see preceding section on periphyton abundance). The mean and standard deviations calculated for three replicate chlorophyll-a measurements (through slides at the same station) taken during 1972 and 1973 (Appendix G) are plotted in

Figure 36 in conjunction with a linear regression model fit to the observed data. The model suggests a constant coefficient of variation, in the range of 50% (with many deviations), which implies that the chlorophyll-a data are compatible with log-normal distribution.

TABLE 30. Average Chlorophyll-a ($\mu\text{g}/\text{cm}^2$) for Heated and Unheated Stations with Time

Date Sampled	Unheated (Sta. 2,7,9)		Heated (Sta. 3,6,11)		Discharge Canal (3A)	Date Sampled	Unheated (Sta. 2,7,9)		Heated (Sta. 3,6,11)		Discharge Canal (3A)
	Mean	Standard Deviation(1)	Mean	Standard Deviation(1)			Mean	Standard Deviation(1)	Mean	Standard Deviation(1)	
1970						1973					
5/19	1.07	1.04	0.35			2/16					0.80
5/29	0.91		0.23	0.11		3/5					0.83
6/12	1.45	0.98	0.54	0.30		4/24	3.81	2.97	3.00	0.90	3.30
6/26	3.26		1.36	1.17		5/9	2.42	0.95	3.90	1.61	1.44
7/11	1.18		1.33	0.61		5/22	0.97	0.73	0.86	0.10	1.94
7/28	1.19		1.39	0.12		6/5	1.37	1.46	1.18	0.74	0.08
8/11	1.41		1.26			6/20	2.58	0.45	2.91	0.62	1.33
8/26	2.14		2.07			7/2	2.84	0.33	2.48	0.22	0.48
9/8	2.18	0.38	2.00	0.24		7/17	2.90	0.54	2.37	0.10	0.16
9/24	3.24	1.60	2.17	0.75		7/31	1.89	0.42	1.92	0.22	0.42
10/6	1.57	1.21	1.53	0.71		8/14	2.23	0.17	2.16	0.17	0.68
10/20	6.89	6.15	6.71	3.96		8/28	1.61	0.67	1.86	0.80	0.07
11/7	8.69	4.86	8.35	5.77		9/11	2.10	0.14	2.37	0.20	0.18
1971						9/24	1.85	1.19	2.56	0.77	0.27
2/16	0.02		0.01			10/9	1.30	1.46	0.88	0.17	1.00
3/4	0.00		0.00			10/26					0.51
5/13	1.27	1.07	0.46	0.28	0.87	11/9	0.11	0.04	0.06	0.03	0.12
5/27	0.98	1.40	0.28	0.18	0.31	11/23	0.04	0.03	0.02	0.03	0.06
6/10	0.90	0.65	0.44		1.68	1974					
6/24	2.91	1.11	2.77	2.11	3.65	5/23	1.40		0.07	0.06	1.43
7/9	2.55		1.38	0.90	0.26	6/10	2.35		1.59	0.71	0.45
7/22	2.84		1.83	1.13	1.16	6/25	1.59	1.06	1.58	0.34	0.39
8/5	2.32	0.82	2.26	0.72	3.02	7/9	2.09	1.04	1.85	0.38	4.61
8/19	2.07	0.65	2.42	0.21	0.37	7/23	1.63	0.65	1.40	0.81	0.92
9/2	1.69	0.58	1.53	0.36	0.17	8/5	2.28	0.46	2.13	0.07	0.67
9/15	1.75	0.99	1.64	0.51	0.13	8/20	2.50	0.50	2.60	0.72	1.80
9/30	1.68	1.47	0.96	0.43	0.73	9/4	3.76	1.35	2.95	1.24	0.56
10/14	2.50	0.65	0.91	1.08	0.65	9/19	3.08	0.91	4.32	1.16	0.00
10/28	2.64		1.02		0.45	10/2	2.53	0.71	1.70	0.51	0.22
1972						10/16	3.79	1.63	4.31	0.94	0.00
5/22	0.44	0.34	0.12	0.10	0.36	10/31	4.36	1.43	3.09	0.89	0.89
6/5	0.40	0.28	0.36	0.10	0.21						
6/19	1.28	1.06	1.39	0.63	1.68						
7/4	1.95	0.51	1.83	0.48	0.21						
7/17	2.78	0.60	2.27	0.46	0.96						
7/31	2.81				3.35						
8/15	2.05				0.35						
9/1	2.96	2.64	0.95	0.17	0.81						
9/18	1.07	0.57	1.31	0.68	0.15						
10/3	2.16	0.93	2.77	1.58	0.04						
10/16	1.61	0.90	2.03	1.14	0.13						
11/1	1.31	0.51	6.54	2.09	0.03						
11/28	0.16				0.06						

(1) All three stations are reported when a standard deviation is recorded.

FIGURE 35. Comparison of Seasonal Relationship Between Mean Chlorophyll-a for Heated Stations (3, 6, 11) and Unheated Stations (2, 7, 9)

FIGURE 36. Mean Chlorophyll-a ($\mu\text{g}/\text{cm}^2$) for Three Replicate Slides Versus The Respective Standard Deviation

Ratio Tests

Both arithmetic and logarithmic ratios calculated for individual heated/control pairs as well as selected stem and leaf displays are in Appendix G. As found in the benthos analysis, the displays support the log transformation of ratios. Arithmetic and logarithmic means and other statistics are presented by year in Table 31. Even though the station arithmetic ratios, 3/7 and 11/2, for operational years were numerically larger than the preoperational year (1970) ratios, the statistical variation was too great for differences to be significant. This is shown in Table 32 where the results of a one-way analysis of variance on log transformed ratios are presented. Each station ratio was analyzed separately and no significant differences were detected between preoperational and operational years. Moreover, examination of the arithmetic means for the 3/7 station ratio (Table 31) indicates that only 1971 and 1973 exhibited ratios substantially higher than the 1970 values. Further examination of individual ratios (by date, Appendix G) for 1971 and 1973 shows several very large values which influenced mean values and caused the higher coefficients of variations shown in Table 31 (also examine individual values for the 11/2 ratio in 1973; Appendix G). The mean yearly values for the station ratio 6/9 (Table 31) generally declined compared to the 1970 mean. Thus, a definitive statement relating the operation of the Monticello Power Plant to periphyton productivity would have been impossible had the general, but not significant, trends discussed above been statistically validated, since changes relative to the preoperational year were inconsistent.

Multiple Regression Model

The best result obtained using stepwise multiple regression to devise a model of periphyton productivity is in Table 33. The percentage of explained variation was 63%, and occurred when a quadratic temperature term entered the equation. While this latter term appears to have no biological interpretation, the measured water temperature from one prior period could be explained. Apparently either more sophisticated models with additional variables, more precise data, or both will be needed to improve the model to a point where "projections" could be attempted to future years.

TABLE 31. Yearly Statistical Summary of Arithmetic and Logarithmic Ratios of Chlorophyll-a ($\mu\text{g}/\text{cm}^2$) for Heated/Control Station Ratios

	<u>Mean</u>	<u>Variance</u>	<u>Standard Deviation</u>	<u>Coefficient of Variation</u>	<u>Number of Observations</u>	<u>($\pm$) 95% Confidence Interval</u>
<u>Arithmetic Ratios</u>						
3/7						
70	1.32	0.53	0.73	55	8	0.16
71	2.56	15.44	3.93	154	10	2.81
72	1.82	2.31	1.52	84	10	1.09
73	2.01	4.12	2.03	101	15	1.12
74	1.49	1.69	1.30	87	10	0.93
6/9						
70	1.15	0.89	0.94	82	11	0.63
71	0.65	0.14	0.38	58	12	0.25
72	1.44	3.69	1.92	133	11	1.29
73	0.84	0.10	0.31	37	15	0.17
74	0.83	0.16	0.39	47	12	0.25
11/2						
70	0.63	0.13	0.36	57	12	0.23
71	1.09	2.13	1.46	134	12	0.93
72	1.23	1.01	1.01	82	10	0.72
73	2.51	20.84	4.57	182	15	2.53
74	1.09	1.39	1.18	108	12	0.75
<u>Logarithmic Ratios</u>						
3/7						
70	+0.057	0.068	0.261		8	
71	+0.131	0.235	0.485		10	
72	+0.141	0.110	0.332		10	
73	+0.171	0.096	0.311		15	
74	+0.089	0.061	0.248		10	
6/9						
70	-0.082	0.153	0.386		11	
71	-0.277	0.658	0.317		12	
72	-0.022	0.187	0.316		11	
73	-0.108	0.212	0.359		15	
74	-0.162	0.263	0.186		12	
11/2						
70	-0.310	0.154	0.392		12	
71	-0.453	0.658	0.811		12	
72	-0.066	0.187	0.433		10	
73	+0.090	0.217	0.461		15	
74	-0.161	0.263	0.531		12	

TABLE 32. Results from One-Way Analyses of Variance of Log Transformed (Base 10) Chlorophyll-a ($\mu\text{g}/\text{cm}^2$) for Heated/Control Station Ratios

Station Ratio	F-Test		Stations Significantly Different ($P < 0.05$)	Comments
	Calculated F	Probability		
6/9	1.08	0.38	none	Variances homogeneous
11/2	1.97	0.11	none	Variances homogeneous
3/7	0.18	0.95	none	Variances homogeneous

TABLE 33. Results from Fitting a Stepwise Multiple Regression Model to Periphyton Productivity Data

Chlorophyll-a Multiple Regression Model	
Variables Used	Best Results Were
Biomass = Chlorophyll-a	$R^2 = .63$
Current speed (ft/sec)	Temperature was lagged one sampling period
River temperature ($^{\circ}\text{C}$)	The square of temperature was used in the model
Dummy variable for month	
Time (day of year)	

Summary

No statistically significant differences in periphyton productivity were attributed to the operation of the Monticello Power Plant. Qualitative examination of the data suggested some possible effects but these were rejected on the basis of inconsistencies in the data. Our efforts to devise a multiple regression model to explain the productivity data were not successful enough to attempt extrapolations to future years.

FISH STUDIES

Introduction

Fish studies utilized electrofishing, seining and creel census procedures to assess species composition and/or population densities. Special studies of impingement, entrainment and cold shock were also initiated. A portion of the 1968-1969 electrofishing study was devoted to a tag-recapture assessment to obtain population estimates for several species. These estimates were also used as an aid in interpretation of a later cold-shock study conducted in 1974. We were unable to statistically evaluate most of the data from these studies for various reasons including lack of catch effort data in the preoperational electrofishing study and incomplete and biased monitoring for impingement and entrainment experiments. Additional specific problems are addressed for each study below, and some qualitative interpretations are offered where appropriate.

Electrofishing

The complete data set for 1973 and 1974 is listed in Appendix H. Explanation of the categories rough and game fish and some further detail are in Tables 34-37 where the data are presented in a different format and additional results for a few specific species are presented. Discharge areas used as headings are those defined by the State of Minnesota (see footnote Table 13). In addition, the available preoperational 1968 data are shown in Table 38. We were unable to assess these data because, a) no shocking times were given so no catch/effort calculations were possible, b) different sectors were shocked far apart in time, see the top of Table 38, and c) there was inconsistent fishing pressure in each sector, third title line of the same table. Electroshocking data for 1969 were reported as totals with no sector differentiation, so the second preoperational year of data was unusable for analysis. The rough fish catch/effort data for 1973 and 1974 are plotted in Figures 37 and 38 because we hoped to find a visually apparent relationship. While no consistent gradation in decreasing catch/effort of the control, outer, intermediate and immediate discharge areas was found, both yearly data sets indicate diminished rough fish catches in the

immediate area when compared to other areas. This result may be a consequence of the larger number of samples (Appendix H) obtained for these areas. Pre-operational data might have clarified this point. Too few measurements (i.e., no catch or small catch/effort values) were available for game fish to allow a similar qualitative visual appraisal. A portion of the tag-recapture data for smallmouth bass obtained during 1968-1969 and used to assess population size is presented in Table 39. Estimates for other species, usually based on a few more recaptures, are found in Hopwood (1970). The size estimates presented there and the final value (609) in Table 39 are of questionable reliability because the Schnabel method, applied by the consultant, assumes a constant population with no recruitment or mortality; hardly the situation in a usually fast-flowing river. The failure to correct for this assumption in a two-year study seems serious. Further, statistical bias (see Ricker, 1975, p. 79) results when either the number of fish marked and examined or the number of recaptures is low (less than 4 is suggested as low by Ricker (1975)). Finally even though the above limitations are ignored, no assessment of variability is presented for any of the population estimates. The intervals are quite large, for example, for smallmouth bass we have estimated the 95% confidence interval (using a Poisson approximation) as 238 to 2432 for the population value (609) given in Table 39. This latter result suggests that many more smallmouth bass should be marked and recaptured so a more reliable population estimate can be obtained; providing that the assumption that smallmouth bass neither emigrate, immigrate, die, or new fish are recruited over two years is even reasonably valid. Ricker (1975, p. 91) suggests the problem is tractable for some species of riverine fish but presumably over shorter time intervals.

**TABLE 34. Electrofishing Catch Per Unit Effort
(fish/hr) in the Sector "A" (Control)**

Species/year	Mar		Apr		May				Time Within Each Month									Jul				Aug						Sep			
	1	2	1	2	1	2	3	4	1	2	3	4	5	6	7	8	9	1	2	3	4	1	2	3	4	5	6	1	2	3	4
-----1973-----																															
Rough Fish ⁽¹⁾	86	120			116				122	141	42							46				90	25					61			
Game Fish ⁽²⁾	0	2			6				3	27	6							10				2	0					5			
Carp	8	26			44				78	99	18							10				38	25					14			
Smallmouth Bass	0	1			1				3	3	1							2				1	0					1			
Maximum Temp.°F	38	53			63				69	72	73							*				68	67					72			
Ambient Temp.°F	38	53			63				69	72	73							*				68	67					72			
Delta Temp.°F	0	0			0				0	0	0											0	0					0			
-----1974-----																															
Rough Fish	*	54	129	106	233	130	133	162	189									81	34			145	70								
Game Fish	*	0	1	1	7	2	49	36	12									6	6			7	14								
Carp	*	11	66	48	8	36	58	81	113									42	16			107	52								
Shorthead Redhorse	*	-	-	-	-	-	-	-	-									-	-			-	-								
Smallmouth Bass	*	0	1	0	7	2	6	1	1									4	4			2	12								
Maximum Temp.°F	*	40	49	54	50	50	65	68	65									75	78			77	76								
Ambient Temp.°F	*	40	49	54	50	50	65	68	65									75	78			77	76								
Delta Temp.°F	*	0	0	0	0	0	0	0	0									0	0			0	0								

* No Sample

(1) Rough fish species included: shorthead redhorse, carp, silver redhorse, black bullhead, barbot, brown bullhead and white sucker.

(2) Game fish species included: rock bass, black crappie, walleye, northern pike, pumpkinseed, smallmouth bass and bluegill.

**TABLE 35. Electrofishing Catch Per Unit Effort (fish/hr)
in the Outer Discharge Area (Along Shore Opposite
Discharge Canal)**

Species/year	Mar		Apr		May				Times Within Each Month									Jul				Aug						Sep			
	1	2	1	2	1	2	3	4	1	2	3	4	5	6	7	8	9	1	2	3	4	1	2	3	4	5	6	1	2	3	4
-----1973-----																															
Rough Fish ⁽¹⁾	*	*	*	274	253	98	225	150	71	153	76	104	174	24				181	79	160	93	154	98	47	49			60	54	145	90
Game Fish ⁽²⁾	*	*	*	0	0	0	0	53	8	12	11	0	14	0				0	0	0	0	0	11	0	0			13	0	0	0
Carp	*	*	*																												
Smallmouth Bass	*	*	*																												
Maximum Temp.°F	*	*	*	54	54	57	63	74	70	69	69	67	75	72				76	72	71	-	73	75	74	72			85	68	96	86
Ambient Temp.°F	*	*	*	54	54	57	63	73	70	69	69	67	75	72				73	70	70		72	74	74	72			68	67	66	64
Delta Temp.°F	*	*	*	0	0	0	0	1	0	0	0	0	0	0				3	2	1		1	1	0	0			17	1	30	22
-----1974-----																															
Rough Fish	*	46	87	126	251	142	150	223	162	264	171							41	53	47		120	97								
Game Fish	*	0	0	0	0	0	0	9	0	62	0							26	0	0		0	11								
Carp	*																														
Shorthead Redhorse	*																														
Smallmouth Bass	*																														
Maximum Temp.°F	*	42	45	53	52	49	58	60	68	66	69							79	82	80		71	74								
Ambient Temp.°F	*	42	45	53	52	49	58	60	68	66	69							76	80	80		71	74								
Delta Temp.°F	*	0	0	0	0	0	0	0	0	0	0							3	2	0		0	0								

* No Sample Taken

(1) Rough fish species included: shorthead redhorse, carp, silver redhorse, black bullhead, barbot, brown bullhead and white sucker.

(2) Game fish species included: rock bass, black crappie, walleye, northern pike, pumpkinseed, smallmouth bass and bluegill.

TABLE 36. Electrofishing Catch Per Unit (fish/hr) Effort
in the Intermediate Discharge Zone (Within
3°F Isotherm)

Species/year	Times Within Each Month																															
	Mar		Apr		May				Jun									Jul				Aug						Sep				
	1		1	2	3	4	1	2	3	4	5	6	7	8	9	1	2	3	4	1	2	3	4	5	6	1	2	3	4			
-----1973-----																																
Rough Fish ⁽¹⁾	0	*	*	48	24	22	150	30	38	70	38	10	6	33	5	8	55	-	76					14	4	5	16	4	19	10	13	24
Game Fish ⁽²⁾	0	*	*	3	18	0	7	21	40	18	15	17	11	13	6	9	13	11	18					15	0	16	6	0	12	9	0	18
Carp	0	*	*	24	8	5	140	27	35	52	27	8	4	16	3	0	15	0	65					13	3	4	13	4	15	7	5	19
Smallmouth Bass	0	*	*	0	0	0	0	3	0	6	5	8	7	7	5	8	10	7	16					0	0	5	0	0	7	9	0	16
Maximum Temp.°F	40	*	*	56	56	88	95	86	89	91	93	76	72	84	104	104	85	86	70					77	79	91	88	86	94	98	98	88
Ambient Temp.°F	40	*	*	56	56	63	68	68	76	76	76	71	72	70	75	73	73	70	70					72	74	75	73	74	73	71	69	63
Delta Temp.°F	0	*	*	0	56	15	27	18	13	15	17	5	0	14	29	31	12	16	0					5	5	16	15	12	21	27	29	25
-----1974-----																																
Rough Fish	*	68	47	66	51	264	147	58	16	45	52							14	0													
Game Fish	*	21	6	9	5	5	0	13	0	0	0							10	0													
Carp	*	13	13	15	18	76	20	31	11	30	39							8	0													
Shorthead Redhorse	*	28	17	19	14	48	63	12	4	0	0							0	0													
Smallmouth Bass	*	9	0	0	0	0	0	8	0	0	0							7	0													
Maximum Temp.°F	*	44	42	55	52	74	83	92	91	94	90							83	88													
Ambient Temp.°F	*	44	42	55	52	62	62	68	72	70	77							83	77													
Delta Temp.°F	*	0	0	0	0	12	21	24	19	24	13							0	11													

* No Sample

(1) Rough fish species included: shorthead redhorse, carp, silver redhorse, black bullhead, barbot, brown bullhead and white sucker.

