Dominion Energy Kewaunee, Inc.
5000 Dominion Boulevard, Glen Allen, VA 23060

Dominion®

November 25, 2008

United States Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, DC 20555-0001

Serial No.:	08-0690
LR/RJG	R0
Docket No.:	50-305
License No.:	DPR-43

DOMINION ENERGY KEWAUNEE, INC.
KEWAUNEE POWER STATION
RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION
LICENSE RENEWAL APPLICATION

By letter dated October 27, 2008, the NRC requested additional information and documents regarding the license renewal application (LRA) for Kewaunee Power Station. The attachment to this letter contains the responses to the Request for Additional Information (RAI) associated with LRA Appendix E, "Applicant's Environmental Report – Operating License Renewal Stage," along with the requested documents.

Should you have any questions regarding this submittal, please contact Mr. Paul C. Aitken, License Renewal Project Manager, Dominion Resources Services, Inc., 5000 Dominion Blvd., Glen Allen, VA, 23060, (804) 273-2818, e-mail: Paul.Aitken@dom.com.

Very truly yours,

J. Alan Price
Vice President – Nuclear Engineering

A135
NRR

COMMONWEALTH OF VIRGINIA)
)
COUNTY OF HENRICO)

The foregoing document was acknowledged before me, in and for the County and Commonwealth aforesaid, today by J. Alan Price, who is Vice President – Nuclear Engineering of Dominion Energy Kewaunee, Inc. He has affirmed before me that he is duly authorized to execute and file the foregoing document in behalf of that Company, and that the statements in the document are true to the best of his knowledge and belief.

Acknowledged before me this 25th day of November, 2008.

My Commission Expires: 4/30/2009.

Ginger Allgood
Notary Public

(SEAL) GINGER LYNN ALLIGOOD
Notary Public
Commonwealth of Virginia
310847
My Commission Expires Apr 30, 2009

Attachment:

Additional Information in Support of Application for Renewed Operating License

Enclosures:

A. Wisconsin Pollutant Discharge Elimination System (WPDES) Permit No. WI-0001571-07-0

B. Kewaunee Power Station Original Clean Water Act Sections 316(a) and 316(b) Demonstrations, and Wisconsin Original Clean Water Act Sections 316(a) and 316(b) Determinations

C. Dominion (Dominion Resources Services) 2008. *Information Requirements Related to Cooling Water Intake Structures - WPDES Permit WI-0001571-07.*

Commitments made in this letter:

None

cc without enclosures:

U.S. Nuclear Regulatory Commission
Regional Administrator, Region III
2443 Warrenville Road
Suite 210
Lisle, IL 60532-4532

Mr. P. S. Tam, Senior Project Manager
U.S. Nuclear Regulatory Commission
One White Flint, Mail Stop O8-H4A
11555 Rockville Pike
Rockville, MD 20852-2738

Ms. S. L. Lopas
Environmental Project Manager
U.S. Nuclear Regulatory Commission
Mail Stop O-11F1
Washington, DC 20555-0001

Mr. J. W. Daily
License Renewal Project Manager
U.S. Nuclear Regulatory Commission
Mail Stop O-11F1
Washington, DC 20555-0001

NRC Senior Resident Inspector
Kewaunee Power Station
N490 Highway 42
Kewaunee, WI 54216

Public Service Commission of Wisconsin
Electric Division
P.O. Box 7854
Madison, WI 53707

Mr. David Zellner
Chairman – Town of Carlton
N2164 County B
Kewaunee, WI 54216

Attachment

Additional Information in Support of Application for Renewed Operating License

Kewaunee Power Station

NRC Request for Additional Information

Aquatic Ecology and Hydrology

NRC Request:

A complete copy of Wisconsin Pollution Discharge and Elimination System (WPDES) Permit No. WI-0001571-07-0, including the accompanying fact sheet, if applicable.

Dominion Response:

The Permit and Fact Sheet are provided in Enclosure A.

NRC Request:

Any Notices of Violation of the WPDES permit, as issued by the Wisconsin Department of Natural Resources in the last five years.

Dominion Response:

Kewaunee Power Station has not been issued any written Notices of Violation (NOVs) or Notices of Noncompliance (NONs) during the last five years. Following a permit exceedance that occurred in the second quarter of 2008, Dominion Energy Kewaunee, Inc. (DEK) provided a verbal notification to the Wisconsin Department of Natural Resources (WDNR). At that time, the WDNR representative informed the site Environmental Compliance Coordinator of a "verbal Notification of Noncompliance," but that it would not result in a written NON.

NRC Request:

Complete copies of the Kewaunee Power Station (KPS) original Clean Water Act Sections 316(a) and 316(b) demonstrations, and Wisconsin's original 316(a) and 316(b) determinations.

Dominion Response:

These documents are provided in Enclosure B.

NRC Request:

Dominion (Dominion Resources Services). 2008. Information Requirements Related to Cooling Water Intake Structures -- WPDES Permit WI-0001571-07. Letter to D. Hantz -- Wisconsin Department of Natural Resources Wastewater Engineer from P.F. Faggert -- Dominion Vice President and Chief Environmental Officer on January 4, 2008.

EA Engineering (EA Engineering, Science, and Technology, Inc.) 2007. Impingement Mortality and Entrainment Characterization Report, Kewaunee Power Station, March 2006 -- February 2007. Submitted to Dominion Resources Services, Inc., Glen Allen, Virginia. August.

WDNR (Wisconsin Department of Natural Resources). 2007. Requirements for Cooling Water Intake Structures -- WPDES Permit WI-0001571-07. Letter to P.F. Faggert -- Dominion Resources Services from D. Hantz -- WDNR Wastewater Engineer on December 2, 2007.

Dominion Response:

Dominion (Dominion Resources Services) 2008 is provided in Enclosure C. Please note that the other two references requested above are included in Dominion (Dominion Resources Services) 2008: WDNR 2007 as Attachment A, and EA Engineering 2007 as sub-Attachment 7 of Attachment C.

<u>Refurbishment</u>

NRC Request:

Will the closing of the Barnwell, South Carolina low-level radioactive waste disposal facility to states outside of the Atlantic Low-Level Waste Compact alter your conclusion in the KPS environmental report (Section 3.2, Refurbishment Activities) that there will not be a need to modify the facility or structures, in light of the potential for long-term storage of low-level radioactive waste?

Dominion Response:

The effects of closing the Barnwell, South Carolina low-level radioactive waste disposal facility to states outside of the Atlantic Low-Level Waste Compact is a current license issue, irrespective of license renewal. Dominion Energy Kewaunee, Inc. (DEK) has no current plans to build a facility for long-term storage of Class B and C waste during the period of extended operation, and is currently pursuing commercial options that would obviate such construction. Therefore, the closing of Barnwell does not change our conclusions regarding license renewal-related construction activities.

Enclosure A

State of Wisconsin \ DEPARTMENT OF NATURAL RESOURCES

WISCONSIN DEPT. OF NATURAL RESOURCES

Jim Doyle, Governor
Scott Hassett, Secretary

101 South Webster Street
P.O. Box 7921
Madison, WI 53707-7921
Telephone (608) 266-2621
FAX (608) 267-3579
TTY Access via relay - 711

Received JUL 26 2005 EP&C

Pamela F. Faggert
Vice President and Chief Environmental Officer
Dominion Energy Kewaunee, Inc.
5000 Dominion Blvd. - 2NW
Glenn Allen, VA 23060

SUBJECT: WPDES Permit Reissuance No. WI-0001571-07-0
Kewaunee Power Station, State Highway 42, Kewaunee, WI

Dear Ms. Faggert:

Your Wisconsin Pollutant Discharge Elimination System (WPDES) Permit is enclosed. As provided for in the public notice for this permit, Dominion Energy Kewaunee, Inc. is being issued this permit based on our receipt of notification of a change of ownership from Wisconsin Public Service Corporation on July 5, 2005 as further documented in your submittal of a stipulation of permit acceptance and permit application. The conditions of the attached permit reissuance were determined using the permit application, information from the WPDES permit file for this facility, other information available to the Department, comments received during the public notice period (previously forwarded to Dominion), and applicable Wisconsin Administrative Codes. All discharges from this facility and actions or reports relating thereto shall be in accordance with the terms and conditions of this permit.

This permit requires you to submit monitoring results to the Department on a periodic basis. Blank copies of the appropriate monitoring forms and instructions for completing them will be mailed to you under separate cover.

The Department has the authority under chs. 160 and 283, Stats., to establish effluent limitations, monitoring requirements, and other permit conditions for discharges to groundwater and surface waters of the State. The Department also has the authority to issue, reissue, modify, suspend or revoke WPDES permits under ch. 283, Stats.

The attached permit contains water quality based effluent limitations which are necessary to ensure that the water quality standards for Lake Michigan are met. You may apply for a variance from the water quality standard used to derive the limitations pursuant to s. 283.15, Stats. by submitting an application to the Director of the Bureau of Watershed Management, P.O. Box 7921, Madison, Wisconsin 53707 within 60 days of the date the permit was issued (see "Date Permit Signed/Issued" after the signature on the front page of the attached permit). Subchapter III of chapter NR 200, Wis. Adm. Code, specifies the procedures that must be followed and the information that must be included when submitting an application for a variance.

To challenge the reasonableness of or necessity for any term or condition of the attached permit, s. 283.63, Stats, and ch. NR 203, Wis. Adm. Code require that you file a verified petition for review with the Secretary of the Department of Natural Resources within 60 days of the date the permit was issued (see "Date Permit Signed/Issued" after the signature on the front page of the attached permit).

Sincerely,

Russell Rasmussen

Russell Rasmussen
Director, Bureau of Watershed Management

Dated: July 18, 2005

cc: Permit File - Central Office
U.S. Fish and Wildlife Service (Electronic Copy via Email)
Gary Kincaid – Green Bay
EPA – Region V (Electronic Copy via Email)

WPDES PERMIT

STATE OF WISCONSIN
DEPARTMENT OF NATURAL RESOURCES

PERMIT TO DISCHARGE UNDER THE WISCONSIN POLLUTANT DISCHARGE ELIMINATION SYSTEM

Dominion Energy Kewaunee, Inc.

is permitted, under the authority of Chapter 283, Wisconsin Statutes, to discharge from a facility located at
State Highway 42, Kewaunee, WI
to

Lake Michigan and an unnamed tributary to Lake Michigan

in accordance with the effluent limitations, monitoring requirements and other conditions set forth in this permit.

The permittee shall not discharge after the date of expiration. If the permittee wishes to continue to discharge after this expiration date an application shall be filed for reissuance of this permit, according to Chapter NR 200, Wis. Adm. Code, at least 180 days prior to the expiration date given below.

State of Wisconsin Department of Natural Resources
For the Secretary

By Russell Rasmussen
Russell Rasmussen
Director, Bureau of Watershed Management

July 18, 2005
Date Permit Signed/Issued

PERMIT TERM: EFFECTIVE DATE – August 01, 2005 **EXPIRATION DATE - June 30, 2010**

TABLE OF CONTENTS

1 Requirements for Cooling Water Intake Structures

1.1 The permittee is authorized to use the offshore cooling water intake structure that exists at the time of issuance of this permit to serve the Kewaunee Nuclear Power Plant.

1.2 The permittee shall submit by January 7, 2008 for Department review information describing the cooling water intake structure, cooling water system operations and source water physical data described in U.S. EPA regulations at 40 CFR 122.21(r)(2, (r)(3), and (r)(5).

1.3 The permittee shall submit by January 7, 2008 for Department review and approval all applicable portions of the comprehensive demonstration study required by the provisions in 40 CFR 125.95(b) for selecting and implementing the compliance alternatives in 40 CFR 125.94 to meet best technology available (BTA) for minimizing adverse environmental impacts associated with the use of the cooling water intake structures.

1.4 The Proposal for Information Collection (40CFR 125.95 (b)(1)) shall be submitted to the Department for review and comment prior to the start of information collection activities described in such proposal.

1.5 Any approval by the Department of submittals required under this section of the permit and the establishment of any additional requirements to implement BTA for the cooling water intake structures for this permittee shall occur only upon modification or reissuance of this permit.

NOTE: Any permit modification is subject to public notice and the public participation procedures under ch. NR 203, Wis. Adm. Code, including public hearings requested under s. NR 203.05 and adjudicatory hearings under NR 203, Subchapter III.

2 In-Plant Requirements

2.1 Sampling Point(s)

Sampling Point Designation	
Sampling Point Number	**Sampling Point Location, WasteType/Sample Contents and Treatment Description (as applicable)**
101	Steam generator blowdown to Outfall 001
201	Floor drains to Outfall 001
301	Service water treatment lagoon overflow to Outfall 001
501	Limits and requirements apply if and when discharge of RO reject wastewater commences from a new reverse osmosis water treatment system (proposed in 2005) to the turbine building standpipe to Outfall 001.
601	Sample point 601 will monitor flow of Lake Michigan water or purified water pumped from the turbine building basement in case of failure of the circulating water system via hose to at or near the Outfall 001 discharge structure.

2.2 Monitoring Requirements and Limitations

The permittee shall comply with the following monitoring requirements and limitations.

2.2.1 Sampling Point 101 - Steam Generator Blowdown

Monitoring Requirements and Limitations					
Parameter	**Limit Type**	**Limit and Units**	**Sample Frequency**	**Sample Type**	**Notes**
Flow Rate		MGD	Weekly	Total Daily	
Suspended Solids, Total	Daily Max	100 mg/L	Monthly	Grab	
Suspended Solids, Total	Monthly Avg	30 mg/L	Monthly	Grab	
Oil & Grease (Hexane or Freon)	Daily Max	20 mg/L	Quarterly	Grab	
Oil & Grease (Hexane or Freon)	Monthly Avg	15 mg/L	Quarterly	Grab	

2.2.2 Sampling Point 201 - Floor Drains to Outfall 001

Monitoring Requirements and Limitations					
Parameter	**Limit Type**	**Limit and Units**	**Sample Frequency**	**Sample Type**	**Notes**
Flow Rate		MGD	Weekly	Total Daily	
Suspended Solids, Total	Daily Max	100 mg/L	Weekly	Grab	
Suspended Solids, Total	Monthly Avg	30 mg/L	Weekly	Grab	
Oil & Grease (Hexane or Freon)	Daily Max	20 mg/L	Monthly	Grab	
Oil & Grease (Hexane or Freon)	Monthly Avg	15 mg/L	Monthly	Grab	

2.2.3 Sampling Point 301 - Service Water Lagoon Overflow

Monitoring Requirements and Limitations					
Parameter	**Limit Type**	**Limit and Units**	**Sample Frequency**	**Sample Type**	**Notes**
Flow Rate		MGD	Weekly	Total Daily	
Suspended Solids, Total	Daily Max	100 mg/L	Weekly	Grab	
Suspended Solids, Total	Monthly Avg	30 mg/L	Weekly	Grab	
Oil & Grease (Hexane or Freon)	Daily Max	20 mg/L	Quarterly	Grab	
Oil & Grease (Hexane or Freon)	Monthly Avg	15 mg/L	Quarterly	Grab	

2.2.4 Sampling Point 501 - RO Reject

Monitoring Requirements and Limitations					
Parameter	Limit Type	Limit and Units	Sample Frequency	Sample Type	Notes
Flow Rate		gpd	Daily	Total Daily	
Suspended Solids, Total	Daily Max	100 mg/L	Weekly	Grab	
Suspended Solids, Total	Monthly Avg	30 mg/L	Weekly	Grab	
Oil & Grease (Hexane or Freon)	Daily Max	20 mg/L	Quarterly	Grab	
Oil & Grease (Hexane or Freon)	Monthly Avg	15 mg/L	Quarterly	Grab	

2.2.4.1 The permittee shall submit any updated information on water treatment additives for use of the reverse osmosis water treatment system for Department review and approval prior to commencing discharge of RO reject wastewater unless additives are the same as those specified in the permit reissuance application (December 2004).

2.2.5 Sampling Point 601 - Turbine Bldg Basement Water

Monitoring Requirements and Limitations					
Parameter	Limit Type	Limit and Units	Sample Frequency	Sample Type	Notes
Flow Rate		MGD	At Discharge	Estimated	In case of failure of the circulating water system, estimated flow shall be reported for each day of discharge

3 Surface Water Requirements

3.1 Sampling Point(s)

Sampling Point Designation	
Sampling Point Number	**Sampling Point Location, WasteType/Sample Contents and Treatment Description**
001	Condenser cooling water and process wastewater sampled prior to discharge to Lake Michigan
002	Outfall 002 monitors flow of water recirculated from 001 to prevent icing of the intake
003	Activated sludge sewage treatment plant effluent sampled prior to discharge to an unnamed tributary to Lake Michigan

3.2 Monitoring Requirements and Effluent Limitations

The permittee shall comply with the following monitoring requirements and limitations.

3.2.1 Sampling Point (Outfall) 001 - Condenser Cooling Water

Monitoring Requirements and Effluent Limitations					
Parameter	**Limit Type**	**Limit and Units**	**Sample Frequency**	**Sample Type**	**Notes**
Flow Rate		MGD	Daily	Continuous	
Temperature Minimum		deg F	Daily	Continuous	
Temperature Maximum		deg F	Daily	Continuous	
Temperature Average		deg F	Daily	Continuous	Temperature Average shall also be reported daily for intake water on DMRs using Sample Point 701 (except if monitoring equipment is out of service for maintenance or replacement, weekly grab samples shall be reported)
pH Field	Daily Max	9.0 su	Weekly	Grab	
pH Field	Daily Min	6.0 su	Weekly	Grab	
Chlorine, Total Residual	Daily Max - Variable	µg/L	Daily	Grab	TRC limit = 200 µg/L if chlorine is added for 160 min/day or less & TRC limit = 38 µg/L if chlorine is added for ≥ 160 min/day.
Chlorine, Total Resdl Discharge Time		min/day	Daily	Record of Addition	The time of chlorination shall not be > 2 hours/day except when chlorinating for zebra mussel control

Monitoring Requirements and Effluent Limitations					
Parameter	Limit Type	Limit and Units	Sample Frequency	Sample Type	Notes
Chlorine, Total Residual	Daily Max	180 lbs/day	See Permit Note	Calculated	TRC mass limit of 180 lb/day and reporting applies only if chlorine is added for > 160 min/day
Thallium, Total Recoverable		μg/L	Once	24-Hr Flow Prop Comp	Results of one test shall be submitted by March 31, 2006
Mercury, Total Recoverable		ng/L	Quarterly	Grab	See 3.2.1.1 below for additional requirements
Acute WET		TU_a	See Listed Qtr(s)	24-Hr Flow Prop Comp	Three Acute WET tests shall be performed during the permit term in the calendar quarters listed below
Chronic WET		rTU_c	See Listed Qtr(s)	24-Hr Flow Prop Comp	Three Chronic WET tests shall be performed during the permit term in the calendar quarters listed below

3.2.1.1 Mercury Monitoring

The permittee shall collect and analyze all mercury samples according to the data quality requirements of ss. NR 106.145(9) and (10), Wisconsin Administrative Code. The limit of quantitation (LOQ) used for the intake, effluent and field blank shall be less than 1.3 ng/L, unless the samples are quantified at levels above 1.3 ng/L. The permittee shall collect at least one mercury field blank for each set of mercury samples (a set of samples may include combinations of intake, influent, effluent or other samples all collected on the same day). The permittee shall report results to the Department on Discharge Monitoring Reports for required effluent samples (Outfall 001) and field blanks (Sample Point 801) and recommended intake water samples (Sample Point 701).

3.2.1.2 Polychlorinated Biphenyls

There shall be no discharge of polychlorinated biphenyl compounds such as those commonly used for transformer fluid.

3.2.1.3 Additives

The permittee shall report increases in the dosage rates of water treatment additives above levels included in the application for reissuance of this permit as an attachment to the monthly DMRs. Additional requirements are included in standard requirements for obtaining approval of any new water treatment additives. The permittee may also use the procedure in the standard requirement for "planned changes" to notify the Department of proposed increases in use of water treatment additives or use of new water treatment additives.

3.2.1.4 Chlorine Sampling Procedure

One grab sample for total residual chlorine shall be collected during the peak chlorine discharge of each chlorination event. The reported value shall be the maximum of the events. A continuous monitor may be used to determine the peak value as long as it duplicates an approved method.

3.2.1.5 Time of Chlorination

Total residual chlorine shall not be added for more than 2 hours per day. The 2 hour limit does not apply to periods when chlorinating for zebra mussel control.

3.2.1.6 Whole Effluent Toxicity (WET) Testing

Primary Control Water: Lake Michigan

Instream Waste Concentration: 9.1%

Dilution series: At least five effluent concentrations and dual controls must be included in each test.

- **Acute:** 100, 50, 25, 12.5, 6.25% and any additional selected by the permittee.
- **Chronic:** 100, 30, 10, 3, 1% (if the IWC $\leq$30%) or 100, 75, 50, 25, 12.5% (if the IWC >30%) and any additional selected by the permittee.

WET Testing Frequency: Tests are required during the following quarters.

- **Acute:** October 1 to December 31, 2005; January 1, 2007 to March 31, 2007; and April 1, 2009 to June 30, 2009
- **Chronic:** October 1 to December 31, 2005; January 1, 2007 to March 31, 2007; and April 1, 2009 to June 30, 2009

Reporting: The permittee shall report test results on the Discharge Monitoring Report form, and also complete the "Whole Effluent Toxicity Test Report Form" (Section 6, "*State of Wisconsin Aquatic Life Toxicity Testing Methods Manual, 2nd Edition*"), for each test. The original, complete, signed version of the Whole Effluent Toxicity Test Report Form shall be sent to the Biomonitoring Coordinator, Bureau of Watershed Management, 101 S. Webster St., P.O. Box 7921, Madison, WI 53707-7921, within 45 days of test completion.

Determination of Positive Results: An acute toxicity test shall be considered positive if the Toxic Unit – Acute (TU_a) is >1.0 for either species. The TU_a shall be calculated as follows: $TU_a = 100/LC_{50}$. An $LC_{50} \geq 100$ equals a TU_a of 1.0. A chronic toxicity test shall be considered positive if the Relative Toxic Unit - Chronic (rTU_c) is > 1.0 for either species. The rTU_c shall be calculated as follows: $rTU_c = IWC/IC_{25}$. An $IC_{25} \geq IWC$ equals an rTU_c of 1.0.

Additional Testing Requirements: Within 90 days of a test which showed positive results, the permittee shall submit the results of at least 2 retests to the Biomonitoring Coordinator on "Whole Effluent Toxicity Test Report Forms". The retests shall be completed using the same species and test methods specified for the original test (see the Standard Requirements section herein).

3.2.2 Sampling Point (Outfall) 002 - Intake De-Ice

Monitoring Requirements and Effluent Limitations					
Parameter	**Limit Type**	**Limit and Units**	**Sample Frequency**	**Sample Type**	**Notes**
Flow Rate		MGD	Monthly	Estimated	

3.2.3 Sampling Point (Outfall) 003 - Sewage Treatment Plant

Monitoring Requirements and Effluent Limitations					
Parameter	**Limit Type**	**Limit and Units**	**Sample Frequency**	**Sample Type**	**Notes**
Flow Rate		MGD	Continuous	Continuous	
BOD_5, Total	Monthly Avg	30 mg/L	3/Week	24-Hr Flow Prop Comp	
BOD_5, Total	Weekly Avg	45 mg/L	3/Week	24-Hr Flow Prop Comp	
Suspended Solids, Total	Monthly Avg	30 mg/L	3/Week	24-Hr Flow Prop Comp	
Suspended Solids, Total	Weekly Avg	45 mg/L	3/Week	24-Hr Flow Prop Comp	
Nitrogen, Ammonia (NH_3-N) Total		mg/L	Monthly	24-Hr Flow Prop Comp	
pH Field	Daily Max	9.0 su	3/Week	Grab	
pH Field	Daily Min	6.0 su	3/Week	Grab	
Mercury, Total Recoverable		ng/L	Monthly	Grab	See 3.2.3.1 below for additional requirements for effluent samples and field blanks
Thallium, Total Recoverable		µg/L	Once	24-Hr Flow Prop Comp	Results of one test shall be submitted by March 31, 2006
Acute WET		TU_a	See Listed Qtr(s)	24-Hr Flow Prop Comp	Two Acute WET tests shall be performed during the permit term in the calendar quarters listed below.
Chronic WET		rTU_c	See Listed Qtr(s)	24-Hr Flow Prop Comp	Two Chronic WET tests shall be performed during the permit term in the calendar quarters listed below.

3.2.3.1 Mercury Monitoring

The permittee shall collect and analyze all mercury samples according to the data quality requirements of ss. NR 106.145(9) and (10), Wisconsin Administrative Code. The limit of quantitation (LOQ) used for the effluent and field blank shall be less than 1.3 ng/L, unless the samples are quantified at levels above 1.3 ng/L. The permittee shall collect at least one mercury field blank for each set of mercury samples (a set of samples may include combinations of intake, influent, effluent or other samples all collected on the same day). The permittee shall report results to the Department on Discharge Monitoring Reports for effluent samples (Outfall 003) and field blanks (Sample Point 801).

3.2.3.2 Reduced Mercury Monitoring

After generating at least 12 mercury results that meet the data quality requirements of ss. NR 106.145(9) and (10), Wis. Adm. Code, the permittee may apply for a permit modification to reduce the monthly monitoring frequency. Under the authority of s. NR 106.145(3)(a)(6), Wis. Adm. Code, the Department may initiate the permit modification process to reduce the monitoring frequency from monthly to once every 3 months.

3.2.3.3 Whole Effluent Toxicity (WET) Testing

Primary Control Water: Lake Michigan

Instream Waste Concentration: 9.1%

Dilution series: At least five effluent concentrations and dual controls must be included in each test.

- **Acute:** 100, 50, 25, 12.5, 6.25% and any additional selected by the permittee.
- **Chronic:** 100, 30, 10, 3, 1% (if the IWC $\leq$30%) or 100, 75, 50, 25, 12.5% (if the IWC >30%) and any additional selected by the permittee.

WET Testing Frequency: Tests are required during the following quarters.

- **Acute:** October 1 to December 31, 2005 and January 1, 2007 to March 31, 2007
- **Chronic:** October 1 to December 31, 2005 and January 1, 2007 to March 31, 2007

Reporting: The permittee shall report test results on the Discharge Monitoring Report form, and also complete the "Whole Effluent Toxicity Test Report Form" (Section 6, "*State of Wisconsin Aquatic Life Toxicity Testing Methods Manual, 2nd Edition*"), for each test. The original, complete, signed version of the Whole Effluent Toxicity Test Report Form shall be sent to the Biomonitoring Coordinator, Bureau of Watershed Management, 101 S. Webster St., P.O. Box 7921, Madison, WI 53707-7921, within 45 days of test completion.

Determination of Positive Results: An acute toxicity test shall be considered positive if the Toxic Unit – Acute (TU_a) is >1.0 for either species. The TU_a shall be calculated as follows: $TU_a = 100/LC_{50}$. An $LC_{50} \geq 100$ equals a TU_a of 1.0. A chronic toxicity test shall be considered positive if the Relative Toxic Unit - Chronic (rTU_c) is > 1.0 for either species. The rTU_c shall be calculated as follows: $rTU_c = IWC/IC_{25}$. An $IC_{25} \geq IWC$ equals an rTU_c of 1.0.

Additional Testing Requirements: Within 90 days of a test which showed positive results, the permittee shall submit the results of at least 2 retests to the Biomonitoring Coordinator on "Whole Effluent Toxicity Test Report Forms". The retests shall be completed using the same species and test methods specified for the original test (see the Standard Requirements section herein).

4 Land Application Requirements

4.1 Sampling Point(s)

The discharge(s) shall be limited to land application of the waste type(s) designated for the listed sampling point(s) on Department approved land spreading sites or by hauling to another facility.

Sampling Point Designation	
Sampling Point Number	**Sampling Point Location, WasteType/Sample Contents and Treatment Description (as applicable)**
004	Outfall 004 is identified for onsite land application of domestic wastewater treatment sludge if needed. Requirements apply only in a calendar year land application occurs.

4.2 Monitoring Requirements and Limitations

The permittee shall comply with the following monitoring requirements and limitations.

4.2.1 Sampling Point (Outfall) 004 - Domestic Wastewater Sludge

Monitoring Requirements and Limitations					
Parameter	**Limit Type**	**Limit and Units**	**Sample Frequency**	**Sample Type**	**Notes**
Solids, Total		Percent	Annual	Composite	
Arsenic Dry Wt	Ceiling	75 mg/kg	Annual	Composite	
Arsenic Dry Wt	High Quality	41 mg/kg	Annual	Composite	
Cadmium Dry Wt	Ceiling	85 mg/kg	Annual	Composite	
Cadmium Dry Wt	High Quality	39 mg/kg	Annual	Composite	
Copper Dry Wt	Ceiling	4,300 mg/kg	Annual	Composite	
Copper Dry Wt	High Quality	1,500 mg/kg	Annual	Composite	
Lead Dry Wt	Ceiling	840 mg/kg	Annual	Composite	
Lead Dry Wt	High Quality	300 mg/kg	Annual	Composite	
Mercury Dry Wt	Ceiling	57 mg/kg	Annual	Composite	
Mercury Dry Wt	High Quality	17 mg/kg	Annual	Composite	
Molybdenum Dry Wt	Ceiling	75 mg/kg	Annual	Composite	
Nickel Dry Wt	Ceiling	420 mg/kg	Annual	Composite	
Nickel Dry Wt	High Quality	420 mg/kg	Annual	Composite	
Selenium Dry Wt	Ceiling	100 mg/kg	Annual	Composite	
Selenium Dry Wt	High Quality	100 mg/kg	Annual	Composite	
Zinc Dry Wt	Ceiling	7,500 mg/kg	Annual	Composite	
Zinc Dry Wt	High Quality	2,800 mg/kg	Annual	Composite	
Nitrogen, Total Kjeldahl		Percent	Annual	Composite	
Nitrogen, Ammonium (NH_4-N) Total		Percent	Annual	Composite	
Phosphorus, Total		Percent	Annual	Composite	
Phosphorus, Water Extractable		Percent	Annual	Composite	

Monitoring Requirements and Limitations					
Parameter	**Limit Type**	**Limit and Units**	**Sample Frequency**	**Sample Type**	**Notes**
Potassium, Total Recoverable		Percent	Annual	Composite	
PCB Total Dry Wt	Ceiling	50 mg/kg	Once	Composite	
PCB Total Dry Wt	High Quality	10 mg/kg	Once	Composite	

Other Sludge Requirements	
Sludge Requirements	**Sample Frequency**
List 3 Requirements – Pathogen Control: The requirements in List 3 shall be met prior to land application of sludge.	**Annual**
List 4 Requirements – Vector Attraction Reduction: The vector attraction reduction shall be satisfied prior to, or at the time of land application as specified in List 4.	**Annual**

4.2.1.1 Requirements Apply Only if Land Application Occurs

Monitoring requirements and limitations apply only during a calendar year when land application of domestic wastewater sludge occurs. Prior to initiating land application of sludge the permittee shall contact the Department's NER office to verify the information that must be submitted to begin land application. The permittee shall also comply with any other applicable local, state or federal regulations.

4.2.1.2 Changes in Feed Sludge Characteristics

If a change in feed sludge characteristics, treatment process, or operational procedures occurs which may result in a significant shift in sludge characteristics, the permittee shall reanalyze the sludge for List 1, 2, 3 and 4 parameters each time such change occurs.

4.2.1.3 Multiple Sludge Sample Points (Outfalls)

If there are multiple sludge sample points (outfalls), but the sludges are not subject to different sludge treatment processes, then a separate List 2 analysis shall be conducted for each sludge type which is land applied, just prior to land application, and the application rate shall be calculated for each sludge type. In this case, List 1, 3, and 4 and PCBs need only be analyzed on a single sludge type, at the specified frequency. If there are multiple sludge sample points (outfalls), due to multiple treatment processes, List 1, 2, 3 and 4 and PCBs shall be analyzed for each sludge type at the specified frequency.

4.2.1.4 Sludge Which Exceeds the High Quality Limit

Cumulative pollutant loading records shall be kept for all bulk land application of sludge which does not meet the high quality limit for any parameter. This requirement applies for the entire calendar year in which any exceedance of Table 3 of s. NR 204.07(5)(c), is experienced. Such loading records shall be kept for all List 1 parameters for each site land applied in that calendar year. The formula to be used for calculating cumulative loading is as follows:

[(Pollutant concentration (mg/kg) x dry tons applied/ac) ÷ 500] + previous loading (lbs/acre) = cumulative lbs pollutant per acre

When a site reaches 90% of the allowable cumulative loading for any metal established in Table 2 of s. NR 204.07(5)(b), the Department shall be so notified through letter or in the comment section of the annual land application report (3400-55).

4.2.1.5 Sludge Analysis for PCBs

The permittee shall analyze the sludge for Total PCBs one time during the first calendar year that land application occurs. The results shall be reported as "PCB Total Dry Wt". Either congener-specific analysis or Aroclor analysis shall be used to determine the PCB concentration. The permittee may determine whether Aroclor or congener specific analysis is performed. Analyses shall be performed in accordance with Table EM in s. NR 219.04, Wis. Adm. Code and the conditions specified in Standard Requirements of this permit. PCB results shall be submitted by January 31, following the specified year of analysis.

4.2.1.6 Lists 1, 2, 3, and 4

List 1 TOTAL SOLIDS AND METALS See the Monitoring Requirements and Limitations table above for monitoring frequency and limitations for the List 1 parameters
Solids, Total (percent)
Arsenic, mg/kg (dry weight)
Cadmium, mg/kg (dry weight)
Copper, mg/kg (dry weight)
Lead, mg/kg (dry weight)
Mercury, mg/kg (dry weight)
Molybdenum, mg/kg (dry weight)
Nickel, mg/kg (dry weight)
Selenium, mg/kg (dry weight)
Zinc, mg/kg (dry weight)

List 2 NUTRIENTS See the Monitoring Requirements and Limitations table above for monitoring frequency for the List 2 parameters
Solids, Total (percent)
Nitrogen Total Kjeldahl (percent)
Nitrogen Ammonium (NH4-N) Total (percent)
Phosphorus Total as P (percent)
Phosphorus, Water Extractable (as percent of Total P)
Potassium Total Recoverable (percent)

List 3

PATHOGEN CONTROL FOR CLASS B SLUDGE

The permittee shall implement pathogen control as listed in List 3. The Department shall be notified of the pathogen control utilized and shall be notified when the permittee decides to utilize alternative pathogen control.

The following requirements shall be met prior to land application of sludge.

Parameter	Unit	Limit
Fecal Coliform*	MPN/gTS or CFU/gTS	2,000,000
OR, ONE OF THE FOLLOWING PROCESS OPTIONS		
Aerobic Digestion	Air Drying	
Anaerobic Digestion	Composting	
Alkaline Stabilization	PSRP Equivalent Process	

* The Fecal Coliform limit shall be reported as the geometric mean of 7 discrete samples on a dry weight basis.

List 4

VECTOR ATTRACTION REDUCTION

The permittee shall implement any one of the vector attraction reduction options specified in List 4. The Department shall be notified of the option utilized and shall be notified when the permittee decides to utilize an alternative option.

One of the following shall be satisfied prior to, or at the time of land application as specified in List 4.

Option	Limit	Where/When it Shall be Met
Volatile Solids Reduction	≥38%	Across the process
Specific Oxygen Uptake Rate	≤1.5 mg O_2/hr/g TS	On aerobic stabilized sludge
Anaerobic bench-scale test	<17 % VS reduction	On anaerobic digested sludge
Aerobic bench-scale test	<15 % VS reduction	On aerobic digested sludge
Aerobic Process	>14 days, Temp >40°C and Avg. Temp > 45°C	On composted sludge
pH adjustment	>12 S.U. (for 2 hours) and >11.5 (for an additional 22 hours)	During the process
Drying without primary solids	>75 % TS	When applied or bagged
Drying with primary solids	>90 % TS	When applied or bagged
Equivalent Process	Approved by the Department	Varies with process
Injection	-	When applied
Incorporation	-	Within 6 hours of application

5 Schedules of Compliance

5.1 Requirements for Cooling Water Intake Structures

Required Action	Date Due
Proposal for information Collection (PIC): Submit a PIC for Department review and comments prior to the start of information collection activities described in such proposal, as specified in permit section 1.4, page 1.	
Cooling Water Intake Information : Submit information required to describe cooling water intake structures, cooling water system operations and source water physical data specified in permit section 1.2, page 1.	01/07/2008
Comprehensive Demonstration Study: Submit a comprehensive demonstration study as specified in permit section 1.3, page 1.	01/07/2008

5.2 Mercury Pollutant Minimization Program

The permittee shall implement a pollutant minimization program whenever, after the first 24 months of mercury monitoring, a mercury effluent limitation(s) is necessary under the procedure in s. NR 106.145(2), Wis. Adm. Code for Outfall 001 or Outfall 003.

Required Action	Date Due
Submit a Mercury Pollutant Minimization Program: The permittee shall develop and submit to the Department a plan for a cost-effective pollutant minimization program (PMP) that has as its goal the reduction of mercury for the purpose of maintaining the effluent at or below the water quality based effluent limitation or potential limitation. The PMP shall meet the requirements of s. NR .106.145(7), Wis. Adm. Code. Note: The Department will notify the permittee of acceptance of or comments on the proposed PMP. The permittee and the Department will then agree on what changes, if any will be made to the PMP. If the Department has not notified the permittee within 90 days of the Department's receipt of the PMP, the permittee may assume that the PMP has been accepted.	03/31/2008
Implement the Mercury Pollutant Minimization Program: The permittee shall implement the PMP as submitted or as amended by agreement of the permittee and the Department.	09/30/2008
Submit Annual Status Reports: The permittee shall submit to the Department an annual status report on the progress of the PMP as required by s. NR 106.145(7), Wis. Adm. Code. Submittal of the first annual status report is required by the Date Due. Note: If the permittee wishes to apply for an alternative mercury effluent limitation, that application is due with the application for permit reissuance by 6 months prior to permit expiration. The permittee should submit or reference the PMP plan as updated by the Annual Status Report or more recent developments as part of that application.	12/31/2008

6 Standard Requirements

NR 205, Wisconsin Administrative Code: The conditions in ss. NR 205.07(1) and NR 205.07(2), Wis. Adm. Code, are included by reference in this permit. The permittee shall comply with all of these requirements. Some of these requirements are outlined in the Standard Requirements section of this permit. Requirements not specifically outlined in the Standard Requirement section of this permit can be found in ss. NR 205.07(1) and NR 205.07(2).

6.1 Reporting and Monitoring Requirements

6.1.1 Monitoring Results

Monitoring results obtained during the previous month shall be summarized and reported on a Department Wastewater Discharge Monitoring Report Form. This report form is to be returned to the Department no later than the date indicated on the form. The original and one copy of the Wastewater Discharge Monitoring Report Form shall be submitted to your DNR regional office. A copy of the Wastewater Discharge Monitoring Report Form shall be retained by the permittee. Sludge monitoring shall be reported on Characteristic Form 3400-49 by January 31, following the year any sludge analysis is performed.

If the permittee monitors any pollutant more frequently than required by this permit, the results of such monitoring shall be included in the calculations and reporting. The data shall be submitted on the Wastewater Discharge Monitoring Report Form or sludge reporting form.

The permittee shall comply with all limits for each parameter regardless of monitoring frequency. For example, monthly, weekly, and/or daily limits shall be met even with monthly monitoring. The permittee may monitor more frequently than required for any parameter.

Calculations for all limitations which require averaging of measurements shall utilize an arithmetic mean unless otherwise specified by the Department in this permit.

6.1.2 Sampling and Testing Procedures

Sampling and laboratory testing procedures shall be performed in accordance with Chapters NR 218 and NR 219, Wis. Adm. Code and shall be performed by a laboratory certified or registered in accordance with the requirements of ch. NR 149, Wis. Adm. Code. Groundwater sample collection and analysis shall be performed in accordance with ch. NR 140, Wis. Adm. Code. The analytical methodologies used shall enable the laboratory to quantitate all substances for which monitoring is required at levels below the effluent limitation. If the required level cannot be met by any of the methods available in NR 219, Wis. Adm. Code, then the method with the lowest limit of detection shall be selected. Additional test procedures may be specified in this permit.

6.1.3 Recording of Results

The permittee shall maintain records which provide the following information for each effluent measurement or sample taken:

- the date, exact place, method and time of sampling or measurements;
- the individual who performed the sampling or measurements;
- the date the analysis was performed;
- the individual who performed the analysis;
- the analytical techniques or methods used; and
- the results of the analysis.

6.1.4 Reporting of Monitoring Results

The permittee shall use the following conventions when reporting effluent monitoring results:

- Pollutant concentrations less than the limit of detection shall be reported as < (less than) the value of the limit of detection. For example, if a substance is not detected at a detection limit of 0.1 mg/L, report the pollutant concentration as < 0.1 mg/L.

- Pollutant concentrations equal to or greater than the limit of detection, but less than the limit of quantitation, shall be reported and the limit of quantitation shall be specified.

- For the purposes of calculating an average or a mass discharge value, the permittee may substitute a 0 (zero) for any pollutant concentration that is less than the limit of detection. However, if the effluent limitation is less than the limit of detection, the department may substitute a value other than zero for results less than the limit of detection, after considering the number of monitoring results that are greater than the limit of detection and if warranted when applying appropriate statistical techniques.

6.1.5 Records Retention

The permittee shall retain records of all monitoring information, including all calibration and maintenance records and all original strip chart recordings for continuous monitoring instrumentation, copies of all reports required by the permit, and records of all data used to complete the application for the permit for a period of at least 3 years from the date of the sample, measurement, report or application. All pertinent sludge information, including permit application information and other documents specified in this permit or s. NR 204.06(9), Wis. Adm. Code shall be retained for a minimum of 5 years.

6.1.6 Other Information

Where the permittee becomes aware that it failed to submit any relevant facts in a permit application or submitted incorrect information in a permit application or in any report to the Department, it shall promptly submit such facts or correct information to the Department.

6.2 System Operating Requirements

6.2.1 Noncompliance Notification

- The permittee shall report the following types of noncompliance by a telephone call to the Department's regional office within 24 hours after becoming aware of the noncompliance:
  - any noncompliance which may endanger health or the environment;
  - any violation of an effluent limitation resulting from an unanticipated bypass;
  - any violation of an effluent limitation resulting from an upset; and
  - any violation of a maximum discharge limitation for any of the pollutants listed by the Department in the permit, either for effluent or sludge.

- A written report describing the noncompliance shall also be submitted to the Department's regional office within 5 days after the permittee becomes aware of the noncompliance. On a case-by-case basis, the Department may waive the requirement for submittal of a written report within 5 days and instruct the permittee to submit the written report with the next regularly scheduled monitoring report. In either case, the written report shall contain a description of the noncompliance and its cause; the period of noncompliance, including exact dates and times; the steps taken or planned to reduce, eliminate and prevent reoccurrence of the noncompliance; and if the noncompliance has not been corrected, the length of time it is expected to continue.

NOTE: Section 292.11(2)(a), Wisconsin Statutes, requires any person who possesses or controls a hazardous substance or who causes the discharge of a hazardous substance to notify the Department of Natural Resources immediately of any discharge not authorized by the permit. The discharge of a hazardous substance that is not authorized by this permit or that violates this permit may be a hazardous substance spill. To report a hazardous substance spill, call DNR's 24-hour HOTLINE at **1-800-943-0003**

6.2.2 Flow Meters

Flow meters shall be calibrated annually, as per s. NR 218.06, Wis. Adm. Code.

6.2.3 Raw Grit and Screenings for Domestic Wastewater Treatment Systems

All raw grit and screenings shall be disposed of at a properly licensed solid waste facility or picked up by a licensed waste hauler. If the facility or haulerare located in Wisconsin, then they shall be licensed under chs. NR 500-536, Wis. Adm. Code.

6.2.4 Sludge Management

All sludge management activities shall be conducted in compliance with ch. NR 204 "Domestic Sewage Sludge Management", Wis. Adm. Code.

6.2.5 Unscheduled Bypassing

Any unscheduled bypass or overflow of wastewater at the treatment works or from the collection system is prohibited, and the Department may take enforcement action against a permittee for such occurrences under s. 283.89, Wis. Stats., unless:

- The bypass was unavoidable to prevent loss of life, personal injury, or severe property damage;
- There were no feasible alternatives to the bypass, such as the use of auxiliary treatment facilities, retention of untreated wastes, or maintenance during normal periods of equipment downtime. This condition is not satisfied if adequate back-up equipment should have been installed in the exercise of reasonable engineering judgment to prevent a bypass which occurred during normal periods of equipment downtime or preventive maintenance; and
- The permittee notified the Department as required in this Section.

Whenever there is an unscheduled bypass or overflow occurrence at the treatment works or from the collection system, the permittee shall notify the Department within 24 hours of initiation of the bypass or overflow occurrence by telephoning the wastewater staff in the regional office as soon as reasonably possible (FAX, email or voice mail, if staff are unavailable).

In addition, the permittee shall within 5 days of conclusion of the bypass or overflow occurrence report the following information to the Department in writing:

- Reason the bypass or overflow occurred, or explanation of other contributing circumstances that resulted in the overflow event. If the overflow or bypass is associated with wet weather, provide data on the amount and duration of the rainfall or snow melt for each separate event.
- Date the bypass or overflow occurred.
- Location where the bypass or overflow occurred.
- Duration of the bypass or overflow and estimated wastewater volume discharged.
- Steps taken or the proposed corrective action planned to prevent similar future occurrences.
- Any other information the permittee believes is relevant.

6.2.6 Scheduled Bypassing

Any construction or normal maintenance which results in a bypass of wastewater from a treatment system is prohibited unless authorized by the Department in writing. If the Department determines that there is significant public interest in the proposed action, the Department may schedule a public hearing or notice a proposal to approve the bypass. Each request shall specify the following minimum information:

- proposed date of bypass;
- estimated duration of the bypass;
- estimated volume of the bypass;
- alternatives to bypassing; and
- measures to mitigate environmental harm caused by the bypass.

6.2.7 Proper Operation and Maintenance

The permittee shall at all times properly operate and maintain all facilities and systems of treatment and control which are installed or used by the permittee to achieve compliance with the conditions of this permit. The wastewater treatment facility shall be under the direct supervision of a state certified operator as required in s. NR 108.06(2), Wis. Adm. Code. Proper operation and maintenance includes effective performance, adequate funding, adequate operator staffing and training as required in ch. NR 114, Wis. Adm. Code, and adequate laboratory and process controls, including appropriate quality assurance procedures. This provision requires the operation of back-up or auxiliary facilities or similar systems only when necessary to achieve compliance with the conditions of the permit.

6.2.8 Spill Reporting

The permittee shall notify the Department in accordance with ch. NR 706 (formerly NR 158), Wis. Adm. Code, in the event that a spill or accidental release of any material or substance results in the discharge of pollutants to the waters of the state at a rate or concentration greater than the effluent limitations established in this permit, or the spill or accidental release of the material is unregulated in this permit, unless the spill or release of pollutants has been reported to the Department in accordance with s. NR 205.07 (1)(s), Wis. Adm. Code.

6.2.9 Planned Changes

In accordance with ss. 283.31(4)(b) and 283.59, Stats., the permittee shall report to the Department any facility expansion, production increase or process modifications which will result in new, different or increased discharges of pollutants. The report shall either be a new permit application, or if the new discharge will not violate the effluent limitations of this permit, a written notice of the new, different or increased discharge. The notice shall contain a description of the new activities, an estimate of the new, different or increased discharge of pollutants and a description of the effect of the new or increased discharge on existing waste treatment facilities. Following receipt of this report, the Department may modify this permit to specify and limit any pollutants not previously regulated in the permit.

6.2.10 Duty to Halt or Reduce Activity

Upon failure or impairment of treatment facility operation, the permittee shall, to the extent necessary to maintain compliance with its permit, curtail production or wastewater discharges or both until the treatment facility operations are restored or an alternative method of treatment is provided.

6.3 Surface Water Requirements

6.3.1 Permittee-Determined Limit of Quantitation Incorporated into this Permit

For pollutants with water quality-based effluent limits below the Limit of Quantification (LOQ) in this permit, the LOQ calculated by the permittee and reported on the Discharge Monitoring Reports (DMRs) is incorporated by reference into this permit. The LOQ shall be reported on the DMRs, shall be the lowest quantifiable level practicable, and shall be no greater than the minimum level (ML) specified in or approved under 40 CFR Part 136 for the pollutant at the time this permit was issued, unless this permit specifies a higher LOQ.

6.3.2 Appropriate Formulas for Effluent Calculations

The permittee shall use the following formulas for calculating effluent results to determine compliance with average limits and mass limits:

Weekly/Monthly average concentration = the sum of all daily results for that week/month, divided by the number of results during that time period.

Weekly Average Mass Discharge (lbs/day): Daily mass = daily concentration (mg/L) x daily flow (MGD) x 8.34, then average the daily mass values for the week.

Monthly Average Mass Discharge (lbs/day): Daily mass = daily concentration (mg/L) x daily flow (MGD) x 8.34, then average the daily mass values for the month.

6.3.3 Visible Foam or Floating Solids

There shall be no discharge of floating solids or visible foam in other than trace amounts.

6.3.4 Whole Effluent Toxicity (WET) Monitoring Requirements

In order to determine the potential impact of the discharge on aquatic organisms, static-renewal toxicity tests shall be performed on the effluent in accordance with the procedures specified in the *"State of Wisconsin Aquatic Life Toxicity Testing Methods Manual, Edition 1" (PUBL-WW-033-096,* as required by NR 219.04, Table A, Wis. Adm. Code). All of the WET tests required in this permit, including any required retests, shall be conducted on the Ceriodaphnia dubia and fathead minnow species. Receiving water samples shall not be collected from any point in contact with the permittee's mixing zone and every attempt shall be made to avoid contact with any other discharge's mixing zone.

6.3.5 Whole Effluent Toxicity (WET) Identification

In the event of serious or repeated toxicity, the permittee may obtain approval from the Department to postpone retests in order to investigate the source(s) of toxicity. In order to postpone these tests, the permittee must provide the following information to the Department in writing, within 30 days of the end of the test which showed a positive result:

- a description of the investigation to be used to identify potential sources of toxicity. Treatment efficiency, housekeeping practices, and chemicals used in operation of the facility should be included in the investigation.
- who will conduct a toxicity identification evaluation (TIE), if required.

Once the above investigation has been completed, the permittee must conduct the postponed test(s) to demonstrate that toxicity has been reduced/eliminated.

6.4 Land Application Requirements

6.4.1 Sludge Management Program Standards And Requirements Based Upon Federally Promulgated Regulations

In the event that new federal sludge standards or regulations are promulgated, the permittee shall comply with the new sludge requirements by the dates established in the regulations, if required by federal law, even if the permit has not yet been modified to incorporate the new federal regulations.

6.4.2 General Sludge Management Information

The General Sludge Management Information Form 3400-48 shall be submitted with your WPDES permit application. This form shall also be updated and submitted prior to any significant sludge management changes.

6.4.3 Sludge Samples

All sludge samples shall be collected at a point and in a manner which will yield sample results which are representative of the sludge being tested, and collected at the time which is appropriate for the specific test.

6.4.4 Less Frequent Sludge Monitoring

Less frequent sludge monitoring may be requested in writing to the Department. Granting such a request requires a permit modification.

6.4.5 Land Application Characteristic Report

Each report shall consist of a Characteristic Form 3400-49 and Lab Report, unless approval for not submitting the lab reports has been given. Both reports shall be submitted by January 31 following each year of analysis.

The permittee shall use the following convention when reporting sludge monitoring results: Pollutant concentrations less than the limit of detection shall be reported as < (less than) the value of the limit of detection. For example, if a substance is not detected at a detection limit of 1.0 mg/kg, report the pollutant concentration as < 1.0 mg/kg.

All results shall be reported on a dry weight basis.

6.4.6 Monitoring and Calculating PCB Concentrations in Sludge

When sludge analysis for "PCB, Total Dry Wt" is required by this permit, the PCB concentration in the sludge shall be determined as follows.

Either congener-specific analysis or Aroclor analysis shall be used to determine the PCB concentration. The permittee may determine whether Aroclor or congener specific analysis is performed. Analyses shall be performed in accordance with the following provisions and Table EM in s. NR 219.04, Wis. Adm. Code.

- EPA Method 1668 may be used to test for all PCB congeners. If this method is employed, all PCB congeners shall be delineated. Non-detects shall be treated as zero. The values that are between the limit of detection and the limit of quantitation shall be used when calculating the total value of all congeners. All results shall be added together and the total PCB concentration by dry weight reported. Note: It is recognized that a number of the congeners will co-elute with others, so there will not be 209 results to sum.
- EPA Method 8082A shall be used for PCB-Aroclor analysis and may be used for congener specific analysis as well. If congener specific analysis is performed using Method 8082A, the list of congeners tested shall include at least congener numbers 5, 18, 31, 44, 52, 66, 87, 101, 110, 138, 141, 151, 153, 170, 180, 183, 187, and 206 plus any other additional congeners which might be reasonably expected to occur in the particular sample. For either type of analysis, the sample shall be extracted using the Soxhlet extraction (EPA Method 3540C) (or the Soxhlet Dean-Stark modification) or the pressurized fluid extraction (EPA Method 3545A). If Aroclor analysis is performed using Method 8082A, clean up steps

of the extract shall be performed as necessary to remove interference and to achieve as close to a limit of detection of 0.11 mg/kg as possible. Reporting protocol, consistent with s. NR 106.07(6)(e), should be as follows: If all Aroclors are less than the LOD, then the Total PCB Dry Wt result should be reported as less than the highest LOD. If a single Aroclor is detected then that is what should be reported for the Total PCB result. If multiple Aroclors are detected, they should be summed and reported as Total PCBs. If congener specific analysis is done using Method 8082A, clean up steps of the extract shall be performed as necessary to remove interference and to achieve as close to a limit of detection of 0.003 mg/kg as possible for each congener. If the aforementioned limits of detection cannot be achieved after using the appropriate clean up techniques, a reporting limit that is achievable for the Aroclors or each congener for the sample shall be determined. This reporting limit shall be reported and qualified indicating the presence of an interference. The lab conducting the analysis shall perform as many of the following methods as necessary to remove interference:

3620C - Florisil	3611B - Alumina
3640A - Gel Permeation	3660B - Sulfur Clean Up (using copper shot instead of powder)
3630C - Silica Gel	3665A - Sulfuric Acid Clean Up

6.4.7 Land Application Report

Land Application Report Form 3400-55 shall be submitted by January 31, following each year non-exceptional quality sludge is land applied. Non-exceptional quality sludge is defined in s. NR 204.07(4), Wis. Adm. Code.

6.4.8 Other Methods of Disposal or Distribution Report

The permittee shall submit Report Form 3400-52 by January 31, following each year sludge is hauled, landfilled, incinerated, or when exceptional quality sludge is distributed or land applied.

6.4.9 Approval to Land Apply

Bulk non-exceptional quality sludge as defined in s. NR 204.07(4), Wis. Adm. Code, may not be applied to land without a written approval letter or Form 3400-122 from the Department unless the Permittee has obtained permission from the Department to self approve sites in accordance with s. NR 204.06 (6), Wis. Adm. Code. Analysis of sludge characteristics is required prior to land application. Application on frozen or snow covered ground is restricted to the extent specified in s. NR 204.07(3) (l), Wis. Adm. Code, and is not allowed once 180 day storage is provided.

6.4.10 Land Application Site Evaluation

For non-exceptional quality sludge, as defined in s. NR 204.07(4), Wis. Adm. Code, a Land Application Site Evaluation Form 3400-53 shall be submitted to the Department for the proposed land application site. The Department will evaluate the proposed site for acceptability and will either approve or deny use of the proposed site. The permittee may obtain permission to approve their own sites in accordance with s. NR 204.06(6), Wis. Adm. Code.

6.4.11 Class B Sludge: Fecal Coliform Limitation

Compliance with the fecal coliform limitation for Class B sludge shall be demonstrated by calculating the geometric mean of at least 7 separate samples. (Note that a Total Solids analysis must be done on each sample). The geometric mean shall be less than 2,000,000 MPN or CFU/g TS. Calculation of the geometric mean can be done using one of the following 2 methods.

Method 1:

Geometric Mean = $(X_1 \times X_2 \times X_3 \ldots \times X_n)^{1/n}$

Where X = Coliform Density value of the sludge sample, and where n = number of samples (at least 7)

Method 2:

Geometric Mean = antilog$[(X_1 + X_2 + X_3 \ldots + X_n) \div n]$

Where X = $\log_{10}$ of Coliform Density value of the sludge sample, and where n = number of samples (at least 7)

Example for Method 2

Sample Number	Coliform Density of Sludge Sample	$\log_{10}$
1	6.0×10^5	5.78
2	4.2×10^6	6.62
3	1.6×10^6	6.20
4	9.0×10^5	5.95
5	4.0×10^5	5.60
6	1.0×10^6	6.00
7	5.1×10^5	5.71

The geometric mean for the seven samples is determined by averaging the $\log_{10}$ values of the coliform density and taking the antilog of that value.

$(5.78 + 6.62 + 6.20 + 5.95 + 5.60 + 6.00 + 5.71) \div 7 = 5.98$

The antilog of 5.98 = 9.5×10^5

6.4.12 Class B Sludge - Vector Control: Injection

No significant amount of the sewage sludge shall be present on the land surface within one hour after the sludge is injected.

6.4.13 Sludge Hauling

If sludge is hauled to another facility, the permittee is required to submit Form 3400-52 to the Department. Information shall include the quantity of sludge hauled, the name, address, phone number, contact person, and permit number of the receiving facility. Form 3400-52 shall be submitted annually by January 31 following each year sludge is hauled.

7 Summary of Reports Due

FOR INFORMATIONAL PURPOSES ONLY

Description	Date	Page
Requirements for Cooling Water Intake Structures -Proposal for information Collection (PIC)	See Permit	13
Requirements for Cooling Water Intake Structures -Cooling Water Intake Information	January 7, 2008	13
Requirements for Cooling Water Intake Structures -Comprehensive Demonstration Study	January 7, 2008	13
Mercury Pollutant Minimization Program -Submit a Mercury Pollutant Minimization Program	March 31, 2008	13
Mercury Pollutant Minimization Program -Implement the Mercury Pollutant Minimization Program	September 30, 2008	13
Mercury Pollutant Minimization Program -Submit Annual Status Reports	December 31, 2008	13
General Sludge Management Information Form 3400-48	prior to any significant sludge management changes	19
Characteristic Form 3400-49 and Lab Report	by January 31 following each year of analysis	19
Land Application Report Form 3400-55	by January 31, following each year non-exceptional quality sludge is land applied	20
Report Form 3400-52	by January 31, following each year sludge is hauled, landfilled, incinerated, or when exceptional quality sludge is distributed or land applied	20
Wastewater Discharge Monitoring Report Form	no later than the date indicated on the form	14

All submittals required by this permit shall be submitted to the Northeast Region, 2984 Shawano Avenue, P.O. Box 10448, Green Bay, WI 54307-0448, except as follows. Report forms shall be submitted to the address printed on the report form. Any facility plans or plans and specifications for municipal, industrial pretreatment and non industrial wastewater systems shall be submitted to the Regional Plan Reviewer (as designated at www.dnr.state.wi.us/org/water/wm/consultant.htm). Any construction plans and specifications for industrial wastewater systems shall be submitted to the Bureau of Watershed Management, P.O. Box 7921, Madison, WI 53707-7921.

Permit Fact Sheet

1 General Information

Permit Number:	WI-0001571-07-0
Permittee Name:	Wisconsin Public Service Corp Kewaunee
Address:	PO Box 19002
City/State/Zip:	Green Bay WI 54307-9002
Discharge Location:	N. 490 State Hwy 42, Kewaunee, WI
Receiving Water:	Lake Michigan and an unnamed tributary to Lake Michigan
StreamFlow ($Q_{7,10}$):	NA
Stream Classification:	Coldwater community, public water supply, Great Lakes system water

2 Facility Description

The Kewaunee facility is a nuclear powered steam electric generating plant with one 520 megawatt generating unit. Operations result in discharge of approximately 494 million gallons per day of condenser cooling water and process wastewater to Lake Michigan through Outfall. The cooling water contribution is over 1000 times greater than the low volume process wastewater flows monitored and limited thru inplant sample points further described below. Intake water is obtained from a cooling water intake structure located approximately 1550 feet offshore in Lake Michigan. A more extensive discussion of wastewater sources submitted with the permit reissuance application is attached. A water flow schematic and location map are also attached.

The permit also contains authorization for recirculation of the main cooling water back to the intake piping to prevent ice formation on the traveling water screens and intake piping in the winter months through Outfall 002.

An on-site activated sludge domestic wastewater treatment system discharges an average flow of 0.0129 MGD to an unnamed tributary to Lake Michigan through Outfall 003. Although sludge from the domestic wastewater extended aeration treatment plant is hauled to Green Bay Met for further treatment and disposal, Outfall 004 is included for land spreading to onsite spreading sites, in case it may be needed in the future.

Sample Point Designation		
Sample Point Number	**Discharge Flow, Units, and Averaging Period (from WPS's 2004 Permit Application)**	**Sample Point Location, WasteType/sample Contents and Treatment Description (as applicable)**
001	494 MGD Max. Annual Average (580 MGD summer, 380 MGD Winter)	Condenser cooling water and process wastewater sampled prior to discharge to Lake Michigan
002	3.96 MGD when discharging	Outfall 002 monitors flow of water recirculated from 001 to prevent icing of the intake
003	0.0129 MGD Annual Average	Activated sludge sewage treatment plant effluent sampled prior to discharge to an unnamed tributary to Lake Michigan
004	Not used during previous permit	Outfall 004 is identified for onsite land application of domestic

Sample Point Designation		
Sample Point Number	**Discharge Flow, Units, and Averaging Period (from WPS's 2004 Permit Application)**	**Sample Point Location, WasteType/sample Contents and Treatment Description (as applicable)**
		wastewater treatment sludge if needed. Requirements apply only in a calendar year land application occurs.
101	0.01 MGD Annual Average	Steam generator blowdown to Outfall 001
201	0.057 MGD Annual Average	Floor drains to Outfall 001
301	0.033 MGD Annual Average	Service water treatment lagoon overflow to Outfall 001
501	The predicted flow of RO reject wastewater would be 0.14 MGD (if and when the RO system would be installed)	Limits and requirements apply if and when discharge of RO reject wastewater commences from a new reverse osmosis water treatment system (proposed in 2005) to the turbine building standpipe to Outfall 001.
601		Sample point 601 will monitor flow of Lake Michigan water or purified water pumped from the turbine building basement in case of failure of the circulating water system via hose to at or near the Outfall 001 discharge structure
701		Intake water sampling point
801		Sample point for reporting mercury field blank results

3 Cooling Water Intake Structures

Section 316(b) of the Clean Water Act requires, and Chapter 283.31(6), Wis. Stats., allows the Department to require that the location, design, construction, and capacity of cooling water intake structures (CWIS) reflect the best technology available (BTA) for minimizing adverse environmental impact. Department guidance (see http://dnr.wi.gov/org/water/wm/wqs/316b/) describes the information needed to evaluate the potential impacts of a CWIS and to determine whether BTA is being used (or proposed) to minimize adverse environmental impacts. The following requirements for the cooling water intake structure are included in permit Section 1 (page 1) consistent with Dept. guidance.

- The permittee is authorized to use the offshore cooling water intake structure that exists at the time of issuance of this permit to serve the Kewaunee Nuclear Power Plant.

- The permittee shall submit by January 7, 2008 for Department review information describing the cooling water intake structure, cooling water system operations and source water physical data described in U.S. EPA regulations at 40 CFR 122.21(r)(2, (r)(3), and (r)(5).

- The permittee shall submit by January 7, 2008 for Department review and approval all applicable portions of the comprehensive demonstration study required by the provisions in 40 CFR 125.95(b) for selecting and implementing the compliance alternatives in 40 CFR 125.94 to meet best technology available (BTA) for minimizing adverse environmental impacts associated with the use of the cooling water intake structures.

- The Proposal for Information Collection (40CFR 125.95(b)(1)) shall be submitted to the Department for review and comment prior to the start of information collection activities described in such proposal.

- Any approval by the Department of submittals required under this section of the permit and the establishment of any additional requirements to implement BTA for the cooling water intake structures for this permittee shall occur only upon modification or reissuance of this permit.

NOTE: Any permit modification is subject to public notice and the public participation procedures under ch. NR 203, Wis. Adm. Code, including public hearings requested under s. NR 203.05 and adjudicatory hearings under NR 203, Subchapter III.

The January 7, 2008 date required in the permit for submittal of required information on the cooling water intake structures and applicable portions of a comprehensive demonstration study was requested by the permittee and is allowed by Department guidance. A proposal for information collection has not yet been submitted, though consultation with the permittee has been ongoing. The condition requiring modification or reissuance of this permit for Department approval of submittals under this section and the establishment of any additional requirements to implement BTA, provides an opportunity for public participation.

4 Influent - Proposed Monitoring

4.1 Sample Point Number:701- Intake Water

Monitoring Requirements and Limitations					
Parameter	**Limit Type**	**Limit and Units**	**Sample Frequency**	**Sample Type**	**Notes**
Mercury, Total Recoverable		ng/L	Quarterly	Grab	
Temperature Average		deg F	Daily	Continuous	

4.1.1 Changes from Previous Permit:

This is a new sample point for intake water which will appear on DMRs (Discharge Monitoring Reports) and is referenced in the permit conditions for Outfall 001.

4.1.2 Explanation of Limits and Monitoring Requirements

This new DMR sample point will be used for reporting results of intake water monitoring. Reporting of average temperature from ongoing continuous monitoring of intake water has been required (in the permit conditions for Outfall 001). Monitoring of intake water for low level mercury to coincide with effluent monitoring for Outfall 001 has been recommended to allow determination of whether mercury is added above intake water levels.

5 Inplant - Proposed Monitoring and Limitations

5.1 Sample Point Number:101- Steam Generator Blowdown

Monitoring Requirements and Limitations					
Parameter	**Limit Type**	**Limit and Units**	**Sample Frequency**	**Sample Type**	**Notes**
Flow Rate		MGD	Weekly	Total Daily	

Monitoring Requirements and Limitations					
Parameter	**Limit Type**	**Limit and Units**	**Sample Frequency**	**Sample Type**	**Notes**
Suspended Solids, Total	Monthly Avg	30 mg/L	Monthly	Grab	
Suspended Solids, Total	Daily Max	100 mg/L	Monthly	Grab	
Oil & Grease (Hexane or Freon)	Monthly Avg	15 mg/L	Quarterly	Grab	
Oil & Grease (Hexane or Freon)	Daily Max	20 mg/L	Quarterly	Grab	

5.1.1 Changes from Previous Permit:

Requirements are identical to the previous permit, except that the test method for oil and grease has been changed to specify use of freon or hexane instead of freon (since the permittee has requested to use existing stocks of freon prior to switching to use of hexane).

5.1.2 Explanation of Limits and Monitoring Requirements

Categorical limits for total suspended solids (TSS) and oil and grease (O&G) are based on classification of this wastewater as a low volume waste under NR 290, Wis. Adm. Code.

5.2 Sample Point Number:201- Floor Drains to Outfall 001

Monitoring Requirements and Limitations					
Parameter	**Limit Type**	**Limit and Units**	**Sample Frequency**	**Sample Type**	**Notes**
Flow Rate		MGD	Weekly	Total Daily	
Suspended Solids, Total	Monthly Avg	30 mg/L	Weekly	Grab	
Suspended Solids, Total	Daily Max	100 mg/L	Weekly	Grab	
Oil & Grease (Hexane or Freon)	Monthly Avg	15 mg/L	Monthly	Grab	
Oil & Grease (Hexane or Freon)	Daily Max	20 mg/L	Monthly	Grab	

5.2.1 Changes from Previous Permit:

Requirements are identical to the previous permit, except that the test method for oil and grease has been changed to specify use of freon or hexane instead of freon (since the permittee has requested to use existing stocks of freon prior to switching to use of hexane).

5.2.2 Explanation of Limits and Monitoring Requirements

Categorical limits for total suspended solids (TSS) and oil and grease (O&G) are based on classification of this wastewater as a low volume waste under NR 290, Wis. Adm. Code.

5.3 Sample Point Number: 301- Service Water Lagoon Overflow

Monitoring Requirements and Limitations					
Parameter	**Limit Type**	**Limit and Units**	**Sample Frequency**	**Sample Type**	**Notes**
Flow Rate		MGD	Weekly	Total Daily	
Suspended Solids, Total	Monthly Avg	30 mg/L	Weekly	Grab	
Suspended Solids, Total	Daily Max	100 mg/L	Weekly	Grab	
Oil & Grease (Hexane or Freon)	Monthly Avg	15 mg/L	Quarterly	Grab	
Oil & Grease (Hexane or Freon)	Daily Max	20 mg/L	Quarterly	Grab	

5.3.1 Changes from Previous Permit:

Requirements are identical to the previous permit, except that the test method for oil and grease has been changed to specify use of freon or hexane instead of freon (since the permittee has requested to use existing stocks of freon prior to switching to use of hexane).

5.3.2 Explanation of Limits and Monitoring Requirements

Categorical limits for total suspended solids (TSS) and oil and grease (O&G) are based on classification of this wastewater as a low volume waste under NR 290, Wis. Adm. Code.

5.4 Sample Point Number: 501- RO Reject

Monitoring Requirements and Limitations					
Parameter	**Limit Type**	**Limit and Units**	**Sample Frequency**	**Sample Type**	**Notes**
Flow Rate		gpd	Daily	Total Daily	
Suspended Solids, Total	Monthly Avg	30 mg/L	Weekly	Grab	
Suspended Solids, Total	Daily Max	100 mg/L	Weekly	Grab	
Oil & Grease (Hexane or Freon)	Monthly Avg	15 mg/L	Quarterly	Grab	
Oil & Grease (Hexane or Freon)	Daily Max	20 mg/L	Quarterly	Grab	

5.4.1 Changes from Previous Permit:

This is a new sample point for discharges from a new proposed Reverse Osmosis System (proposed in 2005) and expected to be installed in the next year or so.

5.4.2 Explanation of Limits and Monitoring Requirements

Limits and requirements apply if and when discharge of RO reject wastewater commences from a new reverse osmosis water treatment system (proposed in 2005) to the turbine building standpipe to Outfall 001. The discharge will include the reject waste stream from the reverse osmosis membranes. A cartridge filter preceding the RO system will generate a reject waste stream that will discharge to the service water lagoons (existing sample point 301). Categorical limits for total suspended solids (TSS) and oil and grease (O&G) are based on classification of this wastewater as a low volume waste under NR 290, Wis. Adm. Code. The frequencies of monitoring for total suspended solids and oil and grease are set at weekly and quarterly respectively, based on predictions that discharge levels of these parameters will be low in relation to the limits. These sampling frequencies are similar to the other internal sampling points for categorical limits. A condition has been added to require submittal of final water treatment additives for approval for use of a new RO system if different from additives included in the permit reissuance application.

5.5 Sample Point Number: 601- Turbine Bldg Basement Water

Monitoring Requirements and Limitations					
Parameter	**Limit Type**	**Limit and Units**	**Sample Frequency**	**Sample Type**	**Notes**
Flow Rate		MGD	At Discharge	Estimated	In case of failure of the circulating water system, estimated flow shall be reported for each day of discharge

5.5.1 Changes from Previous Permit:

This is a new sample point for monitoring very infrequent discharge pumped from the turbine building basement in case of failure of the circulating water system which has been identified as a possibility in contingency planning in 2005.

5.5.2 Explanation of Limits and Monitoring Requirements

Sample point 601 will monitor flow of Lake Michigan water or purified water pumped from the turbine building basement in case of failure of the circulating water system via hose to at or near the Outfall 001 discharge structure. Due to predicted infrequent discharge (which may not even occur), only estimated flow is required to be reported for each day of discharge. The predicted pumping rate for such discharge would be approximately 1000 gpm for 12 hours.

5.6 Sample Point Number: 801- Mercury Field Blank

Monitoring Requirements and Limitations					
Parameter	**Limit Type**	**Limit and Units**	**Sample Frequency**	**Sample Type**	**Notes**
Mercury, Total Recoverable		ng/L	Each Day Mercury is Sampled	Grab	

5.6.1 Changes from Previous Permit:

This is a new sample point added to the DMRs for reporting mercury field blank results which is required in the permit conditions (footnotes) for Outfall 001 and Outfall 003 on any day mercury is sampled.

5.6.2 Explanation of Limits and Monitoring Requirements

The permittee shall collect at least one mercury field blank for each set of mercury samples (a set of samples may include combinations of intake, influent, effluent or other samples all collected on the same day) as required by NR 106.145 Wis. Adm. Code.

6 Surface Water - Proposed Monitoring and Limitations

6.1 Sample Point Number:001- Condenser Cooling Water

Monitoring Requirements and Limitations					
Parameter	**Limit Type**	**Limit and Units**	**Sample Frequency**	**Sample Type**	**Notes**
Flow Rate		MGD	Daily	Continuous	
Temperature Minimum		deg F	Daily	Continuous	
Temperature Maximum		deg F	Daily	Continuous	
Temperature Average		deg F	Daily	Continuous	
pH Field	Daily Min	6.0 su	Weekly	Grab	
pH Field	Daily Max	9.0 su	Weekly	Grab	
Chlorine, Total Residual	Daily Max - Variable	ug/L	Daily	Grab	TRC limit = 200 ug/L if chlorine is added for 160 min/day or less & TRC limit = 38 ug/L if chlorine is added for > 160 min/day
Chlorine, Total Resdl Discharge Time		min/day	Daily	Record of Addition	The time of chlorination shall not be > 2 hours/day except when chlorinating for zebra mussel control
Chlorine, Variable Limit		ug/L	Daily	Calculated	TRC limits are determined based on min/day chlorine addition
Chlorine, Total Residual	Daily Max	180 lbs/day	See Permit Note	Calculated	TRC mass limit of 180 lb/day and reporting applies only if chlorine is added for > 160 min/day
Thallium, Total Recoverable		ug/L	Once	24-Hr Flow Prop Comp	Results of one test shall be submitted by March 31,

Monitoring Requirements and Limitations					
Parameter	**Limit Type**	**Limit and Units**	**Sample Frequency**	**Sample Type**	**Notes**
					2006
Mercury, Total Recoverable		ng/L	Quarterly	Grab	See 3.2.1.1 below for additional requirements
Acute WET		TUa	See Listed Qtr(s)	24-Hr Flow Prop Comp	Three Acute WET tests shall be performed during the permit term in the calendar quarters listed below.
Chronic WET		rTUc	See Listed Qtr(s)	24-Hr Flow Prop Comp	Three Chronic WET tests shall be performed during the permit term in the calendar quarters listed below.

6.1.1 Changes from Previous Permit

Changes to the previous permit include addition of low level mercury monitoring and acute and chronic whole effluent toxicity testing. One additional test for thallium has also been required to supplement data submitted with the permit application. A compliance schedule has been added for a mercury pollutant minimization program. A compliance schedule has also been included to address compliance with regulations specifying requirements for cooling water intake structures for power plants (Clean Water Act, s. 316(b)).

6.1.2 Explanation of Limits and Monitoring Requirements

Water Quality Based Limits and WET Requirements

An evaluation of the need for water quality based limits and monitoring requirements is presented in the attached water quality based effluent limits (WQBEL) recommendations memo dated May 10, 2005.

Water quality based total residual chlorine limits (daily maximum limits of 38 µg/L and 180 lbs/day) apply only when time of chlorination exceeds 160 min/day. Otherwise categorical TRC limits of 200 µg/L apply. The use of water treatment additives above the dosages reported with the permit application or new water treatment additives must be reported to the Department prior to beginning usage.

Acute and chronic whole effluent toxicity (WET) testing has been required three times during the term of the permit as explained in the attached WQBEL recommendations determined in accordance with ss. NR 106.08 and NR 106.09 Wis. Adm. Code (reference the Whole Effluent Toxicity Program Guidance Document (dated June 10, 1998 - Revision #2 - and checklist and WET information, guidance and test methods at http://www.dnr.state.wi.us/org/water/wm/ww/biomon/biomon.htm).

Low level mercury testing has been required quarterly based on data submitted with the permit application (December 2004) that would indicate the effluent levels of mercury are similar to intake levels. A compliance schedule for a mercury pollutant minimization program is included as explained further below. Requirements for mercury are included in s. NR 106.145 Wis. Adm. Code (See http://www.dnr.state.wi.us/org/water/wm/ww/mercury/mercury.htm).

A retest for thallium has been required by March 31, 2006 to supplement test results submitted with the permit application which was nondetectable at a level of detection that was not low enough, as explained further in the attached WQBELs document. If an acceptable retest is submitted prior to permit reissuance, this requirement will be removed from the permit.

Categorical Limits

Categorical limits are identical to those in the previous permit. In addition to the categorical limits for total suspended solids and oil and grease for low volume wastewater in sample points 101, 201,301 and 501 described above, NR 290 Wis. Adm. Code, steam electric regulations also restricts chlorine use in the condenser cooling water system. The permit contains a restriction on chlorine use of 2hrs/day with a 200ug/L daily maximum limit. Chlorine addition to the service water treatment system may occur after chlorination of the circulating water system but does not result in discharge of residual chlorine. As in the previous permit, this facility is allowed to add chlorine for over 2 hours/day when chlorinating for zebra mussel control as allowed in NR 290 Wis. Adm. Code. Time of chlorination was reported to be under 2hrs/day during the previous permit (see attached excel spreadsheet for monitoring data). Consistent with the previous permit and current guidance, water quality based limits for chlorine (Daily Max of 38 ug/L and 180 lbs/day) are only imposed when the facility is chlorinating for more than 160 minutes on any day. Otherwise the categorical daily maximum limit of 200 ug/L applies. The permit also retains a condition on the prohibiting discharge of PCBs.

6.2 Sample Point Number:002- Intake De-Ice

Monitoring Requirements and Limitations					
Parameter	**Limit Type**	**Limit and Units**	**Sample Frequency**	**Sample Type**	**Notes**
Flow Rate		MGD	Monthly	Estimated	

6.2.1 Changes from Previous Permit

No changes.

6.2.2 Explanation of Limits and Monitoring Requirements

Water Quality Based Limits and WET Requirements and Disinfection (if applicable)

Only flow monitoring estimates are required during periods of discharge since the water discharged is effluent from Outfall 001.

6.3 Sample Point Number:003- Sewage Treatment Plant

Monitoring Requirements and Limitations					
Parameter	**Limit Type**	**Limit and Units**	**Sample Frequency**	**Sample Type**	**Notes**
Flow Rate		MGD	Continuous	Continuous	
BOD5, Total	Weekly Avg	45 mg/L	3/Week	24-Hr Flow Prop Comp	
BOD5, Total	Monthly Avg	30 mg/L	3/Week	24-Hr Flow Prop Comp	
Suspended Solids, Total	Weekly Avg	45 mg/L	3/Week	24-Hr Flow Prop Comp	
Suspended Solids,	Monthly Avg	30 mg/L	3/Week	24-Hr Flow	

Monitoring Requirements and Limitations					
Parameter	**Limit Type**	**Limit and Units**	**Sample Frequency**	**Sample Type**	**Notes**
Total				Prop Comp	
Nitrogen, Ammonia (NH3-N) Total		mg/L	Monthly	24-Hr Flow Prop Comp	
pH Field	Daily Max	9.0 su	3/Week	Grab	
pH Field	Daily Min	6.0 su	3/Week	Grab	
Mercury, Total Recoverable		ng/L	Monthly	Grab	See 3.2.3.1 below for additional requirements
Thallium, Total Recoverable		ug/L	Once	24-Hr Flow Prop Comp	Results of one test shall be submitted by March 31, 2006
Acute WET		TUa	See Listed Qtr(s)	24-Hr Flow Prop Comp	Two Acute WET tests shall be performed during the permit term in the calendar quarters listed below.
Chronic WET		rTUa	See Listed Qtr(s)	24-Hr Flow Prop Comp	Two Chronic WET tests shall be performed during the permit term in the calendar quarters listed below.

6.3.1 Changes from Previous Permit

Changes to the previous permit include addition of low level mercury monitoring and acute and chronic whole effluent toxicity testing. One additional test for thallium has also been required to supplement data submitted with the permit application. A compliance schedule has been added for a mercury pollutant minimization program. Ammonia monitoring has been required monthly during the permit vs monthly in the first year of the last permit.

6.3.2 Explanation of Limits and Monitoring Requirements

Water Quality Based Limits and WET Requirements

An evaluation of the need for water quality based limits and monitoring requirements is presented in the attached water quality based effluent limits (WQBEL) recommendations memo dated May 10, 2005.

Acute and chronic whole effluent toxicity (WET) testing has been required twice during the term of the permit as explained in the attached WQBEL recommendations determined in accordance with ss. NR 106.08 and NR 106.09 Wis. Adm. Code (reference the Whole Effluent Toxicity Program Guidance Document (dated June 10, 1998 - Revision #2 - and checklist and WET information, guidance and test methods at http://www.dnr.state.wi.us/org/water/wm/ww/biomon/biomon.htm).

Low level mercury testing has been required monthly based on evaluation of data submitted with the permit application (December 2004). The permittee has indicated that an investigation of potential sources of mercury has been started. A compliance schedule for a mercury pollutant minimization program is included as explained further below. Requirements for mercury are included in s. NR 106.145 Wis. Adm. Code (See http://www.dnr.state.wi.us/org/water/wm/ww/mercury/mercury.htm).

A retest for thallium has been required by March 31, 2006 to supplement test results submitted with the permit application which was nondetectable at a level of detection that was not low enough, as explained further in the attached WQBELs document. If an acceptable retest is submitted prior to permit reissuance, this requirement will be removed from the permit.

Ammonia monitoring has been required monthly to continue to document that ammonia levels are low in comparison to water quality based effluent limits and that nitrification occurs for operation as an extended aeration activated sludge treatment plant.

Categorical Limits

Limits and monitoring requirements for BOD and TSS are identical to the previous permit and represent application of NR 210 (Sewage Treatment Works) requirements to this privately owned domestic sewage treatment plant for discharge to the unnamed tributatry to Lake Michigan.

7 Land Application - Proposed Monitoring and Limitations

7.1 Sample Point Number: 004- Domestic Wastewater Sludge

Monitoring Requirements and Limitations					
Parameter	**Limit Type**	**Limit and Units**	**Sample Frequency**	**Sample Type**	**Notes**
Solids, Total		Percent	Annual	Composite	
Arsenic Dry Wt	Ceiling	75 mg/kg	Annual	Composite	
Arsenic Dry Wt	High Quality	41 mg/kg	Annual	Composite	
Cadmium Dry Wt	High Quality	39 mg/kg	Annual	Composite	
Cadmium Dry Wt	Ceiling	85 mg/kg	Annual	Composite	
Copper Dry Wt	High Quality	1,500 mg/kg	Annual	Composite	
Copper Dry Wt	Ceiling	4,300 mg/kg	Annual	Composite	
Lead Dry Wt	High Quality	300 mg/kg	Annual	Composite	
Lead Dry Wt	Ceiling	840 mg/kg	Annual	Composite	
Mercury Dry Wt	High Quality	17 mg/kg	Annual	Composite	
Mercury Dry Wt	Ceiling	57 mg/kg	Annual	Composite	
Molybdenum Dry Wt	Ceiling	75 mg/kg	Annual	Composite	
Nickel Dry Wt	High Quality	420 mg/kg	Annual	Composite	
Nickel Dry Wt	Ceiling	420 mg/kg	Annual	Composite	
Selenium Dry Wt	Ceiling	100 mg/kg	Annual	Composite	
Selenium Dry Wt	High Quality	100 mg/kg	Annual	Composite	
Zinc Dry Wt	High Quality	2,800 mg/kg	Annual	Composite	

Monitoring Requirements and Limitations					
Parameter	**Limit Type**	**Limit and Units**	**Sample Frequency**	**Sample Type**	**Notes**
Zinc Dry Wt	Ceiling	7,500 mg/kg	Annual	Composite	
Nitrogen, Total Kjeldahl		Percent	Annual	Composite	
Nitrogen, Ammonium (NH4-N) Total		Percent	Annual	Composite	
Phosphorus, Total		Percent	Annual	Composite	
Phosphorus, Water Extractable		Percent	Annual	Composite	
Potassium, Total Recoverable		Percent	Annual	Composite	
PCB Total Dry Wt	High Quality	10 mg/kg	Once	Composite	
PCB Total Dry Wt	Ceiling	50 mg/kg	Once	Composite	

7.1.1 Changes from Previous Permit:

There are no changes to the previous permit except the requirement for a priority pollutant scan has not been retained since the sludge was not landspread during the last permit and the volume generated is very low compared to criteria used for requiring priority pollutant scans.

7.1.2 Explanation of Limits and Monitoring Requirements

Sludge from the domestic wastewater treatment system (estimated by WPS at approximately 150,000 gallons/year with 10% solids) is hauled to and further treated at the Green Bay Met (POTW) or landfilled by Waste Management. Green Bay Met tests sludge it receives periodically. Requirements to provide capacity for storage of sludge for 180 days in NR 204.10 are not applicable. If there is a need to land apply sludge, requirements are identified to notify the Department NER office in Green Bay before initiating any land application. Detailed analysis requirements and limits which are standard for municipal sludge (in NR 204 Wis. Adm. Code) are contained in the permit tables which do not apply unless land application occurs. If land application is to be initiated results of all appropriate testing and other reporting would be necessary prior to beginning land application. The permittee must also comply with all other local, state or federal regulations.

8 Compliance Schedules

8.1 Requirements for Cooling Water Intake Structures

Required Action	Date Due
Proposal for information Collection (PIC): Submit a PIC for Department review and comments prior to the start of information collection activities described in such proposal, as specified in permit section 1.4, page 1.	

Cooling Water Intake Information : Submit information required to describe cooling water intake structures, cooling water system operations and source water physical data specified in permit section 1.2, page 1.	01/07/2008
Comprehensive Demonstration Study: Submit a comprehensive demonstration study as specified in permit section 1.3, page 1.	01/07/2008

8.2 Mercury Pollutant Minimization Program

The permittee shall implement a pollutant minimization program whenever, after the first 24 months of mercury monitoring, a mercury effluent limitation(s) is necessary under the procedure in s. NR 106.145(2), Wis. Adm. Code for Outfall 001 or Outfall 003.

Required Action	Date Due
Submit a Mercury Pollutant Minimization Program: The permittee shall develop and submit to the Department a plan for a cost-effective pollutant minimization program (PMP) that has as its goal the reduction of mercury for the purpose of maintaining the effluent at or below the water quality based effluent limitation or potential limitation. The PMP shall meet the requirements of s. NR 106.145(7), Wis. Adm. Code. Note: The Department will notify the permittee of acceptance of or comments on the proposed PMP. The permittee and the Department will then agree on what changes, if any will be made to the PMP. If the Department has not notified the permittee within 90 days of the Department's receipt of the PMP, the permittee may assume that the PMP has been accepted.	03/31/2008
Implement the Mercury Pollutant Minimization Program: The permittee shall implement the PMP as submitted or as amended by agreement of the permittee and the Department.	09/30/2008
Submit Annual Status Reports: The permittee shall submit to the Department an annual status report on the progress of the PMP as required by s. NR 106.145(7), Wis. Adm. Code. Submittal of the first annual status report is required by the Date Due. Note: If the permittee wishes to apply for an alternative mercury effluent limitation, that application s due with the application for permit reissuance by 6 months prior to permit expiration. The permittee should submit or reference the PMP plan as updated by the Annual Status Report or more recent developments as part of that application.	12/31/2008

8.3 Explanation of Compliance Schedules

Mercury

A pollutant minimization program is required to be completed if after the first 24 months of mercury monitoring, a mercury effluent limitation is necessary under the procedure in s. NR 106.145(2), Wis. Adm. Code for either Outfall 001 or 003. Therefore a PMP is required for the whole power plant if mercury data for either outfall would trigger a potential mercury limit after the first 24 months of mercury monitoring. Requirements for mercury are included in s. NR 106.145 Wis. Adm. Code (See http://www.dnr.state.wi.us/org/water/wm/ww/mercury/mercury.htm).

Requirements for Cooling Water Intake Structures

The compliance schedule requirements summarized for the cooling water intake structures are also included in detail in permit Section 1 (page 1) and explained in more detail above (see 3). The requirements and the required date for submittal of information as January 7, 2008 are consistent with Dept. guidance for cooling water intake structures (see http://dnr.wi.gov/org/water/wm/wqs/316b/).

9 Other Comments:

If the potential change of ownership of this power plant from WPS Kewaunee to Dominion Energy Kewaunee would occur prior to permit reissuance, this permit would be reissued to the new owner, as stated in the permit public notice.

10 Attachments:

Substantial Compliance Determination dated May 2005

Water Flow Schematic(s)

Map(s)

Quantitative Description of Discharges - The attached excel spreadsheet with monitoring data for 1999-March 2005 extracted from the Department's Wastewater Database (SWAMP) is subject to any errors in the database, and is intended to provide a general quantitative description of discharges. Other use of the data (such as for publishing, quoting or enforcement) must be further verified with the Department for accuracy to ensure due diligence appropriate for the intended use.

Water Quality Based Effluent Limits dated May 10, 2005

WET Checklist Summary

Public Notice dated May 26, 2005

11 Proposed Expiration Date:

June 30, 2010

Prepared By:

Dave Hantz, P.E. **Wastewater Engineer**

Date: May 2005

cc: Gary Kincaid NER, EPA Region 5

PROCESS STREAMS AND DESCRIPTIONS FOR OUTFALL 001 (FROM THE 2004 PERMIT APPLICATION BY WPS)

This is the largest plant effluent line. The tributaries are:

1. The return from the condenser water boxes. One or two circulating water pump operation is dependent on lake water temperature in order to satisfy condensate cooling requirements. Normally one pump, approximately 240,000 gpm, is all that is required in the winter months while two pumps, providing a total of 400,000 gpm, are needed in the summer. When the plant is shutdown, water box cooling is not needed. The water boxes are chlorinated to prevent biofouling.
2. Water used for backwashing the circulating water system traveling screens and the service water system strainers. This water is regularly chlorinated to prevent biofouling and reduce the risk of zebra mussel infestation.
3. The turbine-building standpipe serves as the collection point for the returns from the service water system. The bulk of the service water provides equipment and area cooling before it is returned to the standpipe. This water is periodically chlorinated in addition to being screened and strained. A portion of the service water is further treated to remove suspended solids for plant makeup and component cooling loads that require higher quality water (e.g. motor bearings, pump seal, and instrument air compressor cooling).

   A proposed reverse osmosis (RO) system will replace the flocculation and filtration unit, miscellaneous plant uses, and the demineralizer and degas streams that contribute flow to the turbine-building standpipe. A microfiltration unit in front of the RO unit will have a rejection stream that discharges to the service water treatment lagoons. The proposed RO system will have a waste rejection stream that will discharge to the turbine-building standpipe. A new internal outfall sampling point 501 will be created on this waste stream. Seven new chemicals are being proposed for use with the new RO system.

   Currently, the service water is treated with ferric sulfate and lime to clarify and soften the water. The sludge produced in this process is transferred to the service water treatment lagoons. The water is pumped through high-pressure filters to remove any residual floc that may not have settled out. These filters are backwashed to the service water treatment lagoon.

   To provide makeup water for the steam plant and reactor coolant system the filtered service water is demineralized and degassed. Demineralization is accomplished by passing the water through a strong acid cation exchange unit where cationic elements are removed. The water enters a vacuum degasifier which removes the dissolved gases and than passes through a strong base anion exchange unit which removes the anionic impurities.

   The water is then pumped to a mixed-bed ion exchange unit, which removes any residual cations and anions. The resultant high quality water is stored for makeup usage. The regeneration wastes are transferred to the waste neutralization tank.

   a. The service water treatment lagoons discharge via an overflow line. These lagoons receive the waste from the service water treatment system, pH adjusted regeneration waste from the makeup system demineralizers and plant water softener regeneration waste via the waste neutralization tank, and can receive the turbine building sump discharge. Clear overflow from this release path amounts to an average flow of 22.9 gpm. The overflow is monitored, as required by permit, as sample point 301.
   b. The turbine-building sump receives waste from equipment and floor drains in the turbine building. This sump is designed to separate oil from waste drainage. If oil is detected in the weekly samples, an absorbent fiber mat is used for its removal. An average flow of 40 gpm is released from the turbine-

building sump directly to the turbine building standpipe or routed to the service water treatment lagoons. The flow to the turbine-building standpipe is monitored, as required by permit, as sample point 201.

4. The auxiliary building standpipe serves as the collection point for the nonradioactive service water return from the auxiliary building and reactor building equipment cooling. Steam generator blowdown, treated reactor coolant system blowdown, chemical volume and control system waste, equipment and floor drain returns from the auxiliary and containment buildings, and laundry/shower drain returns also empty into this standpipe. The last three returns are batch processes that are tabulated in the annual effluent release report to the NRC.

   a. During start-up and non-routine operation, up to 200 gpm is blown down from the steam generators to monitor and maintain the steam generator water quality. Once system stability is achieved, blow down flow can be recycled. The blow down water is treated service water. The only treatment the water receives prior to discharge is cooling to recover the heat and monitoring for radioactivity. During plant shutdown, the entire steam generator is drained. Usually, less than forty gallons per minute is normally released via this path during these conditions. This stream is monitored, as required by permit, as sample point 101.

   c. The chemical volume and control system (CVCS), in part, is used to adjust the boron concentration in the reactor coolant system during operation. As power generation continues, boron has to be reduced in the reactor coolant system. Normally, reactor coolant is diverted to the CVCS holdup tanks until there is a sufficient volume to recover the boron for reuse. This water is replaced in the reactor coolant system with demineralized water. The diverted coolant water is batch processed by passing through ion exchangers, filters, then and an evaporator. The boric acid solution is saved for reuse and the distillate is recovered and stored in the CVCS monitor tank where it is sampled and discharged.

5. The equipment leak-offs and floor drains from the auxiliary building and containment are collected and treated by a combination of filters, ion exchangers and stored in hold-up tanks. The tanks are monitored for radioactivity and discharged.

Notes from attached water flow diagram for Outfall 001 (from the 2004 permit application):

(a) The demineralizer resin is flushed with clean water after regeneration until the conductivity is within specification limits. Wastewater used for the flush is sent to the turbine building standpipe. A preset specific conductivity indication diverts the waste stream from the standpipe to the waste neutralizing tank on high specific conductivity.

(b) Overflow path or planned draining for maintenance activities of the waste neutralization tank.

(c) Rare alternate drain path when flash tank is out of service.

(d) 1200 gpd during outages and/or routine maintenance.

(e) Service water supply to quench steam when in mode I operation.

(f) Minor batch releases of coolant are released from the emergency diesel generator cooling system when drained for maintenance.

(g) Optional release path, rarely used.

Outfall 002

A recirculation line branches off of the main discharge header just prior to its exiting the plant. In the winter months the warmer effluent stream is used to prevent ice formation on the traveling water screens and intake piping. Approximately 7 gpm of the flow is diverted through a radiation monitor which discharges to the screenhouse pumps. This water receives no additional treatment.

Substantial Compliance Determination

Permittee Name: Wisconsin Public Service Corp Kewaunee		Permit Number: 0001571-07-0
	Compliance?	Comments
Discharge Limits	Yes	
Sampling/testing requirements	Yes	
Groundwater standards	NA	
Reporting requirements	Yes	
Compliance schedules	Yes	
Management plan	NA	
Other:	NA	
Enforcement Considerations		
In substantial compliance?	Yes Comments: Signature: David Hantz and Gary Kincaid Date: 5/16/05 Concurrence: NER Date: 5/05	

Enclosure B

NALCO ENVIRONMENTAL SCIENCES
1500 FRONTAGE ROAD ◦ NORTHBROOK, ILLINOIS 60062 ◦ AREA 312-564-0700

NALCO CHEMICAL COMPANY

REPORT TO

WISCONSIN PUBLIC SERVICE CORPORATION
GREEN BAY, WISCONSIN

KEWAUNEE NUCLEAR POWER PLANT
KEWAUNEE, WISCONSIN

316(a) DEMONSTRATION
TYPE 1: ABSENCE OF PRIOR APPRECIABLE HARM

PREPARED AND SUBMITTED
BY
NALCO ENVIRONMENTAL SCIENCES

Report approved by: B. G. Johnson
B. G. Johnson, Ph.D.
General Manager

April 14, 1976

ACKNOWLEDGEMENTS

The overall supervision of the Environmental Monitoring Program and 316a Demonstration was the responsibility of Dr. B.G. Johnson, General Manager, NALCO Environmental Sciences and Dr. J.A. DeMarte and Dr. B.J. Cox, Project Coordinators. Mr. L.J. LaJeone, Associate Scientist, Fisheries Section directed the environmental and ecological studies while Mr. F.T. Lovorn, Limnology and Oceanography Group Leader directed the thermal plume and physical studies. The preparation of the 316a Demonstration was the responsibility of Mr. G.F. Carpenter, Zooplankton Group Leader, Aquatic Ecology Section.

The authors of the sections of this demonstration have, in most cases, been with the monitoring program for several years and responsible for the annual reports for their respective disciplines. The authors of the major sections of this 316a Demonstration are:

Mr. T.P. Meinz, Wisconsin Public Service Corporation, Section 1.1

Mr. A.W. Williams, Jr., Foley & Lardner Law Firm, Sections 1.2-1.4

Mr. F.T. Lovorn, Engineering and Hydrological Data, Section 4.1

Mr. D.B. Ellis, Water Quality Standards, Section 4.2

Mr. L.J. LaJeone, Fish, Section 4.3.1

Mr. J.H. Rains, Benthos, Section 4.3.2

Mr. J.B. Festin, and Mr. D.G. Redmond, Phytoplankton, Section 4.3.3

Ms. J.M. Urry, Mr. A.L. Restaino and Mr. D.L. Wetzel, Zooplankton, Section 4.3.4

Mr. C.C. Altstaetter, Periphyton, Section 4.3.5

Dr. J.A. DeMarte, Macrophytes, Section 4.3.6

Mr. G. F. Carpenter, Other Sections

The following personnel provided supervisory and editorial assistance to the above authors:

Dr. J.C. Drozd, Water Quality

Mr. L.D. Everhart, Aquatic Ecology

Mr. B.I. Muench, Fish

Drafting of figures was done by Ms. P. Parshall and Ms. N.D. Gara.

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1.0 Introduction

1.1 Licensing and Regulatory History

Kewaunee Nuclear Power Plant utilizes a pressurized water reactor licensed at 1650 MWt. The turbine generator is capable of producing 540 MWe net (560 Mwe gross) of electrical power. The unit began full commerical operation on June 16, 1974 and full power was reached in August 1974 under an operating license issued by the United States Atomic Energy Commission (AEC) on December 21, 1973.

The unit was subjected to a complete and thorough environmental review by the Regulatory Staff on the Nuclear Regulatory Commission (formerly called AEC) persuant to the National Environmental Policy Act of 1969 (PL 92-500). The Staff, in its final Environmental Statement issued in December, 1972, concluded that "the total effect of Plant operation on aquatic biota will be very localized and inconsequential in terms of total Lake Michigan ecology", from the present once through cooling system.

The Kewaunee Plant was involved in a brief licensing proceeding before the AEC Atomic Safety and Licensing Board in February, 1973. As a result of these hearings, on October 23, 1973, the Board issued its final memorandum and order in which the Board approved the order, agreed to by the Applicants, Intervenors, and regulatory staff, for the withdrawal of Intervenors in accordance with an agreement entered into among the three parties. The Agreement resulted in the withdrawal of all matters in controversy.

On August 3, 1973, the Wisconsin Department of Natural Resources (WDNR) issued a certification pursuant to Section 401(a) of the Federal Water Pollution Control Act Amendments of 1972, that operation of the Kewaunee Nuclear Power Plant was meeting the requirements of the Lake Michigan Thermal Standards of the State of Wisconsin, including the submission of monthly reports of temperature and flow data for thermal discharges, chemical and biological data from the sewage treatment plant as well as other Wisconsin water quality standards applicable to waste heat and other discharges from the plant. A copy of the letter of certification is included as Appendix 1.

Monthly reports (Form 3200-28) of temperature, flow, chemical and biological data for the Kewaunee Nuclear Plant are being submitted on a continuing basis as required by Section 05(2)(a) of Chapter NR 102. Section NR 102.05 of the Wisconsin Adminstrative Code established the Lake Michigan chemical mixing zone standards. This report provides justification for requesting exemption, under Section NR 102.07(1)(b), from the thermal limitations.

1.2 Federal Law

Public Law 92-500, the Federal Water Pollution Control Act Amendments of 1972 ("FWPCA") was adopted on October 13, 1972. The Act requires that each state adopt water quality standards for all of its waters, both interstate and intrastate, and that it set up an adminstrative apparatus to issue so-called Pollution Discharge Elimination System permits which will cause the waters to achieve the quality standards set. In addition, the FWPCA dictates that categorical effluent discharge limitations be established for industries which discharge waste water, and that discharge permits be issued which require the installation of the best practicable effluent control technology currently available ("BPT") by July, 1977. The Act stipulates that if BPT technology will not be sufficient to achieve the water quality standards set for the receiving waters, more stringent effluent discharge limitations must be imposed through a "water quality restricted" permit

Superimposed over these statutory standards is Sec. 316(a) of the FWPCA. Section 316(a) impacts on thermal discharge limitations and provides for the following exemption:

> ". . . [W]henever the owner . . . of any such source (subject to FWPCA permit requirements), after opportunity for public hearing, can demonstrate to the satisfaction of the (State) . . . that any effluent limitation proposed for the control of the thermal component of any discharge from such source will require effluent limitations more stringent than necessary to assure the protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife in and on the body of water into which the discharge is to be made, the (State) may

> impose an effluent limitation under such sections for such plant, with respect to the thermal component of such discharge . . . that will assure the protection and propagation . . . in and on that body of water."

Pursuant to the FWPCA, the federal EPA promulgated regulations at 40 C.F.R. Part 423, reported at 39 Federal Register 36, 187 et seq., October 8, 1974 which specifically exempt from any thermal effluent restrictions all generating plants which are "old units" (generating capacity placed in service on or before January 1, 1970 for generating capacity in excess of 500 megawatts and any generating units of less than 500 megawatts placed in service on or before January 1, 1974).

1.3 State Law

On July 21, 1973 Chapter 74 Laws of 1973 (Wisconsin Statutes Chapter 147), became effective. Chapter 147 is the State's enactment of the Wisconsin Pollution Discharge Elimination System permit program (WPDES), which enactment qualified the State to administer the FWPCA program in-state. The following portions of Chapter 147 relate specifically to the FWPCA 316(a) thermal limitation variance process:

> 147.021 Compliance with federal standards. All rules adopted by the department pursuant to this chapter as they relate to point source discharges, effluent limitations, water quality related limitations, municipal monitoring requirements, standards of performance and toxic and pretreatment effluent standards shall comply with and not exceed the requirements of the federal water pollution control act amendments of 1972, P.L. 92-500, and regulations adopted pursuant thereto.
>
> 147.05(4)(a) Any thermal effluent limitation proposed by the department may be modified by it in accordance with s. 147.20, if the owner or operator of the point source which is the subject of the proposed limitation demonstrates to the satisfaction of the department that the proposed limitation is more stringent than necessary to assure the protection and propagation of a balanced indigenous population of shellfish, fish and wildlife in and on the body of water into which the discharge is made.
>
> (b) Any point source of a discharge having a thermal component, the modification of which is commenced after October 18, 1972, and which, is modified, meets the most stringent effluent limitation established under s. 147.04 or subs. (1) and (2), where the limitation assures protection and propagation of a balanced indigenous population of shellfish, fish and wildlife in and on the water into which the discharge is made, shall not be subject to any more stringent effluent limitation

> with respect to the thermal component during either the 10-year period beginning on the date of completion of the modification or the period of depreciation or amortization of the facility for the purpose of section 167 or 169 of the internal revenue code of 1954, whichever ends first.

Therefore, state law, as it has been enacted and has embodied federal regulations, establishes a thermal limitation variance program for those plants properly subject to thermal limitations. Under the federal regulations establishing thermal treatment standards for the steam electric generating source category, the Kewaunee Plant must limit its thermal effluent unless grounds for a variance are demonstrated.

Lake Michigan thermal mixing zone standards were established in Wisconsin Administrative Code Section NR 102.05. Section NR 102.07(1)(b) provides for exemptions from the thermal limitations upon an adequate demonstration of protection for the indigenous population of shellfish, fish and wildlife in the receiving water.

1.4 WPDES Permit

WPDES Permit No. WI-0001571 proposed for the Kewaunee Plant, includes stringent limitations on the permissible temperature of the discharges from the Kewaunee Plant beginning on July 1, 1979. The limitation imposed is as follows:

> "4. Thermal Mixing Zone Limitations and Monitoring Requirements: Beginning on July 1, 1979 and lasting until September 30, 1979, the permittee is authorized to discharge from outfall serial number 001 a heated effluent which shall at no time raise the natural temperature of Lake Michigan more than 3° F at the edge of the mixing zone above the maximum temperature limits . . . ."

1.5 Variance Request

Lake Michigan thermal standards set forth in Chapter NR 102 Wisconsin Department of Natural Resources, July 1975 impose limitations by July 1, 1979 on receiving water body temperatures at the boundary of defined mixing zones. This demonstration is submitted in application for relief from those limitations, in accord with Chapter NR 102.07.

1.6 Demonstration Format

The basic format of this demonstration follows the "Proposed Guidelines for Administration of the 316(a) Regulations" issued by the USEPA in draft form under the date 30 September 1974. The "Proposed Guidelines for Demonstration under Section 316 of Public Law 92-500", September 1974 and "Proposed Outline for 316(a) Demonstration Document", October 1974 issued by the Water Quality Evaluation Section, Wisconsin Department of Natural Resources (WDNR) were also employed in preparation of this document. The demonstration will show that no appreciable harm to the species of shellfish, fish and wildlife in the body of water receiving the discharge has resulted from the thermal component of the Plant's discharge (including interaction with other pollutants). It concludes, therefore, that the thermal component of the Plant discharge has not disturbed " the balanced indigenous community" in the vicinity of Kewaunee Nuclear Power Plant. See the Wisconsin Administrative Code, Chapter NR 209.07(1).

Since the writing of this demonstration was begun before the "Proposed Outline for 316(a) Demonstration Document" was issued by the Wisconsin Department of Natural Resources (October 1975) the format of this demonstration does not follow the outline. In order to facilitate evaluation of this demonstration, the major points in the WDNR outline are cross-referenced in Table 1.1 to the corresponding sections of this demonstration. The 18 questions included in the WDNR outline were considered important to the presentation of a demonstration and are therefore cross-

Table 1.1 Cross referencing of WDNR "Proposed Outline for 316(a) Demonstration Document" to the format of the Kewaunee Nuclear Power Plant 316(a) Demonstration.

Wisconsin Department of Natural Resources Proposed Outline for 316(a) Demonstration Document	This Demonstration
I. Introduction	
A. Description of Project Scope Methods	Annual Reports, Appendices 2-6
B. Summary of Effects and Conclusions	Narrative Summary 2.0 p.18.
C. Variance Request	Variance Request 1.5 p. 8.
II. Site Description	KNPP Description 3.1 p. 39. Location 3.2 p. 40.
A. The Environment and Development	
Water Quality	Lake Michigan Water Conditions 4.2.1 p. 108.
Lake Currents	Lake Currents 4.1.3 p. 58.
Ambient Temperature	Ambient Temperatures and Stratification 4.1.4 p. 69.
Bathymetry	Bathymetry 4.1.5 p. 78.
Historical Climate	Historical Climate 4.1.7 p. 94.
B. The Discharge	
Chemical Discharges	Chlorine and Chemicals used in the Plant 4.2.2 p. 125.
Operational History	Operational History 3.3 p. 41.
Engineering Data	Circulating Water System 4.1.1 p. 48.
III. Thermal Effect of Discharge	
Thermal Modeling	Time-Temperature Relationships 4.1.2 p. 55. Thermal Plume Characteristics 4.1.6 p. 83.
Temperature Effect on Receiving Water	4.1.6 p. 83.
Heat Shock and Cold Shock	Fish 4.3.1.2 p. 197-205. Benthos 4.3.2.2 p. 248-250. Phytoplankton 4.3.3.2 p. 292. Zooplankton 4.3.4.2 p. 346-356. Periphyton 4.3.5.2 p. 414-416.
IV. Effects on Aquatic Life	
A. Fish	Fish 4.3.1 p. 149.
B. Benthos and Macroinvertebrates	Benthos 4.3.2 p.213.
C. Zooplankton	Zooplankton 4.3.4 p.318.
Phytoplankton	Phytoplankton 4.3.3 p.254.
Macrophytes	Macrophytes 4.3.6 p. 421.
Periphyton	Periphyton 4.3.5 p. 383.
D. Extreme Conditions	Thermal Plume 4.1.6 p. 83. Fish 4.3.1.2 p. 186. Benthos 4.3.2.2 p. 239. Phytoplankton 4.3.3.2 p. 279. Zooplankton 4.3.4.2 p. 337. Periphyton 4.3.5.2 p. 407.
E. Interactions of Species Populations	Fish 4.3.1.2 p. 186.
F. Synergistic Effects of Heat with Toxic Chemicals	4.2.2 p.127.
V. Water Body Wide Effects	Fish 4.3.1.3 p. 206. Benthos 4.3.2.3 p.251. Phytoplankton 4.3.3.4 p. 309. Zooplankton 4.3.4.4 p. 376. Periphyton 4.3.5.3 p. 417.
VI. Conclusions	Narrative Summary 2.0 p. 18. Demonstration Conclusion 2.4 p. 38.

referenced in Table 1.2 to the corresponding sections of this demonstration.

This demonstration contains an evaluation of Lake Michigan data collected in the vicinity of Kewaunee Nuclear Power Plant. Site specific studies have been sponsored by Wisconsin Public Service from 1971 to the present. Wisconsin Public Service helped sponsor a radiological study of Lake Michigan by Ayers (1970) which included samples of water and biota from the Kewaunee area. The University of Wisconsin conducted a survey study at the proposed site from 1969 through 1972 (University of Wisconsin 1970, 1971, 1972, 1973). In 1971, the Environmental Sciences Division of Industrial BIO-TEST Laboratories Inc. began the monitoring program which provides the data for this demonstration. The company name was changed to NALCO Environmental Sciences in 1975 and this demonstration has been prepared by the same people who have been conducting the monitoring studies. For the purpose of this demonstration, these studies are separated into two periods; the Preoperational Period from May, 1971 through May, 1974 and the Operational Period from June, 1974 to the present. Operational data are discussed from June 1974 through July 1975. Intake and discharge collections were begun in March when the circulating pumps were operating but no heat exchange was taking place across the condensers. The purpose of these studies was to determine the effects of mechanical damage to entrained organisms in the absence of a thermal discharge. The results are presented in Sections 4.3.3.2 and 4.3.4.2. Fish data are presented through August 1975. NALCO Environmental Sciences personnel have evaluated data from

Table 1.2. Cross Referencing of WDNR Questions from "Proposed Guidelines for Demonstration under Section 316(a) 92-500" to the format of the Kewaunee Nuclear Power Plant 316(a) Demonstration.

Questions from WDNR Proposed Guidelines for Demonstration under Section 316(a) of Public Law 92-500 Sept. 1974.	This Demonstration
1. Are the time of passage, velocity and time-temperature information through the plant, in the discharge facilities and in the center-line of the thermal plume established or adequately predicted?	4.1.1 p. 48 , 4.1.2 p. 55
2a. Are the seasonal phytoplankton populations by number and species known for the receiving water-body?	4.3.3.1 p. 254.
3a. Are the seasonal phytoplankton pupulations by number and species known in the immediate discharge area and in adjacent waterbody segments?	4.3.3.1 p. 254.
4a. Relative to phytoplankton populations of the receiving waterbody, the immediate discharge area and the adjacent waterbody segments, is it known or predicted what portions of the populations are exposed to temperature increased by operation of the plant?	4.3.3.2 p. 279, 4.3.3.3 p. 295.
5a. Are the effects of such exposures on phytoplankton known or predicted (impariment or stimulation of productivity, time-temperature tolerances, population shift both local and throughout the waterbody)?	4.3.3.2 p. 279, 4.3.3.3 p. 295, 4.3.3.4 p. 309.
2b. Are the seasonal zooplankton populations by number and species known for the receiving waterbody?	4.3.4.1 p. 318.
3b. Are the seasonal zooplankton populations by number and species known in the immediate discharge area and in adjacent waterbody segments?	4.3.4.1 p. 318.
4b. Relative to zooplankton populations of the receiving waterbody, the immediate discharge area and the adjacent waterbody segments, is it known or predicted what portions of the populations are exposed to temperature increased by operation of the plant?	4.3.4.2 p. 337, 4.3.4.3 p. 357.
5b. Are the effects of such exposures on zooplankton known or predicted (impariment or stimulation of productivity, time-temperature tolerances, population shift both local and throughout the waterbody?	4.3.4.2 p. 337, 4.3.4.3 p. 357, 4.3.4.4 p. 376.
6. Are the seasonal periphyton populations in the immediate discharge area and adjacent waterbody segments known?	4.3.5.1 p. 383.
7. Are effects of the thermal discharge on periphyton populationd considered, known or predicted?	4.3.5.2 p. 407, 4.3.5.3 p. 417.
8. Are the macroinvertebrate populations in the immediate discharge area and adjacent waterbody segments known?	4.3.2.1 p. 213.

Table 1.2. (continued)

Questions from WDNR Proposed Guidelines for Demonstration under Section 316(a) of Public Law 92-500 Sept. 1974.	This Demonstration
9. Are effects of the thermal discharge on macroinvertebrate population considered, known or predicted?	4.3.2.2 p. 239, 4.3.2.3 p. 251.
10. Are the macrophyton populations in the immediate discharge area and adjacent waterbody segments known?	4.3.2.6 p. 421.
11. Are effects of the thermal discharge on macrophyton populations considered, known or predicted?	4.3.2.6 p. 421.
12. Is the seasonal abundance of fish eggs and larvae by species known in the immediate discharge area and adjacent waterbody segments?	4.3.1.1 p. 149.
13. Is it known or predicted how many fish eggs and larvae by species are exposed to temperatures increased by operation of the plant?	4.3.1.2 p. 186.
14. Are the effects of such exposures of fish eggs and larvae known or predicted?	4.3.1.2 p. 186.
15. Is it known or predicted what impact such effects will have on fish populations in the immediate discharge area, adjacent waterbody segments and the receiving waterbody?	4.3.1.2 p. 181.
16. Are the seasonal abundance and habits of adult fish by species known in the immediate discharge area and adjacent waterbody segments?	4.3.1.1 p. 149.
17. Is it known or predicted what effect the thermal discharge has or will have on these fish and their activities?	4.3.1.2 p. 186.
18. Have the waterbody-wide effects of the thermal discharge been adequately explored?	4.3.1.3 p. 206.

August through November, 1975 and the conclusions presented in this demonstration are further supported by this data (NALCO Environmental Sciences 1976). In all of these studies, sampling was not conducted during the winter months (December through March) due to the severe and often dangerous weather conditions.

The complete demonstration consists of the following documents:

1. Kewaunee Nuclear Power Plant, 316(a) Demonstration Type 1: Absence of Prior Appreciable Harm.

2. Appendix 1: August 3, 1973, Wisconsin Department of Natural Resources certification pursuant to Section 401(a) of the Federal Water Pollution Control Act Amendments of 1972.

3. Appendix 2: Industrial BIO-TEST Laboratories, Inc. 1972. Preoperational thermal monitoring program of Lake Michigan near Kewaunee Nuclear Power Plant. January-December 1971. First Annual Report to Wisconsin Public Service Corporation, Green Bay, Wisconsin. 191 p.

4. Appendix 3: Industrial BIO-TEST Laboratories, Inc. 1973. Preoperational thermal monitoring program of Lake Michigan near Kewaunee Nuclear Power Plant. January-December 1972. Second Annual Report to Wisconsin Public Service Corporation, Green Bay, Wisconsin. 651 p.

5. Appendix 4: Industrial BIO-TEST Laboratories, Inc. 1974. Preoperational thermal monitoring program of Lake Michigan near Kewaunee Nuclear Power Plant. January-Decmeber 1973. Third Annual Report to Wisconsin Public Service Corporation, Green Bay, Wisconsin.

6. Appendix 5: Industrial BIO-TEST Laboratories, Inc. 1975. Operational environmental monitoring program of Lake Michigan near Kewaunee Nuclear Power Plant. January -December 1974. Fourth Annual Report to Wisconsin Public Service Corporation, Green Bay, Wisconsin.

7. Appendix 6: NALCO Environmental Sciences. 1976. Operational environmental monitoring program of Lake Michigan near Kewaunee Nuclear Power Plant. January-December 1975. Fifth Annual Report to Wisconsin Public Service Corporation, Green Bay, Wisconsin.

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1.7 Glossary of Terms

age group - organisms of the same age in a population, usually denoted by roman numerals, e.g. Age Group I, Age Group II, etc.

allochthonous material - organic or inorganic material produced outside the system which has been introduced or transported into the system by currents, falling of dust, etc.

anadromous - going from the sea up a river to spawn.

biovolume - volume of an algal species calculated using measurements of individuals (i.e., diatoms) or of 10 μm lengths of filamentous forms (i.e., Cladophora). The volumes of at least 10 randomly selected individuals or filaments were averaged when possible.

copepodite - juveniles of Copepoda; the developmental stages between larvae and adult.

discharge zone - the maximum surface extent and maximum botton extent of the 2C isotherm for all plumes measured for KNPP except July 1975 (Figure 4.1.18).

ΔT (delta T) - increase above ambient lake temperature due to passage through condensers of KNPP.

drogue - a neutrally buoyant float that drifts with the current.

entrainment - passage through circulating water pumps and condensers at KNPP.

epilithic - living on rock.

epiphyte - algal species attached to other plants (i.e., diatoms attached to Cladophora).

ephippial eggs - overwintering (resting) eggs encased in a hard brown shell produced from the carapace of the ephippial female.

ephippial females - individuals which produce overwintering (resting) eggs in the Cladocrea; usually sexual as opposed to parthenogenic or asexually reproducing females.

exotic - of foreign origin, not native, introduced from abroad.

fastest mile - the fastest one minute mean wind speed from 1912 to 1960.

immotility - absence of appendicular or viscreal movement upon probing immediately (0 hours) after condenser passage.

juvenile - organisms which have not het reached sexual maturity.

mortality - dead zooplankton, as evidenced by lack of appendicular or visceral movement upon probing four hours after condenser passage.

motility - presence of zooplankton appendicular or visceral movement indicating viability upon probing immediately (0 hours) after condenser passage.

nauplii - the larvae of Copepoda; the developmental stages between the hatched egg and the copepodite stage.

omnivorous - eating both animal and plant foods.

parthenogenic eggs - unfertilized eggs produced by parthenogenic females that hatch into offspring identical to the producing female.

parthenogenic female - asexually reproducing females.

pelagic - living at or near open water far from land.

piscivorous - fish-eating.

periodicity - seasonal accurrence or distribution.

periphyton - algal community living attached to a substrate or as an epiphyte on other algae attached to the substrate.

ripe - a stage of sexual development prior to spawning in which gonads of adult fish fill the ventral cavity; eggs become easily visible and testes become white.

spatial distribution - the distribution of a group of organisms over a given area.

splash zone - area of substrate that is kept constantly wet by wave action (generally 10 cm above and below the surface).

standing crop - total organisms (number or biomass) of a group present in a body of water at a particular time.

temporal distribution - the distribution of a group of organisms over a period of time.

year class - animals in a population born during a particular calendar year, e.g., 1972 year class.

young-of-year - organisms which have not yet completed one full year of life.

2.0 NARRATIVE SUMMARY

2.1 ENGINEERING AND HYDROLOGICAL DATA

Kewaunee Nuclear Power Plant, KNPP, utilizes a once-through cooling system (p.48). The normal flow rate is 413,000 gpm with a design maximum rise in temperature of 11.1C (p.48). The intake structure is located approximately 1600 ft offshore (p.48) while the cooling water is discharged from a shoreline outfall structure (p.49). Summer and winter cooling water characteristics are presented (p.51 and 52) as are records of total heat rejected (p.53 and 54).

Lake currents near Kewaunee Nuclear Power Plant are primarily shore parallel in the directions NNE-NE and SSW-SW with speeds most frequently in the range 0.10-0.24 fps (p.58). The direction of net displacement of water past the Plant for the period April-December is northward (p.65).

Maximum temperatures and maximum mean temperatures of the Lake near KNPP occur in August and September with maximum ranges occurring July to September (p.69). Within 1C to 2C, the 10-year record of temperatures measured at municipal water intakes 17.5 km south and 21 km north of KNPP can be considered as a record of the ambient temperature for Lake Michigan near KNPP (p.77). Stratification can develop in the shallow nearshore water but it is weak and breaks down easily (p.72).

The lake bottom was found to be highly irregular near KNPP (p.78). It is believed that a depression immediately in front of the discharge outlet was created by scouring and a small mound just offshore of the depression was built by depositing sediment from both scouring and diversion of alongshore sediment transport (p.81).

The discharge zone for the KNPP thermal plume encompasses an area of approximately 985.3 acres at the surface and 94.5 acres at the bottom (p.89). This surface area is in excess of the 71.74 acres of the Wisconsin DNR standard for KNPP. The thermal plume discharge velocity affects an area of the lake bottom about 250 ft wide extending 400 ft from the outfall structure (p.82). Average, ideal and worst case time-temperature relationships are presented (p.56). The time-temperature relationship for the thermal plume indicate a 55% to 90% reduction in excess temperature within 50 to 75 minutes travel time from the outfall (p.57).

Climatic data are presented and discussed (p.94-105).

2.2 WATER QUALITY

Data collected in Lake Michigan near the Kewaunee Nuclear Power Plant indicated that the chemical quality of the waters in the vicinity of the Plant was representative of general Lake Michigan conditions (p.114). Comparison of water quality within and immediately outside the KNPP thermal plume has shown no harm to Lake Michigan waters (p.116-140).

Dissolved oxygen concentrations decreased slightly in the plume after KNPP operation; however, the decrease was negligible and was not indicative of appreciable harm to this area of Lake Michigan (p.122). Oxygen and nitrogen saturations were close to 100% throughout the study area (p.125). Chlorine has not been used as a defouling agent at KNPP. Other chemicals used (hydrazine and morpholine) were not detected at any time in the discharge or plume (p.125).

Concentrations of nitrogen species (ammonia, nitrate, nitrite, total organic nitrogen) varied little throughout the study although some temporal changes were noted both within and outside the plume (p.128). Soluble orthophosphate concentrations were uniformly low (p.128) while total phosphorus concentrations were related to resuspension of sediments by weather-produced turbulence (p.128). Soluble silica concentrations decreased slightly during the study period at a rate similar to the rest of Lake Michigan and was not related to operation of KNPP (p.130).

Alkalinity and pH were virtually constant during the study period (p.133), but turbidities and suspended solids changed in relation to weather conditions (p.133). Total dissolved solids and specific conductance increased slightly and were not related to KNPP operation (p.136). Concentrations of the major anions and cations (calcium, magnesium, potassium, sodium, chloride, fluoride and sulfate) remained similar throughout the study period and area (p.137).

Bacteria levels and oxygen demands (biochemical and chemical) were low and unrelated to KNPP operation (p.137).

The trace metal values (arsenic, boron, cadmium, chromium, copper, lead, mercury, nickel and zinc) displayed little variation between the preoperational and operational periods (p.138). Iron and manganese varied more widely than the other trace metals, but this variation was in response to weather conditions and turbulence and not to KNPP operation (p.140).

2.3 Aquatic Biota

2.3.1 Fish

The species composition and classification of representative important species of the fishery resource in Lake Michigan near Kewaunee Nuclear Power Plant, according to the Wisconsin Department of Natural Resources, have been presented (p.150). Two species given "changing status" classification, the cisco and the bloater, occur in the area but are very uncommon. The carp is the only species considered "pollution tolerant" that occurs in the vicinity of the Plant.

The relative abundance of fish species are discussed. Nine species are the major constituents of the local fishery, comprising 98% of the total catch to date (p.153). Annual catches and general distribution of major species varied greatly from year to year but appeared unrelated to the thermal discharge of the Kewaunee Nuclear Power Plant.

General life history accounts of representative important species are provided. Major topics of discussion are: general occurrence in Lake Michigan, seasonal migrations, seasonal abundance near the Plant, spawning, age and growth and food habits. Life history information relative to the area near the Kewaunee Nuclear Power Plant were also discussed. Species believed to spawn successfully in the region of the plant by virtue of the collection of eggs, larvae, or young-of-the-year are alewife (p.158), rainbow smelt (p.160), lake chub (p.170), longnose dace (p.172), and slimy sculpin (p.176). Peak abundance of several species in the study area appears to correspond to spawning seasons; however, no spawning habitats have been identified for these species and the area affected by the Plant's thermal discharge is not an important spawning location for any species (p.189).

Prior to Plant operation, the area near the Plant site supported only a very limited sport fishery; however, since operations began, an extensive seasonal salmonid fishery has developed at the Plant's discharge (p.184).

Comparisons of preoperational and operational data showed no appreciable influence of the thermal discharge on the local fishery (p.186). The zone of thermal influence covers a very limited area. There have been no major changes in the species composition, nor have there been any changes in the seasonal abundance and spatial distribution of important species that could be attributed to the thermal discharge (p.186 and 187). No noticeable increase or decrease in the use of the affected area for spawning has been detected (p.189), and there have been no remarkable increases or decreases in the numbers of an individual species (p.186). Observations of carp in the thermal discharge are attributed to attraction to warm water rather than from population expansion due to a degraded environment (p.190).

At certain times of the year many species of fish may be attracted to the thermal discharge. Attraction appears associated with peak abundance in the area and spawning season. Attraction to the thermal discharge may be in response to more preferred temperatures than ambient, but fish will also avoid the discharge when temperatures become too high (p.190-194).

The thermal discharge at the Kewaunee Nuclear Power Plant has had a negligible effect on the normal seasonal migrations of fish. Fish do not spend extended periods of time at thermal discharges and normal migrations continue despite the occasional existence of more preferred temperatures near thermal discharges (p.195-197).

Comparisons of lethal temperature data and Plant discharge temperatures show that the Plant may occasionally discharge heated water which could result in fish mortalities from exposure to such heat levels. Mortalities due to cold shock from reactor shutdown could also result in the winter. However, it is doubtful fish mortalities will occur as the natural seasonal movements and behavioral responses of fish indicate that fish will seldom be subjected to these temperature extremes (p.202-203). No incidences of fish kills at the Kewaunee Nuclear Power Plant have been reported since the Plant began operation (p.205). Any fish egg and larvae mortality which might occur has had no discernable effect on the existing fish community (p.205).

Data collected thus far demonstrate that the discharge of waste heat from the Kewaunee Nuclear Power Plant has caused no appreciable harm to the fishery resource in the discharge zone and has demonstrated no effect on the fishery resource in the area of Lake Michigan immediately outside the discharge zone (p.206).

2.3.2 Benthos

Comparisons of macroinvertebrate data were made between preoperational and operational periods and between sampling locations inside and outside the discharge zone to determine the extent, if any, of the Kewaunee Nuclear Power Plant thermal discharge influence on the macroinvertebrate community.

Two primary macroinvertebrate communities were present during the preoperational period in the vicinity of KNPP (p.222). One community was restricted to the sandy substrates at the shallow 10-ft depth locations and was represented primarily by the worms *Vejdovskyella intermedia* and *Nais* sp. and the midges *Parakiefferiella* sp., *Paracladopelma* sp. and *Polypedilum* (s.s.) Scalaenum Group (p.222). Few significant ($P \leq 0.05$) differences were detected in representative taxa densities between the 10-ft locations (p.229).

The second community was found on the periphyton covered rock substrates at the 20- and 30-ft depth locations (p.229). Preoperational representative taxa were the worms *Limnodrilus hoffmeisteri* and *Vejdovskyella intermedia* and the midges *Microtendipes* sp., *Parakiefferiella* sp. and *Thienemannimyia* Series (p.229). Densities and seasonal distributions for each representative taxon were similar at all 20- and 30-ft locations (p. 230 and 236). Few significant ($P \leq 0.05$) differences were found in the representative taxa densities between locations along the same depth contour (p.236).

Differences between preoperational and operational species composition inside the discharge zone did not constitute an appreciable alteration in the macroinvertebrate community (p.239). Operational representative taxa densities and seasonal distributions inside the discharge zone were similar to densities and seasonal distributions before operation (p.241). Most of the significant ($P \leq 0.05$) differences in operational representative taxa densities between locations inside and outside the discharge zone were attributed to substrate variations (p.243).

Effects of the KNPP thermal discharge on the macroinvertebrate community inside the discharge zone could not be detected, since preoperational and operational densities of the major taxa were similar (p.243).

Representative taxa densities in the Receiving Water Body varied between preoperational and operational periods at locations along the same depth contour (p.251). Most significant ($P \leq 0.05$) differences in representative taxa densities were attributed variations in substrates sampled (p.251). It was concluded that the benthic macroinvertebrates in the Receiving Water Body were not appreciably harmed by the KNPP thermal discharge (p.251).

2.3.3 Phytoplankton

Phytoplankton community structure was studied near Kewaunee Nuclear Power Plant prior to plant operation from May 1972 through April 1974. Phytoplankton density ranged from 332 to 12845 reporting units per milliliter with decreasing abundance observed as distance from shore increased. Phytoplankton near KNPP demonstrated a bimodal periodicity pattern with maxima in spring and fall (p.258). Diatoms dominated the phytoplankton assemblage with green algae the second most diverse group followed by golden-brown and blue-green algae (p.261). Species composition reported near KNPP is typical of nearshore western Lake Michigan as demonstrated by earlier investigators (p.269-274). Data generated during the study indicate only low numbers of nuisance algae exist in the vicinity of KNPP (p.277).

Effects of condenser passage on phytoplankton measured during periods when no heat was exchanged across the condensers (ΔT absent) were observed from March 1973 through April 1974. Immediately following condenser passage with no ΔT, mean reductions of 7%, 12% and 6% were recorded for phytoplankton abundance, carbon fixation rate and chlorophyll a concentration, respectively (p.281-282). No further delayed effects (or recovery) were measured after a 72-hour holding period (p.282). Effects of condenser passage with ΔT present were measured from May 1974 through July 1975. Changes in total phytoplankton abundance measured at the discharge relative to the intake have no consistent relationship to either magnitude of ΔT or ambient Lake Michigan water temperature and resulted in a mean change of <2% (p.285).

No change was observed after the 72-hour holding period (p.285 and 288). A similar depression ($\overline{x}$ = 3%) of chlorophyll a concentration was measured immediately following condenser passage with ΔT and remained the same at the end of the 72-hour holding period indicating no further delayed effects (p.288). A slight (4%) overall stimulation of productivity has been measured at Kewaunee immediately following condenser passage with a ΔT. This is an increase of approximately 16% when compared with the mean 12% reduction noted with a ΔT absent (p.289). Phytoplankton entrained in the thermal plume from KNPP had elevated abundances, carbon fixation rates and chlorophyll a concentrations relative to phytoplankton from a control location. Recovery to near ambient levels of abundance, carbon fixation rate and chlorophyll a concentrations was demonstrated by the time the organisms had reached the outer edge of the thermal plume (p.290 and 291). Again, no long-term effects were observed after the 72-holding period (p.291).

The effect of thermal effluent from KNPP on the phytoplankton community of the receiving waters has been assessed through a comparison of discharge and control areas as well as preoperational-operational data comparisons. Total phytoplankton abundance increased from the preoperational to the operational period due primarily to the occurrence of large numbers of epilithic diatoms (p.296 and 298). A similar increase in the control area measured in 1974 suggests this trend may be due to natural variations. Diatoms remained the most abundant division within experimental and control areas as well as between preoperational and operational periods (p.298). A measurable increase in epilithic diatoms occurred in the discharge area from preoperational to operational periods. The occurrence of these species in the plume area appears seasonally influenced and relates to the scouring action of water in the discharge canal (p.303). Abundant growth of Fragillaria pinnata was recorded in periphyton samples from the discharge canal wall and may be the source of the concentrations of this species in the discharge area plankton. Major algal divisions other than diatoms showed no notable changes throughout the four-year study (p.303 and 305). The bimodal periodicity pattern remained constant from preoperational to operational periods as well as between experimental and control areas (p.305).

Results of phytoplankton studies at control locations indicate that phytoplankton community structure in the western nearshore area of Lake Michigan in the vicinity of KNPP have remained essentially unchanged from the preoperational period (1972-1973) to the operational period (1974-1975)(p.305).

In conclusion, there has been no appreciable harm to the phytoplankton community in either the discharge zone or the receiving water body.

2.3.4 Zooplankton

Zooplankton samples collected from 1971 through 1975 contained a total of 80 taxa. Even though there were considerable differences in zooplankton density between years, a basic pattern of seasonal fluctuation was obvious (Densities were lowest in early spring, increased to a maximum between mid-summer and early fall and generally decreased in the late fall) (p.322). Some of the differences observed in densities between years were related to changes in sampling equipment (p.318). *Bosmina longirostris* and *Cyclops bicuspidatus thomasi* dominated the zooplankton community from 1971 through 1973 (when large meshed nets were used) while immature copepods, the rotifers *Synchaeta*, *Keratella*, *Notholca* and *Polyarthra* with the cladoceran *Bosmina longirostris* dominated the community in 1974 and 1975 (when small meshed nets were used)(p.321).

The 1972 data were used to document variations in composition and density that can occur in a few days. Large differences were reported between samples collected two days apart. These were not considered to be the result of recruitment but indicative of plankton patchiness (p.331-333).

Large differences in population density were observed and documented among locations during the preoperational period. These spatial differences were related to natural variables (p.333-336). Similar differences were observed during the operational period but were not attributed to plant operation since there was no correlation with the thermal plume (p.357-375).

Effects of condenser passage on zooplankton were divided into three categories: mechanical effects due to entrainment without a ΔT, thermal and mechanical effects due to entrainment with a ΔT and plume effects from the mixing of heated discharge and ambient lake water.

When there was no ΔT, zooplankton immotilities just after collection averaged 6.0% while mortalities four hours after collection averaged 4.5% (p.338). This indicated that there was a 25% recovery of the initially immotile organisms. When there was a ΔT, immotility averaged 9.4% while four-hour mortalities averaged 8.5% (p.338). There was no direct correlation between increase in ΔT and zooplankton immotilities. Highest zooplankton immotilities of 18% occurred when the ΔT was 9.5 C while immotilities were only 9% when the ΔT was 15 C (p.346). Lethal temperature limits of zooplankton for which this data are known were presented and were found to be in excess of the worst case conditions defined in the technical specifications for KNPP (p.346). Other studies have shown that water temperatures below 35 C with an exposure time of less than five minutes during the summer do not cause substantial mortalities (p.348).

When comparing the results with no ΔT to those with ΔT, it was found that mechanical effects accounted for much of the immotilities observed (p.348). Binomial regression analysis revealed that immotility of organisms was a linear function of species size when there was no ΔT and that, when a ΔT was present, the immotilities were only slightly higher (p.348). Therefore, mechanical damage was the primary factor in entrainment immotilities.

Plume immotilities were highest at the discharge and decreased as the discharge mixed with lake water. Plume entrainment appeared to have no effect on zooplankton viability (p.353) and plume temperatures did not reach critical thermal tolerance levels for zooplankton (p.353).

Data from the preoperational period were compared to data from the operational period. In both the Cladocera and Copepoda groups (whose densities could be compared for all years) densities were found to be quite similar between the preoperational and operational years (p.359 and 361). An exception to this occurred in early spring 1975 when densities were highest at the discharge and a control location. Densities of Chydorus were higher at the discharge location than other locations; but, since this peak did not last, the effect was not considered important (p.359). The higher densities at the control location were related to Bosmina longirostris but this was not related to plant operation since the location was not under the influence of the plume (p.361).

An examination of community structure between locations inside and locations outside the thermal plume revealed that there was great similarity between locations (p.365-375). No substantial alterations in community structure were found and it was concluded that operation of the plant had not caused appreciable harm to the zooplankton community in the discharge zone (p.375).

The evaluation of effect on the zooplankton community outside the discharge zone was related to the conclusions drawn concerning effects inside the discharge zone. It was concluded that, since no effect was positively identified inside the discharge zone none could be identified outside (p.376). It was also demonstrated that variations in density and composition became less pronounced at greater depths so that small changes in the community in the discharge zone would be undetectable outside the discharge zone (p.377). It was concluded that operation of KNPP had no effect on the zooplankton community outside the discharge zone (p.377).

2.3.5 Periphyton

Samples of periphytic algae were collected from natural shoreline substrates in the vicinity of Kewaunee Nuclear Power Plant from 1971 through July 1975 (p.383). Qualitative analyses were conducted in 1971 and 1972 with quantitative procedures employed thereafter.

There was a consistent seasonal trend in the size of the periphyton standing crop observed during both preoperational and operational periods. Relatively smaller standing crops were encountered in April and May; whereas, the largest standing crops were usually encountered in November (p.385). There were some general differences between locations in the size of the standing crops. A combination of a paucity of substrates and the propensity for scouring due to eroding bluffs and shifting sands resulted in relatively smaller standing crops at the North Control (Location 1)(p.392). Relatively larger standing crops encountered on either side of the discharge canal (Locations 25 and 26) during November 1973-74 were a result of a larger number of substrates available for algal colonization than were present at either of the two control locations. The substrates consisted of rip rap placed at Locations 25 and 26 during construction of the Plant to prevent shoreline erosion. In addition, the substrates at Locations 25 and 26 were usually protected from harsh lake conditions by variations in shoreline and bottom topography (p.393).

The most abundant algae encountered were Ulothrix and Cladophora glomerata (green algae). The largest standing crops of

Cladophora glomerata were generally encountered during September and November; whereas, the largest standing crops of Ulothrix were generally encountered during April, May and July (p.395). The occurrence of these species was most commonly regulated by their different temperature optima (p.395); by the transitional algal growth pattern which occurs after substrate scouring (p.397); and by substrate orientation (p.398).

Diatoms were the second most abundant algal group encountered at the locations bracketing KNPP (p.399). There were no consistent differences in the densities of total diatoms and dominant taxa among locations outside of the discharge canal. The high densities of diatoms encountered during April and May 1975 in the discharge canal and some of the dominant species (i.e., the high numbers of Navicula c.f. radiosa which were restricted to the discharge canal) were probably indicative of the unique canal environment (p.411).

Blue-green algae were usually minor constituents of the periphyton community although relatively high densities of blue-greens were occasionally encountered at the South Control location (Location 18)(p.400). The size of the standing crops of blue-greens in the discharge canal was not distinctly different from other locations particularly at the South Control (p.412). Lyngbya aerugineo-caerulea was the most commonly occurring blue-green at the locations other than the discharge canal (p.406); whereas, the discharge canal populations were usually dominated by Phormidium c.f. retzii and L. aerugineo-caerulea (p. 412). The high numbers of P. c.f. retzii were particularly confined to the discharge canal and were probably indicative of the canal environment.

The seasonal variation between Ulothrix and Cladophora (p.409), the typical occurrence of the dominant diatoms (p.411) and the size of the standing crops (p.412) within the discharge canal were similar to the shoreline periphyton community structure. The occurrence of occasionally higher numbers of diatoms, occasionally higher percentages of blue-green algae and the presence of some of the dominant species in the discharge canal (primarily Navicula c.f. radiosa and Phormidium c.f. retzii) were very localized effects of the operation of KNPP.

Differences in the periphyton assemblages among locations outside the discharge zone were comparable between preoperational and operational periods of KNPP and therefore could not be reflective of any effect of station operation (p.417). This conclusion was particularly supported by the absence at the North and South Control locations of high numbers of some of the species typical to the discharge canal periphyton assemblage.

2.3.6 Macrophytes

No macrophytes were observed in the vicinity of Kewaunee Nuclear Power Plant in either the preoperational or operational study periods (p.421). Due to the absence of aquatic macrophytes no assessment of potential impact of the thermal discharge was made (p.421).

2.4 Demonstration Conclusion

In previous subsections of this Narrative Summary, the environment in the vicinity of Kewaunee Nuclear Power Plant has been described, the discharge zone has been delineated and the major conclusions regarding the effect of the thermal discharge on water quality and the aquatic biota have been presented. Since it has been found that no harm has resulted to the aquatic biota (some potential benefits have been found and all alterations to the aquatic biota were found to be insignificant), it is concluded that the thermal component of the Plant discharge has not disturbed the balanced indigenous communities of fish, shellfish and wildlife in Lake Michigan. Therefore, the limitations imposed by Chapter NR 102 of the Lake Michigan thermal standards through the WPDES Permit issued by the Wisconsin Department of Natural Resources are more stringent than necessary. A modification of the discharge limitations permitting a continuation of thermal discharges will assure the protection and propagation of the balanced indigenous communities of fish, shellfish and wildlife in the vicinity of Kewaunee Nuclear Power Plant. Wisconsin Public Service Corporation thereby requests relief from these limitations for the Kewaunee Nuclear Power Plant as provided by federal regulations under Section 316(a) of Public Law 92-500.

3.0 Kewaunee Nuclear Power Plant

3.1 Description

The Kewaunee Nuclear Power Plant (KNPP) utilizes a pressurized water reactor licensed at 1650 MWt. The turbine generator is capable of producing 540 MWe net (560 MWe gross) of electrical power. The reactor is rated at an ultimate output of 1721.4 MWt with a generator gross output of 586 MWe.

The Plant uses Lake Michigan water in a once-through cooling system which has a shoreline discharge. The cooling water intake structure is located approximately 1,600 ft offshore at a depth of 16 ft. Condenser cooling water is drawn from Lake Michigan at a rate of 287,000 gallons per minute (gpm) during winter and 413,000 gpm during summer. Cooling water is discharged into an outlet basin at the shoreline through a pipe located just below the lake surface.

3.2 Location

Kewaunee Nuclear Power Plant is located on the west shore of Lake Michigan, approximately 8 miles south of Kewaunee, 27 miles southeast of Green Bay and 90 miles north of Milwaukee, Wisconsin. The Plant site is in Carlton Township in the southeast corner of Kewaunee County, Wisconsin.

The total acreage owned as Plant site is 907.57 acres. Overall ground surface at the site is gently rolling to flat with elevations varying from 10 to 100 ft above the level of Lake Michigan. The land surface slopes gradually toward the lake from the higher areas west of the site. The major surface drainage is from three intermittent creeks which pass through the site and discharge into Lake Michigan. At the northern and southern edges of the site, bluffs face the Lake Michigan shore; near the center of the site, the land slopes to a sandy beach.

3.3 Operational History

The Kewaunee Nuclear Power Plant achieved initial criticality on March 7, 1974, at 0813 hours. Initial power generation was reached on April 8, 1974, and the plant was declared commercial on June 16, 1974.

Additional detailed information on the operation of Kewaunee Nuclear Power Plant is available in the following reports:

1. Semi-Annual Operating Report, July 1 through December 31, 1974;
2. Semi-Annual Operating Report, January 1 through June 30, 1975; and
3. Semi-Annual Operating Report, July 1 through December 31, 1975.

3.3.1 Evidence of Compliance with Water Quality Standards

Data collected near Kewaunee Nuclear Power Plant between June 1974 and November 1975 (Ellis 1975, 1976) were compared to applicable water quality standards of the Wisconsin Department of Natural Resources (Chapter NR 102 July 1975). All parameters analyzed were at acceptable state levels. The applicable State Standards related to general water use, fish and aquatic life, recreational use and public water supply. The parameters for which standards exist and the ranges of these parameters in the immediate discharge area are presented below:

	State of Wisconsin Standard	Range of Values near KNPP
Dissolved Oxygen	5 mg/l	9.2-12.6 mg/l
pH	6.0-9.0	8.0-8.6
Fecal Coliform Bacteria	400/100ml	<10/100 ml
Total Dissolved Solids	500 mg/l monthly or 750 mg/l at any time	139-228 mg/l

No unathorized concentrations of substances that alone or in combination with other materials that are known to be toxic to Lake Michigan fish or other aquatic life were present in the KNPP discharge zone. No biocides are presently being used in operation of KNPP.

3.3.2 Records of Shutdowns and Effects

Plant shutdowns during the reporting period are shown in Table 3.3.1 including a short description of the cause, the duration and the corrective actions taken.

Malfunctions and failures of feedwater pumps, the turbine EH control system and two 4160 V bus repairs caused the majority of the plant generation losses.

The effects of Plant shutdowns on the fish populations of Lake Michigan near KNPP are addressed in Section 4.3.1 Fish.

Table 3.3.1. Plant shutdowns, July 1974-June 1975.

Date	Cause	Method of Shutdown	Duration[a] Hours	Plant Status During Shutdown	Corrective Action Taken
7/1/74	Scheduled maint. and test of 100% trip on 6/28/74	Reactor & turbine trip	229.5	Cold shutdown	Repaired leaking manways and valves on NSSS
8/27/74	Broken air line to MSIV	Reactor & turbine trip	11.75	Hot shutdown	Repaired air line
8/27/74	Steam generator steam flow/feed flow mismatch during unit startup	Reactor & turbine	5	Hot shutdown	None
9/2/74	Load reduction of 25% at request of load dispatcher	N/A	0	Reduced load	N/A
9/7/74	Loss of condenser vacuum	N/A	0	Reduced load	Cleaned condensate return tank level control valve
9/8/74	Improper sequencing of turbine control valves	Normal	13.2	Hot shutdown	Check proper sequencing
9/10/74	Broken air line caused MSIV to dip	Reactor & turbine trip	11.6	Hot shutdown	Repaired air line
9/19/74	Scheduled maint. and testing	Normal	711.6	Cold shutdown	Eddy current testing and sludge lance of steam generators
10/26/74	Scheduled maint. on feedwater valve	Normal turbine shutdown. Reactor not shutdown.	20.15	Hot standby	Repaired feedwater pump suction valve
10/31/74	Technician error	Reactor & turbine trip	2.36	Hot shutdown	Cautioned technician to be more careful
11/8/74	Scheduled maint. on feed pump	Normal turbine shutdown. Reactor not shutdown.	42.0	Hot standby	Repaired feed pump

Table 3.3.1. (continued)

Date	Cause	Method of Shutdown	Duration Hours	Plant Status During Shutdown	Corrective Action Taken
11/28/74	Operator error	Reactor & turbine	62.5	Hot shutdown	Operator erroneously opened generator breaker. Experienced turbine control problems while coming backup (not related to the trip)
12/22/74	Forced maint. on a secondary side steam leak	Normal turbine shutdown. Reactor not shutdown	7.45	Hot standby	Reweld annubar on heater drain pipe
1/4/75	Sticking feedwater regulation valve	Manual reduction and trip	25.2	Reduced load	Repaired regulating valve
1/18/75	Feedwater heater inspection and charging line weld repair	Manual	38.7	Hot shutdown	Repaired weld
1/27/75	Turbine overspeed power supply failure	Turbine trip	2.4	Hot shutdown	Repaired power supply
1/25/75	To check for condenser tube leak	Manual	0.0	Reduced load	N/A
2/7/75	Turbine E-H Control erratic	Manual	28.2	Hot shutdown	Repaired and adjusted controller
2/21/75	To repair SG inst. line leak	Manual	7.2	Reduced load	Repaired fitting leak
3/19/75	Spurious closure of turbine stop valve	Runback	0.0	Reduced load	N/A
3/20/75	Spurious closure of turbine stop valve	Runback	0.0	Reduced load	Filtered turbine E-H checked control system
3/28/75	345 KV breaker opened & reheater safety valve gasket leak	Manual	30.8	Hot shutdown	Repaired gasket leak adjusted E-H control

Table 3.3.1. (continued)

Date	Cause	Method of Shutdown	Duration Hours	Plant Status During Shutdown	Corrective Action Taken
3/29/75	Erratic turbine E-H control	Manual	0.0	Reduced load	Adjusted control system
4/2/75	Fault in 4160V main aux. transformer bus	Reactor trip	14.0	Hot shutdown	Switched to reserve aux. transformer
4/5/75	Turbine E-H control repair	Manual	26.4	Hot shutdown	Repair of E-H control by vendor
4/19/75	Turbine E-H fluid leak	Manual	0.0	Reduced load	Repaired leak on intercept valve
4/26/75	Overheating of reserve aux. bus	Manual	101.1	Cold shutdown	Repaired bus connections
5/2/75	Operator error wrong switch operated	Manual	2.83	Hot shutdown	N/A
5/3/75	Turbine E-H fluid leak	Manual	0.0	Reduced load	Repaired leak on intercept valve
5/7/75	Leak in feedwater pump recirculation line	Manual	13.04	Hot shutdown	Repaired crack in 1" line
5/18/75	Feedwater pump failure	Reactor trip	7.95	Hot shutdown	Replacing pump casing
6/19/75	Feedwater pump motor failure	Reactor trip	7.52	Hot shutdown	Motor removed for repair
6/28/75	Feedwater regulating valve not functioning	Reactor trip	11.45	Hot shutdown	Cleaned valve

[a] From generator breaker open to close.

3.3.3 Water Quality Communications

Wisconsin Public Service Corporation has one water quality communication from the Wisconsin Department of Natural Resources to Mr. E. James related to the operation of the Kewaunee Nuclear Power Plant. This communication dated August 3, 1973 from the Division of Environmental Protection (Appendix 1) certified that the proposed KNPP discharge would be in compliance with water quality standards for Lake Michigan as set forth in Chapters NR 102 and 103 of the Wisconsin Administrative Code.

4.0 ENVIRONMENTAL EFFECTS OF PLANT OPERATION

4.1 ENGINEERING AND HYDROLOGICAL DATA

4.1.1 Circulating Water System

The Kewaunee Nuclear Power Plant employs a single pressurized-water reactor and a turbine-generator system with a license power level of 1650 MWt (540 MWe net). The maximum anticipated power capability of the Plant is 1721 MWt.

The circulating water system provides once-through cooling of the main condenser of the steam-electric system. The normal flow rate at the condenser is 413,000 gpm (918 ft^3/sec) with a design maximum rise in water temperature of 11.1 C. This cooling rate is equal to 4.1×10^9 BTU/hr. In winter, the lower temperature of the lake water allows a reduced flow operation, such that only 278,000 gpm (618 ft^3/sec) passes through the condenser, with a design maximum temperature rise of 15.6 C (U.S. AEC 1972).

In normal operation, water for the circulating water system is withdrawn from the lake at the intake structure, passed through the condenser and returned to the lake via the discharge structure. The intake structure for the Plant is located approximately 1600 ft from the shore and consists of three inverted cones with 22 ft diameter openings. The tops of these cones are 1 ft above the lake bottom at an elevation of 563 ft (IGLD). At the mean water level of Lake Michigan (577 ft) (IGLD), water is withdrawn from a depth of 14 ft.

The cooling water from the Plant is discharged in a direction perpendicular to the shoreline from an outfall structure located at lake level on the shore line. During winter, water is recirculated at 3000 gpm (John Richmond, Wisconsin Public Service Corporation, personal communication) from the discharge to the intake forebay on an as needed basis for the purpose of deicing. A description of the outfall configuration and operation is presented in Table 4.1.1.

Cooling water characteristics of the Plant for summer (May-November) and winter (December-April) operations are presented in Tables 4.1.2 and 4.1.3, respectively. These results were derived from June 1974-June 1975 Plant operating data supplied by Wisconsin Public Service Corporation and the load was 90% or less approximately 66% of the time in both winter and summer when the Plant was operating.

Records of total heat rejected via the discharge as a function of time are presented in Figures 4.1.1 and 4.1.2. Long-term fluctuations are illustrated by total heat rejected each month during the Plant's first year of operation. Short-term fluctuations are illustrated by daily total heat rejected in June 1974 and February 1975 as examples of summer and winter operations, respectively.

Table 4.1.1. Kewaunee Nuclear Power Plant outfall configuration and operation.

Length of discharge basin:	130 ft
Number of discharge ports:	one
Dimensions of discharge port:	40 ft W x 5 ft D at 577 ft (IGLD)
Area of discharge port:	197 ft^2 at 577 ft (IGLD)
Angle of discharge:	Surface discharge perpendicular to shoreline
Velocity of discharge:	
A. Maximum	6.9 ft/s at low water level of 575.8 ft
B. Most Usual	2.5 ft/s-3.2 ft/s for 2-pump operation during 1974-1975 lake level range 581.4 ft to 579.4 ft
	2.2 ft/s-2.5 ft/s for 1-pump operation during 1974-1975 lake level range 579.4 ft to 578.8 ft

Table 4.1.2. Summer cooling water characterisitics for Kewaunee Nuclear Power Plant, May-November.

Percent Unit Load	Unit Loading (% Time)	Intake Velocity (ft/sec)	Rate of Cooling Water Flow (ft^3/sec)	Design Condenser ΔT (° C)
20	5.5	0.82	918	2.2
40	2.1	0.82	918	4.4
50	1.6	0.82	918	5.6
60	10.0	0.82	918	6.7
70	12.1	0.82	918	7.8
80	15.6	0.82	918	8.9
90	18.7	0.82	918	9.9
100	34.8	0.82	918	11.1

Table 4.1.3. Winter cooling water characterisitics for Kewaunee Nuclear Power Plant, December-April.

Percent Unit Load	Unit Loading (% Time)	Intake Velocity (ft/sec)	Rate of Cooling Water Flow (ft^3/sec)	Design Condenser ΔT (° C)
20	9.7	0.56	625	3.1
40	4.0	0.56	625	6.2
50	1.4	0.56	625	7.8
60	3.6	0.56	625	9.4
70	15.9	0.56	625	10.9
80	28.9	0.56	625	12.5
90	2.8	0.56	625	14.0
100	33.2	0.56	625	15.6

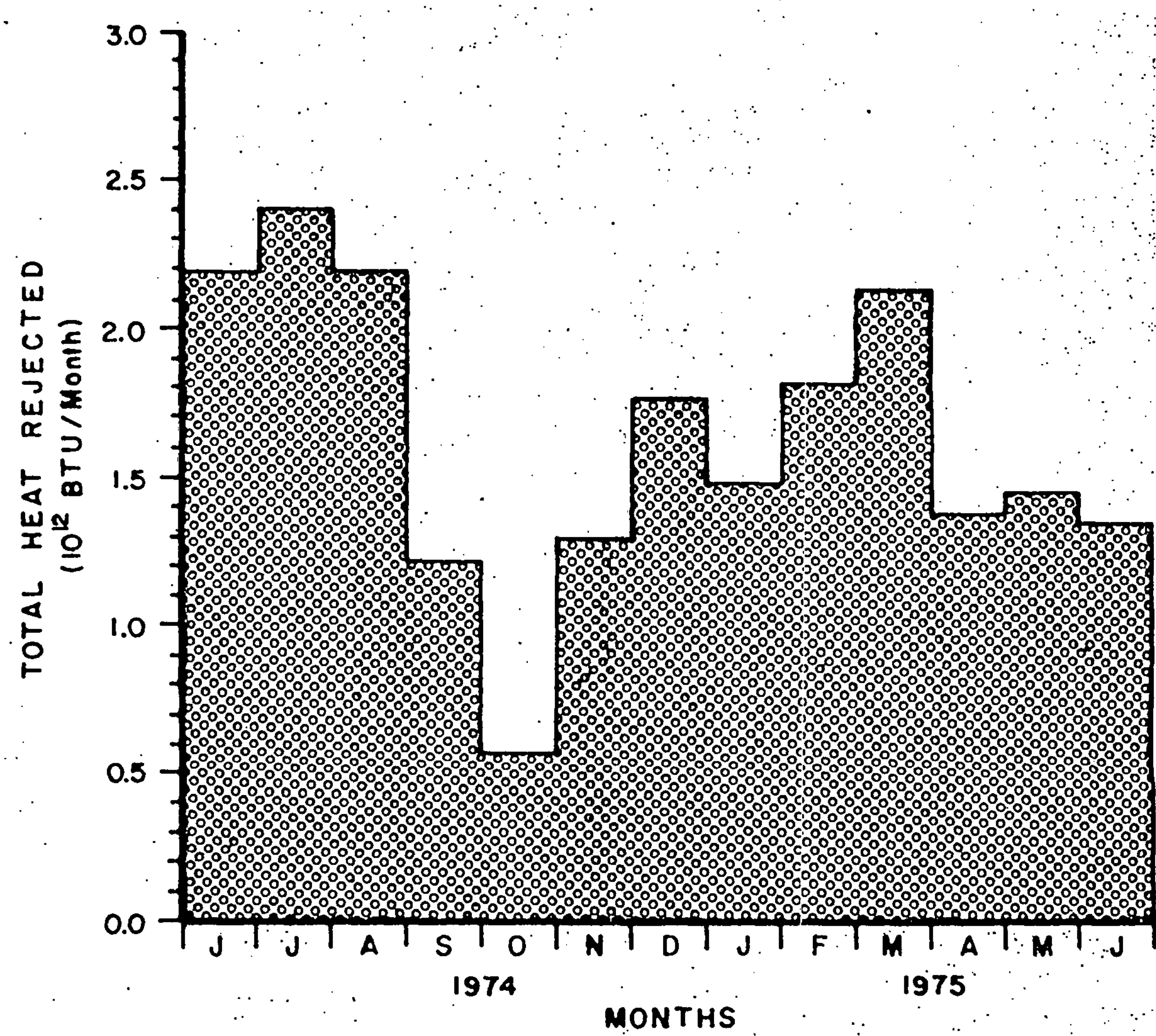
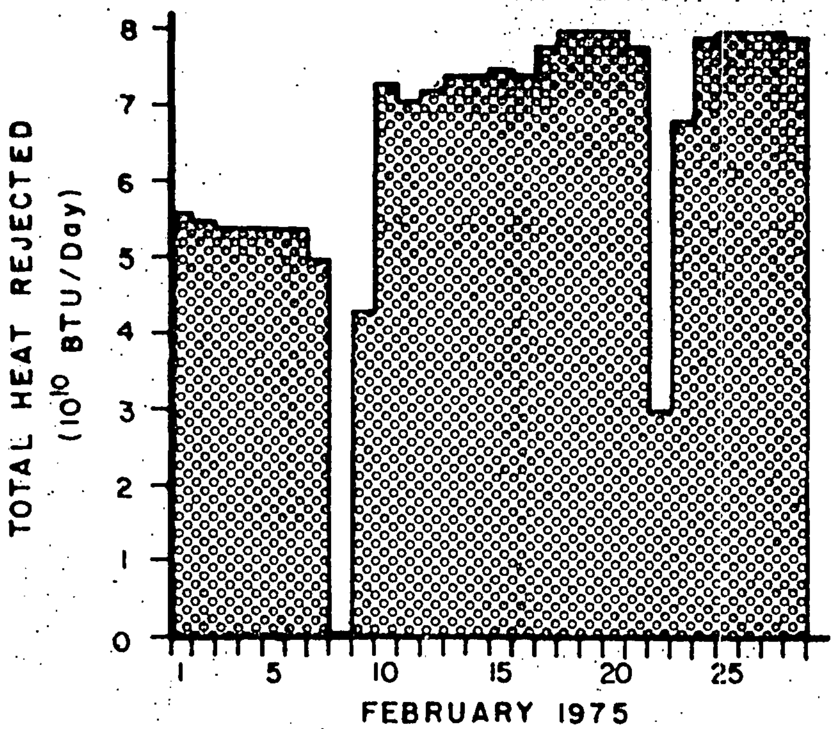


Figure 4.1.1 Monthly mean heat rejected from the Kewaunee Nuclear Power Plant, June 1974-June 1975.



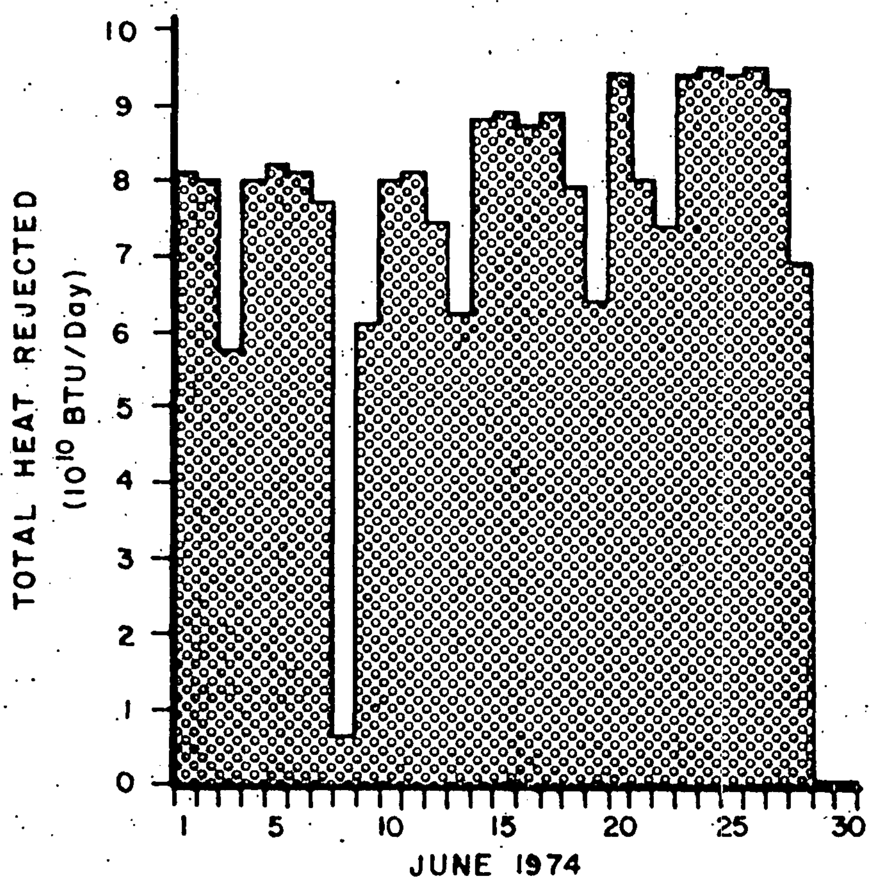


Figure 4.1.2 Daily mean heat rejected from the Kewaunee Nuclear Power Plant during June 1974 and February 1975.

4.1.2 Time-Temperature Relationships

The time-temperature relationship for a thermal discharge indicates the time versus excess temperature exposure history of an organism from the time it is entrained at the intake of a power plant to the point of return to ambient temperature. This relationship is important for assessing the survival potential of the entrained organism.

Time-temperature measurements were made at Kewaunee Nuclear Power Plant in 1974 and 1975 (Industrial BIO-TEST Laboratories, Inc. 1975, p. 23 and 25; 1976, App. 4-A). The data were collected by means of a drogue outfitted with a stripchart recorder and a thermistor set at a depth of 1.6 ft. The drogue, intended to simulate a drifting organism, was released within 108 ft of the outfall structure and allowed to drift with the current while simultaneously recording temperature. A smooth curve was hand fitted to the temperature data to facilitate interpretation.

Time-temperature relationships for the thermal discharge from Kewaunee Nuclear Power Plant are presented in Figure 4.1.3. The initial portion of each curve is based on estimates of the travel time from the intake to the discharge port. The central portion the curves were derived from seven time-temperature profiles for four thermal plumes surveyed on 15 November 1974, 22 November 1974, 20 May 1975, and 21 July 1975. Each curve was extrapolated to ambient temperature based on the location of the drogue when retrieved, ambient current, and extent of the thermal plume.

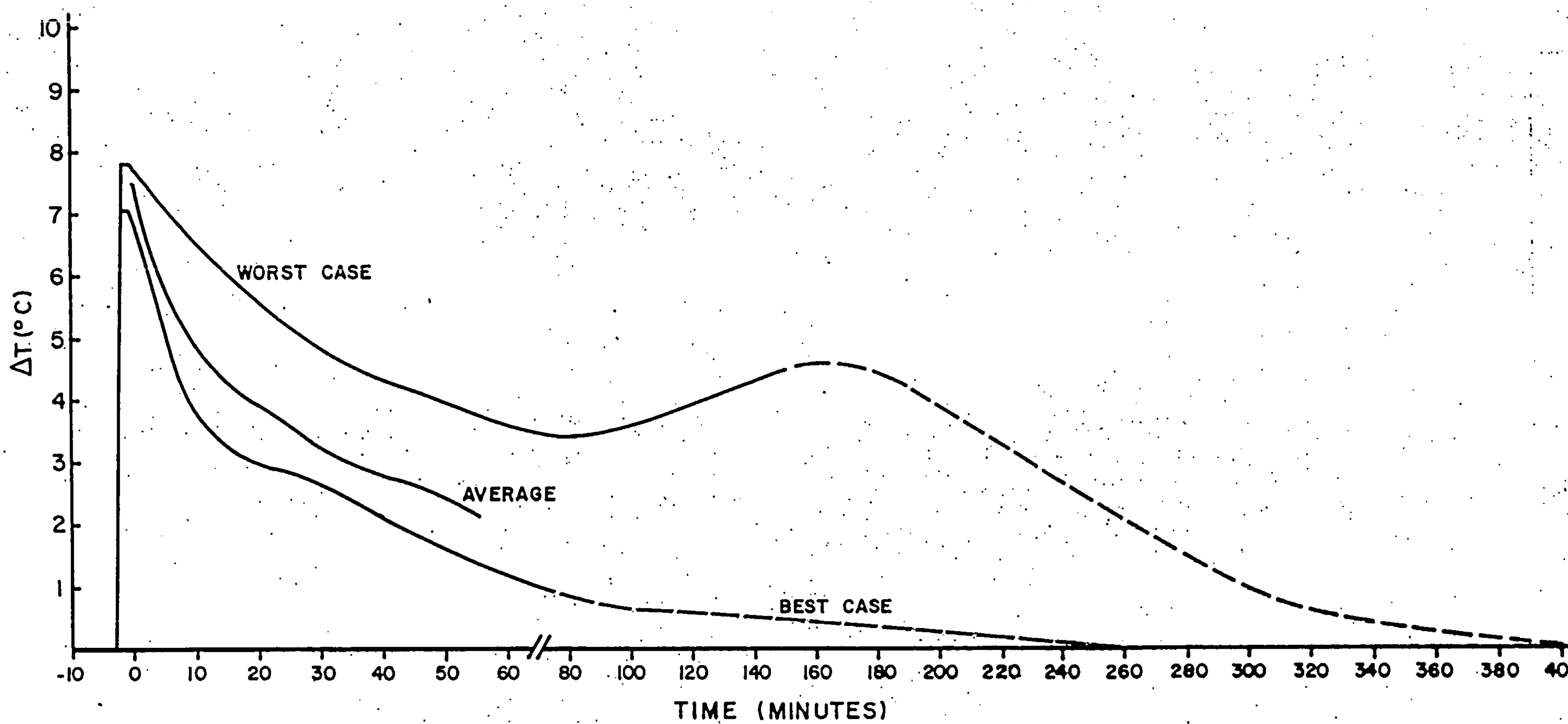


Figure 4.1.3 Time-Temperature profiles for the thermal plume at Kewaunee Nuclear Power Plant. Profiles are plotted as thermal plume excess temperature versus time of travel from the discharge canal outlet. The first 3 minutes are travel time from the intake to the outlet. Dashed line indicates extrapolation.

The average time-temperature relationship shown in Figure 4.1.3 is the mean of the seven measured profiles. The two extreme cases were considered ideal and worst case based on time required to return to ambient.

The reduction in excess temperature within 50 to 75 minutes travel time from the outfall ranges from 55% for the worst case to 90% for the ideal case. The worst case shows a significant increase in excess temperature for travel times longer than 60 to 75 minutes. This is believed to have been a result of the changing configuration of the plume.

4.1.3 Lake Currents

Lake currents in the vicinity of Kewaunee Nuclear Power Plant were measured by Industrial BIO-TEST Laboratories, Inc. in 1973 and 1974 (Industrial BIO-TEST Laboratories, Inc. 1974, Chap. 1; 1975, Chap. 4). The currents were measured by means of moored current meters at a depth of 6.5 ft at each of the mooring locations shown in Figure 4.1.4.

Annual histograms of current direction at each mooring are presented in Figure 4.1.5. The prevailing current directions were parallel to the shore in the direction classes NNE-NE and SSW-SW. Currents approximately 1.55 mi offshore had a somewhat broader distribution in all directions because they were less constrained by the shore line and bathymetry than the currents near shore.

The distribution of wind direction for the period 23 July to 15 December 1974 is also presented in Figure 4.1.5 and represents 68% return of valid data. The prevailing winds were southerly and most frequently ranged from SE to NW. Winds blew least frequently from the ENE.

The bimodal distribution of the current records is not clearly defined in the wind records. Inspection of simultaneous wind and current records (Industrial BIO-TEST Laboratories, Inc. 1975, Chap. 4, p. 30) reveals that the NNE-NE currents are primarily a response to winds from SE to WSW, whereas the S-SW currents occurred during W-NW winds.

