**AN EVALUATION OF ENVIRONMENTAL DATA
RELATING TO SELECTED NUCLEAR POWER
PLANT SITES**

PRAIRIE ISLAND NUCLEAR GENERATING PLANT SITE

**Ishwar P. Murarka
(Project Leader)**

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November 1976

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**DIVISION OF ENVIRONMENTAL IMPACT STUDIES
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by

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Preface

The Office of Regulatory Research, U. S. Nuclear Regulatory Commission, is supporting a program at the Argonne National Laboratory for the evaluation of the data collected by field studies at a number of operating nuclear power plants. The objective is to analyze data from both a disciplinary and a statistical standpoint. Each of the plants chosen is required, by the terms of the licenses granted, to conduct certain monitoring programs. Some plants are running additional programs to serve their own interests. Do such programs meet the interests of ecologists concerned with the protection of biota? What is the precision and accuracy of the results? What decisions are made on the basis of the field data and how valid are such decisions? Answers to such questions would be of great value in establishing the most cost-effective programs for future plants and redesigning the programs for existing plants.

Through the cooperation of the companies operating the plants, the staff obtained the data from a number of installations. As the results were compiled the Laboratory prepared an informal report such as this to present the analysis pertaining to each plant chosen. A summary and intercomparisons of data, together with the Laboratory's recommendations, will be presented in one or more reports to the NRC.

This, the sixth of the informal reports, pertains to the Prairie Island Nuclear Generating Plant. The list of other informal reports in this series is:

ANL/EIS-1 *The Kewaunee Nuclear Power Plant Site.*

ANL/EIS-2 *The Quad-Cities Nuclear Power Station Site.*

ANL/EIS-3 *The Duane Arnold Energy Center Site.*

ANL/EIS-4 *The Three Mile Island Nuclear Station Site.*

ANL/EIS-5 *The Zion Nuclear Power Station Site.*

ANL/EIS-7 *The Nine Mile Point Nuclear Power Station Site.*

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AN EVALUATION OF ENVIRONMENTAL DATA RELATING
TO SELECTED NUCLEAR POWER PLANT SITES

THE PRAIRIE ISLAND NUCLEAR GENERATING PLANT SITE

Abstract

Environmental monitoring data for 1973 through 1975 pertaining to the Prairie Island Nuclear Generating Station (which began commercial operation in December 1973) were analyzed by the most practical qualitative and quantitative methods. Evaluations of aquatic and terrestrial biotic data are presented in this report.

The data indicate no significant immediate deleterious effects on the biota from plant operation, thus confirming preoperational predictions. Although the station has not operated long enough to reveal long-term deleterious effects, present indications do not lead to a concerned prediction that any are developing. Recommendations are suggested for improving monitoring techniques.

THE PLANT

LOCATION

The Prairie Island Nuclear Generating Plant (the plant) is a facility of Northern States Power Company located on the western bank of the Mississippi River in Burnside Township, Goodhue County, Minnesota. The plant site is on a low island terrace associated with the southeastern Minnesota river flood plain. It is situated in a predominantly rural area between the riverside cities of Hastings (13 miles to the northwest) and Red Wing (6 1/2 miles to the southeast) (Fig. 1). The largest nearby population center is the Minneapolis-St. Paul metropolitan area, approximately 35 miles northwest. The Mississippi River, which flows southward between Wisconsin and Minnesota, is about one-half mile east. The Plant has operated since December 1973.

The facility has two pressurized-water reactors. Its principal features are the two containment buildings, the auxiliary and turbine building, administrative offices, the screen house, and four mechanical-draft cooling towers. A switchyard and transmission towers occupy about 40 of the total 560 acres of the plant-site area.

Each of the separate nuclear steam-supply and turbine-generator units (Units 1 and 2) is designed for an ultimate power level of 583 MWe (gross) and

Fig. 1. Geographical Location of the Plant Site.

functions independently. The reactors were built by Westinghouse Electric Corporation.

INTERACTION WITH THE ENVIRONMENT

The plant's four mechanical-draft cooling towers, designed by the Fluor Corporation, are capable of removing essentially all waste heat from the circulating water system of the plant [Final Environmental Statement (FES), p. III-16].¹ Each tower has 12 subunits or "cells." The utility is committed to operate the cooling towers to the maximum extent practicable, in order to minimize entrainment, impingement, and thermal impacts on the river.

The design of the condenser cooling-water system permits various operating modes: once-through flow of river water without cooling towers in operation (open cycle); once-through flow with the cooling towers in operation, to decrease the temperature of the system water before it is discharged back to the river (helper cycle); and recirculation of up to 95% of the condenser cooling-system water through operating cooling towers (closed cycle). In the open-cycle mode, the cooling towers are bypassed and water is drawn from the river at a maximum rate of 1370 cfs (39 m³/sec). The circulating water is discharged back to the river in an amount reduced by the evaporative loss. This mode is used when cooling-tower operation becomes impracticable because of problems due to cold weather or a need for maintenance work. In the helper-cycle mode, the cooling towers are used to the fullest extent possible, but without recycle and with the 1370 cfs direct flow. In the closed-cycle mode, the only water taken from the river is the amount required to compensate for evaporation and drift losses from the cooling towers and for use in the blow-down process to reduce buildup of mineral content in the circulating water. The total intake in this mode is approximately 238 cfs (6.7 m³/sec) (ER, Vol. 1, p. III-37; FES, p. III-8).² During normal operation the effluent for the closed-cycle mode is limited to 150 cfs (4.3 m³/sec) by the Environmental Technical Specifications (ETS).³ The mode of operating may be changed in the main control room without disruption of power-generating operations.

The water-intake canal was prepared by dredging a channel about 700 feet long and 110 feet wide from the screen house to the river shoreline. The channel is widened as it intrudes into the river, forming an approach canal about 600 feet wide and 1800 feet long. The water-discharge canal also was prepared by dredging. The width increases gradually from 100 feet at the discharge structure to over 400 feet at a distance of 700 feet from the shoreline.

The nominal depth of water in the discharge canal is ten feet as it flows toward the main stream of the river. Mixing occurs as the cooling water discharge is diluted by inflow from Sturgeon Lake (Fig. 1) before it reaches the temperature sensors. The combined waters are diverted toward the main channel of the river by dikes erected at three locations between naturally occurring sandbars. Thus, in practice, the maximum allowable heat discharge to the main channel depends largely upon the temperature and volume of the inflow from Sturgeon Lake.

Within a given year considerable variability occurs in the total flow rate of the Mississippi River at the plant-site area (Fig. 2). Each year in the spring, a peak high flow occurs that lasts through June. Low flow occurs

Fig. 2. Total Water Flow Rate of the Mississippi River Near the Plant Site⁴

from August until about the following March. Thus, the flow rate of the river directly affects the thermal plume dilution.

OPERATING HISTORY

Unit 1 of the Prairie Island Plant attained initial criticality and started commercial operation in December 1973. Unit 2 attained initial criticality and started commercial power production in December 1974. Since the plant began commercial operation, daily power generation levels have been reported to the U. S. Nuclear Regulatory Commission (NRC, formerly the Atomic Energy Commission). The data for years 1974 and 1975 (obtained from the NRC gray book) for each unit are plotted in Figures 3 and 4. It is evident that daily power generation fluctuates over the full range from zero output to the maximum level of 583 MWe (net) for each unit.

This operating characteristic influences the environmental measurements and the determination of changes in the biota, water chemistry, and thermal regime in the vicinity of the station.

TERRESTRIAL ASSESSMENT

POTENTIAL AND PREDICTED IMPACTS

Under the requirements of ETS Section 4.1.2 (see Appendix P-1), quantitative data are obtained on the terrestrial fauna and flora within a 1.5-mile radius of the plant so that a determination can be made on the severity of environmental impact. Cooling tower drift is considered a potential source of impact. Bird kills along the 345-kV transmission lines leading from Units 1 and 2 are also identified as a potential impact because the Prairie Island station is located in the Mississippi River Valley, which is a major migratory bird flyway.

No operational impacts on terrestrial ecosystems were predicted in the FES, which treated only impacts on the aquatic ecosystem in the Mississippi River near the cooling-water intake and discharge structures.

OBSERVED IMPACTS

Our examination of the monitoring data on terrestrial biota for 1972, 1973, and 1974 did not indicate that environmental impacts due to plant operation had occurred. For example, data on birds killed from collisions with the two transmission lines demonstrated that catastrophic losses did not occur during the fall migration of 1973. However, the length of time elapsed between the fall migration peak (September and October 1973) and data collection to determine losses (April 21 and May 23, 1974) makes any attempt at quantification of losses questionable.

In general, the environmental monitoring program lacks the sensitivity needed to detect changes in the vegetation and animal populations due to plant operation. Incompleteness of the data base had necessitated additional sampling in order to characterize the biotic communities before plant operations began. The overall terrestrial monitoring program did not identify specific potential areas of impact. As a result, data presented in the plant's 1972, 1973, and

Fig. 3. Daily Power Generation for Prairie Island Unit 1, 1974-1975.

Fig. 4. Daily Power Generation for Prairie Island Unit 2, 1974-1975.

1974 annual reports are poorly organized, with little discussion given to variations in the data and to the impacts of plant operation. The following discussion represents our analysis of the terrestrial monitoring program at this plant.

Before attempting to determine the adequacy of the terrestrial monitoring program, a review was made of impact predictions presented in pertinent sections of the FES and ETS. Operational-impact predictions made in the FES dealt only with the aquatic ecosystem. ETS sections that control the monitoring of terrestrial biotic communities and pertinent physical factors such as erosion, noise, and cooling tower drift and icing, are written in a very general manner (see Appendix P-1). This lack of specificity permits collection of data in any manner that complies with the specifications in the broadest sense. The specifications therefore should clearly delineate sampling methodologies and frequencies, to avoid the gathering of irrelevant information and to obtain adequate data.

Technical Specification 4.1.2 states that the location of a sampling area may be changed during the study if the habitat is altered by factors such as lumbering, farming, or dredging. This option will allow the generation of data which cannot be compared over different years. This is particularly true with respect to quantitative data on animal populations.

The following is a discussion of the adequacies of the monitoring program with respect to each terrestrial group.

Fauna

Insects

Insect sampling was conducted only during 1974. Sweep and soil samples were taken in prairie and lowland forest transects during June, July, and August. Although the sampling techniques are adequate to quantitatively characterize the various biotic communities, it is highly unlikely that they can detect the effects of plant operation. Proper identification of insects is very difficult below the Family level. Consequently, variation in the number of taxonomic groups identified each year may be due to problems of identification, and not to the effects of plant operation.

Birds

A comparison of the number of birds breeding in June 1973 (preoperation) and June 1974 (operation) along 17 transects monitored showed a decline in numbers of birds breeding along seven of the eight transects nearest (within one mile of) the plant. The number of species recorded along these same transects also declined from 1973 to 1974 (Table 1).

The actual number of birds observed along the transects is not considered a strong criterion for demonstrating the effect of plant operations on local bird populations. The better criterion is the number of bird species occupying the various terrestrial communities. For example, the large number of grackles observed along some transects greatly accentuated the increase in numbers reported between 1973 and 1974. However, the effect of plant operation on bird populations cannot be determined with any degree of confidence until data

Table 1. Breeding Bird Species at the Prairie Island Site^a

Transect No.	No. of Species		No. of Individuals		Approximate Distance (ft) and Direction from Plant		Vegetative Community Type
	1973	1974	1973	1974			
1	24	16	66	70	1500	N	Oak savannah
2	33	34	96	87	1500	SSE	Upland and lowland forest
3	16	14	32	20	2600	SW	Abandoned field
4	20	15	38	28	2500	NW	Grassland
5	32	28	60	48	3000	SW	Oak savannah
6	30	19	71	62	4500	SSE	Lowland forest
7	14	8	26	16	2500	S	Sand barrens (xeric prairie)
8	8	11	19	18	3500	W	Abandoned field
9	21	23	53	128	6500	WNW	Oak forest
10	31	29	96	89	7500	SE	Lowland forest
11	12	12	34	40	6500	WNW	Railroad row
12	23	24	64	80	8000	ESE	Lowland forest
13	11	7	120	244	4200	NNW	15-yr mixed conifer stand
14	12	10	57	85	4500	NNW	15-yr mixed conifer stand
15	12	10	34	34	5000	SSE	Marsh
16	10	16	21	57	5000	S	Lowland forest
17	6	11	36	46	8500	NW	Open water marsh

^a Comparisons were for June, except for transects 16 and 17 in which comparisons are for July.

for additional years are obtained and compared. The decline in numbers of species observed along transects within one mile of the plant, however, is suggestive of an operational impact. The extent to which other environmental factors may be responsible for the observed differences in bird species composition can be arrived at only after additional data are gathered on the environmental variables.

Data on numbers of birds killed by striking 345-kV lines and towers leaving the plant were collected on April 21, May 23, and September 13, 1974. Total numbers killed and number of species are as follows: April 21 (40, 22); May 23 (35, 20); and September 13 (21, 12). These data indicate that massive bird kills are not expected from collisions with 345-kV lines, even when these lines traverse a portion of a major migratory flyway.

These data do not permit one to project the fraction of local or migratory birds killed and the consequences to the ecosystem. Additional yearly data on bird kills and on total bird migration through the area are needed before an attempt can be made to address the extent of the impact.

Nesting studies conducted in 1973 and 1974 on the great blue heron, mourning dove, and grackle supposedly were designed to monitor any impacts of plant operations. However, the study areas are located at a distance from which it is not possible to detect effects on nesting success. In the case of great blue herons, weather conditions strongly influence nesting success. The abandonment of a rookery may be due to such natural factors as the death of trees needed for nesting and roosting.