(2) Game fish species included: rock bass, black crappie, walleye, northern pike, pumpkinseed, smallmouth bass and bluegill.

TABLE 37. Electrofishing Catch Per Unit (fish/hr) Effort
in the Immediate Discharge Zone (Within
Discharge Canal)

Species/year	Times Within Each Month																															
	Mar		Apr		May				Jun									Jul				Aug						Sep				
	1	2	1	2	3	4	1	2	3	4	5	6	7	8	9	1	2	3	4	1	2	3	4	5	6	1	2	3	4			
-----1973-----																																
Rough Fish ⁽¹⁾	*	146		213				262	148	141							49	131					62	90	47	56	5	154	148	270	116	
Game Fish ⁽²⁾	*	5		0				22	14	30							0	0					0	13	0	0	0	0	0	0	0	
Carp	*																															
Smallmouth Bass	*																															
Maximum Temp.°F	*	54		71				75	68	74							77	69					72	76	77	71	69	78	76	75	71	
Ambient Temp.°F	*	51		64				61	68	71							70	69					71	74	75	71	69	68	67	66	64	
Delta Temp.°F	*	3		7				14	0	3							7	0					1	2	2	0	0	10	9	9	7	
-----1974-----																																
Rough Fish	*	102	98	178	118	208	141	155	365	347	160	237					21															
Game Fish	*	0	0	0	14	14	0	0	61	13	27	65					0															
Carp	*																															
Shorthead Redhorse	*																															
Smallmouth Bass	*																															
Maximum Temp.°F	*	42	45	55	53	49	64	66	75	72	77						81															
Ambient Temp.°F	*	42	45	55	53	49	60	61	68	72	73						81															
Delta Temp.°F	*	0	0	0	0	0	4	5	7	0	4						0															

* No Sample

(1) Rough fish species included: shorthead redhorse, carp, silver redhorse, black bullhead, barbot, brown bullhead and white sucker.

(2) Game fish species included: rock bass, black crappie, walleye, northern pike, pumpkinseed, smallmouth bass and bluegill.

TABLE 38. Number of Fish Caught Per Electrofishing Run for the Period September 9, 1968 and October 4, 1968

Species	Sector "A" (Runs)										Sector "B" (Runs)								Sector "C" (Runs)							Sector "D" (Runs)		Sector "E" (Runs)		Grand Total
	9 Sep 68					10 Sep 68					27 Sep 68				28 Sep 68				28 Sep 68			4 Oct 68				4 Oct 68		4 Oct 68		
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	1	2	1	2	
Northern Redhorse	6	5	17	5	4	8	7	15	11	13	16	18	14	13	32	25	26	12	28	24	7	13	16	2	11	14	22	7	21	412
Carp	10	30	9	17	10	18	7	9	11	13	5	2	6	13	2	3	10	6	6	3		5	6	3	12	10	10		9	245
Silver Redhorse	1			2	3	3	3	3	2		1	1		1			1	1	1				2	1	2				1	29
Walleye		2		1	1	3		1		2									4					2				2		18
Rock Bass		1																			13				2	1				17
Smallmouth Bass		3			1		2		1					1								1				1		2		12
Black Crappie		1								2											5							2		10
Northern Pike										2																				2
Yellow Perch																										1				1
TOTAL																														746

FIGURE 37. Rough Fish Catch/Unit Effort by Electrofishing - 1973

TABLE 39. Population Estimates of Smallmouth Bass, Schnabel Method

Date/Year	Number Trapped C_t	Number Marked	Cumulative Total Marked in Five Sectors M_t	$C_t M_t$ AXB	$\sum C_t M_t$	Number Recaptured R_t	$\sum R_t$	Estimation of Population in Five Sectors $\frac{\sum C_t M_t}{\sum R_t}$
--1968---								
8/17	1	1						
8/20	1	1	1	1				
8/26	1	1	2	2	3			
9/4	7	7	3	21	24			
9/5\	8	8	10	80	104			
9/6/								
9/9	4	3	18	72	176	1	1	176
9/10	3	3	21	63	239		1	239
9/21	1	1	24	24	263		1	263
10/4	2	2	25	50	313		1	313
10/24	1		27	27	340		1	340
10/25	1		27	27	367		1	367
--1969---								
6/16	2	2	27	54	421		1	421
7/7	1	1	29	29	450		1	450
7/16	2	2	30	60	510		1	510
7/21	2	2	32	64	574		1	574
7/23	2	2	34	68	642		1	642
7/28	7	0	36	252	894		1	894
7/30	3	3	36	108	1002		1	1002
7/31	1	1	39	39	1041		1	1041
8/5	4	4	40	160	1201		1	1201
8/7	1	0	44	44	1245	1	2	622
8/16	1	0	44	44	1289	1	3	426
8/18	1	0	44	44	1333	1	4	333
9/16	11	11	44	484	1817		4	454
9/20	8	4	55	440	2257		4	564
9/23	3	0	59	177	2434		4	609

FIGURE 38. Rough Fish Catch/Unit Effort by Electrofishing - 1974

Seining

The available data where the same river areas were fished both pre-operationally and operationally are given in Table 40. Total catch was reported without any effort data nor an indication of sampling frequency or dates. Hopwood (1974b), indicates that since the percentage distribution for fish totaled over the stations shown in Table 40 did not change during the operational and preoperational periods that the heated water had no effect on the fishing (using rank correlation analysis of operational and preoperational percentage species distribution data). In the absence of effort data or an indication of the dates actually fished, this may be a premature conclusion because it is based on a statistical procedure which ignores the numerical magnitude of species changes.

TABLE 40. Numbers of Fish Collected by Seining for Stations* Fished in 1970 and 1972-1973

Species	Preoperational (1970)			Operational (1972-1973)		
	Upstream	Downstream		Upstream	Downstream	
	1	1	2	3	1	3
Bigmouth Shiner	830	177	318	612	274	608
Common Shiner	6	84	19	52	122	26
Golden Shiner	--	--	--	--	--	--
Sand Shiner	614	96	253	754	404	249
Spotfin Shiner	48	429	461	193	830	271
Spottail Shiner	4	23	3	20	24	4
Blacknose Dace	--	11	--	19	4	--
Longnose Dace	53	14	--	42	3	--
Honeyhead Chub	4	57	7	22	43	23
Johnny Darter	14	90	90	49	84	24
Creek Chub	--	20	--	--	3	--
Bluntnose Minnow	53	321	187	117	506	320
White Sucker	20	66	37	33	105	9
Black Bullhead	--	--	1	--	--	--
Redhorse Sucker	1	6	2	4	7	5
Black Crappie	--	--	2	--	--	--
Smallmouth Bass	34	17	3	41	17	--
Rock Bass	--	--	1	--	--	--
TOTAL	1681	1411	1384	1958	2426	1539

*Preoperational upstream 1 same as station operational upstream 3 and pre-operational downstream 2 same station as operational downstream 3; where upstream are --

It seems incongruous that some differences in species proportions at the same sampling station were not detected after 2 to 3 years. Therefore, we calculated a chi-square (independence) for numbers observed at Station 1 downstream for the operational and preoperational periods which we found to be highly significant ($P < 0.01$). Perusal of Table 40 for disproportionate changes indicates the species which are the large contributors to chi-square (e.g., sand shiners for large numbers observed and creek chubs for small numbers observed). Of course there is no way to distinguish which factor(s) may be the cause of this high chi-square. Some possible compounding factors in addition to operational and preoperational status include differences in

years, months, temperature, river level and combinations of these factors. Because of these changes at the same stations we calculated the percentage of fish seined during preoperational and operational times at upstream and downstream stations (Table 41) to assess possible changes due to operation of the plant. In addition we calculated an analysis of variance for the percentage data (Table 41). Apparently most of the percentage changes are associated with upstream and downstream station differences rather than operation of the plant. The F-values shown are not significant owing to few replications but all of the large values are associated with the upstream-downstream factor.

TABLE 41. Percent of Fish Collected by Seining
in a Given Sampling Run

Group	Preoperational			Operational		
	Upstream	Downstream		Upstream	Downstream	
	1	2	3	4	2	5
Shiners	89.4	57.3	76.2	83.3	68.2	75.2
Other Rough Fish	8.6	41.5	23.4	14.6	31.1	24.8
Game Fish	2.0	1.2	0.4	2.1	0.7	0.0

Sum of Squares				
Source	DF	Shiners	Other Rough	Game
Preop-Op (A)	1	2.41	1.50	0.07
Up-Down (B)	1	391.02	461.28	2.901
Interaction (AB)	1	40.70	36.75	0.101
Residual	2	203.11	183.65	0.565
$F_{A,AB}(1,1)$		0.059	0.041	1.058
$F_{B,AB}(1,1)$		9.607	12.552	28.769
$F_{AB,Residual}(1,2)$		0.398	0.400	0.357

Creel Census

Creel census data were collected only for the operational years 1972 and 1973. The two types of information available from those studies included estimates of fishing pressure and an observation that 1973 fall fishing for smallmouth bass and walleye in the discharge canal exhibited higher catch rates 2.7 and 3.5 fish/hr, respectively, than did the river areas during the regular May to October fishing season in the same year (0.24 and 0.10 fish/hr). Since no estimate was made for the "normally" fished areas in the fall of 1973 and because the source of the fall canal fish is unknown, a conclusion that a new sports fishery has been established may be premature.

Impingement and Entrainment

Data reported for impingement and entrainment are in Tables 42 and 43, respectively. In addition, we recorded the day of the week when each datum was obtained. These are further summarized in Tables 44 and 45 where we show that samples were collected so that some days of the week were never sampled whereas others were sampled frequently. If power demand patterns and associated reactor operation levels are very different for weekends, other days, or periods of days, then the data in Tables 42 and 43 may be biased if used to calculate results for any other period(s). In addition, sampling intervals were not the same over the study periods (see Table 44) which may introduce a further complication unless "steady state" catch conditions exist. We have prepared Figures 39 and 40 to show that for both entrainment and impingement data, captures per day are erratic and probably seasonal; and that comparable samples may be the only way to obtain reliable yearly estimates of total numbers of impinged and entrained fish. With the exception of three sample dates, impinged fish totaled less than 100/day while over 100 fish were entrained on all sampling days (excluding suckers) with some values higher than 1000/day. However, it should be noted (foot-note 2, Table 42) that gamefish were a large part of the impingement "catch" as opposed to the entrainment "catch". Impingement data were not available for spring-summer of 1973 or other large values might have been observed.

TABLE 42. Interpolated⁽¹⁾ Fish Impingement
Data for 1973-1974

<u>Date</u>	<u>Day of Week</u>	<u>Cumulative Time (days)</u>	<u>Number of Fish² Impinged/day</u>
(1973)			
7/11	W	0	5
7/20	F	9	6
7/25	W	14	10
7/30	M	19	10
8/10	F	30	0
8/24	F	44	0
9/14	F	64	15
9/28	F	78	30
10/16	Tu	97	1200
10/24	W	105	75
11/9	F	121	62
11/20	Tu	132	18
12/6	W	149	19
12/12	F	155	18
(1974)			
1/4	F	178	8
1/18	F	192	14
2/1	F	206	5
2/15	F	220	0
3/6	W	239	60
6/4	Tu	323	340
6/17	M	336	18
7/5	F	354	8
7/16	Tu	365	38
7/31	W	380	35
8/14	W	394	35
8/26	M	406	410
9/19	Th	430	15
10/8	Tu	449	5
10/25	F	466	18
11/7	M	479	10
12/3	Tu	503	10
12/12	Th	512	12
12/26	Th	526	12

(1) Interpolated from Figure 2, in Heberling, G.D., 1975, page 319.

(2) Smallmouth bass, black crappie, bluegill, and adult black bullhead made up 75.8 and 88.9% of the fish impinged in 1973 and 1974, respectively.

TABLE 43. Field Fish Entrainment Data for 1973-1974

<u>Date</u>	<u>Day of Week</u>	<u>Cumulative Time (days)</u>	<u>Number of Fish Entrained</u>	<u>Fish Entrained Hour</u>	<u>Estimated⁽¹⁾ Total Fish/Day Entrained</u>	<u>Estimated Total Fish/Day Entrained Excluding Suckers</u>
(1973)						
9/12	W	0	7	0.4	145	104
10/15	M	33	18	1.7	523	523
10/22	M	40	8	1.1	326	326
11/5	M	54	3	0.5	127	127
11/19	M	68	2	0.3	102	102
12/17	M	96	9	1.5	385	385
(1974)						
1/18	F	128	7	1.2	275	235
2/17	Su	158	1	0.2	55	55
3/13	W	182	1	0.3	61	61
5/22	W	252	156	86.7	13104	336
5/30	Th	260	807	350.9	57262	142
6/12	W	273	4069	1356.3	455728	4928
6/20	Th	281	55	110.0	36696	3336
6/28	F	289	740	123.3	43216	292
7/14	Su	305	65	11818.0	3886	2272
7/21	Su	312	33	5.5	1795	1034
7/28	Su	319	32	5.3	1728	378
8/4	Su	326	30	5.0	1644	1096
8/18	Su	340	3	0.5	160	106

SEASONAL SUMMARY

<u>Period</u>	<u>n</u>	<u>All Fish</u>		<u>Excluding Suckers</u>	
		<u>Average Fish/Day</u>	<u>95% Confidence Value</u>	<u>Average Fish/Day</u>	<u>95% Confidence Value</u>
9/12/73 - 3/13/74	9	222	± 125	203	± 135
5/22/74 - 6/28/74	4	37569	±18840	106	±2200
5/22/74 - 6/28/74*	5	121201	±233005	1807	±2727
7/14/74 - 8/18/74	5	1842	± 1188	977	±1040
9/12/73 - 8/18/74	19	32485	±50060	833	± 629

* Data of 6/12/74 is included in 5/22/74 - 6/28/74 period.

(1) See Knutsen, K.M., 1975, page 226 for calculations.

TABLE 44. Examples of Sampling Bias in the Fish Impingement Program

Day of Week	Sample Year		
	1973	1974	Total
Monday	1	3	4
Tuesday	2	4	6
Wednesday	4	3	7
Thursday	-	3	3
Friday	7	6	13
Saturday	-	-	-
Sunday	-	-	-
TOTAL	14	19	33
Range of Sampling Interval Lengths (days)	(5-20)	9-24 (one 84 day period excluded)	
Mean	12	15	
Standard Deviation	5	4	

1. No Saturday or Sunday Samples.
2. Predominance of Friday samples.

TABLE 45. Examples of Sampling Bias in the Fish Entrainment Program

Day of Week	Sample Year		
	1973	1974	Total
Monday	5	-	5
Tuesday	-	-	-
Wednesday	1	3	4
Thursday	-	2	2
Friday	-	2	2
Saturday	-	-	-
Sunday	-	6	6
TOTAL	6	13	19

1. 79% of all samples were collected on Sunday, Monday, and Wednesday.
2. No samples on Tuesday or Saturday.
3. 10/15/73 to 12/17/73 all five samples were collected on Monday.
4. 7/14/74 to 8/18/74 all five samples were collected on Sunday.

FIGURE 39. Fish Entrainment at Monticello

FIGURE 40. Fish Impingement at Monticello

The seasonal summary at the bottom of Table 43 illustrates the shortcomings of attempting to estimate numbers of fish lost to impingement or entrainment using the available data. We have averaged estimates of total fish entrained per day, both including and excluding suckers, (suckers account for 96.8% of the numbers captured) over several time periods and have excluded one very high value in one calculation. Obviously, the estimates of average fish entrained per day are quite different, variable (see 95% confidence values), and sensitive to the occasional extreme observations.

Time series analysis of data sets where several years of data are available has been suggested to circumvent some of the problems indicated above. Moreover, weighted averages (where sampling intervals differ substantially) might provide more accurate daily estimates which can be summed for yearly estimates. This procedure would also circumvent selecting seasons (periods) such as we attempted in Table 43. For example, our calculated daily estimate for the 9/12/73 to 8/10/74 period is 6029 fish per day rather than 32,485 fish per day found as a simple average. All the above procedures cannot provide a completely reliable estimate of total fish impinged or entrained by a power plant unless samples are collected daily, at least during times when large fluctuations in catches can be expected.

Cold Shock

Estimates of winter fish populations residing in the discharge canal, estimates of mortality for various fish species after a defined and controlled drop in winter discharge canal temperature to ambient, and an estimate of species numbers in the river in winter, "near" the canal would be necessary to assess the fractions of fish populations affected by cold shock. We believe the river fish population estimates devised using 1969 data (see section on electroshocking above) are both poor and inappropriate (displaced too far in time) to use as an aid in estimating cold shock effects. Further, we have located two different sets of canal population estimates (p. 326, footnote, Table 14 and in an unpublished document from the Northern States Power Company). Finally, estimates of field mortality due to rapidly falling temperatures were based on from 1 to 6 fish species, observed for 42 hours after cold shock. For these reasons we believe that calculation of estimates of cold shock losses may be subject to criticism.

Summary

We have qualitatively evaluated fish capture data obtained by electrofishing, seining, and two separate creel census. In addition, impingement, entrainment, and cold shock studies were evaluated. We were unable to quantitatively assess the data for changes due to the operation of the

plant. The specific reasons for this failure are in the appropriate sections. No account was taken of the fact that fish may be able to "avoid" certain stressors in any of the above studies.

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APPENDIX A
ENVIRONMENTAL TECHNICAL SPECIFICATIONS
APPENDIX B

TO

FACILITY OPERATING LICENSE NO. DPR-22
for
MONTICELLO NUCLEAR GENERATING PLANT
UNIT 1
NORTHERN STATES POWER COMPANY
DOCKET NO. 50-263

3.0 ENVIRONMENTAL SURVEILLANCE
3.1 Nonradiological Surveillance

3.1.1 Aquatic

General Ecological Survey

Objective

To evaluate the impact of the facility on the biotic environment.

Specification

1. Investigate any changes in the biota that may occur by comparing preoperational data to operational data and control stations to experimental stations.
2. Identify any change in the ecosystem induced by plant operation.
3. Evaluate significance of induced changes, if any, on sustenance of a healthy ecosystem as determined in preoperational studies or as defined by regulatory standards.

Basis

A general ecological survey was initiated in May 1968, 3 years prior to the beginning of plant operation in June 1971. This program has been extensively expanded since its inception. Information gathered from preoperational environmental studies was published in the 1968, 1969 and 1970 Monticello Nuclear Generating Plant Annual Environmental Monitoring and Ecological Studies Program Reports.

1. The program may be modified as necessary to accommodate sampling requirement changes. This program has been continually reviewed and reevaluated since its conception. After 60 months of data have been obtained from the beginning of commercial operation, some of the special studies in Section TS B-3.0 may be eliminated if the results of these studies are conclusive and show no significant harmful environmental effects.