Histograms of current speed at each mooring are presented in Figure 4.1.6. The most frequent speed class is

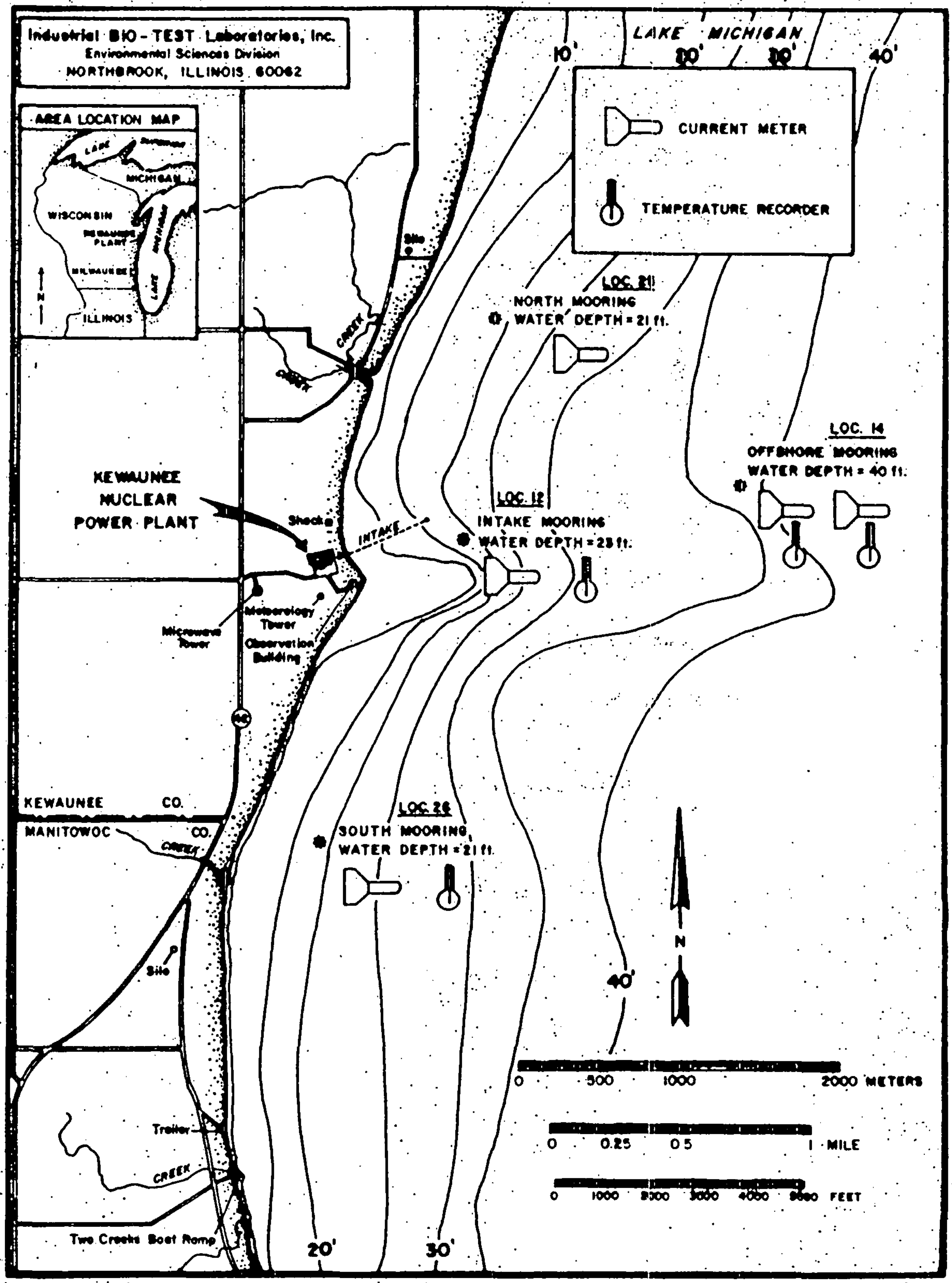


Figure 4.1.4. Current water and thermograph mooring locations in Lake Michigan near Kewaunee Nuclear Power Plant.

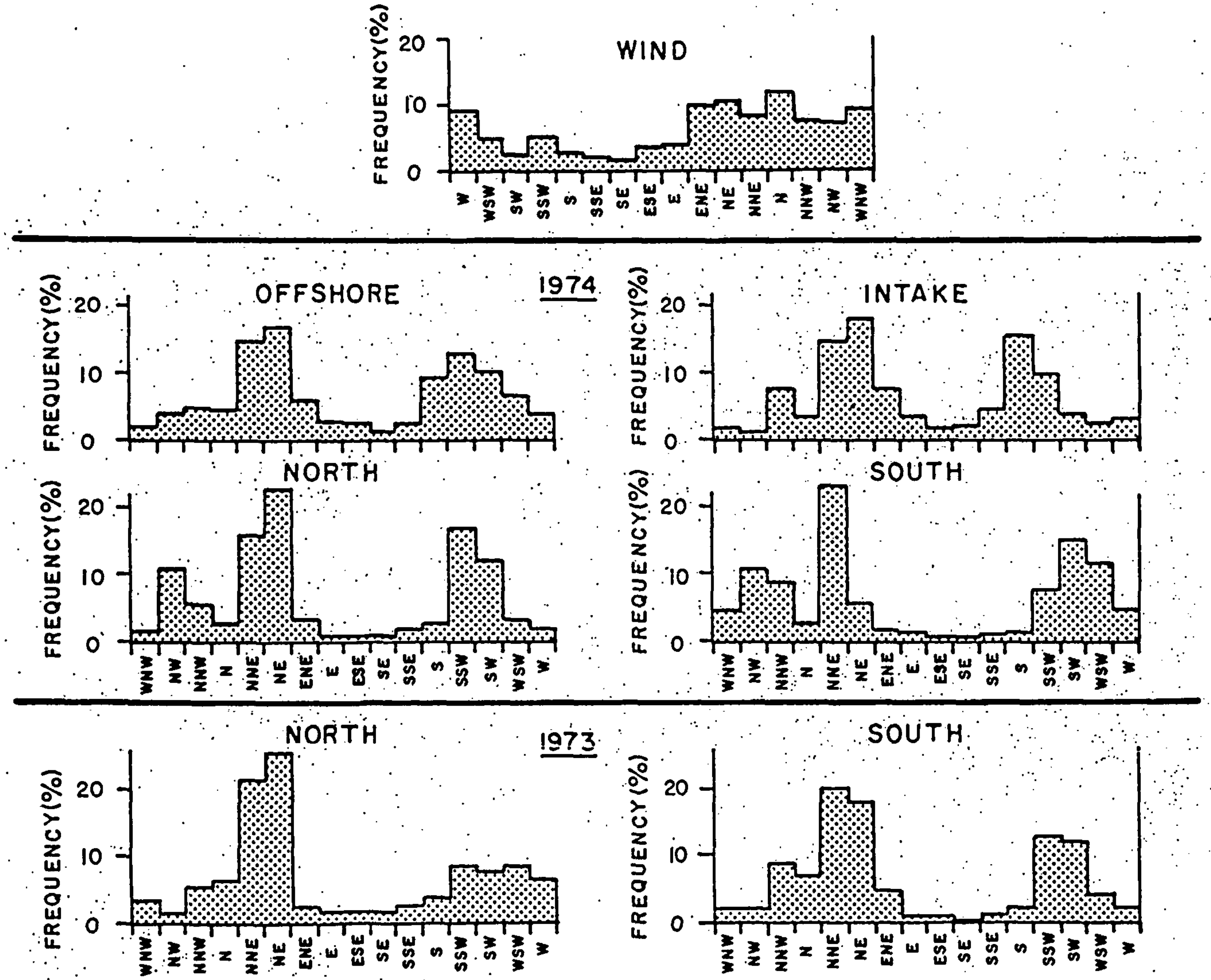


Figure 4.1.5. Histograms of wind and current directions at Kewaunee Nuclear Power Plant on Lake Michigan, 1973-1974. Currents were continuously recorded at a depth of 2 m at the Intake, North, South and Offshore mooring locations.

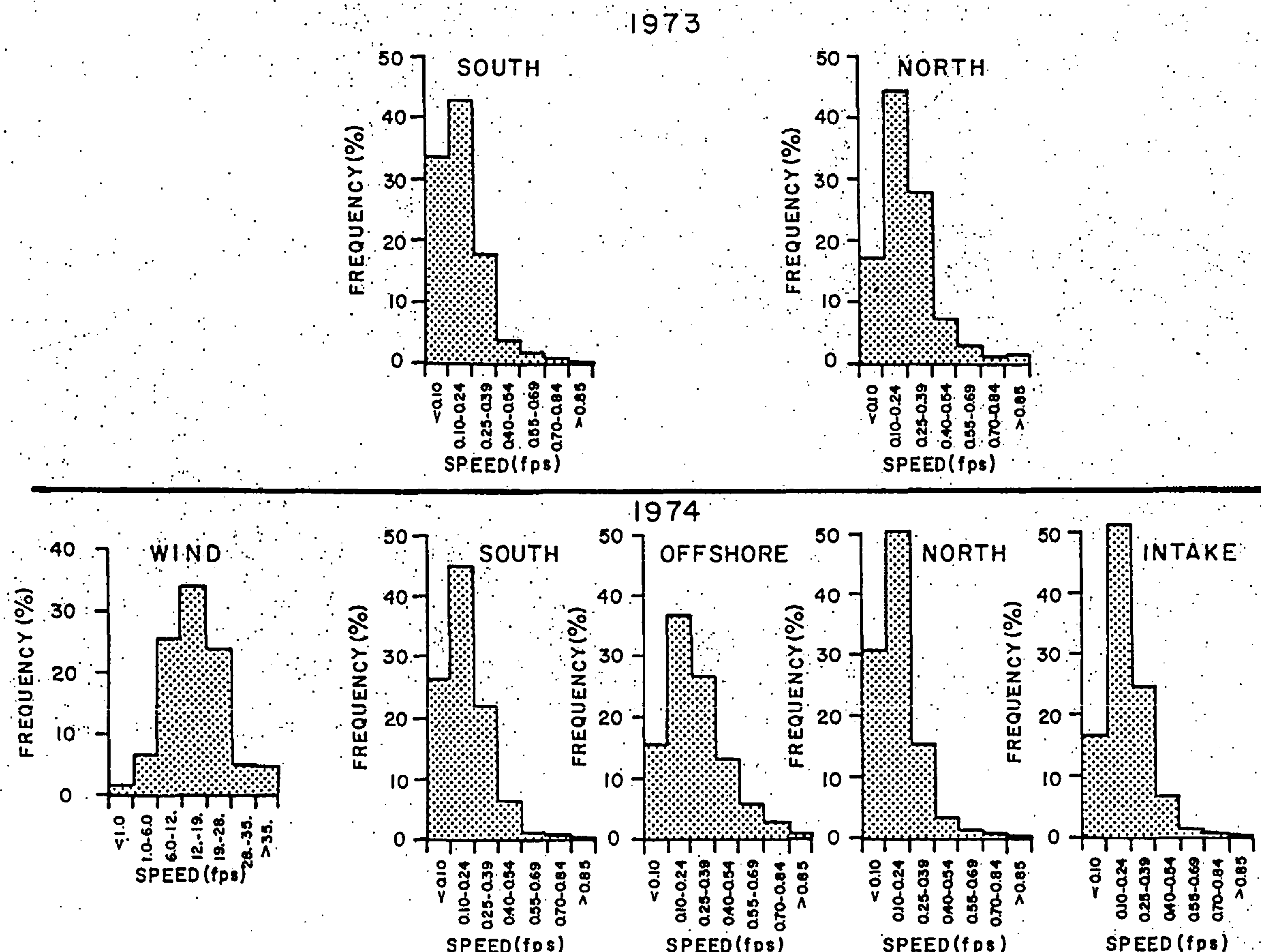


Figure 4.1.6 Histograms of wind and current speeds at Kewaunee Nuclear Power Plant on Lake Michigan, 1973-1974. Currents were continuously recorded at a depth of 2 m at the Intake, North, South, and Offshore mooring locations.

0.10-0.24 fps, occurring approximately 42% of the time. The lowest speed class (<0.10 fps) occurred most frequently at the North Mooring and the higher speed classes occurred most frequently at the Offshore Mooring. There was greater variability of the current speeds 1.55 mi offshore as indicated by the broader current speed distribution at the Offshore Mooring. Table 4.1.4 shows that in most cases the current speeds in any speed class persist for two hours or less and that current direction persists for one hour or less.

Monthly average speeds in 1974 ranged from 0.13 fps to 0.36 fps with the highest speeds at the Offshore Mooring and generally increasing from June to December. The maximum recorded speed was 1.2 fps.

The wind speed distribution for June-December 1974 is presented in Figure 4.1.6. In comparison with current speed histograms, it is apparent that current speeds are approximately one percent of wind speeds.

The monthly occurrence of near calm current conditions (<1.10 fps) for April to December 1973 and June to December 1974 are presented in Figure 4.1.7. The frequency of calm conditions was maximum in June-July and minimum in April-May. A relative minimum and maximum occurred in August-September and October-November, respectively. The frequency of calm conditions was less at the Offshore and Intake Moorings than at the North and South Moorings. This may be a result of water depth and less wind sheltering at the Offshore Mooring and the proximity of the Intake

Table 4.1.4. Persistence of current speed and direction at the Intake Mooring in Lake Michigan near Kewaunee Nuclear Power Plant, June-December 1974. Percent occurrences for which current persisted at any speed or direction for less than or equal to the indicated time.

Persistence (Hours)	Cummulative Percent Direction	Cummulative Percent Speed
1	58	37
2	18	54
3	9	65
4	5	74
5	4	79
10	4	93

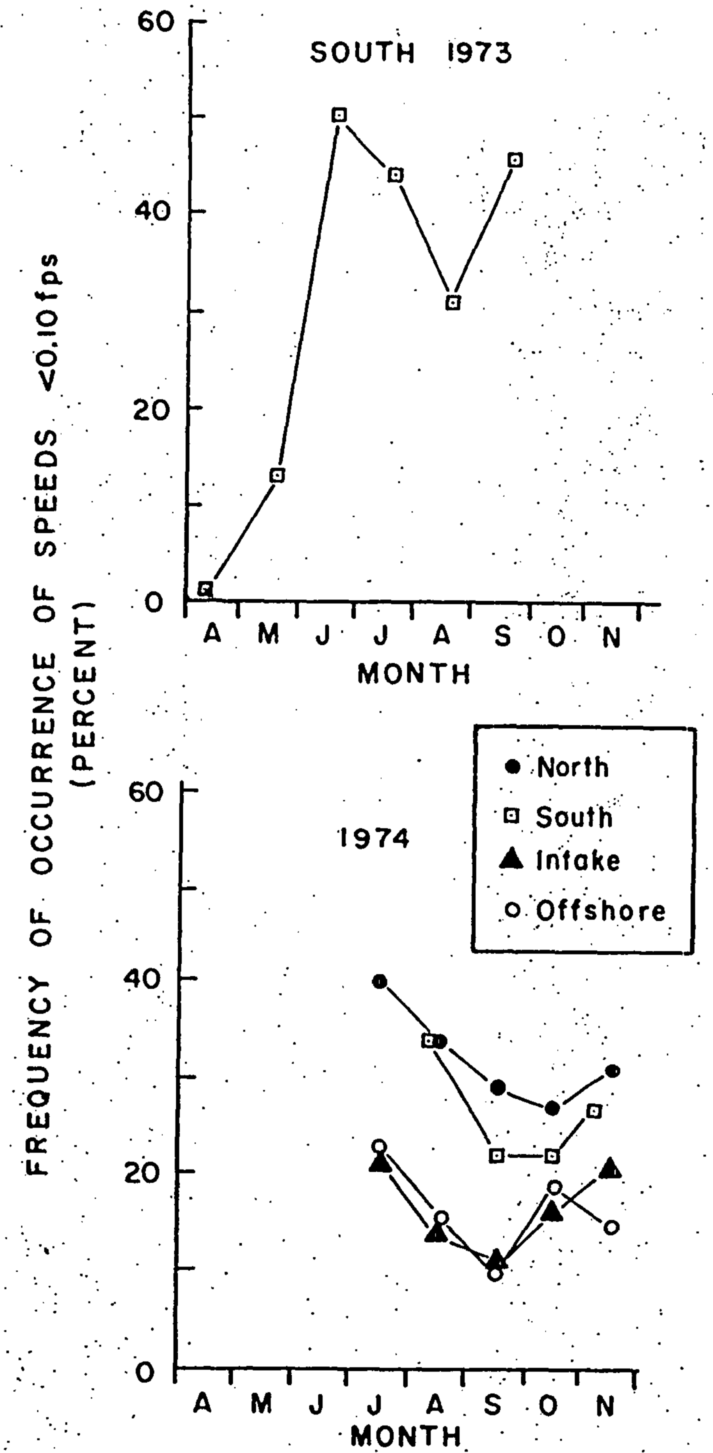


Figure 4.1.7 Frequency of occurence for current speeds less than 0.10 fps in Lake Michigan at Kewaunee Nuclear Power Plant, 1973-1974. Currents were measured at a depth of 2 m at the North, South, and Offshore mooring locations.

Mooring to the discharge outlet. Though not shown, opposite trends are present in the higher speed classes (>0.10 fps) and in the average monthly speeds. These results indicate the general monthly variability of the speed histograms.

The net monthly water displacements at each mooring are presented in Figure 4.1.8 for 1973 and 1974. The length of the arrow is proportional to the displacement and the direction of the arrow indicates the direction of the displacement with respect to True North. Typical monthly net displacements were between 18.6 mi and 37.9 mi northward. The net displacements for the periods April to December 1973 and June to December 1974 were northward. The southward displacements in November and December 1974 were a response to an increase in the frequency of W-NW winds (Industrial BIO-TEST Laboratories, Inc. 1975, Appendix 4-J). Other investigations (FWPCA 1967) indicate that the southward flow is predominant for the period November through March.

The above results agree with the FWPCA observations (FWPCA 1967, Chap. 6, p. 179) that water movements close to shore respond to the winds prevailing over the lake; that the shore currents move northward except for periods in late fall, winter and early spring; and that the average speeds on the western side of the lake range from 0.18 fps to 0.36 fps.

A promontory near KNPP (Figure 4.1.4) is a major topographic feature which has a discernible effect on the current regime near the Plant and its discharge structure. Drogue studies near the promontory in 1974 (Industrial BIO-TEST Laboratories, Inc.

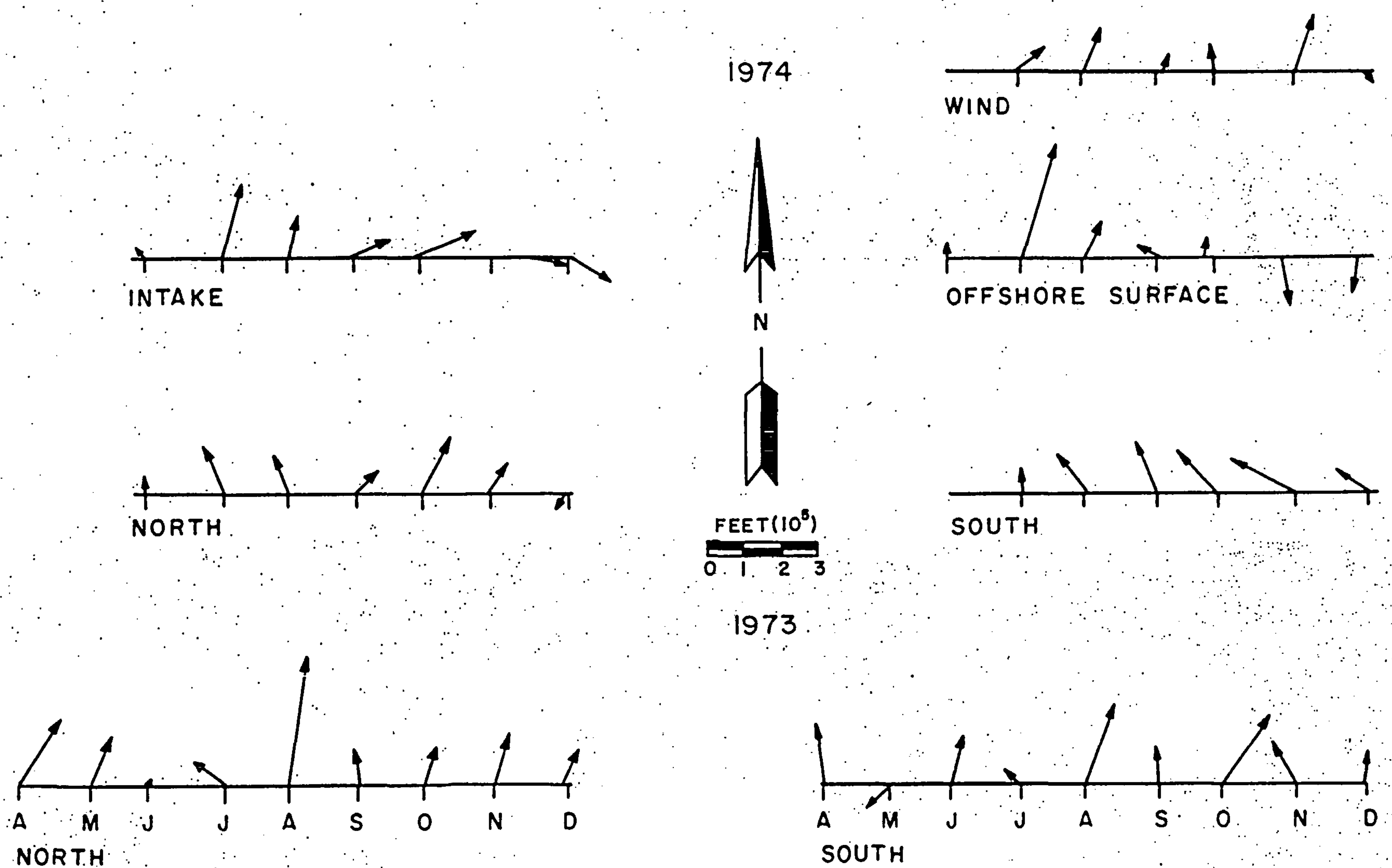


Figure 4.1.8. Monthly net water displacement in Lake Michigan and new wind displacement measured in the vicinity of the Kewaunee Nuclear Power Plant. (Wind displacement is plotted 1/100 the scale shown. The length of the arrow is equivalent to the net displacement and the direction of the arrow is equivalent to the direction of net displacement with respect to True North).

1975, Chap. 5, p. 5) indicated that an eddy circulation north of the promontory was associated with northward currents and affected an area of approximately 104 acres. Southward currents were deflected toward the southeast by the promontory but there was no evidence of an eddy circulation. Results also indicated that the presence of an eddy circulation may depend on the speed of the current.

The effect of the promontory was discernible in other results. For example, the eastward deflection of currents by the promontory was apparent in the consistent eastward component of net water displacement near the Intake Mooring (Figure 4.1.8). However, in 1974, the Plant's thermal discharge may also have been a factor in deflecting the currents eastward at the Intake Mooring.

Drogue studies in the vicinity of KNPP in 1973 and 1974 showed, in agreement with the time-continuous current measurements, that the flow past KNPP was generally spatially homogeneous in speed (Industrial BIO-TEST Laboratories, Inc. 1975, Chap. 4, p. 2). However, the speeds measured at the surface were generally faster by 0.1 to 0.2 fps than those at a depth of 10 ft. There were also directional differences between drogues released at different locations and depths, an effect which was probably due to the bottom topography. Normally, the direction of the drogue trajectory at the surface and the 10 ft depth differed by only a few degrees, but during a period of apparent upwelling on 28 August 1974, the angular difference was appoximately 90 degrees. This indicates the potential for short periods of high current shear even in shallow water.

Current measurements by the FWPCA (FWPCA 1967, Chap. 6, p. 179 and 182) indicate that the offshore currents comprising the general lake circulation are basically separate and quite different from the inshore currents described above. The inshore currents are constrained by boundaries and bottom friction to flow predominantly parallel to shore. The offshore patterns are governed in the winter by long-term wind movements and pressure patterns. During the summer, the net circulation pattern develops into cells which are largely controlled by standing internal waves (FWPCA 1967).

The winter circulation pattern during N-NW winds is southward near the east and west shores and clockwise in both the north and south basins of the lake. Under S-SW winds the winter circulation pattern reverses to northward near the shore and counter-clockwise in the basins. The summer circulation pattern again shows the influence of the prevailing wind direction near shore. However, offshore or mid-lake circulation during the thermally stratified period from early spring through October is dominated by waves of 17 to 18 hour period. These waves produce currents which are rotary in nature and cause opposing flow in the hypolimnion and epilimnion. The net circulation over a period of a month exhibits a cellular structure which is largely controlled by standing internal waves. In the northern basin of the lake, the mid-lake circulation pattern under both N-NE and S-SW winds is comprised of a clockwise circulation cell in the western half and a counterclockwise circulation pattern in the eastern half (FWPCA 1967, Chap. 6, p. 120-126).

4.1.4 Ambient Temperatures and Stratification

Continuous time-series temperature measurements at a depth of 2 m were made concurrently with current measurements in 1973 and 1974 at four mooring locations in Lake Michigan near the Kewaunee Nuclear Power Plant (Figure 4.1.4)(Industrial BIO-TEST Laboratories, Inc. 1974, Chap. 1, p. 8; 1975, Chap. 4, p. 10). Monthly mean temperatures and ranges for 1973 and 1974 are presented in Figure 4.1.9. Only those means which represented more than 80% temperature data for the month were plotted. In both years, maximum means and maximum temperatures occurred in August and the maximum ranges occurred in August 1973 and July 1974. In both years, the mean temperatures each month at all moorings differed by 0.5 C or less.

The periods of greatest temperature range, July-September, were associated with episodes of upwelling. An example of such an event on 7 August 1973 is presented in Figure 4.1.10. In this case the temperature decreased from 19.8 C to 8.5 C in 24 hours resulting in a change of nearly 0.5 C/hour. Upwelling was usually associated with offshore winds (Industrial BIO-TEST Laboratories, Inc. 1974, Chap. 1, p. 22) and often resulted in temperature changes comparable to those associated with Plant operation.

Passage of the thermal bar defined by the 4.0 C isotherm was recorded in both 1973 and 1974. During April 1973, the 4.0 C isotherm progressed from the Intake Mooring to the Offshore Mooring between 17 and 19 April at an average speed of 10.5 ft/hr. The winter thermal bar of 1973 was initially observed at the Intake

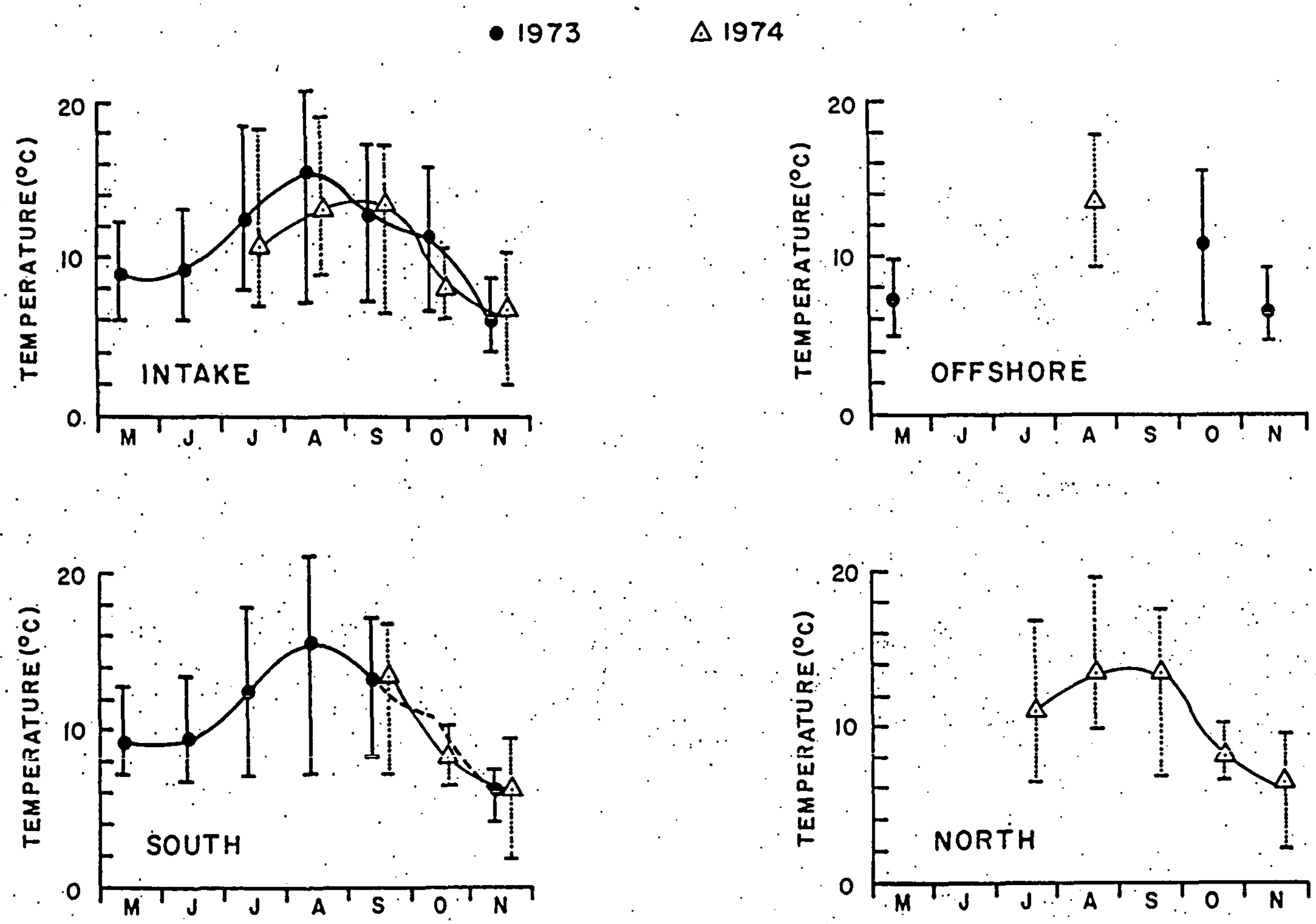


Figure 4.1.9 Monthly mean and range of Lake Michigan temperatures near Kewaunee Nuclear Power Plant, 1973-1974. Temperatures were measured at a depth of 2 m at the North, South, and Offshore mooring locations.

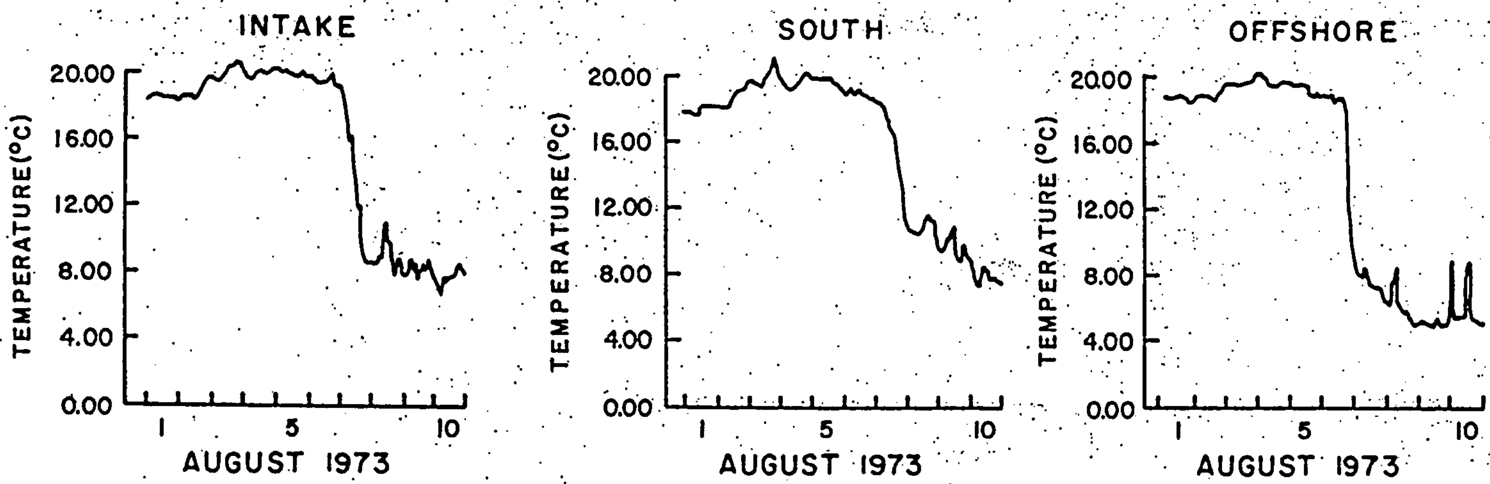


Figure 4.1.10 Upwelling in Lake Michigan near Kewaunee Nuclear Power Plant, August 1973. Temperatures were measured at a depth of 2 m at the Intake, South, and Offshore mooring locations.

Mooring on 1 December. It arrived at the Offshore Mooring on 7 December apparently progressing at an average speed of 3.6 ft/hr. In 1974, instruments were deployed too late to record the spring thermal bar but the winter thermal bar was initially observed at the inshore moorings on 25 November. No data were available for the Offshore Mooring.

Temperature stratification data from sampling loctations nearest the KNPP intake for 1972-1974 are presented in Figure 4.1.11. These data show the temperature difference between surface and bottom and indicate that temperature stratification can develop in the shallow water near the intake but that it is weak and breaks down easily. For example, the August 1972 profiles show a 6.4 C difference between surface (13.7 C) and bottom (7.3 C) on 1 August and nearly isothermal conditions just two days later. The 1974 and 1975 data include the influence of the plume as it passed near the Plant intake. The Plant has a shore line discharge so there is no vertical stratification near the discharge structure.

The annual variation of ambient temperatures of the receiving waters for the years 1964-1975 are presented in Figure 4.1.12 and tabulated in Tables 4.1.5 and 4.1.6. These data are intake temperatures of the Two Rivers municipal water supply and of the Green Bay Water Filtration Plant. The intake of the Two Rivers Plant is located approximately 10.8 mi south of KNPP at a depth of 33 ft and is 1.159 mi offshore. The intake of the Green Bay Plant is located approximately 13 mi north of KNPP at a depth of 55.8 ft and is 1.136 mi offshore. Maximum temperatures most

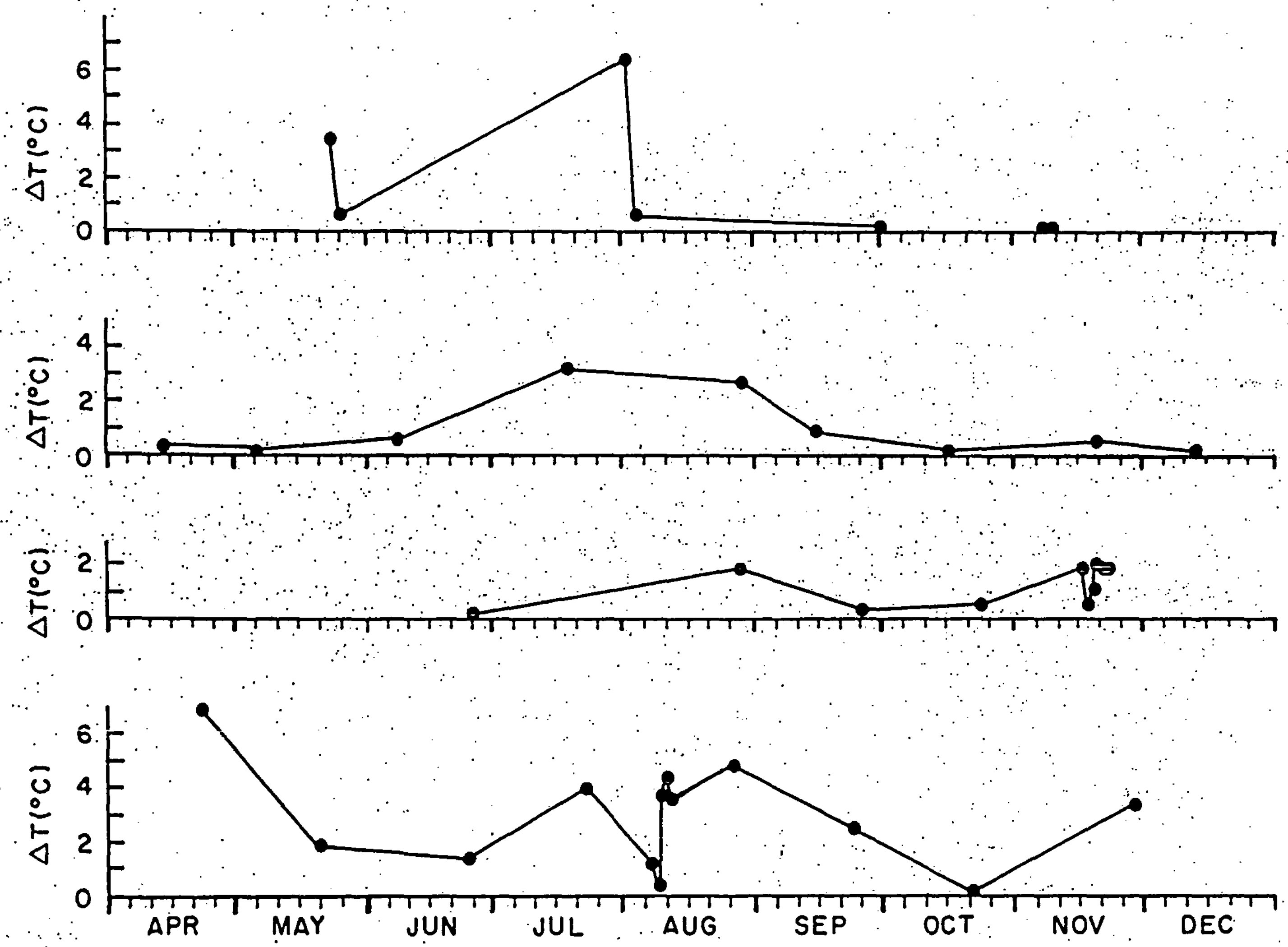


Figure 4.1.11 Temperature stratification characteristics of Lake Michigan near the cooling water intake of Kewaunee Nuclear Power Plant, 1972-1975. ΔT=(surface temperature-bottom temperature).

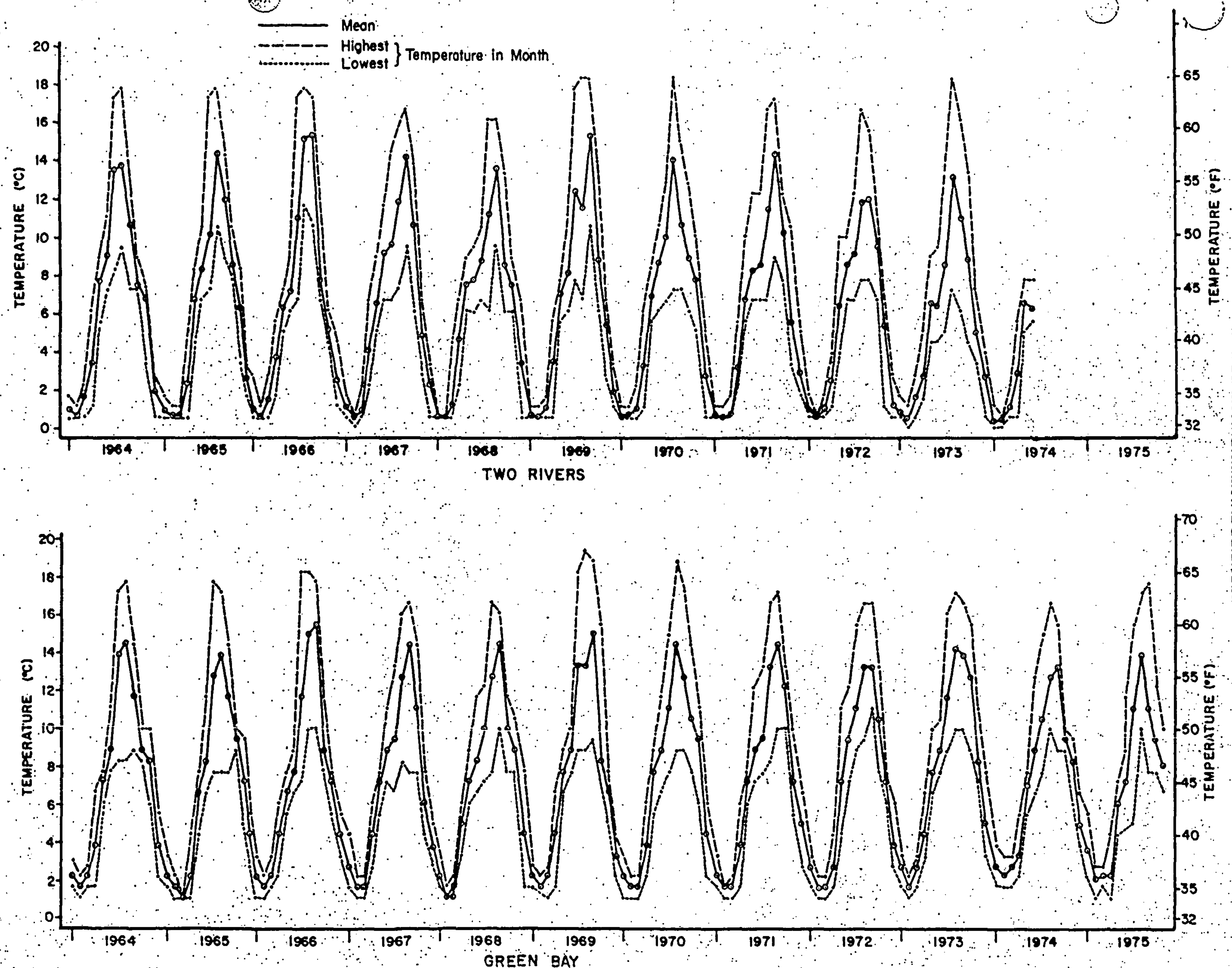


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Figure 4.1.12 Monthly mean and ranges of Lake Michigan temperatures at the intakes of the Two Rivers municipal water supply and the Green Bay water filtration plant.

Table 4.1.5. Monthly averages and extremes of Lake Michigan water temperatures, recorded at the Two Rivers Municipal Water Intake, Two Rivers, Wisconsin, from January 1964 through June 1974. Temperatures in degrees centigrade.

	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Jan.											
Avg.	0.99	0.85	0.92	1.07	0.56	0.63	0.58	0.63	0.89	0.79	0.32
Max.	1.67	1.67	2.78	1.67	0.56	1.11	1.11	1.11	1.67	1.67	1.11
Min.	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.00
Feb.											
Avg.	0.60	0.64	0.60	0.54	0.56	0.58	0.63	0.58	0.56	0.49	0.40
Max.	1.11	1.11	1.11	0.56	0.56	1.11	1.11	1.11	0.56	1.11	0.56
Min.	0.56	0.56	0.56	0.00	0.56	0.56	0.56	0.56	0.56	0.00	0.00
March											
Avg.	1.61	0.69	1.46	0.88	1.18	1.04	0.99	0.65	1.00	1.56	1.03
Max.	2.22	1.11	2.78	2.22	4.44	1.67	2.22	1.67	1.67	2.78	2.22
Min.	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56
April											
Avg.	3.39	2.33	3.61	4.04	4.57	3.53	3.24	3.17	2.47	2.64	2.81
Max.	6.11	4.44	5.56	6.67	6.67	5.56	6.11	5.56	3.89	5.00	5.56
Min.	1.11	0.56	1.67	2.22	2.22	0.56	1.11	2.22	1.11	1.67	0.56
May											
Avg.	7.78	6.65	6.26	6.50	7.56	7.00	6.86	6.65	6.31	6.50	6.51
Max.	8.89	8.33	7.22	8.89	8.89	7.78	8.33	10.00	10.00	8.89	7.78
Min.	5.56	4.44	5.00	5.00	6.11	5.56	5.56	5.56	3.89	4.44	5.00
June											
Avg.	9.00	8.33	7.13	9.18	7.76	8.10	8.60	8.21	8.49	6.35	6.20
Max.	11.11	10.56	8.89	11.67	9.44	11.11	10.56	12.22	10.00	9.44	7.78
Min.	7.22	6.67	6.11	6.67	6.11	6.11	6.11	6.67	6.67	4.44	5.56[a]
July											
Avg.	13.54	10.07	10.96	9.60	8.74	12.36	9.97	8.46	9.06	8.51	
Max.	17.22	17.22	17.22	14.44	10.56	17.78	12.78	12.22	12.22	13.33	
Min.	8.33	7.22	6.67	6.67	6.67	7.78	6.67	6.67	6.67	5.00	
Aug.											
Avg.	13.72	14.31	15.10	11.79	11.17	11.53	13.93	11.40	11.78	13.06	
Max.	17.78	17.78	17.78	15.56	16.11	18.33	18.33	16.67	16.67	18.33	
Min.	9.44	10.56	11.67	7.22	6.11	6.67	7.22	6.67	7.78	7.22	
Sept.											
Avg.	10.64	11.94	15.28	14.15	13.50	15.21	10.76	14.36	11.83	10.88	
Max.	13.33	14.44	17.22	16.67	16.11	18.33	15.00	17.22	15.56	16.11	
Min.	7.22	8.89	10.56	9.44	9.44	10.56	7.22	8.89	7.78	6.11	
Oct.											
Avg.	7.54	8.58	7.69	10.63	8.50	8.82	8.83	10.15	9.47	8.78	
Max.	8.89	10.56	11.67	13.89	13.33	13.89	12.78	12.22	11.67	13.33	
Min.	7.22	7.78	6.67	6.11	6.11	6.11	6.11	7.78	6.67	4.44	
Nov.											
Avg.	6.75	6.26	5.07	4.71	7.47	5.33	7.72	5.56	5.28	4.97	
Max.	8.33	8.33	6.11	6.67	8.89	6.67	10.00	10.56	7.22	7.22	
Min.	3.33	3.33	4.44	2.78	6.11	2.78	5.00	3.33	1.11	3.33	
Dec.											
Avg.	1.88	2.58	2.51	2.26	3.38	1.89	2.72	2.88	1.19	2.61	
Max.	2.78	3.33	4.44	3.33	6.67	3.33	5.00	5.00	2.78	3.89	
Min.	0.56	1.67	1.11	0.56	0.56	1.11	0.56	1.67	0.56	0.56	

[a] One week of data missing.

Table 4.1.6. Monthly averages and extremes of Lake Michigan water temperatures, recorded at the Green Bay Water Intake, near Kewaunee, Wisconsin, from January 1964-November 1975. Temperatures in degrees centigrade.

	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
Jan.												
Avg.	2.22	2.22	2.22	2.78	2.22	2.22	2.22	2.22	2.78	2.78	2.78	3.61
Max.	3.33	3.33	3.33	4.44	3.33	2.78	3.33	3.33	3.33	3.33	3.89	5.56
Min.	1.67	1.67	1.11	1.67	1.67	1.67	1.11	1.67	1.67	1.67	1.67	2.22
Feb.												
Avg.	1.67	1.67	1.67	1.67	1.11	1.67	1.67	1.67	1.67	1.67	2.22	2.10
Max.	2.22	2.22	2.22	2.22	1.67	2.22	2.22	1.67	2.22	2.22	3.33	2.78
Min.	1.11	1.11	1.11	1.11	1.11	1.67	1.11	1.11	1.11	1.11	1.67	1.11
March												
Avg.	2.22	1.11	2.22	1.67	1.67	2.22	1.67	1.67	1.67	2.78	2.78	2.22
Max.	2.78	1.11	3.33	2.22	2.22	2.78	2.22	2.22	2.22	3.33	3.33	2.78
Min.	1.67	1.11	1.67	1.11	1.11	1.11	1.11	1.11	1.11	1.67	1.67	1.67
April												
Avg.	3.89	2.22	4.44	4.44	5.00	4.44	3.89	3.89	2.78	4.44	3.33	2.22
Max.	6.67	4.44	6.11	6.11	6.11	6.67	6.11	6.11	4.44	6.67	5.56	4.44
Min.	1.67	1.11	2.22	2.78	3.33	1.67	2.22	1.67	1.67	3.33	2.22	1.11
May												
Avg.	7.22	6.67	6.67	7.22	7.22	7.78	7.78	7.22	7.22	7.78	7.00	6.11
Max.	7.78	7.78	7.78	7.78	8.89	8.89	8.89	7.78	11.11	10.00	7.78	7.22
Min.	6.11	4.44	5.56	5.56	6.11	6.67	5.56	6.11	4.44	6.67	5.56	4.44
June												
Avg.	8.89	8.33	7.78	8.89	8.33	8.89	8.89	8.89	9.44	8.89	8.89	8.89
Max.	11.11	11.67	8.89	11.11	11.67	10.00	11.67	12.22	12.22	10.56	12.78	11.67
Min.	7.78	6.67	6.67	7.22	6.67	7.78	6.67	7.22	7.22	7.78	6.67	7.22
July												
Avg.	13.89	12.78	11.67	9.44	10.00	13.33	11.11	9.44	11.11	11.67	10.56	11.11
Max.	17.22	17.78	18.33	13.33	12.22	18.33	15.00	13.33	15.56	16.11	15.00	15.56
Min.	8.33	7.78	7.22	6.67	7.22	8.89	7.78	7.78	8.89	7.78	7.78	5.00
Aug.												
Avg.	14.44	13.89	15.00	12.78	12.78	13.33	14.44	13.33	13.33	14.44	12.78	13.89
Max.	17.78	17.22	18.33	16.11	16.67	19.44	18.99	16.67	16.67	17.22	16.67	17.22
Min.	8.33	7.78	10.00	8.33	7.78	8.89	8.89	8.33	9.44	10.00	10.00	10.00
Sept.												
Avg.	11.67	11.67	15.56	14.44	14.44	15.00	12.78	14.44	13.33	13.89	13.33	11.11
Max.	14.44	14.44	17.78	16.67	16.11	18.89	17.22	17.22	16.67	16.67	15.56	17.78
Min.	8.89	7.78	10.00	7.78	10.00	9.44	8.89	10.00	11.11	10.00	8.89	7.78
Oct.												
Avg.	8.89	9.44	8.89	11.11	10.00	8.33	10.56	12.22	10.56	12.78	9.44	9.44
Max.	10.00	10.00	11.67	14.44	11.67	15.56	14.44	13.33	13.33	15.56	10.00	12.22
Min.	8.33	8.89	7.78	7.78	7.78	7.22	7.78	10.00	7.78	8.89	8.89	7.78
Nov.												
Avg.	8.33	7.22	7.22	6.11	8.89	6.67	9.44	7.22	7.22	8.33	8.33	8.06
Max.	10.00	9.44	7.78	7.78	10.56	7.78	11.11	10.00	7.78	11.11	9.44	10.00
Min.	6.11	5.00	5.56	4.44	7.78	5.00	6.11	5.56	6.11	7.22	6.11	6.67
Dec.												
Avg.	3.89	4.44	4.44	3.89	4.44	3.33	4.44	5.00	3.89	5.00	4.94	
Max.	5.56	5.56	5.56	5.00	7.78	4.44	6.11	6.67	6.11	7.78	6.67	
Min.	2.22	2.78	3.33	2.78	1.67	2.22	2.22	2.78	2.78	3.33	3.89	

frequently occurred in August and September while minimum temperatures occurred in January and February. A comparison of mean temperatures at the KNPP, Two Rivers and Green Bay intakes for April-December 1973 showed that the mean temperature at KNPP was 1 C to 2 C higher than Two Rivers and about 1 C lower than Green Bay. Thus, within 1 C to 2 C, the 10 year record of temperature measured at the water supply plants can be considered as a record of the ambient temperatures for Lake Michigan near the KNPP.

4.1.5 Bathymetry

A chart of the bottom topography near the Kewaunee Nuclear Power Plant is presented in Figure 4.1.13. In general, the lake bottom near the Plant is irregular with numerous ridges and troughs extending north and south. The slope of the bottom is 1 in 100 from the shore line to the 20 ft contour, and a slope of 1 in 300 from the 20 ft contour to the 40 ft contour. The average alignment of the isobaths is southwest to northeast except nearshore where the alignment of the isobaths is influenced by the promontory.

The area has two major topographic features. The most prominent feature is the promontory which extends approximately 2500 ft into the water and has a mean width of approximately 1500 ft. The end of the promontory is marked by a steep slope between the 20 ft and 30 ft isobath. It has been determined, (Pezetta 1974; p. 20) that this section of the nearshore zone is an extension of the promontory on which the Plant is located and is made up of a hard glaciolacustrine clay or an exposed area of dolomitic bedrock covered with numerous cobbles which were transported from the clay buffs along shore.

The other prominent feature of the topography is a ridge which is located approximately 1.25 miles offshore. The ridge rises 6 ft off the bottom and extends north-south for 2 miles along the 36 ft isobath. Numerous smaller ridges and troughs extend north-south between the 20 and 50 ft isobaths.

A chart of the bottom topography in the immediate vicinity of the KNPP discharge outlet is presented in Figure 4.1.14. The

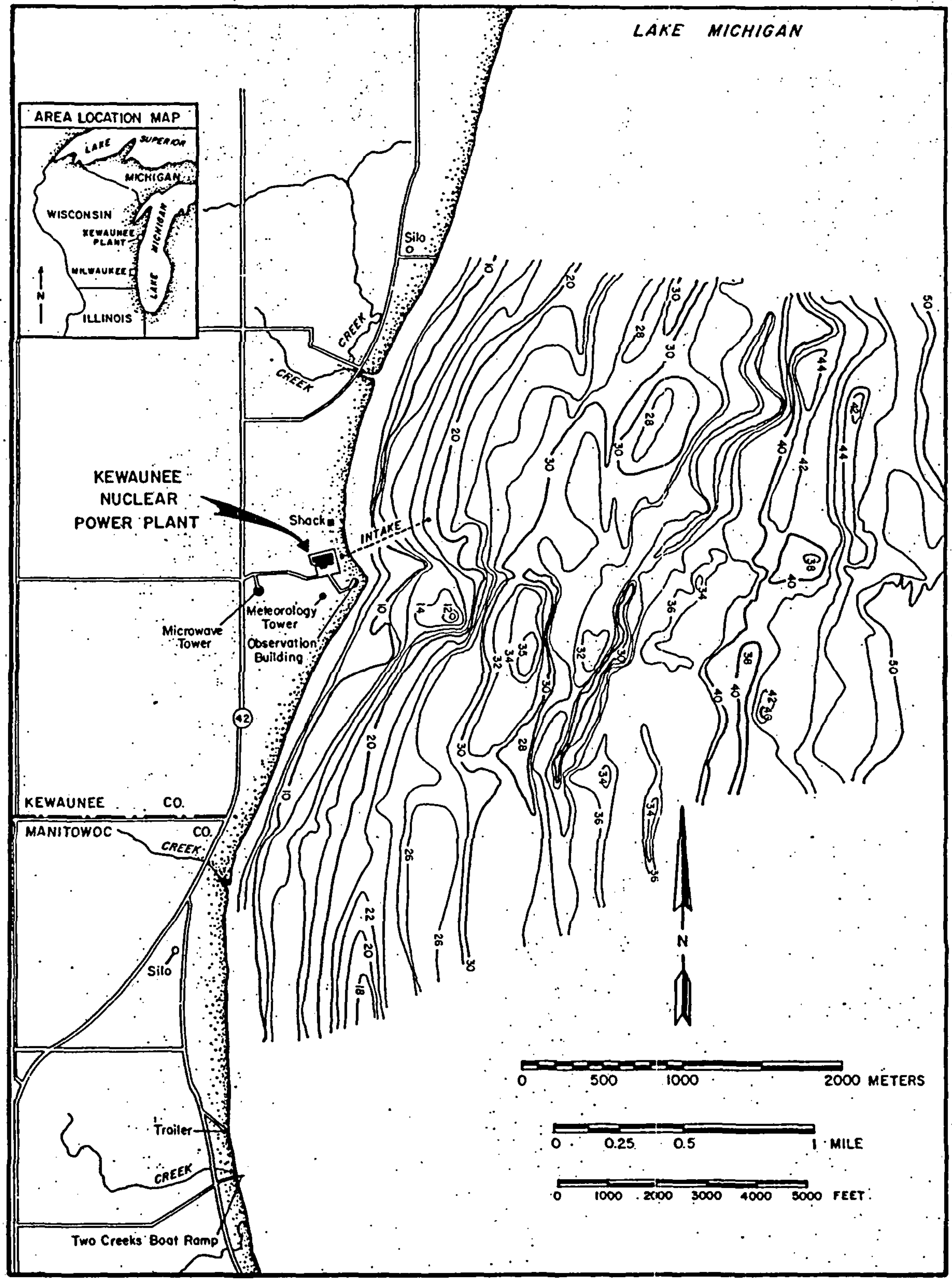

Figure 4.1.13 Bottom topography of Lake Michigan in the vicinity of the Kewaunee Nuclear Power Plant, 29 May 1974. Isobaths are in 2 foot intervals. The mean water level was 580.79 ft IGLD.

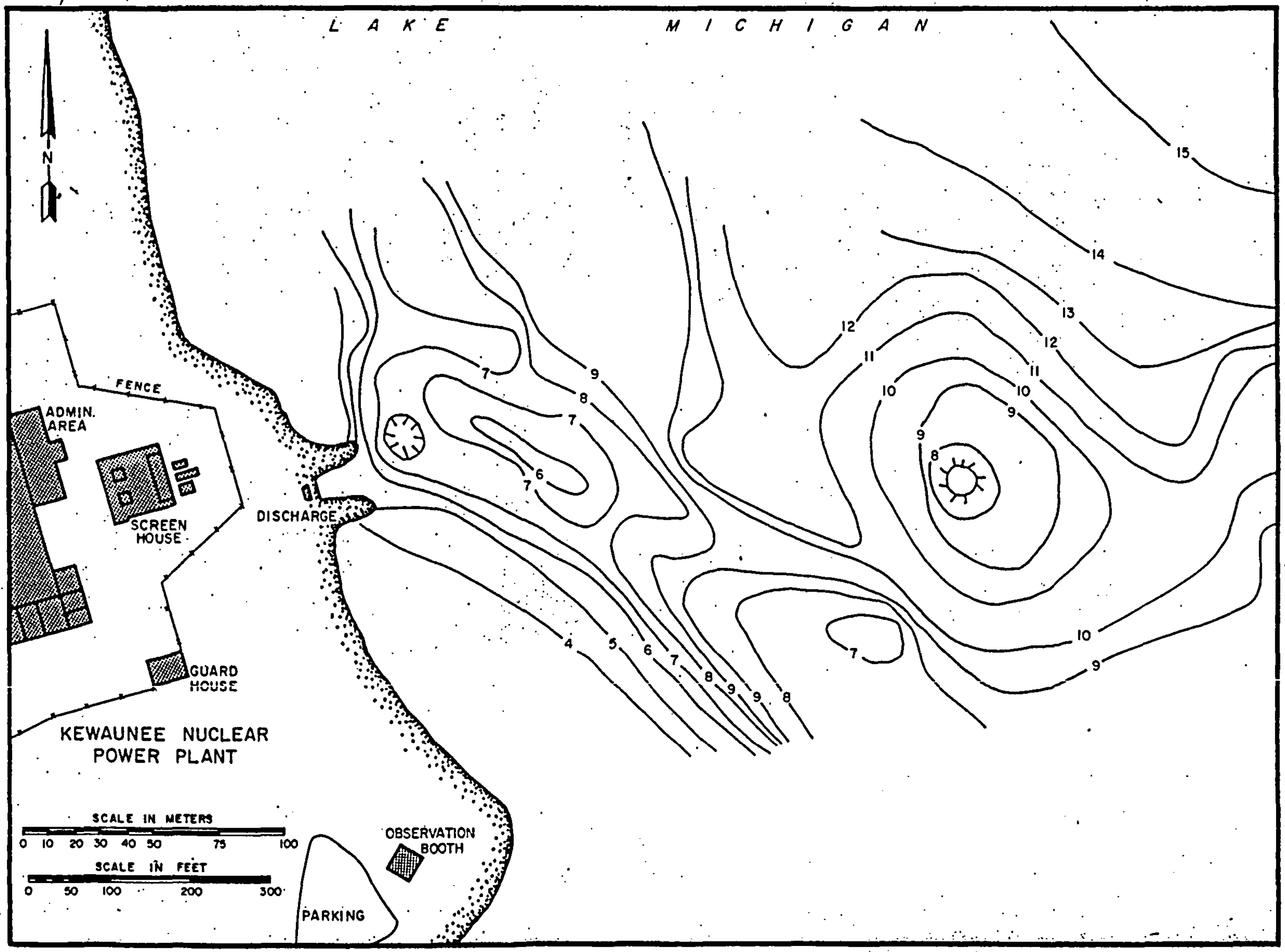

Figure 4.1.14 Bottom topography in the vicinty of the discharge outlet at Kewaunee Nuclear Power Plant on Lake Michigan, 12 November 1974.

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chart reveals features which indicate an apparent influence of the Plant's 413,000 gpm cooling water discharge on the bottom topography.

A small ridge defined by the 7 ft contour just north of the discharge outlet indicates a possible diversion of the alongshore transport of sediment. That is, sediment moving southward could be carried offshore by the high volume discharge from the Plant and deposited where the current velocity drops below that needed to transport the sediment.

This chart also reveals a depression immediately in front of the discharge outlet and a small mound just offshore of the depression and defined by a 7 ft contour. It is believed that the depression was created by scouring and the mound was built by depositing sediment from both scouring and diversion of alongshore sediment transport. This is supported by evidence from the distribution of bottom sediments. The size of the sediments graded from gravel immediately in front of the discharge outlet to fine sand on either side and offshore. (The depression was an area with a large fraction of gravel, whereas the mound was an area with a large fraction of fine sand.) This sorting by size could be a result of selective erosion and deposition of sediment and associated with changes in plume velocity. The sand fraction was scoured from the area immediately in front of the discharge outlet and transported offshore to a point where the plume velocity dropped below that needed to transport the sand.

Though there is sufficient evidence to indicate that the

Plant's discharge scours the bottom and alters the sediment distribution, the size of the affected area is small for sediment sizes greater than or equal to fine sand. Based on the charts of bottom topography, this area extends approximately 400 ft offshore and is about 250 ft wide.

4.1.6 Thermal Plume Characteristics

Industrial BIO-TEST Laboratories, Inc. (1975, Chap. 6., App. 6-A; 1976, Chap. 4, App. 4-A) surveyed 19 thermal plumes at KNPP between June 1974 and July 1975. Eleven of the plumes were associated with a dye study conducted in November 1974. There were no plumes surveyed during the winter period, December 1974-March 1975.

Profiles of three typical thermal plumes surveyed in different seasons are presented in Figures 4.1.15, 4.1.16 and 4.1.17. The associated environmental and Plant operating data are presented in Table 4.1.7. Due to the highly variable configuration of a plume and of ambient conditions, there are not enough data to reliably evaluate specific seasonal changes in the plume.

However, the thermal plume data have been used to determine a discharge zone for KNPP. As defined by the U.S. EPA September 1974 Draft Guidelines for a 316(a) Demonstration, the discharge zone for a power plant is:

> "that portion of the receiving waters which falls within the 2 C excess temperature isotherm 30% or more of the time, as defined by data representing a period of at least a few months and preferably indicative of a complete annual cycle."

A discharge zone was defined for KNPP which included the maximum surface extent and the maximum bottom extent (Figure 4.1.18) of the 2 C isotherm. The surface portion of the zone was determined by drawing a perimeter encompassing the furthest extent of the 2 C isotherms for all plumes except July 1975. (The July plume appeared to be anomalously large and ill defined.) This procedure

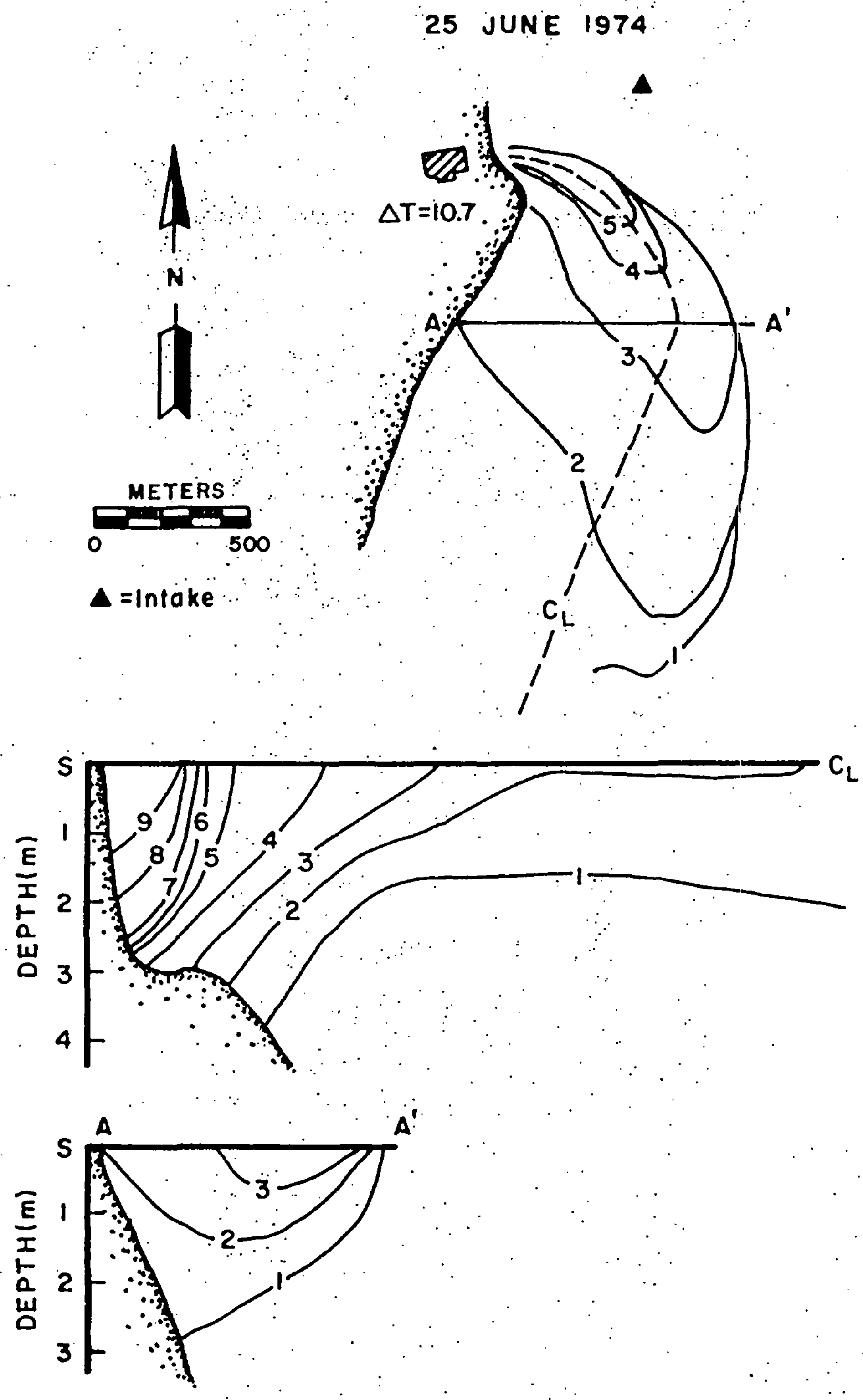


Figure 4.1.15. Isotherms (degrees centigrade) of excess temperatures for the thermal plume at Kewaunee Nuclear Power Plant, on Lake Michigan, 25 June 1974.

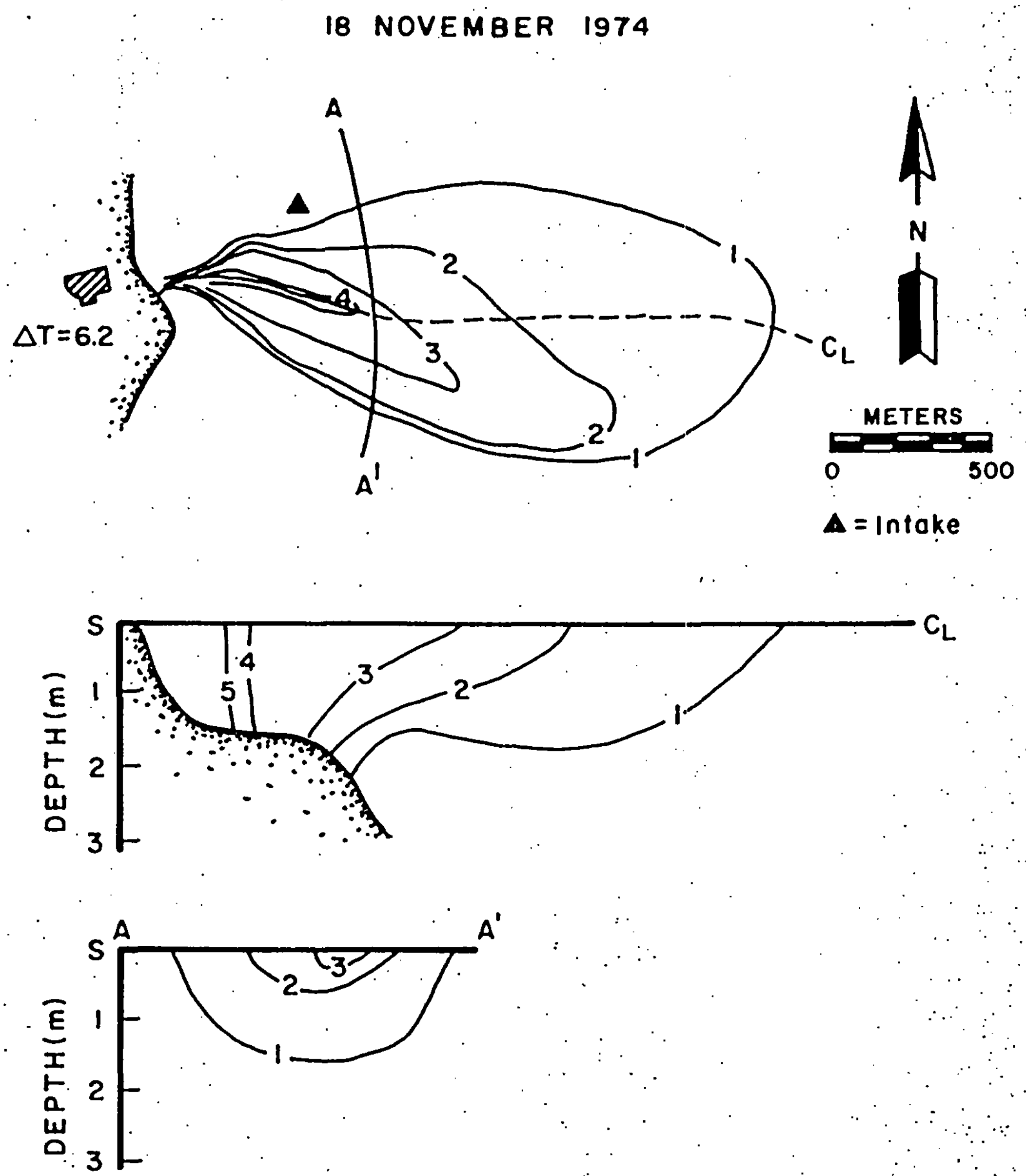
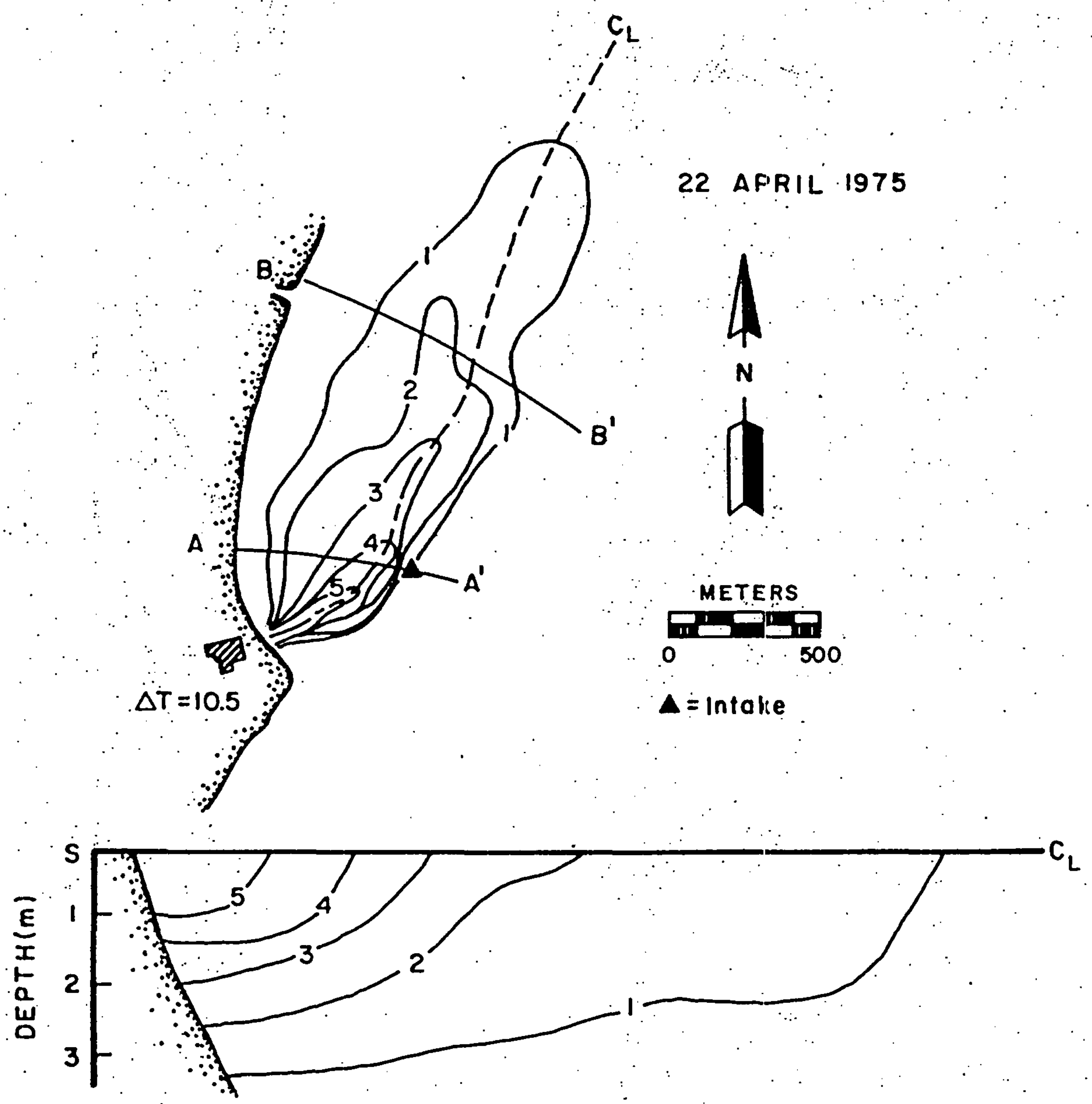


Figure 4.1.16. Isotherms (degrees centigrade) of excess temperature for the thermal plume at Kewaunee Nuclear Power Plant on Lake Michigan, 18 November 1974.



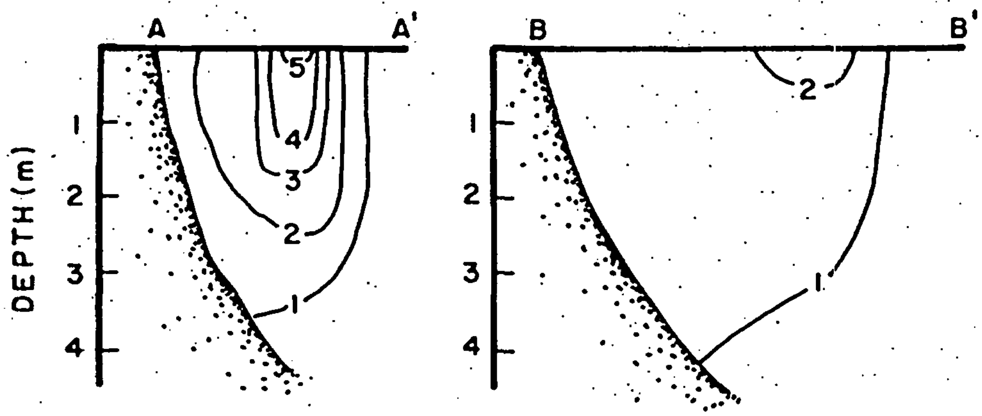


Figure 4.1.17. Isotherms (degrees centigrade) of excess temperature for the thermal plume at Kewaunee Nuclear Power Plant on Lake Michigan, 22 April 1975.

Table 4.1.7. Environmental and plant operating conditions during three thermal plume surveys at Kewaunee Nuclear Power Plant.

	25 Jun 1975	18 Nov 1975	22 Apr 1975
Discharge Rate (cfs)	918	918	918
Temperature (°C)			
Ambient	12.6	6.0	7.8
Intake	12.8	6.5	8.1
Discharge	23.3	12.4	18.3
Ambient Current			
Speed (fps)	0.17	0.11	0.42
Direction	SSW	NE	N
Wind			
Speed (mph)	2.5	13	10
Direction	SW	S	SSE

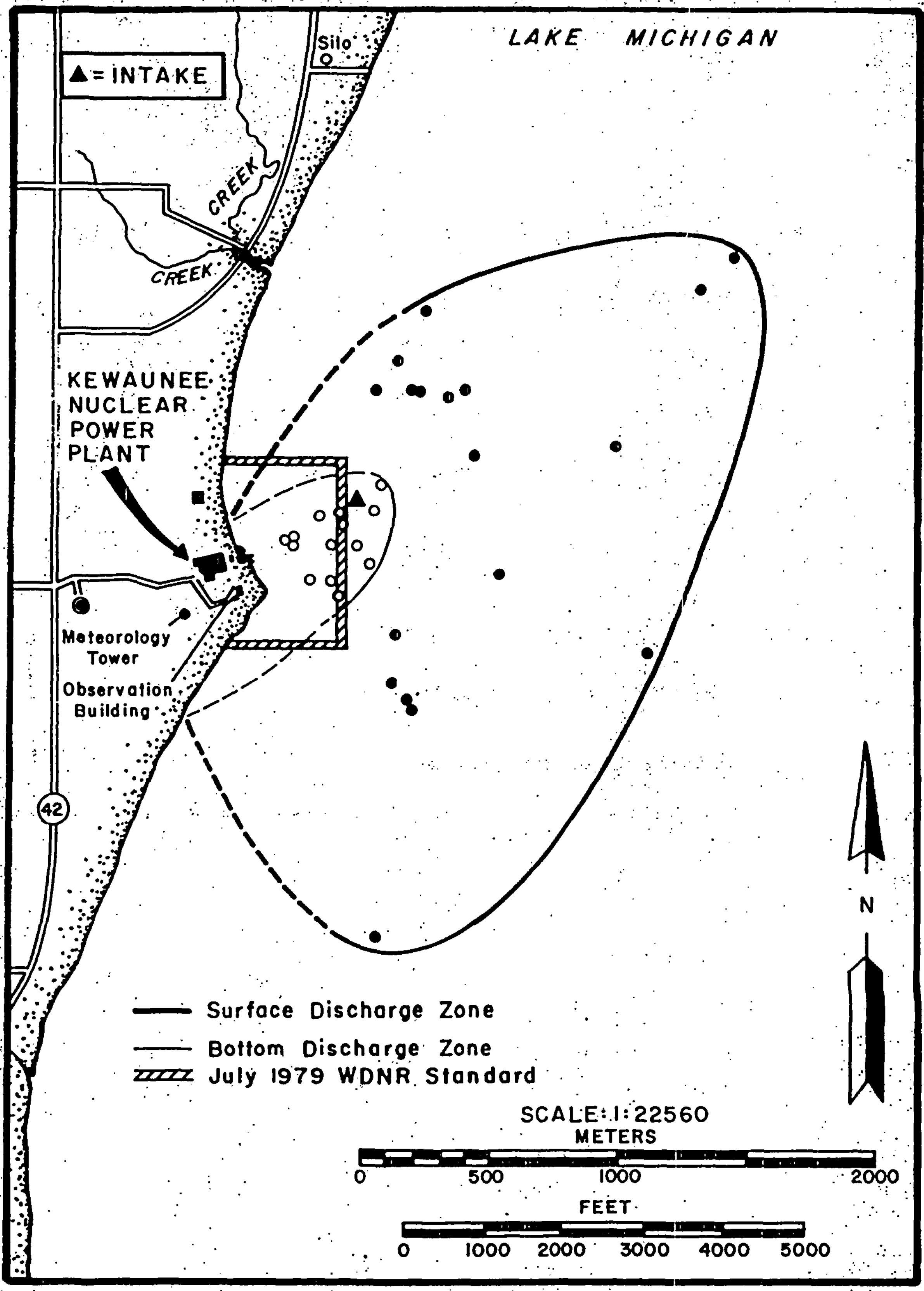


Figure 4.1.18. Configuration area of the surface and bottom thermal discharge zones at Kewaunee Nuclear Power Plant. Solid and open circles represent furthest extents of ΔT=2 C isotherms at surface and bottom, respectively, for plumes surveyed June 1974-June 1975.

defines a larger discharge zone than is required by the September 1974 EPA Guideline definition. The bottom extent of the zone was determined by drawing a perimeter encompassing the points at which the 2 C isotherms intersected the lake bottom. The discharge zone has an area of approximately 985.3 acres at the surface and 94.5 acres at the bottom. In Appendix 1 to Public Notice Number 4WI-0515B issued by the State of Wisconsin Department of Natural Resources on 28 August 1975, the mixing zone as of 1 July, 1979 was defined as "The area within the perimeter of a rectangular figure extending 1,250 feet in both directions along the shoreline and 1,250 feet into the lake." This area is included in Figure 4.1.18 and encompasses an area of 71.74 acres. The discharge zone at Kewaunee Nuclear Power Plant exceeds this limitation.

A graph of the surface velocity of the plume as a function of distance from the discharge outlet is presented in Figure 4.1.19. These data were measured for an offshore directed plume on 15 November 1974 (Industrial BIO-TEST Laboratories, Inc. 1975, Chap. 6, p. 27-28). The exit velocity (3.1 fps) was calculated from the volume discharge rate (918 ft^3/s) and the outlet area (312 ft^2) for a lake elevation of 579.7 ft.

Extreme Conditions

The characteristics of the thermal plume at KNPP for extreme operating conditions in summer and winter were predicted using the KNPP Thermal Plume Model (NALCO Environmental Sciences, 1976). For the summer case, the ambient lake temperature was taken to be 21.1 C (70 F) and the plant discharge temperature was taken

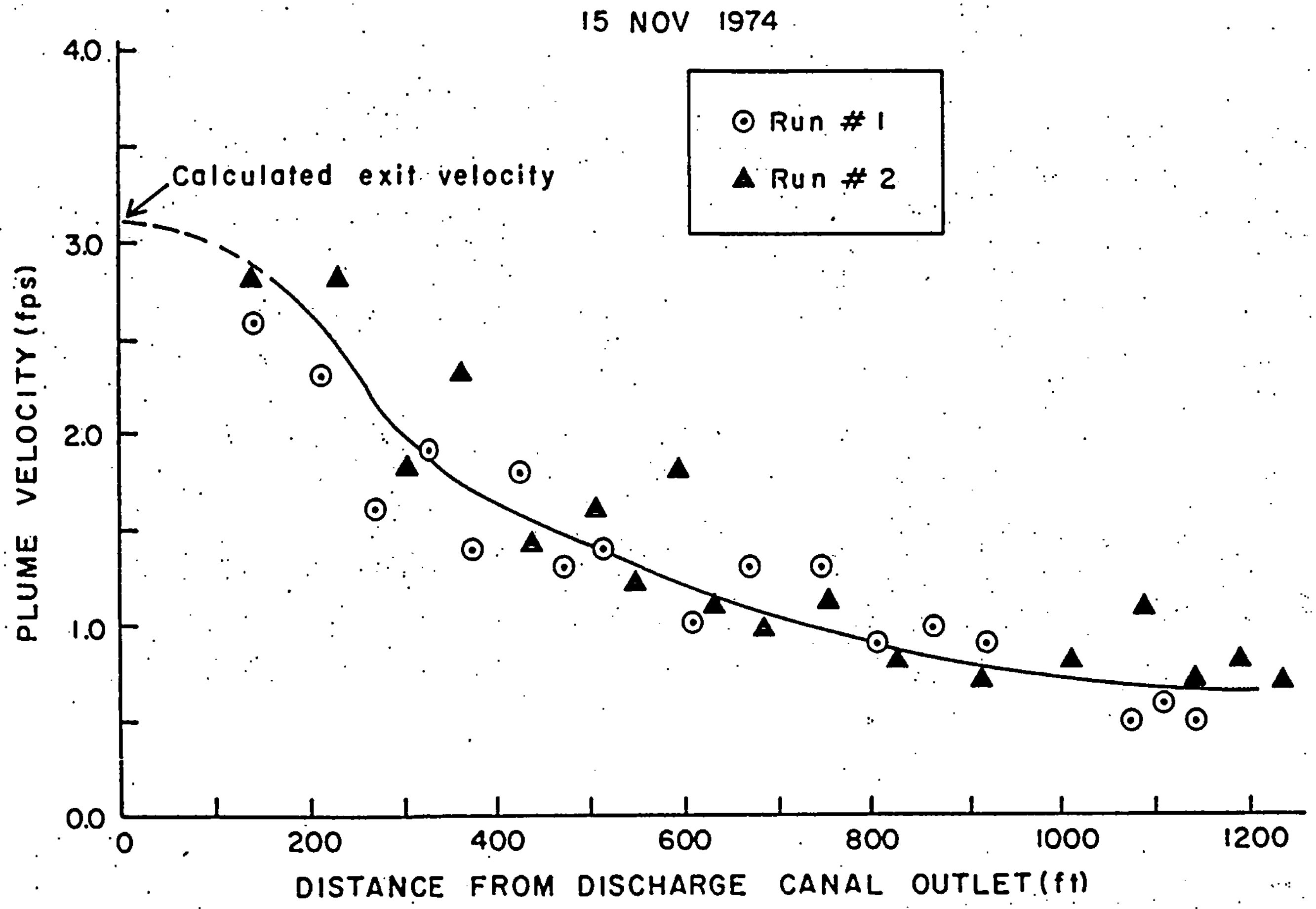


Figure 4.1.19 Plume velocity versus distance from discharge canal outlet for a thermal plume at Kewaunee Nuclear Power Plant. Measurements were made by tracking two drogues released near the outlet.

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to be 30 C. The ambient temperature of 21.1 C is the highest temperature measured at the nearshore south station during the 3-year period, January 1973-December 1975, and occurred on 3 August 1973 (preoperational date). An ambient lake current of 0.8 fps occurred at KNPP for less than 1.5% of the time during summer months at the offshore surface station and 0% of the time at the nearshore stations. Hence the summer plume characteristics were predicted for two cases, one with zero lake current, and the other with a lake current of 0.8 fps (Table 4.1.8.). For the winter plumes, ambient lake temperature was assumed to be 0 C (32 F) and the plant discharge temperature was taken to be 15.5 C. The maximum ambient lake current measured at KNPP during winter months is 1.2 fps, which occurred in November at the Offshore Surface Station. Lake currents above 0.85 fps occurred at the offshore station during winter months for less than 3.3% of the time, and at the nearshore stations, for less than 0.8% of the time. The winter plume characteristics were also predicted for both zero lake current, and for the maximum lake current of 1.2 fps (Table 4.1.9). The sinking plume phenomenon was not considered in predicting the winter plume characteristics. The extreme values of water temperature and lake current speed used for the predictions are noncoincident data measured at KNPP. Even though these conditions did not occur at the same time, their combination can be considered to provide the most unfavorable conditions that would create the largest thermal plumes.

Table 4.1.8. Characteristics of the Kewaunee Nuclear Power Plant thermal plume in summer under extreme conditions.

Summer Case - No Current

Isotherm Temp. (°C)	Ratio ($\Delta T/\Delta T_o$)	Dist. (ft)	Width (ft)	Area (acres)
29.0	0.89	111.4	79.5	0.17
28.0	0.77	147.7	92.4	0.27
27.0	0.66	204.9	112.7	0.46
26.0	0.55	302.1	147.2	0.88
25.0	0.44	486.9	212.7	2.04
24.0	0.32	904.9	361.0	6.45
23.0	0.21	2194.1	818.3	35.45
22.0	0.10	4939.5	1792.2	174.80

Calculated Parameters:

Discharge velocity 0.92 MPS
Initial densimetric Froude number 4.00
Aspect ratio 0.19
Rate of vertical growth 0.5719E-02
Critical depth 1.5 meters
Lake to jet vel. ratio 0.0
DELRHO/RHO 0.2326E-02

Ambient temperature = 21.1 C
Discharge temperature = 30 C
$T_{am} - T_{dis} = \Delta T_o = 8.9$ C
$U_{ambient} = 0$

Summer Case - High Current

Isotherm Temp. (°C)	Ratio ($\Delta T/\Delta T_o$)	Dist. (ft)	Width (ft)	Area (acres)
29.0	0.89	101.4	66.0	0.13
28.0	0.77	174.3	84.8	0.29
27.0	0.66	279.3	111.8	0.62
26.0	0.55	411.7	145.8	1.19
25.0	0.44	663.5	210.5	2.76
24.0	0.32	1233.2	356.8	8.69
23.0	0.21	2989.6	808.1	47.70
22.0	0.10	6727.2	1768.4	234.90

Calculated Parameters:
Discharge velocity 0.92 MPS
Initial densimetric Froude number 4.00
Aspect ratio 0.19
Rate of vertical growth 0.5719E-02
Critical depth 1.5 meters
Lake to jet vel. ratio 0.3
DELRHO/RHO 0.2326E-02

Ambient temperature = 21.1 C
Discharge temperature = 29.0 C
$T_{am} - T_{dis} = \Delta T_o = 8.9$ C
$U_{ambient} = 0.8$ fps

Table 4.1.9. Characteristics of the Kewaunee Nuclear Power Plant thermal plume in winter under extreme conditions.

Winter Case - No Current

Isotherm Temp. (°C)	Ratio (T/ T₀)	Dist. (ft)	Width (ft)	Area (acres)
15.0	0.97	101.5	77.1	0.15
14.0	0.90	124.1	81.3	0.20
13.0	0.84	154.1	86.8	0.26
12.0	0.77	194.6	94.4	0.36
11.0	0.71	250.8	104.8	0.52
10.0	0.65	331.2	119.7	0.78
9.0	0.58	450.3	141.8	1.26
8.0	0.52	609.1	179.0	2.15
7.0	0.45	773.3	241.9	3.69
6.0	0.39	1018.7	336.0	6.76
5.0	0.32	1411.0	486.4	13.55
4.0	0.26	2101.9	751.2	31.18
3.0	0.19	3337.1	1224.7	80.70
2.0	0.13	4994.8	1860.2	183.46
1.0	0.06	9920.4	3748.4	734.26

Calculated Parameters:

Discharge velocity 0.92 MPS
Initial densimetric Froude number 6.73
Aspect ratio 0.19
Rate of vertical growth 0.1142E-01
Critical depth 2.7 meters
Lake to jet vel. ratio 0.0
DELRHO/RHO 0.8204E-03

Ambient temperature = 0 C
Discharge temperature = 15.5 C
$T_{am} - T_{dis} = T_o = 15.5$ C
$U_{ambient} = 0$

Winter Case - High Current

Isotherm Temp. (°C)	Ratio (T/ T₀)	Dist. (ft)	Width (ft)	Area (acres)
15.0	0.97	132.7	51.7	0.14
14.0	0.90	174.9	55.4	0.19
13.0	0.84	235.2	60.8	0.28
12.0	0.77	324.0	68.6	0.44
11.0	0.71	458.9	80.5	0.73
10.0	0.65	671.8	99.3	1.32
9.0	0.58	942.6	215.0	4.00
8.0	0.52	1124.6	248.8	5.53
7.0	0.45	1373.8	295.1	8.01
6.0	0.39	1730.8	361.4	12.35
5.0	0.32	2274.3	462.3	20.76
4.0	0.26	3176.2	629.7	39.49
3.0	0.19	4800.2	1147.3	108.74
2.0	0.13	7183.0	1589.2	225.39
1.0	0.06	14257.0	2900.9	816.63

Calculated Parameters:
Discharge velocity 0.92 MPS
Initial densimetric Froude number 6.73
Aspect ratio 0.19
Rate of vertical growth 0.1142E-01

Critical depth 2.7 meters
Lake to jet vel. ratio 0.4
DELRHO/RHO 0.8204E-03

Ambient temperature 0 C
Discharge temperature 15.5 C
$T_{am} - T_{dis} = \Delta T_o = 15.5$ C
$U_{ambient}$ - 1.2 fps

4.1.7 Historical Climate

Climatic Overview

The Kewaunee Nuclear Power Plant is located on the western shore of Lake Michigan, about 8 miles south of Kewaunee, Wisconsin. Lake Michigan is the second largest lake in the North American Continent and exerts a strong influence on the local climate. The Atlantic Ocean is about 800 miles to the east, and the Gulf of Mexico is about 1000 miles to the south. Lake Michigan and the Gulf of Mexico supply most of the atmospheric moisture observed in the region.

The local weather is also influenced by the polar and tropical air masses which contribute to the mid-latitude large scale atmospheric motions. The interaction of the southward moving polar air mass and the northward moving tropical air mass produce low pressure areas and cyclonic storms. The movement of these air masses and their interaction create the complex and rapidly changing weather patterns observed in this region.

Temperature

Temperature statistics for the period from 1908 to 1974 for Kewaunee, Wisconsin, are presented in Table 4.1.10. The annual mean temperature is 44.1 F and varies from a monthly mean of 18.7 F in January to a monthly mean of 68.0 F in July. During the period of record, the highest temperature recorded was 104 F and the lowest temperature was -27 F. The mean annual diurnal variation is about 17 F. In general, only four days each year have maximum temperatures exceeding 90 F and 151 days have minimum temperatures below 32 F.

Table 4.1.10. Temperature statistics for Kewaunee, Wisconsin, 1908-1974[a].

	Normals (F)			Extremes (F)		Frequency of Temperature Occurrence (Number of days)	
	Mean	Maximum	Minimum	Highest	Lowest	≥90 F	≤32 F
Jan	18.7	28.4	12.7	59	-27	0	31
Feb	20.8	29.9	13.4	56	-26	0	27
Mar	29.3	38.0	23.0	78	-11	0	28
Apr	41.6	50.5	33.8	86	9	0	10
May	51.1	61.1	42.4	93	22	0	2
Jun	61.1	71.4	51.8	100	34	1	0
Jul	68.0	78.5	59.0	104	39	1	0
Aug	67.6	77.8	59.2	102	38	2	0
Sep	59.9	69.6	51.5	98	25	0	0
Oct	49.8	58.7	41.4	85	19	0	4
Nov	36.4	43.3	28.9	73	-6	0	20
Dec	24.4	31.8	17.8	59	-16	0	29
Annual	44.1			104	27	4	151

[a] Values are averages of statistical information derived from records supplied by the U.S. Department of Commerce.

The mean date of the last killing frost is May 6 and the mean date of the first killing frost is October 14. The mean length of frost-free period normally is 161 days. Lake Michigan provides protection against early frosts and the growing season along the lake is about 30 days longer than found 100 miles inland (USCOMM 1968).

Wind

Data collected at Green Bay, Wisconsin (25 miles west of the site), was used to represent the wind at the site. The prevailing wind speed, direction and the fastest mile data (the fastest one minute mean wind speed from 1912 to 1960) are given in Table 4.1.11. The frequency of wind direction occurrences for each month in the middle of the seasons are presented in Figure 4.1.20.

The average wind speed is about 10 mph with the fastest average speeds occurring during the spring season. There are seasonal variations in the distribution of the wind direction sectors with northeasterly winds prevailing in spring and southwesterly winds prevailing during the remainder of the year. Southwesterly winds occur about 14% of the year, while winds from the southwest to northwest quadrant account for almost half of the data (47%). The fastest wind speeds observed during most months of the year have exceeded 60 mph at Green Bay.

The onshore and offshore wind distributions observed at the Kewaunee site are presented below (USAEC 1972):

Table 4.1.11. Wind statistics for Green Bay, Wisconsin, 1912-1960.[a]

	Prevailing Wind		Fastest Mile	
	Speed (mph)	Direction	Speed (mph)	Direction
Jan	11	SW	61	W
Feb	10	SW	66	W
Mar	12	NE	68	W
Apr	12	NE	57	NE
May	11	NE	109	SW
Jun	10	SW	73	SW
Jul	8	SW	70	NE
Aug	8	SW	56	SW
Sep	9	SW	66	W
Oct	10	SW	66	SW
Nov	12	SW	67	W
Dec	11	SW	61	SW
Annual	10	SW	109	SW

[a] USCOMM 1968

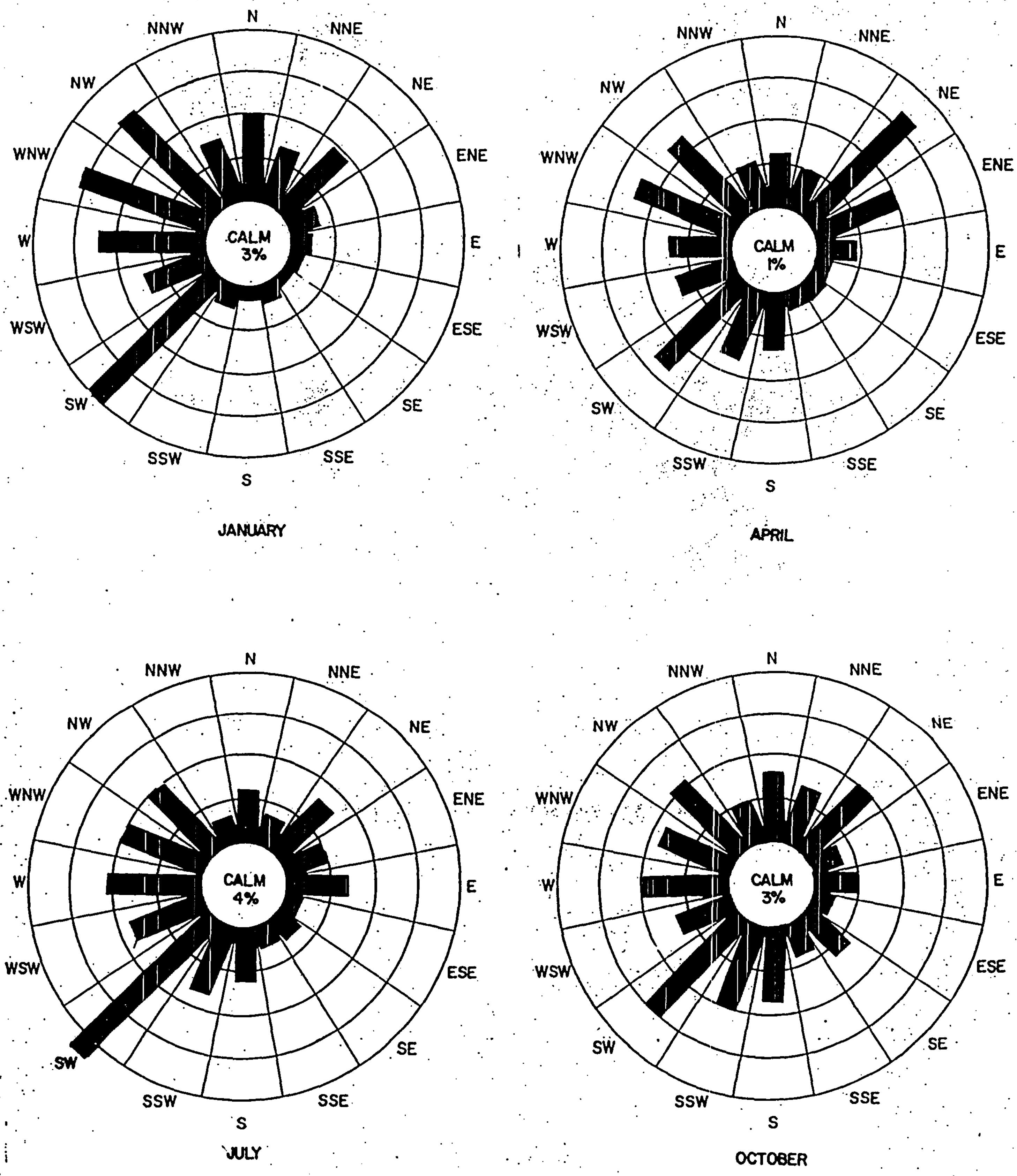

Figure 4.1.20 Wind direction distributions, Green Bay, Wisconsin. Each circle represents 4%.

Wind Distribution Observed at the Kewaunee site (%)

	Onshore (NNE-S)	Offshore (SSW-N)	Calm
Spring	49.15	49.57	1.28
Summer	40.56	58.39	1.05
Autumn	34.47	64.48	1.05
Winter	20.36	78.79	0.85
Annual	36.14	62.81	1.02

It is significant to note that offshore winds (blowing toward Lake Michigan) occur over 60% of the time annually. Onshore winds occur most frequently during the spring and summer. The maximum occurrence of offshore winds is during the autumn and winter. Due to the temperature lag of Lake Michigan, land temperatures are warmer than the lake during spring and summer and colder during autumn and winter. During the spring and summer, a local circulation develops when air is heated by the land, rises and is replaced by cooler air flowing over the lake toward the land. A weak reversal occurs during the autumn and winter; air ascends over the warmer lake surface and is replaced by air flowing from the land. An offshore lake-breeze can occur nocturnally during the summer but is usually quite weak. Onshore lake-breezes normally do not penetrate more than a few miles inland (USAEC 1972).

Precipitation and Evaporation

Precipitation occurs during every month of the year with the heaviest rainfalls occurring during the late spring and summer months (May-September). Table 4.1.12 presents the precipitation statistics for Kewaunee, Wisconsin. During the period of record from 1908 to 1974, the annual rainfall total

Table 4.1.12. Precipitation statistics for Kewaunee, Wisconsin, 1908-1974[a].

	Mean	Maximum	Minimum	Standard Deviation (inches)	Days With Precipitation ≥0.01 inch
Jan	1.44	4.40	0.24	0.90	3
Feb	1.31	4.08	0.00	0.82	3
Mar	1.69	4.25	0.08	0.98	3
Apr	2.52	4.94	0.30	1.15	6
May	3.14	9.39	0.90	1.78	6
Jun	3.22	6.70	0.43	1.52	6
Jul	2.96	9.30	0.53	1.62	6
Aug	2.79	7.04	0.38	1.39	5
Sep	3.15	6.98	0.60	1.68	5
Oct	2.03	4.87	0.00	1.23	5
Nov	2.21	4.56	0.16	1.18	4
Dec	1.57	4.08	0.03	0.92	4
Annual	28.03	38.27	17.13	4.28	56

[a] USCOMM 1975a

varied from about 17 inches in the driest year to over 38 inches in the wettest year. The standard deviation of the annual rainfall at the site is about 4 inches. The annual snowfall is about 39 inches and attains its maximum during February and March (USCOMM 1965a or b).

The mean class A pan evaporation is estimated to be approximately 36 inches annually in the vicinity of Kewaunee (USCOMM 1968).

The mean annual class A pan coefficient (correlation coefficient between the class A pan and lake evaporation) has a value of 0.78 in this region. This is equivalent to a mean lake evaporation of 28 inches. Eighty-one percent of the evaporation occurs between May and October. The lake evaporation is comparable to the annual amount of rainfall, but the evaporation rate exceeds the precipitation rate in the summer and the reverse is true in winter.

Humidity

The moisture content of the atmosphere can be measured by the relative humidity which is a ratio of the amount of water in the air to the amount of water that the air can hold at the observed temperature. The monthly mean relative humidity values at Green Bay, Wisconsin, are given in Table 4.1.13 (USCOMM 1974). The monthly relative humidity means show little variation from month to month and is highest in summer and autumn. Large diurnal variations are observed and these variations are caused by the diurnal temperature changes. The mean diurnal variations for each

Table 4.1.13. Relative humidity at Green Bay, Wisconsin, 1931-1960.[a]

	Relative Humidity (%) Hour of the day (CST)			
	00	06	12	18
Jan	75	75	68	73
Feb	77	79	69	74
Mar	76	78	63	70
Apr	77	78	57	62
May	79	78	54	59
Jun	85	83	59	65
Jul	87	86	59	64
Aug	89	89	59	68
Sep	86	89	57	70
Oct	81	85	56	71
Nov	77	80	65	73
Dec	79	79	72	77
Annual	81	82	62	69

[a] USCOMM 1955, 1965

month show a consistent pattern of highest humidity around sunrise and lowest during the late afternoon.

Sunshine, Solar Radiation and Cloud Cover

Monthly statistics on cloud cover and solar radiation for Green Bay, Wisconsin, are presented in Table 4.1.14. The data show that the region has the highest percentage of cloud cover during the winter (68%) and that during the summer the mean cloud cover drops to 58%. The cloud cover is also reflected in the sunshine statistics where the percent of possible sunshine is only 40% in November and December and reaches a maximum of 70% in July. The cloud cover also affects the amount of solar radiation reaching the ground. The monthly solar radiation totals received at the Kewaunee site are expected to be less than the corresponding values observed at Madison, Wisconsin because the latitude of Kewaunee is about one degree north of Madison and the cloud cover at Kewaunee is approximately 3% higher.

Destructive Storms

The only destructive storms expected in the site area are severe thunderstorms and tornadoes. Hurricanes are not a threat in Wisconsin.

Tornadoes are extremely violent whirlwinds of limited extent that are capable of causing extensive damage to anything in their path. The damage is caused by atmospheric pressure changes and high wind speeds. Wind speeds have been estimated up to 360 mph (USAEC 1974) in tornadoes.

Wisconsin has an average of 20 tornadoes each year (USCOMM 1972), most frequently in spring, which is an average

Table 4.1.14. Sunshine, cloud cover and solar radiation statistics for Green Bay, Wisconsin.[a]

	Solar[b] Radiation (langley/month)	Sky Cover Sunrise to Sunset (%)	Hours of Sunshine	Percent of Possible Sunshine
Jan	148	68	121	44
Feb	220	65	148	51
Mar	313	64	194	55
Apr	394	64	210	56
May	466	64	251	58
Jun	514	62	279	64
Jul	531	56	314	70
Aug	452	57	266	65
Sep	348	59	213	58
Oct	241	63	176	52
Nov	145	72	110	40
Dec	115	71	106	40
Annual	324	64	2338	55
Rec. (yrs)	(46)	(69)	(30)	(57)

[a] USCOMM 1968
[b] Madison, Wisconsin data.

of 348 tornadoes in each 10,000 square mile area (USCOMM 1974). A tornado has a destruction region of about four square miles which implies that the probability of any section being hit by a tornado in any given year is 0.0014 (e.g., a tornado will occur in a specific location approximately every 718 years).

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4.2 WATER QUALITY STUDIES

4.2.1 Lake Michigan Water Conditions

Introduction

The data used in this report are the result of field and laboratory analyses performed by NALCO Environmental Sciences according to standard procedures approved by the U.S. Environmental Protection Agency and the American Public Health Association et al. (Industrial BIO-TEST Laboratories, Inc. 1972 and 1973, Gara and Hawley 1974, Ellis 1975). In several cases data from other sources are utilized.

Chemical and bacteriological parameters monitored and the years in which each was determined are listed in Table 4.2.1. During 1971 water samples were collected at mid-depth from one 5-ft depth contour location, and from the top and bottom of the water column at one 25-ft depth contour location. Both 1971 locations were in front of the KNPP site close to the present Transect III (Locations A, B; Figure 4.2.1). In 1972 a grid of permanent sampling locations was established (Figure 4.2.1) and from 1972 through 1975 samples were collected from the locations and depths described in Table 4.2.2 and profile measurements for basic parameters were made at the locations listed in Table 4.2.3.

A large amount of data has been collected describing the water quality of Lake Michigan near KNPP (Industrial BIO-TEST Laboratories, Inc. 1972 and 1973, Gara and Hawley 1974, Ellis 1975). Other researchers have studied nearby areas of Lake Michigan such as the vicinity of the Point Beach Nuclear Power Plant

Table 4.2.1. Years in which chemical and bacteriological parameters were determined in Lake Michigan water samples near Kewaunee Nuclear Power Plant.

Parameter	Year Monitored				
	1971	1972	1973	1974	1975
General Water Quality Parameters					
1. Alkalinity, total	x	x	x	x	x
2. Calcium	x		x	x	x
3. Chloride	x	x	x	x	x
4. Color, true		x	x	x	x
5. Conductance, specific	x	x	x	x	x
6. Fluoride		x	x	x	x
7. Hardness, total		x	x	x	x
8. Magnesium	x		x	x	x
9. Nitrogen, saturation					x
10. Odor, threshold	x				
11. Oxygen, dissolved	x	x	x	x	x
12. Oxygen, saturation	x	x	x	x	x
13. pH	x	x	x	x	x
14. Potassium		x	x	x	x
15. Residue, filtrable (total dissolved solids)		x	x	x	x
16. Residue, nonfiltrable (total suspended solids)			x	x	x
17. Residue, total (total solids)			x	x	x
18. Sodium		x	x	x	x
19. Sulfate		x	x	x	x
20. Turbidity	x	x	x	x	x
Aquatic Nutrients					
21. Ammonia		x	x	x	x
22. Nitrate	x	x	x	x	x
23. Nitrite		x	x	x	x
24. Organic nitrogen, total		x	x	x	x
25. Orthophosphate, soluble	x	x	x	x	x
26. Phosphorus, total	x	x	x	x	x
27. Silica, soluble	x	x	x	x	x
28. Bacteria, standard plate count (20.0 C and 35.0 C)		x	x	x	x
29. Bacteria, total coliform	*a	*	x	x	x
30. Bacteria, fecal coliform	x	x	x	x	x
31. Bacteria, fecal streptococci	x	x	x	x	x
32. Biochemical oxygen demand (5-day)	x	x	x	x	x
33. Chemical oxygen demand	x	x	x	x	x
34. Chlorine, total				x	x

Table 4.2.1. (continued)

Parameter	1971	1972	1973	1974	1975
	Year Monitored				
35. Hydrazine			x	x	x
36. Morpholine			x	x	x
37. Organic carbon, total	x	x	x	x	x
Trace Elements					
38. Arsenic		x	x	x	x
40. Boron		x	x	x	x
41. Cadmium		x	x	x	x
42. Chromium	x	x	x	x	x
43. Copper		x	x	x	x
43. Iron	x	x	x	x	x
44. Lead		x	x	x	x
45. Manganese		x	x	x	x
46. Mercury		x	x	x	x
47. Nickel		x	x	x	x
48. Zinc		x	x	x	x

[a] Analyzed but not included in this report due to analytical uncertainty.

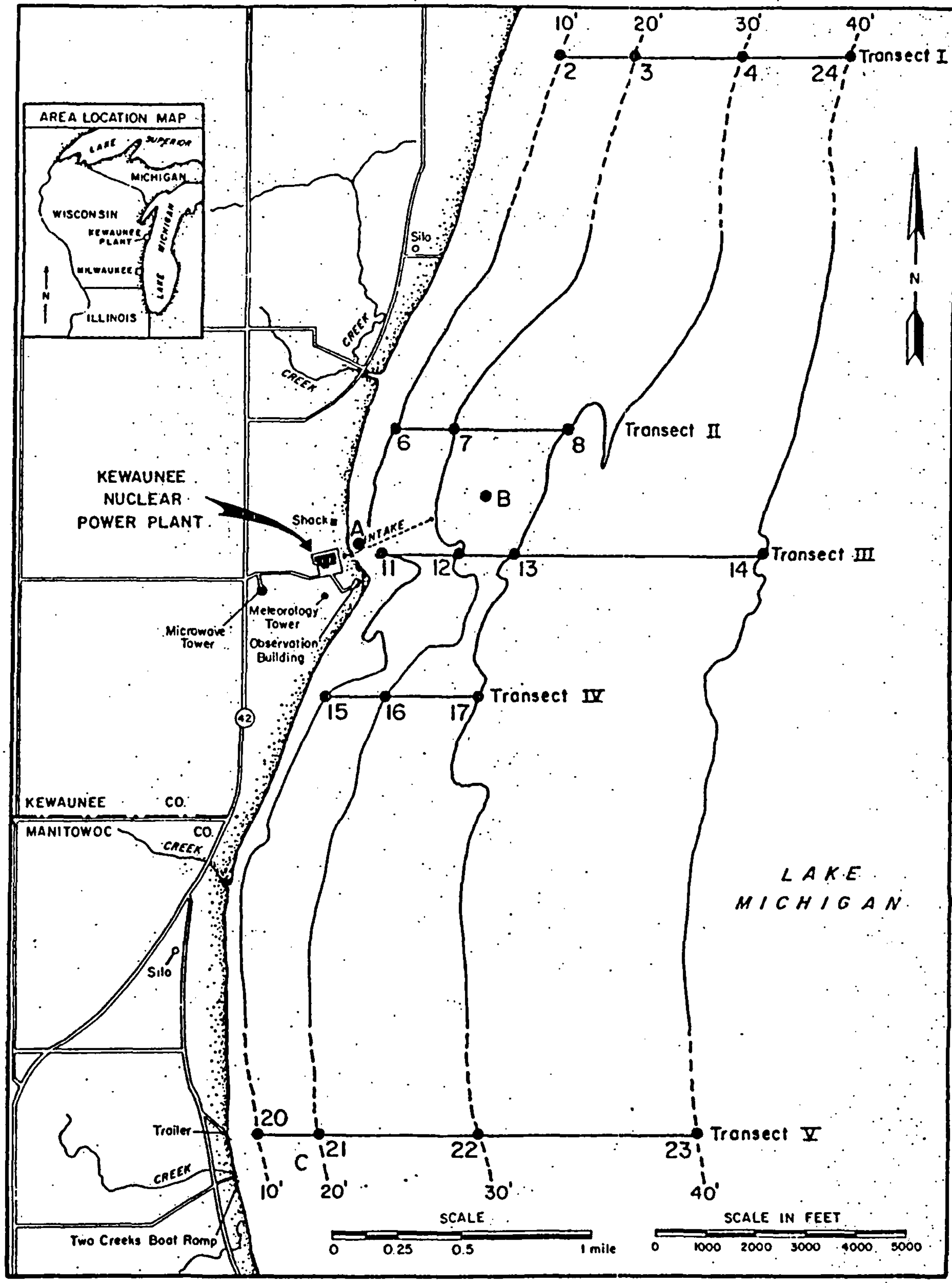


Figure 4.2.1. Chemistry sampling locations near the Kewaunee Nuclear Power Plant, 1971-1975.

Table 4.2.2. Chemistry sampling locations and depths along transects in Lake Michigan near the Kewaunee Nuclear Power Plant, 1972-1975.

Transect	Lake Depth Contour	Sampling Location	Sampling Depth	Description of Transect
I	10 ft	2	M[b]	2.0 miles north of KNPP
	40 ft	24[a]	T,M,B	
II	20 ft	7	T,B	0.5 miles north of KNPP
III	10 ft	11	M	Directly in front of KNPP
	20 ft	12	T,B	
	40 ft	14	T,M,B	
IV	20 ft	16	T,B	0.5 miles south of KNPP
V	10 ft	20	M	2.5 miles south of KNPP
	40 ft	23[a]	T,M,B	

a Not included during the 1972 study.

b T = Top of water column
M = Middle of water column
B = Bottom of water column

Table 4.2.3. Chemical profile locations and parameters in Lake Michigan near Kewaunee Nuclear Power Plant, 1972-1975.

Year	Locations	Parameters
1972	2,3,4,6,7,8,10,11,12, 13,14,15,16,17,20,21,22	Temperature Dissolved Oxygen Oxygen Saturation
1973	All 1972 locations plus Locations 23 and 24	Temperature Dissolved Oxygen Oxygen Saturation
1974	All 1972 locations plus Locations 23 and 24	Temperature Dissolved Oxygen Oxygen Saturation pH Specific Conductance
1975	All 1972 loctations plus Locations 23 and 24	Temperature Dissolved Oxygen Oxygen Saturation pH Specific Conductance

(Weschler et al. 1971). Numerous studies covering large portions of Lake Michigan have also been made, such as work by Beeton (1969) and Schelske and Stoermer (1971 and 1972).

Comparison of data from the area near KNPP with that from other parts of Lake Michigan has shown that the water quality is quite similar in these various sections of the lake (Table 4.2.4). Parameters such as temperature and dissolved oxygen which show seasonal trends display similar patterns both close to KNPP and in other parts of the lake. Certain parameters, such as silica, have shown marked concentration changes with time (Schelske and Stoermer 1972) and these temporal trends have also been noted in the waters near KNPP (Ellis 1975). Such findings strongly indicate that the quality of the waters near KNPP is representative of general Lake Michigan conditions.

Comparison of data from the sampling locations near KNPP has demonstrated the existence of a single, homogeneous water mass in the area (Industrial BIO-TEST Laboratories, Inc. 1972 and 1973, Gara and Hawley 1974, Ellis 1975). The only significant variations from homogeneity occurred in the concentrations of certain weather-related parameters at nearshore locations during periods of high turbulence (Gara and Hawley 1974, Ellis 1975).

Table 4.2.4. Comparison of mean concentrations for selected parameters between samples collected from Lake Michigan in the vicinity of Kewaunee Nuclear Power Plant and mean concentrations from other studies.

Parameter	KNPP (NALCO Environmental Sciences)[a]	Point Beach Nuclear Power Plant (Weschler et al. 1971)	Sheboygan and Green Bay (Baumeister 1972)	Lake Michigan (Beeton 1969)
Alkalinity (mg/l-$CaCO_3$)	109	111	111	
Calcium (mg/l)	34			34
Chloride (mg/l)	7.7		8	8
Iron (mg/l)	0.13		0.16	
Magnesium (mg/l)	11.4			10
Nitrate (mg/l-N)	0.17	0.18	0.2	0.19
Phosphorus, total (mg/l-P)	0.016			0.013
Residue, filtrable (mg/l)	164			160
Silica, soluble (mg/l-SiO_2)	0.61	0.80		0.28[b]
Sodium (mg/l)	4.4		4.5	
Sulfate (mg/l)	19		18	20

[a] Based on data from Industrial BIO-TEST Laboratories (1972 and1973), Gara and Hawley (1974), Ellis (1975), and NALCO Environmental Sciences (1975). (The mean concentrations are pooled data from all locations except the location within the plume).

[b] From Schelske and Callender (1970).

4.2.2 Effects of Plant Operation on the Water Quality of the Discharge Zone

The discharge zone of KNPP has been defined in Section 4.1.6. The only chemistry sampling location consistently under the influence of the plume was Location 11 (Table 4.2.5). Therefore, comparisons were made between the data for Location 11 in the immediate discharge area and the area adjacent to the discharge area (all other sampling locations not located in the plume on the day of sampling) as a means of determining differences that might be attributed to plant operation. In addition, the data for each parameter which was monitored both before and after KNPP operation was further compared on a pre-operational and operational basis (Tables 4.2.6-4.2.9). Mean concentrations of the parameters measured for all years of monitoring at the plume location and at locations outside of the plume were also calculated.

In order to test for water quality trends with time, the data were fitted to a linear regression model. Parameters which displayed cyclic, seasonal trends did not always fit this model precisely; however, linear regression served as a convenient simplifying assumption for a body of data in which the sampling dates, intervals between sampling dates, locations and parameters analyzed varied during the study period from 1971 to 1975. Regression lines for selected parameters were calculated and plotted for the preoperational and operational periods as well as the entire study period from Location 11 data and data from all other locations. Significance tests were performed to

Table 4.2.5. Sampling locations which were within the area of major influence of the Kewaunee Nuclear Power Plant thermal plume at the time of sampling.

Sampling Date	Locations in Plume
25 June 1974	Location 11
23 July 1974	Location 11
23 October 1974	Location 11
12 November 1974	Location 11
22 April 1975	Locations 7,11
20 May 1975	Locations 7,11
24 June 1975	Location 11
22 July 1975	Location 11

Table 4.2.6. Preoperational, operational and entire study means for general water quality parameters near Kewaunee Nuclear Power Plant, 1971-1975.

Parameter	In Plume (Location 11) All Years	Pre-operational	Operational	Outside Plume (all other locations) All Years	Pre-operational	Operational
Alkalinity, total ($mg/l-CaCO_3$)	111	112	107	109	111	106
Calcium (mg/l)	36	37	35	34	35	34
Chloride (mg/l)	7.6	7.6	7.7	7.7	7.6	7.8
Color, true (units)	3	3	3	2	2	2
Conductance, specific (μmhos/cm)	271	267	284	272	263	283
Fluoride (mg/l)	0.10	0.10	0.10	0.10	0.11	0.10
Hardness, total ($mg/l-CaCO_3$)	138	140	134	134	135	131
Magnesium (mg/l)	11.8	12.0	11.6	11.4	11.3	11.4
Oxygen, dissolved (mg/l)	11.1	11.2	10.9	11.2	11.1	11.2
Oxygen, saturation (%)	99	100	99	97	96	97
pH	8.2	8.2	8.2	8.2	8.2	8.2
Potassium (mg/l)	1.3	1.4	1.1	1.2	1.3	1.1
Residue, filtrable (mg/l)	165	162	170	164	163	166
Residue, nonfiltrable (mg/l)	17	23	11	7	8	6
Residue, total (mg/l)	185	188	182	171	170	172
Sodium (mg/l)	4.4	4.4	4.4	4.4	4.4	4.3
Sulfate (mg/l)	19	19	20	19	18	19
Turbidity (N.T.U.)	16	21	7.4	7.7	11	3.1

Table 4.2.7. Preoperational, operational and entire study means for aquatic nutrients at the in-plume location (Location 11) and at all other sampling locations in Lake Michigan near Kewaunee Nuclear Power Plant, 1971-1975.

Parameter	In Plume (Location 11)			Outside Plume (all other locations)		
	All Years	Pre-operational	Operational	All Years	Pre-operational	Operational
Ammonia (mg/l-N)	0.02	0.02	0.02	0.02	0.02	0.02
Nitrate (mg/l-N)	0.19	0.19	0.18	0.17	0.18	0.16
Nitrite (mg/l-N)	0.0028	0.0027	0.0030	0.0026	0.0026	0.0026
Organic nitrogen (mg/l)	0.26	0.25	0.27	0.22	0.23	0.22
Orthophosphate, soluble (mg/l-P)	0.001	0.002	<0.001	0.002	0.003	<0.001
Phosphorus, total (mg/l-P)	0.028	0.034	0.017	0.016	0.019	0.011
Silica, soluble (mg/l-SiO_2)	0.56	0.61	0.47	0.61	0.64	0.58

Table 4.2.8. Preoperational, operational and entire study means for indicators of industrial and municipal contamination at the in-plume location (Location 11) and at all other sampling locations in Lake Michigan near Kewaunee Nuclear Power Plant, 1971-1975.

Parameter	In Plume (Location 11)			Outside Plume (all other locations)		
	All Years	Pre-operational	Operational	All Years	Pre-operational	Operational
Bacteria, total coliform[a] (No./100 ml)	6	7	4	3	5	2
Bacteria, fecal coliform[a] (No./100 ml)	2	2	1	1	1	1
Bacteria, fecal streptococci (No./100 ml)[a]	5	10	2	3	5	2
Bacteria, standard plate count (20.0 C)(No./100 ml)[a]	19000	34000	6200	8800	19000	2800
Bacteria, standard plate count (35.0 C)(No./100 ml)[a]	5000	9600	1300	2800	8300	550
Biochemical oxygen demand (5 day) (mg/l)	1.8	2.1	1.4	1.8	2.0	1.4
Chemical oxygen demand (mg/l)	7.0	7.2	6.5	6.4	6.9	5.7
Chlorine, total (mg/l)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Hydrazine (mg/l)	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Morpholine (mg/l)	<1	<1	<1	<1	<1	<1
Organic carbon, total (mg/l)	7	8	5	6	6	5

[a] Geometric mean.

Table 4.2.9. Preoperational, operational and entire study means for trace metals at the in-plume location (Location 11) and at all other sampling locations in Lake Michigan near Kewaunee Nuclear Power Plant, 1971-1975.

	In Plume (Location 11)			Outside Plume (all other locations)		
Parameter	All Years	Pre-operational	Operational	All Years	Pre-operational	Operational
Arsenic (mg/l)	0.001	<0.001	0.001	0.001	<0.001	0.001
Boron (mg/l)	0.04	0.04	0.04	0.03	0.03	0.04
Cadmium (mg/l)	0.00011	0.00012	0.00005	0.000011	0.00012	0.00005
Chromium (mg/l)	0.0016	0.0019	0.0010	0.0013	0.0016	0.0009
Copper (mg/l)	0.0024	0.0026	0.0021	0.0017	0.0017	0.0016
Iron (mg/l)	0.28	0.36	0.15	0.13	0.17	0.078
Lead (mg/l)	0.003	0.004	<0.001	0.003	0.004	<0.001
Manganese (mg/l)	0.0065	0.0074	0.0049	0.0032	0.0034	0.0029
Mercury (mg/l)	0.00016	0.00018	0.00011	0.00021	0.00025	0.00013
Nickel (mg/l)	0.002	0.003	<0.001	0.001	0.002	<0.001
Zinc (mg/l)	0.012	0.013	0.010	0.011	0.012	0.010

determine if the slopes of regression lines were significantly different from zero. If a difference was detected, the preoperational and operational lines were compared using the Student's "t" test at $P \leq 0.05$.

Dissolved Oxygen

Dissolved oxygen (D.O.) trends were inversely related to those of temperature during the operational period (Figure 4.2.2). The operational D.O. concentrations increased significantly with time and was caused by the imprecision of fit between an incomplete cycle of seasonal data and a linear regression model. This deviation was not related to KNPP operation. If the operational period included data from later in the summer of 1975, when lower values would have occurred, no increase in D.O. would have been observed. The plume location showed a D.O. decrease of 0.3 mg/l between the preoperational and operational periods (related to a small temperature increase). However, the operational mean of 10.9 mg/l was well above the minimum standard of 5 mg/l established by the Wisconsin Department of Natural Resources (DNR)(1975) for the protection of fish and other aquatic life.

Composite vertical profiles were prepared comparing Location 11 with the mean of two non-plume locations (Locations 2 and 20) along the same (10 ft) depth contour for the preoperational and operational periods (Figure 4.2.3). The preoperational data were taken from two dates in August 1972 and June and July 1973 while the operational data were taken from June and July in 1974 and 1975. Temperature profiles are also presented to illustrate

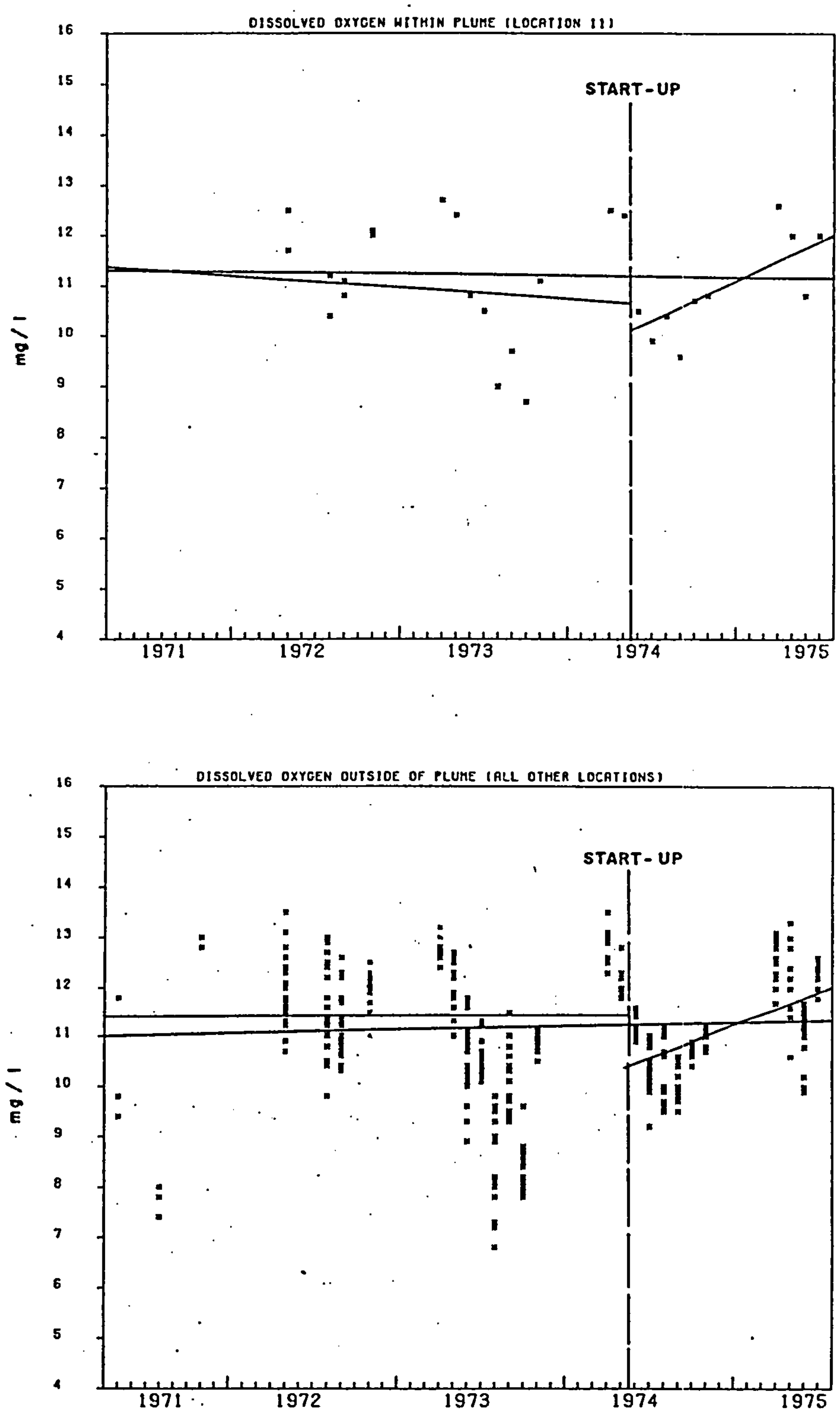


Figure 4.2.2. Dissolved oxygen trends within and outside of the thermal plume for the preoperational, operational and entire study periods in Lake Michigan near Kewaunee Nuclear Power Plant, 1971-1975.

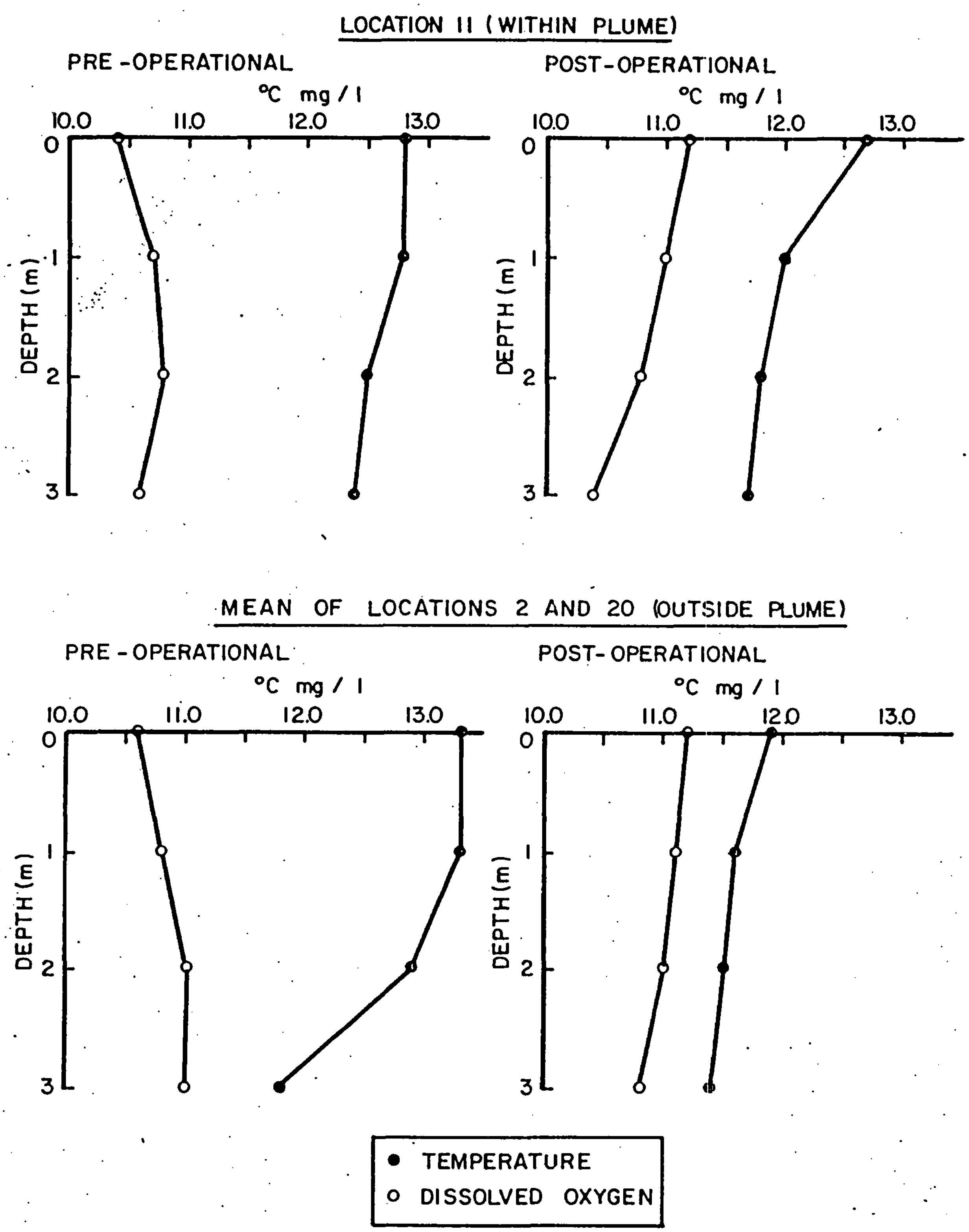


Figure 4.2.3. Temperature and dissolved oxygen depth profiles in Lake Michigan for 10 ft contour locations within and outside of the thermal plume during the preoperational (summer 1972 and 1973) and operational (summer 1974 and 1975) periods of Kewaunee Nuclear Power Plant.

the relationship between D.O. and temperature. D.O. values did not vary significantly throughout the water column nor was there any difference between Location 11 and Locations 2 and 20. Surface values were lower than the rest of the water column at all locations during the preoperational period but this was not observed during the operational period. Since similar patterns and values were observed at both sets of locations, it was concluded that this effect was not due to plant operation.

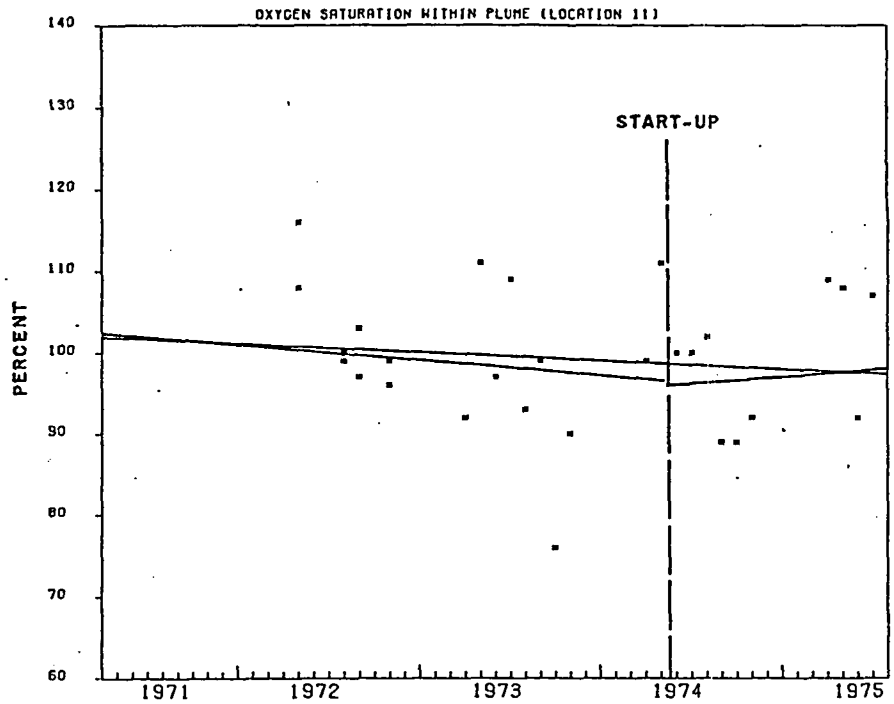
Oxygen and Nitrogen Saturations

Oxygen saturation values ranged from approximately 65% to 125% during the study period (Figure 4.2.4), although the regression line slopes were not significantly different from zero. The mean oxygen saturation declined from 100% to 99%, an insignificant variation.

Dissolved nitrogen saturations were estimated by direct measurement in May 1975. The mean nitrogen saturation in the plume was 100%, which is the characteristic value for natural water systems. No preoperational data are available for comparison.

Chlorine and Chemicals Used in the Plant

Total chlorine was monitored but never detected. This was expected as chlorine is not used at KNPP for condenser defouling, although the Plant does have the capability and permit to chlorinate at a level of 0.1 ppm in the discharge if necessary (Tom Meinz, Wisconsin Public Service Corporation, personal communication, 24 February 1976) (Table 4.2.8). Hydrazine and morpholine, the plant chemicals monitored in both preoperational and



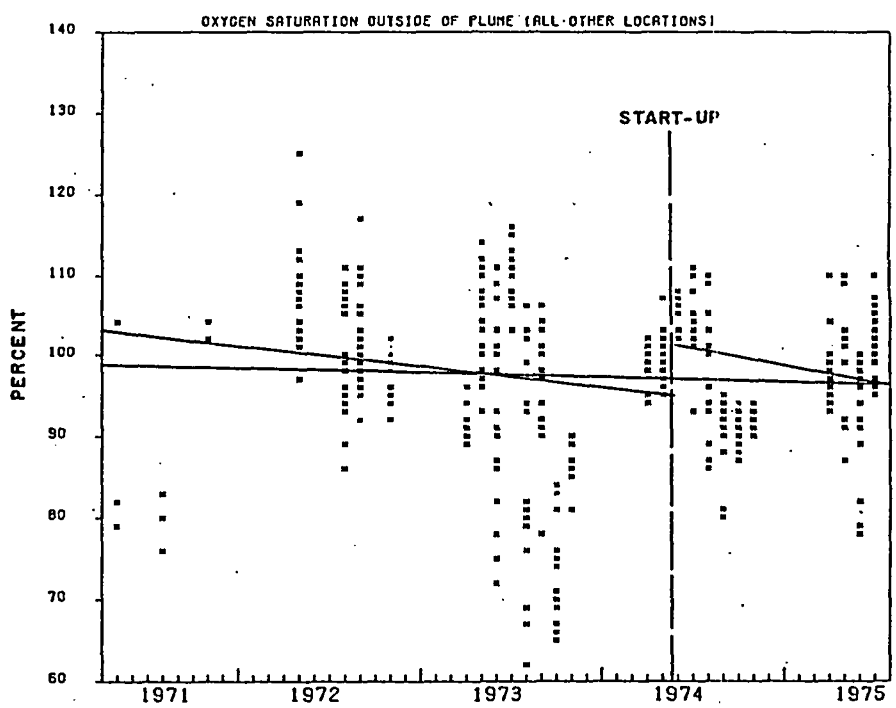


Figure 4.2.4. Oxygen saturation trends within and outside of the thermal plume for the preoperational, operational and entire study periods in Lake Michigan near Kewaunee Nuclear Power Plant, 1971-1975.

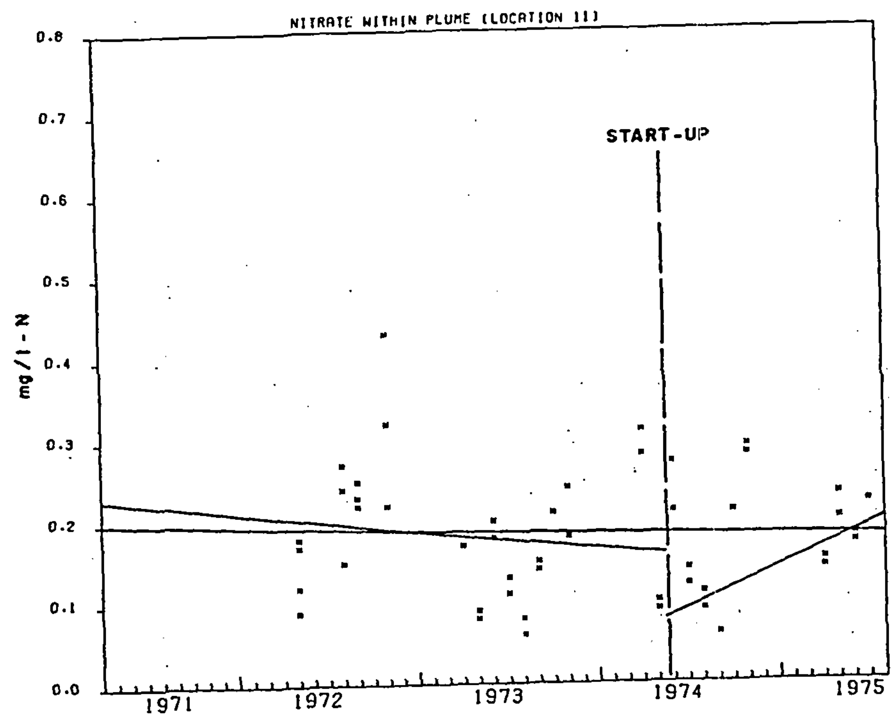
operational periods, were never detected in the KNPP plume (Table 4.2.8). Since no toxic chemicals were measured in the KNPP discharge or plume it is concluded that those chemicals do not represent an appreciable threat to the biota of Lake Michigan either when being considered separately or in synergistic effects with heat.

Nutrients

All mean concentrations of the nitrogen species measured, ammonia, nitrate, nitrite and total organic nitrogen, displayed only minor variations when comparing Location 11 to those not in the plume both prior to and during plant operation (Table 4.2.7). Nitrate was selected to illustrate the typical pattern of nitrogen species results (Figure 4.2.5). No long-term variations in nitrate concentrations were observed either prior to or during KNPP operation, or throughout the entire study period and none of the regression line slopes were significantly different from zero.

Soluble orthophosphate concentrations were near to or below the analytical detection limit of 0.001 mg/l-P during the entire study period. No temporal trends were apparent.

The mean concentration of total phosphorus at Location 11 during the operational period was half that of the preoperational period (Table 4.2.7). A similar concentration ratio was observed at locations outside the area of immediate plume influence, which suggests that these changes were related to differences in turbulence during sampling periods. Phosphorus has been associated with weather-related parameters such as turbidity (Ellis 1975) and is present at high concentrations in Lake Michigan sediments (Schleicher and Kuhn 1970); preoperational sampling in September 1972 and April 1974 followed periods of extreme turbulence due to wave action and the water samples displayed high turbidities and phosphorus concentrations. This factor resulted in the disparity between the preoperational and operational means. However no



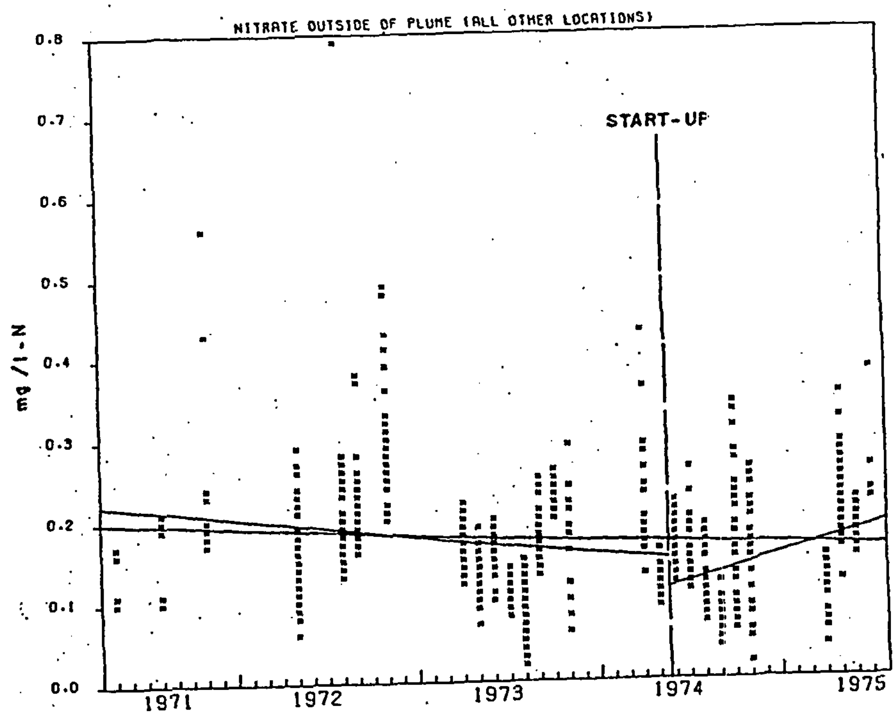
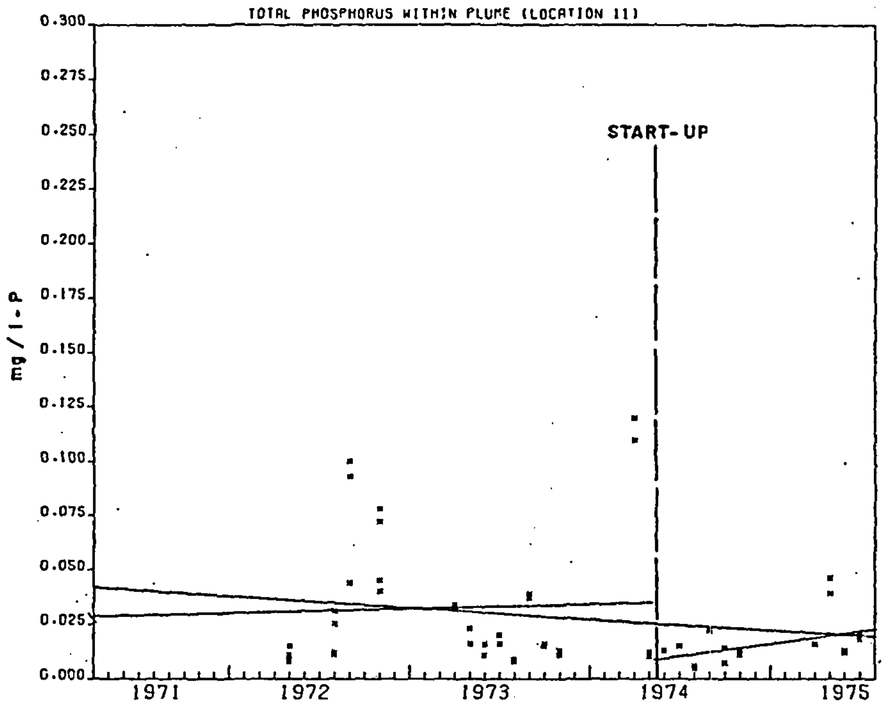


Figure 4.2.5. Nitrate trends within and outside of the thermal plume for the preoperational, operational and entire study periods in Lake Michigan near Kewaunee Nuclear Power Plant, 1971-1975.

long-term trend for phosphorus was observed over the entire sampling period as the regression line slopes were not significantly different from zero (Figure 4.2.6). Therefore, KNPP operation did not influence total phosphorus concentrations.

Soluble silica concentration means decreased slightly between the preoperational and operational periods (Table 4.2.7) both in the plume and outside the immediate discharge area (Figure 4.2.7). Silica concentrations decreased throughout the entire study period at a rate of 0.07 mg/l-SiO_2 per year. A rate of decrease of 0.10 mg/l-SiO_2 per year has been observed in Lake Michigan near Chicago, Illinois, (Schelske and Stoermer 1972) and has been related to a concomitant increase in diatom biomass. The relationship of silica to diatom populations is discussed further in Section 4.3.3. The apparent increase in silica during the operational period was probably due to the fitting of an incomplete cycle of seasonal changes to a linear regression line. Depletion of silica in the summer of 1974 just after the start of KNPP operation was followed by silica replenishment before the 1975 spring sampling and caused an apparent short-term increase. Inclusion of data from later in 1975 would gave produced a much smaller increase. Neither the long-term decrease nor the short-term operational increase were related to plant operation since the same situation was observed at the locations outside of plume influence.



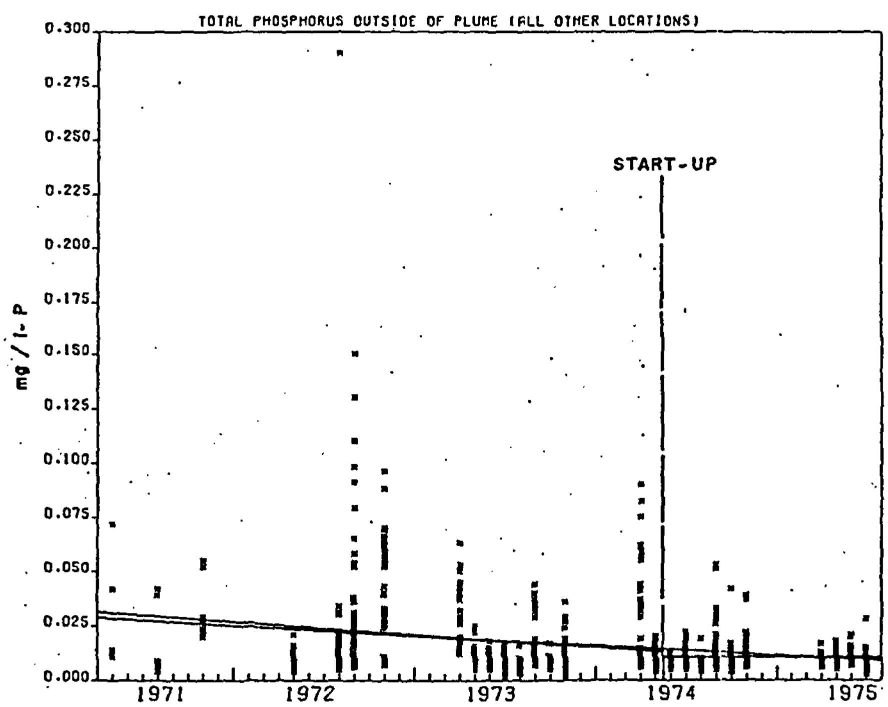


Figure 4.2.6. Total phosphorus trends within and outside of the thermal plume for the preoperational, operational and entire study periods in Lake Michigan near Kewaunee Nuclear Power Plant, 1971-1975.

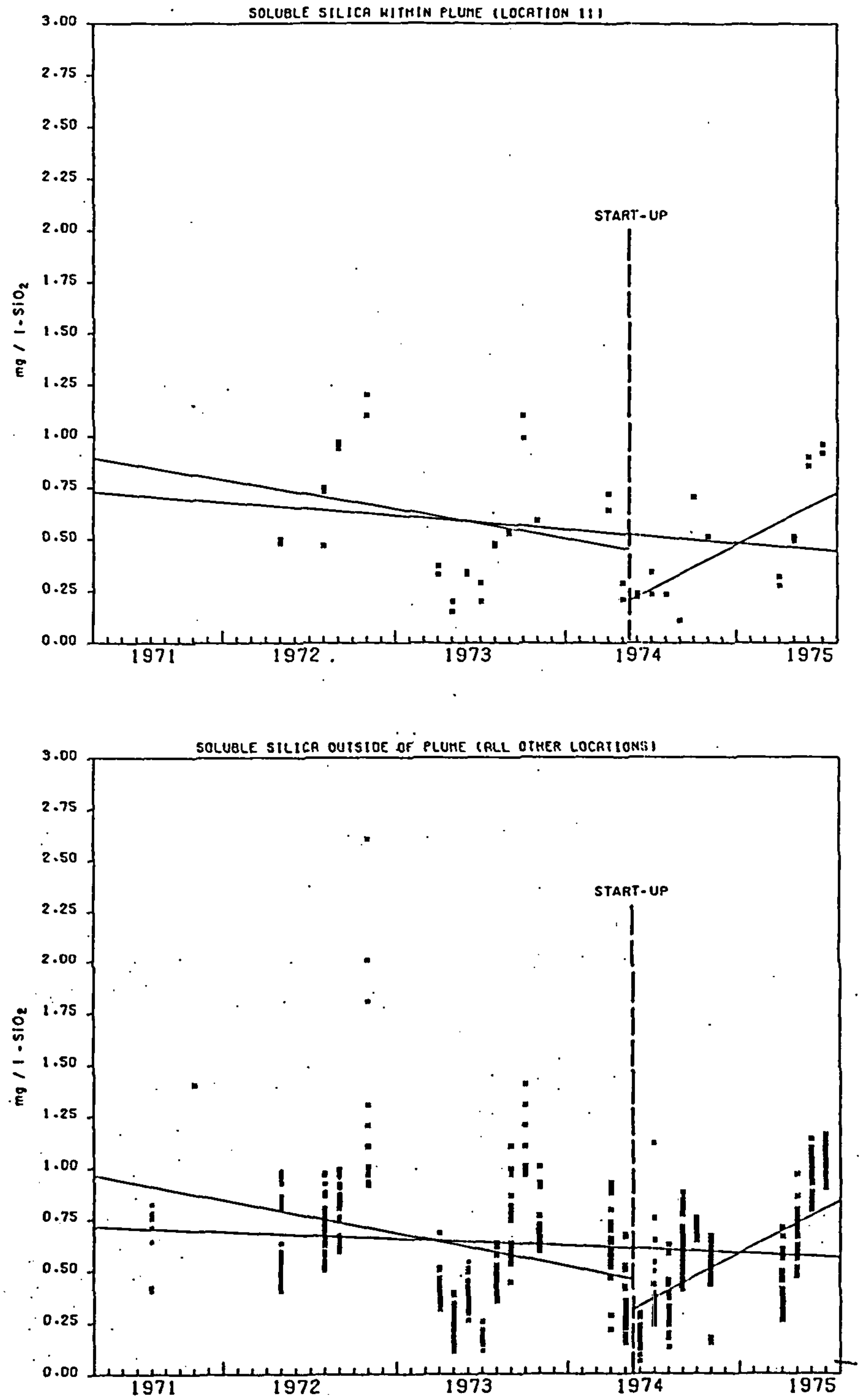


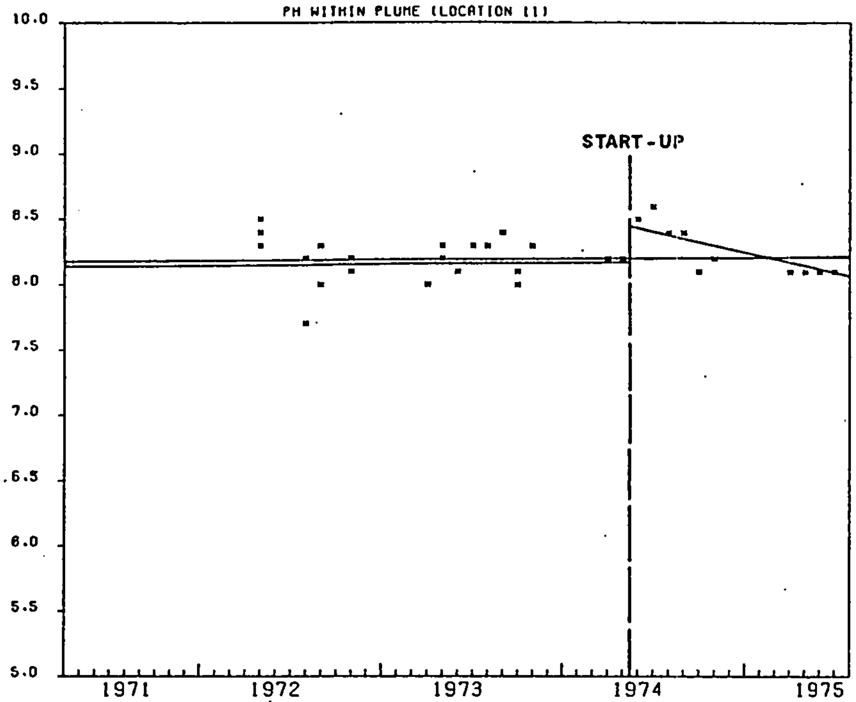
Figure 4.2.7. Soluble silica trends within and outside of the thermal plume for the preoperational, operational and entire study periods in Lake Michigan near Kewaunee Nuclear Power Plant, 1971-1975.

General Water Quality Parameters

Alkalinity and pH varied little between the preoperational and operational periods (Table 4.2.6). Alkalinity declined from 112 to 107 mg/l-$CaCO_3$ while pH remained unchanged at 8.2. There was little change in pH with time (Figure 4.2.8), and no effect of plant operation was observed for either parameter.

Mean turbidity was much higher during the preoperational period than in the operational period (Table 4.2.6). This was due to high turbulence in several months such as September 1972 and April 1974 when wave action was excessive. High turbidity was observed not only in the plume but to a lesser extent throughout the entire KNPP study area (turbulence effects are obscured with increasing depth). This temporal effect produced a slight overall decline in turbidities (Figure 4.2.9), but no change in turbidity was observed during the operational period when the slope was not significantly different from zero. Nonfiltrable residue (total suspended solids) concentrations were closely related to turbidities and also declined between the preoperational and operational periods both in and out of the plume (Table 4.2.6). Turbidity and total suspended solids data indicated that the operation of KNPP had no apparent effect on the suspended material in Lake Michigan waters.

Filtrable residue (total dissolved solids) increased slightly in the plume over the study period; however, a similar trend was observed in the area outside of the plume (Figure 4.2.10). Mean concentrations (Table 4.2.6) were well below the standard of



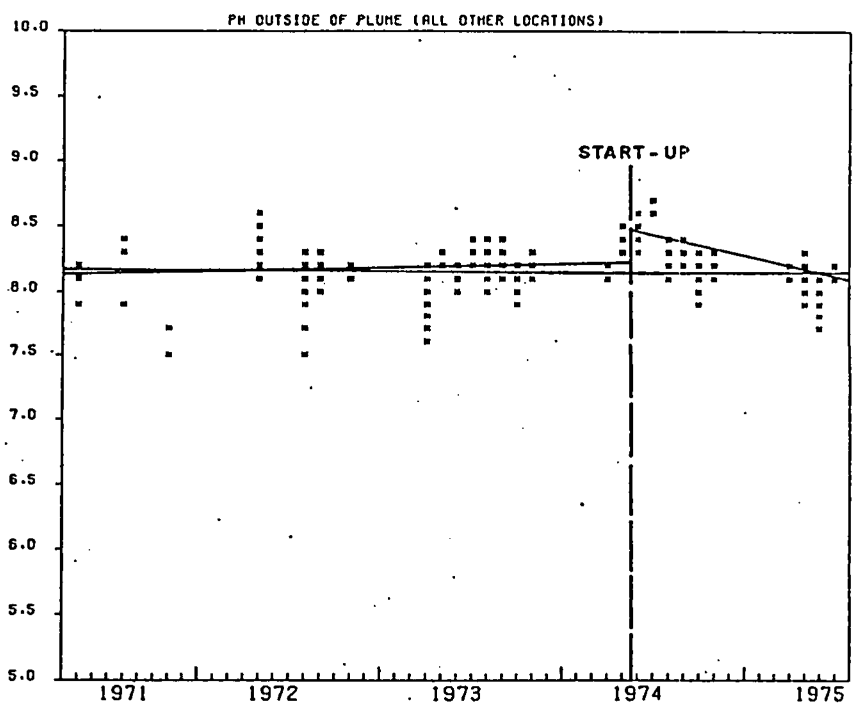
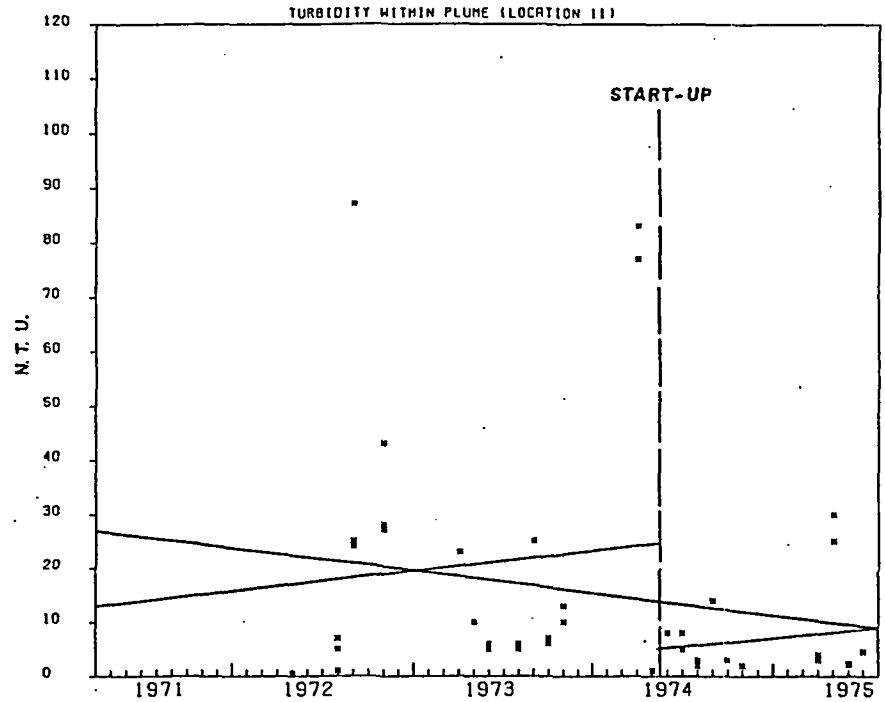


Figure 4.2.8. pH trends within and outside of the thermal plume for the preoperational, operational and entire study periods in Lake Michigan near Kewaunee Nuclear Power Plant, 1971-1975.



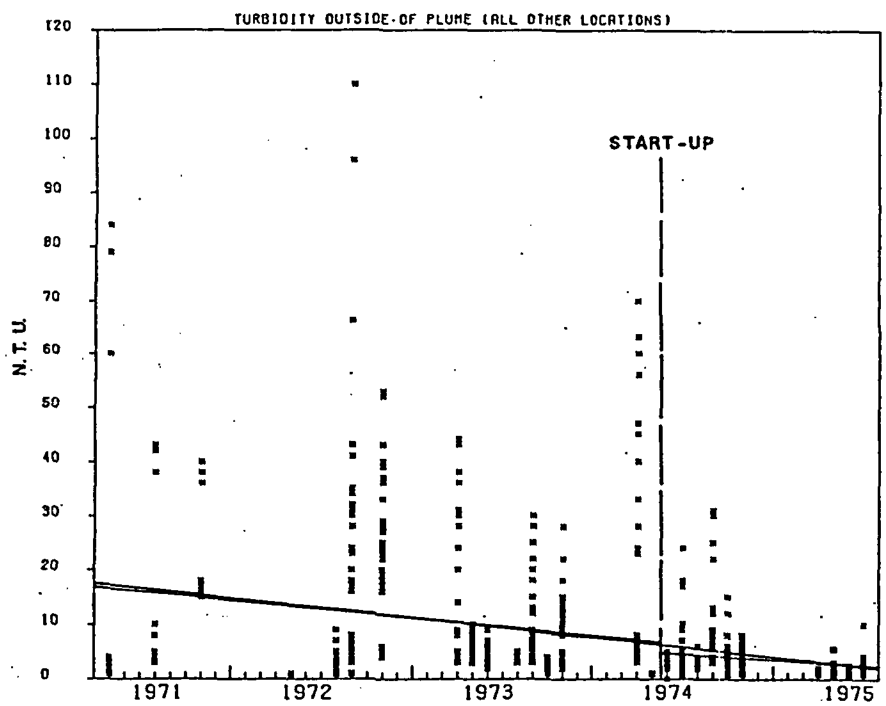
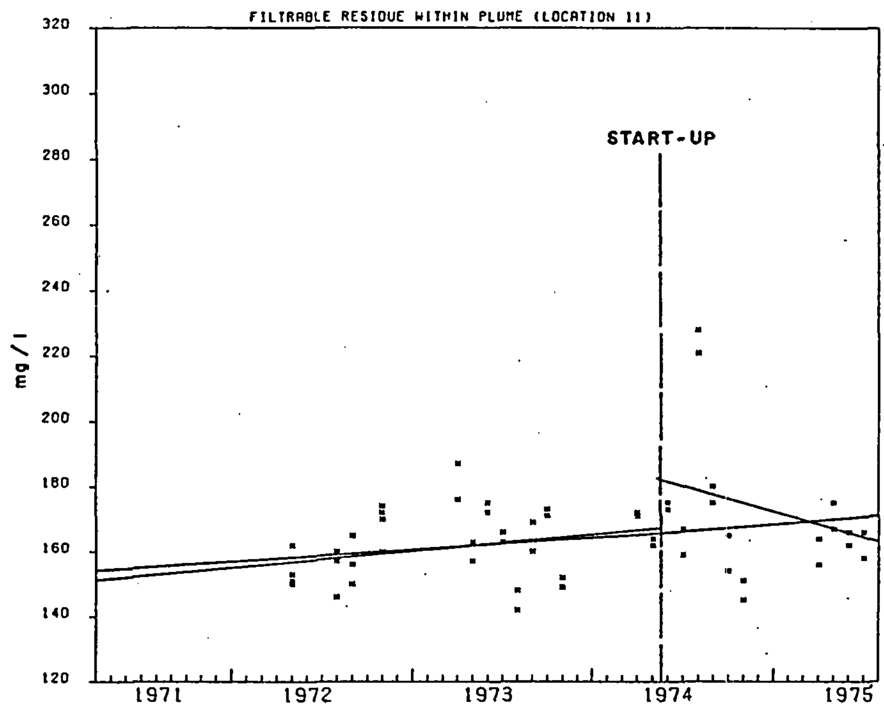


Figure 4.2.9. Turbidity trends within and outside of the thermal plume for the preoperational, operational and entire study periods in Lake Michigan near Kewaunee Nuclear Power Plant, 1971-1975.



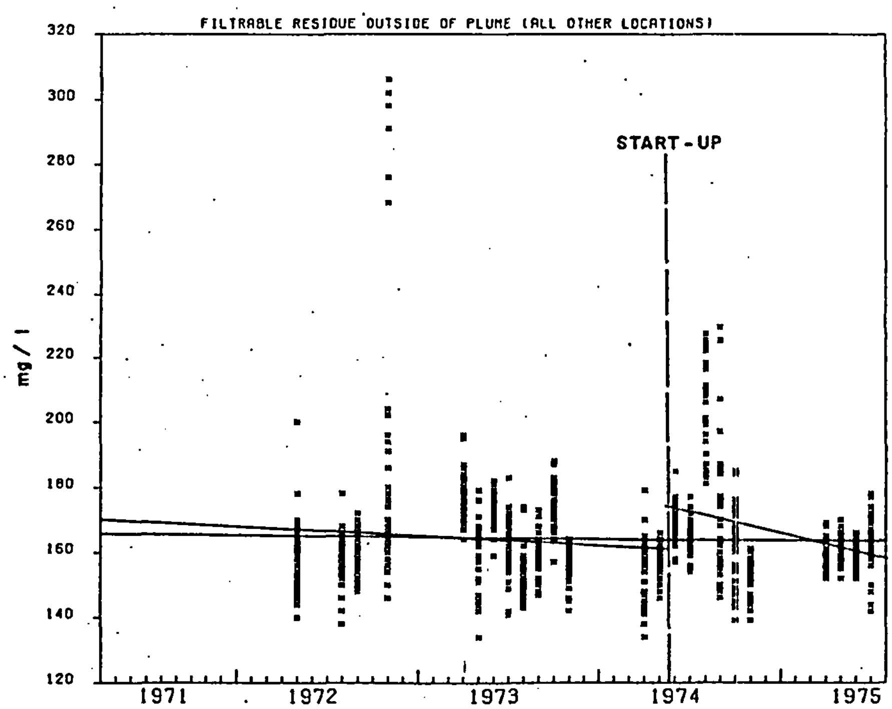


Figure 4.2.10. Filtrable residue (total dissolved solids) trends within and outside of the thermal plume for the preoperational, operational and entire study periods in Lake Michigan near Kewaunee Nuclear Power Plant, 1971-1975.

500 mg/l established by the Wisconsin Department of Natural Resources (1975). Total solids represent the sum of suspended and dissolved solids and showed a slight (6 mg/l) decrease between preoperational and operational means (Table 4.2.6). True color means were constant at 3 units throughout the study period. Specific conductance means followed a pattern similar to the dissolved solids and showed a 6% increase from 267 to 284 μmhos/cm (at 25 C) following the beginning of KNPP operation. Since a similar trend was observed at the locations outside plume influence this trend was not due to plant operation. In general, dissolved materials changed very little and no effect of KNPP operation was discernible.

Major Anions and Cations

The major anions and cations (calcium, magnesium, total hardness, potassium, sodium, chloride, fluoride and sulfate) are conservative constituents and should not change with time in Lake Michigan without input from an outside source. Although Beeton (1969) has shown that chloride and sulfate have increased substantially in Lake Michigan over the last 90 years, no increase between the preoperational and operational periods was found in parameters monitored in the plume waters of KNPP (Table 4.2.6), thus, indicating that KNPP operation has not added measurable quantities of major anions and cations to Lake Michigan.

Bacteria

Total and fecal coliform and fecal streptococci bacteria were present at very low levels in the KNPP plume area throughout the study period (Table 4.2.8). The fecal coliform geometric means were far below the level of 200 per 100 ml established as a standard by the Wisconsin Department of Natural Resources (1975).

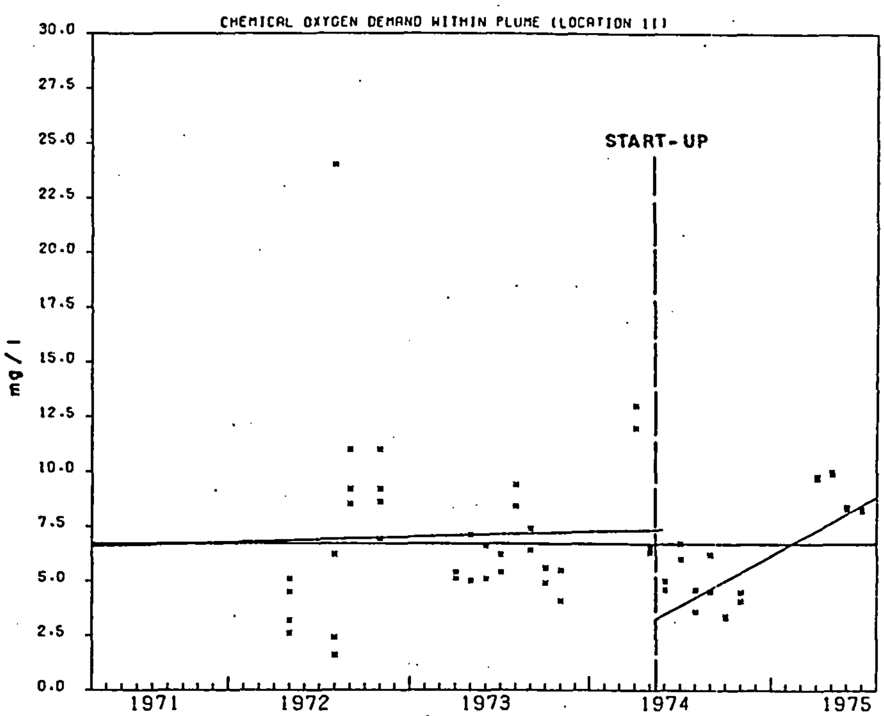
Standard plate count bacteria at 20 C and 35 C decreased significantly between preoperational and operational periods (Table 4.2.8). This decrease was due to a change in sampling techniques for bacteria rather than to a real change in Lake Michigan waters (Ellis 1975).