Mammals

No trends indicating a cause-effect relationship of plant operations on fauna can be seen for small mammals monitored by standard live-trapping techniques. A track census on large- and medium-sized mammals was conducted in 1972. Since no subsequent census was conducted, comparisons could not be made between preoperational and operational periods. No conclusions can be made concerning the occurrence or absence of impacts on the mammals in the locale.

Flora

The vegetation analysis conducted on herbs, shrubs, and trees is inappropriate for detecting the effects of plant operation. The use of point-frame analysis for herbaceous vegetation and point-center-quarter method for shrubs and trees are appropriate techniques for characterizing the vegetation of each forest stratum, but are not sensitive for impact determination.

CRITIQUE, CONCLUSIONS, AND RECOMMENDATIONS

A basic problem in determining the impact of plant operation on the terrestrial biota is explaining--or obtaining data for--the annual variation in population levels of the species being monitored. In general, many terrestrial animals vary considerably in population density from one year to the next. Consequently, many years of data are needed to detect trends having a high degree of reliability. These data are not yet available for the Prairie Island plant site.

In the case of the Prairie Island plant, the monitoring techniques employed lack the sensitivity needed to measure an effect of plant operation. Although many of the techniques are satisfactory for characterizing biotic communities near the plant, monitoring of additional factors is needed for impact evaluation. The presentation of data in the annual reports is not organized in a way to show trends in the data over different years. Probable impacts should be identified and addressed in detail in the reports.

The following recommendations would improve the sensitivity or resolution of the Prairie Island monitoring program.

1. Extensive soil sampling in the vicinity of the cooling towers could be used to monitor salt and heavy-metal accumulation in the soil. Vegetation monitoring in these areas should be objective (e.g., taking photographs to show salt leaf burn or the disappearance of certain plant species). Analyzing the leaf chlorophyll content of common species at the same time each year would be a more sensitive measure of change in plant condition than would comparisons of the diameter at breast height of trees and shrubs or abundance changes in herbaceous vegetation.
2. Bird kills should be determined by an extensive monitoring program during the fall and spring migration periods. The transmission lines should be checked at several times during April and May (perhaps twice a day, early and late in the day), and during September, October, and November.
3. The monitoring program for determining the long-range effects of cooling tower drift on plant and animal succession on permanent quadrants should also include vegetation sampling on control plots.
4. The annual tree and shrub monitoring to determine importance value and continuum indices should be discontinued (at least on an annual basis). These techniques are too insensitive to changes expected from cooling tower drift.
5. The monitoring of biotic communities for large mammal tracks should be continued in the immediate vicinity of the plant. A program to monitor noise levels should be conducted in the same areas used for mammal-track censusing.
6. The great blue heron, mourning dove, and grackle nesting areas studied are too far from the plant to show any impacts of operation. These studies should not be continued on an annual basis.

AQUATIC ASSESSMENT

POTENTIAL AND PREDICTED IMPACTS

Entrainment

Phytoplankton and zooplankton (including some meroplanktonic and/or benthic organisms) and also fish larvae, are subject to entrainment and subsequent destruction at the plant (FES, p. V-13). Potential loss of phytoplankton was

predicted to be inconsequential. Zooplankton losses were also predicted to be essentially insignificant, particularly after cooling towers were built, thus reducing water intake demands (FES, p. V-14). The impact of larval entrainment loss on adult fish populations is not known because quantitative data are lacking on populations of both larvae and adult fish. The water intake rate is only 1 ft/sec, about the same as the flow past the station. At a higher water intake rate, more fish would be entrained. Nevertheless, a potential exists for significant loss of fish larvae, especially because much of the intake water originates in Sturgeon Lake, where production of larvae is higher than in the river channel. Thus, careful monitoring during operation was required (ETS, Appendix B, pp. B-20 and B-21).

Impingement

Fish kills at the intake screens could affect the population characteristics and impair the long-term structure of the ecosystem. Impingement losses at the Prairie Island plant were anticipated. It was recognized that juvenile and adult fish, unable to swim against approximately 1 ft/sec flow rate near the trash rack, would be impinged and consequently destroyed (FES, V-13; ETS, Appendix B, pp. B-4 and B-5, and Sec. 2.3). However, the numbers and variety of most susceptible species were unknown, and predictions were qualitative. Discussions on the maximum approach velocity of the cooling water at the intake, and on the mesh size of the traveling screens, constituted the basis for making predictions regarding impingement at the plant. Consequently, monitoring was required (FES, pp. V-13 through V-15; ETS, pp. B-4, B-5, B-12, B-19, B-20, and Sections 2.3, 3.3).

The fish species of most concern are those for which Minnesota's Department of Natural Resources' Annual Fishing Laws have set daily angler possession limits. Gizzard shad species are the most abundant fish in the area, and therefore are expected to constitute the maximum number of fish impinged. Many other species inhabiting the area are likely to be impinged, but in smaller numbers. It was recognized that only those impingement data obtained during actual station operation would provide an adequate basis for quantitative assessments. Therefore, monitoring for impinged fish at the traveling screens is required by the technical specifications.

Perhaps the most visible effects of power plant operation are the fish kills observed at the cooling water intakes. The number of fish killed during any short period has little significance except as it relates to the general dynamics of the entire fish population in the natural water body. The loss of various species in varying quantities could have an effect on commercial (or other) fisheries of the water body. The species and magnitude of the fish losses at Prairie Island and the resulting stresses on the fisheries are not well understood. These effects vary from one aquatic system to another. It is possible that a reduction of fisheries resources will occur, which would be a potential long-term ecological impact.

A weekly fish kill limit has now been established for the plant. It is not known whether this limit, currently included in the plant's technical specifications, is too high or too low. Without site-specific data on the relationship of fish kill rates to total population numbers, the matter cannot be determined. So it must be granted that, by establishing rational fish kill

limits, the authors of the technical specifications have acted with the best possible foresight on the basis of the information available at the time.

Chemical Discharges

The plant's main condensers are cleaned mechanically, and normally only the service water system is chlorinated. The cooling towers require relatively little chlorine for cleaning, as the baffles are made of polyvinyl chloride, which resists bacterial and algal growth.

The sanitary sewage-disposal system uses septic tanks and drain fields on the plant site, with no direct discharge to the river. Consequently, there is no potential chlorine impact of any significance.

The corrosion inhibitors used in the condenser cooling pipes are orthophosphate, hydrazine, and morpholine-cyclohexylamine. Excess quantities of these and other chemicals are potentially harmful, but they are limited by the technical specifications to provide protection for the aquatic biota and comply with river quality standards (ETS Sections 2.4.2, 2.4.3, and 2.4.4; Appendix B, pp. B-5 through B-8).

Thermal Impact of the Warm Water Plume

The heated discharge from the plant was not expected to have a significant effect on sport fish or commercially important fish species. The predictions were based in part on monitoring data from the applicant's fossil-fuel A. S. King plant, upstream on the St. Croix River (FES, pp. V-17, V-18). Controls on possible thermal excesses are presented in the Technical Specifications, pages B-9 through B-11.

Largely because of cooling towers at the Prairie Island plant, and because it has two units that can be alternately and/or gradually shut down for refueling or repairs, no cold-shock losses of fish were anticipated (FES, pp. V-18 and V-19).

No important chemical effluent impacts were predicted (FES, pp. V-20 and V-21), primarily because mechanical condenser cleaning methods would be used. However, precautions were taken to control chemical effluents if they should be necessary (ETS, Appendix B, pp. B-5 through B-8; Section 2.4).

Some maintenance dredging was predicted, but the impact was to be localized within the plant's intake and discharge areas (FES, p. V-13). Some damage to the benthic community close to the discharge area was predicted. However, controls, and a study of dredging, were required by the Technical Specifications (Appendix B, p. B-22).

Various impacts due to the thermal discharge were predicted (FES, pp. V-15 through V-20), but the net effect on algae and zooplankton was considered inconsequential. Significant impact on the benthic community was considered unlikely, except close to the outfall where scouring of the substratum could occur (FES, p. V-17).

OBSERVED IMPACTS

Methods of Analysis

Nonradiological aquatic-biology data obtained during 1973 through 1975 were examined for possible effects of plant operation. The major biological groups (phytoplankton, zooplankton, rotifers, benthos, and fish) and various subgroups were selected for this evaluation on the basis of their abundance and persistence throughout the seasons, availability of sampling data, and specific biological characteristics (i.e., sessile or planktonic life history, etc.). Fish impingement was studied in detail, and fish abundance data were utilized in conjunction with the evaluation. "Reference" and "stress" stations in the Prairie Island study area were selected by examining the measured thermal plume configurations: Those stations located within thermal plume configurations were designated as "stress" stations; those outside the plume were considered as the "reference" stations.

Environmental data occur in the form of a time series. Sampling a time series and estimating the types and magnitude of change require proper statistical treatment of the data. Classical statistical procedures, such as the t-test, have played an important role in estimating and/or testing for differences in mean values. Time-series data show a strong seasonal component, and non-stationary elements can be present in these data. The mathematical functions representing these types of behavior combine past history and elements of discrete responses. It is also conceivable that the parameters, or even the joint probability distribution function itself, may depend on particular time points. Thus, observations made in a time sequence do not always present random, independent observations from the same distribution.

In an undisturbed environment, the changes and variations measured in an indicator-characteristic (the response variable) follow probability laws. Assumptions concerning probability models have led to estimates of the parameters of these distributions. When disturbances resulting from perturbations of the ecosystem are introduced, it is common to expect changes to occur in the response variable. The magnitude and extent of the changes are generally unknown, *a priori*. Thus, to estimate these changes one must be able to measure responses to the added causal factors. It is appropriate to consider the types of disturbances that may affect the response variable.

For simplicity, assume a time-variable phenomenon in which a pulse of some magnitude is added to the otherwise constant response function. As shown in Figure 5, the effect of this pulse disturbance may be (a) an exponential decay with total recovery to the original conditions; (b) no lasting change in response, i.e., an immediate and complete recovery; (c) prevalence of more subtle conditions, where the effect of the pulse undergoes a very gradual and slow recovery; or (d) no recovery at all. Less likely cases include the situation where the effect may be (e) an intensification, resulting in a long-term increasing impact, or (f) an exponential decay to a new steady-state value.

The task of measuring such responses becomes more complicated when we consider the case of continuous perturbation. The responses to a steadily added pollutant may be a cumulative long-term impact, a short-term adjustment to a new level of behavior, a long-term slow recovery, a short-term fast re-

(a)

(b)

(c)

(d)

(e)

(f)

Fig. 5. Possible Responses to a Pulse Disturbance in a Stable Time Series.

covery, or a long-term slow destruction with no recovery at all. A number of mixed responses are also possible.

Statistical Analysis

Two classes of statistical methods seem logically attractive in environmental impact analyses. With a considerable overlap in the final estimation methods (i.e., least squares analysis), the basic model considerations and accompanying assumptions differ. In the general linear model approach (variance-components analysis in particular), variations in the response variable measured over time and space are separated into assignable sources of such variations and are assumed to be additive. The unexplained part (i.e., residual error) is then assumed to be independently, identically, and normally distributed with unknown common variance. The effects of power plant operation are postulated to be fixed, of constant but unknown magnitude, and equal for all stressed locations.

In the time-series analysis approach, correlation of the response variable with past observations is taken into consideration. The responses to power plant operation are assumed to be functions (linear or non-linear) that can vary in time and space. The residual (error) part could be correlated and may be heterogeneous in variance.

These two classes of methods are applied to plant-impact analysis as follows:

Time-Series Analysis

Time series analyses were not carried out on the Pralile Island environmental data; therefore, only a brief discussion of the method is given here.

In a time-series approach, the basic model for depicting environmental variables and impact response functions consists of the following:

$Y = S_i + A_j + \text{lagged terms} + \text{operational effect function} + \text{random error terms}$, where: S_i is the seasonal effect, A_j is a deterministic component, independent of season; lagged terms represent autoregressive behavior, and the random error term is a white noise component assumed to be normally independently and identically distributed with mean zero and unknown variance σ^2 .

Observations on the biota have a time-series dependence; seasonal, annual, and spatial values are likely to be highly correlated. When a power plant begins operation, the change in the stochastic process is probably not that of an immediate discrete change with no change thereafter. It is more likely that a lagged response will occur, and that the function describing the time-dependent response will be something other than a horizontal straight line. (See Figure 5.) Under such conditions, we must consider the use of time-series analysis methods, especially the method of Box and Tiao⁵ referred to as "intervention analysis". Obtaining a systematic time sampling with evenly spaced observations simplifies the mathematics of this method.

A deviation from Box and Tiao's method can also be used that will relax the requirement for systematic, evenly spaced data. This procedure is to examine the data in the frequency domain rather than in the time domain. If we suppose that the response values are adequately modeled by "k" harmonics, then:

$$y_t = \delta + \sum_{j=1}^k (A_j \sin \alpha_j t + B_j \cos \alpha_j t) + f(t) + u_t$$

where: δ , A_j , B_j are regression coefficients, and u_t is random error assumed to be normally distributed with mean zero and unknown variance σ_u^2 .

The function of interest for environmental impact determination is $f(t)$. If $f(t)$ is a linear or intrinsically linear function, then an ordinary least squares analysis will provide estimates for all the coefficients in the model. Depending on the shape and values of the coefficients, inferences about the nature and extent of the impacts can be drawn. All of these time-series approaches can be used if the collected data samples the stochastic process fairly intensively.