2. These changes and results will be presented in the Annual Environmental Monitoring and Ecological Studies Program Report for the facility.
3. These studies are performed as follows: The program for aquatic ecological studies of the Mississippi River in the vicinity of the Monticello Nuclear Generating Plant has been designed to establish ecological characteristics prior to and during plant operation. Preoperational data are being compared with operational data to verify that the plant is not deleteriously altering the aquatic ecosystem. This study began 3 years prior to plant operation and will continue until specific effects of the plant can be determined and the data show a stabilized aquatic environment. Studies are organized to investigate the aquatic biota and the physical and chemical composition of the environment.

Species are identified and their population and size are determined. Food habits and reproductive cycles of dominant species are studied whenever possible. Due to the seasonal fluctuations of these factors, most sampling programs are carried out on a scheduled year-round basis. It should be noted that this program is designed to remain flexible, so that changes can be made immediately if required. Factors studied are:

Biotic Communities

- Periphyton
- Benthic Macroinvertebrates
- Fish

Physical and Chemical Water Parameters

- Dissolved Oxygen
- Biological Oxygen Demand
- Temperature
- pH
- Conductivity
- Turbidity
- Current Velocity
- Total Dissolved Solids

Total Alkalinity
Total Phosphate
Ortho-phosphate
Nitrate Nitrogen
Chlorides
Iron
Sulfates

Basic Procedures for These Studies Are:

a. Periphyton

Periphyton sampling was initially conducted at 13 locations at the Monticello facility. Comparison of 3 years of preoperational studies with 3 years of operational indicate that only 5 stations are required to monitor any changes that may occur in species diversity, abundance and chlorophyll content due to the plant effluent. The locations are shown in Figure TS-B.4.1.1. There is 1 control station upstream of the discharge canal. One of the downstream stations is outside the thermal plume. Samples are analyzed every 2 weeks except when flooding destroys samplers or hazardous ice conditions exist.

b. Benthic Macroinvertebrates Study

Three years of preoperational and 3 years of operational studies have shown that there have been no significant changes in species diversity or abundance. Because of this the program has been reduced to one upstream control transect C-2 (Figure TSB 4.1.1-2) and one downstream experimental transect E-2 (Figure TSB-4.1.1-2). The experimental transect is located 75 m downstream from the point of discharge. This transect serves as a reliable indicator of changes in species abundance and/or diversity that may occur due to plant discharges. Each transect consists of at least three stations spaced equidistant from each other. Four concrete block

artificial substrates are located on the bottom at each station. These are removed monthly for enumeration, weighing and identification of colonized organisms. Some stations may not be sampled in the winter when unsafe ice conditions exist or when flooding removes sampling devices.

c. Fish

Electro-fishing and seining are the dominant methods used in the fish study. Trapnetting will be used in the future, as an additional sampling method. A representative sample of fish are measured and weighed with some scales removed for age and growth determinations. The fisheries data are used to determine changes in relative abundance and distribution due to the plant discharge. A creel census of the fishery is being conducted to determine quality of fishing. The census usually is conducted from May through November with the exact sampling time dependent upon angler presence.

A biweekly fish census will be conducted in the discharge canal during winter months to determine species distribution and abundance. This data will be used to predict possible harm should a winter shutdown occur. This program will be conducted in accordance with the "Stipulation for Settlement of Contention II-23," dated October 23, 1974, between MPCA, NSP, and NRC Reg. staff.

3.1.2 Physical and Chemical Water Quality Parameters

The water quality study includes the physical and chemical parameters of water which might affect aquatic life. The chemical factors studied and their frequency of measurement is as follows:

<u>Parameter</u>	<u>Frequency</u>
Dissolved Oxygen	Quarterly
Biological Oxygen Demand	Quarterly
Temperature	Continuous at two locations
pH	Quarterly
Conductivity	Quarterly
Turbidity	Quarterly
Current Velocity	Quarterly
Total Dissolved Solids	Quarterly
Total Phosphate	Quarterly
Ortho-phosphate	Quarterly
Nitrate Nitrogen	Quarterly
Chlorides	Quarterly
Iron	Quarterly
Sulfates	Quarterly

A subsurface sample of one gallon of water is taken from each of three stations. One station is located 1000 feet upstream of the intake structure, one is in the discharge canal and the downstream station is 1000 feet below the point of discharge to the river. Intake and discharge temperatures are measured continuously by the plant computer.

Impinged and Entrained Fauna

Objective

To determine monthly variations in species, size, and numbers, of all life stages of fish entrapped; to identify and count any other impinged vertebrates and to record that portion of the entrained fauna which is killed due to passage through the plant.

Specification

Impingement and entrainment studies shall be carried out for at least 2 years after the Appendix B Environmental Technical Specifications are in effect, after which results thus far obtained will be used as a basis for determining whether further studies

or surveillance programs are warranted. Impingement studies shall be conducted every two weeks when the plant is operating. Entrainment studies shall be conducted from May through August for fish and May through October for aquatic insects. Results shall be reported as per reporting as per requirements given in Section 5 of this document.

Data collected during plant operation will be compared with appropriate control station data, thereby providing information to help determine the effect of the plant upon the impinged and entrained biota.

Basis

1. Fish Impingement

Presently the plant is designed to return all impinged fish from the intake traveling screens to the river via low gradient sluice canal. Impinged fish are removed from the screens by periodic washings. All screen washed material is sampled by placing a 1/4 inch mesh net in the sluice canal. All fish collected will be identified, counted and a representative sample measured to determine monthly and seasonal trends in impingement and survivorship. Results will be reported as per reporting requirements described in Section 5 of this document.

2. Impingement of Other Vertebrates and Macroinvertebrates

If aquatic or semi-aquatic vertebrates (such as salamanders, frogs and snakes) or macroinvertebrates (including crayfish and clams, but excluding insects) are impinged, they will be identified, counted and reported as per to reporting conditions described in Section 5 of this document.

3. Entrainment

- a. Estimates on numbers of entrained ichthyoplankton, including organisms up to 3/8 inch in diameter, shall

be made monthly from May through August when peak numbers of fish - fry and eggs are present in the river. Since previous studies have shown no great diel variation in number of fish collected during the day, a representative sample for a day will be collected, identified and mortality determined.

- b. Estimates on number and mortality of entrained aquatic insects will be performed monthly from May through October to coincide with high standing crop, drift rate, and growth periods. A representative subsample of the insects collected will be counted, identified and mortality estimates performed.

4.0 SPECIAL SURVEILLANCE PROGRAM

(parenthetical for Board's information)

(In accordance with the "Stipulation for Settlement of Contention II-23", dated October 23, 1974, MPCA, NSP, and AEC Regulatory staff, a special program of monitoring and data evaluation in the discharge canal will be conducted. A copy of the stipulation has been made available to all parties.)

APPENDIX B

MONTHLY AVERAGE EXCESS BOTTOM TEMPERATURES

APPENDIX C

ORIGINAL BENTHOS DATA

TOTAL NUMBER OF MACRONEMUM
OBSERVED ON 4 SAMPLERS (0.4 m²) AT MONTICELLO

STATIONS

DATE	C1R	C1C	C1L	C2R	C2C	E1E	E1R	E1C	E1L	E2E	E2R	E2L
2-69	-	-	-	-	-	-	-	-	-	-	-	-
5-69	-	-	-	44	52	-	-	4	32	-	16	-
6-69	-	37	5	38	18	-	-	36	156	-	28	36
7-69	-	-	5	24	1	-	-	26	-	-	1	16
8-69	376	1096	1024	256	336	64	1200	408	744	112	128	256
9-69	208	1232	992	336	512	32	832	384	304	20	128	352
10-69	-	-	-	-	16	-	32	32	32	-	16	-
11-69	-	-	-	-	-	-	-	-	-	-	-	2
2-70	-	2	-	-	9	-	-	-	-	-	-	-
5-70	-	4	-	-	8	-	-	-	12	-	-	-
6-70	-	56	96	176	72	128	80	136	384	104	80	232
7-70	-	16	32	32	48	144	32	64	48	64	16	16
8-70	520	416	-	624	64	160	592	624	592	168	480	896
9-70	32	608	160	608	336	32	304	400	176	5	32	96
10-70	-	32	-	-	32	-	-	-	-	-	-	16
11-70	-	-	64	-	-	-	-	-	-	-	-	-
2-71	-	-	-	-	-	-	-	-	-	-	-	-
5-71	-	-	-	-	-	-	-	-	-	-	8	-
6-71	-	-	16	-	-	-	16	-	-	-	-	-
7-71	16	16	32	80	32	280	24	96	80	32	64	256
8-71	16	64	576	32	48	272	288	576	224	80	96	384
9-71	4	352	96	-	96	192	32	160	32	-	-	160
10-71	-	16	-	16	-	-	-	-	-	-	-	-
11-71	-	-	-	-	-	-	-	-	-	-	-	-
6-72	-	-	-	-	-	-	-	32	128	16	32	64
7-72	-	-	-	-	-	-	-	-	-	-	-	-
10-72	-	-	-	-	-	-	-	-	-	-	-	-
11-72	-	-	-	-	-	-	-	48	-	-	-	-
10-73	-	-	-	-	-	-	-	-	-	-	-	-

TOTAL NUMBER OF CHIRONOMINI
OBSERVED ON 4 SAMPLERS (0.4 m²) AT MONTICELLO

STATIONS

DATE	C1R	C1C	C1L	C2R	C2C	E1E	F1R	E1C	F1L	E2E	E2H	E2L
2-69	-	-	5	11	4	-	-	5	-	-	-	-
5-69	-	-	-	120	168	-	-	24	20	-	-	-
6-69	976	2188	996	540	456	-	-	484	368	-	364	360
7-69	2464	1040	2012	-	848	-	664	1080	1360	-	1016	2752
8-69	536	1280	2544	-	1248	512	992	872	1352	992	456	632
9-69	1040	1248	1856	-	608	304	896	816	2048	552	752	992
10-69	2088	3200	2624	-	3088	2192	3520	3712	4336	1568	2208	3392
11-69	636	2284	1340	-	704	1172	1588	4220	2740	177	916	554
2-70	-	329	-	145	591	248	428	-	1384	-	811	-
5-70	-	1660	-	2040	1792	-	1369	-	1960	-	-	-
6-70	2004	3896	5856	2384	3168	1664	1728	1192	2704	552	1392	960
7-70	560	640	1184	656	624	960	496	1072	1072	768	624	1088
8-70	880	880	-	1008	1040	736	688	608	816	552	512	1568
9-70	1144	1760	1592	1632	672	2448	832	720	1920	118	1456	1776
10-70	1356	1392	3320	2640	4320	1912	2384	1232	2976	730	1752	2064
11-70	2592	4368	6332	-	1420	1164	2248	4496	5936	7272	2864	5360
2-71	-	-	-	54	113	56	347	-	-	-	252	-
5-71	-	-	-	478	896	332	-	352	-	-	272	-
6-71	2544	1464	2224	1024	1184	1648	1232	516	1824	560	572	1504
7-71	948	624	4232	496	1280	672	232	400	592	384	464	2016
8-71	2288	1232	12688	2384	3248	1888	2800	2432	6592	1824	2688	3872
9-71	492	352	1216	448	160	352	544	384	1712	808	784	1504
10-71	2176	2272	2080	1232	1040	1280	1392	1888	3024	3100	1824	1504
11-71	-	4704	3776	1720	197	-	-	-	-	-	-	-
6-72	-	-	-	1696	1728	1664	1312	1488	3360	1088	1536	3296
7-72	-	-	-	-	384	-	-	-	-	-	-	-
10-72	-	-	-	168	208	64	120	176	376	464	136	456
11-72	-	-	-	72	32	404	-	160	103	248	80	112
10-73	-	-	-	2496	2584	-	1352	1344	2020	-	-	-

TOTAL NUMBER OF BAETIS
OBSERVED ON 4 SAMPLERS (0.4 m²) AT MONTICELLO
STATIONS

DATE	C1R	C1C	C1L	C2R	C2C	F1E	E1R	F1C	E1L	E2E	E2R	E2L
2-69	-	-	-	-	-	-	-	-	-	-	-	-
5-69	-	-	-	-	-	-	-	-	-	-	-	-
6-69	1268	944	920	1184	652	-	-	140	156	-	300	76
7-69	1872	1264	1244	864	1312	-	816	728	332	-	664	1104
8-69	1232	2040	3760	1592	2416	2432	656	1176	1632	2496	1344	1976
9-69	1296	1232	1472	1376	1328	720	688	784	1472	240	576	752
10-69	200	608	384	608	592	224	304	608	560	28	216	192
11-69	24	4	8	4	-	-	-	-	-	-	-	4
2-70	-	-	-	-	-	-	-	-	-	-	-	-
5-70	-	-	-	-	-	-	-	-	-	-	-	-
6-70	3008	1408	1552	1824	2648	624	544	780	608	1160	480	408
7-70	1024	1008	1424	400	1088	624	408	816	624	960	592	448
8-70	2112	1760	-	2256	2832	2992	1072	2368	1792	1248	656	1888
9-70	1000	2784	1128	2176	1248	4144	1264	992	1920	24	432	656
10-70	112	640	888	592	768	240	192	336	864	10	4	432
11-70	16	16	64	-	4	-	-	16	-	-	40	-
2-71	-	-	-	2	-	-	-	-	-	-	-	-
5-71	-	-	-	-	-	-	-	-	-	-	-	-
6-71	864	3552	2048	1096	1776	832	1360	112	736	880	856	272
7-71	1736	2432	2408	2416	2080	416	240	168	576	1328	880	368
8-71	2640	2768	14309	3440	3792	1984	2384	3312	5664	1192	2016	5280
9-71	356	1008	2656	1264	448	288	608	416	864	160	320	960
10-71	384	688	1504	240	272	240	432	704	752	52	160	816
11-71	-	-	-	-	-	-	-	-	-	-	-	-
6-72	-	-	-	896	544	544	416	768	1632	448	384	576
7-72	-	-	-	-	272	-	-	-	-	-	-	-
10-72	-	-	-	32	32	16	-	-	-	-	4	24
11-72	-	-	-	-	4	4	-	-	-	-	-	-
10-73	-	-	-	-	-	-	-	-	-	-	-	-

TOTAL NUMBER OF STENONEMA
OBSERVED ON 4 SAMPLERS (0.4 m²) AT MONTICELLO
STATIONS

DATE	C1R	C1C	C1L	C2R	C2C	E1E	E1R	E1C	E1L	E2E	E2R	E2L
2-69	-	-	-	10	4	-	-	-	-	-	-	-
5-69	-	-	-	72	40	-	-	1	16	-	32	-
6-69	52	48	76	96	64	-	-	8	4	-	48	-
7-69	160	64	68	80	120	-	120	24	8	-	88	160
8-69	264	200	304	40	184	64	176	152	320	-	60	176
9-69	336	432	544	176	144	112	160	400	640	-	384	400
10-69	352	432	400	80	112	96	48	304	368	-	120	144
11-69	-	16	8	-	8	8	4	-	32	-	2	8
2-70	-	4	-	2	11	-	6	-	16	-	6	-
5-70	-	8	-	128	24	4	4	-	-	-	-	-
6-70	84	16	32	240	216	96	80	28	128	52	112	40
7-70	368	32	48	240	208	80	64	80	176	176	256	256
8-70	144	64	-	80	176	112	64	96	176	256	384	208
9-70	320	352	176	224	112	128	144	256	528	60	640	448
10-70	172	192	1136	64	288	128	128	272	256	36	176	232
11-70	104	144	32	-	-	36	32	16	144	-	32	-
2-71	-	-	-	17	14	5	-	-	-	-	38	-
5-71	-	-	-	10	28	28	-	-	-	-	24	-
6-71	176	16	48	32	48	16	64	4	32	64	20	48
7-71	732	64	208	96	80	112	96	64	112	80	160	144
8-71	208	112	96	64	64	272	320	448	96	168	256	160
9-71	84	304	448	352	240	352	64	320	544	272	128	384
10-71	400	256	480	96	32	144	64	256	240	200	112	304
11-71	-	112	-	-	9	-	-	-	-	-	-	-
6-72	-	-	-	64	32	96	176	32	352	208	96	256
7-72	-	-	-	-	64	-	-	-	-	-	-	-
10-72	-	-	-	32	32	16	16	48	32	40	-	-
11-72	-	-	-	6	-	-	-	-	-	4	2	-
10-73	-	-	-	21	72	-	648	104	96	-	-	-

TOTAL NUMBER OF SIMULIDAE
OBSERVED ON 4 SAMPLERS (0.4 m²) AT MONTICELLO

STATIONS

DATE	C1R	C1C	C1L	C2P	C2C	E1E	E1R	E1C	E1L	E2E	E2R	E2L
2-69	-	-	-	3	2	-	-	-	-	-	-	-
5-69	-	-	-	4	80	-	-	992	30142	-	28308	-
6-69	812	1788	15136	260	44	-	-	764	2148	-	996	1628
7-69	1760	3584	1996	236	176	-	88	3368	1660	-	128	1792
8-69	72	640	1072	48	320	832	160	528	1616	160	116	1056
9-69	16	176	144	304	752	272	160	80	128	-	-	64
10-69	-	720	64	400	752	224	128	192	160	-	16	312
11-69	56	116	32	88	90	80	124	128	144	12	30	26
2-70	-	2	-	-	-	1	4	-	-	-	-	-
5-70	-	148	-	56	16	-	181	-	68	-	-	-
6-70	572	3432	6972	224	96	272	1136	1016	1264	152	576	856
7-70	16	128	640	32	32	-	240	1888	768	16	32	-
8-70	16	112	-	240	256	32	80	208	48	8	-	16
9-70	-	608	48	416	160	96	272	224	432	5	-	32
10-70	4	1136	152	1056	48	64	320	352	288	-	-	16
11-70	-	704	128	-	444	320	528	504	384	8	8	16
2-71	-	-	-	-	-	3	-	-	-	-	-	-
5-71	-	-	-	160	944	4412	-	8408	-	-	6128	-
6-71	592	1672	1668	128	304	128	224	640	1008	48	60	1472
7-71	100	352	608	16	112	176	192	1888	1392	56	128	1056
8-71	48	96	1376	208	416	48	224	2192	3232	-	176	3872
9-71	20	96	-	-	64	-	64	96	32	-	16	192
10-71	-	64	64	-	176	-	-	16	32	-	-	112
11-71	-	-	-	-	-	-	-	-	-	-	-	-
6-72	-	-	-	32	128	-	96	1920	768	-	-	-
7-72	-	-	-	-	288	-	-	-	-	-	-	-
10-72	-	-	-	-	-	-	8	-	-	-	-	-
11-72	-	-	-	-	20	-	-	8	12	-	-	-
10-73	-	-	-	8	24	-	-	8	52	-	-	-