Biochemical Oxygen Demand (B.O.D.), Chemical Oxygen Demand (C.O.D.), and Total Organic Carbon (T.O.C.)

B.O.D. and C.O.D. varied similarly throughout the study. C.O.D. was selected for illustration (Figure 4.2.11). There was an overall decrease in both parameters with time, although a slight increasing trend occurred during KNPP operation. Because these variations were observed at both plume and non-plume locations (Figure 4.2.11), they cannot be ascribed to KNPP operation. The mean of T.O.C. concentration varied only slightly throughout the study and no influence of KNPP operation was discernible.

Trace Metals

Trace metal means within and outside the plume decreased from the preoperational to the operational period, with the exception of arsenic, which increased slightly, and boron, which remained constant (Table 4.2.9). The decreases in iron and manganese were related to the decreases in turbidity, total suspended solids and total phosphorus already noted. The operational



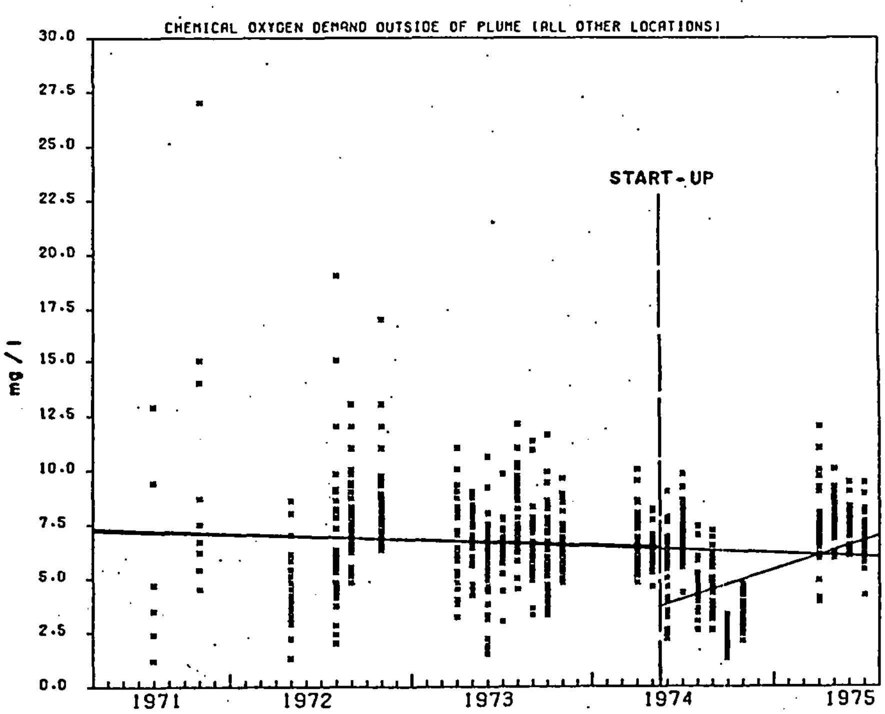
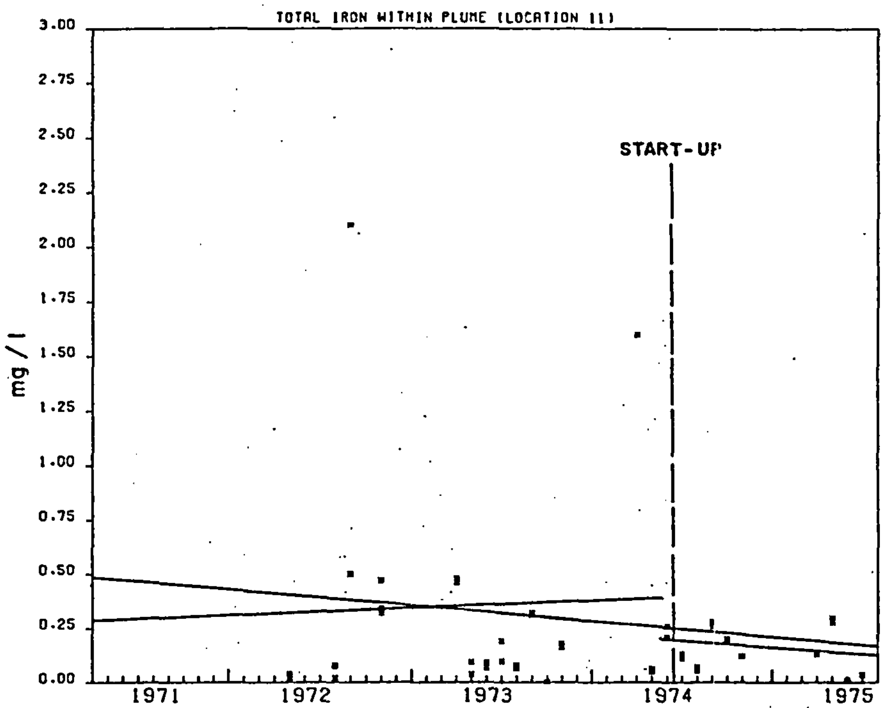


Figure 4.2.11. Chemical oxygen demand trends within and outside of the thermal plume for the preoperational, operational and entire study periods in Lake Michigan near Kewaunee Nuclear Power Plant, 1971-1975.

trends for iron (Figure 4.2.12) and manganese were not significantly different from the preoperational trends, nor were the operational trends significantly different from zero.

Arsenic was the only trace metal whose concentrations increased significantly during the operational period (Table 4.2.9). However, since this variation was between values close to the analytical detection limit and was also observed at the locations outside of the influence of the plume, it was concluded that this trend was not related to plant operation. Therefore, no effect of plant operation was observed for any of the trace metals in the plume area.



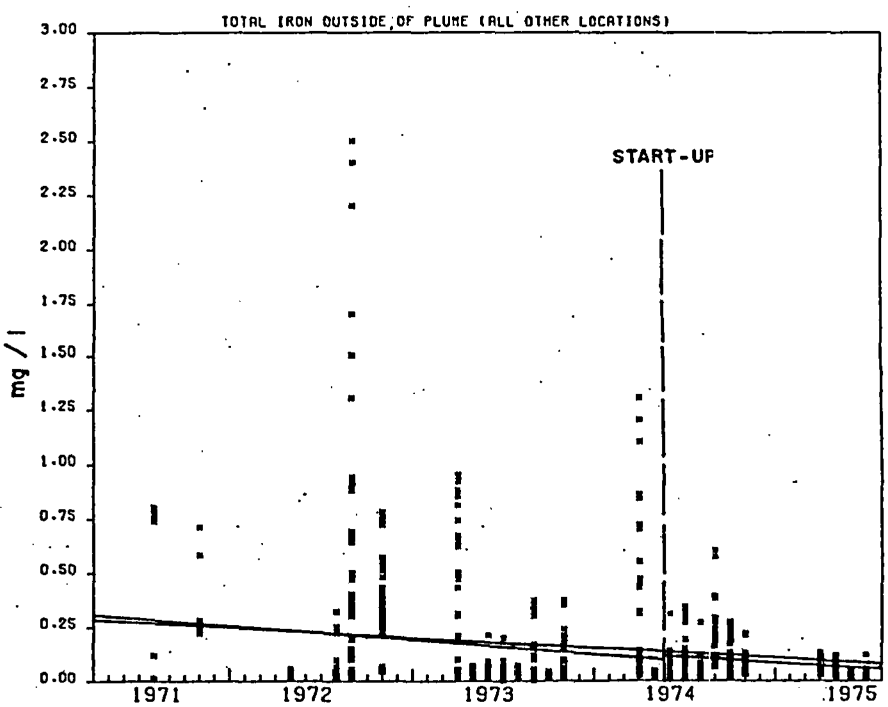


Figure 4.2.12. Total iron trends within and outside of the thermal plume for the pre-operational, operational and entire study periods in Lake Michigan near Kewaunee Nuclear Power Plant, 1971-1975.

4.2.3 <u>The Effect of Plant Operation on the Water Quality of the Receiving Water Body</u>

Assessment of the effects of plant operation on the receiving water body are based on two considerations. Most important is the comparison between the preoperational and operational periods for those locations outside the discharge zone. This material has already been presented in Section 4.2.2 so that, in most cases, only a reiteration of conclusions is necessary. Where changes between preoperational and operational years were observed, examination of the magnitude of effect is made.

<u>Dissolved Oxygen</u>

D.O. trends outside of the plume were similar to the trends previously noted within the plume (Figure 4.2.2) and were related to the format of data presentation. The D.O. mean for the region outside of the plume increased slightly after KNPP operation (Table 4.2.6) but this increase was not considered important.

<u>Oxygen and Nitrogen Saturations</u>

Oxygen and nitrogen saturations in the operational period increased by 1% over the preoperational period (Table 4.2.6). This was not a significant change and, since the oxygen saturation decreased by only 1% in the plume, it was concluded that KNPP operation did not produce a discernible change in saturations either within or outside of the plume.

Dissolved nitrogen saturations were estimated by direct measurement in May 1975. The mean nitrogen saturation for the area outside of the plume was 100%, the same as within the plume. No preoperational data are available for comparison.

Defouling Chemicals Used in the Plant

Total chlorine, hydrazine and morpholine were never detected in the region outside of the KNPP plume (Table 4.2.8).

Nutrients

The mean values for the nitrogen species varied little at the locations outside of the plume (Table 4.2.7) between the preoperational and operational periods. Temporal trends in nitrate concentrations were similar within and outside of the plume (Figure 4.2.5), indicating that changes between the pre-operational and operational periods were due to natural nitrate fluctuations in Lake Michigan rather than to KNPP operation.

Soluble orthophosphate concentrations were near or below the analytical detection limit of 0.001 mg/l-P throughout 1971-1975. No temporal trends of consequence were apparent.

Total phosphorus means were appreciably lower in the region outside of the plume than within the plume. This effect was caused by the increased turbulence and higher turbidity levels present at Location 11 (plume location) compared to the other locations and was related to sediment concentrations, not KNPP operation (Ellis 1975). Preoperational and operational temporal trends for total phosphorus were similar both within and outside the thermal plume (Figure 4.2.6).

Soluble silica displayed similar trends both within and outside of the KNPP plume (Figure 4.2.7). These temporal changes have been related to lake-wide changes in silica concentrations and were not related to KNPP operation (Ellis 1975).

General Water Quality Parameters

Alkalinity and pH means varied little between the preoperational and operational periods (Table 4.2.6). Alkalinity decreased from 111 to 106 mg/l-$CaCO_3$ while pH remained unchanged at 8.2. There was little change in pH with time (Figure 4.2.8), and no effect of KNPP operation was observed for either parameter.

Turbidity means were appreciably lower outside the plume than within it (Table 4.2.6). This was attributed to the higher turbulence observed at Location 11 in relation to the other locations rather than to KNPP operation. Turbidity temporal trends did not change significantly after the beginning of KNPP operation (Figure 4.2.9) and were quite similar to trends for total phosphorus (Figure 4.2.6) and total iron (Figure 4.2.12) for the area outside of the plume. Nonfiltrable residue (total suspended solids) concentrations were related to turbidity levels and were therefore lower outside of the plume than at Location 11. However, no changes of significance were noted between the preoperational and operational periods in the area outside of the plume.

Filtrable residue (total dissolved solids) means increased negligibly outside the plume following KNPP operation (Table 4.2.6); however, the temporal trend for the entire operational period was a decreasing one both within and outside the plume (Figure 4.2.10). Total solids means varied slightly for the entire study period while true color means remained constant (Table 4.2.6). Specific conductance means increased by 9% following KNPP operation (Table 4.2.6). Since this increase is greater than that observed within the plume, it cannot be related to plant operation. Therefore, there is no evidence to show that KNPP operation has been responsible for changes in dissolved materials.

Major Anions and Cations

No significant changes in the mean values of the major anions or cations were detected between the preoperational and operational periods (Table 4.2.6).

Bacteria

Total coliform, fecal coliform and fecal streptococci bacteria were present at very low levels outside the KNPP plume area throughout the study period (Table 4.2.8). Fecal coliform geometric means were well below the level of 200 per 100 ml established as a standard by the Wisconsin Department of Natural Resources (1975). Standard plate count bacteria at 20 C and 35 C decreased greatly between preoperational and operational periods (Table 4.2.8). This decrease was related to a change in sampling techniques for bacteria rather than to a real change in Lake Michigan waters (Ellis 1975).

Biochemical Oxygen Demand (B.O.D.), Chemical Oxygen Demand (C.O.D.) and Total Organic Carbon (T.O.C.)

B.O.D., C.O.D. and T.O.C. mean concentrations were similar within and outside the KNPP plume (Table 4.2.8) and all parameters decreased slightly between the preoperational and operational periods. These changes were not considered important.

Trace Metals

All of the trace metal means for the area outside the plume decreased from the preoperational to the operational period, with the exceptions of arsenic and boron, both of which increased slightly (Table 4.2.9). The only change of significance was that for iron, which was related to the decreases in turbulence-produced suspended material already noted. This was illustrated by the fact that the changes with time for iron (Figure 4.2.12) were very similar for those of phosphorus and turbidity (Figures 4.2.6 and 4.2.9). The iron and manganese means were notably lower outside the plume than within it because the means for the outside area included many offshore locations where weather effects were small compared to the effects measured at Location 11.

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4.3 AQUATIC BIOLOGY STUDIES

4.3.1 Fish

4.3.1.1 Regional Community Structure of Fish in the Vicinity of the Kewaunee Nuclear Power Plant

Studies of the fish community of Lake Michigan in the vicinity of the KNPP have been conducted from 1971 to the present (Industrial BIO-TEST Laboratories, Inc. 1972, 1973; LaJeone 1974, 1975a, 1975b). Much of the data and information presented here are taken directly from these reports since these site-specific data were considered most pertinent to this demonstration. Additional sources of information were utilized principally for supplemental information beyond the scope of these studies and as supportive material where existing data may be lacking.

A list of fish species known to occur in the vicinity of KNPP is given in Table 4.3.1.1. Classification of a species as to its general occurrence in the area was determined from data available in site-specific studies. The table also contains the classification of representative important species for this area of Lake Michigan according to the Wisconsin Department of Natural Resources (WDNR)(1974). None of the fish listed as "important species" are considered endangered by the WDNR (1973 p. 5 and 16); however, the bloater and the cisco are given "changing status" classification, defined as "species that may or may not be holding their own at the present time." The only pollution tolerant species occurring in the vicinity of KNPP is the carp.

Assessment of the fishery near the KNPP has been conducted with the use of gill nets and minnow seine for adult

Table 4.3.1.1. Fish species collected in the vicinity of the Kewaunee Nuclear Power Plant and Wisconsin Department of Natural Resources classification.

Species[a] Scientific Name	Common Name	WDNR Classification[b]	General Occurrence
Alosa pseudoharengus	Alewife	RIS, Cm, F	Abundant
Dorosoma cepedianum	Gizzard shad		Uncommon
Coregonus artedii	Cisco or Lake herring	RIS, Cm, T	Uncommon
Coregonus clupeaformis	Lake whitefish	RIS, Cm	Uncommon
Coregonus hoyi	Bloater	RIS, Cm, T	Uncommon
Prosopium cylindraceum	Round whitefish	RIS, Cm	Uncommon
Oncorhynchus kisutch	Coho salmon	RIS, S	Common
Oncorhynchus tshawytscha	Chinook salmon	RIS, S	Common
Salmo gairdneri	Rainbow trout	RIS, S	Common
Salmo trutta	Brown trout	RIS, S	Common
Salvelinus fontinalis	Brook trout	RIS, S	Uncommon
Salvelinus namaycush	Lake trout	RIS, S	Moderately Abundant
Osmerus mordax	Rainbow smelt	RIS, S, Cm, F	Abundant
Couesius plumbeus	Lake chub	RIS, F	Moderately Abundant
Cyprinus carpio	Carp	RIS, Cm	Uncommon
Notemigonus crysoleucas	Golden shiner		Uncommon
Notropis cornutus	Common shiner		Uncommon
Notropis hudsonius	Spottail shiner		Uncommon
Pimephales promelas	Fathead minnow		Uncommon
Rhinichthys cataractae	Longnose dace		Moderately Abundant
Semotilus atromaculatus	Creek chub		Uncommon
Catostomus catostomus	Longnose sucker	RIS, Cm, F	Moderately Abundant
Catostomus commersoni	White sucker	RIS, Cm, F	Moderately Abundant
Moxostoma macrolepidotum	Shorthead redhorse		Uncommon
Ictalurus melas	Black bullhead		Uncommon
Lota lota	Burbot	RIS, Cm, CI	Uncommon
Pungitius pungitius	Ninespine stickleback		Uncommon
Perca flavescens	Yellow perch	RIS, Cm, S	Moderately Abundant
Cottus bairdi	Mottled sculpin	RIS, F	Uncommon
Cottus cognatus	Slimy sculpin	RIS, F	Common

[a] Species names according to Bailey (1970).

[b] Code: RIS - Representative Important Species; Cm - Commercial; CI - Community Integrity; S - Sport; F - Forage; T - Changing status.

and juvenile fishes and with bottom pumping for collection of fish eggs and larvae. Specifications of these devices and methods employed are described in LaJeone (1975a p.2-3). A map of the study area identifying sampling locations used in the fisheries program is shown in Figure 4.3.1.1.

Monitoring of adult and juvenile fishes has been conducted on a monthly basis (April-November) from 1973 through the present study (LaJeone 1974, 1975a, 1975b). Fish eggs and larvae samples have been collected five times per year during the spawning seasons of principal species (April, May, July, September and November) from 1973 through the present. Data from these studies have provided additional information on the life histories of fishes in the area beyond that of previous studies (Industrial BIO-TEST Laboratories, Inc. 1972, 1973). These earlier studies are not directly comparable to the recent studies as the frequency of sampling and sampling devices were different than those currently in use (LaJeone 1974 p.47).

Relative Abundance of Fish Species

A complete summary of all fish collected by gill net and seine is presented in Table 4.3.1.2. Total numbers of each species for each sampling area for all years of study are given. Relative abundance of a species (% of catch) was calculated for each year of study as well as for the combined five-year period. Major species are defined as those species comprising at least 1% of the total catch of the entire study period.

Alewife greatly outnumbered all other species over the five-year period, comprising 65% of the total catch. The abundance

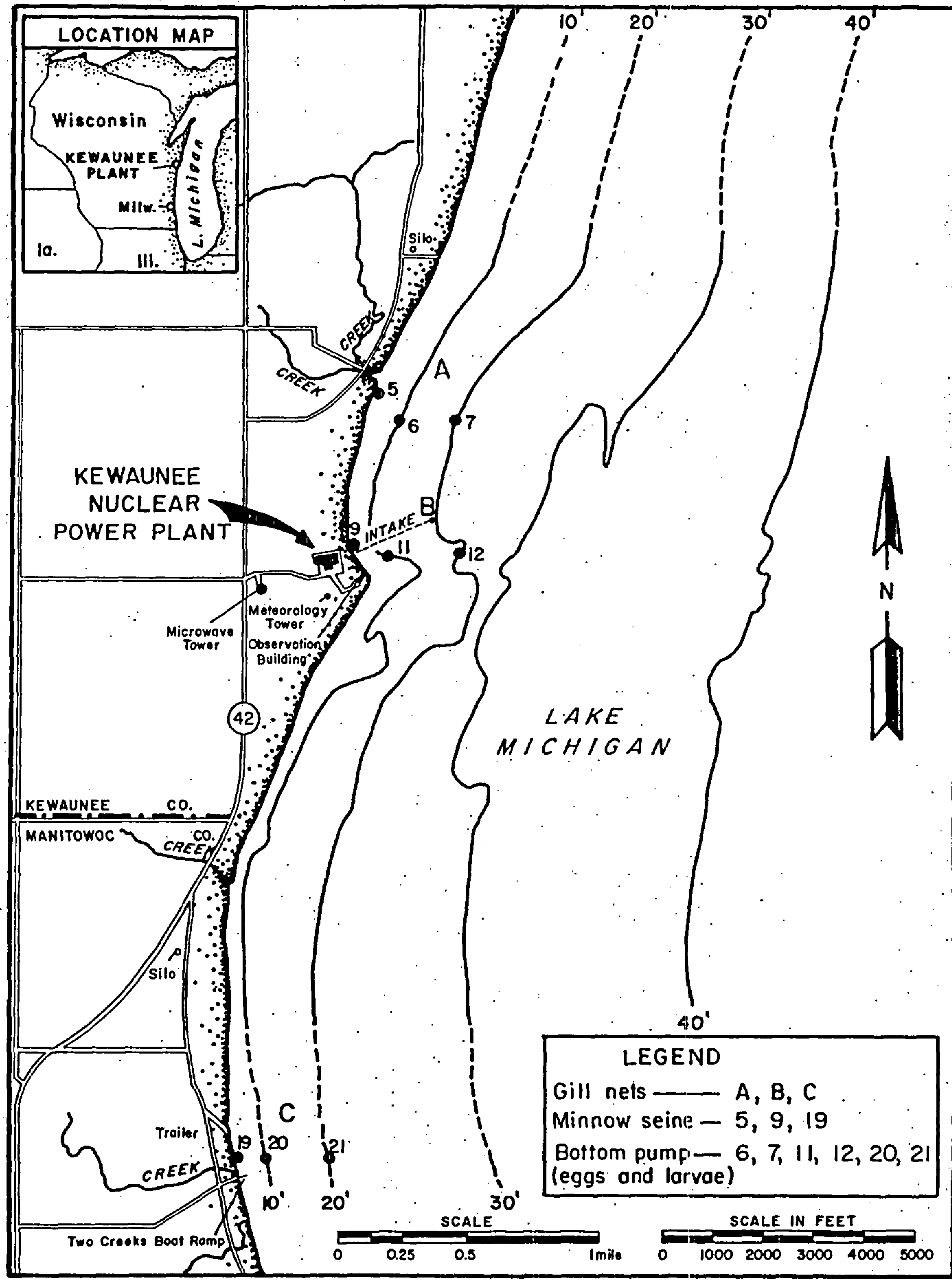


Figure 4.3.1.1. Fish sampling locations used in environmental monitoring studies at the Kewaunee Nuclear Power Plant.

Table 4.3.1.2. Catch summary for all fish species collected by gill net and minnow seine in Lake Michigan near the Kewaunee Nuclear Power Plant from 1971 to date.

	1975[a]					1974					1973				
	Sampling Locations				Percent of	Sampling Locations				Percent of	Sampling Locations				Percent of
Species	A/5[b]	B/9	C/19	Total	Catch	A/5	B/9	C/19	Total	Catch	A/5	B/9	C/19	Total	Catch
Alewife	1758	822	1924	4504	79.4	2305	1177	2881	6363	68.6	1175	654	977	2806	51.7
Rainbow smelt	22	32	21	75	1.3	198	354	451	1003	10.8	172	70	114	356	6.6
Yellow perch	60	154	63	277	4.9	118	115	140	373	4.0	293	303	113	709	13.1
Lake trout	85	75	63	223	3.9	153	157	138	448	4.8	109	141	106	356	6.6
Lake chub	131	38	39	208	3.7	180	126	66	372	4.0	149	115	72	336	6.2
Longnose dace	12	42	123	177	3.1	126	11	47	184	2.0	80	33	31	144	2.7
White sucker	8	12	46	66	1.2	33	22	88	143	1.5	90	126	57	273	5.0
Longnose sucker	7	6	84	97	1.7	14	6	78	98	1.1	13	12	45	70	1.3
Brown trout	2	2	1	5	Tr[c]	57	42	15	114	1.2	7	1	3	11	Tr
Coho salmon	0	0	0	0	-	22	12	11	45	Tr	12	9	4	25	Tr
Chinook salmon	1	0	0	1	Tr	6	10	6	22	Tr	4	0	6	10	Tr
Rainbow trout	0	0	1	1	Tr	5	3	9	17	Tr	1	2	5	8	Tr
Brook trout	0	0	0	0	-	3	2	5	10	Tr	0	0	0	0	-
Lake whitefish	1	0	0	1	Tr	13	20	8	41	Tr	3	2	7	12	Tr
Bloater	0	0	0	0	-	1	1	0	2	Tr	0	0	1	1	Tr
Cisco	2	4	0	6	Tr	0	0	0	0	-	0	0	0	0	-
Round whitefish	3	0	1	4	Tr	0	0	3	3	Tr	0	1	0	1	Tr
Carp	0	0	0	0	-	0	5	3	8	Tr	1	1	0	2	Tr
Golden shiner	0	0	2	2	Tr	0	0	0	0		0	0	0	0	-
Common shiner	0	0	0	0	-	2	0	0	2	Tr	0	0	0	0	-
Spottail shiner	0	0	0	0	-	0	0	0	0	-	3	0	0	3	Tr
Fathead minnow	1	0	0	1	Tr	0	0	0	0	-	1	0	1	2	Tr
Creek chub	0	0	1	1	Tr	0	1	0	1	Tr	0	0	0	0	-
Shorthead redhorse	0	0	0	0	-	0	0	0	0	-	0	1	0	1	Tr
Black bullhead	0	0	0	0	-	0	0	0	0	-	1	1	0	2	Tr
Burbot	0	0	0	0	-	0	0	1	1	Tr	0	0	0	0	-
Ninespine stickleback	0	0	0	0	-	0	1	0	1	Tr	1	1	0	2	Tr
Gizzard shad	0	0	1	1	Tr	0	0	0	0	-	2	0	7	9	Tr
Mottled sculpin	0	0	0	0	-	0	0	0	0	-	1	0	0	1	Tr
Slimy sculpin	2	8	9	19	Tr	10	4	11	25	Tr	80	142	65	287	5.3
Total	2095	1195	2379	5669		3240	2069	3961	9276		2198	1615	1614	5427	
Percent of Annual Catch	37.0	21.1	41.9	100.0		35.0	22.3	42.7	100.0		40.5	29.8	29.7	100.0	

Table 4.3.1.2. (continued)

	1972[d]					1971[e]					
	Sampling Locations				Percent of	Sampling Locations			Percent of	Grand	Percent of
Species	A/5	B/9	C/19	Total	Catch	A/5	B/9	Total	Catch	Total	Total
Alewife	31	55	105	191	14.7	1172	942	2114	72.9	15978	65.0
Rainbow smelt	26	33	70	129	9.9	116	51	167	5.8	1730	7.0
Yellow perch	64	159	65	288	22.1	30	21	51	1.8	1698	6.9
Lake trout	79	117	79	275	21.1	140	214	354	12.2	1656	6.7
Lake chub	28	1	30	59	4.5	8	50	58	2.0	1033	4.2
Longnose dace	44	6	27	77	5.9	31	0	31	1.1	613	2.5
White sucker	29	77	14	120	9.2	11	28	39	1.3	641	2.6
Longnose sucker	9	62	33	104	8.0	5	12	17	Tr	386	1.6
Brown trout	5	8	5	18	1.4	8	5	13	Tr	161	Tr
Coho salmon	3	4	4	11	Tr	1	0	1	Tr	82	Tr
Chinook salmon	1	1	1	3	Tr	0	0	0	-	36	Tr
Rainbow trout	3	6	1	10	Tr	0	2	2	Tr	38	Tr
Brook trout	0	0	0	0	-	5	0	5	Tr	15	Tr
Lake whitefish	0	1	0	1	Tr	0	2	2	Tr	57	Tr
Bloater	1	0	0	1	Tr	0	2	2	Tr	6	Tr
Cisco	0	0	0	0	-	0	0	0	-	6	Tr
Round whitefish	4	6	1	11	Tr	8	0	8	Tr	27	Tr
Carp	0	0	1	1	Tr	0	0	0	-	11	Tr
Golden shiner	0	0	0	0	-	0	0	0	-	2	Tr
Common shiner	0	0	1	1	Tr	0	0	0	-	3	Tr
Spottail shiner	0	0	0	0	-	0	1	1	Tr	4	Tr
Fathead minnow	0	0	0	0	-	7	1	8	Tr	11	Tr
Creek chub	0	0	0	0	-	0	0	0	-	2	Tr
Shorthead redhorse	0	0	0	0	-	0	0	0	-	1	Tr
Black bullhead	0	0	0	0	-	0	0	0	-	2	Tr
Burbot	0	0	0	0	-	0	0	0	-	1	Tr
Ninespine stickleback	0	0	0	0	-	0	0	0	-	3	Tr
Gizzard shad	0	0	0	0	-	0	0	0	-	10	Tr
Mottled sculpin	0	0	0	0	-	0	0	0	-	1	Tr
Slimy sculpin	2	0	1	3	Tr	22	5	27	Tr	361	1.5
Total	329	536	435	1303		1564	1334	2898		24573	
Percent of Annual Catch	25.3	41.2	33.5	100.0		54.0	46.0	100.0			

[a] 1975 data are through August only.
[b] Gill net location/corresponding minnow seine location.
[c] Trace - less than 1%.
[d] 1 1/2" panel of gill net not used in 1972 or 1971.
[e] Locations C/19 not sampled in 1971.

of alewives in the study area is reflective of their abundance throughout Lake Michigan. Other major contributors to the catch are rainbow smelt, yellow perch, lake trout, lake chub, longnose dace, white sucker, longnose sucker and slimy sculpin. These nine species collectively represent 98.5% of the fish collected to date.

Valuable sport species collected in the vicinity of KNPP are lake trout, rainbow trout, brown trout, brook trout, coho salmon and chinook salmon. Abundances of these species are largely determined by the stocking programs of state and federal agancies. Virtually all trout and salmon in Lake Michigan are stocked fish and the abundance of any of these species in a particular area can be greatly influenced by the number of fish stocked at particular locations.

The occurrence of the remaining species listed in Table 4.3.1.2 was sporadic and they did not appear to be permanent residents. Two species given "changing status" classification, the cisco and the bloater, have been taken infrequently and can be considered very uncommon to the area. Carp were also collected infrequently.

Considerable variation in the annual catches of major species occurred within the study area near KNPP (Table 4.3.1.2). Among several factors that may have influenced catches were; weather conditions, currents, time of month sampling was conducted and plant operation. The distribution of fish within the study area also varied from year to year; however, changes in annual abundance and distribution of fishes within the study area have not varied to any greater magnitude subsequent to plant operation than they did prior to plant operation.

Life Histories of Representative Important Species

Descriptions of the life histories of fishes in the vicinity of KNPP are limited primarily to the "representative important species" presented in Table 4.3.1.1. These species are considered to be valuable to the community structure of Lake Michigan and several of them have been studied intensively. The majority of the remaining species are either uncommon to this part of Lake Michigan, or little information is available on their life histories in the lake. Some of the uncommon species may have originated from outside the vicinity of KNPP (harbors, tributary streams) and moved into the area. Species considered "uncommon" are gizzard shad, golden shiner, common shiner, spottail shiner, fathead minnow, creek chub, shorthead redhorse, black bullhead and ninespine stickleback. A summary of the reproductive periods for all species of fish occurring in the vicinity of KNPP is shown in Table 4.3.1.3.

Alewife

The alewife is the most abundant species in the area near KNPP (Table 4.3.1.2) although, based on trawl catches, Reigle (1969a p.5, 1969b p.7) found alewives were more abundant in southern Lake Michigan. Alewives have distinct patterns of seasonal migration in Lake Michigan (Wells 1968 p.3-5). In winter, alewives move to the deep portions of the lake seeking warmer water where adults remain close to the bottom and juveniles inhabit mid-depths. In spring adult alewives migrate into

Table 4.3.1.3. Reproductive period and occurrence of spawning adults for fishes collected in Lake Michigan in vicinity of the Kewaunee Nuclear Power Plant.

Species	Reproductive[a] Period	Months Collected in Spawning Condition
Alewife	mid May - mid August	May - July*[b]
Rainbow smelt	early April - mid May	April - May*
Yellow perch	early May - early July	May - June*
Lake trout	early October - mid December	October
Lake chub	late May - June	June*
Longnose dace	mid May - July	June - July*
White sucker	early April - May	April - May
Longnose sucker	early April - May	May
Rainbow trout	late October - early April	April & October, November
Brown trout	early October - December	October - November
Brook trout	November - December	---[c]
Coho salmon	late September - December	October - November
Chinook salmon	late September - December	October - November
Lake whitefish	November - December	---
Cisco	mid November - mid December	---
Bloater	mid January - mid March	---
Round whitefish	November - early December	---
Carp	late May - August	June
Golden shiner	June - August	---
Common shiner	May - July	---
Spottail shiner	June - July	---
Fathead minnow	mid May - June	---
Creek chub	May - June	---
Shorthead redhorse	late April - May	---
Black bullhead	June - July	---
Burbot	January - March	---*
Ninespine stickleback	June - July	---
Gizzard shad	June - July	---
Mottled sculpin	May	---
Slimy sculpin	May	May*

[a] Information taken primarily from Scott & Crossman (1973).
[b] Asterisk indicates those species believed to spawn successfully within the study area.
[c] None collected in spawning condition.

shallower water off shore while juveniles move closer to the surface but remain in mid-lake. By early summer the adults move into nearshore areas and tributaries where spawning occurs. They remain in shallow nearshore areas until late summer or early fall when they again migrate to deep water. Peak abundance of adult alewives near KNPP occurs in late May or June (Figure 4.3.1.2) although young-of-year are occasionally taken in substantial numbers along shore in September and October (LaJeone 1974 p.12).

Alewives spawn in Lake Michigan from June through August. Peak spawning occurs in July with females producing from 11,000 to 22,000 eggs (Norden 1967 p.387). Catch data from studies near KNPP suggest that peak abundance occurs just prior to or during spawning and that alewives do utilize the shallow areas near KNPP for spawning. Eggs and young-of-year have been collected in the study area with the highest concentration of eggs usually occurring at Location 11 or 12 in July and August (Industrial BIO-TEST Laboratories, Inc. 1973 p.174; LaJeone 1974 p.14, 1975a p.17, 1975b p.20). The extent to which alewives utilize the area near KNPP for spawning is probably much less than in southwestern Lake Michigan. Cochran and Cima (1974 p.236-240) reported considerably higher densities of alewife eggs in the nearshore areas in the vicinity of the Zion Station, Zion, Illinois, using the same sampling procedure.

Alewives are relatively short lived in Lake Michigan. Brown (1972 p.485) reported a few individuals as old as six or seven years. Norden (1967 p.387) reported that few fish exceed four years of age, the majority of spawning fish belonging to age groups

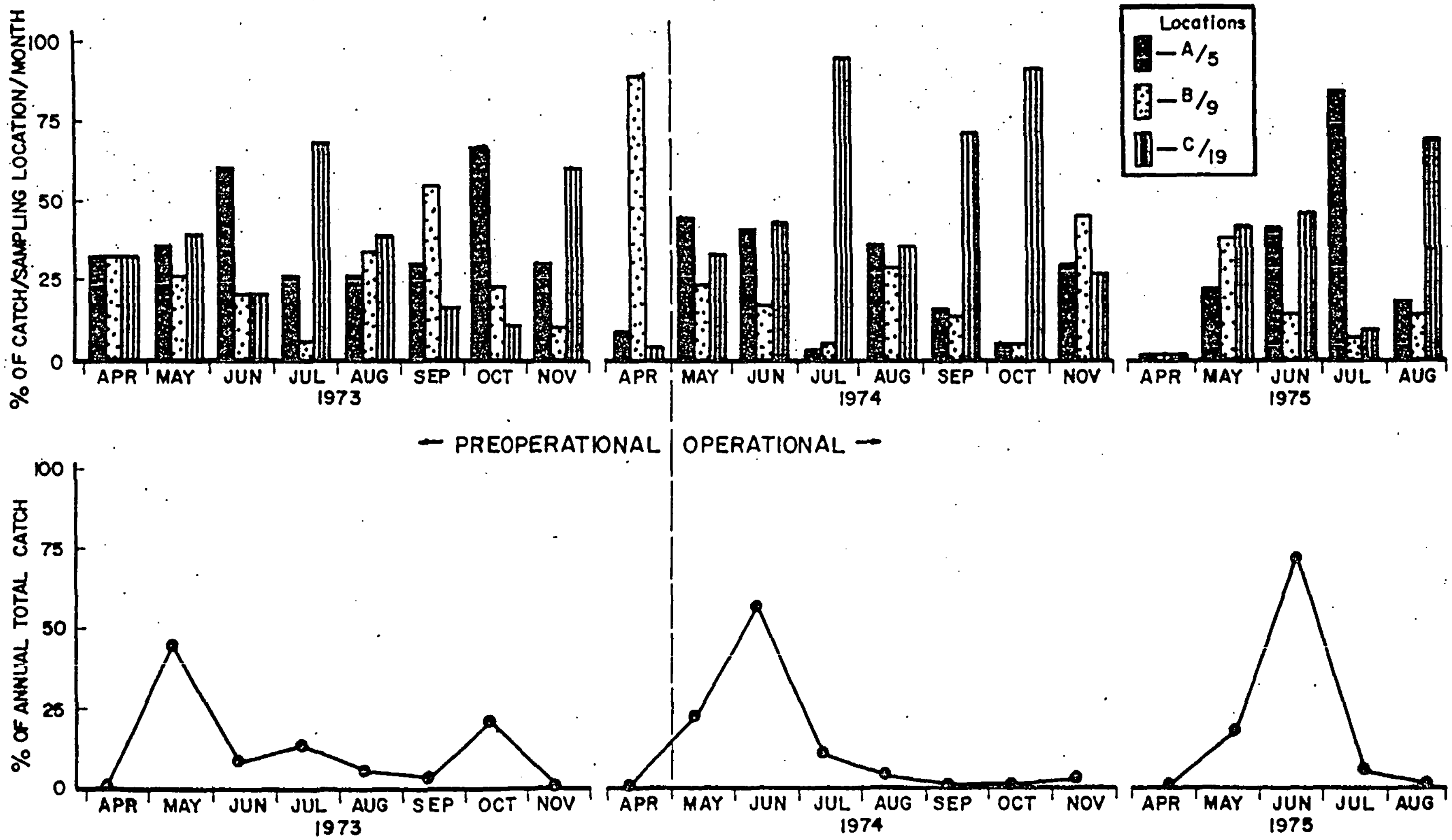


Figure 4.3.1.2. Seasonal abundance and spatial distribution of alewife collected in the vicinity of the Kewaunee Nuclear Power Plant from 1973 to date.

II and III. No age studies of alewives were conducted for fish collected near KNPP, but comparisons of length-frequency data from the study area (LaJeone 1974 p.13, 1975a p.15, 1975b p.17) with data from other workers indicates all expected age groups occur in the vicinity of the plant. Alewives feed principally on zooplankton and evidence has been presented that they are selective for the larger forms of zooplankton (Hutchinson 1971 p.333).

Rainbow Smelt

Smelt is the second most abundant species collected in Lake Michigan near KNPP (Table 4.3.1.2). Reigle (1969a p.5, 1969b p.7) found that smelt were generally more numerous in northern Lake Michigan than in southern Lake Michigan. This species has distinct seasonal movements in the lake (Wells 1968 p.6-8). Young smelt are basically pelagic and remain off shore at 65 to 100 feet in late fall and winter. In spring and summer, young smelt may concentrate in epilimnion waters and along shore. Adult smelt generally inhabit waters from 45 to 230 feet and remain close to the bottom; however, in early spring they migrate into very shallow water along shore and into tributary streams where spawning takes place. Peak abundance near KNPP occurs in late April when substantial numbers of spawning adults are collected (Figure 4.3.1.3).

Smelt spawn successfully along shore near KNPP (LaJeone 1974 p.28, 1975a p.18, 1975b p.46), but the low density of eggs and young-of-year suggest that the area is not used extensively. Much higher densities of eggs were collected nearshore in southwestern Lake Michigan near the Zion Station, Zion, Illinois (Cochran and

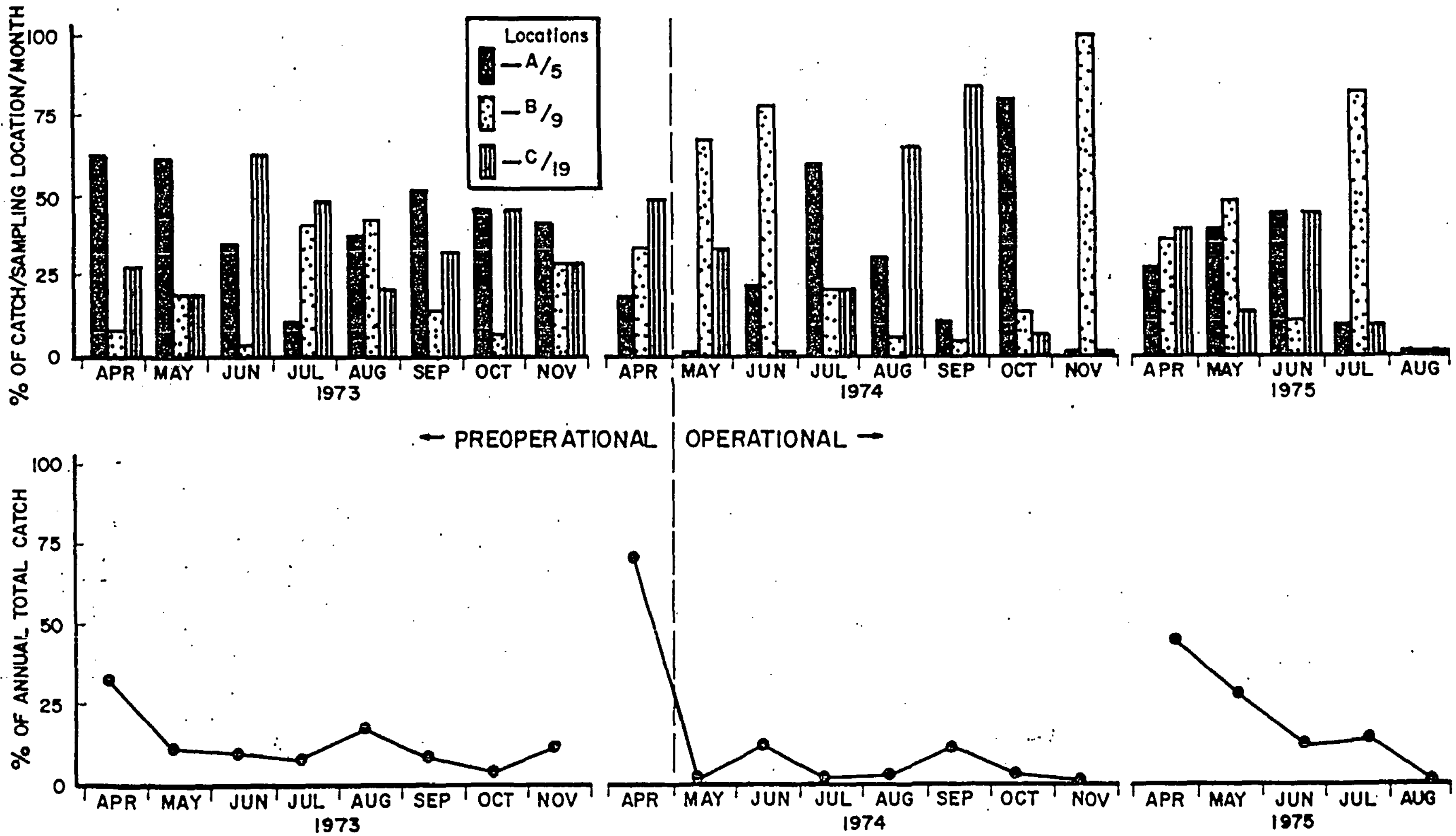


Figure 4.3.1.3. Seasonal abundance and spatial distribution of rainbow smelt collected in the vicinity of the Kewaunee Nuclear Power Plant from 1973 to date.

Cima 1974 p.249-251). In the Kewaunee area smelt may use tributary streams as primary spawning areas, but there are no suitable tributaries in southwestern Lake Michigan in Illinois. Bailey (1964 p.393-394) reported that smelt begin to mature at age two and females dominate age groups IV-VII. Bailey also found the average egg production of females was over 31,000 per individual. No age studies of smelt were conducted but length-frequency data indicate that all expected ages occur in the vicinity of KNPP (LaJeone 1974 p.30, 1975a p.21, 1975b p.47).

Gordon (1961 p.439) found that young smelt fed mainly on crustaceans along with rotifers, fish eggs and algae, while adult smelt fed on *Mysis relicta*, fish and aquatic insects.

Yellow Perch

The yellow perch is third in abundance of species encountered in the vicinity of the KNPP. Reigle (1969a p.11, 1969b p.16) reported that perch were more numerous in southern Lake Michigan and in Green Bay than northern Lake Michigan. In winter, perch are found at depths of 65 to 80 feet. They begin a shoreward migration in May, reside at depths of 45 feet or less during summer and return again to deeper water offshore in the fall. Wells (1968 p.9) reported that young-of-year and yearling perch prefer depths of less than 20 feet. The seasonal occurrence of perch in the vicinity of KNPP seems to follow this general pattern of seasonal movement, but peak abundance in the study area does not conform to a regular pattern from year to year (Figure 4.3.1.4).

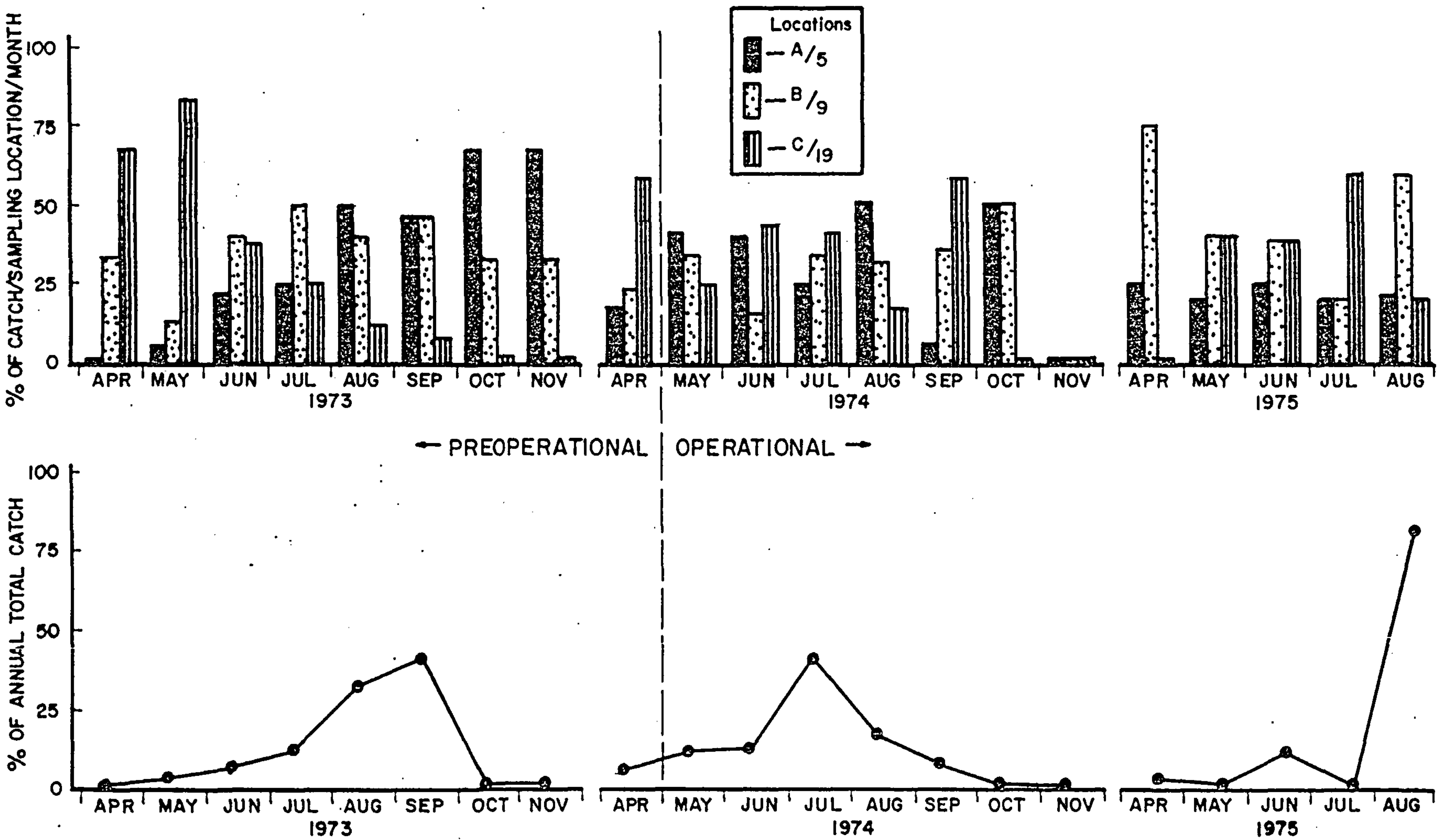


Figure 4.3.1.4. Seasonal abundance and spatial distribution of yellow perch collected in the vicinity of the Kewaunee Nuclear Power Plant from 1973 to date.

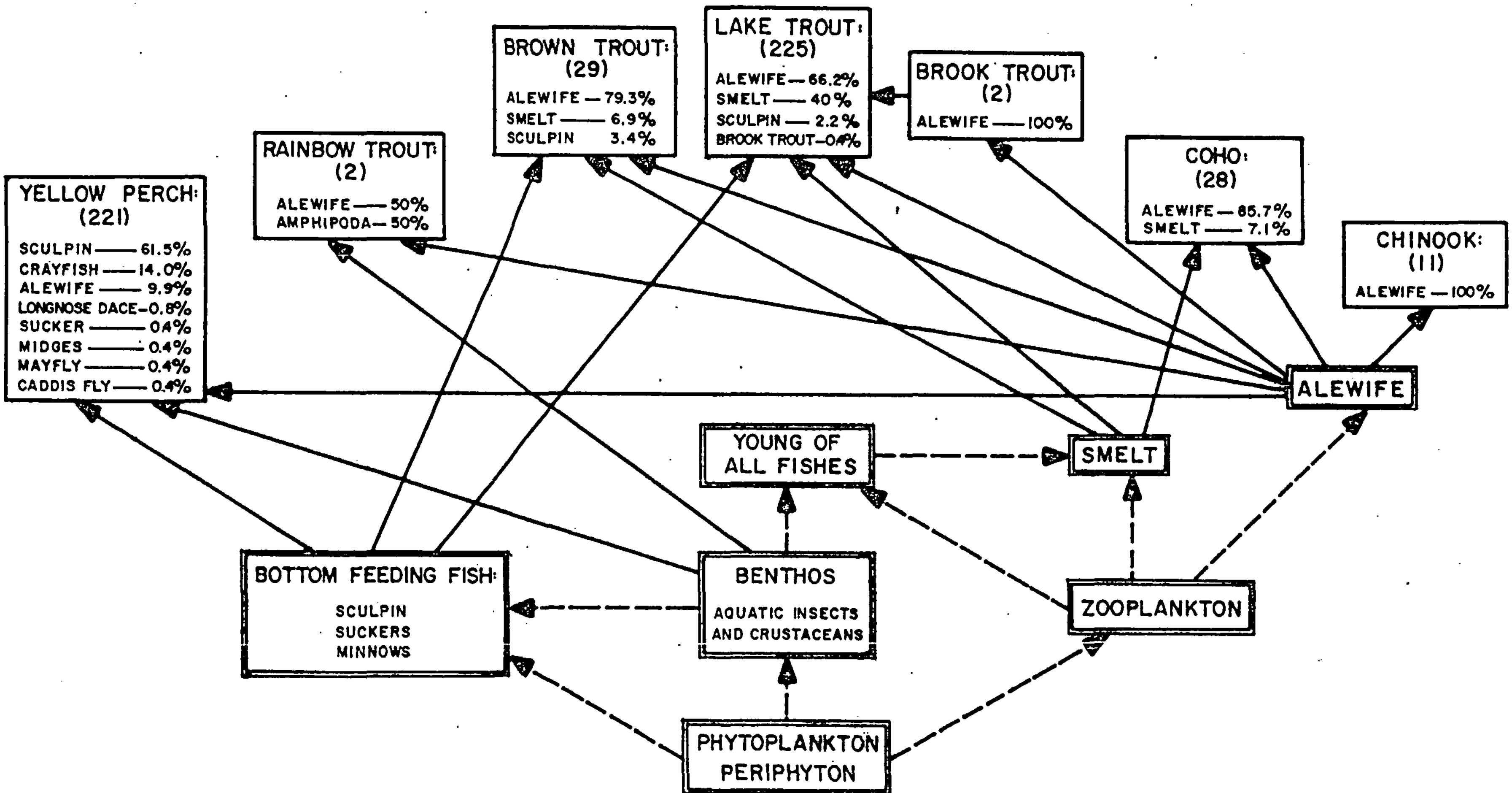
Perch spawn over sand, rubble or on vegetation where eggs are laid in gelatinous strings. Herman et al. (1964 p.5) reported that the average female produces about 23,000 eggs. In the KNPP study area perch have been collected in spawning condition in May and June (LaJeone 1974 p.15, 1975a p.33, 1975b p.30). Spawning probably does occur within the study area in June, but it is doubtful the area is used extensively as peak abundance of perch does not coincide with the spawning period and no young-ofyear or yearling perch have been collected as yet. Eggs of yellow perch have only been collected once (LaJeone 1975b p.20) so, if spawning is successful in the vicinity of KNPP, it is limited.

Yellow perch mature at two or three years of age in Lake Michigan. Age studies of perch in the area have shown that four and five year old fish comprise the majority of the catch, although ages ranged from two to nine years (LaJeone 1974 p.17, 1975a p.32; Industrial BIO-TEST Laboratories, Inc. 1973 p.150). The absence of young perch is further evidence that the majority of perch collected in the study area were probably not produced or reared in the immediate vicinity.

Young perch feed on zooplankton and benthic invertebrates. Larger perch in the vicinity of KNPP feed heavily on sculpin, as well as other fish and crayfish (Figure 4.3.1.5).

Lake Trout

The lake trout is the fourth most abundant species collected in the KNPP area and the most abundant member of the salmonid family. Excellent accounts on the life history of lake trout are given by Eschmeyer (1964), Van Oosten and Eschmeyer (1956)



Note: Broken lines indicate suspected relationships. Solid lines indicate actual determinations. Numbers in parentheses are numbers of stomachs containing food items. Percentage figures indicate frequency of occurrence. Data taken from Industrial BIO-TEST Laboratories, Inc. (1972, 1973); LaJeone (1974, 1975a, 1975b).

Figure 4.3.1.5. Food habits and relationships of Lake Michigan fish species in the vicinity of the Kewaunee Nuclear Power Plant.

and Daly et al. (1962). Lake trout spend the winter months in deep water, moving into shallower water with the spring. In summer, lake trout usually retreat to deeper water again but will remain close to shore if water temperatures are cold. Lake trout move back into shallow water in the fall as the spawning season approaches. Young lake trout seem to prefer to remain in deeper water throughout the year.

Catches of lake trout in the vicinity of KNPP follow a similar pattern. Substantial catches are frequently made in spring (April and May) and decline greatly in summer; however, a large number were taken in June 1975 when westerly winds brought cold water upwelling along the beach (Figure 4.3.1.6). Lake trout numbers increase appreciably in late September and reach peak abundance in late October. By November the trout have left the shallows and moved back to deeper water.

Lake trout in Lake Michigan spawn from mid-October to mid-November along rocky shorelines and reef areas. At this time large concentrations may be encountered. Studies at KNPP have found large concentrations of lake trout in spawning condition in the area in late October (Industrial BIO-TEST Laboratories, Inc. 1972 p.71; LaJeone 1974 p.25, 1975a p.26). Females may produce from 1,000 to 18,000 eggs, depending on their size (Daly et al. 1962 p.6). Original stocks of lake trout in Lake Michigan were eliminated by the sea lamprey and successful reproduction of current stocks, virtually all of which have been planted by state and federal agencies, has not yet been reported (Wells and McLain 1973 p.28). Despite the large catches of spawning adults

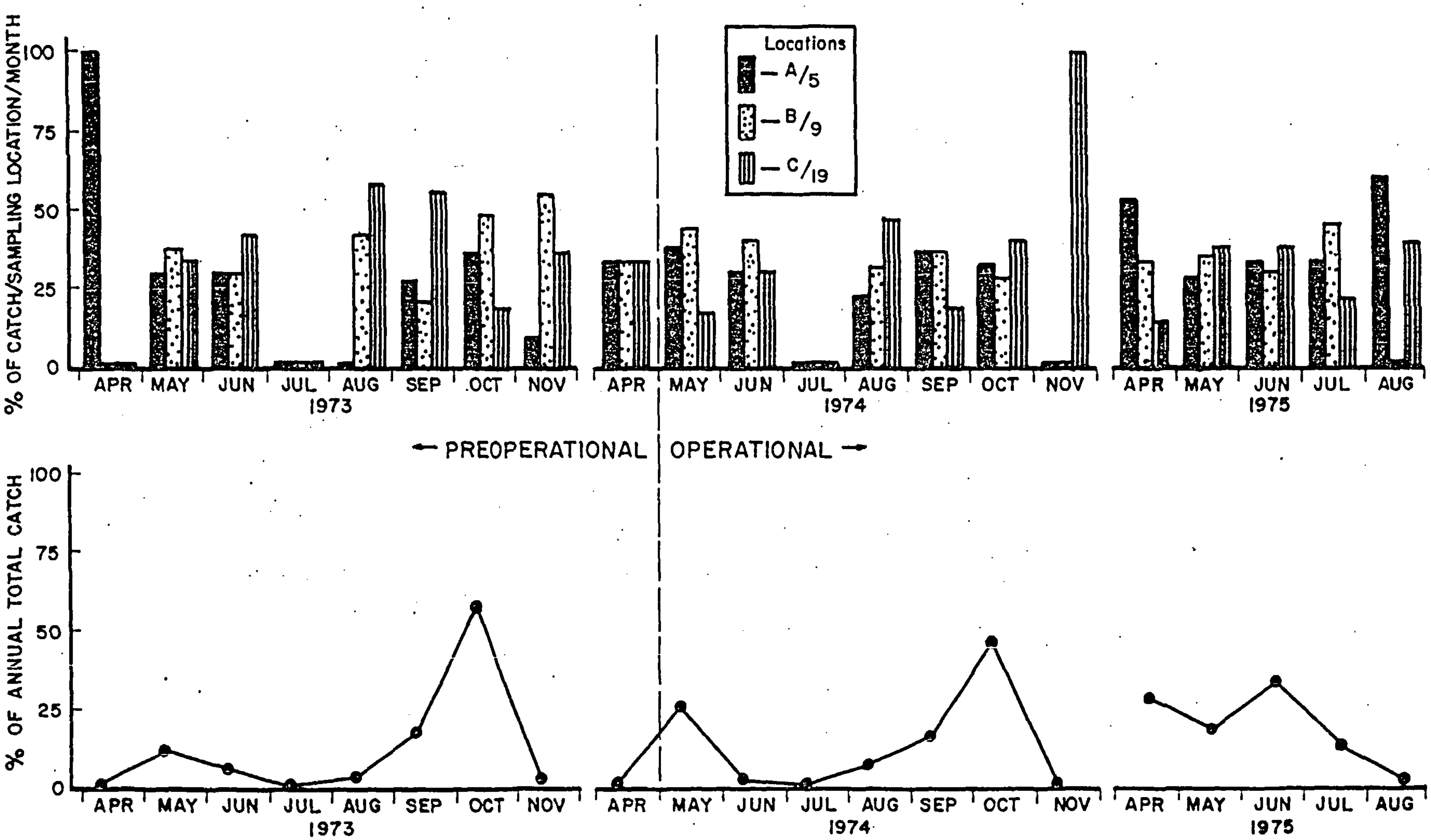


Figure 4.3.1.6. Seasonal abundance and spatial distribution of lake trout in the vicinity of the Kewaunee Nuclear Power Plant from 1973 to date.

in the study area, no eggs, larvae or young-of-year lake trout have been collected (LaJeone 1974 p.25, 1975a p.26).

Ages of lake trout in the vicinity of KNPP range from two to eleven years with age groups VI-VIII comprising the majority of the catch (LaJeone 1974 p.22, 1975a p.25, 1975b p.25). Both sexes were mature at five years of age and a few four year old male fish had also matured. Fall catches consisted almost entirely of sexually mature fish. Younger fish (age groups II-V) were more commonly collected in the spring and early summer.

Young lake trout feed on zooplankton and benthic invertebrates. By three years of age their diet is comprised almost entirely of fish. Lake trout in the area of KNPP feed heavily on alewife and smelt as well as sculpin and occasional other fish species (Figure 4.3.1.5).

Lake Chub

The lake chub is the fifth most common species in the vicinity of KNPP and is the most abundant member of the minnow family. Little is known about the life history of this species and no published accounts relative to its habits in Lake Michigan are available. Scott and Crossman (1973 p.404-405) reported that lake chubs prefer lake habitat and will move to deeper water in summer. They also stated that the species usually undergoes a spawning migration from lakes into tributary streams in the spring. Lake chubs were collected by seine and gill net during almost all months of sampling since 1973 (LaJeone 1974 p.32, 1975a p.34-35, 1975b p.34-35). The species is usually common along shore in spring and reached peak abundance in June of 1974 and 1974 (Figure 4.3.1.7).

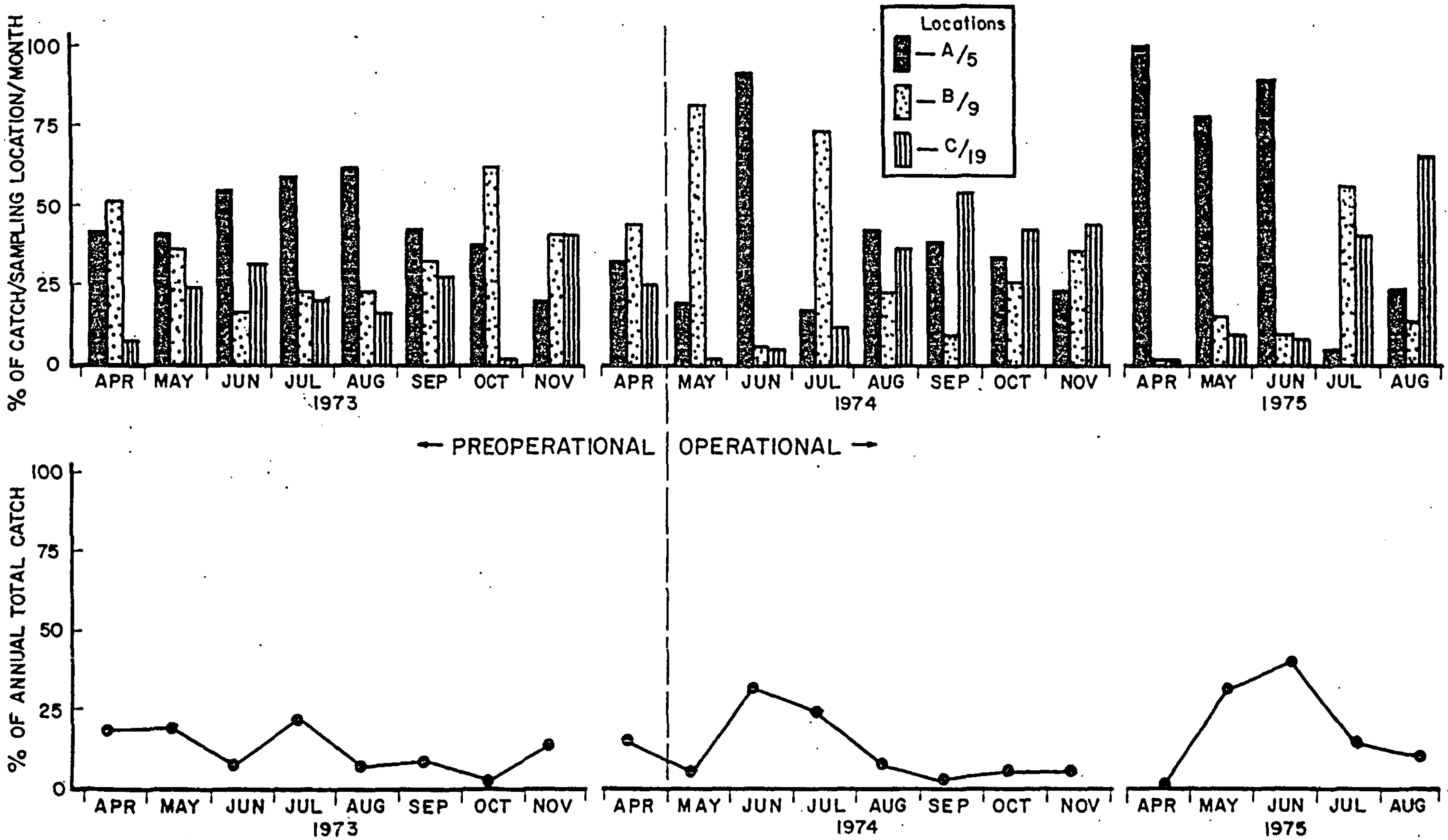


Figure 4.3.1.7. Seasonal abundance and spatial distribution of lake chub collected in the vicinity of the Kewaunee Nuclear Power Plant from 1973 to date.

Adults collected in June were in spawning condition and large catches were taken at Location 5 in 1974 and 1975 where an intermittent tributary was flowing into the lake on both occasions (LaJeone 1975a p.36, 1975b p.33). It appears that lake chub were attracted to this effluent, possibly for spawning, but no investigation of their spawning in the stream was conducted. No eggs or larvae have been collected in Lake Michigan, but reproduction in the study area may be successful nearby as juvenile specimens are fairly common in July and August.

Lake chubs reportedly feed on aquatic insects (Scott and Crossman 1973 p.405). They are also considered forage for larger species, though none have been identified from the stomach contents of fishes examined (Figure 4.3.1.5). Lake chubs in the study area are commonly parasitized with black spot (*Neascus* sp. or *Uvilifer* sp.)(LaJeone 1974 p.31).

Longnose Dace

Longnose dace are not classified as a "representative important species" for this area, but they are the seventh most abundant species collected and the only other member of the minnow family besides the lake chub that is abundant in the vicinity of KNPP. No distinct pattern of seasonal migration has been observed for this species. They occur in inshore waters of large lakes and may move into tributaries for spawning (Scott and Crossman 1973 p.497). Longnose dace have no regular pattern of seasonal abundance in the vicinity of KNPP (Figure 4.3.1.8).

Adults in spawning condition have been collected in June and July. Eggs or larvae have not been collected in

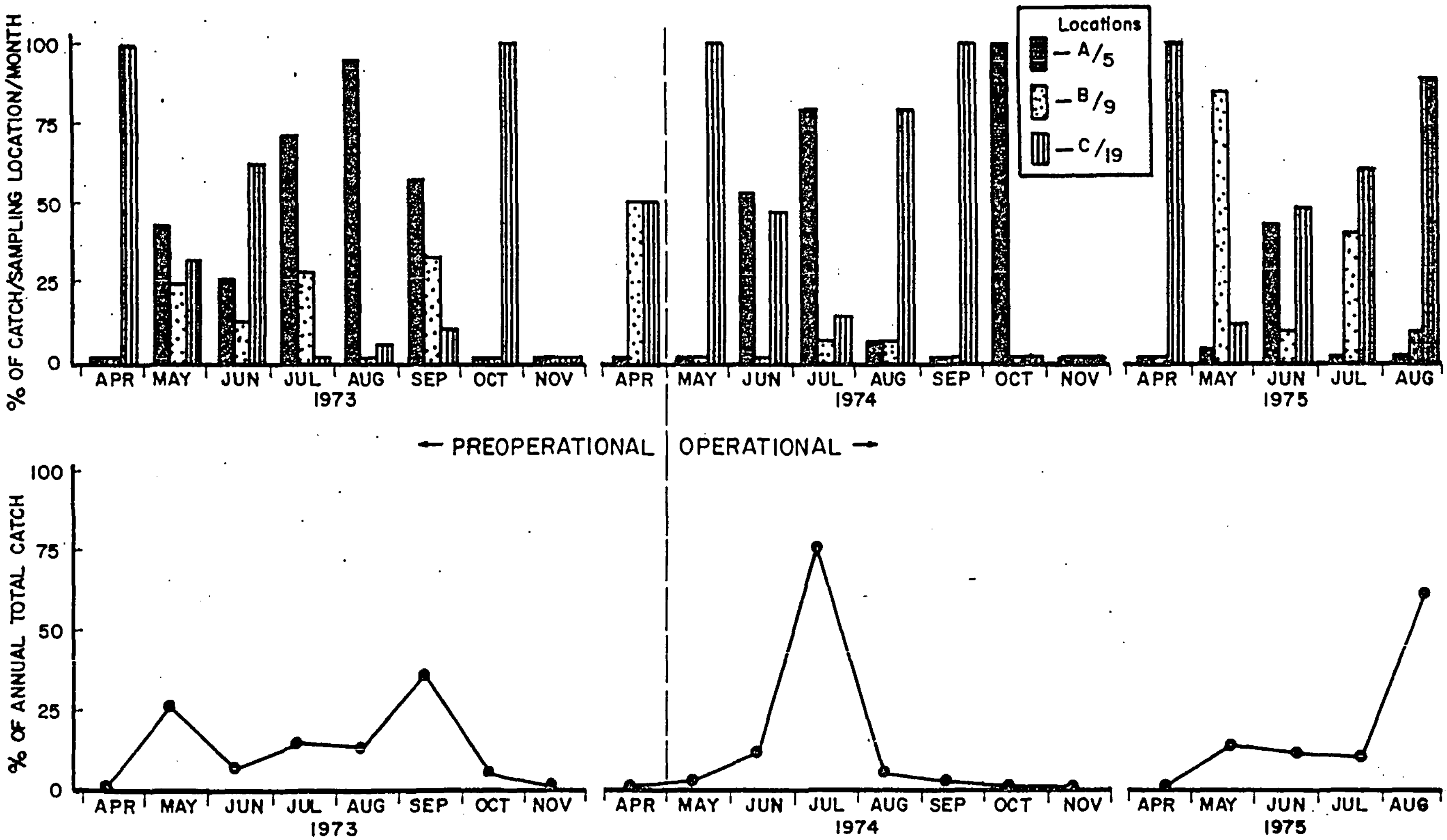


Figure 4.3.1.8. Seasonal abundance and spatial distribution of longnose dace collected in the vicinity of the Kewaunee Nuclear Power Plant from 1973 to date.

Lake Michigan, though one may not expect to encounter eggs of this species at sampling depths of 10 and 20 feet if the species is spawning in tributaries. Juveniles have been collected and it is believed that successful reproduction does occur in or near the study area (LaJeone 1974 p.38, 1975a p.36).

Age studies of longnose dace were not conducted in these monitoring surveys; however, from data presented by Scott and Crossman (1973 p.497), it appears several age groups are present in the KNPP area. No stomachs were examined, but the species reportedly feeds on aquatic insect larvae and other benthos. Dace have been found occasionally in the stomachs of yellow perch (Figure 4.3.1.8).

White Sucker and Longnose Sucker

White and longnose suckers are common in northern Lake Michigan and in the vicinity of KNPP. White and longnose suckers are the sixth and eighth most abundant species collected in the study area, respectively (Table 4.3.1.2). No formal studies on the life history of either species in Lake Michigan could be found in a literature search. The only report for the Great Lakes is a study of the longnose sucker in Lake Superior by Bailey (1969). No distinct patterns of seasonal movements in Lake Michigan are reported, although both species seem to prefer relatively shallow water.

Both species are usually more common in the study area in late summer or early fall. Peak abundance of longnose suckers did not seem to follow a regular pattern between years; however, peak abundance of white suckers occurred in September of 1973 and 1974 and August 1975 (Figures 4.3.1.9 and 4.3.1.10).

Both species migrate up tributary streams in April and May to spawn. A few ripe adult specimens have been collected within the study area, but their relative absence from the area during these particular months (Figures 4.3.1.9 and 4.3.1.10) is an indication that spawning does not occur in the lake in the vicinity of KNPP. Suckers utilize several streams in Manitowoc (Weber et al. 1968 p.41-45) and Kewaunee (Poff and Threinen 1966 p.28) counties for spawning. Bailey (1969 p.1289) reported that larval suckers drift downstream to the lake soon after hatching. Absence of eggs and larvae along with the paucity of juvenile specimens of both species further indicates that the area near KNPP is neither a spawning area or major nursery area for young-of-year (LaJeone 1974 p.38, 1975a p.38 and 44). The vast majority of specimens of both species collected in the study area were mature, adult fish (LaJeone 1974 p.38, 1975a p.38 and 44).

No data was developed on the age or food habits of these species in the vicinity of KNPP. Bailey (1969 p. 1292) found long-nose suckers in Lake Superior to be relatively slow-growing. Both species are bottom browsers, feeding primarily on benthic invertebrates (Scott and Crossman 1973 p.534 and 542).

Slimy and Mottled Sculpin

The slimy sculpin is the ninth in abundance of the species in the vicinity of KNPP. Only one specimen of the mottled sculpin has been collected and this species will not be considered further (Table 4.3.1.2). Wells (1968 p.10) reported that slimy sculpins may be found from nearshore to depths of 330 ft.

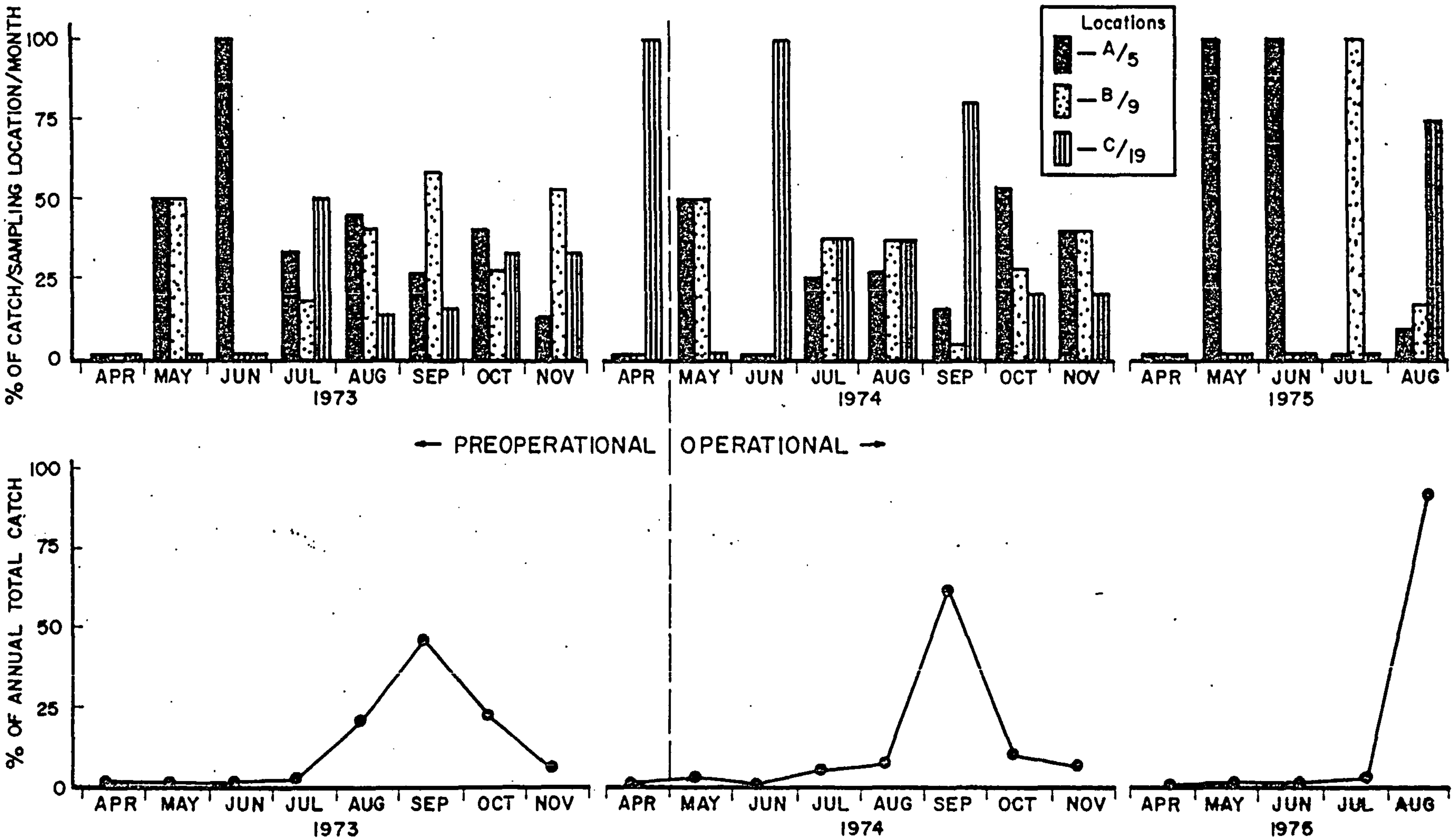


Figure 4.3.1.9. Seasonal abundance and spatial distribution of white sucker collected in the vicinity of the Kewaunee Nuclear Power Plant from 1973 to date.

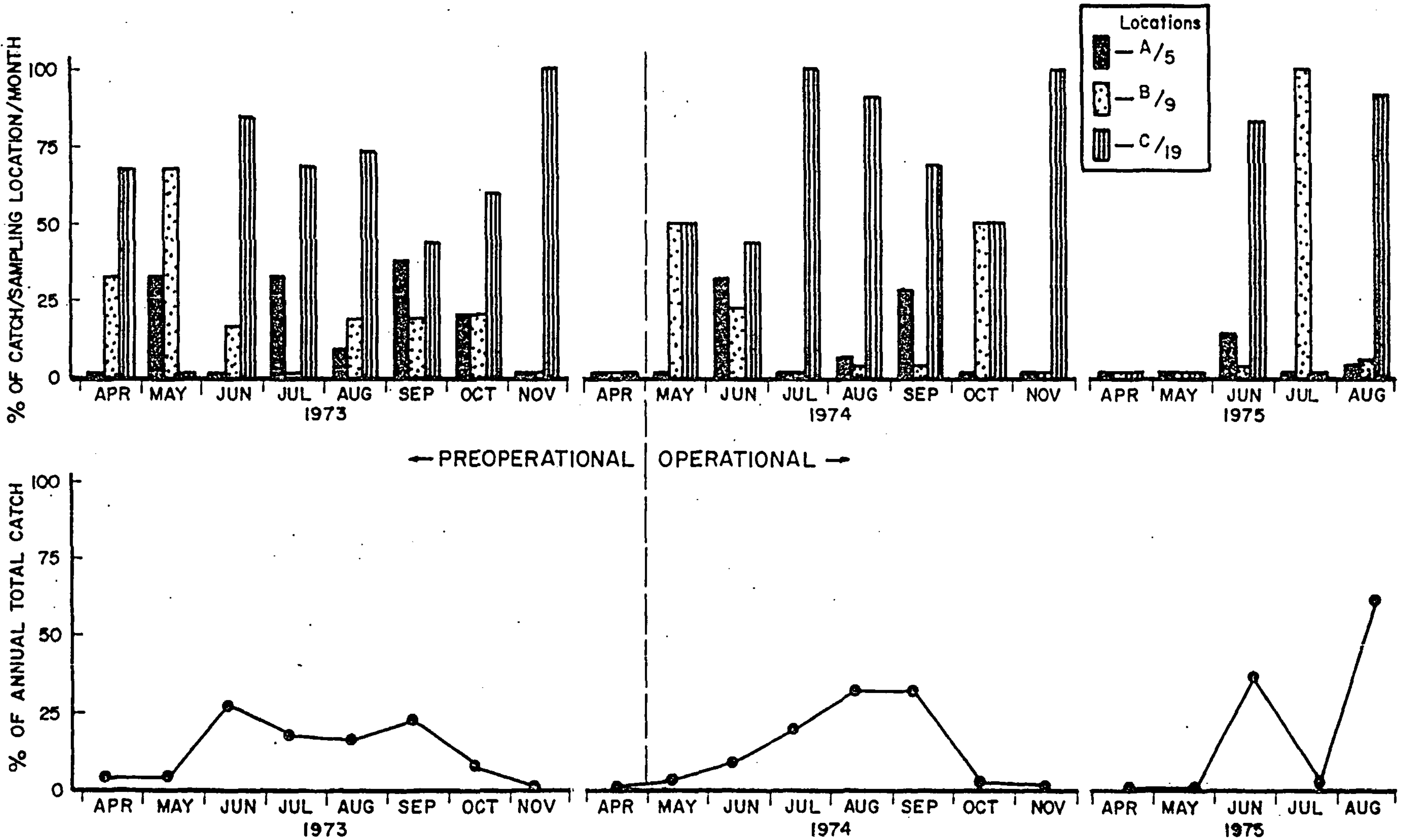


Figure 4.3.1.10. Seasonal abundance and spatial distribution of longnose sucker collected in the vicinity of the Kewaunee Nuclear Power Plant from 1973 to date.

In spring (April and May) slimy sculpins migrate to shallow water where they become quite common. In the summer slimy sculpins move offshore to deeper, cooler water and by fall they are most numerous in deep water. Ordinarily, too few slimy sculpins are captured in the vicinity of KNPP to determine any seasonal movements, but on 21 May 1973 a total of 282 (78% of the total catch to date) was captured by minnow seine (LaJeone 1974 p.38). Diver observations along the bottom, frequent collections of juveniles in bottom pump samples and occurrence in the stomachs of predatory species indicate that slimy sculpins may be far more abundant within the study area than data show. Bottom trawling is not possible in the Kewaunee area due to the rocky substrate (LaJeone 1975a p.47); however, slimy sculpins are effectively sampled in southwestern Lake Michigan by bottom trawl where substantial numbers were collected in April 1974 at depths of 33 and 46 feet (Cochran 1974 p.339).

Slimy sculpins mature at two or three years of age (Rottiers 1965 p.32) and spawning occurs in May with females laying from 100 to 900 eggs. Ripe adults have been collected in April and spent adults have been collected in late May in the vicinity of KNPP. Sculpin eggs have been collected in May (LaJeone 1975a p.17) and several young-of-year were collected in bottom pump samples in July (LaJeone 1975b p.20), indicating successful reproduction in the vicinity of KNPP.

Slimy sculpins feed heavily on amphipods as well as other invertebrates (Cochran 1974 p.343) and are valuable forage for several piscivorous species, particularly yellow perch (Figure 4.3.1.5).

Rainbow, brown and brook trout

These valuable sport species are discussed as a group due to the general similarities of their life histories and management in Lake Michigan. Rainbow and brown trout are considered common to the study area but brook trout are less common. None of these trout are considered native to Lake Michigan, though brook trout may occasionally have strayed into the lake from tributary streams. Virtually all of these three species are stocked in Lake Michigan by state agencies and their abundance in a particular area is largely determined by stocking intensity and location of release. Relatively few individuals of these species were captured in monitoring surveys at KNPP (Table 4.3.1.2), but recent creel census data for 1974 at the KNPP (Wisconsin Department of Natural Resources, 1975 p.24) record large numbers of rainbow and brown trout taken by shore fishermen. Accounts of the life histories of these species are given by MacKay (1963), Brasch et al. (1967) and Brynildson et al. (1967).

All three species prefer shallow, shore areas and river mouths along the lake. These species will remain near shore until water temperatures become too warm when they move to deeper water. Too few brook trout have been collected in the study area to substantiate periods of peak abundance. Brown trout were most commonly encountered in the fall while rainbow trout were collected both in spring and fall.

All three species mature in their second or third years of life in Lake Michigan and migrate into tributary streams to spawn. Several streams in Manitowoc and Kewaunee counties are utilized by rainbow and brown trout (Weber et al. 1968 p.57; Poff and Threinen 1966 p.39). Brown trout and brook trout spawn from mid-October to December. Rainbow trout usually spawn in spring, but increasing numbers of fall spawning fish have been planted in recent years (WDNR 1972 p.15). Adult rainbow trout in spawning condition have been collected in April and November while brown trout in spawning condition were collected in September and October (LaJeone 1975a p.41 and 47). No adult brook trout have been collected. No evidence of spawning success for any of the three species has been found in the vicinity of KNPP.

Young of these species feed on zooplankton and quickly change to a diet of aquatic insects, amphipods and other invertebrates. As they grow larger, their diet changes to fish. Limited data compiled by studies at KNPP list alewife as the most common food of all three species (Figure 4.3.1.5).

No age studies of these species has been conducted in studies at KNPP.

<u>Coho and Chinook Salmon</u>

Both species are considered common in the vicinity of KNPP despite low catch figures (Table 4.3.1.2). They are discussed together as their life histories and management are similar. Coho and chinook salmon are not native to Lake Michigan and their recent introductions, 1966 and 1967, respectively, account for the present extensive sport fishery (Parsons 1973 p.24).

Both species inhabit deeper waters of Lake Michigan in winter and concentrate in the shallow water at the southern end of the lake in spring (Borgeson 1970 p.13). From late spring through summer there is a gradual northward migration until fall when the adult salmon congregate off the mouths of certain tributary streams. In late fall these fish ascend the streams for spawning. Salmon are somewhat pelagic and will remain offshore in deeper water when temperatures become too warm. Both species seldom occur in the vicinity of KNPP until late summer and fall (LaJeone 1974 p.42 and 44, 1975a p.44).

Coho salmon mature at age three and chinook salmon generally at age four or five. Both species have strong homing instincts and most return to spawn in streams where they were originally planted (Tody and Tanner 1966). Spawning occurs anytime from late September to December when adults spawn and then die. Adults of both species have been collected in spawning condition in October and November near KNPP, but no evidence of successful spawning has been observed. Natural reproduction of salmon throughout Lake Michigan is extremely limited and populations are maintained through stocking. Salmon are stocked annually in Ahnapee River, Kewaunee River, Little Manitowoc River and East and West Twin rivers near KNPP.

Stomach analyses of salmon collected near KNPP show both species feed primarily on alewives, though coho salmon occasionally consumed smelt (Figure 4.3.1.5).

No age studies of salmon were conducted in monitoring surveys.

Whitefishes (Cisco, Bloater, Lake Whitefish and Round Whitefish)

These four species are discussed as a group because they are closely related and all are relatively uncommon in fish collections near KNPP. Too few of any of the four species have been collected to completely evaluate their life histories in the vicinity of KNPP (Table 4.3.1.2). The scarcity of these species within the study area is, in part, reflective of their relatively low numbers in Lake Michigan; however, the natural habits of these species, as described below, limiting their seasonal distribution at the relatively shallow sampling depths near KNPP, have also been limiting factors in evaluation of their life histories in the area.

Commercial catch records compiled by Baldwin and Saalfeld (1962 p.114-115) show that cisco were historically most abundant in northern Lake Michigan, particularly in Green Bay, but have become rare in recent years. Bloaters were more common in the Wisconsin waters of Lake Michigan than elsewhere, but the population suffered a collapse in the late 1960's and their numbers are now greatly reduced (WDNR 1973 p.16). Lake whitefish are more numerous in the Michigan waters of Lake Michigan, though substantial numbers are taken in the Wisconsin waters of Green Bay. Round whitefish are usually taken only in northern Lake Michigan and have been most common in Michigan waters.

Cisco are found at all depths but are most abundant near the surface during spring, winter and late fall (Smith 1956 p.130). In summer cisco move offshore into water greater than 30 feet.

They are pelagic spawners and spawn from mid-November to mid-December in shallow nearshore areas. Cisco mature in their second or third year of life and females produce from 3,500 to 11,000 eggs. Their food consists primarily of zooplankton and crustaceans.

Bloaters inhabit deep water (130 to 390 feet) most of the year, but there is a shoreward movement that begins in late spring (Jobes 1949 p.142). Wells (1968 p.6) caught large numbers of bloaters as shallow as 32 feet in July in southern Lake Michigan. Bloaters spawn in winter in deep water. Wells (1966) collected bloater larvae from April through August with largest catches at depths of 260 to 390 feet. Young bloaters feed mainly upon zooplankton while larger fish (over 7 inches) feed primarily on Pontoporeia affinis and Mysis relicta (Wells and Beeton 1963).

Lake whitefish inhabit shallow, shoal areas during the cooler months and seek deeper water and cooler temperatures during the summer (Qadri 1961 p.305). Young whitefish inhabit very shallow nearshore areas and move to deeper water only when temperatures become too warm (Reckahn 1970 p.442). Males begin to mature at age two while females begin maturing at age three (Mraz 1964a p.619). Spawning takes place in shallow, rocky, shoal areas in November and December (Reckahn 1970 p.441). Young lake whitefish feed mainly upon copepods and cladocerans and both juveniles and adults feed primarily on amphipods, chironomid larvae and sphaeriid clams (Qadri 1961 p.303; Reckahn 1970 p.454).

Juveniles of these aforementioned species have been collected in studies near KNPP, but no adults have been collected in spawning condition. No eggs, larvae or young-of-year specimens of these species have been collected from studies conducted in Lake Michigan near the Plant and it is doubtful that spawning occurs in the immediate vicinity of KNPP. Winter data from the study area would be needed to help document this assumption, but the hazards of fishing inshore during ice formation severely restricts winter sampling.

Carp

Carp are uncommon in the fish collections near KNPP (Table 4.3.1.2). Eight of the eleven specimens collected to date were taken in 1974, most commonly at sampling locations nearest the plant's discharge although similar catches have not occurred in 1975 (LaJeone 1975a p.47, 1975b p.55).

Carp are uncommon in the open waters of Lake Michigan adjacent to Wisconsin. They may be fairly common in localized areas such as river mouths and harbors but are not abundant in the lake except in lower Green Bay where they are taken commercially (Baldwin and Saalfeld 1962 p.126-127). In the Great Lakes region spawning may extend from late May through August if water temperatures permit (Scott and Crossman 1973 p.409). Spawning takes place in shallow, weedy areas beginning when temperaures reach 17 C. No suitable spawning habitat exists in the vicinity of KNPP, but suitable habitat does exist in the lower reaches of several rivers tributary to Lake Michigan in Manitowoc and Kewaunee counties. Adult carp in spawning condition have been collected in June in the study area; but, no eggs, larvae or young have been collected. It is believed that carp do not spawn successfully in the lake in the vicinity of KNPP, but that their occurrence stems from nearby harbor areas or streams from which they have strayed.

Carp are omnivorous, feeding on many types of benthic invertebrates and aquatic plants (Scott and Crossman 1973 p.410). No age studies or stomach analyses were conducted on this species in the study area.

Burbot

Burbot are uncommon in the nearshore waters of Lake Michigan, particularly during the months of study at KNPP. Only one adult specimen has been collected to date (Table 4.3.1.2). Historically, burbot were relatively abundant in Lake Michigan but were considered rare by the early 1960's. Their decline was linked to predation by the sea lamprey, but since control of the lamprey there are indications they have increased in numbers, particularly in Green Bay (Wells and McLain 1973 p.44).

Burbot spend the warmer months in deep water. Occasionally, they move to shallower areas and tributaries in early spring. During winter they move into shallow, gravelly areas in less than 10 feet of water where spawning takes place under the ice from January to March (Scott and Crossman 1973 p.643). Spawning occurs only at night, and spawning grounds are abandoned in the daytime. Burbot may spawn successfully somewhere near KNPP as larvae were collected in April 1973 (LaJeone 1974 p.14). No adults have been collected in spawning condition; however, this could be expected since sampling cannot be conducted in the study area during their spawning season.

Burbot grow rapidly during their first four years of life, the young feeding on all kinds of benthic invertebrates (Scott and Crossman 1973 p.644). Adults feed almost exclusively on fish. No data on food habits or ages of burbot could be obtained from studies at KNPP.

The remaining species known to occur in the vicinity of KNPP are all uncommon in this area of Lake Michigan, some of which likely having strayed from nearby streams or harbor areas.

Utilization of Local Fishery Resource

A Lake Michigan commercial fishing industry still exists in nearby Wisconsin waters but the area near KNPP does not attract commercial exploitation. Also, prior to plant operation, the area near KNPP did not support a sport fishery other than seining of smelt during their spring spawning run. Since KNPP began operation, an extensive sport fishery has developed, centered mainly around the thermal discharge. Smelt seining remains popular, but angling for trout and salmon now attracts many fishermen to the plant's discharge area. Bank fishermen far outnumber boat fishermen since land access has been provided by Wisconsin Public Service Corporation by means of a large visitor parking area and unrestricted access to the discharge area. Occasionally, several fishing boats have been observed in the discharge although boat access is limited. Small boats are frequently carried from the parking area and launched along shore while larger boats must travel approximately eight miles from Kewaunee, the nearest reliable launching facility.

A sport fishery has also developed at the nearby Point Beach Nuclear Plant where Spigarelli and Thommes (1974 p.142) reported that salmonid species dominated the catch in April, May, September, October and November and that fishing pressure and angler success were highest in September. Creel census data for 1974, compiled by the WDNR (1975 p.24) indicated that rainbow, brown and lake trout were caught in large numbers at KNPP and that catches of salmonids at KNPP far exceeded those at the Point Beach and the Port Washington facilities. Fishing pressure data for each location indicates that angler success at KNPP was greater than at the Point Beach Nuclear Plant and the Port Washington facility.

4.3.1.2 Effects of Thermal Discharge on the Fish Community in the Discharge Area

Comparison of Preoperational and Operational Conditions

Catch data from studies conducted in the vicinity of KNPP (Table 4.3.1.2) serve to illustrate the great degree of variability in the numbers, relative abundance, distribution and species composition encountered from one year to the next. These variations do not depict changes directly attributable to the operation of KNPP. Changes in the abundance of a species from year to year usually occur at all sampling locations within the study area. There have been no notable changes in catches at sampling locations nearest the plant's discharge (Locations B/9) that have not also occurred at control locations (Locations A/5 and C/19).

Peak abundance of major species does not appear to be related to the operation of KNPP. Abundance and distribution of eight major species have been plotted since 1973 (Figures 4.3.1.2-4.3.1.4 and 4.3.1.6-4.3.1.10). Alewive, smelt, lake trout and white sucker have been relatively consistent regarding months of peak abundance while lake chub, longnose dace, yellow perch and longnose sucker have been more erratic. Longnose sucker show a preference for Locations C/19 over other locations (Figure 4.3.1.10), but none of the other major species were consistently more common at one sampling area than another. During those months when a sufficient number of individuals of a major species have been collected, the largest proportion of that monthly catch seldom occurred at those locations nearest the plant's discharge. Water temperatures at minnow seine and gill net locations and average discharge temperatures from KNPP show that fish sampling locations were unaffected by the plant's thermal effluent (Figure 4.3.1.11). Therefore, larger catches at Locations B/9 than at the other locations, such as occurred in July 1975, were not related to elevated temperature. The higher proportion of catch in July at Locations B/9 was similar to those at the control locations A/5 and C/19. These proportions are typical of natural variation and it can be concluded that the plant's discharge did not affect fish catches.

Failure to detect any influence of KNPP's thermal discharge at Locations B and 9 (Figure 4.3.1.1) was not unexpected. Location 9 is, no doubt, influenced by the discharge when strong east or southeast winds direct the plume along shore; however, such winds also create rough water conditions prohibiting effective shoreline seining. Location B may only occasionally be affected by the plant's thermal plume as wind direction and currents may direct the heated effluent away from the location. In addition, thermal plumes tend to "float" and heated water may pass over the bottom gill nets which extend only 6 ft up off the lake bottom. That influence of the discharge at Location B is probably negligible is confirmed by Lovorn (1975 p.36) who reported a 50% reduction in excess heat within 1300 feet from the discharge structure and only to a depth of 11.5 feet. Location B is situated approximately 1740 feet from the discharge structure in 16 feet of water.

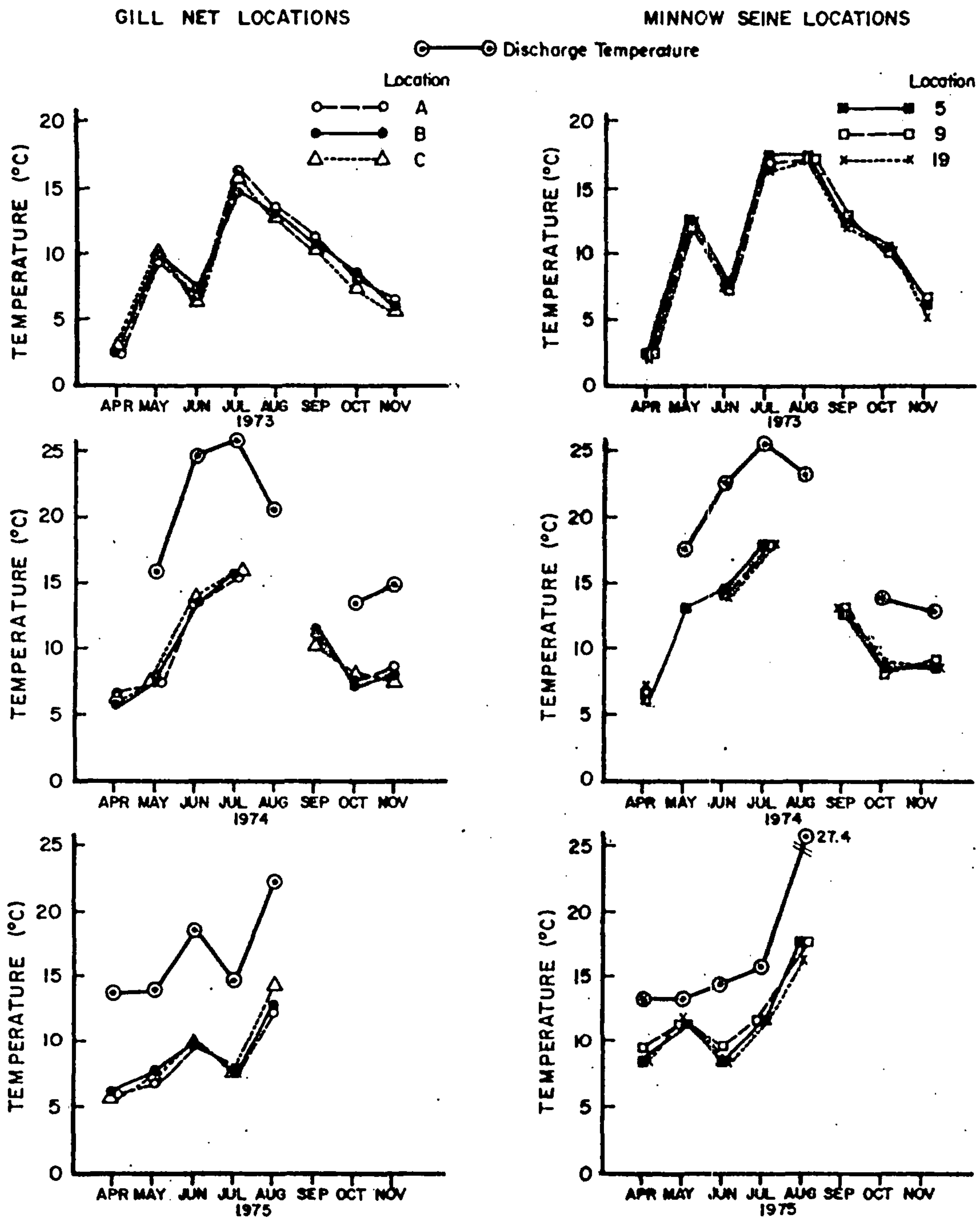


Figure 4.3.1.11. Water temperatures at fish sampling locations and average discharge temperatures on dates of sampling at Kewaunee Nuclear Power Plant from 1973 to date.

Abundance of many species within the study area appears related to their spawning season. Species such as alewives, smelt, lake trout and other trout species are most commonly collected as their spawning season approaches. Similar observations have also been reported at nearby Point Beach Nuclear Plant (Romberg et al. 1973). The absence of white suckers and longnose suckers during their spawning season is attributed to their migration from Lake Michigan up nearby tributaries (LaJeone 1975a p. 38 and 44). No unique spawning habitat has been identified in the vicinity of KNPP which could be influenced by the plant's discharge. Lake trout may attempt to spawn in the area, but no evidence of successful reproduction from the present lake trout stocks in Lake Michigan has yet been reported (Wells and McLain 1973 p.28). Evidence of increased or decreased use of the area for spawning by any species has not been detected following commencement of plant operation.

The survival of cisco and bloater should not be jeopardized by the plant's discharge. Both species are very uncommon in the vicinity of KNPP and it is unlikely that the area is of any great importance to the well-being of these species. Bloaters seldom frequent shallow water and no evidence of either species spawning in the area has been documented.

Carp, uncommon in fish collections near KNPP, have been observed within the heated discharge of the plant (LaJeone 1975a p.47). Similar observations at the Point Beach Nuclear Plant have been reported (Romberg et al. 1973 p.301) where schools of 100 to 200 fish were encountered in May. It was also reported that the numbers of carp were greatly reduced in fall and they did not reappear in appreciable numbers until April. It has been suggested that the numbers of carp residing in the vicinity of KNPP were the result of attraction to the discharge temperature and flow rather than from reproduction in the discharge area (LaJeone 1975a p.58). Preferred temperatures for carp are generally well above ambient Lake Michigan temperatures (Pitt et al. 1956).

Attraction-Avoidance Responses of Fish

At certain times of the year, fish species may be attracted to or avoid thermal discharge areas. Observations at KNPP failed to detect any increased or decreased densities of individual species other than carp in the vicinity of the discharge. Studies at Point Beach Nuclear Plant have found both increased and decreased densities of several species relative to the heated discharge (Spigarelli 1975 p.484; Spigarelli and Romberg 1974 p.119). Fish such as alewives, smelt and salmonid species may become concentrated near thermal discharges in response to a more preferred temperature than ambient, but fish do not necessarily orient themselves near maximum discharge temperatures (Spigarelli and Romberg 1974 p.119).

Laboratory studies by Otto et al. (1975) were conducted to determine preferred and avoidance temperatures for several Lake Michigan fishes (Tables 4.3.1.4 and 4.3.1.5). These data are not directly applicable to field conditions, but they do serve to illustrate possible effects of KNPP discharge. Preferred temperatures of fish vary considerably relative to existing acclimation temperatures. Addition of maximum discharge

Table 4.3.1.4. Temperature preferrenda (°C) for some Lake Michigan fishes acclimated to constant temperatures. From: Otto et al. 1975.

Species	Acclimation Temperature (°C) 5	10	15	20	25
Lake trout	9.0	8.7	10.8	-	-
Rainbow trout	12.2	13.5	14.9	16.0	-
Yellow perch	16.9	19.7	20.0	25.2	26.4
Carp[a]	-	17.0	25.0	27.0	31.0
Fathead minnow	-	21.2	-	26.5	-
Golden shiner	18.6	22.2	25.6	25.8	27.2
Slimy sculpin	8.5	-	11.1	-	-
Acclimation Temperature + Kewaunee ΔT max.	16.1	21.1	26.1	31.1	36.1

[a] Data taken from Pitt, et al. 1956.

Table 4.3.1.5. Temperature preferrenda (°C) for some Lake Michigan fishes acclimated to field temperatures. From: Otto et al. 1975.

Species	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
Alewife (adult)	12	-	-	-	21	19	-	16	16	-	16	11
Alewife (young-of-year)	-	-	-	-	-	-	-	25	24	-	21	19
Carp	-	-	-	-	-	-	31	-	-	-	-	-
Golden shiner	12	16	18	20	23	24	26	-	20	-	14	13
Longnose dace	-	-	-	-	-	-	31	-	-	22	-	-
Rainbow trout	-	13	14	14	15	16	-	-	-	-	-	-
Yellow perch (adult)	13	15	17	19	20	21	-	24	-	20	-	17
Yellow perch (young-of-year)	17	16	20	19	21	25	-	27	-	22	-	19
Kewaunee Monthly Ave. Intake Temp. (°C)	2.4	1.5	2.4	4.1	8.5	8.0	12.3	14.3	13.0	8.5	6.7	3.4
+ Kewaunee ΔT max.	17.9	17.1	18.0	19.6	19.6	19.1	23.4	25.4	24.1	19.6	17.8	20.1

temperatures for KNPP to acclimation temperatures and average monthly intake temperatures shows that preferred temperatures for several species may be exceeded by maximum discharge temperatures (Tables 4.3.1.4 and 4.3.1.5); however, avoidance temperatures for most species may not be exceeded by maximum discharge temperatures unless fish are acclimated to temperatures equal to or exceeding 15 C (Table 4.3.1.6). Comparison of avoidance temperatures of fish (Table 4.3.1.6) with thermal plumes (June, July, October and November) at KNPP (Industrial BIO-TEST Laboratories, Inc. 1975) showed that, when ambient lake temperatures were closely comparable to an acclimation temperature, avoidance levels for most species were seldom exceeded beyond 980 feet from the point of discharge.

The extent to which fish are exposed to temperatures they will avoid due to KNPP discharge is difficult to evaluate. A considerable range of temperatures is available in the immediate vicinity of the thermal discharge and individual fish species may orient themselves at any given temperatures throughout the range. Spigarelli (1975 p.490) noted that fish may move in and out of the heated discharge area at the Point Beach facility and not remain at one temperature for an extended period of time. Also, if avoidance levels are exceeded by heated discharges, fish will reorient themselves to more preferred temperatures (USAEC 1971 p.16-18). Consideration of these observations along with the normal seasonal movements of most species indicates that few fish will be exposed to temperatures exceeding avoidance levels for any appreciable length of time.

Table 4.3.1.6. Avoidance temperatures (°C) of Lake Michigan fish as determined in a +/- choice apparatus. From: Otto et al. 1975.

Species	Acclimation Temperature (°C)				
	5	10	15	20	25
Brook trout	20.0	22.0	21.5	24.0	-
Brown trout	-	21.5	-	-	-
Chinook salmon	20.0	21.5	23.5	-	-
Coho salmon	19.5	22.0	24.5	23.5	-
Lake trout	17.5	18.0	22.0	-	-
Rainbow smelt	10.5	16.0	-	-	-
Rainbow trout	20.5	21.5	23.5	24.5	-
Yellow perch	26.0	30.0	31.0	31.0	33.0
Slimy sculpin	15.0	19.0	23.0	-	-
Acclimation Temperature + Kewaunee ΔT max.	16.1	21.1	26.1	31.1	36.1

Effects of the Discharge on Fish Migrations

None of the data compiled thus far from studies at KNPP give any indication that normal seasonal migrations of fish are altered by the thermal discharge. Inshore-offshore movements of migratory species have not changed since the plant began operation. General patterns in the seasonal abundance of fish following plant operation were unchanged from observations prior to plant operation and no differences in seasonal movements could be detected in either the thermally affected or control areas. Similar observations were reported at the Zion Nuclear Station in southwestern Lake Michigan where Muench (1974 p.198) found that in winter there was a general abandonment of all fish species from all inshore sampling depths without apparent regard to the influence of the station's thermal discharge. Despite occasional attraction of many species to thermal plumes, normal seasonal migrations are not appreciably affected. The virtual absence of fish from the inshore areas in winter illustrates that normal migrations occur even though more preferred temperatures may exist in thermally affected areas.

Mark and recapture studies conducted at KNPP indicate that salmonids and yellow perch are not long-term residents of the study area but frequently move considerable distances away from the area (Figure 4.3.1.12). Mark and recapture studies at the Point Beach Nuclear Plant (Spigarelli 1975 p.487) showed that 80% of the tagged fish recaptured by sport fishermen had migrated away from the Point Beach area with only 22% of these fish taken at other thermal discharges. Low recapture rates of tagged

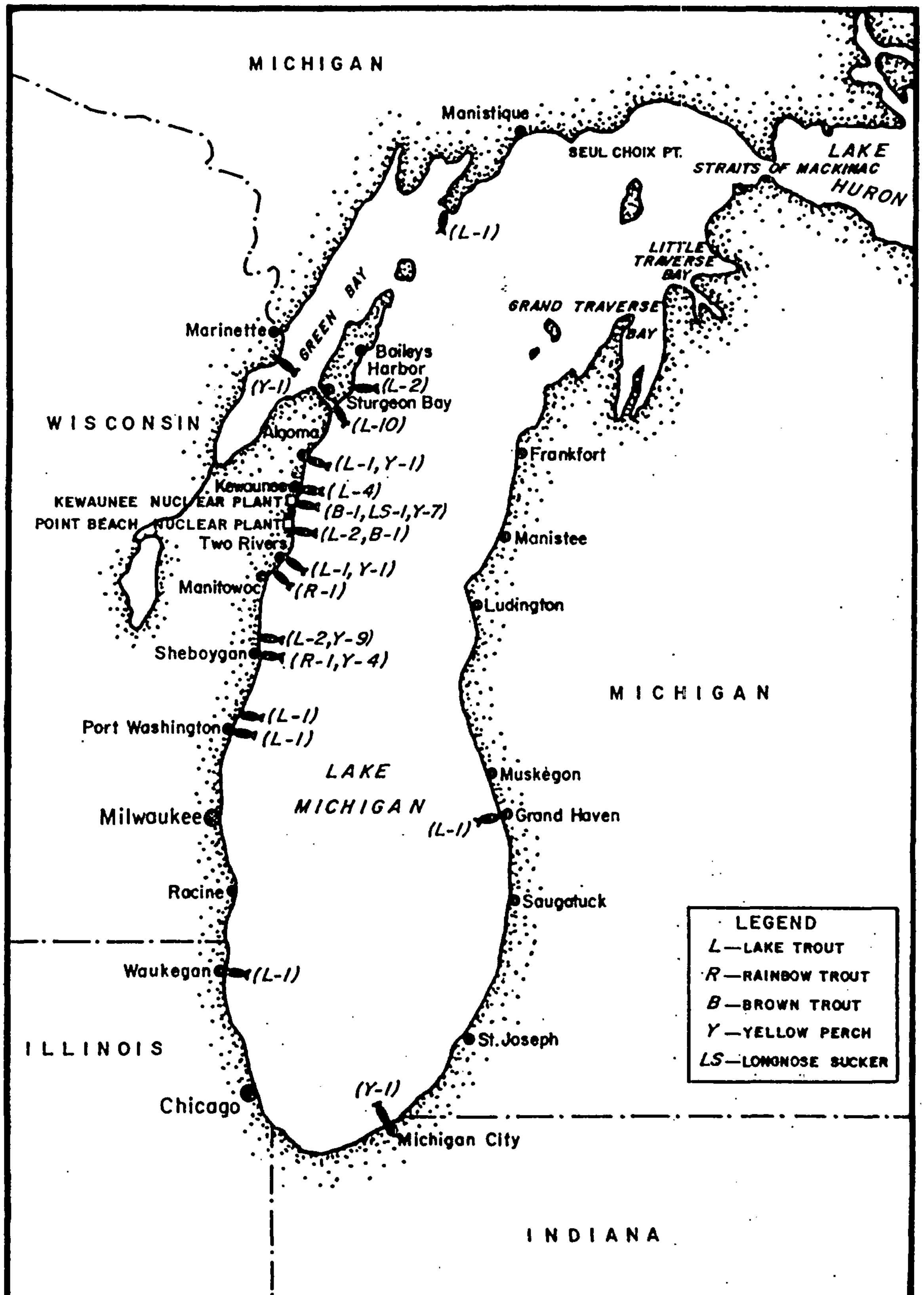


Figure 4.3.1.12. Recapture locations and number of recaptures of fish tagged in the vicinity of the Kewaunee Nuclear Power Plant.

fish in the vicinity of KNPP and the extent of fish movements based on recapture locations demonstrates for these species that movement probably occurs over a large portion of Lake Michigan. It is also doubtful that the thermal discharge of KNPP hinders the upstream migrations of anadromous species. The zone of thermal influence is relatively small and the plant is located approximately eight miles from the nearest tributary utilized by trout and salmon. Along-shore movements of fish should be relatively unaffected by the thermal plume as heated water tends to "float" near the surface, having lesser influence on that portion of the water column below it.

Lethal Effects of the Discharge

Use of Lake Michigan water for condenser cooling may affect fish populations in several ways. Fish eggs and larvae may be entrained in intake water and exposed to rapid increases in temperature during condenser passage. In addition, all life stages of fish may be affected by effluent temperatures at the point of discharge. Lethal effects may occur when fish are exposed to rapid increases in temperature or prolonged exposure to temperatures above tolerance limits (heat shock). Lethal effects may also occur when fish, acclimated to discharge temperatures, are subjected to rapid decreases in temperature due to complete reactor shutdown (cold shock).

Fish mortalities as a result of exposure to increased temperatures may occur in two ways. Fish exposed to rapid increases in temperature lose equilibrium and coordinated movement, at which point they can no longer avoid heat stress and death will occur if temperatures are not quickly reduced. The temperature at loss of equilibrium is defined as the critical thermal maximum (CTM) and could be considered the upper boundary of resistance to high temperatures that would lead to death. Exposure to somewhat lower temperatures for longer periods may also result in fish mortalities. These temperatures are defined as upper incipient lethal temperatures and could be considered the lower boundary of resistance to high temperatures.

Critical thermal maxima were determined for several Lake Michigan fish species acclimated to laboratory temperatures and field temperatures by Otto et al. (1975)(Tables 4.3.1.7 and 4.3.1.8). Upper incipient lethal temperatures for several species at various acclimation temperatures have been reported by other sources (Table 4.3.1.9). Maximum discharge temperatures for KNPP (acclimation temperature + maximum ΔT) have been added to Tables 4.3.1.7 and 4.3.1.9 for comparison. Likewise, average monthly intake temperatures and maximum discharge temperatures for KNPP have been added to Table 4.3.1.8. Expected KNPP discharge temperatures did not exceed CTM's determined for fish acclimated to constant temperature and field regimes (Tables 4.3.1.7 and 4.3.1.8). Upper incipient lethal temperatures were exceeded by KNPP discharge temperatures only at acclimation temperatures of 15 C or higher (Table 4.3.1.9); however, monthly average intake temperatures indicate that discharge temperatures exceeding 23 C occur only in July, August and September (Table 4.3.1.8). The maximum allowable discharge temperature of 30 C would not be encountered except when

Table 4.3.1.7. Summary of critical thermal maxima (°C) for some Lake Michigan fishes at various acclimation temperatures. From: Otto et al. 1975.

Species	Acclimation Temperature (°C)					
	5	10	15	20	25	30
Alewife (adult)	24.7	28.7	29.9	31.9	32.8	-
Alewife (young-of-year)	24.7	26.7	29.5	31.9	34.3	36.7
Brooktrout (yearling)	27.5	28.8	30.0	-	-	-
Brown trout (yearling)	-	27.8	-	-	-	-
Chinook salmon (yearling)	26.4	28.5	29.5	30.2	-	-
Coho salmon (yearling)	26.1	27.3	28.2	29.9	-	-
Fathead minnow	28.5	31.9	32.7	35.7	36.7	38.5
Golden shiner	27.9	30.3	33.0	35.0	37.6	39.0
Longnose dace	28.4	30.5	31.4	33.9	35.4	36.7
Lake trout (yearling)	26.3	25.9	27.9	-	-	-
Rainbow smelt	23.5	24.4	-	-	-	-
Rainbow trout (yearling)	27.9	28.4	29.7	31.1	-	-
Slimy sculpin	23.4	25.0	27.1	29.4	-	-
Spottail shiner	27.7	30.2	31.2	33.3	35.5	37.7
White sucker	27.8	28.7	30.5	32.9	-	-
Yellow perch (adult)	26.6	29.3	31.6	33.8	35.4	-
Yellow perch (young-of-year)	27.5	28.6	30.3	32.6	35.1	-
Acclimation Temperature + Kewaunee ΔT max.	16.1	21.1	26.1	31.1	36.1	41.1

Table 4.3.1.8. Summary of critical thermal maxima (°C) for some Lake Michigan fishes acclimated to field temperatures. From: Otto et al. 1975.

Species	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
Alewife (adult)	-	-	-	26.3	-	28.6	30.1	-	29.7	26.6	-	24.3
Alewife (young-of-year)	-	-	-	-	-	-	-	31.5	-	-	27.1	23.4
Carp (young-of-year)	-	-	-	-	-	-	37.8	-	-	-	33.9	-
Fathead minnow	-	-	-	-	-	-	33.3	-	-	-	-	-
Golden shiner	23.1	26.3	27.7	29.5	32.3	31.5	31.8	-	31.8	-	27.8	25.8
Rainbow smelt	-	-	-	-	24.5	-	-	-	-	-	-	-
Rainbow trout (yearling)	-	26.7	27.4	27.5	29.1	29.3	-	-	-	28.6	-	-
White sucker (young-of-year)	25.0	-	-	-	-	-	30.7	-	28.7	-	-	-
Yellow perch (adult)	24.9	26.3	28.3	28.9	29.8	30.8	-	33.6	-	28.8	-	25.9
Yellow perch (young-of-year)	25.5	24.3	27.5	27.5	28.9	30.2	-	33.6	-	28.8	-	25.9
Kewaunee Monthly Ave. Intake Temp. (°C)	2.4	1.5	2.4	4.1	8.5	8.0	12.3	14.3	13.0	8.5	6.7	3.4
+ Kewaunee ΔT Max.	17.9	17.1	18.0	19.6	19.6	19.1	23.4	25.4	24.1	19.6	17.8	20.1

Table 4.3.1.9. Upper incipient lethal temperatures (°C) for some Lake Michigan fishes at various acclimation temperatures. From: Otto et al. 1975.

Species	Acclimation Temperature (°C)					Reference
	5	10	15	20	25	
Alewife (adult)	-	23.3	23.8	24.5	-	Otto et al 1975
Alewife (young-of-year)	-	26.3	-	30.3	32.1	Otto et al 1975
Bloater	22.6	23.8	24.8	26.6	27.0	Edsall et al 1970
Brook trout	23.7	24.4	25.0	25.3	25.3	Fry et al 1946
Chinook salmon	21.5	24.3	25.0	25.1	-	Brett 1952
Cisco	21.6	24.3	-	26.6	26.0	Edsall & Colby 1970
Coho salmon	21.3	22.5	23.1	23.9	-	Brett 1952
Fathead minnow	-	28.2	-	31.7	33.2	Hart 1947
Golden shiner	-	29.3	30.5	31.8	32.2	Hart 1952
Lake trout	-	22.8	21.5	23.5	-	Gibson & Fry 1954
Rainbow trout (yearling)	23.4	24.7	25.7	25.7	-	Otto et al 1975
Slimy sculpin	18.5	22.5	23.5	-	-	Otto et al 1975
White sucker	26.3	27.7	29.3	29.3	29.3	Hart 1947
Yellow perch	22.2	24.7	27.7	29.8	31.2	Otto et al 1975
Acclimation Temperature + Kewaunee ΔT max.	16.1	21.1	26.1	31.1	36.1	

ambient temperatures reached 19 C. Fish acclimated to 19 C would not be exposed to temperature exceeding CTM's, with the possible exception of coho salmon and slimy sculpin (Table 4.8.1.7). Discharge temperatures of 30 C would exceed upper incipient lethal temperatures of most species acclimated to 20 C (Table 4.3.1.9). Avoidance responses of fish, however, indicate that most species would begin to avoid the discharge area at temperatures far below the 30 C maximum (Table 4.3.1.6) and would therefore not be exposed to lethal temperatures.

Despite the possibility that upper incipient lethal temperatures for several species may occasionally be exceeded by the maximum KNPP discharge temperatures, there appears to be little danger of fish mortalities. Temporal distribution patterns and avoidance responses of fish indicate that few fish will encounter or remain exposed to these lethal temperatures. Most species which might be adversely affected by high discharge temperatures, normally have moved to deeper water during the summer months and would not come in contact with the thermal effluent of the KNPP. Also, avoidance temperatures are usually considerably lower than incipient lethal temperatures (Tables 4.3.1.6 and 4.3.1.9) and fish would be repelled by high discharge temperatures before exposure to lethal temperatures occurs. Spigarelli (1975 p.486) reported that maximum thermal plume densities of fish occurred at intermediate temperatures rather than at high temperatures; thus, the fish present would select areas farther from the point of discharge when maximum plume temperatures become too warm.

Fish mortalities due to abrupt decreases in temperature might occur in winter. Fish attracted to the discharge may become acclimated to the higher temperatures of the discharge and, in the case of a plant shutdown, could be subjected to rapid decreases in temperature down to lake ambient and suffer cold shock. A summary of known lower incipient lethal temperatures for several Lake Michigan fishes indicates that deaths due to cold shock could occur, particularly at higher discharge temperatures (Table 4.3.1.10), but again, seasonal movements and behavioral responses of fish are such that fish mortalities from cold shock are unlikely. As previously stated, the majority of fish leave the inshore areas of the lake in winter and move to deeper water and, therefore, would not be in the vicinity of shoreline thermal discharges. Those fish inhabiting shallow water that may be attracted to thermal discharges in winter also may not be subjected to lethal cold temperatures due to reactor shutdowns, as fish seldom become acclimated to maximum discharge temperatures but tend to orient themselves in areas of intermediate temperatures between discharge maximums and ambient conditions (Spigarelli 1975 p.490). Under these conditions, the drop in temperature that fish would be exposed to during reactor shutdown would be somewhat reduced and may not be sufficient to result in mortality.

Little information is available concerning the effect of thermal shock in condenser passage on the eggs and larvae of Lake Michigan fishes. Marcy (1971 p.1058) found that larval and juvenile fish subjected to a 12.5 C temperature increase in condenser passage

Table 4.3.1.10. Summary of lower incipient lethal temperatures (°C) for some Lake Michigan fishes at various acclimation temperatures. From: Otto et al. 1975.

Species	Acclimation Temperature (°C) 5	10	15	20	25	Reference
Alewife	-	4	5.4	7.8	-	Otto et al 1975
Brook trout	-	-	-	-	0.5	Fry et al 1946
Chinook salmon	<1	0.8	2.5	4.5	-	Brett 1952
Coho salmon	0.2	1.7	3.5	4.5	-	Brett 1952
Fathead minnow	-	-	-	1.5	-	Hart 1947
Golden shiner	-	-	1.5	4.0	7.0	Hart 1952
Lake trout	-	-	-	0.0	-	Gibson and Fry 1954
Rainbow smelt	<1	<1	-	-	-	Otto et al 1975
Rainbow trout	<1	<1	2.0	4.0	-	Otto et al 1975
Slimy sculpin	<1	1	4.0	-	-	Otto et al 1975
Yellow perch	-	1.1	-	-	3.7	Hart 1947
White sucker	-	-	-	2.5	6.0	Hart 1947

[a] Reference to Otto, et al 1975 is published or confirmed data.

down a mile-long discharge canal did not survive at discharge temperatures of 30 C. It is expected that mortalities to fish eggs and larvae subjected to condenser passage do occur at KNPP; however, the only species expected to be influenced to any extent are alewive and smelt as they are the only two species for which any number of eggs and larvae have been found adjacent to the intake of the plant. Both species are abundant in the area, particularly during their spawning seasons, but such mortalities should not affect their status as they spawn in shallow water almost everywhere in Lake Michigan. Similar findings have been demonstrated for the area of Lake Michigan near the Point Beach Nuclear Plant (Wisconsin Electric Power Co. & Wisconsin-Michigan Power Co., 1975).

There have been no reported incidences of fish mortalities at KNPP to date, and under expected operating conditions, it is unlikely that the fish population will be adversely affected by the thermal discharge.

4.3.1.3 Effects of the Thermal Discharge on the Fish Community Outside the Discharge Area

There have been no alterations in the species composition of the fishes in control areas that would be unusual. Variations in the seasonal occurrence, peak abundance and relative abundance of important fish species in control areas appear normal and do not relate to plant operation. Similarly, variations in the spatial distribution of major fish species within the study area cannot be correlated with plant operation. Increased or decreased use of control areas as spawning or nursery sites has not been detected.

No attempt is made to predict possible lake-wide effects of the KNPP discharge on the fishery of Lake Michigan. It is recognized that subtle changes in the fishery may occur that have not yet been determined.

In view of the absence of appreciable harm to the fish community within the immediate discharge area, it was considered unlikely that effects on the fish community outside the discharge area could be detected.

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4.3.2 BENTHOS

4.3.2.1 Lake Michigan Benthic Community Structure in the Kewaunee Area Prior to Plant Operation

Industrial BIO-TEST Laboratories, Inc. has monitored Lake Michigan benthic macroinvertebrates in the vicinity of the KNPP from 1971 through 1975 (Industrial BIO-TEST Laboratories, Inc. 1972, 1973; Rains and Clevenger 1974, 1975). In 1971 a Ponar grab was used but from 1972 through 1975 sampling has been conducted using a diver-operated pump system. The only other Lake Michigan macroinvertebrate community studies conducted in the nearshore zone near KNPP were those reported by Argonne National Laboratories (1972) and the U.S. Atomic Energy Commission (1971). Samples were collected with a Ponar grab in the latter two studies. The general conclusion of both reports was that the macroinvertebrate community was sparse because of unsuitable clay and rocky substrates. Industrial BIO-TEST Laboratories, Inc. (1973) demonstrated that a Ponar grab did not adequately collect quantitative samples from the predominantly rocky substrate at Kewaunee and that the macroinvertebrate community was more diverse and abundant than previously reported. When the pump sampling system was used the total benthos density collected increased by a factor of 30 while the number or richness of taxa increased by a factor of six above that sampled by the Ponar grab (Industrial BIO-TEST Laboratories, Inc. 1973).

Macroinvertebrate data from April 1973 to July 1974 form the basis for the subsequent discussion. Data collected prior to 1973 were used only as supportive information because standardized field and laboratory procedures were not established until 1973 (Rains and Clevenger 1974 Chap. 8, p.2-3). Macroinvertebrates have been collected in spring, summer and fall since 1973; however, winter sampling has not been conducted due to severe and often dangerous lake conditions. KNPP began operation in June 1974 and data obtained after that time were considered operational.

Benthic sampling locations after 1973 were established along the 10-, 20- and 30-ft depth contours (Figure 4.3.2.1). Substrates at sampling locations along the 10-ft contour were primarily sand while along the 20- and 30-ft contours they were basically periphyton covered rocks interspersed with occasional pockets of clay, silt, detritus, sand and gravel (Table 4.3.2.1 and Figure 4.3.2.2).

Macroinvertebrate Community Structure

The macroinvertebrate community during the preoperational study period was comprised of 10 phyla, 16 classes and a total of 116 taxa (Table 4.3.2.2). The predominant macrobenthic groups were Oligochaeta (segmented worms) and Chironomidae (midges). Worm and midge mean densities represented 30% and 41%, respectively, of the total benthos at the 10-ft locations and 45% and 22%, respectively, at 20- and 30-ft locations (Table 4.3.2.3). Amphipoda (scuds), Ephemeroptera (mayflies), Gastropoda (snails) and Trichoptera (caddisflies) were commonly collected but averaged less than 10% of the benthos. Nematoda (round worms), Ostracoda (seed shrimp) and Rhabdocoela (flat worms) occasionally represented a large percent of the benthos; however, these are normally considered meiobenthos and will not be emphasized. None of the macroinvertebrate taxa at

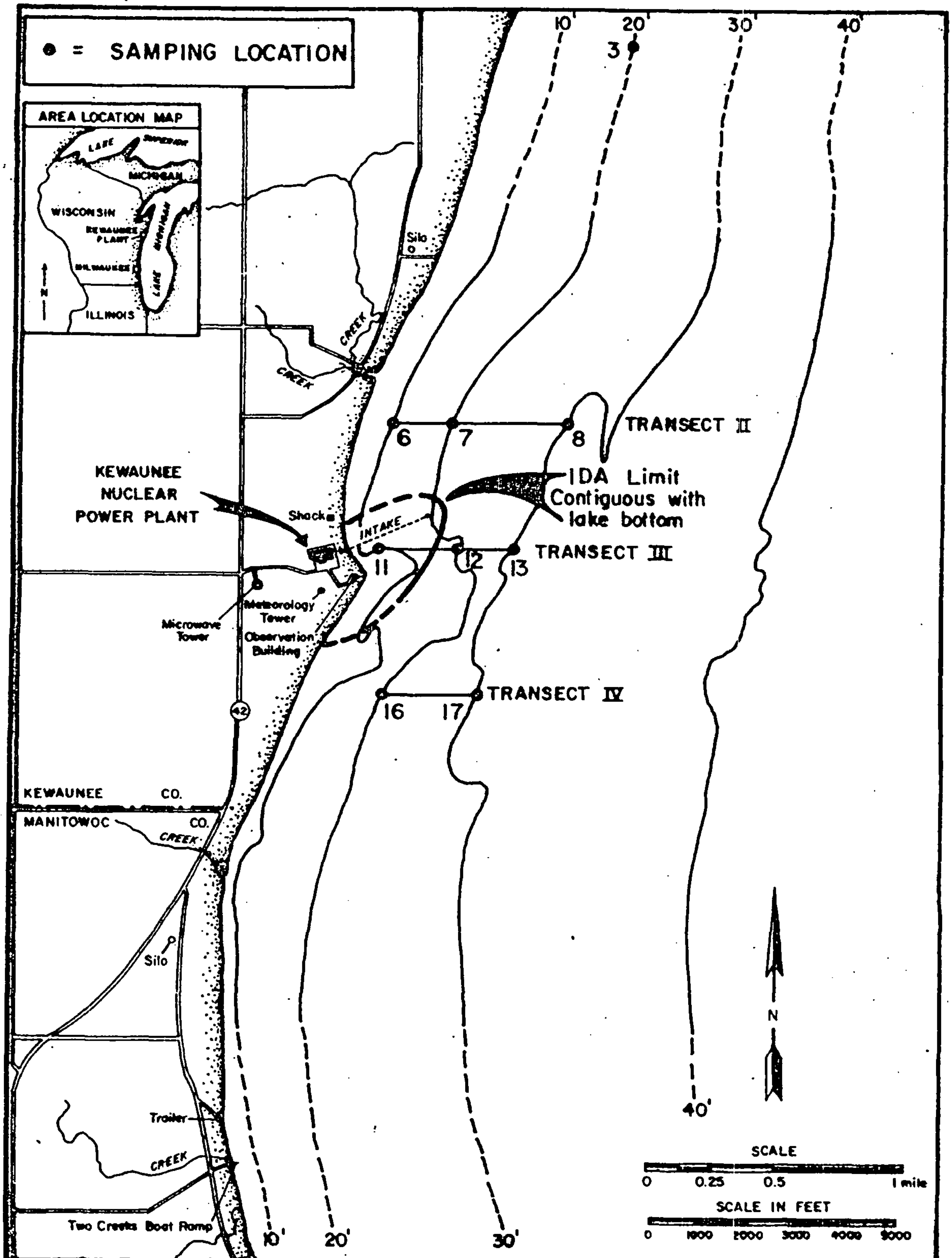

Figure 4.3.2.1. Benthic macroinvertebrate sampling locations and discharge zone (excess 2C temperature isotherm) near the Kewaunee Nuclear Power Plant in 1975.

Table 4.3.2.1. Predominant substrates present at macroinvertebrate sampling locations along the 10-, 20- and 30-ft depth contours of Lake Michigan near Kewaunee Nuclear Power Plant, 1973-1975.

Depth and Sampling Location	1973					1974					1975		
	Apr	May	Jul	Sep	Nov	Apr	May	Jul	Sep	Nov	Apr	May	Jul
10-ft Locations													
Location 6	S[a]	S	S	S	SR	S	SR	S	S	S	S	S	SA
Location 11	S	S	S	SR	S	S	SDR	S	SR	RG	S	S	S
20-ft Locations													
Location 3	R	R	R	R	R	R	RC	R	R	R	R	R	R
Location 7	R	RDC	R	R	R	RC	RC	RDC	C	RC	R	R	RD
Location 12	R	R	R	RG	R	R	RG	R	R	RG	R	R	R
Location 16	R	DC	R	R	DR	DC	CC	DC	DC	RC	DC	R	RD
30-ft Locations													
Location 8	R	R	R	R	RD	RG	RD	RS	RD	RG	R	R	R
Location 13	R	R	RD	R	R	RG	RCG	RSC	RSC	RGC	R	R	R
Location 17	RD	R	R	R	R	GC	GCR	RSG	DCR	C	RGS	RCS	R

[a] Substrate types:
S=Sand
R=Periphyton covered rocks
G=Gravel
D=Detritus and silt
A=Algal clumps
C=Clay
Substrate characterization based on observations by diver during sample collection.

Figure 4.3.2.2. Typical benthic substrate at the 20- and 30-ft locations sampled in Lake Michigan near the Kewaunee Nuclear Power Plant, 1974. Largest rocks are approximately 0.3 m in diameter.

Table 4.3.2.2. Benthic macroinvertebrates collected in Lake Michigan near Kewaunee Nuclear Power Plant, 1973-1975.

- Porifera
  - Demispongia
    - Haplosclerina
      - Spongillidae
        - *Spongila fragilis* Leidy
- Cnidaria
  - Hydrazoa
    - Hydroida
      - Hydridae
        - *Hydra* sp. Linnaeus
- Platyhelminthes
  - Turbellaria
    - Tricladida
      - Planariidae
        - *Dugesia tigrina* (Girard)
    - Rhabdocoela
- Acanthocephala
- Aschelminthes
  - Nematoda
- Tardigrada
- Bryozoa
  - Gymnolaemata
    - Ctenostomata
      - Paludicellidae
        - *Paludicella articulata* (Ehr.)
  - Phylactolaemata
    - Plumatellina
      - Plumatellidae
        - *Fredericella* sp. Gerris
        - *Cristatella mucedo* Cuvier
- Mollusca
  - Gastropoda
    - Pulmonata
      - Lymnaeidae
        - *Lymnaea* sp. Lamarck
      - Physidae
        - *Physa* sp. Praparnaud
      - Planorbidae
        - *Gyraulus eflectus* (Say)
        - *G. parvus* (Say)
    - Ctenobranchiata
      - Pleuroceridae
        - *Goniobasis livescens* (Menke)
      - Hydrobiidae
        - *Amnicola* sp. Gould and Halderman
      - Valvatidae
        - *Valvata perdepressa* Walker
        - *V. sincera* Say
        - *V. tricarinata* (Say)
        - *Valvata* sp. Muller

Table 4.3.2.2. (continued)

Pelecypoda
- Heterodonta
  - Sphaeriidae
    - _Pisidium_ sp. Pfeiffer
    - _Sphaerium_ sp. Scopoli

Annelida
- Oligochaeta
  - Plesiopora
    - Enchytraeidae
    - Glossoscolecidae
      - _Sparganophilus_ sp. Benham
    - Naididae
      - _Chaetogaster diaphanus_ (Gruithuisen)
      - _Nais behningi_ Michaelson
      - _N. bretscheri_ Michaelson
      - _N. communis_ Piguet
      - _N elinguis_ Muller
      - _Nais_ sp. Muller
      - _Paranais frici_ (Harbe)
      - _Piguetiella michiganensis_ (Hiltunen)
      - _Slavina appendiculata_ (d' Udekem)
      - _Stylaria lacustris_ (Linnaeus)
      - _Uncinais uncinata_ (Orstedt)
      - _Vejdovskyella intermedia_ (Boetscher)
    - Tubificidae
      - _Ilyodrilus templetoni_ (Southern)
      - _Limnodrilus angustipenis_ Brinkhurst and Cook
      - _L. claparedeianus_ Ratzel
      - _L. hoffmeisteri_ Claparede
      - _L. hoffmeisteri_ (variant) Claparede
      - _L. profundicola_ (Verril)
      - _L. spiralis_ Eisen
      - _L. udekemianus_ Claparede
      - _Peloscolex freyi_ Brinkhurst
      - _P. multisetosus multisetosus_ (Smith)
      - _P. superiorensis_ (Brinkhurst and Cook)
      - _Potamothrix moldaviensis_ Vejdovsky and Marzek
      - _P. vejdovskyi_ (Herbe)
      - _Tubifex ignotus_ (Stole)
      - _T. tubifex_ Muller
  - Prosopora
    - Lumbriculidae
      - _Stylodrilus heringianus_ Claparede

Branchiobdellida

Hirudinea
- Rhynchobdellida
  - Glossiphonidae
    - _Glossiphonia complanata_ (Linnaeus)
    - _Helobdella elongata_ (Castle)

Table 4.3.2.2. (continued)

Helobdella stagnalis (Linnaeus)
Pisicolidae
Pisicola geometra (Linnaeus)
Pharyngobdellida
Erpobdellidae
D. parva Moore
Arthropoda
Arachnida
Hydracarina
Crustacea
Ostracoda
Mysidacea
Mysidae
Mysis relicta Loven
Amphipoda
Haustoriidae
Pontoporeia affinis Lindstrom
Talitridae
Hyalella azteca (Saussure)
Gammaridae
Gammarus pseudolimnaeus (Bousfield)
Isopoda
Asellidae
Asellus sp. Geoffery St. Hillaire
Lirceus sp. Rafinesque
Decapoda
Astaecidae
Insecta
Collembola
Ephemeroptera
Heptageniidae
Heptagenia sp. Walsh
Stenonema sp. Traver
Tricoptera
Hydropsychidae
Cheumatopsyche sp. Wallengren
Hydropsyche sp. Pictet
Phryganeidae
Agrypnia sp. Curtis
Lepidostomatidae
Lepidostoma sp. Rambur
Leptoceridae
Athripsodes sp. Billberg
Leptocella sp. Banks
Diptera
Ceratopogonidae

Table 4.3.2.2. (continued)

- Chironomidae
  - Tanypodinae
    - *Ablabesmyia* sp. Joh.
    - *Procladius* sp. (Skuse)
    - Thienemannimyia Series
  - Diamesinae
    - *Diamesa* (Pseudokiefferiella) sp. Zavrel
    - *Monodiamesa* sp. Kieff.
    - *Potthastia* sp. Kieff.
  - Orthocladiinae
    - *Corynoneura* sp. (Winn.)
    - *Cricotopus* sp. (V. d. Wulp)
    - *Eukiefferiellus* sp. Kieff.
    - *Heterotrissocladius* sp. Spark
    - *Microcricotopus* sp.
    - *Orthocladius* sp. V. d. Wulp
    - *Parakiefferiella* sp. Thien.
    - *Psectrocladius* sp. Kieff.
    - *Pseudosmittia* sp. (Goefgh.)
    - *Synorthocladius* sp. Thien.
    - *Thienemanniela* sp. Kieff.
    - *Trissocladius* sp. Kieff.
  - Chironominae
    - *Chironomus* sp. (Meigen)
    - *Cladotanytarsus* sp. Kieff.
    - *Cryptochironomus* sp. Kieff.
    - *Cryptocladopelma* sp. Lenz
    - *Demicryptochironomus* sp. Lena
    - near *Demicryptochironomus* sp.
    - *Dicrotendipes* sp. Kieff.
    - *Endochironomus* sp. Kieff.
    - *Micropsectra* l.f. *curvicornis* Tshernovskii
    - *Micropsectra* sp. Kieff.
    - *Microtendipes* sp. Kieff.
    - *Parachironomus* sp. Lenz
    - *Paracladopelma* sp. Harn.
    - *Paralauterborniella* sp. Lenz
    - *Paratanytarsus* sp. Kieff.
    - *Paratendipes* sp. Kieff.
    - *Phaenopsectra* sp. Townes
    - *Polypedilum* (s.s.) Fallax Group Kieff.
    - *Polypedilum* (s.s.) Scalaenum Group Kieff.
    - *Rheotanytarsus* sp. (Bause)
    - *Stictochironomus* sp. Kieff.
    - *Tanytarsus* sp. V. d. Wulp
- Empididae
- Psycodidae
  - *Psycoda* sp. Latreille

Kewaunee were found in nuisance proportions. There is no published list of rare or endangered species for the Kewaunee area and none of the Kewaunee benthic macroinvertebrates would be considered endangered.

The substrate differences between the 10-ft locations (Locations 6 and 11) and the 20- and 30-ft locations (Locations 3, 7, 12 and 16 and Locations 8, 13 and 17, respectively) created a natural divergence in the macroinvertebrate community. The assemblage of organisms at the 10-ft locations was low in density and restricted in species composition when compared to the assemblage at the 20- and 30-ft locations. This was attributable to the greater stress at the 10-ft locations created by shifting of the sandy substrates due to wave action.

Representative macroinvertebrates at the 10-ft locations were the worms, Vejdovskyella intermedia (6%) and Nais sp. (3%), and the midges, Parakiefferiella sp. (7%), Paracladopelma sp. (4%) and Polypedilum (s.s.) Scalaenum Group (6%)(Table 4.3.2.3). Pontoporeia affinis, Nais sp., Limnodrilus profundicola and Near Demicryptochironomus sp. were more abundant at 10-ft locations than at 20- and 30-ft locations, but dense populations were never encountered.

The densities of the predominant worms and midges were low and sporadic at both 10-ft locations (Table 4.3.2.3). Therefore, definite seasonal distribution patterns could not be determined. Most worm and midge densities were less than 100 organisms/m^2 (Figures 4.3.2.3-4.3.2.7). Densities greater than 100 organisms/m^2 usually occurred when periphyton covered

Table 4.3.2.3. Mean densities (No/m^2) and percent composition of representative macroinvertebrates at 10-, 20-, and 30-ft locations during the preoperational phase (April 1973-May 1974) of environmental monitoring at the Kewaunee Nuclear Power Plant.

Representative Taxa	10-ft Locations 6	11	Mean of 10-ft Locations	20-ft Locations 3	7	12	16	30-ft Locations 8	13	17	Mean of 20- and 30-ft Locations
Oligochaeta	604	173	389	1378	1487	1520	1626	5391	2987	4224	2659
	33%	22%	30%	33%	57%	42%	41%	58%	39%	43%	45%
Limnodrilus hoffmeisteri	14	18	16	36	115	59	136	416	77	137	139
	1%	2%	1%	1%	4%	2%	3%	4%	1%	1%	2%
Nais sp.	74	2	38	8	6	103	19	0	11	2	22
	4%	<1%	3%	<1%	<1%	3%	<1%	0%	<1%	<1%	<1%
Vejdovskyella intermedia	105	44	75	257	113	461	502	1201	1631	2184	907
	6%	6%	6%	6%	4%	13%	13%	13%	21%	22%	15%
Chironomidae	605	462	534	2003	672	1309	1084	972	1692	1269	1286
	33%	59%	41%	48%	26%	36%	28%	10%	22%	13%	22%
Microtendipes sp.	31	47	36	477	99	223	38	30	131	145	163
	2%	6%	3%	11%	4%	6%	1%	<1%	2%	1%	3%
Paracladopelma sp.	80	22	51	24	50	11	59	137	136	60	68
	4%	3%	4%	1%	2%	<1%	2%	1%	2%	1%	1%
Parakiefferiella sp.	122	60	91	464	168	456	228	119	362	256	293
	7%	8%	7%	11%	6%	13%	6%	1%	5%	3%	5%
Polypedilum (s.s.) Scalaenum Group	79	72	76	39	29	25	677	63	104	125	152
	4%	9%	6%	1%	1%	1%	17%	1%	1%	1%	3%
Thienemannimyia Series	93	32	63	225	105	141	121	88	179	141	143
	5%	4%	5%	5%	4%	4%	3%	1%	2%	1%	2%
Amphipoda	22	18	20	79	35	106	50	24	38	66	57
	1%	2%	2%	2%	1%	3%	1%	<1%	<1%	1%	1%
Ephemeroptera	16	5	10	21	17	38	33	3	9	17	20
	1%	1%	1%	1%	1%	1%	1%	<1%	<1%	<1%	<1%
Gastropoda	2	5	4	59	17	42	4	26	33	22	29
	<1%	1%	<1%	1%	1%	1%	<1%	<1%	<1%	<1%	<1%
Trichoptera	3	6	5	10	4	15	5	1	8	8	7
	<1%	1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%
Other Benthos	421	14	198	545	285	460	363	2659	2693	4111	1587
	23%	2%	15%	13%	11%	13%	9%	29%	35%	42%	27%
Total Benthos	1811	780	1296	4166	2602	3629	3920	9276	7711	9904	5887

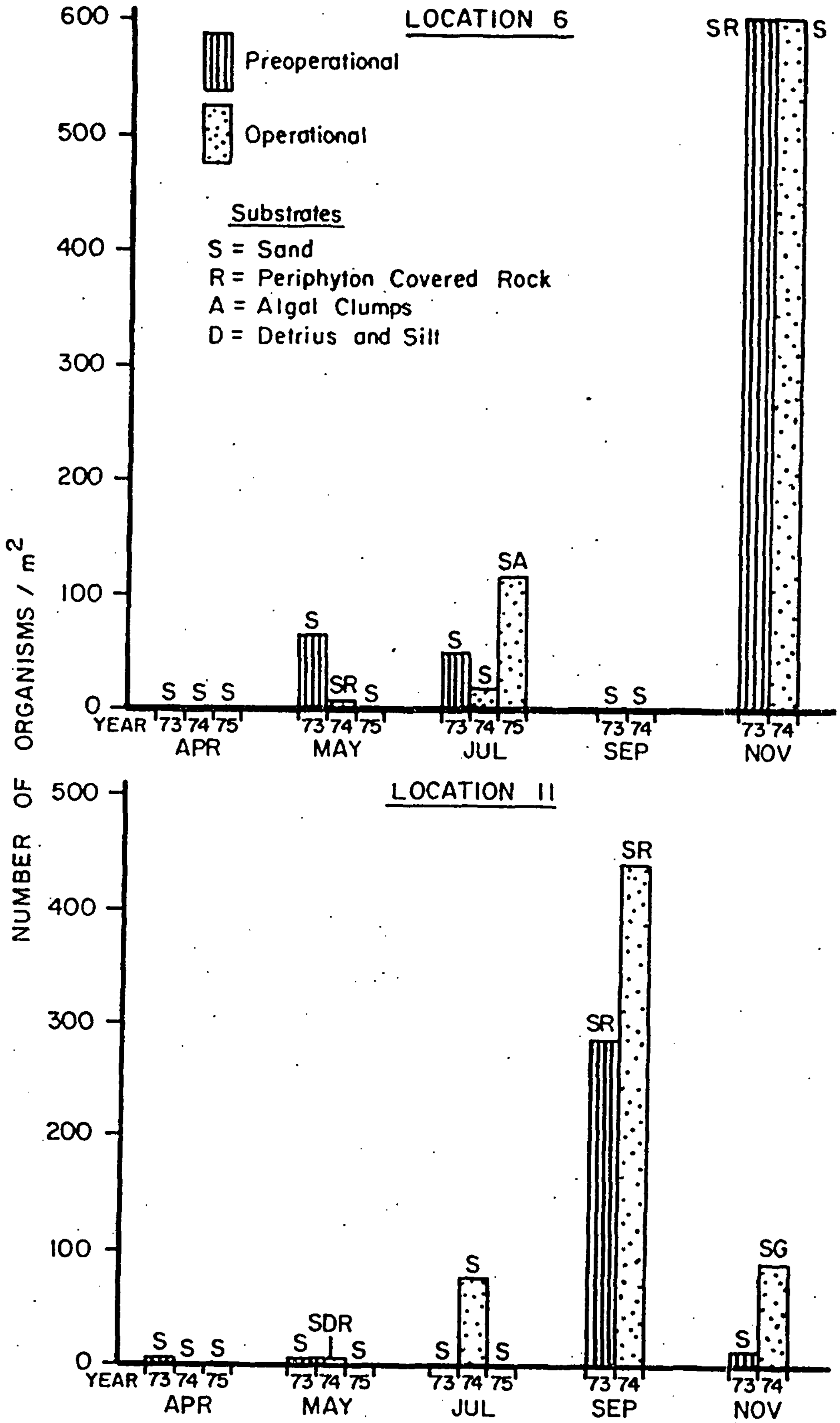

Figure 4.3.2.3. Density (No/m^2) of Vejdovskyella intermedia collected at 10-ft locations in Lake Michigan in the vicinity of the Kewaunee Nuclear Power Plant April 1973-July 1975.

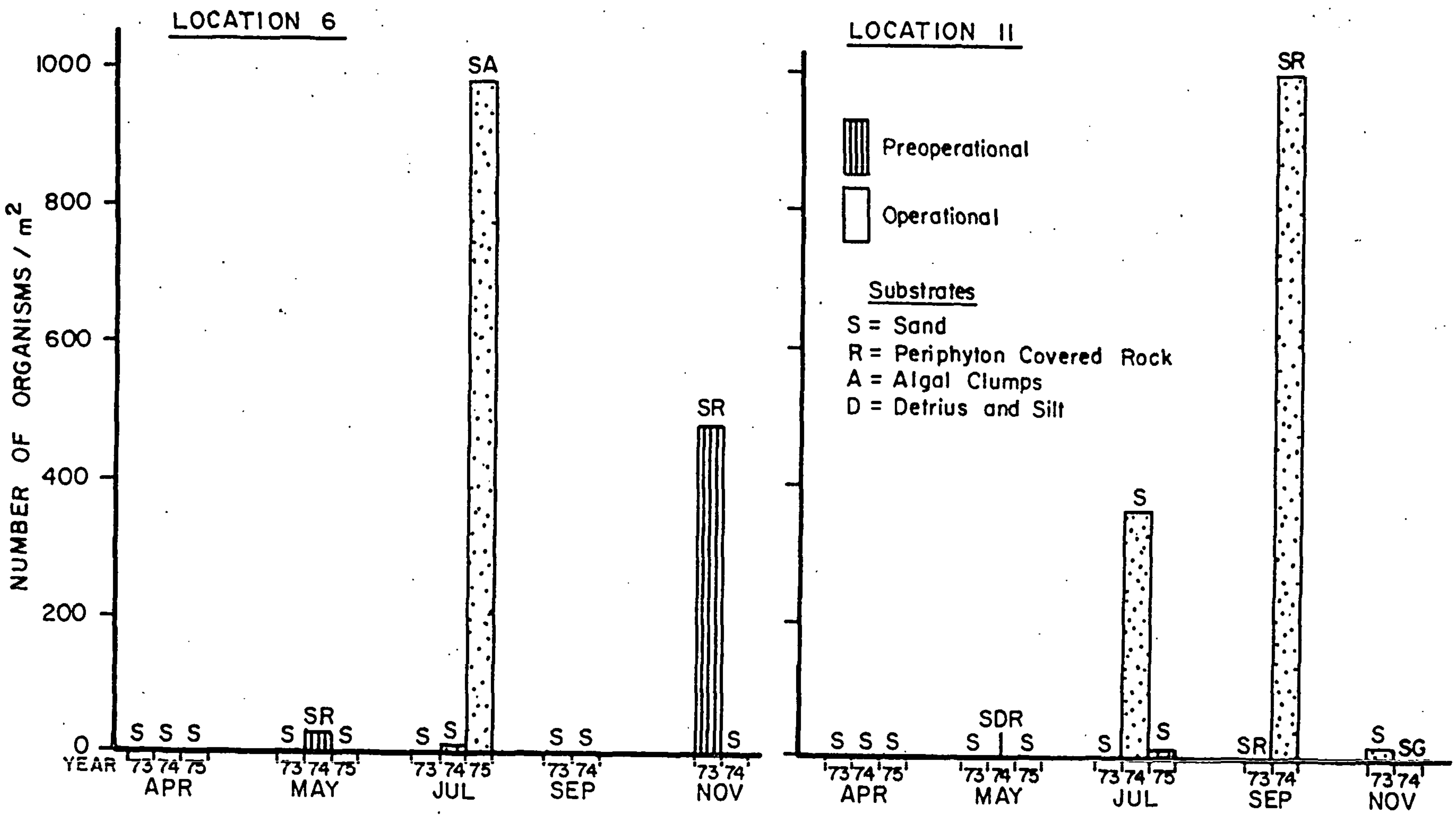

Figure 4.3.2.4. Density (No/m^2) of Nais sp. collected at 10-ft locations in Lake Michigan in the vicinity of the Kewaunee Nuclear Power Plant April 1973-July 1975.

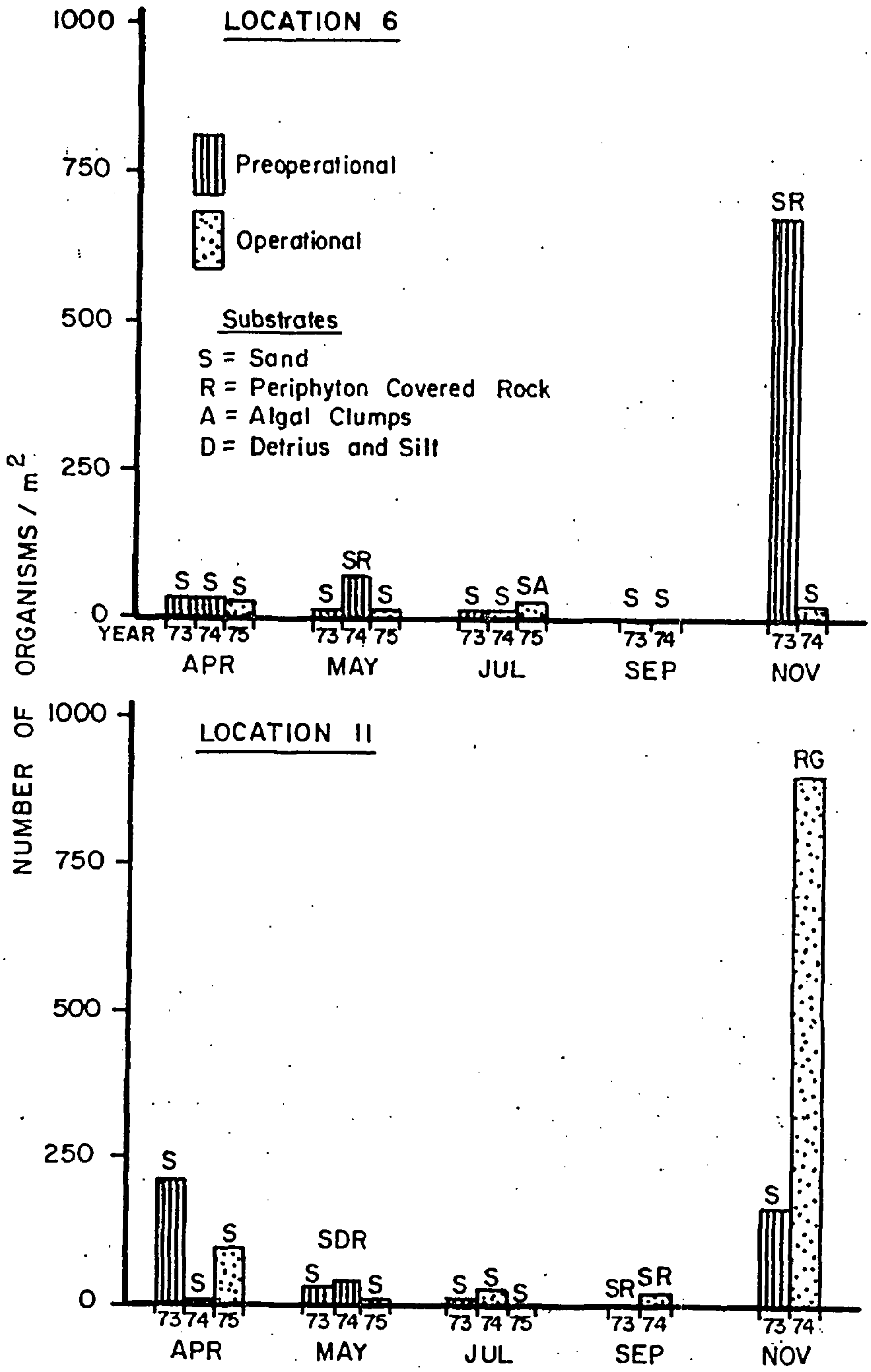

Figure 4.3.2.5. Density (No/m^2) of Parakiefferiella sp. collected at 10-ft locations in Lake Michigan in the vicinity of the Kewaunee Nuclear Power Plant April 1973-July 1975.

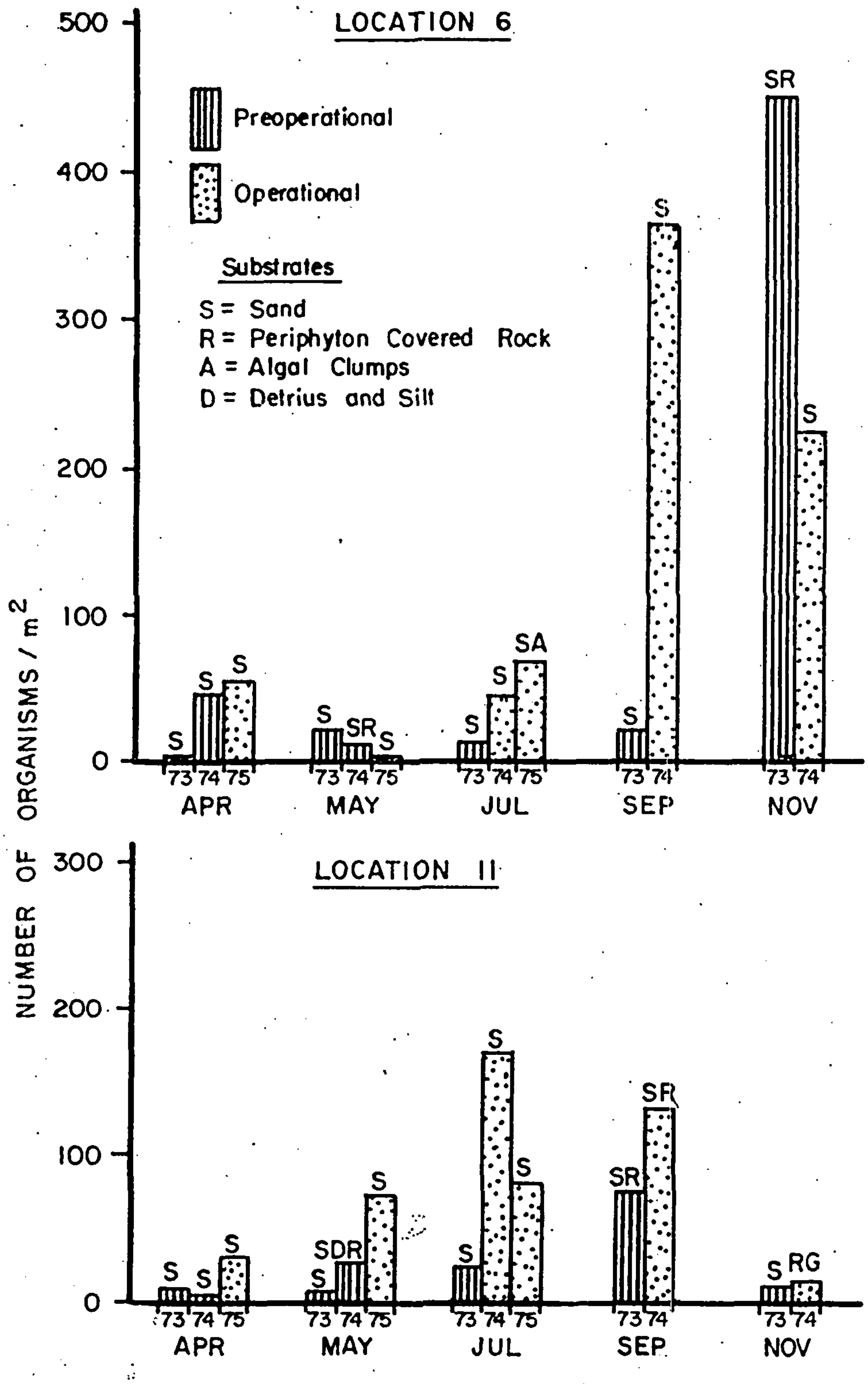

Figure 4.3.2.6. Density (No/m^2) of Paracladopelma sp. collected at 10-ft locations in Lake Michigan in the vicinity of the Kewaunee Nuclear Power Plant April 1973-July 1975.

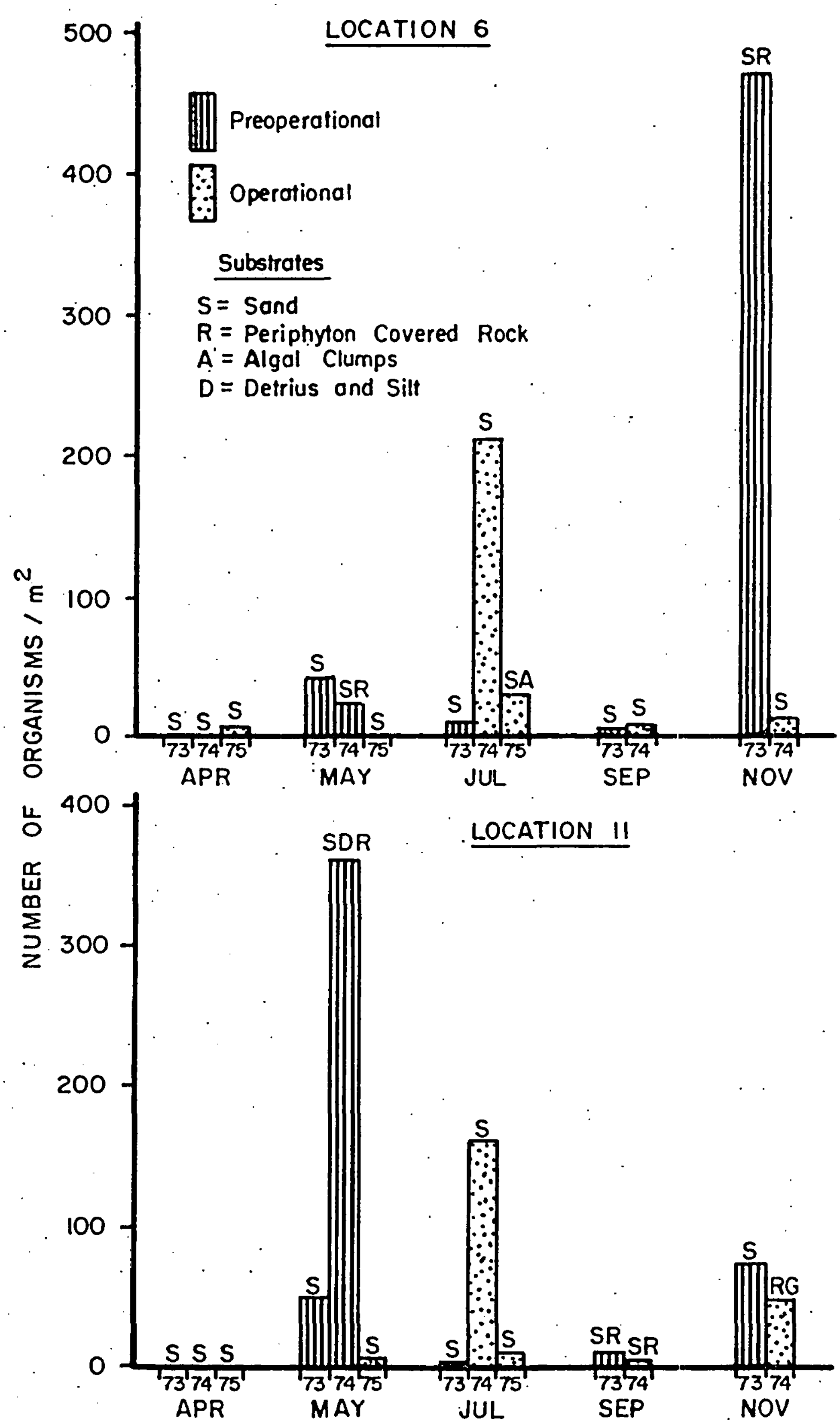

Figure 4.3.2.7. Density (No/m^2) of Polypedilum (S.S.) Scalaenum Group collected at 10-ft locations in Lake Michigan in the vicinity of the Kewaunee Nuclear Power Plant April 1973-July 1975.

rocks were present in the area sampled in addition to the normal sandy substrates (Table 4.3.2.1). The periphyton provided a more stable substrate and greater protection from the abrasive action of the shifting sand. For example, maximum macroinvertebrate densities for all representative taxa occurred in November 1973 at Location 6 when periphyton covered rocks were present.

Differences in the density of dominant taxa between the 10-ft locations were statistically analyzed ($P \leq 0.05$) using Student's "t" test (Rains and Clevenger 1974 p.5, 1975 p.5). The only significant ($P \leq 0.05$) difference between locations occurred in April 1974 when the midges *Parakiefferiella* sp. and *Paracladopelma* sp. were significantly more abundant at Location 6 than at Location 11. The validity of these differences was questionable because the number of specimens was relatively low, even at Location 6.

The macroinvertebrate community was more diverse and more abundant on the periphyton covered rocks at the 20- and 30-ft locations than on the sandy substrates at the 10-ft locations. The periphyton attached to the rocks provided a more stable substrate, shelter and a greater area for colonization than the shifting sand at the 10-ft locations. In addition, wave action at the 20- and 30-ft locations was less influencial than at the 10-ft locations.

Representative macroinvertebrate taxa at the 20-and 30-ft depth locations were the worms *Limnodrilus hoffmeisteri* (2%) and *Vejdovskyella intermedia* (15%) and the midges *Microtendipes* sp. (3%), *Parakiefferiella* sp. (5%) and *Thienemannimyia* Series (2%)

(Table 4.3.2.3).

Seasonal distribution patterns were distinct for the representative taxa at the 20- and 30-ft locations. The density of *Vejdovskyella intermedia* was lowest in April and May and greatest in July, September and November (Figure 4.3.2.8). *Limnodrilus hoffmeisteri* density was greatest in April and May and lowest in July and September (Figure 4.3.2.9). *Parakiefferiella* sp. and *Microtendipes* sp. densities decreased from April to July and increased in September and November (Figures 4.3.2.10 and 4.3.2.11). The density of the midge *Thienemannimyia* Series increased from April to May, decreased from May to September and increased again in November (Figure 4.3.2.12). The seasonal distribution pattern for each representative taxon was similar at most 20- and 30-ft locations. For example, *V. intermedia* and *Microtendipes* sp. densities distinctly increased from July to September at all 20- and 30-ft locations in 1973, although the magnitude of the increase varied between locations.

A comparison of the mean densities of representative taxa at the 20- and 30-ft locations indicated that some locations were more alike than others. The average densities at Locations 3, 12, 13 and 17 were higher or lower depending upon the taxon considered than at Locations 7, 8 and 16 (Table 4.3.2.3). Location substrate differences were the primary cause for variations in the mean densities of representative taxa and, therefore, the distinction of two groups of locations. Silt, detritus and clay were more frequently encountered at Locations 7, 8 and 16 than at Locations 3, 12, 13 and 17. However, periphyton covered rock was still the

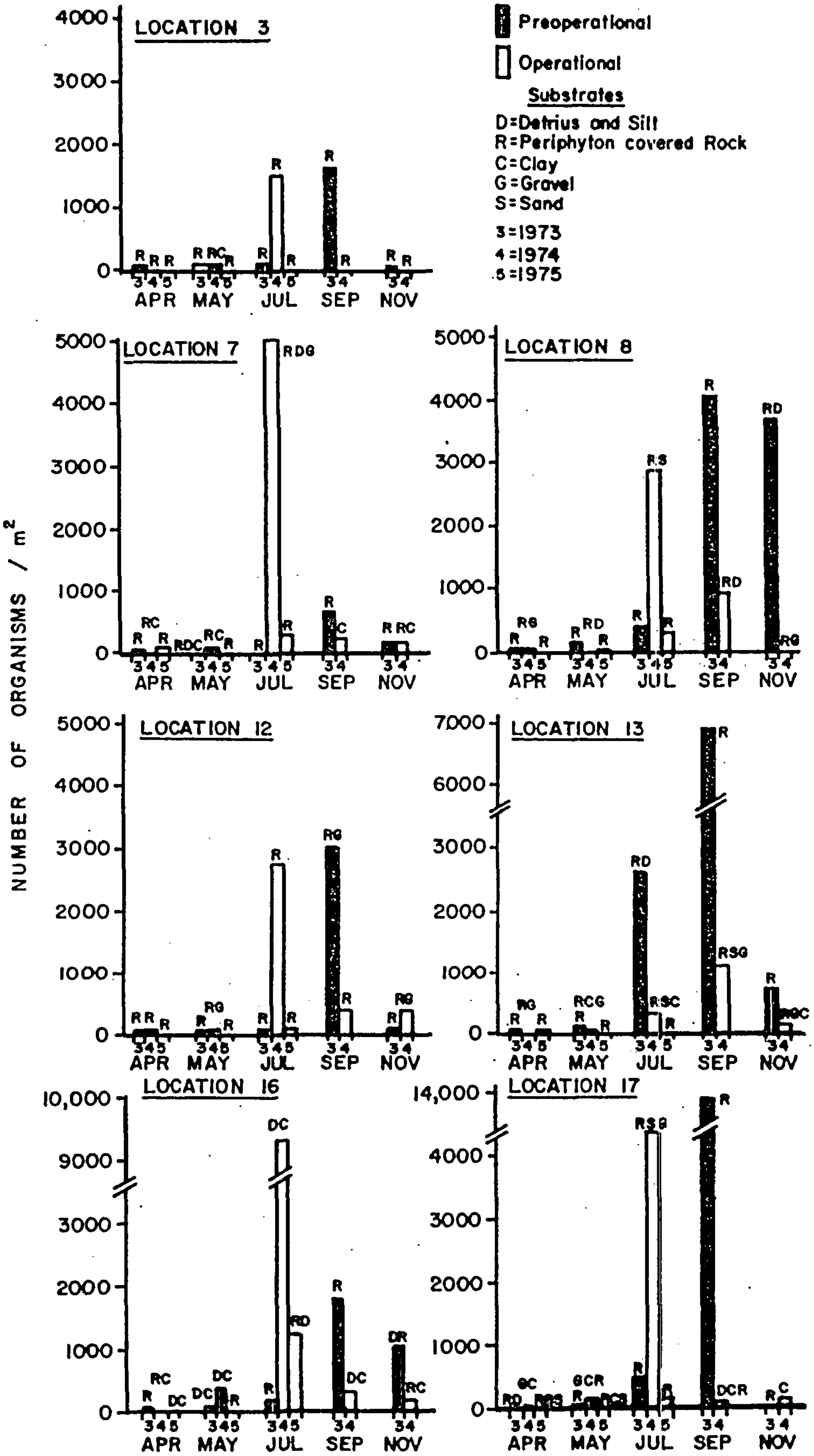

Figure 4.3.2.8. Density (No/m^2) of Vejdovskyella intermedia collected at 20- and 30-ft locations in Lake Michigan in the vicinity of Kewaunee Nuclear Power Plant April 1973-July 1975.