General Linear Models (Variance-Components) Analysis

The general statistical approach taken in applying linear models to environmental data analysis is to consider the biotic groups' spatial and temporal distributions as sums of fixed responses to assignable causal factors. Time, space, and sampling locations, together with replicates, are taken to form a factorial experimental design.

Because biological and physical-chemical data are expected to be correlated, we can take advantage of this relationship in detecting an impact by carrying out multivariate and covariance analyses. However, because of simultaneous covariable measurements are unavailable, we did not carry out such an analysis. Rather, we restricted the analyses to a univariate variance-components form.

Preoperational studies were carried out during the construction of the plant. Testing of the operability of the equipment and other construction-related environmental stresses were reflected in the data collected. It is not clear whether the data-collection schemes were designed to either circumvent any contamination or to take into account such perturbations in the analysis of the data for estimating and testing of impact hypotheses.

Faced with the type of data available from the Prairie Island plant, we are left to make the best analysis we can. So the analytical framework was set to use a general linear regression analysis in a univariate manner. The independent variables are dummy variables, taking a value of 0 or 1, depending on the absence or presence of factor-level effects. The decision to use a linear model in a variance-components form to analyze the data was dictated by a post-hoc analysis that made some sense. Logarithmic transformations were carried out before obtaining the general regressions.

The two general linear models used in these studies are:

$$\text{Model 1: } \ln y = \alpha + \begin{matrix} \text{stations'} \\ \text{effects} \end{matrix} + \begin{matrix} \text{months'} \\ \text{effects} \end{matrix} + \begin{matrix} \text{stations'} \\ \text{effects} \end{matrix} \times \begin{matrix} \text{months'} \\ \text{effects} \end{matrix} + \text{random error}$$

$$\text{Model 2: } \ln y = \alpha + \begin{matrix} \text{years'} \\ \text{effects} \end{matrix} + \begin{matrix} \text{stations'} \\ \text{effects} \end{matrix} + \begin{matrix} \text{months'} \\ \text{effects} \end{matrix} + \begin{matrix} \text{years'} \\ \text{effects} \end{matrix} \times \begin{matrix} \text{stations'} \\ \text{effects} \end{matrix}$$

$$\begin{matrix} \text{years'} \times \\ \text{+ months'} \\ \text{effects} \end{matrix} + \begin{matrix} \text{stations'} \\ \text{effects} \end{matrix} \times \begin{matrix} \text{months'} \\ \text{effects} \end{matrix} + \begin{matrix} \text{years'} \times \\ \text{stations'} \times \\ \text{months'} \text{ effects} \end{matrix} + \text{random error}$$

where y represents the observed values of the dependent variable (benthic, phytoplankton, and zooplankton densities).

The various additive effects are estimated by a number of dummy variables; this number depends on the levels of each factor present for a particular set of data values.

The error terms are assumed to be normally, identically, and independently distributed with mean zero and an unknown constant variance quantity.

Residuals from the fitted models were examined, to gain awareness of special data-points problems. Particular attention was given to "extreme" values and outliers. The presence of such incidences was only used to carry out proper interpretations of the data.

Model 1 was used to analyze year-by-year data and Model 2 was used to analyze preoperation-operation combined-years' data. Effective interpretation with such an approach invited examining the "nested" variance components analysis, with nesting occurring within the year factor.

From the analysis of variance associated with these general linear regressions, individual comparisons were made using either the least significant difference method or single degree-of-freedom sum-of-squares computations. Because the data contain unbalanced items, missing cells, and outliers types of conditions, such an approach provided the reasonably best analysis for estimating and testing the hypotheses.

As previously mentioned, some of the indicator organisms used in this study are euplankton species. These include total phytoplankton and zooplankton (rotifers and total zooplankton). The benthos component includes Chironomidae, Naididae, and Tubificidae. Because of insufficient data, fish were not analyzed except for impingement rates (discussed later in this report). This diverse array includes several trophic levels and both free-floating and sessile organisms. For plankton and benthos, the subgroups represent the major portion of the biomass.

At the Prairie Island plant, 1973 was a preoperational year and 1974 and 1975 were operational years. In comparing preoperational and operational

distributions of the organisms, one must assume that the comparison provides a true estimate of plant operational impact and not merely naturally occurring changes over these years. Comparison of 1973 data with 1974 data provided an estimate of the effects of Unit 1 operation. When 1973 data were compared with the combined 1974 and 1975 data, we obtained an estimate of the effects of Units 1 and 2 together.

Intrayear station comparisons are listed by month and station effects. Interyear components are month, station, year, and station x month and station x year interactions.

Interyear comparisons were also made among stations. Data for all years at each station were compiled and the means computed for each station. The means for selected station pairs were then compared and their statistical significance computed. In many station comparisons, arithmetic data and logarithmic transformation of the data were plotted against time.

Arithmetic and logarithmic graphs of paired stations (where the monthly mean densities of organisms are plotted against time), comparing the 1973-1975 population densities of phytoplankton, zooplankton, and benthos, are given in Appendix P-2, Plots 1-31. Statistical results appear in Tables 2-5. Tables of raw data compiled for the statistical analyses are given in Appendix P-3 (in the same order of topics as in Appendix P-2).

Spatial and temporal comparisons of means and their statistical differences only confirm that if biological measurements are made at various points in time, the observations are expected to differ in values. Therefore, such statistical comparisons are confirmatory only and reveal very little about the nature and extent of environmental changes due to plant operation. However, understanding and appreciating these inherent differences provide an objective basis for a determination of environmental effects. The final hypothesis of interest (the magnitude of environmental change due to plant operation) was tested by considering the significance of the interaction effect in a two-way layout. The basic experimental design for the determination of environmental changes is the following:

	<u>Reference</u>	<u>Stress</u>
Before	M_{11}	M_{12}
After	M_{21}	M_{22}

The interaction comparison of interest is formulated as $D = (M_{11} + M_{22} - M_{21} - M_{12})$ and the single degree-of-freedom test is performed to (a) determine the statistical significance and then (b) determine the biological interpretation of that figure on the local environment.

Thus, tables were prepared to determine, first, station and sampling-period differences by comparing biotic data from stressed and reference locations. The final testing and conclusions were then obtained by analyzing and interpreting the interaction effect in the two-way design.

The locations of phytoplankton sampling stations are shown in Figure 6. Zooplankton and rotifer sampling locations are given in Figure 7. Figure 8

Table 2. Statistical Significance (α -values) of Month and Station Differences in Mean Densities of Selected Prairie Island Biotic Groups

	Phytoplankton			Total Zooplankton		Rotifera			
	1973	1974	1975	1974	1975	1972	1973	1974	1975
Month	0.0001	0.0001	0.0368	0.0001	0.0003	0.0001	0.0001	0.0636	0.0001
Station	0.0027	0.0028	0.0708	<u>0.2149</u>	<u>0.2530</u>	0.0001	<u>0.3855</u>	<u>0.6072</u>	<u>0.5043</u>
	Chironomidae			Naididae			Tubificidae		
	1973	1974	1975	1973	1974	1975	1973	1974	1975
Month	<u>0.5511</u>	<u>0.2485</u>	0.0917	<u>0.3399</u>	<u>0.9799</u>	0.0718	0.1885	<u>0.5294</u>	0.0055
Station	<u>0.2739</u>	<u>0.2866</u>	<u>0.5382</u>	<u>0.7396</u>	0.002	<u>0.5351</u>	<u>0.2445</u>	0.0151	<u>0.8400</u>

For $\alpha \geq 0.2000$, the result is declared not significant. All such results are underlined in the table.

Table 3. Test Stations^a Showing Statistically Different Densities of Organisms for Preoperational and Operational Years

Biological Group	1973-74	1974-75	1973-(74 + 75)
Phytoplankton	0	-	↓ 3
Total Zooplankton	-	↓ 7 ↓ 1	-
Rotifera	↑ 2 ↑ 6		↑ 2 ↑ 6
Benthos			
Naididae	0	-	↓ 7
Chironomidae	0	-	↑ 2 ↑ 6
Tubificidae	0	-	↑ 2

^aStation numbers as in key to Figures 4-6.

↑ Annual mean density greater in operational year 1974 or the mean value for (1974 + 1975).

↓ Annual mean density less than in operational year 1974 or the mean value for (1974 + 1975).

- No data.

0 No significant differences computed.

Table 4. Summary of Means for Aquatic Groups in Selected Plant-Site Areas

Year	Region	Total Phytoplankton, No./ml	Total Zooplankton, No./l	Rotifera, No./l	Naididae, No./m ²	Chironomidae, No./m ²	Tubificidae, No./m ²	Site Area
1973	Upstream	9,000	-	-	20	50	0.0	Main channel
		15,000	-	60	25	35	15	Sturgeon Lake
1973	At plant	-	-	-	-	50	0.0	Main channel
		15,000	-	70	75	27	70	Inshore
1973	Downstream	12,000	-	70	60	10	20	Above dam
		10,000	-	-	-	-	-	Below dam
1974	Upstream	8,000	300	-	5	55	60	Main channel
		12,000	225	285	2.0	60	30	Sturgeon Lake
1974	At plant	-	-	-	-	55	60	Main channel
		15,000	-	260	20	38	170	Inshore
1974	Downstream	8,000	300	-	0.0	40	15	Above dam
		9,000	-	-	-	-	-	Below dam
1975	Upstream	7,000	80	-	0.0	130	160	Main channel
		13,000	-	50	15	1100	1660	Sturgeon Lake
1975	At plant	10,000	-	-	-	130	160	Main channel
		16,000	-	50	130	240	880	Inshore
1975	Downstream	9,000	100	75	1.0	180	200	Above dam
		-	-	-	-	-	-	Below dam

0 = No organisms in sample.

- = No data.

Table 5. Mean Densities of Major Aquatic Groups at Selected Plant-Site Sampling Stations, 1972-1975

Station	Phytoplankton, No./ml			Zooplankton, No./l		Rotifera, No./l				Naididae, No./m ²			Chironomidae, No./m ²			Tubificidae, No./m ²		
	1973	1974	1975	1974	1975	1972	1973	1974	1975	1973	1974	1975	1973	1974	1975	1973	1974	1975
1	-	-	-	307	83	-	-	-	-	19	5	0	52	54	134	0	56	160
2	-	-	-	-	-	-	63	285	51	23	2	13	35	58	1119	15	31	1657
3	14,701	12,466	13,198	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	8,590	8,198	10,004	-	-	-	-	-	-	71	37	31	47	13	14	50	246	660
6	-	-	-	-	-	-	71	260	52	79	3	231	6	63	468	86	92	1105
7	-	-	-	306	104	-	-	-	-	59	0	1	11	42	182	16	13	198
8	-	-	-	-	-	385	70	-	75	-	-	-	-	-	-	-	-	-
9	11,664	7,700	9,386	226	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	10,221	10,618	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16	14,825	15,379	15,590	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

0 = No organisms in sample.

- = No data.

Fig. 6. Phytoplankton Sampling Stations.

Fig. 7. Zooplankton and Rotifer Sampling Stations.

Fig. 8. Benthos Sampling Stations.

KEY TO SAMPLING STATIONS AT PRAIRIE ISLAND GENERATING SITE
(Figs. 6, 7 and 8)

Total Phytoplankton

<u>Station</u>	<u>Location</u>
3	Mouth of Sturgeon Lake (upstream from plant)
5	Main channel (upstream from plant)
9	Main channel, above dam (downstream from plant)
12	Main channel, below dam
16	Discharge, close to plant

Rotifera

2	(X1)* Intake outside (east) of barrier wall
6	(Y2) Barney's Point (effluent after mixing)
8	(C4) Downstream from plant in main channel

Total Zooplankton

1	(B1) Upstream from plant in main channel
7	(C1) Downstream from plant below Barney's Point
9	(B2) Upstream from plant in mouth of Sturgeon Lake

Benthos

1	(B1) Upstream from plant in main channel
2	(X1) Intake outside (east) of barrier wall
5	(Y1) Effluent area near the plant (discharge)
6	(Y2) Barney's Point (plant cooling-water effluent after thorough mixing with water from Sturgeon Lake) (discharge after plume mixing)
7	(C1) Downstream from plant below Barney's Point (main channel after plume mixing and release at Barney's Point)
8	(C4) Downstream from plant in main channel
9	(B2) Upstream from plant in mouth of Sturgeon Lake

*Northern States Power Company designations for these stations are in parentheses.

shows the stations used for benthos sampling. Results of time-series comparisons and variance-components analyses for major aquatic (non-fish) communities are discussed insofar as they indicate the plant's impact on each community.

Total Phytoplankton

Time-Series Comparisons

Time-series graphs showing phytoplankton densities for several station pairs were plotted and analyzed. Available data on total phytoplankton for the years 1973-1975 were used.

The various paired graphs (Appendix P-2, Plots 1-8) indicate considerable variability in phytoplankton densities. Station 3, at the mouth of Sturgeon Lake, usually showed higher density peaks than station 9, in the main channel of the Mississippi River (Appendix P-2, Plots 1 and 1A; Fig. 6). Comparisons of stations 5 and 16 (Plots 7 and 7A) are considered the most indicative of the presence or absence of plant impact. However, no effect of importance can be recognized and no impact value can be assigned.

Variance-Components Analysis

Quantitative analysis of the phytoplankton data showed no significant difference in the annual mean densities at any sampling location when 1973 (preoperational) and 1974 (operational) periods were compared. However, a comparison of the mean densities for 1974 and 1975 with the mean densities for 1973 for station 3 suggested a decrease in the phytoplankton densities (Tables 2-5). It should be noted that the total phytoplankton densities show a statistically significant variability between months and between stations in both the preoperational and operational periods (Table 2). On further examination of the results, it was inferred that no detectable impact due to Prairie Island plant operation has occurred in the first two years of its operation.

