EXHIBIT A

NPDES Permit No. IL0004316 – SIPC Marion Station

ILLINOIS ENVIRONMENTAL PROTECTION AGENCY

1021 NORTH GRAND AVENUE EAST, P.O. BOX 19276, SPRINGFIELD, ILLINOIS 62794-9276 – (217) 782-3397
JAMES R. THOMPSON CENTER, 100 WEST RANDOLPH, SUITE 11-300, CHICAGO, IL 60601 – (312) 814-6026

ROD R. BLAGOJEVICH, GOVERNOR   DOUGLAS P. SCOTT, DIRECTOR

217/782-0610

RECEIVED
FEB 20 2007
So. IL. Power Co-Op

February 1, 2007

Southern Illinois Power Cooperative
11543 Lake of Egypt Road
Marion, Illinois 62959

Re: Southern Illinois Power Cooperative - Marion Station
NPDES Permit No. IL0004316
Final Permit

Gentlemen:

Attached is the final NPDES Permit for your discharge. The Permit as issued covers discharge limitations, monitoring, and reporting requirements. Failure to meet any portion of the Permit could result in civil and/or criminal penalties. The Illinois Environmental Protection Agency is ready and willing to assist you in interpreting any of the conditions of the Permit as they relate specifically to your discharge.

The Agency has begun a program allowing the submittal of electronic Discharge Monitoring Reports (eDMRs) instead of paper Discharge Monitoring Reports (DMRs). If you are interested in eDMRs, more information can be found on the Agency website, http://epa.state.il.us/water/edmr/index.html. If your facility is not registered in the eDMR program, a supply of preprinted paper DMR Forms for your facility will be sent to you prior to the initiation of DMR reporting under the reissued permit. Additional information and instructions will accompany the preprinted DMRs upon their arrival.

The Permit as issued is effective as of the date indicated on the first page of the Permit. You have the right to appeal any condition of the Permit to the Illinois Pollution Control Board within a 35 day period following the issuance date.

Should you have questions concerning the Permit, please contact Blaine Kinsley at the telephone number indicated above.

Sincerely,

Alan Keller

Alan Keller, P.E.
Manager, Permit Section
Division of Water Pollution Control

SAK:BAK:JMC:04110101.jmc

Attachment: Final Permit

cc: Records
Compliance Assurance Section
Marion Region
USEPA
Facility

NPDES Permit No. IL0004316

Illinois Environmental Protection Agency

Division of Water Pollution Control

1021 North Grand Avenue East

Post Office Box 19276

Springfield, Illinois 62794-9276

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM

Reissued (NPDES) Permit

Expiration Date: February 29, 2012

Issue Date: February 1, 2007
Effective Date: March 1, 2007

Name and Address of Permittee:

Southern Illinois Power Cooperative
11543 Lake of Egypt Road
Marion, Illinois 62959

Facility Name and Address:

Southern Illinois Power Cooperative - Marion Station
10825 Lake of Egypt Road
Marion, Illinois 62959
(Williamson County)

Discharge Number and Name:		Receiving Waters:
002	Ash Pond No. 4 Effluent	Little Saline Creek
A02	Chemical Metal Cleaning Wastewater	Little Saline Creek
003	Condenser Cooling Water	Lake of Egypt
004	Intake Screen Backwash	Lake of Egypt
005	Fly Ash and Scrubber Sludge Disposal Pond B-3	Little Saline Creek
A05	Chemical Metal Cleaning Wastewater	Little Saline Creek
006	Storm Water Associated with Industrial Activity	Lake of Egypt

In compliance with the provisions of the Illinois Environmental Protection Act, Title 35 of Ill. Adm. Code, Subtitle C and/or Subtitle D, Chapter 1, and the Clean Water Act (CWA), the above-named permittee is hereby authorized to discharge at the above location to the above-named receiving stream in accordance with the standard conditions and attachments herein.

Permittee is not authorized to discharge after the above expiration date. In order to receive authorization to discharge beyond the expiration date, the permittee shall submit the proper application as required by the Illinois Environmental Protection Agency (IEPA) not later than 180 days prior to the expiration date.

Alan Keller

Alan Keller, P.E.
Manager, Permit Section
Division of Water Pollution Control

SAK:JMC:04110101.jmc

NPDES Permit No. IL0004316

Effluent Limitations and Monitoring

PARAMETER	LOAD LIMITS lbs/day DAF (DMF) 30 DAY AVERAGE	DAILY MAXIMUM	CONCENTRATION LIMITS mg/l 30 DAY AVERAGE	DAILY MAXIMUM	SAMPLE FREQUENCY	SAMPLE TYPE

1. From the effective date of this permit until the expiration date, the effluent of the following discharge(s) shall be monitored and limited at all times as follows:

Outfall: 002 Ash Pond No. 4 Effluent*

This discharge consists of:	Approximate Flow
1. Process wastewater	2.0 MGD
2. Boiler evaporation and blowdown	0.1 MGD
3. Bottom ash slurry	2.5 MGD
4. Coal pile runoff	Intermittent
5. Yard drains	0.005 MGD
6. Floor drains and equipment drains	0.002 MGD
7. Slag storage pile runoff	Intermittent
8. Scrubber sludge slurry water	0.05 MGD
9. Scrubber sludge disposal area runoff	Intermittent

PARAMETER	30 DAY AVERAGE (lbs/day)	DAILY MAXIMUM (lbs/day)	30 DAY AVERAGE (mg/l)	DAILY MAXIMUM (mg/l)	SAMPLE FREQUENCY	SAMPLE TYPE
Flow (MGD)	See Special Condition 1				1/Week	Continuous
pH	See Special Condition 2				1/Week	Grab
Oil and Grease			15	20	2/Month	Grab
Total Suspended Solids			15	30	1/Week	8-Hour Composite
Total Dissolved Solids				1000	1/Month	8-Hour Composite
Iron (total)			2	4	1/Month	8-Hour Composite
Boron				**	1/Month	8-Hour Composite
Fluoride			1.4		1/Month	8-Hour Composite
Copper***			0.023	0.037	1/Month	8-Hour Composite
Mercury****					1/Month	8-Hour Composite

*See Special Condition 13
**See Special Condition 16
***See Special Condition 17
****See Special Condition 19

NPDES Permit No. IL0004316

Effluent Limitations and Monitoring

PARAMETER	LOAD LIMITS lbs/day DAF (DMF)		CONCENTRATION LIMITS mg/l			
	30 DAY AVERAGE	DAILY MAXIMUM	30 DAY AVERAGE	DAILY MAXIMUM	SAMPLE FREQUENCY	SAMPLE TYPE

1. From the effective date of this permit until the expiration date, the effluent of the following discharge(s) shall be monitored and limited at all times as follows:

Outfall: 003 Condenser Cooling Water*

This discharge consists of:	Approximate Flow
1. Condenser cooling water	229 MGD
2. Auxiliary cooling water	0.4 MGD
3. HVAC system discharge	0.4 MGD

Flow (MGD)	See Special Condition 1				Daily	Continuous
Temperature	See Special Condition 4				Daily	Continuous
Total Residual Chlorine	See Special Condition 5			0.2	1/Week	Grab

*See Special Condition 7 and 8 concerning additional thermal discharge requirements.

Outfall: 004 Intake Screen Backwash

See Special Condition 10

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Effluent Limitations and Monitoring

	LOAD LIMITS lbs/day DAF (DMF)		CONCENTRATION LIMITS mg/l			
PARAMETER	30 DAY AVERAGE	DAILY MAXIMUM	30 DAY AVERAGE	DAILY MAXIMUM	SAMPLE FREQUENCY	SAMPLE TYPE

1. From the effective date of this permit until the expiration date, the effluent of the following discharge(s) shall be monitored and limited at all times as follows:

Outfall: 005 Fly Ash and Scrubber Sludge Disposal Pond B-3*

This discharge consists of:	Approximate Flow
1. Fly ash sluice water	Intermittent
2. Scrubber sludge slurry water	Intermittent
3. Floor and equipment drains	Intermittent
4. Yard drains	Intermittent
5. Miscellaneous plant blowdowns	Intermittent
6. Coal Pile Runoff	Intermittent

PARAMETER	30 DAY AVERAGE	DAILY MAXIMUM	30 DAY AVERAGE	DAILY MAXIMUM	SAMPLE FREQUENCY	SAMPLE TYPE
Flow (MGD)	See Special Condition 1				Daily When Discharging	Continuous
pH	See Special Condition 2				Daily When Discharging	Grab
Oil and Grease			15	20	1/Month	Grab
Total Suspended Solids			15	30	Daily When Discharging	Grab
Total Dissolved Solids				1000	1/Month	Grab
Iron (total)			2	4	1/Month	Grab
Boron				9.0**	1/Month	Grab
Zinc***					1/Month	Grab
Mercury****					1/Month	8-Hour Composite

*See Special Condition 13
**See Special Condition 16
***See Special Condition 11
****See Special Condition 19

NPDES Permit No. IL0004316

Effluent Limitations and Monitoring

PARAMETER	LOAD LIMITS lbs/day DAF (DMF) 30 DAY AVERAGE	LOAD LIMITS lbs/day DAF (DMF) DAILY MAXIMUM	CONCENTRATION LIMITS mg/l 30 DAY AVERAGE	CONCENTRATION LIMITS mg/l DAILY MAXIMUM	SAMPLE FREQUENCY	SAMPLE TYPE

1. From the effective date of this permit until the expiration date, the effluent of the following discharge(s) shall be monitored and limited at all times as follows:

Outfalls: A02 and A05 Chemical Metal Cleaning Wastewater

Flow (MGD)					*	Measurement
Iron (total)			1.0	1.0	*	8-Hour Composite
Copper (total)			1.0	1.0	*	8-Hour Composite

*See Special Condition 19

Outfall: 006 Storm Water Associated with Industrial Activity

See Special Condition 15

NPDES Permit No. IL0004316

Special Conditions

SPECIAL CONDITION 1. Flow shall be recorded as a monthly average and daily maximum and shall be reported as such on the DMR form.

SPECIAL CONDITION 2. The pH shall be in the range 6.0 to 9.0. The monthly minimum and monthly maximum values shall be reported on the DMR form.

SPECIAL CONDITION 3. Samples taken in compliance with the effluent monitoring requirements shall be taken at a point representative of the discharge, but prior to entry into the receiving stream. For internal Outfalls A02 and A05, samples shall be taken at a point representative of the discharge, but prior to mixture with other wastestreams. If chemical metal cleaning wastewater is used as scrubber make-up water, samples shall be taken prior to use as make-up water.

SPECIAL CONDITION 4. Discharge of wastewater from this facility must not alone or in combination with other sources cause the receiving stream to violate the following thermal limitations at the edge of the mixing zone which is defined by Section 302.211, Illinois Administration Code, Title 35, Chapter 1, Subtitle C, as amended:

A. Maximum temperature rise above natural temperature must not exceed 5 F (2.8 C).

B. Water temperature at representative locations in the lake shall not exceed the maximum limits in the following table during more than one (1) percent of the hours in the 12-month period ending with any month. Moreover, at no time shall the water temperature at such locations exceed the maximum limits in the following table by more than 3 F (1.7 C).

Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
60	60	60	90	90	90	90	90	90	90	90	60
16	16	16	32	32	32	32	32	32	32	32	16

C. The monthly maximum value shall be reported on the DMR form.

D. The computer model, PDS program, shall be used to predict plume trajectory and the area enclosed by the surface isotherms to determine compliance with the above temperature limitations.

SPECIAL CONDITION 5. Total residual chlorine limit is an instantaneous maximum limit which shall not be exceeded at any time. The maximum weekly value shall be reported on the DMR form.

Results of all weekly grab samples shall be submitted with the monthly DMR form if maximum limit is exceeded during any week.

Chlorine may not be discharged from each units main cooling condenser for more than two hours in any one day.

SPECIAL CONDITION 6. There shall be no discharge of polychlorinated biphenyl compounds.

SPECIAL CONDITION 7 Due to increase in thermal discharge volume Southern Illinois Power Cooperative shall comply with Section 302.211f of Title 35, Chapter 1, Subtitle C: Water Pollution Regulations and Section 316(a) of the CWA by demonstrating that thermal discharge from Marion Generating Station will not cause and cannot reasonably be expected to cause significant ecological damage to Lake of Egypt. Pursuant to 35 Ill. Adm. Code 302.211g no additional monitoring or modification is being required for reissuance of this NPDES Permit.

SPECIAL CONDITION 8. The Permittee's facility has been deemed to meet the criteria as a Phase II existing facility (under section 316(b) of the Clean Water Act) pursuant to 40 CFR 125.91. Therefore, the permittee must fulfill the applicable requirements of 40 CFR 125 subpart J, and 40 CFR 122(r)(2), (3) and (5). The regulation at 40 CFR 125.95 requires submittal of a Proposal for Information Collection (PIC) to support the development of a Comprehensive Demonstration Study (CDS) for the herein permitted facility. The PIC will be reviewed by the Agency and a response will be provided. An extension of time to submit the CDS has been granted. Therefore, you must submit your CDS on or before January 7, 2008. Once the CDS has been reviewed by the Agency and a compliance strategy has been approved, this permit will be modified to include implementation, monitoring, and reporting requirements pursuant to 40 CFR 125.98.

Special Conditions

SPECIAL CONDITION 9. The Permittee shall record monitoring results on Discharge Monitoring Report (DMR) Forms using one such form for each outfall each month.

In the event that an outfall does not discharge during a monthly reporting period, the DMR Form shall be submitted with no discharge indicated.

The Permittee may choose to submit electronic DMRs (eDMRs) instead of mailing paper DMRs to the IEPA. More information, including registration information for the eDMR program, can be obtained on the IEPA website, http://www.epa.state.il.us/water/edmr/index.html.

The completed Discharge Monitoring Report forms shall be submitted to IEPA no later than the last calender day of the following month, unless otherwise specified by the permitting authority.

Permittees not using eDMRs shall mail Discharge Monitoring Reports with an original signature to the IEPA at the following address:

Illinois Environmental Protection Agency
Division of Water Pollution Control
1021 North Grand Avenue East
Post Office Box 19276
Springfield, Illinois 62794-9276

Attention: Compliance Assurance Section, Mail Code # 19

SPECIAL CONDITION 10. There shall be no discharge of collected debris from Outfall 004 Intake Screen Backwash.

SPECIAL CONDITION 11. Sample frequency for zinc at outfall 005 shall be once a month until six samples have been collected; after which and upon written notification to the Agency, the sampling may cease, unless the Agency modifies the permit to require continued sampling at some frequency.

SPECIAL CONDITION 12. For the purpose of this permit, Outfall 003 is limited to non-contact cooling water, free from additives other than chlorine. If the permittee wishes to use cooling water additives, the following information must be submitted to the Agency for review:

a. Brand name;

b. List of active and inactive ingredients expressed as a percentage of the total product;

c. Feed rate and expected discharge concentration;

d. Aquatic toxicity results.

The additive(s) shall not be used until Agency approval has been given.

SPECIAL CONDITION 13. The Permittee shall conduct biomonitoring of the effluent from Outfall 002 and 005. The Permittee shall conduct biomonitoring of the effluent discharge no earlier than one (1) year prior to the expiration date of this Permit. The results shall be submitted with the Permit renewal application.

Biomonitoring

1. Acute Toxicity - Standard definitive acute toxicity tests shall be run on at least two trophic levels of aquatic species (fish, invertebrate) representative of the aquatic community of the receiving stream. Except as noted here and in the IEPA document "Effluent Biomonitoring and Toxicity Assessment", testing must be consistent with Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms (Fourth Ed.) EPA-600/4-90-027. Unless substitute tests are pre-approved; the following tests are required:

   a. Fish - 96 hour static LC_{50} Bioassay using one to two week old fathead minnows (Pimephales promelas).

   b. Invertebrate 48-hour static LC_{50} Bioassay using Ceriodaphnia.

2. Testing Frequency - The above tests shall be conducted on a one time basis using 24-hour composite effluent samples unless otherwise authorized by the IEPA. Results shall be reported according to EPA/600/4-90/027, Section 12, Report Preparation, and shall be submitted to IEPA with the renewal application.

3. Toxicity Assessment - Should the review of the results of the biomonitoring program identify toxicity, the Agency may require that the permittee prepare a plan for toxicity reduction evaluation and identification. This plan shall include an evaluation to determine which chemicals have a potential for being discharged in the plant wastewater, a monitoring program to determine their presence or absence and to identify other compounds which are not being removed by treatment, and other measures as appropriate.

   The Agency may modify this permit during its term to incorporate additional requirements or limitations based on the results of any biomonitoring. In addition, after review of the monitoring results, the Agency may modify this permit to include numerical limitations for specific toxic pollutants. Modifications under this condition shall follow public notice and opportunity for hearing.

SPECIAL CONDITION 14. The Agency has determined that the effluent limitations at outfall 002 and 005 constitute BAT/BCT for storm water which is treated in the existing treatment facilities for purposes of this permit reissuance, and no pollution prevention plan will be required for such storm water. In addition to the chemical specific monitoring required elsewhere in this permit, the permittee shall conduct an annual inspection of the facility site to identify areas contributing to a storm water discharge associated with industrial activity, and determine whether any facility modifications have occurred which result in previously-treated storm water discharges no longer receiving treatment. If any such discharges are identified the permittee shall request a modification of this permit within 30 days after the inspection. Records of the annual inspection shall be retained by the permittee for the term of this permit and be made available to the Agency on request.

SPECIAL CONDITION 15.

STORM WATER POLLUTION PREVENTION PLAN (SWPPP)

A. A storm water pollution prevention plan shall be developed by the permittee for the storm water associated with industrial activity at Outfall 006. The plan shall identify potential sources of pollution which may be expected to affect the quality of storm water discharges associated with the industrial activity at the facility. In addition, the plan shall describe and ensure the implementation of practices which are to be used to reduce the pollutants in storm water discharges associated with industrial activity at the facility and to assure compliance with the terms and conditions of this permit.

B. The plan shall be completed within 180 days of the effective date of this permit. Plans shall provide for compliance with the terms of the plan within 365 days of the effective date of this permit. The owner or operator of the facility shall make a copy of the plan available to the Agency at any reasonable time upon request. [Note: If the plan has already been developed and implemented it shall be maintained in accordance with all requirements of this special condition.]

C. The permittee may be notified by the Agency at any time that the plan does not meet the requirements of this condition. After such notification, the permittee shall make changes to the plan and shall submit a written certification that the requested changes have been made. Unless otherwise provided, the permittee shall have 30 days after such notification to make the changes.

D. The discharger shall amend the plan whenever there is a change in construction, operation, or maintenance which may affect the discharge of significant quantities of pollutants to the waters of the State or if a facility inspection required by paragraph G of this condition indicates that an amendment is needed. The plan should also be amended if the discharger is in violation of any conditions of this permit, or has not achieved the general objective of controlling pollutants in storm water discharges. Amendments to the plan shall be made within the shortest reasonable period of time, and shall be provided to the Agency for review upon request.

E. The plan shall provide a description of potential sources which may be expected to add significant quantities of pollutants to storm water discharges, or which may result in non-storm water discharges from storm water outfalls at the facility. The plan shall include, at a minimum, the following items:

   1. A topographic map extending one-quarter mile beyond the property boundaries of the facility, showing: the facility, surface water bodies, wells (including injection wells), seepage pits, infiltration ponds, and the discharge points where the facility's storm water discharges to a municipal storm drain system or other water body. The requirements of this paragraph may be included on the site map if appropriate.

Special Conditions

2. A site map showing:

   i. The storm water conveyance and discharge structures;

   ii. An outline of the storm water drainage areas for each storm water discharge point;

   iii. Paved areas and buildings;

   iv. Areas used for outdoor manufacturing, storage, or disposal of significant materials, including activities that generate significant quantities of dust or particulates.

   v. Location of existing storm water structural control measures (dikes, coverings, detention facilities, etc.);

   vi. Surface water locations and/or municipal storm drain locations

   vii. Areas of existing and potential soil erosion;

   viii. Vehicle service areas;

   ix. Material loading, unloading, and access areas.

3. A narrative description of the following:

   i. The nature of the industrial activities conducted at the site, including a description of significant materials that are treated, stored or disposed of in a manner to allow exposure to storm water;

   ii. Materials, equipment, and vehicle management practices employed to minimize contact of significant materials with storm water discharges;

   iii. Existing structural and non-structural control measures to reduce pollutants in storm water discharges;

   iv. Industrial storm water discharge treatment facilities;

   v. Methods of onsite storage and disposal of significant materials;

4. A list of the types of pollutants that have a reasonable potential to be present in storm water discharges in significant quantities.

5. An estimate of the size of the facility in acres or square feet, and the percent of the facility that has impervious areas such as pavement or buildings.

6. A summary of existing sampling data describing pollutants in storm water discharges.

F. The plan shall describe the storm water management controls which will be implemented by the facility. The appropriate controls shall reflect identified existing and potential sources of pollutants at the facility. The description of the storm water management controls shall include:

1. Storm Water Pollution Prevention Personnel - Identification by job titles of the individuals who are responsible for developing, implementing, and revising the plan.

2. Preventive Maintenance - Procedures for inspection and maintenance of storm water conveyance system devices such as oil/water separators, catch basins, etc., and inspection and testing of plant equipment and systems that could fail and result in discharges of pollutants to storm water.

3. Good Housekeeping - Good housekeeping requires the maintenance of clean, orderly facility areas that discharge storm water. Material handling areas shall be inspected and cleaned to reduce the potential for pollutants to enter the storm water conveyance system.

4. Spill Prevention and Response - Identification of areas where significant materials can spill into or otherwise enter the storm water conveyance systems and their accompanying drainage points. Specific material handling procedures, storage requirements, spill clean up equipment and procedures should be identified, as appropriate. Internal notification procedures for spills of significant materials should be established.