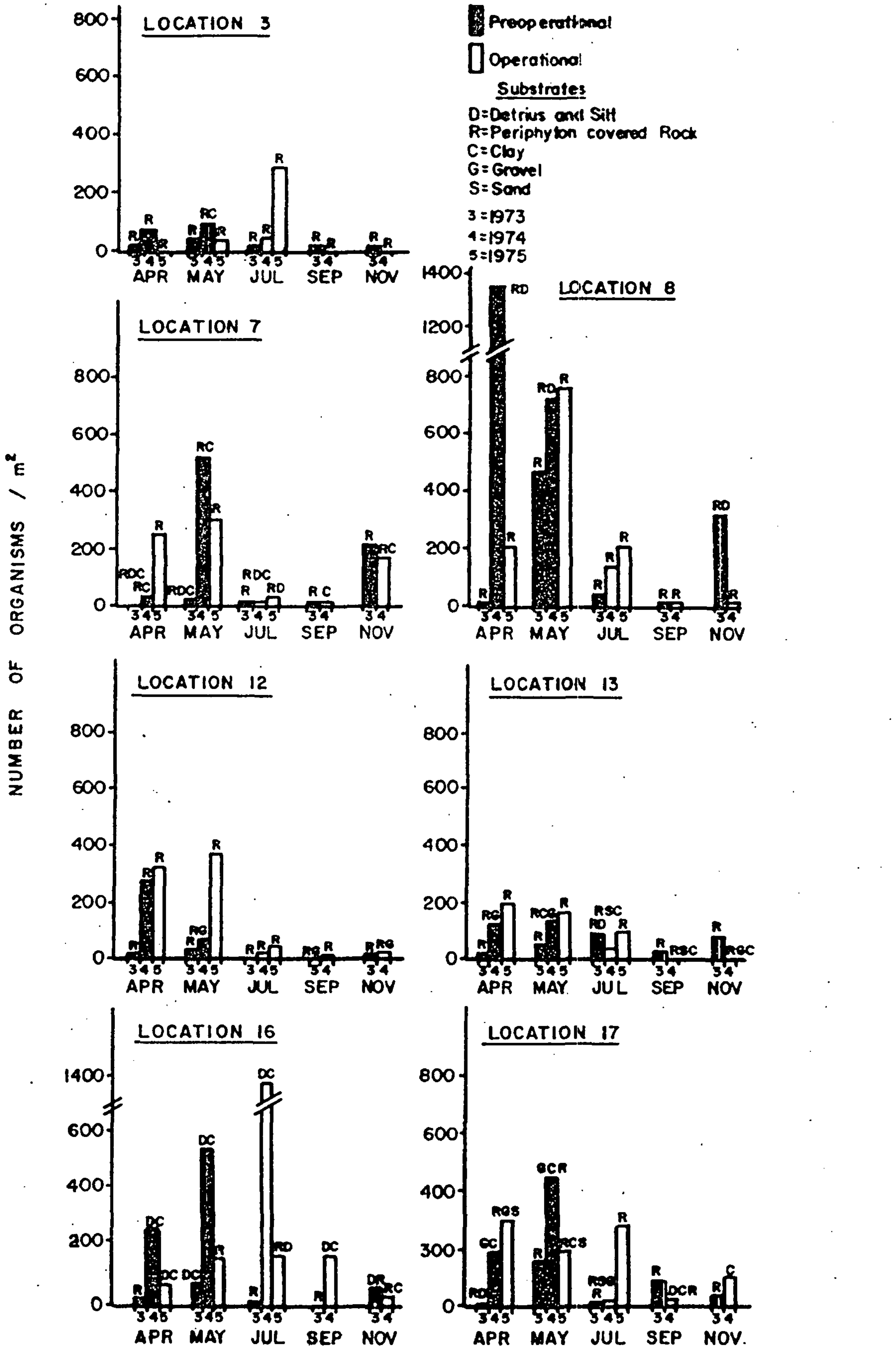

Figure 4.3.2.9. Density (No/m^2) of Limnodrilus hoffmeisteri collected at 20- and 30-ft locations in Lake Michigan, in the vicinity of Kewaunee Nuclear Power Plant April 1973-July 1975.

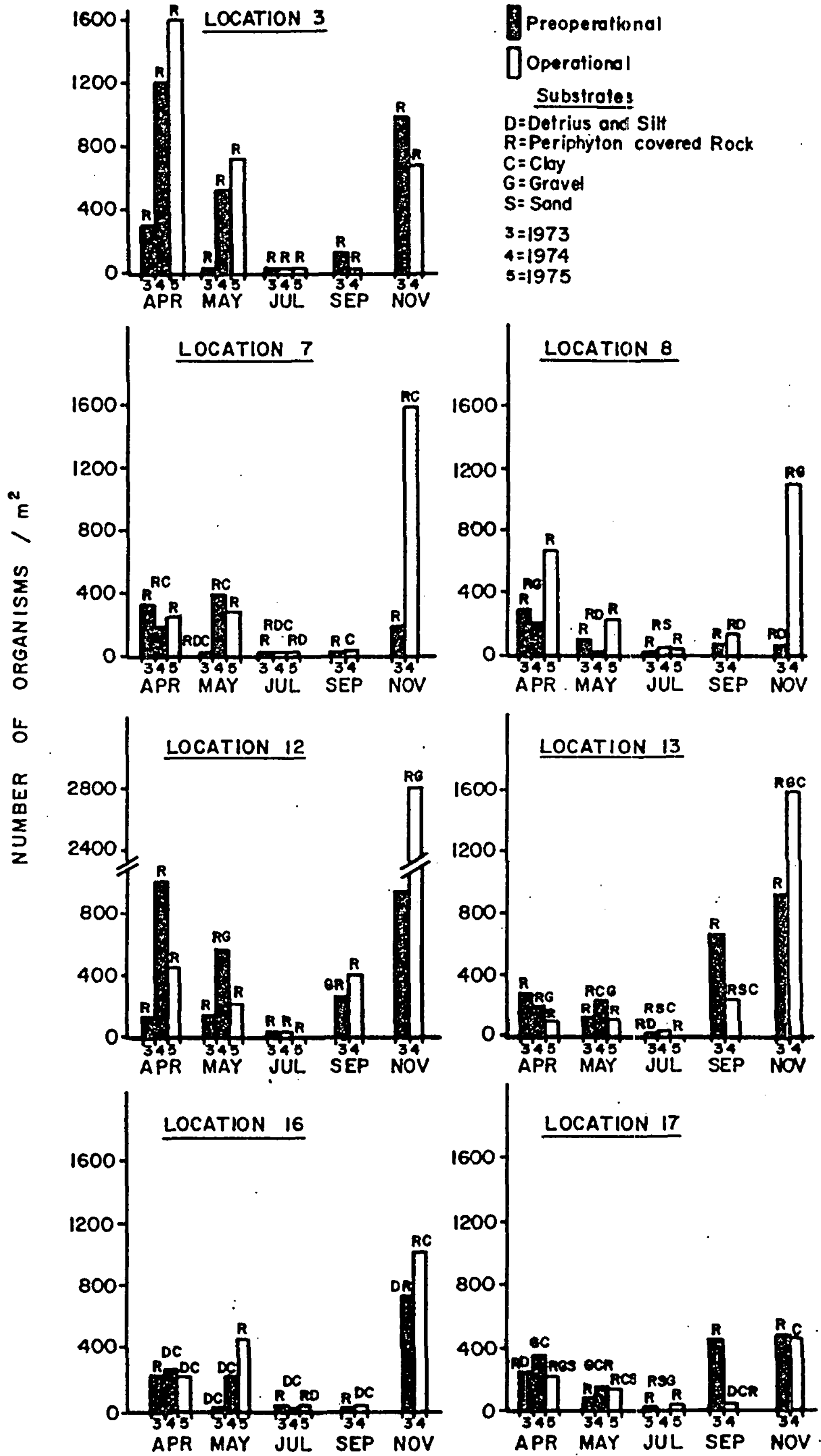

Figure 4.3.2.10 Density (No/m^2) of Parakiefferiella sp. collected at 20- and 30- ft locations in Lake Michigan in the vicinity of the Kewaunee Nuclear Power Plant April 1973-July 1975.

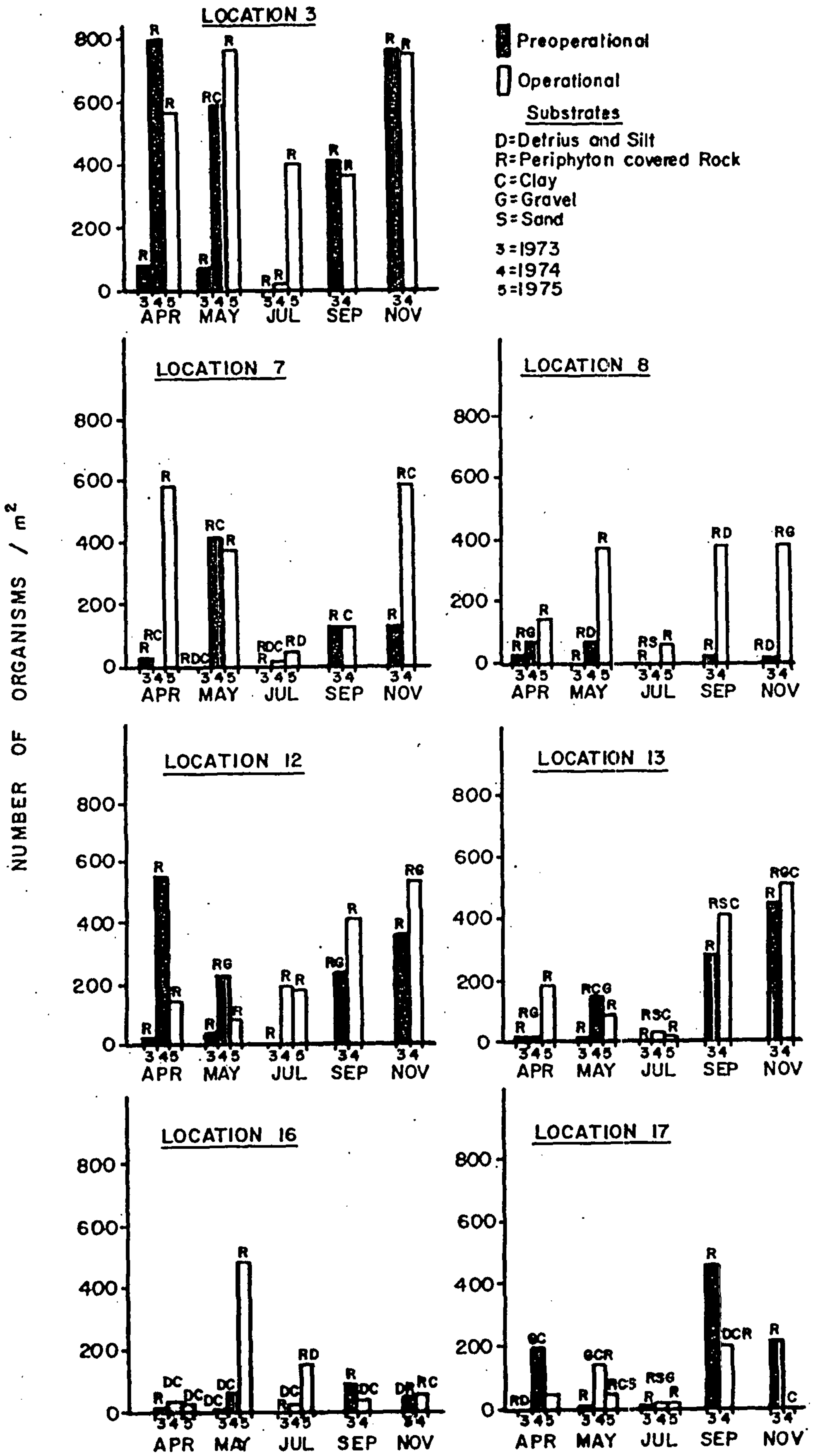

Figure 4.3.2.11. Density (No/m^2) of <u>Microtendipes</u> sp. collected at 20- and 30- ft locations in Lake Michigan in the vicinity of the Kewaunee Nuclear Power Plant April 1973-July 1975.

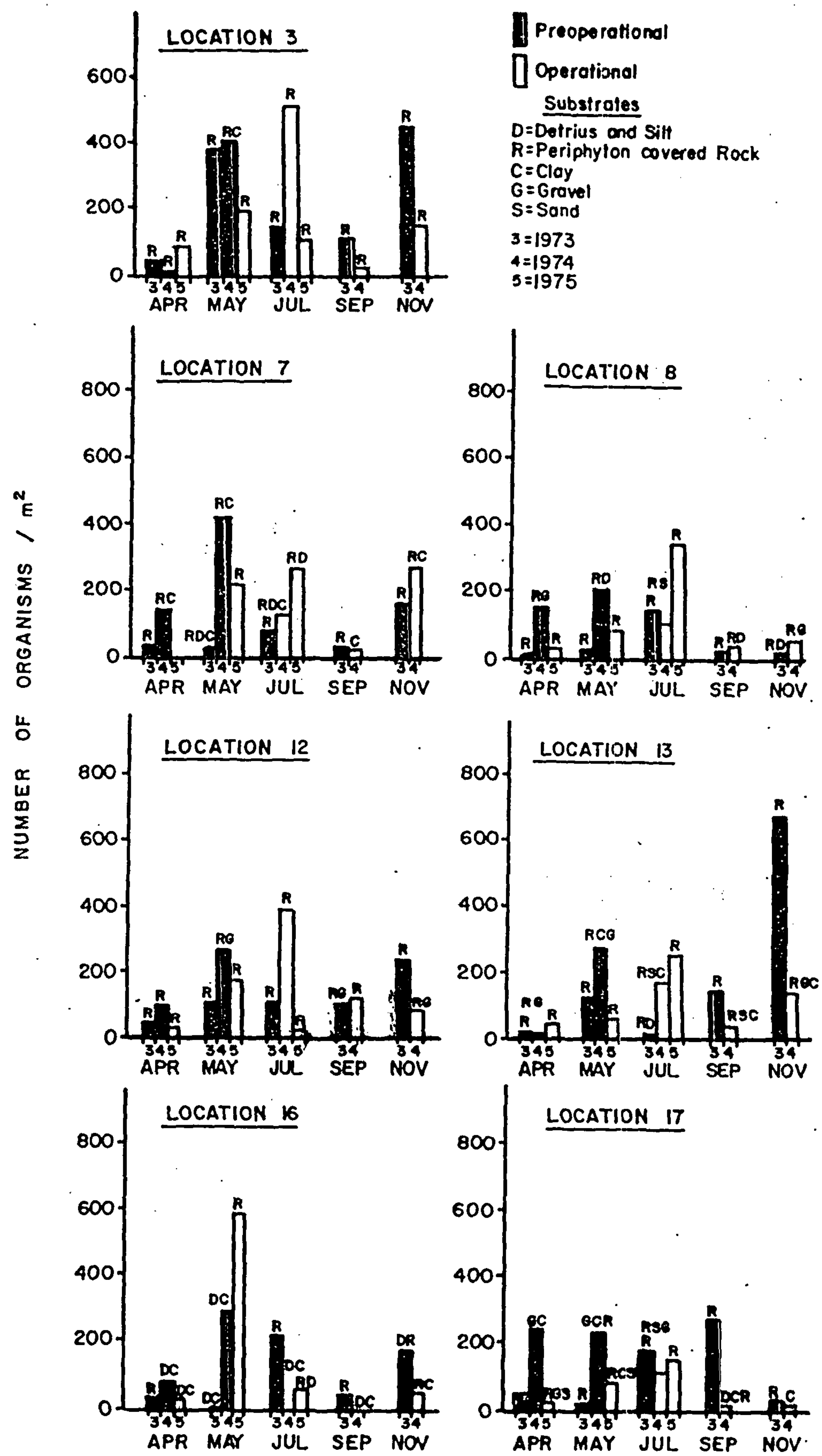

Figure 4.3.2.12. Density (No/m^2) of Thienemannimyia Series collected at 20- and 30-ft locations in Lake Michigan in the vicinity of the Kewaunee Nuclear Power Plant April 1973-July 1975.

primary substrate at all 20- and 30-ft locations (Table 4.3.2.1). The differences between the two groups of locations were supported by statistical comparisons. Significant ($P \leq 0.05$) differences in the densities of representative taxa among 20- and 30-ft locations were determined using one-way analyses of variance (ANOVA) and Tukey's multiple comparison (Rains and Clevenger 1974 p.5, 1975 p.5). Comparisons were made between locations along the same depth contour. Only 29 significant differences were detected in 315 comparisons made during the preoperational period (Table 4.3.2.4). Twenty-three of the 29 significant differences occurred between the two groups of locations. This low number of significant differences illustrated that the densities were generally similar among 20- and 30-ft locations.

An area offshore of Haven, Wisconsin, approximately 35 miles south of the KNPP, was studied from November 1973 to September 1974 by Industrial BIO-TEST Laboratories, Inc. (1974). The Haven Site was located in an area relatively uninfluenced by man and served as a comparison for Kewaunee because the substrates and macroinvertebrate community at both sites were similar among the 20- and 30-ft locations.

Fifty percent of the total macroinverbetrates collected at the Haven Site were worms. Predominant species included the tubificid worms <u>Limnodrilus hoffmeisteri</u>, <u>Potamothrix moldaviensis</u>, <u>P. vejdovskyi</u> and <u>Tubifex tubifex</u> and the naidids <u>Stylaria lacustris</u>, <u>Vejdovskyella intermedia</u> and <u>Nais</u> sp. Crustacea (aquatic arthropods) represented 22% of the total macroinvertebrates and was comprised

Table 4.3.2.4. Significant ($P \leq 0.05$) differences in representative taxa densities between locations along the 20- and 30-ft depth contour in Lake Michigan offshore the Kewaunee Nuclear Power Plant. Comparisons were made only between locations along the same depth contour.

Representative Taxa	Preoperational						
	1973					1974	
	Apr	May	Jul	Sep	Nov	Apr	May
Vejdovskyella intermedia	NS[a]	NS	16>7	NS	16>3,12,7	NS	-[b]
Limnodrilus hoffmeisteri	NS	NS	NS	NS	7>3 8>17	NS	16,7>3,12
Parakiefferiella sp.	NS	NS	NS	12>7	NS	3,12>7,16	13>8
Microtendipes sp.	8>17	NS	NS	NS	3>7,12,16	3,12>7,16	NS
Thienemannimyia Series	NS	NS	17>13	NS	13>8	3>7,12,16	NS

Representative Taxa	Operational					
	1974			1975		
	Jul	Sep	Nov	Apr	May	Jul
Vejdovskyella intermedia	17>13	8,13>7	12,16>3	NS	NS	16>3,7,12 7>3
Limnodrilus hoffmeisteri	16>3,7,12	NS	NS	7,12>3,16	12>3 8>13	16>3,7,12
Parakiefferiella sp.	NS	12>3	12>3	3>7,12,16 8>13,17	NS	NS
Microtendipes sp.	NS	12>16	13,8>17	3,7>12,16	NS	3>7
Thienemannimyia Series	3,7,12>16 3,12>7			7>12,16	NS	3>7

[a] No significant ($P \leq 0.05$) difference.
[b] Insufficient data.

predominantly of seed shrimps, the sow bug *Asellus* sp. and the scud *Gammarus pseudolimnaeus*. Midges (Chironomidae) composed 18% of the macroinvertebrates and were comprised mainly of *Dicrotendipes* sp., *Heterotrissocladius* sp., *Microtendipes* sp., *Parakiefferiella* sp., *Polypedilum* (s.s.) Fallax Group and *Thienemannimyia* Series.

Dominant worms, scuds and midges at the Haven Site were either dominant or commonly collected near KNPP. Similarity in macroinvertebrate communities between Kewaunee and Haven indicated that the community near KNPP was typical for periphyton covered rock substrates in the nearshore area of western Lake Michigan.

4.3.2.2 The Effect of KNPP Operation on the Macroinvertebrate Community in the Discharge Zone

The KNPP discharge zone for macroinvertebrates was delineated as that portion of the lake bottom encompassed by the furthest extent of the 2 C isotherm (Figure 4.3.2.1). This area was determined from vertical temperature profile measurements taken along the plume centerline under various weather conditions. Location 11 was the only location within the discharge zone, while the remaining locations were outside the discharge zone.

Effect on Species Composition

Ninty-four macroinvertebrate taxa have been collected at Location 11 since 1971. Nine of the 94 taxa were found exclusively during preoperational sampling and three were found exclusively during periods of KNPP operation (Table 4.3.2.5). Each of the 12 exclusive taxa were rarely encountered and then only in very low densities ($\leq$3.00 organisms/m^2). The difference in species composition between preoperational and operational phases at locations inside the discharge zone did not constitute an appreciable alteration in the macroinvertebrate community but was merely a manifestation of the rare occurrence of a few taxa.

Effect on Population Dynamics of Representative Taxa

Representative worm and midge densities at Location 11 were generally low and sporadic in occurrence compared to the offshore locations during KNPP operational and preoperational periods (Figures 4.3.2.3-4.3.2.7). Densities at Location 11 were usually less than 100 organisms/m^2. Mean values were somewhat higher for all representative taxa, during the operational period

Table 4.3.2.5. Mean density (No./m^2) of macroinvertebrate taxa exclusive to either preoperational or operational phases of environmental monitoring in the discharge zone of the Kewaunee Nuclear Power Plant.

Taxa	Density (No./m^2) Preoperational Monitoring	Density (No./m^2) Operational Monitoring
Cristatela mucedo	0.00	+[a]
Nais elinguis	0.00	1.33
Limnodrilus claperedeianus	0.43	0.00
L. hoffmeisteri (variant)	0.43	0.00
L. udekemianus	0.43	0.00
Peloscolex superiorensis	2.71	0.00
Helobdella elongata	0.43	0.00
Collembolla	0.43	0.00
Cladotanytarsus sp.	0.00	0.50
Demicryptochironomus sp.	1.14	0.00
Eukiefferiella sp.	1.14	0.00
Tanypus sp.	0.00	0.50
Trissoclodius sp.	3.00	0.00

[a] Present but not enumerated.

except Polypedilum (s.s.) Scalaenum Group (Table 4.3.2.6). Densities greater than $100/m^2$ during the operational period usually occurred when periphyton covered rock substrates were sampled rather than the typical sand substrates. For example, maximum operational densities at Location 11 for Vejdovskyella intermedia and Parakiefferiella sp. occurred in September and November 1974, respectively (Figures 4.3.2.3 and 4.3.2.5). Periphyton covered rocks were present on both occasions (Table 4.3.2.1). Occasional high densities of representative taxa at Location 11 prior to Plant operation were also attributable to the presence of periphyton covered rocks.

Densities of representative taxa during the KNPP operational period at Location 6 were similar to those at Location 11. Densities of representative taxa were usually less than 100 organisms/m^2 (Figures 4.3.2.3-4.3.2.7). Most of the densities that were greater than 100 organisms/m^2 occurred in July 1975 when drifting clumps of algae were present in the sampling area (Table 4.3.2.1). The density of Nais sp. was particularly high at that time (Figure 4.3.2.4). A correlation between high densities of representative taxa and the presence of periphyton also existed before Plant operation at Location 6.

Mean operational densities at Location 6 were lower than mean preoperational densities for all representative taxa, except Nais sp. and Paracladopelma sp. (Table 4.3.2.6). Greater mean preoperational densities for most representative taxa were attributed primarily to the greater number of periphyton covered

Table 4.3.2.6. Mean densities (No./m^2) and percent composition of representative macroinvertebrates at 10-ft locations for preoperational (April 1973-May 1974) and operational (July 1974-July 1975) periods of environmental monitoring at the Kewaunee Nuclear Power Plant.

	Preoperational			Operational		
	Loc 6	Loc 11	Mean of All Locations	Loc 6	Loc 11	Mean of All Locations
Oligochaeta	604	173	389	764	827	796
	33%	22%	30%	41%	43%	42%
Vejdovskyella intermedia	105	44	75	21	98	60
	6%	6%	6%	1%	5%	3%
Nais sp.	74	2	38	165	232	199
	4%	<1%	3%	9%	12%	11%
Chironomidae	605	462	534	651	594	623
	33%	59%	41%	35%	31%	33%
Paracladopelma sp.	80	22	51	125	83	104
	4%	3%	4%	7%	4%	6%
Polypedilum (s.s.) Scalaenum Group	79	72	76	45	39	42
	4%	9%	6%	2%	2%	2%
Parakiefferiella sp.	122	60	91	14	176	95
	7%	8%	7%	1%	9%	5%

rocks that were encountered during preoperational sampling.

Statistically significant ($P \leq 0.05$) differences in the densities of representative taxa during the operational period between Locations 6 and 11 also reflected the substrates influence on organism densities. Five of the seven significant differences (Table 4.3.2.7) between locations occurred when periphyton covered substrates, rather than typical sand substrates, were sampled (Table 4.3.2.1). In each instance, densities were significantly greater on the periphyton substrates except for *Paracladopelma* sp. which occurred in greater abundance on the sandy substrates.

Preoperational and operational densities of representative macroinvertebrate taxa were similar. Most differences between the two phases of monitoring were attributed to substrate variations since it was difficult to obtain samples of precisely the same substrate composition on each sampling trip. Therefore, no effects of the KNPP thermal discharge on the macroinvertebrate community in the discharge area (Location 11) were detected.

Sinking Plume Effects

The Kewaunee macroinvertebrate community could have been under the influence of sinking plumes during the winter months of 1974-1975. However, immediate effects from sinking plumes were not detected at KNPP since winter sampling was not conducted. Sinking plume effects such as early maturation or a shift to warmer water species would be difficult to detect. Temperature fluctuations caused by sinking plumes would be less than natural

Table 4.3.2.7. Significant ($P \leq 0.05$) differences in operational representative taxa densities between locations along the 10-ft depth contour in Lake Michigan offshore the Kewaunee Nuclear Power Plant.

Representative Taxa	Operational					
	1974			1975		
	Jul	Sep	Nov	Apr	May	Jul
Vejdovskyella intermedia	-[a]	11>6	-		-	-
Nais sp.	-	11>6	-		-	6>11
Paracladopelma sp.	11>6	NS[b]	6>11	NS	-	NS
Polypedilum (s.s.) Scalaenum Group	-	NS	NS		-	-
Parakiefferiella sp.	-	-	11>6	11>6	-	-

[a] Insufficient data.
[b] No significant ($P \leq 0.05$) difference.

temperature fluctuations which have been observed. For example, on 6 and 7 August 1973 a temperature drop of approximately 10 C resulted from an upwelling (Industrial BIO-TEST Laboratories, Inc. 1974 Appen. 1-a, p.112). Thus, macroinvertebrates in the vicinity of KNPP must be able to survive rapidly changing natural conditions more extreme than those produced by sinking plumes.

It can be assumed that any appreciable effects of a sinking plume would carried over to the spring of 1975 and would have been detectable then. Since no over-winter effects were observed, sinking plumes at KNPP did not appreciably alter the balanced indigenous macroinvertebrate community.

Organic Fallout Effects

Organic fallout refers to increased total organic carbon in the sediments due to deposition of killed entrained organisms. Such a deposition may cause the macroinvertebrate community to shift to a community with a greater proportion of organic pollution tolerant species. In theory, such a phenomenon could occur at KNPP.

The combined mechanical and thermal impact on entrained phytoplankton and zooplankton at KNPP in 1974 was <10% (Jones et al. 1975 p.28 and Wetzel 1975 p.20). This level would not likely effect the macroinvertebrates unless the deposition of killed, entrained plankton was concentrated in a small specific area in the immediate vicinity of the KNPP discharge. Such a concentration is not likely because the nearshore currents and wave action would keep the buoyant plankton in suspension and would disperse it over a much larger area.

Cook and Powers (1964) attempted to determine if the allochthonous material transported by the St. Joseph River into Lake Michigan adversely affected the lake benthos. The general result was that there was no clear pattern of deposition of the allochthonous organic matter based on the nonuniform distribution of macroinvertebrates. Mozley (1974 p.124) theorized that the suspended materials transported by rivers were deposited irregularly over large regions (several miles) of the nearshore zone by wave action and nearshore currents.

Organic fallout from KNPP condenser passage would be subject to the same drift patterns as suspended allochthonus material. Therefore, this material would not concentrate in the immediate vicinity of the KNPP. Wave action would keep organic fallout in suspension while nearshore currents would transport the material over long distances before deposition.

Limnodrilus hoffmeisteri and *Vejdovskyella intermedia* were the representative macroinvertebrate taxa which were most likely to become more abundant at KNPP if the total organic carbon in the sediments had been appreciably increased. Both of these taxa had higher densities in detritus and silt substrates than on periphyton covered rock substrates, particularly at Location 16 in July 1974 (Rains and Clevenger 1975 p.13 and 21).

No permanent deposition of organic fallout was evident in the KNPP vicinity and the densities of *L. hoffmeisteri* and *V.*

intermedia were not consistently greater throughout the operational phase than before operation at any location (Figures 4.3.2.8-4.3.2.12). *Ilyodrilus templetoni*, *Limnodrilus profundicola*, *L. spiralis*, *Paranis frici*, *Potamothrix moldaviensis*, and *Polypedilum* (s.s.) Scalaenum Group also had greater densities in detritus and silt substrates than on periphyton covered rocks (Rains and Clevenger 1975 p.18, 22 and 26). None of the above organisms were consistently more abundant during operation than before operation at any location.

Effect of Kewaunee Discharge Scouring

The benthic macroinvertebrate community near the Kewaunee discharge may potentially be affected by scouring of natural sediments, or the deposition of scoured sediments. The Kewaunee discharge created a scoured depression with primarily gravel and rock sediments in the area immediately offshore the discharge outlet (Section 4.1.5). The fine sand scoured out of this depression was deposited just beyond the scoured area. No benthos samples were collected from either the scoured area or the deposition mound. However, Location 11 was within 300 ft of the deposition mound and no alterations to the benthic macroinvertebrate community were detected at Location 11. Any alterations to the benthic macroinvertebrate community in either the scoured or deposition area would be due to the change in substrate type and would appear as a redistribution of organisms and not actual mortalities. In addition, any such alteration would not be appreciable relative to the total benthic macroinvertebrate community throughout the Kewaunee nearshore (0-10 ft) area.

Thermal Shock

Thermal shock, or detrimental physiological effects due to rapid temperature change, could hypothetically result from Plant start-up and shut-down. Maximum allowable temperatures above ambient during KNPP operation are 15.5 C and 11.0 C during winter and summer, respectively. Few investigators have evaluated the effect of rapid temperature increases on macroinvertebrates and no investigations have been reported on the effect of rapid temperature decreases. The isopod Asellus intermedius and the amphipods Hyalella azteca and Gammarus pseudolimnaeus were found to have LC50 values (Sprague 1963, p. 408) above the combined temperature of maximum ΔT's expected at KNPP and most ambient Lake Michigan temperatures. Gammarus pseudolimnaeus would be the only species which might experience heat shock, but only when ambient was 14 C or higher. Data presented by Smith (1973, p. 433) indicated that G. pseudolimnaeus acclimated to 18 C could tolerated temperature between 21-26 C for brief periods (hours). Adult Pontoporeia affinis had a 24-hr TL_m of 12 C (Smith 1972, p. 256), which means adult P. affinis would experience heat shock in all instances of Plant start-up. Mysis relicta had a 19.5 C 24-hr TL_m (Smith 1970, p. 419), which indicates it would suffer heat shock if Plant start-up occurred when ambient temperatures were 4 C or greater. However, G. pseudolimnaeus, M. relicta, and P. affinis are capable of migrating or, in the case of P. affinis, burrowing out of the influence of the plume and avoiding lethal temperatures. Stenonema tripunctatum experienced a 25.5 C 96-hr TL_m (Nebeker and Lemke 1968, p. 416) which indicates it would suffer heat shock during the summer when ambient temperatures are 14 C or greater. No other information specific to benthic macroinvertebrate thermal shock is available for taxa collected at Kewaunee.

Several factors would minimize the potential effects of thermal shock on benthic macroinvertebrates: 1) Plant start-up would proceed gradually over a two day period, and allow organisms to acclimate, thus increasing their upper temperature tolerance; 2) some organisms (i.e., M. relicta and amphipods) could migrate from the discharge zone immediately after start-up or shut-down, and thereby avoid thermal shock (death); 3) current velocity fluctuations resulting from Plant start-up and shut-down might cause alterations in the benthic macroinvertebrate community which would be unrelated to thermal fluctuations; 4) the area of the benthic macroinvertebrate environment influenced by the plume would fluctuate dependent upon the plume configuration and position. Thus, rapidly shifting temperatures would be characteristic of the discharge zone and the benthic macroinvertebrates would therby be exposed only temporarily to the thermal plume during normal Plant operation and at start-up or shut-down. Also, since the benthic macroinvertebrate community is sparse in shallow water (0-10 ft) (Section 4.3.2.1), thermal shock effects would therefore not be appreciably harmful to the total shallow water community in the discharge zone.

Wide temperature variations due to natural causes, such as seasonal temperature fluctuations and upwellings, preclude the existence of stenothermic organisms in the KNPP vicinity. Most benthic macroinvertebrates near the Kewaunee Plant are capable of tolerating a wide temperature range or can migrate to favorable environments.

Worst Case Effects

The worst case of heat shock expected at the KNPP would occur when the maximum allowable discharge temperature of 30 C was reached. The only information available on lethal temperatures for benthic macroinvertebrates collected at Kewaunee is on *Asellus intermedius*, *Hyalella azteca*, and *Gammarus pseudolimnaeus* (Sprague 1963, p. 408); *Pontoporeia affinis* (Smith 1972, p. 256); *Stenonema tripunctatum* (Nebeker and Lemke 1968, p. 416); and *Mysis relicta* (Smith 1970, p. 419). The maximum summer discharge temperature of 30 C would be lethal for each of these organisms except *H. azteca* and *A. intermedius*. However, all of these organisms, except *A. intermedius* and *S. tripunctatum*, are capable of extensive horizontal migration and could avoid the area of lethal temperatures.

The benthic macroinvertebrate community in the IDA is sparse (Section 4.3.2.1 p. 199) and the area of the bottom exposed to the maximum temperature is small. Appreciable harm to such a sparse benthic macroinvertebrate community in such a small area would not be appreciable to the total shallow water benthic macroinvertebrate community in the general KNPP area.

4.3.2.3 Effect of Thermal Discharge on the Macroinvertebrate Community Outside the Immediate Discharge Area

Species composition of the Receiving Water Body (all locations outside the IDA) were similar between the preoperational and operational periods and the representative important taxa were identical between periods. The mean densities of these representative taxa were variable both between preoperational and operational periods and between locations along the same depth contour within these periods (Figure 4.3.2.3-4.3.2.12). Few significant ($P \leq 0.05$) differences in representative taxa densities were detected among locations within the preoperational and operational periods and most of these differences were attributed to variations in substrates sampled. Since the differences between the preoperational and operational periods were of the same magnitude as those observed between locations, the differences were not considered important. This was expected since no appreciable harm was detected inside the discharge zone (Section 4.3.2.2). In conclusion, the benthic macroinvertebrates in the Receiving Water Body were not appreciably harmed by the KNPP thermal discharge.

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4.3.3 PHYTOPLANKTON

4.3.3.1 Lake Michigan Phytoplankton Community Structure in the Kewaunee Area Prior to Plant Operation

Numerous qualitative studies since the middle 1800's and an increasing number of quantitative studies during the past 30 years have provided a considerable amount of historical data about the phytoplankton of Lake Michigan. Although the record represents a variety of field and analytical procedures that sometimes make the data incomparable, the studies provide an overview of the phytoplankton community structure of the entire lake. This historical data base, in combination with site specific phytoplankton data collected near KNPP, form the basis for the subsequent discussion.

Studies of the phytoplankton community in the vicinity of the KNPP were first undertaken in 1971 and have continued annually to date. Objectives of the studies have been to document phytoplankton species composition and abundance, spatial variability, seasonal fluctuation and natural yearly variations before and during the period of plant operation.

Triplicate samples for phytoplankton analysis were collected from two locations (5 ft and 25 ft contours) directly offshore from KNPP in May, August and November 1971 (Industrial BIO-TEST Laboratories, Inc. 1972). Duplicate water samples were collected from seven locations in 1972 (Figure 4.3.3.1). Two new sampling locations (Locations 23 and 24) were added in 1973 to the seven sampled during the previous year and these nine locations have remained unchanged through the 1975 program.

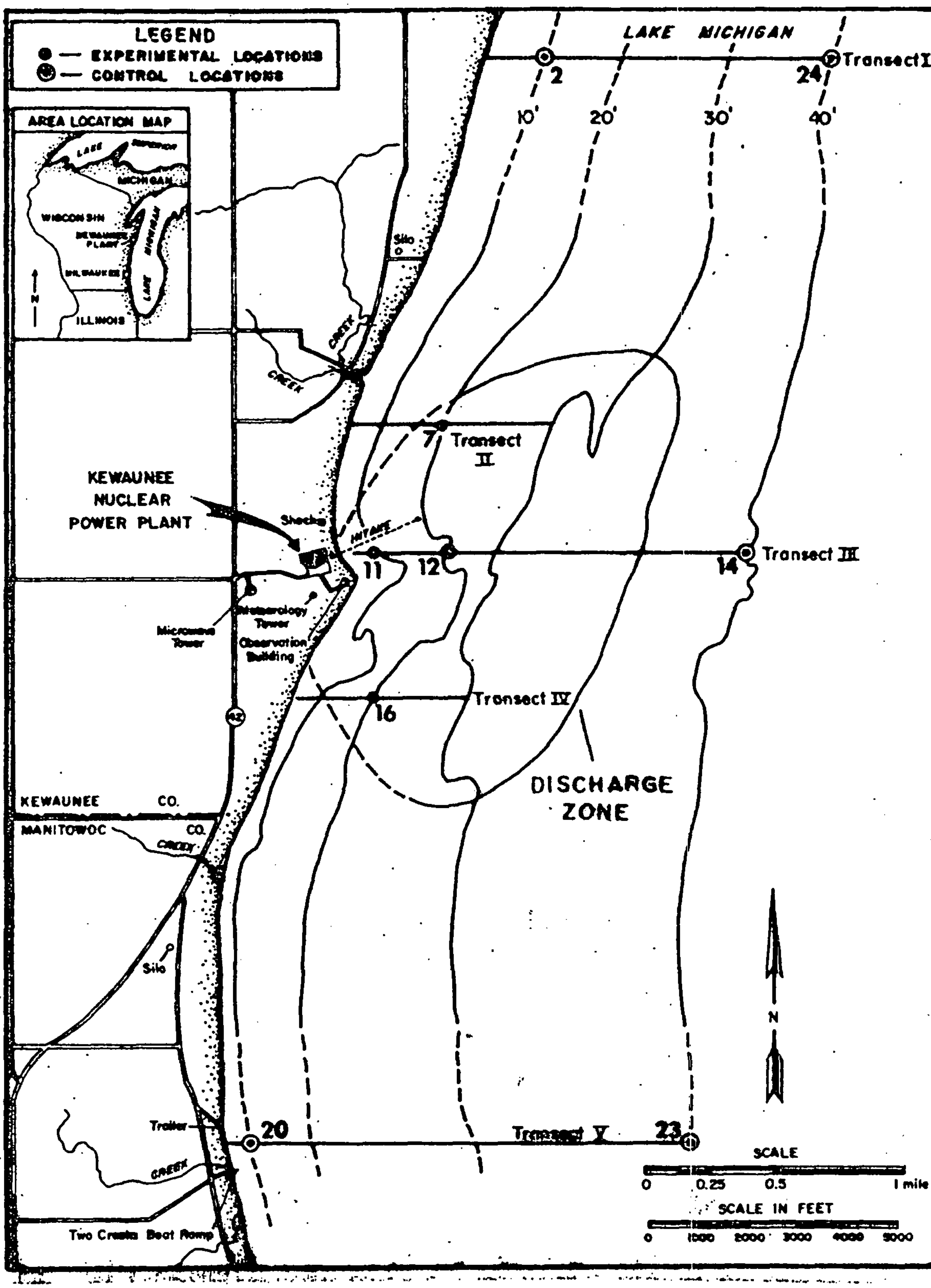

Figure 4.3.3.1. Site map showing position of phytoplankton sampling locations within (experimental) and outside (control) the discharge zone of Kewaunee Nuclear Power Plant.

Samples were collected twice during each of four months (May, August, September and November) in 1972 and monthly from April to November in 1973, 1974 and 1975. Identical field and analytical procedures have been applied on all samples (Industrial BIO-TEST Laboratories, Inc. 1973; Everhart and Rasgus 1974; Festin 1975).

Total Phytoplankton Density and Variability

Phytoplankton density at Kewaunee ranged from 332 to 12845 reporting units per milliliter. These numbers approximated the densities recorded for other western nearshore areas of Lake Michigan (Table 4.3.3.1). Wide variability in phytoplankton density existed between sampling locations at Kewaunee, a trend that also occurs at other localities in the lake. Spatial variability or "patchiness" is a natural phenomenon since phytoplankton populations are controlled by a large number of environmental factors (Industrial BIO-TEST Laboratories, Inc. 1975, p. 114). Beeton (1965, p. 249) reported wide variability in the open-lake area, citing a total phytoplankton yield of 450 to 12000 plankters per milliliter in samples collected by the Bureau of Commercial Fisheries in 1960. He also observed that the southern end of Lake Michigan (particularly near Gary, Indiana) produced higher numbers than the Chicago and Milwaukee areas.

Throughout the 1972-1975 period of study, phytoplankton at Kewaunee followed a trend of progressively decreasing abundance as distance from shore increased. Similar trends were recorded

Table 4.3.3.1. Standing crop minimum and maximum, monthly minimum and maximum means, and yearly mean of phytoplankton abundance units/ml at all sampling locations in each of three nearshore areas of western Lake Michigan.

Lake Michigan Study Site	Period: Year	Period: Months	Standing Crop Min-Max at Various Sampling Locations	Monthly Min-Max	Yearly Mean	Data Source
Kewaunee, Wisconsin	1972	May,Aug,Sep,Nov	546- 6388	914-2475	1868	IBT 1973[a]
	1973	Apr to Nov	332- 3517	706-1975	1303	Everhart and Rasgus 1974
	1974	Apr to Nov	413- 9484	1187-4434	2289	Festin 1975
	1975	Apr to Jul	550-12845	725-3528	1998	Concurrent study
Haven, Wisconsin	Nov 1973 to Oct 1974		657-6072	830-4786	2595	IBT 1974
Waukegan-Zion, Illinois	1970	May to Dec		202-3379	1571	Piala and Lamble 1972
	1971	Apr to Dec		452-5410	2487	IBT 1973[b]
	1972	Jan to Dec		589-4132	1666	Mayhew 1974

for the nearshore phytoplankton at Haven, Wisconsin, and at Waukegan and Zion, Illinois (Figure 4.3.3.2), which indicated that this pattern was characteristic of the western nearshore area of the lake. At Haven, Wisconsin, the phytoplankton populations at the 10 ft and 30 ft contours were approximately the same probably because of the steep slope of the bottom which placed the two contours in close proximity.

Large concentrations of phytoplankton were observed on several occasions at the Kewaunee inshore locations. These occurrences, which were usually transient, were also observed at Grand Haven, Michigan, by Stoermer (1968, p. 149). He attributed the large numbers to the higher nutrient load of the inshore waters as well as to the confining effect of a thermal bar.

Seasonal Periodicity

Monthly fluctuations of Lake Michigan phytoplankton are influenced by the interaction of several physical, chemical and biological factors. The most important factors are length of the photoperiod, temperature, kind and amount of nutrients available and the dominant algal species present in the assemblage. These factors produce two types of seasonal phytoplankton periodicity in Lake Michigan, namely unimodal and bimodal.

Phytoplankton periodicity at Kewaunee followed the bimodal cycle with a maximum in the spring and another in late summer or fall (Figure 4.3.3.3). This type of periodicity appears to be typical in the western nearshore area of the lake as it was observed by Damann (1966, p.11) at Chicago and in other investigations along the Wisconsin shore (Figure 4.3.3.3).

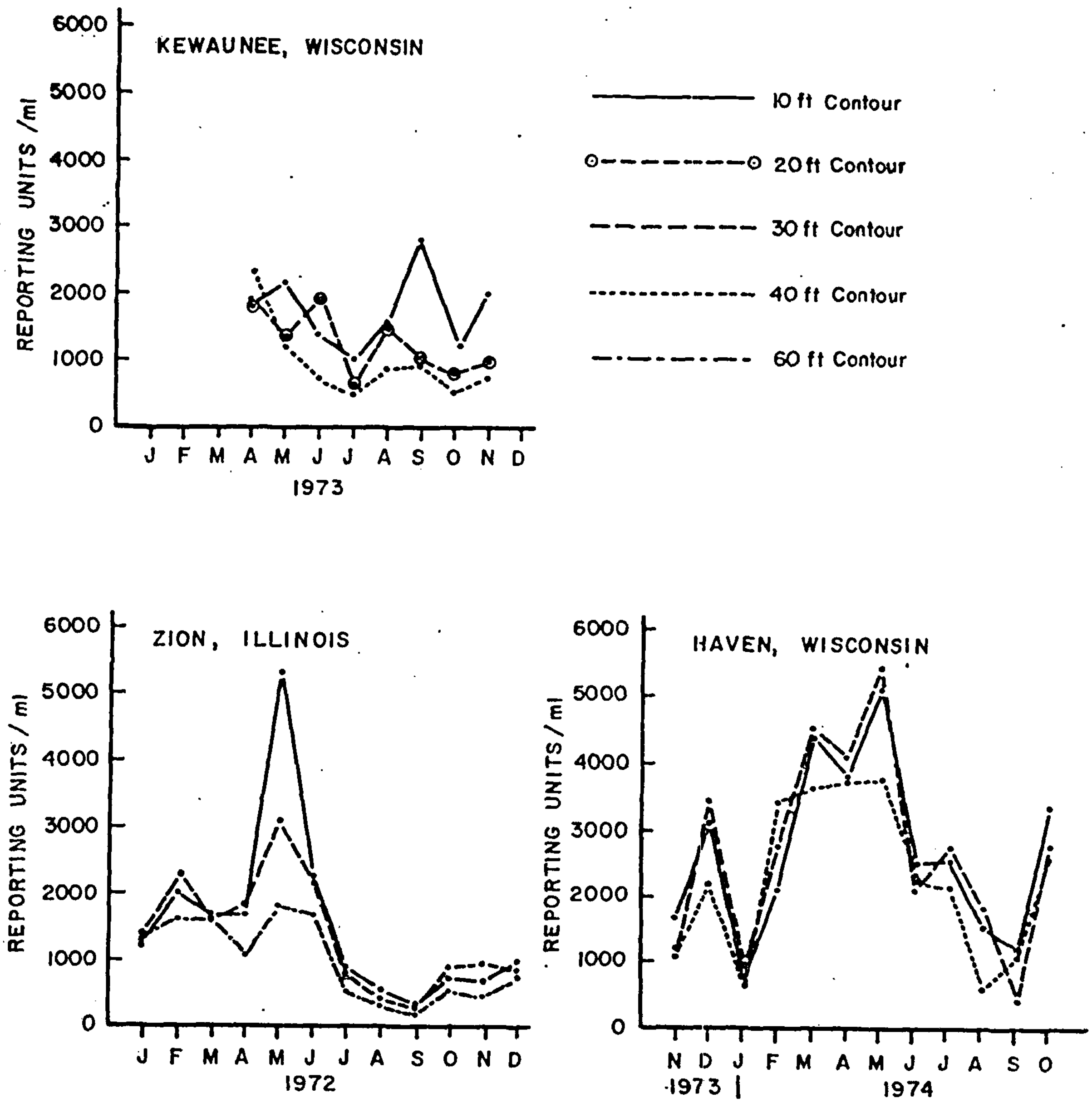

Figure 4.3.3.2. Phytoplankton abundance along various depth contours in three nearshore areas of western Lake Michigan, 1972-1974.

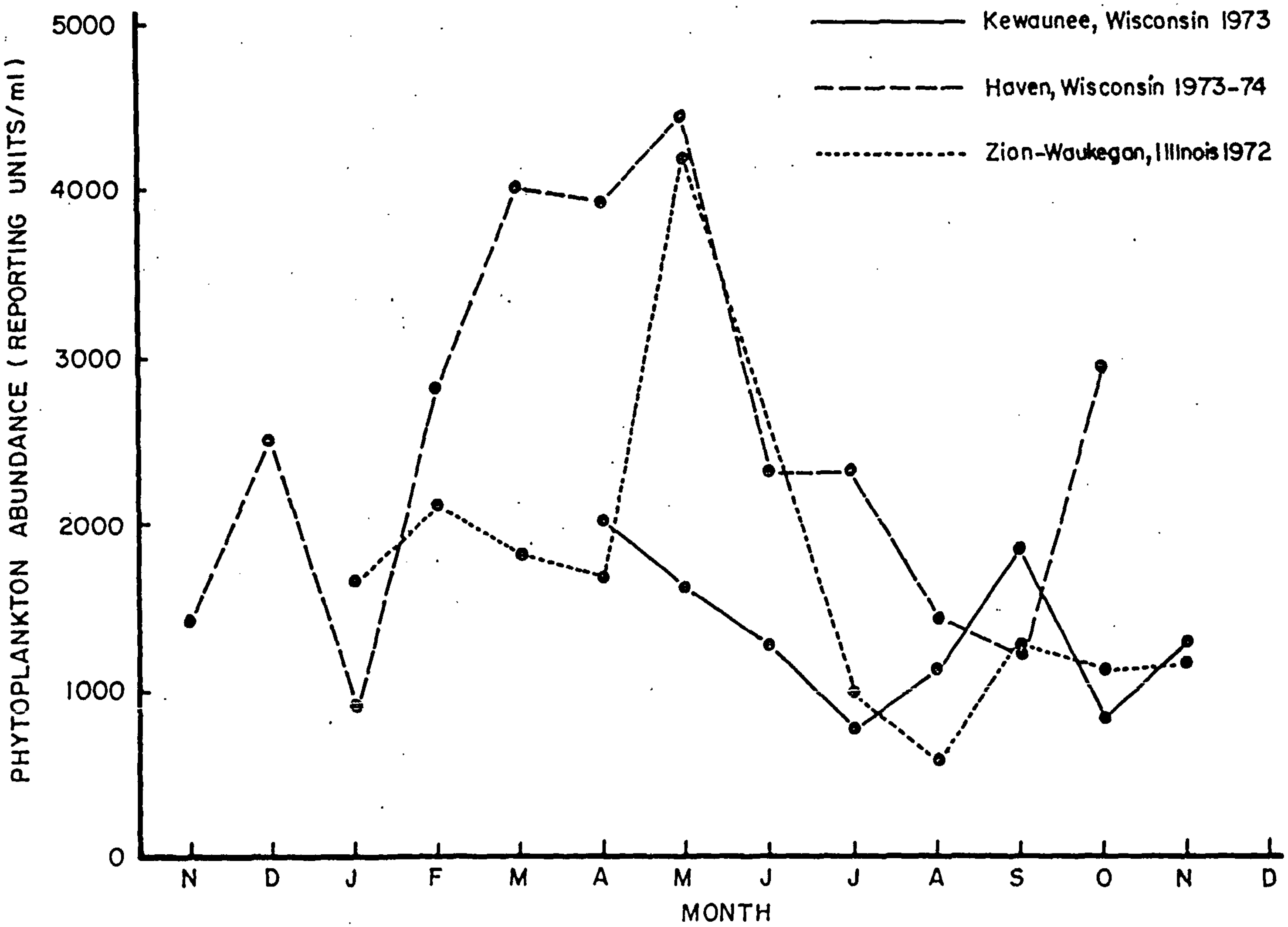

Fig. 4.3.3.3. Monthly variations of total phytoplankton abundance at various near shore areas along western Lake Michigan, 1972-1974.

The unimodal cycle is typified by a summer maximum. This type of periodicity has been described as characteristic of the greater part of the lake, particularly the open-lake area (Stoermer and Kopczynska 1967, p. 105) and the deeper regions of the nearshore area (Damann 1966, p. 12).

Long-Term Population Patterns

Extended population patterns of southern Lake Michigan phytoplankton may be interpreted from the continuous long-term studies of diatoms from the nearshore area at Chicago (Damann 1960, p. 399). Collections for the period 1926 to 1958 showed that the annual standing crop fluctuated from year to year but generally increased over time. The increase was calculated by Beeton (1965, p. 249) to average 13 organisms per milliliter per year over the 33-year period.

Mean phytoplankton abundance at Kewaunee decreased from 1972 to 1973 but increased in 1974 (Table 4.3.3.2).

Algal Composition

Phytoplankton species collected near KNPP were species generally found throughout Lake Michigan (Table 4.3.3.3). The phytoplankton assemblage represented seven major algal groups. They were diatoms (Bacillariophyta), green algae (Chlorophyta), golden-brown algae (Chrysophyta), blue-green algae (Cyanophyta), cryptophytes (Cryptophyta), dinoflagellates (Pyrrhophyta) and euglenoids (Euglenophyta).

The diatoms were the most abundant and diverse algal group. Green algae constituted the second most diverse group while golden-brown and blue-green algae were represented by

Table 4.3.3.2. Mean density of total phytoplankton and diatoms collected at inshore, middle and offshore locations in Lake Michigan near the Kewaunee Nuclear Power Plant, 1972-1974 (Festin 1975).

Locations	Mean Phytoplankton Density (Reporting units/ml)			Mean Diatom Density (Reporting units/ml)		
	1972	1973	1974	1972	1973	1974
Four-Month Mean[a]						
Inshore (Loc. 2, 11, 20)	2376	2059	3156	2126	1707	2851
Middle (Loc. 7, 12, 16)	1352	1123	2087	1081	945	1869
Offshore (Loc. 14, 23, 24)	939[b]	904	1476	625[b]	616	1242
Total Mean	1552	1362	2239	1277	1089	1987
Eight-Month Mean[c]						
Inshore (Loc. 2, 11, 20)	DNC[d]	1708	3149	DNC	1468	2939
Middle (Loc. 7, 12, 16)	DNC	1252	2283	DNC	1072	2114
Offshore (Loc. 14, 23, 24)	DNC	948	1436	DNC	747	1258
Total Mean	DNC	1303	2289	DNC	1096	2104

[a] Samples collected in May, August, September and November.
[b] Mean of only one location (Location 14).
[c] Samples collected from April to November.
[d] DNC = Data not comparable.

Table 4.3.3.3. Phytoplankton organisms collected in samples taken from Lake Michigan near the Kewaunee Nuclear Power Plant, 1971-1973.

Taxon	Taxon

- BACILLARIOPHYTA
  - Centrales
    - Coscinodiscus Ehrenberg
      - unidentified sp.
    - Cyclotella Kutzing
      - atomus Hustedt
      - bodanica Eulenstein
      - comta Kutzing
      - facetia Hohn and Hellerman
      - glomerata Bachmann
      - Kutzingiana Thwaites
      - meneghiniana Kutzing
      - meneghiniana var. plana Fricke
      - michiganiana Skvortzow
      - ocellata Pantoksek
      - operculata (Agardh) Kutzing
      - pseudostelligera Hustedt
      - stelligara (Cleve u. Grunow) Van Heurck
      - unidentified sp.
    - Melosira Agardh
      - ambigua (Grunow) O. Muller
      - distans (Ehrenberg) Kutzing
      - granulata (Ehrenberg) Ralfs
      - granulata var. angustissima O. Muller
      - islandica O. Muller
      - italica (Ehrenberg) Kutzing
      - varians C.A. Agardh
      - unidentified sp.
    - Rhizosolenia Ehrenberg
      - eriensis H.L. Smith
      - longiseta Zacharias
    - Stephanodiscus Ehrenberg
      - alpinus Hustedt ex Huber-Pestalozzi
      - astraea (Ehrenberg) Grunow
      - binderanus (Kutzing) Krieger
      - hantzschii Grunow
      - invisitatus Hohn and Hellerman
      - minutus Grunow ex Cleve and Muller
      - niagarea Ehrenberg
      - tenuis Hustedt
      - transilvanicus Pantocsek
      - unidentified sp. 2
      - unidentified sp. 3
      - unidentified sp.
      - Unidentified centrics
  - Pennales
    - Achnanthes Bory
      - affinis Grunow
      - clevei Grunow
      - clevei var. rostrata Hustedt
      - deflexa Reimer
      - delicatula (Kutzing) Grunow
      - exigua Grunow
      - gibberula Grunow
      - lanceolata (Brebisson) Grunow
      - lanceolata var. dubia Grunow
      - linearis (W. Smith) Grunow
      - marginulata Grunow
      - microcephala (Kutzing) Grunow
      - minutissima Kutzing
      - oestrupi (A. Cleve) Hustedt
      - unidentified sp.
    - Amphipleura Kutzing
      - pellucida Kutzing
    - Amphiprora Ehrenberg
      - ornata Bailey
    - Amphora Ehrenberg
      - coffeaeformis (Agardh) Kutzing
      - ovalis (Kutzing) Kutzing
      - ovalis var. pediculus (Kutzing) Van Heurck
      - perpusilla Grunow
      - Unidentified sp.
    - Asterionella Hassall
      - formosa Hassall
      - formosa var. gracillima (Hantzsch) Grunow
    - Caloneis Cleve
      - bacillum (Grunow Cleve
      - unidentified sp.
    - Cocconeis Ehrenberg
      - diminuta Pantocsek
      - disculus (Schumann) Cleve
      - pediculus Ehrenberg
      - placentula Ehrenberg
      - placentula var. euglypta (Ehrenberg) Cleve
      - unidentified sp.
    - Cymatopleura W. Smith
      - solea (Bredisson and Godey) W. Smith
    - Cymbella Agardh
      - cymbiformis (Agardh Kutzing) Van Heurck
      - cistula (Ehrenberg) Kirchner

Table 4.3.3.3. (continued)

Taxon
Cymbella Agardh
microcephala Grunow
naviculaformis (Auerswald) Kirshner
prostrata (Berkeley) Cleve
pusilla Grunow
sinuata Gregory
turgida Gregory
ventricosa Agardh
unidentified sp.
Denticula Kutzing
tenuis var. crassula (Naegeli) Hustedt
unidentified sp.
Diatoma Bory
tenue Agardh
tenue var. elongatum Lyngbye
vulgare Bory
unidentified sp.
Diploneis Ehrenberg
puella (Schumann) Cleve
smithii (Bredisson ex W. Smith) Cleve
Unidentifed sp.
Epithemia de Bredisson
unidentified sp.
Eunotia Ehrenberg
lunaris f. deratonedides Mayer
unidentified sp.
Fragilaria Lyngbye
brevistriata Grunow
brevistriata var. inflata (Pantocsek) Hustedt
capucina Desmazieres
capucina var. mesolepta Rabenhorst
construens (Ehrenberg Grunow
construens var. binodis (Ehrenberg) Grunow
construens var. pumila Grunow
construens var. venter (Ehrenberg) Grunow
crotonensis Kitton
crotonensis var. oregona Sovereign
intermedia Grunow
leptostauron (Ehrenberg) Hustedt
pinnata Ehrenberg
pinnata var. intercedens (Grunow) Hustedt
pinnata var. lancettula (Schumann) Hustedt
vaucheriae (Kutzing) Petersen
unidentified sp.
Gomphonema Agardh
angustatum (Kutzing) Rabenhorst
Gomphonema Agardh
intricatum var. pumila Grunow
olivaceum (Lyngbye) Kutzing
unidentified sp.
Gyrosigma Hassall
kutzingii (Grunow) Cleve
spencerii (Quekett) Griffet and Henfrey
unidentified sp.
Hantzschia Grunow in Cleve and Grunow
amphioxys (Ehrenberg) Grunow
Meridion Agardh
circulare (Greville) Agardh
Navicula Bory
anglica Ralfs
capitata Ehrenberg
capitata var. hungarica (Grunow) Ross
cincta (Ehrenberg) Ralfs
costulata
cryptocephala Kutzing
cryptocephala var. veneta (Kutzing) Rabenhorst
cryptocephala var. intermedia
cuspidata (Kutzing) Kutzing
decussis Oestrup
exigua Gregory ex Grunow
gastrum (Ehrenberg) Kutzing
gregaria Donkin
hungarica var. capitata
lanceolata (Agardh) Kutzing
longirostris Hustedt
menisculus Schumann
mutica Kutzing
platystoma Ehrenberg
pupula Kutzing
pygmaea Kutzing
radiosa Kutzing
radiosa var. parva Wallace
radiosa var. tenella (Brebisson ex Kutzing) Grunow
reinhardtii (Grunow) Grunow
salinarum Grunow
salinarum var. intermedia (Grunow) Cleve
scutelloides W. Smith ex Gregory
subhamulata Grunow
tripunctata (O.F. Muller) Bory
tuscula Ehrenberg
vanheurckii Patrick
viridula (Kutzing) Kutzing emend. Van Heurck

Table 4.3.3.3. (continued)

Taxon
Navicula Bory
unidentified sp. 2
unidentified sp.
Neidium Pfitzer
binode (Ehrenberg) Hustedt
dubium (Ehrenberg) Cleve
unidentified sp
Nitzschia Hassall
acicularis (Kutzing) W. Smith
acuta Hantzsch
amphibia Grunow
angustata (W. Smith) Grunow
angustata var. acuta Grunow
aniculata (Gregory) Grunow
denticula Grunow
diserta Hustedt
dissipata (Kutzing) Grunow
filiformis (W. Smith) Schutt
fonticola Grunow
fonticola var. capitata (Grunow) A. Cleve
frustulum (Kutzing) Grunow
holsatica Hustedt
hungarica Grunow
linearis (Agardh) W. Smith
palea (Kutzing) W. Smith
paleacea Grunow
sigmoidea (Nitzsch) W. Smith
unidentified sp.
Opephora Petit
martyi Heribaud
Pinnularia Ehrenberg
unidentified sp.
Rhoicosphenia Grunow
curvata (Kutzing) Grunow
Stauroneis Ehrenberg
smithii Grunow
unidentified sp.
Surirella Turpin
angusta Kutzing
ovata Kutzing
unidentified sp.
Synedra Ehrenberg
acus Kutzing
amphicephala Kutzing
delicatissima W. Smith
delicatissima var. angustissima Grunow
Synedra Ehrenberg
famelica Kutzing
filiformis Grunow
parasitica (W. Smith) Hustedt
radians Kutzing
rumpens Kutzing
rumpens var. scotica Grunow
tenera W. Smith
ulna (Nitzch) Ehrenberg
ulna var. chaseana Thomas
ulna var. danica (Kutzing) Van Heurck
ulna var. oxyrhynchus (Kutzing) Van Heurck
unidentified sp.
Tabellaria Ehrenberg
fenestrata (Lyngbye) Kutzing
fenestrata var. geniculata A. Cleve
flocculosa (Roth) Kutzing
Unidentified pennates
CHLOROPHYTA
Non-filamentous
Actinastrum Lagerheim
hantzschii var. fluviatile Schroeder
Ankistrodesmus Croda
falcatus (Corda) Ralfs
falcatus var. mirabilis (West and West) G.S. West
fractus (West and West) Brunnthaler
spiralis (Turner) Lemmermann
Arthrodesmus Ehrenberg
convergens Ehrenberg
incus (Brebisson) Hassall
Botryococcus Kutzing
braunii Kutzing
Chlamydomonas Ehrenberg
unidentified sp.
Closteriopsis Lemmermann
longissima Lemmermann
longissima var. tropica West and West
Closterium Nitzsch
unidentified sp.
Coelastrum Naegeli in Kutzing
microporum Naegeli in A. Braun
reticulatum (Dangeard) Senn
sphaericum Naegeli
unidentified sp.

Table 4.3.3.3. (continued)

Taxon
Cosmarium Corda
depressum (Naegeli) Lundell
unidentified sp.
Crucigenia Morren
irregularis Wille
quadrata Morren
rectangularis (A. Braun) Gay
tetrapedia (Kirchner) West and G.S. West
Dictyosphaerium Naegeli
pulchellum Wood
Elakatothrix Wille
gelatinosa Wille
viridis (Snow) Printz
Franceia Lemmermann
droescheri (lemmerman) G.M. Smith
ovalis (France) Lemmermann
Gloeocystis Naegeli
ampla (Kutzing) Lagerheim
planctonica (West and West) Lemmermann
Golenkinia Chodat
radiata (Chodat) Wille
Kirchneriella Schmidle
contorta (Schmidle) Bohlin
elongata G.M. Smith
lunaris (Kirchner) Moebius
lunaris var. irregularis G.M. Smith
obesa (W. West) Schmidle
Lagerheimia (DeToni) Chodat
ciliata (Lagerheim) Chodat
citriformis (Snow) G.M. Smith
longiseta (Lemmermann) Printz
subsalsa Lemmermann
Micractinium Fesenius
pusillum Fresenius
Nephrocytium Naegeli
agardhianum Naegeli
limneticum (G.M. Smith) G.M. Smith
lunatum W. West
unidentified sp.
Oocystis Naegeli in A. Braun
borgei Snow
gloeocystiformis Borge
lacustris Chodat
parva West and West
pusilla Hansgirg
solitaria Wittrock in Wittrock and Norstedt
submarina Lagerheim

Taxon
Pandorina Bory
morum (Mueller) Bory
Pediastrum Meyen
biradiatum Meyen
boryanum (Turpin) Meneghini
duplex Meyen
duplex var. clathrata (A. Braun) Lagerheim
intergrum Naegeli
simplex (Meyen) Lemmermann
tetras (Ehrenberg) Ralfs
planktosphaeria G.M. Smith
gelatinosa G.M. Smith
Polyblepharides Dangeard
unidentified sp.
Quadrigula Printz
closterioides (Bohlin) Printz
Scenedesmus Meyen
abundans (Kirchner) Chodat
acuminatus (Lagerheim) Chodat
arcuatus Lemmermann
arcuatus var. platydisca G.M. Smith
bernardii G.M. Smith
bijuga (Turpin) Lagerheim
carinatus (Lemmermann) Chodat
denticulatus Lagerheim
dimorphus (Turpin) Kutzing
incrassatalus Bohlin
intermedius Chodat
longispina Chodat
longus Meyen
longus var. naegelii (Brebisson) G.M. Smith
obliquus (Turpin) Kutzing
opoliensis P. Richter
quadricauda (Turpin) Brebisson
quadricauda var. maxima West and West
quadricauda var. westii G.M. Smith
Schizochlamys A. Braun in Kutzing
gelatinosa A. Braun in Kutzing
compacta Prescott
Selenastrum Reinsch
gracile Reinsch
minutum (Naegeli) Collins
westii G.M. Smith
Sphaerocystis Chodat
schroeteri Chodat
Spondylosium Brebisson
planum (Wille) W. and G.S. West
unidentified sp.

Table 4.3.3.3. (continued)

Taxon
Staurastrum Meyen
avicula Brebisson
curvatum W. West
natator var. crassum W. and G.S. West
paradoxum Meyen
unidentified sp.
Tetraedron Kutzing
caudatum (Corda) Hansgirg
minimum (A. Braun) Hansgirg
regulare Kutzing
trigonum (Naegeli) Hansgirg
unidentified sp.
Tetraspora Link
gelatinosa (Vaucher) Desvaux
lamellosa Prescott
Tetrastrum Chodat
staurogeniaeforme (Schroeder) Lemmermann
Treubaria Bernard
setigerum (Archer) G. M. Smith
Filamentous
Cylindrocapsa Reinsch
unidentified sp.
Geminella Turpin
minor (Naegeli) Heering
spiralis (Chodat) G.M. Smith
unidentified sp.
Mougeotia (C.A. Agardh) Wittrock
unidentified sp.
Radiofilum Schmidle
irregulare (Wille) Brunnthaler
Spirogyra Link
unidentified sp.
Ulothrix Kutzing
tenuissima Kutzing
unidentified sp.
CHRYSOPHYTA
Aulomonas Lackey
unidentified sp.
Centritractus Lemmermann
dubius Printz
Chrysosphaerella Lauterborn
longispina Lauterborn
Cladomonas Stein
fruiticulosa Stein
unidentified sp.

Taxon
Diceras Reverdin
phaseolus Fott
Dichotomococcus Korshikov
lunatus Fott
Dinobryon Ehrenberg
bavaricum Imhof
calciformis Bachmann
cylindricum Imhof ex Ahlstrom
divergens Imhof
pediforme (Lemmermann) Steinecke
sertularia Ehrenberg
sociale Ehrenberg
unidentified sp. 1
unidentified sp.
Malomonas Perty
acaroides Perty
caudata Iwanoff
producta (Zacharias)
pseudocoronata Prescott
tonsurata Teiling
unidentified sp.
Monosiga S. Kent
unidentfied sp.
Ophiocytium Naegeli
capitatum var. longispinum (Moebius) Lemmermann
unidentified sp.
Perionella Gobi
planctonica G.M. Smith
Poteriodendron Stein
petiolatum Stein
Rhizochrysis Pasher
limnetica G.M. Smith
Stipitococcus West and West
urceolatus West and West
Synura Ehrenberg
unidentified sp.
Uroglenopsis Lemmermann
americana (Calkins) Lemmermann
CYANOPHYTA
Non-Filamentous
Aphanocapsa Naegeli
delicatissima West and West
elachista West and West
Aphanothece Naegeli
castagnei (Brebisson) Rabenhorst

Table 4.3.3.3. (continued)

Taxon
Aphanothece Naegeli
clathrata G.S. West *in* West and West
microscopica Naegeli
microspora (Meneghini) Rabenhorst
nidulans P. Richter
unidentified sp.
Chroococcus Naegeli
limneticus Lemmermann
minutus (Kutzing) Naegeli
pallidus Naegeli
prescottii Drouet and Daily *in* Drouet
turgidus (Kutzing) Naegeli
Coelosphaerium Naegeli
kutzingianum Naegeli
naegelianum Unger
Gloeocapsa Kutzing
aeruginosa (Carm.) Kutzing
Gloeothece Naegeli
unidentfied sp.
Gomphosphaeria Kutzing
lacustris Chodat
lacustris var. *compacta* Lemmermann
Merismopedia Meyen
convoluta Brebisson *in* Kutzing
glauca (Ehrenberg) Naegeli
Microcystis Kutzing
aeruginosa Kutzing *emend.* Elenkin
incerta Lemmermann
Stichosiphon Geitler
unidentified sp.
Filamentous
Anabaena Bory
circinalis Rabenhorst
flos-aquae (Lyngbye) Brebisson in de Brebisson and Godey
spirodides Klebahn
unidentified sp.
Aphanizomenon Morren
flos-aquae (Linneaus) Ralfs
Lyngbya Agardh
contorta Lemmermann
unidentified sp.
Oscillatoria Vaucher
agardhii Gomont
amoena (Kutzing) Gomont
limnetica Lemmermann

Taxon
Oscillatoria Vaucher
tenuis Agardh
unidentified sp.
EUGLENOPHYTA
Euglena Ehrenberg
minuta Prescott
polymorpha Dangeard
unidentified sp.
Trachelomonas Ehrenberg
unidentified sp.
PYRRHOPHYTA
Ceratium Schrank
hirundinella (O.F. Muller) Dujardin
Glenodinium (Ehrenberg) Stein
quadridens (Stein) Schiller
unidentified sp.
Peridinium Ehrenberg
cinctum (Mueller) Ehrenberg
unidentified sp.
CRYPTOPHYTA
Chilomonas Ehrenberg
unidentified sp.
Cryptomonas Ehrenberg
ovata Ehrenberg
unidentified sp.
Rhodomonas Karsten
lacustris Pascker
minuta var. *nannoplanctica* Skuja
unidentified sp.

approximately the same number of species. The cryptophytes, euglenoids and dinoflagellates were not abundant and were represented by only a few species.

Forty-nine species of phytoplankton were dominant at Kewaunee from 1971 to 1975 (Table 4.3.3.4). Each of these species composed at least 5% of the total phytoplankton at any location. Only 11 species were dominant in four or more months. Ten of the dominant species were diatoms and one was a blue-green alga. The mean percent composition of diatoms in Kewaunee was 81, 82, 90, and 90% for the years 1972, 1973, 1974 and 1975, respectively. These numbers conform with values obtained in baseline studies of phytoplankton at Haven, Wisconsin, and Zion-Waukegan, Illinois (Table 4.3.3.5). At all three sites, the degree of diatom dominance in the phytoplankton varied within and between years. Periodicity curves for the three sites (Figure 4.3.3.4) show that diatom populations exhibited their greatest abundance in spring and fall.

Fragilaria crotonensis, *Tabellaria flocculosa* and *F. pinnata* were consistently the most dominant species in Kewaunee from 1972 to 1974 (Table 4.3.3.4). They occurred in large numbers at certain times of the year and each composed 5% or more of the algal standing crop at one or more sampling locations in at least half of the months sampled each year. *Fragilaria crotonensis* and *T. flocculosa* (which may have also been reported as *T. fenestrata*) have consistently been reported as dominant species in various areas of the lake since the earlier studies of Lake Michigan phytoplankton (Eddy 1927, p. 205; Griffith

Table 4.3.3.4. Dominant phytoplankton which composed 5% or more of the total phytoplankton at any location near the Kewaunee Nuclear Power Plant 1971-1975. Numbers indicate last digit of the year during which the species was dominant.

	Months							
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Bacillariophyta	1[a]2[a]		1[a]2[a]	1[a]2[a]		1[a]	1[a]2[a]	
Centrales								
Cyclotella comta					1			
Cyclotella glomerata				3		3	3	
Cyclotella ocellata				4			3	
Cyclotella stelligera[b]	3,4,5	2,5	3,5	3,4,5	3			4
Cyclotella sp.								2
Melosira islandica		3			2			
Melosira italica		3,5			2	3,4	3,4	
Rhizosolenia eriensis		2,3			2			
Rhizosolenia longiseta			3,4					
Stephanodiscus binderanus		3						
Stephanodiscus hantzschii		2						4
Stephanodiscus hantzschii-tenuis		1						
Stephanodiscus invisitatus		2						
Stephanodiscus minutus	3,4,5	2,5	5					
Stephanodiscus tenuis								
Stephanodiscus sp. 2		5	5					
Stephanodiscus sp.[b]	3,5	3,5	3,5	5		3,4	3,4	3,4
Pennales								
Asterionella formosa[b]			3,4	3,4	4	2	3,4	1,2,3,4
Diatoma tenue				3,4				
Diatoma tenue var. *elongatum*		1,3						
Fragilaria capucina[b]		1,4	3,4	3,4,5	4			
Fragilaria capucina var. *mesolepta*		3						
Fragilaria crotonensis[b]	3,4,5	1,2,3,4,5	3,4,5	3,4,5	1,2,3,4	2,3,4	3,4	1,2,3,4
Fragilaria intermedia	3	4,5			2		4	
Fragilaria pinnata[b]	3,4,5	1,5	4,5	3,4,5	1,2,4	2,3,4	1,2,3,4	
Fragilaria pinnata var. *intercedens*					2			
Fragilaria vaucheriae[b]	4		4,5	4,5	4	4		
Navicula sp.					1			
Nitzschia acicularis		3,5	5					
Nitzschia palea						4		
Nitzschia sp.[b]				3,4	4	2,3,4	4	3,4
Synedra acus		1						
Synedra familica	4			4				
Synedra filiformis[b]	4,5	2,3,4,5	3,4,5	3,5				
Tabellaria flocculosa[b]	3,4,5	1,3,4,5	3,4,5	3,4,5	1,2,4	2,4	4	1,2,4
Chrysophyta								
Dinobryon cylindricum	3,4,5	5						
Dinobryon divergens			4	3	2	2		
Dinobryon sociale		2,3	4	3,4				
Cyanophyta								
Non-filamentous								
Aphanocapsa delicatissima						4		
Aphanocapsa castagnei					3			
Aphanothece clathrata							4	
Aphanothece nidulans					3	4		

Table 4.3.3.4. (continued)

	Months							
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Coelosphaerium naegelianum[b]					3,4	2,3,4	3,4	2,3,4
Gomphosphaeria lacustris						3		
Gomphosphaeria lacustris var. *compacta*					3			2
Filamentous								
Anabaena flos-aquae						2		
Oscillatoria tenuis					2			
Cryptophyta								
Rhodomonas minuta var. *nannoplanctica*		5						3
Rhodomonas sp.					3			

a No samples collected in that year.
b Dominant in four or more months.

Table 4.3.3.5. Yearly mean and monthly minimum and maximum mean diatom abundance and percent composition at various nearshore areas along western Lake Michigan, 1970-1975.

Study Site	Year	Total Diatom Abundance: Yearly Mean Units/ml	Total Diatom Abundance: Monthly Average Range Units/ml	Percent Composition: Yearly Mean %	Percent Composition: Monthly Average Range %
Kewaunee, Wis.	1972[a]	1465	711-2395	81	77-85
	1973[b]	1070	397-1861	82	32-94
	1974[b]	2114	1039-4278	90	79-96
	1975[c]	1836	675-3294	90	89-92
Haven, Wis.	1973-1974	2173	576-4619	84	43-97
Zion-Waukegan, Ill.	1970	1792	391-3253	83	54-96
	1971	2438	170-5362	84	39-98
	1972	1400	295-4037	79	24-98
	1973	1711	438-5693	83	25-99
	1974	2268	216-4919	87	46-97

[a] Samples collected May, August, September and November
[b] Samples collected April-November
[c] Samples collected April-July

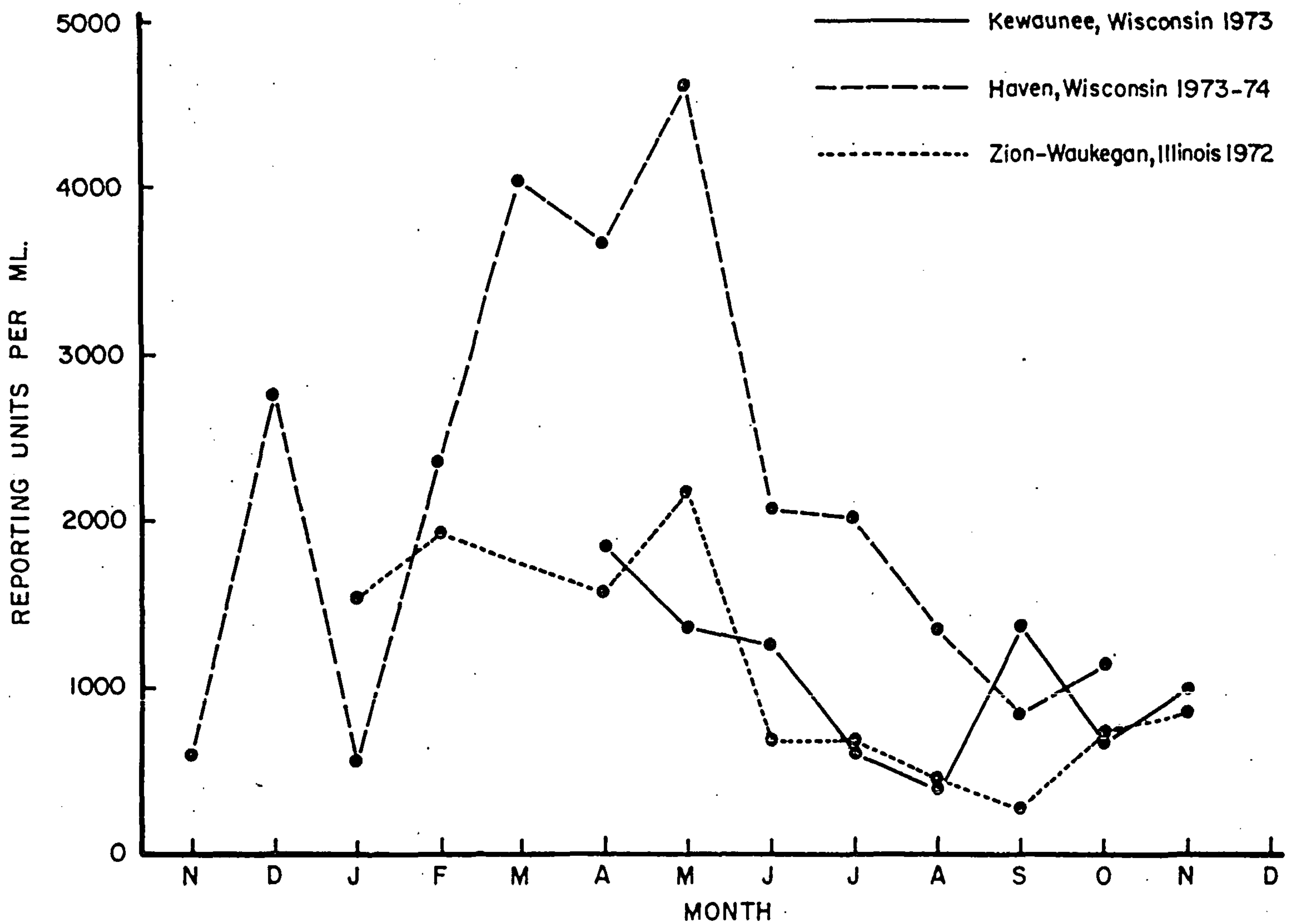

Fig. 4.3.3.4. Monthly density variation of diatans at Kewaunee and two other near shore areas of western Lake Michigan, 1972-1974.

1954, p. 46; Williams and Scott 1962, p. 371; Stoermer and Yang 1970, p. 3, 18 and 53). Asterionella formosa was also periodically dominant near Kewaunee. This species has been reported as widely distributed in Lake Michigan (Stoermer and Yang 1970, p. 3). Reports on recent phytoplankton studies at various nearshore areas of western Lake Michigan have also included F. crotonensis, T. flocculosa and F. pinnata among the most dominant species (Industrial BIO-TEST Laboratories, Inc. 1973, p. 92, 98; Everhart and Rasgus 1974, p. 5; Festin 1975, p. 10, 21; Piala and Lamble 1972, p. VII A-23; Mayhew 1974, p. 121-128; and Industrial BIO-TEST Laboratories 1974, p. 54. Secondarily dominant diatom species which occurred seasonally in measurable numbers near Kewaunee and at other areas of the lake included species of Stephanodiscus, Melosira, Cyclotella, Synedra and Fragilaria.

The seasonal occurrence of large numbers of F. pinnata in the inshore plankton of Lake Michigan near KNPP is a conspicuous feature of the area. A literature search on this species revealed that F. pinnata was a benthic species that had previously exhibited abundance in the plankton of the western nearshore area of Lake Michigan where there were suitable substrates for growth (Stoermer and Yang 1970, p. 23). Abundant occurrences of this pennate diatom in the plankton near KNPP have been associated with the scouring action of the inshore water upon the natural substrates in the general area (Everhart and Rasgus 1974, p. 10; and Festin 1975, p. 13, 28). Although a definite area has not been designated as the source of this organism, the topography and rocky nature of the lake bottom offshore of KNPP suggest the existence of a wide suitable habitat for this species. The bottom slopes gradually from the 30-ft to the 40-ft depth contour thereby creating an extensive area that averages 35 ft in depth (Figure 4.3.3.1). This was the exact depth at which Fox et al. (1967, p. 18) reported Fragilaria to grow most abundantly on artificial substrates in Lake Superior. Fragilaria pinnata can therefore be described as an established species in the vicinity of KNPP and its occurrence in the plankton may be attributed to natural scouring.

Quantitative data for phytoplankton other than diatoms in Lake Michigan are less extensive than for diatoms and are usually less directly comparable, principally because of the wide variety of enumerating systems employed by the different investigators. This notwithstanding, the data collected by various investigators during baseline and pollution surveillance studies at several nearshore areas have documented that each of the major non-diatom divisions are represented in the phytoplankton in varying, but usually small numbers, throughout most of the year (Figure 4.3.3.5). Each of these groups exhibit seasonal variations in populations with peaks occurring at certain times. This periodicity appears to be dissimilar at different areas suggesting that non-diatom populations are probably influenced by local environmental factors to a greater degree than diatoms.

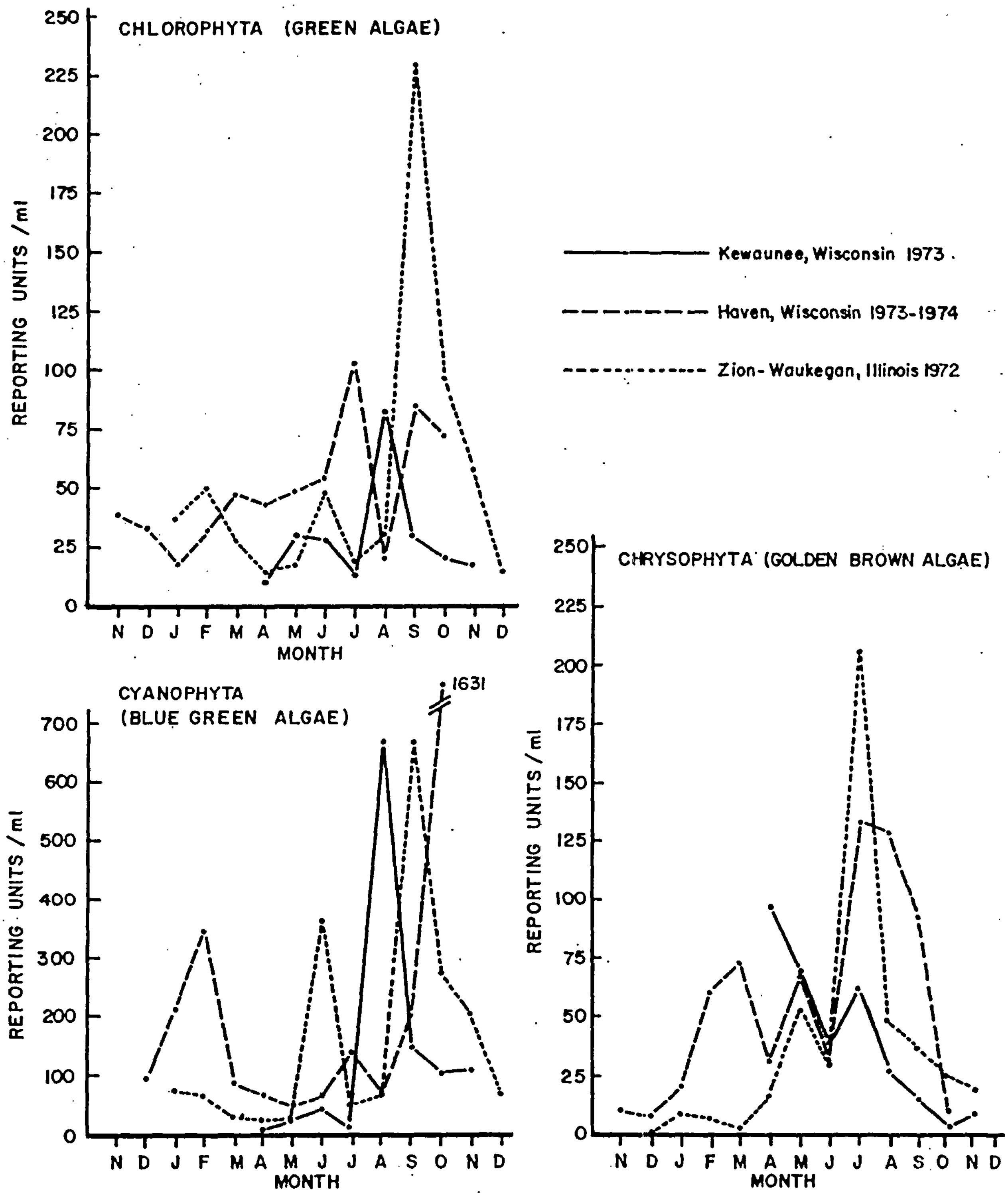

Figure 4.3.3.5. Mean monthly density variation of Chlorophyta, Chrysophyta and Cyanophyta at Kewaunee and two other near shore areas of western Lake Michigan. Identical analytical methods were employed for all three sites except for Haven where non-flamentous colonial species were reported by individual cells rather than by colony units.

Nuisance Phytoplankton in Lakes

Some planktonic algae have been reported to cause nuisance conditions in lakes and rivers. The larger diatoms such as *Tabellaria*, *Fragilaria*, *Asterionella* and *Melosira* have caused periodic problems in municipal water filtration by clogging the sand filters (Mackenthun and Keup 1970, p. 520-521). The centric diatoms *Stephanodiscus hantzschii* and *S. binderanus* have caused turbidity problems at the Chicago Filtration Plant by interferring with coagulation and passing through the filters in large numbers (Vaughn 1961, p. 46-47). In southern Lake Michigan, *Dinobryon* (Chrysophyta) was present in such abundance that a fishy odor was imparted to the water (Palmer 1964, p. 250). Many cases of livestock poisoning have been traced to drinking water contaminated with heavy growths of blue-green algae (Grant and Hughes 1953, p. 334).

Data from the four-year study of the phytoplankton in Lake Michigan in the vicinity of KNPP indicated that *S. hantzschii*, *S. binderanus* and the potential nuisance species of non-diatom algae were present in the study area but only in small numbers. During this study their numbers never reached nuisance proportions as discussed above.

In summary, data collected in the 1972 to 1975 period indicated that the phytoplankton community structure in the nearshore area of Lake Michigan near the KNPP essentially conformed with the lakewide community structure. This was true in regard to total phytoplankton abundance and species composition, spatial variability, seasonal periodicity and the degree of diatom dominance.

4.3.3.2 The Effect of Condenser Passage on Phytoplankton Viability

Phytoplankton carbon fixation rates (measurements of photosynthetic activity) and chlorophyll *a* concentrations (estimates of phytoplankton biomass), as well as phytoplankton abundance and composition, were monitored at KNPP from March 1973 through July 1975. Mechanical and hydrodynamic effects of condenser passage (such as turbulence, abrasion and pressure changes) were evaluated on phytoplankton passing through the plant during periods when heat was not exchanged (ΔT absent) across the condensers. Effects of thermal, in addition to mechanical stress, were assessed on phytoplankton viability at the point of discharge as well as within the thermal plume during periods when heat was exchanged (ΔT present) across the condensers. Analyses were conducted 7 hours after sample collection to assess immediate effects on phytoplankton viability and throughout a 72-hour holding period designed to evaluate possible delayed effects of (or recovery from) condenser passage.

Mechanical Effects

Mechanical effects of pump and condenser passage on phytoplankton abundance, composition, biomass and productivity were monitored from March 1973 through April 1974 at KNPP.

Total phytoplankton abundance measured in samples from the intake forebay and discharge canal was similar at 7 hours after collection during 10 of 14 sampling periods with no ΔT (Figure 4.3.3.6). Sizable reductions in phytoplankton abundance were measured at the discharge relative to the intake forebay during the May and June 1973 sampling periods while

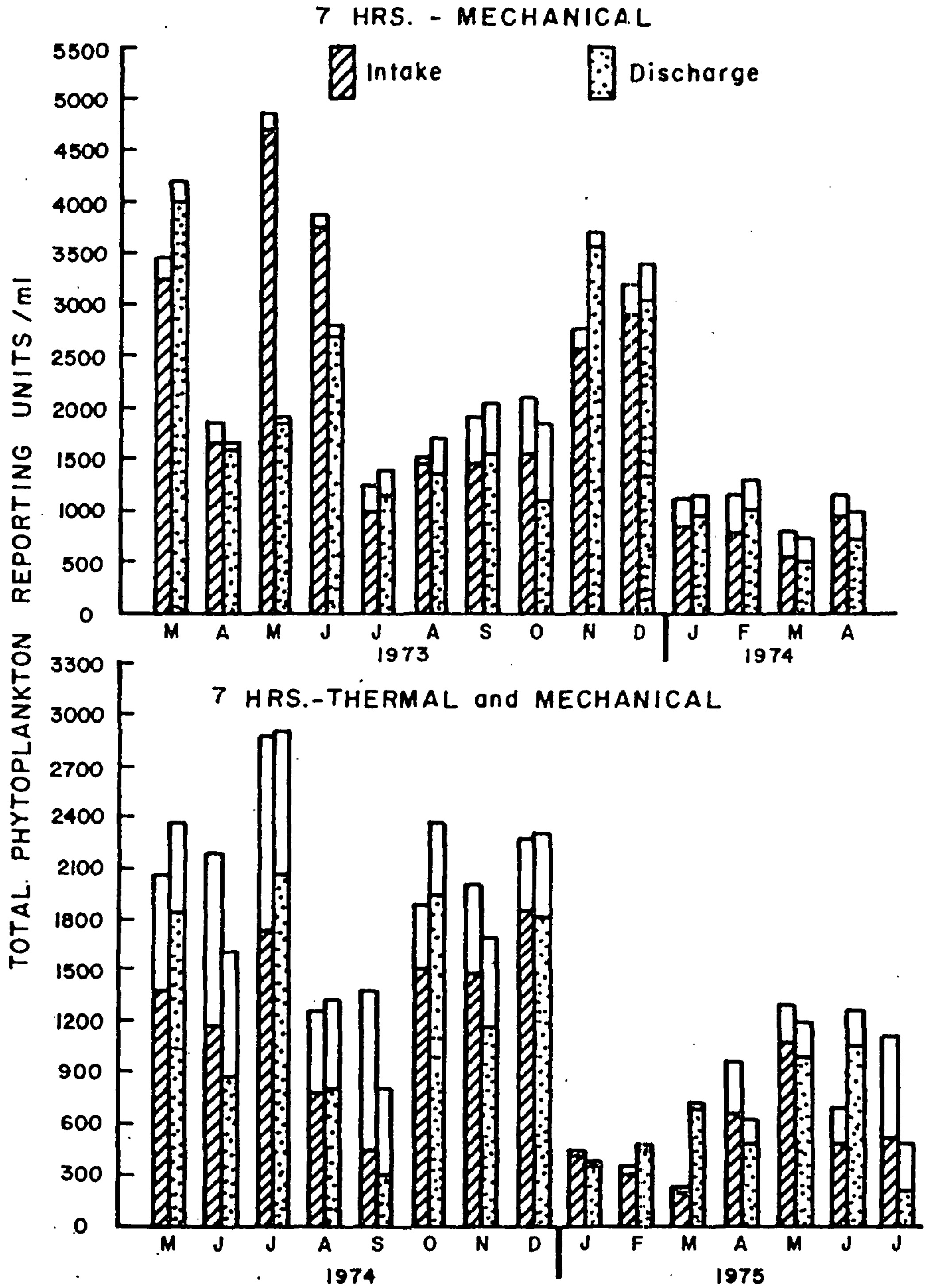

Figure 4.3.3.6. Total phytoplankton abundance and relative percent composition of diatoms (shaded areas) and non-diatoms (unshaded areas) at 7 hours after sample collection during periods of mechanical and mechanical + thermal stress at Kewaunee Nuclear Power Plant, March 1973 through July 1975.

increases of greater than 20% (discharge relative to forebay) were observed in March and November 1973. An overall 7% reduction in phytoplankton abundance of discharge samples relative to intake forebay samples was recorded following condenser passage during periods of mechanical stress. Comparable results were reported by Knight (1973). Diatoms (Bacillariophyta) dominated the phytoplankton assemblage throughout the sampling period with relative abundances ranging from approximately 60% to greater than 95% of the total phytoplankton assemblage. The proportion of diatoms to the total phytoplankton assemblage remained nearly constant in samples collected from the intake forebay and the discharge canal during periods with ΔT absent (Figure 4.3.3.6). Immediate effects of condenser passage with no ΔT were generally not species selective although a few species of slender, fragile pennate diatoms (particularly *Fragilaria crotonensis*, *Tabellaria flocculosa* and *Synedra filiformis*) were reduced in discharge samples compared with intake samples 72 hours after collection (Bremer and Redmond 1974) p. 13.

Mechanical effects of condenser passage on carbon fixation rates and chlorophyll *a* concentrations of entrained phytoplankton were measured as percent difference of discharge samples relative to intake samples. The formula

$$\left(\frac{\text{Discharge}}{\text{Intake}} \times 100\right) - 100$$

was employed to calculate percent difference between discharge and intake samples. Immediate effects of condenser passage with ΔT absent resulted in a general depression of phytoplankton carbon fixation rates as well as chlorophyll a concentrations (Figures 4.3.3.7 and 4.3.3.8). Mean reductions of 12% and 6% were calculated for phytoplankton carbon fixation rates and chlorphyll a concentrations, respectively, immediately following condenser passage with no ΔT. The differences in carbon fixation rates measured between intake and discharge samples were generally statistically significant ($P \leq 0.05$) while differences in chlorophyll a concentrations were usually not statistically significant. Similar levels of reduction were measured for each parameter during analyses at 72 hours after sample collection (Figures 4.3.3.7 and 4.3.3.8) which indicated that there were no delayed effects on phytoplankton viability due to the mechanical stress of condenser passage. Monthly differences measured in all parameters between intake and discharge samples had no apparent correlation to the number of circulating water pumps in operation or ambient Lake Michigan water temperatures.

Phytoplankton entrainment studies on the effects of condenser passage without ΔT conducted at Zion Nuclear Station on southwestern Lake Michigan yielded mean differences between intake and discharge samples of 12% for carbon fixation rates and 11% for chlorophyll a concentration (Redmond 1974). The mean differences measured between intake and discharge samples at KNPP following condenser passage with no ΔT (12% for carbon fixation rate and 6% for chlorophyll a concentration) were similar to those measured at Zion and well below those measured by Flemer et al. (1971)(Maximum of 21% for carbon fixation rate and 22% for chlorophyll a concentration) in a study at a Maryland power plant.

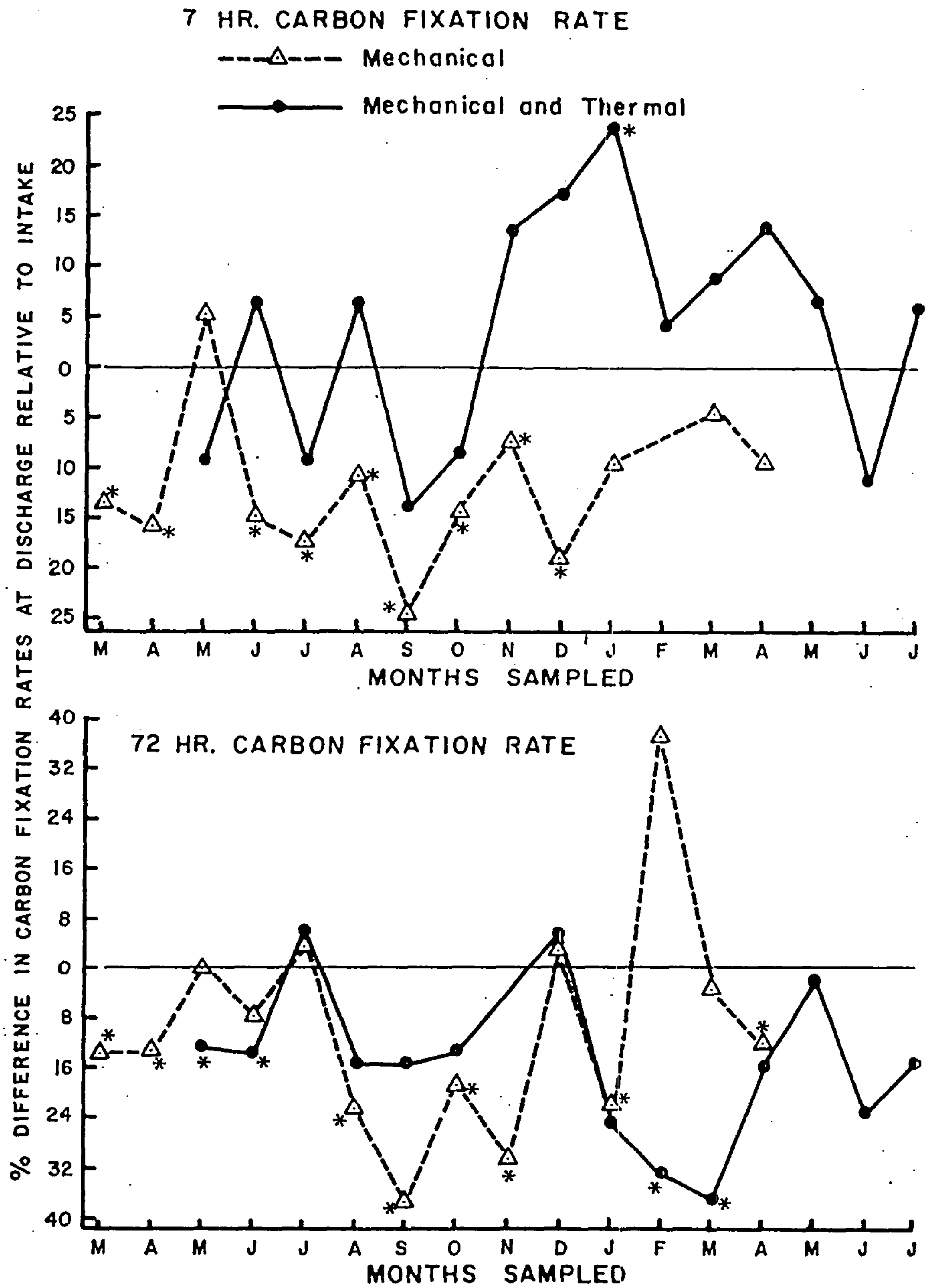

Figure 4.3.3.7. Percent difference of carbon fixation rate in samples from the discharge relative to the forebay at Kewaunee Nuclear Power Plant measured at 7 and 72 hours after collection during periods of mechanical and mechanical + thermal stress. Asterisk denotes statistically significant ($P \leq 0.05$) difference, March 1973 through July 1975.

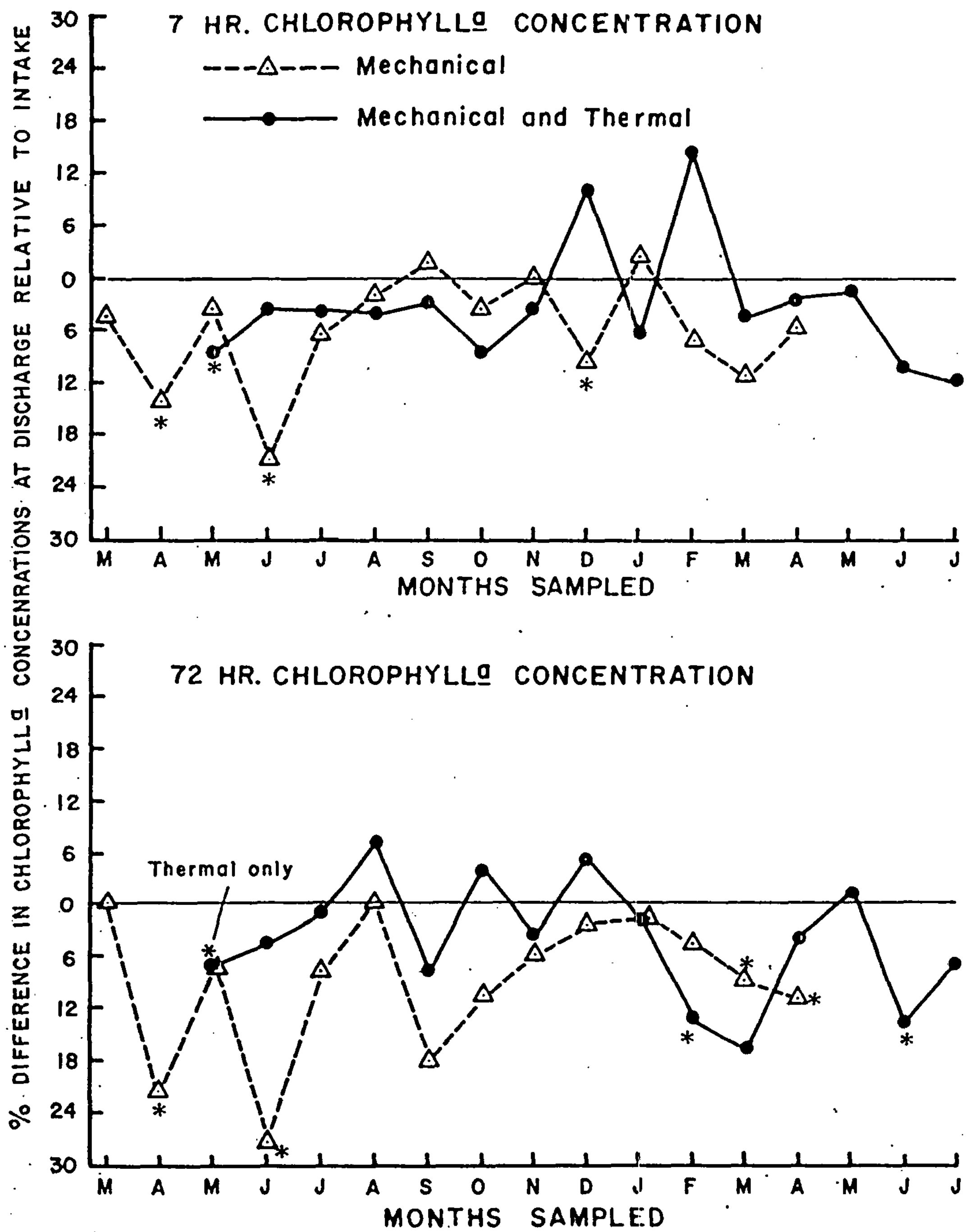

Figure 4.3.3.8. Percent difference in Chlorophyll a concentration in samples from the discharge relative to the forebay at Kewaunee Nuclear Power Plant measured at 7 and 72 hours after collection during periods of mechanical and mechanical + thermal stress. Asterisk denotes statistically significant ($P \leq 0.05$) difference, March 1973 through July 1975.

Combined Thermal and Mechanical Effects

Combined mechanical and thermal effects of condenser passage on phytoplankton abundances, carbon fixation rates and chlorphyll a concentrations were measured at KNPP from May 1974 through July 1975. The plant was operating between 63%-100% capacity with ΔT's ranging from 5.8 C-15.5 C (Table 4.3.3.6).

Alterations of total phytoplankton abundance immediately following condenser passage with simultaneous thermal injection were extremely variable throughout the study period (Figure 4.3.3.6). The elevations and depressions of total phytoplankton abundance measured in discharge samples relative to intake samples followed no discernible pattern and bore no consistent relationship to either magnitude of ΔT or ambient Lake Michigan water temperature. Total phytoplankton abundance measured at the discharge, relative to the intake, was lower five times, higher five times and approximately equal five times (Figure 4.3.3.6). The mean difference in total phytoplankton abundance between intake and discharge samples was less than 2% for all periods with a ΔT present (Figure 4.3.3.6 and 4.3.3.9). As demonstrated in Section 4.3.3.1, phytoplankton are essentially free floating organisms and are therefore subject to a multitude of physical and environmental factors which result in a substantial amount of spatial variability or "patchiness." The seemingly random fluctuations observed in total phytoplankton abundance between intake and discharge samples are undoubtedly the result of sampling a naturally variable, heterogeneous community rather than a true thermal effect of condenser passage. Differences in mean total phytoplankton

Table 4.3.3.6. Summary of physical parameters measured at Kewaunee Nuclear Power Plant March 1973 through July 1975.

Date	Number of Circulating Water Pumps Operating	Water Temperature Intake	Water Temperature Discharge	ΔT (°C)	Percent Turbine Capacity
27 Mar 73	2	3.8 C (38.8 F)	3.8 C (38.8 F)	0.0	0
24 Apr 73	2	7.0 C (44.6 F)	7.0 C (44.6 F)	0.0	0
15 May 73	2	9.8 C (49.6 F)	9.8 C (49.6 F)	0.0	0
19 Jun 73	2	10.0 C (50.0 F)	10.0 C (50.0 F)	0.0	0
17 Jul 73	1	13.0 C (55.4 F)	13.0 C (55.4 F)	0.0	0
14 Aug 73	2	12.0 C (53.6 F)	12.0 C (53.6 F)	0.0	0
4 Sep 73	1	8.5 C (47.3 F)	8.5 C (47.3 F)	0.0	0
23 Oct 73	1	10.2 C (50.4 F)	10.2 C (50.4 F)	0.0	0
18 Nov 73	2	2.0 C (35.6 F)	2.0 C (35.6 F)	0.0	0
11 Dec 73	1	0.5 C (32.9 F)	0.5 C (32.9 F)	0.0	0
21 Jan 74	1	1.0 C (33.8 F)	1.0 C (33.8 F)	0.0	0
18 Feb 74	1	1.0 C (33.8 F)	1.0 C (33.8 F)	0.0	0
5 Mar 74	1	1.8 C (35.2 F)	1.8 C (35.2 F)	0.0	0
2 Apr 74	1	2.0 C (35.6 F)	2.0 C (35.6 F)	0.0	0
22 May 74	2	10.5 C (50.9 F)	17.0 C (62.6 F)	6.5	72
12 Jun 74	2	7.3 C (45.1 F)	15.2 C (59.4 F)	7.9	84
30 Jul 74	2	10.5 C (50.9 F)	19.5 C (67.1 F)	9.0	97
13 Aug 74	2	14.5 C (58.1 F)	24.3 C (75.7 F)	9.8	100
17 Sep 74	2	13.8 C (56.8 F)	24.1 C (75.4 F)	10.3	100
22 Oct 74	2	6.4 C (43.5 F)	14.6 C (58.3 F)	8.2	64
12 Nov 74	2	8.4 C (47.1 F)	15.6 C (60.1 F)	7.2	75
10 Dec 74	1	4.0 C (39.2 F)	16.0 C (60.8 F)	12.0	76
14 Jan 75	1	0.5 C (32.9 F)	11.5 C (52.7 F)	11.0	75
11 Feb 75	1	2.5 C (36.5 F)	17.0 C (62.6 F)	14.5	95
18 Mar 75	1	3.5 C (38.3 F)	19.0 C (66.2 F)	15.5	99
15 Apr 75	2	4.4 C (39.9 F)	13.9 C (57.0 F)	9.5	100
20 May 75	2	10.0 C (50.0 F)	17.5 C (63.5 F)	7.5	63
17 Jun 75	2	9.5 C (49.1 F)	18.0 C (64.4 F)	8.5	85
15 Jul 75	2	18.5 C (65.3 F)	24.3 C (75.7 F)	5.8	66

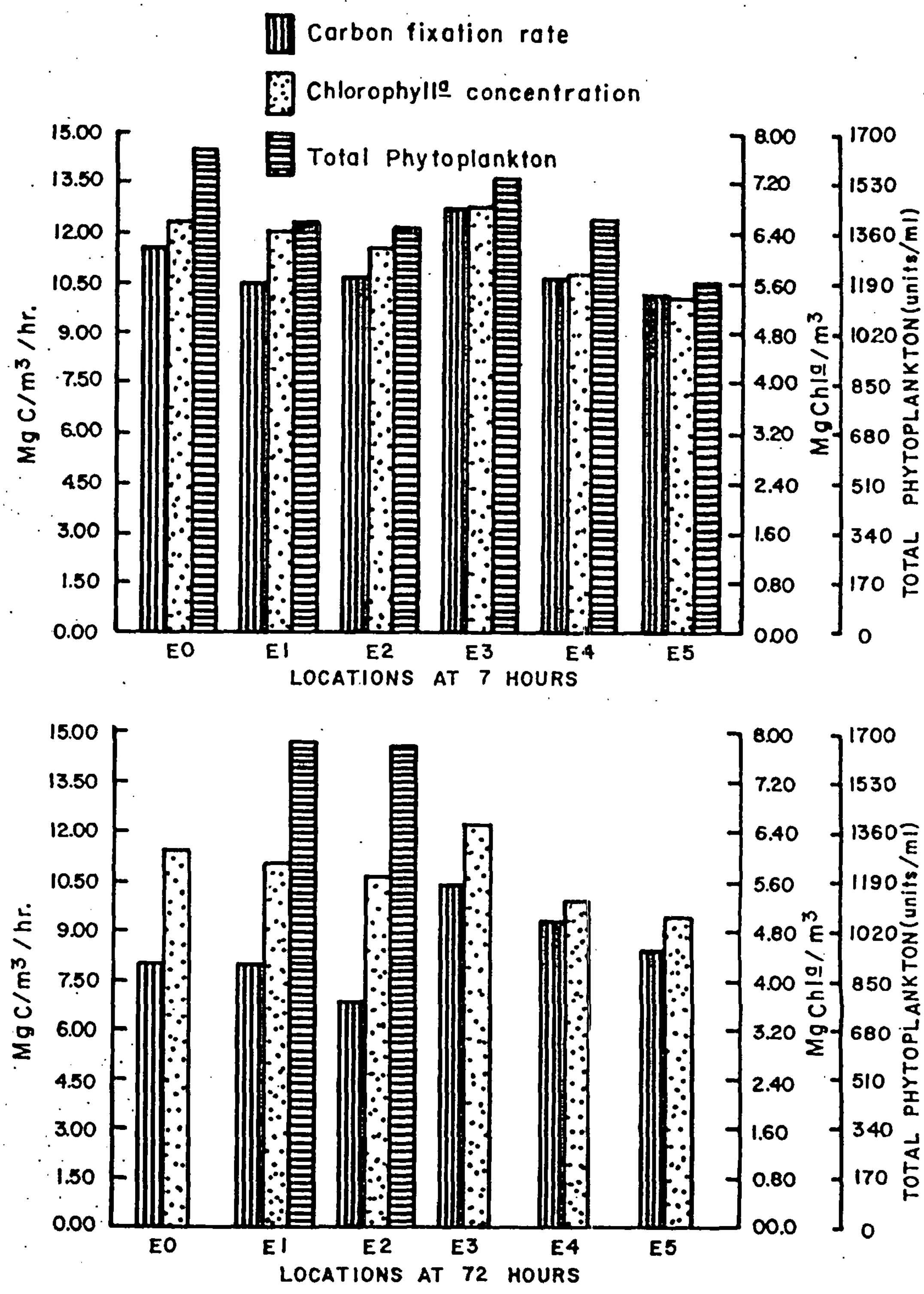

Figure 4.3.3.9. Mean carbon fixation rates, chlorophyll a concentrations and total abundances of phytoplankton measured during thermal discharge at 7 and 72 hours after sample collection from Locations E0 through E5 at Kewaunee Nuclear Power Plant, May 1974 through July 1975.

abundance measured after 72 hours remained less than 2% between intake and discharge samples, an indication that delayed effects of condenser passage with ΔT were non-existent for this parameter (Figure 4.3.3.9).

Condenser passage with thermal elevation resulted in an immediate slight depression of phytoplankton chlorophyll *a* concentrations at the discharge relative to the intake during 13 of 15 sampling periods (Figure 4.3.3.8). These depressions were statistically significant ($P \leq 0.05$) in only May 1974. The mean depression in chlorophyll *a* concentrations at the discharge 7 hours after sample collection was 3% and was considered minimal. Mean phytoplankton chlorophyll *a* concentrations of discharge samples remained approximately 4% lower than intake samples after 72 hours indicating an absence of further thermal effects or recovery from condenser passage. Similar studies performed at Zion Station in 1973 (Restaino et al. 1975) found that the range (2%-8%) and annual mean (5%) of pre- and post-condenser differences in chlorophyll *a* concentrations measured 7 hours after sample collection were comparable to differences measured at Kewaunee during periods with ΔT present. This suggests that the results obtained at Kewaunee were typical effects of condenser passage with thermal injection on phytoplankton chlorophyll *a* concentrations.

Phytoplankton carbon fixation rates measured from May through October 1974 discharge samples at 7 hours after collection varied from 13% lower to 6% higher than intake samples although differences in samples from the two locations were not statistically significant ($P \leq 0.05$) (Figure 4.3.3.7). Fluctuations between locations during this period bore no consistent relationship to either ΔT or ambient Lake Michigan water temperature. A pattern of elevated carbon fixation rates at the discharge relative to the intake was evident after 7 hours from November 1974 through May 1975. The only statistically significant ($P \leq 0.05$) difference, however, was detected in January 1975 (Figure 4.3.3.7). Morgan and Stross (1969, p. 169), Warinner and Brehmer (1966, p. 281) and Redmond et al. (1975, p. 20) each reported increases of phytoplankton carbon fixation rates following condenser passage with ΔT during periods of low ambient water temperatures. Condenser passage with thermal elevation appears to have produced a slight overall stimulation of phytoplankton productivity at KNPP. This was evidenced by a mean 4% increase in carbon fixation rates following condenser passage with a ΔT when compared with a mean 12% decrease measured during periods of mechanical stress only (Figure 4.3.3.7). Carbon fixation rates measured after 72 hours during the May through December 1974 sampling periods were somewhat variable but generally produced no apparent evidence of delayed effects of condenser passage with thermal injection on phytoplankton productivity (Figure 4.3.3.7). The January through April 1975 sampling periods, however, indicated a possible inhibition of productivity at 72 hours. Differences in mean carbon fixation rate between intake and discharge samples were statistically significant ($P \leq 0.05$) at 72 hours during the February and March 1975 sampling periods. A study performed at Point Beach, Wisconsin

(Wisconsin Electric Power Company and Wisconsin-Michigan Power Company 1973), including three sampling periods (May, August and November) produced mean carbon fixation rates which differed by 3% between pre- and post-condenser phytoplankton samples. Although experimental methods employed were considerably different between the two studies, mean carbon fixation rate differences after condenser passage were similar; each demonstrating minor overall effects on phytoplankton productivity immediately following condenser passage with ΔT present.

Plume Entrainment

The effects of thermal plume entrainment on phytoplankton were assessed through comparisons of mean carbon fixation rates, chlorophyll a concentrations and phytoplankton abundance at Locations E3 and E4 (50% and 20%, respectively, of the ΔT + ambient water temperature) with the control location (E5). The influence of Location E0 (mouth of the intake structure) on Location E3 and E4 vs E5 comparisons should be clarified. Mean phytoplankton abundance, chlorophyll a concentration and carbon fixation rate were greater at Location E0 than at Location E5 (Figure 4.3.3.9). Therefore, it was obvious that at least a portion of the differences which occurred between Locations E3, E4 and E5 were due to phytoplankton density dissimilarities and were not wholly a result of plume entrainment. Phytoplankton entrained in the warmest plume water sampled (Location E3) exhibited elevated mean carbon fixation rates (25%), chlorophyll a concentrations (27%) and phytoplankton abundances (30%) when compared with ambient Lake

Michigan levels measured at Location E5 (Figure 4.3.3.9). The initial stimulation of productivity measured in plume-entrained phytoplankton may have been a result of the combined effects of thermal elevation and introduction into well-lighted, potentially nutrient rich inshore surface water (Edsall and Yocum 1972 p. 65).

Evidence of recovery by plume-entrained phytoplankton to near ambient levels (measured at Location E5) of carbon uptake and chlorophyll a concentration was observed in samples from Location E4 at 7 hours after collection (Figure 4.3.3.9). Mean deviations from ambient levels were 4% and 6%, respectively, for carbon fixation rate and chlorophyll a concentration. Mean total phytoplankton abundance at Location E4 remained somewhat higher (16%) than at E5 after 7 hours but had dropped considerably closer to ambient levels when compared with abundance measured at Location E3. Generally, the conclusions reached at 7 hours remained unchanged after 72 hours; initial stimulation of carbon fixation rate and chlorophyll a concentration at Location E3 was followed by a return to near ambient levels at Location E4 (Figure 4.3.3.9). These data indicate that plume entrainment resulted in no long-term or delayed effects on the phytoplankton community.

In summary, the data indicate that entrainment of phytoplankton in the thermal plume resulted in immediate elevation of carbon fixation rates and chlorophyll a concentrations, followed by recovery associated with ambient temperature re-acclimation.

Thermal Shock

Startup of KNPP from no power to full power will result in rapidly warming discharge temperatures over a relatively short period of time. Since the phytoplankton community is practically immotile and is carried along by movements of the water mass. The effects of heat shock are restricted to the time spent in condenser passage and plume entrainment which have been considered previously. In addition, the effects of heat shock in phytoplankton physiology could never exceed the effects of the worst case conditions as discussed below for summer or winter and would rarely approach those effects.

The effect of plant shutdown with resultant rapid cooling of discharge water to ambient Lake Michigan water temperatures may result in cold shock to the phytoplankton community near KNPP. The phytoplankton community, however, is highly transient and is not capable of maintaining itself in the thermal plume. Therefore, the effect of rapid cooling would be identical to that sustained by organisms as they are returned to ambient after entrainment. Since the physiological studies discussed above have shown that the entrained phytoplankton have recovered by the time they reach the outer edge of the thermal plume, it is obvious that cold shock could not present appreciable harm to the community.

Worst Case Conditions

Summer

Operation of KNPP during the summer months could result in a maximum discharge temperature of 30 C with a maximum ambient lake water temperature of 23 C. At these temperatures entrainment of the phytoplankton is likely to cause a reduction in the rate of photosynthesis (Morgan and Stross 1969, p. 169). Previous entrainment studies performed at Zion Station (Restaino et al. 1975, p. 21, 25) and at Kewaunee (Jones et al. 1975, p. 20) however, have demonstrated a general lack of correlation between magnitude of ΔT and the extent of physiological effects in entrained phytoplankton. Studies performed at Waukegan Station on southwestern Lake Michigan during the summer of 1971 resulted in entrainment effects on phytoplankton carbon fixation rates ranging from 50% inhibition to 27% stimulation for discharge water temperatures of 29.2-31.0 C and species composition similar to that observed near KNPP (Industrial BIO-TEST Laboratories, Inc. 1972). Considering the variability of results observed in previous studies, the best prediction of worst case effects for summer conditions at KNPP is alteration of phytoplankton carbon fixation rates between +27% and -50% following condenser passage.

Winter

Discharge temperatures for winter conditions are predicted to peak at 15.5 C with an ambient lake temperature of 0 C. Effects of entrainment studies render similar conditions at KNPP in 1975 resulted in carbon fixation rates at the discharge which ranged from 8% less to 23% more than intake values. (Jones et al., 1975; Redmond 1976). An overall trend toward stimulation of photosynthetic rates was noted as was observed by Morgan and Stross (1969). Consequently, the predicted effect of entrainment during the winter worst case conditions is stimulation of productivity (maximum of 23%) with a slight chance for inhibition (maximum 8%) based on past entrainment studies.

4.3.3.3 The Effect of KNPP Operation on the Phytoplankton Community in the Immediate Discharge Area

The effect of thermal effluents on the phytoplankton community of receiving waters have been studied by many biologists and found to be physically manifested in several ways. The effects, which vary with specific locations and conditions, may take the form of increased algal growth, changes in species composition, gross population shifts from diatoms to green algae to blue-green algae (Patrick 1974, p. 363) or a large decrease in the minimum summer population resulting from depression of photosynthesis (Coutant 1970, p. 348). To evaluate these possible effects, the KNPP study area was divided into an immediate discharge (experimental) area delineated by the maximum extent of the thermal plume and control locations which were outside the influence of the plume. The immediate discharge area (IDA) encompassed four phytoplankton sampling locations (Figure 4.3.3.1): Location 11 was positioned near the discharge canal along the 10-ft depth contour and Locations 7, 12, and 16 were positioned along the 20-ft depth contour. Because of the proximity of Location 11 to the discharge canal, phytoplankton sampled at that point were almost always affected by the thermal discharge and were probably actually in the discharge water. The phytoplankton at Locations 7, 12 and 16 were variably affected because of the changing position of the thermal plume which was dependent upon the direction of current at the time of sampling. Nevertheless, the plankton at these locations was generally affected by the thermal plume.

The control area included five phytoplankton sampling locations. Two locations (Locations 2 and 20) were positioned along the 10-ft depth contour with one located to the north and one to the south of Location 11. Three locations (Locations 14, 23, and 24) were positioned along the 40-ft depth contour. These control locations were never within the thermal plume.

The effect of the thermal discharge upon the phytoplankton community in the immediate discharge area was assessed by comparing operational data (June 1974-July 1975) with preoperational data (1972 and 1973). Data collected in the IDA during the operational period were also compared with data from locations outside (control) the discharge area. Control area means were calculated from mean values obtained at Locations 2, 14, and 20 in order to have data that were comparable for the entire 1972-1975 period. Phytoplankton periodicity at the discharge area and at the control area are graphically compared in Figure 4.3.3.10.

Total phytoplankton abundance increased from the preoperational to the operational period. Yearly mean phytoplankton abundance in the discharge area was 1397, 2528, and 2511 reporting units/ml for 1973, 1974, and 1975, respectively. KNPP was not operational until June 1974 so the 1973 yearly mean represented complete preoperational data, 1974 partialy preoperational and operational data and 1975 complete operational data. The yearly mean for 1972 was based on only four months of samples which did not include the spring peak and therefore would only be of gross comparative value. The marked increase in phytoplankton

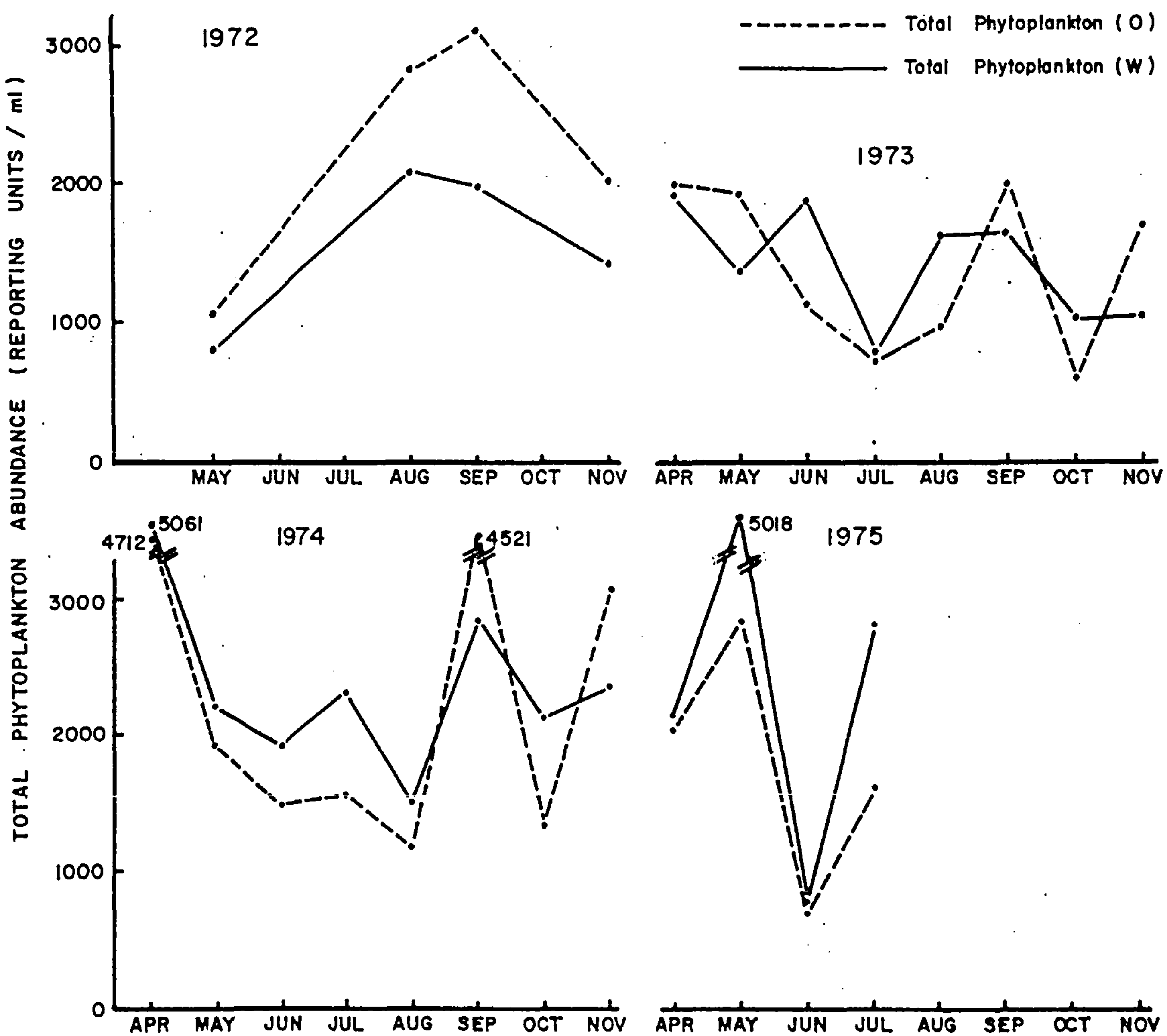

Figure 4.3.3.10. Monthly variations of mean total phytoplankton abundance at locations within and outside the immediate thermal discharge area in Lake Michigan near the Kewaunee Nuclear Power Plant, May 1972 to July 1975.

abundance during the operational period was mainly due to the occurrence of large numbers of epilithic diatoms (species that grow on rocks). Because the increase and decrese of these organisms in the plankton would be almost entirely dependent on natural water movements, no valid interpretation could be made in relating the general phytoplankton population change to the direct influence of the thermal discharge. A similar increase occurred in the control area in 1974 which suggested that this increase may be indicative of seasonal or even yearly variation. The increase in total phytoplankton abundance in 1975, which was greater in the IDA than in the control area, was also dominated by the epilithic diatoms. The occurrence of these organisms will be discussed in detail in a subsequent section.

Diatoms (Bacillariophyta) were consistently the most abundant and diverse algal division during the preoperational and operational periods within the IDA as well as in the control area. Large diatom concentrations at certain locations were the principal cause of general increases in phytoplankton abundance from the preoperational to the operational periods and density differences between the IDA and control locations during the operational period. Annual mean diatom abundance at the IDA and control areas doubled from 1973 to 1974 (Table 4.3.3.7). The increase was largely due to sharp increases in epilithic diatoms during the spring and fall diatom maxima. KNPP was not operational when the very large number of diatoms occurred in the spring of 1974. The density change was, therefore, probably indicative of annual variation. The natural occurrence of wide

Table 4.3.3.7. Selected features of phytoplankton community structure within (experimental) and outside (control) the discharge zone of Kewaunee Nuclear Power Plant, 1972-1975. Values represent yearly (April-November) means at all locations in each area.

	Discharge Zone				Control Area	
	1972[a]	1973	1974	1975[b]	1974	1975[b]
Total phytoplankton abundance (units/ml)	1575	1397	2528	2511	2463	1797
Total diatom abundance	1327	1122	2375	2342	2299	1635
Relative diatom abundance	85	81	93	92	91	91
Most dominant species						
Fragilaria crotonensis						
Abundance (units/ml)		138	324	386	269	323
Monthly abundance range		91-324	129-646	27-633	76-530	30-584
Percent composition		10	13	14	13	15
Monthly percentage range		5-17	6-22	4-28	4-23	4-28
Fragilaria pinnata						
Abundance (units/ml)		130	603	616	497	170
Monthly abundance range		24-319	68-2387	28-1898	35-1801	18-420
Percent composition		9	18	12	14	8
Monthly percentage range		9-23	3-40	4-23	2-35	2-14
Tabellaria flocculosa						
Abundance (units/ml)		121	180	134	174	129
Monthly abundance range		19-467	96-341	82-158	61-355	51-181
Percent composition		8	9	7	9	8
Monthly percentage range		2-24	4-20	7-11	4-18	6-9
Type of seasonal periodicity	DNC[c]	bimodal	bimodal	bimodal	bimodal	bimodal

[a] Yearly means are based on 4 months (May, August, September and November).
[b] Yearly means are based on 4 months (April-July).
[c] DNC - Data not comparable.

year-to-year variation in diatom populations was also observed by Damann (1960, p. 398-399) in the 33-year continuous diatom collections from nearshore Lake Michigan at Chicago.

Fragilaria crotonensis, F. pinnata and Tabellaria flocculosa were consisently the most dominant phytoplankton species during the preoperational and operational periods in the IDA and control areas. Yearly mean percent compositions of each of these species are presented in Table 4.3.3.7 and monthly mean abundances at experimental and control locations are graphically compared in Figure 4.3.3.11 and Figure 4.3.3.12. Yearly mean percent composition of F. crotonensis in the discharge area increased progressively from 1973 to 1975 while that of T. flocculosa increased in 1973 and decreased in 1975. The same trends occurred in the control area suggesting that the density changes were natural yearly variations. The yearly mean percent composition of F. pinnata showed an increase in 1974 which was larger in the IDA than in the control area and a decrease in 1975 that was much larger in the control area than in the IDA. The general predominance of these three species at the IDA persisted from the preoperational period through the first year of KNPP operation.

The measurable increase of epilithic diatoms, particularly F. pinnata, constituted a change in the diatom population of the IDA from the preoperational to the operational periods. Comparison of the monthly mean abundance of F. pinnata (and its varieties) between locations within and outside the IDA (Figure 4.3.3.12) revealed that the 1974 increase in the IDA

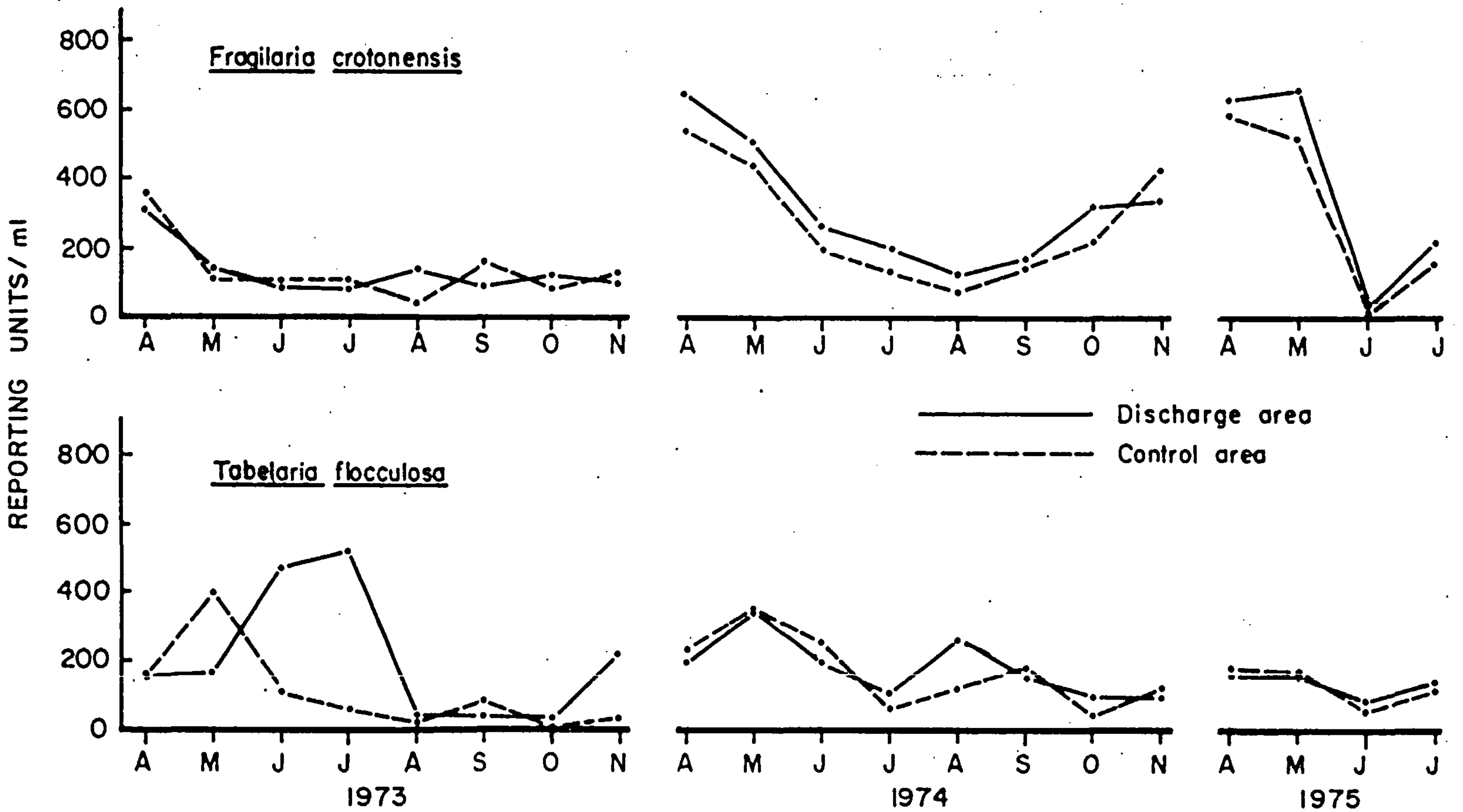

Figure 4.3.3.11. Monthly mean abundance of Fragilaria crotonensis and Tabellaria flocculosa at locations within and outside the discharge zone of Kewaunee Nuclear Power Plant, 1972-1975.

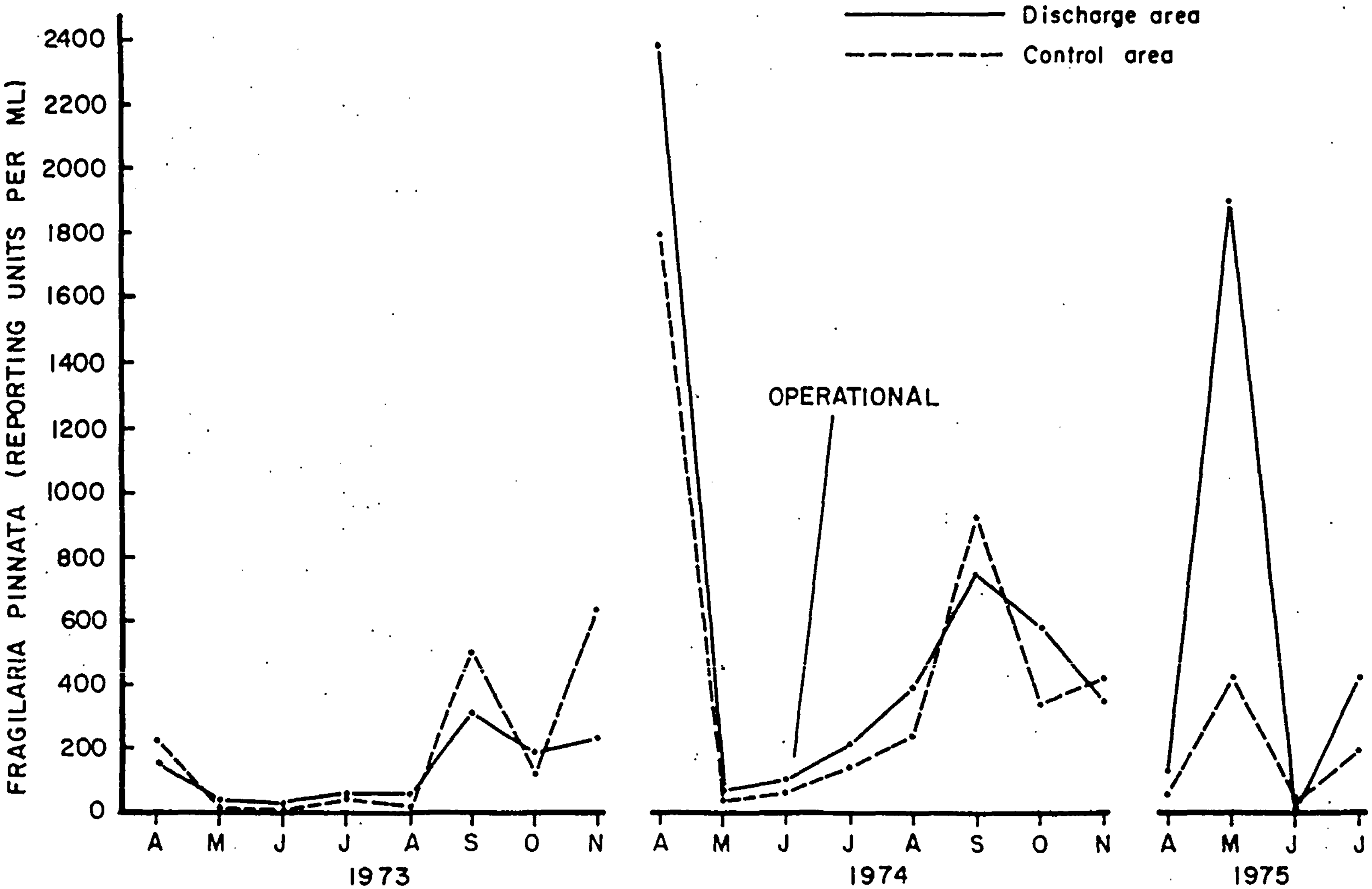

Figure 4.3.3.12. Monthly mean abundance of _Fragilaria pinnata_ at locations within and outside the discharge zone of Kewaunee Nuclear Power Plant in Lake Michigan, 1973-1975.

followed the same seasonal fluctuation in the control area. The greatest abundance occurred in April which was about two months prior to the start of regular plant operation. This occurrence could only have been related to natural scouring. In 1975, however, the spring (May) peak of F. pinnata was much greater in the IDA than in the control area. This indicated that the occurrence of F. pinnata in the plankton of the plume area was seasonally influenced and probably related to the scouring action of the KNPP discharge. In contrast to its minimal growth in the discharge canal in April 1974 (Alstaetter 1975, p. 18), an abundant growth of F. pinnata was recorded in the periphyton samples from the canal wall in May 1975 (Section 4.3.5.2). The canal wall and nearby substrates were the likely sources of the large concentration of this species in the plankton of the IDA. Comparison of the F. pinnata population at Location E0 (Phytoplankton Entrainment Study Location) at the intake structure (1600 ft offshore and at 16-ft depth) and the population at Location 11 near the point of thermal discharge (Figure 4.3.3.13) gave no indication that the cooling water was transferring large numbers of F. pinnata from the bottom to the surface waters in the IDA. The quantitative difference in the occurrence of F. pinnata, and probably other epilithic diatoms in the IDA and in the control area, could therefore be related to scouring caused by the discharge cooling water and the presence of these organisms in or near the discharge canal.

Populations of green algae (Chlorophyta), golden-brown algae (Chrysophyta), blue-green algae (Cyanophyta) and cryptophytes

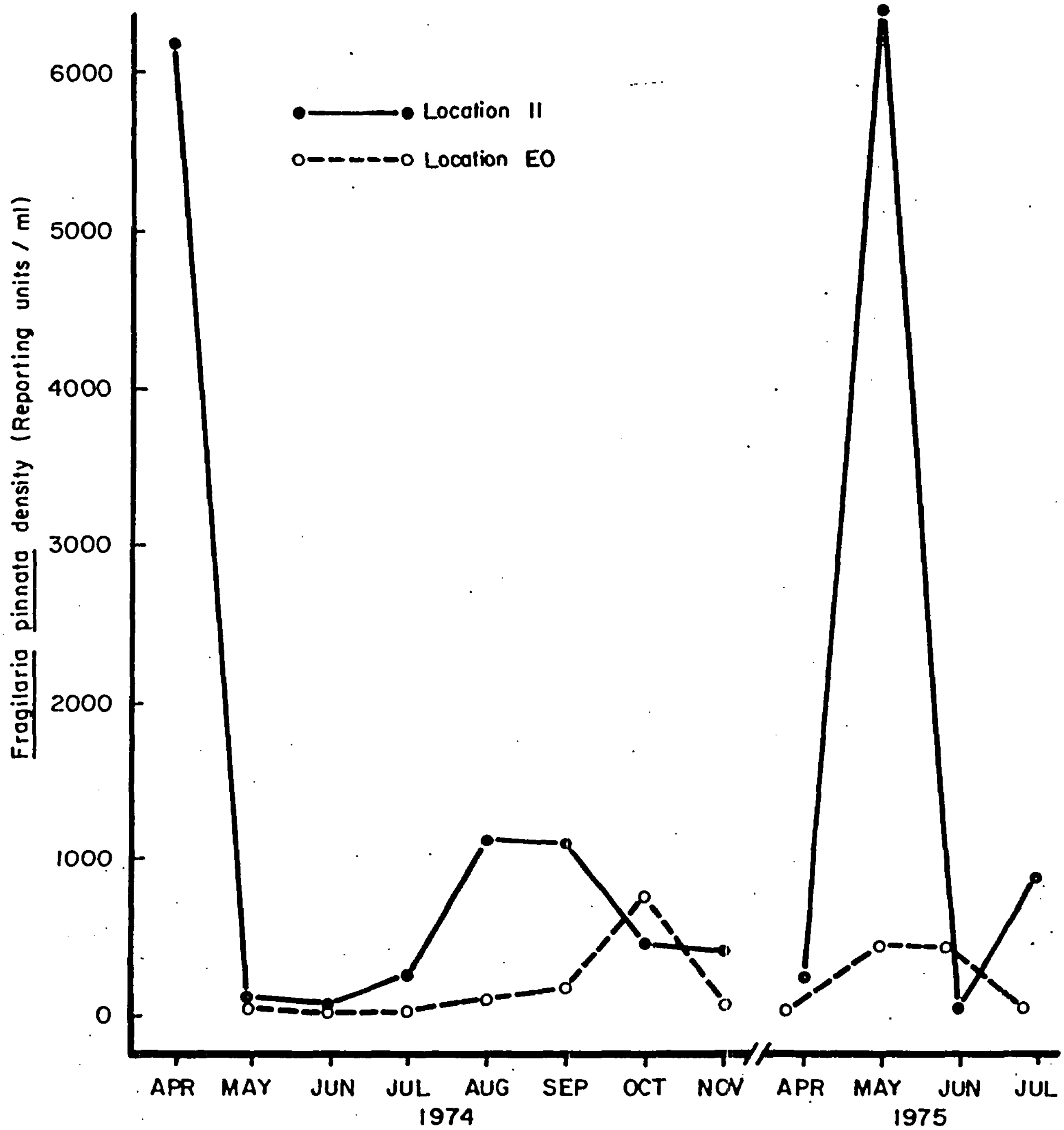

Figure 4.3.3.13. Mean abundance of *Fragilaria pinnata* at Locations 11 and E0 in Lake Michigan near the Kewaunee Nuclear Power Plant, 1974-1975.

(Cryptophyta) remained low throughout the study (Figure 4.3.3.14). Aside from the slight decrease in the blue-green algal peak in 1974, which may have been a yearly variation, populations of each of the major algal divisions changed very little throughout the four-year period. Monthly population variations of these groups in the IDA paralleled those of the control area during 1974 and 1975. Some species of euglenoids (Euglenophyta) and dinoflagellates (Pyrrhophyta) were occasionally present in very small numbers at locations in the IDA and control areas during the preoperational and operational periods.

Seasonal phytoplankton distributions followed a typical bimodal periodicity during the preoperational and operational periods in both the IDA and control areas (Figure 4.3.3.10). Phytoplankton density was highest in the spring (April or May), decreased sharply in the summer (July or August) and increased again in the early fall (September) to produce the second pulse. The spring pulse was equal to or greater than the early fall pulse. The bimodal periodicity pattern was not observed in 1972 because of the infrequency of sampling. The lowest densities were observed either in July or August and did not show any pattern of change in magnitude between the preoperational and operational periods. Seasonal trends in April to July 1975 paralleled the trends of preceeding years.

In summary, the phytoplankton community structure in the IDA of KNPP remained essentially unchanged from the pre-operational to the operational period in terms of species composition and seasonal periodicity for all the major algal

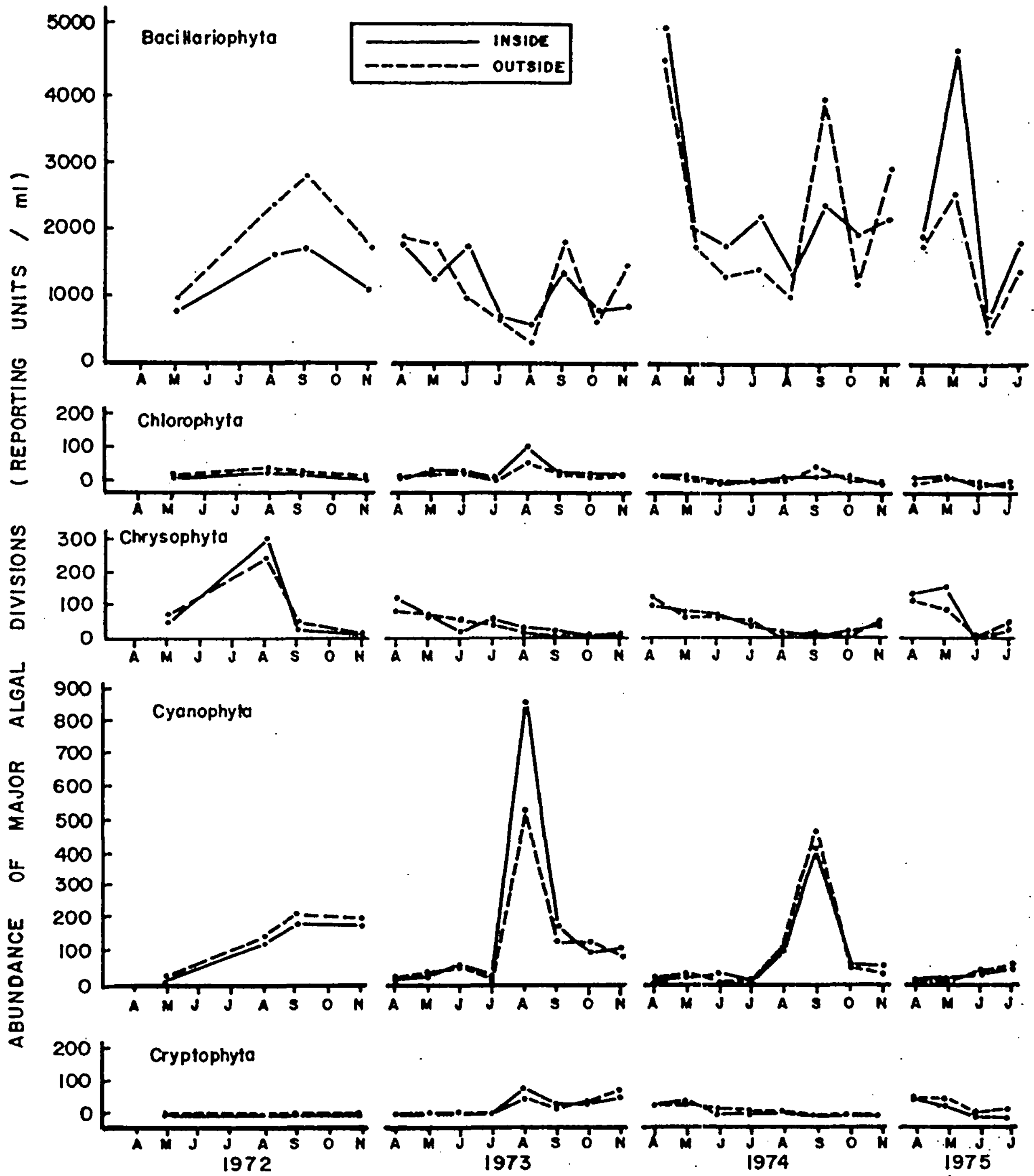

Figure 4.3.3.14. Monthly variations of mean abundance of major algal divisions at locations within and outside the discharge zone in Lake Michigan near the Kewaunee Nuclear Power Plant, May 1972 to July 1975.

component groups. Variations in phytoplankton populations followed a bimodal yearly cycle during the preoperational period as well as during the operational period. Seven major algal divisions were represented in the phytoplankton with the diatoms and green algae composing the first and second most diverse group, respectively.

Total phytoplankton abundance increased from 1973 to 1974 largely because of measurable increase in the number of diatoms. Greater diatom densities during the operational period were mainly due to increased populations of *Fragilaria crotonensis* and *F. pinnata*. *Fragilaria pinnata*, which is a deep water epilithic species, appears to be established in the deeper parts of the nearshore area near KNPP. The occurrence of this species in large numbers within the discharge area in the spring of 1974 was associated with natural scouring by the inshore waters.

Phytoplankton community structure in the IDA and the control area was similar with regard to species composition, dominant species and periodicity. Population changes within and between years from 1972 to 1973 were observed in the IDA and control areas and were indicative of seasonal and yearly variations. Measurable phytoplankton density differences between experimental and control areas in 1975 were mainly due to the occurrence of large numbers of *F. pinnata*. This in turn was probably due to the scouring action of the KNPP discharge cooling water upon the large spring growth of *F. pinnata* in the discharge canal and adjacent substrates. Data collected from the IDA area of

KNPP indicate no essential change in the phytoplankton community structure that could be related directly or principally to the effect of the thermal discharge.

4.3.3.4 The Effect of KNPP Operation on the Phytoplankton Community in the Receiving Water Body

Comparison of the phytoplankton community structure outside the IDA during KNPP operational (1974 and 1975) and preoperational periods (1972 and 1973) would elucidate any effect that the thermal discharge had on the regional phytoplankton assemblage. A number of relevant observations were made from the seasonal periodicity curves on Figures 4.3.3.10 and 4.3.3.14 and Table 4.3.3.8.

The yearly mean total phytoplankton abundance in the control area was alternately high and low from 1972 to 1975. This pattern was largely reflective of changes in diatom densities and will, therefore, be explained accordingly. Diatoms were consistently the most dominant algal group. The percent composition of diatoms was 83%, 80%, 92% and 91% in 1972, 1973, 1974 and 1975, respectively. These changes in relative abundance reflected changes in total diatom density. Mean diatom density decreased from 2005 reporting units/ml in 1972 to 1192 reporting units/ml in 1973. In 1974, the first year of KNPP operation, diatom abundance increased to 2299 reporting units/ml. The marked increase from 1973 to 1974 resulted from differences in the spring populations and summer populations. Mean diatom abundance in April to July 1975 (1635 reporting units/ml) was considerably less than the mean value for the same four-month period of 1974. The increase in 1974 and the decrease in 1975 were mainly due to wide variations in the abundance of Fragilaria pinnata between years (Table 4.3.3.8).

Table 4.3.3.8. Selected features of phytoplankton community structures outside the discharge zone of Kewaunee Nuclear Power Plant in Lake Michigan during 1972 to 1975. Values represent yearly (April-November) means at Locations 2, 14 and 20.

	1972[a]	1973	1974	1975[b]
Total phytoplankton abundance (density, units/ml)	2259	1399	2463	1797
Total diatom abundance (units/ml)	2005	1192	2299	1635
Percent increase (+) or decrease (-) from previous year	2005	1192	2299	1635
Relative diatom abundance	83	80	92	91
Most dominant species				
Fragilaria crotonensis				
Abundance (units/ml)		144	269	323
Monthly abundance range		51-362	76-530	30-584
Percent composition		11	13	15
Monthly percentage range		5-19	4-23	4-28
Fragilaria pinnata				
Abundance (units/ml)		196	497	170
Monthly mean range		5-640	35-1801	18-420
Percent composition		10		
Monthly percentage range		1-24	2-35	2-14
Tabellaria flocculosa				
Abundance (units/ml)		108	174	129
Monthly mean abundance		11-404	61-355	51-181
Percent composition		7	9	8
Monthly percentage range		1-20	4-18	6-9
Type of seasonal periodicity	DNC[c]	bimodal	bimodal	bimodal

[a] Yearly means are based on 4 months (May, August, September and November).
[b] Yearly means are based on 4 months (April-July).
[c] DNC = Data not comparable.

The species from 1972 to 1975 were _Fragilaria crotonensis_, _F. pinnata_ and _Tabellaria flocculosa_ (Industrial BIO-TEST Laboratories, Inc. 1973, p. 92, 98; Everhart and Rasgus 1974, p. 5; and Festin 1975, p. 10, 21). Numerical abundance and percent composition of each of these three species varied from month to month and from year to year (Table 4.3.3.8). _F. crotonensis_ showed a trend of increased abundance from 1972 to 1975 while _F. pinnata_ and _T. flocculosa_ numbers fluctuated from year to year.

Populations of algae other than diatoms were low during most of the study but exhibited measurable increases in certain months (Figure 4.3.3.14). Green algae were always the second most diverse algal group but were present only in small numbers. Mean monthly abundance of the green algae and the cryptophytes never exceeded 120 reporting units/ml. The golden-brown algae were slightly more abundant during the spring months but declined before summer and remained in small numbers throughout the rest of the year. Cyanophytes were present in very small numbers throughout most of the year but produced a pulse in the summer. The summer blue-green pulse at the control area in 1974 was of the same magnitude as that of 1973 but occurred one month later.

Monthly variations in the populations of each non-diatom algal group were seasonal as indicated by their regularity of occurrence during all years of study (Figure 4.3.3.14). The periodicity in the control area followed a typical bimodal curve with maxima occurring in spring and in late summer or early fall during 1972 to 1975.

The seasonal trends observed in the Kewaunee control area were similar to the trends observed in other nearshore areas of western Lake Michigan (Figure 4.3.3.5 and Figure 4.3.3.14). This similarity indicated that KNPP operation has not had an effect upon the phytoplankton in the adjacent Lake Michigan waters.

In summary, results from phytoplankton studies at the control locations indicate that the phytoplankton community structure in the nearshore area of Lake Michigan outside the IDA has remained the same from the preoperational period (1972 to 1973) to the operational period (1974 to 1975). The predominant diatom populations exhibited spatial as well as temporal variability because of the seasonality of the dominant species. Large population changes from month to month and between years were largely attributable to the occurrence of _Fragilaria pinnata_. This organism, a deep water benthic diatom species, appeared to be established in the deeper offshore areas near KNPP from where it was scoured by the nearshore current and incorporated into the plankton. _F. crotonensis_ and _Tabellaria flocculosa_ were also dominant. Increased phytoplankton abundance from 1973 to 1974 was largely contributed by measurable increases in the number of these three species. The diatom changes at Kewaunee were indicative of yearly variation as similarly observed in the 33-year diatom populations at Chicago.

Populations of algae other than diatoms followed an established variability pattern at the control locations throughout the 1972-1975 period. These organisms were usually a very minor portion of the phytoplankton community and there was no detectable change in the species composition or densities from the preoperational to operational periods of study.

Phytoplankton periodicity was bimodal during the preoperational and operational period.

The data collected showed no manifest effects of the thermal discharge upon the regional phytoplankton community adjacent to KNPP.

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4.3.4 ZOOPLANKTON

4.3.4.1. Community Structure and Variability

The analyses of zooplankton population dynamics and community structure reported herein were based on analysis of samples collected in Lake Michigan in the vicinity of the KNPP from 1971 through July 1975 (Table 4.3.4.1, Figure 4.3.4.1). Samples were collected on three dates during 1971 using a Birge Net with a mesh aperture of 0.080 mm. Samples were collected during four months in 1972 using a conical plankton net with a mesh aperture of 0.153 mm hauled vertically through the water column. Collections were made on two successive days each sampling period and the results provided an excellent example of short-term variation in the zooplankton community. The sampling frequency in 1973 was changed to monthly collections from April through November and this was continued in 1974 and 1975. The conical net was used for all collections after 1972 with the mesh aperture being reduced from 0.153 mm in 1972 to 0.120 mm in 1973 and 0.064 mm in 1974 and 1975. Because of the decrease in mesh size, results were not directly comparable among years for all taxa.

Observations of the zooplankton assemblage were altered appreciably by changes made in mesh aperture through the study (Figure 4.3.4.2). The largest zooplankton densities were observed in 1974 and 1975. The major increases in density as a result of the mesh-size reduction were found among the rotifers and nauplii. Rotifer composition increased from a range of 2 to 65% of the zooplankton in 1973 to a range of 50 to 94% in 1974 and 1975. A similar change was observed for the copepods where the nauplii

Table 4.3.4.1. Summary of sampling locations and methods used for zooplankton studies in Lake Michigan near Kewuanee Nuclear Power Plant, 1971-1975.

		1971			1972								1973		1974	1975
Equipment		Birge net; radius 0.06 m, mesh aperture 0.080 mm			Conical net; radius 0.15 m, mesh aperture 0.153 mm								Conical net; radius 0.15 m, mesh aperture 0.120 mm		Conical net; radius 0.15 m mesh aperture 0.064 mm	Same as 1974
Number of replicates		6			2								4[a]		4[a]	4[a]
Location	Depth of tow	May 25	Aug 31	Nov 15	My 23	My 25	Ag 1	Ag 3	Sp 26	Sp 29	Nv 7	Nv 9	Apr 13	May-Nov	Apr-Nov	Apr-Jul
B	6 m	X	X	X												
C	6 m	X	X	X												
2	3 m													X	X	X
6	3 m												X	X	X	X
11	3 m				X	X	X	X	X	X	X	X	X	X	X	X
15	3 m												X	X	X	X
20	3 m													X	X	X
3	6 m													X	X	X
7	3 m				X	X	X	X	X	X	X	X	X			
7	6 m								X	X	X	X	X	X	X	X
12	3 m				X	X	X	X	X	X	X	X	X			
12	6 m				X	X	X	X	X	X	X	X	X	X	X	X
16	3 m				X	X	X	X	X	X	X	X	X			
16	6 m								X	X	X	X	X	X	X	X
21	6 m													X	X	X
4	9 m													X	X	X
8	3 m												X			
8	9 m												X	X	X	X
13	3 m				X	X	X	X	X	X	X	X	X			
13	6 m								X	X	X	X				
13	9 m				X	X	X	X	X	X	X	X	X	X	X	X
17	3 m												X			
17	9 m												X	X	X	X
22	9 m													X	X	X

[a] Each replicate was a composite of two net tows.

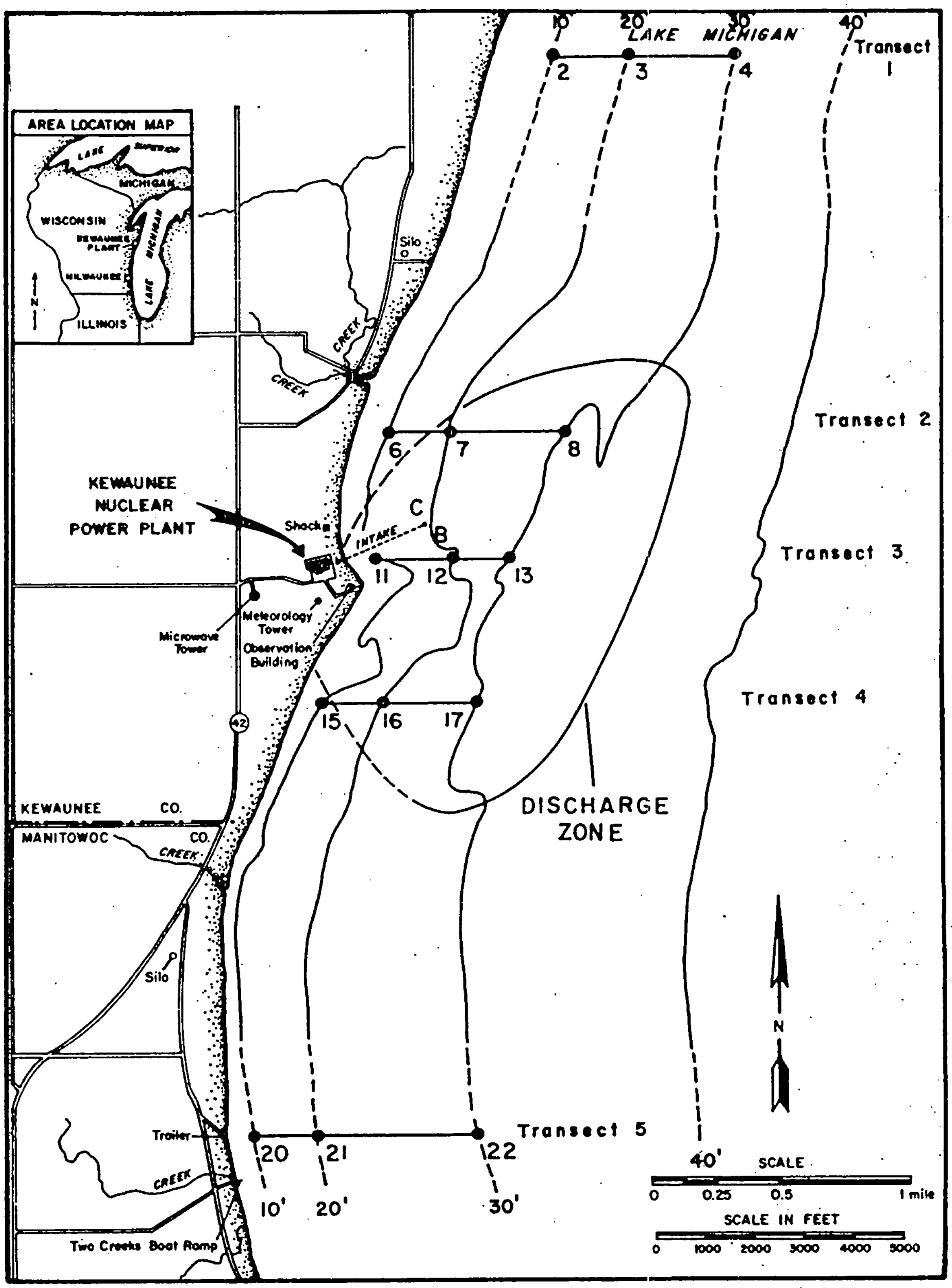

Figure 4.3.4.1. Sampling locations near the Kewaunee Nuclear Power Plant, 1971-1975.

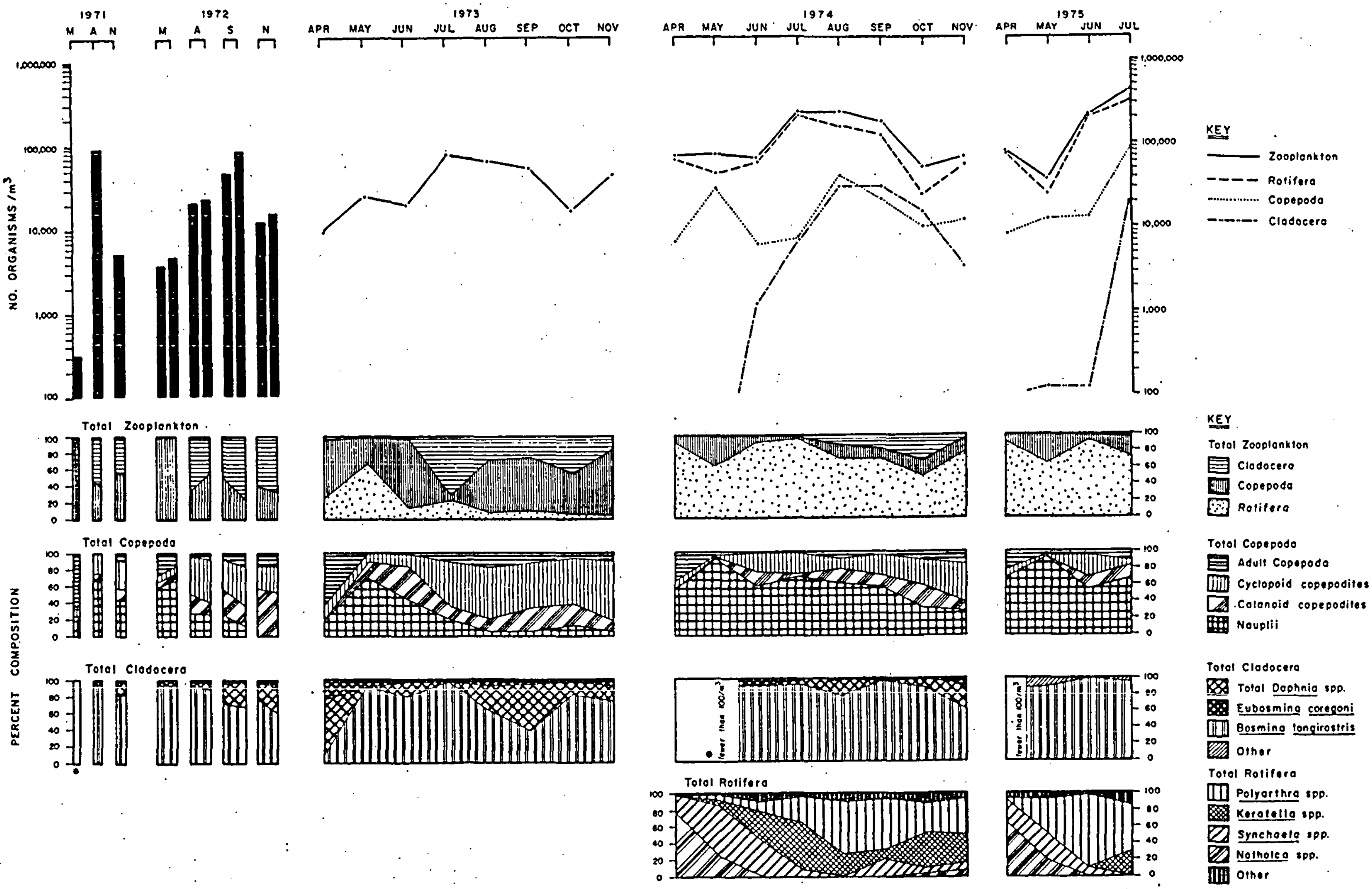

Figure 4.3.4.2. Population dynamics and community structure for total zooplankton, total Copepoda, total Cladocera, and total Rotifera, May 1971-July 1975.

composition increased from a range of 1 to 69% of the total Copepoda in 1972 and 1973 to 17 to 93% in 1974 and 1975. Changes in mesh size did not appreciably affect the results observed for the adult copepods and most of the Cladocera. The results for these groups were, therefore, comparable throughout the study period while improved collections of immature copepods and rotifers provided a more thorough analysis of the entire zooplankton community in 1974 and 1975.

General Considerations

Even though there were considerable differences in zooplankton density between years (partly due to sampling methods as discussed above) a basic pattern of seasonal fluctuation was obvious in all years (Figure 4.3.4.2). Density was lowest in early spring and increased to a maximum between mid-summer and early fall. In both 1973 and 1974, a decline occurred in mid-fall followed by an increase in November. Observations of the winter zooplankton community at other western Lake Michigan sites has revealed that the winter community ordinarily consists of copepods and rotifers with the rotifers numerically dominant (Schar, Urry and Carpenter 1975). The increase in the spring occurs in all groups but is especially pronounced among the shorter life cycled rotifers and Cladocera with a net increase in zooplankton abundance which often exceeds winter abundances by several orders of magnitude.

Fifty-two species of Crustacea and 28 Rotifera taxa were collected from 1971 through 1975 near KNPP (Table 4.3.4.2). For purposes of discussion, each taxon was categorized

Table 4.3.4.2. A list of zooplankton taxa found in the Kewaunee area from May 1971 through July 1975 including notes on the relative importance of each taxon.