Rotifera

Time-Series Comparisons

Several paired stations graphs show Rotifera density data for 1973-1975 (Appendix P-2, Plots 9-11; Fig. 7). A close examination of these plots reveals seasonal differences and high variability in abundance. Even though several locations were not sampled consistently, a general observation indicates no large difference between station pairs. The limited data show no significant effect of plant operation on the Rotifera community.

Variance-Components Analysis

The statistical analysis showed an increase in the mean numbers of rotifers at the intake and the Barney's Point locations after 1973. Comparisons between plant preoperational and operational periods show a statistical difference in the mean densities (Tables 2-5). This increase is quite prominent, but no biological significance can be assigned. It is therefore inferred that no detectable impact on the Rotifera community has occurred during the two years of plant operation.

Total Zooplankton

Time-Series Comparisons

Station pairs were plotted to check for sampling points showing departures from naturally occurring zooplankton densities. Total zooplankton data for 1973-1975 were used (Appendix P-2, Plots 12-13; Fig. 7).

A comparison of reference stations in the main channel showed similar zooplankton densities (Plots 12 and 12A). However, peak densities occurred later at the upstream location (September 1974) than at the downstream station (July 1974).

Another comparison between stations 7 and 9 showed a difference in the occurrence of peaks in the zooplankton densities (Plots 13 and 13A). Station 7 showed a peak in July 1974, followed by a gradual decline. A peak at station 9 was lower in magnitude and occurred later in the year.

These differences in the paired comparisons still present difficulties in interpretation. From a biologist's standpoint, these differences are assigned no significance.

Variance-Components Analysis

Statistical analysis showed a decrease in annual mean density of zooplankton at all the locations in 1974 when compared with 1973 (Tables 2-5). We could not compare the 1973 (preoperational) results to 1974 and 1975 (operational) results because of unavailability of data for 1975. It should also be noted that the mean densities of total zooplankton show a significant effect of months in 1973 and 1974 (Table 2).

As a result of these analyses, we infer that no evidence of impact on the zooplankton community is found.

Chironomidae

Time-Series Comparisons

Station pairs were plotted to check for sampling points showing departures in the abundance of Chironomidae in the vicinity of the Prairie Island plant for the years 1973 through 1975.

Decreases in stress and reference stations peak abundances of Chironomidae were observed from 1973 to 1974 (Appendix P-2, Plots 14-19; Fig. 8). Because the decreases were similar for the stress and reference stations, we conclude that these changes are due to natural variations. A decline, in December 1973, in Chironomidae densities at station 7 in the main channel below the plant is coincident with the start of commercial operation of Unit 1. This change may have been natural or have been plant-induced. A recovery in the following few months indicates that the change may have been transient in nature.

Variations in the time-dependent density distributions are attributed to natural changes. Therefore, the graphical analysis leads to the conclusion that no plant-induced impact on chironomids was found.

Variance-Components Analysis

A comparison of mean densities of chironomids indicated that both the intake and discharge areas show higher densities than other sampling stations. Comparisons indicate that no significant change in mean densities have occurred over the years studied. Although density ranges showed a rather large variability, chironomids located in the plume generally increased or decreased concurrently with those at the reference stations. It is therefore inferred that no important impact due to the Prairie Island plant has occurred for the two years of operation.

Naididae

Time-Series Analysis

Paired station plots for naidids were used in the same manner as for the other biotic groups (Appendix P-2, Plots 20-25; Fig. 8). In general, naidids showed a rather wide fluctuation in abundance until about July 1975, after which a rapid decline was noted. However, by the end of the year, a recovery occurred. The overall results show that the effect of power-plant effluents on the abundance of naidids could not be detected. Separation of plant-induced impacts from the large natural oscillations could not be accomplished.

Variance-Components Analysis

The statistical treatment of naidid-density data revealed that station 7 densities decreased in the two years following plant startup. This is shown by the linear comparison of 1973 mean values with the 1974 and 1975 combined means (Table 3). These significant decreases at station 7 could not be attributed to plant impacts. It is concluded that the statistical analysis shows no detectable impact on naidids in the vicinity of Prairie Island.

Tubificidae

Time-Series Analysis

Graphical comparisons between the reference and stress stations showed that the distribution of tubificids at different locations was very similar (Appendix P-2, Plots 26-31; Fig. 8). Relatively large variations in densities occurred spatially and temporally. These time-dependent changes are reflective of the biological cycle that tubificids follow. We cannot discern any important plant-induced changes in Tubificidae abundance.

Variance-Components Analysis

The statistical analysis showed no detectable impact on tubificid abundance. The variation in densities among years was significant. However, stress and reference stations showed similar changes. As a result, it is inferred that plant operation has not produced an impact on Tubificidae.

Fish Impingement

During 1974 and 1975, fish impingement was monitored at the plant. The data collected were reported by Northern States Power Company to the NRC in

semiannual and annual reports. During 1974, Unit 1 was intermittently operated. In 1974, Units 1 and 2 were both operational. During the entire data-collection period, the plant's cooling system operated under various modes. During 1974, it was operated primarily in a closed-cycle mode with cooling towers. In 1975, because of difficulties with the cooling-tower operation, the plant operated in a helper-cycle mode, and at times in a full open-cycle mode. Data on average intake flow rate (in cubic feet per second) and intake water temperatures were recorded in the plant log book.

Data on fish impingement, plant water flow, and intake-temperatures for 1974 and 1975 were obtained from Northern States Power Company (Tables 6-8). For 1974, the intake water flow rates and temperature values were available as weekly averages and the fish-impingement data (Table 6) for the corresponding week were used. Data were collected more frequently in 1974 than in 1975. Throughout the monitoring period, fish kills of various species were observed; however, the predominant species impinged was the gizzard shad. Other important species impinged were white bass, drum, sunfish, bullheads, and crappies. Figures 9 through 13 show the observed fish kill rates for over a 730-day period in 1974 and 1975. The logarithmic transformation is plotted against time for various species and total impingement.

During 1974 and 1975, the Northern States Power Company reported several environmental events to the NRC. Two events were reported in 1974 and 13 events were reported in 1975 (summarized in Table 9).

According to the ETS, the limit of 175 fish per week was set for several species, including catfish, sunfish, bullheads, and white bass. The angler catch limit imposed on the plant was formulated with the assistance of the Minnesota Department of Natural Resources. In setting the limit, the Prairie Island plant was considered as another fisherman on the water body; therefore, a weekly fisherman limit was used as the limit for the plant.

However, before a fisherman can retain the fish and count it toward the catch limit, it must exceed a specified minimum size. But in the case of the power plant, there is no minimum catchable fish size, and all fish collected at the screen are counted towards the limit. Because immature fish are counted like adults, the technical specifications for the nuclear plant are in essence more strict than for a single fisherman.

Statistical analysis of the fish-impingement data for gizzard shad species was carried out. Multiple regressions using quadratic order variables in time and temperature, together with a linear portion due to the flow variable, were used as the independent variables, and logarithmically transformed gizzard shad impingement data were used as a dependent variable. After a careful study of several regression models we chose the regression equations shown in Table 10. Figures 14-16 provide the fitted values line and the data scatter for gizzard shad impingement at the Prairie Island plant.

A study of the regressions revealed that the gizzard shad impingement cycle started in July each year and ended in June the following year. Since we have only one continuous such cycle, the estimated regression line in Model I is the result of fitting the model to the July 1974 to June 1975 data. The regression explained about 76% of the variation in the data. A regression fit using Model III showed that about 63% of the variation in impingement was

Table 6. Fish Impingement and Plant Data Showing 1974 Weekly Values

BEGIN_MO	BEGIN_DA	BEGIN_YR	END_MO	END_DAY	END_YR	NO_DAYS	TOTAL	GIZZARD	BASS	DRUM	MINNOWS	FLOW	IN_TEMP
1	1	74	1	9	74	7	8819	8750	17	30	2	10	32.0
1	9	74	1	16	74	7	3515	3500	7	8	0	6	32.0
1	16	74	1	23	74	7	889	859	12	7	0	1	32.0
1	23	74	1	30	74	7	262	242	6	8	0	8	32.0
1	30	74	2	6	74	7	4431	4263	48	98	0	11	32.0
2	6	74	2	13	74	7	745	650	14	42	0	18	32.0
2	13	74	2	20	74	7	242	134	9	91	0	18	32.0
2	20	74	2	27	74	7	102	18	10	61	0	11	32.0
2	27	74	3	6	74	7	219	81	10	107	0	10	32.0
3	6	74	3	13	74	7	94	21	3	47	1	8	35.6
3	13	74	3	20	74	7	0	0	0	0	0	3	35.6
3	20	74	3	27	74	7	0	0	0	0	0	1	35.6
3	27	74	4	3	74	7	2	0	0	1	0	4	37.4
4	3	74	4	10	74	7	427	114	8	39	0	8	39.2
4	10	74	4	17	74	7	133	16	43	6	2	12	42.8
4	17	74	4	24	74	7	125	8	36	5	4	8	44.6
4	24	74	5	1	74	7	144	9	36	9	3	6	48.2
5	1	74	5	8	74	7	20	1	3	4	0	2	53.6
5	8	74	5	15	74	7	4	0	0	0	0	1	57.2
5	15	74	5	22	74	7	0	0	0	0	0	3	57.2
5	22	74	5	29	74	7	2	0	0	1	0	1	59.0
5	29	74	6	5	74	7	7	0	1	5	0	1	60.8
6	5	74	6	12	74	7	0	0	0	0	0	1	64.4
6	12	74	6	19	74	7	23	0	0	2	0	8	68.0
6	19	74	6	26	74	7	148	0	1	5	5	6	66.2
6	26	74	7	3	74	7	281	2	8	12	76	19	68.0
7	3	74	7	10	74	7	233	0	6	25	29	19	69.8
7	10	74	7	17	74	7	329	7	67	13	47	19	73.4
7	17	74	7	24	74	7	131	19	53	3	22	16	80.6
7	24	74	7	31	74	7	347	145	164	23	26	17	82.4
7	31	74	8	7	74	7	122	12	55	20	0	17	75.2
8	7	74	8	14	74	7	517	96	175	99	26	12	73.4
8	14	74	8	21	74	7	355	77	43	0	2	12	68.0
8	21	74	8	28	74	7	388	54	20	87	8	17	64.4
8	28	74	9	4	74	7	744	289	23	111	12	13	62.6
9	4	74	9	11	74	7	529	104	8	174	0	8	59.0
9	11	74	9	18	74	7	743	590	7	39	1	3	55.4
9	18	74	9	25	74	7	2	2	0	0	0	1	55.4
9	25	74	10	2	74	7	52	9	2	0	0	2	50.0
10	2	74	10	9	74	7	0	0	0	0	0	3	49.2
10	9	74	10	16	74	7	0	0	0	0	0	1	46.4
10	16	74	10	23	74	7	0	0	0	0	0	1	49.2
10	23	74	10	30	74	7	15553	13797	143	611	336	14	46.4
10	30	74	11	6	74	7	24011	23445	14	389	2	20	44.6
11	6	74	11	13	74	7	57955	57189	30	490	9	19	44.6
11	13	74	11	20	74	7	675	521	9	115	1	18	42.8
11	20	74	11	27	74	7	351	273	8	22	18	18	41.0
11	27	74	12	4	74	7	7651	7183	125	168	98	18	35.9
12	4	74	12	11	74	7	2669	2559	36	21	14	20	33.8
12	11	74	12	18	74	7	2752	2700	20	13	0	26	33.8
12	18	74	12	26	74	7	2575	2458	59	21	5	30	33.8
12	26	74	1	2	75	7	6581	6470	28	17	24	32	32.0

Table 7. Fish Impingement and Plant Data for 1974 (frequency of data collection was less than a week)