5. Storm Water Management Practices - Storm water management practices are practices other than those which control the source of pollutants. They include measures such as installing oil and grit separators, diverting storm water into retention basins, etc. Based on assessment of the potential of various sources to contribute pollutants, measures to remove pollutants from storm water discharge shall be implemented. In developing the plan, the following management practices shall be considered:

   i. Containment - Storage within berms or other secondary containment devices to prevent leaks and spills from entering storm water runoff;

   ii. Oil & Grease Separation - Oil/water separators, booms, skimmers or other methods to minimize oil contaminated storm water discharges;

   iii. Debris & Sediment Control - Screens, booms, sediment ponds or other methods to reduce debris and sediment in storm water discharges;

   iv. Waste Chemical Disposal - Waste chemicals such as antifreeze, degreasers and used oils shall be recycled or disposed of in an approved manner and in a way which prevents them from entering storm water discharges.

   v. Storm Water Diversion - Storm water diversion away from materials manufacturing, storage and other areas of potential storm water contamination;

   vi. Covered Storage or Manufacturing Areas - Covered fueling operations, materials manufacturing and storage areas to prevent contact with storm water.

6. Sediment and Erosion Prevention - The plan shall identify areas which due to topography, activities, or other factors, have a high potential for significant soil erosion and describe measures to limit erosion.

7. Employee Training - Employee training programs shall inform personnel at all levels of responsibility of the components and goals of the storm water pollution control plan. Training should address topics such as spill response, good housekeeping and material management practices. The plan shall identify periodic dates for such training.

8. Inspection Procedures - Qualified plant personnel shall be identified to inspect designated equipment and plant areas. A tracking or follow-up procedure shall be used to ensure appropriate response has been taken in response to an inspection. Inspections and maintenance activities shall be documented and recorded.

G. The permittee shall conduct an annual facility inspection to verify that all elements of the plan, including the site map, potential pollutant sources, and structural and non-structural controls to reduce pollutants in industrial storm water discharges are accurate. Observations that require a response and the appropriate response to the observation shall be retained as part of the plan. Records documenting significant observations made during the site inspection shall be submitted to the Agency in accordance with the reporting requirements of this permit.

H. This plan should briefly describe the appropriate elements of other program requirements, including Spill Prevention Control and Countermeasures (SPCC) plans required under Section 311 of the CWA and the regulations promulgated thereunder, and Best Management Programs under 40 CFR 125.100.

I. The plan is considered a report that shall be available to the public under Section 308(b) of the CWA. The permittee may claim portions of the plan as confidential business information, including any portion describing facility security measures.

J. The plan shall include the signature and title of the person responsible for preparation of the plan and include the date of initial preparation and each amendment thereto.

NPDES Permit No. IL0004316

Special Conditions

Construction Authorization

K. Authorization is hereby granted to construct treatment works and related equipment that may be required by the Storm Water Pollution Prevention developed pursuant to this permit.

This Authorization is issued subject to the following condition(s).

1. If any statement or representation is found to be incorrect, this authorization may be revoked and the permittee there upon waives all rights thereunder.

2. The issuance of this authorization (a) does not release the permittee from any liability for damage to persons or property caused by or resulting from the installation, maintenance or operation of the proposed facilities; (b) does not take into consideration the structural stability of any units or part of this project; and (c) does not release the permittee from compliance with other applicable statutes of the State of Illinois, or other applicable local law, regulations or ordinances.

3. Plans and specifications of all treatment equipment being included as part of the storm water management practice shall be included in the SWPPP.

4. Construction activities which result from treatment equipment installation, including clearing, grading and excavation activities which result in the disturbance of one acre or more of land area, are not covered by this authorization. The permittee shall contact the IEPA regarding the required permit(s).

REPORTING

L. The facility shall submit an annual inspection report to the Illinois Environmental Protection Agency. The report shall include results of the annual facility inspection which is required by Part G of the Storm Water Pollution Prevention Plan of this permit. The report shall also include documentation of any event (spill, treatment unit malfunction, etc.) which would require an inspection, results of the inspection, and any subsequent corrective maintenance activity. The report shall be completed and signed by the authorized facility employee(s) who conducted the inspection(s).

M. The first report shall contain information gathered during the one year time period beginning with the effective date of coverage under this permit and shall be submitted no later than 60 days after this one year period has expired. Each subsequent report shall contain the previous year's information and shall be submitted no later than one year after the previous year's report was due.

N. Annual inspection reports shall be mailed to the following address:

Illinois Environmental Protection Agency
Bureau of Water
Compliance Assurance Section
Annual Inspection Report
1021 North Grand Avenue East
Post Office Box 19276
Springfield, Illinois 62794-9276

O. If the facility performs inspections more frequently than required by this permit, the results shall be included as additional information in the annual report.

SPECIAL CONDITION 16. Once per month, an eight hour composite sample shall be collected at outfalls 002 and 005 for boron. Flow shall be measured at each outfall during this eight hour period.

The daily maximum effluent limitation for boron at outfall 005 is 9.0 mg/l. The daily maximum effluent limitation for boron at outfall 002 shall be calculated utilizing the following formula:

$$\text{Limit 002:} \quad \frac{(9.0\ \text{mg/l}\ (\text{Flow 005} + \text{Flow 002})) - (\text{Flow 005})\ (\text{Conc. 005})}{\text{Flow 002}}$$

Special Conditions

Where:	Limit 002:	Calculated daily maximum effluent limitation for boron at outfall 002
	Flow 002:	Measured effluent flow rate at outfall 002 during 8 hour composite sample period
	Conc. 005:	Measured boron effluent concentration at outfall 005 from 8 hour composite sample period
	Flow 005:	Measured effluent flow rate at outfall 005 during 8 hour composite sample period
	9.0 mg/l:	Stream standard for boron set forth in Illinois Pollution Control Board Adjusted Standard (AS 92 - 10) dated July 1, 1993

Measured boron effluent concentrations at both outfalls from the eight hour composite sample shall be reported on the DMR form. Calculations for the effluent limitation for boron at outfall 002 shall be attached to the DMR form.

SPECIAL CONDITION 17. Pursuant to provisions of 35 IAC Section 309.157, the Permittee may gather data in support of determining a site-specific copper translator. Should the Permittee choose to gather such data, a minimum of twelve (12) effluent and twelve (12) downstream samples shall be taken within a minimum of one week in between samples. Such samples shall be consistent with "The Metals Translator: Calculating a Total Recoverable Permit Limit for Dissolved Criterion."

The IEPA may modify the Permit to include the revised copper limits only if such permit modification is consistent with 35 IAC Section 309.157 and with 40 CFR 122.44(l).

SPECIAL CONDITION 18. Daily Outfall sampling of 002 and 005 (if flowing) for iron and copper shall commence from the first day of use of boiler clean wastewater in the scrubber, and shall continue for seven days following the conclusion of the use of boiler clean wastewater in the scrubber. These sampling results shall be reported in the monthly reports. The applicant shall derive limits using the formula defined in 40 CFR 403.6(l) for the discharges from the outfalls during this period. The calculation used to derive limits shall be submitted with DMR form.

SPECIAL CONDITION 19. Sample frequency for Mercury at outfall(s) 002 and 005 shall be once a month until twelve samples have been collected; after which and upon written notification to the Agency, the sampling may cease, unless the Agency modifies the permit to require continued sampling at some frequency. Monitoring shall be performed using USEPA analytical test method 1631 or equivalent.

Attachment H

Standard Conditions

Definitions

Act means the Illinois Environmental Protection Act, 415 ILCS 5 as Amended.

Agency means the Illinois Environmental Protection Agency.

Board means the Illinois Pollution Control Board.

Clean Water Act (formerly referred to as the Federal Water Pollution Control Act) means Pub. L 92-500, as amended. 33 U.S.C. 1251 et seq.

NPDES (National Pollutant Discharge Elimination System) means the national program for issuing, modifying, revoking and reissuing, terminating, monitoring and enforcing permits, and imposing and enforcing pretreatment requirements, under Sections 307, 402, 318 and 405 of the Clean Water Act.

USEPA means the United States Environmental Protection Agency.

Daily Discharge means the discharge of a pollutant measured during a calendar day or any 24-hour period that reasonably represents the calendar day for purposes of sampling. For pollutants with limitations expressed in units of mass, the "daily discharge" is calculated as the total mass of the pollutant discharged over the day. For pollutants with limitations expressed in other units of measurements, the "daily discharge" is calculated as the average measurement of the pollutant over the day.

Maximum Daily Discharge Limitation (daily maximum) means the highest allowable daily discharge.

Average Monthly Discharge Limitation (30 day average) means the highest allowable average of daily discharges over a calendar month, calculated as the sum of all daily discharges measured during a calendar month divided by the number of daily discharges measured during that month.

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(1) **Duty to comply.** The permittee must comply with all conditions of this permit. Any permit noncompliance constitutes a violation of the Act and is grounds for enforcement action, permit termination, revocation and reissuance, modification, or for denial of a permit renewal application. The permittee shall comply with effluent standards or prohibitions established under Section 307(a) of the Clean Water Act for toxic pollutants within the time provided in the regulations that establish these standards or prohibitions, even if the permit has not yet been modified to incorporate the requirement.

(2) **Duty to reapply.** If the permittee wishes to continue an activity regulated by this permit after the expiration date of this permit, the permittee must apply for and obtain a new permit. If the permittee submits a proper application as required by the Agency no later than 180 days prior to the expiration date, this permit shall continue in full force and effect until the final Agency decision on the application has been made.

(3) **Need to halt or reduce activity not a defense.** It shall not be a defense for a permittee in an enforcement action that it would have been necessary to halt or reduce the permitted activity in order to maintain compliance with the conditions of this permit.

(4) **Duty to mitigate.** The permittee shall take all reasonable steps to minimize or prevent any discharge in violation of this permit which has a reasonable likelihood of adversely affecting human health or the environment.

(5) **Proper operation and maintenance.** The permittee shall at all times properly operate and maintain all facilities and systems of treatment and control (and related appurtenances) which are installed or used by the permittee to achieve compliance with conditions of this permit. Proper operation and maintenance includes effective performance, adequate funding, adequate operator staffing and training, 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) **Permit actions.** This permit may be modified, revoked and reissued, or terminate for cause by the Agency pursuant to 40 CFR 122.62. The filing of a request by th permittee for a permit modification, revocation and reissuance, or termination, or notification of planned changes or anticipated noncompliance, does not stay an permit condition.

(7) **Property rights.** This permit does not convey any property rights of any sort, or an exclusive privilege.

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(a) Enter upon the permittee's premises where a regulated facility or activity i located or conducted, or where records must be kept under the conditions of thi permit;

(b) Have access to and copy, at reasonable times, any records that must be kep under the conditions of this permit;

(c) Inspect at reasonable times any facilities, equipment (including monitoring anc control equipment), practices, or operations regulated or required under thi permit; and

(d) Sample or monitor at reasonable times, for the purpose of assuring permi compliance, or as otherwise authorized by the Act, any substances or parameter at any location.

(10) **Monitoring and records.**

(a) Samples and measurements taken for the purpose of monitoring shall be representative of the monitored activity.

(b) 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 this permit, and records of all data used to complete the application for this permit, for a period of at least 3 years from the date of this permit, measurement, report or application. This period may be extended by request of the Agency at any time

(c) Records of monitoring information shall include:

(1) The date, exact place, and time of sampling or measurements;

(2) The individual(s) who performed the sampling or measurements;

(3) The date(s) analyses were performed;

(4) The individual(s) who performed the analyses;

(5) The analytical techniques or methods used; and

(6) The results of such analyses.

(d) Monitoring must be conducted according to test procedures approved under 40 CFR Part 136, unless other test procedures have been specified in this permit. Where no test procedure under 40 CFR Part 136 has been approved, the permittee must submit to the Agency a test method for approval. The permittee shall calibrate and perform maintenance procedures on all monitoring and analytical instrumentation at intervals to ensure accuracy of measurements.

(11) **Signatory requirement.** All applications, reports or information submitted to the Agency shall be signed and certified.

(a) **Application.** All permit applications shall be signed as follows:

(1) **For a corporation:** by a principal executive officer of at least the level of vice president or a person or position having overall responsibility for environmental matters for the corporation;

(2) **For a partnership or sole proprietorship:** by a general partner or the proprietor, respectively; or

(3) **For a municipality, State, Federal, or other public agency:** by either a principal executive officer or ranking elected official.

(b) **Reports.** All reports required by permits, or other information requested by the Agency shall be signed by a person described in paragraph (a) or by a duly authorized representative of that person. A person is a duly authorized representative only if:

(1) The authorization is made in writing by a person described in paragraph (a); and

(2) The authorization specifies either an individual or a position responsible for the overall operation of the facility, from which the discharge originates, such as a plant manager, superintendent or person of equivalent responsibility; and

(3) The written authorization is submitted to the Agency.

(c) **Changes of Authorization.** If an authorization under (b) is no longer accurate because a different individual or position has responsibility for the overall operation of the facility, a new authorization satisfying the requirements of (b) must be submitted to the Agency prior to or together with any reports, information, or applications to be signed by an authorized representative.

Reporting requirements.

(a) **Planned changes.** The permittee shall give notice to the Agency as soon as possible of any planned physical alterations or additions to the permitted facility.

(b) **Anticipated noncompliance.** The permittee shall give advance notice to the Agency of any planned changes in the permitted facility or activity which may result in noncompliance with permit requirements.

(c) **Compliance schedules.** Reports of compliance or noncompliance with, or any progress reports on, interim and final requirements contained in any compliance schedule of this permit shall be submitted no later than 14 days following each schedule date.

(d) **Monitoring reports.** Monitoring results shall be reported at the intervals specified elsewhere in this permit.

(1) Monitoring results must be reported on a Discharge Monitoring Report (DMR).

(2) If the permittee monitors any pollutant more frequently than required by the permit, using test procedures approved under 40 CFR 136 or as specified in the permit, the results of this monitoring shall be included in the calculation and reporting of the data submitted in the DMR.

(3) Calculations for all limitations which require averaging of measurements shall utilize an arithmetic mean unless otherwise specified by the Agency in the permit.

(e) **Twenty-four hour reporting.** The permittee shall report any noncompliance which may endanger health or the environment. Any information shall be provided orally within 24 hours from the time the permittee becomes aware of the circumstances. A written submission shall also be provided within 5 days of the time the permittee becomes aware of the circumstances. The written submission shall contain a description of the noncompliance and its cause; the period of noncompliance, including exact dates and time; and if the noncompliance has not been corrected, the anticipated time it is expected to continue; and steps taken or planned to reduce, eliminate, and prevent reoccurrence of the noncompliance. The following shall be included as information which must be reported within 24 hours:

(1) Any unanticipated bypass which exceeds any effluent limitation in the permit;

(2) Violation of a maximum daily discharge limitation for any of the pollutants listed by the Agency in the permit to be reported within 24 hours.

The Agency may waive the written report on a case-by-case basis if the oral report has been received within 24 hours.

(f) **Other noncompliance.** The permittee shall report all instances of noncompliance not reported under paragraphs (12)(c), (d), or (e), at the time monitoring reports are submitted. The reports shall contain the information listed in paragraph (12)(e).

(g) **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 Agency, it shall promptly submit such facts or information.

(13) **Transfer of permits.** A permit may be automatically transferred to a new permittee if:

(a) The current permittee notifies the Agency at least 30 days in advance of the proposed transfer date;

(b) The notice includes a written agreement between the existing and new permittees containing a specific date for transfer of permit responsibility, coverage and liability between the current and new permittees; and

(c) The Agency does not notify the existing permittee and the proposed new permittee of its intent to modify or revoke and reissue the permit. If this notice is not received, the transfer is effective on the date specified in the agreement.

(14) All manufacturing, commercial, mining, and silvicultural dischargers must notify the Agency as soon as they know or have reason to believe:

(a) That any activity has occurred or will occur which would result in the discharge of any toxic pollutant identified under Section 307 of the Clean Water Act which is not limited in the permit, if that discharge will exceed the highest of the following notification levels:

(1) One hundred micrograms per liter (100 ug/l);

(2) Two hundred micrograms per liter (200 ug/l) for acrolein and acrylonitrile; five hundred micrograms per liter (500 ug/l) for 2,4-dinitrophenol and for 2-methyl-4,6 dinitrophenol; and one milligram per liter (1 mg/l) for antimony.

(3) Five (5) times the maximum concentration value reported for that pollutant in the NPDES permit application; or

(b) That they have begun or expect to begin to use or manufacture as an intermediate or final product or byproduct any toxic pollutant which was not reported in the NPDES permit application.

(15) All Publicly Owned Treatment Works (POTWs) must provide adequate notice to the Agency of the following:

(a) Any new introduction of pollutants into that POTW from an indirect discharger which would be subject to Sections 301 or 306 of the Clean Water Act if it were directly discharging those pollutants; and

(b) Any substantial change in the volume or character of pollutants being introduced into that POTW by a source introducing pollutants into the POTW at the time of issuance of the permit.

(c) For purposes of this paragraph, adequate notice shall include information on (i) the quality and quantity of effluent introduced into the POTW, and (ii) any anticipated impact of the change on the quantity or quality of effluent to be discharged from the POTW.

(16) If the permit is issued to a publicly owned or publicly regulated treatment works, the permittee shall require any industrial user of such treatment works to comply with federal requirements concerning:

(a) User charges pursuant to Section 204(b) of the Clean Water Act, and applicable regulations appearing in 40 CFR 35;

(b) Toxic pollutant effluent standards and pretreatment standards pursuant to Section 307 of the Clean Water Act; and

(c) Inspection, monitoring and entry pursuant to Section 308 of the Clean Water Act.

(17) If an applicable standard or limitation is promulgated under Section 301(b)(2)(C) and (D), 304(b)(2), or 307(a)(2) and that effluent standard or limitation is more stringent than any effluent limitation in the permit, or controls a pollutant not limited in the permit, the permit shall be promptly modified or revoked, and reissued to conform to that effluent standard or limitation.

(18) Any authorization to construct issued to the permittee pursuant to 35 Ill. Adm. Code 309.154 is hereby incorporated by reference as a condition of this permit.

(19) The permittee shall not make any false statement, representation or certification in any application, record, report, plan or other document submitted to the Agency or the USEPA, or required to be maintained under this permit.

(20) The Clean Water Act provides that any person who violates a permit condition implementing Sections 301, 302, 306, 307, 308, 318, or 405 of the Clean Water Act is subject to a civil penalty not to exceed $10,000 per day of such violation. Any person who willfully or negligently violates permit conditions implementing Sections 301, 302, 306, 307, or 308 of the Clean Water Act is subject to a fine of not less than $2,500 nor more than $25,000 per day of violation, or by imprisonment for not more than one year, or both.

(21) The Clean Water Act provides that any person who falsifies, tampers with, or knowingly renders inaccurate any monitoring device or method required to be maintained under permit shall, upon conviction, be punished by a fine of not more than $10,000 per violation, or by imprisonment for not more than 6 months per violation, or by both.

(22) The Clean Water Act provides that any person who knowingly makes any false statement, representation, or certification in any record or other document submitted or required to be maintained under this permit shall, including monitoring reports or reports of compliance or non-compliance shall, upon conviction, be punished by a fine of not more than $10,000 per violation, or by imprisonment for not more than 6 months per violation, or by both.

(23) Collected screening, slurries, sludges, and other solids shall be disposed of in such a manner as to prevent entry of those wastes (or runoff from the wastes) into waters of the State. The proper authorization for such disposal shall be obtained from the Agency and is incorporated as part hereof by reference.

(24) In case of conflict between these standard conditions and any other condition(s) included in this permit, the other condition(s) shall govern.

(25) The permittee shall comply with, in addition to the requirements of the permit, all applicable provisions of 35 Ill. Adm. Code, Subtitle C, Subtitle D, Subtitle E, and all applicable orders of the Board.

(26) The provisions of this permit are severable, and if any provision of this permit, or the application of any provision of this permit is held invalid, the remaining provisions of this permit shall continue in full force and effect.

(Rev. 3-13-98)

Standard Conditions

Definitions

Act means the Illinois Environmental Protection Act, 415 ILCS 5 as Amended.

Agency means the Illinois Environmental Protection Agency.

Board means the Illinois Pollution Control Board.

Clean Water Act (formerly referred to as the Federal Water Pollution Control Act) means Pub. L 92-500, as amended. 33 U.S.C. 1251 et seq.

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Solutions through Science

UPDATED 316(A) VARIANCE DEMONSTRATION REPORT FOR THE MARION GENERATING STATION

Prepared for:
Southern Illinois Power Cooperative

Prepared by:
ASA Analysis & Communication, Inc.
383 Plattekill Rd
Marlboro, NY 12542

Date
November 8, 2017

EXECUTIVE SUMMARY

Southern Illinois Power Cooperative's (SIPC) Marion Generating Station (MGS) is located approximately 7 miles south of the City of Marion and consists of two coal-fired units (Units 4 and 123) and 2 combined-cycle units (Units 5 and 6). The four turbines for Units 4 and 123 use once-through cooling with a common intake and discharge. The additional boiler that became operational in 2003 resulted in increases of water use and volume of thermal water discharged into the lake. The plant withdraws water for condenser cooling from the Lake of Egypt (LOE).

SIPC submitted a petition in 2014, supported by a 316(a) variance demonstration, requesting alternate effluent limitations for the MGS thermal discharge to the LOE. The Illinois Environmental Protection Agency (IEPA) recommended that the Illinois Pollution Control Board (IPCB) grant SIPC's requested alternative thermal effluent limits but require SIPC to conduct site-specific studies for five biotic categories or provide additional justification for the low impact determination, over the 5-year permit term. The IPCB declined to grant the SIPC's requested relief, pending the completion of the IEPA recommended studies and a renewed demonstration and petition.

This revised demonstration supports SIPC's renewed request for alternative thermal effluent limitations applicable to discharges from MGS under Section 316(a) of the Clean Water Act and 35 Ill. Adm. Code 106, Subpart K and has been prepared consistent with 40 C.F.R. 125.70-125.73 and the 1977 Guidance Manual. SIPC is requesting the following alternate effluent limitation:

> The thermal discharge to Lake of Egypt from the SIPC's Marion Generating Station shall not exceed the following maximum temperatures, measured at the outside edge of the 26-acre mixing zone in Lake of Egypt, by more than 1 percent of the hours in a 12-month period:
>
> 1. 72°F from December through March;
> 2. 90°F from April through May;
> 3. 101°F from June through September; and
> 4. 91°F from October through November.
>
> At no time shall the water temperature at the edge of the mixing zone exceed these maximums by more than 3°F.