TOTAL NUMBER OF HYDROPSYCHE AND CHEUMATOPSYCHE
OBSERVED ON 4 SAMPLERS (0.4 m²) AT MONTICELLO

STATIONS

DATE	C1R	C1C	C1L	C2R	C2C	E1E	E1R	E1C	E1L	E2E	E2R	E2L
2-69	-	-	-	9	-	-	-	67	-	-	-	-
5-69	-	-	-	1456	2148	-	-	156	996	-	576	-
6-69	1368	992	436	2172	1500	-	-	1088	960	-	1420	1476
7-69	6560	5568	5532	3356	5672	-	5192	6392	4168	-	5768	8640
8-69	3120	6880	6928	3888	7652	5568	7184	6584	4712	1016	3028	3360
9-69	7200	7840	7216	7072	8272	10144	13584	11824	11296	356	9472	6656
10-69	3120	5056	3568	2720	2960	4032	6912	6864	5856	216	4656	5024
11-69	200	916	232	208	116	852	1332	3088	1236	30	628	354
2-70	-	229	-	22	562	356	752	-	2552	-	1532	-
5-70	-	2160	-	2000	2440	-	3274	-	5240	-	-	-
6-70	3256	2152	2016	7200	4976	8784	7776	5344	7344	4680	6768	4520
7-70	5000	6000	7264	6048	8736	8288	9872	9820	10080	4912	9520	9568
8-70	3840	4880	-	4544	5808	3760	4976	4928	4560	760	5088	4128
9-70	2896	10976	1716	8992	8368	6416	9792	8264	2360	82	3056	3248
10-70	2104	9136	2080	6672	10048	2168	6624	7536	8896	140	1660	2344
11-70	894	2560	1984	-	548	228	920	1536	2288	40	664	244
2-71	-	-	-	36	62	75	797	-	-	-	700	-
5-71	-	-	-	316	488	492	-	880	-	-	440	-
6-71	1552	1896	1728	2408	3344	7920	6368	2096	3680	2544	3292	4608
7-71	2944	6656	5552	5136	8496	5872	4056	4872	4496	3040	7424	9664
8-71	2192	2176	2688	3312	5024	4432	5168	4608	6208	904	3584	5184
9-71	784	3936	2272	6224	7840	4864	6592	6560	9088	88	2240	6272
10-71	1680	1952	1792	4592	3264	4136	4016	6528	6032	136	3200	3872
11-71	-	4096	3472	712	63	-	-	-	-	-	-	-
6-72	4000	-	-	-	6656	9344	7296	5360	11520	3552	7808	8384
7-72	-	-	-	-	3424	-	-	-	-	-	-	-
10-72	1208	-	-	-	1872	2160	1632	2448	1848	2208	1632	2744
11-72	144	-	-	-	190	592	-	520	441	326	256	482
10-73	-	-	-	1111	1992	-	3098	3320	4072	-	-	-

TOTAL NUMBER OF BENTHIC MACROINVERTEBRATES
OBSERVED ON 4 SAMPLERS (0.4 m²) AT MONTICELLO

STATIONS

DATE	C1R	C1C	C1L	C2R	C2C	E1E	E1R	E1C	E1L	E2E	E2R
2-69	-	-	76	61	53	-	-	104	-	-	-
5-69	-	-	-	1771	2628	-	-	1195	31206	-	28949
6-69	4500	22103	17638	4358	2820	-	-	2550	3860	-	3216
7-69	13009	11584	11029	5452	8290	-	6968	11795	7620	-	7699
8-69	6472	12408	16498	6809	12285	9664	10496	9856	10570	5448	5228
9-69	11008	18120	13425	11344	11904	12000	17072	14946	16528	1604	11776
10-69	6760	11808	10944	9888	8472	8688	12032	13984	12784	2176	7832
11-69	996	4704	2416	1832	1254	3232	3464	10800	5148	875	1742
2-70	-	577	-	194	1203	699	1382	-	4632	-	2415
5-70	-	4232	-	4440	4424	-	4905	-	7400	-	-
6-70	9060	11112	16636	12272	11400	11648	11376	8576	12608	6828	9504
7-70	7744	8080	10928	7856	11040	10416	11456	12768	13328	7616	11712
8-70	8192	8592	-	8992	11456	8176	7856	9328	8304	3752	7600
9-70	6040	18112	5404	14944	11280	13504	12944	11272	12800	359	5968
10-70	6568	15008	18440	13648	20822	6312	11472	10592	15072	970	4704
11-70	5294	10368	13116	-	3468	3696	4960	7368	10416	7336	3776

PERCENT OF TOTAL BENTHIC MACROINVERTEBRATES
OBSERVED AT MONTICELLO

STATIONS

DATE	C1R	C1C	C1L	C2R	C2C	E1F	E1R	E1C	E1L	E2E	E2R
2-69	-0.0	-0.0	6.6	54.1	18.9	-0.0	-0.0	69.2	-0.0	-0.0	-0.0
5-69	-0.0	-0.0	-0.0	95.8	94.7	-0.0	-0.0	98.5	100.0	-0.0	99.9
6-69	99.5	100.0	99.6	98.4	97.0	-0.0	-0.0	98.8	98.2	-0.0	98.1
7-69	98.5	99.4	98.4	83.6	98.1	-0.0	98.7	98.5	98.8	-0.0	99.6
8-69	86.5	97.8	94.8	85.5	98.9	98.0	98.8	98.6	98.2	87.7	98.2
9-69	91.7	67.1	91.1	81.7	97.6	96.5	95.6	95.6	96.1	72.8	96.1
10-69	85.2	84.8	64.3	38.5	88.8	77.9	91.0	83.8	88.5	83.3	92.3
11-69	92.0	70.9	67.1	16.4	73.2	65.3	88.0	68.9	80.7	25.0	90.5
2-70	-0.0	98.1	-0.0	87.1	97.5	86.6	86.1	-0.0	85.3	-0.0	97.3
5-70	-0.0	94.0	-0.0	95.3	96.7	-0.0	98.4	-0.0	98.4	-0.0	-0.0
6-70	98.5	98.6	99.3	98.2	98.0	99.3	99.7	99.1	98.6	98.1	99.0
7-70	90.0	96.8	96.9	94.3	97.2	96.9	97.3	100.0	95.8	90.5	94.3
8-70	89.3	94.4	-0.0	97.3	88.8	95.3	95.1	94.7	96.1	79.7	93.7
9-70	89.3	94.3	89.2	94.0	96.6	98.2	97.4	96.3	57.3	81.9	94.1
10-70	57.1	83.5	41.1	80.8	74.5	71.5	84.1	91.8	88.1	94.4	76.4
11-70	68.1	75.2	65.6	-0.0	69.7	47.3	75.2	89.1	84.0	99.8	95.6

APPENDIX D

BENTHOS STATION RATIOS .

ARITHMETIC AND LOGARITHMIC STATION RATIOS FOR BENTHIC MACROINVERTEBRATES

MACRONEMUM

ARITHMETIC RATIOS							LOGARITHMIC RATIOS (BASE 10)						
DATE	1	2	3	4	5	DATE	1	2	3	4	5		
2-69	.000	.000	.000	.000	.000	2-69	.000	.000	.000	.000	.000		
5-69	.000	2,750	.000	.000	.000	5-69	.000	.439	.000	.000	.000		
6-69	.000	1,357	1,028	.032	.000	6-69	.000	.133	.012	-1,494	.000		
7-69	.000	24,000	.000	.000	.000	7-69	.000	1,380	.000	.000	.000		
8-69	.313	2,000	2,686	1,376	2,286	8-69	-.504	.301	.429	.139	.359		
9-69	.250	2,625	3,208	3,263	17,600	9-69	-.602	.419	.506	.514	1,246		
10-69	.000	.000	.000	.000	.000	10-69	.000	.000	.000	.000	.000		
11-69	.000	.000	.000	.000	.000	11-69	.000	.000	.000	.000	.000		
2-70	.000	.000	.000	.000	.000	2-70	.000	.000	.000	.000	.000		
5-70	.000	.000	.000	.000	.000	5-70	.000	.000	.000	.000	.000		
6-70	.000	2,200	.412	.250	2,231	6-70	.000	.342	-.385	-.602	.348		
7-70	.000	2,000	.250	.667	.250	7-70	.000	.301	-.602	-.176	-.602		
8-70	.541	1,300	.667	.900	5,333	8-70	-.267	.114	-.176	.000	.727		
9-70	.105	19,000	1,520	.909	19,200	9-70	-.978	1,279	.182	-.041	1,283		
10-70	.000	.000	.000	.000	.000	10-70	.000	.000	.000	.000	.000		
11-70	.000	.000	.000	.000	.000	11-70	.000	.000	.000	.000	.000		
2-71	.000	.000	.000	.000	.000	2-71	.000	.000	.000	.000	.000		
5-71	.000	.000	.000	.000	.000	5-71	.000	.000	.000	.000	.000		
6-71	.000	.000	.000	.000	.000	6-71	.000	.000	.000	.000	.000		
7-71	.667	1,250	.167	.400	8,000	7-71	-.176	.097	-.778	-.398	.903		
8-71	.056	.333	.111	2,571	4,800	8-71	-1,255	.477	-.954	.410	.681		
9-71	.125	.000	2,200	3,000	.000	9-71	-.903	.000	.342	.477	.000		
10-71	.000	.000	.000	.000	.000	10-71	.000	.000	.000	.000	.000		
11-71	.000	.000	.000	.000	.000	11-71	.000	.000	.000	.000	.000		
6-72	.000	.000	.000	.000	4,000	6-72	.000	.000	.000	.000	.602		
7-72	.000	.000	.000	.000	.000	7-72	.000	.000	.000	.000	.000		
10-72	.000	.000	.000	.000	.000	10-72	.000	.000	.000	.000	.000		
11-72	.000	.000	.000	.000	.000	11-72	.000	.000	.000	.000	.000		
10-73	.000	.000	.000	.000	.000	10-73	.000	.000	.000	.000	.000		

INTERPRETING STEM AND LEAF DISPLAYS

Stem and leaf displays are very much like histograms, but contain additional information. The stem is in some ways analogous to the class mark or midpoint of the usual histogram while the leaf provides the actual values of the numbers contained in the bars of usual histograms. Thus, a stem and leaf such as -1.4 (9 found at depth of 1 of the logarithm of the Macroneum ratios display, has an actual value of -1.49. Similarly at depth 15 (from the positive end) we find +.4) 12348 which indicates 5 values are plotted; 0.41, 0.42, 0.43, 0.44 and 0.48, respectively. The column labelled depth (which we used above) is simply a convenient way to "count in" from either end to the median value (shown as M under the column labelled scrawl) of the distribution. The symbols H are the quartile points and the astrisks (*) denote the ends of the distribution. Note at depth 19 (actually the first 19 numbers) of the arithmetic display of Macroneum ratios that both the extreme and quartile values occur in the same "bar".

STEM AND LEAF DISPLAYS OF STATION RATIOS FOR BENTHIC MACROINVERTEBRATES

MACRONEMUM

ARITHMETIC RATIOS				LOGARITHMIC RATIOS (BASE 10)			
DEPTH	SCRAWL	STEM	LEAF	DEPTH	SCRAWL	STEM	LEAF
19	*H	0 (	01111122222334457779	1	*	-1.4 (	9
	M	1)	023445	1		-1.3)	
21	H	2 (	0022236678	2		-1.2 (	6
11		3)	023	2		-1.1)	
8		4 (	08	2		-1.0 (	
6		5)	3	5		-0.9)	450
5		6 (		5		-0.8 (	
5		7)		6		-0.7)	8
5		8 (	0	10		-0.6 (	0000
4		9)		11		-0.5)	0.
4		10 (		13	H	-0.4 (	80
4		11)		14		-0.3)	9
4		12 (		15		-0.2 (	7
4		13)		18		-0.1)	888
4		14 (		19		-0.0 (	4
4		15)		20		+0.0)	1
4		16 (			M	+0.1 (	01348
4		17)	6	21		+0.2)	
3		18 (		21		+0.3 (	004456
3		19)	02	15	H	+0.4)	12348
1		20 (		10		+0.5 (	11
1		21)		8		+0.6)	08
1		22 (		6		+0.7 (	3
1		23)		5		+0.8)	
1	*	24 (	0	5		+0.9 (	0
				4		+1.0)	
				4		+1.1 (	
				4		+1.2)	588
				1	*	+1.3 (	8

ARITHMETIC AND LOGARITHMIC STATION RATIOS FOR BENTHIC MACROINVERTEBRATES

BAETIS

DATE	ARITHMETIC RATIOS					DATE	LOGARITHMIC RATIOS (BASE 10)				
	C1R/E1R	C2R/E2R	C1C/E1C	C1C/E1L	E2L/E2E		C1R/E1R	C2R/E2R	C1C/E1L	C1L/E1L	E2L/E2E
2-69	.000	.000	.000	.000	.000	2-69	.000	.000	.000	.000	.000
5-69	.000	.000	.000	.000	.000	5-69	.000	.000	.000	.000	.000
6-69	.000	3.947	6.743	5.897	.000	6-69	.000	.596	.829	.771	.000
7-69	2.294	1.301	1.736	3.747	.000	7-69	.361	.114	.240	.574	.000
8-69	1.878	1.185	1.735	2.304	.792	8-69	.274	.074	.239	.362	-.101
9-69	1.884	2.389	1.571	1.000	3.133	9-69	.275	.378	.196	0.000	.496
10-69	.658	2.815	1.000	.686	6.857	10-69	-.182	.449	0.000	-.164	.836
11-69	.000	.000	.000	.000	.000	11-69	.000	.000	.000	.000	.000
2-70	.000	.000	.000	.000	.000	2-70	.000	.000	.000	.000	.000
5-70	.000	.000	.000	.000	.000	5-70	.000	.000	.000	.000	.000
6-70	5.529	3.800	1.805	2.553	.352	6-70	.743	.580	.257	.407	-.454
7-70	2.266	.676	1.235	2.282	.467	7-70	.359	-.170	.092	.358	-.331
8-70	1.970	3.439	.743	.000	1.513	8-70	.294	.536	.129	.000	.180
9-70	.791	5.037	2.806	.588	27.333	9-70	-.102	.702	.448	-.231	1.437
10-70	.583	148.000	1.905	1.028	43.200	10-70	-.234	2.170	.280	.012	1.635
11-70	.000	.000	1.000	.000	.000	11-70	.000	.000	.000	.000	.000
2-71	.000	.000	.000	.000	.000	2-71	.000	.000	.000	.000	.000
5-71	.000	.000	.000	.000	.000	5-71	.000	.000	.000	.000	.000
6-71	.635	1.280	31.714	2.783	.309	6-71	-.197	.107	1.501	.444	-.510
7-71	7.233	2.745	14.476	4.181	.277	7-71	.859	.439	1.161	.621	-.557
8-71	1.107	1.706	.836	2.526	4.430	8-71	.044	.232	-.078	.402	.646
9-71	.586	3.950	2.423	3.074	6.000	9-71	-.232	.597	.384	.486	.778
10-71	.889	1.500	.977	2.000	15.692	10-71	-.051	.176	-.010	.301	1.196
11-71	.000	.000	.000	.000	.000	11-71	.000	.000	.000	.000	.000
6-72	.000	2.333	.000	.000	1.286	6-72	.000	.368	.000	.000	.109
7-72	.000	.000	.000	.000	.000	7-72	.000	.000	.000	.000	.000
10-72	.000	8.000	.000	.000	.000	10-72	.000	.903	.000	.000	.000
11-72	.000	.000	.000	.000	.000	11-72	.000	.000	.000	.000	.000
10-73	.000	.000	.000	.000	.000	10-73	.000	.000	.000	.000	.000

BAETIS

D-5

ARITHMETIC AND LOGARITHMIC STATION RATIOS FOR BENTHIC MACROINVERTEBRATES

STENONEMA

DATE		ARITHMETIC RATIO				DATE	LOGARITHMIC RATIOS (BASE 10)			
		C1B/E1R	C2R/E2R	C1C/E1C	C1L/E1L E2L/E2E		C1R/E1R	C2R/E2R	C1C/E1L	C1L/E1L E2L/E2E
2-69	.000	.000	.000	.000	.000	2-69	.000	.000	.000	.000
5-69	.000	2.250	.000	.000	.000	5-69	.000	.352	.000	.000
6-69	.000	2.000	6.000	19.000	.000	6-69	.000	.301	.778	1.279
7-69	1.333	.909	2.667	8.500	.000	7-69	.125	.041	.426	.929
8-69	1.500	.667	1.316	.950	.000	8-69	.176	.176	.119	.022
9-69	2.100	.458	1.080	.850	.000	9-69	.322	.339	.053	.071
10-69	7.333	.667	1.421	1.087	.000	10-69	.865	.176	.153	.036
11-69	.000	.000	.000	.250	.000	11-69	.000	.000	.000	.000
2-70	.000	.333	.000	.000	.000	2-70	.000	.477	.000	.000
5-70	.000	.000	.000	.000	.000	5-70	.000	.000	.000	.000
6-70	1.050	2.143	.571	.250	.769	6-70	.021	.331	.243	.602
7-70	5.750	.938	.400	.273	1.455	7-70	.760	.028	.398	.564
8-70	2.250	.208	.667	.000	.333	8-70	.352	.681	.176	.000
9-70	2.222	.350	1.375	.333	7.167	9-70	.347	.456	.138	.477
10-70	1.344	.364	.706	4.438	6.444	10-70	.128	.439	.151	.647
11-70	3.250	.000	9.000	.222	.000	11-70	.512	.000	.954	.653
2-71	.000	.447	.000	.000	.000	2-71	.000	.349	.000	.000
5-71	.000	.417	.000	.000	.000	5-71	.000	.380	.000	.000
6-71	2.750	1.600	4.000	1.500	.750	6-71	.439	.204	.602	.176
7-71	7.625	.600	1.000	1.857	1.800	7-71	.882	.222	0.000	.269
8-71	.650	.250	.250	1.000	.952	8-71	.187	.602	.602	.021
9-71	1.313	2.750	.950	.824	1.412	9-71	.118	.439	.022	.084
10-71	6.250	.857	1.000	2.000	1.520	10-71	.796	.067	0.000	.301
11-71	.000	.000	.000	.000	.000	11-71	.000	.000	.000	.000
6-72	.000	.667	.000	.000	1.231	6-72	.000	.176	.000	.090
7-72	.000	.000	.000	.000	.000	7-72	.000	.000	.000	.000
10-72	.000	.000	.000	.000	.000	10-72	.000	.000	.000	.000
11-72	.000	3.000	.000	.000	.000	11-72	.000	.477	.000	.000
10-73	.000	.000	.000	.000	.000	10-73	.000	.000	.000	.000

STEM AND LEAF DISPLAYS OF STATION RATIOS FOR BENTHIC MACROINVERTEBRATES

STENONEMA

ARITHMETIC RATIOS

DEPTH	SCRAWL	STEM	LEAF
31	*H	0 (	2222223334444456667777788888999
	M	1)	000000011233334445555689
24	H	2 (	0011222788
14		3)	02
12		4 (	04
10		5)	8
9		6 (	024
6		7)	356
3		8 (	5
2		9)	0
1		10 (	
1		11)	
1		12 (	
1		13)	
1		14 (	
1		15)	
1		16 (	
1		17)	
1		18 (	
1	*	19)	0

LOGARITHMIC RATIOS (BASE 10)

DEPTH	SCRAWL	STEM	LEAF
6	*	-,6 (	850000
7		-,5)	6
12		-,4 (	88640
15		-,3)	854
17		-,2 (	42
25	H	-,1)	98888521
35		-,0 (	9877432220
	M	+,0)	002349
38		+,1 (	22234556888
27		+,2)	067
24	H	+,3 (	0023555
17		+,4)	3448
13		+,5 (	1
12		+,6)	05
10		+,7 (	68
8		+,8)	01778
3		+,9 (	35
1		+1,0)	
1		+1,1 (	
1	*	+1,2)	8