BEGIN_MO	BEGIN_DA	BEGIN_YR	END_MO	END_DAY	END_YR	NO_DAYS	TOTAL	GIZZARD	BASS	DRUM	MINNOWS
4	10	74	4	15	74	5	103	12	26	6	0
4	15	74	4	17	74	2	41	4	17	0	0
7	3	74	7	8	74	5	174	0	3	22	0
7	8	74	7	10	74	2	59	0	3	3	0
7	10	74	7	12	74	2	104	0	7	5	0
7	12	74	7	15	74	3	121	1	38	4	0
7	15	74	7	17	74	2	107	6	25	4	0
7	17	74	7	19	74	2	50	14	15	2	0
7	19	74	7	22	74	3	54	4	15	1	0
7	22	74	7	24	74	2	46	1	23	0	0
7	24	74	7	26	74	2	43	2	25	3	0
7	26	74	7	29	74	3	88	30	29	9	0
7	29	74	7	31	74	2	335	113	110	11	0
7	31	74	8	2	74	2	30	0	13	1	0
8	2	74	8	5	74	3	63	11	29	9	0
8	5	74	8	7	74	2	29	1	13	10	0
8	7	74	8	9	74	2	236	44	100	38	0
8	9	74	8	12	74	3	213	47	61	49	0
8	12	74	8	14	74	2	62	5	14	12	0
8	14	74	8	16	74	2	134	54	24	16	0
8	16	74	8	19	74	3	78	3	7	36	0
8	19	74	8	21	74	2	146	20	12	45	0
8	21	74	8	23	74	2	87	14	6	23	0
8	23	74	8	26	74	3	160	28	9	38	0
8	26	74	8	28	74	2	144	12	5	26	0
8	28	74	8	30	74	2	73	9	4	52	0
8	30	74	9	2	74	3	508	242	13	45	0
9	2	74	9	4	74	2	123	38	6	14	0
9	4	74	9	6	74	2	169	31	4	50	0
9	6	74	9	9	74	3	195	59	2	93	0
9	9	74	9	11	74	2	166	59	2	31	0
9	11	74	9	13	74	2	71	20	1	12	0
9	13	74	9	16	74	3	151	122	3	4	0
9	16	74	9	18	74	2	521	448	3	23	0
9	18	74	9	20	74	2	0	0	0	0	0
9	20	74	9	25	74	5	0	0	0	0	0
9	25	74	9	27	74	2	54	9	2	0	0
9	27	74	9	30	74	3	0	0	0	0	0
9	30	74	10	2	74	2	0	0	0	0	0
10	2	74	10	4	74	2	0	0	0	0	0
10	4	74	10	7	74	3	0	0	0	0	0
10	7	74	10	9	74	2	0	0	0	0	0
10	9	74	10	11	74	2	0	0	0	0	0
10	11	74	10	14	74	3	0	0	0	0	0
10	14	74	10	16	74	2	0	0	0	0	0
10	16	74	10	18	74	2	0	0	0	0	0
10	18	74	10	21	74	3	0	0	0	0	0
10	21	74	10	23	74	2	0	0	0	0	0
10	23	74	10	25	74	2	10575	10150	20	228	13
10	25	74	10	28	74	3	4904	3625	116	364	39
10	28	74	10	30	74	2	79	22	1	19	0
10	30	74	11	1	74	2	260	175	7	26	1
11	1	74	11	4	74	3	3433	3320	1	72	0
11	4	74	11	6	74	2	20312	19950	6	291	0
11	6	74	11	7	74	1	56036	54600	19	410	0

Table 7. Continued

BEGIN_MO	BEGIN_DA	BEGIN_YR	END_MO	END_DAY	END_YR	NO_DAYS	TCTAL	GIZZARD	BASS	DRUM	MINNOWS
11	7	74	11	8	74	1	404	348	0	31	0
11	8	74	11	11	74	3	723	680	5	22	0
11	11	74	11	13	74	2	1605	1560	4	26	0
11	13	74	11	15	74	2	450	412	5	19	0
11	15	74	11	18	74	3	164	67	1	89	0
11	18	74	11	20	74	2	63	42	3	7	0
11	20	74	11	22	74	2	48	36	2	6	0
11	22	74	11	25	74	3	41	23	1	6	0
11	25	74	11	27	74	2	263	214	5	10	0
11	27	74	12	2	74	5	7200	6756	115	160	0
12	2	74	12	4	74	2	451	427	10	8	0
12	4	74	12	6	74	2	247	198	9	9	0
12	6	74	12	9	74	3	1982	1940	18	10	0
12	9	74	12	11	74	2	443	421	9	2	0
12	11	74	12	13	74	2	86	66	8	6	0
12	13	74	12	16	74	3	103	89	5	4	0
12	16	74	12	17	74	1	956	945	6	1	0
12	17	74	12	18	74	1	1607	1600	1	2	0
12	18	74	12	19	74	1	139	135	3	0	0
12	19	74	12	20	74	1	64	58	0	0	0
12	20	74	12	23	74	3	847	780	39	10	0
12	23	74	12	26	74	3	1529	1485	17	11	0
12	26	74	12	27	74	1	828	770	3	12	0
12	27	74	12	30	74	3	2797	2760	16	4	0
12	30	74	1	2	75	4	2966	2940	9	1	0

Table 8. Fish Impingement and Flant Data for 1975 (frequency of data collection was less than a week)

BEGIN_MO	BEGIN_DA	BEGIN_YR	END_MO	END_DAY	END_YR	NO_DAYS	TOTAL	GIZZARD	BASS	DRUM	MINNOWS	FLOW	IN_TEMP
1	2	75	1	3	75	1	341	324	5	8	0	150	32
1	3	75	1	6	75	3	1510	1490	7	4	0	150	32
1	6	75	1	8	75	2	2582	2550	19	3	0	150	32
1	8	75	1	10	75	2	89	59	12	2	0	150	32
1	10	75	1	13	75	3	2107	2047	23	5	0	150	32
1	13	75	1	14	75	1	96	84	2	5	0	150	32
1	14	75	1	15	75	1	81	73	2	0	0	150	32
1	15	75	1	17	75	2	273	261	6	2	0	150	32
1	17	75	1	20	75	3	244	221	7	4	0	150	32
1	20	75	1	22	75	2	290	268	4	7	0	150	32
1	22	75	1	24	75	2	448	415	5	6	0	150	32
1	24	75	1	27	75	3	603	586	4	6	0	150	32
1	27	75	1	29	75	2	864	836	6	8	0	150	32
1	29	75	1	31	75	2	1306	1285	5	10	0	150	32
1	31	75	2	3	75	3	1024	998	3	7	0	150	32
2	3	75	2	5	75	2	995	974	3	8	0	150	32
2	5	75	2	7	75	2	975	951	2	10	0	150	32
2	7	75	2	10	75	3	566	538	5	8	0	150	32
2	10	75	2	12	75	2	667	647	1	9	0	150	32
2	12	75	2	14	75	2	1270	1235	5	22	0	207	32
2	14	75	2	17	75	3	1014	676	9	21	0	230	32
2	17	75	2	19	75	2	345	308	10	20	0	343	32
2	19	75	2	21	75	2	134	94	8	22	0	354	32
2	21	75	2	24	75	3	242	204	9	18	0	224	32
2	24	75	2	26	75	2	227	191	10	18	0	359	32
2	26	75	2	28	75	2	73	51	3	12	0	348	32
2	28	75	3	3	75	3	322	363	10	29	0	297	32
3	3	75	3	5	75	2	856	836	4	10	0	205	32
3	5	75	3	7	75	2	372	350	2	12	0	150	32
3	7	75	3	10	75	3	338	312	9	8	0	219	32
3	10	75	3	12	75	2	54	41	4	7	0	225	32
3	12	75	3	14	75	2	222	190	8	16	0	225	32
3	14	75	3	17	75	3	187	165	3	5	0	236	35
3	17	75	3	18	75	1	742	692	3	19	0	479	41
3	18	75	3	19	75	1	359	297	7	22	0	337	34
3	19	75	3	20	75	1	134	75	13	12	0	282	34
3	20	75	3	22	75	2	144	78	8	23	1	219	35
3	22	75	3	24	75	2	146	97	4	11	0	227	34
3	24	75	3	25	75	1	115	101	0	2	0	296	33
3	25	75	3	26	75	1	118	104	0	3	0	374	33
3	26	75	3	27	75	1	83	66	1	4	0	410	33
3	27	75	3	28	75	1	119	94	2	3	0	410	33
3	28	75	3	31	75	3	201	138	8	24	0	409	33
4	31	75	4	2	75	2	85	66	0	10	0	410	33
4	2	75	4	4	75	2	68	44	3	11	0	410	33
4	4	75	4	7	75	3	102	167	4	11	0	453	33
4	7	75	4	8	75	1	54	28	0	1	0	490	33
4	7	75	4	9	75	2	49	25	2	8	0	490	33
4	9	75	4	14	75	5	152	78	4	15	0	490	33
4	14	75	4	16	75	2	73	42	1	2	0	486	41
4	16	75	4	18	75	2	199	128	10	6	0	490	44
4	18	75	4	21	75	3	175	54	2	15	0	490	44
4	21	75	4	23	75	2	128	92	1	0	0	490	44
4	23	75	4	25	75	2	146	104	1	0	0	490	42
4	25	75	4	26	75	1	437	43	5	1	0	490	42

Table 8. Continued

BEGIN_MO	BEGIN_DA	BEGIN_YR	END_MO	END_DAY	END_YR	NO_DAYS	TOTAL	GIZZARD	BASS	DRUM	MINNOWS	FLOW	IN_TEMP
4	26	75	4	28	75	2	819	41	21	4	8	490	43
4	28	75	4	29	75	1	79	16	14	1	3	490	42
4	29	75	4	30	75	1	646	71	3	2	9	490	42
4	30	75	5	2	75	2	507	38	14	6	13	490	42
5	2	75	5	6	75	4	1443	377	24	29	45	490	42
5	6	75	5	7	75	1	309	90	19	10	0	490	42
5	7	75	5	9	75	2	386	89	39	12	4	490	42
5	9	75	5	12	75	3	182	21	25	11	2	459	44
5	12	75	5	14	75	2	126	3	10	26	1	340	53
5	14	75	5	19	75	5	33	2	1	5	0	777	64
5	19	75	5	21	75	2	97	1	13	15	0	753	69
5	21	75	5	23	75	2	115	7	14	29	0	894	70
5	23	75	5	27	75	4	281	0	30	36	0	1054	69
5	27	75	5	28	75	1	130	0	7	18	9	897	69
5	28	75	5	30	75	2	120	2	11	11	1	653	65
5	30	75	6	2	75	3	115	1	9	14	0	333	69
6	2	75	6	6	75	4	69	0	1	3	0	249	68
6	6	75	6	9	75	3	24	0	0	2	0	327	68
6	9	75	6	11	75	2	52	3	0	4	0	327	68
6	11	75	6	17	75	6	173	2	1	1	0	587	69
6	17	75	6	30	75	13	15	0	0	1	0	332	74
6	30	75	7	14	75	14	35	0	0	1	0	632	79
7	14	75	7	21	75	7	704	58	269	12	0	815	76
7	21	75	7	23	75	2	413	32	121	21	0	988	78
7	23	75	7	25	75	2	502	183	106	29	0	891	77
7	25	75	7	28	75	3	346	97	85	25	0	984	77
7	28	75	7	30	75	2	116	33	27	10	0	989	81
7	30	75	8	1	75	2	214	57	27	30	0	989	82
8	1	75	8	4	75	3	242	69	53	26	2	838	81
8	4	75	8	6	75	2	153	42	20	13	0	646	81
8	6	75	8	8	75	2	717	387	95	59	32	969	79
8	8	75	8	11	75	3	255	55	9	17	0	502	80
8	11	75	8	13	75	2	852	776	24	4	0	172	79
8	13	75	8	15	75	2	477	410	10	11	0	225	77
8	15	75	8	18	75	3	1329	1084	41	38	0	279	75
8	18	75	8	20	75	2	147	72	10	11	0	588	74
8	20	75	8	22	75	2	151	45	12	30	0	390	75
8	22	75	8	25	75	3	634	249	42	35	0	560	75
8	25	75	8	27	75	2	671	64	153	31	0	363	73
8	27	75	8	29	75	2	255	22	32	11	0	293	73
8	29	75	9	2	75	4	187	118	15	7	0	539	73
9	2	75	9	3	75	1	635	376	41	30	0	547	73
9	3	75	9	5	75	2	212	83	36	12	0	458	72
9	5	75	9	8	75	3	239	71	28	16	0	381	71
9	8	75	9	10	75	2	268	131	9	21	0	566	73
9	10	75	9	12	75	2	460	239	31	20	0	409	67
9	12	75	9	15	75	3	231	123	23	18	0	279	64
9	15	75	9	17	75	2	262	89	24	18	0	383	64
9	17	75	9	19	75	2	234	129	11	23	0	358	66
9	19	75	9	22	75	3	176	71	21	23	0	257	62
9	22	75	9	24	75	2	291	133	6	40	0	286	59
9	24	75	9	26	75	2	227	62	7	43	0	200	60
9	26	75	9	29	75	3	536	190	7	51	0	214	60
9	29	75	10	1	75	2	954	277	15	53	0	225	60
10	1	75	10	3	75	2	998	142	13	115	0	179	56