SIPC agreed to implement supplemental site-specific pilot studies for the phytoplankton, zooplankton/meroplankton, macroinvertebrate and shellfish, and habitat former biotic categories, as well as studies designed to address nuisance and thermally-sensitive representative important species (RIS) of fish. Data collection for the biotic category analyses was focused on parameters that would allow an evaluation of key criteria outlined in the U.S. Environmental Protection Agency's (USEPA) Draft Guidance Manual for the successful demonstration of lack of appreciable harm. A draft study plan was submitted to the IEPA on November 2, 2015 as part of the early screening information requirement in accordance with 35 III. Admin. Code 106.1115 and 40 C.F.R. §125.72. The IEPA approved the SIPC's Detailed Plan of Study on March 24, 2016. The Detailed Plan of Study was implemented during the summer and fall of 2016.

The site-specific supplemental pilot studies conducted in 2016 on phytoplankton, zooplankton/meroplankton, benthic macroinvertebrates and shellfish, and habitat formers showed no differences in these communities among lake zones that could be attributable to the MGS thermal discharge. The 2016 electrofishing data shows that the fish community of the LOE has remained relatively stable over the last 20 years. Based on the electrofishing CPUE data for Common Carp, there does not appear to be a proliferation of this nuisance species. Based on data collected during the current survey, Black Crappie are surviving, naturally reproducing, and growing quickly in the LOE and do not appear to be adversely affected by the MGS thermal discharge.

The data collected during the supplemental pilot studies, along with the historical data on the LOE fish RIS, demonstrate that the MGS operation and thermal discharge have not caused appreciable harm to the balanced, indigenous community of LOE. More specifically, with regard to phenomena indicative of appreciable harm:

- No increase is evident in the presence and/or abundance of any nuisance species in the LOE as a result of the thermal discharge. The community in the lower lake zone in the vicinity of the MGS has not become dominated by heat-tolerant species and is comparable, in terms of the species present, to the community in other zones of the LOE.
- There is no substantial decrease in the abundance of fish RIS or changes in fish community species composition and abundance based on the results of current and historical electrofishing data. While there are no historical data available for the other biotic categories, the similar abundance, and in most cases community composition, between lake zones suggest that there has been no decrease in indigenous species in those biotic categories. EIU (2017) found that in general the aquatic community in the LOE was similar to other oligotrophic (low nutrient) systems in Illinois.
- There is no indication that the aquatic community has been changed in a way that makes its structure simpler or unnatural for the locality. The number of fish species and the species abundance structure of the fish community in the vicinity of the MGS is comparable to that of other Illinois cooling and ambient reservoirs (EIU 2017).
- The MGS has not caused an unaesthetic appearance or odor of the receiving water.
- The MGS has not eliminated an established or potential recreational use of the LOE or local vicinity. To the contrary, the LOE is heavily utilized by recreational fishermen and is host to numerous fishing tournaments each year.
- There is no evidence of a reduction in the successful completion of life-cycles of indigenous species in the LOE, based on the continued presence and abundance of key fish species and the similarity of communities between lake zones for the other biotic categories. For fish, this conclusion is also supported by the biothermal assessment conducted by Amec in the 2013 Demonstration.

Based upon these findings and those from the 2013 retrospective and predictive assessments, this revised Demonstration concludes that the proposed alternative thermal effluent limitations will assure the protection and propagation of a balanced, indigenous community in and on the LOE, thereby satisfying the 316(a) criteria.

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1 INTRODUCTION

1.1 ROADMAP TO DEMONSTRATION

This Demonstration supports the Southern Illinois Power Cooperative's (SIPC's) request for alternative thermal effluent limitations applicable to discharges from Marion Generating Station (MGS) under Section 316(a) of the Clean Water Act and 35 Ill. Adm. Code 106, Subpart K. It has been prepared consistent with 40 C.F.R. 125.70-125.73 and the Draft Interagency Technical Guidance Manual (USEPA 1977) (1977 Guidance Manual). In addition, this Demonstration relies upon monitoring and data collection on and around the Lake of Egypt (LOE) from 1977 through 2016. The monitoring and data collection programs include

- Fish studies conducted by Dr. Roy Heidinger of Southern Illinois University (SIU) in 1977, 1986, 1988, 1990, 1995, 2000, and 2007;
- Fish and temperature and dissolved oxygen studies conducted by Southern Illinois University at Carbondale (SIUC) from1997 to 1999;
- Impingement and fish surveys conducted by MACTEC from 2005-2007;
- Fish electrofishing surveys conducted by MACTEC in 2010;
- Water temperature measurements and thermal modeling conducted by MACTEC (now Amec Foster Wheeler or "Amec") in 2006 and 2010; and
- Fish, biotic category, and water temperature and dissolved oxygen (DO) data collection conducted by EIU in 2016.

This Demonstration also relies upon many conclusions from Amec's 2013 316(a) Demonstration ("2013 Demonstration") [1], which includes both prospective and retrospective analyses, and explains how Eastern Illinois University's (EIU) 2016 data collection supplements the 2013 Demonstration with additional site-specific biotic category studies. This Demonstration concludes that the proposed alternative thermal effluent limitations will assure the protection and propagation of a balanced, indigenous community (BIC) of shellfish, fish and wildlife in and on the LOE, thereby satisfying the 316(a) criteria.

Section 1 provides background information, including the SIPC's requested alternative thermal effluent limitations and a summary of interactions with the Illinois Environmental Protection Agency (IEPA) and Illinois Pollution Control Board (IPCB) on the SIPC's previous petition for alternate effluent limitations. Section 2 presents the Master Rationale, which summarizes the key findings of this Demonstration in support of the conclusion that the BIC of the LOE will be protected under the proposed alternative thermal effluent limits. A brief summary of the supplemental studies is provided in Section 3 along with operational and environmental data from the year of study. Section 4 presents the biotic category rationales, including the results of the supplemental studies. Appendix A contains the approved Detailed Plan of Study. Appendix B is the detailed report of the supplemental study results prepared by Eastern Illinois University (EIU). Appendix C presents the 2013 Demonstration report by Amec.

1.1.1 Overview of the 2013 316(a) Demonstration

The 2013 Demonstration used information and data from other Illinois cooling lakes to support that the LOE is a low impact area for five of the six biotic categories (phytoplankton, zooplankton and meroplankton, macroinvertebrates and shellfish, habitat formers, and other wildlife) (USEPA

[1] Evaluation of Site-Specific Thermal Standards at Marion Power Plant. AMEC Environment & Infrastructure, Inc. Oct. 2013.

1977). The fish biotic category analysis was largely based on a comparison of fisheries data collected pre- and post-2003 from the LOE. Pre-2003 data were from fisheries surveys conducted by the SIUC from 1997 to 1999. Post-2003 data consisted fisheries surveys conducted by MACTEC in 2005, 2006, and 2010 and impingement sampling conducted from 2005 through 2007. In addition, MACTEC/Amec conducted temperature monitoring and modeling along with a predictive thermal assessment. These data from the LOE were supplemented with existing data on all the biotic categories, including fish, from other Illinois cooling lakes.

Analysis of the fisheries data showed that the fish community post-2003 was similar to that from pre-2003, indicating the fish were adapted to the warmer temperatures of the LOE and the community was healthy and self-sustaining (Amec 2013). Temperature data and thermal modeling showed the proposed alternative thermal limits would not affect the lake's thermal regime and that sufficient areas of refuge were available to fish even under extreme thermal conditions (Amec 2013). The 2013 Demonstration retrospective assessment concluded that there was no evidence of appreciable harm to any of the biotic categories addressed in the 1977 Guidance Manual. The prospective analysis concluded that the protection and propagation of a balanced, indigenous community of shellfish, fish, and wildlife in and on the LOE would be assured under the requested alternate effluent limits for the MGS's thermal discharges.

1.1.2 Overview of SIPC's Previous Request for Alternative Effluent Limitations

The SIPC relied on the 2013 Demonstration in petitioning the IPCB for alternate thermal effluent limitations applicable to the SIPC's discharges to the LOE. The IEPA recommended that the IPCB grant the SIPC's requested alternative thermal effluent limits. However, it found that the SIPC provided inadequate justification that the LOE was a site of low potential impact for phytoplankton, zooplankton and meroplankton, macroinvertebrates and shellfish, and habitat former biotic categories. The IEPA recommended that the IPCB impose permit conditions requiring the SIPC to conduct site-specific studies for these biotic categories or provide additional justification for the low impact determination, over the 5-year permit term. The IEPA also recommended that the SIPC conduct additional studies on thermally-sensitive (Black Crappie and White Crappie) and nuisance fish (Common Carp) species over the 5-year permit term. The IEPA recommended that the SIPC's study of thermally-sensitive fish evaluate whether there are areas in the LOE of potential refugia from both high temperature and low dissolved oxygen. The SIPC agreed to implement the suggested studies.

On November 20, 2014, the IPCB declined to grant the SIPC's requested relief, finding that the SIPC did not provide sufficient information to support a low potential impact determination for the phytoplankton, zooplankton/meroplankton, macroinvertebrate and shellfish, and habitat former biotic categories. Additionally, the IPCB found that the SIPC did not consider all the necessary representative important species (RIS) fish categories. The IPCB agreed that the LOE is a site of low potential impact with regard to the other wildlife biotic category. However, according to the Board, the SIPC did not provide sufficient information to determine that the SIPC's thermal discharges resulted in no appreciable harm to the LOE. The IPCB denied the SIPC's petition for alternate effluent limitations, finding SIPC had not demonstrated that the applicable thermal effluent limitation found in SIPC's NPDES permit 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 Lake of Egypt.

1.1.3 SIPC supplemental studies - IEPA Interactions and Approvals

ASA Analysis and Communication, Inc. (ASA), consulting with SIPC, designed a study plan in response to the IEPA and the IPCB requirements. Dr. Robert E. Colombo of EIU was retained to lead a team to conduct the LOE field sampling and laboratory analyses. A draft study plan was submitted to the IEPA on November 2, 2015 as part of the early screening information requirement in accordance with 35 Ill. Admin. Code 106.1115 and 40 C.F.R. §125.72. The SIPC met with the IEPA on December 2, 2015 to review the early screening information and solicit comments on the proposed studies. The SIPC's Detailed Plan of Study incorporated comments and suggestions received at that meeting. The IEPA approved the SIPC's Detailed Plan of Study on March 24, 2016. The approved Detailed Plan of Study is presented in Appendix A.

EIU, with oversight from ASA, conducted the supplemental studies in 2016. Samples were processed and the resulting data analyzed by EIU and the Illinois Natural History Survey Kaskaskia Biological Station. EIU prepared a report detailing the methods, analyses, and results of the supplemental studies. SIPC met with IEPA on May 2, 2017 to present the results of the 2016 data collection. At that meeting, IEPA concluded that one year of data was sufficient to satisfy 316(a) requirements and directed SIPC to finalize the report and proceed with its request for relief.

1.2 DESCRIPTION OF MARION STATION AND OPERATIONAL HISTORY

The SIPC is a consumer-owned generation and transmission cooperative, with headquarters in Marion, Illinois. The MGS is located approximately 7 miles south of the City of Marion and consists of two coal-fired units (Units 4 and 123) and 2 combined-cycle units (Units 5 and 6). Unit 4 is a 173-megawatt (MW) net cyclone boiler which came on line in 1978 and provides steam to one large turbine. Unit 123 is a 109 MW net circulating fluidized bed (CFB) boiler which came on line in 2003 and provides steam to three small turbines. Units 5 and 6 are nominally rated at approximately 83 MW. The four turbines for Units 4 and 123 use once-through cooling with a common intake and discharge. The additional boiler that became operational in 2003 resulted in increases of water use and volume of thermal water discharged into the lake.

The plant withdraws water for cooling from the LOE, which was created by the SIPC in 1963, by impounding the south fork of the Saline River. The original stream ran in a northerly direction, so the dam impounding the lake is at its northern end. The plant is located along the northwest bank of the lake (Figure 1-1) and for the purposes of this study is considered to be in the lower section of the lake. The once-through cooling water discharges back into a cove of the lake separated from the intake structure by a narrow peninsula (Figure 1-2). In this report, lake sections will be referred to as "lower," referring to areas close to the dam at the northern end; "upper," referring to areas more distant from the dam toward the southern end; and "middle", referring to the area between the lower and upper lake.

The SIPC owns the land around the lake up to the 50-year high water elevation, but does allow access for fishing and recreational activities to shoreline residents and members of the public. The LOE is approximately 2,300 acres in surface area and has approximately 93 miles of shoreline. The lake level generally varies between 499 and 501 feet mean sea level (msl) (MACTEC 2007). The average depth is 18 feet, with a maximum depth of 52 feet.

Heidinger (2007) describes the LOE fish community composition as one that is typical of southern Illinois reservoirs including, but not limited to, Largemouth Bass, Bluegill, White and Black Crappie, Redear Sunfish, Gizzard Shad, Longear Sunfish, and Common Carp. While these species appear to have been present since shortly after the construction of the lake, some have been supplemented by a periodic fish stocking program implemented by the SIPC as part of their ongoing management of the LOE (Table 1-1). Stocking began in 1971 with the stocking of Threadfin Shad to increase the forage base for predatory fish based on a recommendation from

Dr. Roy Heidinger. Threadfin Shad have been able to survive, reproduce, and maintain a healthy population due the warmer LOE water temperatures during the winter months (Heidinger 2007). Most recently the SIPC has stocked Black Crappie fingerlings in an effort to maintain and enhance the population. A history of the SIPC stocking program is presented in Table 1-1.

Table 1-1. Summary of Fish Stocking in the LOE (Heidinger, 2007; Amec 2013).

Year	Fish	Size/Stage	Number
1971	Threadfin Shad	Adults	1,200
1985	Walleye	4”- 6” fingerlings	8,000
1986	Hybrid Striped Bass	Fry	250,000
1986	Hybrid Striped Bass	1”- 2” fingerlings	500
1987	Hybrid Striped Bass	1”- 2” fingerlings	15,000
1987	Inland Silverside	Adults	500
1988	Hybrid Striped Bass	1”- 2” fingerlings	15,000
1989	Hybrid Striped Bass	1”- 2” fingerlings	15,000
1990	Hybrid Striped Bass	1”- 2” fingerlings	15,000
1991	Hybrid Striped Bass	1”- 2” fingerlings	10,000
1992	Hybrid Striped Bass	1”- 2” fingerlings	10,000
1993	Hybrid Striped Bass	1”- 2” fingerlings	10,000
1994	Hybrid Striped Bass	1”- 2” fingerlings	10,000
1996	Hybrid Striped Bass	1”- 2” fingerlings	2,000
2008	Black Crappie	2”- 3” fingerlings	15,000
2009	Black Crappie	2”- 3” fingerlings	20,000
2010	Black Crappie	2”- 3” fingerlings	20,000
2015	Black Crappie	2”- 3” fingerlings	20,000

The MGS operates as a base-load facility. The mean annual load factors for the last 8 years at the Marion plant are presented in Table 1-2 The facility has no plans to add or retire any units, so the projected load factors are expected to be similar.

Table 1-2. Mean Annual Load Factors for the Marion Generating Station.

Year	Unit 123	Unit 4
2009	79%	75%
2010	85%	76%
2011	84%	80%
2012	82%	74%
2013	78%	75%
2014	81%	73%
2015	82%	77%
2016	76%	71%

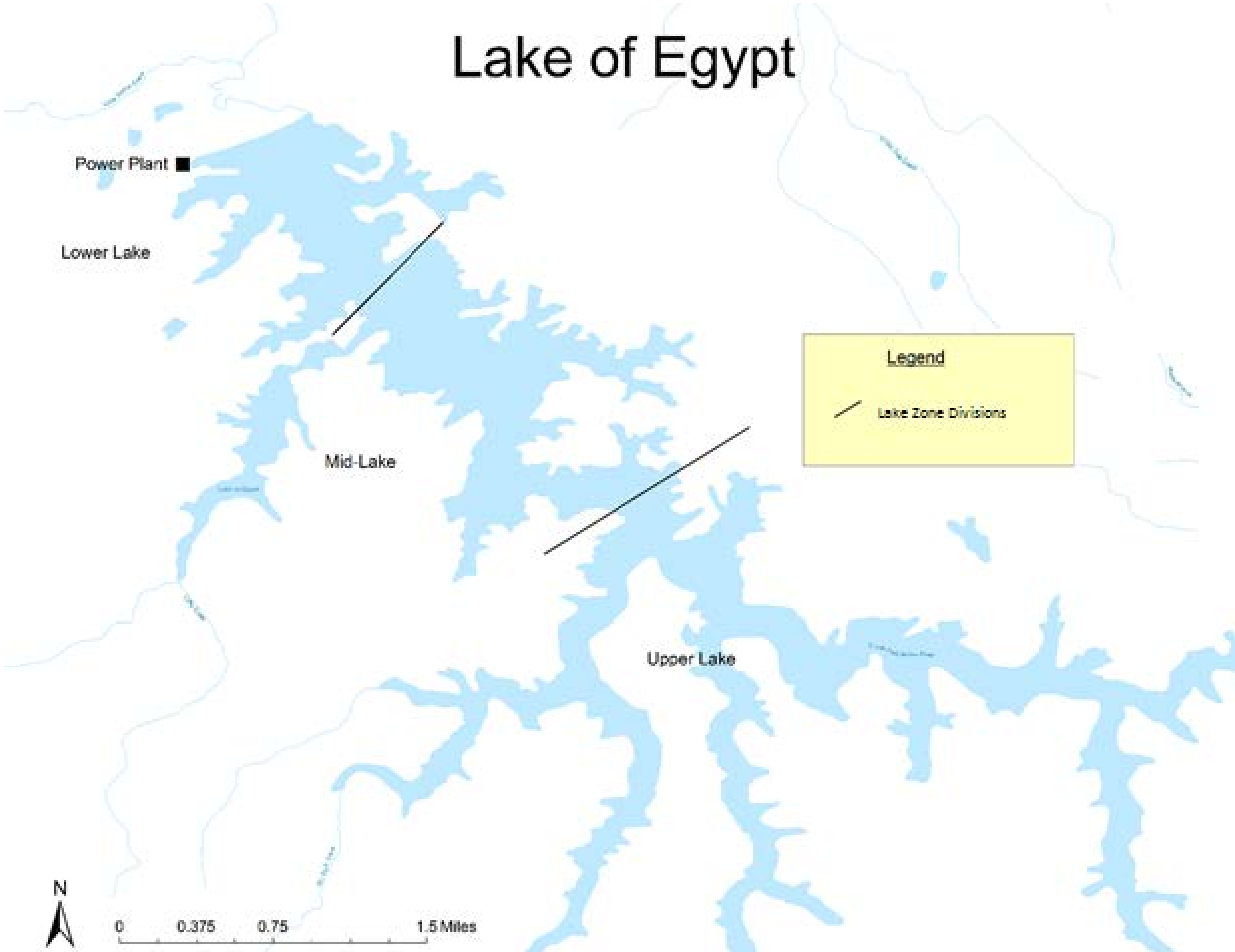

Figure 1-1. Location of the Marion Generating Station.

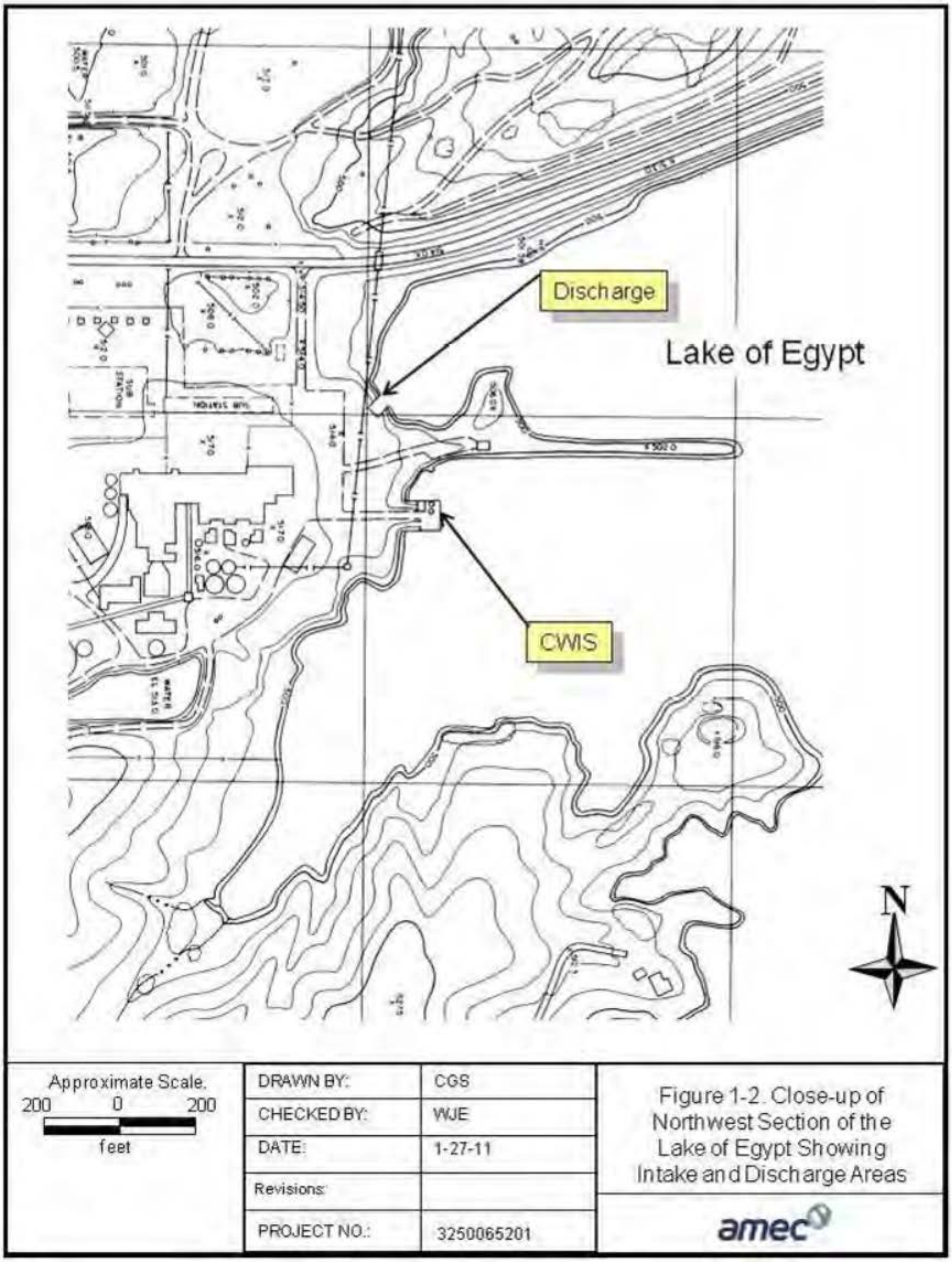

Figure 1-2. Close-up of Intake and Discharge Areas of the Marion Generating Station. Taken from Amec 2013.