Taxa	1971	1972	1973	1974	April-July 1975
Copepoda					
nauplii	D [a]	D	D	D	D
calanoid copepodites	D	D	D	D	D
cyclopoid copepodites	D	D	D	D	D
Cyclops bicuspidatus thomasi	D	SD [b]	D	SD	SD
Cyclops vernalis	SD	R [c]	R	R	R
Diaptomus ashlandi	* [d]	*	*	R	SD
Diaptomus minutus	*	*	*	R	R
Diaptomus oregonensis	*	*	*	R	R
Diaptomus sicilis	*	*	*	R	VR
Diaptomus siciloides	*	- [e]	VR [f]	VR	VR
Epischura lacustris	R	R	R	VR	VR
Ergasilus chautauquaensis	-	-	VR	-	-
Eucyclops agilis	-	-	VR	VR	VR
Eucyclops prionophorus	-	-	-	VR	-
Eurytemora affinis	SD	R	R	VR	VR
Lernaea spp.	-	-	-	VR	-
Limnocalanus macrurus	-	R	VR	R	R
Mesocyclops edax	R	VR	VR	VR	VR
Paracyclops fimbriatus poppei	-	VR	VR	-	-
Tropocyclops prasinus mexicanus	R	R	SD	R	R
Cladocera					
Acroperus harpae	-	-	-	VR	-
Alona barbulata	-	-	-	VR	VR
Alona circumfimbriata	-	-	-	VR	VR
Alona guttata	-	-	VR	VR	VR
Alona pulchella	-	-	-	VR	-
Alona quadrangularis	-	-	VR	VR	VR
Biapertura affinis	VR	-	VR	VR	VR
Bosmina longirostris	D	D	D	D	D
Camptocercus rectirostris	-	-	-	VR	VR
Ceriodaphnia lacustris	VR	-	VR	VR	VR
Ceriodaphnia quadrangula	VR	VR	VR	VR	VR
Chydorus gibbus	-	-	-	VR	-
Chydorus globosus	-	-	VR	-	-
Chydorus latus	-	VR	-	-	-
Chydorus piger	-	-	-	VR	-
Chydorus poppei	-	-	-	VR	-
Chydorus sphaericus	SD	R	SD	VR	VR
Daphnia galeata mendotae	VR	D	SD	R	VR
Daphnia longiremis	VR	SD	SD	VR	VR
Daphnia pulicaria	-	-	VR	-	-
Daphnia parvula	-	-	-	-	VR

Table 4.3.4.2. (continued)

Taxa	1971	1972	1973	1974	April-July 1975
D. retrocurva	D	D	SD	SD	VR
D. schødleri	-	-	VR	-	-
Diaphanosoma brachyurum	-	VR	VR	VR	-
Diaphanosoma leuchtenbergianum	-	VR	VR	VR	-
Disparalona rostrata	-	VR	-	VR	VR
Eubosmina coregoni	R	D	SD	R	R
Eurycercus lamellatus	-	VR	-	VR	-
Holopedium gibberum	R	SD	R	R	VR
Ilyocryptus spinifer	-	-	-	VR	-
Ilyocryptus sordidus	-	-	-	VR	-
Leptodora kindtii	VR	R	VR	VR	VR
Leydigia leydigi	-	-	VR	VR	-
Macrothrix laticornis	VR	VR	VR	VR	VR
Polyphemus pediculis	VR	VR	R	-	-
Rhynchotalona falcata	-	-	-	VR	-
Scapholeberis spp.	-	VR	-	-	-
Rotifera					
Anuraeopsis spp.				-	VR
Ascomorpha spp.				VR	-
Asplanchna spp.				R	R
Bdelloid Rotifera spp.				R	VR
Brachionus spp.				R	R
Cephalodella spp.				R	VR
Chromogaster spp.				R	-
Collotheca spp.				SD	VR
Conochilus spp.				SD	SD
Encentrum spp.				R	VR
Euchlanis spp.				R	VR
Filinia spp.				SD	R
Gastropus spp.				SD	R
Hexarthra spp.				VR	-
Kellicottia spp.				SD	SD
Keratella spp.				D	D
Lecane spp.				VR	VR
Lepadella spp.				-	VR
Mytilina spp.				VR	-
Monostyla spp.				R	VR
Notholca spp.				D	D
Notommata spp.				VR	VR
Ploesoma spp.				SD	D
Polyarthra spp.				D	D
Pompholyx spp.				VR	-
Synchaeta spp.				D	D

Table 4.3.4.2. (continued)

Taxa	1971	1972	1973	1974	April-July 1975
Trichocerca spp.				SD	R
Trichotria spp.				R	VR

[a] D = 15% or more of the total zooplankton.
[b] SD = 3 to 10% of the total zooplankton.
[c] R = Less than 3% of the total zooplankton.
[d] * = Only the males of these species were identified in 1971-1973. Occurrence was rare.
[e] - = Species did not occur in the samples.
[f] VR = Occasional or solitary.

according to its abundance as being either dominant, subdominant, rare or very rare. Taxa considered dominants constituted 15% or more of the zooplankton on at least one sampling date while a subdominant taxon usually constituted 3% to 14%. Rare taxa represented less than 3% of the community while very rare taxa were single or solitary specimens. The rare taxa were not discussed in detail except to establish the community structure.

The zooplankton community was usually dominated at any one time by a few taxa whose fluctuations in density were responsible for most of the variation in the community (Figure 4.3.4.2). Zooplankton community dynamics were dominated by the density fluctuations of four major genera of rotifers: *Notholca*, *Synchaeta*, *Polyarthra* and *Keratella*. Among the copepods, the immature taxa were most important with nauplii almost always the most abundant forms. *Bosmina longirostris* was the most influential cladoceran and had a pronounced effect on the total zooplankton in the summer. Another cladoceran, *Daphnia retrocurva* was dominant in 1972 (Total *Daphnia*, Figure 4.3.4.2) but since then, *B. longirostris* has been the only dominant cladoceran.

Subdominant taxa were important members of the zooplankton assemblage although they did not approach the densities characteristic of the dominant forms. *Cyclops bicuspidatus thomasi*, *C. vernalis*, *Diaptomus ashlandi* and *Tropocyclops prasinus mexicanus* were subdominant taxa as were *Daphnia galeata mendotae*, *Chydorus sphaericus* and *Eubosmina coregoni* in the Cladocera. Several rotifer genera such as *Filinia*, *Conochilus*, *Kellicotia* and *Ploesoma* were also included in this category.

Some subdominant taxa such as T. prasinus mexicanus and E. coregoni were more abundant in one year than another (Figure 4.3.4.2). Other taxa were occasionally dominant at one location but were of reduced importance when considered in the monthly mean. For example, Ploesoma was dominant at Location 11 in July 1975 while C. vernalis was important at Location 6 in July 1974.

Each of the taxa designated as rare or very rare in Table 4.3.4.1 was encountered in insufficient quantities for accurate population estimates or statistical analysis. Taxa, such as the diaptomid copepods, occurred at low densities but were important qualitative constituents of the pelagic plankton having produced the calanoid copepodites and some of the nauplii which were important numerical constituents. The dominant and subdominant taxa listed above were considered as the representative important species and they have received primary emphasis in the subsequent discussion.

There are no zooplankton species which can be considered unique to the Kewaunee area as nearly all the taxa listed are widespread in North America and most have been previously collected in Lake Michigan (Schar 1974 p.89-93; Gannon 1972 p.59-61; Stemberger 1973 p.11; and McGrath and Dvorak 1974 p. 114-115). No zooplankton species have been included on published rare or endangered species lists of the Great Lakes region. The only economic importance of the zooplankton is to serve as an intermediate step in the energy web from the primary producer to the secondary consumer. In this respect, the zooplankton community is important to the fish community as a food source as mentioned for individual fish species in Section 4.3.5.1. A review of the literature failed to produce and reported incidence of zooplankton species considered a nuisance. The fish parasites Ergasilus, and Lernaea, which become members of the plankton during part of their life cycles, occurred in the samples at extremely low densities but have not been reported as having an impact on Lake Michigan fish.

Long-Term Variations

The annual zooplankton density fluctuations observed near KNPP (Industrial BIO-TEST Laboratories, Inc. 1972 and 1973) were typical of long-term variations which have been observed elsewhere in Lake Michigan (McGrath and Dvorak 1974, Schar 1974 and Dvorak 1975). These variations included seasonal blooms in abundance that occurred at different times within a season and density maxima for total zooplankton and individual species that varied considerably between years.

The variable timing of a seasonal bloom was evident in the zooplankton data collected near KNPP in 1973 as compared to 1974 and 1975 (Figure 4.3.4.2). The spring bloom of Cladocera was underway when sampling was initiated in April 1973, while in 1974 and 1975, the bloom did not begin until May. The early appearance of the Cladocera was directly related to Daphnia longiremis which typically occurs in early spring and fall (Watson and Carpenter 1974 p.312-314).

Density variations can be quite large between years. Mean densities in July 1975 were twice as large as the densities in July 1974 which was the maximum density observed in that year.

Densities were higher in 1975 for all major groups which indicated that the increase was typical of the whole community and not just a few species.

Some zooplankton species in the Kewaunee area have been numerous during one year and not another. Tropocyclops prasinus mexicanus, Holopedium gibberum and Daphnia longiremis illustrated this phenomenon (Figure 4.3.4.3).

Tropocyclops prasinus mexicanus was very abundant in 1973 near KNPP (Urry 1974 p.25) as well as near the Donald C. Cook Nuclear Power Plant on southeastern Lake Michigan (Stewart 1974 p.296), the Zion Nuclear Power Plant near the Illinois and Wisconsin state lines (McGrath and Dvorak 1974 p.116 and 155-157) and the Point Beach Nuclear Plant just south of KNPP (WEPC and WMPC 1973 Chap. 6, p.168). In 1974, T. prasinus mexicanus was rarely encountered near KNPP (Urry 1975, p. 37) and a similar decline was also observed at Point Beach and Zion Nuclear Power Plants.

Maximum densities of Holopedium gibberum were considerably higher in 1971 through 1973 than they were in 1974. The decrease between 1971-1973 and 1974 was one order of magnitude. Stewart (1974 p.321) also reported that H. gibberum failed to produce a fall bloom in 1973 in contrast to 1971 and 1972 when densities were similar to those found near KNPP.

An atypical occurrence of Daphnia longiremis was observed in 1974 when summer densities were much lower than in previous years. The population was restricted to only an August maximum rather than occurring at moderate densities throughout the spring

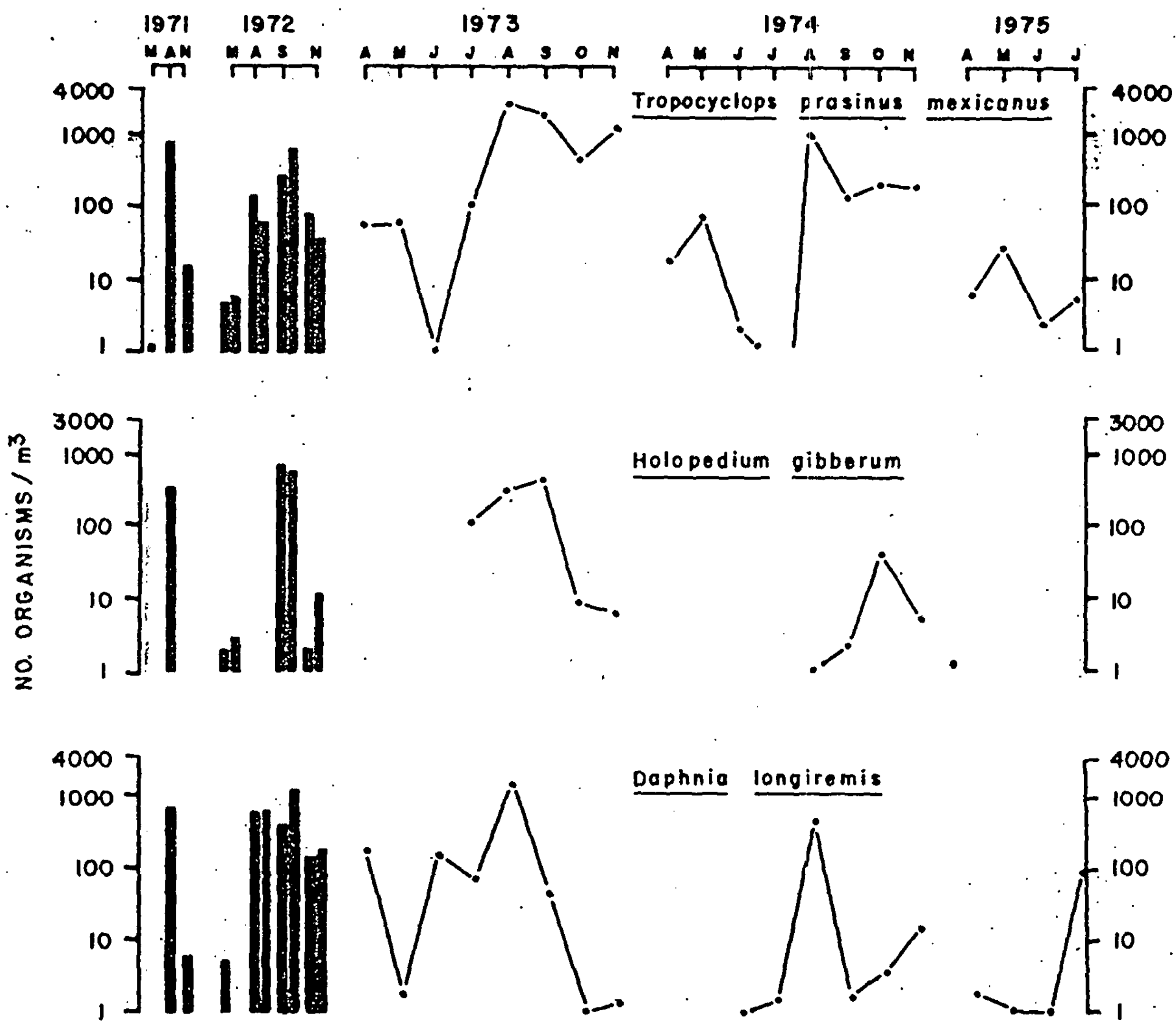

Figure 4.3.4.3. Population dymanics for three species of zooplankton in the Kewaunee area, May 1971-July 1975.

and summer. Results of sampling during the first four months of 1975 revealed a more typical pattern for the species as the seasonal bloom seemed to already be in progress.

These differences in annual production reflect variable environmental conditions such as food availability, seasonal temperatures and photoperiod. The timing and magnitude of blooms has been directly related to the heat content of water and the level of eutrophication (Patalas 1972 p.1456). Stewart (1974 p.251) attributed the differences in zooplankton population dynamics between 1972 and 1973 in southeastern Lake Michigan to differences in weather and concomitant variations in the phytoplankton community. Fish predation has also been found to affect zooplankton densities (Wells 1970 p.562, Zaret 1972).

Short-Term Variations

The preoperational study near KNPP in 1972 afforded an excellent opportunity to observe alterations in community or population density that occurred over a short time period (Industrial BIO-TEST Laboratories, Inc. 1973a). Statistically significant differences in density between closely spaced collection dates were detected in all sampling periods for most of the important taxa (Figures 4.3.4.2 and 4.3.4.3). On the community level, total zooplankton densities were almost twice as large on 29 September as on 26 September 1972 (Figure 4.3.4.2). These fluctuations were traceable to changes in the major groups and individual taxa. Within a four-day time span, the total cladoceran density nearly tripled due to greater numbers of *Daphnia* and *Bosmina*. A similar phenomenon occurred in August 1972, when total copepod densities tripled due to substantially higher numbers of Cyclops bicuspidatus thomasi (Figure 4.3.4.4).

These fluctuations were not indicative of actual zooplankton recruitment but rather of plankton patchiness as demonstrated by Ragotski and Bryson (1953). They found that zooplankton patches quickly shifted position in Lake Mendota in response to wind induced currents and resulted in wide daily fluctuations in population densities at their sampling locations. Variations of this magnitude have also been reported in western Lake Erie and were typical of the zooplankton community (Jahoda 1948).

Spatial Variation

Zooplankton may become concentrated in small areas or patches for varying reasons that are only partially understood. Large differences in population density among sampling locations have been commonly observed in the Kewaunee area throughout the study. Data from the 1972 preoperational monitoring program were used to illustrate patchiness near the surface of the water. Five locations in the area now considered the immediate discharge area were sampled from 10 feet to the surface on eight sampling days. Concentrations of organisms from 3 to 10 times more dense at one or two locations than at the other locations was a common occurrence. For example, the density of Tropocyclops prasinus mexicanus was 1000 organisms/m^3 at Location 12 on 26 September while densities at the four surrounding locations were only 95, 140, 24 and 120 organisms/m^3. A similar result was observed on 1 August when Eubosmina coregoni was four times more abundant at Location 13 than at any of the other locations.

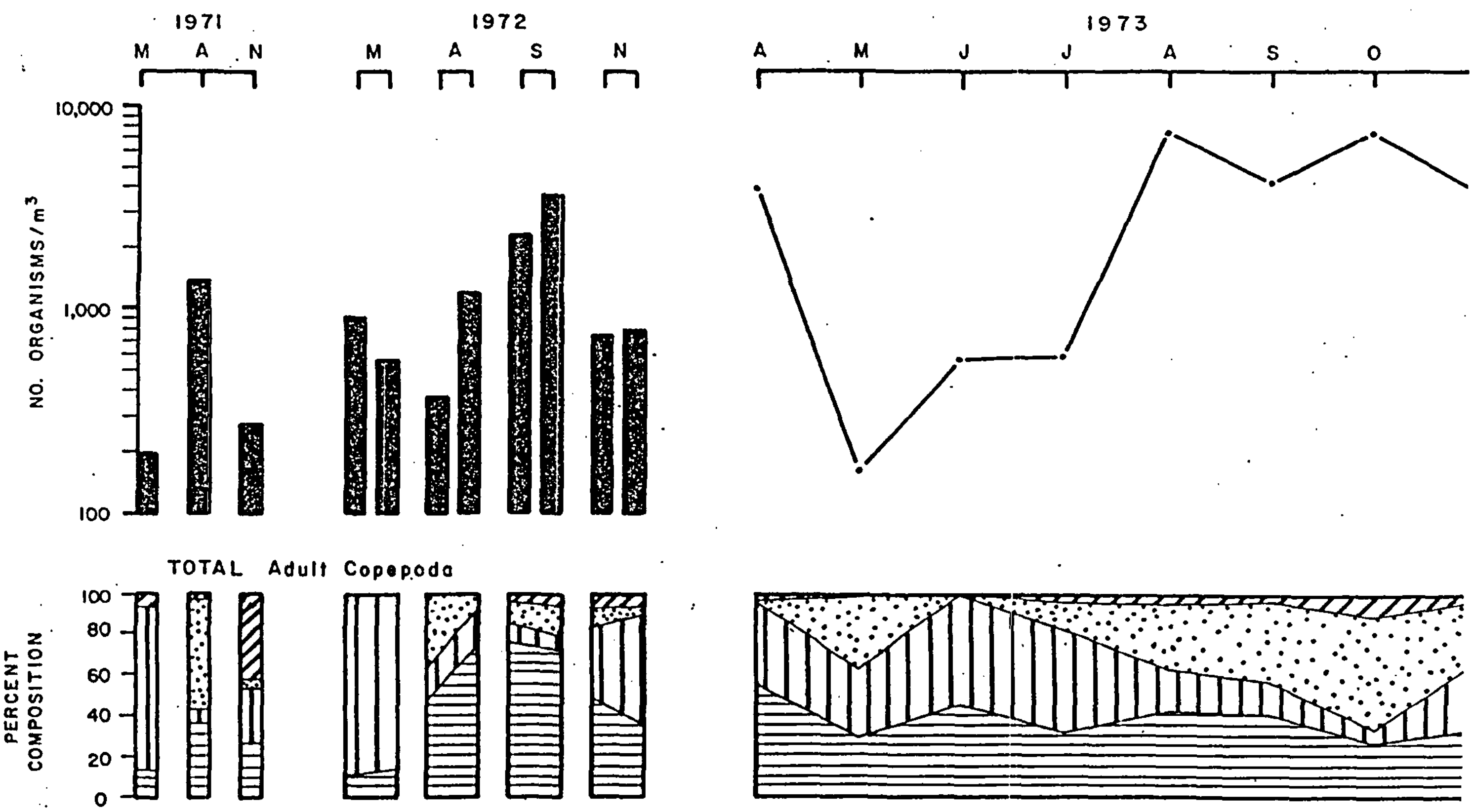

Figure 4.3.4.4. Population dynamics and community structure for Total Adult Copepoda in the vicinity of the KNPP, May 1971-July 1975.

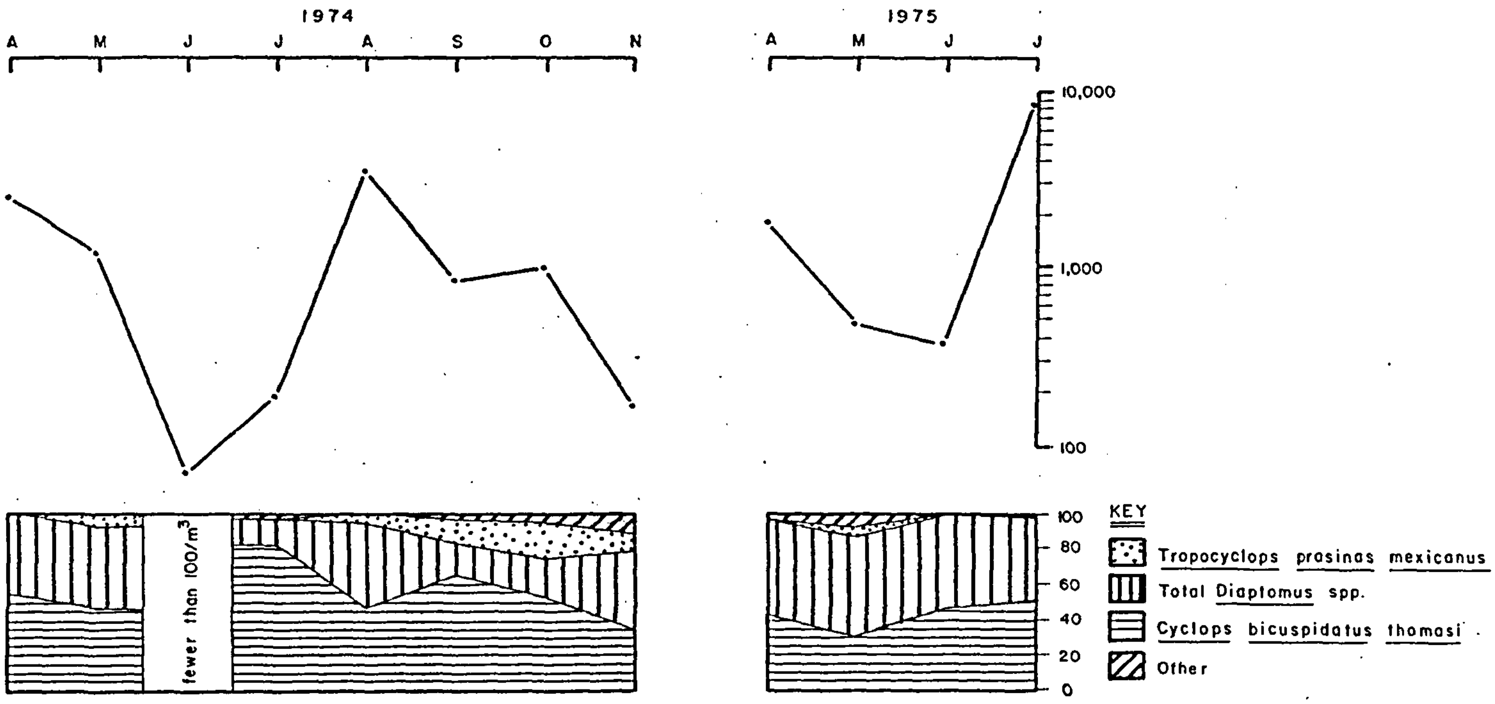

Figure 4.3.4.4 (Continued)

During the 1973, 1974 and 1975 studies, patchiness was repeatedly observed and statistically analyzed on a depth contour basis. The influence that a few species at a single location had on the zooplankton community was observed in October 1973 at Location 20 in relation to other locations on the 10 ft depth contour. High mean densities for the depth contour were attributable to significantly greater densities at Location 20 than at the other locations for *Cyclops bicuspidatus thomasi*, *Bosmina longirostris*, *Daphnia galeata mendotae* and *D. retrocurva*. Rotifera were also significantly more abundant at Location 20 than at three of the other locations of the depth contour. During August 1974, the greatest zooplankton density occurred at Location 15 and significant differences among the inshore contour locations were detected for many taxa and groups. These differences were typical of the population fluctuations observed throughout the study near KNPP. Patterns of density distribution could not be discerned since densities at one location were never found to be consistently higher or lower than at the other locations from month to month.

Several explanations were available for the density extremes observed in the zooplankton near KNPP. Ragotski and Bryson (1953) investigated the effects of wind driven currents on the distribution of *Daphnia pulex* in a small area of Lake Mendota, Wisconsin. They found that eddies, which led to local upwellings, concentrated organisms in small patches at a density several orders of magnitude greater than in the surrounding water. This was the most probable explanation for much of the variability observed near KNPP since local upwellings of profundal waters occurred frequently during the summer (Section 4.1.5).

Another possible explanation for the density extremes observed among Cladocera and Rotifera at Kewaunee was contained in a study by King (1972 p.415). Using laboratory cultures of the rotifer Euchlanis dilitata as an example, he advanced the theory that a clone of a rotifer species was able to take advantage of conditions in a small water mass to magnify its population enormously in a short time. Each clone had the ability to flourish in a given set of seasonal conditions because of a genetically predetermined physiological adaptation. These genetically determined adaptive modes produced population maxima in one clone under a different set of conditions than would produce maxima in another clone. When environmental conditions reached a certain point, the hatching of resting eggs was triggered and a huge population might emerge in a short time.

Swarming of zooplankton was another possible cause for the patchiness observed in the Kewaunee area. Ratzlaff (1974 p.994) studied swarming among Moina affinis. He collected clumps (284 organisms/ml) composed almost entirely of mature M. affinis that were males, epphipial females and parthenogenic brooding females. In the surrounding area, the M. affinis population composed 26% of the zooplankton and consisted of parthenogenic females, immature females and a few males.

Considering the above explanations, it can be concluded that the local variations in density observed near KNPP were typical of the zooplankton community and may have been due to many natural factors.

4.3.4.2 Review of Observations of Condenser Passage Effects on Zooplankton

Zooplankton entrained through the condensers at Kewaunee Nuclear Power Plant were monitored from March 1973 through July 1975. The effects of condenser passage on zooplankton have been divided into three categories: mechanical effects related to the physical trauma of being entrained and forced through sequences of pumps and condenser tubes prior to being ejected back into the lake; thermal effects resulting from the sudden increase in water temperature which occurs in the condenser tubes; and plume effects from the mixing of heated discharge and ambient lake water. The effects of entrainment have been determined by examining zooplankton before and after condenser passage under a variety of plant operating conditions. In each case, survival analyses were conducted immediately after sample collection and at four hours to take account for possible recovery from temporary shock after condenser passage. Immotility (0 hr) was defined as the absence of appendicular and visceral movement upon probing while the term mortality denoted those organisms which failed to recover (become motile) after four hours.

Plant Entrainment

Mechanical Effects

The mechanical effect of condenser passage on entrained zooplankton was determined from March 1973 through April 1974 when the Kewaunee Nuclear Power Plant was circulating cooling water with no ΔT (no power being generated). During that period, entrained zooplankton immotilities (0 hr) ranged from 0.7% to 10.7%, averaging 6.0% (Table 4.3.4.3). Zooplankton mortalities as observed four hours after condenser passage averaged 4.5% (4 hrs) indicating a recovery of 25% of the initially immotile organisms. Entrained populations of dominant copepods, such as immature copepods, and Cyclops bicuspidatus thomasi averaged 3.0% immotility while Diaptomus ashlandi, D. minutus and D. oregonensis averaged 8.2% immotility. The dominant cladoceran, Bosmina longirostris, averaged 2.7% immotility (Wetzel and Restaino 1974 Chap. 6, p.8-16, Wetzel 1975 Chap. 6, p.10-18). Studies at Waukegan Generating Station and Zion Nuclear Station located on the southwest shore of Lake Michigan showed that entrained zooplankton immotilities averaged 6.0% and 7.8%, respectively, when the stations were operating at 0% turbine capacity (no ΔT) (Industrial BIO-TEST Laboratories, Inc. 1972b p.39 and Restaino et al. 1975a p.39). These results were similar to those observed at Kewaunee Nuclear Power Plant and are indicative of zooplankton immotility at power plants operating without heat ejection (no ΔT).

Thermal and Mechanical Effects

The combined effects of thermal and mechanical factors on zooplankton during condenser passage were determined from May 1974 through July 1975. Differences in immotility between intake and discharge samples were significant in 11 of 14 months with individual values ranging from 0.5% to 14.2% and averaging 9.4% (Table 4.3.4.4). Zooplankton mortality as noted four hours after entrainment averaged 8.5%. Recovery

Table 4.3.4.3. Differential mortality of crustacean zooplankton between intake and discharge without heat production with corresponding water temperatures and turbine capacities, Kewaunee Nuclear Power Plant, March-December 1973 and January-April 1974.

Sampling Date	Temperature (°C) Intake	Temperature (°C) Discharge	Turbine Capacity	Hours Analyzed	Percents: Immotility Intake (Location 1)	Percents: Mortality Discharge (Location 2)	Percent Differential Mortality
1973							
27 March	3.8	3.9	0	0[a]	7.3	16.7	9.4*[b]
				4	7.4	13.8	6.4*
24 April	7.2	7.2	0	0	2.1	9.0	6.8*
				4	3.8	11.1	7.2*
15 May	8.5	8.5	0	0	3.6	7.2	3.6*
				4	3.0	6.5	3.5*
19 June	10.0	10.0	0	0	8.1	13.3	5.2*
				4	7.8	10.0	2.2
17 July	12.8	12.8	0	0	3.2	13.9	10.7*
				4	5.8	9.7	3.9
14 August	10.3	10.3	0	0	4.3	10.9	6.5*
				4	8.1	12.0	3.9
4 September	8.5	8.5	0	0	7.1	7.7	0.7
				4	10.8	10.4	0.0
23 October	8.9	8.9	0	0	3.6	6.8	3.2
				4	3.1	7.7	4.7*
18 November	6.8	6.8	0	0	3.6	10.3	6.6*
				4	3.9	15.4	11.5*
18 December	0.0	0.0	0	0	7.0	15.5	8.6*
				4	8.3	15.5	7.2*

Table 4.3.4.3. (continued)

Sampling Date	Temperature (°C) Intake	Temperature (°C) Discharge	Turbine Capacity	Hours Analyzed	Percents Immotility Intake (Location 1)	Percents Mortality Discharge (Location 2)	Percent Differential Mortality
1974							
21 January	0.9	0.9	0	0	5.0	9.4	4.4*
				4	6.9	9.8	2.9
18 February	0.5	0.5	0	0	3.0	11.3	8.3*
				4	6.0	5.3	0
5 March	1.7	2.0	0	0	1.7	8.9	7.2*
				4	1.8	9.5	7.7*
2 April	1.7	1.7	0	0	5.2	7.3	2.1
				4	8.4	10.4	2.0

a 0 Immotility
4 Mortality

b *Chi-Square Test Significant at the 0.05 level.

Table 4.3.4.4. Differential mortality of crustacean zooplankton between intake and discharge during heat production with corresponding water temperatures and turbine capacities, Kewaunee Nuclear Power Plant, May-December 1974 and January-July 1975.

Sampling Date	Temperature (°C) Intake	Temperature (°C) Discharge	Turbine Capacity	Hours Analyzed	Percents Immotility Intake (Location 1)	Percents Mortality Discharge (Location 2)	Percent Differential Mortality
1974							
21 May	10.0	18.0	72	0[a]	5.5	13.7	8.2*[b]
				4	9.9	19.3	9.4*
11 June	7.3	15.2	84	0	6.5	11.9	5.4*
				4	5.2	15.0	9.8*
29 July	11.8	19.0	97	0	11.5	17.5	6.0*
				4	9.6	27.2	17.6*
28 August	14.3	24.1	100	0	1.5	12.8	11.3*
				4	6.8	15.9	9.1*
16 September	16.2	26.0	100	0	13.3	26.5	13.2*
				4	15.4	30.2	14.8*
21 October	4.5	13.5	64	0	4.7	11.1	6.4*
				4	4.4	10.5	6.1*
11 November	9.0	16.7	75	0	2.5	12.5	10.0*
				4	3.3	9.8	6.5*
9 December	2.0	14.5	77	0	5.5	17.6	12.1*
				4	14.1	15.6	1.5
1975							
13 January	1.0	12.5	75	0	5.2	16.2	11.0*
				4	4.8	16.0	11.1*
10 February	1.0	14.0	95	0	6.4	14.5	8.0*
				4	7.6	13.7	6.2*

Table 4.3.4.4. (continued)

Sampling Date	Temperature (°C) Intake	Temperature (°C) Discharge	Turbine Capacity	Hours Analyzed	Percents Immotility Intake (Location 1)	Percents Mortality Discharge (Location 2)	Percent Differential Mortality
17 March	4.0	19.0	99	0	5.0	14.0	9.0*
				4	6.6	15.5	8.9*
14 April	4.5	19.4	99	0	3.1	17.3	14.2*
				4	6.8	14.3	7.5*
19 May	9.7	15.9	63	0	7.6	15.0	7.4*
				4	2.7	13.3	10.6*
16 June	10.5	18.2	87	0	8.6	9.1	0.5
				4	9.7	7.5	0.0
14 July	18.3	27.8	91	0	3.2	21.2	18.0*
				4	8.1	17.2	9.1*

[a] 0 Immotility
4 Mortality

[b] * Chi-Square Test Significant at the 0.05 level.

from thermal and mechanical shock of condenser passage occurred on 9 of 15 sampling periods.

Nauplii and cyclopoid copepodites were less susceptible to thermal effects during entrainment than were calanoid copepodites. Nauplii averaged 6.4% immotility and 9.2% mortality from May through August 1974 and April through July 1975 during the periods of highest population density (Figure 4.3.4.5). Calanoid copepodites averaged 12.8% immotility and 12.9% mortality, from May 1974 through July 1975, while cyclopoid copepodites averaged 9.3% immotility and 8.6% mortality. Calanoid copepodite immotilities and mortalities prior to thermal additions (March 1973 through April 1974) averaged 0.3% and 7.1%, respectively.

Copepodites (calanoid and cyclopoid) appeared most susceptible to condenser passage effects on 28 August averaging 33.9% immotility when their populations constituted only 7.6% of the zoopankton community (microcrustacea).

The adult copepod, _Cyclops bicuspidatus thomasi_, averaged 12.5% immotility and 9.4% mortality from May 1974 through May 1975 (Figure 4.3.4.6). When _C. bicuspidatus thomasi_ densities averaged 4% of the zooplankton community (microcrustacea) in August and September 1974 and May 1975, immotility and mortality were highest ranging between 15% and 33%. _Diaptomus oregonensis_ averaged 17.3% immotility and 13.4% mortality. Immotility and mortality varied from 5.7% and 0.0%, respectively, in May 1975 to 42.2% and 20.0%, respectively, in August 1975.

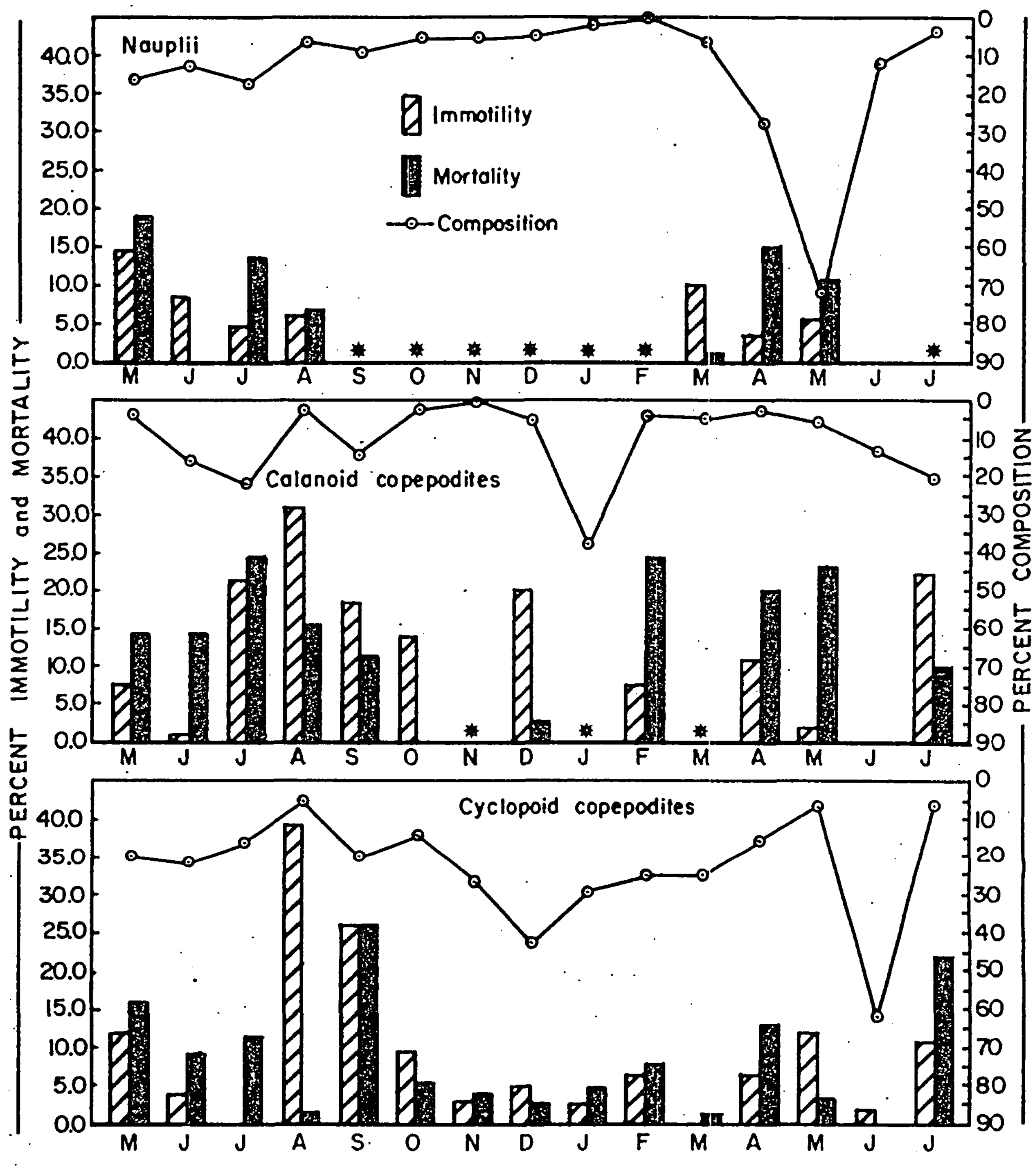

Figure 4.3.4.5. Effects of condenser passage on immature zooplankton, Kewaunee Nuclear Power Plant, May 1974 through July 1975. (asterisk indicates insufficient numbers for calculations.)

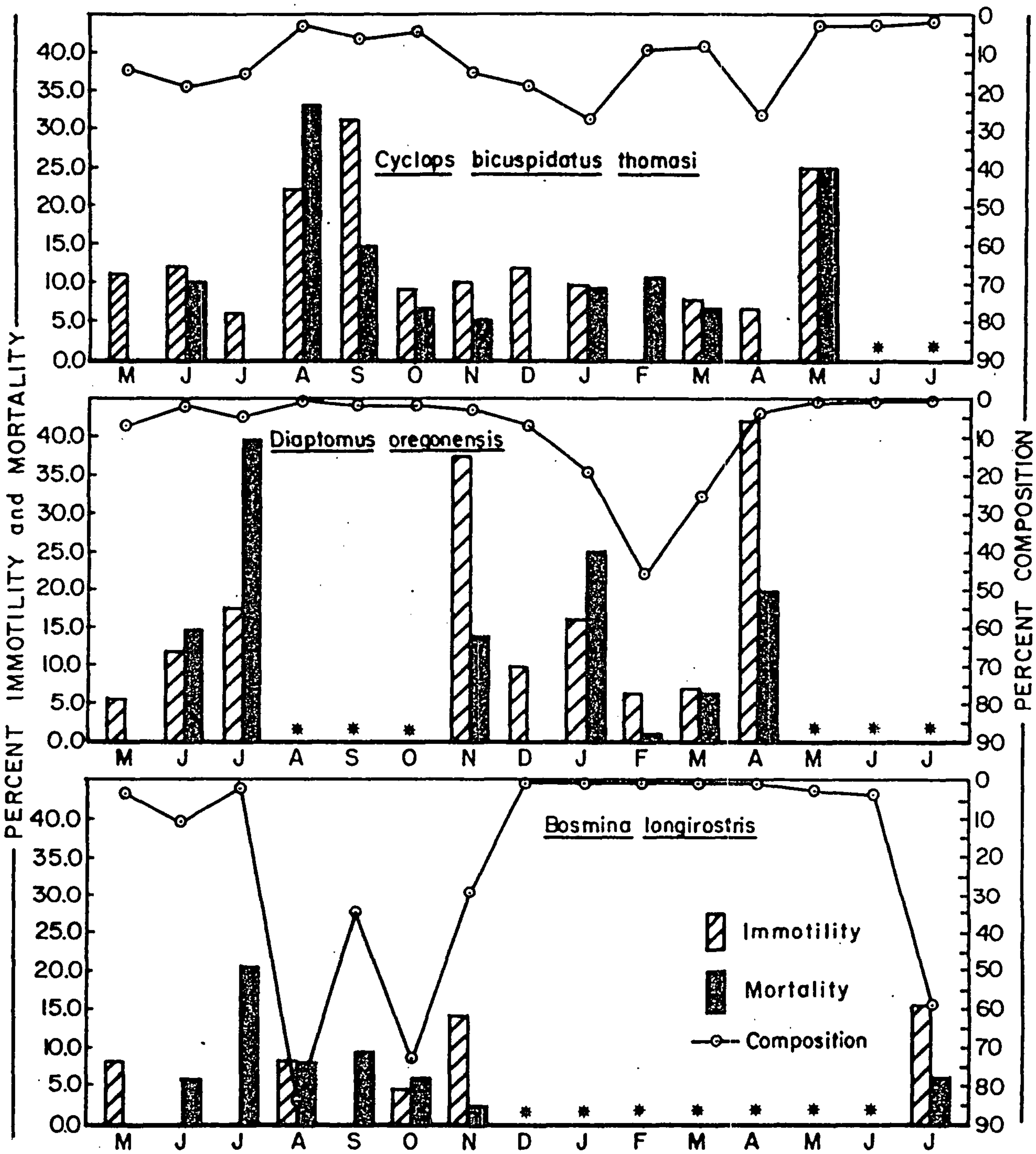

Figure 4.3.4.6. Effects of condenser passage on abundant adult zooplankton, Kewaunee Nuclear Power Plant, May 1974 through July 1975. (asterisk indicates insufficient numbers for calculations.)

The predominant cladoceran, Bosmina longirostris, averaged 6.3% immotility and 7.3% mortality after condenser passage from May through November 1975 and during July 1975.

There appeared to be no direct correlation between increases in temperature across the condensers (ΔT) and zooplankton immotilities. Highest zooplankton immotilities (18.0%) occurred in July 1975 when the ΔT across the condenser was 9.5 C (17.1 F) (Table 4.3.4.3). When the ΔT across the condensers reached a maximum of 15.0 C (27.0 F), zooplankton immotility was 9.0%. Intake-discharge studies at Waukegan Generating Station showed that zooplankton were not adversely affected when exposed to temperature increases (ΔT) from 5.5 C to 12.5 C (9.9 F to 22.5 F) above ambient (Industrial BIO-TEST Laboratories, Inc. 1972 p.37). Similar results were reported by Restaino et al. (1975 p.42) for the Zion Station when zooplankton were exposed to temperature increases (ΔT) from 5.0 C to 11.0 C (9.0 F to 19.8 F). The direct effects of thermal shock may not be detrimental as long as discharge water temperatures do not surpass the upper lethal temperature of entrained organisms (Youngs 1970 p.315-354). The lethal temperature limits of zooplankton for which this data is known are presented in Table 4.3.4.5. It can be seen that the majority of the species have thermal limits for in excess of the worst case conditions defined in the technical specifications for KNPP (Section 4.1).

Organisms exposed to temperature changes within their range of tolerance have been shown to adjust to new conditions by altering various metabolic functions (Warren 1971 p.105).

Table 4.3.4.5. Zooplankton lethal temperature limits (°C).

Taxon	Lethal Limit	Developmental Maximum	Optimal Growth	Reference
Cladocera				
Alona spp.	40.6			Jensen et al. 1969
Bosmina longirostris		21-22		Bhajan and Hynes, 1972
Ceriodaphnia laticaudata	42.8			Altmann and Dittmer, 1966
Chydorus sphaericus	35-36		23	Smirnov, 1971
Daphnia longispina	42.2	35		Altmann and Dittmer, 1966
D. magna	41.1			Brown, 1929
D. pulex	43.9	35		Altmann and Dittmer, 1966
	41.1			Brown, 1929
Macrothrix rosea	50			Altmann and Dittmer, 1966
				Brown, 1929
Moina rectirostris	47.2			Altmann and Dittmer, 1966
Simocephalus vetulus	42.8			Altmann and Dittmer, 1966
Copepoda				
Cyclops bicuspidatus thomasi	33.9		15	Armitage and Tash, 1967
				Krueger, 1973
C. serrulatus	30-38			Altmann and Dittmer, 1966
C. vernalis	28.9-38	38	20-23	Coker, 1934
				Hunt, 1972
Diaptomus spp. (mixture of *ashlandi*, *minutus*, *oregonensis*, *sicilis*)	32.2			Krueger, 1973
Mesocyclops leuckarti			22	Andrews, 1953
Rotifera				
Brachionus			20	Nayar, 1965
Euchlanus		19-27		Edmondson, 1946
		23		King, 1970
Lecane		27-29		Edmondson, 1946
Synchaeta			15-16	Edmondson, 1946

Studies have shown that condenser water temperature below a critical level of 35.0 C (95.0 F) for exposure time under five minutes during the summer does not cause substantial mortality (Bader and Roessler 1971 p.1-29, Churchill and Wojtalik 1969 p.80-86 and Krueger 1975 p.66-83). Based on the low number of zooplankton affected by entrainment at Kewaunee Nuclear Power Plant, temperatures beyond the tolerance range for zooplankton were not reached during condenser passage.

Mechanical effects of condenser passage accounted for most immotilities when compared to the combined thermal and mechanical effects (Figure 4.3.4.7). When the plant was operating at 0% turbine capacity (no ΔT), mechanical effects during entrainment were more detrimental to large organisms (>0.95 mm) than to small ones (<0.5 mm) and percent immotility varied directly with zooplankton species size from March 1973 through April 1974 (Wetzel 1975 p.15). Organisms less than 0.05 mm in length, such as nauplii, cyclopoid copepodites and Bosmina longirostris averaged 3.3% differential immotility while organisms exceeding 0.95 mm such as Diaptomus ashlandi, D. oregonensis and Daphnia retrocurva had a 9.8% mean differential immotility.

Binomial regression analyses of zooplankton immotility at the intake and discharge showed that immotility of entrained organisms was a linear function of species size when heat was not exchanged across the condenser (Figure 4.3.4.8 and Table 4.3.4.6). Similar results were obtained at Zion Station (Restaino et al. 1975 p.45), Waukegan Generating Station (Industrial BIO-TEST Laboratories,

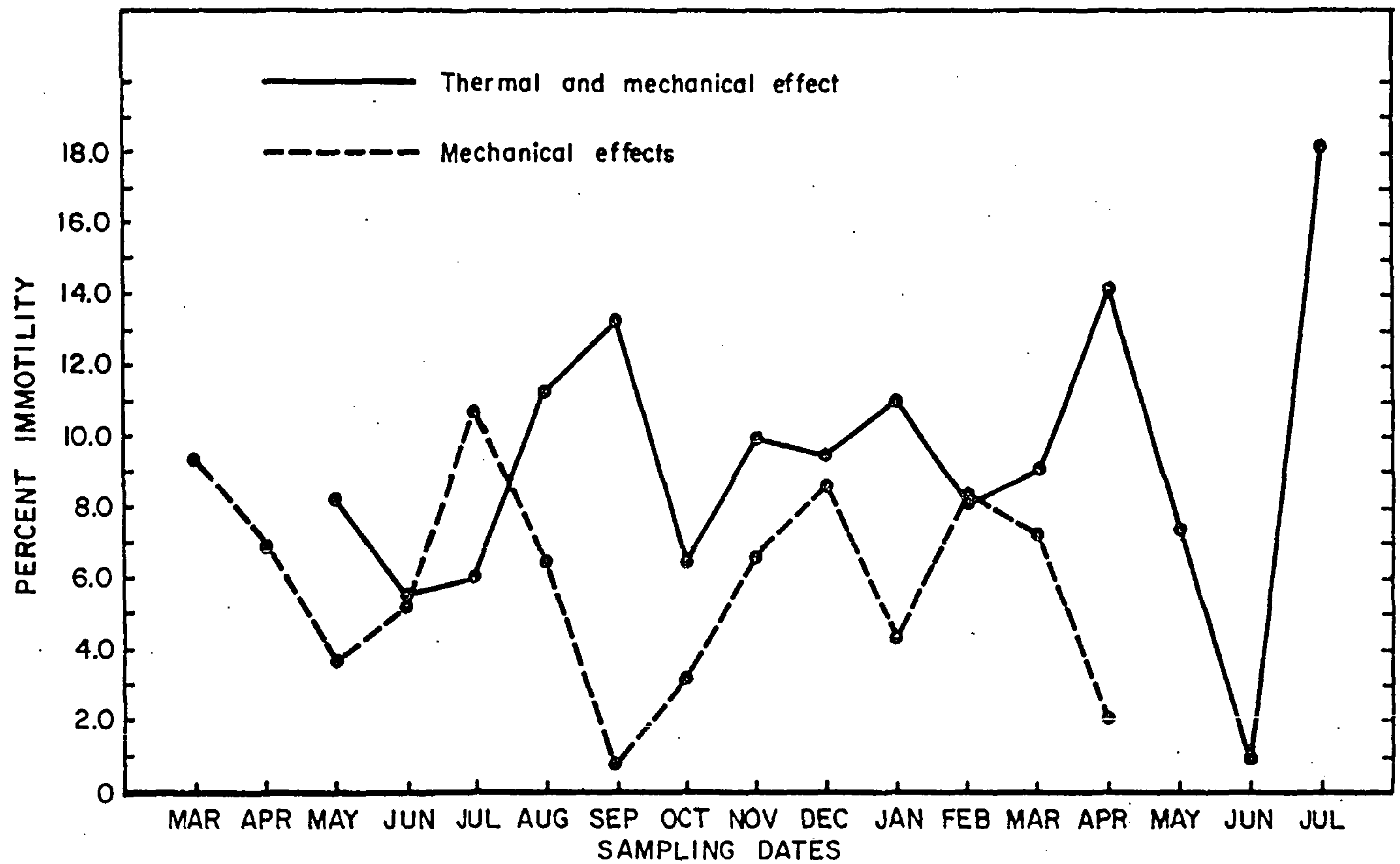

Figure 4.3.4.7. Percent immotility with and without thermal exchange across the condensers, Kewaunee Nuclear Power Plant, March 1973 through July 1975.

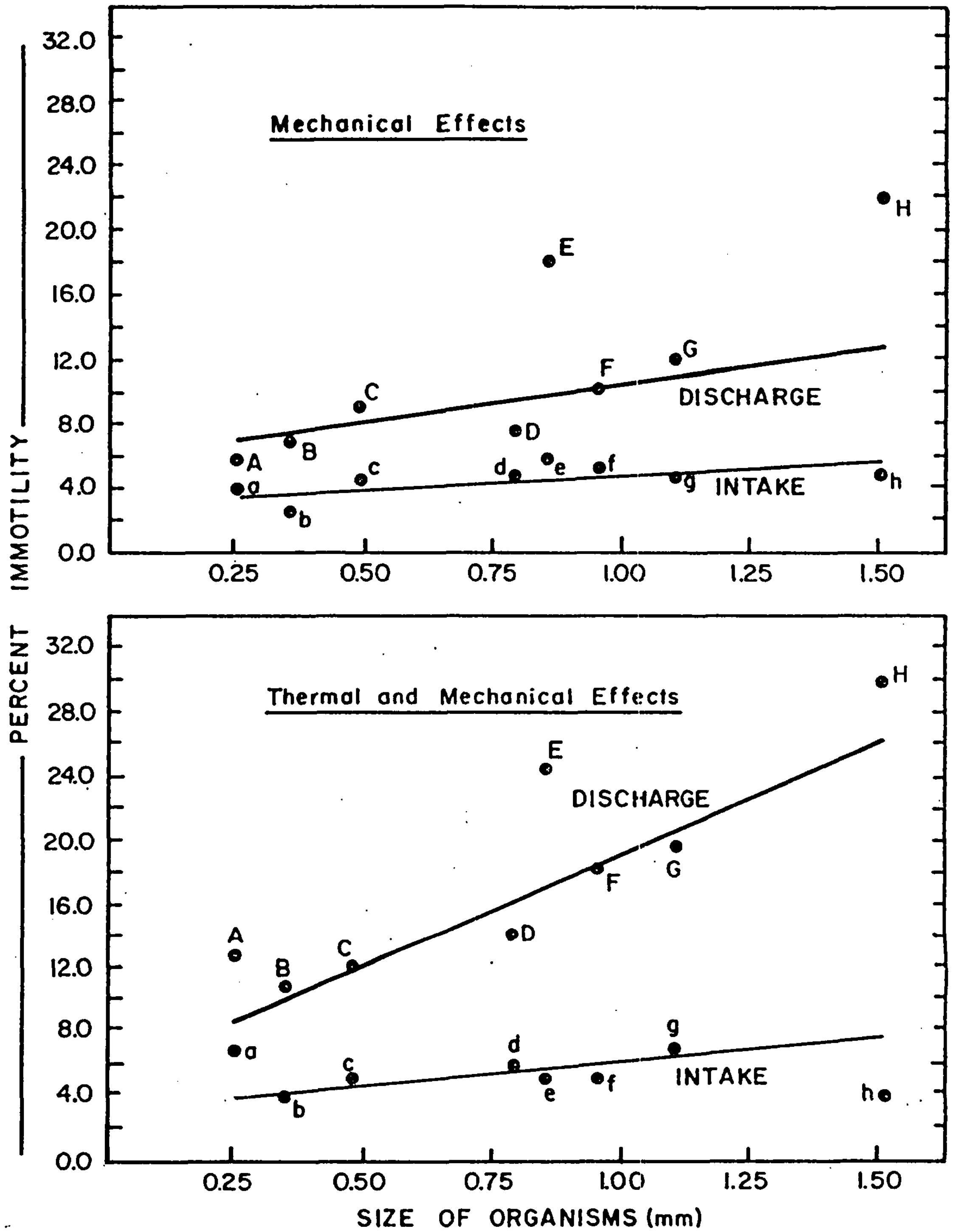

Figure 4.3.4.8. Binomial regression analysis of condenser passage effects on zooplankton with and without heat exchanged across the condensers, Kewaunee Nuclear Power Plant, March 1973 through July 1975. (Letters are referenced in Table 4)

Table 4.3.4.6. Typical zooplankton length values for organisms which are dominant at Kewaunee Nuclear Power Plant, as obtained from the references indicated.

Organisms	Symbol	Mean Size (mm)	Range (mm)	Reference
nauplii	a,A[a]	0.25	0.15-0.35	Gannon 1971 (Personal communication)
Bosmina longirostris	b,B	0.34	0.28-0.42	Gannon 1971 (Personal communication)
cyclopoid copepodites	c,C	0.47	0.35-0.58	Gannon 1971 (Personal communication)
Cyclops bicuspidatus thomasi	d,D	0.78	0.57-0.96	Gannon 1971 (Personal communication)
Diaptomus minutus	e,E	0.85	0.78-0.90	Wells 1970
Diaptomus ashlandi	f,F	0.95	0.90-1.00	Wells 1970
Diaptomus oregonensis	g,G	1.10	1.00-1.20	Gannon 1971 (Personal communication)
Daphnia retrocurva	h,H	1.50	1.30-3.00	Edmondson 1959

[a] Symbol used for Figure 4.3.4.8.

Inc. 1972b p.39) and North Omaha Power Station (Industrial BIO-TEST Laboratories, Inc. 1973b p.129). Thermal and mechanical effects of condenser passage monitored from May 1974 through July 1975 resulted in 6.8% differential immotility for representative zooplankton species smaller than 0.50 mm in length and 13.8% immotility for species larger than 0.95 mm in length. A comparison of binomial regression analyses showed that entrainment effects with thermal additions were greater than effects of entrainment without heat. In other words, the combined thermal and mechanical effects of condenser passage were slightly greater than mechanical effects alone. This indicates that mechanical damage was the primary factor of zooplankton immotility during entrainment while Kewaunee Nuclear Power Plant was operating. The combined thermal and mechanical effects contributed to immotility of zooplankton in all size categories with larger organisms (>0.95 mm) being less tolerant of the thermal stress than smaller ones (<0.50 mm).

Plume Entrainment

Plume entrainment of zooplankton was monitored from May through November 1974 and during April and May 1975. These locations were not geographically fixed from month to month but were repositioned in relation to the plume on each sampling trip. Samples were collected at three feet depth within the plume (Locations E3 and E4) and at control locations E0 and E5. Location E0 was three feet from the lake bottom near the intake structure and E5 was three feet from the lake surface outside the plume influence. Average immotilities at control locations E0 and E5 were

6.2% and 8.7%, respectively (Table 4.3.4.7). Plume locations E3 and E4 had mean immotilities of 13.0% and 12.3% while immotilities averaged 15.3% at Location E2 (discharge). Decreases in percent immotility were apparent as discharge outflow mixed with lake water which diluted the higher concentrations of immotile organisms observed at the discharge (Location E2). A dilution effect also was observed after the four-hour holding period as total zooplankton mortality decreased from 16.4% at Location E2 to 13.9% and 13.1% at Locations E3 and E4, respectively. Mortalities at Locations E0 and E5 averaged 9.7% and 11.4% (Table 4.3.4.7). Based on the observed percent immotility and mortality, plume entrainment appeared to have had no adverse effect on zooplankton viability.

Similar decreases in percent immotility were observed among plume entrained zooplankton at Allen Steam Plant located on Lake Wylie, North Carolina (Restaino 1975b p.668-670). Total zooplankton (microcrustacea) immotility decreased from 43% at the discharge to 20.8% in the mixing zone of discharge and lake water where water temperatures ranged from 5.5 C to 9.0 C above ambient. Where plume temperatures ranged from 1.0 C to 5.0 C above ambient, mean zooplankton immotility further decreased to 15.2%.

Thermal tolerance studies on Lake Michigan zooplankton *Cyclops bicuspidatus thomasi* and *Diaptomus* spp. revealed that thermal conditions approached tolerance limits only at ambient lake temperature of 20 C (68.0 F) or more (Krueger 1975 p.76-83). Median 24-hour lethal temperatures (LT50s) for *Diaptomus* spp. ranged from

Table 4.3.4.7. Percent immotility and mortality of crustacean zooplankton among lake locations, Kewaunee Nuclear Power Plant, May-November 1974 and April-July 1975.

Total Zooplankton (Microcrustacea)	Hours Analyzed	Percent Immotility and Mortality Among Locations				
		E0	E2	E3	E4	E5
1974						
21 May	0	4.2	13.7	9.4	4.4	16.9
	4	11.3	19.3	15.7	7.4	5.3
11 June	0	8.5	11.9	10.1	15.5	10.9
	4	7.6	15.0	17.2	14.4	19.6
29 July	0	8.2	17.5	12.4	9.4	12.4
	4	10.2	27.2	11.7	9.2	5.3
28 August	0	5.4	12.8	14.5	11.1	3.1
	4	9.7	15.9	15.4	12.1	16.3
16 September	0	6.3	26.5	19.5	12.7	10.7
	4	21.3	30.2	11.1	16.4	19.9
21 October	0	8.8	11.1	10.7	11.5	7.3
	4	8.6	10.5	10.5	9.9	8.0
11 November	0	2.8	12.5	15.3	8.5	4.1
	4	9.7	9.8	12.8	8.8	8.6
1975						
14 April	0	6.9	17.3	18.9	20.3	8.2
	4	7.0	14.3	19.2	19.6	9.7
19 May	0	7.7	15.0	9.1	19.7	8.0
	4	7.8	13.3	10.7	13.4	8.4

Table 4.3.4.7. (continued)

Total Zooplankton (Microcrustacea)	Hours Analyzed	Percent Immotility and Mortality Among Locations				
		E0	E2	E3	E4	E5
16 June	0	3.0	9.1	11.3	8.3	4.6
	4	5.8	7.5	14.8	9.0	9.7
14 July	0	5.9	21.2	12.0	13.6	9.8
	4	7.9	17.2	13.4	24.0	14.8

28.4 C to 36.2 C when the organisms were acclimated to temperatures from 1 C to 15 C (32 F-59 F). LT50 for Diaptomus spp. at 20 C acclimation was 30.0 C (86.0 F) for 60 minutes exposure.

Median effective temperatures (ET50s) at which 50% of Cyclops bicuspidatus thomasi experienced shock but did not die ranged from 23.3 C to 33.9 C (73.9 F-93.0 F) when the organisms were acclimated to temperatures between 5 C and 25 C. The plume temperature on 14 July 1975 was 23 C (73.4 F) and approached ET50 levels for C. bicuspidatus thomasi. During this time, the organism comprised only 1.7% of the microcrustacea assemblage. Since LT50s for C. bicuspidatus thomasi would be even greater than the 23 C ET50s, few if any mortalities would result from heat shock.

Cold shock effects might result from complete plant shutdown. The presence of zooplankton in the plume is transitory with the entrained organisms being returned to within 2 C of ambient conditions within one hour under average and best case conditions (Section 4.1.2). Zooplankton are incapable of maintaining themselves in the plume and so that the effect of cold shock is essentially comparable to the effect of returning an organism to ambient conditions in the above studies. Since immotilities decreased as the discharge water mixed with lake water and plant shutdown would result in a reduction of heat discharged, the organisms would return to ambient conditions sooner. Therefore, cold shock effects are not expected to be detrimental to entrained zooplankton.

4.3.4.3 Effects of Thermal Discharge on the Zooplankton Community in the Immediate Discharge Area

The presence or absence of impact on the zooplankton community due to KNPP operation was assessed using two basic forms of comparison: comparison between the data collected at locations within and outside the Immediate Discharge Area (IDA) during the plant operational period (June 1974 through July 1975); and comparison between data collected during the preoperational and operational years. The analysis of the operational data was simplified by examining those locations which were under the influence of the thermal plume on each sampling date in relation to the other locations. Location 11 was of particular importance as it was the closest to the plant discharge and was in the plume on every sampling date except August and September 1974. The figures presented in support of the subsequent discussion contain shaded areas that indicate whether a location was included in the plume at the time of sampling.

The determination of whether a location was under the influence of the plume was based on the plume mapping studies (Section 4.1.8) which were conducted on the biological sampling days and measurement of temperatures at the time of sample collection at each location. During August and September 1974 the plant was not generating any power at the time of biological sampling (Section 4.1.1).

Possible effects on the zooplankton community due to a thermal discharge would include a change in community density at a location under the influence of the thermal plume or an alteration of community structure as a result of an increase or decrease in density of a particular species or group. Increases in abundance might be due to passive concentration or organisms by the plant, selective concentration by a population or community in the warmer water, or enhanced recruitment to a population in response to the warmer water. Decreases in the community might be the result of avoidance of the warmer water, the actual destruction of organisms either by mechanical and thermal damage during plant passage, or by exceeding thermal (reproductive or lethal) limits of taxa in the plume

Passive concentration of zooplankton by a power plant discharge was observed in Lake Monona, Wisconsin (Brauer et al. 1972 p.30). It was concluded that the discharge currents concentrated the zooplankton in a small bay and simulated localized production in the discharge area. Since the KNPP discharge plumes were not restricted by the shoreline but were dispersed by lake currents (Section 4.1.3), concentration of the organisms would not be expected and has not been observed.

Selective concentration of a population or community in the warm discharge of the KNPP also would be unlikely since distribution of plankton is strongly influenced by currents (Hutchinson 1969 p.293 and 797). The strong discharge current and lake currents would make it virtually impossible for zooplankton to maintain themselves in the plume. Enhanced recruitment would be difficult to document because the organisms would probably not remain in the plume for sufficient time to increase development rate.

Decreased zooplankton densities in the plume due to avoidance of the warmer water would also be unlikely for the reasons mentioned above and because of the condenser passage effects previously discussed in Section 4.3.4.2.

Comparisons between the preoperational and operational periods were difficult to make. The preoperational data was most valuable for identification of the basic structure of the zooplankton community in the Kewaunee area and evaluation of the temporal variations and patchiness as described in Section 4.3.4.1. As demonstrated in Section 4.3.4.1, comparisons between 1973 and 1974-1975 were only possible for the cladocera and adult copepods since the smaller bodied rotifers and immature copepods were only partially sampled with the large meshed nets used in 1973.

Cladoceran densities at the 3 m contour were very similar between preoperational and operational years (Figures 4.3.4.2 and 4.3.4.9). Densities reached somewhat higher maxima in 1974 and 1975 although the higher values in 1974 were observed only at one of the control locations. An early spring peak occurred in 1975 and was highest at Location 11 and one of the controls. This was not observed in the spring of 1973 or 1974. Data collected in the spring of 1974 were preoperational data since KNPP did not become operational until June. The spring 1975 peak at Location 11 included *Chydorus* in greater proportions than at the other locations. It was possible that the thermal effluent caused an earlier emergence of *Chydorus* at Location 11 or the larger numbers may have resulted from patchiness as

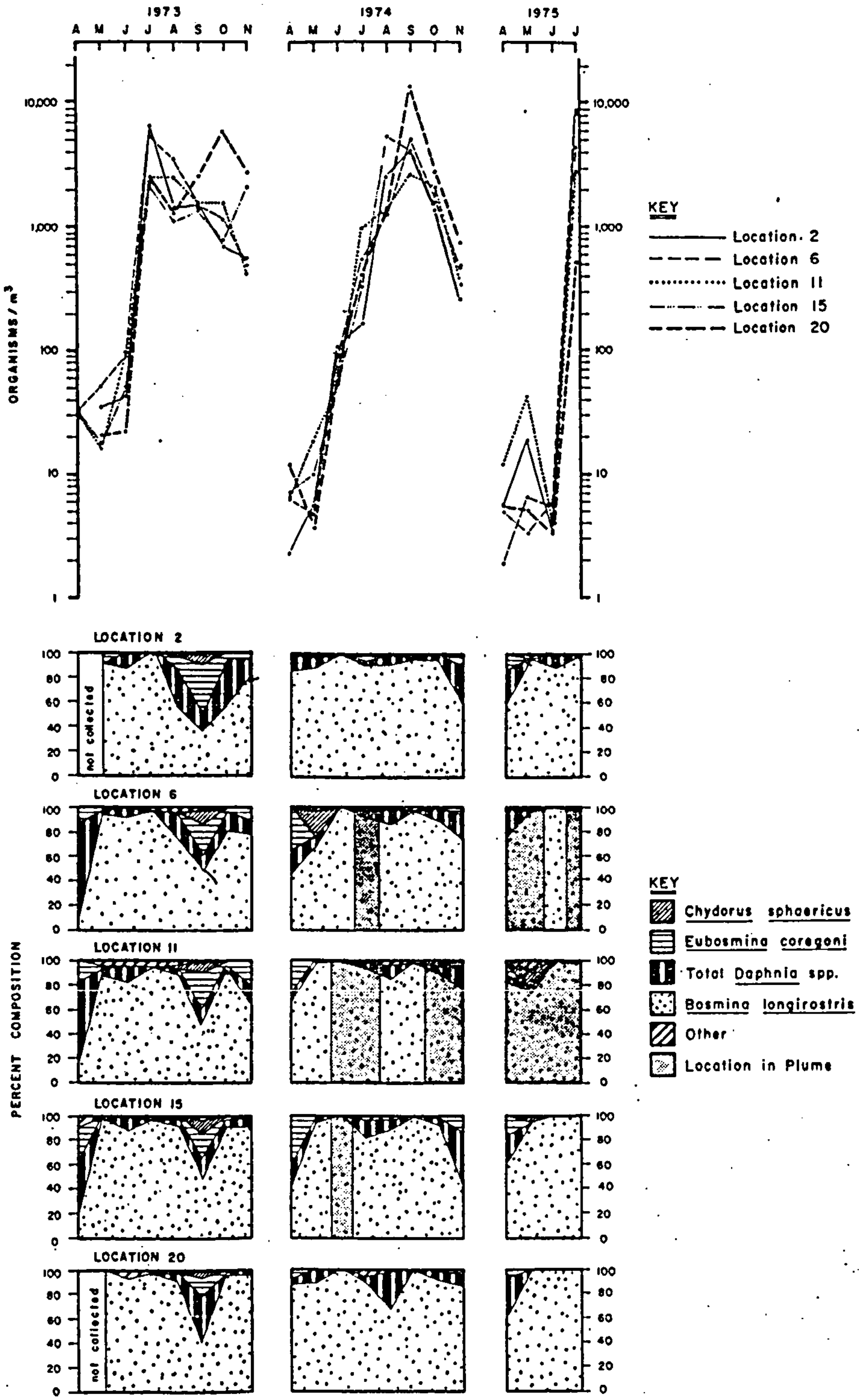

Figure 4.3.4.9. Population dynamics and community structure for total Cladocera inshore locations in the Kewaunee area, April 1973-July 1975.

discussed previously. Regardless, since densities were so low and the peak of this species did not last, the implied effect could not be considered important. The 1975 peak which occurred at control Location 2 was due to higher densities of Bosmina longirostris but there was no evidence that the increase was related to plant operation since Location 2 was not under the influence of the thermal plume.

The copepod density cycles were virtually identical between preoperational and operational years (Figures 4.3.4.2, 4.3.4.10 and 4.3.4.11). The maxima and minima occurred in the same months in all years and density levels were identical. The only noticeable difference in relative composition was observed for Tropocyclops prasinus mexicanus but this was demonstrated earlier to be a lakewide phenomenon (Section 4.3.4.1).

Densities of total zooplankton were quite different among locations on the 10 ft contour (Figure 4.3.4.12) and yet the same basic pattern of monthly density fluctuations was apparent for all locations. Monthly densities were quite variable but no pattern or consistent density relationship among locations could be found in either 1974 or 1975. The greatest degree of density variation was observed in August and September 1974 when KNPP was not operating. In June 1975, zooplankton densities at two experimental locations which were not in the plume (Locations 6 and 15) were appreciably higher than at the other locations. Densities at Location 11 which was in the plume were similar to those at the control locations.

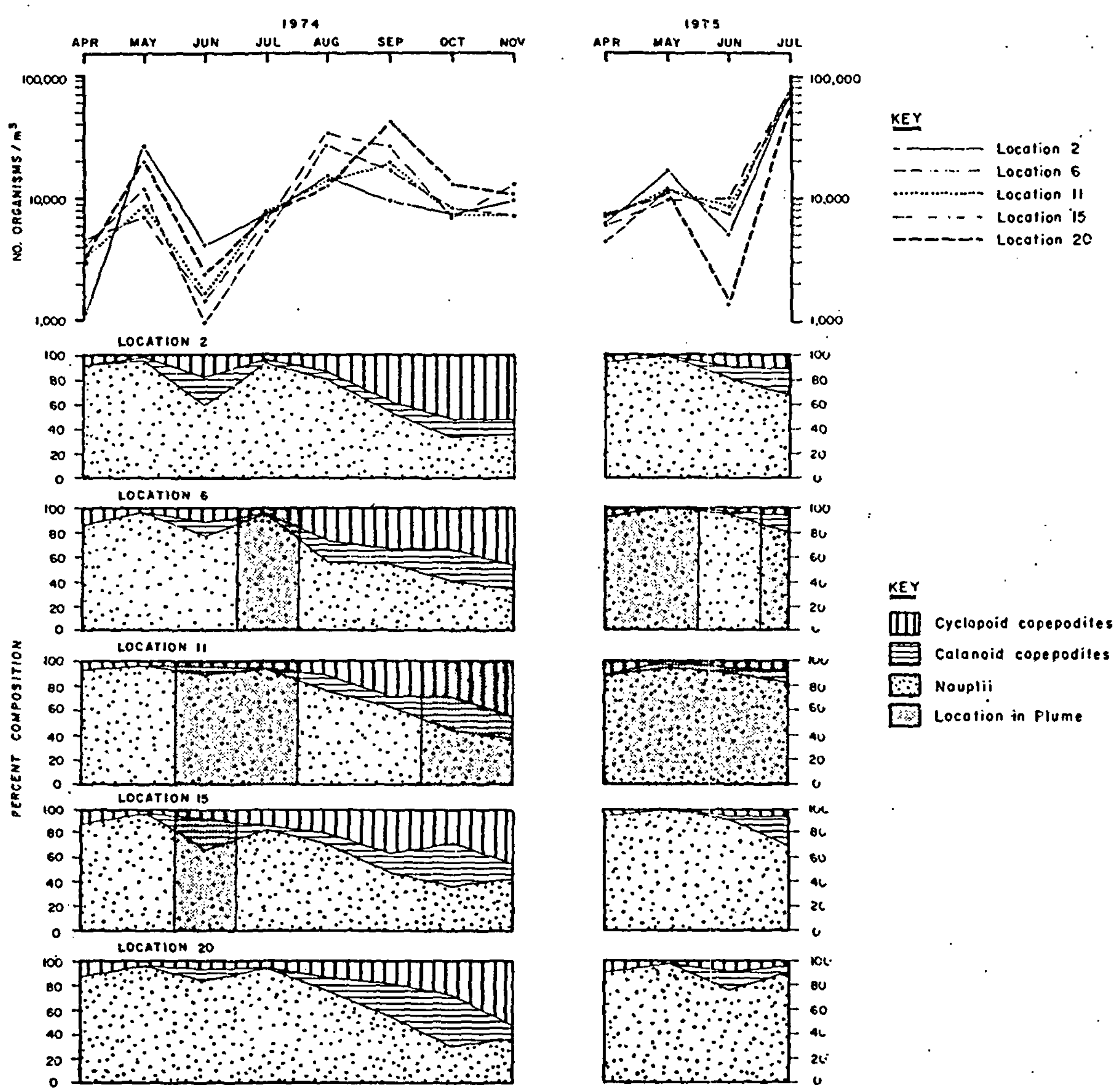

Figure 4.3.4.10. Population dynamics and community structure (percent compostion) for total Immature Copepoda at five inshore locations (10-ft contour) in the Kewaunee area, April 1974-July 1975.

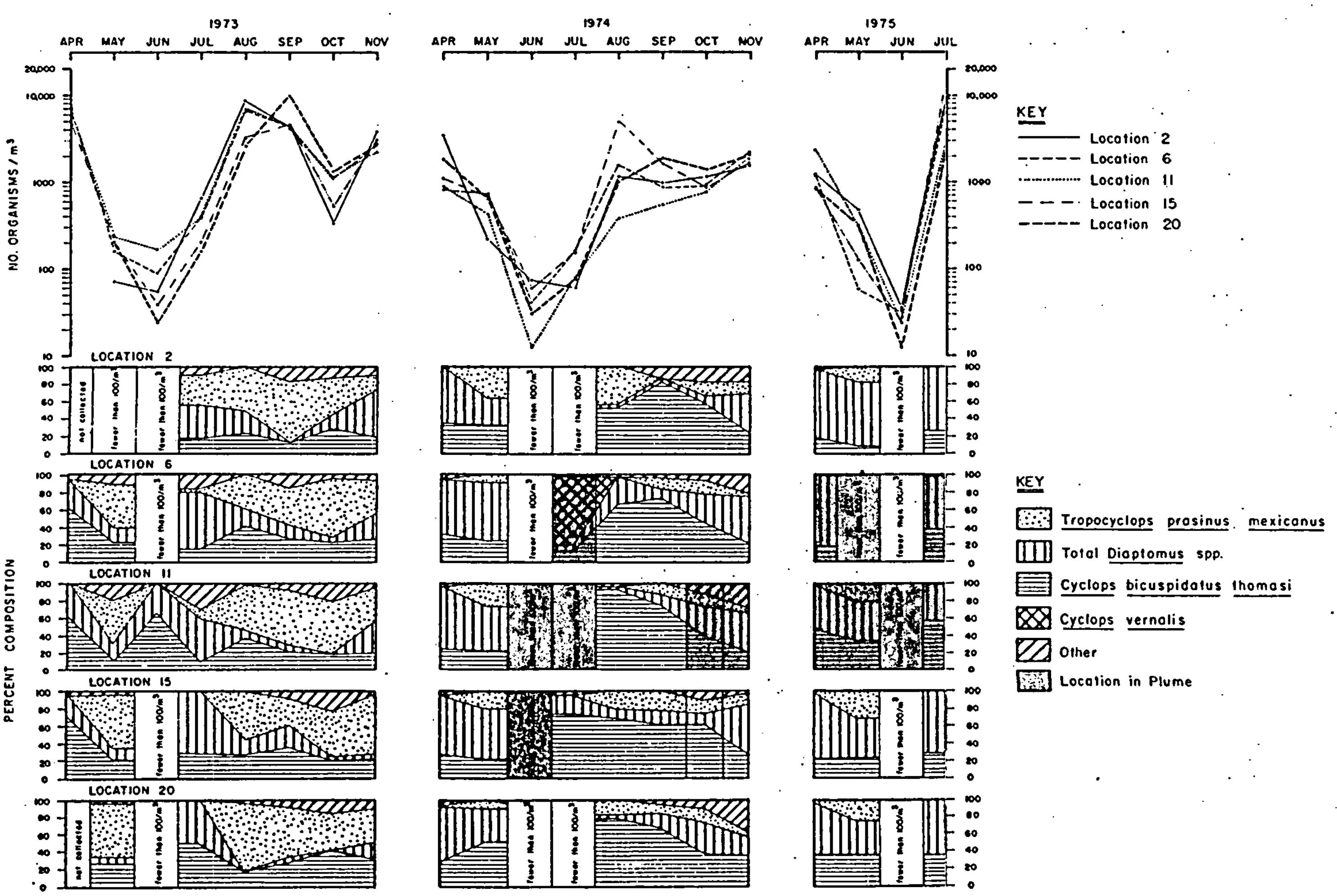

Figure 4.3.4.11. Population dynamics and community structure for total Adult Copepoda at five inshore locations in the Kewaunee area, April 1973-July 1975.

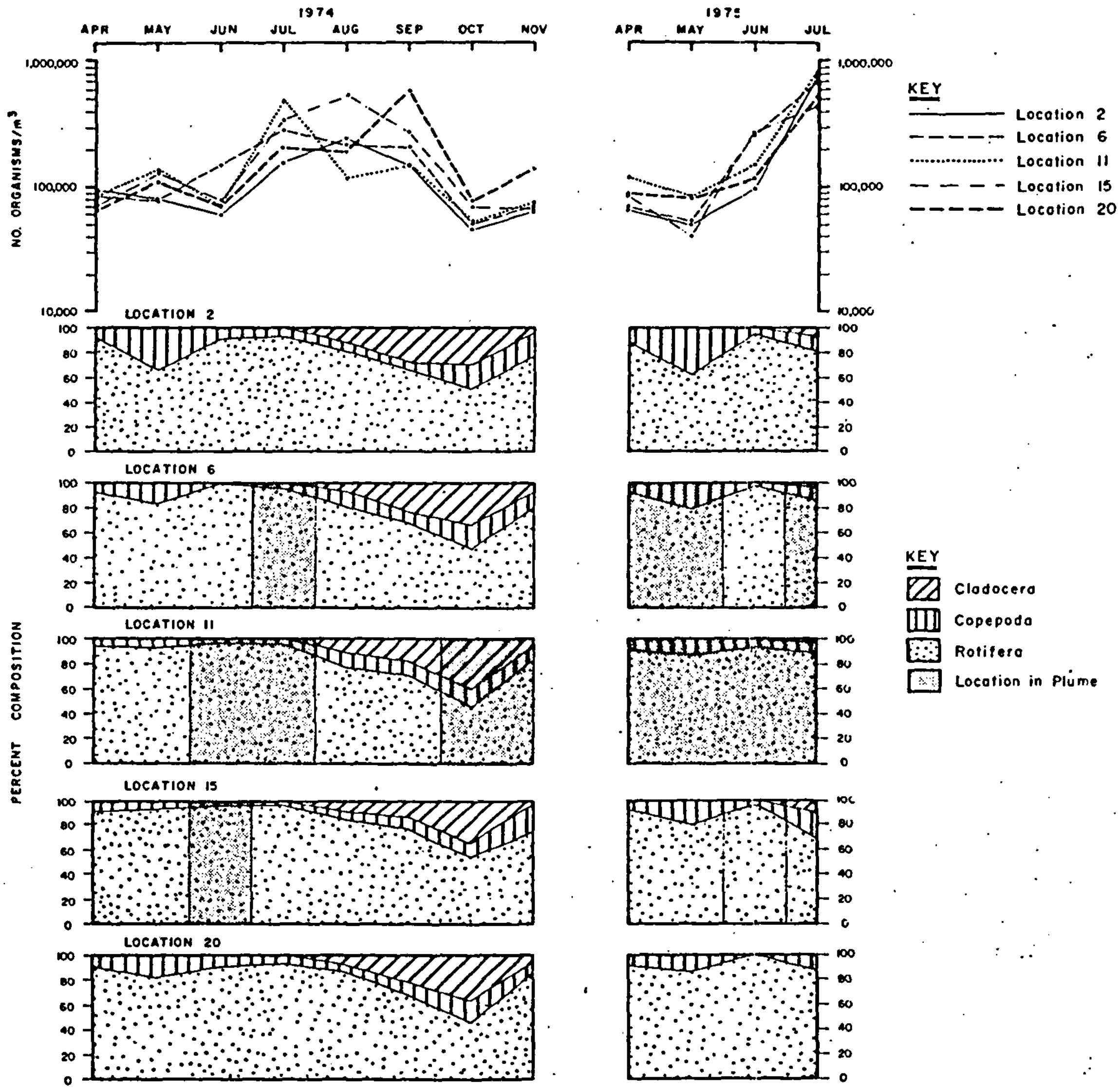

Figure 4.3.4.12. Population dynamics and community structure (percent composition) for total zooplankton at five inshore locations in the Kewaunee area, April 1974-July 1975.

When the zooplankton community composition, as evidenced by the major groups, was examined (Figure 4.3.4.12), it appeared that independent density dynamics obscured similarities among the locations. Further examination of the detailed community structure at all the 10 ft locations revealed that the locations were similar in composition (Figures 4.3.4.9, 4.3.4.10 and 4.3.4.11). A more detailed description of each of the representative important species or taxa in each of the major groups is considered below.

Total zooplankton dynamics were governed largely by Rotifera dynamics (Figures 4.3.4.2 and 4.3.4.12) and rotifer dynamics in western Lake Michigan result from fluctuations of four major genera: Notholca, Synchaeta, Polyarthra and Keratella (Figure 4.3.4.13). Even though rotifer densities were quite variable among locations, the composition was extremely constant between experimental and control locations indicating that there has been no alteration of the structure as a result of KNPP operation. The community was nearly identical at all locations with density variations independent of the thermal effluent. There was one notable exception to this pattern. In June of 1974 and 1975, the relative importance of Synchaeta did not decline at Location 20 the way it declined at the other locations. It was difficult to find a reason for this occurrence but since it was observed at only one of the control locations, it could not have been related to KNPP operation.

Total Cladocera among the inshore locations exhibited a variety of differences in population density on many of the sampling dates; however, an analysis of the composition of the Cladocera populations by location again revealed very few differences in

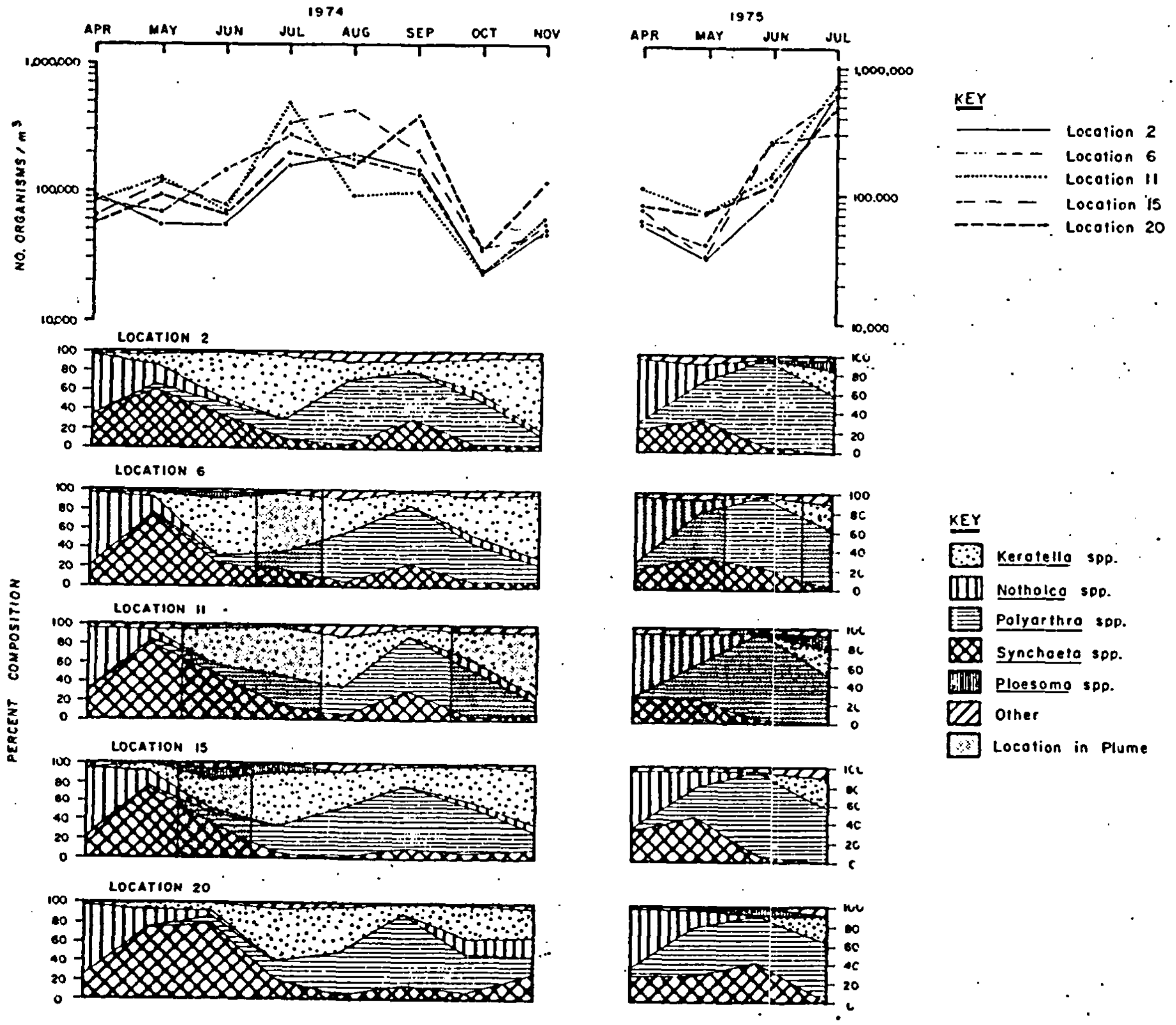

Figure 4.3.4.13. Population dynamics and community structure (percent composition) for total Rotifera at five inshore locations (10-ft contour) in the Kewaunee area, April 1974-July 1975.

community structure (Figure 4.3.4.9). As was discussed in Section 4.3.4.1, the populations of Daphnia and Eubosmina diminished from 1973 to 1974 but the phenomenon was not peculiar to the Kewaunee area. Bosmina longirostris strongly dominated the cladocera at all locations while the relative importance of the other taxa was minor.

As in the rotifers and Cladocera, total immature copepods exhibited considerable variability in their population densities among locations but only slight differences in community structure (Figure 4.3.4.10). The immature taxa dominated the copepods with nauplii being the most abundant forms, but differences in relative composition were not detected among locations.

The total adult copepods did not have as uniform a community structure as was characteristic of the other zooplankton groups (Figure 4.3.4.11). Although the same species were dominant at all locations, the relative proportions of these dominant copepods were quite variable. There did not appear to be any pattern in these variations nor was there any apparent correlation with the thermal plume. In July 1974, however, Cyclops vernalis dominated the adult copepods at Location 6 (which was under the influence of the plume) although it was practically non-existent elsewhere. The predominance of C. vernalis was probably a manifestation of the patchiness that characterizes the distribution of many planktonic organisms since it was not present in the August samples. Close inspection of the July data revealed that one of the four replicate samples from Location 6 yielded C. vernalis at a density of $400/m^3$, a second replicate produced a density of $40/m^3$ and no C. vernalis were observed in the other two replicates. One small patch of C. vernalis, coupled with low densities of the other copepods, was responsible for the apparent dominance at Location 6.

The results at the 6 and 9 m depth contours were nearly identical to those observed at the 3 m depth contour. Since the findings were so comparable among all depths sampled and to save repetition, only two groups of the representative important species (adult copepods and rotifers) were selected for discussion at the 20 and 30 ft contours.

The variability in density and composition among locations along a depth contour decreased as distance from shore increased. This was probably due to the high energy, turbulent conditions in the shallow water and undoubtedly accounted for some of the unexplained variability at the 3 m depth contour mentioned previously.

At the 20 ft depth contour, the same basic seasonal pattern was observed for the adult copepods in 1973, 1974 and 1975 (Figure 4.3.4.14). The decline in June and July was more pronounced in 1974 and 1975 than in 1973 and the scatter between location values at that time was greater than in other months or most of 1973. In July 1974, an extremely low density was observed at Location 7 which was under the influence of the thermal plume. However, densities at Location 12, which was also under plume influence and closer to the plant, were higher than at Location 7 and both control locations. This contrast in densities between two plume locations indicated that the low densities were probably not

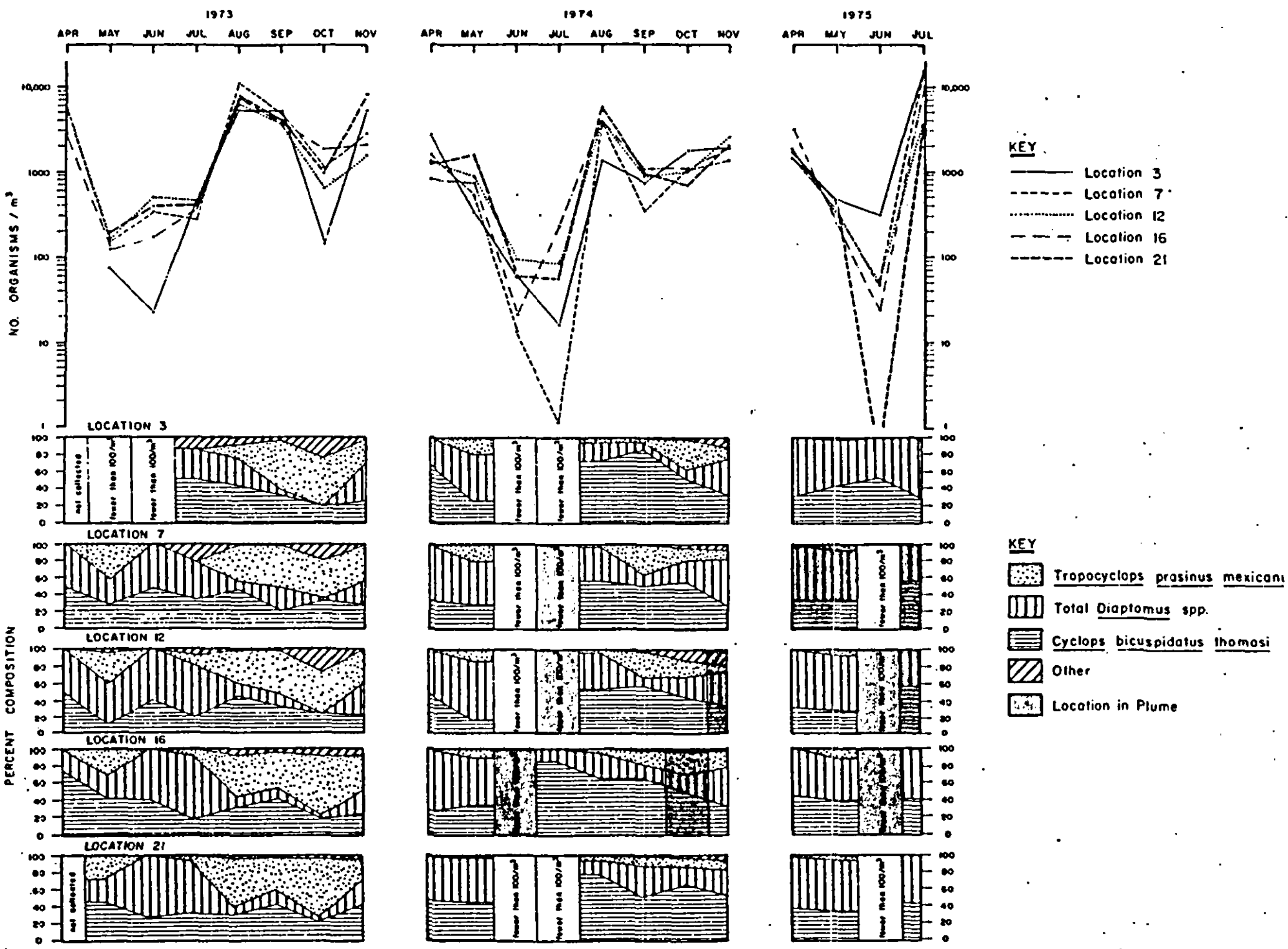

Figure 4.3.4.14. Population dynamics and community structure for total Adult Copepoda at five middle locations in the Kewaunee area, April 1973-July 1975.

plume related because the organisms at both locations would be expected to respond to temperature effects in a like manner. It was also important to note that the largest density depressions observed in June and October 1973 and June 1975 were found at different control locations; i.e., Location 3 in 1973 and Location 21 in 1975.

The rotifer community along the 20 ft contour (Figure 4.3.4.15) was very stable throughout the operational period of KNPP. The density cycles at all locations followed the same general pattern although in May 1974 densities at Location 21 were considerably lower than at the other locations, and in July 1974, values were much higher at Locations 12 and 16. Since the May sampling occurred during the preoperational period, the depression was obviously not plant related. In July, Location 12 was under the influence of the plume but Location 16 was not and yet densities were similar between the two locations. Location 7 was also under the plume influence in July but densities were similar to those at the control locations beyond the plant influence. It was therefore concluded that the July results did not reflect plant influence. This conclusion was further supported by comparing the community composition at all locations. The percent composition of the major rotifers was almost identical at all locations throughout 1974 and 1975 in spite of the fact that some locations were under the influence of the plume.

Sampling locations at the 30 ft depth contour were seldom under the influence of the plume (Figure 4.3.4.16).

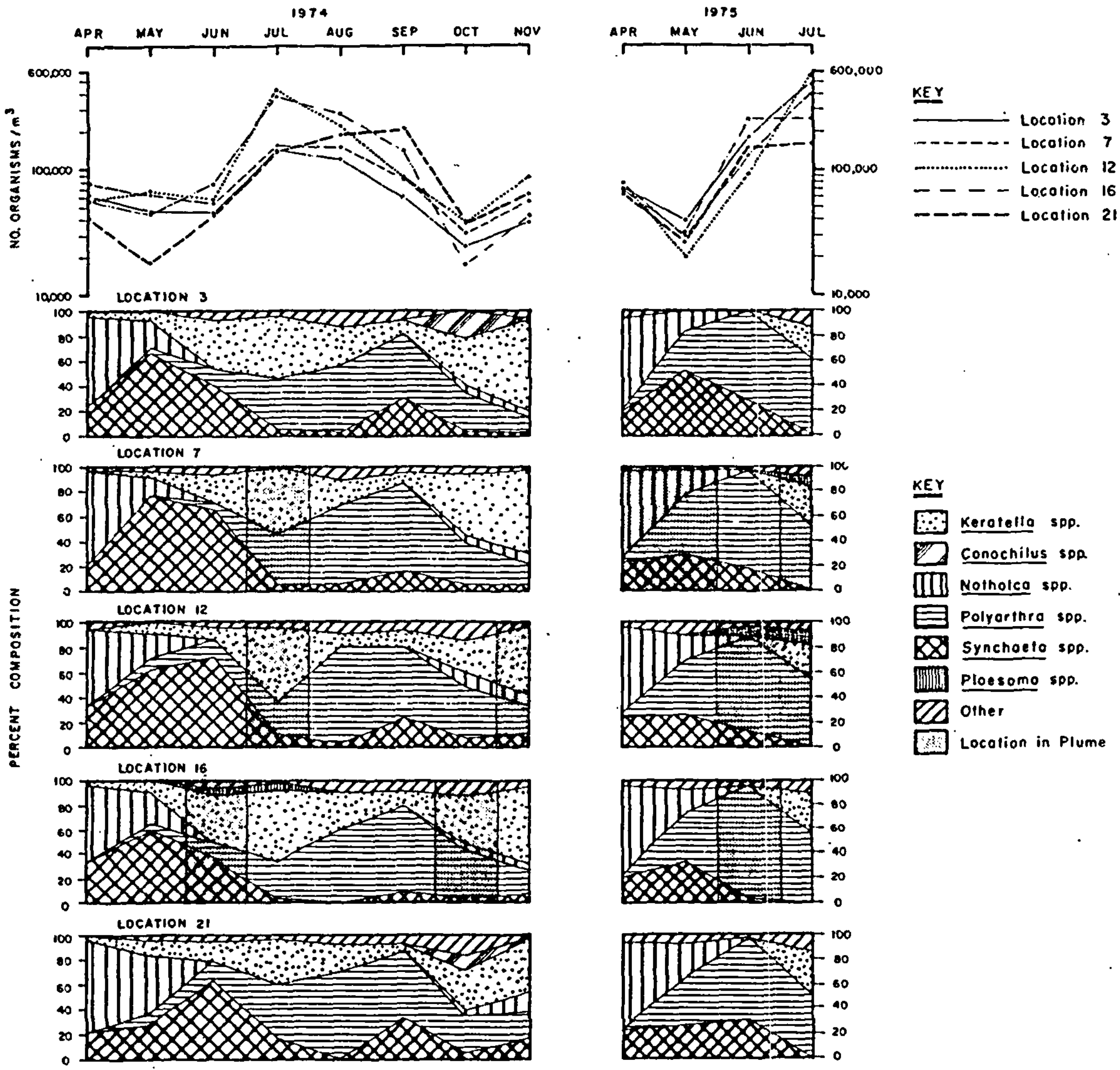

Figure 4.3.4.15. Population dynamics and community structure (percent composition) for total Rotifera at five locations at the 6m (20-ft) contour in the vicinity of Kewaunee Nuclear Power Plant, April 1974-July 1975.

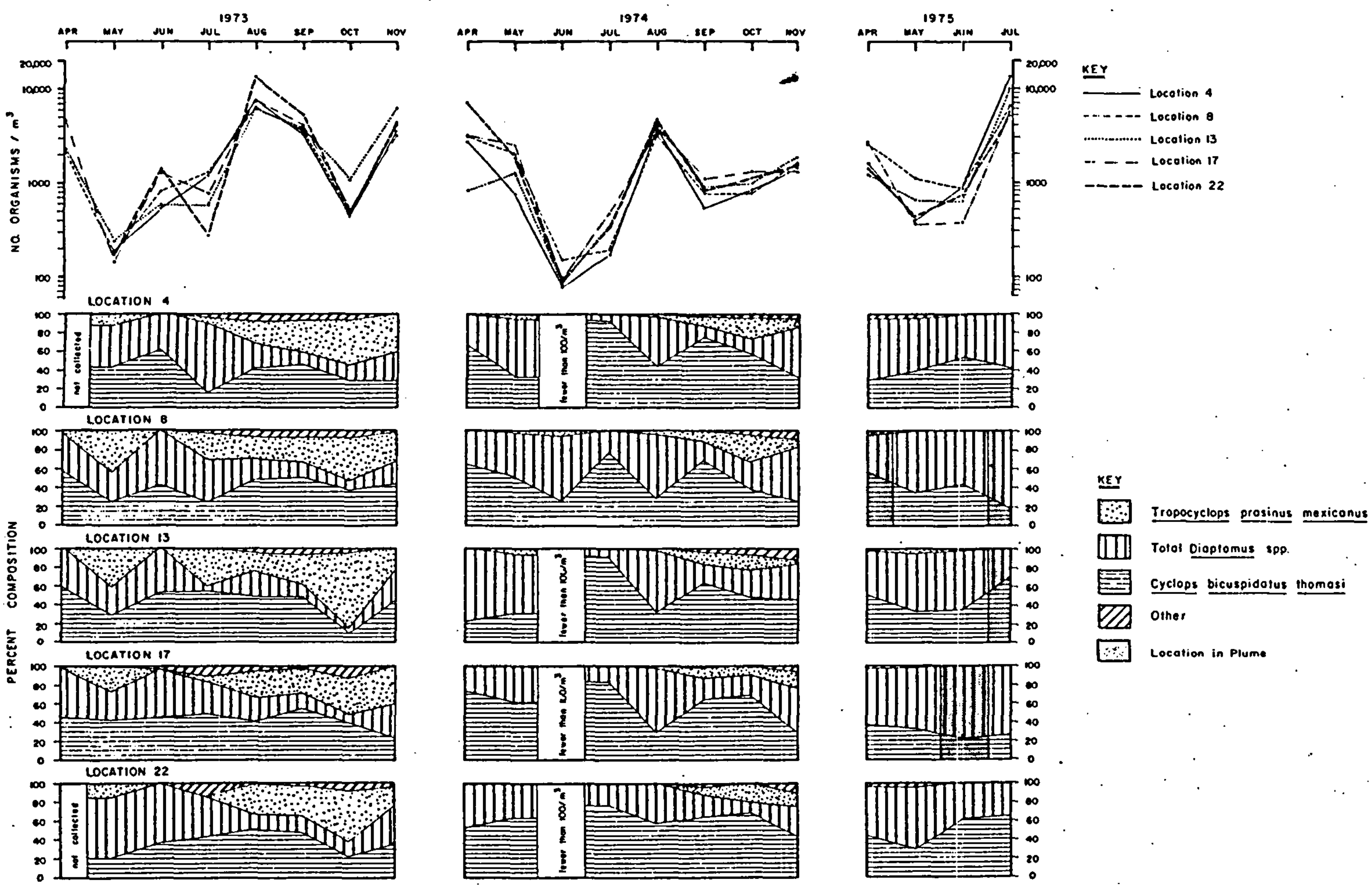

Figure 4.3.4.16. Population dynamics and community structure for total Adult Copepoda at five deep locations in the Kewaunee area, April 1973-July 1975.

Total copepod densities were very similar on all dates except June 1975 when densities were somewhat lower at Location 17 than at the other locations. This occurred at a time when Location 17 was under the influence of the plume. The relative composition of Cyclops bicuspidatus thomasi was also lower than at the other locations in June 1975. As demonstrated in Section 4.3.4.2, this species was not appreciably affected by either condenser passage or by thermal shock although Diaptomus was affected. Since the only copepods found at Location 17 besides C. bicuspidatus thomasi were Diaptomus, and these occurred at a larger relative composition than at the other locations, it was doubtful that the low densities of C. bicuspidatus thomasi were related to plant operation. Further analysis of copepod community composition revealed little that could possibly have been related to plant operation. Tropocyclops prasinus mexicanus was more prominent in 1973 than it was in 1974 and 1975. This overall reduction was described in Section 4.3.4.1 as a lakewide phenomenon. Even at lower densities, however, the relative composition of this species was very similar among locations of the 30 ft contour. Cyclops bicuspidatus thomasi was more important in 1974 than in 1973 but 1975 values were similar to those in 1973.

Among the rotifers, a high degree of similarity existed among locations along the 30 ft contour (Figure 4.3.4.17). Density patterns of total rotifers followed the same trends at all locations and actual values were also very similar. The most variable results were found at the control locations (particularly in September 1974 and May 1975 at Location 4 and in October 1974 for

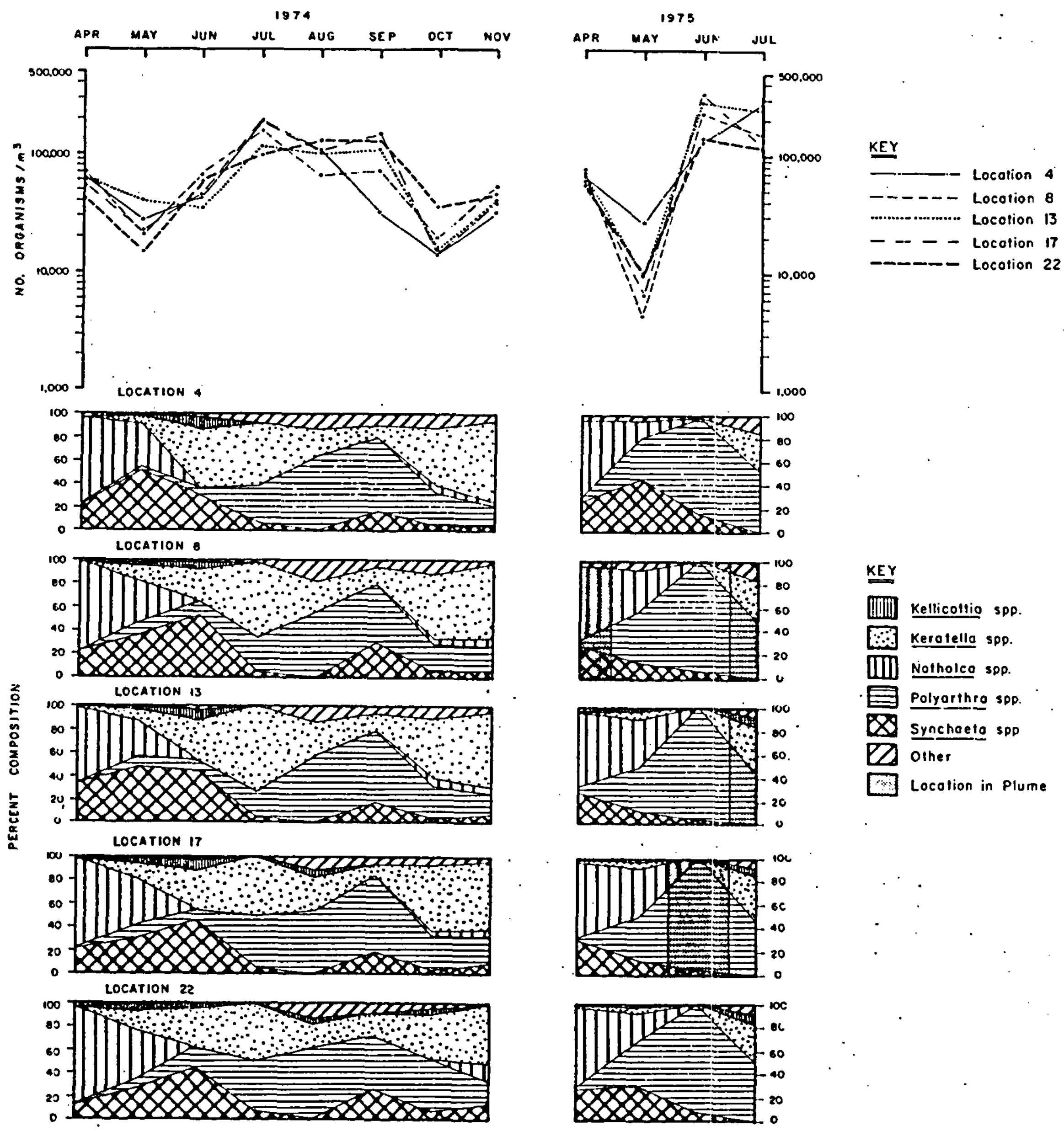

Figure 4.3.4.17. Population dynamics and community structure (percent composition) for Total Rotifera at five locations on the 30-ft contour in the Kewaunee area, April 1974-July 1975.

Location 22). Since these were isolated instances and the results from the other locations on these dates were very similar, it must be concluded that the community composition had not been altered by plant operation. This conclusion was further substantiated by the fact that the percent composition of the major rotifer genera was almost identical among locations.

In conclusion, no alterations in community density were detected between preoperational and operational data which were not typical of the preoperational years. Density variations were less pronounced at the 30 ft depth contour than at 20 ft while the 10 ft depth contour was the most variable. The structural integrity of the zooplankton community was also found to be unaffected in comparisons of preoperational to operational periods and experimental to control locations.

4.3.4.4 Effects of Thermal Discharge on the Zooplankton Community Outside the Immediate Discharge Area

This portion of the demonstration is dependent upon the extent of the effect observed in the immediate discharge area and how the locations in this area compare to the control locations which are representative of the receiving water body. It is also dependent upon an evaluation of the control locations between the preoperational and operational periods and how any observed differences might be related to lakewide trends.

It was demonstrated in the previous section (Section 4.3.4.3) that no appreciable harm to the zooplankton community was detectable in the Immediate Discharge Area as a result of the operation of KNPP. Therefore, it is reasonable that, if no immediate effect could be detected, it is unlikely that an effect could be detected in the receiving water body after dilution of the plume waters had occurred.

Variations among years were previously discussed in Section 4.3.4.1, and differences in individual taxa such as Tropocylops prasinus mexicanus and Daphnia were shown to be lakewide phenomena and typical of the annual zooplankton cycle. Other than these taxa, there has been no alteration in community structure in terms of new species. This was readily evident in the total copepods (for example, Figures 4.3.4.11, 4.3.4.12 and 4.3.4.13) where the same taxa were consistently important from year to year, the only variations being in relative composition. These composition fluctuations have already been discussed in Section 4.3.4.1 and it was obvious that they were of the same magnitude as those discussed in relation to short- and long-term cycles.

It was also established (Section 4.3.4.3) that variations among locations in densities and compositon became less pronounced at the greater depth contours. This demonstrated that localized variation was rapidly reduced; therefore, any impact on the community a few miles from the Plant would be below the level of detection and indistinguishable from natural variability.

The relationship between the volume of water passing through the plant and the vast quantities of water available in Lake Michigan must also be considered. Since most of the variations between control and experimental locations were very small, it was obvious that the great dilution potential of Lake Michigan would overshadow any pattern in the data relative to receiving water body effects. Differences would therefore be reduced to detection limits of these studies. The conclusion can, therefore, be made that the operation of KNPP has produced no appreciable harm to the zooplankton in the receiving water body.

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4.3.5 PERIPHYTON

4.3.5.1 Lake Michigan Periphyton Community Structure in the Kewaunee Area Prior to Plant Operation

Sampling Locations

Samples of periphytic algae were collected from natural shoreline substrates in the "splash zone" from three locations (D, E, F) in the vicinity of Kewaunee Nuclear Power Plant (KNPP) during 1971 (Figure 4.3.5.1). The respective North and South Control Locations 1 and 18 were sampled from the 1972 through 1975 monitoring programs (Figure 4.3.5.1). The discharge canal, Location 9, was sampled during 1974 and 1975 as well as Locations 25 and 26 which bracketed the discharge canal (Figure 4.3.5.1). Samples were collected from Location 9 during 1972 and 1973; however, the 1972-73 Location 9 was not in the discharge canal but was the combined area of Locations 25 and 26. Samples were qualitatively analyzed using a relative abundance counting procedure during 1971 and 1972 (Industrial BIO-TEST Laboratories, Inc. 1972, p. 14; 1973, p. 28). A quantitative analysis procedure with density expressed as numbers of individuals per square centimeter and biovolume per square decimeter was utilized for the 1973, 1974 and 1975 monitoring programs (Delinck 1974, p. 2; Altstaetter 1975a, p. 2; Altstaetter 1975b). Biomass (ash-free dry weight) and chlorophyll *a* content were also analyzed during 1974 and 1975. Sampling was conducted three times in 1971, quarterly in 1972-73, five times in 1974 and three times in 1975.

During the five year history of the Kewaunee studies variability has occurred in the data as a result of improved

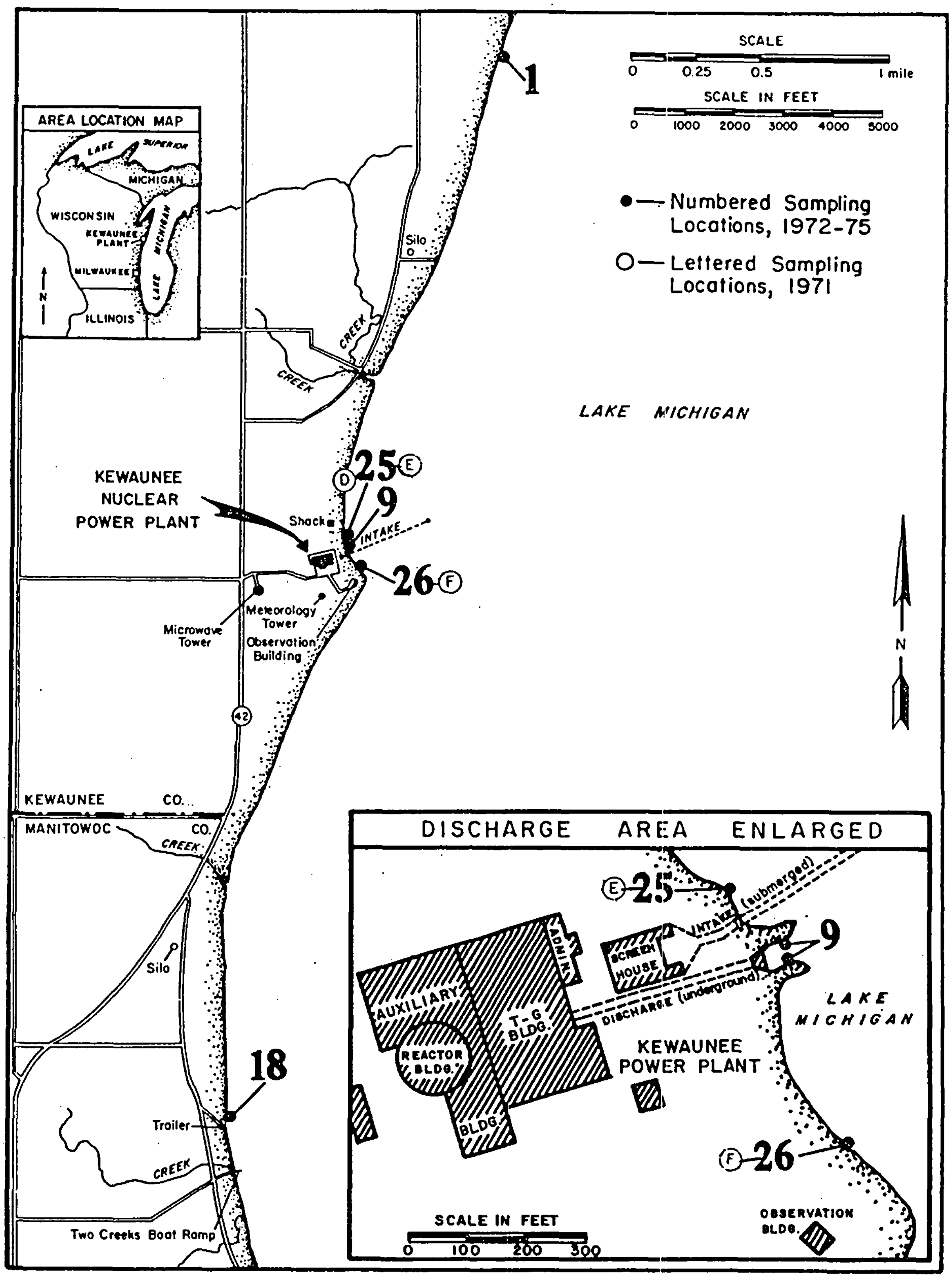


Figure 4.3.5.1. Periphyton sampling locations in western Lake Michigan near Kewaunee Nuclear Power Plant, 1971-1975.

taxonomy and refinement of sample preparation procedures. For example, during the 1971 through 1973 sample analyses, three synonyms of the diatom Fragilaria vaucheriae (Patrick and Reimer 1966, p. 120) were considered separate taxa. Also, during 1973, the sample processing procedures for diatoms may have resulted in under estimation of the diatom densities at all locations. Improved analytical techniques were utilized in 1974 and 1975 and resulted in greater diatom densities being reported than in 1973. Therefore, comparisons were not made in the subsequent discussion between the number of diatoms per square decimeter encountered during 1973 and the numbers encountered during 1974-75.

Periphyton Abundance

There was a consistent seasonal trend in the periphytic algal standing crop encountered during the quantitative phase of the monitoring program. A relatively smaller standing crop was encountered during April and May; whereas, the largest standing crop was usually encountered in November (Table 4.3.5.1 and Figures 4.3.5.2-4.3.5.5). There were a few differences between years in the standing crop as measured by mean total biovolume; however, the differences were not consistent. The standing crop encountered at Location 25 during April and May of 1974 was larger than in April and May 1975; whereas, on the south side of the discharge canal at Location 26 the reverse was true. Standing crops from the South Control (Location 18) during July 1973 and 1975 were larger than those encountered near the discharge canal at Location 26 during the same months.

Table 4.3.5.1. Mean number of individuals (No. x $10^4/cm^2$) and mean total biovolume (µl x $10/dm^2$) of the algal divisions collected from natural substrates in Lake Michigan near Kewaunee Nuclear Power Plant, May 1973-July 1975.

Sampling Date and Location	Chlorophyta				Bacillariophyta				Cyanophyta				Rhodophyta			
	No.x10^4 /cm^2	%	µlx10 /dm^2	%	No.x10^4 /cm^2	%	µlx10 /dm^2	%	No.x10^4 /cm^2	%	µlx10 /dm^2	%	No.x10^4 /cm^2	%	µlx10 /dm^2	%
21 May 1973																
1	0.0	0	0.0	0	95.9	71	8.8	91	39.6	29	0.9	9	0.0	0	0.0	0
"9"	25.3	63	11.9	87	14.6	37	1.7	12	0.0	0	0.0	0	0.0	0	0.0	0
18	0.0	0	0.0	0	99.8	95	14.9	99	5.5	5	0.1	1	0.0	0	0.0	0
23 July 1973																
1	1106.8	99	652.7	99	2.3	<1	0.1	<1	0.0	0	0.0	0	0.0	0	0.0	0
"9"	971.9	94	2180.0	99	54.4	5	4.6	<1	9.1	1	0.1	<1	0.0	0	0.0	0
18	1090.4	79	3999.8	99	228.0	16	29.6	1	62.7	4	1.0	<1	0.0	0	0.0	0
24 September 1973																
1	2641.7	93	3299.1	99	208.3	7	8.5	<1	2.2	<1	<0.1	<1	0.0	0	0.0	0
"9"	2550.0	95	654.3	97	118.9	4	22.0	3	0.0	0	0.0	0	0.0	0	0.0	0
18	637.8	82	332.4	98	111.7	14	5.7	2	25.0	3	0.1	<1	0.0	0	0.0	0
7 November 1973																
1	1060.1	69	2398.7	94	473.7	31	149.2	6	0.0	0	0.0	0	0.0	0	0.0	0
"9"	2867.2	97	13262.7	99	74.8	2	26.1	<1	16.9	1	<0.1	<1	0.0	0	0.0	0
18	1003.8	98	6109.8	99	21.6	2	1.9	<1	0.0	0	0.0	0	0.0	0	0.0	0
22 April 1974																
1	1642.9	88	399.4	98	135.5	7	8.6	2	86.7	5	0.6	<1	0.0	0	0.0	0
9	3299.2	80	816.8	96	548.9	13	26.9	3	274.8	7	3.9	<1	0.0	0	0.0	0
18	370.4	20	92.0	65	189.6	10	25.1	17	1253.3	69	25.4	18	0.0	0	0.0	0
25	3416.3	86	848.6	98	99.2	3	7.9	1	441.5	11	7.9	1	0.0	0	0.0	0
26	1274.8	61	315.3	93	172.6	8	12.2	3	634.8	30	12.0	3	0.0	0	0.0	0
22 May 1974																
1	276.3	57	54.8	85	179.2	37	8.7	13	27.4	6	1.2	2	0.0	0	0.0	0
9	201.5	39	50.0	93	52.6	10	2.2	4	262.2	51	1.4	2	0.0	0	0.0	0
18	173.3	13	43.1	43	281.5	21	20.3	20	853.3	65	35.6	36	0.0	0	0.0	0
25	2033.3	79	631.8	96	357.0	14	16.1	2	188.9	7	7.4	1	0.0	0	0.0	0
26	800.7	77	245.2	96	234.1	23	10.8	4	0.0	0	0.0	0	0.0	0	0.0	0
24 July 1974																
1	766.0	22	1177.8	90	2696.2	77	118.1	9	5.9	<1	<0.1	<1	32.6	1	4.9	<1
9	106.7	2	115.8	62	671.8	11	26.2	14	5427.4	87	45.2	24	0.0	0	0.0	0
18	114.1	19	176.5	86	452.6	74	29.4	14	44.4	7	0.3	<1	0.0	0	0.0	0
25	1278.5	63	1982.5	98	644.4	32	35.5	2	88.1	4	3.3	<1	0.0	0	0.0	0
26	945.2	66	1671.1	98	391.1	27	26.6	1	2.2	<1	<0.1	<1	98.0	7	14.5	1

Table 4.3.5.1. (continued)

Sampling Date and Location	Chlorophyta No.x10^4 /cm^2	%	Chlorophyta µlx10 /dm^2	%	Bacillariophyta No.x10^4 /cm^2	%	Bacillariophyta µlx10 /dm^2	%	Cyanophyta No.x10^4 /cm^2	%	Cyanophyta µlx10 /dm^2	%	Rhodophyta No.x10^4 /cm^2	%	Rhodophyta µlx10 /dm^2	%
24 September 1974																
1	348.9	43	877.6	97	388.1	48	24.4	3	75.5	9	0.1	<1	0.0	0	0.0	0
9	825.2	58	1291.1	98	185.9	13	8.4	1	203.7	14	0.5	<1	211.8	15	19.2	1
18	1181.5	50	2229.2	98	314.8	13	17.4	1	861.5	36	34.1	1	0.0	0	0.0	0
25	1191.1	77	2174.2	99	215.5	14	15.6	1	135.5	9	2.7	<1	0.0	0	0.0	0
26	922.2	51	1860.4	85	456.3	25	42.5	2	154.8	8	2.3	<1	269.6	15	287.4	13
12 November 1974																
1	2574.1	68	1679.4	99	1151.8	30	20.3	1	51.8	1	0.2	<1	0.0	0	0.0	0
9	625.9	26	1410.2	98	814.8	34	18.9	1	977.8	40	2.7	<1	0.0	0	0.0	0
18	1572.2	62	2954.0	99	702.8	28	22.4	1	272.2	11	4.2	<1	0.0	0	0.0	0
25	2703.7	58	5661.3	99	1744.4	38	64.7	1	189.8	4	1.7	<1	0.0	0	0.0	0
26	1925.9	69	4067.3	92	247.2	9	13.0	<1	260.2	9	0.8	<1	351.8	13	340.0	8
22 April 1975																
1	409.4	46	74.7	83	456.9	51	15.2	17	28.9	3	0.1	<1	0.0	0	0.0	0
9	221.7	5	50.1	42	2114.9	46	55.0	46	2295.5	49	14.2	12	0.0	0	0.0	0
18	350.5	49	63.9	76	357.8	50	19.7	23	0.0	0	0.0	0	0.0	0	0.0	0
25	1163.3	66	568.3	96	464.1	26	24.1	4	140.5	8	0.9	<1	0.0	0	0.0	0
26	1480.5	42	1250.9	47	363.6	10	15.7	<1	595.5	17	10.1	<1	1049.4	30	1374.6	52
20 May 1975																
1	417.4	55	161.5	96	171.6	23	3.5	2	169.8	22	2.2	1	0.0	0	0.0	0
9	862.7	15	816.4	90	3333.8	57	75.5	8	1672.9	28	15.6	2	0.0	0	0.0	0
18	696.7	81	99.6	95	113.9	13	3.9	4	48.0	5	0.8	1	0.0	0	0.0	0
25	1213.3	67	470.0	97	443.3	24	11.4	2	164.0	9	1.3	<1	0.0	0	0.0	0
26	1096.0	36	200.8	18	220.0	7	5.4	<1	962.5	32	6.4	<1	758.3	25	895.1	81
22 July 1975																
1	432.6	17	477.1	92	1451.8	58	31.8	6	607.4	24	7.1	1	0.0	0	0.0	0
9	211.8	5	109.1	73	1489.8	38	28.7	19	2158.5	56	12.2	8	0.0	0	0.0	0
18	1887.4	72	2081.8	99	470.4	18	13.3	1	277.0	10	3.7	<1	0.0	0	0.0	0
25	2032.6	62	2242.0	98	1076.3	33	29.5	1	177.0	5	2.6	<1	0.0	0	0.0	0
26	1367.4	41	1508.2	52	734.1	22	21.2	1	555.5	17	5.3	<1	674.1	20	1361.6	47

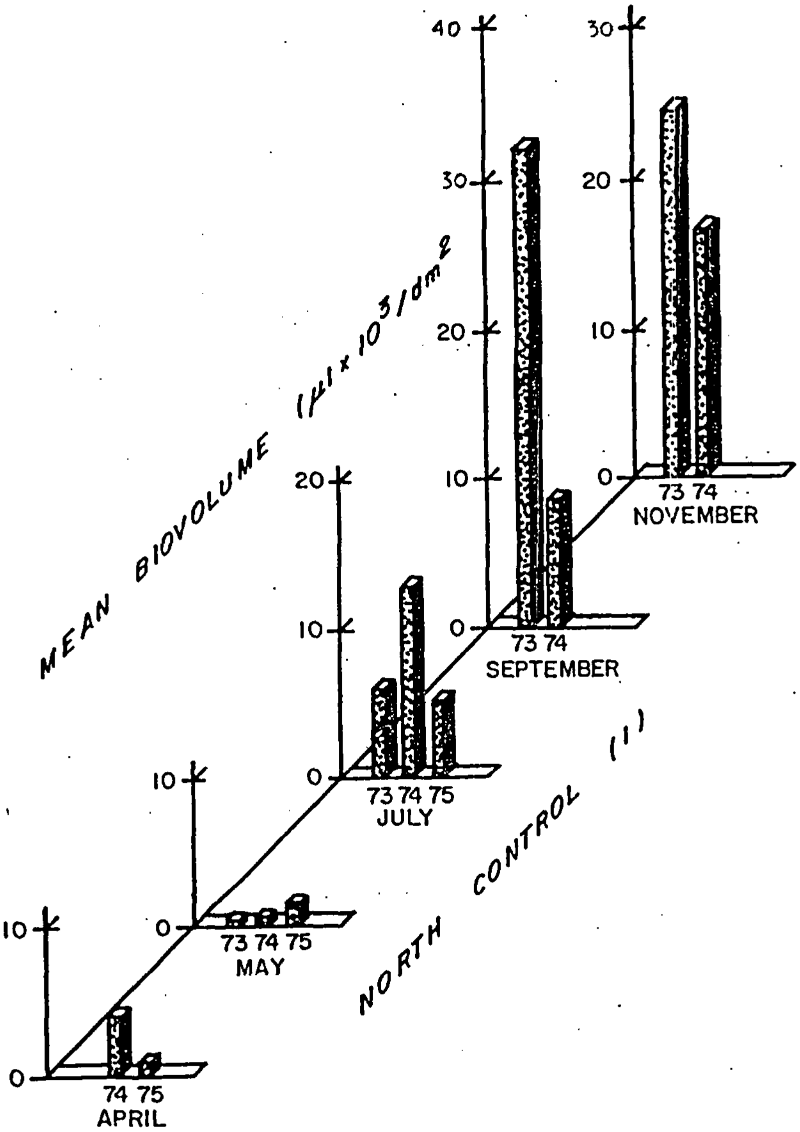


Figure 4.3.5.2. Mean total biovolume of periphytic algae collected from the Kewaunee Nuclear Power Plant, North Control (Location 1), May 1973-July 1975.

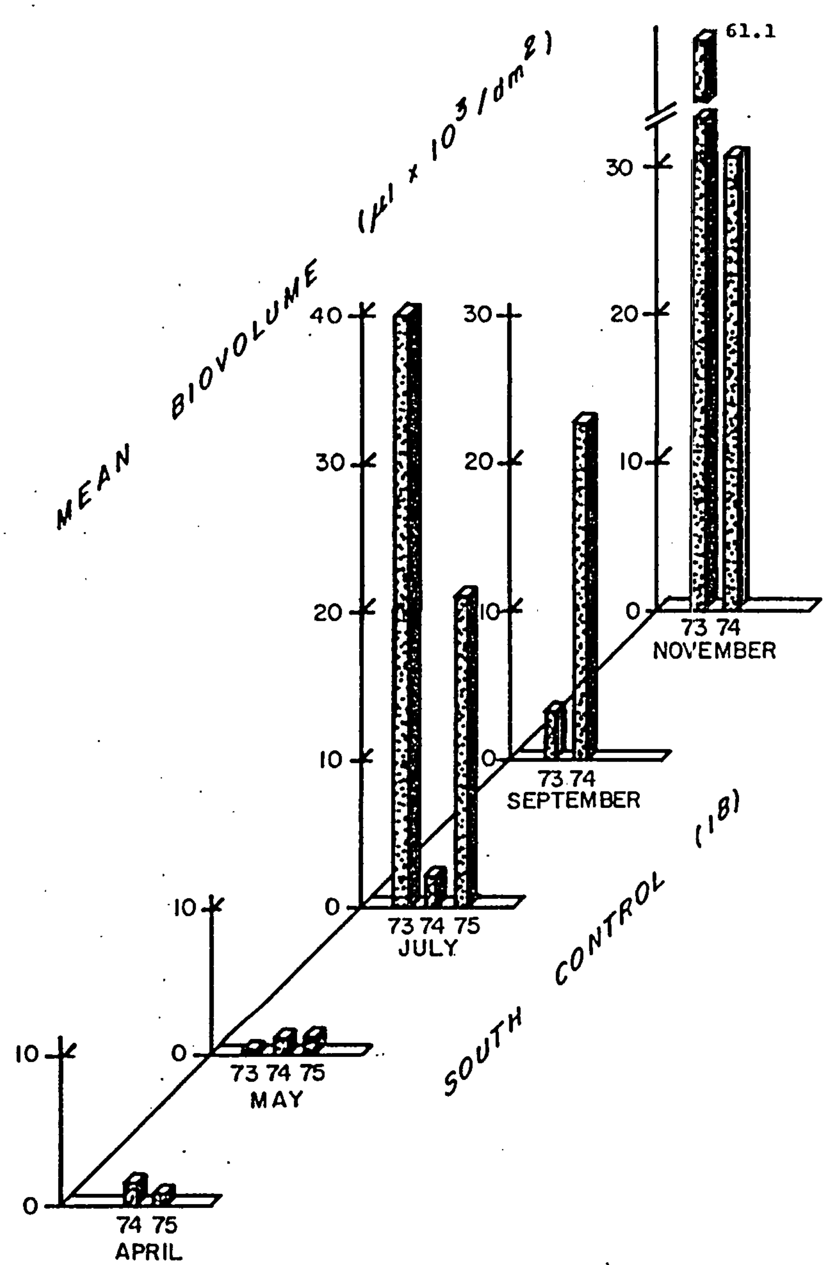


Figure 4.3.5.3. Mean total biovolume of periphytic algae collected from the Kewaunee Nuclear Power Plant, South Control (Location 18), May 1973-July 1975.

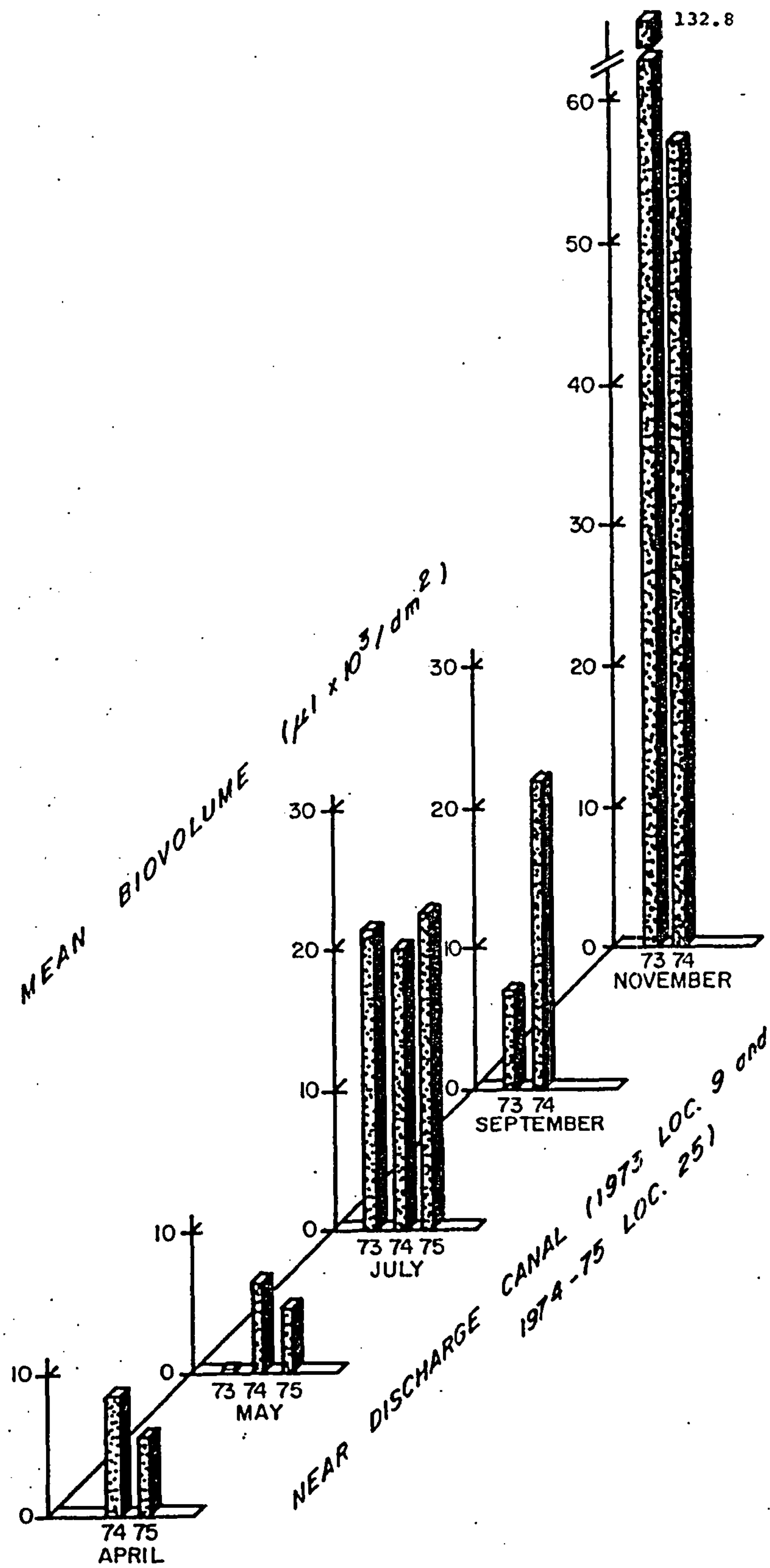


Figure 4.3.5.4. Mean total biovolume of periphytic algae collected from near the Kewaunee Nuclear Power Plant discharge canal (1973 Location 9 and 1974-75 Location 25), May 1973-July 1975.

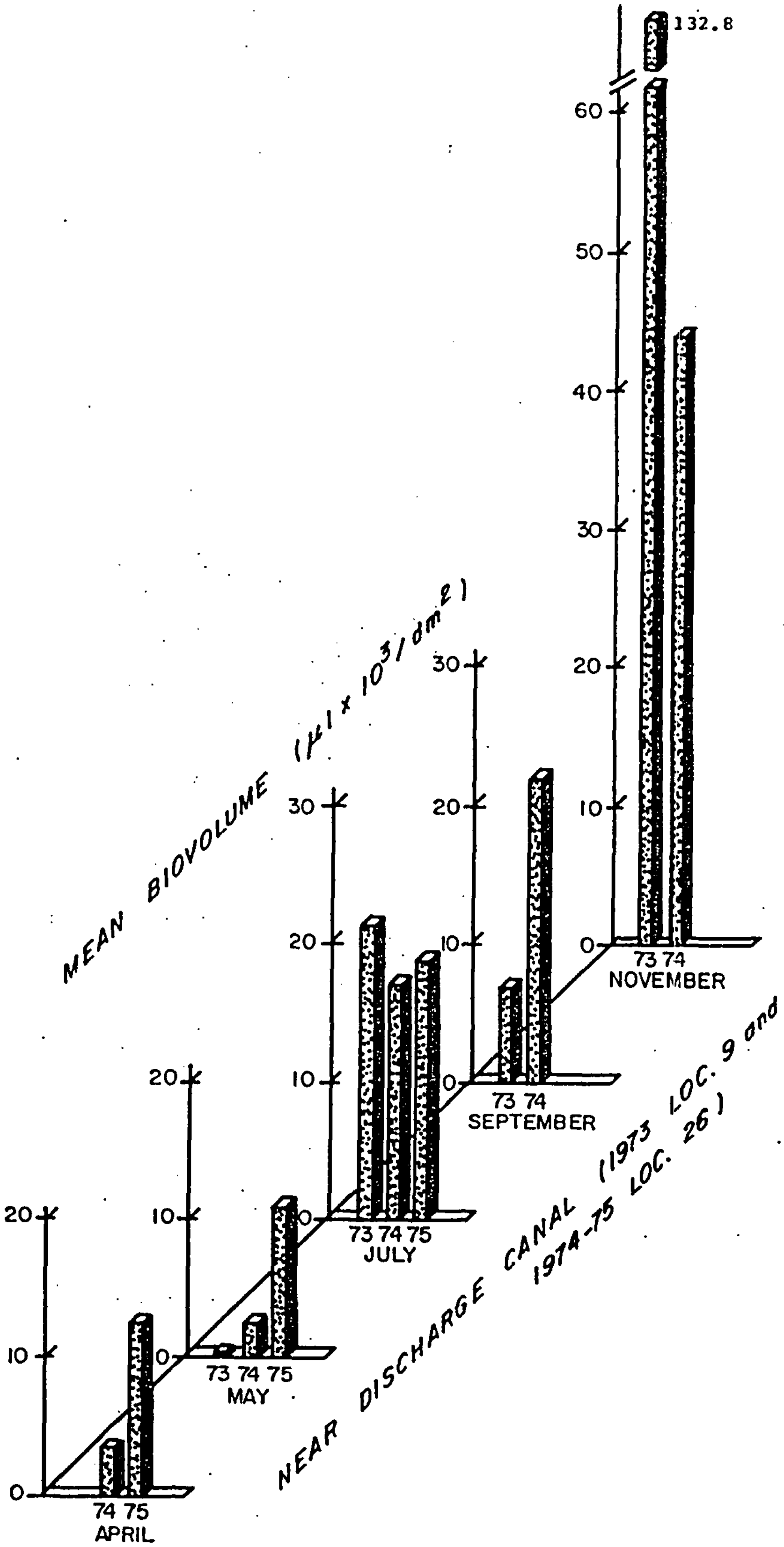


Figure 4.3.5.5. Mean total biovolume of periphytic algae collected from near the Kewaunee Nuclear Power Plant discharge zone (1973 Location 9 and 1974-75 Location 26), May 1973-July 1975.

The standing crop (μl/dm^2) reported for the sampling location near the discharge area (Figures 4.3.5.4 and 4.3.5.5) in November 1973 was more than twice as large as any standing crop reported during the entire monitoring program. This large November standing crop was a result of using an unusually large biovolume conversion number for Cladophora (the dominant alga). The measurement of basal filaments of Cladophora (70-100 μm in diameter) could possibly result in such a high number; however, in averaging the biovolume conversion for the branches of Cladophora (approximately 24-27 μm in diameter) a much smaller standing crop would result. It is highly improbable that only basal filaments were present in the November samples; therefore, the standing crop reported is probably two times too large.

Two major conclusions were obvious from the data presented in Figures 4.3.5.2-4.3.5.5. First, the standing crop encountered at the North Control (Location 1) was usually smaller than at the South Control (Location 18) and near the discharge area (Location 25 and 26). Second, the standing crops encountered from locations near the discharge area during November 1973 and 1974 were greater than at either control location. A combination of a paucity of substrates and the propensity for scouring caused by adjacent eroding bluffs and shifting sand resulted in a relatively smaller standing crop at the North Control location. There were many more substrates available for algal colonization at Locations 25 and 26 than at either of the two control locations. The substrates were rip rap placed at Locations 25 and 26 during Plant construction for protection of the shoreline. The more abundant substrates at Locations 25 and 26 not only "sheltered" the attached algae from direct wave action but also were usually protected from harsh lake conditions (as evident from field observations) because of slight variations in the lake shoreline and bottom topography. These and other variables which affected the size of the standing crops will be further discussed in subsequent sections.

Biomass and chlorophyll a content generally followed the same trend as mean total biovolume with low values occurring in April and May and relatively higher values in September and November (Figure 4.3.5.6). There was, however, considerable variation among the biomass, chlorophyll a and biovolume expressions of standing crops. These variations were attributed to: the differences between one sampled area of substrate and another (i.e., zonation of algal growth); non-algal material included in the biomass samples such as detritus, invertebrates or dead algae; the different amounts of chlorophyll a per unit of biomass or biovolume among algal species; and the variable amounts of chlorophyll a present between rapidly reproducing and senescent algal populations.

The chlorophyll a to biomass, chlorophyll a to biovolume and biomass to biovolume ratios can reflect general differences in the physiological condition of algal crops over time and between locations. However, the natural variability of standing crops in the present study was too great for meaningful utilization of the individual ratios. Mean ratios were therefore calculated for the purpose of comparing results of methods of analyses obtained from

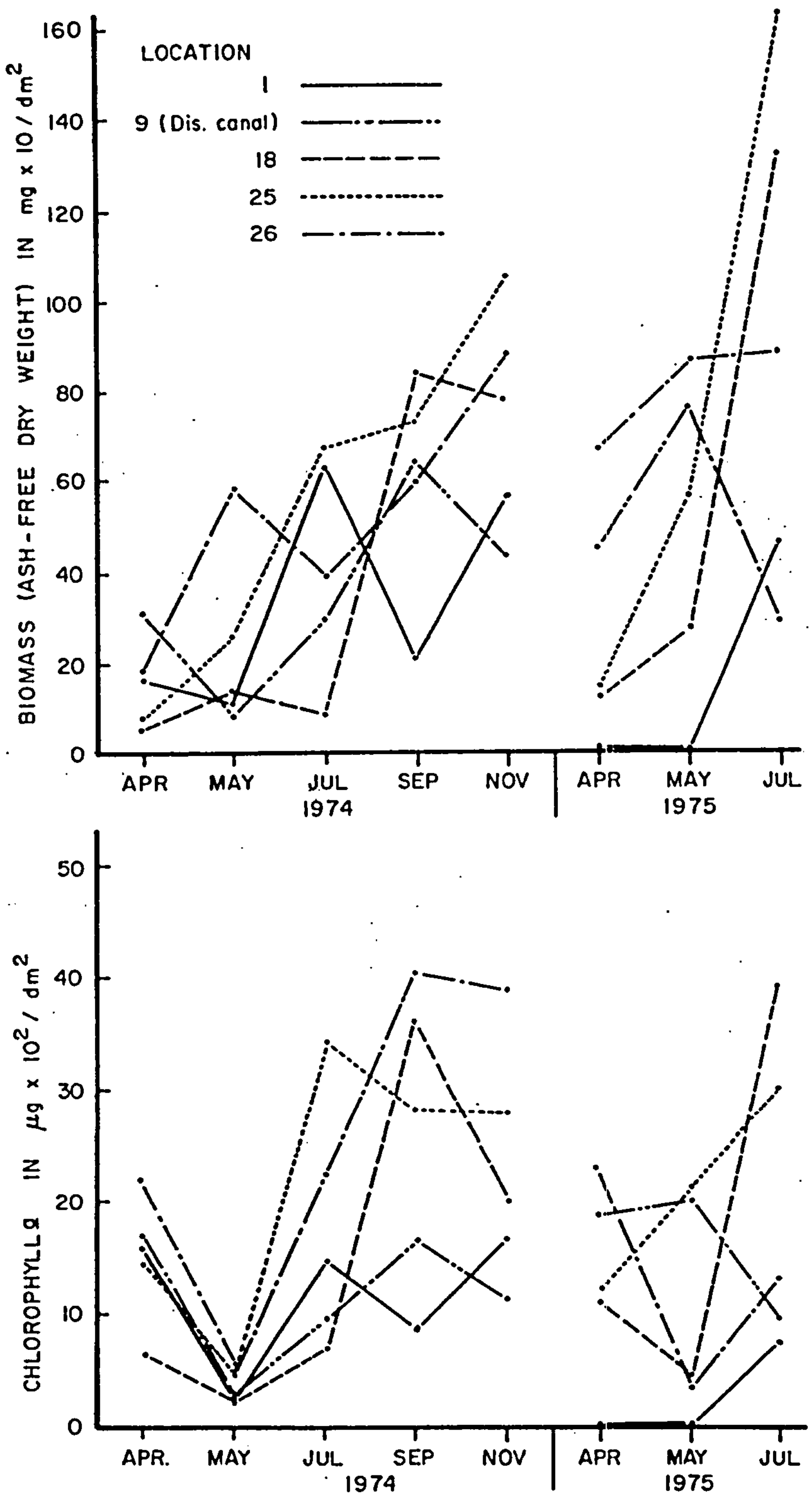


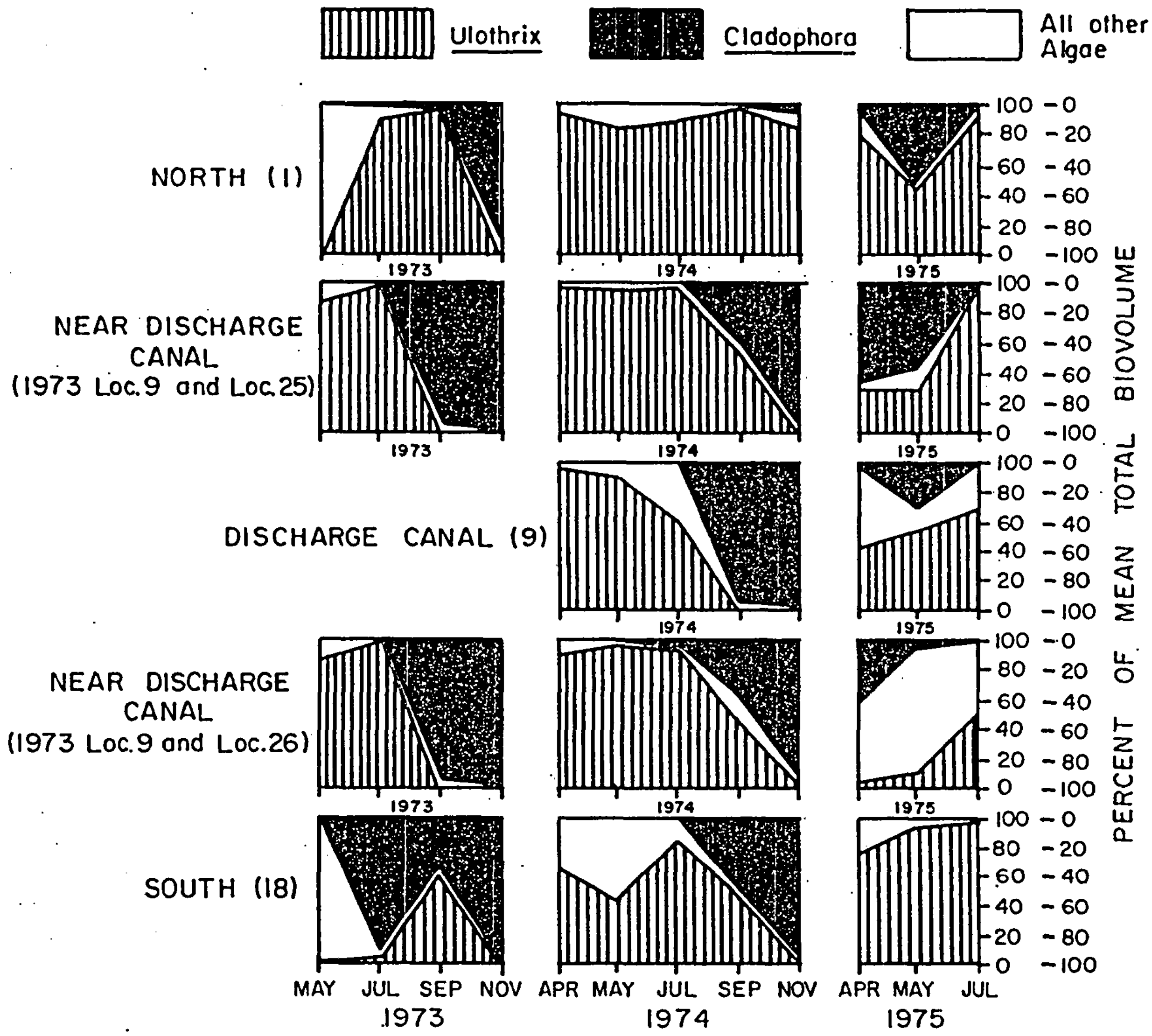
Figure 4.3.5.6. Mean biomass and chlorophyll a content of periphyton collected from sampling locations near Kewaunee Nuclear Power Plant, April 1974-July 1975.

this study to data obtained by other authors. The average April 1974 through July 1975 ratios were: 0.0045 grams of chlorophyll a per gram of biomass (ash-free dry weight); 0.29 grams of chlorophyll a per liter of algae; and 82.50 grams of biomass per liter of algae. These ratios were similar to those reported by Manning and Juday (1941 cited from Wright 1958, p. 152), Riley (1941 cited from Wright 1958, p. 152), Stokes et al. (1970, p. 37), Wright (1959, p. 239) and Altstaetter (1975c, p. 24). This similarity suggests that the three measures of standing crop utilized in the Kewaunee monitoring program produced data that conformed with expected values.

Periphyton Community Composition

Green Algae (Chlorophyta)

The most visually abundant algae encountered during the qualitative phase of the monitoring program were usually species of *Ulothrix* and *Cladophora glomerata*. During the quantitative phase (1973-1975), these two algae usually composed over 90% of the mean total biovolume. The largest standing crops of *Cladophora glomerata* were generally encountered during September and November; whereas, the largest standing crops of *Ulothrix* were generally encountered during April, May and July (Figure 4.3.5.7). This separation over time is partly due to the temperature optima of these species. *Ulothrix zonata*, the most common species of *Ulothrix* encountered near KNPP, grows best at water temperatures below 15 C (Blum 1956, p. 303). *Cladophora glomerata* reportedly grows best at water temperatures of approximately 18 C (Storr and Sweeney 1971, p. 121) although it has also been observed to grow



Note: Values for Ulothrix and Cladophora should be interpreted from the ascending and descending scales, respectively.

Figure 4.3.5.7. Percent of mean total biovolume of Ulothrix and Cladophora from samples of periphytic algae collected near Kewaunee Nuclear Power Plant, May 1973-July 1975.

vigorously at water temperatures of 7 C to 15 C (Herbst 1969, p. 94). This seasonal variation between Ulothrix and C. glomerata and their common occurrence as major constituents of the shoreline periphyton community has been well documented in other areas of Lake Michigan (Altstaetter 1974, p. 9; Alstaetter 1975c, p. 12; Herbst 1969, p. 94; Neil and Owen 1964, p. 114; Industrial BIO-TEST Laboratories, Inc. 1974, p. 122).

The largest standing crops of Cladophora from the shoreline substrates near KNPP were usually not encountered during the periods of warmest water temperatures (July and August). This was probably a result of the littoral zone Cladophora giving rise to zoospores during July and August which attached to the shoreline substrates. The zoosporés, in turn, produced the relatively large standing crops of Cladophora encountered on the shoreline substrates during September and November. A similar pattern of Cladophora growth and zoospore production has been noted by Whitton (1970, p. 468). This same growth pattern has also been documented in southwestern Lake Michigan (Altstaetter 1975c, p. 18).

The seasonal occurrence of Cladophora was not apparent at the North Control Location 1 during September and November 1974 (Figure 4.3.5.7). Substrate scouring was observed at this location, as previously mentioned, more often than at the other locations. A successional algal growth pattern naturally occurs after scouring and requires from two to four weeks to complete. For example, after scouring during periods of Cladophora predominance, succession begins with a community dominated by diatoms, continues to one dominated by Ulothrix, and then returns to a Cladophora predominance (Altstaetter 1975c, p. 13; Herbst 1969, p. 95). Transitional standing crops were probably sampled at Location 1 in September and November 1974 which resulted in the high percent occurrence of Ulothrix.

The periphyton community north of the discharge canal (Location 25) during April and May 1975 was dominated by Cladophora (over 50% of the mean total biovolume) and Ulothrix (approximately 30% of the mean total biovolume). This population of Cladophora probably originated from the 1974 fall population and was completely replaced by Ulothrix by July 1975. The periphyton community south of the discharge canal (Location 26) during April through July 1975 was also composed of Cladophora and Ulothrix populations; however, the dominant alga was Bangia atropurpurea (a red alga). The only possible explanation for the abundance of Bangia at Location 26 and not at Location 25 was a result of substrate orientation. The substrates at Location 26 were often vertically placed and thereby created "spray" when they were struck by waves. The substrates at Location 25 were more horizontally placed causing little wave "spray." This "spray" zone appeared to favor the growth of B. atropurpurea during certain times of the year. A dominant population of Bangia was similarly encountered in Lake Michigan near Zion, Illinois, during April and May 1975 growing on vertically oriented shoreline substrates (Altstaetter 1975c, p. 14). Ulothrix, diatoms and blue-green algae have also been observed growing at different "splash zone" depths in the vicinity of KNPP and in other areas of Lake Michigan

(Altstaetter 1974, p. 10; Altstaetter 1975c, p. 14). Similar findings have been noted by other authors (Evans and Stockner 1972, p. 35; Round 1965, p. 89; Tryon and Hartman 1959, p. 17).

Variations in the abundance of Ulothrix and Cladophora can also result from fluctuating light intensities and water temperatures. A series of cloudy days can sharply reduce the production of Cladophora (Blum 1957, p. 389; Whitton 1970, p. 461); whereas, Ulothrix may increase production as a result of its ability to utilize relatively lower light intensities than Cladophora (McMillan and Verdiun 1953, p. 377). Fluctuating temperatures caused by upwellings of colder profundal waters can also alter algal production as diatoms and Ulothrix generally metabolize better at colder water temperatures than Cladophora (Herbst 1969, p. 94). There can also be variations in standing crop size because of the detachment and breakage of Cladophora filaments, i.e., the filaments easily break when they reach from 20 to 40 cm in length and also Cladophora filaments are generally weaker during zoospore production (Storr and Sweeney 1971, p. 121).

Diatoms (Bacillariophyta)

Diatoms were the second most abundant periphytic algal group encountered at the locations bracketing KNPP. Achnanthes minutissima, Diatoma tenue, Fragilaria vaucheriae, F. pinnata, Gomphonema olivaceum, Nitzschia dissipata and Rhoicosphenia curvata were the most common species and occurred typically at all locations. Each species composed at least 5% or more of the mean total numbers of individuals collected from at least one location on at least one sampling date. These same species were also reported as qualitatively abundant during the 1971-72 monitoring program and all have been reported as major constituents of the diatom periphyton community in other areas of Lake Michigan (Altstaetter 1974, p. 13; Altstaetter 1975c, p. 13; University of Wisconsin-Milwaukee 1971; Wisconsin Electric Power Company and Wisconsin Michigan Power Company 1973, p. 109; Industrial BIO-TEST Laboratories, Inc. 1974, p. 129).

There were some differences in the densities of total diatoms and dominant taxa among locations (Figures 4.3.5.8-4.3.5.10). The diatom density at Location 25 was considerably greater than the density at Location 26 during November 1974. This was primarily a result of relatively greater numbers of _Fragilaria vaucheriae_ and _F. pinnata_ at Location 25 (Figure 4.3.5.9). There was a peak in diatom density at the North Control (Location 1) during July 1974 that was considerably higher than peaks from any other location. This peak and a smaller but similar peak during July 1975 was primarily a result of large numbers of _Fragilaria vaucheriae_ and _Diatoma tenue_.

Blue-Green Algae (Cyanophyta)

Blue-green algae were usually minor constituents of the periphyton community and generally composed less than 4% of the mean total biovolume (Table 4.3.5.1 and Figure 4.3.5.11). There were, however, relatively high densities ($\mu l/dm^2$) of blue-greens at Location 18 during April, May and September 1974 (Figure 4.3.5.12). The populations of blue-greens at Location 18 during April and May 1974, respectively, composed 18% and 36% of the mean total biovolume (Figure 4.3.5.11), whereas, during

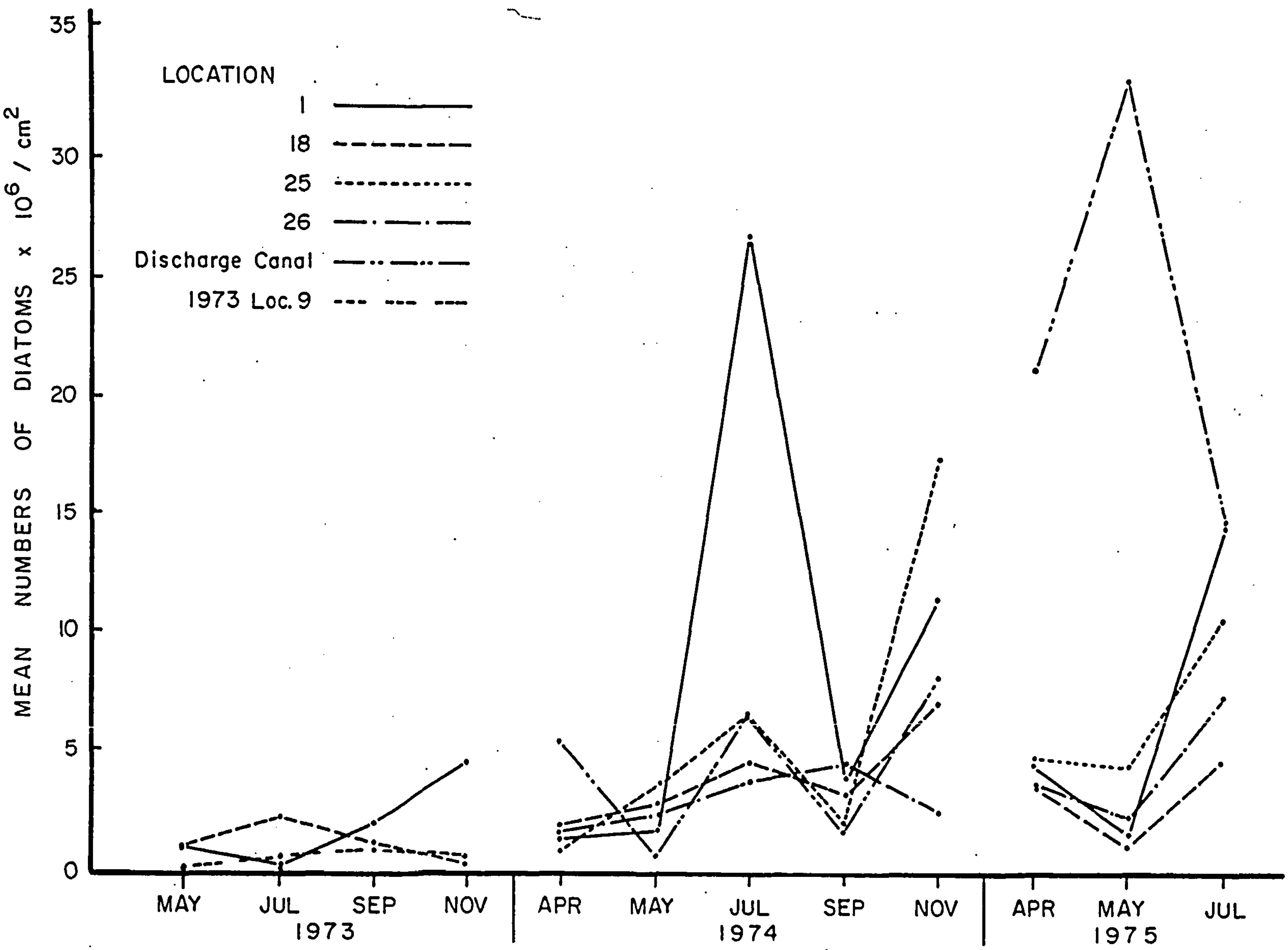


Figure 4.3.5.8. Mean numbers of diatoms from samples of periphytic algae collected from locations near Kewaunee Nuclear Power Plant, May 1973-July 1975.

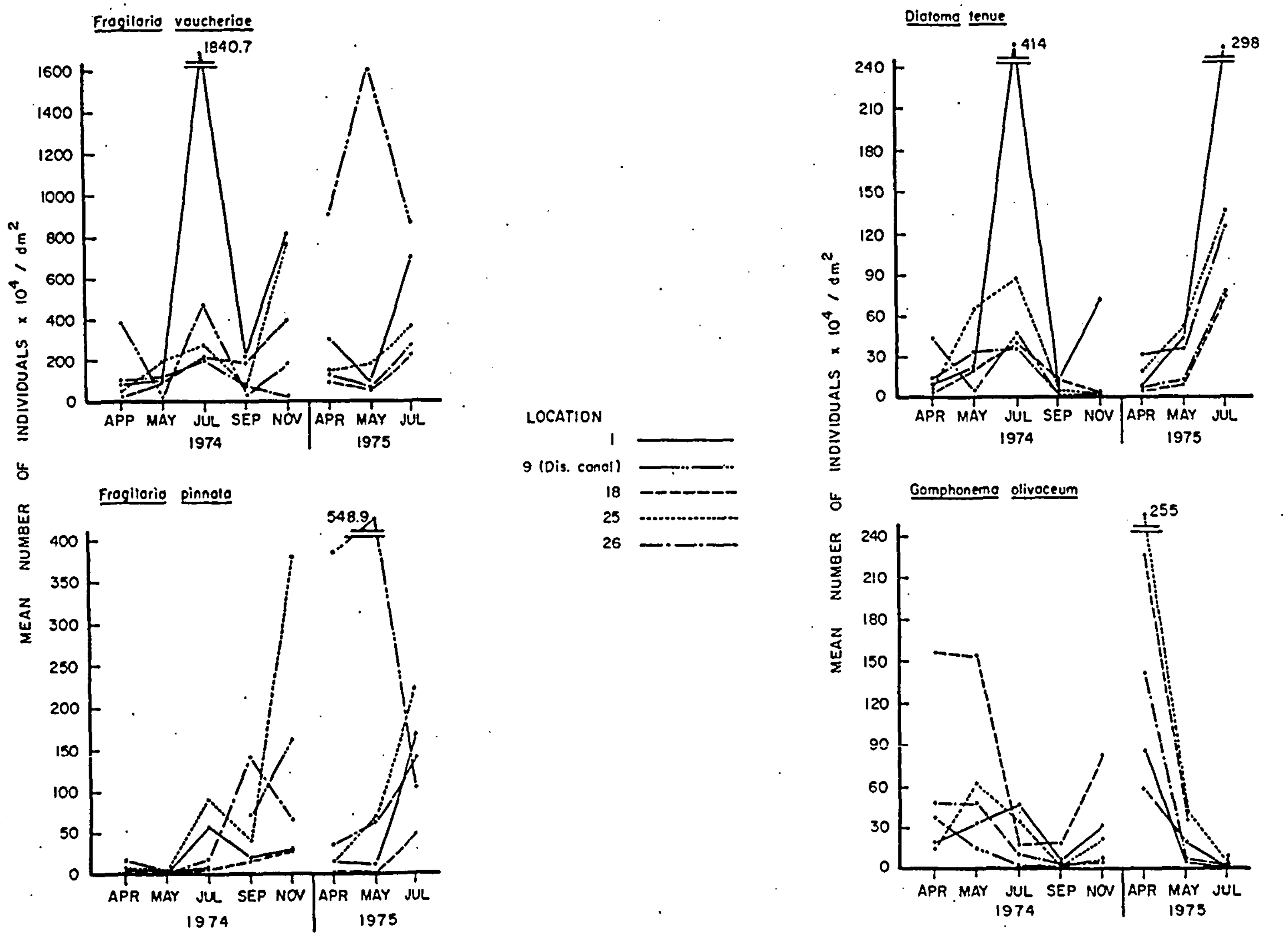


Figure 4.3.5.9. Mean numbers of Fragilaria vaucheriae, F. pinnata, Diatoma tenue and Gomphonema olivaceum collected from sampling locations near Kewaunee Nuclear Power Plant, April 1974-July 1975.

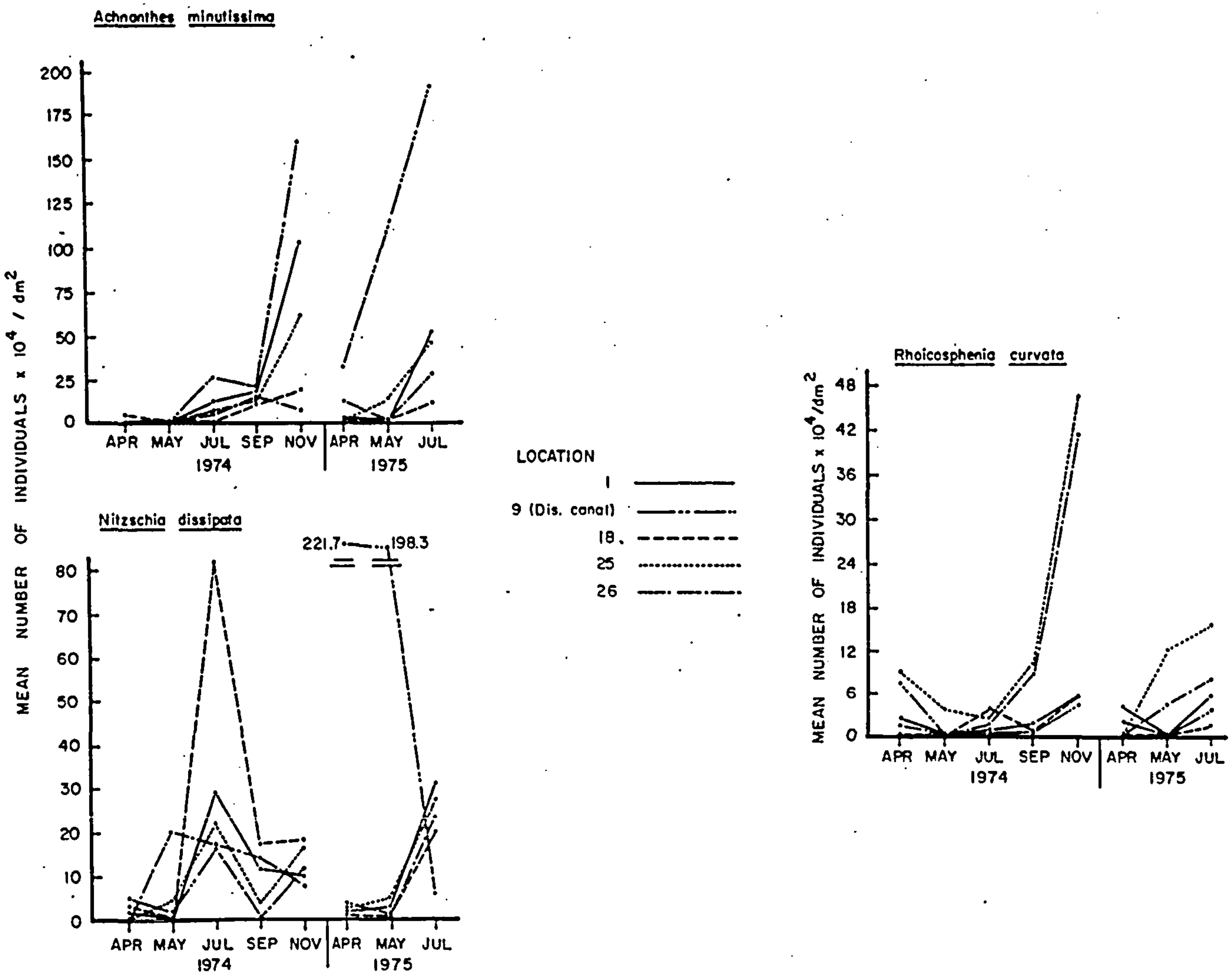


Figure 4.3.5.10. Mean numbers of Achnanthes minutissima, Nitzschia dissipata and Rhoicosphenia curvata collected from sampling locations near Kewaunee Nuclear Power Plant, April 1974-July 1975.