Table 8. Continued

BEGIN_MO	BEGIN_DA	BEGIN_YR	END_MO	END_DAY	END_YR	NO_DAYS	TOTAL	GIZZARD	BASS	DRUM	MINNOWS	FLOW	IN_TEMP
10	3	75	10	6	75	3	1412	399	20	152	0	299	59.0
10	6	75	10	8	75	2	803	337	18	99	0	505	62.0
10	8	75	10	9	75	1	315	166	14	82	0	435	64.0
10	9	75	10	10	75	1	2500	2182	13	162	0	297	61.0
10	10	75	10	13	75	3	1526	1013	30	280	0	295	59.0
10	13	75	10	14	75	1	607	78	4	79	0	236	60.0
10	14	75	10	15	75	1	367	221	2	60	0	468	61.0
10	15	75	10	16	75	1	210	152	2	13	0	168	57.0
10	16	75	10	17	75	1	395	179	3	39	0	150	56.0
10	17	75	10	20	75	3	240	95	8	14	0	150	54.0
10	20	75	10	21	75	1	45	16	2	5	0	131	54.0
10	21	75	10	22	75	1	252	156	6	25	0	150	54.0
10	22	75	10	23	75	1	232	83	5	12	0	171	55.0
10	23	75	10	24	75	1	211	107	18	12	0	150	55.0
10	24	75	10	27	75	3	5033	4700	19	143	0	150	55.0
10	27	75	10	28	75	1	2660	2450	6	153	0	150	55.8
10	28	75	10	29	75	1	257	179	4	53	0	150	55.7
10	29	75	10	30	75	1	289	244	9	0	0	150	54.9
10	30	75	10	31	75	1	1337	1254	15	24	0	155	54.6
10	31	75	11	3	75	3	889	744	21	42	0	134	51.3
11	3	75	11	4	75	1	172	140	2	1	0	149	51.6
11	4	75	11	5	75	1	83	50	4	11	0	148	50.9
11	5	75	11	7	75	2	161	83	5	22	0	242	53.5
11	7	75	11	10	75	3	2767	2539	15	25	0	144	55.9
11	10	75	11	11	75	1	2930	2748	4	36	0	150	53.5
11	11	75	11	12	75	1	351	211	0	7	0	150	55.1
11	12	75	11	14	75	2	672	320	34	43	0	150	55.5
11	14	75	11	17	75	3	765	289	99	43	0	150	35.5
11	17	75	11	19	75	2	1458	1275	31	0	0	150	35.2
11	19	75	11	20	75	1	245	187	6	8	0	150	35.1
11	20	75	11	21	75	1	388	206	8	70	0	150	34.6
11	21	75	11	24	75	3	846	636	42	73	0	150	35.5
11	24	75	11	25	75	1	677	478	65	79	0	157	35.2
11	25	75	11	26	75	1	859	799	19	13	0	150	35.1
11	26	75	12	1	75	5	11199	11093	22	12	0	150	34.1
12	1	75	12	3	75	2	511	484	5	2	0	150	34.1
12	3	75	12	5	75	2	258	203	3	7	0	153	33.9
12	5	75	12	8	75	3	263	188	14	12	0	150	34.1
12	8	75	12	10	75	2	625	525	22	10	0	137	32.7
12	10	75	12	12	75	2	1680	1590	13	9	0	150	32.0
12	12	75	12	15	75	3	2538	2490	6	1	0	150	32.0
12	15	75	12	17	75	2	1072	1018	8	5	0	150	32.0
12	17	75	12	19	75	2	50	31	4	1	0	150	32.0
12	19	75	12	22	75	3	1589	1466	0	36	3	150	32.0
12	22	75	12	24	75	2	215	126	11	1	0	150	32.0
12	24	75	12	26	75	2	331	211	19	2	0	150	32.0
12	26	75	12	29	75	3	1267	1183	15	2	0	150	32.0
12	29	75	12	31	75	2	483	428	3	0	0	150	32.0

Figure 9. Time-Series Plot of Total Fish Impingement at the Prairie Island Plant, 1974-1975.

Fig. 10. Time-Series Plot of Gizzard Shad Impingement at the Prairie Island Plant, 1974-1975.

Fig. 11. Time-Series Plot of Bass Impingement at the Prairie Island Plant, 1974-1975.

Fig. 12. Time-Series Plot of Drum Impingement at the Prairie Island Plant, 1974-1975.

Fig. 13. Time-Series Plot of Minnow Impingement at the Prairie Island Plant, 1974-1975.

Table 9. Summary of Enviromental Events Reported on Fish Impingement
at the Prairie Island Plant, 1974-1975

Period of the Reported Event	Environmental Event
October 23-30, 1974	328 catfish and 182 sunfish impinged. Limit is 175 fish of each type.
November 6-13, 1974	178 sunfish impinged. Limit is 175 fish.
April 30-May 7, 1975	1377 bullheads impinged
April 23-30, 1975	1767 bullheads impinged
July 16-23, 1975	546 white bass, 421 crappies and 45 northern pike impinged. Limit: 175 each, white bass and crappie; 35 for northern pike.
July 23-30, 1975	218 white bass impinged. Limit is 175.
August 6-13, 1975	207 catfish impinged. Limit is 175.
August 20-27, 1975	387 catfish and 207 white bass impinged. Limit is 175 each.
September 23-October 1, 1975	861 catfish impinged. Limit is 175.
October 1-8, 1975	1650 catfish impinged. Limit is 175.
October 8-15, 1975	853 non-protected fish impinged. Limit is 700.
October 15-22, 1975	227 catfish impinged. Limit is 175.
November 5-12, 1975	321 catfish impinged. Limit is 175.
November 12-19, 1975	658 catfish impinged. Limit is 175.
December 24-31, 1975	212 catfish impinged. Limit is 175.

Table 10. Regression Analysis Results for Gizzard Shad Impingement
at the Prairie Island Plant, 1974-1975

	Regression Equation	R ²
Model I	$y^a = 1.658 + 0.0544 \times \text{Time} - 0.00016 \times \text{Time}^2 - 0.0012 \times \text{Flow}$ $(2.408)^b \quad (0.013) \quad (0.000034) \quad (0.00087)$ $+ 0.1440 \times \text{Temperature} - 0.00155 \times \text{Temperature}^2$ $(0.0739) \quad (0.00069)$ <p>(For the period July 1974 to June 1975, n = 97)</p>	0.762
Model II	$y^a = 0.0574 \times \text{Time} - 0.0001724 \times \text{Time}^2 + 0.0345 \times \text{Temperature}$ $(0.0095)^b \quad (0.000023) \quad (0.0454)$ $- 0.000307 \times \text{Temperature}^2 + 0.00068 \times \text{Flow}$ $(0.00054) \quad (0.00056)$ <p>(For the period January 1975 to December 1975, n = 158)</p>	0.946
Model III	$y^a = 1.1992 + 0.0557 \times \text{Time} - 0.000178 \times \text{Time}^2 + 0.00123 \times \text{Flow}$ $(1.45)^b \quad (0.0107) \quad (0.000027) \quad (0.00045)$ $+ 0.00068 \times \text{Temperature} - 0.000040 \times \text{Temperature}^2$ $(0.048) \quad (0.00051)$ <p>(For 1974 and 1975, n = 196)</p>	0.625

^aWhere $y = \ln \left(\frac{\text{No. of gizzard shad impinged}}{\text{No. of days in the sampling period}} \right) + 1.0$

^bThe values in parentheses are the standard errors of the coefficients.

Fig. 14. Plot of Gizzard Shad Impingement Rates Showing the Data Scatter and Regression Curve Using Model I.

Fig. 15. Plot of Gizzard Shad Impingement Rates Showing the Data Scatter and Regression Curve Using Model II.

Fig. 16. Plot of Gizzard Shad Impingement Rates Showing the Data Scatter and Regression Curve Using Model III.

explained for the years 1974 and 1975. Because the data for 1974 were averaged over weekly periods, we decided to use the same structural model form to fit to the 1975 year data. Results from the regression analysis using Model II showed that about 95% of the variation in impingement in the year 1975 was explained by the model.

Examination of the regression equations in Table 10 revealed that the coefficients are stable. The linear component in the models showed an overall increase in fish impingement rates within a cycle. The quadratic component in the model is significant and becomes dominant as the time value is increased. Moderating effects of temperature and water flow are relatively small. It appears that the time-based distribution of fish in the vicinity of the intake area is the most important factor in deciding fish-impingement rates at various times of the year.

Even though an apparently satisfactory regression model has been found, there are a number of deficiencies in this model. However, this should be considered only a beginning of an effort that is likely to give rise to a more satisfactory methodology. We have undertaken additional work to abstract, from available data, those mathematical functions which depend on plant variables and environmental variables. This will also generalize the statistics and dynamics of fish impingement.

DISCUSSION

In the present work, data from the Prairie Island site were analyzed to determine whether or not the power station has induced significant damage to the aquatic biota over the two years of its commercial operation (1974-1975). Our analysis indicates that, although a potentially adverse impact on the aquatic biota might exist, no evidence of such an impact has been found.

At the same time, it is conceivable that a significant detrimental impact has already occurred in one or more of the biologic groups (from fish to phytoplankton), but cannot be detected due to imprecise monitoring methodology and the lack of sufficient information about aquatic populations. Possible improvements in the monitoring scheme and methodology are addressed in the following (critique) section of this report.

Phytoplankton and Zooplankton

Our analysis of the plankton data indicates that impacts on phytoplankton and zooplankton due to the Prairie Island plant have not occurred during the two years of its operation. Because plankton are ubiquitous in the riverine system and reproduce rapidly, it is hard to discern changes in the abundance of these organisms.

Because Unit 1 of the Prairie Island plant was in operation during part of the 1974 year of sampling, it is possible that the thermal impact accelerated the peak production of total zooplankton. However, in 1975 the peaks at stations both upstream and downstream from the plant were simultaneously diminished in magnitude (Appendix B, Plots 12 and 12A). Unit 2 began commercial operation in December of 1974; thus, the 1975 sampling was done with both units operating.

In spite of this, no difference was seen between the timing or relative magnitude of the upstream and downstream peaks in total zooplankton density. Consequently, the difference in occurrence of the 1974 peaks was probably due to natural events.

Benthos

Our analysis has not shown significant plant-induced changes to the benthic community. However, this conclusion is based on very limited data, and plant-induced damage to the benthos could have occurred without being detected by the present methodology.

Chironomidae

Although the monthly statistics for chironomids showed a rather large variability, those organisms in the plume generally increased or decreased in harmony with those at reference stations. No important plant-induced impacts for Chironomidae were differentiated.

Naididae

Although wide variations in naiddid density occurred, none were attributed to power-plant effluents, as similar and often simultaneous changes occurred at the reference stations.

Tubificidae

Tubificid population densities varied considerably from 1973 through 1975, but none of the data indicate an important positive or negative impact induced by the Prairie Island plant.

Fish

The group for which we have the least confidence in detecting a plant-induced alteration in population numbers or structure is the fish. Two major aspects of the fish-monitoring procedure at Prairie Island are in need of revision, namely, fish impingement and entrainment losses of fish eggs and larvae (ichthyoplankton). Endemic fish population estimates are also needed. Our conclusions are not based on knowledge of population sizes, but on numbers of individuals of various species counted at paired reference (upstream) and effluent-impacted (plume or downstream) sampling stations. Consequently, our conclusion of no significant damage is based on extremely limited data.

Because the Prairie Island plant uses cooling towers, thus using relatively little makeup water from the Mississippi River System, the potential loss of aquatic organisms in the system due to entrainment, impingement, or high ΔT is reduced. The organisms entrained are lost, but entrainment is substantially less than with an open-cycle cooling system.

CRITIQUE, CONCLUSIONS, AND RECOMMENDATIONS

As is common in many ecological monitoring programs, data collection at Prairie Island was not set up and followed for an adequate evaluation of the generating station's influence on the aquatic system. Rather, the emphasis

has been on evaluating data in relation to ETS requirements. The following observations and conclusions are drawn as a result of our analysis of the environmental monitoring data.

General Comments

1. A coordinated effort is needed between the group mapping or predicting the thermal plume configuration, and that group collecting biological data for impact evaluations.
2. The location of "reference" and "stress" stations in any ecological impact evaluation is one of the most critical aspects of the study. More stations representing areas of graded heat and chemical loading relative to the plume configuration are needed at the Prairie Island site. These stations should be paired with reference areas which have similar ecological and biological characteristics. Some of the stations in the main channel can be eliminated to achieve this pairing.
3. The sampling of endemic fish populations in the vicinity of the generating station was inadequate for the proper evaluation of fish-impingement impacts to the fisheries of the region. Adult fish sampling varied from year to year and was inconsistent within years. Several stations lacked adequate data altogether.
4. Since the highest numbers of larval fish were captured near the outlet of Sturgeon Lake, which supplies a large proportion of the cooling water for the station, the significance of the larval fish loss should be determined.
5. Inconsistent sampling efforts must be eliminated. It is biologically unsound to compare 50-, 200-, and 250-m ichthyoplankton tows, as it is highly unlikely that these organisms are homogeneously distributed. Inconsistent sampling efforts could introduce considerable error into the data, making interpretation difficult.
6. Changes in gear or station location during the study are antiproductive unless properly handled. The best technique for collecting a specific organism should be chosen at the beginning of the monitoring program--as limited by the state of the art. If a change in gear becomes necessary, a continuation of at least one year with both collectors is necessary for intercalibration. (We do not think that accurate intercalibration is ordinarily possible.) Any change in station location or frequency of collection should be absolutely justifiable and should in no way affect the treatment of data in the overall evaluation. The complete elimination of station 19 at Prairie Island, presumably in lieu of a special study in Sturgeon Lake, is unjustifiable. The station eliminated was the only river channel station within the influence of the discharge plume.
7. Some sampling stations were changed from year to year and/or sampling at designated stations was not consistent within or between years. This inconsistency in station location and sampling make data from these locations of limited use.

8. The definition of biological groups analyzed in the plant's annual reports is confusing. For example, two definitions of total phytoplankton were found: (a) total phytoplankton are made up of species which represent 95% of the total, and (b) total phytoplankton consists of all species of phytoplankton present. This confusion may result in the compilation and computation of data classified under an incorrect heading and can result in subsequent errors in impact evaluations.
9. The practice of changing consultants while a monitoring program is in progress usually results in inconsistent data collection and sampling station designation, which leads to inadequate and inconsistent data for impact evaluations.
10. It should be noted that, in our analyses of the given data, the effect of Prairie Island plant operation cannot be distinguished from naturally occurring variability for the phytoplankton, zooplankton, and benthos groups of organisms. Fish impingement losses are considered to affect a very small fraction of the fisheries in the area. However, small long-term changes could be occurring in the biological system, and consistent monitoring would be needed to provide a preventive surveillance adequate for preventive measures.

Fish Impingement

Data collection for fish impingement is currently required at the Prairie Island plant for the full 52 weeks in a year. The data collection could be made on a consecutive seven-day basis for periodic but fewer weeks and still obtain the total fish impingement during that period. Because of ETS limits set on impingement rates for a seven-day period, the monitoring requirement is tuned toward detecting excess impingement over allowed rates.

Observations on fish kills for the two-year period of commercial operation have cited several deviations from ETS requirements. However, such environmental events may not be biologically significant, although the impingement rate exceeds State of Minnesota catch limits for a fisherman.