1.2.1 Current NPDES permit requirements and requested alternative limits

The MGS National Pollutant Discharge Elimination System ("NPDES") Permit (NPDES Permit No. IL0004316) was re-issued by the IEPA on February 1, 2007, effective March 1, 2007. The SIPC submitted a timely application for renewal. Special Condition 4 of the SIPC's NPDES permit, which is based on the Illinois general use water quality standards for temperature[2] states:

> Discharge of wastewater from this facility must not alone or in combination with other sources cause the receiving stream to violate the following thermal limitations at the edge of the mixing zone which is defined by Section 302.211, Illinois Administration [sic] Code. Title 35, Chapter 1, Subtitle C, as amended:
>
> A. Maximum temperature rise above natural temperature must not exceed 5°F (2.8°C).
>
> B. Water temperature at representative locations in the lake shall not exceed the maximum limits in the following table during more than one (1) percent of the hours in the 12-month period ending with any month. Moreover, at no time shall the water temperature at such locations exceed the maximum limits in the following table by more than 3°F (1.7°C).

Month	ºC	ºF	Month	ºC	ºF
Jan.	16	60	Jul.	32	90
Feb.	16	60	Aug.	32	90
Mar.	16	60	Sept.	32	90
Apr.	32	90	Oct.	32	90
May	32	90	Nov.	32	90
Jun.	32	90	Dec.	16	60

The SIPC has met with the IEPA over the past several years to discuss the MGS's thermal discharges to the LOE. As discussed in prior meetings, the IPCB has determined that the seasonal temperature limits found in Section 302.211(e) do not apply to lakes.[3] Accordingly, Section 302.211(e) does not apply to the LOE and Special Condition 4(B) of the SIPC's NPDES permit will not be included upon reissuance. The remaining applicable section of Special Condition 4 prohibits a temperature rise of more than 5°F above natural temperatures beyond the edge of the mixing zone and is based on Section 302.211(d) of the IPCB's water quality standards.[4]

At this time, the SIPC is requesting the following alternate effluent limitation:

> The thermal discharge to Lake of Egypt from the SIPC's Marion Generating Station shall not exceed the following maximum temperatures, measured at the outside edge of the 26-acre mixing zone in Lake of Egypt, by more than 1 percent of the hours in a 12-month period:
>
> 1. 72°F from December through March;

[2] IPCB precedent establishes that the Illinois water quality standards on which Special Condition 4 is based do not apply to lakes and, therefore, do not apply to SIPC's discharges to Lake of Egypt.

[3] *See Board of Trustees of Southern Illinois University Governing Southern Illinois University, Edwardsville v. IEPA*, PCB 02-105, slip op. at 13 (Aug. 4, 2005) (holding that Section 302.211(e) applies only to rivers).

[4] 35 Ill. Adm. Code 302.211(d).

2. 90°F from April through May;
3. 101°F from June through September; and
4. 91°F from October through November.

At no time shall the water temperature at the edge of the mixing zone exceed these maximums by more than 3°F.

1.3 DEMONSTRATION APPROACH

ASA's 2016 studies are intended to supplement the information in the 2013 Demonstration for the MGS to show that the 5°F rise above natural temperature is more stringent than necessary to assure the protection and propagation of a balanced aquatic community (BIC) in and on the LOE. Specifically, the SIPC will rely on previously submitted data for the following biotic categories:

- Other vertebrate wildlife, and
- Fish in the commercially or recreationally important and food-chain prey species RIS categories.
    - Commercially and/or recreationally important RIS
        - Largemouth Bass
        - Bluegill
        - Channel Catfish
    - Forage/Food chain RIS
        - Threadfin Shad
        - Gizzard Shad

The SIPC conducted new site-specific pilot studies based on comments and recommendations by the IEPA and the IPCB to address the following biotic categories:

- Phytoplankton;
- Zooplankton/meroplankton;
- Shellfish and macroinvertebrates;
- Habitat formers; and
- Fish in the thermally sensitive and nuisance species RIS categories.
    - Thermally sensitive RIS
        - White Crappie
        - Black Crappie
    - Nuisance RIS
        - Common Carp
        - Rusty Crayfish (desk top evaluation)

This 316(a) variance demonstration evaluates data from the 2016 site-specific pilot studies and from Amec's 2013 316(a) demonstration, other cooling lake studies, and available historical and literature information to demonstrate the absence of prior appreciable harm based on the criteria outlined in the 1977 United States Environmental Protection Agency (USEPA) guidance manual (USEPA 1977).

2 MASTER RATIONALE

Under Section 316(a) of the CWA, a permittee may obtain an alternative thermal effluent limitation upon establishing, to the satisfaction of the permitting agency, that its thermal discharge, combined with other potential impacts on the aquatic biota, will assure the protection and propagation of the BIC in and on the receiving water body. As defined in the regulations (40 CFR 125.71(c), 35 Ill. Adm. Code 106.1110), a BIC is a

> biotic community typically characterized by diversity, the capacity to sustain itself through cyclic seasonal changes, presence of necessary food chain species, and by a lack of domination by pollution tolerant species. A BIC may include historically non-native species introduced in connection with a program of wildlife management and species whose presence or abundance results from substantial, irreversible environmental modifications. Normally, however, such a community will not include species whose presence or abundance is attributable to the introduction of pollutants that will be eliminated by compliance by all sources with section 301(b)(2) of the CWA; and may not include species whose presence or abundance is attributable to alternative thermal effluent limitations imposed pursuant to this Subpart or through regulatory relief from otherwise applicable thermal limitations under Chapter I of Subtitle C or standards granted by the Board. 35 Ill. Adm. Code 106.1110; *see also* 40 C.F.R. § 125.71(c).

An applicant may support a 316(a) Demonstration using predictive methods, or in the case of an existing facility such as the MGS, use studies to demonstrate the absence of prior appreciable harm. This Demonstration relies on these multiple lines of evidence (a Type II demonstration) to show that the requested thermal effluent limits will remain protective of the RIS. The retrospective analysis shows that the MGS operation and thermal discharge has caused no appreciable harm to any of the biotic categories identified in the 1977 Guidance Manual. The prospective analysis, conducted by Amec in the 2013 Demonstration, predicts the requested effluent limits will remain protective even under future worst-case conditions.

In general, USEPA has determined that a community need not be protected from mere “disturbance,” but rather that communities will be adequately protected if “appreciable harm” is avoided. According to USEPA, “appreciable harm” occurs if a thermal discharge causes such phenomena as the following:

- Substantial increase in abundance or distribution of any nuisance species or heat-tolerant community not representative of the highest community development achievable in receiving waters of comparable quality.
- Substantial decrease of formerly indigenous species, other than nuisance species.
- Changes in community structure to resemble a simpler successional stage than is natural for the locality and season in question.
- Unaesthetic appearance, odor, or taste of the waters.
- Elimination of an established or potential economic or recreational use of the waters.
- Reduction of the successful completion of life cycles of indigenous species, including those of migratory species.
- Substantial reduction of community heterogeneity or trophic structure.

The recently collected LOE site-specific data for phytoplankton, zooplankton/meroplankton, benthic macroinvertebrates and shellfish, and habitat formers, along with the recent and historical data on the LOE fish RIS demonstrates that the MGS operation and thermal discharge has not caused appreciable harm to the LOE BIC. More specifically, with regard to the above phenomena indicative of appreciable harm:

- No increase is evident in the presence and/or abundance of any nuisance species in the LOE as a result of the thermal discharge. The community present in the lower lake zone in the vicinity of the MGS has not become dominated by heat-tolerant species and is comparable, in terms of the species present, to the community in other zones of the LOE.
- No substantial decrease in the abundance of fish RIS based on the results of current and historical electrofishing data. While there is no historical data available for the other biotic categories, the similar abundance, and in most cases community composition, between lake zones suggest that there has been no decrease in indigenous species in those biotic categories.
- There is no indication that the aquatic community has been changed in a way that makes its structure simpler or unnatural for the locality. The number of fish species and the species abundance structure of the fish community in the vicinity of the MGS is comparable to that of other Illinois cooling and ambient reservoirs (EIU 2017).
- The MGS has not caused an unaesthetic appearance or odor of the receiving water.
- The MGS has not eliminated an established or potential recreational use of the LOE or local vicinity. To the contrary, the LOE is heavily utilized by recreational fishermen and is host to numerous fishing tournaments each year.
- There is no evidence of a reduction in the successful completion of life-cycles of indigenous species in the LOE based on the continued presence and abundance of key fish species and the similarity of communities between lake zones for the other biotic categories. For fish, this conclusion is also supported by the biothermal assessment conducted by Amec in the 2013 Demonstration.
- There have been no changes in species composition and abundance in the fish community of the LOE. While historical data is not available for the other biotic categories, EIU (2017) found that in general the aquatic community in the LOE was similar to other oligotrophic (low nutrient) systems in Illinois.

As part of the 2013 Demonstration, Amec conducted hydrothermal modeling and a predictive biothermal assessment to evaluate whether the proposed alternate effluent limitations would affect the thermal regime of the LOE and cause appreciable harm to the selected fish RIS. Amec used a hydrothermal model to predict water temperatures under normal and stressed conditions during summer and winter time periods. Normal conditions were defined as the conditions present during June-July 2010 for summer and during January-February 2011 for winter. Stressed conditions were defined using 95% non-exceedance values for a 20-year record of environmental parameters reflecting a set of weather/climatic conditions that are considered to be rarely exceeded in terms of potentially generating warmer lake temperatures. Amec's analysis of the LOE thermal regime and the temperature limits for growth and mortality for the selected RIS showed that, under most conditions, substantial areas of the LOE remained as suitable habitat for all RIS. Amec (2013) concluded that, even under stressed conditions, areas of thermal refugia were present.

In summary, the results of the current supplemental site-specific studies and the information from the 2013 Demonstration support the conclusion that the MGS thermal discharge will continue to assure the protection and propagation of a balanced indigenous community in the LOE.

3 SUPPLEMENTAL PILOT STUDIES

3.1 STUDY PLAN OVERVIEW

The supplemental studies were designed as pilot studies to collect basic site-specific information on the four biotic categories and additional fish RIS identified by both the IEPA and IPCB. Data collection for the biotic category analyses was focused on parameters that would allow an evaluation of key criteria outlined in the 1977 Guidance Manual for the successful demonstration of lack of appreciable harm.

The objective of the supplemental studies was to collect site-specific data sufficient to evaluate whether:

- the criteria for lack of appreciable harm are being met for each identified biotic category;
- there is a demonstrated substantial increase in abundance of nuisance fish species (Common Carp) as a result of the influence of the MGS thermal discharge; and
- there is sufficient refuge habitat with acceptable temperature and dissolved oxygen concentrations for White Crappie and Black Crappie during periods of elevated summer temperatures.

Field temperature measurements and hydrothermal modeling conducted by MACTEC/Amec between 2006 and 2013 (Amec 2013) were used in conjunction with historical sampling conducted by SIUC and MACTEC/Amec to approximate a division between the lower, middle, and upper zones of the LOE (Figure 1-1). The primary objective in evaluating these areas was to ensure that sample collection locations were stratified by their degree of potential thermal exposure.

The supplemental pilot studies were conducted from June through September 2016 with some additional fish collections in October and November 2016. The supplemental pilot studies were implemented as outlined in the Detailed Plan of Study with the exception of zooplankton/meroplankton. Zooplankton/meroplankton sample collection, while not included in the approved Detailed Plan of Study, was incorporated into the implementation of the supplemental pilot studies following further discussions with the IEPA.

3.2 ENVIRONMENTAL AND PLANT OPERATING CONDITIONS IN 2016

Environmental and plant operating conditions during the study year were compared to the range of historical values to place the study year in context to typical environmental and plant operating conditions.

3.2.1 Environmental Conditions

Study year environmental conditions were approximated using mean daily air temperature data obtained from the Illinois State Water Survey Carbondale Station. Mean daily air temperature was obtained for the study year (2016) and the historical period from 1990 through 2016.

During the June through September 2016, mean daily air temperature was generally higher than the historical (1990-2016) average over the same period (Figure 3-1). This pattern was generally true for the entire study year except for brief excursions of cooler temperatures. These data indicate that the LOE was generally exposed to warmer than average air temperatures during the study year and period. Therefore, it is likely that LOE water temperatures were also warmer than average during at least the study period.

3.2.2 Plant Operating Conditions

Plant operating conditions were represented by mean annual load factors from both the study year (2016) and from 2009 through 2016. Plant operation data for Units 123 and 4 and combined for the period of study are shown in Figure 3-2. While the mean annual load factor for 2016 was slightly lower than in most prior years (Table 1-2), the mean load factors for the period of study (June through September) were approximately 83% and 82% for Units 123 and 4, respectively (Table 3-1, Figure 3-2). These load factors show that the plant was operating at normal capacity during the study period.

Table 3-1. Mean Load Factors for the Marion Generating Station Units 123 and 4 During the Period of Study from June through September 2016.

Month	Unit 123	Unit 4
June	87.5%	68.3%
July	82.9%	87.7%
August	82.4%	89.8%
September	80.6%	80.2%
June-September	83.3%	81.6%

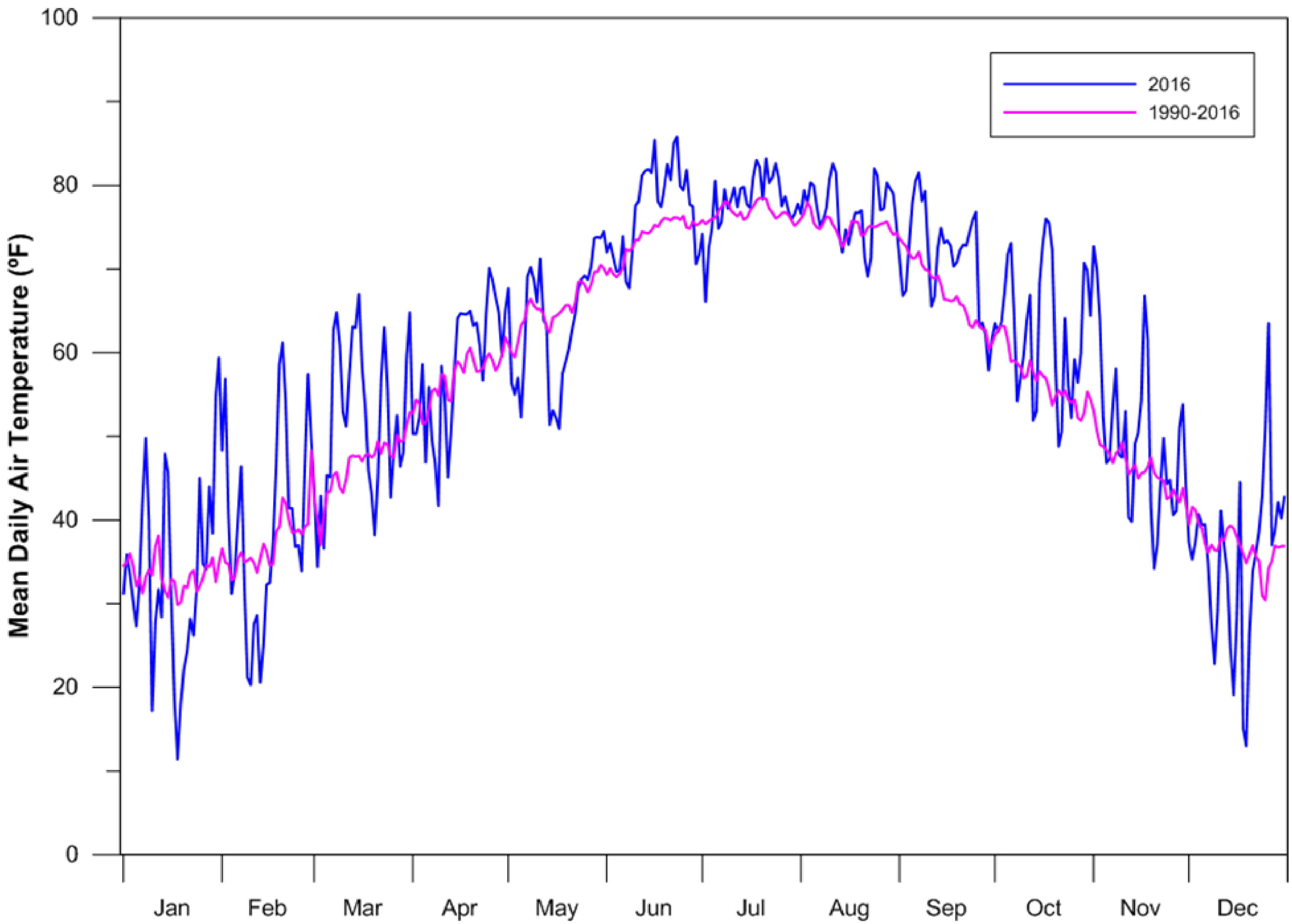

Figure 3-1. Air Temperature Data from the Illinois State Water Survey Carbondale Station for the Period 1990-2016 and the Study Year 2016.

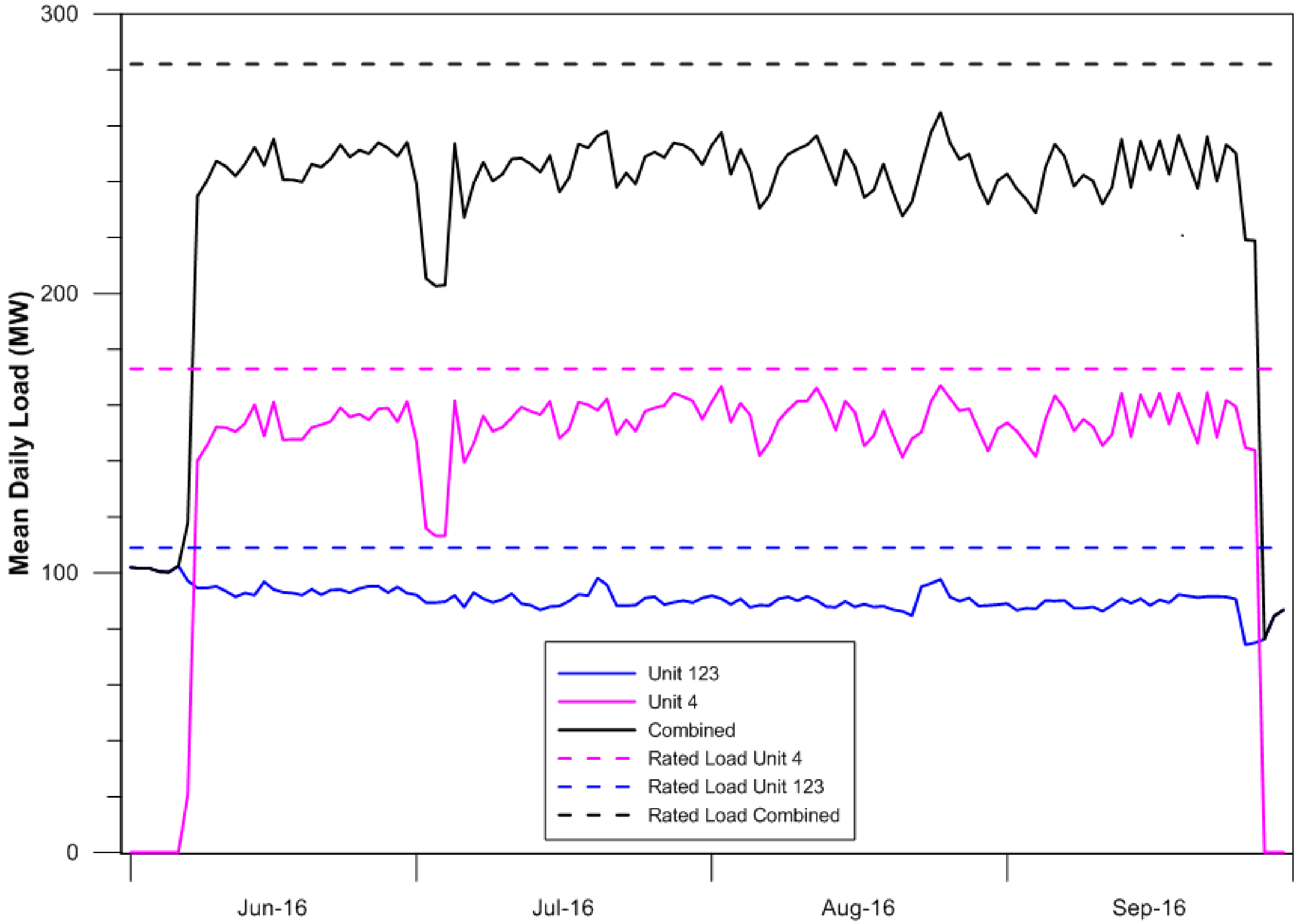

Figure 3-2. Mean Daily and Rated Loads for Units 123 and 4 and Combined for the 2016 Period of Study, June through September.

4 BIOTIC CATEGORY RATIONALES

4.1 INTRODUCTION AND BIOTIC CATEGORIES

The 1977 Guidance Manual identifies six biotic categories that must be evaluated to determine whether the criteria for the protection and propagation of the BIC have been met (USEPA 1977). This section presents arguments based on analysis of the data collected during the site-specific supplemental pilot studies and incorporates data and conclusions from the 2013 Demonstration to demonstrate that the criteria for a successful demonstration for each of the six biotic categories have been met.