ARITHMETIC AND LOGARITHMIC STATION RATIOS FOR BENTHIC MACROINVERTEBRATES

CHIRONOMINI

DATE	ARITHMETIC RATIOS					DATE	LOGARITHMIC RATIOS (BASE 10)				
	C1R/E1R	C2R/E2R	C1C/E1C	C1L/E1L	E2L/E2E		C1R/E1R	C2R/E2R	C1C/E1C	C1L/E1L	E2L/E2E
2-69	.000	.000	.000	.000	.000	2-69	.000	.000	.000	.000	.000
5-69	.000	.000	.000	.000	.000	5-69	.000	.000	.000	.000	.000
6-69	.000	1.484	4.521	2.707	.000	6-69	.000	.171	.655	.432	.000
7-69	3.711	.000	.963	1.479	.000	7-69	.569	.000	-.016	.170	.000
8-69	.540	.000	1.468	1.882	.637	8-69	-.267	.000	.167	.275	-.196
9-69	1.161	.000	1.529	.906	1.797	9-69	.065	.000	.185	-.043	.255
10-69	.593	.000	.862	.605	2.163	10-69	-.227	.000	-.064	-.218	.335
11-69	.401	.000	.541	.489	3.130	11-69	-.397	.000	-.267	-.311	.496
2-70	.000	.179	.000	.000	.000	2-70	.000	.748	.000	.000	.000
5-70	.000	.000	.000	.000	.000	5-70	.000	.000	.000	.000	.000
6-70	1.160	1.713	3.268	2.166	1.739	6-70	.064	.234	.514	.336	.240
7-70	1.129	1.051	.597	1.104	1.417	7-70	.053	.022	-.224	.043	.151
8-70	1.279	1.969	1.447	.000	2.841	8-70	.107	.294	.161	.000	.453
9-70	1.375	1.121	2.444	.829	15.051	9-70	.138	.050	.388	-.081	1.178
10-70	.569	1.507	1.130	1.116	2.827	10-70	-.245	.178	.053	.048	.451
11-70	1.153	.000	.972	1.067	.737	11-70	.062	.000	-.013	.028	-.132
2-71	.000	.214	.000	.000	.000	2-71	.000	.669	.000	.000	.000
5-71	.000	1.757	.000	.000	.000	5-71	.000	.245	.000	.000	.000
6-71	2.065	1.790	2.837	1.219	2.686	6-71	.315	.253	.453	.086	.429
7-71	4.066	1.069	1.560	7.149	5.250	7-71	.611	.029	.193	.854	.720
8-71	.817	.887	.507	1.925	2.123	8-71	-.088	-.052	-.295	.284	.327
9-71	.904	.571	.917	.710	1.861	9-71	-.044	-.243	-.038	-.149	.270
10-71	1.563	.675	1.203	.688	.485	10-71	.194	-.170	.080	-.163	-.314
11-71	.000	.000	.000	.000	.000	11-71	.000	.000	.000	.000	.000
6-72	.000	1.104	.000	.000	3.029	6-72	.000	.043	.000	.000	.481
7-72	.000	.000	.000	.000	.000	7-72	.000	.000	.000	.000	.000
10-72	.000	1.235	.000	.000	.983	10-72	.000	.092	.000	.000	.008
11-72	.000	.950	.000	.000	.452	11-72	.000	-.022	.000	.000	-.345
10-73	.000	.000	.000	.000	.000	10-73	.000	.000	.000	.000	.000

STEM AND LEAF DISPLAYS OF STATION RATIOS FOR BENTHIC MACROINVERTEBRATES

CHIRONOMINI

ARITHMETIC RATIOS				LOGARITHMIC RATIOS (BASE 10)			
DEPTH	SCRAWL	STEM	LEAF	DEPTH	SCRAWL	STEM	LEAF
26	*H	0 (	22455555566666677778899999	1	*	-,7 (	5
	MH	1)	00001111111112222223444555	2		-,6)	7
			556677888999	2		-,5 (	
20		2 (	01122477888	3		-,4)	0
9		3)	0137	7		-,3 (	5110
5		4 (	15	15		-,2)	77543220
3		5)	2	19		-,1 (	7653
2		6 (		30	H	-,0)	98654442211
2		7)	1		M	+,0 (	233445555666899
1		8 (		39		+,1)	14567778899
1		9)		28	H	+,2 (	344557789
1		10 (		19		+,3)	13449
1		11)		14		+,4 (	335558
1		12 (		8		+,5)	017
1		13)		5		+,6 (	16
1		14 (		3		+,7)	2
1	*	15)	1	2		+,8 (	5
				1		+,9)	
				1		+1,0 (	
				1	*	+1,1)	8

ARITHMETIC AND LOGARITHMIC STATION RATIOS FOR BENTHIC MACROINVERTEBRATES

SIMULIDAE

ARITHMETIC RATIO						LOGARITHMIC RATIOS (BASE 10)					
DATE	C1B/E1R	C2R/E2R	C1C/E1C	C1L/E1L	E2L/E2E	DATE	C1R/E1R	C2R/E2R	C1C/E1C	C1L/E1L	E2L/E2E
2-69	.000	.000	.000	.000	.000	2-69	.000	.000	.000	.000	.000
5-69	.000	0.000	.000	.000	.000	5-69	.000	0.000	.000	.000	.000
6-69	.000	.261	23.414	7.047	.000	6-69	.000	-.583	1.369	.846	.000
7-69	20.000	1.844	1.064	1.202	.000	7-69	1.301	.266	.027	.080	.000
8-69	.450	.414	1.212	.663	6.600	8-69	-.347	-.383	.084	-.178	.820
9-69	.100	.000	2.200	1.125	.000	9-69	-1.000	.000	.342	.051	.000
10-69	.000	25.000	3.750	.400	.000	10-69	.000	1.398	.574	-.398	.000
11-69	.452	2.933	.906	.222	2.167	11-69	-.345	.467	-.043	-.653	.336
2-70	.000	.000	.000	.000	.000	2-70	.000	.000	.000	.000	.000
5-70	.000	.000	.000	.000	.000	5-70	.000	.000	.000	.000	.000
6-70	.504	.389	3.378	5.516	5.632	6-70	-.298	-.410	.529	.742	.751
7-70	.067	1.000	.068	.833	.000	7-70	-1.176	0.000	-1.169	-.079	.000
8-70	.200	.000	.538	.000	2.000	8-70	-.699	.000	-.269	.000	.301
9-70	.000	.000	2.714	.111	6.400	9-70	.000	.000	.434	-.954	.806
10-70	.013	.000	3.227	.528	.000	10-70	-1.903	.000	.509	-.278	.000
11-70	.000	.000	1.397	.333	2.000	11-70	.000	.000	.145	-.477	.301
2-71	.000	.000	.000	.000	.000	2-71	.000	.000	.000	.000	.000
5-71	.000	.026	.000	.000	.000	5-71	.000	-1.583	.000	.000	.000
6-71	2.643	2.133	2.613	1.655	30.667	6-71	.422	.329	.417	.219	1.487
7-71	.521	.125	.186	.437	18.857	7-71	-.283	-.903	-.729	-.360	1.275
8-71	.214	1.182	.044	.426	.000	8-71	-.669	.073	-1.359	-.371	.000
9-71	.313	.000	1.000	.000	.000	9-71	-.505	.000	0.000	.000	.000
10-71	.000	.000	4.000	2.000	.000	10-71	.000	.000	.602	.301	.000
11-71	.000	.000	.000	.000	.000	11-71	.000	.000	.000	.000	.000
6-72	.000	.000	.000	.000	.000	6-72	.000	.000	.000	.000	.000
7-72	.000	.000	.000	.000	.000	7-72	.000	.000	.000	.000	.000
10-72	.000	.000	.000	.000	.000	10-72	.000	.000	.000	.000	.000
11-72	.000	.000	.000	.000	.000	11-72	.000	.000	.000	.000	.000
10-73	.000	.000	.000	.000	.000	10-73	.000	.000	.000	.000	.000

STEM AND LEAF DISPLAYS OF STATION RATIOS FOR BENTHIC MACROINVERTEBRATES

SIMULIDAE

ARITHMETIC RATIOS				LOGARITHMIC RATIOS (BASE 10)			
DEPTH	SCRAWL	STEM	LEAF	DEPTH	SCRAWL	STEM	LEAF
30	*H	0 (	0000111111222233	1	*	-3.8	(5
			344444445555789	1		-3.7	)
	M	1)	0011222478	1		-3.6	(
24	H	2 (	0001226679	1		-3.5	)
14		3)	248	1		-3.4	(
11		4 (	0	1		-3.3	)
10		5)	56	1		-3.2	(
8		6 (	46	1		-3.1	)
6		7)	0	1		-3.0	(
5		8 (		1		-2.9	)
5		9)		1		-2.8	(
5		10 (		1		-2.7	)
5		11)		1		-2.6	(
5		12 (		1		-2.5	)
5		13)		1		-2.4	(
5		14 (		1		-2.3	)
5		15)		1		-2.2	(
5		16 (		1		-2.1	)
5		17)		1		-2.0	(
5		18 (	9	2		-1.9	)
4		19)		2		-1.8	(
4		20 (	0	2		-1.7	)
3		21)		2		-1.6	(
3		22 (		3		-1.5	)
3		23)	4	3		-1.4	(
2		24 (		4		-1.3	)
2		25)	0	4		-1.2	(
1		26 (					
1		27)					
1		28 (					
1		29)					
1		30 (	7				

ARITHMETIC AND LOGARITHMIC STATION RATIOS FOR BENTHIC MACROINVERTEBRATES

HYDROPSYCHE AND CHEUMATOPSYCHE

DATE	ARITHMETIC RATIO					DATE	LOGARITHMIC RATIOS (BASE 10)				
	C1R/E1R	C2R/E2R	C1C/E1C	C1L/E1L	E2L/E2E		C1R/E1R	C2R/E2R	C1C/E1C	C1L/E1L	E2L/E2E
2-69	.000	.000	.000	.000	.000	2-69	.000	.000	.000	.000	.000
5-69	.000	2.528	.000	.000	.000	5-69	.000	.403	.000	.000	.000
6-69	.000	1.530	.912	.454	.000	6-69	.000	.185	-.040	-.343	.000
7-69	1.263	.582	.871	1.327	.000	7-69	.102	-.235	-.060	.123	.000
8-69	.434	1.284	1.045	1.470	3.307	8-69	-.362	.109	.019	.167	.519
9-69	.530	.747	.663	.639	18.697	9-69	-.276	-.127	-.178	-.195	1.272
10-69	.451	.584	.737	.609	23.259	10-69	-.345	-.233	-.133	-.215	1.367
11-69	.150	.331	.297	.188	11.800	11-69	-.823	-.480	-.528	-.727	1.072
2-70	.000	.014	.000	.000	.000	2-70	.000	-1.843	.000	.000	.000
5-70	.000	.000	.000	.000	.000	5-70	.000	.000	.000	.000	.000
6-70	.419	1.064	.403	.275	.966	6-70	-.378	.027	-.395	-.561	-.015
7-70	.506	.635	.611	.721	1.948	7-70	-.295	-.197	-.214	-.142	.290
8-70	.772	.893	.990	.000	5.432	8-70	-.113	-.049	-.004	.000	.735
9-70	.296	2.942	1.328	.727	39.510	9-70	-.529	.469	.123	-.138	1.596
10-70	.318	4.019	1.212	.234	16.743	10-70	-.498	.604	.084	-.631	1.224
11-70	.972	.000	1.667	.867	6.100	11-70	-.012	.000	.222	-.062	.785
2-71	.000	.051	.000	.000	.000	2-71	.000	-1.289	.000	.000	.000
5-71	.000	.718	.000	.000	.000	5-71	.000	-.144	.000	.000	.000
6-71	.244	.731	.905	.470	1.811	6-71	-.613	-.136	-.044	-.328	.258
7-71	.726	.692	1.360	1.235	3.179	7-71	-.139	-.160	.136	.092	.502
8-71	.424	.924	.472	.433	5.735	8-71	-.372	-.034	-.326	-.364	.758
9-71	.119	2.779	.600	.250	71.273	9-71	-.925	.444	-.222	-.602	1.853
10-71	.418	1.435	.299	.297	28.471	10-71	-.378	.157	-.524	-.527	1.454
11-71	.000	.000	.000	.000	.000	11-71	.000	.000	.000	.000	.000
6-72	.548	.000	.000	.000	2.360	6-72	-.261	.000	.000	.000	.373
7-72	.000	.000	.000	.000	.000	7-72	.000	.000	.000	.000	.000
10-72	.740	.000	.000	.000	1.243	10-72	-.131	.000	.000	.000	.094
11-72	.000	.000	.000	.000	1.479	11-72	.000	.000	.000	.000	.170
10-73	.000	.000	.000	.000	.000	10-73	.000	.000	.000	.000	.000

HYDROPSYCHE AND CHEUMATOPSYCHE

ARITHMETIC RATIOS

LOGARITHMIC RATIOS (BASE 10)

D-13

APPENDIX E

ORIGINAL PERIPHYTON DATA

TOTAL NUMBERS (cells/cm²) OF PERIPHYTIC ALGAE OBSERVED AT MONTICELLO

DATE	STATIONS						
	2	7	9	3	6	11	3A
	---	---	---	---	---	---	---
7-28-70	7468468	4894302	-	2958086	2958086	2510643	-
8-25-70	1027427	1456428	-	728230	-	-	-
7-22-71	1050021	-	-	-	-	-	-
8-19-71	356694	4575238	7757298	4764301	13821705	9535905	4535805
10-28-71	3184	1393	-	51191	16886	-	13532
5-22-72	12754	1000	4650	2080	1200	1360	-
6- 5-72	4075140	31480	71540	1435980	29199	15650	23940
6-19-72	12245875	3219280	23655370	11279530	6881972	4508589	24700
7- 4-72	5031141	5206860	10150000	3304720	21088408	12063443	79170
7-17-72	24891908	10013670	6613590	3629830	17174658	23943134	199830
7-31-72	6811311	-	21308520	-	-	-	10397750
8-15-72	-	-	3539220	-	-	-	2981160
9- 1-72	8538558	900	9900970	14840	1747323	780	602390
9-18-72	31250	2210	3068450	139300	35085	26120	15900
10- 3-72	32412	37090	16470	4620	139968	23470	2210
10-17-72	41846	10030	19620	12630	7130	49250	76230
11- 1-72	7080	4580	15350	8200	1900	20530	3880
11-28-72	-	19250	7200	-	-	-	900
3- 3-73	-	-	-	-	1467	-	7210
4-24-73	92220	350	6748530	349380	2983000	-	9920
5- 9-73	1368000	5460	2257000	57500	4794000	-	107810
5-22-73	3798500	120	168340	231000	15220	-	596700
6- 5-73	10386	14580	101680	12170	481680	121440	661200
6-20-73	43421680	11700840	45901560	54469800	53100900	51501746	602120
7- 2-73	39102000	62660480	15452480	4107960	28632720	19860720	5500
7-17-73	68401080	44943120	67400480	48600240	64980720	54041080	26100
7-31-73	56501400	61361200	28901080	61400640	43201080	61560600	3390
8-14-73	38861500	22531000	61541110	66280120	41976240	64980036	6357500
8-28-73	39121160	231260	61540540	2616120	43626660	43201720	263600
9-11-73	74302640	42421640	26000480	8060	32350880	64721240	36841840
9-25-73	3538260	41302280	52500660	71580	60720900	71153540	898960
10- 9-73	8570	33650	98555	18080	197460	54400	4960
10-26-73	3760	-	-	-	-	-	985920
11- 9-73	240	240	-	640	720	-	-
5-22-74	1031978	409626	882406	533	1636	7612	3307808
6-10-74	8786350	-	26458462	1223802	958574	978560	4902910
6-25-74	1204072	-	3552176	5233415	828618	2462562	623210
7- 9-74	4024900	96702180	5755468	831882	4622414	786532	1111429
7-23-74	3366320	999800	13900340	2381710	1788170	2703020	4982
8- 5-74	1103100	806300	2937900	873800	809200	3264300	2376
8-20-74	4855200	1281900	1815590	1570900	1970920	1581200	3712900
9- 4-74	1563840	1530900	4203000	1170700	1931400	2132400	344120
9-19-74	735500	572300	469700	695640	2030300	1020500	122860
10- 2-74	306300	267520	378200	176432	1938700	623300	22941
10-16-74	43040	429900	469500	227200	510300	476500	3011
11- 3-74	107500	245000	489900	272300	296400	296000	34880

TOTAL NUMBERS (cells/cm²) OF THE PERIPHYTIC ALGA

Gomphnama olivaceum OBSERVED AT MONTICELLO

STATIONS

DATE	2	7	9	3	6	11	3A
	---	---	---	---	---	---	---
5-22-72	300	-	400	120	-	120	120
6- 5-72	284	-	-	-	300	240	-
6-19-72	-	-	-	-	-	420	-
7- 4-72	120	-	-	-	-	120	-
7-17-72	120	-	-	-	-	-	300
9- 1-72	-	-	120	-	-	-	-
9-18-72	-	-	120	-	300	-	-
10- 3-72	2100	21600	900	400	78715	1350	120
10-17-72	4900	2800	4500	-	1300	6500	900
11- 1-72	300	1100	2800	400	-	900	730
11-28-72	-	1350	400	-	-	-	-
2-16-73	-	-	-	-	420	29200	-
3- 3-73	-	-	-	-	507	310	120
4-24-73	-	20	-	120	120	2000	2300
5-22-73	-	-	-	21000	-	-	120
6- 5-73	186	1300	120	-	48000	120	-
6-20-73	-	-	-	-	-	-	120
7- 2-73	-	-	-	-	-	-	640
9-25-73	977000	-	-	-	-	-	-
10- 9-73	-	-	-	240	-	320	240
11- 9-73	-	-	-	-	-	420	-
5-22-74	236990	29652	85576	43	110	406	652170
6-10-74	530	-	-	1300	-	-	-
6-25-74	-	-	-	100	-	-	-
7- 9-74	-	-	10304	-	-	129250	-
7-23-74	10	-	-	-	-	-	-
8- 5-74	30600	-	-	-	-	-	-
8-20-74	-	469200	-	-	-	-	-
9- 4-74	-	100	10300	-	-	-	-
9-19-74	-	13700	-	-	-	-	-
10- 2-74	-	-	-	-	-	112300	-
10-16-74	-	-	-	-	-	129200	-
11- 3-74	-	-	-	-	27200	-	-

TOTAL NUMBERS (cells/cm²) OF THE PERIPHYTIC ALGA Cybellasinuata
OBSERVED AT MONTICELLO