An angler's fish catch limit does not appear, *per se*, to be equivalent to the fish loss limit by impingement at the plant. One reason appears to be that most of the fish impinged and killed at the Prairie Island plant are young-of-the-year and one-year-old fish, which have a natural high mortality rate. A reduction due to fish-impingement loss in this age group may not have the same level of effect on the population as a reduction, by fishing, of the higher age group of fish. It is therefore necessary that age-specific losses be estimated, and a translation to the overall fish population be made, before a decision on the impact of plant impingement on fish population can be obtained. A second reason is that the plant serves a large number of people. Therefore, the combined limits of more than one fisherman would seem applicable to the plant, provided that (a) there is no significant impact on the fish population and (b) a rational, equivalent number of fishermen can be arrived at.

An examination of fish-impingement logarithms versus time indicates clearly that the fish-impingement rate is dependent on the time of the year. Moreover, it is an observable mathematical function that can be given by seg-

mented straight lines for the different time periods. An approximation using quadratic order polynomials was made and the results showed a high amount of variability explained by the regressions. The time-dependent function, whether a set of segmented lines or other continuous functions, merely models the fish behavior, movement and time-dependent response on their growth, and capability to avoid impingement. These functional relationships are usually different for species in the same water body. After careful examination, we arrived at the following conclusions.

1. On the basis of graphical and quantitative analyses, it can be said that the daily impingement rate is a time-dependent function for which parameters can be established by the use of impingement data. It is apparent that the mean value for the entire year is not a proper statistic to use as a rate for some specific time of the year. Instead, a species-specific impingement-rate function may be obtained to represent expected impingement rates for a yearly cycle.
2. If the primary purpose of fish-impingement monitoring is to estimate the numbers, species, and length frequency distribution of the fishes, then statistically valid sampling schemes may be used. The estimates can be assured to have a given level of precision. Sampling at a lower frequency is desirable because of its resource effectiveness without loss in information for decision making.
3. In the Prairie Island case, it appears that fish impingement is low during March through September. During October through February, one is likely to observe relatively large numbers of impingements. We used this natural stratification to arrive at a sampling scheme for the plant. Statistical considerations lead to the recommendations that fish impingement be sampled for one day per week for the entire year. During October through February the sampling intensity should be two days per week. This stratified systematic sampling scheme will provide a means to estimate the time-dependent fish-impingement-rate function.

In recommending this type of sampling scheme, it is recognized that the year's data can be divided into two strata: (1) the period when impingements number less than ETS limits, and (2) the period when chances of exceeding these limits exist. A probability sampling on the basis of fewer observations for stratum 1 and more for stratum 2 is desirable in order to detect days on which the fish-impingement rate has exceeded the angler catch limit.

4. The environmental event reports and recorded numbers of fish kills during 1974 and 1975 indicate that, even with the two units in operation, the 1975 impingement rate was somewhat lower than that of 1974. In 1974, Unit 1 was intermittently operational. A gross estimate of fish abundance in the river body in 1973-1975 is indicated in the sein data given in Table 11. There was a large decline in catch per unit effort between 1973 and 1974 and a smaller decline in catch per unit effort in 1975. This pattern in fish abundance may be reflected in the impingement data. In the absence of dependable fish population estimates, it is not possible to calculate the effect of fish-impingement losses to the fisheries. It is, however,

Table 11. Total Numbers of Young-of-the-Year Fish Collected by Seining in the Prairie Island Vicinity, 1973-1975

Species	1973 0.33 ha seined		1974 1.41 ha seined		1975 1.38 ha seined ^a	
	No.	No./ha	No.	No./ha	No.	No./ha
Longnose gar	- ^b	-	-	-	1	0.72
Shortnose gar	-	-	2	1.42	-	-
Bowfin	-	-	-	-	1	0.72
Gizzard shad	1,729	5,239.39	329	233.33	755	547.10
Northern pike	-	-	1	0.71	-	-
Carp	4	12.12	2	1.42	-	-
Minnows and darters	504	1,527.27	1,300	921.99	676	489.86
Smallmouth buffalo	-	-	3	2.13	17	12.32
Bigmouth buffalo	-	-	-	-	41	29.71
Carp sucker	98	296.97	9	6.38	77	55.80
White sucker	-	-	-	-	1	0.72
Shorthead redhorse	-	-	7	4.96	8	5.80
Bullheads	-	-	1	0.71	2	1.45
Channel catfish	-	-	9	6.38	-	-
Tadpole madtom	-	-	-	-	3	2.17
White bass	1,523	4,615.15	230	163.12	201	145.65
Sunfish	13	39.39	23	16.31	26	18.84
Crappies	22	66.67	39	27.66	72	52.17
Smallmouth bass	-	-	1	0.71	1	0.72
Yellow perch	-	-	8	5.67	6	4.35
Sauger	26	78.79	9	6.38	14	10.14
Walleye	-	-	-	-	2	1.45
Freshwater drum	100	303.03	39	27.66	10	7.25
Total	4,019	12,178.79	2,012	1,426.95	1,914	1,386.96

Catches are expressed as total numbers and numbers per hectare (ha) seined.

^a1975 area is an estimate.

^bHyphen (-) indicates no fish were caught.

felt that the impingement losses of the young-of-the-year and one-year-old age classes recorded during 1974 and 1975 periods are a very small fraction of the fish population. Due to a high mortality in the classes most impinged, the translation of this loss to future fish populations is uncertain.

5. It is thought that the frequency of environmental events recorded during the 1975 period may result from too stringent impingement limits. If we assume that the limits are correct and that environmental effects will occur if the limits are exceeded, then unacceptable environmental impacts are allowed to occur without any regulatory action. It is our recommendation that the limits be revised, taking into consideration minimum catchable size of fish to be counted toward the limit. It is also recommended that age-specific losses be measured and compared against the annual natural mortality of those age groups. Other approaches to determining the effects of fish-impingement losses on the water body would be to consider the sustained yield and determine if the biological productivity is above the sustained yield.
6. Other approaches toward determining the significance of fish impingement losses might be considered. One such approach would be to use the sustained yield as a measure of biological productivity and compare the loss in biomass in relation to the sustained yield.

References

1. "Final Environmental Statement Related to the Prairie Island Nuclear Generating Plant," USAEC Directorate of Licensing, Dockets No. 50-282 and 50-306, U.S. Atomic Energy Commission, Washington, D. C., May 1973.
2. "Prairie Island Nuclear Generating Plant Units 1 and 2 Environmental Report--Operating License Stage, Dockets No. 50-282 and 50-306," Northern States Power Company, Minneapolis, Minnesota, May 1971.
3. "Northern States Power Prairie Island Nuclear Generating Plant, Units 1 and 2, Environmental Technical Specifications," U. S. Atomic Energy Commission, Washington, D. C., n.d.
4. E. L. Kuehnast, "Climate of Minnesota," In "Climates of the States," Vol. 2., pp. 706-724, National Oceanic and Atmospheric Administration, Department of Commerce (published by the Water Information Center, Inc., Port Washington, New York), 1972.
5. G. E. P. Box and G. C. Tiao, "Intervention Analysis with Applications to Economic and Environmental Problems," J. Am. Stat. Assoc. 70:70-79, 1975.

Appendix P-1. Excerpts from Section 4 of Environmental
Technical Specifications on Terrestrial Communities

4.1.2 Terrestrial

Objective: See TS B-4.1.1.A objectives.

Specification: See TS B-4.1.1.A specifications.

Basis: The terrestrial ecological studies program is designed to identify the flora and fauna within a 1.5 mile radius of the plant. Data will be related to plant effluents, particularly the cooling tower plume.

Vegetation is being studied in the following habitat types: prairie, sand hill or sand terraces, oak openings, wet lowlands, and conifer plantations. Qualitative and quantitative data are gathered. The size and composition of terrestrial vegetation, insects, mammals and birds in the habitats listed previously are being determined.

Location of a sampling area may be changed during the study if the habitat is altered by factors not associated with the plant (i.e., the dredging, lumbering, or farming of an area now being studied).

Reports of the terrestrial ecological studies are made annually in the Annual Environmental Monitoring and Ecological Studies Program Report.

4.2 PHYSICAL

4.2.1 Thermal Plume Mapping

Objective: To delineate the dimensional configuration of the heated water plume as it flows from the outfall down the discharge canal, into the river and down to Lock and Dam No. 3.

Specification: Study the specific area of the river influenced by the heated water as it flows into Truttman's slough and the river. These temperature surveys will be made for each operational mode under the various climatic and river flow rate conditions that prevail during the year. Selected isotherms in the range from ambient to the discharge temperature will be plotted. These surveys will continue until the 3-dimensional pattern of the heated water is determined for both circulating water system operating modes and over a range of flow rates and ambient temperature.

Basis: Sampling transects will be established across the river from just upstream of the plant intake to downstream of Lock and Dam No. 3. At least 5 sampling points spaced equally along each transect will be used. Temperatures will be taken at one-foot intervals from the surface to the bottom. Instrumentation will be accurate to within 0.5°F.

4.2.2 Dredging

Objective: To determine the effect of maintenance dredging on the aquatic environment.

Specification: A study of the effects on the water quality and aquatic biota will be made during dredging operations. The study will include an estimate of the benthic macroinvertebrate community and measurement of water quality parameters.

Basis: Any maintenance dredging work in the approach and/or discharge canals will conform to applicable Federal, State, or local regulations at the time of dredging.

4.2.3 Cooling Tower Fog and Icing

Objective: To determine the area of influence that the cooling tower plume has on the onsite and offsite areas.

Specification: A study will be performed to characterize the dimensions of the cooling tower plume and extent and density of ice.

Basis: Visual observations confirmed by photographs will be taken of the cooling tower plumes. Fog visimeters are located at three locations surrounding the plant. One is located at the meteorological tower, the second at Lock and Dam No. 3, the third adjacent to U. S. Highway 61 near the plant road intersection.

4.2.4 Noise

Objective: To determine the sound levels in the onsite and offsite environment.

Specification: To study the noise impact of the operation of the Prairie Island Plant on the onsite and offsite environment.

Basis: A sound survey was completed in 1972 to quantify the construction noise levels. A survey will be completed during plant operation (both units) to quantify the operational sound levels. If these operational levels are acceptable to the AEC, the surveys will be terminated.

4.2.5 Erosion

Objective: To determine (1) the amount of erosion on the slopes adjacent to the river and the plant's circulating water system canals, and (2) the amount of erosion and deposition within and adjacent to dredged river approaches leading to and from the plant's circulating system canals.

Specification: Twice per year the onsite property will be surveyed for areas of erosion, and once per year the dredged offsite channel bottoms and boundaries will be sounded for significant contour changes, for comparison

with topographical data of prior years. Onsite surveys will include photographs of the areas inspected, and, if significant erosion is apparent, the area will be regraded and covered with sufficient vegetation, rip-rap, or construction substrate (i.e., asphalt, gravel) to prevent further erosion. Correction of offsite plant-related problems, if evident, will be made after consulting with the applicable Federal, State, and local authorities.

Basis: Erosion control is a fundamental environmental consideration. Of concern is the harm to all aquatic biota caused by movement and suspension of river bed materials, and by periodic dredging.

APPENDIX P-2
ARITHMETIC AND LOGARITHMIC PLOTS OF MONTHLY ABUNDANCES OF AQUATIC
BIOTA AT VARIOUS STATIONS FOR THE 1973-1975 TIME PERIOD

	<u>P-2 Plot</u>
Comparison of Total Phytoplankton, Stations 3 and 9	1
Comparison of Total Phytoplankton, Stations 5 and 9	2
Comparison of Total Phytoplankton, Stations 3 and 12	3
Comparison of Total Phytoplankton, Stations 5 and 12	4
Comparison of Total Phytoplankton, Stations 9 and 12	5
Comparison of Total Phytoplankton, Stations 3 and 16	6
Comparison of Total Phytoplankton, Stations 5 and 16	7
Comparison of Total Phytoplankton, Stations 9 and 16	8
Comparison of Rotifera, Stations 2 and 6	9
Comparison of Rotifera, Stations 2 and 8	10
Comparison of Rotifera, Stations 6 and 8	11
Comparison of Total Zooplankton, Stations 1 and 7	12
Comparison of Total Zooplankton, Stations 9 and 7	13
Comparison of Total Zooplankton, Stations 1 and 2	14
Comparison of Total Zooplankton, Stations 2 and 5	15
Comparison of Chironomidae, Stations 2 and 6	16
Comparison of Chironomidae, Stations 5 and 6	17
Comparison of Chironomidae, Stations 2 and 7	18
Comparison of Chironomidae, Stations 1 and 7	19
Comparison of Naididae, Stations 1 and 2	20
Comparison of Naididae, Stations 2 and 5	21
Comparison of Naididae, Stations 2 and 6	22
Comparison of Naididae, Stations 1 and 7	23
Comparison of Naididae, Stations 2 and 7	24
Comparison of Naididae, Stations 5 and 6	25
Comparison of Tubificidae, Stations 1 and 2	26
Comparison of Tubificidae, Stations 2 and 5	27
Comparison of Tubificidae, Stations 2 and 6	28
Comparison of Tubificidae, Stations 1 and 7	29
Comparison of Tubificidae, Stations 5 and 6	30
Comparison of Tubificidae, Stations 2 and 7	31