As described in Section 1.1.2, the 2013 Demonstration adequately addressed the other vertebrate wildlife and commercially and recreational important and forage/food chain fish RIS biotic categories. The IEPA and IPCB concurred with the AMEC conclusion that the LOE was an area of low potential impact for other wildlife.

The remaining biotic categories formed the basis for the supplemental pilot studies and are addressed below. All the data from the supplemental pilot studies were collected and analyzed by EIU. This section presents the 1977 Guidance Manual Criteria, an overview of the supplemental study objectives, methods, a summary of the results of the EIU analyses, information from the 2013 Demonstration that is used to support the current studies, and a conclusion on whether the biotic category criteria have been met for each biotic category. The EIU report is presented in Appendix B.

4.2 PHYTOPLANKTON

4.2.1 Decision Criteria

The 1977 Guidance Manual states that the phytoplankton section of a 316(a) demonstration will be judged successful if the applicant can demonstrate that:

- A shift towards nuisance species of phytoplankton is not likely to occur.
- There is little likelihood that the discharge will alter the indigenous community from a detrital to phytoplankton based system.
- Appreciable harm to the balanced indigenous population is not likely to occur as a result of phytoplankton community changes caused by the heated discharge.

Examples of data USEPA cites that can used in this demonstration include standing crop estimates, the presence and relative abundance of nuisance forms, and the dominant forms present.

4.2.2 Pilot Study Objectives and Methods

The objectives of the site-specific supplemental pilot studies were to collect site-specific data on the phytoplankton species composition and relative abundance within the three lake zones to evaluate:

- whether there are differences in species composition and relative abundance among the zones that may be attributed to temperature increases resulting from the thermal discharge, and

- the presence and abundance of any nuisance and/or thermally-tolerant species within the lower lake zone relative to the other two lake zones.

Phytoplankton samples were collected monthly from June 2016 through August 2016 resulting in a total of three sample collection periods. During each sample collection period, samples for phytoplankton and water chemistry nutrient analysis were collected from three locations within each of the three lake zones (a total of nine samples per collection period).

There were no known locations of past phytoplankton sampling in the LOE to consider in the selection of the current sampling locations. Phytoplankton and water chemistry nutrient samples were collected from the locations shown in Figure 4-1.

4.2.3 Summary of Results

The phytoplankton community in the LOE was dominated by diatoms - the most common form of freshwater phytoplankton - and showed a natural progression in composition over the June to August sampling period (EIU 2017). A total of 46 genera from seven phyla was identified in the LOE samples (EIU 2017 Appendix A). Water chemistry sample analysis indicated the LOE is relatively nutrient poor and therefore favors phytoplankton forms that fix atmospheric nitrogen such as Cyanobacteria. The phylum Dinophyta, a known heat-tolerant (nuisance) form, was identified from all three lake zones but was most abundant in the middle and upper lake zones.

While the relative abundance of phytoplankton was similar among lake zones, there were significant differences in the phytoplankton community structure between the lower, middle, and upper lake zones. These differences were attributed in large part to the higher proportions of blue-green algae in the middle and upper lake zones. The presence of blue-green algae (Cyanobacteria), particularly in the middle and upper lake zones, is attributable to the lower nutrient levels in those zones relative to the lower lake zone (EIU 2017).

EIU (2017) described the phytoplankton community as one that would be expected in mid-western lakes with low nutrient levels. All three lake zones had similar phytoplankton abundance. While members of one heat-tolerant phylum (Dinophyta) were identified in all three lake zones, they were most abundant in the upper lake zone farthest from the plant's discharge.

4.2.4 Additional supporting information and data

In the absence of site-specific data, the 2013 Demonstration relied on both observations from the LOE and information and studies from other cooling lakes to support the lack of appreciable harm to the LOE phytoplankton community. The arguments presented in Section 4.1 of the 2013 Demonstration provide additional support to the recently collected site-specific data showing no prior appreciable harm. Specifically;

- Studies on cooling lakes Sangchris and Newton showed no adverse effects on their respective phytoplankton communities (Moran 1981);
- Phytoplankton communities generally are short-lived and reproduce quickly. If there were any temporary effects on the community, there are extensive areas outside the thermal zone of influence that could serve as areas of refuge and/or sources for recolonization; and
- The LOE phytoplankton community has developed under the current environmental conditions (heated effluent at the lower end of the lake) and there is no indication of community impairment.

4.2.5 Conclusion

The site-specific phytoplankton community data collected from the LOE shows that the LOE phytoplankton community is similar to that expected in mid-western lakes. While statistically significant differences in phytoplankton community composition between the lake zones were identified, these differences were directly linked to the lower nutrient levels in the middle and upper lake relative to the lower lake zone. All three lake zones sampled were similar in the relative abundance of phytoplankton and did not show a proliferation of nuisance or heat tolerant species. The absence of any changes to, or differences in, the phytoplankton community related to the thermal discharge means no resulting appreciable harm to the balanced indigenous population in the LOE.

These results demonstrate that the phytoplankton community meets the criteria set forth by the USEPA for no appreciable harm from the MGS thermal discharge. This conclusion is further supported by data from other cooling lakes similarly showing no adverse effects on their respective phytoplankton communities.

4.3 ZOOPLANKTON/MEROPLANKTON

4.3.1 Decision Criteria

The 1977 Guidance Manual states that the zooplankton/meroplankton section of a 316(a) demonstration will be judged successful if the applicant can demonstrate that:

- Changes in the zooplankton/meroplankton community in the primary study area that may be caused by the heated discharge will not result in appreciable harm to the balanced indigenous fish and shellfish population.
- The heated discharge is not likely to alter the standing crop or relative abundance with respect to natural population fluctuations in the far-field study area from those values typical of the receiving water body segment prior to plant operation.
- The thermal plume does not constitute a barrier to free movement (drift) of zooplankton/meroplankton.

Examples of data USEPA cites that can used in this demonstration include standing crop estimates, relative abundance, community structure, and seasonal variations.

4.3.2 Pilot Study Objectives and Methods

The objectives of the site-specific supplemental pilot studies were to collect site-specific data on zooplankton/meroplankton species composition and relative abundance within the three lake zones to evaluate:

- whether there are differences in species composition and relative abundance among the zones that may be attributed to temperature increases resulting from the thermal discharge, and
- the presence and abundance of any nuisance and/or thermally-tolerant species within the lower lake zone relative to the other two lake zones.

Zooplankton/meroplankton samples were collected monthly from June 2016 through August 2016 resulting in a total of three sample collection periods. During each sample collection period,

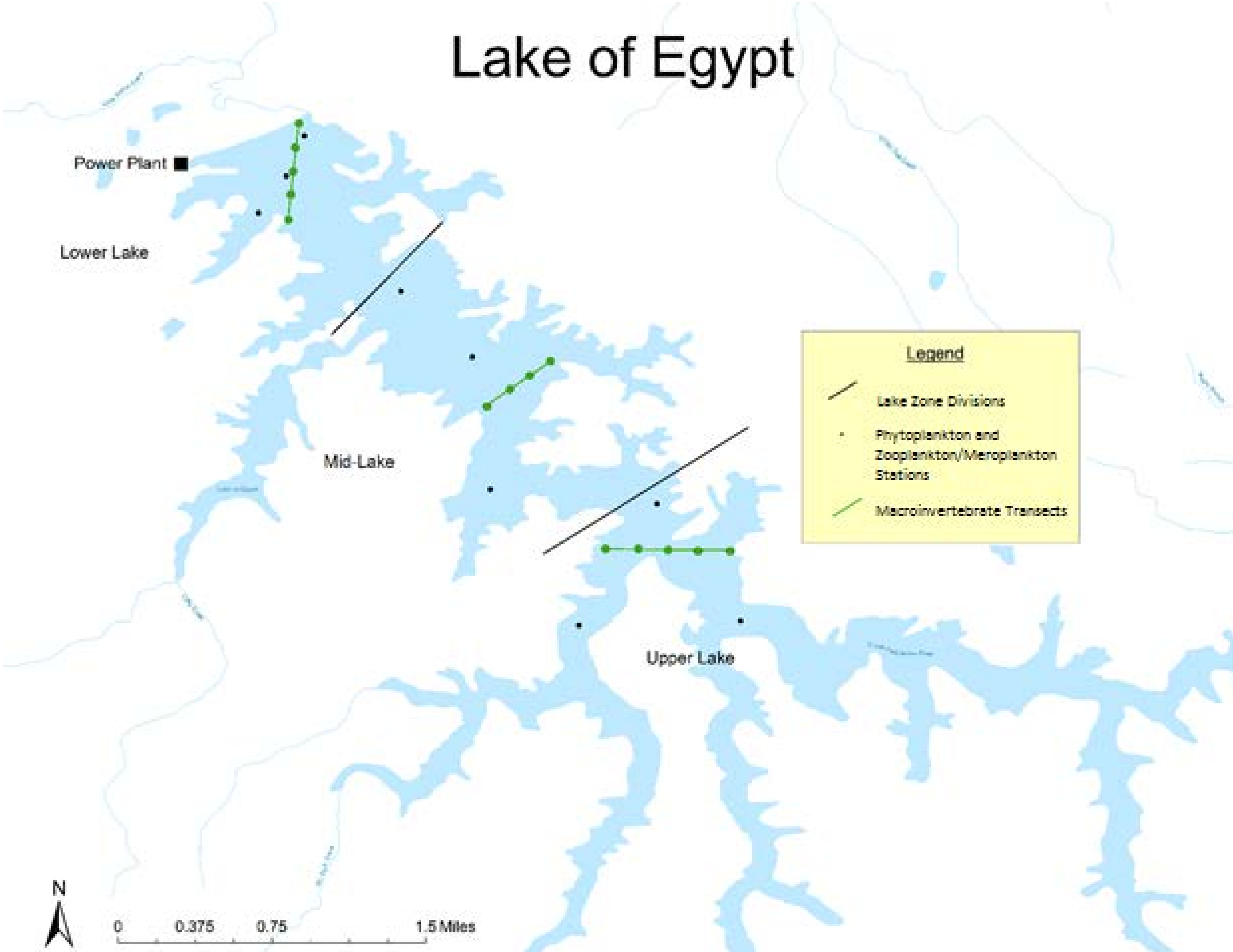

Figure 4-1. Phytoplankton, Zooplankton and Meroplankton, and Benthic Macroinvertebrate Sample Collection Locations on the Lake of Egypt.

samples for zooplankton/meroplankton were collected concurrently with phytoplankton and water chemistry nutrient samples from three locations within each of the three lake zones (a total of nine samples per collection period).

There were no known locations of past zooplankton/meroplankton sampling in the LOE to consider in the selection of the current sampling locations. Zooplankton/meroplankton samples were collected from the locations shown in Figure 4-1.

4.3.3 Supporting site-specific data

A total of nine zooplankton taxa were identified in the samples collected from the LOE, however the zooplankton community was dominated by rotifers (EIU 2017). The highest zooplankton density was observed in June, declining thereafter in all lake zones. Zooplankton density was highest in the lower lake zone relative to the middle and upper lake zones. EIU (2017) found no difference in zooplankton community structure between the different lake zones. Zooplankton community composition was similar to that found in other Illinois cooling and ambient reservoirs (Mulhollem et al 2015).

4.3.4 Additional supporting information and data

In the absence of site-specific data, the 2013 Demonstration relied on both observations from the LOE and information and studies from other cooling lakes to support the lack of appreciable harm to the LOE zooplankton/meroplankton community. The arguments presented in Section 4.2 of the 2013 Demonstration provide additional support to the recently collected site-specific data showing no prior appreciable harm. Specifically;

- Studies on Lake Sangchris showed no changes in zooplankton diversity between heated and unheated arms of the lake (Waite 1981). While biomass and abundance was lower during the summer in the areas exposed to thermal loading, these same areas showed increases in these parameters in the other seasons;
- Studies on Newton lake showed wide variation in zooplankton densities but did not identify any trends associated with thermal loading (Heidinger et al 2000);
- The fact that the fish community in the LOE has remained similar and stable indicates that the underlying trophic levels such as zooplankton and meroplankton have not been appreciably harmed, or that any harm has not resulted in adverse effects to the fish community; and
- The downstream location of the discharge minimizes the potential for the thermal discharge to present a barrier or to negatively affect the free movement of zooplankton and meroplankton.

4.3.5 Conclusion

The site-specific zooplankton/meroplankton community data collected from the LOE shows that the LOE zooplankton/meroplankton community is similar to that expected in mid-western cooling lakes and ambient reservoirs. Within the LOE, the zooplankton/meroplankton community structure was similar in all three lake zones. The lower lake zone where the MGS thermal discharge is located showed the highest zooplankton/meroplankton density compared to the other lake zones. These data show that zooplankton/meroplankton relative abundance and community structure has not been adversely affected by the MGS thermal discharge. The abundance of zooplankton/meroplankton in the lower lake and absence of any community differences between the lake zones, suggest that the MGS thermal discharge is not a lethal barrier to zooplankton/meroplankton movement. The absence of any changes to, or differences in, the zooplankton/meroplankton community related to the thermal discharge means no resulting appreciable harm to the balanced indigenous population in the LOE.

These results demonstrate that the zooplankton/meroplankton community meets the criteria set forth by the USEPA for no appreciable harm from the MGS thermal discharge. This conclusion is further supported by data from other cooling lakes similarly showing no adverse effects on their respective zooplankton/meroplankton communities.

4.4 MACROINVERTEBRATES AND SHELLFISH

4.4.1 Criteria

The 1977 Guidance Manual states that the macroinvertebrate and shellfish section of a 316(a) demonstration will be judged successful if the applicant can demonstrate that:

- No demonstrated reduction in standing crop unless it can be shown that any reductions do not result in appreciable harm to the balanced and indigenous community within the waterbody.
- No reductions in the components of diversity unless it can be shown that any such reductions do not affect the critical functions of the waterbody.
- Food is not a factor limiting the production of the fish community.
- The discharge of waste heat does not impair critical functions which can be demonstrated if the discharge area does not include spawning or nursery sites for important macroinvertebrates or shellfish. [5]

Examples of data USEPA cites that can used in this demonstration include standing crop estimates, relative abundance, community structure, diversity, presence and relative abundance of nuisance forms, and seasonal variations.

4.4.2 Pilot Study Objectives and Methods

The objectives of the site-specific supplemental pilot studies were to collect site-specific data on macroinvertebrate and shellfish species composition and relative abundance within the three lake zones to evaluate:

- whether there are differences in species composition and relative abundance among the zones that may be attributed to temperature increases resulting from the thermal discharge, and
- the presence and abundance of any nuisance and/or thermally-tolerant species within the lower lake zone relative to the other two lake zones.

Benthic macroinvertebrate and shellfish samples were collected monthly from June 2016 through August 2016 resulting in a total of three sample collection periods. During each sample collection period, one transect was sampled in each of the lake zones. A minimum of three, and up to five,

[5] Because LOE is not a riverine site, drift is not considered a decision criterion for macroinvertebrates and shellfish.

locations were sampled along each transect to account for potential differences in the macroinvertebrate and shellfish community with depth and substrate composition.

There were no known locations of past macroinvertebrate and shellfish sampling in the LOE to consider in the selection of the current sampling locations. The macroinvertebrate and shellfish samples were collected from the locations shown in Figure 4-1.

4.4.3 Supporting site-specific data

The benthic macroinvertebrate community in the LOE was comprised primarily of bloodworms, midges, and glassworms though crustaceans and bivalves were also collected. In general, EIU (2017) found that benthic macroinvertebrate abundance was low and scores for indices of diversity, richness, and evenness were also low in all lake zones. There was no difference in the benthic macroinvertebrate community structure or various community indices between lake zones. No commercially or recreationally important benthic macroinvertebrate or shellfish species were collected during the current surveys. The paucity of benthic macroinvertebrates was attributed to the lack of substrate heterogeneity throughout the LOE. The substrate in all lake zones was found to be primarily comprised of fine sediments and there was no difference in the proportional abundance of substrate types between lake zones (EIU 2017).

4.4.4 Additional supporting information and data

In the absence of site-specific data, the 2013 demonstration relied on both observations from the LOE and information and studies from other cooling lakes to support the lack of appreciable harm to the LOE benthic macroinvertebrate and shellfish community. The arguments presented in Section 4.4 of the 2013 demonstration provide additional support to the recently collected site-specific data showing no prior appreciable harm. Specifically;

- Based on the characteristics of similar Illinois impoundments, there are no species of commercial or recreational value present in the lake;
- Webb (1981) reported that, in Lake Sangchris in central Illinois, macroinvertebrate assemblages were similar between areas influenced by thermal discharge and uninfluenced control areas, and it is similarly unlikely that a substantial detrimental influence exists in the Lake of Egypt;
- Although macroinvertebrates likely serve as an important forage component in the Lake of Egypt, the relative stability of the fish community in terms of composition and abundance indicate that food availability does not limit fish production; and
- Since there are no important (i.e., commercially or recreationally important) shellfish or macroinvertebrate species in the Lake of Egypt, there are no spawning or nursery sites associated with them.

4.4.5 Conclusion

The site-specific benthic macroinvertebrate and shellfish community data collected from the LOE shows that benthic macroinvertebrate and shellfish abundance was low in all lake zones. Community composition, evaluated using diversity, richness, and evenness indices, was similar among lake zones. These data show that benthic macroinvertebrate and shellfish community abundance and diversity has not been adversely affected by the MGS thermal discharge. In addition, no spawning or nursery sites for commercially or recreationally important benthic macroinvertebrate or shellfish species are in the thermal discharges zone since none of these species were identified in the LOE. The absence of any changes to, or differences in, the benthic macroinvertebrate and shellfish community related to the thermal discharge means no resulting appreciable harm to the balanced indigenous population in the LOE.

These results demonstrate that the benthic macroinvertebrate and shellfish community meets the criteria set forth by the USEPA for no appreciable harm from the MGS thermal discharge. This conclusion is further supported by data from other cooling lakes similarly showing no adverse effects on their respective benthic macroinvertebrate and shellfish communities.

4.5 HABITAT FORMERS

4.5.1 Criteria

The 1977 Guidance Manual states that the habitat former section of a 316(a) demonstration will be judged successful if the applicant can demonstrate that:

- The heated discharge will not result in any deterioration of the habitat former community or that no appreciable harm to the balanced indigenous population will result from such deterioration.
- The heated discharge will not have an adverse impact on threatened and endangered species as a result of impact on habitat formers.
- Habitat formers will not be excluded from establishing due to the thermal discharge.
- Important fish and shellfish will not be thermally excluded from using habitat former habitat.

4.5.2 Pilot Study Objectives and Methods

The objectives of the site-specific supplemental pilot studies were to collect site-specific data on the presence and relative abundance of habitat formers within the three lake zones to evaluate potential differences that may be attributed to temperature increases resulting from the thermal discharge.

Data on habitat formers (emergent and submerged aquatic vegetation [SAV]) in the LOE were collected once during the summer period in 2016 (August). The entire main shoreline of the lake was surveyed using a Lowrance HD-10 sidescan sonar with structure scan in the littoral zone at a speed of no greater than 5 mph. Up to two randomly selected areas of SAVs in each of the three lake zones was mapped at no greater than 3 mph to provide a higher resolution map. Additionally, three transects within each of these two areas per zone were assessed for SAV species composition

4.5.3 Supporting site-specific data

The habitat former survey found both emergent and submerged aquatic vegetation along portions of the shoreline in all lake zones in the LOE (EIU 2017). Shoreline emergent vegetation covered approximately 81% of the LOE shoreline and was dominated by water willow, a common form of shoreline vegetation in Illinois, in all lake zones. EIU (2017) found submerged aquatic vegetation was present along approximately 22% of the LOE shoreline. The low amount of SAV was attributed to the rapid increase in depth along most of the LOE shoreline. Where submerged aquatic vegetation was present, the dominant forms were exotic milfoil in the upper lake zone, pondweed in the middle lake zone, and slender naiad in the lower lake zone. While EIU (2017) found a lower percentage of the shoreline in the lower lake zone occupied by water willow, the lower lake zone had a higher proportion of SAV than the other lake zones. The lower proportion of water willow in the lower lake zone is likely due to the presence of the dam and other habitat unsuitable for shoreline plant growth. Based on the presence of both emergent and submerged aquatic vegetation in all lake zone areas with suitable habitat, the MGS thermal discharge does not appear to be affecting habitat formers in the LOE.

4.5.4 Additional supporting information and data

In the absence of site-specific data, the 2013 Demonstration relied on both observations from the LOE and information and studies from other cooling lakes to support the lack of appreciable harm to the LOE habitat former community. The arguments presented in Section 4.3 of the 2013 Demonstration provide additional support to the recently collected site-specific data showing no prior appreciable harm. Specifically;

- Amec (2013) cited a study (ESE 1995) that reported that communities in warmer areas of the upper Illinois River drainage were not impaired in comparison to the sampled communities in cooler areas;
- Amec (2013) noted areas supporting aquatic macrophytes were present in the downstream area of the LOE where the MGS discharge is located; and
- No threatened or endangered fish species are present in the LOE thus no adverse impact would be expected to species of concern even if the thermal discharge had a negative effect on habitat formers.

4.5.5 Conclusion

The site-specific habitat former data collected from the LOE showed that both emergent and submerged aquatic vegetation are present in all lake zones in the LOE. Their presence was directly related to available habitat conducive to vegetative growth. In particular, submerged aquatic vegetation appeared to be limited by a rapid increase in water depth immediately offshore. Therefore, the presence of the thermal discharge does not appear to be responsible for any absence of habitat formers in the lower lake zone. In addition, the absence of suitable habitat, and not the thermal discharge, is preventing the establishment of habitat formers in areas where they do not currently exist.

These results demonstrate that the habitat former community meets the criteria set forth by the USEPA for no appreciable harm from the MGS thermal discharge.

4.6 FISH

As described in Sections 1.1.2 and 1.3, the 2013 Demonstration successfully demonstrated the lack of appreciable harm for the commercially and recreationally important and forage/prey fish RIS categories. As a result, the IEPA and IPCB did not recommend any additional studies for these RIS categories. While this section focuses on the results of the supplemental studies for the nuisance and thermally-sensitive RIS categories, a brief comparison of the fish community based on electrofishing results from the current study with previous studies is also presented.