STATIONS							
DATE	2	7	9	3	6	11	3A
	---	---	---	---	---	---	---
5-22-72	120	-	-	-	-	-	-
6- 5-72	2072	-	3700	-	-	-	-
6-19-72	2316	-	28500	300	1800	1350	-
7- 4-72	7300	1350	8700	120	4100	1350	-
7-17-72	7300	-	3100	120	86499	1400	-
7-31-72	4500	-	4500	-	-	-	-
9- 1-72	120	-	-	-	-	-	-
6-20-73	-	-	120	-	2700000	2500000	-
7- 2-73	8640000	13680000	1476000	120	3116000	2460000	460
7-17-73	-	120	-	-	-	-	-
7-31-73	-	-	240	-	-	-	-
8-14-73	120	-	-	120	120	120	420
8-28-73	-	-	-	-	-	1200	-
9-11-73	-	320	-	-	640	640	-
5-22-74	8601	-	8526	-	18	-	16200
6-10-74	73800	-	6490	2800	6490	2040	-
6-25-74	132650	-	5100	-	27210	-	-
7- 9-74	1000	103800	40820	15310	-	-	-
7-23-74	-	-	-	-	-	10	-
8- 5-74	100	-	6800	-	-	-	72
8-20-74	-	-	-	100	10200	-	-
9- 4-74	-	-	-	100	-	100	100
9-19-74	-	13600	-	-	10200	-	-
10- 2-74	-	-	-	-	-	100	-

TOTAL NUMBERS (cells/cm²) OF THE PERIPHYTIC ALGA

Achnanthes laceolata OBSERVED AT MONTICELLO

DATE	STATIONS						
	2	7	9	3	6	11	3A
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5-22-72	-	-	-	-	-	-	2070
6- 5-72	-	120	2750	120	300	-	3820
6-19-72	-	-	3400	300	420	1400	5640
7- 4-72	-	-	27120	300	1250	600	2100
7-17-72	-	-	1870	120	3920	-	1950
7-31-72	120	-	2160	-	-	-	3600
8-15-72	-	-	120	-	-	-	-
9- 1-72	499717	-	-	400	-	-	220
9-18-72	-	-	730	-	-	-	-
10- 3-72	-	-	-	-	240	-	-
10-17-72	-	-	-	900	120	-	-
5- 9-73	-	-	-	-	-	-	200
6-20-73	-	-	2700120	-	-	-	59800
7- 2-73	-	-	-	-	-	-	120
7-17-73	-	-	120	-	-	120	-
7-31-73	-	-	3580120	-	-	-	920
8-14-73	-	25000	120	-	-	-	239000
8-28-73	1560000	-	-	-	2186000	-	-
9-11-73	11300000	8400000	2940000	120	3210000	-	11800000
9-25-73	-	420	-	420	120	8500000	-
10- 9-73	-	-	-	420	-	-	340
10-26-73	120	-	-	-	-	-	360
5-22-74	-	8526	8526	18	18	-	1800
6-10-74	45510	-	14130	1410	15770	4080	-
6-25-74	30612	-	35700	-	10	47618	-
7- 9-74	52042	-	-	15310	40816	6122	248900
7-23-74	-	-	-	51300	-	10200	-
8- 5-74	20400	-	13700	-	-	100	100
8-20-74	-	-	102000	30600	183600	51000	1703400
9- 4-74	61200	100	142800	550800	95200	200	16320
9-19-74	27200	6800	20400	100	112200	10200	2910
10- 2-74	-	-	88400	-	100	100	-
10-16-74	-	-	20400	100	-	-	-

TOTAL NUMBERS (cells/cm²) OF THE PERIPHYTIC ALGA

Gomthonema parvulum OBSERVED AT MONTICELLO

STATIONS

DATE	2	7	9	3	6	11	3A
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6- 5-72	900	30270	2800	879000	6500	4500	2600
6-19-72	731	17900	1100000	342400	1499999	23789	-
7- 4-72	894	2600	400	2100	1100	59685	-
7-17-72	120	2100	-	730	120	730	-
7-31-72	731	-	-	-	-	-	4100
8-15-72	-	-	2100	-	-	-	-
9- 1-72	784	120	730	730	103800	120	-
9-18-72	1800	900	60000	78700	6704	23908	120
10- 3-72	5400	2800	730	1800	15000	5400	-
10-17-72	-	2100	300	1800	730	550	120
11- 1-72	-	120	-	300	-	-	120
11-28-72	-	2800	-	-	-	-	120
6- 5-73	1000	1400	480	1130	48000	36000	-
6-20-73	4000000	585000	-	-	-	-	120
7- 2-73	4300000	240	480	1400000	480	240	-
7-17-73	240	120	240	120	120	240	120
7-31-73	320	120	-	120	120	240	-
8-14-73	420	-	-	-	-	-	-
8-28-73	-	-	-	120	-	-	27600
9-11-73	120	-	-	-	-	-	12000
9-25-73	900000	120	-	248	-	-	13000000
10- 9-73	-	-	240	120	-	-	240
5-22-74	-	229509	8526	43	464	-	-
6-10-74	12300	-	-	890	6490	-	-
6-25-74	112244	-	35710	40820	20408	455780	-
7- 9-74	6802	494570	234690	100	40820	299320	-
7-23-74	100	-	-	-	30600	-	-
8- 5-74	100	-	20400	6800	-	-	-
8-20-74	-	20400	-	-	102000	-	-
9- 4-74	10200	-	100	-	-	-	-
9-19-74	40800	13600	20400	1200	714000	183600	-
10- 2-74	-	-	100	8160	-	-	-
11- 3-74	-	-	-	-	100	-	-

TOTAL NUMBERS (cells/cm²) OF THE PERIPTYIC ALGA

Cocconeis placentula OBSERVED AT MONTICELLO

STATIONS

DATE	2	7	9	3	6	11	3A
7-28-70	344351	508059	-	318954	330236	419146	-
8-25-70	251211	427614	-	375406	-	-	-
7-22-71	54763	-	742872	523820	-	378594	66668
8-19-71	28509	538106	623822	578583	721443	292863	107145
10-28-71	2388	995	-	-	1988	-	398
6-5-72	3891300	550	60000	565200	19679	3700	120
6-19-72	7434800	3200000	21000000	10900000	4391303	1804348	1400
7-4-72	4391300	5200000	10000000	3200000	20909000	5891304	300
7-17-72	24636400	10000000	60000000	3500000	16272727	11782608	13600
7-31-72	5000000	-	18400000	-	-	-	65000
8-15-72	-	-	3500000	-	-	-	900
9-1-72	7535000	-	6000000	11000	1493000	120	-
9-18-72	23800	400	3000000	18000	38000	1350	120
10-3-72	18000	2800	300	400	31791	3100	400
10-17-72	120	300	-	2100	400	1100	900
11-1-72	-	-	-	120	-	-	-
11-28-72	-	550	-	-	-	-	-
6-5-73	1000	5800	50000	4000	192000	60000	480
6-20-73	17000000	8000000	11000000	12000000	11000000	12000000	240
7-2-73	17500000	28500000	7500000	1600000	16000000	10000000	680
7-17-73	20000000	11000000	-	11000000	14000000	13000000	7750
7-31-73	26000000	27000000	14000000	27000000	16000000	21000000	130
8-14-73	13000000	21000000	21000000	21000000	18000000	21000000	2000000
8-28-73	24000000	180000	21000000	2000000	22000000	22000000	-
9-11-73	34000000	22000000	10000000	2500	16000000	31000000	-
9-25-73	400000	9000000	15000000	26000	21000000	21000000	21000000
10-9-73	1000	6000	33000	1800	92000	21000	1200
10-26-73	2200	-	-	-	-	-	250000
5-22-74	18894	18732	8526	86	134	406	1600
6-10-74	4879000	-	26400000	1200000	827270	714280	10
6-25-74	346936	-	331630	544215	503400	163264	100
7-9-74	530608	76000000	520404	515302	265304	163264	122450
7-23-74	612000	591600	238000	418200	591600	550800	1200
8-5-74	530400	591600	442000	408000	584800	550800	72
8-20-74	489600	591600	448800	622200	550800	-	561000
9-4-74	693600	652800	418200	346800	360400	624600	16320
9-19-74	374000	360400	265200	346800	346800	469200	46650
10-2-74	-	10200	34000	24480	40800	326400	2040
10-16-74	-	100	-	6800	100	6800	-
11-3-74	-	100	-	-	13600	-	100

TOTAL NUMBERS (cells/cm²) OF THE PERIPHYTIC ALGA

Chroococcus minimus OBSERVED AT MONTICELLO

STATIONS

DATE	2	7	9	3	6	11	3A
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7-28-70	6412834	3533833	-	2407678	2049159	2730881	-
8-25-70	635085	635070	-	231453	-	-	-
6- 5-72	3700	-	-	-	-	5500	-
6-19-72	4786608	2300	1500000	34600	978260	869515	400
7- 4-72	234414	-	97800	97800	168478	217391	71800
7-17-72	244565	9730	598000	127200	798912	374999	300
7-31-72	1804347	-	2900000	-	-	-	2400000
8-15-72	-	-	34600	-	-	-	-
9- 1-72	495000	-	3000000	730	168476	120	-
9-18-72	730	-	1500	34600	3700	120	1600
10- 3-72	-	3700	300	-	-	300	300
10-17-72	-	-	-	-	-	-	65700
6- 5-73	1000	1400	20000	4500	96000	12000	-
6-20-73	8600000	2340000	32000000	41000000	32000000	34000000	60000
7- 2-73	8600000	13700000	3500000	350000	3200000	5100000	-
7-17-73	41000000	29000000	47000000	32000000	41000000	34000000	-
7-31-73	29000000	34000000	8000000	34000000	27000000	41000000	-
8-14-73	26000000	2000000	41000000	41000000	22000000	41000000	4000000
8-28-73	12000000	50000	41000000	1000000	17000000	22000000	14000
9-11-73	17000000	7000000	10000000	-	10000000	31000000	120
9-25-73	600000	5000000	10000000	-	10000000	120	150000
10- 9-73	2000	240	-	1800	420	-	-
5-22-74	-	18732	-	-	10	-	16000
6-10-74	3772000	-	31790	2060	95150	255100	-
6-25-74	551016	-	3020380	4081600	142860	1659850	-
7- 9-74	3333300	20000000	4795880	285710	4107110	102040	126530
7-23-74	2754000	316200	13600000	1912500	1122000	2142000	-
8- 5-74	510000	100	2448000	459000	217600	2703000	100
8-20-74	4335000	183600	1190000	918000	734400	1530000	1320000
9- 4-74	714000	877200	3468000	47600	1428000	1479000	269200
9-19-74	68000	100	100	13600	765000	357000	-
10- 2-74	27200	-	-	1000	5100	-	-

TOTAL NUMBERS (cells/cm²) OF THE PERIPYITIC ALGA

Navicula cf. rhynchocephala OBSERVED AT MONTICELLO

STATIONS

DATE	2	7	9	3	6	11	3A
	---	---	---	---	---	---	---
5-22-72	400	-	120	-	-	-	-
6- 5-72	-	-	-	-	-	120	120
6-19-72	-	-	-	300	300	120	120
7- 4-72	300	300	400	300	400	-	-
7-17-72	120	120	-	120	300	120	-
7-31-72	-	-	-	-	-	-	120
9- 1-72	-	-	-	400	120	-	-
9-18-72	300	-	400	120	400	-	-
10- 3-72	1350	730	1800	-	1350	1100	-
10-17-72	1600	730	1100	300	730	7300	1600
11- 1-72	-	120	1600	-	-	1600	300
11-28-72	-	-	550	-	-	-	-
4-24-73	1200	-	1200	120	1520	120	120
5- 9-73	500	-	-	-	-	-	-
5-22-73	190000	-	5050	120	120	13420	107400
6- 5-73	-	1400	10000	120	120	120	120
6-20-73	2200000	-	-	-	1800000	360	320
7- 2-73	-	240	-	-	-	120	-
7-17-73	120	240	-	-	120	120	-
7-31-73	120	120	-	240	240	-	-
9-11-73	8500000	-	-	-	-	-	120
9-25-73	79000	4600000	1500000	8670	5000000	5200000	1200
10- 9-73	1030	3300	-	120	46000	7340	420
11- 9-73	-	-	-	-	240	-	-
5-22-74	30174	-	43239	-	18	406	215500
6-10-74	-	-	-	410	-	-	10
6-25-74	-	-	5100	-	-	-	-
7- 9-74	-	-	100	10	5102	6802	10
7-23-74	100	-	13600	-	-	-	-
8- 5-74	10200	61200	100	-	-	-	-
8-20-74	-	10200	-	-	10200	-	-
9- 4-74	100	100	100	6800	-	100	-
9-19-74	54400	13600	6800	100	10200	100	32060
10- 2-74	81600	51000	81600	24480	100	30600	-
10-16-74	14280	112200	142800	20400	40800	81600	1000
11- 3-74	100	-	-	-	-	-	-

TOTAL NUMBERS (cells/cm²) OF THE PERIPHYTIC ALGA *Synedria ulna*

OBSERVED AT MONTICELLO

DATE	STATIONS						
	2	7	9	3	6	11	3A
	---	---	---	---	---	---	---
5-22-72	3150	-	240	520	300	520	400
6- 5-72	120	-	-	-	-	-	120
6-19-72	420	-	-	-	-	-	120
7- 4-72	550	420	120	120	-	120	-
7-17-72	-	120	-	-	-	-	-
9-18-72	-	-	120	-	420	-	-
10- 3-72	300	300	2100	-	700	2000	-
10-17-72	3520	730	2550	120	400	4500	400
11- 1-72	1520	900	850	2100	550	4020	400
11-28-72	-	120	850	-	-	-	-
2-16-73	-	-	-	-	120	120	-
3- 3-73	-	-	-	-	120	100	-
4-24-73	4240	110	6534000	19560	2135200	3900	1400
5- 9-73	456000	2184	902800	25875	2157300	198000	2020
5-22-73	189900	-	16834	21000	1500	10700	24000
6- 5-73	240	-	120	-	240	-	-
6-20-73	360	-	120	120	120	120	-
9-25-73	120	2300000	5000000	-	-	120	-
10- 9-73	120	120	120	-	240	-	-
10-26-73	120	-	-	-	-	-	-
11- 9-73	-	120	-	-	-	-	-
5-22-74	277488	-	131859	86	214	1818	173912
6-10-74	120	-	100	100	406	-	10
8- 5-74	-	100	-	-	-	-	-
9- 4-74	100	-	-	-	-	-	-
10- 2-74	20400	51000	-	900	-	-	-
10-16-74	-	-	100	6900	30600	200	-
11- 3-74	10200	20400	71500	200	20400	-	-

TOTAL NUMBERS (cells/cm²) OF THE PERIPHYTIC ALGA *Synedria ulna*

OBSERVED AT MONTICELLO

STATIONS

DATE	2	7	9	3	6	11	3A
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7-22-71	"	"	"	"	"	"	4752
8-19-71	"	"	"	"	"	"	7143
6- 5-72	"	"	"	"	"	"	730
6-19-72	"	"	"	"	"	"	31000
7- 4-72	"	"	"	"	"	"	550
7-17-72	"	"	120	"	"	"	175000
7-31-72	"	"	120	"	"	"	7440000
8-15-72	"	"	"	"	"	"	730
9- 1-72	300	"	"	"	"	"	"
9-18-72	"	"	120	"	"	"	120
6-20-73	"	"	"	"	"	"	120000
7-17-73	"	"	"	"	"	"	130
7-31-73	"	"	120	"	"	"	720
8-14-73	"	"	"	"	"	"	500000
8-28-73	2000000	"	"	"	2000000	"	194000
9-11-73	"	3000000	500000	3400	1600000	"	"
10- 9-73	"	"	"	5400	"	"	120
10-26-73	"	"	"	"	"	"	740000
7- 9-74	"	"	"	"	"	"	24489
8-20-74	"	"	"	"	"	"	112200
9- 4-74	"	"	"	"	"	"	36720
9-19-74	"	27200	"	1200	"	"	32000
10- 2-74	"	"	"	"	"	"	2040
10-16-74	"	"	"	"	"	"	1800

TOTAL NUMBERS (cells/cm²) OF THE PERIPHYTIC ALGA

Synedria ulna OBSERVED AT MONTICELLO

DATE	STATIONS						
	2	7	9	3	6	11	3A
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5-22-72	300	-	550	-	-	120	-
6- 5-72	120	-	120	-	-	300	-
6-19-72	120	-	120	-	1350	300	120
7- 4-72	300	-	-	120	300	120	120
7-17-72	-	-	-	-	-	120	-
9-18-72	120	-	-	-	120	-	-
10- 3-72	300	300	300	-	3400	1100	-
10-17-72	120	-	1800	-	550	550	400
11- 1-72	-	-	3700	300	-	1350	300
11-28-72	-	120	550	-	-	-	300
2-16-73	-	-	-	-	2100	8400	120
3- 3-73	-	-	-	-	120	120	-
4-24-73	84000	90	143110	310340	390000	3900	3700
5- 9-73	114000	1092	451400	5750	479400	44000	103400
5-22-73	1519205	120	64270	84000	5600	53680	107400
6- 5-73	2500	1400	20000	1000	48000	12000	120
6-20-73	2200000	-	-	120	480	240	-
7- 2-73	480	-	-	-	-	-	540
7-17-73	120	-	-	-	-	-	-
8-28-73	-	-	-	120	-	-	-
9-11-73	120	-	-	-	-	-	640
9-25-73	40000	1800000	1200000	120	2160000	4275000	20000
10- 9-73	1500	3300	16000	800	-	-	120
10-26-73	240	-	-	-	-	-	-
11- 9-73	120	-	-	120	240	-	-
5-22-74	78396	-	136374	61	110	406	1250000
6-10-74	410	-	-	4860	890	-	10
7- 9-74	-	-	100	-	-	-	-
8- 5-74	-	-	-	-	-	-	72
8-20-74	-	100	-	-	-	-	-
9- 4-74	30600	-	-	-	-	-	-
9-19-74	47600	27200	6800	100	-	100	-
10- 2-74	100	30600	40800	100	56100	100	4080
10-16-74	8160	122400	61200	1200	61200	6800	-
11- 3-74	100	-	81600	6800	74800	132600	10200

TOTAL NUMBERS (cells/cm²) OF THE PERIPHYTIC ALGA *Synedria ulna*

OBSERVED AT MONTICELLO

STATIONS							
DATE	2	7	9	3	6	11	3A
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7-28-70	406447	530639	-	62097	80442	330236	-
8-25-70	95968	211690	-	53629	-	-	-
7-22-71	366674	-	5064387	1400028	-	6161118	35715
8-19-71	324870	3761980	6871566	4071510	12435963	9221613	4335801

TOTAL NUMBERS (cells/cm²) OF THE PERIPHYTIC ALGA *Synedria ulna*

OBSERVED AT MONTICELLO

STATIONS							
DATE	2	7	9	3	6	11	34
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5-22-72	400	400	120	-	-	120	-
6-19-72	300	-	-	-	-	-	120
7- 4-72	300	120	120	120	-	-	-
7-17-72	-	120	-	-	-	-	-
9-18-72	-	-	120	-	-	-	-
10- 3-72	300	120	300	-	-	400	-
10-17-72	21600	550	1350	-	900	7300	400
11- 1-72	4900	2100	3100	4500	1350	3700	400
11-28-72	-	2300	550	-	-	-	120
2-16-73	-	-	-	-	540	180	120
3- 3-73	-	-	-	-	120	120	-
4-24-73	2100	90	67600	16000	455000	1100	120
5- 9-73	796180	2184	901480	25755	2156380	197020	45
5-22-73	949625	-	24000	52500	1400	46150	115000
6- 5-73	2500	1400	120	120	24000	480	120
6-20-73	240	-	-	-	-	-	-
9-25-73	198000	6900000	12000000	-	420	120	97750
10- 9-73	1030	16670	23000	420	23000	14000	420
10-26-73	120	-	-	-	-	-	-
5-22-74	43992	-	18732	18	10	892	50347
6-10-74	10	-	-	-	-	-	-
9- 4-74	40800	100	-	-	-	-	-
9-19-74	54400	20400	6800	13600	100	100	-
10- 2-74	136000	91800	40800	36720	100	100	2040
10-16-74	18360	163200	214200	183600	142800	224400	-
11- 3-74	96900	204000	132600	244800	122400	81600	10200