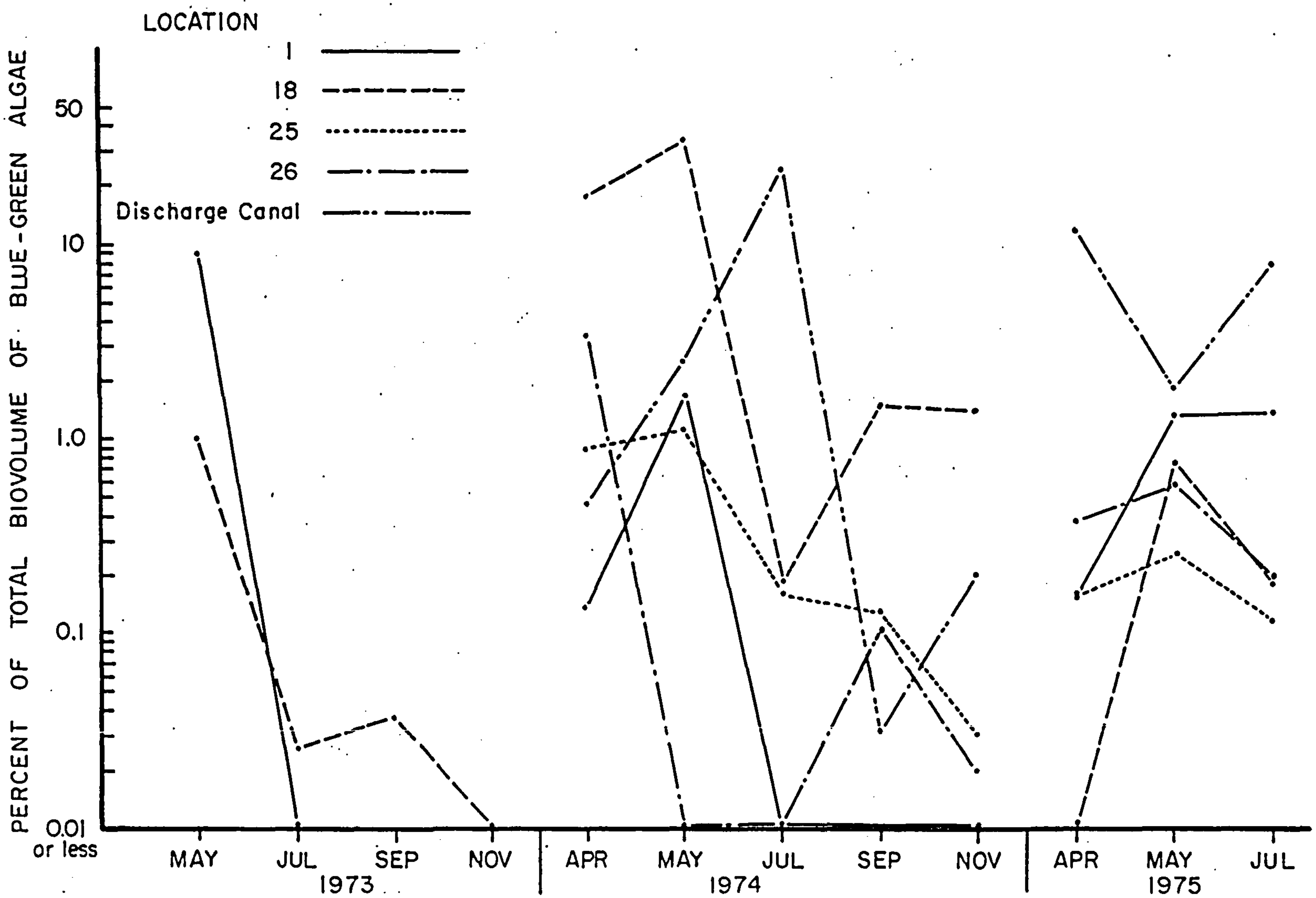


Figure 4.3.5.11. Percent of mean total biovolume of blue-green algae collected from sampling locations near Kewaunee Nuclear Power Plant, May 1973-July 1975.

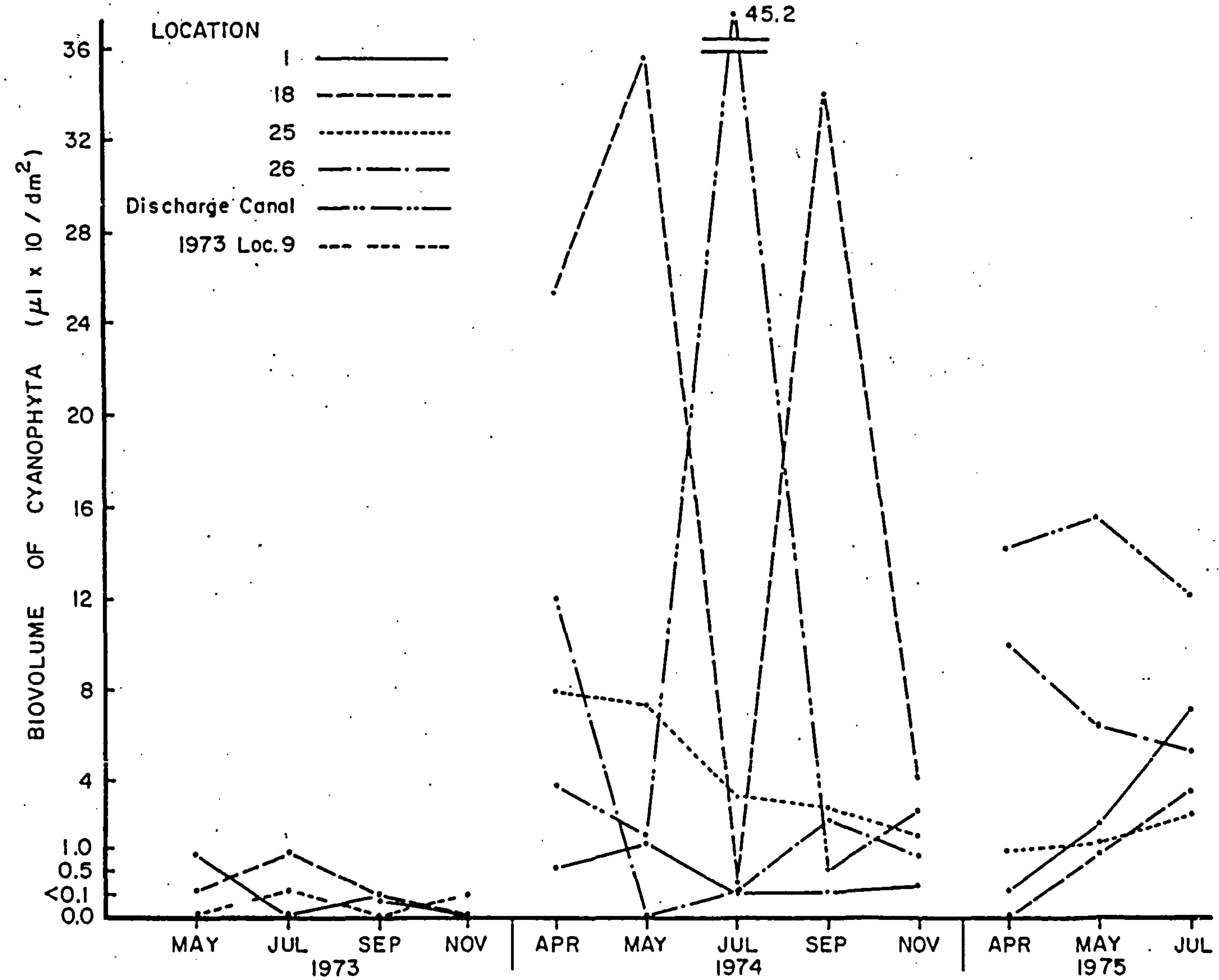


Figure 4.3.5.12. Mean total biovolume of the division Cyanophyta (blue-green algae) collected from sampling locations near Kewaunee Nuclear Power Plant, May 1973-July 1975.

September they composed only 1.5%. These relatively large populations of blue-green algae were primarily composed of Lyngbya aerugineo-caerulea which also occurred commonly at Locations 1, 25 and 26.

4.3.5.2 The Effect of KNPP Operation on the Periphyton Community in the Immediate Discharge Area

The detection of an impact on the periphyton assemblage due to plant operation would depend upon the interpretation of abnormal alterations of community structure. The typical seasonal distribution of species and the natural variations in the periphyton assemblage in the Kewaunee area were documented from preoperational data and data from locations outside the immediate discharge area. Deviations in the periphyton community structure as a result of a thermal impact could occur in the form of altered algal dominance. Among the algal divisions, diatoms are represented by the largest number of species with relatively low temperature tolerances (generally below 30 C); green algae can generally tolerate a wider temperature span; and blue-green algae include the most species that are tolerant of very high temperatures (Patrick 1969, p. 161). There are species in all algal divisions, however, that can tolerate the unusual temperature extreme for their division.

Results of studies on the effects of thermal enrichment on algae generally indicate that: blue-green algae often become dominant when the water temperature exceeds 35.0 C and is maintained above this temperature for fairly long periods of time; green algae become more abundant when temperatures are maintained for several weeks between 32.5 C and 35.0 C; and diatoms usually dominate below these temperatures (if the aquatic environment has not been adversely affected by other types of "pollution") (Patrick 1969, p. 182). It is not probable that only blue-green algae would predominate in the discharge canal periphyton community since the highest discharge canal water temperature is 30 C according to the plant technical specifications (Section 4.1).

Potentially undesirable aspects of a thermal impact on algal periphyton would include: altered seasonal growth patterns of individual species or divisions; invasion into the community of those species that are tolerant of higher temperatures (such as blue-green algae); and a great increase or decrease in the abundance of representatives from one or more algal divisions. The latter factor would probably be of most concern in the Kewaunee area. A significant increase of blue-green or green algae would be undesirable because of the non-utilization of blue greens in the food chain and the overall nuisance potential of large quantities of either of the two algal divisions.

Two periphyton sampling locations (Locations 25 and 26) were considered to be in the immediate discharge area (Section 4.1, Engineering and Hydrological Data). However, during periphyton sampling from April 1974 through July 1975, the water temperatures at these two locations rarely differed by more than 1 C from the temperatures at the North and South Control locations. The single exception occurred on 24 July 1974 when the respective water temperatures from Locations 1, 18 and 25 were 18.5 C, 18.2 C and 18.5 C while the temperature at Location 26 was 22 C. Because this was the only sizeable temperature difference recorded among the sampling locations, it was probable that the substrates at Locations 25 and 26 were seldom influenced by the KNPP thermal effluent.

There were as many differences attributed to natural variation in the periphyton assemblages between Locations 25 and 26 as there were between the control locations and Locations 25 and 26. For example, there were dominant populations of *Bangia atropurpurea* during April and May 1975 at Location 26 but not at Location 25 (Table 4.3.5.1 and Figure 4.3.5.7). There was also a peak in diatom density at Location 25 and not at Location 26 during November 1974 (Table 4.3.5.1 and Figure 4.3.5.8). The differences between Locations 25 and 26 were attributed to the aforementioned differences in substrate orientation.

There was evidence of larger standing crops of periphyton at Locations 25 and 26 than at the control locations, but this trend was occasionally evident during the preoperational period (Figures 4.3.5.2-4.3.5.5). This was probably a result of the greater number of substrates available for algal colonization and the protection afforded the substrates by slight variations in the shoreline and bottom topography.

The typical seasonal distribution of *Ulothrix* and *Cladophora* observed in preoperational studies and at control locations was apparent in the discharge canal (Figure 4.3.5.7). *Ulothrix* dominated (by biovolume) the periphyton community in the canal during April, May and July of 1974 and 1975; whereas, *Cladophora* was dominant (by biovolume) during September and November 1974.

There were two species of diatoms out of the seven previously mentioned dominant species which seemed to "prefer"

Locations 25 and 26 over Locations 1 and 18 (Figures 4.3.5.9 and 4.3.5.10). Rhoicosphenia curvata was more abundant at Locations 25 and 26 during September and November 1974 than at any other location (Figure 4.3.5.10); however, this was directly related to the relatively greater standing crops of the large filamentous green alga Cladophora at these two locations. Since R. curvata is primarily an epiphyte on Cladophora (Lowe 1974, p. 288), the large number of Cladophora filaments at Locations 25 and 26 provided a greater area for R. curvata colonization than at the other sampling locations. Fragilaria pinnata was generally more abundant at Locations 25, and 26 and in the discharge canal than at Locations 1 and 18 during 1974 and 1975 (Figure 4.3.5.9). The presence of this species will be further discussed in following paragraphs.

Some of the factors affecting periphyton within the discharge canal must be clarified prior to the presentation of the discharge canal community. The major environmental factors present in the discharge canal and not at the other locations are constant thermal enrichment (unless the plant is not operating) and constant current. Some of the potential effects of thermal enrichment have already been discussed. Current velocity can also regulate the abundance of certain species of diatoms and certain species of blue-green algae (McIntire 1968, p. 529). Any difference between the discharge canal algal assemblages and those encountered at other locations are, therefore, the result of thermal enrichment, constant current or a combination of the two factors.

All of the dominant diatom taxa occurred typically in the discharge canal (Figures 4.3.5.9 and 4.3.5.10) although there were obvious differences in diatom abundance between the canal and the other locations. Relatively higher densities were encountered during April and May 1975 in the discharge canal (Figure 4.3.5.8). This was probably a result of the different environment found in the canal (i.e., current velocity, substrate differences and thermal enrichment) than at the other locations. The high densities encountered during April and May 1975 were a result of high numbers of *Fragilaria vaucheriae*, *F. pinnata*, *Nitzschia dissipata* and *Navicula* c.f. *radiosa*. The high number of *N.* c.f. *radiosa* was particularly confined to the discharge canal and was probably indicative of the canal's unique environment. The relatively higher numbers of *F. pinnata* in the discharge canal and at Locations 25 and 26 than at the other locations was possibly reflective of the canal's environment; however, the inconsistent peak abundances at these three locations and also a peak of *F. pinnata* at Location 1 in July 1975 (Figure 4.3.5.9) places doubt on the assumption that *F. pinnata* was responding to the environmental conditions in the canal.

Blue-green algae composed more than 4% of the mean total biovolume in the discharge canal only during July 1974 (24%), April 1975 (12%) and July 1975 (8%)(Figure 4.3.5.11). Blue-greens were considerably more abundant in the discharge canal than at the other locations in July 1974 and only slightly more abundant in April, May and July 1975 (Figure 4.3.5.12). However, the size of the standing crop of blue-greens in the discharge canal was not distinctly different than the standing crop at the other locations, particularly at Location 18 (the South Control)(Figure 4.3.5.12). The most common blue-green alga at Location 18 and at the other locations was Lyngbya aerugineo-caerulea; however, the discharge canal populations were usually co-dominated by Phormidium c.f. retzii and L. aeurgineo-caerulea. The high numbers of P. c.f. retzii were confined to the discharge canal and were probably indicative of the unique environment found in the canal.

The standing crop of algae in the discharge canal (as measured by biovolume, biomass and chlorophyll a content) was within the size range observed at the other locations (Figures 4.3.5.6, and 4.3.5.13). There were differences in standing crop size between 1974 and 1975 during April, May and July. The constant current in the discharge canal probably maintained a fairly stable standing crop except when sloughing (caused by mechanical abrasion) occurred when the algal crop reached some maximum size. Also, fluctuating temperatures caused by plant shut-downs or different operating rates may have altered the standing crop.

The seasonal variation between Ulothrix and Cladophora, the typical seasonal occurrence of the dominant diatoms and the size of the algal standing crop were similar at all periphyton sampling locations. The occurrence in the discharge canal of occasionally higher numbers of diatoms, occasionally higher percentages of blue-green algae and the presence of some of the dominant species (primarily the high numbers of Phormidium c.f.

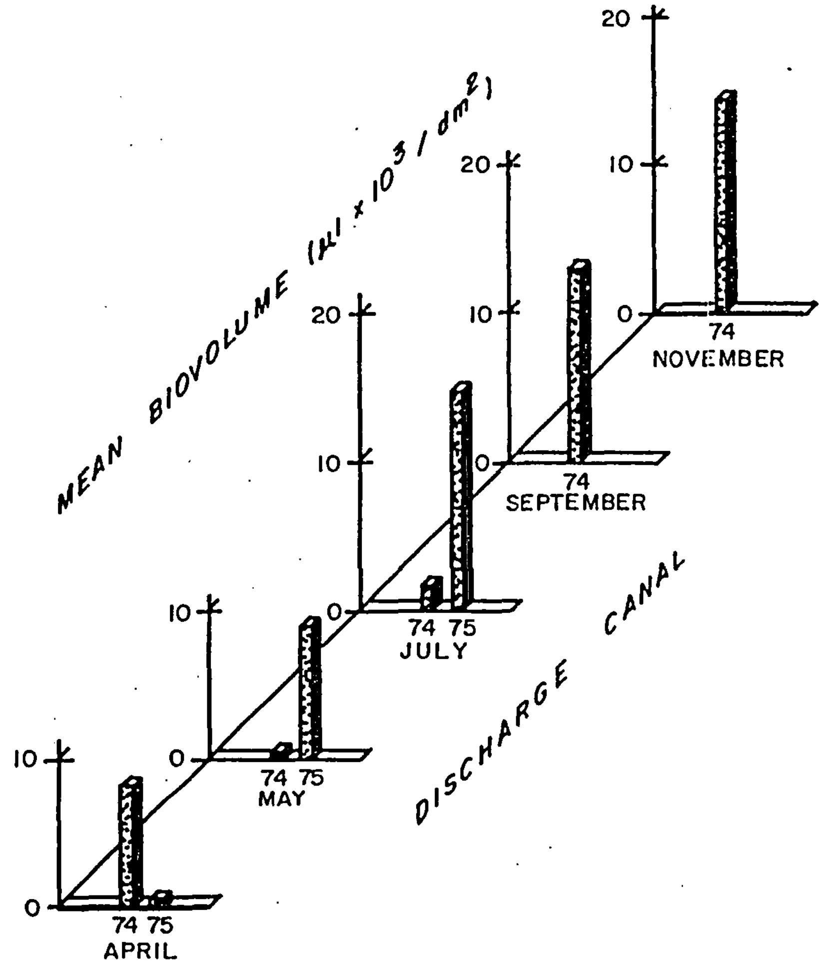


Figure 4.3.5.13. Mean total biovolume of periphytic algae collected from the Kewaunee Nuclear Power Plant discharge canal (Location 9), April 1974-July 1975.

retzii, *Navicula* c.f. *radiosa* and possibly *Fragilaria pinnata*) were probably very localized effects of the operation of KNPP.

The condition referred to as thermal shock can occur when no acclimation time is possible due to an abrupt change in temperature. Cold shock caused by a sudden plant shut-down would probably be more of an abrupt stress than heat shock because plant start-up would be slower and, therefore allow for more acclimation time. Various physiological responses ranging from mortality to minor changes in metabolism would result from heat or cold shock depending upon the magnitude of the temperature change.

Relatively few researchers have attempted to study the effect of sudden water temperature changes on algae. One species of blue-green algae could withstand a sudden change from 70 C to room temperature without apparent damage; whereas, another blue-green alga was very sensitive to changes from its acclimated temperature (Patrick 1969, p. 171). General implications from laboratory studies on diatom communities subjected to sudden heat stress were: 1) the nutritive value of diatoms could be altered which would affect other components of the food web; and 2) damage to cell pigments could depress metabolism (Lanza and Cairns 1972, p. 341). Laboratory studies are important to isolate effects of thermal stress. However, Phinney and McIntire have proposed in their study on algal communities developed in laboratory streams (1965, p. 341) " . . . that determinations of the physiological responses of individual organisms or of unispecific cultures in vitro do not always accurately represent the responses of more complex community aggregations". Correlations between these isolated effects and the ultimate effect of thermal stress upon natural algal populations should therefore, be interpreted with caution.

The effects of thermal stress would only be reflected in the discharge canal periphytic algal community. Some of the previously mentioned responses to heat shock would probably result in a decrease of certain species while others might increase. A sudden decrease in water temperature would decrease the rates of heat tolerant species which would be reflected in a subsequently smaller standing crop. Thus, some of the species which were present in the discharge canal that possibly "preferred" the relatively warmer water (i.e., Phormidium c.f. retzii and Navicula c.f. radiosa) would probably show a reduction. However, this species reduction might not occur as an after effect of thermal stress because, as previously mentioned, the canal's constant current might have been the factor regulating the abundance of some of these species.

The results of either heat or cold shock caused by the maximum water temperature fluctuation would only be displayed as a temporary alteration of discharge canal community structure. Some of the species would probably not be affected, some would persist in a non-reproductive state (such as some form of resting spore), while others would be soon replaced by "seed" species carried in by condenser water. The return to a typical seasonal discharge canal community would probably require from two to four weeks after the maximum water temperature fluctuation. This same time span is also required for a seasonally typical periphytic algal community to develop on shoreline substrates after the substrates have been scoured.

4.3.5.3 The Effect of KNPP Operation on the Periphyton Community in the Receiving Water Body

There were differences between the two control locations (Locations 1 and 18) in the size of the algal standing crop (Figures 4.3.5.2, 4.3.5.3 and 4.3.5.6), the abundance of total diatoms and dominant taxa (Figures 4.3.5.8-4.3.5.10) and the abundance of the blue-green algae (Figure 4.3.5.12). The differences occurred during the preoperational and operational periods of KNPP and were not indicative of any effect of station operation. This was particularly true owing to the absence at both Control Locations 1 and 18 of high numbers of some of the species that were typical of the discharge canal periphyton assemblage. Both the seasonal distribution of dominant populations of Ulothrix and Cladophora and the dominant diatom species were similar to those documented in other areas of western and southwestern Lake Michigan. This indicates that during both preoperation and operation of KNPP there existed a typical periphytic algal assemblage in the vicinity of KNPP.

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4.3.6 Aquatic Macrophytes

Aquatic Macrophytes refers to those submersed vascular plants which are rooted in the lake bottom. Environmental Monitoring Programs have been conducted annually in Lake Michigan near the Kewaunee Nuclear Power Plant since 1971. During this study period no aquatic macrophytes were observed throughout the study area shown in Figure 4.2.1.

Shoreline surveys, aerial photographs and SCUBA diver observations were employed to evaluate the entire study area for macrophyte growth and no macrophytes were observed. The lake bottom within the 10 ft depth contour near the Kewaunee Plant consists mainly of sand and gravel (Appendix 4: Physical Studies, Chapter 2: Bottom Topography pp. 10-15). This physical feature along with strong wave action are mainly responsible for the lack of aquatic macrophyte growth within the study area.

Due to the absence of aquatic macrophytes in the vicinity of Kewaunee Nuclear Power Plant, no assessment of potential effect of a thermal discharge on macrophytes will be included in this document.

APPENDIX I

State of Wisconsin \ DEPARTMENT OF NATURAL RESOURCES

L. P. Voigt
Secretary

BOX 450
MADISON, WISCONSIN 53701

August 3, 1973

IN REPLY REFER TO: 3210-5

Wisconsin Public Service Corporation
P. O. Box 1200
Green Bay, Wisconsin 54301

Attn: Mr. Evan James, Senior Vice President
Power Generation and Engineering

Dear Sirs:

This is in response to your request to the Wisconsin Department of Natural Resources for State certification in accordance with Section 401(a) of the Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500) for the proposed discharge to Lake Michigan from the Kewaunee Nuclear Power Plant located in the Town of Carlton, Kewaunee County, Wisconsin.

Notice of the application was published by the Department on July 2, 1973, and required that written comments be submitted by July 20, 1973. A total of 39 letters were received. Based on an evaluation of the comments, public hearing was not deemed necessary.

It is hereby certified that for the proposed discharge from the Kewaunee Nuclear Power Plant there are no applicable effluent limitations promulgated pursuant to provisions of Sections 301, 302, 306 and 307 of the 1972 Amendments and that the proposed discharge will be in compliance with water quality standards for Lake Michigan as set forth in Chapters NR 102 and 103 of the Wisconsin Administrative Code.

Very truly yours,
Division of Environmental Protection

Thomas G. Frangos
Administrator

State of Wisconsin \ DEPARTMENT OF NATURAL RESOURCES

September 13, 1976

Anthony S. Earl
Secretary

BOX 450
MADISON, WISCONSIN 53701

IN REPLY REFER TO: 8300

Mr. Allen W. Williams, Jr.
Attorney at Law
Foley & Lardner
777 East Wisconsin Avenue
Milwaukee, Wisconsin 53202

Mr. Kenneth Euers, President
Brown County Conservation Alliance
1406 9th Street
Green Bay, Wisconsin 54304

Mr. Thomas D. Eisele, Deputy Director
The Lake Michigan Federation
53 West Jackson Blvd.
Chicago, Illinois 60604

Mr. Daniel F. Buss, Program Manager
CDM/Limnetics, Point Beach Nuclear Plant
6132 West Fond du Lac Avenue
Milwaukee, Wisconsin 53218

Mr. Bill Rudolph, Vice President
CDM/Limnetics, Point Beach Nuclear Plant
6132 West Fond du Lac Avenue
Milwaukee, Wisconsin 53218

Mr. Charles H. Wahtola
Wisconsin Electric Power Company
231 West Michigan Avenue
Milwaukee, Wisconsin 53201

Mr. Robert J. Mussallem
Attorney at Law
P. O. Box 7921
Madison, Wisconsin 53707

Re: Petition of Wisconsin Public Service Corporation for the Imposition of Alternative Effluent Limitations and Thermal Mixing Zone Requirements for the Kewaunee Nuclear Power Plant, Town of Carlton, Kewaunee County - EX-76-143

Gentlemen:

Please find enclosed a copy of Findings of Fact, Conclusion of Law and Order in regard to the above-captioned matter.

Sincerely,

Maurice H. Van Susteren

Maurice H. Van Susteren
Hearing Examiner

Enc.
jf

9-17-76

BEFORE THE

DEPARTMENT OF NATURAL RESOURCES

Petition of Wisconsin Public Service Corporation for the Imposition of Alternative Effluent Limitations and Thermal Mixing Zone Requirements for the Kewaunee Nuclear Power Plant, Town of Carlton, Kewaunee County	)	EX-76-143 WI-0001571

FINDINGS OF FACT, CONCLUSION OF LAW AND ORDER

In May of 1976 the Wisconsin Public Service Corporation for and on behalf of itself as the manager and for Wisconsin Power and Light Company and Madison Gas and Electric Company as co-owners filed a petition with the Department of Natural Resources for a public adjudicatory hearing pursuant to Sections 147.05(4)(a) and 147.20, Wisconsin Statutes, and Wisconsin Administrative Code NR 209.05 and 102.07 for the imposition of alternative effluent limitations and thermal mixing zone requirements for the Kewaunee Nuclear Power Plant in the Town of Carlton, Kewaunee County.

The petitioner is required by Wisconsin Administrative Code NR 102.05 to control the thermal component of its discharge to Lake Michigan such that by July 1, 1979 the thermal discharge shall not raise the temperature of the receiving water more than 3° F above the existing natural temperature at the edge of a mixing zone nor raise the temperature at the edge of the mixing zone above the maximum temperature limits as set out in the Administrative Code. The thermal mixing zone is as defined in Wisconsin Administrative Code NR 102.05.

In addition to the foregoing thermal discharge and mixing requirements the petitioner is required by Section 147.04, Wisconsin Statutes, and Wisconsin Administrative Code NR 290.11 to control the thermal component of its discharge such that by July 1, 1981 there shall be no discharge of heat from the main condensers except blowdown from recirculated cooling water systems provided that the temperature of the blowdown does not exceed at any time the lowest temperature of the recirculated cooling water prior to the addition of the make-up water.

The petitioner requests that the thermal component of its discharge be exempted from the thermal mixing zone requirements of NR 102.05 and further that it be subjected to the following alternative effluent limitations in lieu of that required by Wisconsin Administrative Code NR 290.11:

"The thermal discharge from the plant shall not have a flow rate of more than 450,000 gallons per minute nor have a temperature increase between the intake and discharge of more than 30° F."

The petitioner submitted a demonstration pursuant to Wisconsin Administrative Code NR 209.03(2)(a) and 102.06 in support of the petition.

Public hearing was held August 10, 1976 at Kewaunee, Wisconsin before Examiner Maurice H. Van Susteren.

APPEARANCES:

IN SUPPORT:

Wisconsin Public Service Corporation, by

Allen W. Williams, Jr., Attorney
Milwaukee

AS INTEREST MAY APPEAR:

Brown County Conservation Alliance, by

Kenneth Euers, President
Green Bay

The Lake Michigan Federation, by

Thomas D. Eisele, Deputy Director
Chicago, Illinois

Department of Natural Resources
Division of Environmental Standards, by

Robert J. Mussallem, Attorney
Madison

CDM/Limnetics, by

Daniel F. Buss, Program Manager - Point Beach Nuclear Plant
Milwaukee

Bill Rudolph, President
Milwaukee

Wisconsin Electric Power Company, by

Charles H. Wahtola
Milwaukee

FINDINGS OF FACT

1. The Kewaunee Nuclear Power Plant, Town of Carlton, Kewaunee County operated by the Wisconsin Public Service Corporation has a pressurized water reactor licensed at 1650 M Wt and a turbine generator of 540 M We. The unit began full commercial operation in 1974 and reached full power in August 1974.

2. The plant uses a once through cooling system with a normal flow rate of 413,000 gpm with a design maximum rise in temperature of 11.1° C. The intake structure is located approximately 1600 feet offshore and cooling water is discharged from a shoreline outfall structure.

3. Lake currents at the plant parallel the shore in the direction N NE - NE and S SW - SW with speeds most frequently in the range of 0.10-0.24 fps. The direction of net displacement of water past the plant for the period April-December 1973 and June to October 1974 was northward. Maximum and maximum mean temperatures of the lake near the plant in 1973-1974 occurred in August with maximum ranges occurring in August 1973 and July 1974. Stratification develops in the shallow nearshore area but breaks down easily.

4. The discharge zone for the plant thermal plume encompasses an area of approximately 985.3 acres at the surface and 94.5 acres at the bottom. The surface area is in excess of the 71.74 acres of the Department standard for the plant. The thermal plume discharge velocity affects an area of the lake bottom about 250 feet wide extending 400 feet from the outfall. There is a 55% to 90% reduction in excess temperature within 50 to 75 minutes travel time from the outfall.

5. The chemical quality of the water in the plant vicinity is representative of general lake conditions with no change in the major anions and cations. Water quality generally within and immediately outside the thermal plume is essentially the same considering dissolved oxygen, nitrogen species, orthophosphate and soluble silica concentrations. Alkalinity and pH were virtually constant but turbidities and suspended solids changed in relation to weather conditions. Bacteria levels, oxygen demands and trace metal values show little if any differences between preoperational and operational periods.

6. The Department chose 30 species of fish as representative important species and posed 18 questions as part of the demonstration. The list embraces fish considered to have other values such as commercial, community integrity, sport, forage and changing status.

Alewife, rainbow smelt, yellow perch, lake trout, lake chub, longnose dace, white sucker, longnose sucker and slimy sculpin are the major constituents of the local fishery comprising 98% of the total catch. Annual catches and general distribution of major species are unrelated to the thermal discharge of the plant.

The life history of the representative important species was studied to include general occurrence in Lake Michigan, seasonal migrations, seasonal abundance near the plant, spawning, growth and food habits.

Species believed to spawn successfully in areas near the plant are alewife, rainbow smelt, lake chub, longnose dace and slimy sculpin. Peak abundances of alewife, smelt, trout and white sucker appear to correspond to their respective spawning seasons but no spawning habitat was identified for the various species.

The area affected by the plant's thermal discharge is not an important spawning location for any species. The area has, however, developed an extensive seasonal salmonid fishery at the plant outfall.

The thermal discharge has had no appreciable influence on the local fishery. No major changes in species composition, seasonal abundance or spatial distribution of the representative important species has occurred since the plant began operating. The outfall, however, has attracted certain species namely, the carp. Attraction to the thermal discharge is in response to the higher temperatures but fish also avoid the discharge when temperatures become too high. The discharge at the outfall has only a negligible effect on the normal seasonal migrations of fish. No fish kills have occurred since the plant began operation.

The discharge of waste heat from the plant has caused no harm to the representative species in the discharge zone and has no effect on the representative species immediately outside the discharge zone.

7. Densities and seasonal distributions of macroinvertebrates have not changed by operation of the plant and the thermal discharge has had no effect on the macroinvertebrate community within the discharge zone.

8. The phytoplankton community has remained essentially unchanged from preoperational to operational periods. The plant operation has caused no harm to the phytoplankton community inside and outside the discharge zone.

9. The operation of the plant had no effect on zooplankton either inside or outside the discharge zone.

10. Periphytic algae collected in both preoperation and operation phases show little if any change in locations outside the discharge zone. Standing crop variations show a consistent seasonal trend. The larger standing crops, however, are found on either side of the discharge canal. The canal riprap erosion control walls provide a favorable substrate for algal colonization.

11. No macrophytes were observed in the vicinity of the plant in either the preoperational or operational phases.

12. An immediate primary benefit of plant operation is the development of an extensive salmonid fishery in the immediate discharge area.

13. The Department finds that no appreciable harm has resulted from the thermal component of the discharge, taking into account the interaction of such component with other pollutants and the additive effect of other thermal discharges, to a balanced, indigenous community of shellfish, fish and wildlife in and on the receiving water of Lake Michigan.

14. The thermal mixing zone requirements of Wisconsin Administrative Code NR 102 are more stringent than necessary to assure a balanced indigenous community of shellfish, fish and wildlife in Lake Michigan.

15. Discharge limitations of 450,000 gallons per minute and a temperature increase between intake and discharge of 30° F or less will assure the protection and propagation of balanced indigenous communities of fish, shellfish and wildlife in the vicinity of the Kewaunee Nuclear Power Plant in Lake Michigan.

CONCLUSION OF LAW

The Department of Natural Resources has the authority and power under Chapter 147, Wisconsin Statutes, and Wisconsin Administrative Code Chapters NR 102 and 209 and in accordance with the foregoing findings of fact to issue an order imposing alternative effluent limitations and to exempt the thermal component of the petitioners discharge from existing thermal mixing zone requirements of Wisconsin Administrative Code NR 102.05.

ORDER

THE DEPARTMENT, THEREFORE, ORDERS:

1. The petition of Wisconsin Public Service Corporation for the imposition of alternative effluent limitations and exemption from thermal mixing zone requirements for the Kewaunee Nuclear Power Plant be, and the same is hereby granted.

2. The petitioner is exempted from the thermal mixing zone requirements of Wisconsin Administrative Code NR 102.05 and is subjected to the following alternative effluent limitations in lieu of that required by Wisconsin Administrative Code NR 290.11:

The thermal discharge from the plant shall not have a flow rate of more than 450,000 gallons per minute nor have a temperature increase between the intake and discharge of more than 30° F.

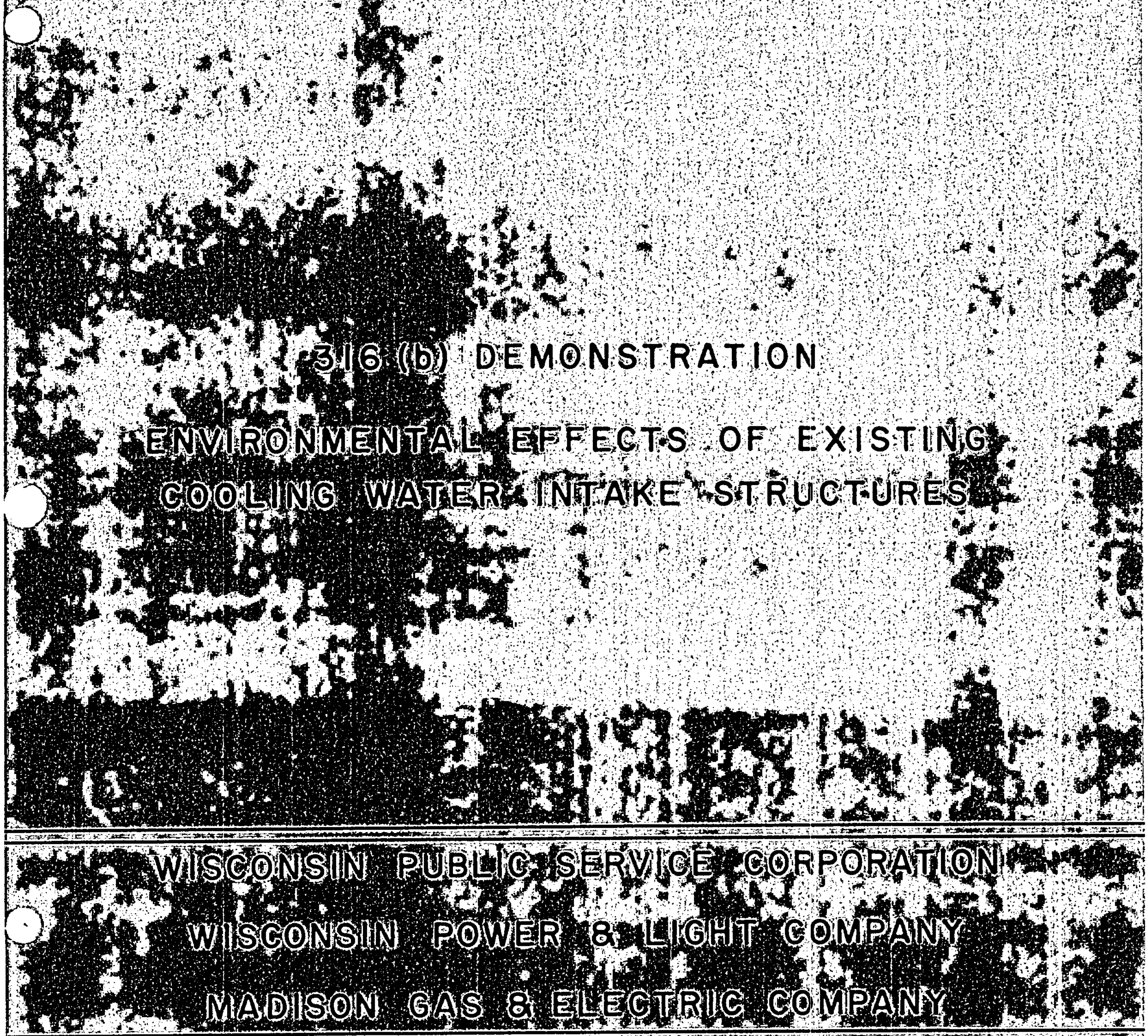
Dated at Madison, Wisconsin, this 13th day of September, 1976.

STATE OF WISCONSIN DEPARTMENT OF NATURAL RESOURCES
For the Secretary

By Maurice H. Van Susteren

Maurice H. Van Susteren
Hearing Examiner

KEWAUNEE NUCLEAR POWER PLANT



316 (b) DEMONSTRATION

ENVIRONMENTAL EFFECTS OF EXISTING COOLING WATER INTAKE STRUCTURES

WISCONSIN PUBLIC SERVICE CORPORATION

WISCONSIN POWER & LIGHT COMPANY

MADISON GAS & ELECTRIC COMPANY

NALCO ENVIRONMENTAL SCIENCES
1500 FRONTAGE ROAD ◦ NORTHBROOK, ILLINOIS 60062 ◦ AREA 312-564-0700

NALCO CHEMICAL COMPANY

REPORT TO

WISCONSIN PUBLIC SERVICE CORPORATION
GREEN BAY, WISCONSIN

KEWAUNEE NUCLEAR POWER PLANT
KEWAUNEE, WISCONSIN

316(b) DEMONSTRATION

ENVIRONMENTAL EFFECTS OF EXISTING COOLING WATER INTAKE STRUCTURES

PREPARED AND SUBMITTED
BY
NALCO ENVIRONMENTAL SCIENCES

Report approved by: B. G. Johnson

B. G. Johnson, Ph.D.
General Manager

ACKNOWLEDGEMENTS

The overall supervision of the 316(b) Demonstration was the responsibility of Dr. B. G. Johnson, General Manager, NALCO Environmental Sciences, and Dr. J. A. DeMarte and Dr. B. J. Cox, Project Coordinators. Mr. A. L. Restaino and Mr. J. Rice shared Project Leader responsibilities for the impingement and entrainment studies. The preparation of the 316(b) Demonstration was the responsibility of Mr. A. L. Restaino, Scientist, Environmental Physiology Section.

Personnel that provided technical and supervisory assistance were:

Mr. T. P. Meinz, Wisconsin Public Service Corporation

Mr. E. N. Newman, Wisconsin Public Service Corporation

Mr. L. J. LaJeone, Fisheries Biology

Mr. B. Muench, Fisheries Biology

Mr. D. Wetzel, Environmental Physiology

Mr. W. Iverson, Environmental Physiology

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I. Introduction

Section 316(b) of Public Law 92-500 and Section 147.02(g), Wisconsin Statutes, require that the location, design, construction, and capacity of cooling water intake structures reflect the "best technology available for minimizing adverse environmental impact." As required by Wisconsin Pollution Discharge Elimination System Permit WI-0001571, a one-year study was undertaken to determine the environmental impact of the present cooling water intake structure of the Kewaunee Nuclear Power Plant.

Data were collected to quantify intake effects on all life stages of fish and to describe peripheral factors which may directly influence the results. Total number of fish impinged with corresponding size and weight was obtained by sampling all adult and juvenile fish removed from the cooling water by the trash rack/traveling screen barrier system. Fish eggs, larvae, and small juveniles not removed by the barrier systems pass through the Plant's condenser system. Sampling for entrained fish eggs and larvae was conducted during reproductive periods. Data collected were used to identify and estimate the total number of eggs, larvae, and juveniles which passed through the Plant. This report summarizes the effects of the intake structure at Kewaunee Nuclear Power Plant on the various species and life stages of fish entrained in the cooling water system.

II. Present Intake Structure

The Kewaunee Nuclear Power Plant is located on the west shore of Lake Michigan, approximately 8 miles south of Kewaunee and 90 miles north of Milwaukee (Figure 1). The facility employs a single pressurized water reactor (PWR) nuclear generating unit and produces a net output of 540 megawatts electric (MWe). The Plant is classified as a base load unit which normally operates 24 hours per day and 7 days per week. A once-through cooling system is employed with a water flow of 412,000 GPM from May through November and 281,000 GPM from December through April. Cooling water is drawn into the Plant from a submerged intake located 1550 ft offshore through 10 ft diameter steel pipe at a velocity ranging from 1.7 to 3.3 m/sec (Figure 2). An air bubbler system operates continuously around the intake inlet to discourage fish from being attracted to the intake. Water from the intake pipe enters the forebay, a rectangular concrete structure having a maximum capacity of approximaterly 3000 m^3 (792,600 gallons) of water (Figure 3). Forebay water passes through traveling screens before entering two centrifugal circulating water pumps. Water velocities in the forebay ranged from 0.22 to 0.88 m/sec at maximum flow and from 0.10 to 0.50 m/sec during minimum flow (Table 1).

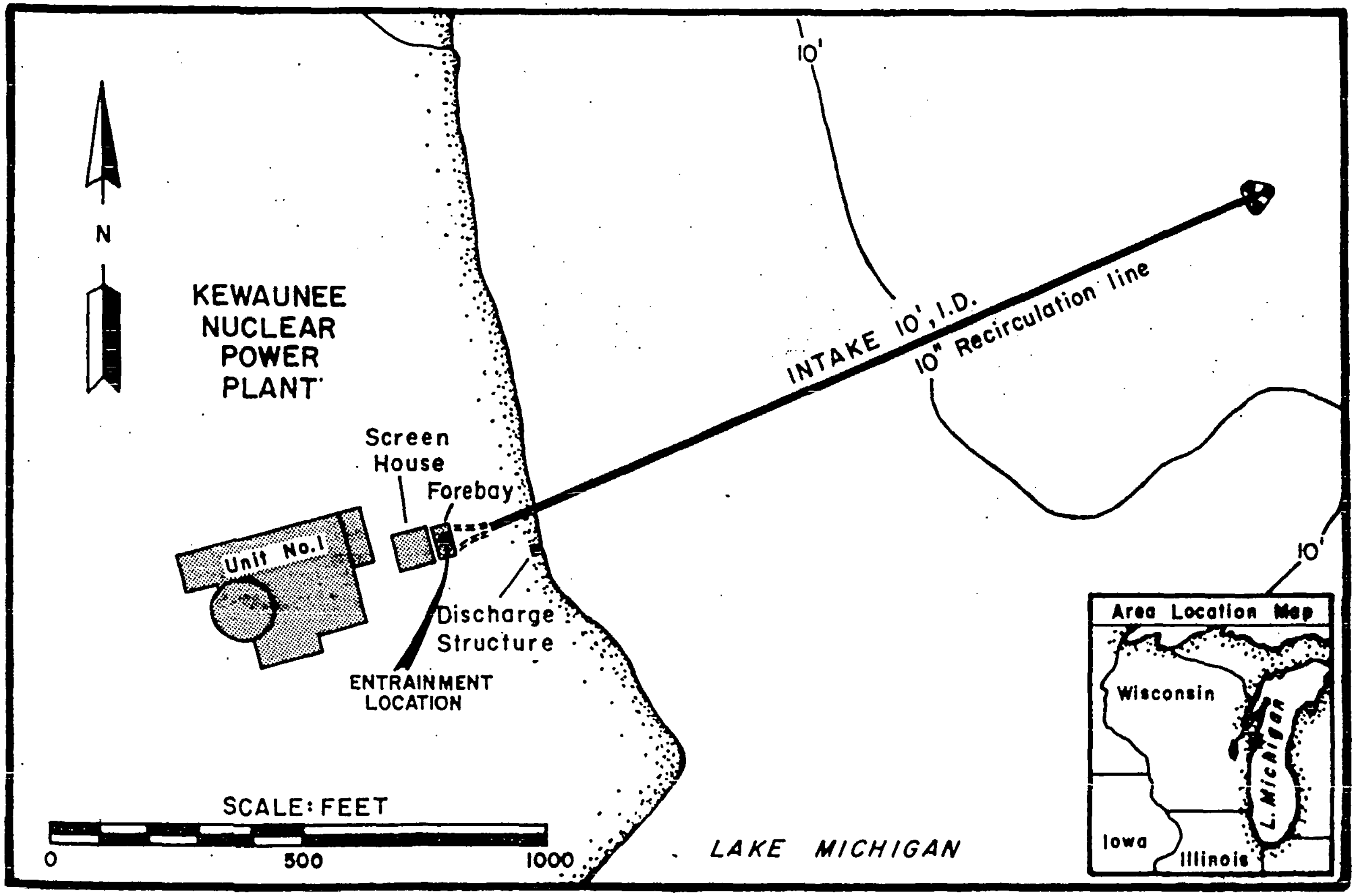

Figure 1. Schematic of Kewaunee Nuclear Power Plant showing plant location and entrainment sampling site, April 1975 through March 1976.

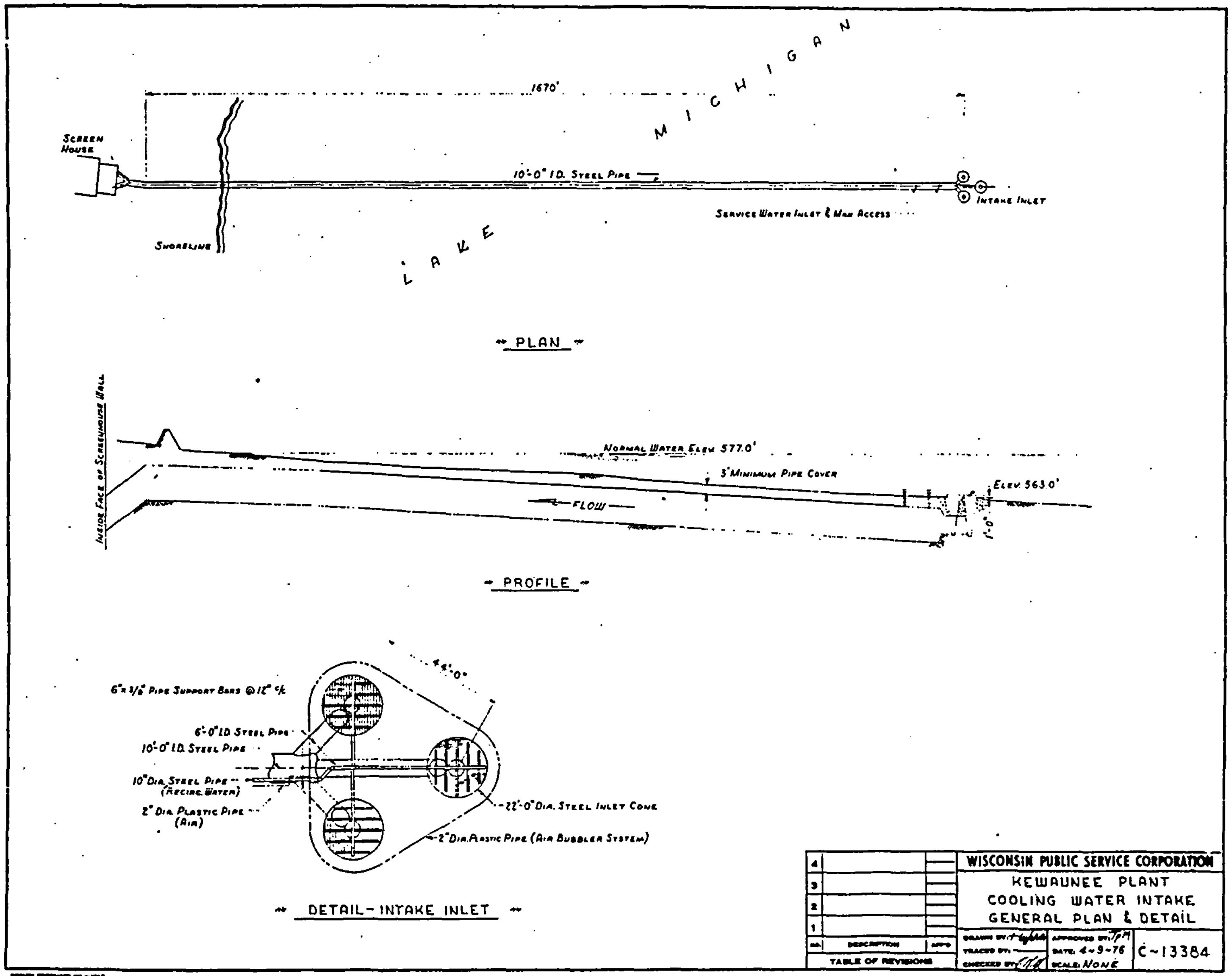

Figure 2. Description of intake inlet and pipe in relation to the bottom contour of Lake Michigan at Kewaunee Nuclear Power Plant.

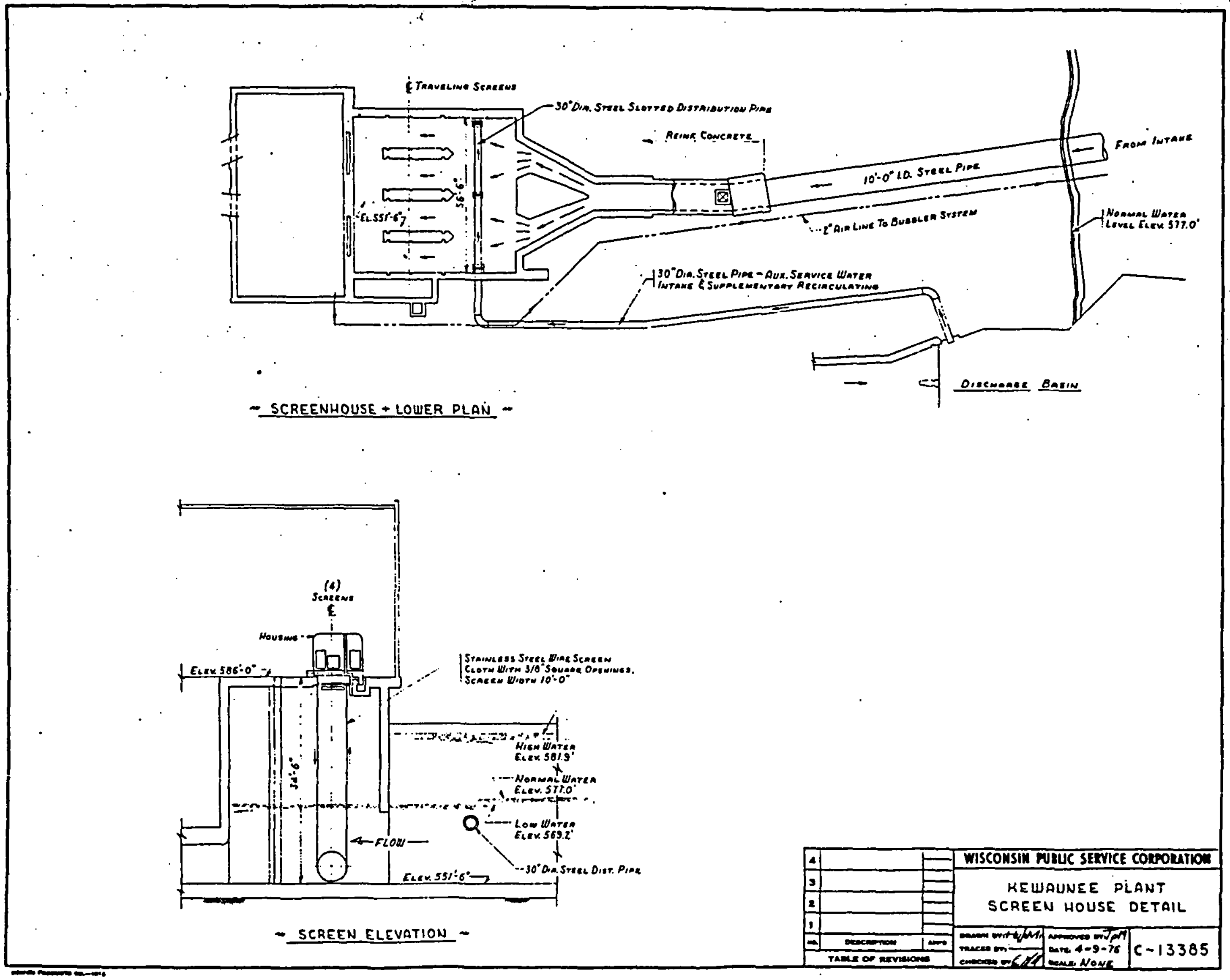

Figure 3. Description of intake forebay, screenhouse and traveling screens at Kewaunee Nuclear Power Plant.

Table 1. Water current velocities (meter/second) measured in front of the traveling screens at the surface, mid and bottom depths in the intake forebay during operation of one and two circulating water pumps at the Kewaunee Nuclear Power Plant, 26 August and 4 November 1975.

	Screen 1 - South		Screen 2 - North	
	Trash Rack 1	Trash Rack 2	Trash Rack 3	Trash Rack 4
1 Pump				
Surface	0.10	0.15	0.35	0.25
Mid-depth	0.35	0.50	0.35	0.30
Bottom	0.10	0.10	0.10	0.10
2 Pumps				
Surface	0.40	0.43	0.32	0.36
Mid-depth	0.24	0.32	0.29	0.39
Bottom	0.22	0.76	0.88	0.53

Four traveling screens are positioned in the forebay and are made of woven wire with 3/8 in. openings. These screens extend from the forebay bottom to approximately 10 ft above the water level (Figure 3). The area of each screen immersed during maximum flow is 300 ft^2. The screens travel vertically and are automatically activated every 4 hours for 45 minutes (normal operation), or they can be operated manually and/or automatically upon a 6 inch pressure drop for 10 minutes. High velocity water jets remove material from the screens, forcing it into a sluiceway which empties into a large woven collection basket with 3/8 inch openings. Water and any debris not retained in the collection basket are piped to the discharge. A cable hoist and pulley system allows the basket to be removed from its concrete structure, emptied, and cleaned of impinged fish and detritus.

The deicing system at Kewaunee consists of one pump with a maximum flow rate of approximately 3000 GPM. Discharge water is pumped through a 10 inch diameter recirculation pipe (adjacent to the intake pipe) which is distributed over the three inlet cones and is operational during periods of ice formation (Figure 1). The traveling screens are visually checked frequently for anchor ice. During deicing, water temperature in the forebay ranges from 1 to 3 C (34 to 37 F).

Although the chlorination system is available, the Plant has never chlorinated to control the growth of fouling organisms in the condenser tubes. The scouring effect of silt passing through the condensers has been sufficient to prevent the growth of fouling organisms.

III. Sampling Data

A. Adult and Juvenile Fish

Adult and juvenile fish impinged on the Kewaunee Nuclear Power Plant traveling screens were monitored by Plant personnel. NALCO Environmental Sciences biologists provided detailed sampling methods, equipment, and taxonomic keys by Eddy (1969), Hubbs and Lagler (1970), and Morris, Morris, and Witt (1974). Periodic observations of impingement monitoring activities were made by WPSC Staff Biologist and NALCO ES personnel and assistance was provided with identification of unknown fish.

Sampling was conducted from two to seven days per week from 1 April 1975 through 31 March 1976 to coincide with the fish egg and larvae entrainment sampling. The Kewaunee impingement program exceeded the recommended 316(b) sampling interval of once every four days. All fish removed from the traveling screens were counted and provided the actual number of fish impinged during the study.

Impinged fish were washed from the screens into a discharge sluice and collected in a basket made from stainless steel bars with 3/8 inch openings. Fish collected were identified to family or species, measured to the nearest centimeter for total length and weighed to the nearest five gram increment. When the total number of alewife or smelt exceeded 50, all large fish such as trout, salmon, yellow perch, carp, suckers etc. were removed from the trash basket, weighed and measured. A 10% subsample of the remaining alewife or smelt, which occasionally included a few cyprinids or slimy sculpins, were enumerated, weighed and measured. Those species of fish in the subsamples were then estimated for total number of impinged fish.

Raw fish impingement data were forwarded to NALCO ES biologists for summation. Summary tables including total number and total weight collected per species and sampling date have been prepared (Appendix Tables 1 through 12). The total number and weight of impinged fish were determined by combining the number of fish impinged monthly. When sufficient numbers of fish per species were collected, monthly or yearly length frequency distributions were drawn. Plant operating data for impingement sampling periods were extracted from hourly computer summaries of Plant conditions supplied by Wisconsin Public Service Corporation. These data included average flow at rated pump capacities and intake and discharge temperatures. No counting mechanism was installed to determine the number of screen rotations since the last sampling period. Since all impinged fish were counted, a counting mechanism for screen rotation did not seem necessary.

B. Eggs and Larvae

Sampling for entrained fish eggs, larvae, and juveniles was conducted weekly from April through August 1975 and twice monthly from September 1975 through March 1976. Samples were collected from the intake forebay (Figure 1).

Entrainment samples consisted of four replicates (two nets set twice) taken at 1600, 2400, and 0800 hours during one 24 hour period. Zero mesh (526 μ opening) Nitex conical plankton nets with one meter diameter openings were used. Each net was equipped with a General Oceanics Model 2030 digital flow meter centered in the net opening. The total number of cubic meters sampled per net was computed using the appropriate formula. A target number of 50 m^3 per replicate was chosen; however, the actual number varied with sampling conditions.

Fish eggs, larvae, and debris were field sorted using a fluorescent lighted macroscope and fish eggs and larvae were preserved in 10% formalin for laboratory analysis. Eggs were counted and measured to the nearest 0.1 millimeter using a Bausch & Lomb Stereo Zoom 7 microscope fitted with an ocular micrometer. If eggs were too numerous to count, a subsample was taken and the total number estimated. Analysis of time of year, egg diameter, and temperature yielded tentative species identification of eggs.

Larvae were measured to the nearest 0.1 mm, identified to species, or, in some cases, genus or family using Fish (1932), Mansueti and Hardy (1967), Norden (1961), various single species references and NALCO ES reference collections. Juveniles were separated from larvae when young fish attained full adult fin ray counts (Mansueti and Hardy 1967). This system, although somewhat arbitrary, was intended to give only an indication of the relative age and size of the fish entrained. All larvae and juveniles of each species were combined as young-of-year.

Plant operating data recorded on entrainment sampling days included intake and discharge temperatures, water flow and turbine capacity (amount of power being generated) at the time each sample was collected.

Monthly summary tables were prepared for Plant operating conditions and total numbers and concentration ($No./m^3$) of fish eggs, larvae, and juveniles (Appendix Tables 13 through 24). Observed densities of eggs and larvae by species were calculated per sampling day and a monthly mean computed. The estimated total number of entrained eggs and larvae was calculated using the formula:

$$\text{Total Entrained} = \text{Mean Monthly Density } (No./m^3) \times \text{Mean Observed Flow } (m^3/min) \times 1440 \text{ Min/Day} \times \text{Days/Month}$$

C. Additional Data

1. Supplementary Plant Operating Data

Current measurements were taken at the intake forebay during maximum (2 pumps) and minimum (1 pump) water flow. Water velocities were measured in front of the trash racks using a General Oceanics 2031/2035 Direct Reading Current Meter. Velocities were recorded in a water column at the surface, mid, and bottom depths. This provided a minimum-maximum velocity range under various operating conditions.

2. Fishery Data

The fish community in the vicinity of the Kewaunee Nuclear Power Plant (KNPP) has been studied from 1971 to the present (Industrial BIO-TEST Laboratories, Inc. 1972, 1973; LaJeone 1974, 1975, 1976). A list of fish species known to occur in the KNPP area is presented in Table 2. Classification of species by occurrence in the area was from specific KNPP studies. The table also contains the classification of representative important species for this area of Lake Michigan according to the Wisconsin Department of Natural

Table 2. Fish species collected in the vicinity of the Kewaunee Nuclear Power Plant and Wisconsin Department of Natural Resources classification.

Species[a]		WDNR	General
Scientific Name	Common Name	Classification[b]	Occurrence
Alosa pseudoharengus	Alewife	RIS, Cm, F	Abundant
Dorosoma cepedianum	Gizzard shad		Uncommon
Coregonus artedii	Cisco or Lake herring	RIS, Cm, T	Uncommon
Coregonus clupeaformis	Lake whitefish	RIS, Cm	Uncommon
Coregonus hoyi	Bloater	RIS, Cm, T	Uncommon
Prosopium cylindraceum	Round whitefish	RIS, Cm	Uncommon
Oncorhynchus kisutch	Coho salmon	RIS, S	Common
Oncorhynchus tshawytscha	Chinook salmon	RIS, S	Common
Salmo gairdneri	Rainbow trout	RIS, S	Common
Salmo trutta	Brown trout	RIS, S	Common
Salvelinus fontinalis	Brook trout	RIS, S	Uncommon
Salvelinus namaycush	Lake trout	RIS, S	Moderately Abundant
Osmerus mordax	Rainbow smelt	RIS, S, Cm, F	Abundant
Couesius plumbeus	Lake chub	RIS, F	Moderately Abundant
Cyprinus carpio	Carp	RIS, Cm	Uncommon
Notemigonus crysoleucas	Golden shiner		Uncommon
Notropis cornutus	Common shiner		Uncommon
Notropis hudsonius	Spottail shiner		Uncommon
Pimephales promelas	Fathead minnow		Uncommon
Rhinichthys cataractae	Longnose dace		Moderately Abundant
Semotilus atromaculatus	Creek chub		Uncommon
Catostomus catostomus	Longnose sucker	RIS, Cm, F	Moderately Abundant
Catostomus commersoni	White sucker	RIS, Cm, F	Moderately Abundant
Moxostoma macrolepidotum	Shorthead redhorse		Uncommon
Ictalurus melas	Black bullhead		Ucommon
Lota lota	Burbot	RIS, Cm, CI	Uncommon
Pungitius pungitius	Ninespine stickleback		Uncommon
Perca flavescens	Yellow perch	RIS, Cm, S	Moderately Abundant
Cottus bairdi	Mottled sculpin	RIS, F	Uncommon
Cottus cognatus	Slimy sculpin	RIS, F	Common

[a] Species names according to Bailey (1970).

[b] Code: RIS-Representative Important Species; Cm-Commercial; CI-Community Integrity; S-Sport; F-Forage; T-Changing status.

Resources (WDNR)(1974). Fish species considered abundant or moderately abundant in the KNPP area included alewife, rainbow smelt, lake trout, yellow perch, longnose sucker, white sucker, lake chub, and longnose dace.

None of the fish species listed as "important species" are considered endangered by the WDNR (1973, p. 5 and 16); however, the bloater and the cisco are given "changing status" classification indicating a possible decline in numbers. Carp is the only pollution tolerant species in the KNPP vicinity (Table 2).

Over a three year period from 1973-1975 alewife comprised 91.9% of the total catch (Table 3). The large numbers of alewife in the KNPP area was reflective of their abundance throughout Lake Michigan. Other major species which comprised 0.1% or more of the total catch, in order of abundance, were rainbow smelt, lake trout, yellow perch, lake chub, white sucker, longnose dace, slimy sculpin, longnose sucker, and brown trout. These ten species represented 99.8% of the fish collected in the study area.

Important sport species collected in the KNPP area besides lake trout and brown trout included rainbow trout, brook trout, coho salmon, and chinook salmon. These species were infrequently collected; however, their numbers were largely determined by the stocking programs of state and federal agencies. Nearly all trout and salmon in Lake Michigan are stocked; the abundance of those species in an area can be directly influenced by the number of fish stocked at particular locations.

Table 3. Catch totals of individual fish species collected by gill net and minnow seine in Lake Michigan near the Kewaunee Nuclear Power Plant, 1973 - 1975 environmental monitoring studies.

Species	Total Numbers	Percent of Catch
Alewife	83676	91.9
Rainbow smelt	1476	1.6
Lake trout	1374	1.5
Yellow perch	1360	1.5
Lake chub	957	1.1
White sucker	555	0.6
Longnose dace	520	0.6
Slimy sculpin	341	0.4
Longnose sucker	275	0.3
Brown trout	241	0.3
Coho salmon	71	<0.1
Lake whitefish	55	<0.1
Chinook salmon	33	<0.1
Rainbow trout	27	<0.1
Round whitefish	13	<0.1
Carp	12	<0.1
Brook trout	12	<0.1
Gizzard shad	10	<0.1
Cisco	6	<0.1
Common shiner	4	<0.1
Fathead minnow	4	<0.1
Bloater	3	<0.1
Ninespine stickleback	3	<0.1
Spottail shiner	3	<0.1
Black bullhead	2	<0.1
Golden shiner	2	<0.1
Creek chub	2	<0.1
Burbot	1	<0.1
Mottled sculpin	1	<0.1
Shorthead redhorse	1	<0.1
Total	91040	

The remaining species listed in Table 3 occurred infrequently and did not appear to be permanent residents. Two species, cisco and bloater, that were given "changing status" classification, were considered very uncommon to the KNPP area (LaJeone 1976, p. 54). Carp were also collected infrequently.

Considerable variation in the annual catches of major species has occurred within the study area near KNPP (Industrial BIO-TEST Laboratories, Inc. 1973; LaJeone 1974, 1975, 1976). Several factors such as weather conditions, currents, or time of sampling may have influenced the catches. However, annual abundance variations and distribution of fishes within the study area have not varied greatly prior or subsequent to Plant operation.

The ten species of fish comprising 0.1% or more of the total catches (1973-1975) in the KNPP area would be expected to predominate impingement-entrainment sampling. However, all life stages of each species should not be expected since the immediate area of KNPP does not conform to the spawning habits or habitats for all species. LaJeone (1974, p. 13 and 30; 1975, p. 15 and 21; 1976, p. 17 and 47) indicated that all age groups for alewife and rainbow smelt probably occurred in the vicinity of the KNPP. He also found that the majority of eggs collected in the near shore waters (intake area) were alewife and rainbow smelt (1976, p. 20).

Lake sampling, referred to as the lake monitoring program, was conducted from April through November 1975 near KNPP and was documented in the fifth annual report to WPSC by NALCO Environmental Sciences (LaJeone 1976). Fish sampling locations in

Lake Michigan were the same as those used from 1972 through 1975 (Industrial BIO-TEST Laboratories, Inc. 1973, LaJeone 1974 and 1975). Fish were collected by 957 foot gill nets along the 15 foot contour at locations approximately one-half mile north of the Plant, directly offshore from the mouth of the discharge and about two miles south of the Plant. Minnow seining was conducted along three shore locations at similar distances from the Plant as the gill net locations. Fish eggs and larvae samples were collected by pumping off the lake bottom at six locations. Gill net mesh size ranged from 1 1/2 to 5 1/2 inches. The seine measured 30 ft x 6 ft of 1/4 inch Ace mesh with a 6 ft x 6 ft bag of 1/8 inch Ace mesh. Eight gill net and seine samples were taken at each location during the study with each gill net sample lasting 18 hours and each seine collection usually consisting of two hauls.

Comparisons between the mean daily number of fish impinged per month at KNPP with the average number of fish collected per sampling area (one gill net plus corresponding seine location) were made throughout the report.

IV. Analysis of Effect of Intake

A. Adult and Juvenile Fish

1. General

Thirty-one species of fish were collected from the Kewaunee Nuclear Power Plant (KNPP) traveling screens from April 1975 through March 1976 (Table 4 and Figure 4). Alewife, rainbow smelt, slimy sculpin, longnose dace, suckers, trout, carp and yellow perch were collected in ten or more of the months sampled. Other species collected in seven of twelve months sampled included lake chub, bullhead and whitefish. The remaining species were collected intermittently throughout the year. January was the most diverse month with 22 species present, while in March, April and May less than 13 species were impinged. The species most often collected during impingement sampling were similar to those taken during the lake monitoring program near KNPP (Table 5).

A total of 215,108 fish, weighing 6210 kg, was impinged on the KNPP traveling screens (Table 4). Monthly impingement totals ranged from 931 fish collected in March to 57871 fish collected in June. The number of fish impinged from December through April was low and relatively constant, averaging 2731 fish per month. In July, August and November impinged fish averaged 31552 per month. The total number of fish impinged by the Plant during the twelve month study was less than three times the number of fish collected in the eight sampling days of the lake monitoring program (Table 5).

Table 4. Total number of adult fish impinged at Kewaunee Nuclear Power Plant, April 1975 through March 1976.

Species		Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Total	% of Total
Alewife	number	120	12954	56487	28355	24397	11547	15255	29750	0	6	9	3	178883	83.2
	weight (kg)	3.260	381.930	1810.740	890.880	631.077	333.686	356.575	361.560	0.000	0.178	0.852	0.268	4771.006	76.8
Rainbow smelt	number	1855	233	1037	874	819	1466	2578	4947	589	2378	1830	600	19206	8.9
	weight (kg)	33.130	4.000	18.611	17.550	16.601	29.485	65.525	122.224	19.852	67.602	62.250	23.434	480.264	7.7
Slimy sculpin	number	450	75	205	281	580	579	460	1171	2510	1323	731	275	8640	4.0
	weight (kg)	4.500	0.570	1.700	1.522	2.210	2.124	1.845	4.314	8.310	5.917	3.795	1.216	38.023	0.6
Longnose dace	number	20	18	45	923	952	1569	476	361	9	6	10	0	4389	2.0
	weight (kg)	0.230	0.340	2.537	5.331	9.697	18.984	4.196	4.338	0.079	0.050	1.143	0.000	46.925	0.8
Lake chub	number	0	0	0	26	318	754	130	248	62	39	6	1	1584	0.7
	weight (kg)	0.000	0.000	0.000	1.363	8.673	20.841	4.617	9.316	2.634	1.721	0.260	0.028	49.453	0.8
Sucker[a]	number	79	94	50	58	165	284	70	75	33	50	10	32	1000	0.5
	weight (kg)	23.500	48.530	34.750	36.170	85.160	110.256	28.118	26.894	8.552	14.803	3.843	10.833	431.409	6.9
Trout[b]	number	173	3	3	5	4	7	11	44	40	34	8	12	344	0.2
	weight (kg)	6.150	4.400	1.550	11.125	4.975	14.770	18.631	52.307	6.869	17.660	0.727	1.446	140.610	2.3
Gizzard shad	number	0	0	0	0	0	0	56	105	147	3	0	0	311	0.1
	weight (kg)	0.000	0.000	0.000	0.000	0.000	0.000	2.888	2.979	8.292	0.766	0.000	0.000	14.925	0.2
Carp	number	16	2	1	1	4	169	2	9	9	26	15	5	259	0.1
	weight (kg)	38.300	5.000	1.500	1.875	1.819	5.537	2.547	19.900	20.955	44.807	6.572	15.918	164.730	2.7
Yellow perch	number	23	8	28	59	21	34	11	29	8	20	4	0	245	0.1
	weight (kg)	3.270	2.490	6.150	13.860	3.660	7.489	1.042	1.411	0.105	0.351	0.553	0.000	40.381	0.7
Bullhead[c]	number	0	0	0	5	0	61	14	12	3	12	3	1	111	<0.1
	weight (kg)	0.000	0.000	0.000	0.604	0.000	5.533	1.032	2.131	0.465	1.242	0.184	0.280	11.471	0.2
Ninespine stickleback	number	0	0	12	14	20	0	0	0	3	5	1	0	55	<0.1
	weight (kg)	0.000	0.000	0.016	0.063	0.090	0.000	0.000	0.000	0.009	0.014	0.004	0.000	0.196	<0.1
Troutperch	number	0	0	0	0	10	0	0	3	15	8	3	0	39	<0.1
	weight (kg)	0.000	0.000	0.000	0.000	0.060	0.000	0.000	0.052	0.221	0.092	0.046	0.000	0.471	<0.1
Whitefish[d]	number	0	1	1	1	0	1	1	2	2	4	0	0	13	<0.1
	weight (kg)	0.000	0.450	1.150	0.600	0.000	0.750	1.200	1.350	0.460	5.075	0.000	0.000	11.035	0.2
Pumpkinseed	number	0	0	0	0	0	1	0	1	3	3	1	0	9	<0.1
	weight (kg)	0.000	0.000	0.000	0.000	0.000	0.014	0.000	0.002	0.023	0.047	0.065	0.000	0.151	<0.1
Burbot	number	0	0	0	0	0	1	0	1	0	3	0	2	7	<0.1
	weight (kg)	0.000	0.000	0.000	0.000	0.000	0.445	0.000	0.800	0.000	1.735	0.000	1.020	4.000	<0.1
Common shiner	number	0	0	0	3	0	0	0	0	0	0	1	0	4	<0.1
	weight (kg)	0.000	0.000	0.000	0.115	0.000	0.000	0.000	0.000	0.000	0.000	0.010	0.000	0.125	<0.1
Salmon[e]	number	0	0	0	1	0	0	1	0	0	0	1	0	3	<0.1
	weight (kg)	0.000	0.000	0.000	0.800	0.000	0.000	0.070	0.000	0.000	0.000	3.175	0.000	4.045	<0.1
Lamprey	number	0	0	2	0	0	0	0	0	0	0	0	0	2	<0.1
	weight (kg)	0.000	0.000	0.310	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.310	<0.1
Northern pike	number	0	0	0	0	0	0	0	0	0	1	1	0	2	<0.1
	weight (kg)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.150	0.225	0.000	0.375	<0.1
Bloater	number	0	0	0	1	0	0	0	0	0	0	0	0	1	<0.1
	weight (kg)	0.000	0.000	0.000	0.072	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.072	<0.1
Blacknose dace	number	0	0	0	1	0	0	0	0	0	0	0	0	1	<0.1
	weight (kg)	0.000	0.000	0.000	0.030	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.030	<0.1
Total	number	2736	13388	57871	30608	27290	16473	19065	36758	3433	3921	2634	931	215108	
	weight (kg)	112.340	447.710	1879.014	981.960	764.022	549.914	488.286	609.578	76.826	162.210	83.704	54.443	6210.007	

[a] = Consists of white sucker, longnose sucker and shorthead redhorse.
[b] = Consists of brook trout, brown trout, lake trout and rainbow trout.
[c] = Consists of brown bullhead and yellow bullhead.
[d] = Consists of lake whitefish and round whitefish.
[e] = Consists of coho salmon and chinook salmon.

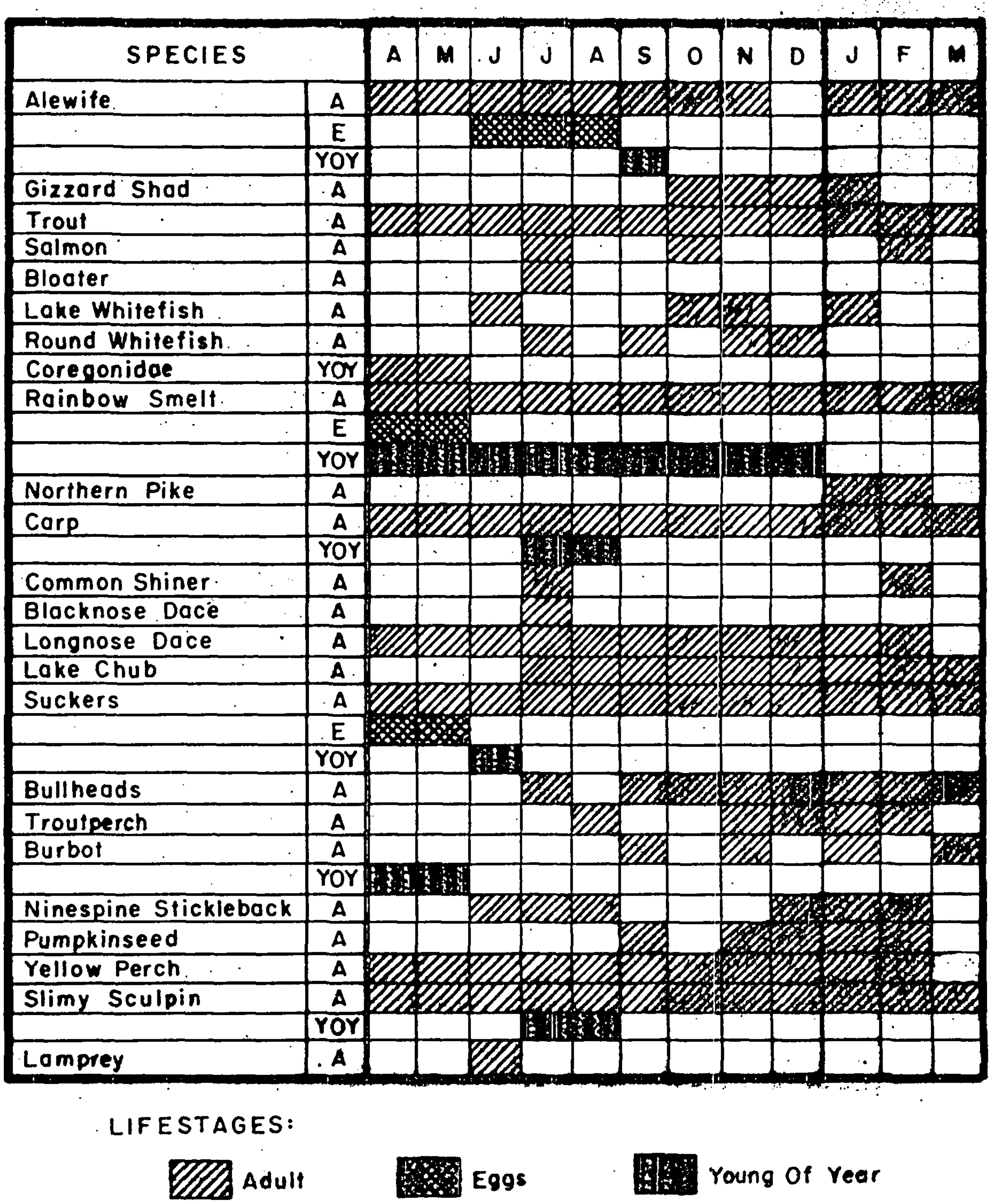

Figure 4. Monthly occurrence of various life stages of fish at Kewaunee Nuclear Power Plant, April 1975 through March 1976. Adult life stage includes impinged adults and juveniles, eggs include those inferred from impingement and entrainment data and young-of-year includes entrained larvae and juveniles.

Table 5. Catch totals of individual fish species collected by gill net and minnow seine in Lake Michigan near the Kewaunee Nuclear Power Plant, April through November 1975, during the environmental monitoring study.

Species	Total Numbers	Percent of Catch
Alewife	74507	97.6
Trout	690	0.9
Yellow perch	278	0.4
Lake chub	249	0.3
Sucker	246	0.3
Longnose dace	192	0.2
Rainbow smelt	117	0.1
Slimy sculpin	29	<0.1
Whitefish	11	<0.1
Cisco	6	<0.1
Carp	2	<0.1
Golden shiner	2	<0.1
Common shiner	2	<0.1
Fathead minnow	2	<0.1
Coho salmon	1	<0.1
Chinook salmon	1	<0.1
Gizzard shad	1	<0.1
Creek chub	1	<0.1
Total	76337	

The principal taxa impinged by the Plant, in decreasing order of abundance, consisted of alewife, rainbow smelt, slimy sculpin, longnose dace, lake chub, suckers, trout, gizzard shad, carp and yellow perch (Table 4). Each of these taxa comprised 0.1% or more of the total catch and collectively accounted for 99.7% of all fish impinged at KNPP. These taxa comprised 99.8% of the total catch during the lake monitoring program (Table 5).

2. Discussion of Species

a. Alewife

Alewife was the most abundant species impinged at KNPP during the study. A total of 178,883 was collected, comprising 83.2% of the total number and 76.8% of the total weight (4771 kg) (Table 4). The relative abundance (number impinged per month) of alewives appeared to follow established seasonal patterns of migration in Lake Michigan (Wells 1968, p. 3-5). Only 18 alewives were collected during the winter (December through March) when fish inhabited the deep portions of the lake. In the spring, when alewives migrated to shallow nearshore waters, the number of fish impinged increased reaching a peak abundance of 56487 in June. After spawning, alewives gradually dispersed to deep water in late summer and early fall. The number of alewives impinged during this period declined slowly until alewives were absent from the December impingement samples.

Length frequency distributions compared with age and growth data reported by Norden (1967, p. 387) indicated that all age groups of alewives occurred at various times within the study area (Figure 5). Alewives impinged from June through November ranged from 6 to 22 centimeters. Seventy percent of the alewives collected ranged from 16 to 20 cm (adults) and 10% of the total ranged from 6 to 9 cm (yearling or young-of-year). This coincided with length frequency data reported by LaJeone (1976, p. 14) during the lake monitoring program near KNPP. Impinged adults were most numerous during the summer, reached peak abundance in September (88% of total) and declined in November (57% of total). Yearling alewives were common in June representing 11% of the total, whereas young-of-year were impinged in substantial numbers in October and November (25% of total). Peak abundance of adult alewives recorded during the lake monitoring program occurred in June and represented 71% of the total catch (LaJeone 1976, p. 13).

During the lake monitoring program, alewives constituted 97.6% (74507) of the total catch (Table 5) (LaJeone 1976, p. 13-14). Seasonal occurrence and relative abundance patterns of alewives impinged on the traveling screens were similar to those found during field collections near KNPP. However, 2.4 times as many alewives were impinged by the Plant than were collected during the lake monitoring program. This was probably a direct reflection of sampling effort since field sampling during the lake monitoring program was conducted only eight days during 1975. A comparison of daily impingement rates with lake sampling rates from one location showed that alewives were impinged most frequently in June, July, August, October and November (Table 6). The rates of alewives captured in Lake Michigan during April, May and September were

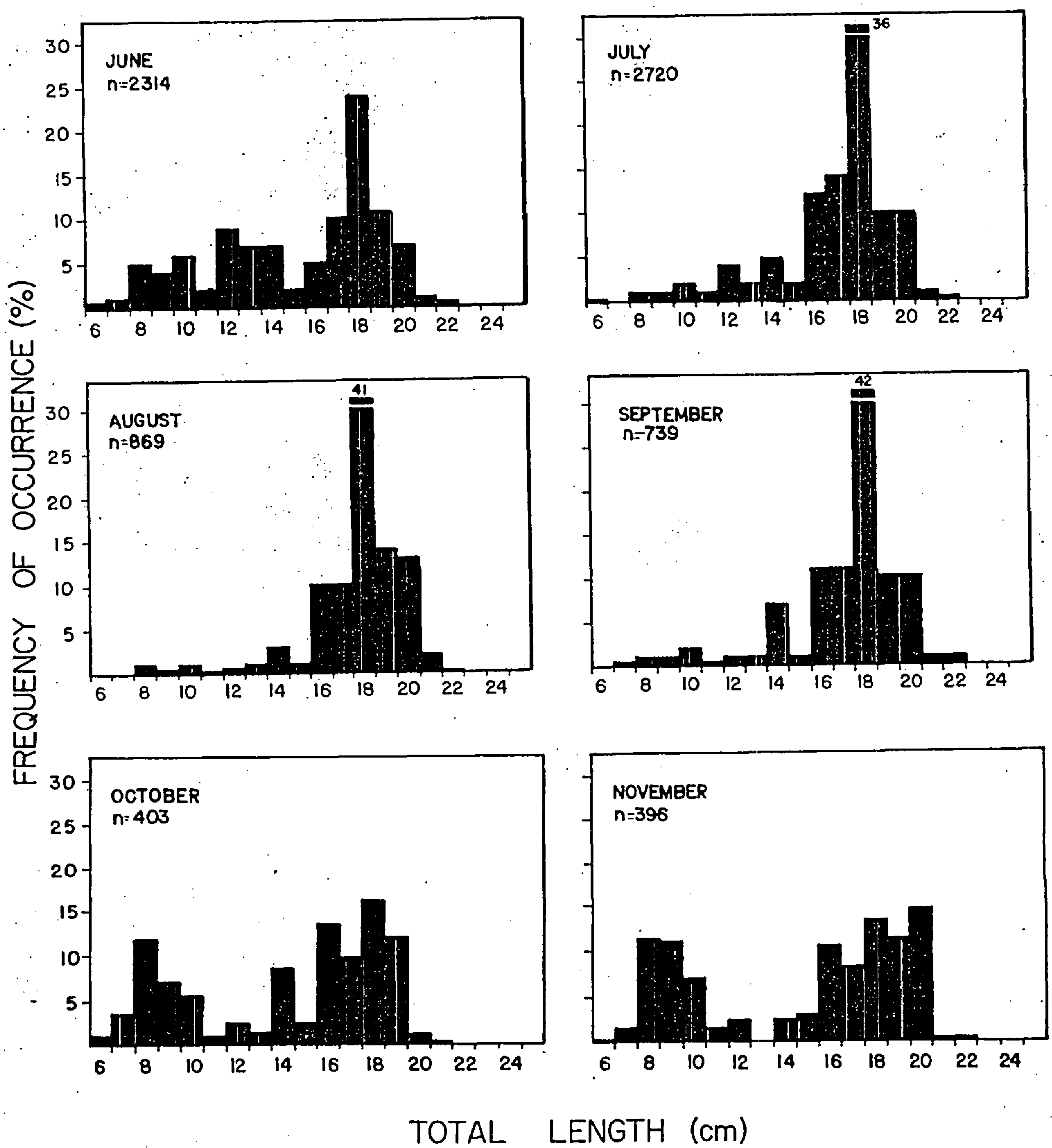

Figure 5. Length frequency distribution of alewife impinged on the traveling screens at Kewaunee Nuclear Power Plant, June through November 1975.

Table 6. Comparison of daily impingement rates and single location catch rates of principle fish species during the 1975 environmental monitoring program at Kewaunee Nuclear Power Plant.

Species		Average Number of Fish Impinged or Collected/Day/Month											
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec
Alewife	KNPP[a]	6.9	0.4	0.1	4.0	417.9	1882.9	914.7	787.0	384.9	492.1	939.7	0
	L.M.[b]	-[c]	-	-	0	290.3	1092.0	88.0	31.0	23326.7	0.7	7.0	-
Rainbow smelt	KNPP	33.1	16.3	8.7	61.8	7.5	34.6	28.2	26.4	48.9	83.2	111.9	19.0
	L.M.	-	-	-	11.3	7.0	3.0	3.7	0	10.7	3.0	0.3	-
Slimy sculpin	KNPP	0	0	0.26	15.0	2.4	6.8	9.1	18.7	19.3	14.8	38.7	81.0
	L.M.	-	-	-	2.0	2.7	0.7	0.7	0.3	3.0	0.3	0	-
Longnose dace	KNPP	0	0	0	0.7	0.6	1.5	29.8	30.7	52.3	15.4	11.5	0.3
	L.M.	-	-	-	0.3	8.7	7.0	6.7	36.3	4.0	1.0	0	-
Lake chub	KNPP	0	0	0	0	0	0	0.8	10.3	25.1	4.2	8.0	2.0
	L.M.	-	-	-	0.3	23.0	28.3	10.0	7.6	7.0	5.3	1.3	-
Suckers[d]	KNPP	4.6	2.5	6.0	2.6	3.0	1.7	1.9	5.1	9.5	2.3	2.3	1.1
	L.M.	-	-	-	0	0.3	12.3	1.3	40.3	13.7	11.3	2.7	-
Trout[e]	KNPP	6.9	3.0	1.9	5.8	0.1	0.1	0.2	0.1	0.2	0.4	1.2	1.3
	L.M.	-	-	-	22.7	14.3	26.3	11.0	2.0	60.3	58.3	35.0	-
Gizzard shad	KNPP	0	0	0	0	0	0	0	0	0	1.8	3.4	4.7
	L.M.	-	-	-	0	0	0	0	0.3	0	0	0	-
Carp	KNPP	0.5	0.2	0.3	0.5	0.1	<0.1	<0.1	0.1	5.6	<0.1	0.3	0.3
	L.M.	-	-	-	0	0	0	0	0	0.3	0.3	0	-
Yellow perch	KNPP	<0.1	0.3	0.2	0.8	0.3	0.9	1.9	0.7	1.1	0.4	0.9	0.3
	L.M.	-	-	-	2.7	1.7	10.7	1.7	75.7	0	0.3	0	-

[a] Indicates average number of fish impinged at Kewaunee Nuclear Power Plant per day during a month.

[b] Indicates average number of fish collected per sampling area (one gill net location plus corresponding seineing location) in Lake Michigan in environmental monitoring program. Gill nets were set for 18 hours.

[c] Sampling not conducted.

[d] Consists of white sucker, longnose sucker and shorthead redhorse.

[e] Consists of brook trout, browntrout, lake trout and rainbow trout.

greater than or comparable to the rates of alewives impinged. In September, approximately 23000 alewives were collected from one seine, whereas the average daily rate of impingement during September was only 385 alewives (Table 6). During the eight days of sampling from one location near KNPP a total of 24838 alewives was collected while average daily rates of impingement for each of the eight months total only 5834 alewives (Table 6).

Edsall's estimate of the alewife minimum biomass in Lake Michigan was 1.47 metric tons (1.47 x 10^9 kg) (Limnetics 1976, p. II 1-8). The percentage of that biomass (4771 kg) impinged at KNPP in 1975-1976 was small (0.0003%). Brown estimated in 1973 a minimum alewife biomass in Michigan waters of Lake Michigan at 100 million kg (MDNR 1974, p. 22). Removal of alewives at KNPP amounted to only 0.005% of that estimate. The weight of alewives impinged at KNPP represented only 0.02% of the total commercial production (1.8 million kg) of alewives in Wisconsin waters of Lake Michigan (Limnetics 1976, p. II 1-17).

b. Rainbow Smelt

Rainbow smelt was the second most abundant species impinged at KNPP, comprising 8.9% of the total fish catch (19206) and 7.7% of the total fish weight (480 kg)(Table 4). This species was collected each month with peak abundances occurring in October (2578) and November (4947). During the spring and summer, April through September, when adults and young smelt concentrated nearshore, 6284 specimens were collected on the traveling screens. From October through February the number of impinged smelt increased, representing 64% of all smelt impinged throughout the year.

Length frequency data from the impingement study as well as the lake monitoring program (LaJeone 1976, p. 46) indicated that all expected age groups of smelt occurred in the vicinity of the Plant. Smelt impinged from June through January ranged from 6 to 25 centimeters (Figure 6). Forty-three percent and 39% of the fish collected ranged from 16 to 20 cm (adults) and from 11 to 15 cm (small adults), respectively, with the 6 to 9 cm (yearling and young-of-year) range representing 3% of the total. Adults were most abundant in November (63%); however, a substantial number of adults were present in each of the seven months. LaJeone (1976, p. 47) found that large adults (19 to 26 cm) in the KNPP area accounted for nearly 100% of the smelt collected in April. Smaller adults, probably from later year classes, were impinged in all eight months with the highest percentage occurring in June (51%). Yearling smelt were infrequently impinged in June and July, whereas specimens considered young-of-year were collected in small numbers in August, September and October.

The number of smelt impinged at KNPP was considerably greater than the 117 smelt collected in the lake monitoring program (Table 5). Again, this was probably related to the field sampling effort, the effectiveness of gill netting and the greatly reduced smelt catch in 1975 (LaJeone 1976, p. 43). Smelt catches near KNPP totaled 1003 and 356 in 1973 and 1974, respectively (LaJeone 1974, p. 16; 1975, p. 28). The U.S. Department of Interior estimated from bottom trawl catches in 1974 that smelt biomass in Lake Michigan was at least 14 million kg (Limnetics 1976,

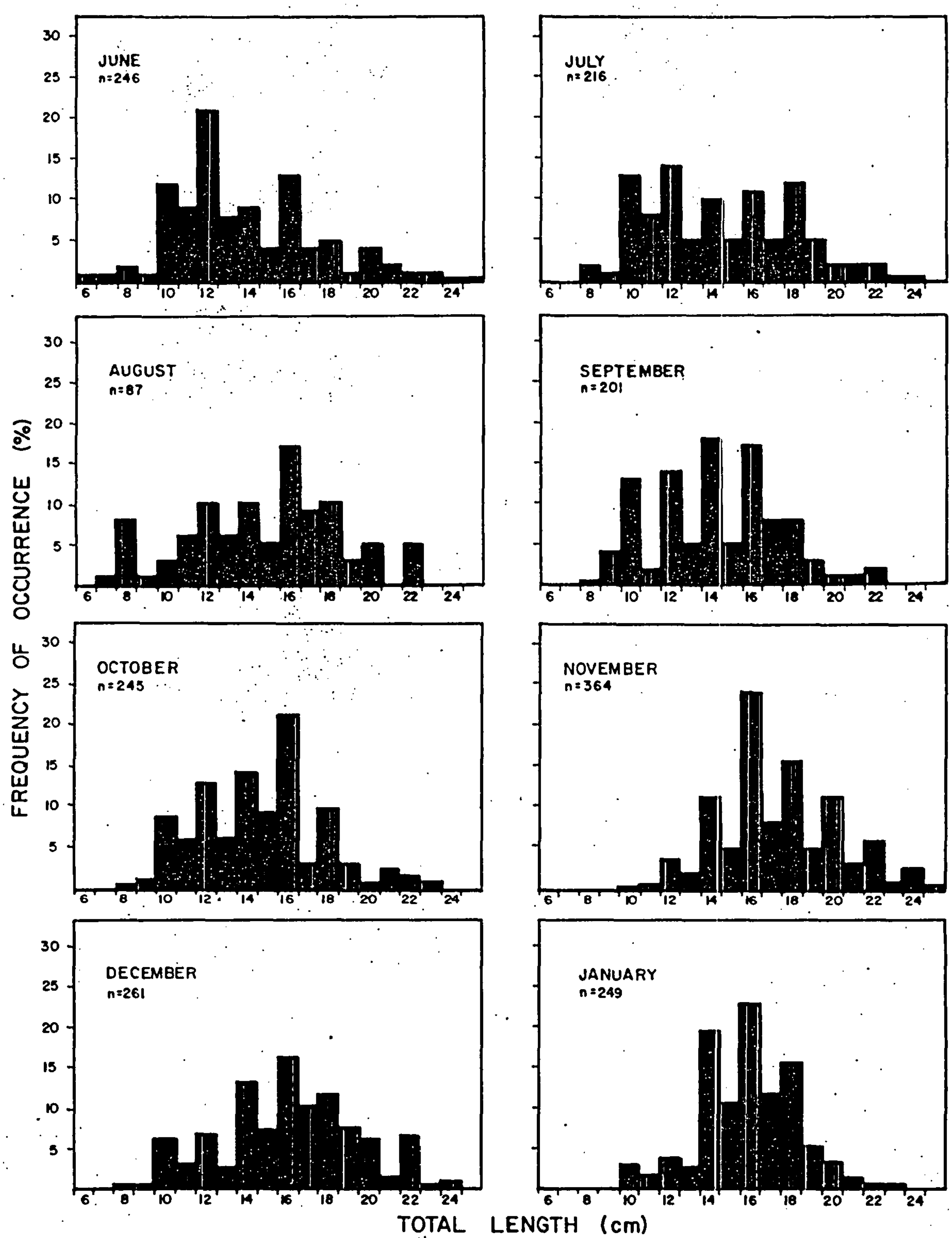

Figure 6. Length frequency distribution of rainbow smelt impinged on the traveling screens at Kewaunee Nuclear Power Plant, June 1975 through January 1976.

p. II 2-8). This conservative estimate represented only the benthic smelt population available to bottom trawling. The percentage of that biomass impinged at KNPP was only 0.003%. Biomass of smelt removed by KNPP amounted to only 0.3% of the commercial catch (153 thousand kg) in Wisconsin waters of Lake Michigan in 1974 (Limnetics 1976, p. II 2-14).

c. Slimy Sculpin

The slimy sculpin was third in abundance of species impinged at KNPP. A total of 8640 was collected, comprising 4% of the total number and 0.6% of the total weight (38 kg) (Table 4). This species was collected each month and reached peak abundance in December (2510). In the spring (April and May) 525 specimens were impinged at the Plant. During late fall and winter (November through February) the number of impinged sculpin totaled 5735, representing 66% of all slimy sculpin impinged.

Impinged slimy sculpins ranged in length from 4 to 10.5 cm, but the majority ranged from 6.0 to 7.5 cm (Appendix Tables 1 through 12). Few slimy sculpin under 6 cm were collected. Due to the 3/8 inch mesh size of the traveling screens, juvenile fish were not impinged. Juvenile and young-of-year sculpins were regularly collected near KNPP from bottom pump samples taken during the lake monitoring program (LaJeone 1976, p. 51-52).

Slimy sculpins were infrequently collected near KNPP during the lake monitoring program (Table 5). However, frequent collections of juveniles in bottom pump samples and their occurrence in the stomachs of predatory species indicated that slimy sculpins may be abundant within the KNPP area (LaJeone 1976, p. 51 and 54). The U.S. Department of Interior estimated slimy sculpin biomass production from 1974 bottom trawl catches to be at least 1.77 million kg (Limnetics 1976, p. II 5-3). This conservative estimate included only those fish in the water column and not those lying on the lake bottom. Based on this estimate, the slimy sculpins impinged on the screens at KNPP comprised only 0.002% of the total estimated biomass.

d. Longnose Dace

Longnose dace was the fourth most common species impinged at KNPP and was the most abundant member of the minnow family. A total of 4389 was impinged, representing 2.0% of the total fish catch and 0.8% of the total fish weight (47 kg)(Table 4). No distinct pattern of seasonal migration has been reported for this species. Longnose dace were impinged each month except March, with peak abundance occurring in September. During March through June, 83 longnose dace were impinged with numbers increasing to 3444 from July through September. The number of longnose dace declined during the fall until only 25 specimens were impinged from December through February. LaJeone (1976, p. 36) also found that longnose dace were most numerous in the KNPP area from June through August.

Length frequency distributions from July through November showed that all longnose dace impinged were adults ranging from 8 to 15 cm in length (Figure 7). This was comparable to data collected during the lake monitoring program near KNPP, with the exception of a few young-of-year collected in September and October (LaJeone 1976, p. 39).

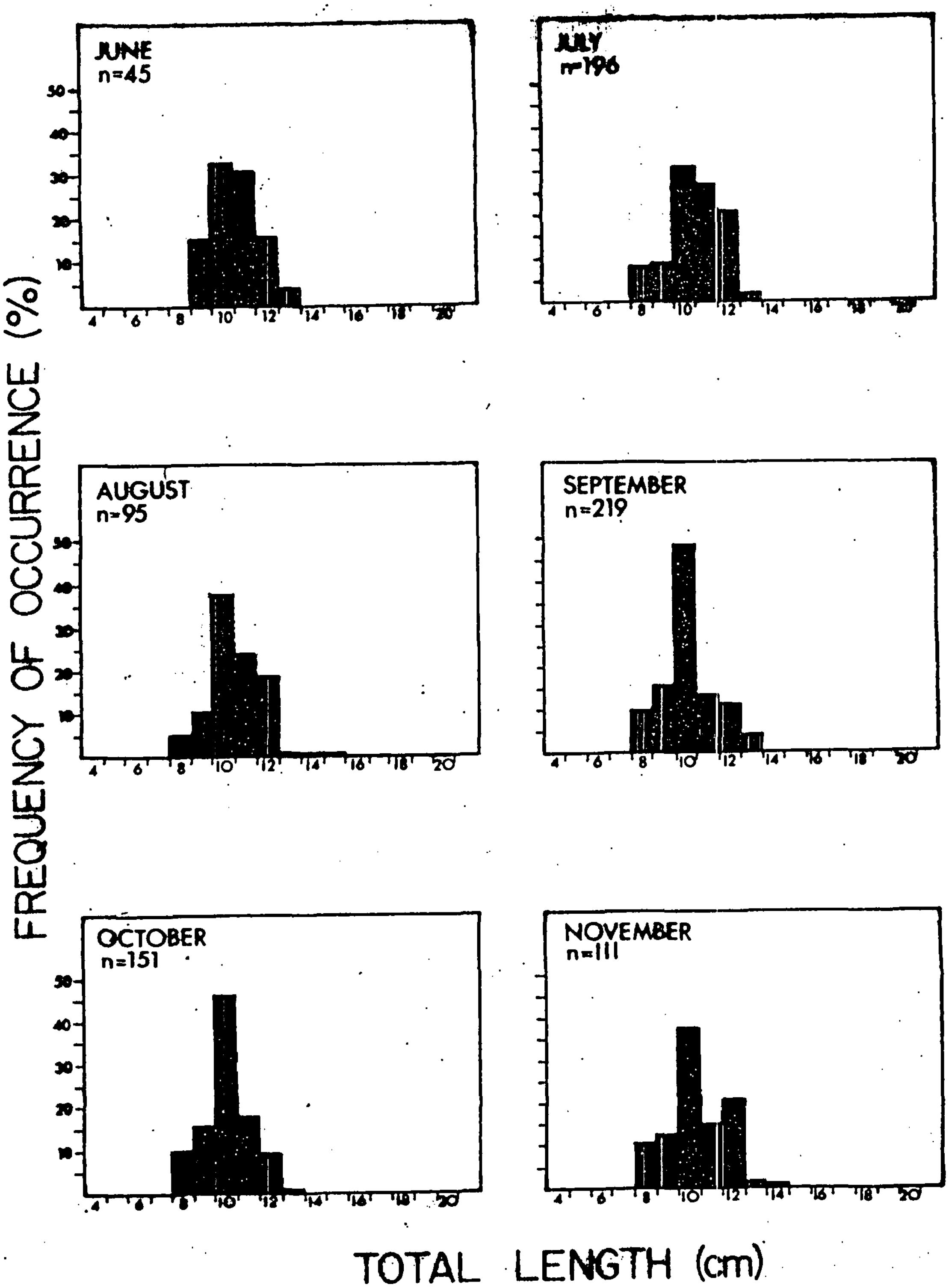

Figure 7. Length frequency distribution of longnose dace impinged on the traveling screens at Kewaunee Nuclear Power Plant, June through November 1975.

Longnose dace were collected in low numbers (192) near the KNPP during the lake monitoring program (Table 5). The sum of the average daily numbers of longnose dace impinged each month from April through November was three times greater than the lake catch rates during that time. However, the lake catch rates were greater than or comparable to daily impingement rates during four of the eight lake collections (Table 6).

e. Lake Chub

Lake chub, another member of the minnow family, was the fifth most abundant species impinged at KNPP. A total of 1584 was collected, representing 0.7% of the total fish catch and 0.8% of the total fish weight (49 kg)(Table 4). Lake chubs were initially collected in July (26) and reached a peak abundance of 754 in September. The number of lake chubs decreased during the fall and winter until they were absent from the April impingement samples. Lake chubs were collected in every sampling month during the lake monitoring program; however, catches were too small and variable to depict any pattern in spatial distribution (LaJeone 1976, p. 33).

Lake chubs impinged from August through January ranged from 8 to 20 cm in length and averaged 15 cm (Figure 8). The majority of lake chubs impinged were adults. Lake chubs collected in May and June during the lake monitoring program consisted primarily of larger, adult fish, whereas small, juvenile fish predominated the July and August collections (LaJeone, p. 36).

Lake chubs collected during the lake monitoring study comprised 0.3% (249) of the total fish catch (Table 5).

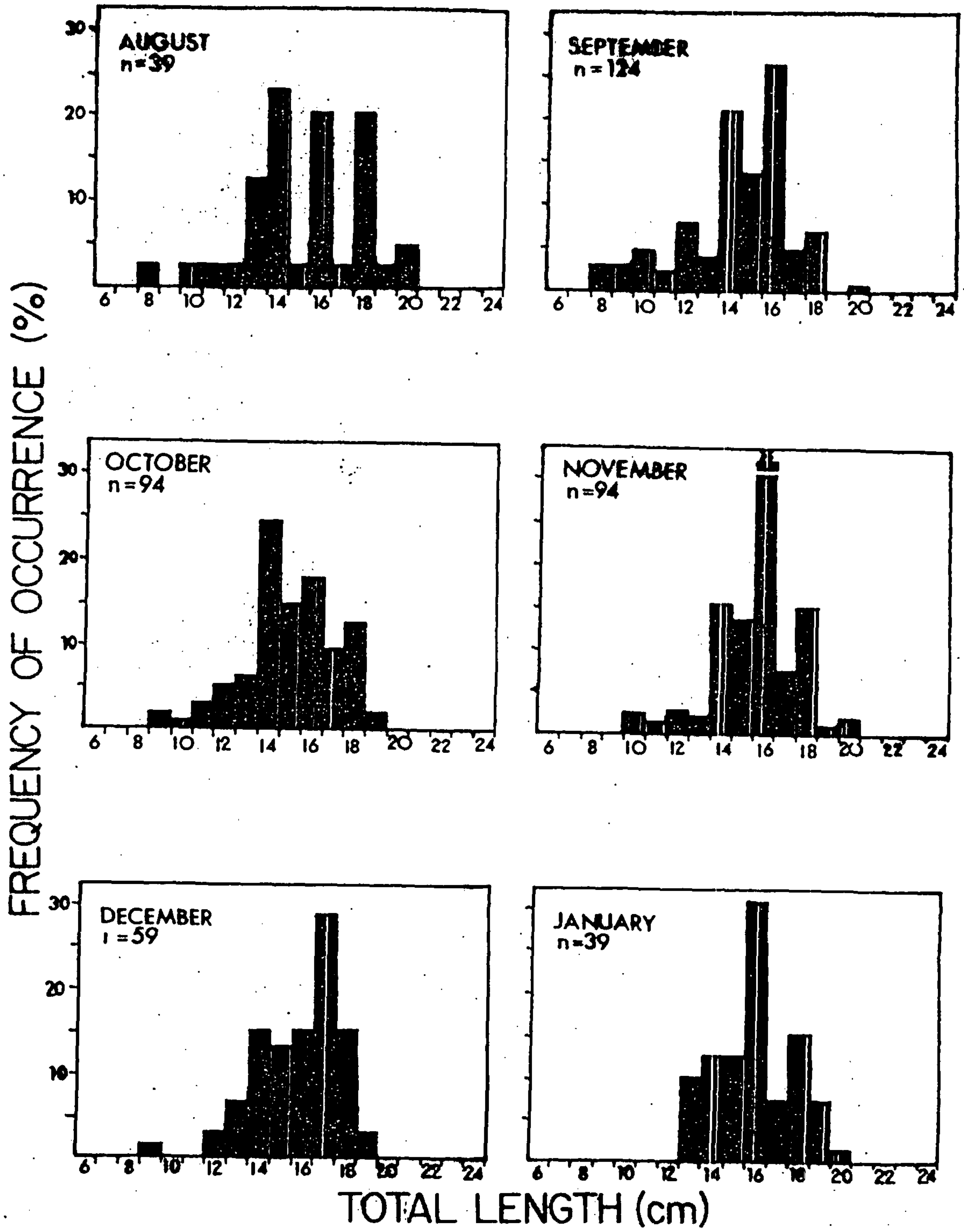

Figure 8. Length frequency distribution of lake chub impinged on the traveling screens at Kewaunee Nuclear Power Plant, August 1975 through January 1976.

Comparison of daily impingement rates of lake chub with daily rates of fish collected from one location in the lake indicated that the numbers of lake chub collected in Lake Michigan were greater than those impinged in five of eight months (Table 6). The daily catch of lake chubs from lake sampling during May through July averaged 20 fish, whereas the average daily impingement during those months was less than one. The number of lake chub collected in one sampling in each of the eight months (April through November) during the lake monitoring program was nearly twice the average daily number impinged by the Plant during those months.

f. Sucker

As a group, suckers were sixth in abundance, comprising 0.5% of the total number (1000) and 6.9% of the total weight (431 kg) of impinged fish (Table 4). Suckers were impinged each month and had peak and lowest abundances of 284 in September and 10 in February. White and longnose suckers were most common, averaging 61.9% and 31.5%, respectively (Appendix Tables 1 through 12) of the suckers. Many white and longnose suckers were impinged during the summer (July through September), representing nearly 50% of all suckers impinged. No distinct patterns of seasonal movement in Lake Michigan have been reported, although both species were collected in shallow water near the KNPP area during the lake monitoring study (LaJeone 1976, p. 41 and 52). LaJeone (1974, p. 31 and 38; 1975, p. 34 and 38; 1976, p. 39 and 51) found that peak abundance of white suckers occurred in September of 1973-1974 and

August 1975; however, peak abundance of longnose suckers followed no consistent pattern among years.

Length measurements of white and longnose suckers ranged from 5 to 56 cm with the majority of specimens being adults (Appendix Tables 1 through 12). Only a small number of juvenile specimens were impinged. LaJeone (1976, p. 39 and 51) collected primarily adult white and longnose suckers in the KNPP area in 1975, except for one yearling and one young-of-year collected in June and July, respectively.

Shorthead redhorse was the least abundant sucker impinged at KNPP. This species occurred in seven of twelve months sampled and comprised 6.6% of the total sucker catch (53). Shorthead redhorse were not collected near the KNPP area during the 1975 lake monitoring program (LaJeone 1976, p. 10).

g. Trout

Trout, as a group, were seventh in abundance and represented 0.2% of the total number (344) and 2.3% of the total weight (141 kg) of impinged fish (Table 4). Trout were impinged each month and were common from November through January with peak abundance of 173 impinged in April. The numbers of trout impinged from October through December (95) reflected inshore migrations during spawning (Eschmeyer 1964). Brown, lake and rainbow trout were most common, comprising 45.5%, 32.0% and 21.9% of the total number of trout impinged (Appendix Tables 1 through 12). Only one brook trout was impinged during the twelve months sampled. LaJeone (1976, p. 21 and 46) found that fluctuations in monthly catches from

August to September 1975 and again from October to November 1975 were normal occurrences for lake and brown trout in the KNPP area (Industrial BIO-TEST Laboratories, Inc. 1973; LaJeone 1974, 1975) and were related to inshore-offshore movements probably associated with spawning.

Length frequency distributions of impinged brown and lake trout ranged from 8 to 73 cm (Appendix Tables 1 through 12) with the majority of fish ranging from 30 to 50 cm. Only 20 trout impinged during the twelve months sampled were less than 10 cm. Similar length measurements were recorded for brown trout collected during the lake monitoring program, whereas lake trout were considerably larger ranging from 42 to 90 cm (LaJeone 1976, p. 27 and 49).

The number of trout impinged at KNPP was considerably less than the 690 trout collected during eight sampling days of the lake monitoring program (Table 5). Based on daily catch, the number of trout collected from one gill net sample (18 hr) in each of the eight months was 29 times the average daily number impinged by the Plant during those months (Table 6). During September through November, when trout migrate near shore for spawning, the daily catch from gill nets averaged 51 trout while the average daily impingement for those months averaged less than one fish. Even though trout were abundant in the KNPP area at certain times, their impingement rate was extremely low. One apparent reason is their swimming speed capabilities. The average intake water velocity (0.6 m/sec) at KNPP was well below their sustained swim speed capabilities (Otto et al. 1975, p. 162; Morgan and Moore

1972, p. 14). Impinged trout represented less than 0.02% of the 1.9 million planted in Wisconsin waters of Lake Michigan in 1974 (Limnetics 1976, p. II 10-15, 14-10, 18-10). The impingement of 344 trout is of little importance relative to the 31000 trout that were harvested by sport fishermen at KNPP in 1974 (WDNR 1975, p. 24).

h. Gizzard Shad

Gizzard shad ranked eighth in total number of fish impinged at KNPP. A total of 311 comprised 0.1% of the total fish catch and 0.2% of the total weight (15 kg) of impinged fish (Table 4). Gizzard shad were only impinged from October through January with largest numbers impinged in November (105) and December (147). According to LaJeone (1976, p. 11), this species is very uncommon in fish collections near the KNPP area of Lake Michigan. During the lake monitoring program, a total of ten gizzard shad was collected from seine hauls in the fall of 1973 and 1975 (LaJeone 1974, p. 8; 1976, p. 11).

Impinged gizzard shad ranged in length from 5 to 32 cm with the 10 to 18 cm size categories being most abundant (Figure 9). Adults comprised the majority of the catch with a few young-of-year impinged in December.

i. Carp

Carp was the ninth most abundant species impinged at KNPP. A total of 259 was collected, comprising 0.1% of the total fish catch and 2.7% of the total fish weight (165 kg) (Table 4). Few carp were collected each month except in September

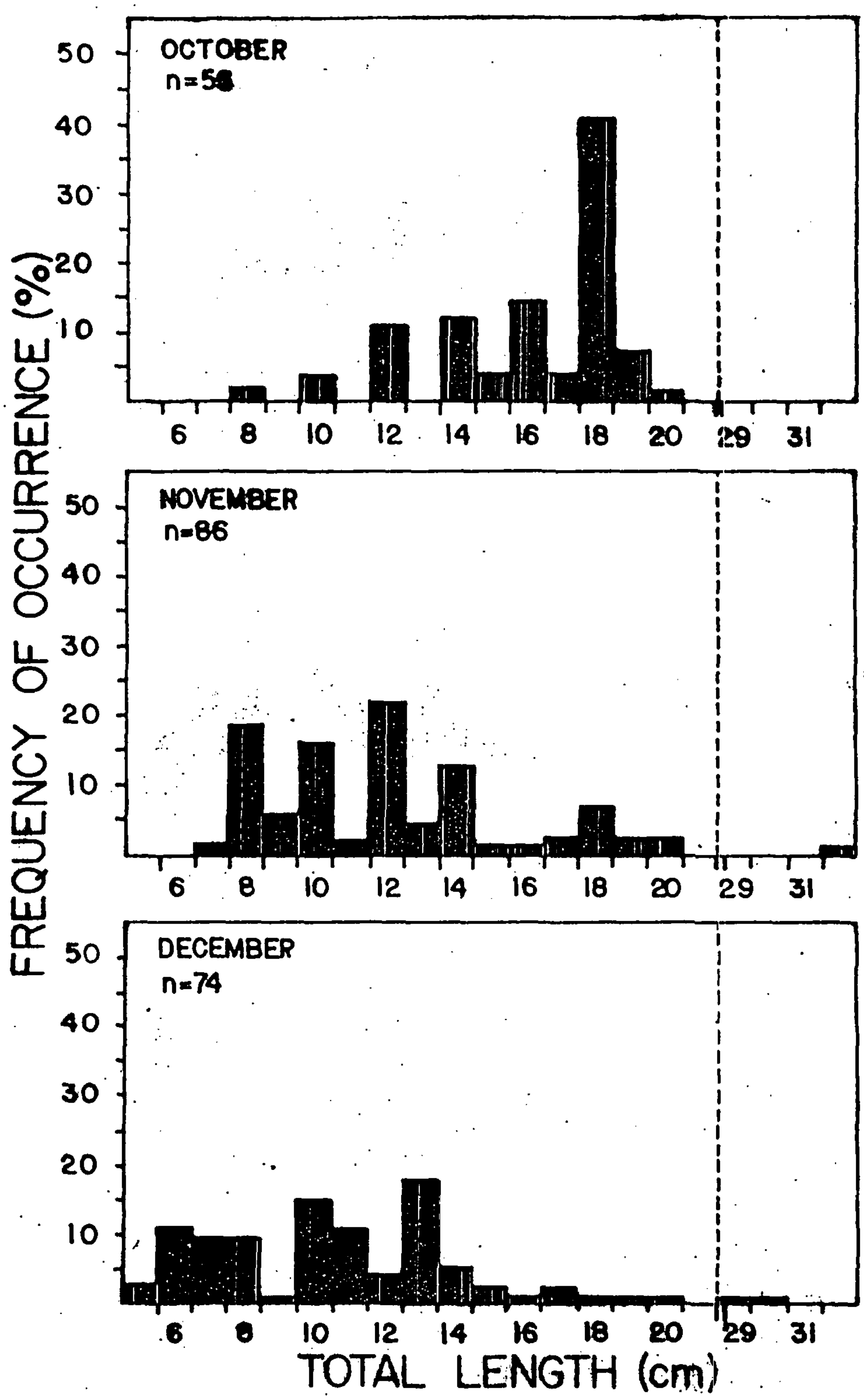

Figure 9. Length frequency distribution of gizzard shad impinged on the traveling screens at Kewaunee Nuclear Power Plant, October through December 1975.

when 65% of the total (169) were impinged. Carp were uncommon in the fish collections near KNPP; eight of eleven specimens collected during the lake monitoring program in 1974 were taken at sampling locations nearest the Plant's discharge (LaJeone 1975, p. 47). The large number of carp impinged in September may be due to the attraction of carp to the heated discharge area.

Impinged carp ranged in length from 6 to 100 cm with fish ranging from 40 to 60 cm comprising the majority of the catch for all months except September (Appendix Tables 1 through 12). In September, 98% of the impinged carp were less than 15 cm (Figure 10).

The daily rate of impingement of carp was less than one fish per day in all months except September (Table 6). Although only two carp were collected during the lake monitoring program, the difference between no fish per day, for most days when monitoring was conducted, was not appreciably different from less than one fish per day impinged by the Plant. The 165 kg of carp removed from the traveling screens at KNPP represented only 0.01% of the commercial harvest of carp (1.45 million kg) in Wisconsin waters of Lake Michigan in 1974 (Limnetics 1976, p. II 15-8).

j. Yellow Perch

Yellow perch was the tenth most abundant species impinged at KNPP and comprised 0.1% of the total fish catch (245) and 0.7% of the total fish weight (40 kg)(Table 4). This species was most common from June through September when 142 individuals were impinged. Prior to the summer collections, 55 yellow perch

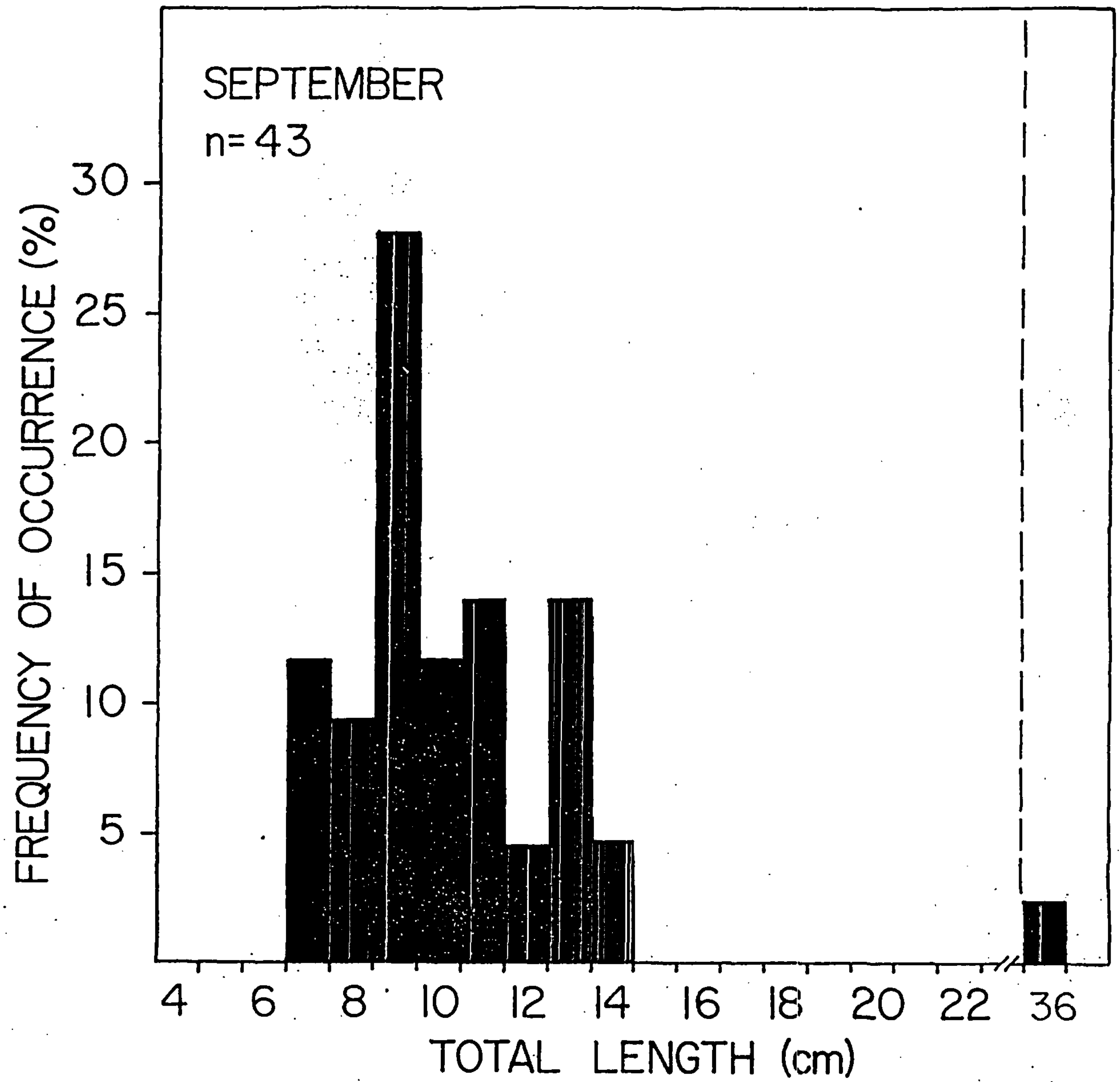

Figure 10. Length frequency distribution of carp impinged on the traveling screens at Kewaunee Nuclear Power Plant, September 1975.

were impinged, whereas only 48 individuals were collected after September. LaJeone (1974, p. 16; 1975, p. 29; 1976, p. 30) found that peak abundance of yellow perch collected near KNPP occurred in September 1973, July 1974 and August 1975.

Yellow perch impinged from June through September ranged from 18 to 35 cm and averaged 23 cm. Adults were the only fish impinged (Figure 11). LaJeone (1976, p. 30) found that age groups V and VI were most abundant near KNPP during the 1975 lake monitoring program and that, of the fish aged, none was younger than age group IV. In previous studies younger perch have been collected near KNPP (LaJeone 1976, p. 30).

The number of yellow perch impinged at KNPP was less than the 278 collected during the eight sampling days of the lake monitoring program (LaJeone 1976, p. 26)(Table 5). Based on daily catch, the number of yellow perch collected from one gill net sample (18 hr) in each of the eight months was 12 times the average daily number impinged by the Plant during those months (Table 6). In August, when yellow perch were most abundant during lake collections, the daily gill net catch from one location was 75 fish, and the average rate of impingement was less than one fish. High abundances of yellow perch in the KNPP vicinity were not reflected by their impingement. The average intake water velocity (0.6 m/sec) was below the maximum sustained swim speed for yellow perch (0.7 to 0.9 m/sec)(Otto et al. 1975, p. 166). The 40 kg of yellow perch impinged at KNPP was 0.01% of the commercial production (380 thousand kg) in Wisconsin waters of Lake Michigan in 1974 (Limnetics 1976, p. II 4-15).

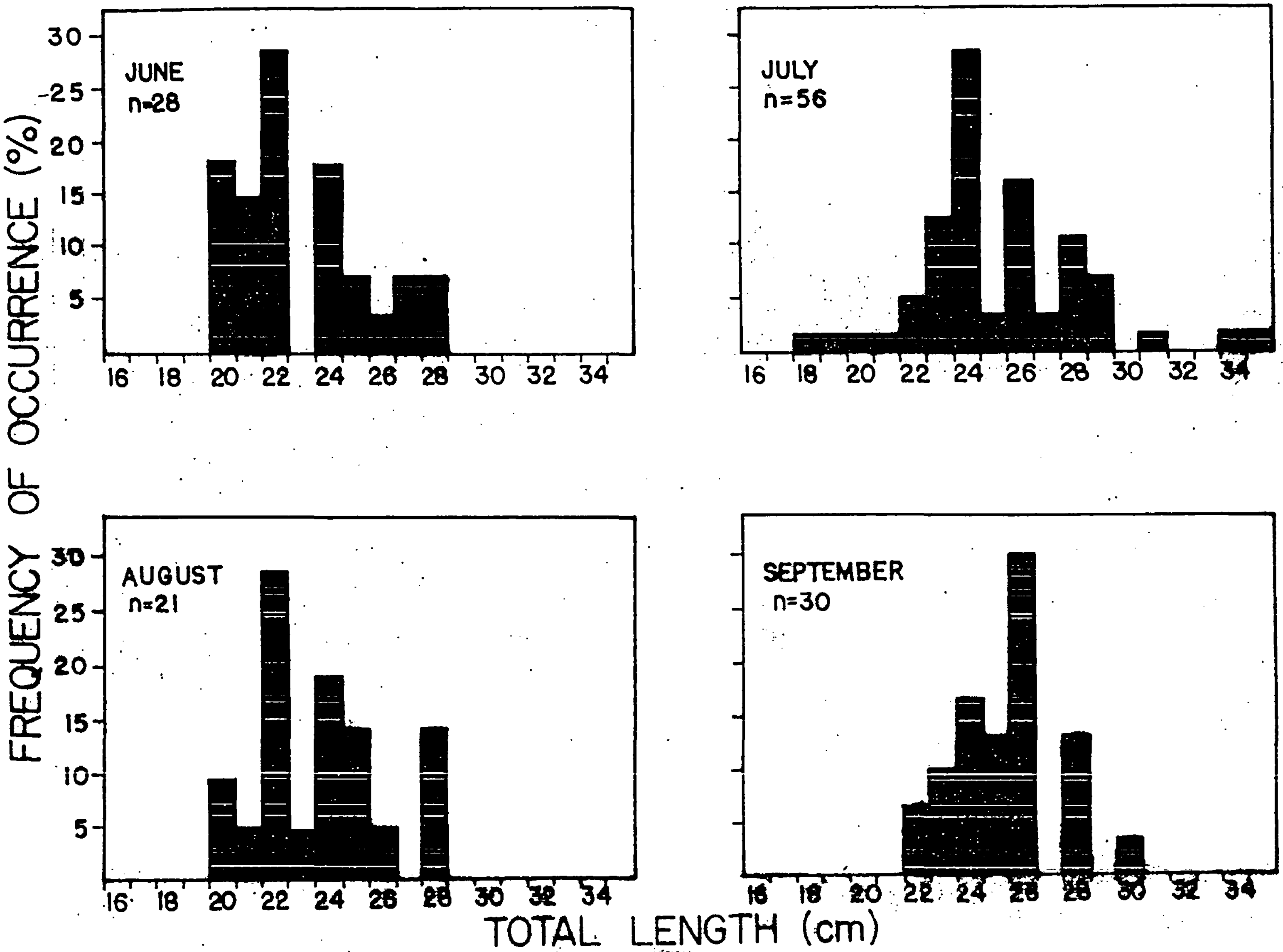

Figure 11. Length frequency distribution of yellow perch impinged on the traveling screens at Kewaunee Nuclear Power Plant, June through September 1975.

k. Miscellaneous Species

Bullheads were infrequently impinged at KNPP. One hundred and eleven brown and yellow bullheads were collected from July through March with 61 individuals impinged in September (Table 4). These species were absent from field collections near KNPP during the 1975 lake monitoring program; however, two black bullheads were collected in 1973 (LaJeone 1974, p. 48).

Ninespine stickleback were impinged in six of twelve months sampled with 46 of the 55 individuals collected from June through August (Table 4). LaJeone (1974, p. 48; 1975, p. 10) collected only three individuals near KNPP during the 1973-1975 lake monitoring program.

Salmonids that were infrequently impinged at KNPP included lake whitefish, round whitefish, bloater, coho salmon and chinook salmon. The total catch of all five species amounted to only 17 fish (Table 4). Populations of coho and chinook salmon were influenced by the number of fish stocked near the KNPP area. In 1974, a total 303,000 salmon were planted in tributaries near the Plant and an estimated 1200 salmon were caught by sport fishermen at KNPP (WDNR 1974; 1975, p. 24). Maximum sustained swimming speeds for salmon were well above the average intake velocity at KNPP (Paulik and DeLacy 1957, p. 20-30). The three salmon impinged compared to the number stocked or caught at KNPP was inconsequential.

The remainder of fish impinged at KNPP consisted of 39 troutperch, 9 pumpkinseed, 7 burbot, 4 common shiner, 2 lamprey, 2 northern pike and 1 blacknose dace (Table 4).

B. Eggs

1. General

Sampling for fish eggs was conducted in the KNPP forebay from April 1975 through March 1976. Fish eggs collected from April through August were alewife (68.5%), rainbow smelt (30.3%), Catostomidae (white or longnose sucker)(0.8%) and unidentifiable taxa (0.04%) (Table 7 and Figure 4). One unidentifiable egg was found in October and no eggs were observed during the remainder of the sampling year. Catostomid and rainbow smelt eggs were present in April and May while alewife eggs were prevalent in June, July and August.

A total of 3224 fish eggs was collected from the forebay samples. Initial sampling in April resulted in 920 eggs with subsequent collections yielding a peak density of 1777 in July, a decrease in August (383) and only one egg in October (Tables 8 through 13). Peak egg concentrations in the forebay corresponded with the largest number of eggs collected from bottom pump samples taken during the lake monitoring program near KNPP (LaJeone 1976, p. 20).

The estimated total number of fish eggs entrained through the Plant was 52.6 million as determined from monthly densities and intake flows (Table 14). Numbers were highest during the summer when an estimated 43.9 million eggs were entrained in July and August. Approximately 8.7 million eggs were entrained from April through June and 32.7 thousand eggs in October.

Table 7. Occurrence, total numbers and percent of total for various taxa of fish eggs and larvae collected from samples taken in the intake forebay at Kewaunee Nuclear Power Plant, April 1975 through March 1976.

Taxa	Occurrence	Total Number	Percent of Total
Eggs			
Rainbow smelt	April-May	976	30.3
Alewife	June-August	2208	68.5
Catostomidae	April-May	26	0.8
Unidentified	July and October	14	0.4
Total		3224	
Larvae & Juveniles			
Rainbow smelt	April-December	411	89.7
Coregonidae	April-May	5	1.1
Burbot	April-May	6	1.3
Catostomidae	June	1	0.2
Carp	July-August	12	2.6
Alewife	July-September	20	4.4
Slimy sculpin	July-August	3	0.7
Total		458	

Table 8. Total numbers, mean concentrations and measurements of eggs and larvae entrained at Kewaunee Nuclear Power Plant, April 1975.

Species	April 1 Number	April 1 Number/m³	April 8 Number	April 8 Number/m³	April 15 Number	April 15 Number/m³	April 22 Number	April 22 Number/m³	April 29 Number	April 29 Number/m³	April Total Number	April Mean Number/m³	Diameter or Total Length (mm) Mean	Diameter or Total Length (mm) Range
Burbot														
Eggs	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	-	-
Larvae	1	0.001	0	0.000	0	0.000	0	0.000	0	0.000	1	<0.001	4.8	-
Smelt														
Eggs	0	0.000	2	0.002	0	0.000	0	0.000	896	0.697	898	0.140	1.0	0.7-1.2
Larvae	0	0.000	0	0.000	0	0.000	0	0.000	8	0.006	8	0.001	6.5	5.8-8.0
Coregonidae														
Eggs	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	-	-
Larvae	0	0.000	0	0.000	1	0.001	0	0.000	0	0.000	1	<0.001	14.0	-
Catostomidae														
Eggs	0	0.000	0	0.000	0	0.000	0	0.000	22	0.020	22	0.004	2.8	2.7-3.0
Larvae	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	-	-

Table 9. Total numbers, mean concentrations and measurements of eggs and larvae entrained at Kewaunee Nuclear Power Plant, May 1975.

Species	May 6 Number	May 6 Number/m³	May 13 Number	May 13 Number/m³	May 20 Number	May 20 Number/m³	May 27 Number	May 27 Number/m³	May Total Number	May Mean Number/m³	Diameter or Total Length (mm) Mean	Diameter or Total Length (mm) Range
Burbot												
Eggs	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	-	-
Larvae	0	0.000	3	0.003	2	0.001	0	0.000	5	0.001	4.8	4.5- 5.2
Smelt												
Eggs	1	0.001	76	0.074	1	0.001	0	0.000	78	0.019	1.0	0.6- 1.2
Larvae	10	0.007	7	0.007	127	0.088	3	0.002	147	0.026	6.7	5.5-12.0
Coregonidae												
Eggs	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	-	-
Larvae	2	0.002	2	0.002	0	0.000	0	0.000	4	0.001	15.5	13.8-17.0
Catostomidae												
Eggs	0	0.000	4	0.004	0	0.000	0	0.000	4	0.001	3.0	2.3- 3.7
Larvae	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	-	-

Table 10. Total numbers, mean concentrations and measurements of eggs and larvae entrained at Kewaunee Nuclear Power Plant, June 1975.

Species	June 3		June 10		June 17		June 24		June		Diameter or Total Length (mm)	
	Number	Number/m^3	Number	Number/m^3	Number	Number/m^3	Number	Number/m^3	Total Number	Mean Number/m^3	Mean	Range
Alewife												
Eggs	0	0.000	0	0.000	0	0.000	61	0.084	61	0.021	0.8	0.6-1.1
Larvae	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	-	-
Smelt												
Eggs	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	-	-
Larvae	1	0.011	0	0.000	0	0.000	0	0.000	1	<0.001	6.2	-
Catostomidae												
Eggs	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	-	-
Larvae	0	0.000	0	0.000	1	0.001	0	0.000	1	<0.001	13.6	-

Table 11. . Total numbers, mean concentrations and measurements of eggs and larvae entrained at Kewaunee Nuclear Power Plant, July 1975.

Species	July 1		July 8		July 15		July 22		July 29		July		Diameter or Total Length (mm)	
	Number	Number/m^3	Number	Number/m^3	Number	Number/m^3	Number	Number/m^3	Number	Number/m^3	Total Number	Mean Number/m^3	Mean	Range
Alewife														
Eggs	19	0.025	919	1.364	769	1.095	35	0.048	22	0.035	1764	0.513	1.0	0.6- 1.1
Larvae	0	0.000	0	0.000	4	0.006	0	0.000	8	0.013	12	0.003	11.9	8.0-20.0
Carp														
Eggs	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	-	-
Larvae	10	0.013	1	0.002	0	0.000	0	0.000	0	0.000	11	0.003	7.9	5.6-10.5
Slimy Sculpin														
Eggs	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	-	-
Larvae	0	0.000	0	0.000	2	0.003	0	0.000	0	0.000	2	0.001	8.8	8.1- 9.4
Smelt														
Eggs	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	-	-
Larvae	0	0.000	2	0.003	0	0.000	43	0.054	6	0.010	51	0.014	12.1	9.5-19.0
Juveniles	0	0.000	1	0.001	44	0.061	2	0.002	0	0.000	47	0.012	27.6	21.0-32.0
Unidentified														
Eggs	0	0.000	13	0.019	0	0.000	0	0.000	0	0.000	13	0.004	1.7	1.5- 1.9
Larvae	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	-	-

Table 12. . Total numbers, mean concentrations and measurements of eggs and larvae entrained at Kewaunee Nuclear Power Plant, August 1975.

Species	August 5		August 12		August 19		August 26		August		Diameter or Total Length (mm)	
	Number	Number/m^3	Number	Number/m^3	Number	Number/m^3	Number	Number/m^3	Total Number	Mean Number/m^3	Mean	Range
Alewife												
Eggs	322	0.451	36	0.049	25	0.029	0	0.000	383	0.132	1.0	0.6- 1.1
Larvae	1	0.001	0	0.000	2	0.002	0	0.000	3	0.001	13.1	12.0-14.6
Smelt												
Eggs	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	-	-
Larvae	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	-	-
Juveniles	31	0.044	1	0.001	3	0.004	0	0.000	35	0.012	24.6	20.0-29.3
Carp												
Eggs	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	-	-
Larvae	0	0.000	0	0.000	0	0.000	1	0.002	1	<0.001	8.7	-
Slimy Sculpin												
Eggs	0	0.000	0	0.000	0	0.000	0	0.000	0	0.000	-	-
Larvae	1	0.001	0	0.000	0	0.000	0	0.000	1	<0.001	10.0	-

Table 13. . Total numbers, mean concentrations and measurements of eggs and larvae entrained at Kewaunee Nuclear Power Plant, September - December 1975.

Species	September 10 Number	September 10 Number/m^3	September 23 Number	September 23 Number/m^3	September Total Number	September Mean Number/m^3	Diameter or Total Length (mm) Mean	Diameter or Total Length (mm) Range
Alewife								
Eggs	0	0.000	0	0.000	0	0.000	-	-
Larvae	0	0.000	0	0.000	0	0.000	-	-
Juveniles	5	0.012	0	0.000	5	0.006	29.6	22.0-44.0
Smelt								
Eggs	0	0.000	0	0.000	0	0.000	-	-
Larvae	0	0.000	0	0.000	0	0.000	-	
Juveniles	43	0.086	0	0.000	43	0.043	32.4	22.5-43.0

Species	October 13 Number	October 13 Number/m^3	October 28 Number	October 28 Number/m^3	October Total Number	October Mean Number/m^3	Diameter or Total Length (mm) Mean	Diameter or Total Length (mm) Range
Smelt								
Eggs	0	0.000	0	0.000	0	0.000	-	-
Larvae	0	0.000	0	0.000	0	0.000	-	-
Juveniles	3	0.005	56	0.122	59	0.064	42.9	34.5-52.0
Unidentified								
Eggs	0	0.000	1	0.001	1	<0.001	2.0	-
Larvae	0	0.000	0	0.000	0	0.000	-	-
Juveniles	0	0.000	0	0.000	0	0.000	-	-

Species	November 4 Number	November 4 Number/m^3	November 17 Number	November 17 Number/m^3	November Total Number	November Mean Number/m^3	Diameter or Total Length (mm) Mean	Diameter or Total Length (mm) Range
Smelt								
Eggs	0	0.000	0	0.000	0	0.000	-	-
Larvae	0	0.000	0	0.000	0	0.000	-	-
Juveniles	16	0.030	3	0.004	19	0.017	46.0	36.0-51.0

Species	December 2 Number	December 2 Number/m^3	December 15 Number	December 15 Number/m^3	December Total Number	December Mean Number/m^3	Diameter or Total Length (mm) Mean	Diameter or Total Length (mm) Range
Smelt								
Eggs	0	0.000	0	0.000	0	0.000	-	-
Larvae	0	0.000	0	0.000	0	0.000	-	-
Juveniles	1	0.004	0	0.000	1	0.002	72.0	-

Table 14. Estimated total number (x 10^3) of fish eggs, larvae and juveniles entrained at Kewaunee Nuclear Power Plant, April - December, 1975. Monthly estimates based on mean number (m^3 x mean observed flow extrapolated to one month).

Species	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Eggs: Total Number x 10^3	Eggs: Percent of Total	Larvae and Juveniles: Total Number x 10^3	Larvae and Juveniles: Percent of Total
Alewife																
Eggs	0	0	1374.6	34698.6	8928.3	0	0	0	0	0	0	0	45001.5	85.5	-	-
Larvae	0	0	0	202.9	67.6	0	0	0	0	0	0	0	-	-	270.5	2.0
Juveniles	0	0	0	0	0	392.7	0	0	0	0	0	0	-	-	392.7	2.9
Burbot																
Eggs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Larvae	8.3	67.6	0	0	0	0	0	0	0	0	0	0	-	-	75.9	0.6
Carp																
Eggs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Larvae	0	0	0	202.9	33.8	0	0	0	0	0	0	0	-	-	236.7	1.7
Catostomidae																
Eggs	165.8	67.6	0	0	0	0	0	0	0	0	0	0	233.4	0.4	-	-
Larvae	0	0	16.4	0	0	0	0	0	0	0	0	0	-	-	16.4	0.1
Coregonidae																
Eggs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Larvae	8.3	67.6	0	0	0	0	0	0	0	0	0	0	-	-	75.9	0.6
Slimy sculpin																
Eggs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-
Larvae	0	0	0	67.6	16.9	0	0	0	0	0	0	0	-	-	84.5	0.6
Rainbow smelt																
Eggs	5803.7	1285.1	0	0	0	0	0	0	0	0	0	0	7088.9	13.5	-	-
Larvae	41.5	1758.7	16.4	946.9	0	0	0	0	0	0	0	0	-	-	2763.5	20.3
Juveniles	0	0	0	811.7	811.7	2814.6	4189.2	1020.0	67.6	0	0	0	-	-	9714.8	71.3
Unidentified																
Eggs	0	0	0	270.6	0	0	32.7	0	0	0	0	0	303.3	0.6	-	-
Larvae	0	0	0	0	0	0	0	0	0	0	0	0	-	-	0	0
Total													52627.1		13630.9	

2. Discussion of Species

a. Rainbow Smelt

A total of 976 rainbow smelt eggs was collected from samples taken in the forebay from 8 April through 20 May and comprised 30.3% of all eggs collected (Table 7). Peak abundance occurred in late April with 896 eggs representing 92% of all entrained smelt eggs (Table 8). Highest numbers of smelt eggs collected from bottom pump samples in the lake near KNPP also occurred in April 1974 and 1975 (LaJeone 1975, p. 17; 1976, p. 20). Monthly densities of entrained smelt eggs during April and May were $0.140/m^3$ and $0.019/m^3$, respectively (Tables 8 and 9).

An estimated 7.1 million rainbow smelt eggs were entrained during April and May at the KNPP (Table 14). During those months an estimated 1185 adult female smelt were removed from the KNPP traveling screens, representing a potential egg loss of 42 million (35500 per female) (Cima et al. 1975, p. 142). If one assumes that only one-fourth of the 1185 impinged females were unspawned and each had an average fecundity of 35500 eggs, the approximate loss of eggs would be 10.5 million. This is 1.4 times the estimated loss of free eggs due to condenser passage during the spawning period. If forebay collections of smelt eggs were influenced by the release of eggs from entrapped adult females passing from intake to forebay (1600 ft), as indicated from entrainment studies at Zion Station (Cima et al. 1976, p. 35), the potential egg loss during impingement would even be higher than that of entrainment. The number of eggs lost due to entrainment during April and

May would be equivalent to the potential egg production of only 200 ripe adult females.

b. Alewife

A total of 2208 alewife eggs was collected from samples taken in the KNPP forebay from 24 June through 19 August and represented 68.5% of all eggs collected (Table 7). The largest number of alewife eggs was obtained in mid-July (8 and 15) when 1688 eggs comprised 76.4% of all alewife eggs collected (Table 11). The occurrence of alewife eggs in the forebay coincided with the peak number of alewife eggs collected from bottom pump samples in the KNPP area during the 1973-1975 lake monitoring program (LaJeone 1974, p. 14; 1975, p. 17; 1976, p. 20). Monthly densities of alewife eggs collected in the forebay were $0.021/m^3$ in June, $0.513/m^3$ in July and $0.132/m^3$ in August (Tables 10 through 12).

An estimated 45 million alewife eggs passed through KNPP from July through August (Table 14). It was estimated that more than 54500 adult female alewives were removed during those months from the KNPP traveling screens, representing a potential loss of egg production of 572 million eggs (10500 eggs per female) (Cima et al. 1976, p. 142). The potential egg loss from impinged unspawned females is greater than those lost to entrainment. Since many of the free eggs entrained are fertilized, it is reasonable to assume that a proportion of those fertilized eggs will survive condenser passage and be redeposited in the lake (Schubel 1974 as cited by Otto et al. 1975, p. 74). The estimated number of alewife eggs passed through the condensers at KNPP would be equivalent to the potential egg production of only 4286 ripe adult females.

c. Miscellaneous Taxa

Catostomid (white or longnose sucker) eggs were infrequently collected from forebay samples. A total of 26 catostomid eggs was collected during April and May comprising 0.8% of all eggs sampled (Table 7). An estimated 233,000 catostomid eggs were entrained during those months at KNPP (Table 14). The potential number of eggs lost due to entrainment would be equivalent to the potential egg production of six adult females (white or longnose sucker) of average fecundity (Limnetics 1976 p. II 8-5, 9-4).

The remaining 14 eggs collected from forebay samples were unidentifiable. Thirteen of these were collected on 8 July with one collected on 28 October (Tables 11 and 13). An estimated 303,000 unidentifiable eggs were entrained at KNPP during July and October (Table 14).

C. Larvae

1. General

Fish larvae and juveniles were sampled in the KNPP intake forebay from April 1975 through March 1976. The 458 larval and juvenile fish collected included rainbow smelt (89.7%), alewife (4.4%), carp (2.6%), burbot (1.3%), Coregonidae (whitefish)(1.1%), slimy sculpin (0.7%) and Catostomidae (white or longnose sucker) (0.2%)(Table 7). The total number of larvae and juveniles ranged from 168 in spring (April through June) to 211 in summer (July through September) with 79 in fall (October through December). No fish larvae or juveniles were collected from January through March.

The total estimated number of fish larvae and juveniles entrained at KNPP was 13.6 million as determined from monthly densities and intake flows (Table 14). Estimated numbers of entrained fish (larvae and juveniles) for spring, summer and fall were 2.0, 6.4 and 5.2 million, respectively.

2. Discussion of Species

a. Rainbow Smelt

Four hundred and eleven immature smelt (larvae and juveniles) were collected from samples taken in the KNPP forebay and comprised 89.7% of all immature fish collected (Table 7). Larvae were entrained from April through July; 147 of the 207 individuals were collected in May (Tables 8 through 11). Juvenile smelt were initially collected in July with numbers increasing to 102 in September and October. The number of juveniles declined during the fall until only 20 specimens were collected in November and December (Tables 11 through 13). Monthly densities of smelt larvae ranged from less than $0.001/m^3$ to $0.026/m^3$ averaging $0.011/m^3$, while monthly densities for juvenile smelt ranged from $0.002/m^3$ to $0.064/m^3$ and averaged $0.025/m^3$ (Tables 8 through 13).

Lengths of smelt larvae collected from April through July ranged from 5 to 19 mm (Figure 12). Nearly 60% of the larvae collected in April and May were 6.0 mm while 78% of those collected in June and July ranged from 9 to 13 mm. The majority of juvenile smelt collected from July through September and from October through December averaged 28.2 and 44.7 mm in length, respectively (Tables 11 through 13).

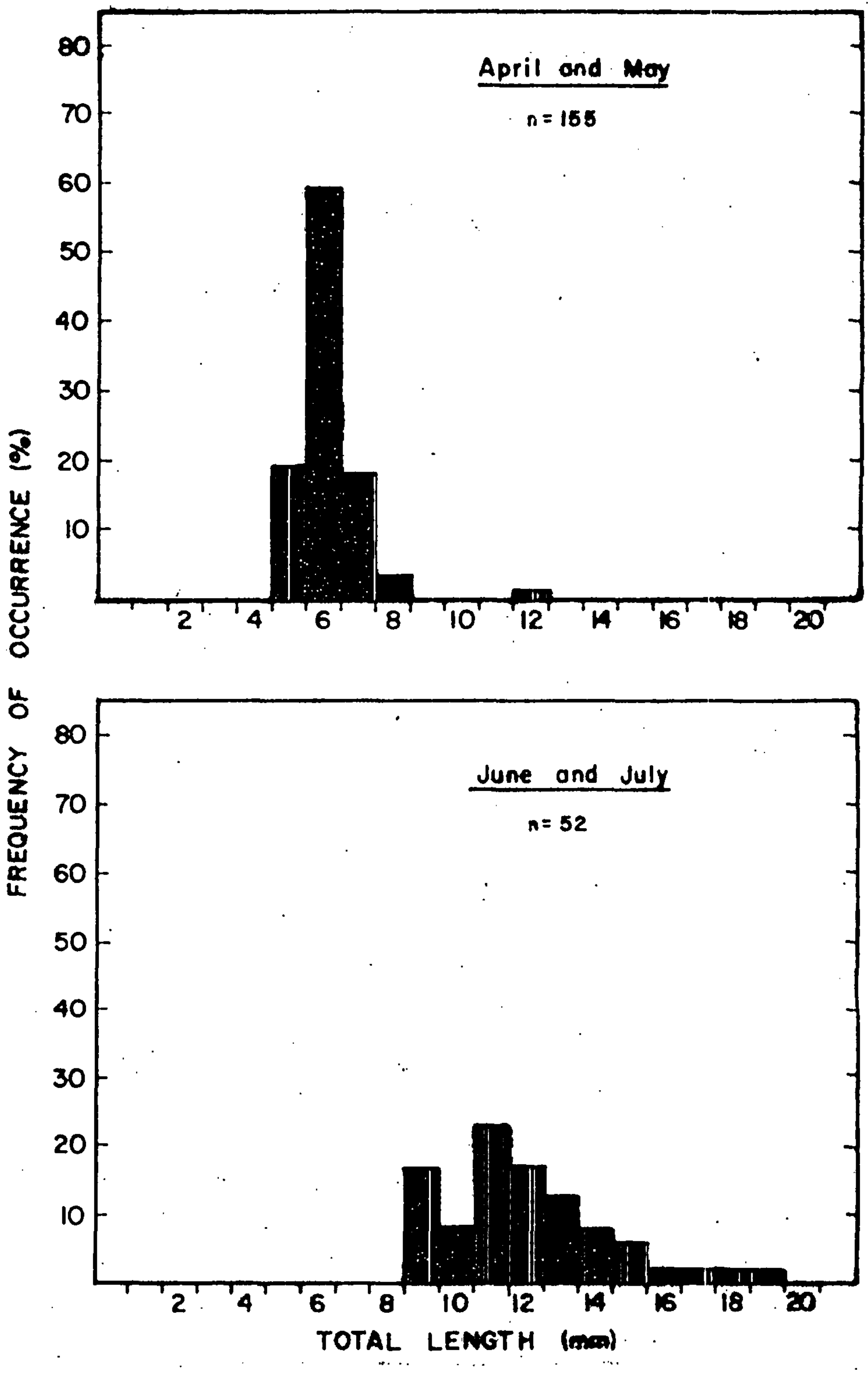

Figure 12. Length frequency distribution of rainbow smelt entrained at Kewaunee Nuclear Power Plant, April through July 1975.

An estimated 2.76 million smelt larvae and 9.71 million juveniles were entrained at KNPP from April through December. Rupp (1965, p. 165) found that 1.065% of the potential egg production of smelt survived to the larval stage at a variety of lake and stream spawning sites in Maine. According to Rupp's survival rate, the loss of larvae and juveniles at KNPP was equivalent to the larval production of 33000 females.

No survival data is available for entrained smelt larvae or juveniles. However, fish entrainment studies on the Missouri River at Fort Calhoun Station and Cooper Nuclear Station have found that a portion of the larval and juvenile fish entrained will survive condenser passage. Observed mortalities (discharge minus intake) from entrainment ranged from 3 to 13% at Cooper and from 3 to 29% at Fort Calhoun (NALCO Environmental Sciences 1975, p. 4.0 113; Patulski 1975, p. 90). Based on these studies, the mortality of larval and juvenile fish at KNPP would be equivalent to the larval production of 4630 smelt females. One hundred percent mortalities were assumed in this report to establish the worst possible case.

b. Alewife

Fifteen alewife larvae and five juveniles were collected from samples taken in the KNPP forebay from July through September (Tables 11 through 13). Larvae were collected in July and August and ranged in length from 8 to 20 mm, whereas juveniles collected in September ranged from 22 to 44 mm in length. Monthly densities of alewife larvae were $0.003/m^3$ in July and $0.001/m^3$ in August while juveniles averaged $0.006/m^3$ in September.

From July through September an estimated 271 thousand alewife larvae and 393 thousand juveniles were entrained by the Plant (Table 14). Based on the 0.06% (Otto et al. 1975, p. 85) survival rate of alewife eggs to the larval migratory stage, the estimated number of larvae and juveniles lost to entrainment would be equivalent to the larval production of 105,400 females of average fecundity. Otto et al. (1975, p. 76) found that only a 0.03% survival rate of eggs to the larval stage would be required to replace the spawning adults assuming no subsequent mortality. The numbers of larval and juvenile alewives lost to entrainment were considerably less than the loss of production capacity resulting from impingement of 179,000 alewives on the KNPP traveling screens.

c. Carp

Twelve carp larvae were collected from samples taken in the forebay and represented 2.6% of the total number of larval and juvenile fish collected (Table 7). Carp larvae were collected in July (11) and August (1) and ranged from 5.6 to 10.5 mm with a mean length of 7.9 mm (Tables 11 and 12). Monthly densities of carp larvae were $0.003/m^3$ in July and less than $0.001/m^3$ in August.

A predicted 237,000 carp larvae were entrained during July and August at KNPP (Table 14). Since the fecundity of carp can range from 200 thousand to 1.2 million eggs per female (Limnetics 1976, p. II 15-2), the number of larval fish lost to entrainment was quite small compared to the larval production capacity of carp in the KNPP area.

d. Burbot

Six burbot larvae averaging 4.8 mm in length were collected from forebay samples during April and May (Tables 8 and 9). Mean larval densities for each month averaged $0.001/m^3$. An estimated 76000 burbot larvae were entrained at KNPP during April and May (Table 14). Fecundity estimates for adult burbot (300 thousand to 1.1 million eggs per female) indicated that the predicted number of larvae lost to entrainment would be minimal (Limnetics 1976, p. II 19-3).

e. Miscellaneous Taxa

The remainder of fish larvae collected from samples taken in the forebay consisted of 5 coregonids (April and May), 3 slimy sculpins (July and August) and 1 catostomid (June) (Table 7). During the months these fish larvae were present, an estimated 76000 coregonids, 85000 slimy sculpins and 16400 catostomids were entrained at KNPP (Table 14). The estimated number of larvae lost to entrainment would be equivalent to the potential larval production capacity of 1 catostomid, 323 slimy sculpin and 10 coregonid adult females (Cima et al. 1976, p. 142; Limnetics 1976, p. II 3-7, 8-5, 9-4, 11-6, 27-2).

V. Conclusions

Thirty-one species of fish were collected from Kewaunee Nuclear Power Plant traveling screens from April 1975 through March 1976. Total number and weight of all fish impinged were 215,108 and 6210 kg, respectively. Alewife (83.2%) and rainbow smelt (8.9%) constituted nearly 92% of the impinged fish. Other principle taxa comprising 0.1% or more of the total catch included slimy sculpin (4.0%), longnose dace (2.0%), lake chub (0.7%), suckers (0.5), trout (0.2%), gizzard shad (0.1%), carp (0.1%) and yellow perch (0.1%). The greatest number of species was taken in January and fewest in March, April and May. Greatest numbers of fish were impinged in June and July due to the peak numbers of alewife.

Seasonal occurrence and relative abundance patterns for most of the principle species collected from the traveling screens were similar to those of field collections taken during the lake monitoring program near the KNPP intake in 1975.

Removal of 178,883 alewives and 19206 rainbow smelt from the KNPP traveling screens represented only 0.02% and 0.3%, respectively, of the total commercial production for those species in Wisconsin waters of Lake Michigan in 1974. The biomass of alewives and smelt removed from the lake was negligible compared to the total alewife and smelt biomass in Lake Michigan. The weight of slimy sculpins and yellow perch impinged at KNPP was less than 0.01% of their total commercial production in Lake Michigan in 1974.

A total of 344 trout (rainbow, lake, brown and brook trout) was impinged at KNPP during the study. Impinged trout represented less than 0.02% of the 1.9 million planted in Wisconsin waters of Lake Michigan in 1974. The total number of trout removed from the KNPP traveling screens was of little importance relative to the 31000 trout that were harvested by sport fishermen at KNPP in 1974.

In 1974, a total of 303000 coho and chinook salmon was planted in tributaries near the Plant and an estimated 1200 salmon were caught by sport fishermen at KNPP. The three salmon impinged compared to the number stocked or caught at KNPP were inconsequential.

Commercial fish such as round whitefish and lake whitefish were infrequently impinged at KNPP. The total catch of both species amounted to only 13 fish.

Bloater was the only species impinged at KNPP which has been given "changing status" classification by the WDNR. Only one bloater was impinged during the study. The lake monitoring program has shown bloaters to be extremely uncommon in the near shore waters of KNPP and it is doubtful that the area near KNPP is important to the well being of this species.

The only pollution tolerant species impinged at KNPP was carp. The daily rate of impinged carp was less than one fish per day in all months except September. During the lake monitoring program the majority of carp were collected near the Plant discharge indicating an attraction to the heated water.

A total of 3224 fish eggs was collected from samples taken in the KNPP forebay from April 1975 through March 1976. Alewife

(68.5%) and rainbow smelt (30.3%) comprised nearly 99% of all eggs collected. Rainbow smelt eggs were present in April and May entrainment collections and alewife eggs were prevalent from June through August. Total estimated numbers of entrained alewife and smelt eggs were 7.1 and 45.0 million, respectively.

The estimated number of alewife and smelt eggs lost due to entrainment would be equivalent to the potential egg production of 4286 ripe alewife females and 200 ripe smelt females. The potential number of eggs lost during the impingement of unspawned females would be greater than those entrained within the Plant. Laboratory studies have indicated that a portion of entrained fertilized eggs will survive condenser passage.

Seven fish taxa (larvae and juveniles) were identified during the entrainment study at KNPP. The 458 immature fish collected included rainbow smelt (89.7%), alewife (4.4%), carp (2.6%), burbot (1.3%), Coregonidae (whitefish)(1.1%), slimy sculpin (0.7%) and Catostomidae (white or longnose sucker)(0.2%).

Smelt larvae were entrained from April through July with juveniles present from July through December. An estimated 2.76 million larvae and 9.71 million juveniles were entrained at KNPP.

Alewife larvae and juveniles were collected from forebay samples during July through September. The estimated 664,000 immature alewives entrained were equivalent to the larval production of 105,400 females.

During July and August a predicted 237,000 carp larvae were entrained at the Plant. The loss of larval carp to entrainment was quite small compared to the high larval production capacity of carp.

An estimated 85000 slimy sculpin, 76000 burbot, 76000 coregonid and 16400 catostomid larvae were entrained at KNPP. The number of larvae entrained would be equivalent to the potential larval production of 323 slimy sculpin, 1 burbot, 10 coregonid and 1 catostomid females.

A 100% mortality for entrained fish larvae and juveniles was assumed in this report to establish the worst possible case. However, fish entrainment studies have shown that larval and juvenile mortalities were considerably less than 100%.

The overall conclusion of the 316(b) Demonstration is that impingement of fish and entrainment of eggs and larvae at KNPP had no major environmental impact on the fish community of Lake Michigan near KNPP. Therefore, the present cooling water intake system reflects "best available technology."

The impingement of adult and juvenile fish on the KNPP traveling screens was 100% accurate since all impinged fish were enumerated.

The estimated numbers of entrained eggs and larvae were determined from four replicate samples taken three times daily in the forebay. The frequency of random sampling concentrated during peak spawning periods gave an accurate representation of entrainment at KNPP.

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APPENDIX

APPENDIX
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Table 1. Summary of plant operating data and fish impingement data supplied by Plant personnel at Kewaunee Nuclear Power Plant, April 1975.

		4/1-4/4	4/5-4/8	4/9-4/12	4/13-4/16	4/17-4/20	4/21-4/24	4/25-4/28	4/29-4/30	Monthly Totals	Total Length (cm) Range	Mean
Parameter												
Average flow (m^3/min)		757.6	757.6	757.6	1136.4	947.0	1515.2	757.6	757.6			
Intake temperature (°C)		0-2	0-2	2-8	4-8	6-11	7-10	7-8	+[a]			
Discharge temperature (°C)		0-9	0-14	13-20	10-21	9-22	11-16	7-14	+			
Number of times screens operated since last sample		-[b]	-	-	-	-	-	-	-			
Species												
Alewife	number	0	100	0	0	*[c]	0	0	20	120	7.6-15.2	x[d]
	weight (kg)	0.000	2.700	0.000	0.000		0.000	0.000	0.560	3.260		
Carp	number	1	0	2	10	*	0	2	1	16	45.7-66.0	x
	weight (kg)	3.200	0.000	4.500	18.000		0.000	9.000	3.600	38.300		
Longnose dace	number	0	0	0	20	*	0	0	0	20	5.0-5.8	x
	weight (kg)	0.000	0.000	0.000	0.230		0.000	0.000	0.000	0.230		
Rainbow smelt	number	60	500	120	900	*	100	25	150	1855	7.6-25.4	x
	weight (kg)	1.200	6.800	1.400	19.800		1.400	0.230	2.300	33.130		
Sculpin	number	0	0	0	450	*	0	0	0	450	4.0-5.0	x
	weight (kg)	0.000	0.000	0.000	4.500		0.000	0.000	0.000	4.500		
Sucker	number	14	0	0	10	*	20	25	10	79	20.3-45.7	x
	weight (kg)	6.300	0.000	0.000	1.400		5.400	6.800	3.600	23.500		
Trout	number	8	6	5	150	*	1	1	2	173	7.6-30.4	x
	weight (kg)	0.340	0.400	0.400	3.200		0.900	0.680	0.230	6.150		
Yellow perch	number	0	1	0	0	*	20	0	2	23	7.6-22.9	x
	weight (kg)	0.000	0.230	0.000	0.000		2.700	0.000	0.340	3.270		

[a] + = No data recorded.
[b] - = No counting mechanism installed.
[c] * = Trash basket not emptied.
[d] x = Not recorded.

Table 2. Summary of plant operating data and fish impingement data supplied by Plant personnel at Kewaunee Nuclear Power Plant, May 1975.

Parameter		5/1-5/4	5/5-5/8	5/9-5/12	5/13-5/16	5/17-5/20	5/21-5/24	5/25-5/28	5/29-5/31			
Average flow (m^3/min)		1515.2	1515.2	1515.2	1515.2	1515.2	1515.2	1515.2	1515.2			
Intake temperature (°C)		6-9	6-9	8-11	9-12	9-12	8-11	7-13	9-12			
Discharge temperature (°C)		7-16	10-15	14-18	15-19	11-19	13-15	12-16	13-17			
Number of times screens operated since last sample		-[a]	-	-	-	-	-	-	-			
Species										**Monthly Totals**	**Total Length (cm) Range**	**Mean**
Alewife	number	6	8	10	155	675	5000	4000	3100	12954	2.5-20.3	+[b]
	weight (kg)	0.450	0.230	0.340	5.110	11.300	135.000	135.000	94.500	381.930		
Carp	number	0	1	0	0	0	0	1	0	2	38.1-60.9	49.5
	weight (kg)	0.000	1.600	0.000	0.000	0.000	0.000	3.400	0.000	5.000		
Longnose dace	number	0	9	9	0	0	0	0	0	18	7.6-15.2	+
	weight (kg)	0.000	0.110	0.230	0.000	0.000	0.000	0.000	0.000	0.340		
Rainbow smelt	number	200	4	4	5	0	0	15	5	233	7.6-25.4	+
	weight (kg)	2.300	0.230	0.230	0.110	0.000	0.000	0.790	0.340	4.000		
Sculpin	number	0	55	20	0	0	0	0	0	75	4.0-5.5	+
	weight (kg)	0.000	0.230	0.340	0.000	0.000	0.000	0.000	0.000	0.570		
Sucker	number	10	23	10	30	2	2	15	2	94	5.0-60.9	+
	weight (kg)	0.930	18.500	4.500	14.900	1.400	1.600	5.300	1.400	48.530		
Trout	number	0	0	0	3	0	0	0	0	3	30.5-50.8	+
	weight (kg)	0.000	0.000	0.000	4.400	0.000	0.000	0.000	0.000	4.400		
Whitefish	number	0	0	0	0	0	0	1	0	1	32.9	32.9
	weight (kg)	0.000	0.000	0.000	0.000	0.000	0.000	0.450	0.000	0.450		
Yellow perch	number	0	2	1	1	4	0	0	0	8	15.2-32.9	+
	weight (kg)	0.000	0.630	0.110	0.150	1.600	0.000	0.000	0.000	2.490		

[a]-No counting mechanism installed.
[b]+Not recorded.

Table 3. Summary of plant operating data and fish impingement data supplied by Plant personnel at Kewaunee Nuclear Power Plant, June 1975.

Parameter	6/1-6/4	6/5-6/8	6/9-6/12	6/13-6/16	6/17-6/20	6/21-6/24	6/25-6/28	6/29-6/30
Average flow (m^3/min)	1515.2	1515.2	1515.2	1515.2	1515.2	1515.2	1515.2	1515.2
Intake temperature (°C)	8-12	8-11	9-13	9-12	9-11	8-11	10-15	11-20
Discharge temperature (°C)	11-18	13-18	15-20	15-19	11-17	12-18	12-22	17-26
Number of times screens operated since last sample	-[a]	-	-	-	-	-	-	-

Species		6/1-6/4	6/5-6/8	6/9-6/12	6/13-6/16	6/17-6/20	6/21-6/24	6/25-6/28	6/29-6/30	Monthly Totals	Total Length (cm) Range	Mean
Alewife	number	4450	4500	5750	850	8770	8787	12580	10800	56487	6.0-22.0	18.0
	weight (kg)	154.000	117.000	184.500	30.260	294.800	298.680	398.000	334.000	1810.740		
Brown trout	number	0	0	0	0	0	0	0	2	2	29.3-41.4	35.4
	weight (kg)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.075	1.075		
Carp	number	0	0	0	0	1	0	0	0	1	53.3	53.3
	weight (kg)	0.000	0.000	0.000	0.000	1.500	0.000	0.000	0.000	1.500		
Lake whitefish	number	0	0	0	0	1	0	0	0	1	43.5	43.5
	weight (kg)	0.000	0.000	0.000	0.000	1.150	0.000	0.000	0.000	1.150		
Lamprey	number	0	0	0	1	0	1	0	0	2	35.0-43.0	39.0
	weight (kg)	0.000	0.000	0.000	0.200	0.000	0.110	0.000	0.000	0.310		
Longnose dace	number	0	0	0	0	13	2	16	14	45	9.0-13.4	10.6
	weight (kg)	0.000	0.000	0.000	0.000	0.135	0.032	1.630	0.740	2.537		
Longnose sucker	number	0	0	0	0	5	0	3	1	9	30.0-45.5	38.9
	weight (kg)	0.000	0.000	0.000	0.000	3.175	0.000	1.350	0.350	4.875		
Ninespine stickleback	number	0	0	0	0	4	0	7	1	12	6.5-8.0	7.7
	weight (kg)	0.000	0.000	0.000	0.000	0.008	0.000	0.005	0.003	0.016		
Rainbow smelt	number	0	0	0	5	927	53	44	8	1037	6.0-25.0	12.0
	weight (kg)	0.000	0.000	0.000	0.050	15.732	1.229	1.335	0.265	18.611		
Rainbow trout	number	0	0	0	0	0	0	1	0	1	35.3	35.3
	weight (kg)	0.000	0.000	0.000	0.000	0.000	0.000	0.475	0.000	0.475		
Slimy sculpin	number	0	0	50	43	82	4	24	2	205	5.5 8.3	6.5
	weight (kg)	0.000	0.000	0.450	0.700	0.226	0.230	0.086	0.008	1.700		
Sucker	number	6	3	7	5	0	2	0	0	23	25.4-53.3	+[b]
	weight (kg)	3.600	2.500	4.600	6.300	0.000	1.800	0.000	0.000	18.800		
White sucker	number	0	0	0	0	1	2	11	4	18	30.5-49.6	38.8
	weight (kg)	0.000	0.000	0.000	0.000	0.525	0.790	7.080	2.680	11.075		
Yellow perch	number	0	0	3	0	12	11	1	1	28	20.0-28.4	23.0
	weight (kg)	0.000	0.000	0.680	0.000	2.855	2.300	0.135	0.180	6.150		

[a]-No counting mechanism installed.
[b]+Not recorded.

Table 4. Summary of plant operating data and fish impingement data supplied by Plant personnel at Kewaunee Nuclear Power Plant, July 1975.

Parameter	7/1-7/4	7/5-7/8	7/9-7/12	7/13-7/16	7/17-7/20	7/21-7/24	7/25-7/28	7/29-7/31
Average flow (m^3/min)	1515.2	1515.2	1515.2	1515.2	1515.2	1515.2	1515.2	1515.2
Intake temperature (°C)	11-19	8-16	14-18	11-21	8-12	8-15	8-12	7-11
Discharge temperature (°C)	17-25	14-21	19-25	16-27	10-18	13-17	14-19	15-17
Number of times screens operated since last sample	-[a]	-	-	-	-	-	-	-

Species		7/1-7/4	7/5-7/8	7/9-7/12	7/13-7/16	7/17-7/20	7/21-7/24	7/25-7/28	7/29-7/31	Monthly Totals	Total Length (cm) Range	Total Length (cm) Mean
Alewife	number	4640	7040	3640	3390	2255	4130	1280	1980	28355	6.0-22.0	18.0
	weight (kg)	157.000	227.500	138.000	83.700	54.680	122.000	43.000	65.000	890.880		
Blacknose dace	number	0	0	0	1	0	0	0	0	1	16.0	16.0
	weight (kg)	0.000	0.000	0.000	0.030	0.000	0.000	0.000	0.000	0.030		
Brown trout	number	0	2	0	1	0	0	0	0	3	35.7-54.0	46.9
	weight (kg)	0.000	3.100	0.000	2.500	0.000	0.000	0.000	0.000	5.600		
Carp	number	1	0	0	0	0	0	0	0	1	45.8	45.8
	weight (kg)	1.875	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.875		
Common shiner	number	0	0	0	3	0	0	0	0	3	15.5-19.5	17.7
	weight (kg)	0.000	0.000	0.000	0.115	0.000	0.000	0.000	0.000	0.115		
Lake chub	number	0	5	2	0	2	4	10	3	26	13.0-19.4	17.7
	weight (kg)	0.000	0.240	0.085	0.000	0.100	0.200	0.650	0.088	1.363		
Lake trout	number	1	0	1	0	0	0	0	0	2	47.7-73.0	60.3
	weight (kg)	1.925	0.000	3.600	0.000	0.000	0.000	0.000	0.000	5.525		
Longnose dace	number	41	29	40	340	423	20	20	10	923	7.5-13.0	10.5
	weight (kg)	0.350	0.347	0.427	3.360	3.682	0.200	0.200	0.050	5.331		
Longnose sucker	number	2	6	3	12	4	0	3	0	30	24.5-50.5	39.3
	weight (kg)	1.375	4.060	1.525	5.420	1.775	0.000	1.800	0.000	15.955		
Ninespine stickleback	number	0	2	1	0	0	11	0	0	14	6.7-8.3	7.3
	weight (kg)	0.000	0.005	0.003	0.000	0.000	0.055	0.000	0.000	0.063		
Rainbow smelt	number	15	83	52	54	0	600	40	30	874	8.0-24.0	14.0
	weight (kg)	0.295	1.908	1.047	1.210	0.000	11.520	0.220	1.350	17.550		
Round whitefish	number	0	0	0	0	0	1	0	0	1	40.0	40.0
	weight (kg)	0.000	0.000	0.000	0.000	0.000	0.600	0.000	0.000	0.600		
Salmon	number	0	0	0	0	0	1	0	0	1	41.3	41.3
	weight (kg)	0.000	0.000	0.000	0.000	0.000	0.800	0.000	0.000	0.800		
Shorthead redhorse	number	1	0	0	0	1	0	0	0	2	37.0-45.1	41.1
	weight (kg)	0.875	0.000	0.000	0.000	0.400	0.000	0.000	0.000	1.275		
Slimy sculpin	number	34	31	30	97	4	65	20	0	281	5.5-9.0	6.9
	weight (kg)	0.131	0.149	0.152	0.540	0.020	0.470	0.060	0.000	1.522		
White sucker	number	1	8	4	3	6	3	1	0	26	31.1-54.5	43.2
	weight (kg)	0.550	6.250	3.070	3.030	3.815	1.600	0.625	0.000	18.940		
Yellow perch	number	2	13	7	13	21	2	1	0	59	17.8-35.0	24.5
	weight (kg)	0.530	2.745	1.420	3.180	5.400	0.325	0.260	0.000	13.860		

[a]-No counting mechanism installed.