4.6.1 Criteria

The 1977 Guidance Manual states that the fish section of a 316(a) demonstration will be judged successful if the applicant can demonstrate that the fish community will not suffer appreciable harm from:

- A proliferation of nuisance species due to the plant thermal discharge.
- Direct or indirect mortality from cold shock.
- Direct or indirect mortality from excess heat.
- Reduced reproductive success or growth as a result of the thermal discharge.
- Exclusion from unacceptably large areas.
- Blockage from migration.

4.6.2 Pilot Study Objectives and Methods

Nuisance Species

The objectives of the site-specific supplemental pilot studies were to collect current data on Common Carp abundance for comparison with historically collected data from the same locations. In addition, a desk top evaluation of Rusty Crayfish literature was conducted to assess the potential for this species to become a localized nuisance as a result of the MGS thermal loading.

Electrofishing targeting Common Carp was conducted once during the fall of 2016 to coincide with the time period of historical data collection. Sample locations within the lower and upper lake zones replicated or were similar to historical sampling locations used by SIUC (Heidinger et al 2000) and AMEC (AMEC 2013) to the degree possible. Sampling locations were added in the middle lake zone. While Common Carp were targeted, all species were identified and enumerated. The electrofishing locations are shown in Figure 4-2.

Thermally-Sensitive Species

Two sets of data were collected as part of the evaluation of the potential effects of the thermal loading to the LOE on the thermally-sensitive White Crappie and Black Crappie.

A temperature and dissolved oxygen (DO) monitoring survey was conducted to evaluate the availability of thermal refuge habitat (acceptable temperature and dissolved oxygen levels) during the period of high surface water temperatures.

An age-growth study was conducted and compared to historical results reported by Dr. Roy Heidinger (Heidinger 1998, 1999, 2007) to evaluate the age-class structure and condition of Black and White Crappie inhabiting the LOE.

Temperature and DO measurements were collected weekly from June through September 2016 from five locations within each of the three lake zones. Sample collection stations were selected to approximate the location of historical data collection (Heidinger et al 2000) and to provide additional sample points for greater spatial coverage within each zone. The sample locations for each lake zone are shown in Figure 4-3.

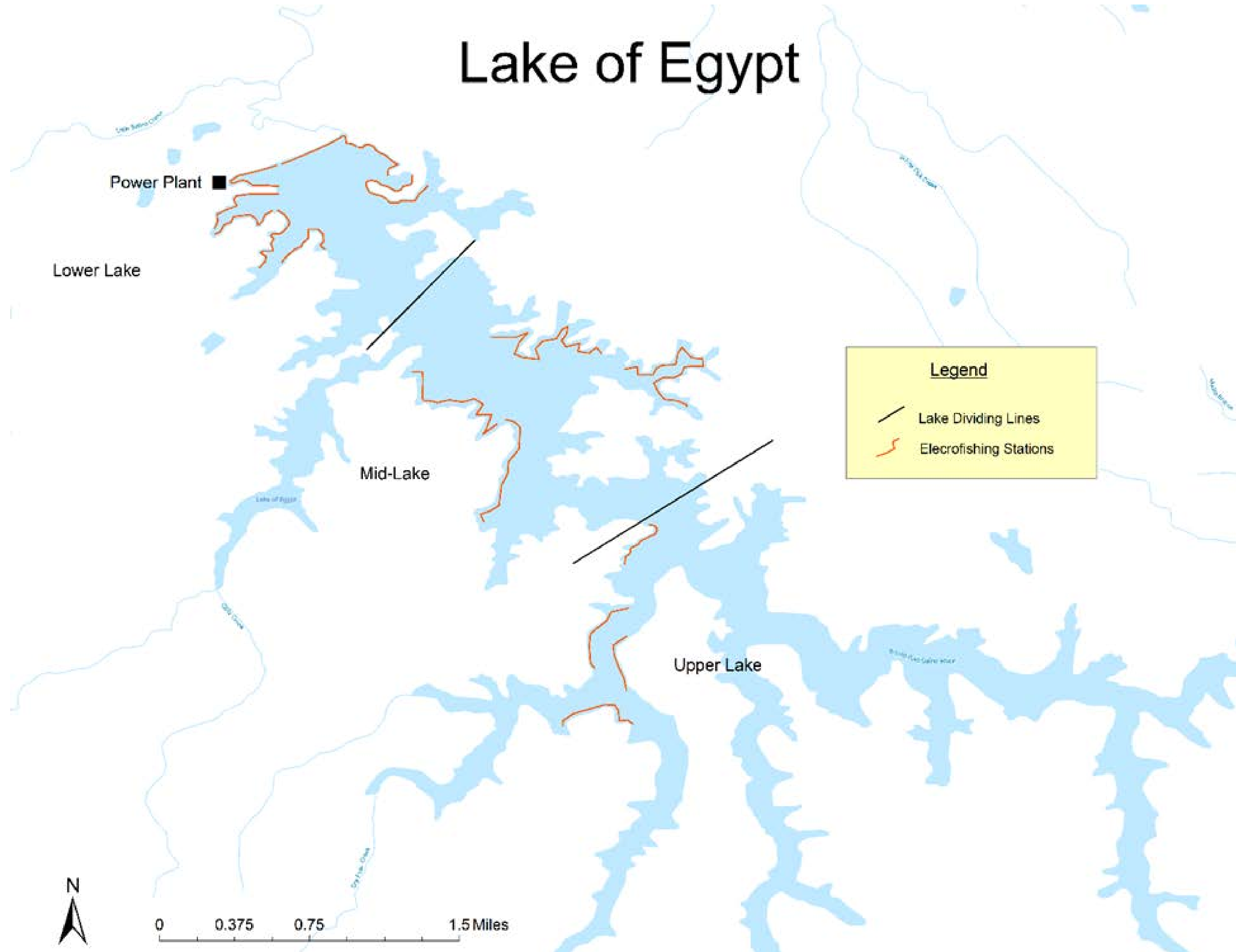

Figure 4-2. Electrofishing Sample Collection Locations.

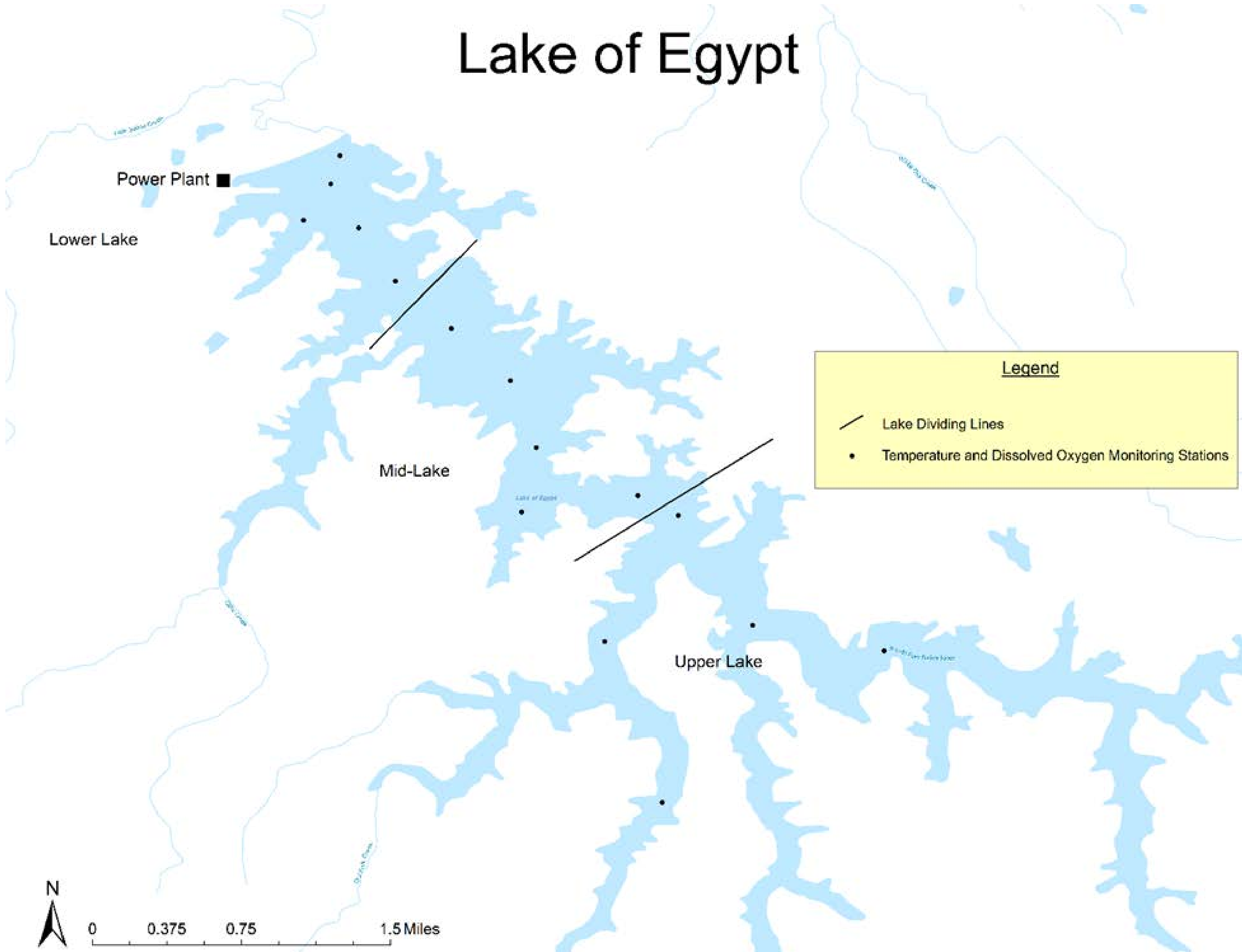

Figure 4-3. Temperature and Dissolved Oxygen Sample Collection Locations.

Additional electrofishing effort and sampling using fyke nets were conducted to collect Black Crappie and White Crappie specimens from throughout the LOE in the fall of 2016 for an age-growth analysis.

4.6.3 Site-Specific Supporting Information

The following sections summarize the results of the supplemental studies conducted by EIU to support the evaluation of potential appreciable harm to the overall fish community and to nuisance and thermally-sensitive RIS categories.

4.6.3.1 Fish categories satisfied by the original demonstration

The 2013 Demonstration concluded that there was no appreciable harm to fish species in the commercially and recreationally important (Largemouth Bass, Bluegill, and Channel Catfish) and food-chain/prey (Threadfin and Gizzard Shad) RIS categories. While these species were not the focus of the current supplemental pilot studies, data on all fish collected were recorded by EIU during the electrofishing effort targeting Common Carp and White Crappie and Black Crappie. Catch per unit (CPUE) data from the supplemental pilot studies conducted in the fall in the lower lake zone was compared to historical CPUE data collected during the same season and in the same portion of the LOE (Table 4-1).

A comparison of the most abundant species based on CPUE between the current supplemental studies and historical data presented in Table 3-4 of the 2013 Demonstration shows that the top four most abundant species are the same across all surveys in the lower lake zone from 1997-98 to the current study. Bluegill was by far the most abundant species in all surveys. Largemouth Bass, Redear Sunfish, and Longear Sunfish were the next most abundant species in all surveys, though not always in that order (Table 3-1). This same pattern of abundance was found by EIU (2017) in the middle and upper lake zones and by Amec (2010) in the upper lake zone (Amec did not sample the middle lake zone).

Bluegill and Largemouth Bass were collected from all lake zones during the current supplemental pilot studies. Bluegill were substantially more abundant (CPUE more than double that in the other lake zones) in the lower lake zone compared to the middle and upper lake zones where abundance was similar. Bluegill CPUE from the supplemental studies was approximately double the highest previous reported value from 2010. Largemouth Bass CPUE was highest in the middle lake zone followed by the lower lake zone and lowest in the upper lake zone. Largemouth Bass CPUE was higher than that reported in 2010 but approximately half of the values reported in 1997, 98, and 2006.

Gizzard Shad CPUE was approximately half of the reported value from 1997-98 while threadfin shad was approximately 6 times greater than the CPUE reported from 2010. Similar to prior studies, both shad species were more abundant in the lower lake zone than in the middle or upper lake zones (EIU 2017).

The fish data from the current supplemental pilot studies shows that the fish community in the lower lake zone of the LOE has been consistent over the last twenty years (Table 4-1). The continued presence and abundance of the key commercially and recreationally important and food chain/prey species provides further support for the lack of appreciable harm to these fish RIS categories.

Table 4-1. Comparison of Electrofishing Catch per Unit Effort (CPUE) Between the Current Supplemental Studies and Historical Studies on the LOE. CPUE Data for SIUC and MACTEC Studies Taken from Table 3-4 in Amec 2013. EIU Data is From the Lower-Lake Zone to be Comparable to Historical Data Reported from the Lower Lake.

Species	SIUC 1997	SIUC 1998	MACTEC 2005	MACTEC 2006	MACTEC 2010	EIU 2017
Gizzard Shad	19.2	15.9				7.4
Threadfin Shad		1.3			3.7	25.1
Common Carp	1.2	1.4	2.0	4.0		1.1
Golden Shiner	1.2					1.1
Black Bullhead						
Yellow Bullhead				2.0	2.9	
Channel Catfish					1.3	
Blackstripe Topminnow			3.0			2.3
Brook Silverside		1.4				5.1
Inland Silverside			1.0	4.0		
Green Sunfish	11.2		1.0	3.0	5.0	0.6
Warmouth			3.0	2.0	4.0	2.9
Bluegill	130.1	93.0	56.0	100.0	141.1	278.9
Longear Sunfish	23.0	9.5	4.0	2.0	30.0	38.3
Redear Sunfish	56.1	39.8	20.0	46.0	15.1	42.3
Hybrid Sunfish		1.3				5.7
Largemouth Bass	65.7	56.1	21.0	67.0	19.3	29.1
White Crappie	4.8					
Black Crappie	2.5	3.8	1.0		1.3	2.3
Brown Bullhead						6.3
Spotter Sucker						1.7

4.6.3.2 Nuisance species

Common Carp

Electrofishing was conducted in all three lake zones to evaluate whether Common Carp were increasing in abundance due to the influence of the thermal discharge. Only 2 Common Carp were collected from the LOE (total from all three lake zones) representing a CPUE of 0.53 (EIU 2017). Common Carp were collected only from the lower lake zone. If only the fishing effort in the lower lake zone is considered, the CPUE increases to 1.14. Common carp CPUE reported by Amec (2013) from previous studies ranged from 1.3 to 4.0. The perceived increase in CPUE between SIUC studies from 1997-98 and that reported by MACTEC in 2005 and 2006 was cited by the IEPA and IPCB as a potential indication of the proliferation of the nuisance species. Based upon the data collected during the supplemental pilot studies showing a CPUE less than that reported in 2005-06 and similar to that reported from the 1997-98 studies, common carp do not appear to be proliferating in the LOE as a result of the MGS thermal discharge.

4.6.3.3 Thermally sensitive species

Water temperature and DO profiles were stratified with depth in all lake zones during all sampling months (EIU 2017). Water temperature was similar in all lake zones in June. While water temperature in all lake zones was close to or exceeded 30° C in July and August, it was consistently higher in the lower lake zone. Water temperatures fell below 30° C in September in the middle and upper lake zones but remained near 30° C in the lower lake zone. Peak water temperatures in the lower lake zone coincided with the lowest measured DO concentrations of approximately 3 mg/l. The lower lake zone DO was consistently lower than DO in the other two lake zones during each month of sampling (EIU 2017). Even though water temperatures exceeded 30° C during August in the middle and upper lake zone, EUI measured DO concentrations above 4 mg/l in both zones and over 6 mg/l in the upper lake zone.

No White Crappie were collected during any of the supplemental studies sampling on the LOE (EIU 2017). A total of 46 Black Crappie was collected from all surveys combined and ranged in length from 173 to 366 mm total length and from 1 to 5 years in age (EIU 2017). The dominant age class was age 2 fish. EIU (2017) found Black Crappie collected to be in excellent condition having a relative weight of 100 +/- 2. The shift in abundance from White Crappie in historical collections (Heidinger 2007) to Black Crappie in the more recent and current surveys (Heidinger 2007; EIU 2017) may be due to the reduction nutrients which has led to increased water clarity. Clearer waters are preferred by Black Crappie and have been shown to lead to reduced survival of White Crappie young of the year due to increased predation (EIU 2017, p 22).

The age structure of Black Crappie collected during the supplemental studies was similar to that found by Heidinger in 2007 (EIU 2017). EIU (2017) found Black Crappie to be growing faster than previously reported for this population by Heidinger (2007).

4.6.4 Additional supporting information and data

4.6.4.1 Fish categories satisfied by the original demonstration

Amec (2013) compared LOE electrofishing data collected prior to 2003 to that collected after 2003 when the new boiler was installed at the MGS. This comparison showed the LOE fish community composition had not changed between the two periods and the most abundant species were also similar (Amec 2013, Section 4.5.1). The biothermal assessment conducted as part of the 2013 Demonstration showed that under the typical summer condition modeled, almost all of the selected RIS (Gizzard Shad, Threadfin Shad, Largemouth Bass, Bluegill, and Channel Catfish) would have all surface waters of the LOE below their upper incipient lethal temperature (UILT) (Amec 2013, Section 6.2.3) and, therefore, would not be excluded from any areas of the LOE. The more thermally-sensitive Black Crappie and White Crappie would only potentially be excluded from 29% of the LOE surface waters based on the comparison of summer modeled condition and their UILT (Amec 2013).

The biothermal assessment also suggests that fish kills due to excess heat are not likely to occur based upon the predicted water temperatures and the UILT limits of the RIS evaluated. Fish also appear to have ample areas of thermal refuge available if surface temperatures in the lower lake were to approach or exceed a species' UILT (Amec 2013). The 2013 Demonstration also pointed to the lack of observed fish kills during summer or winter periods on the LOE. The SIPC helps to mitigate against potential instances of cold shock mortality by planning plant outages in the spring and fall seasons when the effect of reducing or eliminating the thermal discharge for a period of time would be minimized (Amec 2013). Planned outages also typically involve only one unit at a time, thereby reducing the potential temperature differential.

4.6.4.2 Nuisance Species

Common Carp

No additional information or data was required to support the conclusion that Common Carp are not increasing in abundance as a result of the MGS thermal discharge. The 2013 Demonstration did not address Common Carp individually.

Rusty Crayfish

The Rusty Crayfish (*Orconectes rusticus*), an invasive species capable of out-competing native species, was identified by the IEPA as another potential nuisance species that could show an increase in abundance in the LOE due to the MGS thermal discharge. The Rusty Crayfish was present in impingement samples collected in 2005-2007 at the MGS intake (MACTEC 2008). The SIPC agreed to conduct a desktop evaluation of the potential for the Rusty Crayfish to proliferate in the LOE due the thermal discharge as a part of the supplemental pilot studies.

The Rusty Crayfish spawns in the late summer, early fall, or early spring and typically has a lifespan of three to four years (Gunderson, 2008). Rusty Crayfish habitat requirements include permanent waterbodies that provide suitable water quality year-round, such as lakes, ponds, and streams, preferring areas that offer rocks, logs, or other debris as cover. Suitable substrates include clay, silt, sand, gravel, or rock (Conrad et al 2017). The species exhibits a tendency to favor clear water (Capelli 1982) and is usually found at water depths of less than one meter.

In its natural habitat, the Rusty Crayfish may seasonally be exposed to water temperatures from near 0°-39°C; preferred water temperatures are 20-25°C (Mundahl and Benton 1990). Layne et al (1987) collected Rusty Crayfish from an Ohio creek where annual water temperatures ranged from near 0-30°C, and according to the authors, probably exceeded 30°C during summer. The maximum growth rate of juveniles probably occurs at water temperatures between 26 and 28°C; the maximum juvenile survival rate occurs between 20-22°C (Conrad et al, 2017). At temperatures greater than 30°C, the Rusty Crayfish has been observed digging burrows in the sand beneath rocks near shore as a means of escaping higher temperatures (Conrad et al 2017).

Spoor (1955) determined the heat tolerance of the Rusty Crayfish by testing their survival for 12-hours at water temperatures of 33, 34, 35, 36 and 37°C. Test specimens were field collected from waters with temperatures ranging from 22–26°C, and were maintained at that same temperature range in the lab. The observed 12-hour median heat-tolerance limit for the crayfish was 36.4°C; the 24-hour median heat-tolerance limit was 35.6°C. No specimen survived 12 hours at 37°C. Crayfish that were acclimated to a temperature of 30°C had a 12-hour median tolerance limit of 36.6°C; a few specimens acclimated to this higher temperature survived >12 hours at 37°C. Such results suggested that 36.6°C was close to the maximum heat-tolerance limit for the population from which test specimens were collected (Spoor 1955).

The experimental data on Rusty Crayfish temperature tolerance show that the species is capable of surviving at elevated water temperatures that could be experienced near a thermal discharge during the warm summer months. However, the Rusty Crayfish’s cited preferred temperature and those for maximum juvenile growth and survival are well below 30°C. This suggests that while the Rusty Crayfish may be able to survive at elevated temperatures, those conditions would not be conducive to their increased reproduction and growth.

Their preference for clear water could provide an alternate explanation for any potential increase in their population. As described by Heidinger (2007), the LOE water clarity has improved since about 1990 when the sewage treatment facility and septic systems that provided the source of nutrients were eliminated. Both Heidinger (2007) and EIU (2017) cited the increase in water clarity as the factor responsible for the reduction in White Crappie abundance and concomitant increase in Black Crappie.

Based upon the information compiled in this desktop study, the Rusty Crayfish would not be expected to proliferate due to the MGS thermal discharge.

4.6.4.3 Thermally-Sensitive Species

While the 2013 Demonstration did not address Black Crappie and White Crappie as thermally-sensitive species, Crappie were evaluated as one of the RIS. Site-specific electrofishing data were collected in several years prior to the 2013 Demonstration and showed that Black and White Crappie were present in the LOE, albeit at low numbers. The relatively low CPUE for both Crappie species were attributed to the yearly variability and cyclical nature of Crappie populations.

The 2013 Demonstration biothermal assessment showed that during the warmer summer months when water temperatures in the area of the thermal discharge may cause avoidance, other areas of the LOE would have suitable water temperatures for fish, including Crappie.