TOTAL PERIPHYTON ABUNDANCE AT MONTICELLO NUCLEAR

POWER STATION FOR DISCHARGE CANAL STATION 3A

TOTAL PERIPHYTON ABUNDANCE AT MONTICELLO NUCLEAR

POWER STATION FOR HEATED STATION 11

TOTAL PERIPHYTON ABUNDANCE AT MONTICELLO NUCLEAR

POWER STATION FOR HEATED STATION 6

TOTAL PERIPHYTON ABUNDANCE AT MONTICELLO NUCLEAR

POWER STATION FOR HEATED STATION 3

TOTAL PERIPHYTON ABUNDANCE AT MONTICELLO NUCLEAR

POWER STATION FOR CONTROL STATION 9

TOTAL PERIPHYTON ABUNDANCE AT MONTICELLO NUCLEAR

POWER STATION FOR CONTROL STATION 7

TOTAL PERIPHYTON ABUNDANCE AT MONTICELLO NUCLEAR

POWER STATION FOR CONTROL STATION 2

APPENDIX F

LOGARITHM (BASE 10) OF TOTAL PERIPHYTON

Logarithm (Base 10) of Total Periphyton (cells/cm²) Arranged
by Sampling Date, Season, and Distance (ft) from Canal Station 3A

1972							
Reactor Status	Stations						Sample Date
	3A(0)	3(550)	6(2200)	7(2200)	9(3300)	11(5300)	
Spring (April, May, and June)							
On	---	3.318	3.079	3.000	3.667	3.134	5/22
On	4.379	6.157	4.465	4.498	4.855	4.195	6/5
On	<u>4.393</u>	<u>7.052</u>	<u>6.838</u>	<u>6.508</u>	<u>7.374</u>	<u>6.654</u>	6/19
	4.386	5.509	4.794	4.669	5.299	4.662	Station Mean
	0.010	1.950	1.901	1.760	1.893	1.807	Station Standard Deviation
Summer (July, August, and September)							
On	4.899	6.519	7.324	6.717	7.006	7.081	7/4
Off	5.301	6.560	7.235	7.001	6.820	7.397	7/17
Off	7.017	---	---	---	7.329	---	7/31
On	6.474	---	---	---	6.549	---	8/15
On	5.780	4.171	6.242	2.954	6.996	2.892	9/1
On	<u>4.201</u>	<u>5.144</u>	<u>4.545</u>	<u>3.344</u>	<u>6.487</u>	<u>4.417</u>	9/18
	5.612	5.599	6.337	5.0040	6.865	5.4468	Station Mean
	1.034	1.157	1.291	2.151	0.315	2.165	Station Standard Deviation
Fall (October, November, and December)							
On	3.344	3.665	5.146	4.569	4.217	4.371	10/3
On	4.882	4.101	3.853	4.001	4.293	4.692	10/17
On	3.589	3.914	3.279	3.661	4.186	4.312	11/1
On	<u>2.954</u>	---	---	<u>4.284</u>	<u>3.857</u>	---	11/28
	3.6923	3.8933	4.093	4.129	4.138	4.458	Station Mean
	0.835	0.219	0.781	0.389	0.193	0.205	Station Standard Deviation

Summary - 1972		
Season	Mean	Standard Deviation
Spring	4.916	1.153
Summer	5.871	1.414
Fall	4.056	0.539
All Seasons	5.047	1.451

Logarithm (Base 10) of Total Periphyton (cells/cm²) Arranged
by Sampling Date, Season, and Distance (ft) from Canal Station 3A

1973							
Reactor Status	Stations						Sample Date
	3A(0)	3(550)	6(2200)	7(2200)	9(3300)	11(5300)	
Spring (April, May, and June)							
Off	3.997	5.543	6.475	2.544	6.829	---	4/24
Off	5.033	4.760	6.681	3.737	6.354	---	5/9
On	5.776	5.364	4.182	2.079	5.226	---	5/22
On	5.820	4.085	5.683	4.164	5.007	5.084	6/5
Off	<u>5.780</u>	<u>7.736</u>	<u>7.725</u>	<u>7.068</u>	<u>7.662</u>	<u>7.712</u>	6/20
	5.281	5.498	6.149	3.918	6.216	6.398	Station Mean
	0.790	1.376	1.319	1.955	1.110	---	Station Standard Deviation
Summer (July, August, and September)							
On	3.740	6.614	7.457	7.797	7.189	7.298	7/2
On	4.417	7.687	7.813	7.653	7.829	7.733	7/17
On	3.530	7.788	7.635	7.708	7.461	7.789	7/31
On	6.803	7.821	7.623	7.353	7.789	7.813	8/14
On	5.421	6.418	7.640	5.364	7.789	7.636	8/28
On	7.566	3.906	7.510	7.628	7.415	7.811	9/11
On	<u>5.954</u>	<u>4.855</u>	<u>7.783</u>	<u>7.616</u>	<u>7.720</u>	<u>7.852</u>	9/25
	5.347	6.441	7.637	7.314	7.599	7.705	Station Mean
	1.536	1.541	0.130	0.872	0.245	0.193	Station Standard Deviation
Fall (October, November, and December)							
On	3.695	4.257	5.295	4.527	4.994	4.736	10/9
On	<u>3.994</u>	<u>2.806</u>	<u>2.857</u>	<u>2.380</u>	---	---	11/9
	3.845	3.531	4.076	3.454	4.994	4.736	Station Mean

Summary - 1973		
Season	Mean	Standard Deviation
Spring	5.485	1.549
Summer	7.007	1.254
Fall	4.154	1.415
All Seasons	6.061	1.707

Logarithm (Base 10) of Total Periphyton (cells/cm²) Arranged
by Sampling Date, Season, and Distance (ft) from Canal Station 3A

1974							
Reactor Status	Stations						Sample Date
	3A(0)	3(550)	6(2200)	7(2200)	9(3300)	11(5300)	
Spring (April, May, and June)							
Off	6.520	2.727	3.214	5.612	5.946	3.881	5/22
Off	6.690	6.088	5.982	---	7.423	5.991	6/10
On	<u>5.795</u>	<u>6.719</u>	<u>5.918</u>	<u>---</u>	<u>6.550</u>	<u>6.391</u>	6/25
	6.335	5.178	5.038	5.612	6.640	5.421	Station Mean
	0.476	2.146	1.580	---	0.743	1.348	Station Standard Deviation
Summer (July, August, and September)							
Off	6.046	5.920	6.665	7.985	6.760	5.896	7/9
On	3.697	6.377	6.252	6.000	7.143	6.432	7/23
On	3.376	5.941	5.908	5.906	6.468	6.514	8/5
On	6.570	6.196	6.295	6.108	6.259	6.199	8/20
On	5.537	6.068	6.286	6.185	6.624	6.329	9/4
On	<u>5.089</u>	<u>5.842</u>	<u>6.308</u>	<u>5.758</u>	<u>5.672</u>	<u>6.009</u>	9/19
	5.053	6.057	6.286	6.324	6.488	6.230	Station Mean
	1.278	0.200	0.240	0.828	0.498	0.242	Station Standard Deviation
Fall (October, November, and December)							
On	4.361	5.247	6.288	5.427	5.578	5.795	10/2
On	3.479	5.356	5.708	5.633	5.672	5.678	10/16
On	<u>4.543</u>	<u>5.435</u>	<u>5.472</u>	<u>5.389</u>	<u>5.690</u>	<u>5.471</u>	11/3
	4.127	5.346	5.822	5.483	5.647	5.648	Station Mean
	0.569	0.095	0.420	0.131	0.060	0.164	Station Standard Deviation

Summary - 1974		
Season	Mean	Standard Deviation
Spring	5.715	1.307
Summer	6.073	0.787
Fall	5.346	0.635
All Seasons	5.804	0.938

APPENDIX G

ORIGINAL PRIMARY PRODUCTIVITY DATA

PERIPHYTON CHLOROPHYLL-A ($\mu\text{g}/\text{cm}^2$) VALUES

FOR MONTICELLO NUCLEAR POWER STATION

DATE	CONTROL STATIONS			HEATED STATIONS			
	2	7	9	3	6	11	3A
	----	----	----	----	----	----	----
5-19-70	1.010	.060	2.130	.150	.560	.000	.000
5-29-70	.650	.000	1.160	.100	.320	.260	.000
6-12-70	1.540	.420	2.380	.240	.550	.840	.000
6-26-70	2.420	.000	4.060	1.550	2.430	.110	.000
7-11-70	1.640	.000	.710	1.680	1.690	.630	.000
7-28-70	1.090	.000	1.290	1.430	1.250	1.480	.000
8-11-70	1.410	.000	.000	.000	1.120	1.390	.000
8-26-70	2.250	2.020	.000	2.640	.000	1.490	.000
9- 8-70	2.610	2.000	1.920	2.180	1.730	2.100	.000
9-24-70	4.930	3.030	1.750	1.440	2.140	2.940	.000
10- 6-70	2.970	.890	.850	1.650	.770	2.170	.000
10-20-70	13.450	5.970	1.260	4.840	4.030	11.260	.000
11- 7-70	14.110	7.250	4.710	14.270	8.040	2.750	.000
2-16-71	.020	.000	.000	.010	.020	.000	.000
3- 4-71	.000	.000	.000	.000	.000	.000	.000
5-13-71	1.690	.050	2.060	.670	.570	.140	.870
5-27-71	.250	.100	2.600	.380	.380	.070	.310
6-10-71	1.530	.230	.950	.000	.870	.010	1.680
6-24-71	3.780	1.660	3.300	3.190	4.610	.490	3.650
7- 9-71	2.490	.000	2.610	1.450	2.240	.450	.260
7-22-71	2.520	.000	3.150	3.020	1.700	.770	1.160
8- 5-71	1.380	2.660	2.910	2.360	2.920	1.490	3.020
8-19-71	1.360	2.230	2.620	2.650	2.230	2.380	.370
9- 2-71	1.240	1.480	2.340	1.750	1.110	1.720	.170
9-15-71	.670	1.990	2.600	1.820	1.070	2.040	.630
9-30-71	.220	1.680	3.160	1.350	.500	1.030	.730
10-14-71	2.870	1.750	2.880	.310	2.160	.260	.650
10-28-71	4.400	.870	.000	1.110	.920	.000	.450
3-16-72	.000	.000	.020	.000	.000	.000	.000
5-22-72	.750	.070	.490	.030	.170	.160	.360
6- 5-72	.650	.090	.460	.290	.360	.440	.210
6-19-72	1.050	.360	2.440	.770	1.360	2.040	1.680
7- 4-72	1.580	1.740	2.530	1.290	2.190	2.000	.210
7-17-72	3.360	2.160	2.810	1.860	2.760	2.200	.960
7-31-72	3.300	.000	2.310	.000	.000	.000	3.350
8-15-72	.000	.000	2.050	.000	.000	.000	.346
9- 1-72	5.720	.470	2.690	1.060	1.030	.760	.810
9-18-72	1.130	.470	1.610	.530	1.690	1.720	.150
10- 3-72	2.790	1.090	2.610	.960	3.860	3.500	.040
10-16-72	2.410	.640	1.780	.730	2.860	2.500	.130
11- 1-72	1.550	1.660	.720	8.940	5.110	5.570	.030
11-28-72	.000	.080	.230	.000	.150	.000	.060

PERIPHYTON CHLOROPHYLL-A ($\mu\text{g}/\text{cm}^2$) VALUES

FOR MONTICELLO NUCLEAR POWER STATION

DATE	CONTROL STATIONS			HEATED STATIONS			
	2	7	9	3	6	11	3A
	----	----	----	----	----	----	----
1-16-73	.000	.000	.000	.000	.000	.000	.000
2-16-73	.000	.000	.000	.000	2.040	.000	.800
3- 5-73	.000	.000	.000	.000	.830	.000	.830
4-24-73	3.010	.650	7.780	2.380	4.280	2.350	3.300
5- 9-73	2.350	1.290	3.630	2.330	3.260	6.120	1.440
5-22-73	.860	.130	1.910	.970	.900	.700	1.940
6- 5-73	.550	.140	3.420	.810	2.210	.510	.080
6-20-73	2.880	1.940	2.900	2.160	3.680	2.880	1.330
7- 2-73	3.160	2.370	2.970	2.220	2.750	2.470	.480
7-17-73	2.400	2.640	3.650	2.410	2.260	2.450	.160
7-31-73	2.170	2.190	1.290	1.710	1.810	2.230	.420
8-14-73	2.410	2.270	2.010	2.140	1.970	2.360	.680
8-28-73	1.650	.770	2.410	1.040	1.960	2.590	.070
9-11-73	2.070	1.970	2.260	2.100	2.570	2.430	.180
9-24-73	.580	1.540	3.440	1.870	2.180	3.620	.270
10- 9-73	.060	.500	3.340	.650	.910	1.090	1.000
10-26-73	.690	.000	.000	.000	.000	.000	.510
11- 9-73	.150	.050	.110	.040	.110	.030	.120
11-23-73	.070	.010	.030	.010	.030	.030	.060
5-23-74	1.040	.000	1.760	.040	.140	.030	1.430
6-10-74	2.470	.000	2.220	1.090	2.400	1.290	.450
6-25-74	2.030	.380	2.370	1.930	1.570	1.250	.390
7- 9-74	2.290	.960	3.010	1.460	2.210	1.890	4.610
7-23-74	2.200	.920	1.770	.740	2.300	1.150	.920
8- 5-74	2.220	1.850	2.770	2.150	2.050	2.180	.670
8-20-74	2.050	2.400	3.040	2.030	3.410	2.350	1.800
9- 4-74	3.170	2.810	5.310	4.360	2.020	2.480	.560
9-19-74	2.370	4.100	2.770	5.440	3.120	4.400	.000
10- 2-74	3.340	2.250	2.000	2.230	1.210	1.660	.220
10-16-74	.910	3.760	3.710	3.460	5.320	4.150	.000
10-31-74	3.580	6.010	3.490	4.080	2.350	2.840	.890

STATISTICAL ANALYSIS OF REPLICATE
DETERMINATIONS OF CHLOROPHYLL-A ($\mu\text{g}/\text{cm}^2$)

DATE	N	MEAN	STD. DEV.	C.V.
5-22-72	3.	.75	.0192	2.6
5-22-72	3.	.36	.0302	8.4
6- 5-72	3.	.65	.3351	51.4
6- 5-72	3.	.29	.2617	90.2
6- 5-72	3.	.35	.2988	84.5
6- 5-72	3.	.09	.0272	30.7
6- 5-72	3.	.46	.4581	99.4
6- 5-72	3.	.42	.1336	31.7
6- 5-72	3.	.21	.1108	52.5
6-19-72	3.	1.04	.8209	78.7
6-19-72	3.	.80	.6041	75.4
6-19-72	3.	1.02	1.0905	107.4
6-19-72	3.	.37	.4360	118.7
6-19-72	3.	2.45	.3928	16.0
6-19-72	3.	2.04	1.6529	80.8
6-19-72	3.	1.63	.7762	47.8
7- 4-72	3.	1.57	.9436	60.0
7- 4-72	3.	1.29	.2816	21.9
7- 4-72	3.	2.22	.4519	20.4
7- 4-72	3.	1.73	.3069	17.7
7- 4-72	3.	2.52	.2376	9.4
7- 4-72	3.	2.01	.2651	13.2
7- 4-72	3.	.17	.0442	26.3
7-17-72	3.	3.36	.7440.	22.2
7-17-72	3.	2.76	.1629	5.9
7-17-72	3.	2.36	.5946	25.2
7-17-72	3.	2.82	.2848	10.1
7-17-72	3.	2.22	.2290	10.3
7-17-72	3.	.97	.1932	20.0
7-31-72	3.	2.70	.3545	13.1
7-31-72	3.	2.31	.9047	39.1
7-31-72	3.	2.34	.5259	22.5
8-15-72	3.	2.06	.6235	30.3
8-15-72	3.	3.67	2.1223	57.8
9- 1-72	3.	5.76	.3730	6.5
9- 1-72	3.	1.07	.3187	29.7
9- 1-72	3.	1.02	.6104	59.9
9- 1-72	3.	.47	.1587	33.6
9- 1-72	3.	2.68	.2215	8.3
9- 1-72	3.	.76	.3161	41.8
9- 1-72	3.	.81	.3783	46.9
9-18-72	3.	1.13	.5071	45.0
9-18-72	3.	.54	.2605	48.6
9-18-72	3.	1.80	.6857	38.1
9-18-72	3.	.47	.2836	60.7
9-18-72	3.	2.05	.2477	12.1
9-18-72	3.	1.73	.2285	13.2
9-18-72	3.	.15	.0274	18.2
10- 3-72	3.	2.79	1.4798	53.1
10- 3-72	3.	.96	.3577	37.1
10- 3-72	3.	3.88	1.9244	49.6

STATISTICAL ANALYSIS OF REPLICATE
DETERMINATIONS OF CHLOROPHYLL-A ($\mu\text{g}/\text{cm}^2$)

DATE	N	MEAN	STD. DEV.	C.V.
10- 3-72	3.	1.10	.4506	41.1
10- 3-72	3.	2.71	.6491	23.9
10- 3-72	3.	3.50	1.9882	56.8
10- 3-72	3.	.03	.0174	58.6
10-16-72	3.	2.41	2.0092	83.5
10-16-72	3.	.72	.3620	50.1
10-16-72	3.	2.89	1.4301	49.4
10-16-72	3.	.64	.4886	76.9
10-16-72	3.	1.77	1.9368	109.2
10-16-72	3.	2.19	1.6792	76.5
10-16-72	3.	.14	.0818	60.1
11- 1-72	3.	1.56	.8301	53.2
11- 1-72	3.	8.98	1.2047	13.4
11- 1-72	3.	5.10	1.6378	32.1
11- 1-72	3.	1.73	2.5527	147.4
11- 1-72	3.	.72	.7364	101.7
11- 1-72	3.	5.57	3.4651	62.2
11- 1-72	3.	.10	.1064	104.3
11-28-72	3.	.15	.0403	27.1
11-28-72	3.	.08	.0633	83.2
11-28-72	3.	.22	.1622	72.6
11-28-72	3.	.06	.0425	69.7
4-24-73	3.	3.01	1.3687	45.4
4-24-73	3.	2.38	.7992	33.6
4-24-73	3.	8.39	8.8747	105.8
4-24-73	3.	.43	.2260	52.5
4-24-73	3.	7.93	4.1144	51.9
4-24-73	3.	.37	3.3881	907.4
4-24-73	3.	3.29	.3060	9.3
5- 9-73	3.	2.35	1.4321	60.8
5- 9-73	3.	2.33	.8087	34.8
5- 9-73	3.	3.25	1.3013	40.1
5- 9-73	3.	1.28	.1193	9.3
5- 9-73	3.	3.90	2.1008	53.8
5- 9-73	3.	6.04	1.2299	20.3
5- 9-73	3.	.70	.1032	14.7
5-22-73	3.	.86	1.2719	147.8
5-22-73	3.	.90	.8296	92.5
5-22-73	3.	.13	.0510	39.0
5-22-73	3.	1.93	.3833	19.9
5-22-73	3.	.70	.6779	97.0
5-22-73	3.	1.93	.2460	12.7
6- 3-73	3.	.01	.7086	8435.7
6- 3-73	3.	.81	.3065	37.8
6- 3-73	3.	2.20	.9914	45.0
6- 3-73	3.	.14	.0873	60.6
6- 3-73	3.	3.41	1.1636	34.1
6- 3-73	3.	.51	.3350	65.4
6- 3-73	3.	.08	.0292	38.6
6-20-73	3.	2.89	.1220	4.2
6-20-73	3.	2.17	.7906	36.5