Table 5. Summary of plant operating data and fish impingement data supplied by Plant personnel at Kewaunee Nuclear Power Plant, August 1975.

Parameter	8/1-8/4	8/5-8/8	8/9-8/12	8/13-8/16	8/17-8/20	8/21-8/24	8/25-8/28	8/29-8/31
Average flow (m^3/min)	1515.2	1515.2	1515.2	1515.2	1515.2	1515.2	1515.2	1515.2
Intake temperature (°C)	7-12	12-20	9-20	10-18	15-20	17-21	14-20	15-19
Discharge temperature (°C)	15-20	20-28	16-28	18-26	20-29	25-29	15-28	15-28
Number of times screens operated since last sample	-[a]	-	-	-	-	-	-	-

Species		8/1-8/4	8/5-8/8	8/9-8/12	8/13-8/16	8/17-8/20	8/21-8/24	8/25-8/28	8/29-8/31	Monthly Totals	Total Length (cm) Range	Total Length (cm) Mean
Alewife	number	2180	1770	4137	3140	2150	2470	7430	1120	24397	8.0-22.0	18.0
	weight (kg)	64.000	69.000	122.670	108.000	48.500	60.907	197.000	30.000	631.077		
Bloater	number	0	0	1	0	0	0	0	0	1	21.0	21.0
	weight (kg)	0.000	0.000	0.072	0.000	0.000	0.000	0.000	0.000	0.072		
Brown bullhead	number	0	0	0	0	0	0	1	0	1	23.5	23.5
	weight (kg)	0.000	0.000	0.000	0.000	0.000	0.000	0.140	0.000	0.140		
Brown trout	number	0	0	0	0	0	2	1	0	3	31.5-56.0	45.7
	weight (kg)	0.000	0.000	0.000	0.000	0.000	1.805	2.800	0.000	4.605		
Carp	number	0	0	1	0	0	0	0	3	4	8.0-57.5	21.6
	weight (kg)	0.000	0.000	1.775	0.000	0.000	0.000	0.000	0.044	1.819		
Lake chub	number	1	22	2	2	10	1	190	90	318	7.5-20	15.5
	weight (kg)	0.030	0.878	0.087	0.073	0.460	0.045	4.840	2.290	8.673		
Longnose dace	number	40	260	50	100	50	92	190	170	952	8.0-15.0	10.0
	weight (kg)	0.340	2.710	0.630	0.970	0.430	1.007	1.960	1.650	9.697		
Longnose sucker	number	1	3	0	7	9	6	14	2	49	19.0-53.0	40.4
	weight (kg)	0.550	1.425	0.000	2.360	4.315	5.050	9.070	0.960	30.005		
Ninespine stickleback	number	0	0	0	0	0	0	20	0	20	8.0	8.0
	weight (kg)	0.000	0.000	0.000	0.000	0.000	0.000	0.090	0.000	0.090		
Rainbow smelt	number	60	100	60	110	20	39	230	200	819	7.0-22.0	15.8
	weight (kg)	0.920	1.730	0.800	1.760	0.670	2.371	4.540	3.810	16.601		
Rainbow trout	number	0	0	0	0	0	0	1	0	1	31.5	31.5
	weight (kg)	0.000	0.000	0.000	0.000	0.000	0.000	0.370	0.000	0.370		
Shorthead redhorse	number	0	0	0	0	0	0	2	0	2	37.5-41.0	39.2
	weight (kg)	0.000	0.000	0.000	0.000	0.000	0.000	1.180	0.000	1.180		
Slimy sculpin	number	20	20	20	50	20	50	270	130	580	5.0-7.5	6.5
	weight (kg)	0.040	0.070	0.050	0.190	0.090	0.220	1.060	0.490	2.210		
Troutperch	number	0	0	0	10	0	0	0	0	10	10.0	10.0
	weight (kg)	0.000	0.000	0.000	0.060	0.000	0.000	0.000	0.000	0.060		
White sucker	number	4	2	2	7	27	33	30	9	114	17.8-50.0	38.0
	weight (kg)	1.580	0.378	1.975	3.763	12.085	13.905	16.895	3.394	53.975		
Yellow bullhead	number	0	1	0	0	0	0	1	2	4	11.0-22.0	18.2
	weight (kg)	0.000	0.019	0.000	0.000	0.000	0.000	0.200	0.245	0.464		
Yellow perch	number	1	2	3	3	2	6	4	0	21	20.0-28.0	22.5
	weight (kg)	0.122	0.294	0.377	0.495	0.462	1.265	0.645	0.000	3.660		

[a]-No counting mechanism installed.

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Table 6. Summary of plant operating data and fish impingement data supplied by Plant personnel at Kewaunee Nuclear Power Plant, September 1975.

Parameter		9/1-9/4	9/5-9/8	9/9-9/12	9/13-9/16	9/17-9/20	9/21-9/24	9/25-9/28	9/29-9/30			
Average flow (m^3/min)		1515.2	1515.2	1515.2	1515.2	1515.2	1515.2	1515.2	1515.2			
Intake temperature (°C)		18-20	17-20	15-18	+[a]	9-11	8-14	8-15	13-15			
Discharge temperature (°C)		19-28	22-25	15-23	+	11-14	12-17	16-23	21-22			
Number of times screens operated since last sample		-[b]	-	-	-	-	-	-	-			
Species										**Monthly Totals**	**Total Length (cm) Range**	**Mean**
Alewife	number	1000	2320	3070	750	557	3280	526	44	11547	7.0-22.0	18.2
	weight (kg)	29.880	69.140	86.000	22.120	13.278	98.000	13.892	1.376	333.686		
Brown trout	number	1	2	3	0	0	0	0	0	6	44.0-55.0	50.3
	weight (kg)	2.100	4.850	7.400	0.000	0.000	0.000	0.000	0.000	14.350		
Burbot	number	0	1	0	0	0	0	0	0	1	43.0	43.0
	weight (kg)	0.000	0.455	0.000	0.000	0.000	0.000	0.000	0.000	0.445		
Carp	number	127	21	7	4	5	1	3	1	169	6.0-65.0	10.6
	weight (kg)	1.097	0.404	0.112	0.043	0.061	0.005	0.015	3.800	5.537		
Lake chub	number	180	180	150	90	20	109	16	9	754	8.0-19.5	14.8
	weight (kg)	5.930	3.950	4.100	2.470	0.406	3.244	0.464	0.277	20.841		
Longnose dace	number	340	170	340	130	7	241	305	36	1569	8.0-12.8	10.0
	weight (kg)	3.570	1.920	3.340	1.190	0.083	2.305	3.132	0.312	18.984		
Longnose sucker	number	44	9	10	3	0	6	2	6	80	17.0-50.5	40.7
	weight (kg)	9.240	8.438	9.560	2.025	0.000	3.615	0.915	2.630	36.423		
Pumpkinseed	number	1	0	0	0	0	0	0	0	1	8.5	8.5
	weight (kg)	0.014	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.014		
Rainbow smelt	number	210	60	270	40	30	471	370	15	1466	8.0-22.0	14.5
	weight (kg)	4.460	1.800	2.940	0.690	0.964	9.865	8.520	0.246	29.485		
Rainbow trout	number	0	0	0	0	0	0	0	1	1	33.0	33.0
	weight (kg)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.420	0.420		
Round whitefish	number	0	0	0	0	0	0	0	1	1	45.0	45.0
	weight (kg)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.750	0.750		
Shorthead redhorse	number	0	2	6	4	0	7	1	2	22	34.0-45.5	37.6
	weight (kg)	0.000	0.672	2.295	1.760	0.000	2.305	0.275	0.710	8.017		
Slimy sculpin	number	150	100	170	70	7	35	21	26	579	5.5-9.0	6.9
	weight (kg)	0.620	0.450	0.530	0.210	0.026	0.125	0.073	0.090	2.125		
White sucker	number	22	74	35	9	11	15	9	7	182	13.0-47.0	29.4
	weight (kg)	9.301	20.755	20.770	3.180	2.935	4.545	1.855	2.475	65.816		
Yellow bullhead	number	16	15	10	4	3	5	5	3	61	6.0-28.0	16.2
	weight (kg)	1.335	1.254	1.298	0.540	0.168	0.636	0.122	0.180	5.533		
Yellow perch	number	4	0	26	1	0	1	2	0	34.	15.5-30.0	25.5
	weight (kg)	0.965	0.000	5.309	0.255	0.000	0.335	0.625	0.000	7.489		

[a] + = No data recorded.
[b] - = No counting mechanism installed.

Table 7. Summary of plant operating data and fish impingement data supplied by Plant personnel at Kewaunee Nuclear Power Plant, October 1975.

Parameter		10/1-10/4	10/5-10/8	10/9-10/12	10/13-10/16	10/17-10/20	10/21-10/24	10/25-10/28	10/29-10/31			
Average flow (m^3/min)		1515.2	1515.2	1515.2	1515.2	1515.2	1515.2	1515.2	1515.2			
Intake Temperature (°C)		12-14	9-14	8-10	9-12	8-11	9-12	9-13	x[b]			
Discharge Temperature (°C)		20-22	17-23	16-19	11-20	16-19	14-20	11-21	x			
Number of times screens operated since last sample		-[a]	-	-	-	-	-	-	-			

Species		10/1-10/4	10/5-10/8	10/9-10/12	10/13-10/16	10/17-10/20	10/21-10/24	10/25-10/28	10/29-10/31	Monthly Totals	Total Length (cm) Range	Mean
Alewife	number	539	2274	1050	7550	470	+[c]	2620	752	15255	5.5-21.0	16.5
	weight (kg)	12.048	55.206	29.000	163.000	5.750		74.000	17.571	356.575		
Brown trout	number	0	1	1	1	0	+	4	2	9	16.0-59.0	41.4
	weight (kg)	0.000	0.840	2.350	0.050	0.000		9.520	5.700	18.460		
Carp	number	1	1	0	0	0	+	0	0	2	14.0-66.0	40.0
	weight (kg)	2.500	0.047	0.000	0.000	0.000		0.000	0.000	2.547		
Gizzard shad	number	0	5	12	13	11	+	12	3	56	8.5-20.0	17.8
	weight (kg)	0.000	0.226	0.695	0.797	0.600		0.499	0.071	2.888		
Lake chub	number	7	10	7	4	1	+	73	28	130	9.0-19.0	15.0
	weight (kg)	0.228	0.385	0.171	0.106	0.040		2.731	0.956	4.617		
Lake whitefish	number	0	0	0	1	0	+	0	0	1	55.0	55.0
	weight (kg)	0.000	0.000	0.000	1.200	0.000		0.000	0.000	1.200		
Longnose dace	number	44	80	24	44	8	+	210	66	476	8.0-13.0	10.0
	weight (kg)	0.391	0.732	0.218	0.360	0.066		2.210	0.219	4.196		
Longnose sucker	number	2	5	2	2	0	+	0	5	16	19.5-50.0	36.4
	weight (kg)	1.170	4.025	1.265	0.990	0.000		0.000	1.350	8.800		
Rainbow smelt	number	18	97	370	5	1	+	620	1467	2578	8.0-26.0	15.0
	weight (kg)	0.279	1.882	8.570	0.093	0.010		15.470	39.221	65.525		
Rainbow trout	number	0	0	1	0	0	+	0	1	2	14.5-25.5	20.0
	weight (kg)	0.000	0.000	0.036	0.000	0.000		0.000	0.135	0.171		
Salmon	number	0	0	0	0	0	+	0	1	1	18.5	18.5
	weight (kg)	0.000	0.000	0.000	0.000	0.000		0.000	0.070	0.070		
Shorthead redhorse	number	0	0	3	3	0	+	3	0	9	35.5-46.5	38.9
	weight (kg)	0.000	0.000	1.060	1.570	0.000		1.415	0.000	4.045		
Slimy sculpin	number	43	69	21	63	0	+	150	114	460	5.5-9.5	7.0
	weight (kg)	0.164	0.247	0.071	0.201	0.000		0.550	0.612	1.845		
White sucker	number	4	3	7	15	0	+	10	6	45	10.0-51.0	31.8
	weight (kg)	1.710	1.265	2.075	3.411	0.000		5.423	1.389	15.273		
Yellow bullhead	number	3	4	1	1	0	+	2	3	14	6.5-22.0	16.6
	weight (kg)	0.430	0.212	0.075	0.030	0.000		0.137	0.148	1.032		
Yellow perch	number	0	1	0	0	0	+	5	5	11	9.5-24.5	16.8
	weight (kg)	0.000	0.015	0.000	0.000	0.000		0.603	0.424	1.042		

[a]- = No counting mechanism installed.
[b]x = Temperatures not recorded.
[c]+ = Fish basket not emptied.

Table 8. Summary of plant operating data and fish impingement data supplied by Plant personnel at Kewaunee Nuclear Power Plant, November 1975.

Parameter	11/1-11/4	11/5-11/8	11/9-11/12	11/13-11/16	11/17-11/20	11/21-11/24	11/25-11/28	11/29-11/30
Average flow (m^3/min)	947.0	1325.8	1515.2	1515.2	1515.2	1515.2	1515.2	1515.2
Intake Temperature (°C)	9-10	8-10	7-11	5-9	6-10	4-9	2-7	4-10
Discharge Temperature (°C)	10-13	9-15	9-18	6-16	13-17	11-16	4-15	10-17
Number of times screens operated since last sample	-[a]	-	-	-	-	-	-	-

Species		11/1-11/4	11/5-11/8	11/9-11/12	11/13-11/16	11/17-11/20	11/21-11/24	11/25-11/28	11/29-11/30	Monthly Totals	Total Length (cm) Range	Mean
Alewife	number	2540	2080	6370	2100	15650	1000	7	3	29750	6.0-22.0	15.0
	weight (kg)	66.000	61.000	62.000	65.000	87.500	22.700	0.274	0.086	361.560		
Brown trout	number	5	2	2	0	9	3	1	1	23	16.5-66.0	48.7
	weight (kg)	12.600	6.500	6.100	0.000	20.356	1.110	1.105	2.165	49.936		
Burbot	number	0	0	0	1	0	0	0	0	1	42.0	42.0
	weight (kg)	0.000	0.000	0.000	0.800	0.000	0.000	0.000	0.000	0.800		
Carp	number	1	0	1	2	0	1	2	2	9	8.5-71.0	50.9
	weight (kg)	4.300	0.000	0.008	2.117	0.000	3.000	3.975	6.500	19.900		
Gizzard shad	number	4	2	6	22	22	6	24	19	105	7.0-32.5	11.5
	weight (kg)	0.169	0.048	0.567	0.250	0.904	0.130	0.362	0.549	2.979		
Lake chub	number	20	8	37	60	57	27	27	12	248	9.5-31.0	16.0
	weight (kg)	0.562	0.364	0.993	2.237	2.653	0.824	1.213	0.452	9.316		
Lake trout	number	2	1	1	1	0	1	1	4	11	13.5-35.5	19.5
	weight (kg)	0.086	0.410	0.040	0.014	0.000	0.025	0.024	0.575	1.174		
Lake whitefish	number	0	0	0	0	0	1	0	0	1	42.0	42.0
	weight (kg)	0.000	0.000	0.000	0.000	0.000	0.640	0.000	0.000	0.640		
Longnose dace	number	57	10	58	150	55	14	14	3	361	8.0-13.5	10.0
	weight (kg)	0.541	0.095	0.762	1.850	0.779	0.139	0.148	0.024	4.338		
Longnose sucker	number	2	4	5	1	5	6	2	4	29	18.5-49.0	32.2
	weight (kg)	1.315	1.435	1.510	0.415	1.960	1.575	0.286	1.950	10.176		
Pumpkinseed	number	1	0	0	0	0	0	0	0	1	4.0	4.0
	weight (kg)	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002		
Rainbow smelt	number	2670	212	610	310	412	660	62	11	4947	10.0-25.0	16.5
	weight (kg)	51.000	0.838	18.790	10.315	14.676	24.450	1.787	0.368	122.224		
Rainbow trout	number	1	0	2	6	0	0	1	0	10	17.0-32.5	21.0
	weight (kg)	0.065	0.000	0.467	0.520	0.000	0.000	0.145	0.000	1.197		
Round whitefish	number	0	0	0	0	0	0	0	1	1	46.0	46.0
	weight (kg)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.710	0.710		
Shorthead redhorse	number	0	0	0	1	2	1	0	0	4	35.5-40.0	38.2
	weight (kg)	0.000	0.000	0.000	0.450	0.760	0.540	0.000	0.000	1.750		
Slimy sculpin	number	79	18	240	130	221	440	31	12	1171	5.5-10.5	7.2
	weight (kg)	0.403	0.057	0.930	0.460	0.792	1.540	0.094	0.038	4.314		
Troutperch	number	0	0	0	0	0	0	3	0	3	13.0-15.5	14.5
	weight (kg)	0.000	0.000	0.000	0.000	0.000	0.000	0.052	0.000	0.052		
White sucker	number	6	2	5	3	7	3	5	11	42	12.0-41.0	26.2
	weight (kg)	1.119	0.743	0.429	0.580	1.420	0.555	2.447	7.675	14.968		
Yellow bullhead	number	3	1	0	1	1	1	2	7	15	6.0-32.5	19.1
	weight (kg)	0.025	0.014	0.000	0.180	0.520	0.200	0.033	1.184	2.156		
Yellow perch	number	5	1	4	0	4	2	2	11	29	8.5-32.5	12.5
	weight (kg)	0.618	0.020	0.258	0.000	0.050	0.024	0.027	0.414	1.411		

[a] - = No counting mechanism installed.

Table 9. Summary of plant operating data and fish impingement data supplied by Plant personnel at Kewaunee Nuclear Power Plant, December 1975.

Parameter	12/1-12/4	12/5-12/8	12/9-12/12	12/13-12/16	12/17-12/20	12/21-12/24	12/25-12/28	12/29-12/31
Average flow (m^3/min)	757.6	757.6	757.6	757.6	757.6	757.6	757.6	757.6
Intake Temperature (°C)	2-8	3-8	2-8	3-8	1-7	1-6	1-6	2-6
Discharge Temperature (°C)	4-20	9-19	14-20	14-20	2-19	12-19	13-19	15-20
Number of times screens operated since last sample	-[a]	-	-	-	-	-	-	-

Species		12/1-12/4	12/5-12/8	12/9-12/12	12/13-12/16	12/17-12/20	12/21-12/24	12/25-12/28	12/29-12/31	Monthly Totals	Total Length (cm) Range	Mean
Brown trout	number	2	2	0	0	0	10	0	1	15	17.0-54.5	25.3
	weight (kg)	1.850	0.959	0.000	0.000	0.000	2.415	0.000	0.065	5.289		
Carp	number	0	2	0	2	0	4	1	0	9	7.0-75.0	34.6
	weight (kg)	0.000	0.013	0.000	8.800	0.000	9.032	3.110	0.000	20.955		
Gizzard shad	number	9	12	0	23	12	84	5	2	147	5.5-30.0	11.3
	weight (kg)	0.057	0.189	0.000	0.495	0.148	7.296	0.084	0.023	8.292		
Lake chub	number	6	10	3	9	22	7	2	3	62	12.5-19.0	15.9
	weight (kg)	0.200	0.400	0.140	0.431	0.880	0.292	0.111	0.180	2.634		
Lake trout	number	1	2	0	1	4	4	2	1	15	13.0-24.5	19.1
	weight (kg)	0.020	0.059	0.000	0.065	0.219	0.342	0.222	0.027	0.954		
Longnose dace	number	5	3	0	0	0	0	0	1	9	8.5-11.0	9.7
	weight (kg)	0.047	0.024	0.000	0.000	0.000	0.000	0.000	0.008	0.079		
Longnose sucker	number	1	2	0	0	3	2	1	0	9	11.0-45.5	23.8
	weight (kg)	0.710	0.197	0.000	0.000	0.685	0.248	0.011	0.000	1.851		
Ninespine stickleback	number	0	1	0	0	1	0	0	1	3	7.5-8.5	8.2
	weight (kg)	0.000	0.003	0.000	0.000	0.003	0.000	0.000	0.003	0.009		
Pumpkinseed	number	0	1	0	0	1	0	0	1	3	4.5-9.0	6.7
	weight (kg)	0.000	0.008	0.000	0.000	0.002	0.000	0.000	0.013	0.023		
Rainbow smelt	number	36	44	120	18	82	169	90	130	589	8.0-24.0	16.0
	weight (kg)	1.089	0.811	3.140	0.462	2.589	4.741	3.940	3.080	19.852		
Rainbow trout	number	0	1	0	2	0	3	3	1	10	16.5-21.0	18.5
	weight (kg)	0.000	0.045	0.000	0.153	0.000	0.186	0.183	0.059	0.626		
Round whitefish	number	0	0	0	0	0	0	1	0	1	37.5	37.5
	weight (kg)	0.000	0.000	0.000	0.000	0.000	0.000	0.424	0.000	0.424		
Slimy sculpin	number	300	760	230	160	440	270	170	180	2510	5.5-9.0	7.18
	weight (kg)	1.080	2.580	0.740	0.580	1.350	0.880	0.500	0.600	8.310		
Troutperch	number	4	4	0	0	3	1	2	1	15	7.0-15.0	11.1
	weight (kg)	0.038	0.045	0.000	0.000	0.048	0.030	0.049	0.011	0.221		
Whitefish	number	0	0	0	0	1	0	0	0	1	16.5	16.5
	weight (kg)	0.000	0.000	0.000	0.000	0.036	0.000	0.000	0.000	0.036		
White sucker	number	2	5	5	2	5	3	1	1	24	16.0-48.0	27.6
	weight (kg)	0.336	0.871	2.705	0.622	1.241	0.260	0.575	0.091	6.701		
Yellow bullhead	number	0	0	0	0	1	2	0	0	3	20.0-23.5	21.5
	weight (kg)	0.000	0.000	0.000	0.000	0.205	0.260	0.000	0.000	0.465		
Yellow perch	number	1	2	1	1	1	2	0	0	8	8.5-13.0	10.7
	weight (kg)	0.012	0.032	0.011	0.008	0.014	0.028	0.000	0.000	0.105		

[a] - = No counting mechanism installed.

Table 10. Summary of plant operating data and fish impingement data supplied by Plant personnel at Kewaunee Nuclear Power Plant, January 1976.

Parameter	1/1-1/4	1/5-1/8	1/9-1/12	1/13-1/16	1/17-1/20	1/21-1/24	1/25-1/28	1/29-1/31
Average flow (m^3/min)	757.6	757.6	757.6	757.6	757.6	757.6	852.3	757.6
Intake Temperature (°C)	0-5	0-4	0-3	0-2	0-5	0-4	0-5	0-5
Discharge Temperature (°C)	11-18	11-17	11-16	1-14	11-17	1-17	11-18	11-18
Number of times screens operated since last sample	-[a]	-	-	-	-	-	-	-

Species		1/1-1/4	1/5-1/8	1/9-1/12	1/13-1/16	1/17-1/20	1/21-1/24	1/25-1/28	1/29-1/31	Monthly Totals	Total Length (cm) Range	Mean
Alewife	number	1	0	1	1	0	2	1	0	6	12.0-18.0	15.0
	weight (kg)	0.020	0.000	0.036	0.035	0.000	0.079	0.008	0.000	0.178		
Brown bullhead	number	0	0	0	0	1	0	0	0	1	6.5	6.5
	weight (kg)	0.000	0.000	0.000	0.000	0.004	0.000	0.000	0.000	0.004		
Brown trout	number	3	2	0	10	3	0	0	0	18	14.0-51.0	22.4
	weight (kg)	14.936	0.130	0.000	0.933	0.258	0.000	0.000	0.000	16.257		
Burbot	number	1	0	0	1	1	0	0	0	3	44.5-56.0	49.5
	weight (kg)	0.465	0.000	0.000	0.770	1.500	0.000	0.000	0.000	1.735		
Carp	number	3	9	1	11	1	0	1	0	26	7.0-99.5	32.5
	weight (kg)	0.062	12.594	2.450	29.667	0.028	0.000	0.006	0.000	44.807		
Gizzard shad	number	0	2	0	1	0	0	0	0	3	9.0-39.0	19.3
	weight (kg)	0.000	0.016	0.000	0.750	0.000	0.000	0.000	0.000	0.766		
Lake chub	number	0	10	12	7	8	2	0	0	39	13.0-19.5	16.1
	weight (kg)	0.000	0.407	0.540	0.330	0.396	0.048	0.000	0.000	1.721		
Lake trout	number	0	1	5	4	2	1	0	0	13	16.5-27.5	22.3
	weight (kg)	0.000	0.067	0.393	0.493	0.224	0.038	0.000	0.000	1.215		
Lake whitefish	number	0	0	0	1	3	0	0	0	4	46.0-52.0	49.3
	weight (kg)	0.000	0.000	0.000	1.525	3.550	0.000	0.000	0.000	5.075		
Longnose dace	number	0	3	0	0	0	2	0	1	6	8.5-11.0	10.0
	weight (kg)	0.000	0.036	0.000	0.000	0.000	0.008	0.000	0.006	0.050		
Longnose sucker	number	0	2	2	5	4	0	2	0	15	22.5-56.0	34.0
	weight (kg)	0.000	0.643	0.830	1.895	2.417	0.000	0.827	0.000	6.612		
Ninespine stickleback	number	1	0	1	0	0	3	0	0	5	6.5-8.0	7.1
	weight (kg)	0.007	0.000	0.003	0.000	0.000	0.004	0.000	0.000	0.014		
Northern pike	number	0	1	0	0	0	0	0	0	1	29.5	29.5
	weight (kg)	0.000	0.150	0.000	0.000	0.000	0.000	0.000	0.000	0.150		
Pumpkinseed	number	0	1	0	2	0	0	0	0	3	5.0-11.5	7.2
	weight (kg)	0.000	0.006	0.000	0.041	0.000	0.000	0.000	0.000	0.047		
Rainbow smelt	number	7	39	202	300	450	350	830	200	2378	6.0-23.0	15.8
	weight (kg)	0.262	0.820	5.687	8.700	12.340	9.290	25.893	4.610	67.602		
Rainbow trout	number	0	0	0	2	0	0	1	0	3	17.5-21.0	18.8
	weight (kg)	0.000	0.000	0.000	0.134	0.000	0.000	0.054	0.000	0.188		
Shorthead redhorse	number	0	5	2	1	4	0	0	1	13	17.0-26.5	20.0
	weight (kg)	0.000	0.301	0.235	0.085	0.258	0.000	0.000	0.046	0.925		
Slimy sculpin	number	1	147	250	220	210	290	105	100	1323	5.5-9.0	7.4
	weight (kg)	0.006	0.442	1.550	1.120	0.820	1.150	0.524	0.310	5.917		
Troutperch	number	0	0	2	0	1	4	1	0	8	8.0-13.0	11.1
	weight (kg)	0.000	0.000	0.031	0.000	0.008	0.046	0.007	0.000	0.092		
White sucker	number	0	5	4	5	4	1	2	3	24	8.5-54.0	27.9
	weight (kg)	0.000	0.544	2.932	1.640	1.068	0.062	0.720	1.020	7.989		
Yellow bullhead	number	0	2	4	3	1	0	1	0	11	6.0-25.5	17.2
	weight (kg)	0.000	0.290	0.131	0.560	0.190	0.000	0.067	0.000	1.238		
Yellow perch	number	0	1	1	1	1	1	1	0	6	10.5-27.5	14.3
	weight (kg)	0.000	0.257	0.013	0.020	0.012	0.012	0.037	0.000	0.351		

[a] - = No counting mechanism installed.

Table 11. Summary of plant operating data and fish impingement data supplied by Plant personnel at Kewaunee Nuclear Power Plant, February, 1976.

Parameter	2/1-2/4	2/5-2/8	2/9-2/12	2/13-2/16	2/17-2/20	2/21-2/24	2/25-2/28	2/29
Average flow (m^3/min)	757.6	757.6	757.6	757.6	631.3	757.6	757.6	757.6
Intake Temperature (°C)	0-5	0-5	0-5	0-2	x[b]	x	x	x
Discharge Temperature (°C)	11-18	11-18	11-18	7-13	x	x	x	x
Number of times screens operated since last sample	-[a]	-	-	-	-	-	-	-

Species		2/1-2/4	2/5-2/8	2/9-2/12	2/13-2/16	2/17-2/20	2/21-2/24	2/25-2/28	2/29	Monthly Totals	Total Length (cm) Range	Mean
Alewife	number	1	0	3	0	2	3	0	+[c]	9	8.2-18.8	15.5
	weight (kg)	0.040	0.000	0.058	0.000	0.642	0.130	0.000		0.852		
Brown bullhead	number	2	0	0	0	0	0	0	+	2	11.8-19.0	15.4
	weight (kg)	0.110	0.000	0.000	0.000	0.000	0.000	0.000		0.110		
Brown trout	number	0	1	0	0	0	0	0	+	1	18.0	18.0
	weight (kg)	0.000	0.060	0.000	0.000	0.000	0.000	0.000		0.060		
Carp	number	5	0	8	0	0	1	1	+	15	6.5-73.0	20.9
	weight (kg)	0.089	0.000	0.134	0.000	0.000	3.628	2.721		6.572		
Common shiner	number	0	0	0	1	0	0	0	+	1	9.6	9.6
	weight (kg)	0.000	0.000	0.000	0.010	0.000	0.000	0.000		0.010		
Lake chub	number	0	0	6	0	0	0	0	+	6	11.5-18.0	16.0
	weight (kg)	0.000	0.000	0.260	0.000	0.000	0.000	0.000		0.260		
Lake trout	number	3	1	0	0	0	1	1	+	6	12.0-30.2	22.5
	weight (kg)	0.258	0.211	0.000	0.000	0.000	0.120	0.010		0.599		
Longnose dace	number	4	0	3	0	3	0	0	+	10	8.6-71.0	24.4
	weight (kg)	0.029	0.000	0.034	0.000	1.080	0.000	0.000		1.143		
Longnose sucker	number	2	2	0	0	0	2	0	+	6	12.0-45.0	30.0
	weight (kg)	1.018	0.784	0.000	0.000	0.000	0.076	0.000		1.878		
Ninespine stickleback	number	1	0	0	0	0	0	0	+	1	7.0	7.0
	weight (kg)	0.004	0.000	0.000	0.000	0.000	0.000	0.000		0.004		
Northern pike	number	1	0	0	0	0	0	0	+	1	33.5	33.5
	weight (kg)	0.225	0.000	0.000	0.000	0.000	0.000	0.000		0.225		
Pumpkinseed	number	0	0	0	1	0	0	0	+	1	15.2	15.2
	weight (kg)	0.000	0.000	0.000	0.065	0.000	0.000	0.000		0.065		
Rainbow smelt	number	700	240	370	140	180	160	40	+	1830	14.0-23.0	17.3
	weight (kg)	23.220	7.540	11.610	4.960	6.740	7.020	1.160		62.250		
Rainbow trout	number	0	1	0	0	0	0	0	+	1	21.0	21.0
	weight (kg)	0.000	0.068	0.000	0.000	0.000	0.000	0.000		0.068		
Salmon	number	0	0	0	0	0	1	0	+	1	63.0	63.0
	weight (kg)	0.000	0.000	0.000	0.000	0.000	3.175	0.000		3.175		
Shorthead redhorse	number	0	0	0	0	1	0	0	+	1	31.0	31.0
	weight (kg)	0.000	0.000	0.000	0.000	0.260	0.000	0.000		0.260		
Slimy sculpin	number	209	6	226	70	90	90	40	+	731	5.5-9.0	6.7
	weight (kg)	0.768	0.017	1.250	0.500	0.640	0.440	0.180		3.795		
Troutperch	number	3	0	0	0	0	0	0	+	3	12.6-15.0	13.4
	weight (kg)	0.046	0.000	0.000	0.000	0.000	0.000	0.000		0.046		
White sucker	number	0	1	2	0	0	0	0	+	3	20.5-51.0	35.2
	weight (kg)	0.000	1.425	0.280	0.000	0.000	0.000	0.000		1.705		
Yellow bullhead	number	1	0	0	0	0	0	0	+	1	17.2	17.2
	weight (kg)	0.074	0.000	0.000	0.000	0.000	0.000	0.000		0.074		
Yellow perch	number	1	0	3	0	0	0	0	+	4	10.0-11.2	10.6
	weight (kg)	0.009	0.000	0.040	0.000	0.000	0.000	0.000		0.553		

[a] - = No counting mechanism installed.
[b] x = Temperatures not recorded.
[c] + = Fish baskets not emptied.

Table 12. Summary of plant operating data and fish impingement data supplied by Plant personnel at Kewaunee Nuclear Power Plant, March 1976.

Parameter	3/1-3/4	3/5-3/8	3/9-3/12	3/13-3/16	3/17-3/20	3/21-3/24	3/25-3/28	3/29-3/31
Average flow (m^3/min)	441.9	757.6	757.6	757.6	757.6	757.6	757.6	757.6
Intake Temperature (°C)	x[a]	x	x	x	x	x	x	x
Discharge Temperature (°C)	x	x	x	x	x	x	x	x
Number of times screens operated since last sample	-[b]	-	-	-	-	-	-	-

Species		3/1-3/4	3/5-3/8	3/9-3/12	3/13-3/16	3/17-3/20	3/21-3/24	3/25-3/28	3/29-3/31	Monthly Totals	Total Length (cm) Range	Mean
Alewife	number	1	2	0	0	0	+[c]	+	+	3	19.5-22.5	20.6
	weight (kg)	0.080	0.188	0.000	0.000	0.000				0.268		
Brook trout	number	1	0	0	0	0	+	+	+	1	18.6	18.6
	weight (kg)	0.058	0.000	0.000	0.000	0.000				0.058		
Brown trout	number	0	1	0	0	0	+	+	+	1	24.5	24.5
	weight (kg)	0.000	0.160	0.000	0.000	0.000				0.160		
Burbot	number	0	2	0	0	0	+	+	+	2	40.0-42.5	41.3
	weight (kg)	0.000	1.020	0.000	0.000	0.000				1.020		
Carp	number	1	3	1	0	0	+	+	+	5	17.0-81.0	58.2
	weight (kg)	0.454	15.422	0.042	0.000	0.000				15.918		
Lake chub	number	0	0	1	0	0	+	+	+	1	14.0	14.0
	weight (kg)	0.000	0.000	0.028	0.000	0.000				0.028		
Lake trout	number	1	9	0	0	0	+	+	+	10	18.0-29.0	21.7
	weight (kg)	0.134	1.094	0.000	0.000	0.000				1.228		
Longnose sucker	number	2	0	3	3	2	+	+	+	10	15.0-41.0	26.1
	weight (kg)	0.115	0.000	0.676	0.208	0.548				1.547		
Rainbow smelt	number	230	40	30	200	100	+	+	+	600	12.0-24.0	17.8
	weight (kg)	11.000	1.820	0.074	6.320	4.220				23.434		
Slimy sculpin	number	55	10	50	70	90	+	+	+	275	6.0-8.6	6.9
	weight (kg)	0.402	0.073	0.011	0.290	0.440				1.216		
White sucker	number	1	21	0	0	0	+	+	+	22	24.6-46.0	34.7
	weight (kg)	0.122	9.164	0.000	0.000	0.000				9.286		
Yellow bullhead	number	0	1	0	0	0	+	+	+	1	26.0	26.0
	weight (kg)	0.000	0.280	0.000	0.000	0.000				0.280		

[a] x = Temperatures not recorded.
[b] - = No counting mechanism installed.
[c] + = Fish basket not emptied.

Table 13. Total, mean numbers and concentrations of fish eggs, larvae and juveniles collected at Kewaunee Nuclear Power Plant, April 1975.

Date	Time	Replicate	Temperature (°C) Intake	Temperature (°C) Discharge	Total Flow Through Plant (m^3/min)	% Turbine Capacity	Eggs Number	Eggs Number/m^3	Larvae Number	Larvae Number/m^3
Apr 1	1600	A	1.0	8.0	757.6	65	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
	2400	A	1.5	8.5	757.6	65	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	1	0.010
		D					0	0.000	0	0.000
Apr 2	0800	A	1.5	8.5	757.6	65	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
	Mean				757.6	65	0.000	0.000	0.083	0.001
Apr 8	1600	A	1.5	13.5	757.6	96	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
	2400	A	2.0	13.5	757.6	96	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
Apr 9	0800	A	1.5	13.5	757.6	96	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					2	0.029	0	0.000
	Mean				757.6	96	0.167	0.002	0.000	0.000
Apr 15	1600	A	4.5	13.5	1515.2	100	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
	2400	A	4.5	13.5	1515.2	100	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	1	0.007
		D					0	0.000	0	0.000
Apr 16	0800	A	4.5	18.0	757.6	95	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
	Mean				1262.7	98	0.000	0.000	0.083	0.001
Apr 22	1600	A	8.5	14.0	757.6	93	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
	2400	A	8.0	14.0	1515.2	93	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
Apr 23	0800	A	7.0	14.0	1515.2	93	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
	Mean				1262.7	93	0.000	0.000	0.000	0.000

Table 13. (continued)

Date	Time	Replicate	Temperature (°C) Intake	Temperature (°C) Discharge	Total Flow Through Plant (m^3/min)	% Turbine Capacity	Eggs Number	Eggs Number/m^3	Larvae Number	Larvae Number/m^3
Apr 29	1600	A	9.5	9.5	757.6	0	25	0.323	1	0.013
		B					40	0.416	0	0.000
		C					32	0.350	0	0.000
		D					44	0.461	0	0.000
	2400	A	9.5	9.5	757.6	0	75	0.755	0	0.000
		B					68	0.840	1	0.012
		C					86	0.730	0	0.000
		D					53	0.541	0	0.000
Apr 30	0800	A	9.0	9.0	757.6	0	83	0.816	2	0.020
		B					102	0.814	1	0.008
		C					141	1.252	1	0.008
		D					169	1.310	2	0.015
	Mean				757.6	0	76.500	0.717	0.667	0.006
			Grand Total		-	-	920.000		10.000	
			Grand Mean		959.6	70.4	15.333	0.143	0.167	0.001

Table 14. Total, mean numbers and concentrations of fish eggs, larvae and juveniles collected at Kewaunee Nuclear Power Plant, May 1975.

Date	Time	Replicate	Temperature (°C) Intake	Temperature (°C) Discharge	Total Flow Through Plant (m^3/min)	% Turbine Capacity	Eggs Number	Eggs Number/m^3	Larvae Number	Larvae Number/m^3
May 6	1600	A	7.0	13.5	1515.2	86	0	0.000	3	0.025
		B					0	0.000	1	0.008
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
	2400	A	7.0	14.0	1515.2	90	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
May 7	0800	A	7.0	7.0	1515.2	0	0	0.000	3	0.023
		B					0	0.000	5	0.046
		C					0	0.000	0	0.000
		D					1	0.007	0	0.000
	Mean				1515.2	59	0.083	0.001	1.000	0.009
May 13	1600	A	11.5	18.5	1515.2	89	10	0.099	0	0.000
		B					4	0.054	0	0.000
		C					8	0.116	0	0.000
		D					10	0.104	0	0.000
	2400	A	11.0	18.5	1515.2	90	5	0.050	1	0.010
		B					10	0.116	2	0.023
		C					6	0.036	1	0.014
		D					14	0.126	2	0.018
May 14	0800	A	11.0	18.5	1515.2	90	2	0.027	1	0.013
		B					2	0.023	3	0.035
		C					3	0.046	1	0.015
		D					6	0.093	1	0.016
	Mean				1515.2	90	6.667	0.078	1.000	0.012
May 20	1600	A	10.0	14.5	1515.2	64	0	0.000	22	0.213
		B					0	0.000	11	0.107
		C					0	0.000	42	0.318
		D					0	0.000	42	0.318
	2400	A	9.0	14.0	1515.2	63	0	0.000	4	0.028
		B					0	0.000	4	0.028
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
May 21	0800	A	9.0	12.5	1515.2	63	0	0.000	2	0.029
		B					0	0.000	0	0.000
		C					1	0.014	1	0.014
		D					0	0.000	1	0.014
	Mean				1515.2	63	0.083	0.001	10.750	0.089
May 27	1600	A	9.0	13.5	1515.2	61	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
	2400	A	8.5	13.0	1515.2	62	0	0.000	0	0.000
		B					0	0.000	1	0.007
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000

Table 14. (continued)

Date	Time	Replicate	Temperature (°C) Intake	Temperature (°C) Discharge	Total Flow Through Plant (m^3/min)	% Turbine Capacity	Eggs Number	Eggs Number/m^3	Larvae Number	Larvae Number/m^3
May 28	0800	A	8.5	13.0	1515.2	62	0	0.000	1	0.009
		B					0	0.000	0	0.000
		C					0	0.000	1	0.010
		D					0	0.000	0	0.000
	Mean				1515.2	62	0	0.000	0.250	0.002
			Grand Total		-	-	82.000		156.000	
			Grand Mean		1515.2	68.5	1.367	0.020	1.083	0.028

Table 15. Total, mean numbers and concentrations of fish eggs, larvae and juveniles collected at Kewaunee Nuclear Power Plant, June 1975.

Date	Time	Replicate	Temperature (°C) Intake	Temperature (°C) Discharge	Total Flow Through Plant (m^3/min)	% Turbine Capacity	Eggs Number	Eggs Number/m^3	Larvae Number	Larvae Number/m^3
Jun 3	1600	A	11.0	16.0	1515.2	64	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
	2400	A	9.0	10.5	1515.2	31	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	1	0.011
		D					0	0.000	0	0.000
Jun 4	0800	A	9.0	13.0	1515.2	58	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
	Mean				1515.2	51	0.000	0.000	0.083	0.001
Jun 10	1600	A	11.5	18.0	1515.2	87	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
	2400	A	12.0	18.5	1515.2	89	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
Jun 11	0800	A	11.5	18.0	1515.2	87	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
	Mean				1515.2	88	0.000	0.000	0.000	0.000
Jun 17	1600	A	10.0	17.0	1515.2	83	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
	2400	A	10.0	17.0	1515.2	83	0	0.000	1	0.017
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
Jun 18	0800	A	9.0	15.5	1515.2	83	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
	Mean				1515.2	83	0.000	0.000	0.083	0.001
Jun 24	1600	A	10.0	17.0	1515.2	90	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					1	0.011	0	0.000
		D					0	0.000	0	0.000
	2400	A	10.0	17.0	1515.2	87	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000

Table 15. (continued)

Date	Time	Replicate	Temperature (°C) Intake	Temperature (°C) Discharge	Total Flow Through Plant (m³/min)	% Turbine Capacity	Eggs Number	Eggs Number/m³	Larvae Number	Larvae Number/m³
Jun 25	0800	A	9.5	16.5	1515.2	88	15	0.240	0	0.000
		B					10	0.160	0	0.000
		C					15	0.258	0	0.000
		D					20	0.344	0	0.000
	Mean				1515.2	88	5.083	0.084	0.000	0.000
		Grand Total			-	-	61.000		2.000	
		Grand Mean			1515.2	77.5	1.271	0.021	0.042	0.001

Table 16. Total, mean numbers and concentrations of fish eggs, larvae and juveniles collected at Kewaunee Nuclear Power Plant, July 1975.

Date	Time	Replicate	Temperature (°C) Intake	Discharge	Total Flow Through Plant (m^3/min)	% Turbine Capacity	Eggs Number	Number/m^3	Larvae and Juveniles Number	Number/m^3
Jul 1	1600	A	20.0	26.0	1515.2	66	0	0.000	0	0.000
		B					2	0.029	0	0.000
		C					3	0.045	0	0.000
		D					3	0.045	0	0.000
	2400	A	15.5	21.0	1515.2	67	0	0.000	2	0.024
		B					0	0.000	2	0.024
		C					0	0.000	1	0.017
		D					4	0.051	2	0.026
Jul 2	0800	A	12.0	18.0	1515.2	70	3	0.072	1	0.024
		B					0	0.000	2	0.037
		C					2	0.033	0	0.000
		D					2	0.023	0	0.000
	Mean				1515.2	68	1.583	0.025	0.833	0.013
Jul 8	1600	A	14.0	19.5	1515.2	70	165	2.721	0	0.000
		B					222	3.474	1	0.016
		C					205	3.590	0	0.000
		D					267	5.495	1	0.020
	2400	A	14.0	19.5	1515.2	70	15	0.248	0	0.000
		B					17	0.346	0	0.000
		C					14	0.247	0	0.000
		D					24	0.429	0	0.000
Jul 9	0800	A	14.0	20.0	1515.2	72	1	0.019	1	0.019
		B					0	0.000	0	0.000
		C					1	0.015	0	0.000
		D					1	0.021	1	0.021
	Mean				1515.2	71	77.667	1.383	0.333	0.006
Jul 15	1600	A	18.5	23.0	1515.2	67	134	2.247	1	0.017
		B					185	3.341	1	0.018
		C					101	1.740	1	0.017
		D					128	2.160	2	0.034
	2400	A	18.0	24.0	1515.2	67	44	0.766	9	0.157
		B					37	0.508	7	0.096
		C					54	0.969	12	0.215
		D					68	1.110	13	0.213
Jul 16	0800	A	15.0	21.0	1515.2	68	2	0.027	1	0.014
		B					4	0.067	0	0.000
		C					5	0.084	3	0.050
		D					7	0.121	0	0.000
	Mean				1515.2	67	64.033	1.095	4.167	0.069
Jul 22	1600	A	9.0	14.5	1515.2	70	5	0.085	3	0.051
		B					10	0.167	1	0.017
		C					7	0.103	2	0.029
		D					9	0.169	1	0.019
	2400	A	9.5	15.0	1515.2	72	0	0.000	6	0.108
		B					1	0.017	7	0.119
		C					1	0.012	9	0.108
		D					2	0.023	10	0.115

Table 16. (continued)

Date	Time	Replicate	Temperature (°C) Intake	Temperature (°C) Discharge	Total Flow Through Plant (m^3/min)	% Turbine Capacity	Eggs Number	Eggs Number/m^3	Larvae and Juveniles Number	Larvae and Juveniles Number/m^3
Jul 23	0800	A	9.5	15.0	1515.2	72	0	0.000	1	0.018
		B					0	0.000	3	0.050
		C					0	0.000	1	0.018
		D					0	0.000	1	0.017
	Mean				1515.2	71	2.917	0.048	3.375	0.056
Jul 29	1600	A	11.0	18.5	1515.2	93	5	0.079	0	0.000
		B					3	0.057	1	0.019
		C					3	0.053	2	0.035
		D					3	0.052	3	0.052
	2400	A	8.5	16.0	1515.2	94	2	0.033	0	0.000
		B					1	0.022	1	0.022
		C					0	0.000	1	0.017
		D					4	0.101	1	0.025
Jul 30	0800	A	7.5	15.5	1515.2	94	1	0.018	1	0.018
		B					0	0.000	0	0.000
		C					0	0.000	4	0.088
		D					0	0.000	0	0.000
	Mean				1515.2	94	1.833	0.035	1.167	0.023
			Grand Total		-	-	1777.000		123.000	
			Grand Mean		1515.2	74	29.167	0.517	2.050	0.033

Table 17. Total, mean numbers and concentrations of fish eggs, larvae and juveniles collected at Kewaunee Nuclear Power Plant, August 1975.

Date	Time	Replicate	Temperature (°C) Intake	Temperature (°C) Discharge	Total Flow Through Plant (m^3/min)	% Turbine Capacity	Eggs Number	Eggs Number/m^3	Larvae and Juveniles Number	Larvae and Juveniles Number/m^3
Aug 5	1600	A	14.5	22.5	1515.2	97	24	0.570	1	0.024
		B					22	0.339	1	0.015
		C					28	0.423	5	0.085
		D					27	0.470	4	0.070
	2400	A	15.5	23.5	1515.2	97	29	0.525	3	0.054
		B					17	0.328	2	0.039
		C					31	0.566	4	0.073
		D					32	0.498	1	0.016
Aug 6	0800	A	15.5	23.5	1515.2	96	22	0.329	3	0.045
		B					34	0.469	1	0.014
		C					24	0.404	6	0.101
		D					32	0.495	2	0.031
	Mean				1515.2	97	26.833	0.451	2.750	0.047
Aug 12	1600	A	10.0	20.0	1515.2	99	4	0.063	0	0.000
		B					2	0.030	0	0.000
		C					5	0.093	0	0.000
		D					5	0.083	0	0.000
	2400	A	10.0	20.0	1515.2	99	4	0.066	0	0.000
		B					6	0.101	0	0.000
		C					3	0.050	0	0.000
		D					6	0.096	0	0.000
Aug 13	0800	A	10.5	20.5	1515.2	99	0	0.000	1	0.017
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					1	0.020	0	0.000
	Mean				1515.2	99	3.000	0.049	0.083	0.001
Aug 19	1600	A	19.0	27.5	1515.2	98	1	0.017	0	0.000
		B					0	0.000	2	0.034
		C					2	0.029	0	0.000
		D					1	0.017	0	0.000
	2400	A	19.0	27.5	1515.2	99	3	0.038	0	0.000
		B					1	0.017	0	0.000
		C					2	0.033	0	0.000
		D					5	0.052	0	0.000
Aug 20	0800	A	18.5	27.5	1515.2	98	4	0.057	1	0.014
		B					1	0.016	1	0.016
		C					2	0.029	1	0.015
		D					3	0.040	0	0.000
	Mean				1515.2	98	2.083	0.029	0.419	0.006
Aug 26	1600	A	15.0	23.5	1515.2	95	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	1	0.019
		D					0	0.000	0	0.000
	2400	A	14.0	21.5	1515.2	95	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000

Table 17. (continued)

Date	Time	Replicate	Temperature (°C) Intake	Temperature (°C) Discharge	Total Flow Through Plant (m^3/min)	% Turbine Capacity	Eggs Number	Eggs Number/m^3	Larvae and Juveniles Number	Larvae and Juveniles Number/m^3
Aug 27	0800	A	13.5	22.5	1515.2	95	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
	Mean				1515.2	95	0	0.000	0.083	0.002
			Grand Total		-	-	383.000		40.000	
			Grand Mean		1515.2	97	7.979	0.132	0.833	0.014

Table 18. Total, mean numbers and concentrations of fish eggs, larvae and juveniles collected at Kewaunee Nuclear Power Plant, September 1975.

Date	Time	Replicate	Temperature (°C) Intake	Temperature (°C) Discharge	Total Flow Through Plant (m^3/min)	% Turbine Capacity	Eggs Number	Eggs Number/m^3	Larvae and Juveniles Number	Larvae and Juveniles Number/m^3
Sep 10	1600	A	16.0	21.0	1515.2	59	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	1	0.025
		D					0	0.000	1	0.019
	2400	A	15.0	19.0	1515.2	4	0	0.000	14	0.274
		B					0	0.000	9	0.189
		C					0	0.000	11	0.243
		D					0	0.000	9	0.342
Sep 11	0800	A	14.5	14.5	1515.2	0	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	3	0.079
	Mean				1515.2	21	0	0.000	4.000	0.098
Sep 23	1600	A	8.5	14.0	1515.2	62	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
	2400	A	8.5	14.5	1515.2	65	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
Sep 24	0800	A	8.0	18.0	1515.2	99	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
	Mean				1515.2	75	0.000	0.000	0.000	0.000
			Grand Totals		-	-	0.000		48.000	
			Grand Mean		1515.2	48	0.000	0.000	2.000	0.049

Table 19. Total, mean numbers and concentrations of fish eggs, larvae and juveniles collected at Kewaunee Nuclear Power Plant, October 1975.

Date	Time	Replicate	Temperature (°C) Intake	Temperature (°C) Discharge	Total Flow Through Plant (m^3/min)	% Turbine Capacity	Eggs Number	Eggs Number/m^3	Larvae and Juveniles Number	Larvae and Juveniles Number/m^3
Oct 13	1600	A	10.5	20.5	1515.2	99	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
	2400	A	10.0	20.0	1515.2	99	0	0.000	0	0.000
		B					0	0.000	1	0.030
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
Oct 14	0800	A	10.0	20.0	1515.2	99	0	0.000	0	0.000
		B					0	0.000	1	0.014
		C					0	0.000	1	0.018
		D					0	0.000	0	0.000
	Mean				1515.2	99	0.000	0.000	0.250	0.005
Oct 28	1600	A	9.5	9.5	1515.2	0	0	0.000	0	0.000
		B					1	0.016	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	1	0.026
	2400	A	9.5	9.5	1515.2	0	0	0.000	15	0.312
		B					0	0.000	21	0.626
		C					0	0.000	7	0.183
		D					0	0.000	9	0.180
Oct 29	0800	A	9.5	9.5	757.6	0	0	0.000	2	0.084
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	1	0.050
	Mean				1262.7	0	0.083	0.001	4.667	0.122
			Grand Totals		-	-	1.000		59	
			Grand Mean		1388.9	50	0.042	0.001	2.458	0.064

Table 20. Total, mean numbers and concentrations of fish eggs, larvae and juveniles collected at Kewaunee Nuclear Power Plant, November 1975.

Date	Time	Replicate	Temperature (°C) Intake	Temperature (°C) Discharge	Total Flow Through Plant (m^3/min)	% Turbine Capacity	Eggs Number	Eggs Number/m^3	Larvae and Juveniles Number	Larvae and Juveniles Number/m^3
Nov 4	1600	A	9.5	9.5	757.6	0	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
	2400	A	9.0	9.0	1515.2	0	0	0.000	4	0.090
		B					0	0.000	4	0.081
		C					0	0.000	3	0.061
		D					0	0.000	5	0.130
Nov 5	0800	A	8.5	12.0	1515.2	46	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
	Mean				1262.7	15	0.000	0.000	1.833	0.030
Nov 17	1600	A	7.5	17.5	1515.2	98	0	0.000	0	0.000
		B					0	0.000	1	0.018
		C					0	0.000	0	0.000
		D					0	0.000	1	0.018
	2400	A	8.0	18.0	1515.2	98	0	0.000	0	0.000
		B					0	0.000	1	0.017
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
Nov 18	0800	A	8.0	18.0	1515.2	98	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
	Mean				1515.2	98	0.000	0.000	0.250	0.004
			Grand Totals		-	-	0.000		25.000	
			Grand Mean		1388.9	56	0.000	0.000	1.042	0.017

Table 21. Total, mean numbers and concentrations of fish eggs, larvae and juveniles collected at Kewaunee Nuclear Power Plant, December 1975.

Date	Time	Replicate	Temperature (°C) Intake	Temperature (°C) Discharge	Total Flow Through Plant (m^3/min)	% Turbine Capacity	Eggs Number	Eggs Number/m^3	Larvae Number	Larvae Number/m^3
Dec 2	1600	A	4.5	16.5	757.6	94	0	0.000	0	0.000
		B					0	0.000	1	0.045
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
	2400	A	4.5	16.5	757.6	94	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
Dec 3	0800	A	3.0	15.5	757.6	94	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
	Mean				757.6	94	0.000	0.000	0.083	0.004
Dec 15	1600	A	3.0	19.0	757.6	99	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
	2400	A	3.0	19.0	757.6	99	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
Dec 16	0800	A	3.5	19.0	757.6	99	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
	Mean				757.6	99	0.000	0.000	0.000	0.000
			Grand Totals		-	-	0.000		1.000	
			Grand Mean		757.6	96	0.000	0.000	0.042	0.002

Table 22. Total, mean numbers and concentrations of fish eggs, larvae and juveniles collected at Kewaunee Nuclear Power Plant, January 1976.

Date	Time	Replicate	Temperature (°C) Intake	Temperature (°C) Discharge	Total Flow Through Plant (m^3/min)	% Turbine Capacity	Eggs Number	Eggs Number/m^3	Larvae Number	Larvae Number/m^3
Jan 14	1600	A	0.0	0.5	757.6	0	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
	2400	A	0.0	0.0	757.6	0	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
Jan 15	0800	A	1.0	7.5	757.6	50	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
	Mean				757.6	17	0.000	0.000	0.000	0.000
Jan 26	1600	A	0.0	12.5	757.6	99	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
	2400	A	0.0	12.5	757.6	99	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
Jan 27	0800	A	0.0	12.5	757.6	99	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
	Mean				757.6	99	0.000	0.000	0.000	0.000
			Grand Totals		-	-	0.000		0.000	
			Grand Mean		757.6	58	0.000	0.000	0.000	0.000

Table 23. Total, mean numbers and concentrations of fish eggs larvae and juveniles collected at Kewaunee Nuclear Power Plant, February, 1976.

Date	Time	Replicate	Temperature (°C) Intake	Discharge	Total Flow Through Plant (m^3/min)	% Turbine Capacity	Eggs Number	Eggs Number/m^3	Larvae Number	Larvae Number/m^3
Feb 9	1600	A	1.0	17.0	757.6	99	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
	2400	A	1.0	17.0	757.6	99	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
Feb 10	0800	A	1.0	17.0	757.6	99	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
	Mean				757.6	99	0.000	0.000	0.000	0.000
Feb 24	1600	A	1.0	1.5	757.6	0	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
	2400	A	1.0	1.5	757.6	0	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
Feb 25	0800	A	1.0	1.5	757.6	0	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
	Mean				757.6	0	0.000	0.000	0.000	0.000
		Grand Totals			-	-	0.000		0.000	
		Grand Mean			757.6	50	0.000	0.000	0.000	0.000

Table 24. Total, mean numbers and concentrations of fish eggs, larvae and juveniles collected at Kewaunee Nuclear Power Plant, March 1976.

Date	Time	Replicate	Temperature (°C) Intake	Discharge	Total Flow Through Plant (m^3/min)	% Turbine Capacity	Eggs Number	Number/m^3	Larvae Number	Number/m^3
Mar 10	1600	A	1.0	1.0	757.6	0	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
	2400	A	1.5	1.5	757.6	0	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
Mar 11	0800	A	1.5	1.5	757.6	0	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
	Mean				757.6	0	0.000	0.000	0.000	0.000
Mar	1600	A	6.0	6.0	757.6	0	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
	2400	A	5.5	5.5	757.6	0	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
Mar	0800	A	6.0	6.0	757.6	0	0	0.000	0	0.000
		B					0	0.000	0	0.000
		C					0	0.000	0	0.000
		D					0	0.000	0	0.000
	Mean				757.6	0	0.000	0.000	0.000	0.000
			Grand Totals		-	-	0.000		0.000	
			Grand Mean		757.6	0	0.000	0.000	0.000	0.000

Table 25. The amount of water sampled per time period, total volume of water sampled per day and percent of plant intake volume sampled at Kewaunee Nuclear Power Plant, April 1975 through March 1976.

Date	Volume of Water Sampled (m^3) 1600 hrs	2400 hrs	0800 hrs	Total Volume of Water Sampled (m^3)	% of Plant intake volume sample
1975					
1-2 Apr	455.8	447.2	432.3	1335.3	0.41
8-9	390.3	451.8	397.6	1239.7	0.40
15-16	482.0	480.3	487.8	1450.1	0.30
22-23	456.4	438.0	321.9	1216.3	0.26
29-30	360.2	396.0	468.7	1224.9	0.38
6-7 May	532.7	560.1	452.8	1545.6	0.28
13-14	340.0	366.0	288.4	994.4	0.21
20-21	470.7	515.2	275.4	1261.3	0.46
27-28	298.6	643.8	433.2	1375.6	0.26
3-4 Jun	300.2	492.9	355.4	1148.5	0.25
10-11	369.5	440.5	430.5	1240.5	0.27
17-18	260.8	235.2	236.6	732.6	0.15
24-25	356.9	218.1	241.4	816.4	0.22
1-2 Jul	267.2	300.5	240.3	808.0	0.31
8-9	230.2	222.3	224.5	677.0	0.24
15-16	232.1	247.0	249.7	728.8	0.27
22-23	239.2	284.7	228.0	751.9	0.28
29-30	230.3	205.5	193.5	629.3	0.35
5-6 Aug	223.7	226.1	263.6	713.4	0.37
12-13	244.2	242.6	226.9	713.7	0.20
19-20	244.2	294.5	274.4	813.1	0.22
26-27	218.2	210.0	230.6	658.8	0.38
10-11 Sept	193.0	201.6	164.5	559.1	0.31
23-24	242.2	213.8	406.4	862.4	0.34
13-14 Oct	222.2	173.4	204.9	600.5	0.33
28-29	208.4	169.7	81.1	459.2	0.25
4-5 Nov	121.2	181.0	174.5	476.7	0.31
17-18	224.0	233.0	224.2	681.2	0.37
2-3 Dec	95.2	95.2	95.2	285.6	0.31
15-16	271.3	271.3	271.3	813.9	0.30
1976					
14-15 Jan	140.4	140.4	140.4	421.2	0.46
26-27	292.8	292.8	292.8	878.4	0.48
9-10 Feb	306.0	306.0	306.0	918.0	0.50
24-25	240.2	240.2	240.2	720.6	0.40
10-11 Mar	247.9	247.9	247.9	743.7	0.41
29-30	285.3	257.3	285.5	828.1	0.30

State of Wisconsin \ DEPARTMENT OF NATURAL RESOURCES

Anthony S. Earl
Secretary

BOX 7921
MADISON, WISCONSIN 53707

August 24, 1977

IN REPLY REFER TO: 3200

Mr. E. W. James, Senior Vice President
Wisconsin Public Service Corporation
Box 1200
Green Bay, Wisconsin 54305

Dear Mr. James:

Based upon our review of your Cooling Water Intake Structure Final Report for the Kewaunee Nuclear Power Plant, we have determined the location and operation of this intake structure to have minimal environmental impact. Therefore, it is the Department's determination that no modifications of your cooling water intake structure or operations be required for compliance with Section 147.02(6), Wisconsin Statutes.

The Department has based their conclusion upon the following factors:

1. Although Alewife entrainment was high, they are extremely abundant in Lake Michigan and are considered a nuisance species:

2. Trout impingement equaled only 10.8% of the total number harvested at the power plant by sport fisherman. Alewife and smelt together comprised 92.1% of the total species impinged. Their environmental and economic value makes the loss of the total number entrapped insignificant.

If you have comments or questions about this determination, please feel free to contact Mr. Lee Liebenstein of the Water Quality Evaluation Section at (608) 266-8117.

Sincerely,
Division of Environmental Standards

Thomas A. Kroehn

Thomas A. Kroehn
Administrator

cc: Lee Liebenstein - WQE
Robert Chiesa - IWW
James Addis - Fish Management
James Huntoon - EI
U.S. - EPA - Region V
Lake Michigan District
Permit File

Enclosure C

Pamela F. Faggert
Vice President and Chief Environmental Officer

Dominion Resources Services, Inc.
5000 Dominion Boulevard, Glen Allen, Virginia 23060
Phone: 804-273-3467

Dominion®

Certified Mail
Return Receipt Requested

January 4, 2008

Mr. Dave Hantz
Wisconsin Department of Natural Resources
101 S. Webster Street
Madison, Wisconsin 53707-7921

Re: Information Requirements Related to Cooling Water Intake Structures
WPDES Permit WI-000-071571

Dear Mr. Hantz:

The enclosed document provides the information requested in your December 3, 2007 letter to Dominion regarding the above subject matter. Your letter noted that EPA has suspended the Phase II regulation for cooling water intake structures at existing facilities, which includes submittal of a Comprehensive Demonstration Study. We understand that the information now requested is consistent with a guidance memorandum dated August 14, 2007 (revised November 7, 2007) providing template language to all permit drafters in the state. The information is provided in consecutive order following each respective topical section listed in your letter.

Please contact Oula Shehab-Dandan in my department at (804) 273-2697 or Ted Maloney at Kewaunee (920) 388-8863 if you have any questions.

Sincerely,

Pamela F. Faggert

Pamela F. Faggert

Attachments:
Attachment A. Wisconsin DNR December 3, 2007 letter
Attachment B. Wisconsin DNR Guidance Memorandum August 14, 2007 (revised November 7, 2007)
Attachment C. Cooling Water Intake Structure Information Submittal

ATTACHMENT A

State of Wisconsin \ DEPARTMENT OF NATURAL RESOURCES

WISCONSIN DEPT. OF NATURAL RESOURCES

Jim Doyle, Governor
Matthew J. Frank, Secretary

101 South Webster Street
P.O. Box 7921
Madison, WI 53707-7921
Telephone (608) 266-2621
FAX (608) 267-3579
TTY Access via relay - 711

December 3, 2007

Ms. Pamela Faggert
Dominion Resources Services, Inc.
5000 Dominion Blvd.
Glenn Allen, VA 23060

SUBJECT: Requirements for Cooling Water Intake Structures
WPDES Permit WI-0001571-07

Dear Pamela:

As requested, this letter will address Dominion's questions on the 316(b) requirements in WPDES permit No. WI-0001571-07 for the offshore cooling water intake structure in Lake Michigan for the Kewaunee Power Generating Station. These requirements include conditions 1.2 and 1.3 (copied in *italics* below from permit page 1 and further referenced in the accompanying compliance schedule 5.1 on permit page 13).

1.2 The permittee shall submit by January 7, 2008 for Department review information describing the cooling water intake structure, cooling water system operations and source water physical data described in U.S. EPA regulations at 40 CFR 122.21(r)(2, (r)(3), and (r)(5).

1.3 The permittee shall submit by January 7, 2008 for Department review and approval all applicable portions of the comprehensive demonstration study required by the provisions in 40 CFR 125.95(b) for selecting and implementing the compliance alternatives in 40 CFR 125.94 to meet best technology available (BTA) for minimizing adverse environmental impacts associated with the use of the cooling water intake structures.

The Department has identified information needed to address 316(b) requirements in current WPDES permits (see attached guidance dated August 14, 2007, revised November 7, 2007), since on July 9, 2007, the U.S. Environmental Protection Agency suspended the "Phase II" regulations directly referenced in WPDES permits which applied to existing power generating facilities (72 Fed. Reg. No. 130, pp. 37107-37109, July 9, 2007). Suspended regulations included requirements for submittal of a comprehensive demonstration study.

Based on best professional judgment, information in items 1) to 4) below must be submitted by January 7, 2008 to address WPDES permit WI-0001571-07 conditions referenced above.

1) ***Source water physical data.*** These include:
   a) A narrative description and scaled drawings showing the physical configuration of all source water bodies used by the facility, including areal dimensions, depths, salinity and temperature regimes, and other documentation that supports a determination of the water body type where each cooling water intake structure is located;

b) Identification and characterization of the source waterbody's hydrological and geomorphological features, as well as the methods used to conduct any physical studies to determine the intake's area of influence within the waterbody and the results of such studies;
c) Locational maps showing all intake structures and effluent outfalls for the facility.

2) *Cooling water intake structure and cooling system data.* These include:
a) A narrative description of the configuration of each of the cooling water intake structures, where each is located in the water body and in the water column;
b) Latitude and longitude in degrees, minutes, and seconds for each of the cooling water intake structures;
c) A narrative description of the operation of each of the cooling water intake structures and cooling system, including design intake flows, daily hours of operation, any structural or operational controls currently used at the facility to reduce impingement mortality and/or entrainment, number of days of the year in operation and seasonal changes in operation of the system, if applicable;
d) A flow distribution and water balance diagram that includes all sources of water to the facility, recirculating flows, and discharges; and
e) Engineering drawings of the cooling water intake structure and the cooling system.

3) *Source water biological characterization data.*
This information is required to characterize the biological community in the vicinity of the cooling water intake structure and to characterize the operation of the cooling water intake structures. This supporting information must include data that is representative of current conditions. The information submitted must include:
a) *Impingement Mortality and/or Entrainment Characterization Study.* If the cooling water intake structure has a through-screen velocity that exceeds 0.5 fps, an Impingement Mortality Characterization Study must be submitted. If the facility has a capacity utilization rate of 15% or more, and is located on a Great Lake or a river and uses more than 5% of the mean annual flow, an entrainment characterization study must be submitted. The purpose of these studies is to provide information to support a determination of current estimated impingement mortality and entrainment. The Impingement Mortality and/or Entrainment Characterization Study must include the following:
i) Taxonomic identifications of all life stages of fish, shellfish, and any species protected under Federal, State, or Tribal Law (including threatened or endangered species) that are in the vicinity of the cooling water intake structure(s) and are susceptible to impingement and entrainment;
ii) A characterization of all life stages of fish, shellfish, and any species protected under Federal, State, or Tribal Law (including threatened or endangered species) identified pursuant to paragraph (3)(a)(i), including a description of the abundance and temporal and spatial characteristics in the vicinity of the cooling water intake structure(s), based on sufficient data to characterize annual, seasonal, and diel variations in impingement mortality and entrainment (*e.g.* , related to climate and weather differences, spawning, feeding and water column migration). These may include historical data that are representative of the current operation of the facility and of biological conditions at the site;
iii) Documentation or estimation of the current impingement mortality and entrainment of all life stages of fish, shellfish, and any species protected under Federal, State, or Tribal Law (including threatened or endangered species) identified pursuant to paragraph (3)(a)(i) and an estimate of impingement mortality and entrainment of all such species and their life stages based upon representative impingement mortality and entrainment data. The documentation should include all data that are representative of the current operation of your facility and of biological conditions at the site. Impingement mortality and entrainment samples to support biological characterizations must be collected during periods of representative operational flows for the cooling water intake structure and the flows associated with the samples must be documented;

b) Documentation of any public participation or consultation with Federal or State agencies undertaken in planning for the collection, collection or analysis and presentation of the information required under this section; and

c) When the submitted information includes data collected using field studies conducted within the last 5 years, supporting documentation for such studies must include a description of all methods and quality assurance procedures for sampling, and data analysis including a description of the study area; taxonomic identification of sampled and evaluated biological assemblages (including all life stages of fish and shellfish); and sampling and data analysis methods. The sampling and/or data analysis methods you use must be appropriate for a quantitative survey and based on consideration of methods used in other biological studies performed within the same source water body. The study area should include, at a minimum, the area of influence of the cooling water intake structure.

4) *Assessment of the Cooling Water System*

a) A discussion of additional structural or operational actions that would further reduce environmental impacts caused by the cooling water intake.

b) A discussion or description of structural or operational actions that are planned to be implemented within the next 5 years to reduce adverse environmental impacts caused by the cooling water intake.

When the Department reviews information submitted, we will contact you if we have questions or if we desire to request clarifying information and provide reasonable time for Dominion's response.

Please contact me at 608-266-1198 if you have any questions.

Sincerely,

David Hantz, P.E.
Wastewater Engineer
Bureau of Watershed Management

cc: Permit File – Region and Central Office
Gary Kincaid
Ted Maloney and Oula K. Shehab-Dandan - Dominion

ATTACHMENT B

CORRESPONDENCE/MEMORANDUM

State of Wisconsin

DATE: August 14, 2007 (revised November 7, 2007) FILE REF:

TO: Permit Drafters Responsible for "Phase II" Power Facilities

FROM: Kari Fleming – WT/2

SUBJECT: Template Language for Permits, Letters, and Other Correspondence

On July 9, 2007, the U.S. Environmental Protection Agency (USEPA) suspended the "Phase II" regulations which applied to existing power generating facilities (72 Fed. Reg. No. 130, pp. 37107-37109, July 9, 2007), which have been remanded back to EPA for revision by the Second District Court of Appeals. In suspending the rules, U.S. EPA stated that *"...EPA by this action is not suspending 40 CFR 125.90(b). This retains the requirement that permitting authorities develop BPJ controls for existing facility cooling water intake structures that reflect the best technology available for minimizing adverse environmental impact. This provision directs permitting authorities to establish section 316(b) requirements on a BPJ basis for existing facilities not subject to categorical section 316(b) regulations."* The following provides some guidance regarding what information Department staff will need to make BPJ decisions.

The following is to be used to draft language for permits, letters, or other communication to "Phase II" existing facilities, explaining the information that is needed to address 316(b) requirements. Each of these facilities was given a chance to provide comment, and the comments that were received have been incorporated into this document. This language should be modified by the permit drafter, when necessary, to fit site-specific situations.

1) ***Source water physical data.*** These include:
   a) A narrative description and scaled drawings showing the physical configuration of all source water bodies used by the facility, including areal dimensions, depths, salinity and temperature regimes, and other documentation that supports a determination of the water body type where each cooling water intake structure is located;
   b) Identification and characterization of the source waterbody's hydrological and geomorphological features, as well as the methods used to conduct any physical studies to determine the intake's area of influence within the waterbody and the results of such studies;
   c) Locational maps showing all intake structures and effluent outfalls for the facility.

2) ***Cooling water intake structure and cooling system data.*** These include:
   a) A narrative description of the configuration of each of the cooling water intake structures, where each is located in the water body and in the water column;
   b) Latitude and longitude in degrees, minutes, and seconds for each of the cooling water intake structures;
   c) A narrative description of the operation of each of the cooling water intake structures and cooling system, including design intake flows, daily hours of operation, any structural or operational controls currently used at the facility to reduce impingement mortality and/or entrainment, number of days of the year in operation and seasonal changes in operation of the system, if applicable;
   d) A flow distribution and water balance diagram that includes all sources of water to the facility, recirculating flows, and discharges; and
   e) Engineering drawings of the cooling water intake structure and the cooling system.

3) ***Source water biological characterization data.***
   This information is required to characterize the biological community in the vicinity of the cooling water intake structure and to characterize the operation of the cooling water intake structures. This

supporting information must include data that is representative of current conditions. The information submitted must include:

a) *Impingement Mortality and/or Entrainment Characterization Study.* If the cooling water intake structure has a through-screen velocity that exceeds 0.5 fps, an Impingement Mortality Characterization Study must be submitted. If the facility has a capacity utilization rate of 15% or more, and is located on a Great Lake or a river and uses more than 5% of the mean annual flow, an entrainment characterization study must be submitted. The purpose of these studies is to provide information to support a determination of current estimated impingement mortality and entrainment. The Impingement Mortality and/or Entrainment Characterization Study must include the following:
   i) Taxonomic identifications of all life stages of fish, shellfish, and any species protected under Federal, State, or Tribal Law (including threatened or endangered species) that are in the vicinity of the cooling water intake structure(s) and are susceptible to impingement and entrainment;
   ii) A characterization of all life stages of fish, shellfish, and any species protected under Federal, State, or Tribal Law (including threatened or endangered species) identified pursuant to paragraph (3)(a)(i), including a description of the abundance and temporal and spatial characteristics in the vicinity of the cooling water intake structure(s), based on sufficient data to characterize annual, seasonal, and diel variations in impingement mortality and entrainment (*e.g.*, related to climate and weather differences, spawning, feeding and water column migration). These may include historical data that are representative of the current operation of the facility and of biological conditions at the site;
   iii) Documentation or estimation of the current impingement mortality and entrainment of all life stages of fish, shellfish, and any species protected under Federal, State, or Tribal Law (including threatened or endangered species) identified pursuant to paragraph (3)(a)(i) and an estimate of impingement mortality and entrainment of all such species and their life stages based upon representative impingement mortality and entrainment data. The documentation should include all data that are representative of the current operation of your facility and of biological conditions at the site. Impingement mortality and entrainment samples to support biological characterizations must be collected during periods of representative operational flows for the cooling water intake structure and the flows associated with the samples must be documented;

b) Documentation of any public participation or consultation with Federal or State agencies undertaken in planning for the collection, collection or analysis and presentation of the information required under this section; and

c) When the submitted information includes data collected using field studies conducted within the last 5 years, supporting documentation for such studies must include a description of all methods and quality assurance procedures for sampling, and data analysis including a description of the study area; taxonomic identification of sampled and evaluated biological assemblages (including all life stages of fish and shellfish); and sampling and data analysis methods. The sampling and/or data analysis methods you use must be appropriate for a quantitative survey and based on consideration of methods used in other biological studies performed within the same source water body. The study area should include, at a minimum, the area of influence of the cooling water intake structure.

4) ***Assessment of the Cooling Water System***
   a) A discussion of additional structural or operational actions that would further reduce environmental impacts caused by the cooling water intake.
   b) A discussion or description of structural or operational actions that are planned to be implemented within the next 5 years to reduce adverse environmental impacts caused by the cooling water intake.

Cc: Duane Schuettpelz – WT/2
Chuck Hammer – LS/5

ATTACHMENT C

Dominion

Dominion Resources, Inc.

Kewaunee Power Station

WPDES WI-0001571-07
Cooling Water Intake Structure
Information Submittal

Submitted to

Wisconsin Department of Natural Resources
101 S. Webster Street
Madison, Wisconsin 53707-7921

January 4, 2008

TABLE OF CONTENTS

SECTION 1

Source Water Physical Data

Section 1(a)
A narrative description and scaled drawings showing the physical configuration of all source water bodies used by the facility, including areal dimensions, depths, salinity and temperature regimes, and other documentation that supports a determination of the water body type where each cooling water intake structure is located.

The Kewaunee Power Station uses Lake Michigan as its source of cooling water. At its maximum, Lake Michigan is 118 miles wide and 307 miles long. It has an average depth of 279 feet, maximum depth of 925 feet, and a total volume of 1,180 cubic miles. It is considered a low salinity water body with a total chlorides level about 12 mg/L, which calculates into a salinity of less than 0.1 PPT. The temperature regime can be found in the detailed response to section 1(b). See Attachment 1 for the drawings showing the physical configurations of Lake Michigan.

Section 1(b)
Identification and characterization of the source waterbody's hydrological and geomorphological features, as well as the methods used to conduct any physical studies to determine the intake's area of influence within the waterbody and the results of such studies.

The hydrological characterization of Lake Michigan is greatly determined by the temperature stratification and circulation patterns of lake water. At the beginning of March, a warming trend starts in the lake water and at the end of May all of the water in the lake has reached approximately 40°F, which is the temperature of maximum water density. Until the temperature reaches this point, the surface water is colder than the deeper water in the lake. The colder surface water, which remains at approximately 34°F, is lighter than the 40°F deeper water. This layer of colder water circulates on the surface of the warmer deep water, reaching depths of 25 to 30 feet from the surface.

When all the water in the lake reaches approximately 40°F, the thermocline layer disappears and thorough mixing of the water in the lake takes place. However, when the ambient air temperature warms up the surface water, a thermocline layer is formed again at depths of 30 to 50 feet from the surface. This occurs from May to July and at this time parts of the water in the lake reach 65°F to 70°F. Consequently, the warmer and lighter surface water circulates above the denser and relatively stagnant 40°F water at the bottom of the lake. This condition continues until a cooling trend starts in September, reaching a peak about the last part of January, at which time the water in the lake again reaches an overall temperature of 40°F. At this time, mixing of the waters in the lake takes place until a colder and lighter layer of surface water starts to build up.

The circulating water intake is a submerged crib-type intake located in approximately 15 feet of water. A thermocline does not exist in the vicinity of the intake since it is located at depths greater than the intake structure. Summertime water temperatures are generally above the thermocline. Historical data for lake water temperatures applied to the Kewaunee site were taken from the city of Green Bay's Rostok intake located near Kewaunee, at approximately 50-foot water depth. The water temperatures at the Rostok intake are generally above the thermocline.

The geomorphological characterization of Lake Michigan near the Kewaunee Power Station has been documented by the National Oceanic & Atmospheric Administrations National Geophysical Data Center. As noted on the drawing in Attachment 2, the local lake bottom is dominated by the Two Rivers Ridge and the Door-Leelanau Ridge which is an arcuate ridge so named because it is partly underlain by glacial till of the same name. The Two Rivers Ridge is presumed to be site of an end moraine marking the outer limits of the last readvance of glacier ice (Two Rivers) extending this far south in the lake. Till deposits associated with the Two Rivers readvance underlie the ridge and also crop out on the Wisconsin shore in the vicinity of the town of Two Rivers, Wisconsin. A foundation of bedrock apparently underlies this ridge, probably composed of resistant middle Devonian carbonates, which have been stripped away by glacial erosion from the deeper basin to the north. The bedrock core of this ridge with its north-facing relief probably stalled the readvance of the Two Rivers ice lobe and ultimately determined the position of the end moraine. Farther north a smaller ridge extends across the deepest basin of the lake between Door County, Wisconsin and Leelanau County, Michigan. This ridge is also arcuate, convex to the south, favoring the suggestion that it, too, marks the position of an end moraine associated with a minor, even younger, re-advance of the retreating Lake Michigan ice lobe.

No physical studies have been made to determine the area of influence for the Kewaunee Power Station.

Section 1(c)
Locational maps showing all intake structures and effluent outfalls for the facility.

Maps and plans showing the location of the Kewaunee Power Station, the site layout, the location of the water intake structure, and location of the wastewater outfalls can be found in Attachment 3.

SECTION 2

Cooling Water Intake Structure and Cooling System Data

Section 2(a-c)

a) ***A narrative description of the configuration of each of the cooling water intake structures, where each is located in the water body and in the water column.***

b) ***Latitude and longitude in degrees, minutes, and seconds for each of the cooling water intake structures.***

c) ***A narrative description of the operation of each of the cooling water intake structures and cooling system, including design intake flows, daily hours of operation, any structural or operational controls currently used at the facility to reduce impingement mortality and/or entrainment, number of days of the year in operation and seasonal changes in operation of the system, if applicable.***

The Kewaunee Power Station's circulating water intake system is designed to provide a reliable supply of Lake Michigan water, regardless of weather or lake conditions, to the suction of two circulating water pumps, four service water pumps and two fire pumps. The intake system and screenhouse are shown in Attachment 4. The intake structure geographical location is N44'-20.653 and W87'-31.698 (Lat. 44° 20' 39", Long. 87° 31' 42"). The intake structure is located approximately 1600 feet from the shore in a water depth of 15 feet. The intake consists of a submerged cluster of three vertical 22-foot diameter inlets with trash grilles of 2 feet by 2 feet. The trash grilles are provided with recirculated water to remove any ice formations. During winter operation the inlet crib and auxiliary inlets are below the ice blanket and are at least 450 feet outboard of maximum windrow ice development.

The spacing of the three inlet cones and the auxiliary inlets is such that the largest lake barge could not directly cover all water inlets. Any four of the inlets could be blocked and still leave an inlet capacity of greater than the 24,000 gpm required cooling water. The inlets are reduced to 6-foot diameter steel pipes which join at a trifurcation into one 10-foot diameter steel pipe which is buried a minimum of 3 feet below lake floor and coated inside and out with asphaltum. The velocity at the surface of the intakes at the full plant load is <1 fps.

The plant intake is equipped with two auxiliary water intake tees 50 and 100 feet shoreward of the intake crib. Each tee has a 30-inch opening rising vertically to 1 foot above the lake bottom. Special screened cover plates are suspended 12 inches above the intake openings to exclude entrainment of debris. Each auxiliary water intake can supply water in excess of 24,000 gpm.

The 10-foot diameter steel intake pipe carries the water to a 56.5-foot by 25-foot forebay with an overflow weir whose crest is at Elevation 582.5 feet. The weir has a bottom length of 38.5 feet and side slopes of 45 degrees. From the forebay, water passes through four 10-foot wide by 36-foot long traveling screens with a mesh size of 3/8 inch. Two of the screens can be powered from diesel generators. One is supplied from each of the emergency power buses. The screens are provided with automatic water back washing. The water is then pumped by two vertical dry-pit circulating water pumps; each designed to supply 210,000 gpm at a total differential head of 27.5 feet.

Normal operation is with two circulating water pumps and three or four service water pumps operating. As the temperature of the lake cools, the plant will operate with only one circulating water pump. The intake velocity, as stated before, is less than one foot per second with both circulating water pumps operating. Water velocity through the traveling water screens at design flow is less than 2.4 feet per second at low water depth. The plant normally operates 24 hours per day 7 days per week and only shuts down every 18 months for about a month to refuel or infrequently as needed for maintenance purposes.

Circulating water is returned to the lake from the discharge tunnel by a 10-foot diameter concrete pipe to a discharge structure with sheet piling walls and a concrete floor slab. Recirculating water for de-icing the inlet grilles is taken from the 10-foot diameter discharge line by a recirculating water pump. Traveling screens backwash water and debris are returned to this line. A 30-inch recirculating water line is provided to recirculate water directly to the traveling screen inlet to prevent ice formation.

The circulating water discharge facility is an onshore structure discharging at the shoreline and designed for minimum impact on the lake environment. The discharge at the shore edge is from a 40-foot wide channel, 5 feet deep (at normal lake level). Design outlet velocities range from a minimum 2.5-fps to 4.7-fps. The discharge structure provides the termination for the circulating water discharge pipe, a transition from the 120-inch pipe to the open discharge bay, and the outlet to the lake. The discharge bay receives the discharge circulating water from the submerged pipe transition outlet. At the upstream end, the floor of the discharge bay rises as the sides widen. The downstream portion of the discharge bay is a rectangular channel, 40 feet wide. The discharge bay is normally 5 feet deep but may range from a minimum of 3.4 feet at lowest lake level to 9.9 feet at highest lake level. The discharge flows into the shallow beach area, and generally tends to stratify at the surface.

The cooling water intake system design was reviewed for its environmental effects by the 1976 version of the 316(b) study titled "316(b) Demonstration Environmental Effects of Existing Cooling Water Intake Structures". The study concluded that the cooling water intake system "had no major environmental impact on the fish community of Lake Michigan near the Kewaunee Power Station.

Section 2(d)
A flow distribution and water balance diagram that includes all sources of water to the facility, recirculating flows, and discharges.

See Attachment 5 for the diagram titled "Kewaunee Power Station Water Flow Diagram". This diagram is the current water flow document submitted to the WDNR as part of an updated WPDES Application.

Section 2(e)
Engineering drawings of the cooling water intake structure and the cooling system.

The engineering drawings that describe the intake structure and the Circulating Water System can be found in Attachment 4

SECTION 3

Source Water Baseline Biological Characterization Data

Dominion has arranged for EA Engineering, Science, and Technology, Inc. to prepare an "Impingement Mortality and Entrainment Characterization Report" (EA Report) for the Kewaunee Power Station. The study was conducted between February 2006 and January 2007 in accordance with the Proposal for Information Collection approved by the Wisconsin Department of Natural Resources. The attached report (Attachment 7) is used here to document the responses to the requested information found in Section 3 for the August 14, 2007 (revised November 7, 2007) WDNR Guidance Memorandum. Section 3 of the memo is titled "Source Water Baseline Biological Characterization Data" which is further broken into sections a(i), a(ii), a(iii), b, and c.

This information is required to characterize the biological community in the vicinity of the cooling water intake structure and to characterize the operation of the cooling water intake structures. This supporting information must include data that is representative of current conditions. The information submitted must include:

Section 3(a) Impingement Mortality and/or Entrainment Characterization Study. If the cooling water intake structure has a through-screen velocity that exceeds 0.5 fps, an Impingement Mortality Characterization Study must be submitted. If the facility has a capacity utilization rate of 15% or more, and is located on a Great Lake or a river and uses more than 5% of the mean annual flow, an entrainment characterization study must be submitted. The purpose of these studies is to provide information to support a determination of current estimated impingement mortality and entrainment. The Impingement Mortality and/or Entrainment Characterization Study must include the following:

> ***Section 3(a)(i)***
> ***Taxonomic identifications of all life stages of fish, shellfish, and any species protected under Federal, State, or Tribal Law (including threatened or endangered species) that are in the vicinity of the cooling water intake structure(s) and are susceptible to impingement and entrainment.***
>
> The EA Report uses common names for the fish and shellfish in question. Table 1 cross-references the fish and shellfish taxonomic name to the common name. The specific species that are susceptible to impingement can be found in Section 3.2.7 and those susceptible to entrainment can be found in Section 4.2.6 of the EA Report.
>
> No Federal or State, threatened or endangered species listed on the Wisconsin Department of Natural Resources website were observed at the Kewaunee Power Station.

Section 3(a)(ii)
A characterization of all life stages of fish, shellfish, and any species protected under Federal, State, or Tribal Law (including threatened or endangered species) identified pursuant to paragraph (3)(a)(i), including a description of the abundance and temporal and spatial characteristics in the vicinity of the cooling water intake structure(s), based on sufficient data to characterize annual, seasonal, and diel variations in impingement mortality and entrainment (e.g. , related to climate and weather differences, spawning, feeding and water column migration). These may include historical data that are representative of the current operation of the facility and of biological conditions at the site.

The Proposal for Information Collection was designed to determine the current ambient baseline biota for Lake Michigan near the Kewaunee Power Station in addition to the impingement mortality and entrainment.

The data compiled in Tables 8 through 18 in the EA Report represents the ambient temporal and spatial characteristics, and the annual, seasonal and diel variations in abundance of all life stages of fish and shellfish in the vicinity of the cooling water structure.

Section 3(a)(iii)
Documentation or estimation of the current impingement mortality and entrainment of all life stages of fish, shellfish, and any species protected under Federal, State, or Tribal Law (including threatened or endangered species) identified pursuant to paragraph (3)(a)(i) and an estimate of impingement mortality and entrainment of all such species and their life stages based upon representative impingement mortality and entrainment data. The documentation should include all data that are representative of the current operation of your facility and of biological conditions at the site. Impingement mortality and entrainment samples to support biological characterizations must be collected during periods of representative operational flows for the cooling water intake structure and the flows associated with the samples must be documented.

The data compiled in Tables 3 through 7 in the EA Report documents the current fish and shellfish impingement mortality. The ambient and impingement mortality data was compared in Table 19. Comparison of historical and recent impingement data can be found in Table 20. A summary of impingement mortality study can be found in Section 3.2.7.

The data compiled in Tables 22 through 29 in the EA Report documents the current fish and shellfish entrainment. The ambient and the entrainment data was compared in Table 32. Comparison of historical and recent entrainment data can be found in Table 33. A summary of entrainment study can be found in Section 4.2.6.

Section 3(b)
Documentation of any public participation or consultation with Federal or State agencies undertaken in planning for the collection, collection or analysis and presentation of the information required under this section.

The public did not participate in the process of planning for this Proposal of Information Collection (PIC). The Wisconsin Department of Natural Resources did review and comment upon the specifics of the Kewaunee Power Station PIC. The comments were incorporated in the PIC.

Section 3(c)
When the submitted information includes data collected using field studies conducted within the last 5 years, supporting documentation for such studies must include a description of all methods and quality assurance procedures for sampling, and data analysis including a description of the study area; taxonomic identification of sampled and evaluated biological assemblages (including all life stages of fish and shellfish); and sampling and data analysis methods. The sampling and/or data analysis methods you use must be appropriate for a quantitative survey and based on consideration of methods used in other biological studies performed within the same source water body. The study area should include, at a minimum, the area of influence of the cooling water intake structure.

The Quality Assurance Plan for the Impingement Mortality and Entrainment study was submitted as part of the Information Collection Package to the WDNR on October 25, 2005. The WDNR reviewed and approved the proposal. A copy of the Quality Assurance Plan is included in Attachment 8.

SECTION 4

Assessment of the Cooling Water System

Section 4(a)
A discussion of additional structural or operational actions that would further reduce environmental impacts caused by the cooling water intake.

As a condition of the original Wisconsin Pollution Discharge Elimination System (WPDES) Permit (No. WI-0001571) issued to Kewaunee Power Station (KPS), Wisconsin Public Service Corporation (WPSC) was required to perform a one-year study to evaluate the environmental impact of the KPS cooling water intake structure. Entrainment and impingement studies were conducted over the April 1, 1975 through March 31, 1976 timeframe. Results suggest that the cooling water intake had no major impacts on the fish community of Lake Michigan near KPS. The WDNR concurred with this determination and indicated that the present cooling water intake system reflects best available technology. WPDES permits issued subsequent to this (1977) determination contained no monitoring requirements and no conditions related to entrainment or impingement. The current WPDES permit, which was issued July 18, 2005 and expires June 30, 2010, reflects the State's conclusion that KPS, by operating in conformance with the permit, is in compliance with the requirements of Section 316(b) of the CWA.

The information provided in Attachment 7 of this document (Section 3) suggest that differences noted in impingement and entrainment estimates between 1975-1976 and 2006-2007 are attributed to differences in fish abundance near the KPS as a reflection of fish community changes in Lake Michigan in the years between the studies. Any environmental impacts to Lake Michigan fishes are still considered minimal with no additional structural or operational actions necessary at this time, pending new rule development as noted below.

A submittal of a Proposal for Information Collection (PIC) was a requirement in the now suspended EPA Phase II regulations for existing facilities with cooling water intake structures. This PIC proposal was submitted in October 2005, revised in February 2006, and was approved by the WDNR. In it plans were proposed for biological studies as well as compliance options that would be evaluated. These options included potential credit for the existing offshore intake location and various technologies such as coarse and fine mesh Ristroph screens, wedge wire screens, barrier nets, and strobe lights. With the suspension of the regulation as noted in the December 3, 2007 letter to Dominion, evaluation of these technologies have not been pursued pending promulgation by EPA of new regulations that are expected over the next few years that are consistent with recent and any future court decisions.

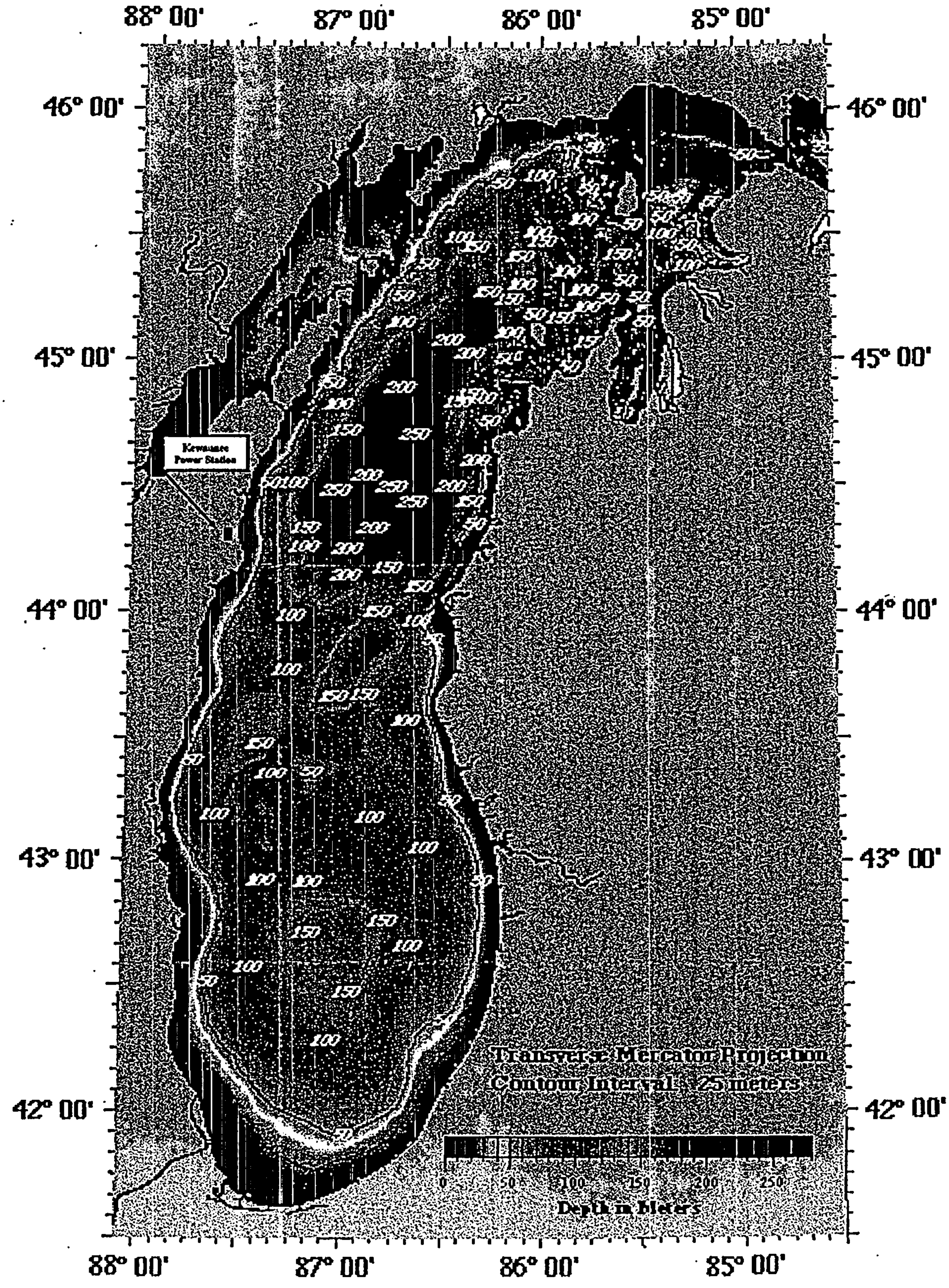
Section 4(b)
A discussion or description of structural or operational actions that are planned to be implemented within the next 5 years to reduce adverse environmental impacts caused by the cooling water intake.

No additional structural or operational actions have been evaluated as possible measures to reduce environmental impacts caused by the current cooling water intake system design.

ATTACHMENT 1

Kewaunee Power Station
Physical Configuration/Bathymetry of Lake Michigan

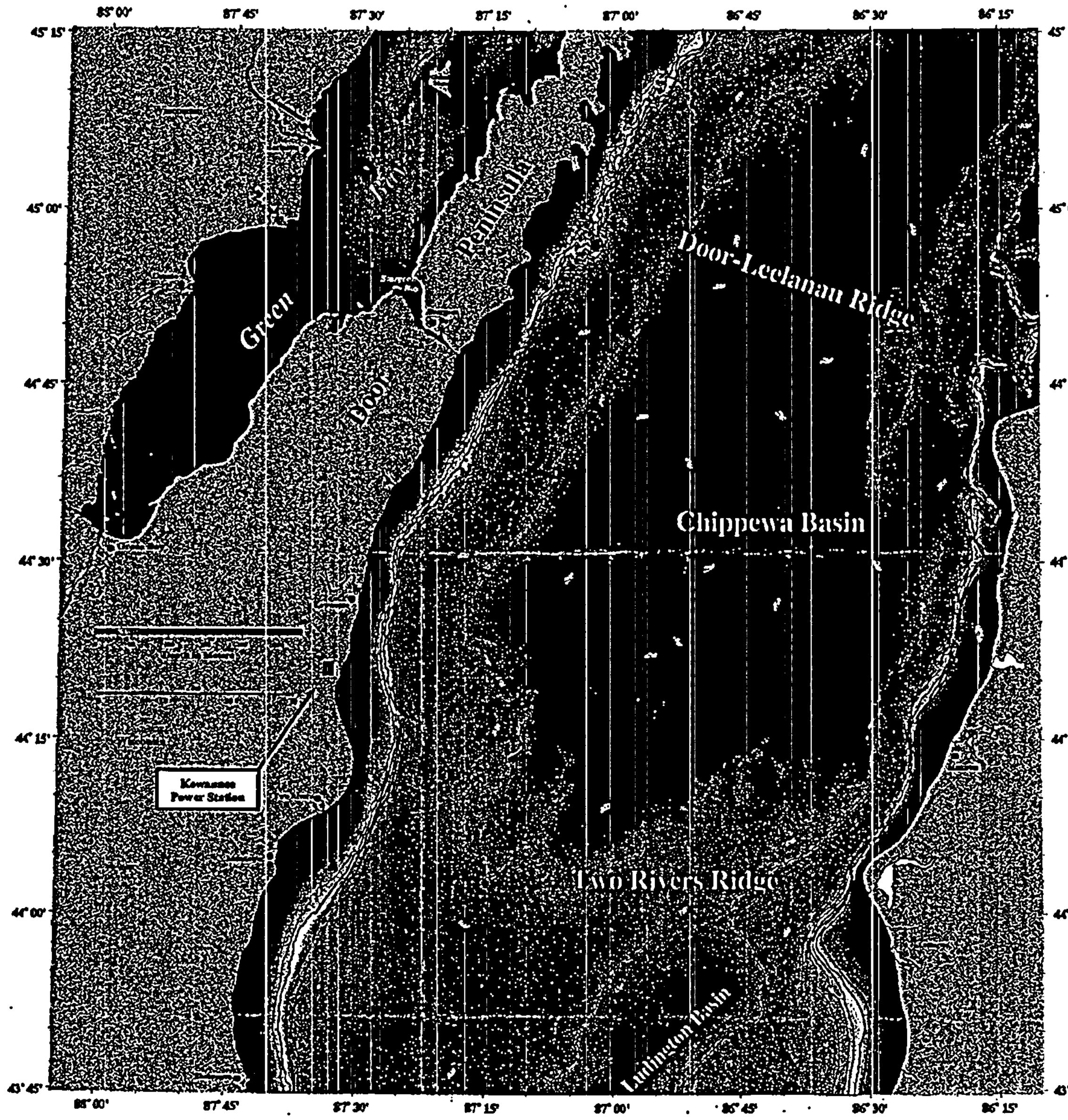
Attachment 1
Kewaunee Power Station
Great Lakes Environmental Research Laboratory
Physical Configuration/Bathymetry of Lake Michigan



ATTACHMENT 2

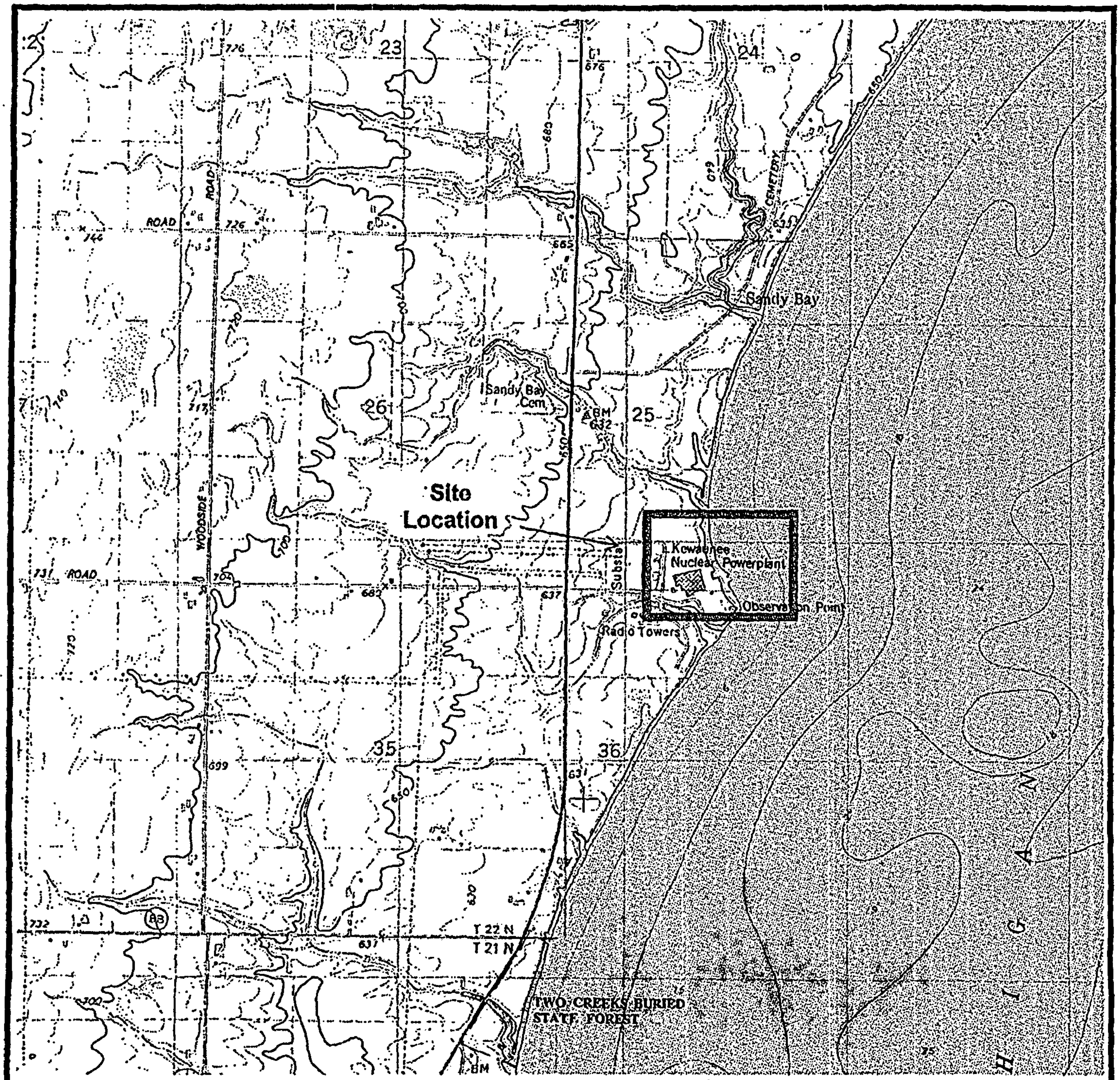
Kewaunee Power Station
Geomorphologic Characterization of Lake Michigan

Attachment 2
Kewaunee Power Station
Great Lakes Environmental Research Laboratory
Geomorphologic Characterization of Lake Michigan



ATTACHMENT 3

Kewaunee Power Station
Site Location
Site Layout
Water Intake Location
Wastewater Outfalls Locations



SOURCE:
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Two Creeks, Wisconsin
1978

GRAPHIC SCALE (approx.)

2000 0 2000 4000

1" = 2000'

CONTOUR INTERVAL = 10 FEET

APPROXIMATE QUADRANGLE LOCATION

N

PROJECT:
[redacted]

Kewaunee Power Station
Kewaunee, Wisconsin

[redacted]

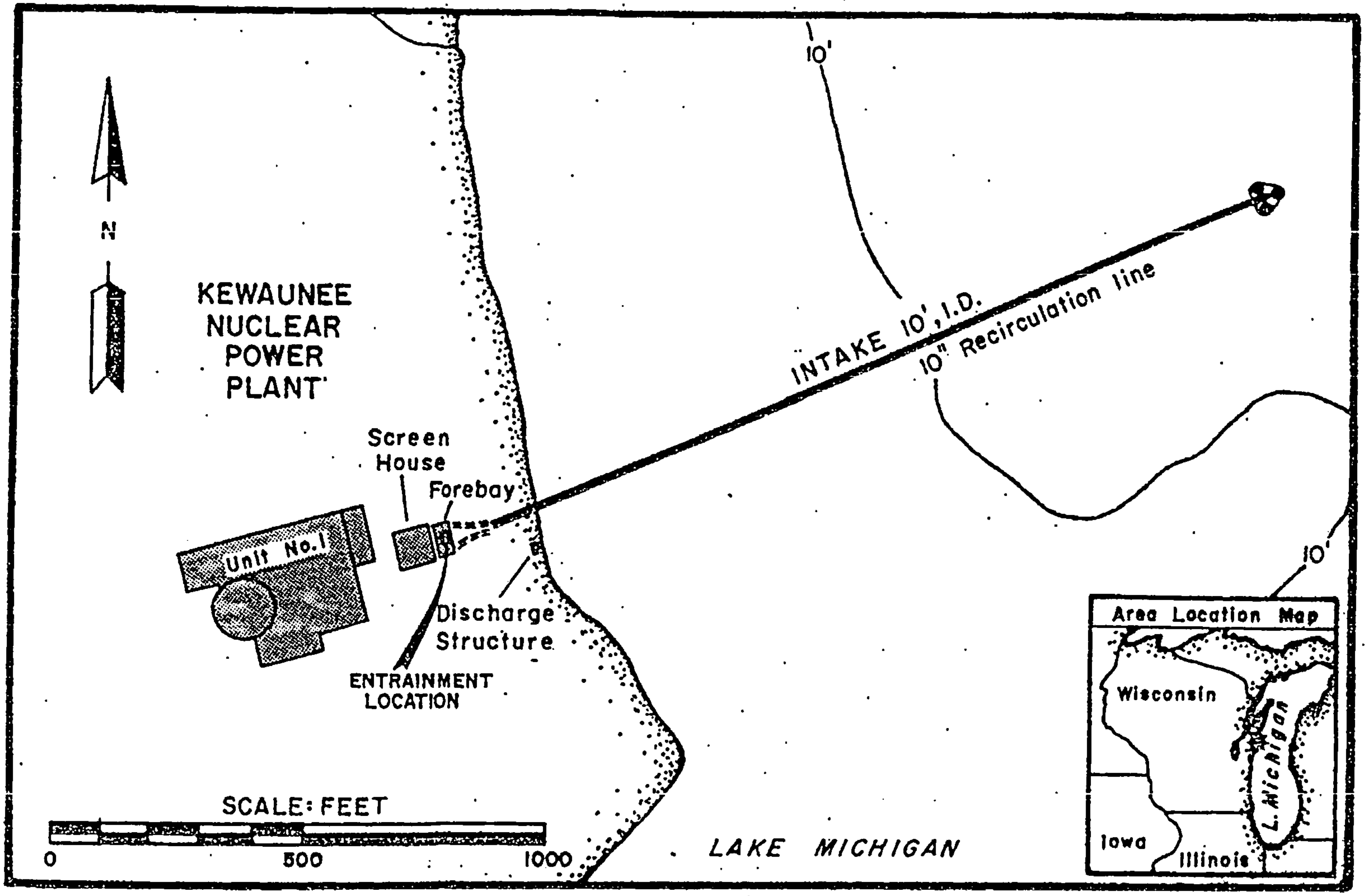
FIGURE TITLE:
Site Location Map
Kewaunee Power Station
Kewaunee, Wisconsin

[redacted]

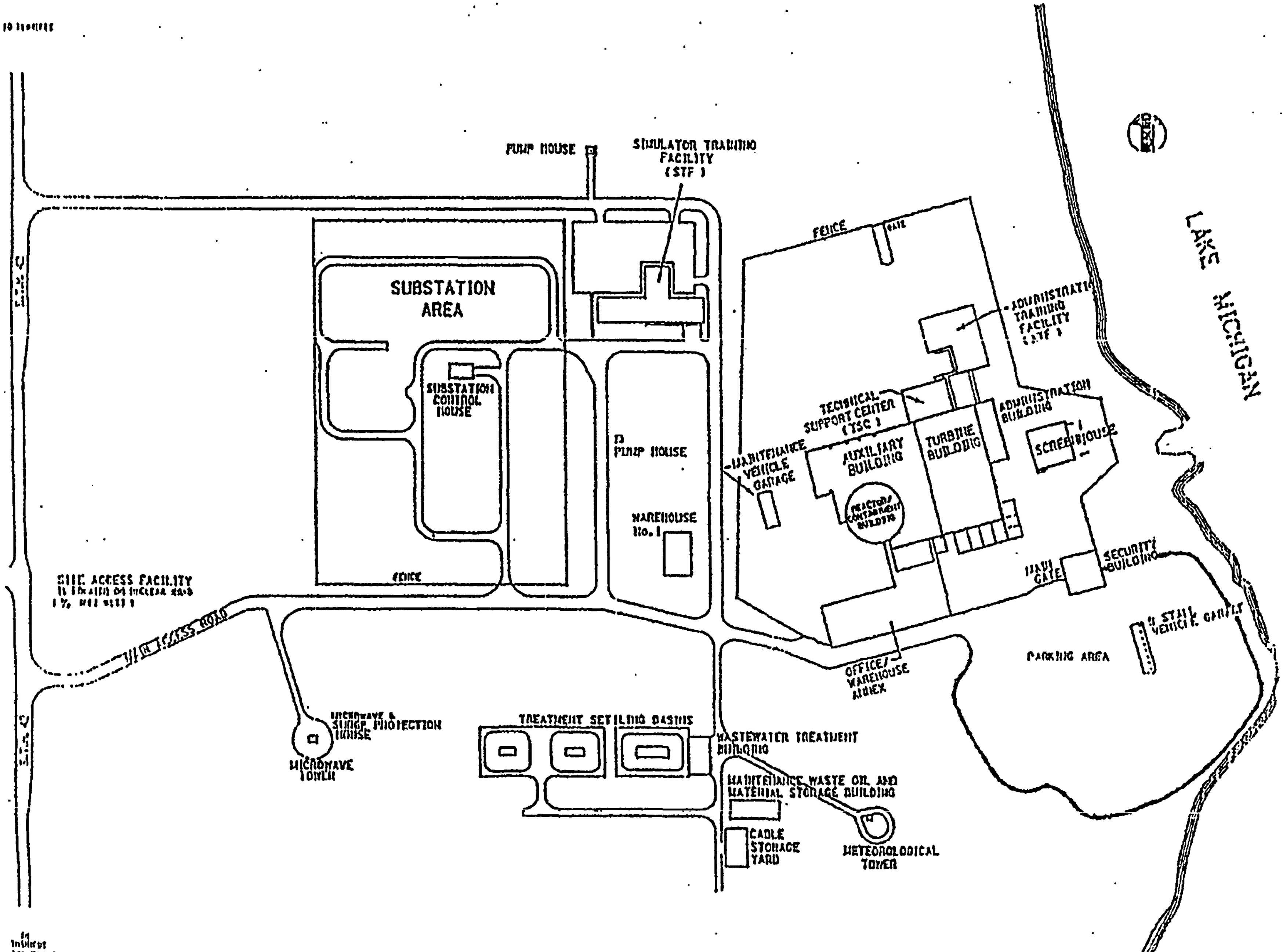
DATE: 10/12/06

SCALE: AS SHOWN

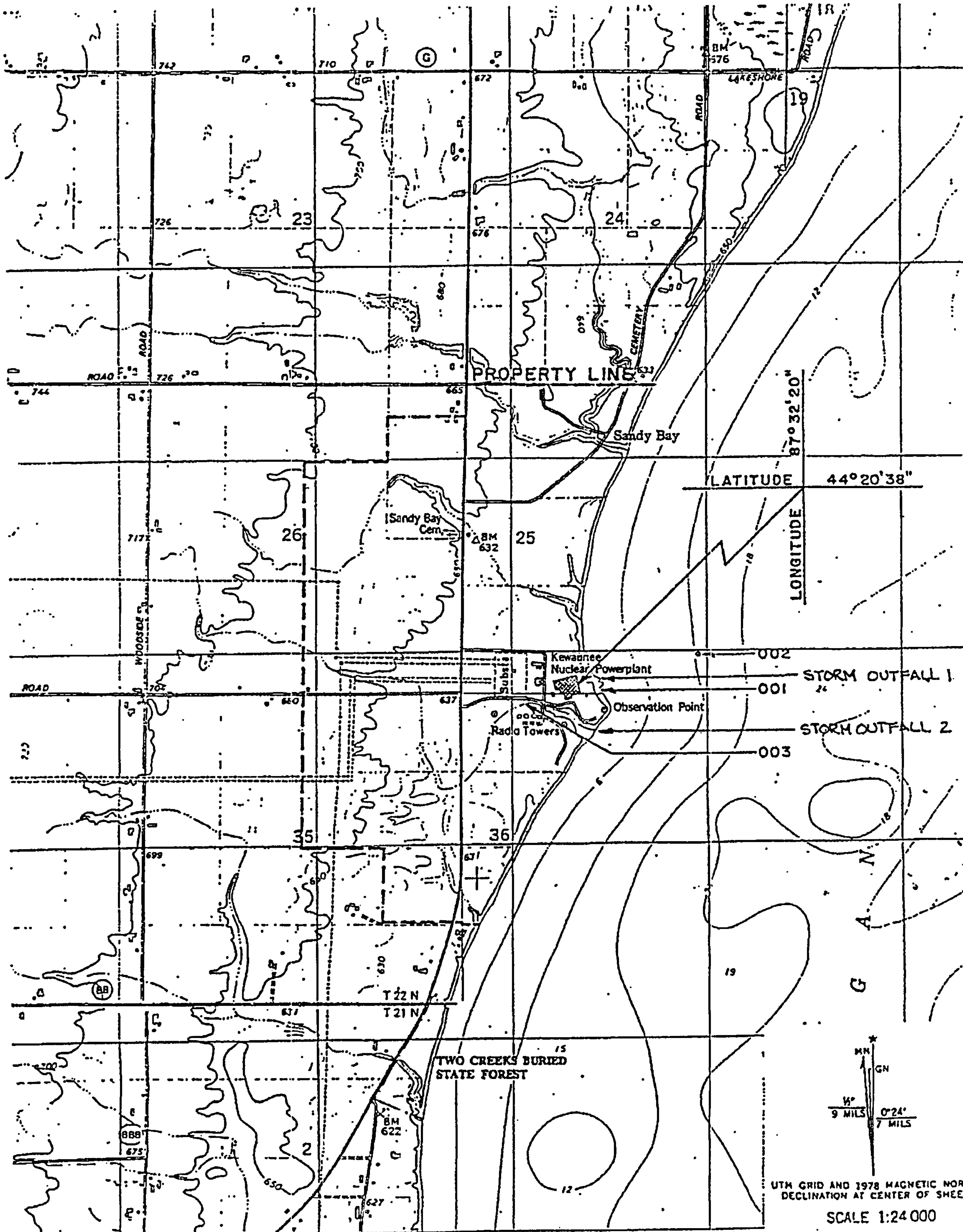
[redacted]



Schematic of Kewaunee Nuclear Power Plant showing plant location and entrainment sampling site.


PUMP HOUSE
SIMULATOR TRAINING FACILITY (STF)
SUBSTATION AREA
SUBSTATION CONTROL HOUSE
PUMP HOUSE
WAREHOUSE No. 1
FENCE
FENCE
LAKE MICHIGAN
ADMINISTRATIVE TRAINING FACILITY
TECHNICAL SUPPORT CENTER (TSC)
ADMINISTRATION BUILDING
AUXILIARY BUILDING
TURBINE BUILDING
SCREENHOUSE
MAINTENANCE VEHICLE GARAGE
SECURITY BUILDING
SITE ACCESS FACILITY
OFFICE/ WAREHOUSE ANNEX
PARKING AREA
MICROWAVE & SURGE PROTECTION HOUSE
MICROWAVE TOWER
TREATMENT SETTLING BASINS
WASTEWATER TREATMENT BUILDING
MAINTENANCE WASTE OIL AND MATERIAL STORAGE BUILDING
CABLE STORAGE YARD
METEOROLOGICAL TOWER

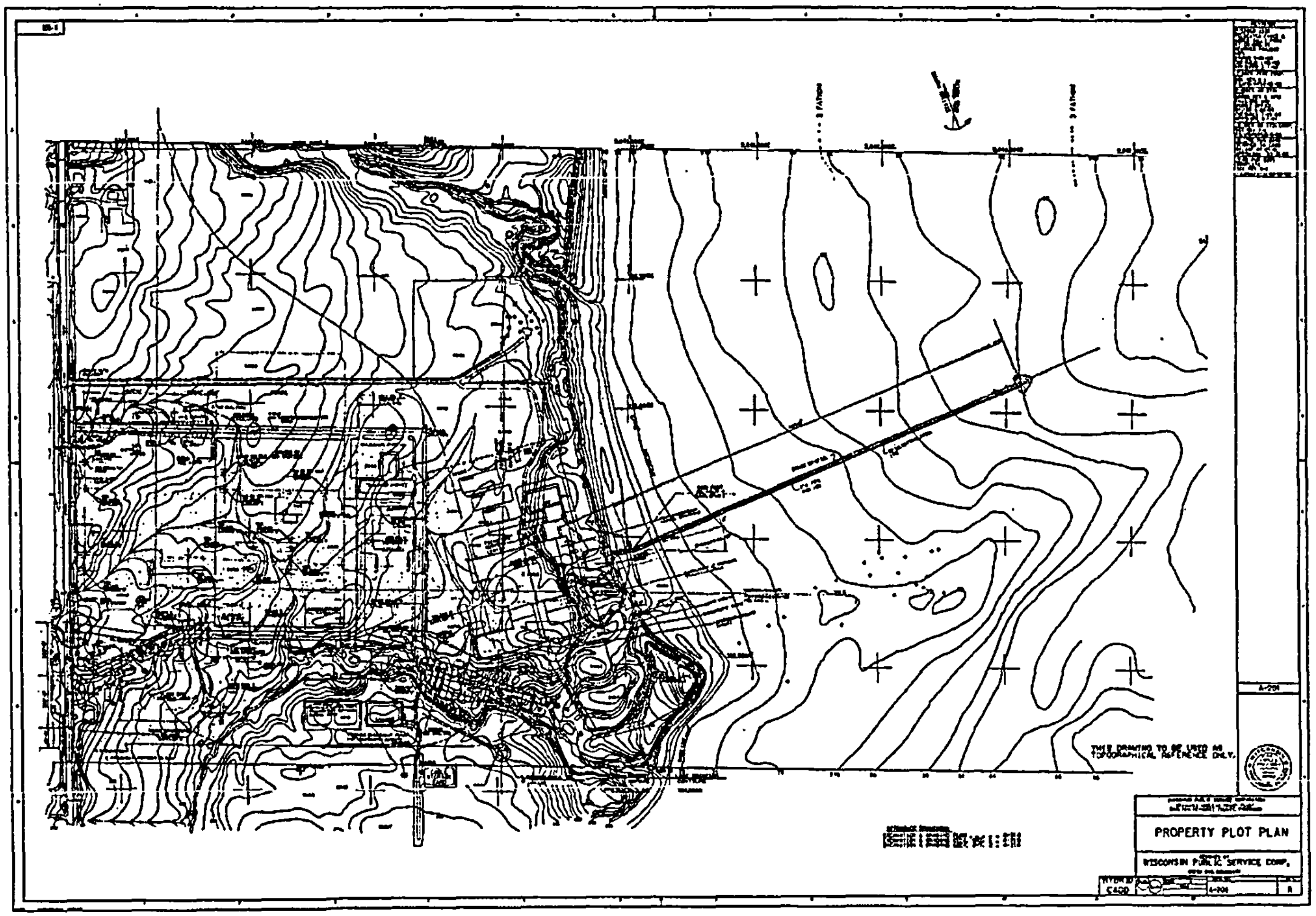
SITE LAYOUT



OUTFALLS LOCATIONS

ATTACHMENT 4

Kewaunee Power Station
Intake System and Screenhouse Drawings



A-204
THIS DRAWING TO BE USED AS TOPOGRAPHICAL REFERENCE ONLY.
PROPERTY PLOT PLAN
WISCONSIN PUBLIC SERVICE CORP.
CADD
A-204
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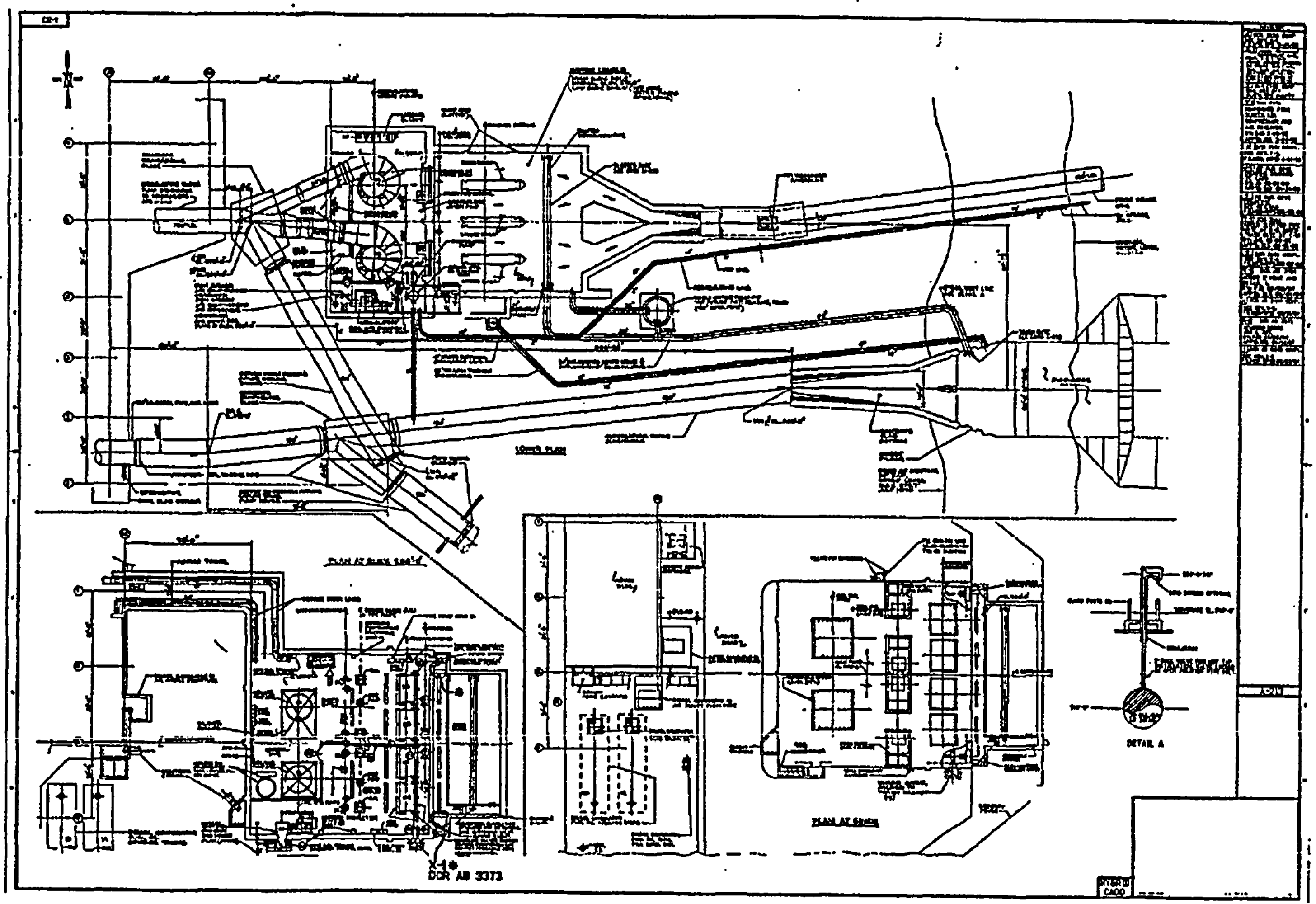
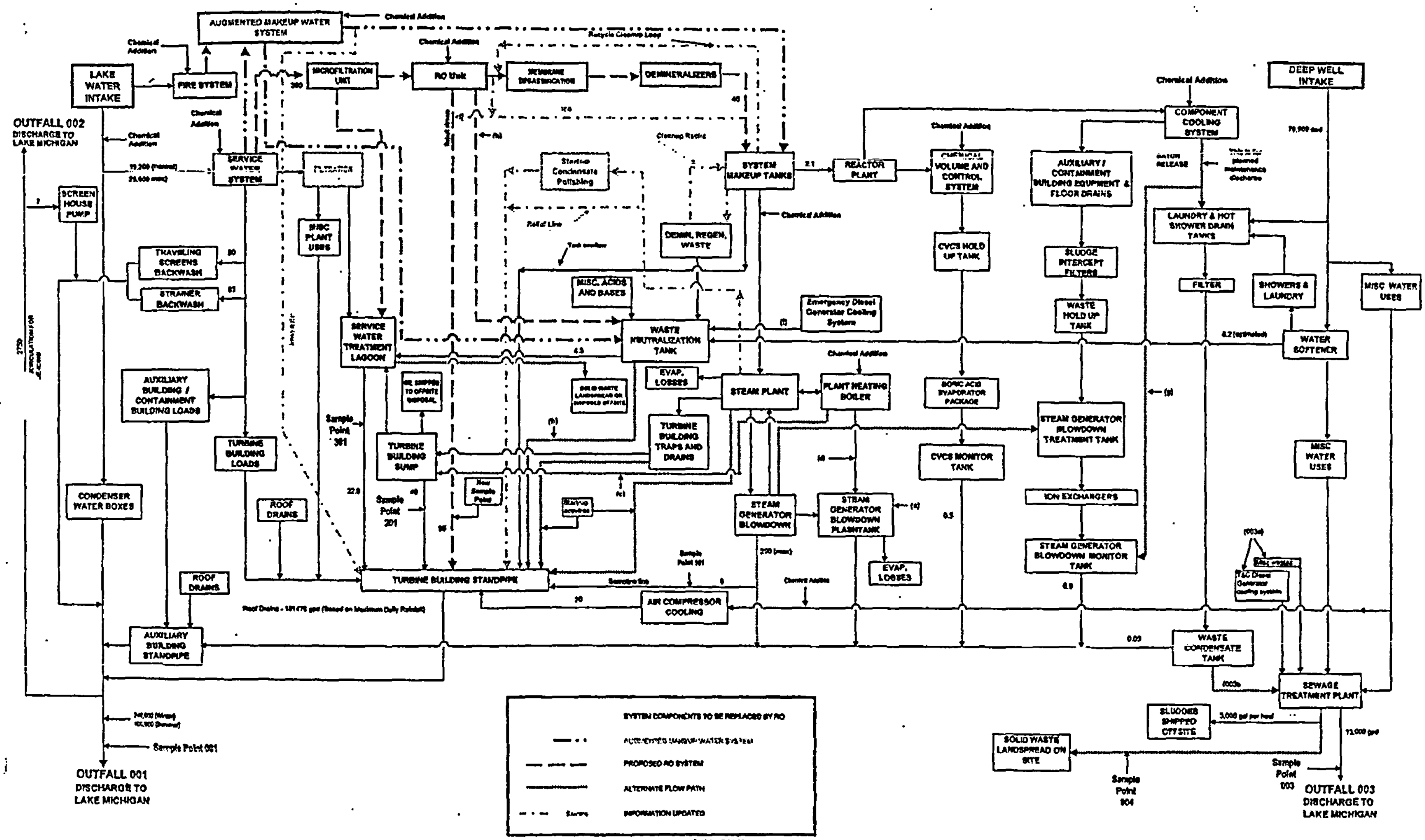
Figure 1.2-9 General Arrangement Screenhouse and Circulating Water Discharge



ATTACHMENT 5

Kewaunee Power Station
Water Flow Diagram

KEWAUNEE POWER STATION
WATER FLOW DIAGRAM
Note: Flows listed are average gpm unless otherwise noted.

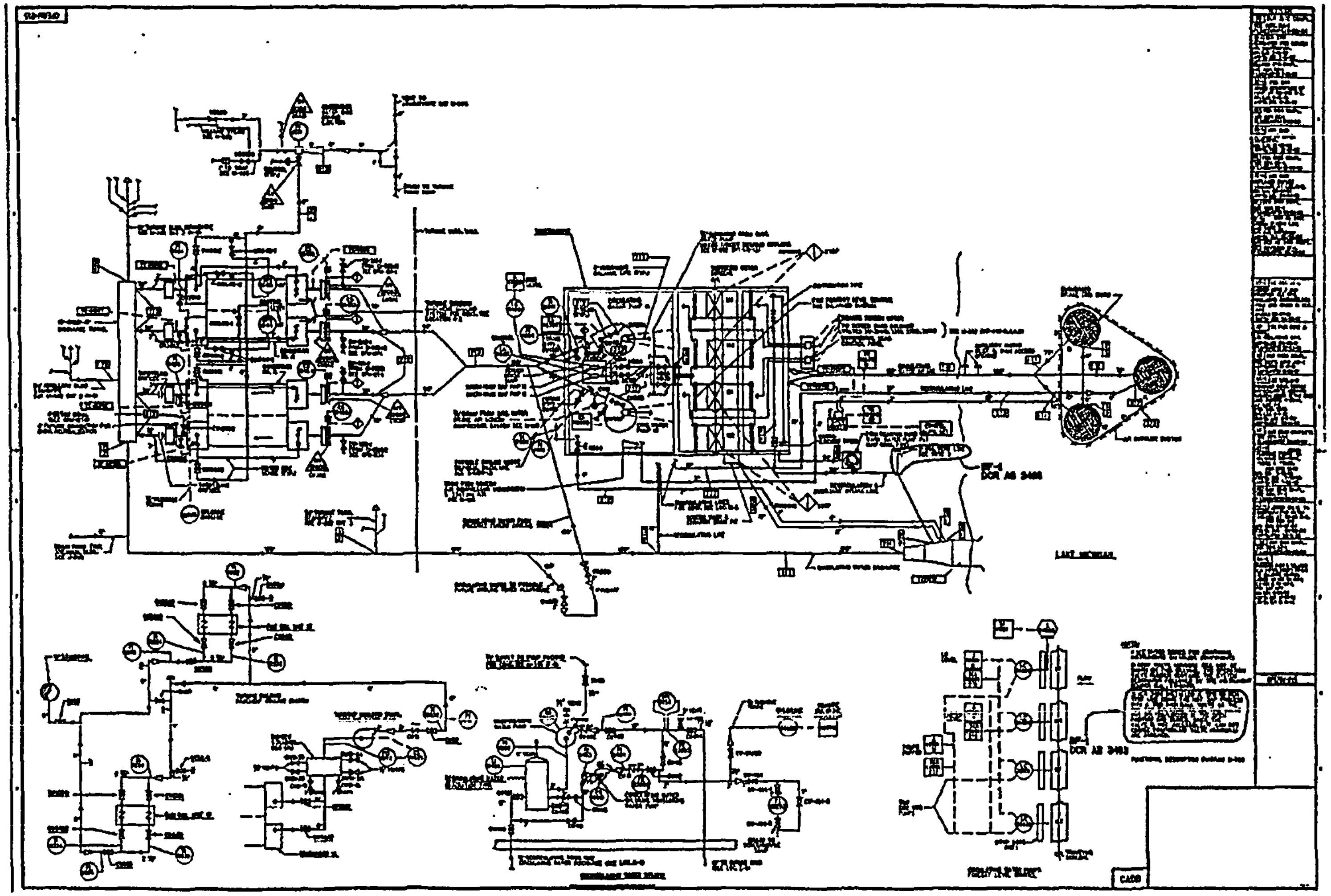


Revision 5-24-06

ATTACHMENT 6

Kewaunee Power Station
Flow Diagram for Circulating Water System

Figure 10.2-7 Flow Diagram Circulating Water System



ATTACHMENT 7

Kewaunee Power Station
Impingement Mortality and Entrainment Characterization Report
March 2006 – February 2007

Impingement Mortality and Entrainment Characterization Report
Kewaunee Power Station
March 2006 – February 2007

Prepared for

Dominion Resources Services, Inc.
5000 Dominion Boulevard
Glen Allen, Virginia 23060

Prepared by

EA Engineering, Science, and Technology, Inc.
15 Loveton Circle
Sparks, Maryland 21152

FINAL Report
August 2007

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1.0 INTRODUCTION

Kewaunee Power Station is located on the western shore of Lake Michigan eight miles south of Kewaunee and 90 miles north of Milwaukee, Wisconsin (Figure 1).

The Proposal for Information Collection (PIC) for the Kewaunee Power Station (Dominion 2005) was submitted to the Wisconsin Department on Natural Resources (WDNR) in Febuary 2005 and subsequently approved by WDNR. A field impingement and entrainment study wasinitiated in February 2006 in accord with the approved PIC and completed in February 2007 and is the subject of this report.

This report represents the results of the Impingement Mortality and Entrainment Characterization Study for Kewaunee Power Station, based on field collections made between February 2006 and February 2007.

2.0 GENERATING STATION DESCRIPTION

2.1 SITE DESCRIPTION

Kewaunee Power Station is located in Wisconsin on the western shore of Lake Michigan (Figure 1). The surrounding land area is primarily rural and agricultural in nature. The inshore area of Lake Michigan is characterized by gravel and rubble substrates, with a relatively shallow gradient toward offshore. No large tributaries enter the study area.

2.2 STATION DESCRIPTION

Kewaunee Power Station consists of a single pressurized water reactor nuclear generating unit with a net output of 540 megawatts electric (MWe). The station is a base-loaded facility, operating at all times except during repair or fueling outages. Once-through cooling water is drawn into the station from a submerged intake approximately 1,600 feet offshore (Figure 1) through a 10-foot diameter pipe and into a concrete forebay onshore. Cooling-water passes through four vertical traveling screens consisting of woven-wire mesh with 3/8-inch openings. There are two circulating-water pumps behind the traveling screens, each with a capacity of 200,268 gallons per minute (gpm). After transiting the condensers, cooling-water is routed back to the lake via a surface discharge (Figure 1).

Debris and organisms washed from the traveling screens are routed to a collection basket downstream of the screens.

2.3 HABITAT AND BIOLOGICAL COMMUNITY

In the near vicinity of Kewaunee Power Station, Lake Michigan is relatively shallow, ranging from shallow depths inshore up to approximately 15-20 feet at 1,600 feet offshore where the submerged intake is located. Ultimately, the bottom deepens out to 600+ feet in the central part of the lake (Chippewa Basin). The near shore substrate is primarily cobble and gravel, with some boulder, sand, and silt. The site is open to the lake, and subject to wind disturbance from all quadrants except the west. This area of the lakeshore is primarily rural and agricultural in nature.

The current biological community of Lake Michigan is an amalgam of native and introduced species of both fish and invertebrates. The fauna has undergone many changes over the years. The early, native fish community was typified by deepwater species such as such as the bloater, lake herring, and lake whitefish; top predators such as the lake trout and walleye; pumpkinseed and smallmouth bass of the sunfish family; demersal species such as white sucker and freshwater drum; intermediate predators such as white bass and yellow perch; and various small forage species including the emerald shiner.[1]

Alterations to the fish community began early, with the introduction of common carp and brown trout in the 1890s, followed by rainbow smelt in the early 1900s (UWSGI 2002). The parasitic sea lamprey entered the Upper Great Lakes via the Welland Canal and were first noted in Lake Michigan in 1936 (Fetterolf undated). Lamprey abundance quickly increased and began to take a toll on native fish, first the lake trout, and after that population was essentially decimated, whitefish species. As a result of the reduction in top predators, alewife—another exotic that reached Lake Michigan from the lower lakes in about 1950—numbers exploded. Native fishes that preyed on planktonic and other smaller organisms were adversely affected by competition with alewives. Some measure of control of the alewife population was effected by large stocking programs of Pacific salmon (e.g., coho, Chinook) and other salmonids beginning in the 1960s. Although stocking programs in Lake Michigan have been reduced in recent years, stocking of Pacific salmonids continues throughout the lake. This has created a better (but fluctuating) balance between the alewife and salmonid predators. A more recent wave of exotic species introduction and community change is represented by the round goby, which is a European species thought to have been introduced to the Great Lakes in the discharge of ballast water from ocean-going ships. It has been known to inhabit Lake Michigan since 1993 (Madenjian et al. 2006). Although studies are ongoing, the round goby may be adversely affecting a wide range of species including sculpins, lake trout, and yellow perch.

Change has also occurred in the invertebrate community, and one of the most recent introductions has resulted in substantial change in the Lake Michigan ecosystem. Again as an apparent result of ballast-water discharges, two dreissenid mussels—zebra and quagga mussels—became established and exploded in abundance beginning in the 1990s. The dreissenid mussels attain prolific densities and filter large volumes of water, removing phytoplankton biomass that would normally have been consumed by other organisms (NOAA/GLERL 2004). One of these other organisms, the small amphipod *Diporeia*, normally the dominant offshore invertebrate and food source for many fish, has declined by approximately 90 percent between 1993 and 2002. Changes brought about

[1] Common and scientific names of finfish in this report follow Nelson et al. 2004.

by the dreissenid mussels have been implicated in declines in abundance and/or body condition of whitefish species, yellow perch, and other species. Another species *Hemimysis anomala*, a small, mysid shrimp, was first reported in 2006 and it appears to be established. Its effect on the Lake Michigan biological community is unknown.

3.0 IMPINGEMENT STUDY AT KEWAUNEE POWER STATION

3.1 METHODS

3.1.1 Impingement Sampling

Impingement sampling was carried out at Kewaunee Power Station from February 2006 through January 2007. Sampling frequency was once per week from March through August 2006, and twice per month otherwise. Sampling was not conducted in September due to a plant outage. Each sampling event consisted of a complete 24-hour collection of impinged organisms. Typical collection periods ran from 0900 hours on the first morning to 0900 on the second morning. When debris and organism loads were light, the collection basket downstream of the traveling screens was allowed to accumulate sample for the full 24-hour period. When debris and/or organism loads were heavier, the basket was checked and emptied periodically during the 24-hour sample period. Resulting organisms were accumulated as a single, 24-hour impingement sample.

All fish collected during a sample were identified and counted, and up to 50 individuals per species were individually measured (nearest mm) and weighed (nearest 0.1 gm). If more than 50 individuals per species were encountered, the excess over 50 was counted and batch weighed. When very large numbers of a single species were encountered (>100), the count and batch weight of the initial 100 were used to extrapolate the count of the remaining specimens (which were batch weighed). Taxonomic resources included Becker (1983), Page (1985), Pflieger (1975), and Smith (2002). Scientific and common names of fish and shellfish mentioned in this report are provided in Table 1.

3.1.2 Water Quality

Water quality measurements were made with a YSI Model 556 water quality analyzer that was calibrated prior to each sampling event. All water quality parameters (water temperature, dissolved oxygen, pH, and conductivity) were measured in shallow water just off the beach just north of the power station at the start of the 24-hour impingement sampling event. All biological and water quality data were recorded on standard data sheets.

3.1.3 Ambient Juvenile and Adult Fish Sampling

Juvenile and adult fish in the vicinity of Kewaunee Power Station were sampled twice per month, weather permitting, from April through October 2006. Three locations (Figure 2) were sampled by both seine and experimental gill nets. The northernmost locations (Seine 1, nearshore [NS] 1, and offshore [OS] 1), represented a reference site. The locations designated as "2" and "3" bracketed the near vicinity of the power station. The "NS" and "OS" locations were established at the 6-8-foot depth contour and 15-foot depth contour, respectively. Note that the NS and OS locations are shown in Figure 2 as transects, consistent with the tow paths of ambient plankton collections described later in this report. Gill nets were set at the northern end of each of these transects. The gill nets were 300-foot long by 6-foot deep, and contained six, 50-panels of 0.5, 1.0, 1.5, 2.0. 2.5, and 3.0-inch bar mesh netting. The nets were set perpendicular to shore with the small mesh toward shore and fished over night. At each location and sampling date, two seine hauls were made with a 25-foot long bag seine with 1/8-inch mesh netting.

All juvenile and adult fish collected in the ambient program were processed as described above for impingement, except that only 15 fish per species were individually measured and weighed.

3.1.4 Data Analysis

All data were entered into an SQL Server database using a Microsoft Access®-based, "front-end" data-entry template. Reports were then printed out and proofed against the original data sheets, and electronic corrections made as necessary. All data manipulations, calculations, and summaries included in this report were performed within the database, or in Microsoft Excel® formats exported from the database.

An example of the impingement calculation sequence is provided in Appendix A, Table A-1 using actual data for impingement of rainbow smelt at Kewaunee Power Station. Cooling-water flow, based on circulating water pump operation, was recorded for each sampling event. If the cooling-water volume during the 24-hour sampling event was less than maximum plant capacity for 24 hours, an adjustment factor was calculated to increase the initial 24-hour estimate to a number that would have been expected under maximum cooling-water flow for the 24-hour period. At Kewaunee Power Station, this typically applies to the months of October through March, when only one pump is operated. During April through August, both circulating-water pumps were used, and the actual impingement catch for the 24-hour sampling event was the catch at maximum cooling-water flow capacity. When only one pump was in use during winter, the actual impingement catch for the 24-hour period was multiplied by a factor of 2 to extrapolate the actual catch to that which would have been expected if both pumps were operating. This impingement catch (adjusted up or not, as necessary) was then multiplied by the number of calendar days represented by the sampling event. This value was then added to analogous values calculated for the other 33 extrapolation periods to estimate the total impingement, under maximum cooling-water flow conditions, for the entire study year. Additional calculation details are provided in Appendix A.

3.2 IMPINGEMENT RESULTS

3.2.1 Composition and Abundance

During February 2006 through January 2007, 692,195 impinged fish and crayfish weighing 2,814 kilograms were collected from the traveling screens at Kewaunee Power Station (Table 2). The collection was overwhelmingly dominated by alewife, which accounted for 99.7 percent of the catch by number and 94.8 percent by weight. Only five other finfish—ninespine stickleback, rainbow smelt, yellow perch, mottled sculpin, and spottail shiner—exceeded 100 individuals collected during the study year. An additional 25 species of finfish and one species of crayfish were collected.

Although some impinged fish were collected in all months (except September which was not sampled), the abundance in June and July 2006 accounted for over 90 percent of all impinged fish (primarily alewife) collected during the year (Table 3 and Appendix B). A lesser peak in alewife abundance occurred in October and November 2006. Other common species—rainbow smelt, ninespine stickleback, mottled sculpin, and northern clearwater crayfish—were most abundant during late spring and summer. Yellow perch exhibited two peaks in abundance, one in August 2006 and one in January 2007.

3.2.2 Length Frequency

Length-frequency distributions were developed for two common species, alewife and yellow perch (Tables 4 and 5), and length statistics for all impinged species are provided in Appendix C. Of 1,087 alewives measured, 776 or 71 percent were less than 100 mm in total length. These were probably all young of the (2006) year, based on Madenjian et al. (2003). Lengths recorded up to 180+ mm may have represented 4 to 6 year-old individuals. Impinged yellow perch were also predominantly young of the year between 50 and 90 mm in length (Table 5) based on Becker (1993), Carlander (1997), and Scott and Crossman (1973). The relatively few individuals that measured between 90 and 330+ mm may have included Ages 1+ up to Ages 7-9 (Carlander 1997).

The preponderance of young fish in the impingement samples is consistent with observations of other researchers (e.g., Porak and Tranquilli 1981). Note in Section 3.2.5 below that larger individuals were proportionally more abundant in ambient lake samples relative to impingement.

3.2.3 Monthly and Annual Estimates of Impingement

The impingement sampling data were used in conjunction with station cooling-water flow to project total monthly and annual estimated impingement based on maximum cooling-water flow capacity. The results are displayed in Table 6. A total of 5,613,799 fish and crayfish were estimated to have been impinged during the study year. Alewife accounted for 99.6 percent of this total estimate. Other common (> 1,000 individuals) but much less abundant species included gizzard shad, spottail shiner, rainbow smelt, ninespine stickleback, mottled sculpin, yellow perch, and northern clearwater crayfish. Monthly estimates generally followed the sample data (Table 3), with nearly 90 percent of the annual estimated total occurring in May through July 2006.

3.2.4 Water Quality Associated with Impingement Sampling

Measurements of dissolved oxygen (DO), pH, conductivity, and water temperature were made in conjunction with impingement sampling (Table 7). The data reflect a typical north-temperate lake environment, with DO and water temperature following their inverse relationship (Figure 3). The water temperature curve is not smooth, possibly owing to the influence of heated discharge water at the water quality monitoring location. For example, there was a nearly 19 C increase in water temperature from 23 March to 30 March (and a concomitant decline in DO). Data records indicated a steady SE wind on that 30 March sampling occasion which evidently blew discharge effluent into the inshore water quality sampling location. Dissolved oxygen generally inversely varied with water temperature, as was most evident during summer. The DO reading on 10 August was quite low, well below the warm-water water quality standard of 5 mg/L. This (single) reading was considered an anomaly since the mean of four readings (7.4 mg/L) taken at the same location during the same time period in conjunction with entrainment sampling was well above the water quality standard for DO. The pH and conductivity readings were unremarkable and the pH values were all within the Wisconsin water quality standard range of 6.0 – 9.0 for the protection of warmwater fish.

3.2.5 Comparison of 2006-2007 Impingement Data to Concurrent Ambient Juvenile and Adult Fish Data

3.2.5.1 Ambient Lake Program: Juvenile and Adult Fish

As described in Section 3.1.3, juvenile and adult fish and crayfish were sampled at three locations near Kewaunee Power Station between April and October 2006 using experimental gill nets and seines. The gill net sampling data are displayed in Tables 8 and 9 for the inshore and offshore locations, respectively. For both locations, peak abundances were documented in May, with a smaller peak in October for the inshore location, all driven largely by alewife abundance. To better examine spatial differences, the catches were combined by location (north to south) and inshore/offshore (Tables 10 and 11). Alewife dominated all locations, and was slightly more abundant inshore, and at Stations 2 and 3 nearest Kewaunee Power Station. Some differences may reflect species' life-history strategies, e.g., the higher inshore abundances of longnose dace and spottail shiner (Table 11). No consistent pattern was evident that would suggest markedly different communities north or south of the station, or between inshore and offshore locations.

Seine data are displayed by species, date, and sampling station in Table 12. These data were combined for the study period in Table 13 to illustrate any differences among sampling stations. Catches were higher from May through August at all locations. Overall, Station 1 produced higher seine catches, due largely to alewife abundance, particularly on 8 May and 14 August (Table 12). Lake chub abundance was notably higher at Station 2, due almost entirely to a single large catch on 31 July (Table 12). There was no consistent pattern of greater or lesser abundance at any one sampling station.

Length statistics for all ambient fish are provided in Appendix D; length-frequency tables were developed for five of the more common species (Tables 14 - 18). Alewife ranged in length from at least 20 mm up to 210+ mm (Table 14), with large groupings in the 60 – 80 mm and 100 – 130 mm range. The smaller grouping (virtually all fish less than 100 mm) may be assumed to be young of the (2006) year, based on Madenjian et al. (2003).

The larger group may be Age 1 or older based on literature (e.g., Carlander 1969), but the bimodal distribution in Table 14 suggests they are Age 1+ fish spawned in 2005. The round whitefish were larger fish with the largest grouping between 410 and 430 mm (Table 15). These were at least Age 5 fish based on Carlander (1969). The bulk of the white suckers collected were larger fish between 340 mm and 550 mm (Table 16). Based on length-at-age data in Carlander (1969), these were probably at least Age 3 fish and possibly older. Longnose sucker groupings were evident at 230 – 260 mm and possibly at 350 – 380 mm (Table 17). These were larger, probably mature fish between 3 and 5 years old, and likely older in the upper end of the sample length range. The relative few smallest individuals collected may have been Age 1+ based on Carlander (1969). The lake trout collected (Table 18) were all older fish, from possibly Age 5 up to Age 13.

3.2.5.2 Comparison of Ambient and Impingement Data

Ambient juvenile/adult data and impingement data are compared in Table 19. Alewife dominated both collections, but more so in impingement. To elucidate differences among other species, alewife numbers were not included in the "percent of total" calculations. A number of species made up a substantial percent of the ambient catch relative to the impingement catch. These included lake chub, longnose dace, white sucker, longnose sucker, round whitefish, brown trout, and lake trout (Table 19). Conversely, rainbow smelt, threespine stickleback, ninespine stickleback, mottled sculpin, and northern clearwater crayfish were relatively more abundant in impingement samples. A few species, i.e., gizzard shad, spottail shiner, and yellow perch, produced similar percentages in the two programs. Spatial occurrence may have influenced these results, at least in part. But differing "sampling" efficiency between the intake screens and the ambient gear was very likely also a factor. Note that all of the species mentioned as more abundant in impingement samples were smaller, and thus less able to avoid intake currents, whereas most of the species listed as more abundant in ambient samples were larger species, e.g., white sucker, lake trout. Although the ambient data represent the community that is potentially vulnerable to impingement, some species are more likely to be impinged than others.

Mean length data from Appendix C (impingement) and Appendix D (ambient) are summarized below for common species.

Species	Impingement (mm)	Ambient (mm)
Alewife	93.4	91.1
Burbot	337.7	497.7
Gizzard shad	104.4	302.1
Longnose dace	90.7	71.9
Longnose sucker	334.8	323.1
Ninespine stickleback	69.3	45.0
Rainbow smelt	106.2	369.5
Round whitefish	366.6	405.3
Spottail shiner	88.3	92.9
White sucker	441.0	440.4
Yellow perch	87.8	285.6

Mixed results are evident in these comparisons, and not entirely supportive of the general contention that impingement affects the smaller members of a species. Mean lengths of several species—alewife, longnose sucker, spottail shiner, and white sucker—are virtually the same between the two programs and provide no evidence of selectivity in either area. Longnose dace and ninespine stickleback were actually larger in the impingement samples. However, burbot, gizzard shad, rainbow smelt, round whitefish, and yellow perch all produced larger individuals in the ambient samples. This could reflect different spatial distributions among size groups within a species, but very likely reflects greater vulnerability of the smaller size groups to impingement.

3.2.6 Historical Impingement Studies

NALCO (undated) presented the results of an impingement study at Kewaunee Power Station carried out from April 1975 through March 1976. Twenty-four hour collections of impinged fish were made during 2 to 7 days per week during the annual study period. Data from each collection were extrapolated across those days not sampled to provide monthly and annual total estimates of number and weight of impinged fish.

A total of 215,108 fish weighing 6,210 kg was estimated to have been impinged during the historic study period (Table 20). Seventeen individual species were collected in addition to five "family" groups (e.g., "sucker," "trout," etc.). Alewife accounted for 83 percent by number and 77 percent by weight of the total estimated impinged. Rainbow smelt (8.9 percent by number), slimy sculpin (4 percent by number), and longnose dace (2 percent by number) were common. No other species or family group accounted for more than 0.7 percent by number of the total impinged during the year. Based on compilations in NALCO (undated), nearly 88 percent of the impingement total occurred during the months of June through November 1975, and this distribution was heavily influenced by alewife.

The annual estimated numbers impinged were compared between the 1975 – 1976 study and 2006 – 2007 study (Table 21). The total estimate for the 2006 – 2007 study period was greater than that in 1975 – 1976, due almost entirely to the greater number of alewife estimated impinged in 2006 – 2007. The combined totals of species other than alewife did not differ greatly between study years. However, there were some notable differences between years for some species. The estimated number impinged of spottail shiner, burbot, ninespine stickleback, threespine stickleback, mottled sculpin, and yellow perch were substantially greater in 2006 – 2007. Conversely, longnose dace, lake chub, rainbow smelt, and slimy sculpin were much more abundant in 1975 – 1976.

Some of the differences between study years may be explained by changes in the fish communities in Lake Michigan. For example, the 12-fold greater abundance of yellow perch in 2006 – 2007 may reflect an increasing lake population in recent years. Bunnell et al. (2007) reported that the 2005 year class of yellow perch was by far the largest in a 33-year record. Greater impingement catches of burbot in 2006 – 2007 are consistent with the greater density of adult burbot reported by Bunnell et al. (2007) from the mid-1980s to 2006. The greater abundance of alewife in 2006 – 2007 is misleading since the lake-wide population has been declining for several years (Bunnell et al. 2007). Spatial distribution has been patchy and some areas may produce relatively high numbers (i.e., at Kewaunee), but the overall population level is down in the lake. Rainbow smelt impingement was notably lower in 2006 – 2007 and this may be related to their declining numbers since the mid-1990s.

3.2.7 Impingement Summary

- An impingement study was carried out at Kewaunee Power Station from February 2006 through January 2007. Sampling was conducted weekly from March through August 2006, and twice in each other month. Samples were not collected in September 2006 due to a planned outage at the station.

- A total of 692,072 fish and 123 crayfish weighing 2,814 kilograms was collected from the traveling screens. Thirty-one species of finfish representing 14 families, plus one crayfish species were collected. Alewife, with 690,402 individuals collected, accounted for 99.7 percent of the entire annual collection. Ninespine stickleback, rainbow smelt, yellow perch, and mottled sculpin were next in order of abundance, and together composed just 0.17 percent of the collection.

- Impingement rates were highest during May through July 2006 when 96 percent of the annual collection, primarily alewife, was recorded.

- The majority of impinged fish were the smaller, younger individuals of nearly all species.

- Based on maximum cooling-water flow at Kewaunee Power Station, an estimated 5,612,695 finfish and 1,104 crayfish were estimated to have been impinged during the study year. As already indicated based on sampling data, alewife was overwhelmingly dominant, with an estimated 5,592,692 impinged.

- Water quality measurements were typical for a north temperate lake, and pH and dissolved oxygen levels were nearly all within acceptable Water Quality Standards for Lake Michigan waters. One low dissolved oxygen concentration of 2.2 milligrams per liter was recorded during the study year and was considered anomalous.

- Ambient Lake Michigan sampling of juvenile and adult fish was conducted with gill nets and seines at three locations near Kewaunee Power Station. Alewife dominated the catches, and catch rates differed little between locations north or south of Kewuanee Power Station or inshore and offshore sampling locations.

- Similar species groups occurred in ambient and impingement samples, but proportional differences occurred, i.e., some species (e.g., rainbow smelt, ninespine stickleback) were more abundant in impingement samples and others (e.g., lake chub, longnose sucker) in ambient samples. Although not evident for all species, a number of species (e.g., burbot, gizzard shad, yellow perch) produced smaller individuals in impingement samples relative to ambient samples.

- The impingement results for 2006 – 2007 were compared to a prior impingement study conducted in 1975 – 1976. The most obvious difference between the studies was the difference in annual estimated impingement of alewife: 5.5 million in 2006 – 2007 versus 178,883 in 1975 – 1976. Other differences included greater abundance of longnose dace, lake chub, rainbow smelt, and slimy sculpin in 1975 – 1976, and greater abundance of gizzard shad, spottail shiner, ninespine stickleback, mottled sculpin, and yellow perch in 2006 – 2007. These differences were attributed to differences in abundance near Kewaunee Power Station as a reflection of lake community changes in the years between the studies.

- The fish and crayfish collected in all of the studies in 2006 – 2007 were considered representative for that year.

4.0 ENTRAINMENT STUDY AT KEWAUNEE POWER STATION

4.1 METHODS

4.1.1 Entrainment Sampling

Entrainment sampling was carried out at Kewaunee Power Station from March 2006 through February 2007. Sampling frequency was weekly from March through August 2006, and twice a month otherwise, except only once in September 2006 due to a planned outage at the station. Samples were collected from mid-depth in the discharge canal using a single, 0.5-meter diameter, conical plankton net consisting of 335 μm mesh netting. A General Oceanics (GO) 2030R mechanical flowmeter was affixed in the net mouth to support sample-volume calculations. Samples were collected every six hours over a 24-hour sampling event, typically beginning at 1000 hours. During each sample period, two, sequential samples (replicates) were collected, each consisting of a 6-minute deployment. Resulting samples were preserved in 5 percent buffered formalin and Rose Bengal dye and transported to the laboratory for processing.

In the laboratory, samples were sorted with the aid of lighted magnifying rings to separate organisms from debris. Extremely abundant samples were split with a Motodo plankton splitter to obtain manageable portions for sorting. All fish eggs and larvae and invertebrates were stored in labeled vials for subsequent identification.

Entrained organisms were identified under magnification. Taxonomic resources included Smith (2001), Auer (1982), Holland-Bartels et al. (1990), and Fuiman et al. (1983). For each sample, up to 20 fish larvae of each taxon and life stage were measured to the nearest 0.1 mm with an ocular micrometer.

4.1.2 Water Quality

Measurements of water temperature, dissolved oxygen, pH, and conductivity were made with a YSI Model 556 water quality analyzer at the same beach location as the impingement water quality. One set of measurements was recorded in association with each of the four entrainment samples during a 24-hour sampling event.

4.1.3 Ambient Ichthyoplankton and Invertebrate Sampling

Ambient ichthyoplankton and invertebrate sampling was conducted concurrently with entrainment sampling, weather permitting, at three locations and two depth contours in the vicinity of Kewaunee Power Station (Figure 2). Samples were collected with paired, conical plankton nets of 0.5-meter mouth diameter and constructed of 335-μm mesh netting. Each net had a GO 2030R mechanical flowmeter affixed in the mouth to support calculation of sample volumes. At the shallow locations (NS1, NS2, NS3), a single mid-depth tow was made. At the deeper locations (OS1, OS2, OS3), stepped oblique tows (surface to bottom) were made. All tows were six minutes in length, which typically provided at least 50 M^3 of sample volume.

Field and laboratory processing of samples was as described above for entrainment samples.

4.1.4 Data Analysis

All data were entered into an SQL Server database using a Microsoft Access®-based, "front-end" data-entry template. Reports were then printed out and proofed against the original data sheets, and electronic corrections made as necessary. All data manipulations, calculations, and summaries included in this report were performed within the database, or in Microsoft Excel® formats exported from the database.

An example of the entrainment calculation sequence is provided in Figure 4 using actual data from one of the sampling events at Kewaunee Power Station. The density of burbot yolk-sac larvae in each individual sample (replicate) (8 per 24-hour event) is displayed by sampling time. Densities of replicate samples were averaged, and then densities were averaged over the four sampling times to produce an average density (number/100 M^3) for the 24-hour sampling period. This 24-hour average density was then multiplied by the maximum station cooling-water flow in cubic meters to calculate the total number of burbot larvae entrained during the 24-hour period. This value was then multiplied by the number of calendar days represented by the 4/27-28/2006 sampling event to project the total number of burbot entrained during that period. This value was then added to the analogous values from the other 36 extrapolation periods during the study year to estimate the total number of burbot larvae entrained during the study year, under maximum cooling-water flow conditions. Additional calculation details are provided in Appendix A.

4.2 RESULTS

4.2.1 Composition and Abundance

During the 12-month course of the study, 15 ichthyoplankton taxa in several developmental stages were identified (Table 22). In addition, three macrozooplankton taxa were identified. Greatest abundance was exhibited by *Gammarus* sp., which accounted for 93 percent of entrained organisms based on annual density. Unidentified fish eggs were next in abundance, although at less than 3 percent. Burbot, alewife, and common carp were the most abundant fish larvae. Young life stages of fish were primarily present during spring and summer (Table 23). Note peak densities of burbot larvae in April; unidentified fish eggs and common carp larvae in June; rainbow smelt larvae in July; and alewife larvae in August. Of the three invertebrate forms entrained, *Gammarus* sp. was present in all months, but produced the highest densities in July through November. The exotic species *Hemimysis anomala* (bloody-red mysid) and the native species *Mysis relicta* occurred in entrainment samples only during the colder months of March and April, and December through February. Water temperature and other measured water quality parameters are compiled in Table 24.

Length statistics for entrained fish larvae are provided in Table 25.

4.2.2 Monthly and Annual Estimates of Total Entrainment

Entrainment density data were used in conjunction with station cooling-water flow data to estimate the total number of each ichthyoplankton and invertebrate taxon entrained, both on a monthly and annual basis (Table 26). Invertebrates, primarily *Gammarus* sp., accounted for the majority of organisms estimated entrained at 1,494.22 X 10^6 for the year, or 96 percent of the total. Among finfish life stages, unidentified eggs produced the highest annual total at 25.28 X 10^6. Burbot yolk-sac larvae (7.82 X 10^6), alewife larvae and juveniles (3.81 X 10^6), common carp larvae (5.4 X 10^6), Clupeidae sp. larvae (1.96 X 10^6), and Cyprinidae sp. larvae (2.8 X 10^6) followed in abundance. The total annual estimate of all finfish life stages entrained was 54.7 X 10^6.

4.2.3 Comparison of Entrainment and Ambient Lake Michigan Densities

4.2.3.1 Ambient Lake Michigan Ichthyoplankton and Invertebrate Data

As described in Section 4.1.3 above, ichthyoplankton and invertebrates were sampled at three inshore and off shore locations near Kewaunee Power Station between March and October 2006. The data are displayed in Tables 27 and 28 for inshore and offshore locations, respectively. Temporally, the ambient data are similar to entrainment, with young life stages of finfish primarily occurring in spring and summer, and invertebrates, chiefly *Gammarus* sp., present throughout the March – October period.

A review of Tables 27 and 28 reveals a few differences among the north-south sampling stations. Alewife yolk-sac larvae and Clupeidae yolk-sac larvae (possibly also alewife) tended to be more abundant at location 1. Unidentified fish eggs were markedly less abundant at location 2, relative to 1 and 3. In contrast, over the study year, *Gammarus* sp. was rather evenly distributed among the three sampling locations. To better examine inshore vs. offshore densities, the results were combined in Tables 29. Overall average density was slightly higher offshore, due to the substantial contribution of Gammarus sp. at that location. However, the more common fish taxa were more abundant inshore, i.e., alewife yolk-sac larvae, Clupeidae sp. larvae, Coregoninae (whitefish) sp. yolk-sac larvae, and unidentified fish eggs. Burbot yolk-sac larvae were an exception, with virtually identical densities inshore and offshore. The inshore-offshore distributions did not reflect notable community differences. The somewhat higher inshore densities of eggs and several common larval forms may reflect greater inshore spawning activity.

Water quality data from the inshore and offshore ambient ichthyoplankton sampling locations are displayed in Tables 30 and 31, respectively.

4.2.3.2 Entrainment vs. Ambient Densities

Overall densities of ichthyoplankton and invertebrates were compared between entrainment and ambient sampling programs (Table 32). The combined average density for all organisms was nearly three times higher in entrainment samples due to relatively high densities of *Gammarus* sp. and other invertebrates as well as some fish larvae (common carp, other cyprinids, and rainbow smelt) in entrainment samples. Conversely, clupeid yolk–sac larvae occurred in higher densities in ambient samples.

The reason for these differences is not clear. Although similar plankton nets were used in both programs, possible differences in through-net flow velocities may have been a factor. It is also possible that densities of some taxa near the bottom, i.e., at the contour of the offshore, submerged intake, were in fact higher than surface or mid-level waters, which were included in the stepped-oblique sampling technique used at the offshore contour in the ambient program.

4.2.4 Comparison of Entrainment Data and Ambient Juvenile and Adult Data

Many of the juvenile and adult fish that were occasional or common in the gill net and/or seine collections (Tables 11 and 12) were collected as larvae in entrainment samples (Table 22). These include alewife, common carp, ninespine stickleback, rainbow smelt, round goby, burbot, and white sucker. All of these species are known to spawn in relatively shallow, inshore areas (Charlebois et al. 1997; Scott and Crossman 1973) and thus their young life stages were not unexpected at Kewaunee Power Station.

4.2.5 Historical Entrainment Studies

A previous entrainment study was conducted at Kewaunee Power Station from April 1975 to March 1976 by NALCO (undated). Annual entrainment estimates from that study are provided in Table 33. Two-thirds of the estimated 66 million organisms entrained during that study were alewife eggs. Rainbow smelt eggs, larvae, and juveniles accounted for an additional 30 percent of the total entrained.

The total estimated number (X 10^6) of forms common to one or both of the historical and 2006 studies is compared below (data derived from Tables 26 and 33).

Species	1975 – 1976	2006
Fish eggs	52.627	25.28
Rainbow smelt juveniles	9.715	3.22
Rainbow smelt larvae	2.764	1.32
Alewife juveniles	0.393	0.29
Alewife larvae	0.271	3.52
Common carp larvae	0.237	5.40
Burbot larvae	0.076	7.82
Slimy sculpin larvae	0.085	0.00
Coregoninae (whitefish) larvae	0.076	0.80

Catostomidae (sucker) larvae	0.016	0.12
Total Ichthyoplankton	66.26	54.70

In terms of total number of young life stages of fish estimated entrained, the two study results were quite similar, at 55 – 66 million entrained. However, there were some notable annual differences for some species. Rainbow smelt larvae and juveniles were nearly three times as abundant during the 1975 – 1976 study, and the estimate of fish eggs entrained was twice as high in the earlier study. Conversely, abundances of alewife larvae, common carp larvae, burbot larvae, Coregoninae larvae, and Catostomidae larvae were greater in 2006 by factors ranging from 7 to 103.

These differences may in large part reflect changes in species abundances in Lake Michigan in the intervening years between the studies. In the earlier discussion of impingement in this report, it was noted that abundance of burbot was higher in 2006 – 2007, and this is consistent with the entrainment comparison. Similarly, rainbow smelt and slimy sculpin were markedly lower in impingement abundance, and again this is consistent with the entrainment comparison. Alewife, although reduced in abundance lake-wide (Bunnell et al. 2007), were apparently locally abundant near Kewaunee during the study. Unlike impingement, where factors other than abundance can affect impingement rates, entrainment abundance generally reflects water column abundance in the vicinity of the power station.

4.2.6 Entrainment Summary

- Entrainment and ambient (Lake Michigan) ichthyoplankton and invertebrate studies were carried out at Kewaunee Power Station from March 2006 through February 2007. Sampling was done weekly from March through August 2006, weather permitting, and twice a month otherwise. Entrainment samples were collected from mid-depth in the discharge channel with a 0.5-M diameter conical plankton net, and ambient samples consisted of mid-depth (inshore) or oblique tows (offshore) with a double-net frame (0.5-M diameter).

- Thirty-five taxa/life stages of ichthyoplankton and three taxa of invertebrates were entrained during the study. The invertebrate *Gammarus* sp. accounted for nearly 94 percent of entrained organisms on an annual density basis. Unidentified fish eggs were next in abundance at 2.9 percent. Burbot, common carp, and alewife larvae were next in abundance and together composed nearly 2 percent of entrained organisms.

- Entrainment samples contained fish eggs and/or larvae during April through August 2006, with the greatest density (fish eggs) in June. Invertebrates, particularly *Gammarus* sp., were present in all months with a peak in September 2006.

- Based on maximum cooling-water flow at Kewaunee Power Station, an estimated 1.55 billion organisms were entrained during the study year. The vast majority of these (1.5 billion) were invertebrates, primarily *Gammarus* sp. Of 55 million ichthyoplankton forms entrained, eggs (25.3 million), burbot larvae (7.8 million), common carp larvae (5.4 million), alewife larvae (3.5 million), and rainbow smelt juveniles (3.2 million) were most abundant.