Heidinger (2007) found the Black Crappie growth rate to be accelerated between 1988 and 2007. He also found Black Crappie to be in excellent condition with a mean relative weight of 98% which was within the desirable range of 95-105%. Black Crappie collected during the 2007 monitoring effort were found to represent the 2002 to 2006 year classes showing evidence of natural reproduction and recruitment. Heidinger (2007) concluded that Black Crappie were recruiting at low levels and while overall numbers were low, Black Crappie were in excellent condition. White Crappie populations had decreased relative to prior years. Heidinger (2007) attributed the low recruitment in both species and the decreasing White Crappie population to the reduction in nutrients entering the LOE.

4.6.5 Conclusion

Overall, the MGS thermal discharge does not appear to be causing appreciable harm to the fish community in the LOE. This is evidenced by the relatively consistent community composition since approximately 1997, the absence of differences in community composition between lake zones, the higher density of fish found in the lower lake zone relative to the middle and upper lake zones, and the excellent condition of fish in the LOE based on Largemouth Bass and Black Crappie condition indices. The excellent condition of the fish in the LOE also suggests that the lower trophic levels are healthy and are providing a sufficient food base for fish populations. There have been no reported thermally related fish kills in the LOE and based upon the data and information presented in the 2013 Demonstration, there is limited potential for thermally related fish kills in the future.

The electrofishing data from the supplemental studies suggest that there is no proliferation of nuisance species as evidenced by the low Common Carp CPUE relative to prior years.

The temperature and dissolved oxygen data show that Black Crappie may avoid the lower lake zone due to high temperatures above their thermal tolerance limits and low DO during the summer months (July and August). During peak temperatures in August, avoidance may even occur in areas of the middle lake zone. However, slightly lower temperatures and DO concentrations well above 4.0 mg/l were present throughout the upper lake zone and portions of the middle lake zone providing ample areas of thermal refuge during these periods.

The evidence of natural reproduction in the Black Crappie population, coupled with their observed faster growth rate and excellent overall condition shows there is no reduced reproductive success or growth as a result of the plant discharges. Rather, it demonstrates that Black Crappie are adapted to the thermal regime of the LOE and have available areas of refuge from unfavorable temperatures and DO during the summer period.

4.7 OTHER WILDLIFE

In their 2014 decision, the IPCB agreed with SIPC's assessment that the LOE constituted an area of low potential impact for the other wildlife biotic category. Therefore, no site-specific studies were conducted for this biotic category.

4.8 SUMMARY

The site-specific supplemental studies conducted in 2016 on the LOE for the phytoplankton, zooplankton/meroplankton, benthic macroinvertebrates and shellfish, and habitat former biotic categories showed no differences in these communities between lake zones attributable to the MGS thermal discharge. The significant difference between lake zones for the phytoplankton community was attributed to differences in nutrient concentrations between the lake zones. The only heat-tolerant phytoplankton taxon that was present in all three lake zones of the LOE was most abundant in the upper lake zone farthest from the MGS discharge. Habitat former distribution, while not significantly different between lake zones, is driven by the availability of suitable habitat. Other than the one phytoplankton taxon, no other heat-tolerant or nuisance species were identified in the other biotic categories. These site-specific data show that the MGS thermal discharge has not caused appreciable harm to the organisms in these biotic categories.

While not the focus of the supplemental studies, the 2016 electrofishing data shows that the fish community of the LOE has not changed over the last 20 years and that the pattern of most abundant species is the same between all lake zones. This further supports the conclusion from the 2013 demonstration that there has been no appreciable harm to the recreationally and commercially important and forage/prey species fish RIS categories.

Based on the CPUE data in the current studies for Common Carp, there does not appear to be a proliferation of nuisance species as a result of the MGS thermal discharge.

The Black Crappie in the LOE are in excellent condition and are growing faster than found in previous surveys. The Black Crappie populations is also self-sustaining based upon the age-classes represented in the current survey which provide evidence of natural reproduction. While high temperatures and low DO are present in the lower lake zone during the summer, the upper lake zone has lower temperatures and acceptable DO concentrations to provide areas of refuge during the summer. Based on all the Black Crappie data collected during the current survey, Black Crappie are clearly surviving, naturally reproducing, and growing quickly in the LOE and do not appear to be adversely affected by the MGS thermal discharge.

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APPENDIX A.

Marion Generating Station 316(a) Study Plan

MARION GENERATING STATION
316(A) STUDY PLAN

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January 29, 2016

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1 INTRODUCTION

Southern Illinois Power Cooperative (SIPC) will conduct supplemental biological and water quality studies on Lake of Egypt (LOE) to support an updated Clean Water Act (CWA) §316(a) demonstration. The demonstration will support a request that alternate thermal effluent limits be included in the Marion Generating Station's National Pollutant Discharge Elimination System (NPDES) permit. ASA Analysis and Communication (ASA), consulting with SIPC, has designed the study plan outlined below in response to the Illinois Environmental Protection Agency (IEPA) and the Illinois Pollution Control Board (IPCB) requirements. Dr. Robert E. Colombo of Eastern Illinois University (EIU) has been retained to lead a team to conduct the field sampling and laboratory analyses. A draft study plan was submitted to IEPA on November 2, 2015 as part of the early screening information requirement in accordance with IL 35 III. Admin. Code 106.1115 and 40 C.F.R. §125.72. SIPC met with IEPA on December 2, 2015 to review the early screening information and solicit comments on the proposed studies. This final study plan incorporates comments and suggestions received at that meeting.

2 BACKGROUND

The Marion Station's NPDES Permit (NPDES Permit No. IL0004316) was re-issued by IEPA on February 1, 2007, with an effective date of March 1, 2007. Per Special Condition No. 7 of the February 2007 NPDES permit for SIPC's Marion Power Plant, the IEPA required the utility to comply with Illinois Administrative Code 302.211(f) and Section 316(a) of the CWA by demonstrating that the thermal discharge from the plant "will not cause and cannot reasonably be expected to cause significant ecological damage to the Lake of Egypt."

From 1997 through 2007, Southern Illinois University-Carbondale (SIUC) conducted various studies and authored reports on the effect of Marion Station's thermal discharge on aquatic life. SIPC supplemented those studies beginning in 2006 and prepared a 316(a) demonstration to show that no appreciable harm had occurred to the fish, macroinvertebrate, and shellfish populations of LOE and that the applicable water quality standards were more stringent than necessary to support a balanced indigenous community in LOE. SIPC filed a petition for alternate thermal effluent limits, supported by the 316(a) demonstration, with the IPCB in January 2015. Despite IEPA's support for SIPC's petition, the IPCB denied SIPC's petition claiming the petition contained insufficient information for biotic category analysis, lacked site-specific data, did not consider all necessary representative important species (RIS) categories, and did not contain sufficient support that the RIS would not suffer appreciable harm.

Both IEPA and IPCB recommended the following additional studies be conducted to address agency concerns:

- "Pilot" studies for the phytoplankton, zooplankton, macroinvertebrate and shellfish, and habitat former biotic categories (as defined in the 1977 USEPA Draft 316(a) Guidance Manual);
- Study of common carp as a nuisance species in LOE; and
- Increased study of white crappie and black crappie with a focus on their thermal tolerance and available refuge habitat during the summer season.

3 STUDY PLAN

In accordance with IL 35 III. Admin Code 106.1120, this study plan specifies the nature and extent of the following information to be used in the demonstration:

- Biological, hydrographical, and meteorological data
- Physical monitoring data
- Engineering or diffusion models
- Laboratory studies
- Representative important species
- Other relevant information

SIPC intends to conduct supplemental studies as recommended by the IEPA and the IPCB. The data and information collected by the proposed supplemental studies will be used in conjunction with information from SIPC's previously submitted 316(a) demonstration and data collected from other cooling lakes to support an updated 316(a) demonstration. The sections below provide a discussion of the source(s) of data and information that SIPC intends to use in updating its 316(a) demonstration. Specific detail on the proposed supplemental studies is provided in Section 4.

3.1 BIOLOGICAL, HYDROGRAPHICAL, AND METEOROLOGICAL DATA

3.1.1 Biological Data

As described in the *Draft Interagency 316(a) Technical Guidance Manual and Guide for Thermal Effects Sections of Nuclear Facilities Environmental Impact Statements*[6] ("Draft 316(a) Guidance Manual"), the biological data is addressed through six biotic categories. The anticipated sources of data and information that will be used for each of these biotic categories for the updated/revised demonstration is presented in the following sections.

3.1.1.1 Phytoplankton

Three primary sources of data will be used in updating the 316(a) demonstration for phytoplankton.

1. Site-specific field studies conducted in LOE during 2016 to provide basic community level information for phytoplankton from three lake zones; lower-lake, mid-lake, and upper-lake (details on proposed studies are presented in Section 4 of this study plan)
2. Phytoplankton study data from other Illinois cooling lakes
3. Historical data and information summarized in the previously submitted demonstration

3.1.1.2 Zooplankton and Meroplankton

A revised argument will be presented to support LOE as an area of low potential impact (LPI) for zooplankton and meroplankton. The argument will be based on meeting the criterion in the Draft 316(a) Guidance Manual that states if the discharge affects only a relatively small portion of the receiving water body, the site may be classified as one of LPI for zooplankton and meroplankton.

3.1.1.3 Macroinvertebrates and Shellfish

Three primary sources of data will be used in updating the 316(a) demonstration for macroinvertebrates and shellfish:

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[6] *Draft Interagency 316(a) Technical Guidance Manual and Guide for Thermal Effects Sections of Nuclear Facilities Environmental Impact Statements, U.S. Environmental Protection Agency, Office of Water Enforcement, Permits Division, Industrial Permits Branch (May 1, 1977).*

1. Site-specific field studies conducted in LOE during 2016 to provide basic community level information for macroinvertebrates and shellfish from three lake zones; lower-lake, mid-lake, and upper-lake (details on proposed studies are presented in the Section 4 of this study plan)
2. Macroinvertebrate and shellfish study data from other Illinois cooling lakes
3. Historical data and information summarized in the previously submitted demonstration

3.1.1.4 Habitat Formers

Two primary sources of data will be used in updating the 316(a) demonstration for habitat formers (submerged aquatic vegetation (SAV)):

1. Site-specific field studies conducted in LOE during 2016 to provide basic community level information for habitat formers from three lake zones; lower-lake, mid-lake, and upper-lake (details on proposed studies are presented in the Section 4 of this study plan)
2. Habitat former study data from other Illinois cooling lakes

3.1.1.5 Other Vertebrate Wildlife

The evaluation of other vertebrate wildlife in the previously submitted demonstration concluded that LOE could be classified as an area of LPI for this biotic category. The IPCB concurred with this opinion in their evaluation of the thermal variance petition. Therefore, no updates to this category were considered necessary and no additional studies or efforts are planned.

3.1.1.6 Fish

The fish community will be addressed by evaluating the representative important species categories (RIS) outlined in the previously submitted demonstration and by adding two additional categories (see Section 3.5). RIS categories addressed in the previously submitted demonstration will not be updated, but rely on the arguments presented in that demonstration. For the two new categories of RIS – nuisance species and thermally-sensitive species – new site-specific data will be collected from LOE.

- Nuisance species - an electrofishing survey will be conducted in the fall of 2016 at the same locations used by SIUC and AMEC to collect data on the relative abundance of common carp.
- Thermally-sensitive species – an expanded temperature/dissolved oxygen monitoring survey will be conducted from July through September 2016 to evaluate the availability of thermal refuge habitat for white crappie and black crappie. In addition, white crappie and black crappie will be collected for an age/growth study using the same methods as those used by Dr. Roy Heidinger from the late 1990s through 2007.

The specific details of the studies proposed for each new RIS category are presented in Section 4 of this study plan.

3.1.2 Hydrographical Data

No new hydrographical surveys are planned during the period of supplemental studies. Available hydrographical information includes:

1. Near-field bathymetry data (AMEC 2013)

Additional sources may be identified and used as necessary.

3.1.3 Meteorological Data

Meteorological conditions will be recorded in the field concurrent with the conduct of the proposed supplemental studies and will be supplemented by data from the SIU–Carbondale weather station, which is operated as part of the Illinois Climatic Network (ICN) – Water & Atmospheric Resources Monitoring (WARM) Program–www.isws.illinois.edu/warm/datatype.asp (AMEC 2013).

3.2 PHYSICAL MONITORING DATA

Physical monitoring data for the Marion Generating Station, including intake and discharge flows and temperatures, and other relevant station operational data, will be obtained from the facility to update the data reported in the 2013 demonstration and to relate to conditions in LOE during data collection.

3.3 ENGINEERING OR DIFFUSION MODELS

No new engineering or modeling studies are planned during the period of supplemental field studies. Results of the modeling conducted by AMEC in preparing the 2013 demonstration were reviewed as input to the process of selecting sampling locations for the supplemental biotic category and temperature and dissolved oxygen survey studies.

3.4 LABORATORY STUDIES

No laboratory studies are planned as part of the updated demonstration. However, laboratory analyses of phytoplankton and macroinvertebrate samples will be conducted. In addition, a review and compilation of the most recent literature on white and black crappie laboratory-derived thermal tolerances and thresholds will be conducted to update the information presented in the previously submitted demonstration. Thermal tolerance and response to thermal loading literature will also be reviewed for common carp and the rusty crayfish.

3.5 REPRESENTATIVE IMPORTANT SPECIES

The RIS categories include those addressed in the previously submitted demonstration and two additional categories that will be addressed using the data collected from the proposed supplemental studies. No additional studies are planned for the following RIS addressed in the 2013 demonstration:

- Forage/Food chain RIS
    - Threadfin shad
    - Gizzard shad
- Commercially and/or recreationally important RIS
    - Largemouth bass
    - Bluegill
    - Channel catfish

The additional RIS categories and species that will be evaluated through the proposed supplemental studies presented in Section 4 include:

- Nuisance RIS
  - Common carp
  - Rusty crayfish
- Thermally-sensitive RIS
  - White crappie
  - Black crappie

3.6 OTHER RELEVANT INFORMATION

Currently it is not anticipated that any other information will be necessary to update the 316(a) demonstration.

4 SUPPLEMENTAL STUDIES

The proposed supplemental studies described in this section were designed to be directly responsive to comments on the previously submitted 316(a) demonstration and the study recommendations provided by IEPA and the IPCB. Comments received during the screening information presentation have also been incorporated.

Objective
The objective of the proposed supplemental studies is to collect basic site-specific data sufficient to evaluate whether:

- The criteria for lack of appreciable harm are being met for each biotic category;
- There is a demonstrated proliferation of nuisance fish species (common carp) as a result of the influence of the Marion Station thermal discharge; and
- There is sufficient refuge habitat with acceptable temperature and dissolved oxygen concentrations for white crappie and black crappie during periods of elevated summer temperatures.

Approach Overview
There are two main components to the proposed study plan:

- Biotic category studies
  - Phytoplankton
  - Zooplankton and meroplankton
  - Macroinvertebrates and shellfish
  - Habitat formers
- RIS category studies
  - Nuisance species
  - Thermally-sensitive species

Samples for biotic category studies will be collected from three lake zones: lower-lake, mid-lake, and upper-lake. Samples for RIS category studies will be collected from historical sites for comparability where possible.

Data collection for the biotic category analyses, with the exception of zooplankton and meroplankton, will be focused on parameters that will allow an evaluation of key criteria outlined in the Draft 316(a) Guidance Manual for the successful demonstration of lack of appreciable harm.

For zooplankton and meroplankton, a renewed argument will be presented that LOE is an area of LPI for zooplankton.

4.1 BIOTIC CATEGORY STUDIES

4.1.1 Delineation of Sample Collection Zones

Field temperature measurements and hydrothermal modeling conducted by AMEC between 2006 and 2013 (AMEC 2013) were used in conjunction with historical sampling conducted by SIUC and AMEC to approximate a division between the lower-, mid- and upper-zones of LOE. The primary objective in estimating these areas was to ensure that sample collection locations were stratified by their degree of potential thermal exposure.

4.1.2 Phytoplankton

Objective
To collect site-specific data on species composition and relative abundance within the three lake zones to evaluate:

- Whether there are differences in species composition and relative abundance between the zones that may be attributed to temperature increases resulting from the thermal discharge, and
- The presence and abundance of any nuisance and/or thermally-tolerant species within the lower-lake zone relative to the other lake zones.

Sample Collection
Phytoplankton samples will be collected monthly from June 2016 through August 2016 resulting in a total of 3 sample collection periods. During each sample collection period, samples for phytoplankton and nutrient analysis will be collected from a minimum of 3 locations within each of the three lake zones (a total of 9 samples per collection period).

There were no known locations of past phytoplankton sampling in LOE to consider in the selection of the current sampling locations. The approximate planned locations for phytoplankton and nutrient sample collection are shown in Figure 1.

Sampling Methods
All sampling locations will be recorded by GPS in the field. Water at each location will be collected at equal intervals from the surface to the bottom of the euphotic zone with a Van Dorn horizontal bottle sampler and combined to form a composite sample. Depth of the photic zone will be estimated by 2x Secchi depth (USEPA 2012a). In addition to water collection, temperature (°C) and DO (mg L^{-1}) data will be collected at each phytoplankton sampling location every 0.5 m from surface to bottom using a field multi-probe (YSI-85; YSI Inc., Yellow Springs, OH)

Phytoplankton samples (approximately 1 L) will be preserved with buffered Lugol's solution (5 mL per 1 L bottle; USEPA 2012a). All samples will be stored on ice in acid-washed amber bottles and returned to EIU where phytoplankton will be identified and quantified to the lowest practicable taxonomic level (usually to order).

For nutrient analysis, a single 1 L sample will be taken from the first composite sample collected at each location. Water samples will be stored in acid-washed containers, kept on ice, and typically analyzed within 24 h of collection.

Laboratory Analyses
Phytoplankton will be enumerated using the sedimentation method with an inverted compound microscope (e.g., USEPA 2012b). Sedimentation chambers (5-10 ml) will be used in conjunction with a Whipple ocular micrometer for enumeration. The exact laboratory protocol will be dependent on phytoplankton density.

Nutrient analyses will include:

- Ammonia (determined using nesslerization);
- Nitrate (determined using cadmium reduction);
- Total nitrogen (determined by persulfate digestion);
- Total phosphorus (determined by persulfate digestion); and
- Alkalinity (determined by inflection point titration with HCL).

The methods for nutrient analysis will be adapted from *Standard Methods for the Examination of Water and Wastewater 22nd Edition* (Way 2012) and the *National Lakes Assessment Laboratory Operations Manual* (USEPA 2012b).

Data Analysis
Phytoplankton data will be reported and summarized by location, lake zone, and month. Anticipated analyses include evaluating the similarities and differences in the phytoplankton species composition and relative abundance within each lake zone during each sample collection period, including a comparison of the presence and relative abundance of any thermally-tolerant species. The variance within each lake zone will be estimated.

Nutrient chemistry analysis will be reported by location for each sample collection period. Nutrient concentrations in each sample will be compared among the three lake zones.

4.1.3 Zooplankton and Meroplankton

Objective
To demonstrate that the thermal discharge affects a small portion of the receiving water body thereby showing that LOE meets the criterion for an area of LPI for zooplankton and meroplankton.

Approach
LOE is reported by multiple sources to cover 2,300 acres (AMEC 2013; Wikipedia; Egypt.uslakes.info; www.sipower.org).

Hydrothermal modeling and temperature measurements conducted as part of the 2013 demonstration will be used to estimate the area of thermal influence during the critical periods for zooplankton and meroplankton - spring, summer, and fall. These areas will be compared to the total lake area to determine the potential percentage of area affected.

4.1.4 Macroinvertebrates and Shellfish

Objective
To collect site-specific data on species composition and relative abundance within the three lake zones to evaluate:

- Whether there are differences in species composition and relative abundance between the zones that may be attributed to temperature increases resulting from the thermal discharge, and
- The presence and abundance of any nuisance and/or thermally-tolerant species within the lower-lake zone relative to the other lake zones.

Sample Collection

Macroinvertebrate and shellfish samples will be collected monthly from June 2016 through August 2016 resulting in a total of 3 sample collection periods. During each sample collection period 1 transect will be sampled in each of the lake zones – lower-lake, mid-lake, and upper-lake. A minimum of 3, and up to 5, locations will be sampled along each transect to account for potential differences in the macroinvertebrate and shellfish community with depth and substrate composition.

There were no known locations of past macroinvertebrate and shellfish sampling in LOE to consider in the selection of the current sampling locations. The approximate planned locations for macroinvertebrate and shellfish sample collection are shown in Figure 1.

Sampling Methods

Each zone will be bisected with one transect, and 3 to 5 petite Ponar dredge samples will be taken from approximately equal distances from the shore and each other along the transect (exact number of dredge samples will be dependent on the length of each transect). Transects will be delineated so that shallow water (<1 m) habitat is adequately sampled, and duplicate dredge samples will be taken at each location and composited for invertebrate identification. An additional sample will be collected for field substrate classification. All transect locations will be recorded with GPS in the field.

Invertebrates will be initially separated from inorganic and organic material in the field using a 504 µm bucket sieve and placed in 70% ethanol. Substrates collected along each transect will be characterized in the field using methods modified from David et al. (1998) and USEPA (2012a) where the approximate percentage of each substrate type present at each location (e.g., gravel, sand, silt) will be recorded.

Laboratory Analyses

A gridded screen will be used to sort a randomized 300-organism subsample of the invertebrates collected at each location (*see* USEPA 2012b for specific methods). Macroinvertebrates will be viewed under a stereo dissecting microscope and identified to lowest taxon practicable (*see* Table 4.1 in USEPA 2012b).

Data Analysis

Macroinvertebrate and shellfish data will be reported and summarized by location, transect, lake zone, and month. Anticipated analyses include evaluating the similarities and differences in the macroinvertebrate and shellfish species composition and relative abundance within each lake zone during each sample collection period, including a comparison of the presence and relative abundance of any thermally-tolerant or thermally-sensitive species. Appropriate species and diversity indices (e.g., taxa richness; percent Ephemeroptera, Plecoptera, and Trichoptera (EPT); Shannon-Weiner diversity index; percent oligocheata) will be calculated. Grain size/substrate results will be reported by station for each sample collection period.