STATISTICAL ANALYSIS OF REPLICATE
DETERMINATIONS OF CHLOROPHYLL-A ($\mu\text{g}/\text{cm}^2$)

DATE	N	MEAN	STD. DEV.	C.V.
6-20-73	3.	3.67	.7874	21.4
6-20-73	3.	1.95	.4798	24.6
6-20-73	3.	2.91	.2228	7.7
6-20-73	3.	4.13	2.1868	53.0
6-20-73	3.	1.94	.7970	41.0
7- 2-73	3.	3.15	.1903	6.0
7- 2-73	3.	2.22	.6210	28.0
7- 2-73	3.	2.74	.1873	6.8
7- 2-73	3.	2.37	.0426	1.8
7- 2-73	3.	2.95	.2626	8.9
7- 2-73	3.	2.48	.1570	6.3
7- 2-73	3.	.49	.2045	42.1
7-17-73	3.	2.40	.0757	3.2
7-17-73	3.	2.41	.4590	19.0
7-17-73	3.	2.26	.2242	9.9
7-17-73	3.	2.64	.3345	12.7
7-17-73	3.	3.65	.4898	13.4
7-17-73	3.	2.44	.2758	11.3
7-17-73	3.	.16	.1569	95.8
7-31-73	3.	2.17	.0476	2.2
7-31-73	3.	1.80	.2918	16.2
7-31-73	3.	1.81	.0900	5.0
7-31-73	3.	2.48	.6127	24.7
7-31-73	3.	1.31	.0677	5.2
7-31-73	3.	2.23	.2491	11.2
7-31-73	3.	.42	.2303	54.6
8-14-73	3.	2.39	.2736	11.4
8-14-73	3.	2.15	.2643	12.3
8-14-73	3.	1.97	.6046	30.6
8-14-73	3.	2.24	.1213	5.4
8-14-73	3.	2.02	.0928	4.6
8-14-73	3.	2.38	.5323	22.4
8-14-73	3.	.65	.1180	18.0
8-28-73	3.	1.64	.6564	39.9
8-28-73	3.	1.04	.2679	25.7
8-28-73	3.	1.96	.1033	5.3
8-28-73	3.	.77	.2403	31.4
8-28-73	3.	2.43	.4390	18.1
8-28-73	3.	2.59	.0766	3.0
8-28-73	3.	.07	.0207	29.5
9-11-73	3.	2.08	.6723	32.3
9-11-73	3.	2.08	.0493	2.4
9-11-73	3.	2.57	.6734	26.2
9-11-73	3.	1.97	1.0185	51.8
9-11-73	3.	2.25	.1218	5.4
9-11-73	3.	2.43	.2500	10.3
9-11-73	3.	.18	.0430	23.4
9-24-73	3.	.58	.1163	20.1
9-24-73	3.	1.87	.2455	13.2
9-24-73	3.	2.18	.5143	23.6
9-24-73	3.	1.53	.9122	59.5

STATISTICAL ANALYSIS OF REPLICATE
DETERMINATIONS OF CHLOROPHYLL-A ($\mu\text{g}/\text{cm}^2$)

DATE	N	MEAN	STD. DEV.	C.V.
9-24-73	3.	2.08	2.3271	111.9
9-24-73	3.	3.63	1.1537	31.8
9-24-73	3.	.27	.1108	40.8
10- 9-73	3.	-.01	.1531-1354.9	
10- 9-73	3.	.64	.4778	74.1
10- 9-73	3.	.91	.2192	24.1
10- 9-73	3.	.41	.0702	17.3
10- 9-73	3.	3.32	.4539	13.7
10- 9-73	3.	1.08	.1238	11.4
10- 9-73	3.	1.00	.1660	16.6
10-26-73	3.	.69	.7789	112.4
10-26-73	3.	.52	.0163	3.2
11- 9-73	3.	.16	.0690	44.5
11- 9-73	3.	.04	.0262	67.4
11- 9-73	3.	.11	.0291	26.4
11- 9-73	3.	.05	.0309	59.0
11- 9-73	3.	.04	.0168	42.4
11- 9-73	3.	.13	.0834	64.9
11-23-73	3.	.07	.0218	32.6
11-23-73	3.	.01	.0044	56.4
11-23-73	3.	.03	.0197	57.3
11-23-73	3.	.00	.0241	964.0
11-23-73	3.	.03	.0132	51.0
11-23-73	3.	.03	.0105	33.8
11-23-73	3.	.06	.0171	29.2

ARITHMETIC AND LOGARITHMIC (BASE 10) RATIOS OF

CHLOROPHYLL-A ($\mu\text{g}/\text{cm}^2$) FOR HEATED/

CONTROLS STATIONS

DATE	ARITHMETIC RATIOS			LOGARITHMIC (BASE 10) RATIOS		
	3/7	6/9	11/2	3/7	6/9	11/2
	----	----	----	----	----	----
5-19-70	2.500	.263	.000	.398	-.580	.000
5-29-70	.000	.276	.400	.000	-.559	-.398
6-12-70	.571	.231	.545	-.243	-.636	-.263
6-26-70	.000	.599	.045	.000	-.223	-1.342
7-11-70	.000	2.380	.384	.000	.377	-.416
7-28-70	.000	.969	1.358	.000	-.014	.133
8-11-70	.000	.000	.986	.000	.000	-.006
8-26-70	1.307	.000	.662	.116	.000	-.179
9- 8-70	1.090	.901	.805	.037	-.045	-.094
9-24-70	.475	1.223	.596	-.323	.087	-.224
10- 6-70	1.854	.906	.731	.268	-.043	-.136
10-20-70	.811	3.198	.837	-.091	.505	-.077
11- 7-70	1.968	1.707	.195	.294	.232	-.710
2-16-71	.000	.000	.000	.000	.000	.000
3- 4-71	.000	.000	.000	.000	.000	.000
5-13-71	13.400	.277	.083	1.127	-.558	-1.082
5-27-71	3.800	.146	.280	.580	-.835	-.553
6-10-71	.000	.916	.007	.000	-.038	-2.185
6-24-71	1.922	1.397	.130	.284	.145	-.887
7- 9-71	.000	.858	.181	.000	-.066	-.743
7-22-71	.000	.540	.306	.000	-.268	-.515
8- 5-71	.887	1.003	1.080	-.052	.001	.033
8-19-71	1.188	.851	1.750	.075	-.070	.243
9- 2-71	1.182	.474	1.387	.073	-.324	.142
9-15-71	.915	.412	3.045	-.039	-.386	.484
9-30-71	.804	.158	4.682	-.095	-.801	.670
10-14-71	.177	.750	.091	-.752	-.125	-1.043
10-28-71	1.276	.000	.000	.106	.000	.000
3-16-72	.000	.000	.000	.000	.000	.000
5-22-72	.429	.347	.213	-.368	-.460	-.671
6- 5-72	3.222	.783	.677	.508	-.106	-.169
6-19-72	2.139	.557	1.943	.330	-.254	.288
7- 4-72	.741	.866	1.266	-.130	-.063	.102
7-17-72	.861	.982	.655	-.065	-.008	-.184
7-31-72	.000	.000	.000	.000	.000	.000
8-15-72	.000	.000	.000	.000	.000	.000
9- 1-72	2.255	.383	.133	.353	-.417	-.877
9-18-72	1.128	1.050	1.522	.052	.021	.182
10- 3-72	.881	1.479	1.254	-.055	.170	.098
10-16-72	1.141	1.607	1.037	.057	.206	.016
11- 1-72	5.386	7.097	3.594	.731	.851	.556
11-28-72	.000	.652	.000	.000	-.186	.000

ARITHMETIC AND LOGARITHMIC (BASE 10) RATIOS OF
CHLOROPHYLL-A ($\mu\text{g}/\text{cm}^2$) FOR HEATED/
CONTROLS STATIONS

DATE	ARITHMETIC RATIOS			LOGARITHMIC (BASE 10) RATIOS		
	3/7	6/9	11/2	3/7	6/9	11/2
----	----	----	----	----	----	----
1-16-73	.000	.000	.000	.000	.000	.000
2-16-73	.000	.000	.000	.000	.000	.000
3- 5-73	.000	.000	.000	.000	.000	.000
4-24-73	3.662	.550	.781	.564	-.260	-.107
5- 9-73	1.806	.898	2.604	.257	-.047	.416
5-22-73	7.462	.471	.814	.873	-.327	-.089
6- 5-73	5.786	.646	.927	.762	-.190	-.033
6-20-73	1.113	1.269	1.000	.047	.103	0.000
7- 2-73	.937	.926	.782	-.028	-.033	-.107
7-17-73	.913	.619	1.021	-.040	-.208	.009
7-31-73	.781	1.403	1.028	-.107	.147	.012
8-14-73	.943	.980	.979	-.026	-.009	-.009
8-28-73	1.351	.813	1.570	.131	-.090	.196
9-11-73	1.066	1.137	1.174	.028	.056	.070
9-24-73	1.214	.634	6.241	.084	-.198	.795
10- 9-73	1.300	.272	18.167	.114	-.565	1.259
10-26-73	.000	.000	.000	.000	.000	.000
11- 9-73	.800	1.000	.200	-.097	0.000	-.699
11-23-73	1.000	1.000	.429	0.000	0.000	-.368
5-23-74	.000	.080	.029	.000	-1.099	-1.540
6-10-74	.000	1.081	.522	.000	.034	-.282
6-25-74	5.079	.662	.616	.706	-.179	-.211
7- 9-74	1.521	.734	.825	.182	-.134	-.083
7-23-74	.804	1.299	.523	-.095	.114	-.282
8- 5-74	1.162	.740	.982	.065	-.131	-.008
8-20-74	.846	1.122	1.146	-.073	.050	.059
9- 4-74	1.552	.380	.782	.191	-.420	-.107
9-19-74	1.327	1.126	1.857	.123	.052	.269
10- 2-74	.991	.605	.497	-.004	-.218	-.304
10-16-74	.920	1.434	4.560	-.036	.157	.659
10-31-74	.679	.673	.793	-.168	-.172	-.101

STEM AND LEAF DISPLAYS OF LOGARITHMIC RATIOS
OF INDIVIDUAL HEATED/CONTROL STATIONS FOR CHLOROPHYLL-A ($\mu\text{gm}/\text{cm}^2$)

RATIO STATIONS 3/7			
DEPTH	SCRAWL	STEM	LEAF
1	*	- .7 (	5
1		- .6)	
1		- .5 (	
1		- .4)	
3		- .3 (	72
4		- .2)	4
8		- .1 (	7310
21	H	- .0)	9997665444330
	M	+ .0 (	0345567778
22		+ .1)	1122389
15	H	+ .2 (	6789
11		+ .3)	35
9		+ .4 (	0
8		+ .5)	168
5		+ .6 (	
5		+ .7)	136
2		+ .8 (	7
1		+ .9)	
1		+ 1.0 (	
1	*	+ 1.1)	3

RATIO STATIONS 6/9			
DEPTH	SCRAWL	STEM	LEAF
1	*	- 1.1 (	0
1		- 1.0)	
1		- .9 (	
3		- .8)	40
3		- .7 (	
4		- .6)	4
8		- .5 (	8666
11		- .4)	622
14		- .3 (	932
21	H	- .2)	7652210
29		- .1 (	99873321
	M	- .0)	9776554431110
19	H	+ .0 (	00235569
11		+ .1)	015567
5		+ .2 (	13
3		+ .3)	8
2		+ .4 (	
2		+ .5)	0
1		+ .6 (	
1		+ .7)	
1	*	+ .8 (	5

RATIO STATIONS 11/2			
DEPTH	SCRAWL	STEM	LEAF
1	*	- 2.1 (	8
1		- 2.0)	
1		- 1.9 (	
1		- 1.8)	
1		- 1.7 (	
1		- 1.6)	
2		- 1.5 (	4
2		- 1.4)	
3		- 1.3 (	4
3		- 1.2)	
3		- 1.1 (	
5		- 1.0)	84
5		- .9 (	
7		- .8)	98
10		- .7 (	410
11		- .6)	7
13		- .5 (	51
15		- .4)	20
17	H	- .3 (	70
22		- .2)	88621
30		- .1 (	887411110
	M	- .0)	998831111
23		+ .0 (	0112367
16	H	+ .1)	00348
11		+ .2 (	0479
7		+ .3)	
7		+ .4 (	28
5		+ .5)	6
4		+ .6 (	67
2		+ .7)	
2		+ .8 (	0
1		+ .9)	
1		+ 1.0 (	
1		+ 1.1)	
1	*	+ 1.2 (	6

STEM AND LEAF DISPLAYS OF LOGARITHMIC RATIOS
OF INDIVIDUAL HEATED/CONTROL STATIONS FOR CHLOROPHYLL-A

Arithmetic Display

DEPTH	SCRAWL	STEM	LEAF
	*H	0	(00011111122222223333333444444555555566666666777777777788888888888889
	H		(9999999999999999
82	H	1	) 00000000000000001111111112222223333333444445556667689999
22		2	(013456
16		3	) 022678
10		4	(67
8		5	) 148
5		6	(2
4		7	) 15
2		8	(
2		9	)
2		10	(
2		11	)
2		12	(
2		13	) 4
1		14	(
1		15	)
1		16	(
1		17	)
1	*	18	(2

Logarithmic Display

DEPTH	SCRAWL	STEM	LEAF
1	*	-2.1	(8
1		-2.0	)
1		-1.9	(
1		-1.8	)
1		-1.7	(
1		-1.6	)
2		-1.5	(4
2		-1.4	)
3		-1.3	(4
3		-1.2	)
4		-1.1	(0
6		-1.0	) 84
6		-.9	(
10		-.8	) 9840
14		-.7	(5410
16		-.6	) 74
22		-.5	(866651
27		-.4	) 62220
34		-.3	(9773220
47	H	-.2	) 8876654222110
67	H	-.1	(99888777433321111100
	H	-.0	) 999998877766655544443333111111000
73		+0.0	(000112233345555666777789
49	H	+0.1	) 000111223345567889
31		+0.2	(0134677899
21		+0.3	) 358
18		+0.4	(028
15		+0.5	) 01668
10		+0.6	(67
8		+0.7	) 136
5		+0.8	(057
2		+0.9	)
2		+1.0	(
2		+1.1	) 3
1	*	+1.2	(6

APPENDIX H

ELECTROFISHING DATA (CATCH/EFFORT)

COURSEFISH CATCH/UNIT EFFORT BY ELECTROFISHING FOR 1973

<u>Month</u>	<u>Sampling Sequence</u>	<u>Electrofishing Sector Location</u>			
		<u>Control</u>	<u>Discharge Area</u>		
			<u>Outer</u>	<u>Intermediate</u>	<u>Immediate</u>
Mar	1	86			
	2				
Apr	1	120		146	
	2				
May	1	116	274	213	48
	2		253		24
	3		98		22
	4		225		150
Jun	1	122	150	262	30
	2	141	71	148	38
	3	42	153	141	70
	4		76		38
	5		104		10
	6		174		6
	7		24		33
	8				5
	9				8
Jul	1	46	181	49	55
	2		79	131	
	3		160		76
	4		93		
Aug	1	90	154	62	14
	2	25	98	90	4
	3		47	47	5
	4		49	56	16
	5			5	4
	6				19
Sep	1	61	60	154	10
	2		54	148	13
	3		145	270	24

COURSEFISH CATCH/UNIT EFFORT BY ELECTROFISHING FOR 1974

<u>Month</u>	<u>Sampling Sequence</u>	<u>Electrofishing Sector Location</u>			
		<u>Control</u>	<u>Outer</u>	<u>Discharge Area</u>	
				<u>Intermediate</u>	<u>Immediate</u>
Mar	1				
	2				
Apr	1	54	44	102	68
	2	129	87	98	47
May	1	106	126	178	66
	2	233	251	118	51
	3	130	142	208	264
	4	133	150	141	147
Jun	1	162	223	155	58
	2	189	162	365	16
	3		264	347	45
	4		171	160	52
	5			237	
	6				
	7				
	8				
	9				
Jul	1	81	41	21	14
	2	34	53		0
	3		47		
	4				
Aug	1	145	120		
	2	70	97		
	3				
	4				
	5				
	6				
Sep	1				
	2				
	3				

GAME FISH CATCH/UNIT EFFORT ELECTROFISHING FOR 1973

<u>Month</u>	<u>Sampling Sequence</u>	<u>Electrofishing Sector Location</u>			
		<u>Control</u>	<u>Discharge Area</u>		
			<u>Outer</u>	<u>Intermediate</u>	<u>Immediate</u>
Mar	1				
	2				
Apr	1	0	0	0	21
	2	1	0	0	6
May	1	1	0	0	9
	2	7	0	14	5
	3	2	0	14	5
	4	49	0	0	0
Jun	1	36	9	0	13
	2	12	0	61	0
	3		62	13	0
	4		0	27	0
	5			65	
	6				
	7				
	8				
	9				
Jul	1	6	26	0	10
	2	6	0		0
	3		0		
	4				
Aug	1	7	0		
	2	14	11		
	3				
	4				
	5				
	6				
Sep	1				
	2				
	3				

GAME FISH CATCH/UNIT EFFORT ELECTROFISHING FOR 1974

<u>Month</u>	<u>Sampling Sequence</u>	<u>Electrofishing Sector Location</u>			
		<u>Control</u>	<u>Outer</u>	<u>Discharge Area</u>	
				<u>Intermediate</u>	<u>Immediate</u>
Mar	1				
	2				
Apr	1	0	0	0	21
	2	1	0	0	6
May	1	1	0	0	9
	2	7	0	14	5
	3	2	0	14	5
	4	49	0	0	0
Jun	1	36	9	0	13
	2	12	0	61	0
	3		62	13	0
	4		0	27	0
	5			65	
	6				
	7				
	8				
	9				
Jul	1	6	26	0	10
	2	6	0		0
	3		0		
	4				
Aug	1	7	0		
	2	14	11		
	3				
	4				
	5				
	6				
Sep	1				
	2				
	3				

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