- Many of the same taxa were recorded in both entrainment and ambient (lake) sampling. Densities tended to be higher in entrainment samples for some of the more common taxa.

- Species know to spawn in relatively shallow, inshore areas, which were entrained as larvae (e.g. alewife, common carp, ninespine stickleback, rainbow smelt, round goby, burbot, and white sucker), were all occasionally to commonly encountered in the ambient juvenile/adult sampling program.

- Some differences were noted between the results of the 2006 – 2007 entrainment study and the 1975 – 1976 entrainment study. Fish eggs and rainbow smelt larvae and juveniles were more than twice as abundant in 1975 – 1976. Conversely, abundances of alewife, common carp, burbot, whitefish, and sucker larvae were greater in 2006 – 2007. These differences were attributed to fish community changes in Lake Michigan in the years between the studies.

- The fish collected in all of the studies in 2006 – 2007 were considered representative for that year.

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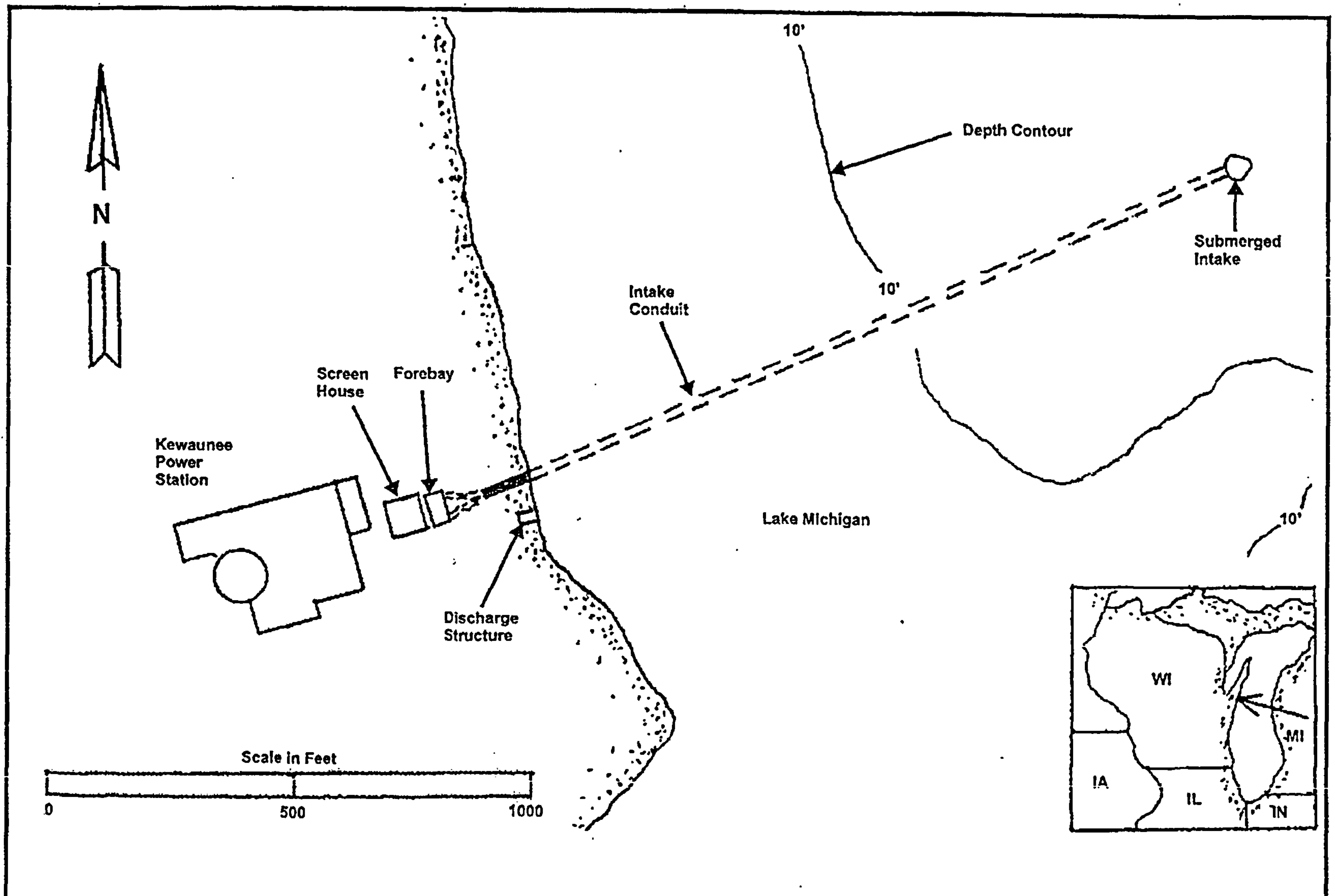

Figure 1. Schematic Representation of Kewaunee Power Station Intake and Discharge Structures.

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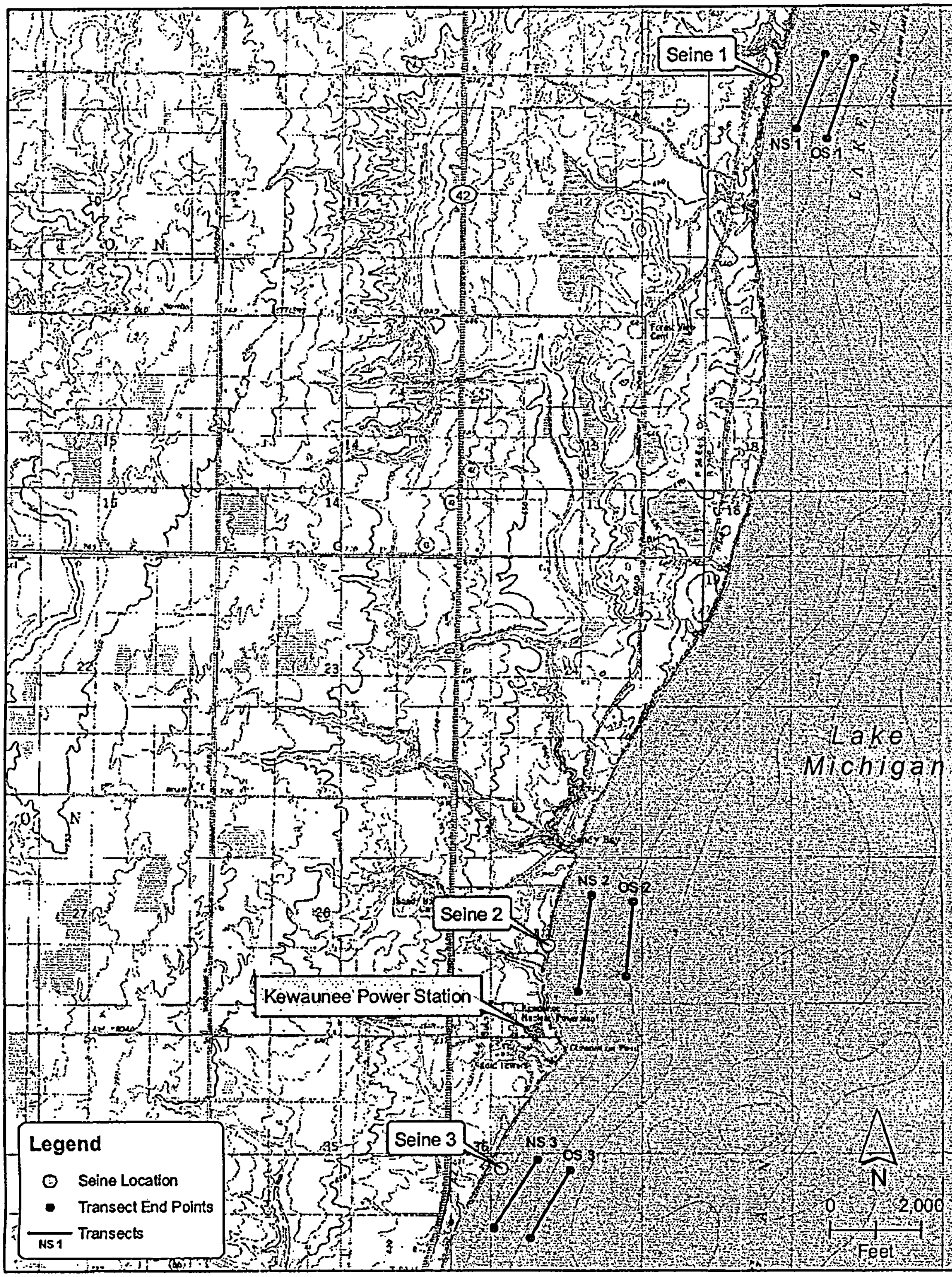

Figure 2. Vicinity of Kewaunee Power Station Showing Ambient Sampling Locations.

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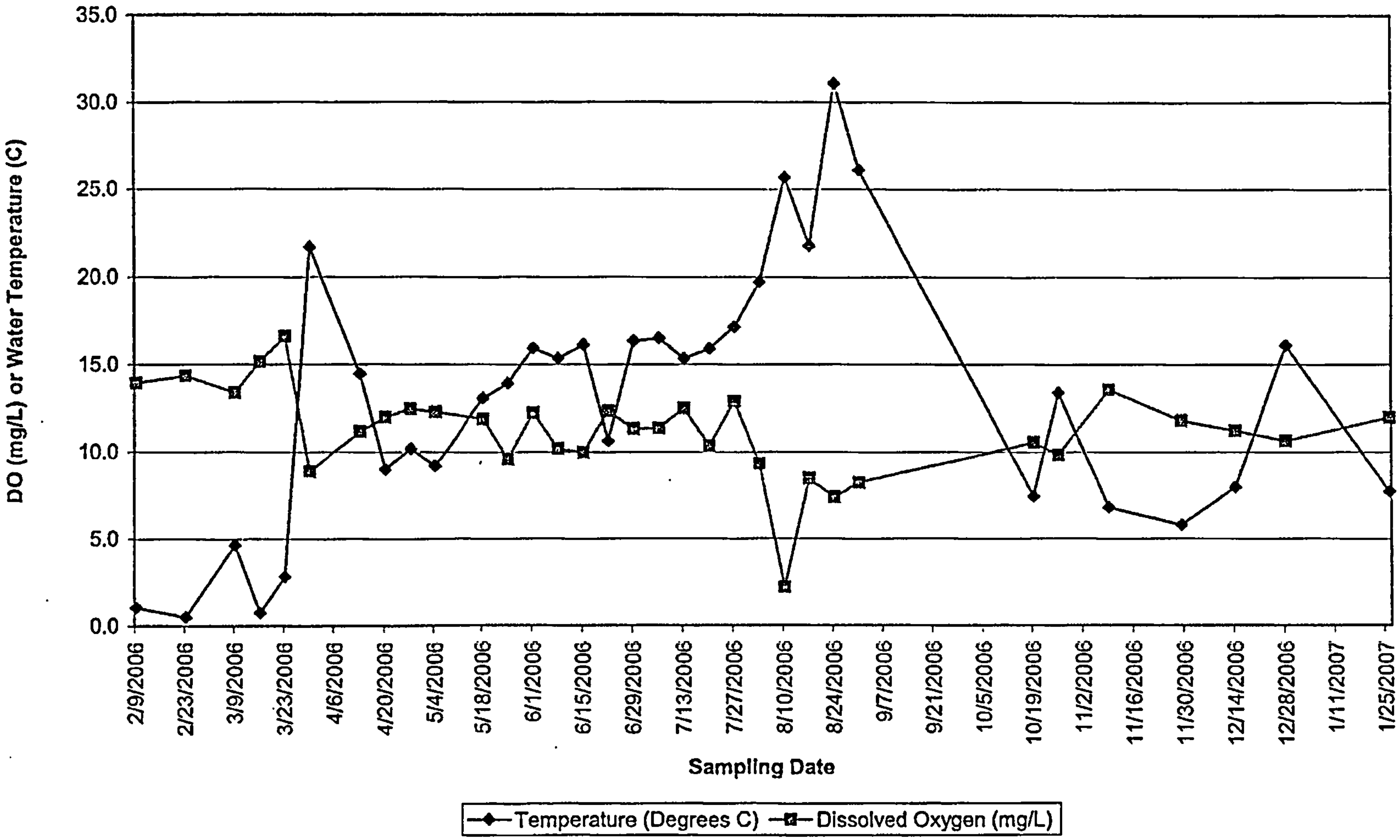
Figure 3 Relationship of Dissolved Oxygen (DO) and Water Temperature Measured in Conjunction with Impingement Sampling



Number Entrained per 100 Cubic Meters

Sample Set:
Burbot yolk-sac larvae
4/27-28/2006

	Rep A	Rep B	Average of Replicates
10am	23.7	32.3	28.0
4PM	45.0	53.3	49.2
10PM	59.3	74.3	66.8
4AM	58.8	45.4	52.1
		24-HOUR AVERAGE=	49.0

Maximum plant flow in 24 hours = 2,183,568 M^3

Total larvae entrained in the 24-hour period= 2,183,568 M^3 X 49.0/100 M^3 = 1,069,948 larvae

Calendar days represented by the 4/27-28/2006 sample set = 7 days

Total estimated larvae entrained during the 7-day period represented by the 4/27-28/2006 sample set = 7 days X 1,069,948 = 7,489,636 larvae

Total estimated larvae entrained during the study year = 7,489,636 larvae entrained in 4/27-28/2006 7-day extrapolation period

PLUS

333,364 larvae entrained during remaining 36 extrapolation periods

= 7,823,000 larvae estimated entrained during the study year

Figure 4 Entrainment Calculation Schematic: Extrapolation of Burbot Larvae Numbers from a Single Sampling Event to the Annual Total, Kewaunee Power Station

TABLE 1 LIST OF COMMON AND SCIENTIFIC NAMES OF FISH AND SHELLFISH MENTIONED IN THIS REPORT

Family		Common Name	Scientific name
Petromyzontidae	Lampreys	Sea lamprey	Petromyzon marinus
		Silver lamprey	Ichthyomyzon unicuspis
Clupeidae	Herrings	Alewife	Alosa pseudoharengus
		Gizzard shad	Dorosoma cepedianum
Cyprinidae	Carps and minnows	Common carp	Cyprinus carpio
		Lake chub	Couesius plumbeus
		Brassy minnow	Hybognathus hankinsoni
		Common shiner	Luxilus cornutus
		Emerald shiner	Notropis atherinoides
		Spottail shiner	Notropis hudsonius
		Fathead minnow	Pimephales promelas
		Longnose dace	Rhinichthys cataractae
		Blacknose dace	Rhinichthys atratulus
		Creek chub	Semotilus atromaculatus
Catostomidae	Suckers	White sucker	Catostomus commersonii
		Longnose sucker	Catostomus catostomus
		Shorthead redhorse	Moxostoma macrolepidotum
Ictaluridae	North American catfishes	Yellow bullhead	Ameiurus natalis
		Brown bullhead	Ameiurus nebulosus
		Black bullhead	Ameiurus melas
		Channel catfish	Ictalurus punctatus
Esocidae	Pikes	Northern pike	Esox lucius
Osmeridae	Smelts	Rainbow smelt	Osmerus mordax
Salmonidae	Trouts and salmons	Lake whitefish	Coregonus clupeaformis
		Bloater	Coregonus hoyi
		Chinook salmon	Oncorhynchus tshawytscha
		Coho salmon	Oncorhynchus kisutch
		Rainbow trout	Oncorhynchus mykiss
		Round whitefish	Prosopium cylindraceum
		Brown trout	Salmo trutta
		Lake trout	Salvelinus namaycush
		Brook trout	Salvelinus fontinalis
Percopsidae	Trout-perches	Trout-perch	Percopsis omiscomaycus
Gadidae	Cods	Burbot	Lota lota
Fundulidae	Topminnows	Banded killifish	Fundulus diaphanus
Gasterosteidae	Sticklebacks	Threespine stickleback	Gasterosteus aculeatus
		Ninespine stickleback	Pungitius pungitius

TABLE 1 (Continued)

	Family	Common Name	Scientific name
Cottidae	Sculpins	Mottled sculpin Slimy sculpin Deepwater sculpin	Cottus bairdii Cottus cognatus Myoxocephalus thompsonii
Moronidae	Temperate basses	White perch Yellow bass	Morone americana Morone mississippiensis
Centrarchidae	Sunfishes	Pumpkinseed Bluegill Smallmouth bass	Lepomis gibbosus Lepomis macrochirus Micropterus dolomieu
Percidae	Perches	Yellow perch	Perca flavescens
Gobiidae	Gobies	Round goby	Neogobius melanostomus
Cambaridae	Crayfish	Northern clearwater crayfish	Orconectes propinquus
Mysidae	Opposum shrimps	Opposum shrimp Bloody-red mysid	Mysis relicta Hemimysis anomala
Haustoriidae	Amphipods	Amphipod	Diporeia affinis
Gammaridae	Amphipods	Amphipod	Gammarus spp.
Talitridae	Amphipods	Amphipod	Hyalella azteca
Dreissenidae	Zebra and Quagga mussels	Zebra mussel Quagga mussel	Dreissena polymorpha Dreissena bugensis

Note: Finfish names follow Nelson et al. 2004; sources of invertebrate names include Smith (2001), Kipp and Ricciardi (2007), Fetzner (2006), Central Michigan University (2007), and GLERL (2007).

TABLE 2 RANKED ABUNDANCE AND PERCENT COMPOSITION OF IMPINGED FISH AND CRAYFISH COLLECTED AT KEWAUNEE POWER STATION, FEBRUARY 2006 -- JANUARY 2007

Species	Number	Percent	Weight (g)	Percent
Alewife	690,402	99.741	2,666,686.5	94.755
Ninespine stickleback	572	0.083	1,457.0	0.052
Rainbow smelt	300	0.043	1,899.8	0.068
Yellow perch	164	0.024	2,277.1	0.081
Mottled sculpin	145	0.021	1,035.8	0.037
Spottail shiner	125	0.018	738.1	0.026
Northern clearwater crayfish	123	0.018	462.2	0.016
Longnose sucker	62	0.009	19,317.5	0.686
Threespine stickleback	55	0.008	93.8	0.003
White sucker	52	0.008	42,053.8	1.494
Longnose dace	50	0.007	379.4	0.013
Gizzard shad	41	0.006	422.6	0.015
Burbot	27	0.004	17,423.4	0.619
Slimy sculpin	18	0.003	112.6	0.004
Round goby	12	0.002	284.9	0.010
Channel catfish	8	0.001	5,599.6	0.199
Lake trout	7	0.001	19,300.3	0.686
Round whitefish	7	0.001	4,056.0	0.144
Black bullhead	3	<0.001	571.5	0.020
Common carp	3	<0.001	16,505.8	0.586
Smallmouth bass	3	<0.001	126.2	0.004
Brown trout	2	<0.001	3,520.3	0.125
Chinook salmon	2	<0.001	8,120.3	0.289
Lake whitefish	2	<0.001	379.6	0.013
Bloater	1	<0.001	6.0	<0.001
Bluegill	1	<0.001	60.0	0.002
Catostominae	1	<0.001	18.7	0.001
Cottidae	1	<0.001	5.6	<0.001
Creek chub	1	<0.001	2.0	<0.001
Pumpkinseed	1	<0.001	36.0	0.001
Rock bass	1	<0.001	52.5	0.002
Shorthead redhorse	1	<0.001	1,240.3	0.044
Silver lamprey	1	<0.001	59.5	0.002
White perch	1	<0.001	4.8	<0.001
Total	**692,195**	**100**	**2,814,309.5**	**100**

TABLE 3 MONTHLY IMPINGEMENT (SAMPLING) CATCH AT KEWAUNEE POWER STATION, FEBRUARY 2006 - JANUARY 2007

	2006											2007	Annual
Taxon/Species	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Total
Silver lamprey			1										1
Alewife			1,182	37,932	378,358	248,961	4,613		9,251	10,097	8		690,402
Gizzard shad									2	4	34	1	41
Common carp	1	1										1	3
Spottail shiner		1					113		1		2	8	125
Longnose dace	2	2	3	2	1	2	33		3		1	1	50
Creek chub							1						1
White sucker	2	7	5	2	7	10	17			2			52
Longnose sucker	1	1			11	14	33			1		1	62
Shorthead redhorse					1			N					1
Catostominae								O	1				1
Black bullhead	1							T			2		3
Channel catfish	3						1			1	2	1	8
Rainbow smelt		2	3	46	192	14	5	S	3	1	18	16	300
Lake whitefish			1					A			1		2
Bloater								M			1		1
Chinook salmon					1		1	P					2
Round whitefish		1				1		L			2	3	7
Brown trout							1	E				1	2
Lake trout					2		5	D					7
Burbot	2	7	3	1	1	2	8				2	1	27
Threespine stickleback		1	2	5	16	26				1		4	55
Ninespine stickleback			2	86	458	19	6					1	572
Mottled sculpin	14	5	5	10	38	16	37		17		1	2	145
Slimy sculpin	3	2	1	8		4							18
Cottidae										1			1
White perch									1				1
Pumpkinseed							1						1
Bluegill												1	1
Rock bass												1	1
Smallmouth bass						1	2						3
Yellow perch	5	1	1		26	4	48		7	3	18	51	164
Round goby			5				5		2				12
Northern clearwater crayfish	1		1		1	35	75		1			9	123
Totals	35	31	1,215	38,092	379,113	249,109	5,005	0	9,289	10,111	92	103	692,195

TABLE 4 LENGTH-FREQUENCY DISTRIBUTION OF ALEWIFE IMPINGED AT KEWAUNEE POWER STATION

Date	N	Mean Length (mm)	50 to 59.9 mm	60 to 69.9 mm	70 to 79.9 mm	80 to 89.9 mm	90 to 99.9 mm	100 to 109.9 mm	110 to 119.9 mm	120 to 129.9 mm	130 to 139.9 mm	140 to 149.9 mm	150 to 159.9 mm	160 to 169.9 mm	170 to 179.9 mm	180 to 189.9 mm
02/09/06																
02/23/06																
03/09/06																
03/16/06																
03/23/06																
03/30/06																
04/13/06	3	66		2	1											
04/20/06	50	83		3	23	12	8	2		1			1			
04/27/06	50	83	1	5	20	15	4		2	1			1	1		
05/04/06	50	82		2	23	14	6	2	3							
05/18/06	51	82		1	21	20	4	5								
05/25/06	51	82	1	1	22	13	11	1	2							
06/01/06	50	86			19	17	7	4		1	1			1		
06/08/06	50	85		3	14	16	12	2	3							
06/15/06	50	88		3	10	17	11	5	3		1					
06/22/06	50	84		2	20	12	9	5	2							
06/29/06	50	90		2	15	8	9	11	4			1				
07/06/06	50	103			2	8	6	16	11	4	3					
07/13/06	50	102			3	7	14	13	8	2	1	1	1			
07/20/06	50	90		1	9	21	5	9	3	1		1				
07/27/06	50	89			20	14	5	5	3	1				2		
08/03/06	50	115			1	3	12	9	13	2	2	1		3	4	
08/10/06	50	120			2	4	5	12	9	2	1	4	5	3	2	1
08/17/06	50	124			5		8	12	5		2		4	7	6	1
08/24/06	52	112		1	2	13	8	6	7	1	1	2	3	5	3	
08/31/06	18	90	1	3	2	3	5	1		1		1	1			
10/19/06	50	90		2	11	11	16	6	2		1			1		
10/26/06	50	86			11	19	14	4	2							
11/09/06	50	83		2	16	22	8	2								
11/29/06	4	79		1	1	1	1									
12/14/06	7	77			6	1										
12/28/06	1	83				1										
01/11/07																
01/26/07																
Total	1087		3	34	279	272	188	132	82	17	13	11	16	23	15	2

TABLE 5 LENGTH-FREQUENCY DISTRIBUTION OF YELLOW PERCH IMPINGED AT KEWAUNEE POWER STATION

Date	N	Mean Length (mm)	50 to 69.9 mm	70 to 89.9 mm	90 to 109.9 mm	110 to 129.9 mm	130 to 149.9 mm	150 to 169.9 mm	170 to 189.9 mm	190 to 209.9 mm	210 to 229.9 mm	230 to 249.9 mm	250 to 269.9 mm	270 to 289.9 mm	290 to 309.9 mm	310 to 329.9 mm	330 to 349.9 mm
02/09/06	5	83		4	1												
02/23/06																	
03/09/06																	
03/16/06																	
03/23/06	1	66	1														
03/30/06																	
04/13/06	1	100			1												
04/20/06																	
04/27/06																	
05/04/06																	
05/18/06																	
05/25/06																	
06/01/06																	
06/08/06	1	90			1												
06/15/06																	
06/22/06	5	73	2	3													
06/29/06	1	81		1													
07/06/06																	
07/13/06																	
07/20/06																	
07/27/06	4	212		1							1			1	1		
08/03/06	2	98			2												
08/10/06	12	89	1	6	2	3											
08/17/06	23	111		7	11	3							1				1
08/24/06	5	110			3	2											
08/31/06	6	59	6														
10/19/06	1	80		1													
10/26/06	6	87	1	4			1										
11/09/06	3	131				2		1									
11/29/06																	
12/14/06	11	74	4	6	1												
12/28/06	7	75	2	4	1												
01/11/07	50	71	16	33		1											
01/26/07	1	80		1													
Total	145		33	71	23	11	1	1	0	0	1	0	1	1	1	0	1

TABLE 6 MONTHLY AND ANNUAL IMPINGEMENT ESTIMATES AT KEWAUNEE POWER STATION, FEBRUARY 2006 - JANUARY 2007

Species	2006											2007	Total Annual Estimate
	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	
Silver lamprey	0	0	10	0	0	0	0	0	0	0	0	0	10
Alewife	0	0	8,283	1,054,966	2,048,767	1,837,619	31,191	33,200	251,538	326,806	314	8	5,592,692
Gizzard shad	0	0	0	0	0	0	0	0	36	116	956	108	1,216
Common carp	30	14	0	0	0	0	0	0	0	0	0	26	70
Spottail shiner	0	14	0	0	0	0	722	575	18	4	50	232	1,615
Longnose dace	52	32	33	27	7	16	202	225	54	12	20	34	714
Creek chub	0	0	0	0	0	0	4	25	0	0	0	0	29
White sucker	60	102	65	48	41	79	109	25	0	56	12	0	597
Longnose sucker	26	14	12	0	71	118	208	75	0	26	12	28	590
Shorthead redhorse	0	0	0	0	7	0	0	0	0	0	0	0	7
Catostominae	0	0	0	0	0	0	0	0	18	4	0	0	22
Black bullhead	30	0	0	0	0	0	0	0	0	0	60	0	90
Channel catfish	86	4	0	0	0	1	6	0	0	26	62	34	219
Rainbow smelt	0	28	24	803	1,119	104	23	100	54	42	510	472	3,279
Lake whitefish	0	0	10	0	0	0	0	0	0	0	20	8	38
Bloater	0	0	0	0	0	0	0	0	0	0	20	8	28
Chinook salmon	0	0	0	0	7	0	4	25	0	0	0	0	36
Round whitefish	0	20	0	0	0	7	0	0	0	0	50	92	169
Brown trout	0	0	0	0	0	0	7	0	0	0	0	28	35
Lake trout	0	0	0	0	12	2	35	0	0	0	0	0	49
Burbot	52	116	48	7	7	14	56	0	0	0	40	44	384
Threespine stickleback	0	14	17	50	112	182	0	0	0	26	12	112	525
Ninespine stickleback	0	0	14	1,247	2,983	139	37	25	0	0	0	28	4,473
Mottled sculpin	384	94	77	213	239	115	244	170	488	40	20	64	2,148
Slimy sculpin	90	28	10	121	0	28	0	0	0	0	0	0	277
Cottidae	0	0	0	0	0	0	0	0	0	26	12	0	38
White perch	0	0	0	0	0	0	0	0	18	4	0	0	22
Pumpkinseed	0	0	0	0	0	0	4	25	0	0	0	0	29
Bluegill	0	0	0	0	0	0	0	0	0	0	0	28	28
Smallmouth bass	0	0	0	0	0	7	11	25	0	0	0	0	43
Rock bass	0	0	0	0	0	0	0	0	0	0	0	26	26
Yellow perch	150	14	10	0	180	32	316	160	152	114	470	1,482	3,080
Round goby	0	0	38	0	0	0	35	0	36	8	0	0	117
Northern clearwater crayfish	26	4	7	0	7	288	479	25	18	4	0	246	1,104
Totals	986	498	8,658	1,057,482	2,053,559	1,838,751	33,693	34,680	252,430	327,314	2,640	3,108	5,613,799

TABLE 7 WATER QUALITY VALUES ASSOCIATED WITH IMPINGEMENT SAMPLING, KEWAUNEE POWER STATION, FEBRUARY 2006 – JANUARY 2007

Sampling Event	Temperature (Degrees C)	Dissolved Oxygen (mg/L)	pH (pH units)	Conductivity (µs/cm)
02/09/06	1.1	13.9	8.9	210
02/23/06	0.5	14.4	8.2	294
03/09/06	4.6	13.4	8.2	327
03/16/06	0.8	15.2	8.4	309
03/23/06	2.8	16.6	8.2	327
03/30/06	21.7	8.9	8.4	296
04/13/06	14.5	11.2	8.3	273
04/20/06	9.0	12.0	8.6	306
04/27/06	10.2	12.5	8.5	321
05/04/06	9.2	12.3	8.3	280
05/18/06	13.0	11.9	8.3	497
05/25/06	13.9	9.6	8.4	281
06/01/06	15.9	12.2	8.5	258
06/08/06	15.3	10.2	8.5	299
06/15/06	16.1	10.0	8.5	281
06/22/06	10.6	12.3	8.5	206
06/29/06	16.3	11.3	8.6	287
07/06/06	16.5	11.3	8.4	281
07/13/06	15.3	12.5	8.6	227
07/20/06	15.9	10.3	8.5	235
07/27/06	17.1	12.9	8.6	243
08/03/06	19.7	9.3	8.6	260
08/10/06	25.7	2.2	7.8	280
08/17/06	21.8	8.5	8.5	276
08/24/06	31.1	7.4	8.3	291
08/31/06	26.1	8.2	8.2	290
10/19/06	7.4	10.5	8.7	No Data*
10/26/06	13.4	9.8	8.2	295
11/09/06	6.8	13.6	8.2	298
11/29/06	5.8	11.8	8.3	275
12/14/06	8.0	11.2	8.2	272
12/28/06	16.1	10.6	8.3	274
01/26/07	7.7	12.0	8.4	296

*No Data due to equipment malfunction

TABLE 8 SUMMARY OF AMBIENT NEAR SHORE GILL NET DATA AT KEWAUNEE POWER STATION: NUMBER OF FISH CAUGHT PER HOUR BY SAMPLING STATION AND DATE

Species	4/10/2006			4/24/2006			5/8/2006			5/22/2006			6/12/2006			6/26/2006			7/17/2006		
Sampling Stations =	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Alewife						0.3	1.8	29.5	36.4	14.3	15.3	22.9	1.8	0.3	0.2	0.8	3.4	0.5	0.1	0.1	0.1
Gizzard shad			0.1		0.04					0.1	0.1										
Common carp																					
Longnose dace								0.2					0.7	0.2		0.5	0.1	0.1			
Spottail shiner								0.1			0.1		0.1	0.3		0.2	0.3	0.4			0.04
White sucker		0.1	0.1		0.2	0.1	0.1	0.1	0.4	0.2	0.1	0.6	0.3	0.3	0.3	0.1	0.3	1.0	0.3	0.1	0.3
Longnose sucker					0.04		0.6	1.4	1.2	0.9	0.2	0.5	0.3	0.8	1.2	0.3	0.3	1.4		0.1	0.1
Black bullhead																					
Rainbow smelt	0.1													0.1							
Brown trout		0.1			0.04				0.2		0.1	0.1	0.1		0.1	0.1	0.1	0.2			
Rainbow trout														0.1							
Lake trout			0.7	0.0			0.5	0.4	0.5	0.2	0.1			0.1			0.1				
Chinook salmon									0.1	0.2	0.1						0.1	0.1			0.04
Coho salmon																					
Bloater																					
Lake whitefish							0.1														
Round whitefish	0.4	0.1	0.1			0.1	0.1	0.2	0.1	0.2	0.1	0.1									
Burbot										0.1				0.1							0.04
White perch																					
Yellow perch														0.2	0.3		0.1	1.0	0.2	0.0	0.7
Round goby											0.1			0.1							
Northern clearwater crayfish																					
Total	0.5	0.4	1.1	0.0	0.3	0.4	3.1	31.8	38.9	16.1	16.2	24.1	3.2	2.1	2.0	2.0	4.7	4.6	0.6	0.3	1.4

Species	7/31/2006			8/14/2006			8/28/2006			9/13/2006			9/25/2006			10/9/2006			10/23/2006		
Sampling Stations =	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Alewife	0.04	0.04			0.04		0.2		0.04	0.2	0.2	0.2	4.4	0.8	5.7			0.1	11.1	19.7	0.3
Gizzard shad							0.1	0.3	0.1	0.1	0.1	0.1							0.1		0.6
Common carp								0.1		0.1											
Longnose dace					0.04		0.1		0.0												
Spottail shiner					0.04		0.4	0.4	0.8	2.0	0.6	0.3				0.4		0.1			
White sucker		0.04	0.2		0.04	0.1	0.8	0.7	0.3	0.4	0.8	0.6	0.2	0.2	0.7	0.3	0.2	0.2	0.4	0.3	0.2
Longnose sucker		0.04		0.2	0.1	0.1	0.2	0.1	0.4	0.7	0.5	0.3	0.3	0.6	1.2	0.1	0.2	0.4	0.4	0.2	0.3
Black bullhead											0.1							0.1			
Rainbow smelt																0.1					
Brown trout										0.2	0.1		0.04	0.1					0.4	0.5	0.2
Rainbow trout																					
Lake trout	0.1	0.1	0.1										0.7	0.7	0.6	0.2	0.04	0.1	0.1		
Chinook salmon		0.2	0.04					0.04		0.1	0.1	0.1									
Coho salmon											0.1						0.04			0.1	
Bloater							0.04														
Lake whitefish																					
Round whitefish										0.1		0.04	0.1	0.2	0.2		0.04		0.1	0.1	0.1
Burbot						0.04															
White perch								0.04								0.1	0.04				
Yellow perch		0.1	0.2		0.04																
Round goby				0.1														0.1	0.1		
Northern clearwater crayfish			0.04																		
Total	0.1	0.5	0.8	0.3	0.3	0.2	1.9	1.6	1.4	3.8	2.4	1.5	5.8	2.8	8.4	1.0	0.5	1.0	12.6	20.9	1.7

TABLE 9 SUMMARY OF AMBIENT OFFSHORE GILL NET DATA AT KEWAUNEE POWER STATION: NUMBER OF FISH CAUGHT PER HOUR BY SAMPLING STATION AND DATE

Species	4/10/2006			4/24/2006			5/8/2006			5/22/2006			6/12/2006		
Sampling Stations =	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Alewife							0.6	22.7	34.8	16.1	15.6	16.4	1.2		0.2
Gizzard shad											0.1				
Common carp															
Longnose dace											0.1		0.1		
Spottail shiner															
Lake chub													0.1		
White sucker				0.1							0.1		0.2	0.1	0.1
Longnose sucker								0.6	0.2	0.2	0.3	0.1	0.5	0.1	0.7
Rainbow smelt												0.1	0.1		
Brown trout		0.1													
Rainbow trout															
Lake trout		0.3		0.04				0.1	0.2	0.1		0.1			0.1
Chinook salmon															
Round whitefish	0.7		0.3	0.2				0.1	0.2	0.7	0.4	0.2	0.1		
Burbot				0.04							0.1				
Pumpkinseed															
Smallmouth bass															
Yellow perch													0.1	0.1	0.2
Round goby															
Northern clearwater crayfish															
Total	0.7	0.4	0.3	0.4	0.0	0.0	0.6	23.6	35.4	17.1	16.6	16.9	2.2	0.3	1.2

Species	6/26/2006			7/17/2006			7/31/2006			8/14/2006			8/28/2006		
Sampling Stations =	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Alewife	1.9	0.2	0.3	0.0	0.1	0.1	0.0	1.4	0.1				0.2	0.04	0.1
Gizzard shad														0.2	
Common carp														0.04	
Longnose dace															
Spottail shiner													0.04	0.1	
Lake chub													0.0		
White sucker	0.2	0.2	0.2	0.1	0.04	0.1		0.1	0.3	0.0	0.0	0.1	0.5	0.5	0.5
Longnose sucker	0.3	0.1	0.4			0.1		0.3	0.1	0.0	0.1		0.1	0.1	0.1
Rainbow smelt															
Brown trout		0.1													
Rainbow trout															
Lake trout							0.04								
Chinook salmon		0.1	0.1			0.1		0.1							
Round whitefish	0.1	0.1							0.04						
Burbot															
Pumpkinseed															
Smallmouth bass															
Yellow perch	0.2	0.1	0.4	0.1		0.5	0.1		0.4						
Round goby										0.04					
Northern clearwater crayfish									0.04		0.04				
Total	2.7	0.6	1.2	0.3	0.1	0.8	0.2	1.9	1.0	0.1	0.2	0.1	0.8	0.9	0.7

Species	9/13/2006			9/25/2006			10/9/2006			10/23/2006		
Sampling Stations =	1	2	3	1	2	3	1	2	3	1	2	3
Alewife	0.2		0.2	3.6	0.8	3.3		0.2	0.3	8.2	9.1	0.1
Gizzard shad	0.1										0.1	
Common carp		0.1	0.04									
Longnose dace	0.1		0.04									
Spottail shiner	0.5	0.2	0.1					0.04				0.1
Lake chub		0.1										
White sucker	0.6	0.5	0.4	0.1	0.3	0.3	0.3	0.3	0.9	0.3	0.1	
Longnose sucker	0.5	1.4	0.5	0.4	0.3	0.4	0.5	0.4	0.9	0.1	0.1	
Rainbow smelt		0.1										
Brown trout		0.1								0.1	0.1	0.1
Rainbow trout									0.1			
Lake trout			0.04	0.5	0.2	0.5	0.3	0.1	0.2	0.1	0.1	0.1
Chinook salmon	0.1	0.1	0.04	0.04								0.2
Round whitefish	0.1	0.1	0.1	0.4	0.1	0.3	0.1	0.1	0.3		0.1	
Burbot			0.04			0.1						0.1
Pumpkinseed		0.1										
Smallmouth bass	0.1											
Yellow perch												
Round goby		0.1										
Northern clearwater crayfish												
Total	2.3	2.6	1.6	4.9	1.7	4.9	1.2	1.2	2.8	8.7	9.5	0.6

TABLE 10 AVERAGE CATCH PER GILL NET HOUR
KEWAUNEE POWER STATION
APRIL - OCTOBER 2006

Species	Sampling Stations		
	1	2	3
Alewife	2.378	4.272	4.374
Gizzard shad	0.015	0.029	0.033
Common carp	0.002	0.008	0.001
Longnose dace	0.051	0.018	0.005
Spottail shiner	0.130	0.077	0.055
Lake chub	0.003	0.003	0.000
White sucker	0.196	0.191	0.289
Longnose sucker	0.236	0.287	0.373
Black bullhead	0.000	0.002	0.002
Rainbow smelt	0.008	0.005	0.002
Brown trout	0.031	0.046	0.026
Rainbow trout	0.000	0.002	0.004
Lake trout	0.101	0.075	0.117
Chinook salmon	0.014	0.021	0.023
Coho salmon	0.000	0.005	0.000
Bloater	0.001	0.000	0.000
Lake whitefish	0.003	0.000	0.000
Round whitefish	0.114	0.060	0.077
Burbot	0.003	0.004	0.010
Pumpkinseed	0.000	0.002	0.000
Smallmouth bass	0.002	0.000	0.000
White perch	0.002	0.003	0.000
Yellow perch	0.024	0.023	0.128
Round goby	0.008	0.007	0.002
Northern clearwater crayfish	0.000	0.001	0.003
Average =	0.133	0.206	0.221

Note: Near shore and offshore locations combined

TABLE 11 AVERAGE CATCH PER HOUR AT NEAR SHORE AND OFFSHORE GILL NET LOCATIONS

Species/ Taxon	Sampling Area	
	Near Shore	Offshore
Alewife	4.071	3.278
Gizzard shad	0.042	0.009
Common carp	0.003	0.004
Longnose dace	0.043	0.006
Spottail shiner	0.149	0.025
Lake chub	0.000	0.004
White sucker	0.275	0.176
Longnose sucker	0.359	0.238
Black bullhead	0.002	0.000
Rainbow smelt	0.007	0.004
Brown trout	0.057	0.012
Rainbow trout	0.001	0.002
Lake trout	0.126	0.069
Chinook salmon	0.022	0.017
Coho salmon	0.004	0.000
Bloater	0.001	0.000
Lake whitefish	0.002	0.000
Round whitefish	0.051	0.116
Burbot	0.004	0.007
White perch	0.003	0.000
Pumpkinseed	0.000	0.001
Smallmouth bass	0.000	0.001
Yellow perch	0.068	0.048
Round goby	0.009	0.002
Northern clearwater crayfish	0.001	0.002
Location Average	0.212	0.161

Note: North to south sampling locations 1, 2, and 3 combined

TABLE 12 SUMMARY OF AMBIENT SEINE DATA AT KEWAUNEE POWER STATION: MEAN NUMBER OF FISH CAUGHT BY SAMPLING STATION AND DATE

Species	4/10/2006			4/24/2006			5/8/2006			5/22/2006			6/12/2006			6/26/2006			7/17/2006		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Alewife				6.5		43	388	2	34	23		54	8.5	19	82	29	20	34	22	33	18
Common carp															0.5						
Emerald shiner							1			0.5				0.5			0.5				
Spottail shiner	0.5			1			0.5					0.5	1	0.5	1	1	7	0.5			0.5
Common shiner																					
Fathead minnow												0.5	0.5	1	1		0.5	1.5		0.5	
Lake chub														0.5							
Longnose dace			1							0.5		1.5	3.5	0.5	21	1.5	2	1	0.5	5.5	
Brassy minnow																					
White sucker														0.5							
Rainbow smelt	0.5			0.5	0.5	1	2.5		1			1	0.5	0.5	0.5	0.5	0.5				
Brown trout				0.5																	
Bloater																					
Banded killifish																					
Ninespine stickleback												0.5	0.5								
Threespine stickleback					0.5							3.5									
Mottled sculpin																					
Yellow perch																			0.5		
Round goby																					
Total	1	0	1	8.5	1	44	392	2	35	24	0	62	15	23	106	32	31	37	23	39	18

Species	7/31/2006			8/14/2006			8/28/2006			9/13/2006			9/25/2006			10/9/2006			10/23/2006		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Alewife	87	28	7.5	140	1		27	1	8.5				9.5	1	2.5						
Common carp																					
Emerald shiner							1				0 5									1	
Spottail shiner		0.5	1			1.5	8			0.5	3.5		3.5	2	6	1		0.5		0.5	
Common shiner											0.5			1	4						
Fathead minnow		4			0.5	0.5	1	0.5	1.5	1			1.5	0.5	1.5			1			
Lake chub		46			0.5						1							0.5			
Longnose dace	23	0.5			4	2.5	17	1	1		4		1	2.5	0.5	1.5		2.5			
Brassy minnow		0.5																			
White sucker																					
Rainbow smelt	1.5		0.5	0.5			0.5						8		0.5	0.5		0.5			
Brown trout																0.5					
Bloater																0.5		0.5	0.5	2.5	
Banded killifish													0.5								
Ninespine stickleback	1						0.5				0.5				0.5	1					
Threespine stickleback						0.5															
Mottled sculpin													0.5								
Yellow perch																					
Round goby	0.5																				
Total	113	77	9	141	6	5	55	2.5	11	1.5	10	0	25	7	16	5	0	5.5	0.5	4	0

TABLE 13 AVERAGE CATCH PER SEINE HAUL IN EACH SAMPLING AREA NEAR KEWAUNEE POWER STATION, APRIL - OCTOBER 2006

Species	Sampling Area 1	2	3
Alewife	52.82	7.32	20.11
Common carp	0.00	0.00	0.04
Lake chub	0.00	3.39	0.04
Brassy minnow	0.00	0.04	0.00
Common shiner	0.00	0.11	0.29
Emerald shiner	0.18	0.18	0.00
Spottail shiner	1.21	1.00	0.82
Fathead minnow	0.29	0.54	0.54
Longnose dace	3.39	1.43	2.18
White sucker	0.00	0.04	0.00
Rainbow smelt	1.11	0.11	0.36
Bloater	0.07	0.18	0.04
Brown trout	0.07	0.00	0.00
Banded killifish	0.04	0.00	0.00
Ninespine stickleback	0.21	0.04	0.07
Threespine stickleback	0.00	0.04	0.29
Mottled sculpin	0.04	0.00	0.00
Yellow perch	0.04	0.00	0.00
Round goby	0.04	0.00	0.00
Average =	3.13	0.76	1.30

TABLE 14 LENGTH-FREQUENCY DISTRIBUTION OF ALEWIFE COLLECTED DURING AMBIENT STUDIES AT KEWAUNEE POWER STATION

Date	N	Mean Length (mm)	20 to 29.9 mm	30 to 39.9 mm	40 to 49.9 mm	50 to 59.9 mm	60 to 69.9 mm	70 to 79.9 mm	80 to 89.9 mm	90 to 99.9 mm	100 to 109.9 mm	110 to 119.9 mm	120 to 129.9 mm	130 to 139.9 mm	140 to 149.9 mm	150 to 159.9 mm	160 to 169.9 mm	170 to 179.9 mm	190 to 199.9 mm	200 to 209.9 mm	210 to 219.9 mm
04/10/06																					
04/24/06	34	80				1	13	8	4	2		3	2	1							
05/08/06	133	95				1	25	8	7	5	11	56	19								1
05/22/06	156	100				2	16	29	14	3	7	61	21	1							2
06/12/06	116	93				2	17	32	13	8	3	22	13	4					1	1	
06/26/06	143	95					17	41	11	7	3	34	27	1			1	1			
07/17/06	44	96					5	16	8	1	1	11	1	1							
07/31/06	72	90				1	10	15	15	6	5	15	4				1				
08/14/06	33	67	27	5							1										
08/28/06	61	45	31	15	2					1	6	6									
09/13/06	21	101							1	6	11	3									
09/25/06	118	94		14	10	2				2	46	39	3	2							
10/09/06	10	106							1		5	4									
10/23/06	65	102								17	43	5									
Total	1006		58	34	12	9	103	149	74	58	142	259	90	10	0	0	2	1	1	1	3

TABLE 15 LENGTH-FREQUENCY DISTRIBUTION OF ROUND WHITEFISH COLLECTED DURING AMBIENT STUDIES AT KEWAUNEE POWER STATION

Date	N	Mean Length (mm)	270 to 289.9 mm	290 to 309.9 mm	310 to 329.9 mm	330 to 349.9 mm	350 to 369.9 mm	370 to 389.9 mm	390 to 409.9 mm	410 to 429.9 mm	430 to 449.9 mm	450 to 469.9 mm	470 to 489.9 mm	490 to 509.9 mm	510 to 529.9 mm
04/10/06	12	371	1		3	1	1	1		4	1				
04/24/06	5	398				1		1		2	1				
05/08/06	9	399			1	1		1	2	1	2	1			
05/22/06	34	405			4	3	1	1	4	10	7	2	1		1
06/12/06	1	440									1				
06/26/06	4	437								1	2	1			
07/17/06															
07/31/06	1	440									1				
08/14/06															
08/28/06															
09/13/06	10	429					1			3	3	3			
09/25/06	28	412				2	5		4	6	6	2	3		
10/09/06	8	380		1	1	1			2	2		1			
10/23/06	6	415					1			3	2				
Total	**118**		**1**	**1**	**9**	**9**	**9**	**4**	**12**	**32**	**26**	**10**	**4**	**0**	**1**

TABLE 16 LENGTH-FREQUENCY DISTRIBUTION OF WHITE SUCKER COLLECTED DURING AMBIENT STUDIES AT KEWAUNEE POWER STATION

Date	N	Mean Length (mm)	60 to 94.9 mm	95 to 129.9 mm	130 to 164.9 mm	165 to 199.9 mm	200 to 234.9 mm	235 to 269.9 mm	270 to 304.9 mm	305 to 339.9 mm	340 to 374.9 mm	375 to 409.9 mm	410 to 449.9 mm	445 to 479.9 mm	480 to 514.9 mm	515 to 549.9 mm	550 to 584.9 mm
04/10/06	2	428										1		1			
04/24/06	8	402						2		1	1			1	2	1	
05/08/06	6	502												3	1		2
05/22/06	19	493											3	5	5	3	3
06/12/06	26	456	1								2		2	13	4	2	2
06/26/06	40	475								1		1	5	16	10	4	3
07/17/06	23	486									1		2	7	5	6	2
07/31/06	16	481									1	1	1	6	1	5	1
08/14/06	8	418								1	2		1	3	1		
08/28/06	83	393					1	3	1	6	36	8	2	11	10	4	1
09/13/06	67	397					3	5	1	5	14	8	6	13	8	4	
09/25/06	39	477								1	2		4	15	4	10	3
10/09/06	34	438					2	1		1	7		5	5	3	7	3
10/23/06	24	477								1	2		2	6	4	7	2
Total	395		1	0	0	0	6	11	2	17	68	19	33	105	58	53	22

TABLE 17 LENGTH-FREQUENCY DISTRIBUTION OF LONGNOSE SUCKER COLLECTED DURIN AMBIENT STUDIES AT KEWAUNEE POWER STATION

Date	N	Mean Length (mm)	110 to 139.9 mm	140 to 169.9 mm	170 to 199.9 mm	200 to 229.9 mm	230 to 259.9 mm	260 to 289.9 mm	290 to 319.9 mm	320 to 349.9 mm	350 to 379.9 mm	380 to 409.9 mm	410 to 439.9 mm	440 to 469.9 mm	470 to 499.9 mm	500 to 529.9 mm	530 to 559.9 mm	560 to 589.9 mm
04/10/06																		
04/24/06	1	489													1			
05/08/06	51	358					9	4		4	14	9	5	4		1		1
05/22/06	40	290	7		1	1	13	1		4	3	3	1	4	1	1		
06/12/06	61	324				4	12	10	1	2	16	12	2	1	1			
06/26/06	45	295				2	16	11		1	10	4		1				
07/17/06	7	320					2	1			3	1						
07/31/06	10	291					6			1	2		1					
08/14/06	12	211	6				4						1	1				
08/28/06	24	280				2	9	7	2			3	1					
09/13/06	67	350				1	12	7	2	6	14	9	9	5	2			
09/25/06	62	330				1	17	3	3	10	12	7	4	4	1			
10/09/06	41	314				1	10	4	5	10	7	1	1	2				
10/23/06	21	383						1		8	1	4	1	5	1			
Total	442		13		1	12	110	49	13	46	82	53	26	27	7	2	0	1

TABLE 18 LENGTH-FREQUENCY DISTRIBUTION OF LAKE TROUT COLLECTED DURING AMBIENT STUDIES AT KEWAUNEE POWER STATION

Date	N	Mean Length (mm)	530 to 559.9 mm	560 to 589.9 mm	590 to 619.9 mm	620 to 649.9 mm	650 to 679.9 mm	680 to 709.9 mm	710 to 739.9 mm	740 to 769.9 mm	770 to 799.9 mm	800 to 829.9 mm	830 to 859.9 mm	860 to 889.9 mm	890 to 919.9 mm	920 to 949.9 mm
04/10/06	8	672			1	2	1	2	1	1						
04/24/06	2	638	1						1							
05/08/06	23	670	2		2	4	6	4	2	1	1	1				
05/22/06	8	755					1	2	2		1		1	1		
06/12/06	2	788								1		1				
06/26/06	1	670					1									
07/17/06																
07/31/06	8	702				1	2	2	1	1	1					
08/14/06																
08/28/06																
09/13/06	1	671					1									
09/25/06	66	747			2	3	3	6	16	14	11	5	5		1	
10/09/06	18	733					4	2	5	2	4					1
10/23/06	5	672		1		1		1	1	1						
Total	**142**		**3**	**1**	**5**	**11**	**19**	**19**	**29**	**21**	**18**	**7**	**6**	**1**	**1**	**1**

TABLE 19 COMPARISON OF IMPINGEMENT DATA AND AMBIENT JUVENILE/ADULT DATA COLLECTED AT KEWAUNEE POWER STATION

Species	Impingement		Ambient	
	Number Collected	Percent of Total	Number Collected	Percent of Total
Silver lamprey	1	0.06	0	0.00
Alewife	690,402	—	7,358	—
Gizzard shad	41	2.29	44	1.98
Common carp	3	0.17	8	0.36
Lake chub	0	0.00	166	7.45
Brassy minnow	0	0.00	1	0.04
Common shiner	0	0.00	11	0.49
Emerald shiner	0	0.00	10	0.45
Spottail shiner	125	6.97	242	10.87
Fathead minnow	0	0.00	38	1.71
Longnose dace	50	2.79	241	10.82
Creek chub	1	0.06	0	0.00
White sucker	52	2.90	397	17.83
Longnose sucker	62	3.46	493	22.14
Shorthead redhorse	1	0.06	0	0.00
Catostominae	1	0.06	0	0.00
Black bullhead	3	0.17	2	0.09
Channel catfish	8	0.45	0	0.00
Rainbow smelt	300	16.73	51	2.29
Lake whitefish	2	0.11	1	0.04
Bloater	1	0.06	9	0.40
Chinook salmon	2	0.11	34	1.53
Coho salmon	0	0.00	3	0.13
Rainbow trout	0	0.00	2	0.09
Round whitefish	7	0.39	118	5.30
Brown trout	2	0.11	53	2.38
Lake trout	7	0.39	145	6.51
Burbot	27	1.51	11	0.49
Banded killifish	0	0.00	1	0.04
Threespine stickleback	55	3.07	9	0.40
Ninespine stickleback	572	31.90	9	0.40
Mottled sculpin	145	8.09	1	0.04
Slimy sculpin	18	1.00	0	0.00
Cottidae	1	0.06	0	0.00
White perch	1	0.06	3	0.13
Pumpkinseed	1	0.06	1	0.04
Bluegill	1	0.06	0	0.00
Rock bass	1	0.06	0	0.00
Smallmouth bass	3	0.17	1	0.04
Yellow perch	164	9.15	108	4.85
Round goby	12	0.67	11	0.49
Northern clearwater crayfish	123	6.86	3	0.13
Total	**692,195**	**100**	**9,585**	**100**
Number of Species	32		33	

Note: Alewife not included in percent of total calculations

TABLE 20 RANKED ABUNDANCE AND PERCENT COMPOSITION OF FISH ESTIMATED IMPINGED AT KEWAUNEE POWER STATION, APRIL 1975 -- MARCH 1976

Species	Number	Percent	Weight (kg)	Percent
Alewife	178,883	83.2	4771.01	76.8
Rainbow smelt	19,206	8.9	480.26	7.7
Slimy sculpin	8,640	4.0	38.02	0.6
Longnose dace	4,389	2.0	46.93	0.8
Lake chub	1,584	0.7	49.45	0.8
Sucker[a]	1,000	0.5	431.41	6.9
Trout[b]	344	0.2	140.61	2.3
Gizzard shad	311	0.1	14.93	0.2
Common carp	259	0.1	164.73	2.7
Yellow perch	245	0.1	40.38	0.7
Bullhead[c]	111	0.1	11.47	0.2
Ninespine stickleback	55	<0.1	0.20	<0.1
Trout-perch	39	<0.1	0.47	<0.1
Whitefish[d]	13	<0.1	11.04	0.2
Pumpkinseed	9	<0.1	0.15	<0.1
Burbot	7	<0.1	4.00	0.1
Common shiner	4	<0.1	0.13	<0.1
Salmon[e]	3	<0.1	4.05	0.1
Sea lamprey	2	<0.1	0.31	<0.1
Northern pike	2	<0.1	0.38	<0.1
Bloater	1	<0.1	0.07	<0.1
Blacknose dace	1	<0.1	0.03	<0.1
Total	**215,108**	**100**	**6210.01**	**100**

Data from NALCO (undated)

[a]includes white sucker, longnose sucker, and shorthead redhorse
[b]includes brook trout, brown trout, rainbow trout, and lake trout
[c]includes brown bullhead and yellow bullhead
[d]includes lake whitefish and round whitefish
[e]includes coho salmon and chinook salmon

TABLE 21 COMPARISON OF ANNUAL ESTIMATED NUMBER OF FISH IMPINGED AT KEWAUNEE POWER STATION IN 1975 - 1976 VS 2006 - 2007

	2006 - 2007		1975 - 1976	
Species	**Number**	**Percent**	**Number**	**Percent**
Sea lamprey	0	0.000	2	0.001
Silver lamprey	10	<0.001	0	<0.001
Alewife	5,592,692	99.624	178,883	83.160
Gizzard shad	1,216	0.022	311	0.145
Common carp	70	0.001	259	0.120
Spottail shiner	1,615	0.029	0	<0.001
Common shiner	0	0.000	4	0.002
Longnose dace	714	0.013	4,389	2.040
Blacknose dace	0	0.000	1	<0.001
Creek chub	29	0.001	0	<0.001
Lake chub	0	0.000	1,584	0.736
Sucker group	1,216	0.022	1,000	0.465
Bullhead group	309	0.006	111	0.052
Northern pike	0	0.000	2	0.001
Rainbow smelt	3,279	0.058	19,206	8.929
Trout group	84	0.001	344	0.160
Whitefish group	207	0.004	13	0.006
Salmon group	36	0.001	3	0.001
Bloater	28	<0.001	1	<0.001
Burbot	384	0.007	7	0.003
Trout-perch	0	0.000	39	0.018
Ninespine stickleback	4,473	0.080	55	0.026
Threespine stickleback	525	0.009	0	<0.001
Mottled sculpin	2,148	0.038	0	<0.001
Slimy sculpin	277	0.005	8,640	4.017
Cottidae	38	0.001	0	<0.001
White perch	22	<0.001	0	<0.001
Smallmouth bass	43	0.001	0	<0.001
Bluegill	28	<0.001	0	<0.001
Pumpkinseed	29	0.001	9	0.004
Rock bass	26	<0.001	0	<0.001
Yellow perch	3,080	0.055	245	0.114
Round goby	117	0.002	0	<0.001
Northern clearwater crayfish	1,104	0.020	0	<0.001
Total	**5,613,799**	**100**	**215,108**	**100**

Note: 1975 - 1976 data from NALCO (undated)

TABLE 22 AVERAGE DENSITY AND PERCENT COMPOSITION OF ICHTHYOPLANKTON AND INVERTEBRATES ENTRAINED AT KEWAUNEE POWER STATION, MARCH 2006 – FEBRUARY 2007

Species/Taxon	Average No./100 M^3	Percent	Cumulative Percent
Gammarus sp.	143.019	93.570	93.57
Unidentified egg - fertilized egg	4.365	2.856	96.43
Burbot - yolk-sac larvae	1.384	0.905	97.33
Common carp - yolk-sac larvae	0.950	0.622	97.95
Alewife - yolk-sac larvae	0.611	0.400	98.35
Cyprinidae sp. - yolk-sac larvae	0.461	0.301	98.65
Mysis relicta	0.363	0.237	98.89
Clupeidae sp. larvae - unstaged	0.340	0.223	99.11
Rainbow smelt - juvenile	0.304	0.199	99.31
Rainbow smelt - post-yolk sac larvae	0.209	0.137	99.45
Coregoninae sp. - yolk-sac larvae	0.109	0.071	99.52
Unidentified egg - unstaged	0.105	0.069	99.59
Percidae sp. - yolk-sac larvae	0.087	0.057	99.65
Gasterosteidae sp. - post-yolk sac larvae	0.073	0.047	99.69
Hemimysis anomala	0.066	0.043	99.74
Unidentifiable larvae - unstaged	0.059	0.038	99.78
Alewife - juvenile	0.051	0.034	99.81
Gasterosteidae - yolk-sac larvae	0.045	0.029	99.84
Ninespine stickleback - juvenile	0.036	0.023	99.86
Cyprinidae sp. larvae - unstaged	0.029	0.019	99.88
Coregoninae sp. - post-yolk sac larvae	0.026	0.017	99.90
Round goby - yolk-sac larvae	0.013	0.008	99.91
Ninespine stickleback - post-yolk sac larvae	0.013	0.008	99.92
Rainbow smelt - yolk-sac larvae	0.012	0.008	99.92
Alewife - post-yolk sac larvae	0.012	0.008	99.93
Round goby - post-yolk sac larvae	0.012	0.008	99.94
Catostomus sp. - yolk-sac larvae	0.011	0.007	99.95
Unidentifiable larvae - yolk-sac larvae	0.011	0.007	99.95
Percidae sp. - post-yolk sac larvae	0.011	0.007	99.96
Catostomus sp. - post-yolk sac larvae	0.010	0.006	99.97
White sucker - yolk-sac larvae	0.009	0.006	99.97
Deepwater sculpin - post-yolk sac larvae	0.007	0.004	99.98
Clupeidae sp. - yolk-sac larvae	0.006	0.004	99.98
Cyprinidae sp. - post-yolk sac larvae	0.006	0.004	99.98
Rainbow smelt larvae - unstaged	0.006	0.004	99.99
Deepwater sculpin - juvenile	0.006	0.004	99.99
Coregoninae sp.larvae - unstaged	0.006	0.004	100.00
Common carp larvae - unstaged	0.005	0.004	100.00

TABLE 23 AVERAGE MONTHLY DENSITY (NO./100 M^3) OF ICHTHYOPLANKTON AND INVERTEBRATES ENTRAINED AT KEWAUNEE POWER STATION, MARCH 2006 - FEBRUARY 2007

Species/Taxon	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Alewife - juvenile	0	0	0	0	0	0.38	0	0	0	0	0	0
Alewife - post-yolk sac larvae	0	0	0	0	0.05	0.05	0	0	0	0	0	0
Alewife - yolk-sac larvae	0	0	0	0	1.34	3.45	0	0	0	0	0	0
Clupeidae sp. larvae - unstaged	0	0	0	0	0.14	2.40	0	0	0	0	0	0
Clupeidae sp. - yolk-sac larvae	0	0	0	0	0	0.05	0	0	0	0	0	0
Common carp larvae - unstaged	0	0	0	0.04	0	0	0	0	0	0	0	0
Common carp - yolk-sac larvae	0	0	0	6.85	0.05	0.14	0	0	0	0	0	0
Cyprinidae sp. larvae - unstaged	0	0	0	0.14	0.10	0	0	0	0	0	0	0
Cyprinidae sp. - post-yolk sac larvae	0	0	0	0.04	0	0	0	0	0	0	0	0
Cyprinidae sp. - yolk-sac larvae	0	0	0	2.10	1.58	0.04	0	0	0	0	0	0
White sucker - yolk-sac larvae	0	0	0	0.07	0	0	0	0	0	0	0	0
Catostomus sp. - post-yolk sac larvae	0	0	0	0.07	0	0	0	0	0	0	0	0
Catostomus sp. - yolk-sac larvae	0	0	0	0.08	0	0	0	0	0	0	0	0
Rainbow smelt - juvenile	0	0	0	0	0.10	0.26	0	1.39	0.69	2.12	0.58	0
Rainbow smelt - post-yolk sac larvae	0	0	0	0.50	0.70	0.48	0	0	0	0	0	0
Rainbow smelt larvae - unstaged	0	0	0	0	0	0	0	0	0	0.11	0	0
Rainbow smelt - yolk-sac larvae	0	0.06	0.06	0	0	0	0	0	0	0	0	0
Coregoninae sp. larvae - unstaged	0	0.05	0	0	0	0	0	0	0	0	0	0
Coregoninae sp. - post-yolk sac larvae	0	0.24	0	0	0	0	0	0	0	0	0	0
Coregoninae sp. - yolk-sac larvae	0	1.01	0	0	0	0	0	0	0	0	0	0
Burbot - yolk-sac larvae	0	12.58	0.23	0	0	0	0	0	0	0	0	0
Ninespine stickleback - juvenile	0	0	0	0	0	0.26	0	0	0	0	0	0
Ninespine stickleback - post-yolk sac larvae	0	0	0	0	0	0.09	0	0	0	0	0	0
Gasterosteidae sp. - post-yolk sac larvae	0	0	0	0.25	0.25	0.08	0	0	0	0	0	0
Gasterosteidae sp. - yolk-sac larvae	0	0	0	0.29	0.05	0	0	0	0	0	0	0
Deepwater sculpin - juvenile	0	0	0	0	0	0	0	0	0	0	0.11	0
Deepwater sculpin - post-yolk sac larvae	0	0.06	0	0	0	0	0	0	0	0	0	0
Percidae sp. - post-yolk sac larvae	0	0	0	0.08	0	0	0	0	0	0	0	0
Percidae sp. - yolk-sac larvae	0	0	0	0.64	0	0	0	0	0	0	0	0
Round goby - post-yolk sac larvae	0	0	0	0.05	0.05	0	0	0	0	0	0	0
Round goby - yolk-sac larvae	0	0	0	0.10	0	0	0	0	0	0	0	0

TABLE 23 (Continued)

Species/Taxon	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Unidentifiable larvae - unstaged	0	0	0	0.04	0.44	0.04	0	0	0	0	0	0
Unidentifiable larvae - yolk-sac larvae	0	0	0	0	0.10	0	0	0	0	0	0	0
Unidentified egg - fertilized egg	0.06	0.54	0.53	24.52	8.60	0	0	0	0	0	0	0
Unidentified egg - unstaged	0	0	0	0.69	0.11	0	0	0	0	0	0	0
Gammarus sp.	48.50	55.91	88.28	84.61	118.90	299.88	1191.02	253.24	110.14	43.51	41.58	17.48
Hemimysis anomala	0	0	0	0	0	0	0	0.11	0	0.56	0.34	0.21
Mysis relicta	1.66	0.09	0	0	0	0	0	0	0	0.45	1.48	1.28
Total	50.22	70.54	89.09	121.17	132.56	307.62	1191.02	254.74	110.83	46.75	44.09	18.97

TABLE 24 MEAN WATER QUALITY VALUES ASSOCIATED WITH ENTRAINMENT SAMPLING, KEWAUNEE POWER STATION, MARCH 2006 – FEBRUARY 2007

Sampling Event	Temperature (Degrees C)	Dissolved Oxygen (mg/L)	pH (pH units)	Conductivity (µs/cm)
03/09/06	4.0	13.2	8.4	384.5
03/16/06	2.2	14.3	8.5	302.8
03/23/06	3.1	16.3	7.7	344.0
03/30/06	18.3	9.8	8.4	285.3
04/06/06	10.3	12.0	8.4	314.8
04/13/06	12.3	12.2	8.3	268.3
04/20/06	11.0	11.4	8.6	306.8
04/27/06	10.4	12.4	8.5	312.0
05/04/06	10.8	12.5	8.3	274.8
05/11/06	7.5	16.3	8.3	276.8
05/18/06	10.6	12.6	8.4	353.8
05/25/06	13.1	10.4	8.4	271.5
06/01/06	15.9	12.2	8.4	271.8
06/08/06	15.4	11.3	8.5	287.8
06/15/06	17.4	10.8	8.7	280.0
06/22/06	11.0	13.2	8.5	206.8
06/29/06	16.0	12.2	8.7	274.3
07/06/06	17.0	11.5	8.6	276.5
07/13/06	17.9	11.5	8.6	242.0
07/20/06	15.4	12.0	8.6	231.5
07/27/06	18.5	11.2	8.5	257.5
08/03/06	19.4	9.3	8.6	260.8
08/10/06	23.0	7.4	8.5	266.5
08/17/06	20.9	8.6	8.5	291.0
08/24/06	28.8	7.7	8.2	289.0
08/31/06	25.5	7.9	8.1	288.3
09/05/06	21.6	6.8	7.3	291.0
10/19/06	7.9	10.6	8.6	188.3
10/26/06	10.8	10.3	8.3	297.3
11/09/06	10.4	12.8	8.3	294.5
11/29/06	14.3	10.5	8.2	250.5
12/14/06	18.8	10.0	8.3	278.3
12/28/06	15.2	8.8	8.3	275.5
01/11/07	15.1	10.0	8.2	292.5
01/25/07	0.7	14.2	8.1	290.5
02/07/07	0.4	11.1	8.1	265.5
02/21/07	11.2	10.0	8.2	294.0

TABLE 25 LENGTH STATISTICS FOR FISH LARVAE ENTRAINED AT KEWAUNEE POWER STATION, MARCH 2006 – FEBRUARY 2007

Species/Taxon	N	Min mm	Max mm	Avg mm	StdDev mm
Alewife	70	3.5	26.8	7.0	6.8
Clupeidae sp.	37	3.1	6.1	4.1	0.6
Common carp	143	4.2	10	5.9	0.6
Cyprinidae sp.	87	4.1	8.5	5.3	1.1
White sucker	2	12.7	13	12.9	0.2
Catostomus sp.	4	12.6	13.5	13.1	0.5
Rainbow smelt	88	5.5	55.2	29.1	12.6
Coregoninae sp.	22	12	16.3	14.1	1.1
Burbot	128	3.2	5	4.2	0.4
Ninespine stickleback	8	11.7	24.1	19.5	4.8
Gasterosteidae sp.	20	7.2	10.5	7.9	0.8
Deepwater sculpin	2	11.2	18.4	14.8	5.1
Percidae sp.	16	5.5	8.6	7.2	1.1
Round goby	4	7.8	10	8.6	1.0

TABLE 26 MONTHLY AND ANNUAL ENTRAINMENT ESTIMATES (X 10^6) FOR KEWAUNEE POWER STATION, MARCH 2006 - FEBRUARY 2007

Species/Life Stage	2006										2007		Annual Totals
	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	
Alewife-juvenile	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	**0.29**
Alewife-post-yolk sac larvae	0.00	0.00	0.00	0.00	0.03	0.02	0.01	0.00	0.00	0.00	0.00	0.00	**0.06**
Alewife-yolk-sac larvae	0.00	0.00	0.00	0.00	0.83	2.63	0.00	0.00	0.00	0.00	0.00	0.00	**3.46**
Clupeidae sp.-unstaged	0.00	0.00	0.00	0.00	0.10	1.81	0.01	0.00	0.00	0.00	0.00	0.00	**1.92**
Clupeidae sp.-yolk-sac larvae	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	**0.04**
Common carp larvae-unstaged	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.03**
Common carp-yolk-sac larvae	0.00	0.00	0.88	4.27	0.12	0.10	0.00	0.00	0.00	0.00	0.00	0.00	**5.37**
Cyprinidae sp.-unstaged	0.00	0.00	0.01	0.09	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.16**
Cyprinidae sp.-post-yolk sac larvae	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.03**
Cyprinidae sp.-yolk-sac larvae	0.00	0.00	0.02	1.34	1.21	0.03	0.00	0.00	0.00	0.00	0.00	0.00	**2.61**
White sucker-yolk-sac larvae	0.00	0.00	0.02	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.05**
Catostomus sp.-post-yolk sac larvae	0.00	0.00	0.02	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.06**
Catostomus sp.-yolk-sac larvae	0.00	0.00	0.03	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.06**
Rainbow smelt-juvenile	0.00	0.00	0.00	0.00	0.07	0.19	0.02	0.62	0.53	1.30	0.50	0.00	**3.22**
Rainbow smelt-post-yolk sac larvae	0.00	0.00	0.00	0.29	0.53	0.35	0.01	0.00	0.00	0.00	0.00	0.00	**1.18**
Rainbow smelt larvae-unstaged	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	**0.07**
Rainbow smelt-yolk-sac larvae	0.00	0.04	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.07**
Coregoninae sp.-unstaged	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.03**
Coregoninae sp.-post-yolk sac larvae	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.15**
Coregoninae sp.-yolk-sac larvae	0.00	0.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.62**
Burbot-yolk-sac larvae	0.00	7.69	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**7.82**
Ninespine stickleback-juvenile	0.00	0.00	0.00	0.00	0.00	0.19	0.01	0.00	0.00	0.00	0.00	0.00	**0.20**
Ninespine stickleback-post-yolk sac larvae	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	**0.07**
Gasterosteidae sp.-post-yolk sac larvae	0.00	0.00	0.00	0.16	0.18	0.06	0.00	0.00	0.00	0.00	0.00	0.00	**0.41**
Gasterosteidae sp.-yolk-sac larvae	0.00	0.00	0.00	0.16	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.25**
Deepwater sculpin-juvenile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	**0.07**
Deepwater sculpin-post-yolk sac larvae	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.04**
Percidae sp.-post-yolk sac larvae	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.06**
Percidae sp.-yolk-sac larvae	0.00	0.00	0.00	0.47	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.49**
Round goby-post-yolk sac larvae	0.00	0.00	0.00	0.03	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.07**
Round goby-yolk-sac larvae	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.07**
Unidentifiable larvae-unstaged	0.00	0.00	0.00	0.03	0.27	0.03	0.00	0.00	0.00	0.00	0.00	0.00	**0.33**

TABLE 26 (Continued)

Species/Life Stage	2006										2007		Totals
	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	
Unidentifiable larvae-yolk-sac larvae	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06
Unidentified egg-fertilized egg	0.03	0.33	2.24	16.36	5.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	24.68
Unidentified egg-unstaged	0.00	0.00	0.00	0.53	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60
Gammarus sp.	29.63	38.48	59.89	54.09	84.84	208.10	679.27	187.00	76.07	38.53	27.63	10.69	1494.22
Hemimysis anomala	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.01	0.30	0.27	0.13	0.74
Mysis relicta	1.20	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.90	0.78	3.22
Totals	30.86	47.44	63.31	78.09	94.25	213.91	679.33	187.66	76.61	40.47	29.36	11.60	1552.88

TABLE 27 AMBIENT DENSITIES (NO./100 M³) OF ICHTHYOPLANKTON AND INVERTEBRATES AT NEAR SHORE LOCATIONS BY DATE

Organism-LifeStage	3/23/2006			3/30/2006			4/6/2006			4/13/2006			4/20/2006			4/27/2006			5/4/2006			5/18/2006			5/25/2006			6/1/2006		
Sampling Station =	NS1	NS2	NS3	NS1	NS2	NS3	NS1	NS2	NS3	NS1	NS2	NS3	NS1	NS2	NS3	NS1	NS2	NS3	NS1	NS2	NS3	NS1	NS2	NS3	NS1	NS2	NS3	NS1	NS2	NS3
Alewife-juvenile																														
Alewife-post-yolk sac larvae																														
Alewife larvae-unstaged																														
Alewife-yolk-sac larvae																														
Alosa sp.-yolk-sac larvae																														
Clupeidae sp.-post-yolk sac larvae																														
Clupeidae sp. larvae-unstaged																														
Clupeidae sp.-yolk-sac larvae																	0.27													
Common carp larvae-unstaged																														
Common carp yolk-sac larvae																													0.13	
Pimephales sp.-yolk-sac larvae																														
Cyprinidae sp.-yolk-sac larvae																														
Rainbow smelt-juvenile																														
Rainbow smelt-post-yolk sac larvae																						0.12	0.15	0.12				0.29		
Rainbow smelt larvae-unstaged																		0.26												
Rainbow smelt-yolk-sac larvae															0.25	0.15	0.26	0.54										3.26		
Coregoninae-post-yolk sac larvae																0.13		0.14												
Coregoninae larvae-unstaged																0.28	0.13													
Coregoninae-yolk-sac larvae							0.77	0.29	0.12			0.27	13.23	1.38	8.04	6.30	8.23	3.18												
Burbot-yolk-sac larvae														0.29		25.07	46.54	31.87	4.09	0.13	0.58				0.14					
Gasterosteidae-post-yolk sac larvae																												0.13		
Gasterosteidae-yolk-sac larvae																														
Cottidae-juvenile																														
Cottidae-post-yolk sac larvae																														
Lepomis sp.-yolk-sac larvae																														
Yellow perch-yolk-sac larvae																								0.14						
Percidae sp. larvae-unstaged																														
Percidae sp.-yolk-sac larvae																														
Round goby-post-yolk sac larvae																														
Unidentifiable larvae-unstaged																0.28			0.14					0.66						
Unidentified egg-fertilized egg														0.14														1.26	1.54	0.14
Unidentified egg-yolk-unstaged																														
Gammarus sp.	56.24	48.00	95.55	0.77	1.39	0.93	36.13	15.24	20.75	0.52	8.84	28.80	33.98	17.98	75.64	63.52	129.44	649.87	16.02	72.57	37.74	22.12	26.21	17.12	4.87	0.65	1.04	51.22	10.14	1.10
Mysis relicta		0.54							0.13		0.40																			
Totals:	56.24	48.53	95.55	0.77	1.39	0.93	36.90	15.54	21.01	0.52	9.24	29.07	47.21	19.79	84.13	95.71	184.88	685.68	20.25	72.89	38.32	22.25	26.36	18.04	5.01	0.55	1.04	56.17	11.80	1.24

TABLE 27 CONTINUED

Organism-LifeStage	6/8/2006			6/15/2006			6/22/2006			6/29/2006			7/6/2006			7/13/2006			7/20/2006			7/27/2006			8/3/2006			8/10/2006		
Sampling Station #	NS1	NS2	NS3	NS1	NS2	NS3	NS1	NS2	NS3	NS1	NS2	NS3	NS1	NS2	NS3	NS1	NS2	NS3	NS1	NS2	NS3	NS1	NS2	NS3	NS1	NS2	NS3	NS1	NS2	NS3
Alewife-juvenile																														
Alewife-post-yolk sac larvae								0.15																	0.14					
Alewife larvae-unstaged																	0.16				0.44						0.18			
Alewife-yolk-sac larvae												1.73	2.10	0.58	4.98	0.57			9.93	1.47	3.42	13.64	10.71	15.74	19.86	1.26	2.84	0.54		0.13
Alosa sp.-yolk-sac larvae												0.14							0.26	0.14	0.29	0.14								
Clupeidae sp.-post-yolk sac larvae					0.17														0.13		0.14				0.84					
Clupeidae sp. larvae-unstaged								0.16				0.78			0.45				0.39	0.79	1.39	6.37	8.11	3.86	3.20		0.18	0.28		
Clupeidae sp.-yolk-sac larvae												0.41	0.30			0.59	0.31		2.46	1.35	3.17	5.01	1.77	10.06	37.32	2.10	3.99	0.54		
Common carp larvae-unstaged																0.14														
Common carp-yolk-sac larvae				0.35	0.71	0.51				0.59	0.15		0.96	0.15	0.13										0.28	0.15		0.28	0.14	
Pimephales sp.-yolk-sac larvae											0.15																			
Cyprinidae sp.-yolk-sac larvae											0.29																			
Rainbow smelt-juvenile																														
Rainbow smelt-post-yolk sac larvae						0.14				1.45	0.92	0.57				0.15					0.43	0.40	2.78	0.27						
Rainbow smelt larvae-unstaged																														
Rainbow smelt-yolk-sac larvae																														
Coregoninae-post-yolk sac larvae																														
Coregoninae larvae-unstaged																														
Coregoninae-yolk-sac larvae																														
Burbot-yolk-sac larvae																														
Gasterosteidae-post-yolk sac larvae											0.15	0.41							0.13		0.14						0.28			
Gasterosteidae-yolk-sac larvae				1.70	0.14	1.07	0.30			4.36	0.17		0.15			0.99	0.16					0.27								
Cottidae-juvenile													0.15			0.13				0.13										
Cottidae-post-yolk sac larvae					0.14					1.45												0.14	0.14							
Lepomis sp.-yolk-sac larvae		0.15																												
Yellow perch-yolk-sac larvae				0.33	0.29	0.27				0.29										0.14										
Percidae sp. larvae-unstaged				0.17	0.17	0.28																								
Percidae sp.-yolk-sac larvae					0.14																									
Round goby-post-yolk sac larvae																														
Unidentifiable larvae-unstaged			0.16		0.14						0.14	0.64	0.33		0.15				0.14	0.13	0.27	0.81			2.05					
Unidentified egg-fertilized egg			0.15	0.79	2.11					0.44		26.29	7.02	0.72	8.79	26.85	1.66	2.52	0.26	1.32	6.88	1.45		1.45	50.87	0.15	6.82			0.13
Unidentified egg-yolk-unstaged																					0.13									
Gammarus sp.	53.11		1.35	43.06	5.70	39.85	0.31	0.63	0.06	27.67	3.82	4.15	3.41	5.02	2.65	69.27	21.57	7.90	11.96	2.94	30.05	38.49	27.71	16.20	32.53	49.19	108.24	8.80	0.68	5.41
Mysis relicta																														
Totals:	53.11	0.15	1.66	46.40	9.76	42.12	0.61	0.93	0.66	36.25	5.77	35.10	14.42	6.47	17.14	100.49	23.86	10.42	25.65	8.41	46.73	84.72	51.23	47.60	147.10	52.85	122.48	10.44	0.82	5.67

TABLE 27 CONTINUED

Organism-LifeStage	8/17/2006			8/24/2006			8/31/2006			9/5/2006			10/19/2006			10/26/2006		
Sampling Station =	NS1	NS2	NS3	NS1	NS2	NS3	NS1	NS2	NS3	NS1	NS2	NS3	NS1	NS2	NS3	NS1	NS2	NS3
Alewife-juvenile	10.13	2.04	0.26					0.15		0.29		0.15						
Alewife-post-yolk sac larvae	0.72						0.15	0.58										
Alewife larvae-unstaged																		
Alewife-yolk-sac larvae																		
Alosa sp.-yolk-sac larvae																		
Clupeidae sp.-post-yolk sac larvae		0.14						0.16	0.27									
Clupeidae sp. larvae-unstaged			0.57															
Clupeidae sp.-yolk-sac larvae																		
Common carp larvae-unstaged																		
Common carp-yolk-sac larvae																		
Pimephales sp.-yolk-sac larvae																		
Cyprinidae sp.-yolk-sac larvae																		
Rainbow smelt-juvenile																	1.33	
Rainbow smelt-post-yolk sac larvae																0.15	0.15	
Rainbow smelt larvae-unstaged																		
Rainbow smelt-yolk-sac larvae																		
Coregoninae-post-yolk sac larvae																		
Coregoninae larvae-unstaged																		
Coregoninae-yolk-sac larvae																		
Burbot-yolk-sac larvae																		
Gasterosteidae-post-yolk sac larvae																		
Gasterosteidae-yolk-sac larvae																		
Cottidae-juvenile																		
Cottidae-post-yolk sac larvae																		
Lepomis sp.-yolk-sac larvae																		
Yellow perch-yolk-sac larvae																		
Percidae sp. larvae-unstaged																		
Percidae sp.-yolk-sac larvae																		
Round goby-post-yolk sac larvae	0.15		0.40															
Unidentifiable larvae-unstaged																		
Unidentified egg-fertilized egg																		
Unidentified egg-yolk-unstaged																		
Gammarus sp.	24.36	6.23	15.33	3.23	0.30	1.99	0.14	8.55	0.27	20.51	93.00	469.59	169.64	26.05	40.07	77.74	32.83	60.76
Mysis relicta																		
Totals:	35.36	8.40	16.55	3.23	0.30	1.99	0.29	9.43	0.54	20.80	93.00	469.74	169.64	26.05	40.07	77.88	34.30	60.76

TABLE 28 AMBIENT DENSITIES (NO./100 M^3) OF ICHTHYOPLANKTON AND INVERTEBRATES AT OFFSHORE LOCATIONS BY DATE

Organism-LifeStage	3/23/2006			3/30/2006			4/6/2006			4/13/2006			4/20/2006			4/27/2006			5/4/2006			5/18/2006			5/25/2006		
Sampling Station =	OS1	OS2	OS3	OS1	OS2	OS3	OS1	OS2	OS3	OS1	OS2	OS3	OS1	OS2	OS3	OS1	OS2	OS3	OS1	OS2	OS3	OS1	OS2	OS3	OS1	OS2	OS3
Alewife-juvenile																											
Alewife-post-yolk sac larvae																											
Alewife larvae-unstaged																											
Alewife-yolk-sac larvae																											
Alosa sp.-post-yolk sac larvae																											
Alosa sp.-yolk-sac larvae																											
Clupeidae sp.-post-yolk sac larvae																											
Clupeidae sp. larvae-unstaged																											
Clupeidae sp.-yolk-sac larvae																											
Common carp larvae-unstaged																											
Common carp-yolk-sac larvae																											
Cyprinidae sp.-post-yolk sac larvae																											
Cyprinidae sp.-yolk-sac larvae																											
Catostomidae sp.-yolk-sac larvae																				0.15							
Rainbow smelt-juvenile			0.14																								
Rainbow smelt-post-yolk sac larvae																	0.14					0.31				0.13	0.52
Rainbow smelt larvae-unstaged																											
Rainbow smelt-yolk-sac larvae														0.27													
Coregoninae-post-yolk sac larvae																0.57											
Coregoninae-yolk-sac larvae		0.21					0.12		0.12				3.50	0.90	0.66	6.47	1.13	1.12									
Burbot-post-yolk sac larvae																											
Burbot larvae-unstaged																	0.12										
Burbot-yolk-sac larvae													0.46	0.15	0.16	38.49	41.46	15.30	3.08	0.83	0.55				0.24	0.13	
Ninespine stickleback-adult																											
Ninespine stickleback-juvenile																											
Ninespine stickleback-post-yolk sac larvae																											
Gasterosteidae-post-yolk sac larvae																											
Gasterosteidae larvae-unstaged																											
Gasterosteidae-yolk-sac larvae																											
deepwater sculpin-post-yolk sac larvae							0.12																				
deepwater sculpin-yolk-sac larvae							0.12																				
Mottled sculpin-adult																											
Slimy sculpin-adult																											
Cottidae-adult																											
Cottidae-juvenile																											
Cottidae-post-yolk sac larvae																											
Cottidae sp. larvae-unstaged																											
Yellow perch-yolk-sac larvae																						0.11		0.17			
Percidae sp.-yolk-sac larvae																						0.18					
Unidentifiable larvae-unstaged	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.14	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified egg-fertilized egg																											
Gammarus sp.	60.21	338.67	33.67	11.18	15.88	27.58	6.12	19.08	48.41	4.75	10.42	17.19	9.16	32.54	47.18	72.17	34.41	156.66	7.89	36.75	47.13	49.75	252.38	29.73	1.70	7.44	2.39
Hyalella azteca							0.12																				
Amphipods									2.98																		
Hemimysis anomala																											
Mysis relicta	0.16	0.35					0.46		0.12			0.15															
Northern clearwater crayfish																											
Orconectes sp.																					0.28		0.24				
Totals:	60.37	339.22	33.81	11.18	15.88	27.58	7.05	19.08	51.83	4.75	10.42	17.34	13.29	33.85	48.34	115.86	77.26	176.07	10.97	37.74	47.94	50.35	252.61	29.90	1.94	7.69	2.91

TABLE 28 CONTINUED

Organism-LifeStage	6/1/2006			6/8/2006			8/15/2006			6/22/2006			6/29/2006			7/6/2006			7/13/2006			7/20/2006			7/27/2006		
Sampling Station =	OS1	OS2	OS3	OS1	OS2	OS3	OS1	OS2	OS3	OS1	OS2	OS3	OS1	OS2	OS3	OS1	OS2	OS3	OS1	OS2	OS3	OS1	OS2	OS3	OS1	OS2	OS3
Alewife-juvenile																											
Alewife-post-yolk sac larvae																							0.15				
Alewife larvae-unstaged																								0.14			
Alewife-yolk-sac larvae															0.42	0.31			0.31		0.26	5.47	1.51	8.92	0.14	2.15	2.38
Alosa sp.-post-yolk sac larvae								0.13																0.44			
Alosa sp.-yolk-sac larvae																						0.53	0.56	0.15		0.29	
Clupeidae sp.-post-yolk sac larvae								0.83	0.33										0.15								
Clupeidae sp. larvae-unstaged														0.28								0.13	0.14	1.13			0.58
Clupeidae sp.-yolk-sac larvae																			1.21		0.58	2.82	1.67	2.66	0.82	1.11	1.67
Common carp larvae-unstaged												0.19															
Common carp-yolk-sac larvae								0.63	0.33			0.19			0.27									0.29			
Cyprinidae sp.-post-yolk sac larvae														0.14													
Cyprinidae sp.-yolk-sac larvae								0.31						0.30		0.15		0.16	0.13							0.15	
Catostomidae sp.-yolk-sac larvae																											
Rainbow smelt-juvenile																											
Rainbow smelt-post-yolk sac larvae										0.15	0.14	0.14	1.33	1.94	1.57	0.15		0.28	0.14	0.28	0.14	1.22	2.26	0.27	0.27	0.74	0.28
Rainbow smelt larvae-unstaged																							0.29				
Rainbow smelt-yolk-sac larvae																											
Coregoninae-post-yolk sac larvae																											
Coregoninae-yolk-sac larvae																											
Burbot-post-yolk sac larvae																								0.13		0.15	
Burbot larvae-unstaged																											
Burbot-yolk-sac larvae																											
Ninespine stickleback-adult																											
Ninespine stickleback-juvenile																											0.27
Ninespine stickleback-post-yolk sac larvae																								0.14		0.14	
Gasterosteidae-post-yolk sac larvae							0.40	0.32	1.12			0.76	1.05	0.30	0.42	1.07	6.74	0.44	1.37			0.67			0.14		0.14
Gasterosteidae larvae-unstaged																			0.13								
Gasterosteidae-yolk-sac larvae							5.31	1.03					3.75	0.32	0.55			0.13	1.21			0.14					
deepwater sculpin-post-yolk sac larvae																											
deepwater sculpin-yolk-sac larvae																											
Mottled sculpin-adult																											
Slimy sculpin-adult																											0.13
Cottidae-adult																									0.67	1.00	0.14
Cottidae-juvenile													0.31		0.14	0.62	6.08		0.69	0.14		1.24	0.14	0.42	0.39	0.43	0.14
Cottidae-post-yolk sac larvae							0.16						0.15	0.46		0.16			0.67						0.13		
Cottidae sp. larvae-unstaged																0.16											
Yellow perch-yolk-sac larvae								0.32	0.13				0.29	0.28						0.14	0.15						
Percidae sp.-yolk-sac larvae							0.13		0.29					0.16													
Unidentifiable larvae-unstaged	0.00	0.00	0.00	0.00	0.00	0	0.00	0.16	0.25	0.00	0.00	0.00	0.30	0.43	0.13	0.00	0.25	0.00	0.27	0.00	0.00	0.27	0.00	0.00	0.00	0.00	0.14
Unidentified egg-fertilized egg	8.02	0.89			2.19		0.33	15.83						0.14	0.14	0.47	0.14	7.68	0.14		4.97	0.95	0.69	2.33	1.53	0.14	2.29
Gammarus sp.	85.00	24.63	10.75	0.15			72.13	35.30	8.42	0.29	36.69	18.81	49.27	15.28	8.52	61.99	587.21	5.35	121.32	10.92	10.19	178.09	61.99	128.99	321.10	87.70	103.50
Hyalella azteca																											
Amphipods																											
Hemimysis anomala																											
Mysis relicta																											
Northern clearwater crayfish																	0.25										
Orconectes sp.	0.16																							0.15		0.27	
Totals:	93.18	25.43	10.75	0.15	2.19	0.00	78.46	54.85	10.86	0.44	36.83	20.09	56.44	20.03	12.14	65.08	600.66	14.02	127.72	11.46	16.29	191.50	69.27	146.16	325.19	84.27	111.61

TABLE 28 CONTINUED

Organism-LifeStage	8/3/2006			8/10/2006			8/17/2006			8/24/2006			8/31/2006			9/5/2006			10/19/2006			10/26/2006		
Sampling Station =	OS1	OS2	OS3	OS1	OS2	OS3	OS1	OS2	OS3	OS1	OS2	OS3	OS1	OS2	OS3	OS1	OS2	OS3	OS1	OS2	OS3	OS1	OS2	OS3
Alewife-juvenile							1.75	0.99							0.29	0.13								
Alewife-post-yolk sac larvae							0.15		0.15					0.14										
Alewife larvae-unstaged																								
Alewife-yolk-sac larvae	4.11	0.96	2.22	0.59																				
Alosa sp.-post-yolk sac larvae	0.14																							
Alosa sp.-yolk-sac larvae		0.14	0.58	0.15																				
Clupeidae sp.-post-yolk sac larvae				0.15									0.14											
Clupeidae sp. larvae-unstaged	0.27		0.15	0.29										0.13		0.15								
Clupeidae sp.-yolk-sac larvae	9.61	2.35	3.67	0.45																				
Common carp larvae-unstaged																								
Common carp-yolk-sac larvae		0.14		0.15																				
Cyprinidae sp.-post-yolk sac larvae																								
Cyprinidae sp.-yolk-sac larvae																								
Catostomidae sp.-yolk-sac larvae																								
Rainbow smelt-juvenile																			0.15			0.30		0.15
Rainbow smelt-post-yolk sac larvae		0.14							0.15															
Rainbow smelt larvae-unstaged																								
Rainbow smelt-yolk-sac larvae																								
Coregoninae-post-yolk sac larvae																								
Coregoninae-yolk-sac larvae																								
Burbot-post-yolk sac larvae																								
Burbot larvae-unstaged																								
Burbot-yolk-sac larvae																								
Ninespine stickleback-adult								0.14																
Ninespine stickleback-juvenile																								
Ninespine stickleback-post-yolk sac larvae																								
Gasterosteidae-post-yolk sac larvae																								
Gasterosteidae larvae-unstaged																								
Gasterosteidae-yolk-sac larvae																								
deepwater sculpin-post-yolk sac larvae																								
deepwater sculpin-yolk-sac larvae																								
Mottled sculpin-adult												0.15				0.13								
Slimy sculpin-adult																								
Cottidae-adult		0.96					0.73	0.14																
Cottidae-juvenile																								
Cottidae-post-yolk sac larvae																								
Cottidae sp. larvae-unstaged																								
Yellow perch-yolk-sac larvae																								
Percidae sp.-yolk-sac larvae																								
Unidentifiable larvae-unstaged	0.14	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified egg-fertilized egg	5.47																							
Gammarus sp.	37.61	43.98	6.09	0.74	3.89	3.57	83.64	65.32	69.19	0.14	0.44	42.36	0.15	1.41	0.09	32.28	100.38	141.44	274.88	69.00	92.06	37.48	111.29	15.31
Hyalella azteca																								
Amphipods																								
Hemimysis anomala																				0.13	0.14			
Mysis relicta																								
Northern clearwater crayfish																								
Orconectes sp.																							0.16	
Totals:	57.35	48.66	12.85	2.51	3.89	3.57	86.27	66.60	69.48	0.14	0.44	42.52	0.29	1.68	0.97	32.68	100.38	141.44	275.03	69.13	92.20	37.79	111.45	15.46

TABLE 30 MEAN WATER QUALITY VALUES ASSOCIATED WITH NEAR SHORE AMBIENT ICHTHYOPLANKTON SAMPLING, KEWAUNEE POWER STATION, MARCH -- OCTOBER 2006

Sampling Event	Sampling Station	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	pH (units)	Temperature (C)
03/23/06	NS-1	297	16.2	8.4	2.3
	NS-2	298	15.8	8.4	2.6
	NS-3	290	14.8	8.4	6.9
03/30/06	NS-1	293	14.2	8.2	8.6
	NS-2	289	14.4	8.2	10.6
	NS-3	286	15.2	8.4	7.5
04/06/06	NS-1	287	14.6	8.2	7.5
	NS-2	281	14.2	8.2	9.2
	NS-3	280	14.4	8.2	7.7
04/13/06	NS-1	278	16.1	8.3	7.2
	NS-2	282	16.5	8.4	8.7
	NS-3	295	14.7	8.8	8.9
04/20/06	NS-1	285	16.5	8.2	9.8
	NS-2	279	13.6	8.2	10.2
	NS-3	281	13.6	8.2	10.2
04/27/06	NS-1	255	10.2	8.7	9.0
	NS-2	246	10.1	8.7	9.1
	NS-3	249	9.7	8.6	9.6
05/04/06	NS-1	258	12.6	8.4	7.7
	NS-2	259	12.2	8.4	9.1
	NS-3	259	12.1	8.4	9.2
05/18/06	NS-1	283	10.7	8.1	9.6
	NS-2	282	10.5	8.1	9.9
	NS-3	284	10.4	8.1	9.7
05/25/06	NS-1	283	13.0	9.4	8.8
	NS-2	283	11.8	8.5	12.0
	NS-3	283	12.0	8.2	11.6
06/01/06	NS-1	298	11.8	8.4	12.3
	NS-2	290	11.0	8.4	13.0
	NS-3	285	10.4	8.3	14.1
06/08/06	NS-1	281	14.9	8.6	12.6
	NS-2	280	13.3	8.4	12.9
	NS-3	278	13.7	8.4	13.0
06/15/06	NS-1	281	13.5	8.8	15.6
	NS-2	285	12.4	8.6	16.2
	NS-3	285	11.9	8.6	16.5
06/22/06	NS-1	248	14.0	8.2	7.0
	NS-2	247	13.9	8.3	8.5
	NS-3	246	14.0	8.3	8.9
06/29/06	NS-1	276	13.8	8.7	14.8
	NS-2	276	13.4	8.7	14.9
	NS-3	275	13.7	8.7	15.2
07/06/06	NS-1	280	16.2	8.6	13.7
	NS-2	281	15.8	8.6	15.0
	NS-3	281	15.1	8.6	16.0
07/13/06	NS-1	282	14.6	8.7	15.2
	NS-2	286	12.9	8.6	16.4
	NS-3	285	12.4	8.6	17.6
07/20/06	NS-1	283	13.8	8.5	13.6
	NS-2	284	13.7	8.4	13.7
	NS-3	285	13.0	8.4	15.0
07/27/06	NS-1	287	12.7	8.6	15.6
	NS-2	288	11.4	8.4	16.7
	NS-3	288	11.8	8.5	17.1

TABLE 30 (Continued)

Sampling Event	Sampling Station	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	pH (units)	Temperature (C)
08/03/06	NS-1	279	10.0	8.6	19.4
	NS-2	280	9.8	8.6	19.0
	NS-3	279	10.9	8.6	19.9
08/10/06	NS-1	229	8.5	8.4	21.6
	NS-2	228	9.1	8.5	22.0
	NS-3	230	8.7	8.5	23.6
08/17/06	NS-1	279	9.3	8.5	18.6
	NS-2	279	9.2	8.5	19.7
	NS-3	279	9.1	8.5	20.3
08/24/06	NS-1	275	7.9	8.2	20.3
	NS-2	282	7.0	8.1	25.3
	NS-3	278	7.5	8.2	23.3
08/31/06	NS-1	279	7.6	8.2	21.0
	NS-2	281	7.2	8.1	23.7
	NS-3	278	8.0	8.3	22.5
09/05/06	NS-1	276	8.8	8.4	21.0
	NS-2	279	8.3	8.2	21.3
	NS-3	278	8.4	8.2	21.5
10/19/06	NS-1	277	12.3	8.1	7.5
	NS-2	280	12.0	8.0	8.1
	NS-3	282	12.1	8.1	8.1
10/26/06	NS-1	288	12.2	8.2	6.1
	NS-2	291	12.2	8.2	7.2
	NS-3	283	12.4	8.2	6.6

TABLE 31 MEAN WATER QUALITY VALUES ASSOCIATED WITH OFFSHORE AMBIENT ICHTHYOPLANKTON SAMPLING, KEWAUNEE POWER STATION, MARCH -- OCTOBER 2006

Sampling Station	Sampling Station	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	pH (units)	Temperature (C)
03/23/06	OS-1	296	16.3	8.5	2.1
	OS-2	290	15.9	8.4	2.1
	OS-3	290	15.2	8.4	4.7
03/30/06	OS-1	292	16.2	8.1	6.4
	OS-2	287	16.3	8.1	5.6
	OS-3	286	15.8	8.1	7.1
04/06/06	OS-1	284	15.8	8.3	6.7
	OS-2	281	15.1	8.2	8.2
	OS-3	278	15.9	8.2	7.0
04/13/06	OS-1	275	18.2	8.5	6.7
	OS-2	281	17.0	8.3	8.1
	OS-3	292	15.9	8.2	8.4
04/20/06	OS-1	282	15.8	8.2	8.8
	OS-2	279	14.0	8.2	9.8
	OS-3	282	13.6	8.2	9.9
04/27/06	OS-1	253	9.9	8.6	8.4
	OS-2	245	9.8	8.6	8.1
	OS-3	245	9.8	8.6	8.7
05/04/06	OS-1	259	12.9	8.4	7.3
	OS-2	259	12.2	8.4	8.8
	OS-3	258	12.2	8.4	8.8
05/18/06	OS-1	273	11.3	8.1	9.2
	OS-2	272	10.5	8.1	9.3
	OS-3	270	10.8	8.1	9.3
05/25/06	OS-1	283	12.9	8.8	8.0
	OS-2	283	12.6	8.4	10.4
	OS-3	284	12.4	9.0	10.0
06/01/06	OS-1	295	11.5	8.3	11.2
	OS-2	284	10.9	8.3	11.6
	OS-3	285	10.8	8.3	11.8
06/08/06	OS-1	281	15.4	8.6	11.2
	OS-2	278	13.9	8.4	10.8
	OS-3	277	13.7	8.4	11.2
06/15/06	OS-1	282	12.8	8.7	15.0
	OS-2	285	12.2	8.9	15.6
	OS-3	286	11.8	8.5	15.9
06/22/06	OS-1	248	13.6	8.2	6.2
	OS-2	247	13.6	8.3	7.9
	OS-3	246	13.7	8.3	8.4
06/29/06	OS-1	277	13.5	8.6	14.6
	OS-2	276	13.3	8.6	15.0
	OS-3	277	12.8	8.6	15.3
07/06/06	OS-1	282	15.9	8.6	13.6
	OS-2	281	15.4	8.6	14.9
	OS-3	281	15.2	8.6	15.3
07/13/06	OS-1	284	13.8	8.6	14.7
	OS-2	285	12.8	8.6	15.9
	OS-3	286	12.2	8.5	16.7
07/20/06	OS-1	283	14.3	8.4	12.6
	OS-2	284	14.2	8.4	12.9
	OS-3	285	13.5	8.4	13.9
07/27/06	OS-1	287	12.3	8.4	14.7
	OS-2	288	11.6	8.4	15.9
	OS-3	288	11.5	8.4	16.4

TABLE 31 (Continued)

Sampling Station	Sampling Station	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	pH (units)	Temperature (C)
08/03/06	OS-1	279	10.1	8.6	19.6
	OS-2	280	10.1	8.5	19.2
	OS-3	280	10.6	8.6	19.8
08/10/06	OS-1	228	8.8	8.5	21.3
	OS-2	229	8.6	8.4	21.7
	OS-3	229	8.7	8.4	21.7
08/17/06	OS-1	277	9.6	8.5	17.9
	OS-2	278	9.4	8.5	18.9
	OS-3	279	9.1	8.5	19.7
08/24/06	OS-1	275	8.0	8.3	20.4
	OS-2	277	8.1	8.2	22.4
	OS-3	276	7.9	8.3	21.7
08/31/06	OS-1	278	7.6	8.3	21.1
	OS-2	279	7.9	8.2	22.5
	OS-3	278	7.9	8.2	21.7
09/05/06	OS-1	276	8.8	8.4	21.0
	OS-2	278	8.3	8.3	21.3
	OS-3	278	8.4	8.2	21.4
10/19/06	OS-1	277	12.7	8.0	7.4
	OS-2	280	12.0	8.0	8.0
	OS-3	281	12.3	8.1	8.1
10/26/06	OS-1	285	12.8	8.2	5.8
	OS-2	284	12.2	8.2	7.0
	OS-3	284	12.4	8.2	6.7

TABLE 32 COMPARISON OF ICHTHYOPLANKTON AND INVERTEBRATE DENSITIES IN ENTRAINMENT AND AMBIENT SAMPLES

Species/Taxon/Life Stage	Entrainment		Ambient	
	Average No./100 M^3	Percent of Total	Average No./100 M^3	Percent of Total
Alewife - juvenile	0.051	0.03	0.104	0.19
Alewife - post-yolk sac larvae	0.012	0.01	0.015	0.03
Alewife larvae - unstaged	0.000	0.00	0.006	0.01
Alewife - yolk-sac larvae	0.611	0.40	0.764	1.36
Alosa sp. - post-yolk sac larvae	0.000	0.00	0.005	0.01
Alosa sp. - yolk-sac larvae	0.000	0.00	0.021	0.04
Clupeidae sp. - post-yolk sac larvae	0.000	0.00	0.022	0.04
Clupeidae sp. larvae - unstaged	0.340	0.22	0.191	0.34
Clupeidae sp. - yolk-sac larvae	0.006	<0.01	0.630	1.13
Common carp larvae - unstaged	0.005	<0.01	0.002	<0.01
Common carp - yolk-sac larvae	0.950	0.62	0.042	0.08
Pimephales sp. - yolk-sac larvae	0.000	0.00	0.001	<0.01
Cyprinidae sp. - post-yolk sac larvae	0.006	<0.01	0.001	<0.01
Cyprinidae sp. larvae - unstaged	0.029	0.02	0.000	0.00
Cyprinidae sp. - yolk-sac larvae	0.461	0.30	0.010	0.02
White sucker - yolk-sac larvae	0.009	0.01	0.000	0.00
Catostomidae sp. - post-yolk sac larvae	0.010	0.01	0.000	0.00
Catostomidae sp. - yolk-sac larvae	0.011	0.01	0.001	<0.01
Rainbow smelt - juvenile	0.304	0.20	0.013	0.02
Rainbow smelt - post-yolk sac larvae	0.209	0.14	0.133	0.24
Rainbow smelt - unstaged	0.006	<0.01	0.003	0.01
Rainbow smelt - yolk-sac larvae	0.012	0.01	0.030	0.05
Coregoninae sp. - post-yolk sac larvae	0.026	0.02	0.006	0.01
Coregoninae sp. larvae - unstaged	0.006	<0.01	0.003	0.01
Coregoninae sp. - yolk-sac larvae	0.109	0.07	0.360	0.64
Burbot - post-yolk sac larvae	0.000	0.00	0.002	<0.01
Burbot larvae - unstaged	0.000	0.00	0.001	<0.01
Burbot - yolk-sac larvae	1.384	0.91	1.348	2.41
Ninespine stickleback - adult	0.000	0.00	0.001	<0.01
Ninespine stickleback - juvenile	0.036	0.02	0.002	<0.01
Ninespine stickleback - post-yolk sac larvae	0.013	0.01	0.002	<0.01
Gasterosteidae sp. - post-yolk sac larave	0.073	0.05	0.104	0.19
Gasterosteidae sp. larvae - unstaged	0.000	0.00	0.001	<0.01
Gasterosteidae sp. - yolk-sac larave	0.045	0.03	0.138	0.25
Mottled sculpin - adult	0.000	0.00	0.002	<0.01
Slimy sculpin - adult	0.000	0.00	0.001	<0.01
Deepwater sculpin - post-yolk sac larvae	0.007	<0.01	0.001	<0.01
Deepwater sculpin - yolk-sac larvae	0.000	0.00	0.001	<0.01
Deepwater sculpin - juvenile	0.006	<0.01	0.000	0.00
Cottidae sp. - juvenile	0.000	0.00	0.067	0.12
Cottidae sp. larvae - unstaged	0.000	0.00	0.001	<0.01
Cottidae sp. - adult	0.000	0.00	0.023	0.04
Cottidae sp. - post-yolk sac larvae	0.000	0.00	0.023	0.04
Lepomis sp. larvae-unstaged	0.000	0.00	0.001	<0.01
Yellow perch - yolk-sac larvae	0.000	0.00	0.020	0.04

TABLE 32 (Continued)

Species/Taxon/Life Stage	Entrainment		Ambient	
	Average	Percent of	Average	Percent of
Percidae sp. - post-yolk sac larvae	0.011	0.01	0.000	0.00
Percidae sp. larvae - unstaged	0.000	0.00	0.004	0.01
Percidae sp. - yolk-sac larave	0.087	0.06	0.006	0.01
Round goby - post-yolk sac larvae	0.012	0.01	0.000	0.00
Round goby - yolk-sac larvae	0.013	0.01	0.000	0.00
Damaged larvae - unstaged	0.059	0.04	0.058	0.10
Damaged larvae - yolk-sac larvae	0.011	0.01	0.000	0.00
Unidentified egg - fertilized egg	4.365	2.86	1.319	2.36
Unidentified egg - unstaged	0.105	0.07	0.000	0.00
Hyalella azteca	0.000	0.00	0.001	<0.01
Gammarus sp.	143.019	93.57	50.463	90.11
Amphipods	0.000	0.00	0.019	0.03
Hemimysis anomala	0.066	0.04	0.002	<0.01
Mysis relicta	0.363	0.24	0.015	0.03
Northern clearwater crayfish	0.000	0.00	0.002	<0.01
Orconectes sp.	0.000	0.00	0.008	0.01
Average =	2.51	100.0	0.92	100.0

TABLE 33 ESTIMATED TOTAL NUMBER OF ICHTHYOPLANKTON ENTRAINED AT KEWAUNEE POWER STATION, APRIL 1975 - MARCH 1976

Species/Taxon	Estimated No. Entrained (X 10^6)	Percent	Cumulative Percent
Alewife eggs	45.002	67.92	67.92
Rainbow smelt juveniles	9.715	14.66	82.58
Rainbow smelt eggs	7.089	10.70	93.28
Rainbow smelt larvae	2.764	4.17	97.45
Alewife juveniles	0.393	0.59	98.04
Unidentified eggs	0.303	0.46	98.50
Alewife larvae	0.271	0.41	98.91
Common carp larvae	0.237	0.36	99.27
Catostomidae eggs	0.233	0.35	99.62
Burbot larvae	0.076	0.11	99.73
Slimy sculpin larvae	0.085	0.13	99.86
Coregoninae larvae	0.076	0.11	99.98
Catostomidae larvae	0.016	0.02	100.00

Data from NALCO (undated)

APPENDIX A

Impingement, Entrainment, and Ambient Ichthyoplankton Calculation Procedures

A.1. INTRODUCTION

The Dominion Resources 316b database stores plant operating conditions, water quality data, and organism data collected for three main types of sampling events: entrainment, impingement, and ambient (Lake Michigan) ichthyoplankton sampling. Data for juvenile/adult fish sampling events, which occur at off-site sampling locations, are also stored in the database. One of the main project objectives is to generate estimates of monthly and annual organism estimates, based on the collected organism data. This appendix describes the impingement, entrainment, and ambient ichthyoplankton calculation procedures for Kewaunee Power Station.

A.2. SAMPLING SCHEDULE AND EXTRAPOLATION RANGE

Sampling was scheduled weekly from March through August, and twice a month otherwise.

Each Parent Event date had an assigned date range where each date in the range was assigned the same (entrained or impinged) organism estimate that was recorded during the parent event date. The date range is established by counting halfway back to the prior parent event, and halfway forward to the subsequent parent event. A small example for three parent dates is presented below:

Parent Date	Range Start	Range End	Day Count
3/23/06	3/20/06	3/26/06	7
3/30/06	3/27/06	4/6/06	11
4/13/06	4/7/06	4/16/06	10

A.3. *IMPINGEMENT CALCULATION PROCEDURES*

A.3.1 Overview

Kewaunee Power Station has a single sampling station or specific location where impingement samples were collected from the screen-wash troughs. The database stores the screen-wash sampling station, the circulating-water pumps associated with the sampling station, the flow rate for each circulating-water pump, and the number of traveling screens. The identities of the pumps operating at the time of sample collection were recorded to allow later calculation of sample volumes. The organism estimates and pump flow data were combined to ultimately yield annual organism estimates at plant maximum flow conditions. The maximum daily cooling-water flow capacity for the station is 2,183,553 cubic meters (M^3).

At Kewaunee Power Station, impingement samples were collected as a single, 24-hour sample.

A.3.2 Organism Data

In each sample collected, the organisms were identified to species. For individual organisms the weight and length were recorded. If large numbers of a particular organism were collected, the organisms were combined as a batch weight and batch count. Thus, a given sample could have individual and batch organism counts associated with it.

A.3.3 Impingement Flow Calculations

Circulating-water pumps that were operating during a sampling event were recorded and their design flow rates were used to calculate actual and maximum cooling-water flow for the sampling period.

A.3.4 Impingement Parent Event Organism Estimates

For each type of organism, the objective was to calculate a 24-hour organism estimate at maximum plant flow conditions. This is the final organism estimate for the 24-hour parent impingement event. As described below, the actual pump flow was adjusted to the maximum capacity pump flow for the impingement calculations.

The 24-hour organism estimate for each parent event was calculated in steps as follows:

1. Calculate the 24-hour organism estimate: This is simply the tally of each species collected during the 24-hour sampling event.

2. Calculate sample flow volume: The sample volume is calculated by adding the flow of all pumps (either 1 or 2 at Kewaunee) operating during the 24-hour period to get the total actual station flow in M^3 units.

3. Calculate final 24-hour maximum flow volume-based estimates: The initial 24-hour sample count is a non-adjusted 24-hr organism estimate. If the 24-hour measured flow was not at the maximum rate (all pumps on full) then the non-adjusted 24-hour organism estimate was adjusted to the 24-hour maximum flow-based estimate (Table A-1).

Table A-1 illustrates how the flow is adjusted if both pumps were not operating during a sampling event. For example, note that during the 3/16/2006 sampling event for rainbow smelt impingement, only one of two pumps was operating (note the 45,491 M^3/hr in the "Sample Volume" column for that date). The next column contains the volume (90,982 M^3) that would have gone through the station in one hour had both pumps been operating. Since the maximum flow volume is twice the actual flow volume, the "count in 24-hour sample" (2 rainbow smelt) is multiplied by 2 to generate the "24-hour count at max flow") (4 rainbow smelt).

A.3.5 Impingement Yearly, Parent Event, and Monthly Organism Estimates

The parent event-date range estimate is calculated as in the following example. The 3/16/2006 parent event had a 24-hour maximum flow-based estimate of 4 rainbow smelt (Table A-1). That final estimate of 4 rainbow smelt was applied to the 3/16/06 parent date range of 3/13/0606 to 3/19/06, or 7 days in March 2006. For the 3/16/06 parent-event date range, the associated final rainbow smelt impingement estimate was 28, i.e., 4 rainbow smelt from the parent event times 7 days in the range = 28.

For monthly estimates, the parent-event estimate data are still used to assign the impingement estimates to each day in the month. For example, the monthly impingement estimate rainbow smelt in May 2006 required the use of four parent events as shown below:

Parent date	Start date	End Date
5/4/06	5/1/06	5/11/06
5/18/06	5/12/06	5/21/06
5/25/06	5/22/06	5/28/06
6/1/06	5/29/06	6/4/06

The 5/4/06 event spans 11 days in May, the 5/18/06 event spans 10 days in May, the 5/25/06 event spans 7 days in May, and the 6/1/06 parent event includes 3 days in May. Therefore the May 2006 monthly total of rainbow smelt, for example, would be calculated as the sum of:

5/4/06 parent 24-hour organism estimate of 28 * 11 days = 308 smelt;
5/18/06 parent 24-hour organism estimate of 8 * 10 days = 80 smelt;
5/25/06 parent 24-hour organism estimate of 28 * 7 days = 196 smelt; and
6/1/06 parent 24-hour organism estimate of 73 * 3 days = 219 smelt.

Thus, 803 rainbow smelt were estimated to have been impinged during May 2006 (see Table A-1 and Table 6 of this report).

The yearly totals are simply the sum of all the parent, or monthly, total estimates.

Note that the date ranges assigned to each parent event span exactly 365 days for the year.

A.4. ENTRAINMENT DATA

A.4.1 Overview

The entrainment samples were collected from the discharge channel. Four replicate pairs of samples were collected from mid-depth with a plankton net. The four sample pairs were grouped as follows:

Hour Group A: event 1, Reps A and B 10 a.m.(10:00)
Hour Group B: event 2, Reps A and B 4 p.m. (16:00)
Hour Group C: event 3, Reps A and B 10 p.m. (22:00)
Hour Group D: event 4, Reps A and B 4 a.m. (04:00—the following day)

The data from the four sampling events were combined to represent the parent event, as illustrated below.

Site	ParentEvent Date	Ent Time	Event Number	FlowMeter	SampleName	FlwNet Count
Kewaunee	10/26/2006	1000	1	GO 2030R	KW-042006-01-AE-DIS-N	11,621
Kewaunee	10/26/2006	1000	1	GO 2030R	KW-042006-01-BE-DIS-N	11,608
Kewaunee	10/26/2006	1600	2	GO 2030R	KW-042006-02-AE-DIS-N	11,845
Kewaunee	10/26/2006	1600	2	GO 2030R	KW-042006-02-BE-DIS-N	11,002
Kewaunee	10/26/2006	2200	3	GO 2030R	KW-042006-03-AE-DIS-N	10,987
Kewaunee	10/26/2006	2200	3	GO 2030R	KW-042006-03-BE-DIS-N	10,342
Kewaunee	10/26/2006	0400	4	GO 2030R	KW-042006-04-AE-DIS-N	11,126
Kewaunee	10/26/2006	0400	4	GO 2030R	KW-042006-04-BE-DIS-N	10,085

A.4.2 Organism Data

In each sample collected, the organisms were identified by species or lowest practicable taxonomic level and life stage (egg, larvae, juvenile, etc). For individual fish larvae, the length (0.1 mm) was recorded for 20 specimens of each taxon. If large numbers of a particular organism/life stage were collected, the organisms in excess of the 20 measured organisms were combined as a batch count. Thus a given sample could have individual and batch organism counts associated with it.

A.4.3 Entrainment Sample-Volume Calculations

Each sample collected had a corresponding sample volume measurement. The sample flow through the net was measured with a mechanical flow meter. For each flow measurement the flow meter initial, final, and net "counts" were recorded. The net count was used in a formula to calculate the water sample volume (in cubic meters) associated with a sample. The flow meter and volume formula are as follows:

Meter Name	Formula	Factor1	Factor2
GO 2030R	NetCount/9480.774 * 50 = cubic meters	9,480.77	50.00

Using the flow meter ID, formula, and net counts recorded, the final sample volume in cubic meters (M^3) was calculated for each sample, as: (net count / factor1) * factor 2.

A.4.4 Entrainment Parent 24-hour Average Organism Densities

For each species/ life stage of organism, the objective was to calculate a 24-hour average organism density (#/100 M^3 sample volume). This would be considered the final organism density for the 24-hour parent event.

The 24-hour final density for each parent event was calculated in steps as follows:

1. Adjust each organism/life stage count in each sample to the standard 100 M^3 sample volume.

2. The standard densities were averaged for each of the four Hour Groups (A, B, C, D).

3. The four averages were averaged to yield a final 24-hour average density.

An example calculation for burbot yolk-sac larvae from the 4/27/2006 parent date is presented in the Table A-2.

A.4.6 Calculation of Entrainment Final (Annual) Organism Estimates

Sampling was normally weekly from March through August and (September excepted) twice a month otherwise. There were 37 parent events during the annual study. Each parent event was assigned a date range, to each date of which the 24-hour final organism estimate for the parent date was applied. The date range for a parent event may span across two different months. Below is a tabulation of parent date ranges for Kewaunee Power Line Station:

Kewaunee Power Station Parent Event dates and Applied Ranges:

Parent Date	Range Start	Range End	Day Count
03/09/06	3/1/2006	3/12/2006	12
03/16/06	3/13/2006	3/19/2006	7
03/23/06	3/20/2006	3/26/2006	7
03/30/06	3/27/2006	4/2/2006	7
04/06/06	4/3/2006	4/9/2006	7
04/13/06	4/10/2006	4/16/2006	7
04/20/06	4/17/2006	4/23/2006	7
04/27/06	4/24/2006	4/30/2006	7
05/04/06	5/1/2006	5/7/2006	7
05/11/06	5/8/2006	5/14/2006	7
05/18/06	5/15/2006	5/21/2006	7
05/25/06	5/22/2006	5/28/2006	7
06/01/06	5/29/2006	6/4/2006	7
06/08/06	6/5/2006	6/11/2006	7
06/15/06	6/12/2006	6/18/2006	7
06/22/06	6/19/2006	6/25/2006	7
06/29/06	6/26/2006	7/2/2006	7
07/06/06	7/3/2006	7/9/2006	7
07/13/06	7/10/2006	7/16/2006	7
07/20/06	7/17/2006	7/23/2006	7
07/27/06	7/24/2006	7/30/2005	7
08/03/06	7/31/2006	8/6/2006	7
08/10/06	8/7/2006	8/13/2006	7
08/17/06	8/14/2006	8/20/2006	7
08/24/06	8/21/2006	8/27/2006	7
08/31/06	8/28/2006	9/2/2006	6
09/05/06	9/3/2006	9/27/2006	25
10/19/06	9/28/2006	10/22/2006	25
10/26/06	10/23/2006	11/2/2006	11
11/09/06	11/3/2006	11/17/2006	15
11/29/06	11/18/2006	12/6/2006	19
12/14/06	12/7/2006	12/21/2006	15
12/28/06	12/22/2006	1/4/2007	14
01/11/07	1/5/2007	1/18/2007	14
01/25/07	1/19/2007	1/31/2007	13
02/07/07	2/1/2007	2/14/2007	14
02/21/07	2/15/2007	2/28/2007	14

An annual organism estimate at maximum flow operation was calculated in three steps:

1. The final 24-hour organism density for each parent event (in 100 M^3 volume) was used with the maximum daily circulating-water flow to calculate the estimated number of organisms entrained during the 24-hour parent event. For example, the maximum 24-hour cooling-water flow at Kewaunee Power Station is 2,183,568 M^3. The burbot larvae average density for the 4/27/2006 parent event was 49.023/100M^3 (Table A-2). The 24-hour estimate adjusted for the maximum flow volume is 1,070,451 ([2,183,568/100]*49.023) total larvae entrained.

1. The final 24-hour organism estimate at maximum flow volume was applied to each day in the parent date range. For example, the burbot larvae 24-hour estimate for the Kewaunee Power Station 4/27/2006 parent event was 1,070,451 at maximum flow. The 4/27/2006 parent date

range was 4/24/06 to 4/30/06 (7 days), therefore the 24-hour maximum flow-based estimate was multiplied by 7 to get the final maximum estimate for that date range of 7,493,157 larvae.

2. The sums of 24-hour organism estimates (at maximum flow volume) for each date range were then summed to yield the final annual organism estimate, for maximum flow conditions.

A.5. AMBIENT ICHTHYOPLANKTON DATA

A.5.1 Overview

The ambient ichthyoplankton samples were collected at designated locations in the vicinity of the plant intake. During each parent event there were usually 48 samples collected. Much like the entrainment data, samples were organized in four hour groups:

Hour Group A: event 1, Reps A and B 10 a.m.(10:00)
Hour Group B: event 2, Reps A and B 4 p.m. (16:00)
Hour Group C: event 3, Reps A and B 10 p.m. (22:00)
Hour Group D: event 4, Reps A and B 4 a.m. (04:00—the following day)

The samples consisted of an oblique (surface, mid-depth, bottom) tow at each of three offshore locations, and mid-depth tows at each of three inshore locations. Sample volume calculations were based on counts from flow meters affixed in the mouth of each net.

A.5.2 Organism Data

In each sample collected, the organisms were identified by species and life stage (egg, larvae, juvenile, etc). For individual fish larvae, the length (0.1 mm) was recorded. If large numbers of a particular organism/life stage were collected, the organisms were combined as a batch count. Thus a given sample could have individual and batch organism counts associated with it.

A.5.3 Ambient Ich Sample-Volume Calculations

Each sample collected had a corresponding water flow (volume) measurement. The flow was measured with a General Oceanics (GO) mechanical flow meter. For each flow measurement the flow meter initial, final, and net counts were recorded. The net count was used in a formula to calculate the water sample volume (in cubic meters) associated with a sample. The flow meter and volume formula is as follows:

Meter Name	Formula	Factor1	Factor2
GO 2030R	NetCount/9480.774 * 50 = cubic meters	9,480.77	50.00

Using the flow meter ID, formula, and net counts recorded, the final sample volume in cubic meters (M^3) was calculated for each sample, as: (net count / factor1) * factor 2.

A.5.4 Final Organism Density Calculations

Unlike the impingement and entrainment data, the ambient ich data were not processed into final yearly estimates. The organism counts for each organism/life stage were presented as average organism densities (#/100 M^3 sample volume) for each 24-hour parent event.

The time duration of the sample is not a factor in the calculations. The 6-minute tow time was established, based on experience, to generate a sample volume of roughly 40-60 cubic meters of water. So it is only the flow meter net count (and associated formula) that figures in the calculations.

The process for obtaining the average density was as follows. For each parent event the raw organism counts were adjusted to a 100 M^3 standard sample volume. Most actual sample volumes were 40-60 M^3 volume. For example, for a sample volume of 46.7 M^3, and a raw count of 18 round goby larvae, the sample density is calculated as ([100/46.7]*18= 38.5 round goby larvae per 100 M^3. When averaged with the remaining samples from the parent event, the result is the organism density representing the entire 24-hour period at a given sampling location.

TABLE A-1 CALCULATION SEQUENCE FOR IMPINGEMENT ESTIMATE FOR RAINBOW SMELT

Dominion Resourcces - Impingment Organism Count Totals (24 Hour)

Site	Organism
Kewaunee	Rainbow smelt

Parent Date	Station	# Pumps On	Count in 24-Hr sample	Sample Vol. (M3/Hr)	Station Max Vol. (M3/Hr)	Site Max Vol. (M3) in 24 hr	24-Hour Count at Max Flow	Parent Start	Parent End	Day Count	Total Max Count in Parent Range
2/9/2006	Station 1	1	0	45,491	90,982	2,183,568	0	2/1/2006	2/15/2006	15	0
2/23/2006	Station 1	1	0	45,491	90,982	2,183,568	0	2/16/2006	3/2/2006	15	0
3/9/2006	Station 1	1	0	45,491	90,982	2,183,568	0	3/3/2006	3/12/2006	10	0
3/16/2006	Station 1	1	2	45,491	90,982	2,183,568	4	3/13/2006	3/19/2006	7	28
3/23/2006	Station 1	1	0	45,491	90,982	2,183,568	0	3/20/2006	3/26/2006	7	0
3/30/2006	Station 1	1	0	45,491	90,982	2,183,568	0	3/27/2006	4/6/2006	11	0
4/13/2006	Station 1	2	1	90,982	90,982	2,183,568	1	4/7/2006	4/16/2006	10	10
4/20/2006	Station 1	2	0	90,982	90,982	2,183,568	0	4/17/2006	4/23/2006	7	0
4/27/2006	Station 1	2	2	90,982	90,982	2,183,568	2	4/24/2006	4/30/2006	7	14
5/4/2006	Station 1	1	14	45,491	90,982	2,183,568	28	5/1/2006	5/11/2006	11	308
5/18/2006	Station 1	1	4	45,491	90,982	2,183,568	8	5/12/2006	5/21/2006	10	80
5/25/2006	Station 1	2	28	90,982	90,982	2,183,568	28	5/22/2006	5/28/2006	7	196
6/1/2006	Station 1	2	73	90,982	90,982	2,183,568	73	5/29/2006	6/4/2006	7	511
6/8/2006	Station 1	2	80	90,982	90,982	2,183,568	80	6/5/2006	6/11/2006	7	560
6/15/2006	Station 1	2	1	90,982	90,982	2,183,568	1	6/12/2006	6/18/2006	7	7
6/22/2006	Station 1	2	35	90,982	90,982	2,183,568	35	6/19/2006	6/25/2006	7	245
6/29/2006	Station 1	2	3	90,982	90,982	2,183,568	3	6/26/2006	7/2/2006	7	21
7/6/2006	Station 1	2	0	90,982	90,982	2,183,568	0	7/3/2006	7/9/2006	7	0
7/13/2006	Station 1	2	0	90,982	90,982	2,183,568	0	7/10/2006	7/16/2006	7	0
7/20/2006	Station 1	2	10	90,982	90,982	2,183,568	10	7/17/2006	7/23/2006	7	70
7/27/2006	Station 1	2	4	90,982	90,982	2,183,568	4	7/24/2006	7/30/2006	7	28
8/3/2006	Station 1	2	0	90,982	90,982	2,183,568	0	7/31/2006	8/6/2006	7	0
8/10/2006	Station 1	2	0	90,982	90,982	2,183,568	0	8/7/2006	8/13/2006	7	0
8/17/2006	Station 1	2	1	90,982	90,982	2,183,568	1	8/14/2006	8/20/2006	7	7
8/24/2006	Station 1	2	0	90,982	90,982	2,183,568	0	8/21/2006	8/27/2006	7	0
8/31/2006	Station 1	2	4	90,982	90,982	2,183,568	4	8/28/2006	9/25/2006	29	116
10/19/2006	Station 1	1	0	45,491	90,982	2,183,568	0	9/26/2006	10/22/2006	27	0

TABLE A-1 CALCULATION SEQUENCE FOR IMPINGEMENT ESTIMATE FOR RAINBOW SMELT

Dominion Resourcces - Impingment Organism Count Totals (24 Hour)

Site	Organism
Kewaunee	Rainbow smelt

Parent Date	Station	# Pumps On	Count in 24-Hr sample	Sample Vol. (M3/Hr)	Station Max Vol. (M3/Hr)	Site Max Vol. (M3) in 24 hr	24-Hour Count at Max Flow	Parent Start	Parent End	Day Count	Total Max Count In Parent Range
10/26/2006	Station 1	1	3	45,491	90,982	2,183,568	6	10/23/2006	11/2/2006	11	66
11/9/2006	Station 1	1	1	45,491	90,982	2,183,568	2	11/3/2006	11/17/2006	15	30
11/29/2006	Station 1	1	0	45,491	90,982	2,183,568	0	11/18/2006	12/6/2006	19	0
12/14/2006	Station 1	1	15	45,491	90,982	2,183,568	30	12/7/2006	12/21/2006	15	450
12/28/2006	Station 1	1	3	45,491	90,982	2,183,568	6	12/22/2006	1/4/2007	14	84
1/11/2007	Station 1	1	16	45,491	90,982	2,183,568	32	1/5/2007	1/18/2007	14	448
1/26/2007	Station 1	1	0	45,491	90,982	2,183,568	0	1/19/2007	1/31/2007	13	0
								Annual Total:		365	3,279

TABLE A-2 CALCULATION SEQUENCE FOR 24-HOUR ENTRAINMENT ESTIMATE FOR BURBOT, 4/27/06 PARENT EVENT

Dominion Power - Entrainment Organism Count Averages (24 Hour)

Site	Date	Organism
Kewaunee	4/27/2006	Burbot - yolk-sac larvae

Event Group: Group 1

Event #	Depth	Left/Right	Sample Vol M3	Count in Sample	Indiv or Batch		Count in 100 M3
1	Middle	A	39.357	13	IND	IND	33.031
1	Middle	B	42.124	19	BATCH	IND	45.105
					Event Group Average:		39.068

Event Group: Group 2

Event #	Depth	Left/Right	Sample Vol M3	Count in Sample	Indiv or Batch		Count in 100 M3
2	Middle	A	36.594	23	BATCH	IND	62.852
2	Middle	B	39.006	29	BATCH	IND	74.348
					Event Group Average:		68.600

Event Group: Group 3

Event #	Depth	Left/Right	Sample Vol M3	Count in Sample	Indiv or Batch		Count in 100 M3
3	Middle	A	37.464	31	BATCH	IND	82.747
3	Middle	B	38.571	40	BATCH	IND	103.705
					Event Group Average:		93.226

Event Group: Group 4

Event #	Depth	Left/Right	Sample Vol M3	Count in Sample	Indiv or Batch		Count in 100 M3
4	Middle	A	36.568	30	BATCH	IND	82.040
4	Middle	B	36.307	23	BATCH	IND	63.349
					Event Group Average:		72.694

Burbot - yolk-sac larvae		
	Average 24-hour count in 100m3:	68.397
	Site Maximum Flow in 24 Hour (m3):	2183568
	Average Count in 24 Hour (m3) at Max Fow:	1493000

APPENDIX B

Impingement Daily Sample Counts

TABLE B-1 KEWAUNEE POWER STATION IMPINGEMENT DATA - RAW DATA FEBRUARY 2006 – JANUARY 2007

Species/Taxon	February		March				April			May			June				
	9	23	9	16	23	30	13	20	27	4	18	25	1	8	15	22	29
Silver lamprey							1										
Alewife							3	69	1,110	17,695	1,510	18,827	168,629	115,126	20,561	27,116	48,926
Gizzard shad																	
Common carp	1			1													
Spottail shiner				1													
Longnose dace		2		1		1		2	1		1	1		1			
Creek chub																	
White sucker	2		2	2	1	2	2	3		1	1		2		3	1	1
Longnose sucker		1				1									1	7	3
Shorthead redhorse																1	
Catostominae sp.																	
Black bullhead	1																
Channel catfish	2	1															
Rainbow smelt				2			1		2	14	4	28	73	80	1	35	3
Lake whitefish							1										
Bloater																	
Chinook salmon																1	
Round whitefish			1														
Brown trout																	
Lake trout															1		1
Burbot		2	3	1	1	2	1	2				1				1	
Threespine stickleback					1		1		1	1		4		7	2	7	
Ninespine stickleback								1	1	5	27	54	73	267	21	95	2
Mottled sculpin	5	9		1	1	3	2	1	2	6	2	2	9	20	9		
Slimy sculpin	3			1	1		1				5	3					
Cottidae																	
White perch																	
Pumpkinseed																	
Bluegill																	
Smallmouth bass																	
Rock bass																	
Yellow perch	5				1		1							7		18	1
Round goby							1	2	2								
Northern clearwater crayfish		1						1							1		
Total	19	16	6	10	6	9	15	81	1,119	17,622	1,550	18,920	168,786	115,508	20,600	27,282	46,937

Species/Taxon	July				August					October		November		December		January		Annual Total
	6	13	20	27	3	10	17	24	31	19	26	9	29	14	28	11	26	
Silver lamprey																		1
Alewife	105,198	39,325	78,617	25,821	1,040	186	3,199	168	20	3,270	5,981	10,090	7	7	1			690,402
Gizzard shad											2	1	3	24	10	1		41
Common carp																	1	3
Spottail shiner						17		73	23		1			1	1	8		125
Longnose dace			2		2	15	3	4	9		3				1		1	50
Creek chub									1									1
White sucker	3	1	4	2	7	3	2	4	1			1	1					52
Longnose sucker	3	3	4	4	14	11	2	3	3				1			1		62
Shorthead redhorse																		1
Catostominae sp.											1							1
Black bullhead														2				3
Channel catfish					1								1	1	1		1	8
Rainbow smelt			10	4			1		4		3	1		15	3	16		300
Lake whitefish															1			2
Bloater															1			1
Chinook salmon									1									2
Round whitefish				1										1	1	3		7
Brown trout							1									1		2
Lake trout						5												7
Burbot				2		8		2							2	1		27
Threespine stickleback	10		16										1			4		55
Ninespine stickleback	10	4	4	1	2	1	1	1	1							1		572
Mottled sculpin		8	2	6	3	7	10	13	4	7	10				1	2		145
Slimy sculpin		4																18
Cottidae													1					1
White perch											1							1
Pumpkinseed									1									1
Bluegill																1		1
Smallmouth bass				1				1	1									3
Rock bass																	1	1
Yellow perch				4	2	12	23	5	6	1	6	3		11	7	50	1	164
Round goby							2	3			2							12
Northern clearwater crayfish			6	29	43	13	12	6	1		1					6	3	123
Total	105,224	39,345	78,665	25,875	1,114	276	3,256	283	76	3,278	6,011	10,096	15	62	30	95	8	692,195

APPENDIX C

Length Statistics for Impinged Fish

TABLE C-1 LENGTH STATICTICS FOR IMPINGED ORGANISMS AT KEAWAUNEE POWER STATION, FEBRUARY 2006 – JANUARY 2007

Species/Taxon	N	Min mm	Max mm	Avg mm	StdDev mm
Silver lamprey	1	271	271	271.0	--
Alewife	1037	50	186	93.4	22.8
Gizzard shad	41	80	132	104.4	12.3
Common carp	3	611	858	707.7	132.0
Spottail shiner	102	40	132	88.3	13.4
Creek chub	1	59	59	59.0	--
Longnose dace	50	67	128	90.7	16.1
White sucker	43	196	575	441.0	74.9
Longnose sucker	59	152	487	334.8	75.6
Shorthead redhorse	1	508	508	508.0	--
Catostominae sp.	1	115	115	115.0	--
Black bullhead	3	202	270	228.7	36.3
Channel catfish	8	67	759	208.4	229.9
Rainbow smelt	124	39	172	106.2	28.4
Bloater	1	97	97	97.0	--
Lake whitefish	2	204	328	266.0	87.7
Round whitefish	7	158	585	366.6	167.8
Chinook salmon	2	590	875	732.5	201.5
Brown trout	2	470	616	543.0	103.2
Lake trout	7	546	805	678.7	100.4
Burbot	27	82	791	337.7	245.2
Ninespine stickleback	191	45	88	69.3	8.2
Threespine stickleback	23	47	66	56.6	5.5
Mottled sculpin	113	38	117	78.4	15.1
Slimy sculpin	15	54	96	69.9	11.5
Cottidae sp.	1	66	66	66.0	--
White perch	1	73	73	73.0	--
Smallmouth bass	3	65	199	136.0	67.4
Bluegill	1	145	145	145.0	--
Pumpkinseed	1	121	121	121.0	--
Rock bass	1	139	139	139.0	--
Yellow perch	145	52	335	87.8	39.9
Round goby	12	72	182	108.4	30.6
Northern clearwater crayfish	123	29	68	50.7	6.7

APPENDIX D

Length Statistics for Fish Collected in Ambient Studies

TABLE D-1 LENGTH STATISTICS FOR FISH COLLECTED DURING AMBIENT STUDIES AT KEWAUNEE POWER STATION

Species/Taxon	N	Min mm	Max mm	Avg mm	StDev mm
Alewife	1006	22	219	91.1	29.7
Gizzard shad	44	85	485	302.1	145.8
Common carp	8	269	688	600.6	131.6
Lake chub	42	28	203	49.2	33.8
Brassy minnow	1	36	36	36.0	
Common shiner	11	40	62	51.0	8.4
Emerald shiner	10	62	105	87.2	12.0
Spottail shiner	216	18	130	92.9	29.2
Fathead minnow	33	28	61	42.1	9.4
Longnose dace	204	20	126	71.9	27.9
White sucker	395	67	583	440.4	81.7
Longnose sucker	442	110	577	323.1	82.6
Black bullhead	2	259	262	260.5	2.1
Rainbow smelt	50	0.2	171	64.7	39.4
Bloater	9	68	140	83.7	22.0
Lake whitefish	1	546	546	546.0	
Round whitefish	118	277	518	405.3	46.3
Brown trout	53	142	842	523.5	156.7
Rainbow trout	2	225	514	369.5	204.4
Lake trout	142	537	929	722.4	69.6
Chinook salmon	31	118	868	610.0	217.3
Coho salmon	3	374	680	575.0	174.1
Burbot	11	129	771	497.7	163.9
Banded killifish	1	46	46	46.0	
Ninespine stickleback	9	22	61	45.0	13.0
Threespine stickleback	9	30	64	53.9	9.8
Mottled sculpin	1	52	52	52.0	
White perch	3	82	160	109.7	43.7
Smallmouth bass	1	380	380	380.0	
Pumpkinseed	1	120	120	120.0	
Yellow perch	104	97	378	285.6	69.3
Round goby	11	45	192	113.4	49.5

APPENDIX E

Density of Ichthyoplankton and Invertebrates in Entrainment Samples

TABLE E-1 AVERAGE DENSITY (NO./100 M^3) OF ICHTHYOPLANKTON ENTRAINED AT KEWAUNEE POWER STATION, MARCH 2006 - FEBRUARY 2007

Species/Taxon	2006																
	March				April				May				June				
	9	16	23	30	6	13	20	27	4	11	18	25	1	8	15	22	29
Alewife - juvenile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Alewife - post-yolk sac larvae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Alewife - yolk-sac larvae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Clupeidae sp. - unstaged	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Clupeidae sp. - yolk-sac larvae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Common carp - unstaged	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00
Common carp - yolk-sac larvae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.42	1.69	17.02	0.19	1.93
Cyprinidae sp. - unstaged	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.47	0.00	0.00
Cyprinidae sp. - post-yolk sac larvae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22
Cyprinidae sp. - yolk-sac larvae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.37	0.90	3.21	0.45	5.58
White sucker - yolk-sac larvae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00
Catostomus sp. - post-yolk sac larvae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.37	0.00	0.00	0.00	0.00
Catostomus sp. - yolk-sac larvae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.42	0.00	0.00	0.00	0.00
Rainbow smelt - juvenile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rainbow smelt - post-yolk sac larvae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.38	2.14
Rainbow smelt - unstaged	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rainbow smelt - yolk-sac larvae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coregoninae - unstaged	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coregoninae - post-yolk sac larvae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coregoninae - yolk-sac larvae	0.00	0.00	0.00	0.00	0.23	0.18	2.02	1.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Burbot - yolk-sac larvae	0.00	0.00	0.00	0.00	0.00	0.00	1.28	49.02	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ninespine stickleback - juvenile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ninespine stickleback - post-yolk sac larvae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gasterosteidae - post-yolk sac larvae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.58	0.68
Gasterosteidae - yolk-sac larvae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.44
Deepwater sculpin - juvenile	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Deepwater sculpin - post-yolk sac larvae	0.00	0.00	0.00	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Percidae sp. - post-yolk sac larvae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.00
Percidae sp. - yolk-sac larvae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.51	0.22	0.49
Round goby - post-yolk sac larvae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24
Round goby - yolk-sac larvae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.00	0.00
Unidentifiable larvae - unstaged	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00
Unidentifiable larvae - yolk-sac larvae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified egg - fertilized egg	0.00	0.00	0.22	0.00	0.00	0.00	2.16	0.00	0.00	0.00	1.13	0.89	29.37	36.79	29.26	16.82	10.38
Unidentified egg - unstaged	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.46	0.00	0.00
Gammarus sp.	39.76	33.79	21.40	89.04	29.15	38.23	31.73	126.54	79.02	126.63	114.31	33.20	88.69	60.87	127.59	37.51	108.18
Hemimysis anomala	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mysis relicta	1.85	4.09	0.23	0.48	0.00	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Species/Taxon	2006																2007			
	July				August					Sept	October		November		December		January		February	
	6	13	20	27	3	10	17	24	31	5	19	26	9	29	14	28	11	25	7	21
Alewife - juvenile	0.00	0.00	0.00	0.00	0.00	0.00	0.23	1.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Alewife - post-yolk sac larvae	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Alewife - yolk-sac larvae	0.00	0.93	2.28	2.16	0.24	17.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Clupeidae sp. - unstaged	0.00	0.19	0.38	0.00	0.46	11.33	0.00	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Clupeidae sp. - yolk-sac larvae	0.00	0.00	0.00	0.00	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Common carp - unstaged	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Common carp - yolk-sac larvae	0.00	0.21	0.00	0.00	0.24	0.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cyprinidae sp. - unstaged	0.00	0.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cyprinidae sp. - post-yolk sac larvae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cyprinidae sp. - yolk-sac larvae	0.77	4.96	0.41	0.19	0.00	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
White sucker - yolk-sac larvae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Catostomus sp. - post-yolk sac larvae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Catostomus sp. - yolk-sac larvae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rainbow smelt - juvenile	0.00	0.00	0.19	0.20	0.65	0.22	0.45	0.00	0.00	0.00	0.25	2.53	0.88	0.70	2.60	1.64	1.15	0.00	0.00	0.00
Rainbow smelt - post-yolk sac larvae	0.00	0.40	2.19	0.22	0.42	0.70	0.86	0.21	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rainbow smelt - unstaged	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.00	0.00	0.00	0.00
Rainbow smelt - yolk-sac larvae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coregoninae - unstaged	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coregoninae - post-yolk sac larvae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coregoninae - yolk-sac larvae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Burbot - yolk-sac larvae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ninespine stickleback - juvenile	0.00	0.00	0.00	0.00	0.00	1.10	0.00	0.00	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ninespine stickleback - post-yolk sac larvae	0.00	0.00	0.00	0.00	0.00	0.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gasterosteidae - post-yolk sac larvae	0.41	0.21	0.00	0.39	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gasterosteidae - yolk-sac larvae	0.00	0.00	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Deepwater sculpin - juvenile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.00	0.00
Deepwater sculpin - post-yolk sac larvae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Percidae sp. - post-yolk sac larvae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Percidae sp. - yolk-sac larvae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Round goby - post-yolk sac larvae	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Round goby - yolk-sac larvae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentifiable larvae - unstaged	0.00	0.38	0.60	0.77	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentifiable larvae - yolk-sac larvae	0.00	0.00	0.20	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified egg - fertilized egg	4.54	6.49	22.65	0.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified egg - unstaged	0.00	0.00	0.00	0.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gammarus sp.	101.70	124.73	59.85	189.30	341.90	404.20	278.97	265.67	207.65	1191.02	308.04	198.44	111.09	109.19	47.94	39.08	29.51	53.66	13.07	21.89
Hemimysis anomala	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.00	0.48	0.66	0.69	0.00	0.20	0.21
Mysis relicta	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.25	1.05	1.11	1.94	0.01

ATTACHMENT 8

Kewaunee Power Station
Proposal of Information Collection
Quality Assurance Plan

Dominion

ATTACHMENT 8.

QUALITY ASSURANCE PLAN FOR IMPINGEMENT MORTALITY and/or ENTRAINMENT (IM&E) STUDIES

Prepared for

Dominion Electric Environmental Services

Prepared by:
ASA Analysis & Communication, Inc.
90 East Main St.
P.O. Box 57
Washingtonville, NY 10992

September 26, 2005

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1 INTRODUCTION

This Quality Assurance Plan has been prepared in support of Proposals for Information Collection (PIC) for Dominion power plants. The plan describes the Quality Assurance / Quality Control program[1] that will be used for collecting new data on impingement mortality and/or entrainment, as appropriate, currently occurring at the Dominion plants. These data will be incorporated into the Impingement Mortality and/or Entrainment (IM&E) Characterization Studies and the Comprehensive Demonstration Studies to be submitted in the application for the NPDES permit renewals for the plants.

The IM&E studies proposed for the Dominions plants are a process having the following stages:

- Study Design
- Study Mobilization
- Sample Collection
- Sample Analysis
- Data Management
- Data Analysis and Reporting
- Record Keeping

This process forms the basis for the design and implementation of the QA Plan. It is recognized that poor execution at any stage of the process can negate proper execution of the remaining stages, resulting in the failure to meet the objectives of the study. The QA Plan addresses the entire process in the following sections.

This document is submitted specifically in support of the PIC for the facility.

An integral part of designing the IM&E studies was the full consideration of study objectives, the types of data collected and their intended use, and the objectives defined for data quality.

1.1 STUDY OBJECTIVES

The IM&E sampling plan, included as a component of the PIC, has been designed to provide data on the rates of impingement mortality and entrainment currently occurring at the power plant. Data collected by the IM&E sampling plan also will serve as a foundation for estimating the calculation baseline, needed for determining the levels of impingement mortality and entrainment reduction being achieved at the plant, presently and in the future.

The Phase II Rule requires that the IM&E Characterization Study provide:

[1] Quality assurance (QA) is defined as the integrated system of management activities involving planning, implementation, assessment, reporting and quality improvement that will ensure that the collected data are of the type and quality necessary for demonstrating compliance with the Clean Water Act §316(b) Phase II Rule. Quality control (QC) is the system of activities that will evaluate the sampling program as it is being conducted and compare the collected data against designated specifications.

1. Taxonomic identifications of all life stages of fish, shellfish, and protected species in the vicinity of the cooling water intake structure and susceptible to impingement and entrainment;
2. A characterization of these species and life stages in terms of their abundance and their spatial and temporal distribution, sufficient to characterize the annual, seasonal and diel variations in impingement mortality and entrainment; and
3. Documentation of current impingement mortality and entrainment of these species and life stages.

In addition to these basic requirements, the IM&E Characterization Study will provide information necessary for choosing an appropriate Rule compliance alternative..

1.2 TYPES OF DATA AND THEIR USES

The types of raw data that will be collected and their intended uses are shown in Table 1-1.

Table 1-1 Types of Raw Data Collected in the IM&E Monitoring and Their Intended Uses

RAW DATA	TYPE	USE
Sample count by taxon and life stage	Quantitative	Mean daily, monthly or annual impingement or entrainment rates (numerical)
Subsample count by taxon and life stage	Quantitative	Extrapolate from subsample count to estimated total sample count of impinged or entrained organisms
Organism length	Quantitative (mm)	Life stage determination or length/age relationship
Organism weight	Quantitative (g)	Mean daily, monthly or annual impingement or entrainment rates (biomass)
Batch weight by taxon and life stage	Quantitative (g)	Mean daily, monthly or annual impingement or entrainment rates (alternative biomass method)
Organism age	Quantitative (years)	Age structure and economic benefit models
Organism condition	Qualitative (parasites, fungus or indications of disease, injury or stress)	Morbidity analysis
Sample duration	Quantitative (min)	Extrapolation to total daily (24-hour) impingement or entrainment
Sample volume	Quantitative (gal or m^3)	Organism density estimates and extrapolation to total daily impingement or entrainment based on circulating pump volume
Circulating pump volume	Quantitative (gal or m^3)	In combination with sample volume and density estimates, extrapolation to total impingement or entrainment
Number of screens operating and sampled	Quantitative (count)	Possible extrapolation to total impingement if some screens not operating while circulating pump is on
Physical/chemical parameters (water temperature, DO, salinity/conductivity)	Quantitative (°F or °C, mg/l, or S)	Evaluation of possible causes of impingement or entrainment abundance or mortality
Number held for survival testing by taxon and life stage	Quantitative (count)	Impingement or entrainment survival testing or literature review
Number alive by taxon and life stage	Quantitative (count)	Impingement or entrainment survival testing or literature review

1.3 DATA QUALITY OBJECTIVES

In considering the desired objectives for data quality, several data quality indicators (DQIs) were addressed. The study design and QA Plan consider these indicators, as shown in Table 1-2.

Table 1-2 Data Quality Indicators Considered In Designing the IM&E Studies

DQI	Definition	QA Treatment
Precision	Agreement among repeated measurements of a property (e.g., impingement counts), expressed as a range, standard deviation, or coefficient of variation.	Standardized sampling procedures and designed the study to increase precision by using stratification and by optimizing sample numbers and sample allocation.
Bias	Systematic or persistent distortion of a measurement process that causes errors in one direction.	Designed sampling methodology to minimize bias. Will use reference materials or known standards for instrument measurements.
Accuracy	Overall agreement of a measurement with its true value; includes a combination random error (precision) and systematic error (bias).	Designed sampling methodology to maximize accuracy. Will use reference materials (e.g., taxonomic reference collection) or known standards for instrument measurements.
Representativeness	Qualitative term referring to whether the data accurately represent the sampled population.	Included all data sources (e.g., screens and units), population states (e.g., diel and seasonal variance), and affected organisms in study design.
Comparability	Qualitative term expressing measure of confidence that one data set can be compared to another for decision making.	Standardized sampling gear and methodology, especially between baseline studies and verification monitoring. Considered gear and methodology used previously on source waterbody.
Completeness	Measure of amount of valid data needed.	Will evaluate whether amount of valid data successfully collected meets study objectives.

2 QA MANAGEMENT

An effective QA/QC program relies upon having a clearly defined management structure. The management structure includes all individuals with responsibility for conducting the sampling program, but with the additional responsibility for ensuring generation of quality data. The management structure will involve all individuals with the authority and responsibility to enforce the QA Plan for the studies and to make corrective actions, as necessary. These individuals will include decision makers, data generators and data users. The roles and responsibilities of each individual will be defined by job title.

The overall responsibility for the successful completion of the studies lies with Dominion's Environmental Program Manager. He/she will have support staff within Dominion to which specific roles and responsibilities may be assigned for specific tasks, such as operating traveling screens during impingement monitoring, providing and overseeing safety precautions, obtaining necessary plant operation data, or arranging for work space and utilities for sampling and processing crews. The support staff will answer directly to Dominion's Environmental Program Manager, but may communicate with contractor staff as needed on a daily basis. The Dominion Environmental Program Manager will be the ultimate decision maker for the studies and will rely on expert advice provided by any contracted firms or individuals performing the studies.

In terms of the QA/QC Program, the most important individual will be the QA Officer. The QA Officer will be independent of those individuals generating and using the data collected during the study. The QA Officer will have experience in performing QA/QC programs for §316(b) studies, if possible, or otherwise will have comparable experience in aquatic monitoring surveys. He/she will have the ultimate responsibility for implementing the QA Plan and will organize and/or conduct reviews and technical assessments (surveillance or audits) of the study activities. The QA Officer will answer directly to the Dominion Environmental Program Manager but will coordinate his/her actions with the Dominion Biology Manager or Designee.

QA will incorporate redundancy as a means for ensuring the QA/QC functions are completed, by imposing two layers of responsibility. The first layer will be responsibility for performing an activity. The second layer will be the responsibility for overseeing the activity to be sure that it is performed, and performed accurately. The person designated for "activity responsibility" is the person in the position most likely to be directly involved in a specified QA activity or in a supervisory role for that activity. The person designated for "oversight responsibility" is the person who would most benefit from having the QA activity completed satisfactorily, i.e., they would have a vested interest or be most knowledgeable about the functions of the QA activity. The following sections of the QA Plan correspond to the stages in the study process named earlier in Section 1. Under each element of the QA Plan in these sections, the QA Management positions designated to have activity responsibility and oversight responsibility are specified.

3 STUDY MOBILIZATION

Mobilization for Dominion IM&E studies will include all activities prior to the actual start of sample collection. During this phase, several key activities occur which are critical to the production of high quality data. For each activity, certain elements of the QA plan will be implemented in order to ensure the quality of the data produced by the study.

3.1 STUDY OBJECTIVES

Prior to design of the study, the objectives for the study are clearly defined and written. The objectives are stated as quantitatively as possible, such as:

- Estimate total annual impingement (all fish species combined) with a coefficient of variation of 20% or less.
- Estimate total annual impingement with a coefficient of variation of 25% or less for each of the five most abundant species.

The written objectives form the basis for the study design.

Activity Responsibility: Dominion Environmental Program Manager
Oversight Responsibility: QA Officer

3.2 SITE ACCESS & SERVICES

Site access issues and ancillary services that may be required for an IM&E study will be evaluated. The evaluation will consider site entry issues, access to sample collection points, equipment storage and security, support required from operations staff, other support (e.g. utilities, copying, restrooms), safety, and potential labor union issues.

Activity Responsibility: Dominion environmental staff
Oversight Responsibility: Dominion Environmental Program Manager

3.3 STUDY DESIGN

The IM&E studies are designed using the written objectives as guidance. Proper consideration is given to practical issues identified in 3.2, and to statistical considerations of bias, power, and precision of estimates produced to set sampling parameters. To the extent possible, SOPs specify the key characteristics or operating parameters of sampling equipment.

Activity Responsibility: Dominion Environmental Program Manager
Oversight Responsibility: QA Officer

3.4 SCOPE OF WORK (SOW) AND REQUEST FOR PROPOSALS (RFP)

The study objectives and design will be used to prepare a clear and detailed Scope of Work that will describe the tasks required for the IM&E study. If the project is to be outsourced, the scope of work will form the basis for the RFP. The RFP will set a schedule that allows for adequate time for contractor response to the RFP, the contractor selection process, study mobilization, sample collection and analysis, data management and analysis, and report preparation prior to required submittal dates to regulatory agencies. The RFP will require that the selected contractor adhere to all aspects of the QA plan and will prepare SOPs according to Plan guidelines.

Activity Responsibility: Dominion Environmental Program Manager
Oversight Responsibility: QA Officer

3.5 CONTRACTOR SELECTION

Potential bidders will be evaluated prior to release of the RFP to ensure that all firms receiving the RFP have the capability to perform the work adequately. The bid evaluation process will emphasize technical capability demonstrated in the proposals received and proposed costs.

Activity Responsibility: Dominion Environmental and Purchasing Staff
Oversight Responsibility: Dominion Environmental Program Manager

3.6 EQUIPMENT ACQUISITION AND DEVELOPMENT

Sampling equipment will be acquired and/or constructed according to specifications in the study design and RFP. Adequate backup equipment will be provided to ensure the study design can be followed in the event of equipment failure or loss. Prior to initiation of sampling, equipment will be tested or otherwise confirmed to meet specifications. A calibration program will be instituted for equipment requiring calibration. Any deviations from specifications must have prior approval.

Activity Responsibility: Dominion Biology Manager or Designee
Oversight Responsibility: QA Officer

3.7 STANDARD OPERATING PROCEDURES (SOPS)

SOPs for review and approval prior to initiation of sampling will be prepared. The SOPs will cover all aspects of sample collection, sample analysis, and data management. SOPs will be controlled documents and will be assigned to study personnel according to a specified distribution list. Each SOP copy will be identified by a unique serial number. The draft SOPs will be used to guide project personnel in conducting these phases of the project; however, changes to the draft SOP may be necessary as the study progresses. SOPs will be updated as needed and will specify the effective dates when changes are to be implemented. (Specific topics to be covered in the SOPs are provided in later sections.)

Activity Responsibility: Dominion Biology Manager or Designee
Oversight Responsibility: QA Officer

3.8 PROJECT PERSONNEL

Staff will have appropriate levels of education and training for their assigned roles. Training in site-specific sampling and sample analysis procedures (SOPs) will be documented in the program files. Training may include trial sampling efforts and analysis of trial samples.

Activity Responsibility: Dominion Biology Manager or Designee
Oversight Responsibility: QA Officer

4 SAMPLE COLLECTION

The sample collection stage is critical for maintaining data quality. Failures at this stage are often uncorrectable because design-specified sampling times cannot be repeated once they have passed. When precise timing of sampling is not crucial, poorly executed sampling events may be repeated, but only if the deficiencies are recognized immediately. Therefore, the focus at this stage will be on preventing sampling deficiencies rather than on correcting them. Elements of the QA Plan for the sample collection stage are:

4.1 STANDARD OPERATING PROCEDURES (SOPS)

Detailed SOPs covering all steps in sample collection will be developed and will be explicitly followed by staff performing the study. An example of a sample collection SOP in outline form is shown in Illustration 4-1.

Activity Responsibility: Dominion Biology Manager or Designee
Oversight Responsibility: QA Officer

4.2 QA ASSESSMENTS

Adherence to sample collection SOPs will be observed and documented through technical assessments, such as activity surveillance or audits. These technical assessments will be conducted by the QA officer, or a person under his/her direct supervision, and will be scheduled throughout the course of the study. The assessments also will include checks on quantitative items (e.g., correct mesh nets). They will incorporate a checklist of items based on the SOPs, and will include observations relevant to performance of sampling that may not be covered by the SOP. Careful attention will be paid to the initiation of the study when staff may be less familiar with the SOPs. Reports of surveillance or audit results will be distributed to the Dominion Biology Manager..

Activity Responsibility: QA Officer
Oversight Responsibility: Dominion Biology Manager

4.3 CORRECTION OF VARIANCES

Any variances indicated in the QA assessments will be corrected as rapidly as possible. A corrective action memo, indicating the audit finding and the action taken, will be produced for program files.

Activity Responsibility: Dominion Biology Manager
Oversight Responsibility: QA Officer

Illustration 4-1 Example Sample Collection SOP Outline

1. Title Page (including date and copy number)
2. Distribution List
3. Update Process and History
4. Introduction
    a. Objectives
    b. Study Design
    c. Project Schedule
5. Sample Collection Procedures
    a. General project sampling
        i. Site personnel and roles
        ii. Equipment Required
        iii. Presampling Procedures
            1. Safety-related equipment
            2. Sampling gear set-up and preparation
            3. Equipment inspection
            4. Equipment calibration
            5. Testing
        iv. Sampling Procedures
            1. Collection process
            2. Sample voiding criteria
            3. Sample preservation and labeling
            4. Sample transport, storage, chain-of-custody
        v. Post-sampling Procedures
            1. Equipment tear-down and storage
            2. Equipment inspection
            3. Data sheet completion and storage
    b. Collection efficiency sampling
    c. Other specialized sampling
6. Reference Materials
    a. Sampling licenses and permits
    b. Location diagrams and maps
    c. Emergency contacts
        i. Contractor internal
        ii. Dominion
        iii. Emergency services
    d. Data sheet examples
    e. Variable names, definitions and codes

5 SAMPLE PROCESSING

Depending on the available facilities, sample processing may be done on site immediately following sample collection, or may be done at some later time by on-site or off-site staff. This QA plan recognizes that some level of error is inevitable at this stage, and includes elements to eliminate, reduce, and/or quantify those errors.

5.1 STANDARD OPERATING PROCEDURES

The SOPs for sample processing will describe in detail the process for tracking samples, finding and removing organisms, identifying organisms, determining key organism characteristics (e.g. weight, length, age, condition), and recording the data. An example of a Sample Processing SOP in outline form is shown in Illustration 5-1. The Sample Processing SOP will be subject to the same control and documentation process described in Section 4.

Activity Responsibility: Lab / Field Designee
Oversight Responsibility: QA Officer

5.2 VOUCHER SPECIMENS AND VERIFICATION

A reference collection of specimens of all life stages for all collected and verified fish and target shellfish taxa will be maintained at the site of sample analysis for use by project staff. Taxonomic references also will be kept there. A list of these references will be included in the SOP. A recognized taxonomy expert will be enlisted to assist with difficult specimens.

Activity Responsibility: Lab / Field Designee
Oversight Responsibility: QA Officer

5.3 QA ASSESSMENTS

Adherence to sample processing SOPs will be observed and documented through technical assessments, such as activity surveillance or audits. These technical assessments will be conducted by the QA officer, or a person under his/her direct supervision, and will be scheduled throughout the course of the study. The assessments will include checks on quantitative items (e.g., taxonomic identification and counts, measurements). They will incorporate a checklist of items based on the SOPs, but will also include observations relevant to performance of sampling processing that may not be covered by the SOP. Careful attention will be paid to the initiation of the study when staff may be less familiar with the SOPs. Reports of surveillance or audit results will be distributed to the Dominion Biology Manager or Designee..

Activity Responsibility: QA Officer
Oversight Responsibility: Dominion Biology Manager or Designee

5.4 CORRECTION OF VARIANCES

Any variances indicated in the QA assessments will be corrected as rapidly as possible. A corrective action memo, indicating the audit finding and the action taken, will be produced for program files.

Activity Responsibility: Dominion Biology Manager or Designee
Oversight Responsibility: QA Officer

5.5 QUALITY CONTROL INSPECTIONS

Certain aspects of sample analysis may be subjected to re-analysis through quality control inspections. Data potentially subject to inspection include:

- Detection and removal of organisms from detritus and debris
- Sample splitting
- Identification of life stage and taxon
- Organism counts
- Length measurements
- Weight measurements
- Condition determination

An inspection plan will be employed which specifies the type of plan, definition of items and lots to be inspected, failure criteria, inspection frequencies, and Average Outgoing Quality Limit (AOQL). The QC inspection plan will be described in the sample analysis SOP prepared by the contractor. All errors that are found during QC inspections will be corrected.

The results of the QC inspection program will be incorporated into the final study report, and will include analysis of the inspection data to estimate the Average Outgoing Quality (AOQ) for inspected items.

Activity Responsibility: Lab / Field Designee
Oversight Responsibility: QA Officer

Illustration 5-1 Example Sample Processing SOP Outline

1. Title Page (including date and copy number)
2. Distribution List
3. Update Process and History
4. Introduction
    a. Objectives
    b. Study Design
    c. Project Schedule
5. Sample Processing Procedures
    a. General project samples
        i. Site personnel and roles
            1. Training requirements
        ii. Equipment Required
        iii. Sample Tracking Procedures
        iv. Sample Splitting or Subsampling Procedures
        v. Sampling Analysis Procedures
            1. Organism sorting
            2. Organism identification
            3. Organism characteristics
        vi. Post-analysis Procedures
            1. Reference Specimens
            2. (Re)preservation
            3. Waste disposal
            4. Data sheet completion and storage
        vii. Quality Control Inspection Procedures
    b. Collection efficiency samples
    c. Other specialized samples
6. Reference Materials
    a. Sampling licenses and permits
    b. Location diagrams and maps
    c. Emergency contacts
        i. Contractor internal
        ii. Dominion
        iii. Emergency services
    d. Data sheet examples
    e. Variable names, definitions and codes

6 DATA MANAGEMENT

Data management is an important stage of the IM&E study, when errors inadvertently are added to the data or when previous errors can be identified and corrected, in some cases. Due to recent changes in instrumentation and computer technology, there are many options for incorporating raw data values into electronic formats. The traditional way, in which data are entered onto paper data forms by hand and then "keypunched" into a computer-readable format, is becoming less common. Hand-held and laptop computers sometimes have replaced the data sheets entirely, and instruments may now download data directly to computers.

In general, it is good practice to reduce the number of steps in the process that changes observations and measurements into data. However, in the course of simplifying the process, the ability to correct errors may be reduced if physical records are eliminated. Thus there can be a tradeoff: as the process is simplified and the opportunity for errors is reduced, the ability to correct errors also is reduced. This trade-off will be considered when preparing SOPs for data management.

6.1 STANDARD OPERATING PROCEDURES

The SOPs for data management will be prepared and will detail the process for converting measurements and observations into electronic-format data files ready for analysis. As appropriate for the measurement methods employed, the process will cover data sheet review, data entry, data validation, file conversion to different formats, and data preservation.

Activity Responsibility: Data Analysis/Database Designee
Oversight Responsibility: QA Officer

6.2 DATA SHEET REVIEW

For data flows that use paper records, the records will be reviewed for legibility and completeness before conversion to electronic formats.

Activity Responsibility: Data Analysis/Database Designee
Oversight Responsibility: QA Officer

6.3 DATA ENTRY REVIEW

For data flows that are entered from paper records, an inspection program will be designed and implemented to identify data entry errors, correct errors identified, and provide a quantitative measure of the quality of the data entry process.

Activity Responsibility: Data Analysis/Database Designee
Oversight Responsibility: QA Officer

6.4 DIRECT DATA ENTRY

For data flows using direct data entry (data are entered directly into electronic storage without a paper input record), the entry process will employ data validation software to immediately identify common types of invalid data entries (e.g., invalid codes, weight values out of reasonable bounds based on length, missing values). Data will be uploaded to a temporary storage device or printed to a paper record as soon as reasonably possible.

Activity Responsibility: Data Analysis/Database Designee
Oversight Responsibility: QA Officer

6.5 DATA VALIDATION

Once data have been converted to electronic format, they will be subjected to error-checking software that will identify common types of errors, such as missing variable values, values out of range, variables out of range based on value of another variable (e.g. weight and length), missing records, and duplicate records.

Activity Responsibility: Data Analysis/Database Designee
Oversight Responsibility: QA Officer

6.6 CONVERSION TO FINAL FORMAT

If raw data are converted to a different format for end use, such as ASCII to a SAS data set, the software used to make the conversion will be retained and documented..

Activity Responsibility: Data Analysis/Database Designee
Oversight Responsibility: QA Officer

6.7 DATA DOCUMENTATION

Data documentation will include a list of the names of all variables and number of data records in the final data sets, definitions of the variables, and explanations of code values.

Activity Responsibility: Data Analysis/Database Designee
Oversight Responsibility: QA Officer

6.8 DATA PRESERVATION

Prior to study report submission, the final data sets will be maintained on a storage device with a backup. Data backup will be done on a regular basis.

Activity Responsibility: Data Analysis/Database Designee
Oversight Responsibility: Dominion Biology Manager or Designee

7 DATA ANALYSIS AND REPORTING

In this stage of the process, information is obtained from the data, interpreted, and presented in a formal report. Although errors in this stage are correctable, they detract from the confidence placed in the studies and should be kept to a minimum.

7.1 REPORT OUTLINE AND ANALYTICAL REVIEW

Prior to the initiation of data analysis activities, a draft outline for the study report will be prepared and reviewed for approval. The outline will include the major sections and subsections of the report, and will describe the analytical methods to be used. The outline will reflect the study objectives and regulatory requirements. It will contain sections to describe the QA program for the study.
Activity Responsibility: Dominion Biology Manager or Designee
Oversight Responsibility: Dominion Environmental Program Manager

7.2 REPORT REVIEW

The study report will undergo an internal review phase prior to completion to ensure that it conforms to the outline and meets regulatory requirements. A draft report will be submitted in accordance with the schedule in the RFP. Dominion will review the report and submit comments. The author will resolve comments and produce the final report in accordance with the schedule and requirements in the RFP.

Activity Responsibility: Dominion Biology Manager, QA Officer
Oversight Responsibility: Dominion Environmental Program Manager

8 RECORD KEEPING

Record keeping requirements for IM&E studies are extensive due to the continuing need to renew discharge permits every 5 years under CWA §316(b). Due to the renewal process, it may be necessary to access information collected 5, 10, 15 or more years previously. Information collected under a comprehensive QA program may be invaluable in documenting changes in the levels of IM&E and in comparing effectiveness of new technologies that may arise in the future. Standard business practices for record keeping may not be sufficient for IM&E studies.

8.1 PAPER DOCUMENTS

Paper documents generated during the project will be scanned and stored as Portable Document Format (PDF) files and transmitted to Dominion at conclusion of the study on media specified in the RFP. The documents will include:

- Correspondence (Letters and memos in project file)
- Log books
- SOPs
- Final Project Report

Dominion will maintain the PDF files with proper consideration of media deterioration and changes in data storage technology until Dominion no longer owns the facility or the facility is no longer subject to §316 regulation.

Activity Responsibility: Dominion Biology Manager or Designee
Oversight Responsibility: Dominion Environmental Program Manager

8.2 DATA PRESERVATION

Once the study report has been submitted to the agencies, two copies of all data files will be transmitted to Dominion on media specified in the RFP. The data files will include:

- Images (pdf format) of paper data sheets
- Data files in initial entry format (e.g. ASCII)
- Intermediate data files
- Final data files in storage format
- Listing of final data files (pdf format)
- Data Management SOP (pdf format)
- Data Documentation (pdf format)
- Computer programs (format of use)
- Computer programs (pdf format)

The data files will be maintained with proper consideration of media deterioration and changes in data storage technology until Dominion no longer owns the facility or the facility is no longer subject to §316 regulation.

Activity Responsibility: Dominion Biology Manager or Designee
Oversight Responsibility: Dominion Environmental Program Manager