APPENDIX P-3
SUMMARY TABLES OF DATA USED FOR THE
EVALUATION OF VARIOUS BIOTIC GROUPS

	<u>P-3 Table</u>
Total Phytoplankton, Station 3	1
Total Phytoplankton, Station 5	2
Total Phytoplankton, Station 9	3
Total Phytoplankton, Station 12	4
Total Phytoplankton, Station 16	5
Total Zooplankton, Station 1	6
Total Zooplankton, Station 7	7
Total Zooplankton, Station 9	8
Rotifera, Station 8	9
Rotifera, Station 6	10
Rotifera, Station 2	11
Benthos, Station 1	12
Benthos, Station 2	13
Benthos, Station 5	14
Benthos, Station 6	15
Benthos, Station 7	16

Table P-3.1. Total Phytoplankton, Station 3

DATE	# OBSN	TOTAL PHYTOPLANKTON (#/ML)	DATE	# OBSN	TOTAL PHYTOPLANKTON (#/ML)
MAR 1973	2	2004 (1293.3)	APR 1974	2	21200 (2969.8)
APR 1973	2	42188 (24660.3)	MAY 1974	2	27400 (5939.7)
MAY 1973	2	18243 (8765.3)	JUN 1974	1	5600
JUN 1973	2	10883 (434.2)	JUL 1974	3	12433 (2900.6)
JUL 1973	2	21428 (10129.3)	AUG 1974	2	16400 (3818.4)
AUG 1973	2	12825 (8209.5)	SEP 1974	2	16800 (10606.6)
SEP 1973	2	12751 (805.4)	OCT 1974	2	12700 (9758.1)
OCT 1973	2	7365 (1633.4)	NOV 1974	2	10400 (2828.4)
NOV 1973	2	4620 (127.3)	DEC 1974	3	1933 (950.4)
JAN 1974	1	1800	JUN 1975	1	17880
MAR 1974	1	1900	JUL 1975	1	6990
			AUG 1975	1	15015

DATE	# OBSN	TOTAL PHYTOPLANKTON (#/ML)
SEP 1975	1	15780
OCT 1975	1	16330
NOV 1975	1	5190

Table P-3.2. Total Phytoplankton, Station 5

TOTAL PHYTOPLANKTON				TOTAL PHYTOPLANKTON			
DATE		# OBSN	(#/ML)	DATE		# OBSN	(#/ML)
MAR	1973	2	1275 (642.1)	APR	1974	2	29700 (35496.8)
APR	1973	1	41205	MAY	1974	2	13500 (4808.3)
MAY	1973	2	16958 (10596.0)	JUN	1974	1	3600
JUN	1973	2	6435 (721.2)	JUL	1974	3	5200 (2594.2)
JUL	1973	2	7778 (4210.8)	AUG	1974	2	7900 (4808.3)
AUG	1973	2	7049 (3735.6)	SEP	1974	2	3800 (2262.7)
SEP	1973	2	5835 (275.8)	OCT	1974	2	10400 (3818.4)
OCT	1973	2	2925 (2609.2)	NOV	1974	2	4100 (282.8)
NOV	1973	2	4155 (784.9)	DEC	1974	2	1850 (1343.5)
JAN	1974	1	250	JUN	1975	1	12300
MAR	1974	1	2000	JUL	1975	1	12780
				AUG	1975	1	2905

TOTAL PHYTOPLANKTON			
DATE		# OBSN	(#/ML)
SEP	1975	1	12960
OCT	1975	1	13830
NOV	1975	1	5250

Table P-3.3. Total Phytoplankton, Station 9

DATE	# OBSN	TOTAL PHYTOPLANKTON (#/ML)	DATE	# OBSN	TOTAL PHYTOPLANKTON (#/ML)
MAR 1973	2	1808 (1388.8)	MAR 1974	3	4600 (4677.6)
APR 1973	2	48188 (10659.6)	APR 1974	3	13333 (5773.5)
MAY 1973	2	19073 (15453.8)	MAY 1974	3	14000 (5291.5)
JUN 1973	2	6390 (848.5)	JUN 1974	3	8167 (2020.7)
JUL 1973	2	6635 (1958.7)	JUL 1974	3	8000 (4272.0)
AUG 1973	2	6775 (2368.8)	AUG 1974	3	7100 (2007.5)
SEP 1973	2	6540 (339.4)	SEP 1974	3	7333 (5507.6)
OCT 1973	2	5940 (3479.0)	OCT 1974	3	11333 (9073.8)
NOV 1973	2	3630 (212.1)	NOV 1974	3	5867 (3008.9)
JAN 1974	1	500	DEC 1974	2	2300 (2404.2)
FEB 1974	2	1050 (636.4)	JUN 1975	1	11880

DATE	# OBSN	TOTAL PHYTOPLANKTON (#/ML)
JUL 1975	1	9480
AUG 1975	1	5655
SEP 1975	1	10530

Table P-3.4. Total Phytoplankton, Station 12

DATE	# OBSN	TOTAL PHYTOPLANKTON (#/ML)	DATE	# OBSN	TOTAL PHYTOPLANKTON (#/ML)
MAR 1973	2	1181 (1224.0)	JUN 1974	1	4600
APR 1973	2	39613 (548.0)	JUL 1974	3	9900 (2206.8)
MAY 1973	2	12600 (5091.2)	AUG 1974	2	8950 (1343.5)
JUN 1973	2	6330 (4200.2)	SEP 1974	2	11250 (8838.8)
JUL 1973	1	6000	OCT 1974	2	14900 (6364.0)
AUG 1973	2	5700 (5600.3)	NOV 1974	2	2700 (2828.4)
SEP 1973	2	8115 (2906.2)	DEC 1974	1	2200
OCT 1973	2	6035 (2877.9)			
NOV 1973	2	4305 (360.6)			
APR 1974	2	16650 (4737.6)			
MAY 1974	2	17550 (8414.6)			

Table P-3.5. Total Phytoplankton, Station 16

DATE	# OBSN	TOTAL PHYTOPLANKTON (#/ML)	DATE	# OBSN	TOTAL PHYTOPLANKTON (#/ML)
MAR 1973	1	2000	JUN 1974	1	8300
APR 1973	1	41000	JUL 1974	3	16400 (8492.9)
MAY 1973	1	18000	AUG 1974	2	9050 (2757.7)
JUN 1973	2	12520 (2093.0)	SEP 1974	2	33650 (12940.1)
JUL 1973	2	18390 (13024.9)	OCT 1974	2	19400 (565.7)
AUG 1973	2	18210 (7806.5)	NOV 1974	1	12300
SEP 1973	3	22060 (3822.7)	DEC 1974	3	2933 (1205.5)
OCT 1973	3	11200 (4833.4)	JUN 1975	1	24540
NOV 1973	3	2610 (1192.1)	JUL 1975	1	17850
MAR 1974	1	1800	AUG 1975	1	8985
APR 1974	2	19650 (5444.7)	SEP 1975	1	10065
MAY 1974	2	24150 (6293.3)	OCT 1975	1	18120
			NOV 1975	1	13980

Table P-3.6. Total Zooplankton, Station 1

DATE		# OBSN	TOTAL ZOOPLANKTON (#/M**3)
APR	1974	1	68
MAY	1974	1	80
JUN	1974	1	148
JUL	1974	1	494
AUG	1974	1	497
SEP	1974	1	670
NOV	1974	1	190
MAR	1975	1	8
APR	1975	1	23
MAY	1975	1	14
JUN	1975	1	30
JUL	1975	1	230
SEP	1975	1	197
OCT	1975	1	106
NOV	1975	1	51

Table P-3.7. Total Zooplankton, Station 7

DATE		# OBSN	TOTAL ZOOPLANKTON (# / 1000)
APR	1974	1	71
MAY	1974	1	100
JUN	1974	1	199
JUL	1974	1	709
AUG	1974	1	528
SEP	1974	1	405
NOV	1974	1	130
APR	1975	1	29
MAY	1975	1	11
JUN	1975	1	35
JUL	1975	1	220
SEP	1975	1	206
OCT	1975	1	114
NOV	1975	1	109

Table P-3.8. Total Zooplankton, Station 9

DATE		# OBSN	TOTAL ZOOPLANKTON (#/M**3)
APR	1974	1	63
MAY	1974	1	85
JUN	1974	1	178
JUL	1974	1	348
AUG	1974	1	426
SEP	1974	1	320
NOV	1974	1	160

Table P-3.9. Rotifera, Station 8

DATE		# OBSN	ROTIFERA (#/M**3)	DATE		# OBSN	ROTIFERA (#/M**3)
JAN	1972	1	8	JUN	1973	1	108
FEB	1972	1	16	JUL	1973	1	120
MAR	1972	1	18	AUG	1973	1	110
APR	1972	1	82	SEP	1973	1	152
MAY	1972	1	494	MAR	1975	1	2
JUN	1972	1	736	APR	1975	1	3
JUL	1972	1	662	MAY	1975	1	5
SEP	1972	1	108	JUN	1975	1	27
OCT	1972	1	1274	JUL	1975	1	304
NOV	1972	1	710	SEP	1975	1	75
DEC	1972	1	128	OCT	1975	1	126
JAN	1973	1	0	NOV	1975	1	55
FEB	1973	1	5				
MAR	1973	1	2				
APR	1973	1	10				
MAY	1973	1	125				

Table P-3.10. Rotifera, Station 6

DATE		# OBSN	ROTIFERA (#, M**3)	DATE		# OBSN	ROTIFERA (#, M**3)
JAN	1973	1	5	JAN	1975	1	72
FEB	1973	1	4	FEB	1975	1	2
MAR	1973	1	2	MAR	1975	1	1
APR	1973	1	33	APR	1975	1	2
MAY	1973	1	156	MAY	1975	1	11
JUN	1973	1	107	JUN	1975	1	29
JUL	1973	1	101	JUL	1975	1	184
AUG	1973	1	85	SEP	1975	1	41
SEP	1973	1	145	OCT	1975	1	105
APR	1974	1	88	NOV	1975	1	78
MAY	1974	1	150	DEC	1975	1	37
JUN	1974	1	216				
JUL	1974	1	482				
AUG	1974	1	355				
SEP	1974	1	225				
NOV	1974	1	305				

Table P-3.11. Rotifera, Station 2

DATE	# OBSN	ROTIFERA (#/M**3)	DATE	# OBSN	ROTIFERA (#/M**3)
JAN 1973	1	3	JAN 1973	1	7
FEB 1973	1	10	FEB 1973	1	2
MAR 1973	1	6	MAR 1973	1	3
APR 1973	1	30	APR 1973	1	3
MAY 1973	1	148	MAY 1973	1	19
JUN 1973	1	97	JUN 1973	1	48
JUL 1973	1	97	JUL 1973	1	177
AUG 1973	1	58	SEP 1973	1	95
SEP 1973	1	114	OCT 1973	1	100
APR 1974	1	110	NOV 1973	1	55
MAY 1974	1	220			
JUN 1974	1	286			
JUL 1974	1	439			
AUG 1974	1	342			
SEP 1974	1	460			
NOV 1974	1	140			

Table P-3.12. Benthos, Station 1

DATE	# OBSN	NAIDIDAE (#/M**2)	CHIRONOMIDAE (#/M**2)	TUBIFICIDAE (#/M**2)
OCT 1973	1	19	38	0
NOV 1973	1	5	55	0
DEC 1973	1	32	64	0
OCT 1974	1	8	50	100
NOV 1974	1	7	61	51
DEC 1974	1	0	52	16
JUL 1975	1	0	0	0
SEP 1975	1	0	10	478
DEC 1975	1	0	392	0

Table P-3.13. Benthos, Station 2

DATE		# OBSN	NAIDIDAE (#/M**2)	CHIRONOMIDAE (#/M**2)	TUBIFICIDAE (#/M**2)
OCT	1973	1	43	67	30
NOV	1973	1	3	3	0
OCT	1974	1	2	102	52
NOV	1974	1	0	55	12
DEC	1974	1	4	18	29
MAR	1975	1	51	4205	6410
JUL	1975	1	0	54	147
SEP	1975	1	0	57	72
DEC	1975	1	0	158	0

Table P-3.14. Benthos, Station 5

DATE		# OBSN	NAIDIDAE (#/M**2)	CHIRONOMIDAE (#/M**2)	TUBIFICIDAE (#/M**2)
OCT	1973	1	32	16	3
NOV	1973	1	17	23	30
DEC	1973	1	163	103	117
OCT	1974	1	30	8	156
NOV	1974	1	38	23	385
DEC	1974	1	43	8	196
MAR	1975	1	123	15	923
JUL	1975	1	0	0	849
SEP	1975	1	0	32	867
DEC	1975	1	0	7	0

Table P-3.15. Benthos, Station 6

DATE		# OBSN	NAIDIDAE (#/M**2)	CHIRONOMIDAE (#/M**2)	TUBIFICIDAE (#/M**2)
OCT	1973	1	150	4	12
NOV	1973	1	54	10	76
DEC	1973	1	33	4	171
OCT	1974	1	8	118	143
NOV	1974	1	0	54	103
DEC	1974	1	0	18	29
MAR	1975	1	923	961	4369
JUL	1975	1	0	392	0
SEP	1975	1	0	255	54
DEC	1975	1	0	262	0

Table P-3.16. Benthos, Station 7

DATE	# OBSN	NAJIDAE (#/M**2)	CHIRONOMIDAE (#/M**2)	TUBIFICIDAE (#/M**2)
OCT 1973	1	166	23	23
NOV 1973	1	10	10	24
DEC 1973	1	0	0	0
OCT 1974	1	0	38	10
NOV 1974	1	0	33	5
DEC 1974	1	0	56	24
JUL 1975	1	0	64	0
SEP 1975	1	0	10	594
DEC 1975	1	3	4/1	0