4.1.5 Habitat Formers

Objective

To collect site-specific data on the presence and relative abundance of habitat formers within the three lake zones to evaluate potential differences that may be attributed to temperature increases resulting from the thermal discharge.

Sample Collection

Data on habitat formers (SAV) in LOE will be collected once during the summer period in 2016. It is anticipated that the entire main shoreline of the lake will be surveyed during this period with more detailed surveys for species identification and relative abundance occurring in areas where habitat formers are present.

Sampling Methods

The entire shoreline of LOE will be mapped using a Lowrance HD-10 sidescan sonar with structure scan once during August 2016. Mapping will be conducted in the littoral zone at a speed of no greater than 5 mph. Areas in which SAVs are located will be marked with a GPS coordinate for further examination. Up to 2 randomly selected areas of SAVs in each of the 3 lake zones will be mapped at no greater than 3 mph to provide a higher resolution map. Additionally, three transects within each of these 2 areas per zone will be assessed for SAV density and species composition. To determine density and species composition, five - 0.25 m^2 quadrats will be characterized along each transect. All specimens within the quadrats will be identified to lowest taxonomic group practicable.

Data Analysis

Habitat former data will be mapped to show areas of habitat former presence/absence. Data on species composition and relative abundance for shoreline areas surveyed in more detail (due to substantial habitat former presence) will be compared between lake zones.

4.2 RIS CATEGORY STUDIES

4.2.1 Nuisance Species

Objective

To collect current data on common carp abundance for comparison with historically collected data from the same locations.

Sample Collection

Electrofishing targeting common carp will be conducted once during the fall of 2016 to coincide with the time period of historical data collection. Sample locations within the lower- and upper-lake zones will replicate or be similar to historical sampling locations used by SIUC (Heidinger et al 2000) and by AMEC (AMEC 2013) to the degree possible. Sampling locations will be added in the mid-lake zone. Approximate electrofishing locations are shown in Figure 2.

Sampling Methods

Boat electrofishing will be conducted along transects (approximately 15 min, continuous power, 5-10 amperes) using 3-phase alternating current (AC) with a balanced dropper array. This will allow an unbiased comparison to data collected by SIUC prior to 2003. Temperature (°C), DO (mg L^{-1}), and specific conductivity (µS cm^{-1}) will be measured from surface to bottom (0.5-m intervals) at each location within the center of each transect using a field multi-probe (YSI Inc., Yellow Springs, OH).

All fish collected will be held in an aerated livewell, identified to species, measured (nearest mm, total length [TL]), and weighed (nearest g) before being released. A subset (depending on the number collected) of white crappie and black crappie will be taken for age analysis (see Section 4.2.2.2).

Data Analysis
As an index of relative abundance, catch per unit effort (CPUE; fish caught hr^{-1} electrofishing) for all species will be calculated for each transect and each lake zone. Catch per unit effort and size data will be compared to historically collected data on common carp from LOE and other Illinois cooling lakes.

Size structure of the common carp population will be assessed with length-frequency distributions for each zone and the lake as a whole. To provide a numerical representation of size structure, proportional size distribution (PSD) of common carp will be assessed [PSD = 100 (number of fish ≥ stock length / number of fish ≥ quality length; Neumann et al. 2012, Gabelhouse 1984). Relative weight (W_r; an index of condition where higher values indicate healthier fish with generally better growth rates) will be calculated for common carp using the equation:

$Log_{10}(W_s) = -4.639 + 2.920\ Log_{10}(\text{total length})$ (Bister et al. 2000)

where W_s is a length-specific standard weight (g).

Common carp W_r will be compared to that in other populations to determine the overall health of the population in LOE.

A literature review of common carp responses to thermal loading will also be conducted and summarized to evaluate the potential for the thermal loading to LOE to result in an increase in the carp population.

A literature review of rusty crayfish responses to thermal loading will be conducted and summarized to evaluate the potential for the thermal loading to LOE to result in an increase in the rusty crayfish population.

4.2.2 Thermally-Sensitive Species

Two sets of data will be collected as part of the evaluation of the potential effects of the thermal loading to LOE on the thermally-sensitive white crappie and black crappie.

A temperature and dissolved oxygen monitoring survey will be conducted to evaluate the availability of thermal refuge habitat (acceptable temperature and dissolved oxygen levels) during the period of high surface water temperatures.

An age-growth study will be conducted and compared to historical results reported by Dr. Roy Heidinger (Heidinger 1998, 1999, 2007)

4.2.2.1 Temperature and Dissolved Oxygen Monitoring

Sample Collection
Temperature and dissolved oxygen measurements will be collected weekly from June through September 2016 from a minimum of 5 locations within each of the three lake zones. Sample collection stations were selected to approximate the location of historical data collection

(Heidinger et al 2000) and to provide additional sample points for greater spatial coverage within each zone. Example locations for sample collection in each lake zone is shown in Figure 3.

Sampling Methods
Temperature (°C) and DO (mg L^{-1}) will be measured from surface to bottom (0.5-m intervals) weekly at each sampling location using a field multi-probe (YSI Inc., Yellow Springs, OH). Sampling locations will be recorded with GPS in the field.

Data Analysis
Water column vertical profile measurements of temperature and dissolved oxygen will be presented by date and summarized by location and lake zone. Changes in each parameter at each location over the duration of the study period will be evaluated.

The recent literature on black crappie and white crappie thermal and dissolved oxygen tolerance levels relative to acute and chronic effects will be reviewed and used to update the information presented in the 2013 demonstration. Field data will then be compared to these tolerance limits to evaluate whether depth strata of acceptable temperature and dissolved oxygen levels are available as areas of potential refuge habitat.

4.2.2.2 Age-Growth Analysis

Sample Collection
A variety of sampling gears (e.g., electrofishing, fyke nets) will be used to collect black crappie and white crappie specimens from throughout LOE in the fall of 2016 for an age-growth analysis. A maximum of 3 days of fishing effort will be conducted to obtain sufficient specimens for a meaningful study. Once a sufficient number of specimens is obtained, fishing will be terminated even if less than 3 days.

Sampling Methods
White crappie and black crappie specimens captured during the electrofishing efforts for common carp described in Section 4.2.2.1 will be used for the age-growth analysis. In addition, fyke nets (1 m × 2 m, 13mm bar mesh, 9 m lead lines) will be set at depths of 3 m or less off shoreline points in random locations throughout LOE (e.g., Pope et al. 2009) to collect additional specimens to ensure an adequate sample size. After retrieving the nets, all fish collected will be held in an aerated livewell, measured (nearest mm, TL), and weighed (nearest g) before being released. The first 100 individuals of each species collected will be sacrificed and taken back to the laboratory at EIU for aging by otoliths.

Laboratory Analysis
Each fish taken from the population for age analysis will be given a unique identification number. Sagittal otoliths will be removed for aging by disconnecting the operculum and accessing the cranial chamber anteriorly. Otoliths will be cleaned and air dried, then placed in immersion oil and viewed with a stereo microscope under low magnification (7-40x) using reflected light. Age of fish will be estimated by counting the number of annuli (visual growth bands) using two independent readers.

Data Analysis
Length-frequency distributions will be constructed for black crappie and white crappie and used to compare the size structure of fish in LOE to other black crappie and white crappie populations in Illinois and to historical data from LOE. Size structure will be assessed by calculating the PSD of white crappie and black crappie along with relative size structure of preferred (PSD-P),

memorable (PSD-M) and trophy (PSD-T) sized fish [100 (number of fish ≥ specified length / number of fish ≥ quality length)] in LOE. Length classes used for black crappie and white crappie will be: Stock ≥ 130 mm, Quality ≥ 200 mm, Preferred ≥ 250 mm, Memorable ≥ 300 mm, and Trophy ≥ 380 mm (Gabelhouse, 1984). Relative weight will be calculated for white crappie and black crappie using the equations:

Black crappie: $Log_{10}(W_s) = -5.618 + 3.345\ Log_{10}(\text{total length})$ (Murphy et al., 1991)

White crappie: $Log_{10}(W_s) = -5.642 + 3.332\ Log_{10}(\text{total length})$ (Murphy et al., 1991)

where W_s is a length-specific standard weight (g).

Age data from known-age fish and ages developed using an age length key for unaged fish will be used to estimate growth with a von Bertalanffy growth model (Isely and Grabowski 2007). The von Bertalanffy model assumes that growth is asymptotic, reaching a theoretical maximum value (L_∞) at a constant growth trajectory (K). Catch curve analysis (Ricker 1975) will be used to assess mortality of white and black crappie populations in LOE. A catch curve is a simple regression of age against the log-transformed frequency. The slope of the catch curve estimates the instantaneous mortality of the population (Z). This estimate of Z is used to determine the total annual mortality (A) from the equation $A = 1 - e^{-Z}$. Mortality estimates will be calculated from electrofishing and fyke netting data separately to avoid any gear selective bias. The age structure of white crappie and black crappie will be compared to data for LOE collected by Heidinger (1988, 1990, 2007).

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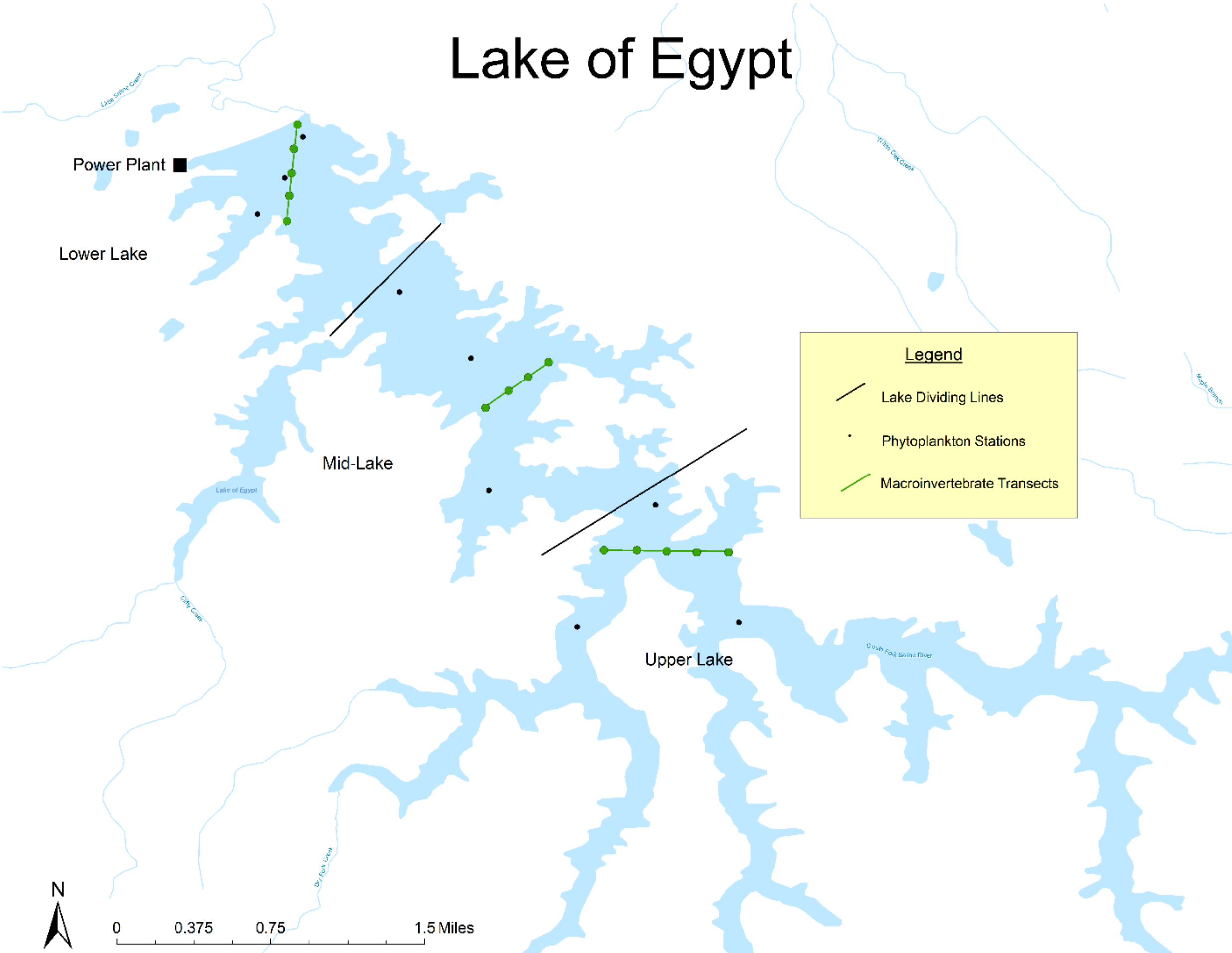

Figure 5-1. Example phytoplankton and macroinvertebrate sample collection locations.

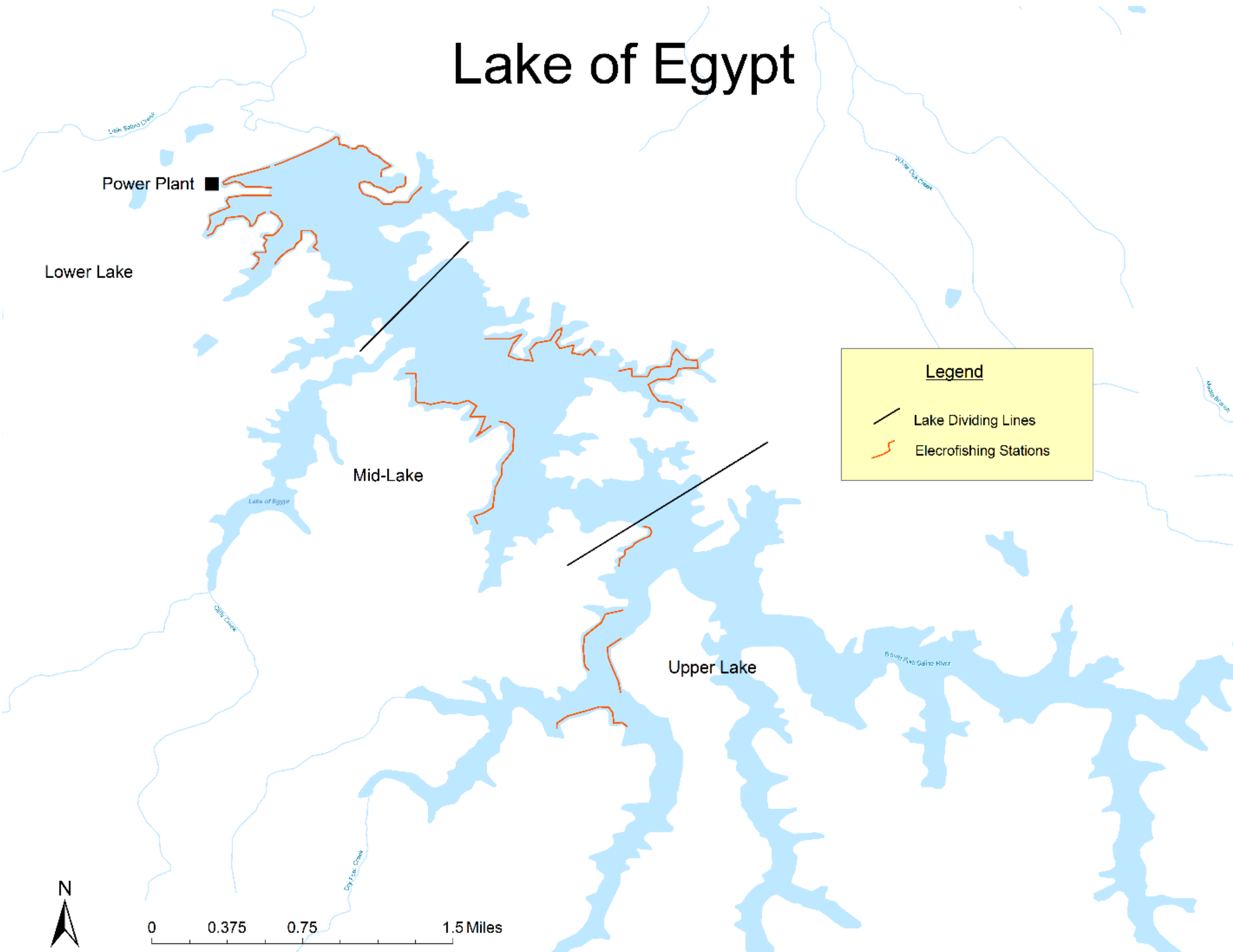

Figure 5-2. Approximate electrofishing sampling locations for common carp.

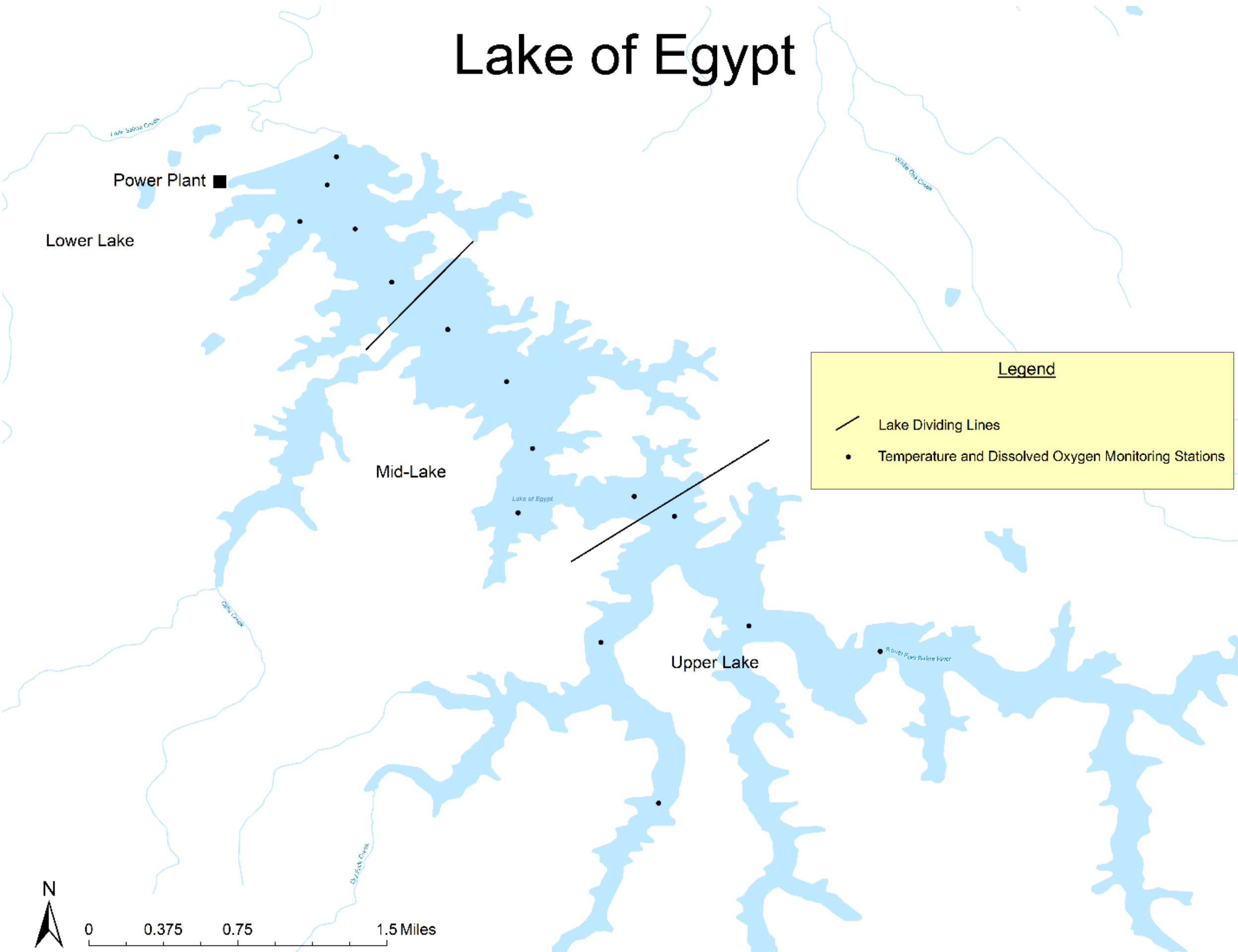

Figure 5-3. White crappie and black crappie example temperature and dissolved oxygen sample collection locations.

APPENDIX B.

Supplemental Data Collection for the Marion Generating Station 316(a) Studies

Eastern Illinois University

Southern Illinois Power Cooperative

Supplemental Data Collection for the Marion Generating Station 316(a) Studies

Eastern Illinois University

June 2016 - October 2016

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3 INTRODUCTION

Lake of Egypt (LOE) is a cooling lake for the Southern Illinois Power Cooperative (SIPC) Marion Generating Station. It is located in Williamson and Johnson counties, Illinois. The cooling lake (Lake of Egypt) was constructed in 1962 and has a surface area of 2,300 acres. In 2007, the IEPA reissued the National Pollution Discharge Elimination System (NPDES) permit to the SIPC Marion Station. As a condition for the NPDES permit, the IEPA required SIPC to demonstrate that the thermal effluent does not cause significant ecological damage to Lake of Egypt. In order to study the potential impacts of the thermal load on the Lake of Egypt, several aquatic communities need to be assessed.

An aquatic ecosystem has several different communities that can be affected by altered temperature regimes. The phytoplankton community can be impacted by temperature. Such impacts may lead to an alteration of the herbivorous zooplankton community (Bush et al 1974, Moran 1981, Laws 1993). As with the phytoplankton, zooplankton community structure can be altered due to a change in the temperature regime (U.S.E.P.A. 1974, Achenbach and Lampert 1997, Wetzel 2001). Although limited research has been conducted on the alteration of zooplankton, it has been postulated that increased temperature could favor smaller bodied zooplankters (Auchenbach and Lampert 1997). The aquatic benthic community is generally less impacted by thermal loading than are the fishes (Bush et al. 1974). Fishes generally can handle increased temperature better than decreasing temperatures (Tarzwell 1970).

Historically, Southern Illinois University conducted fish surveys of Lake of Egypt; however, little attention has been given to other biotic categories. In 2016, EIU conducted the following supplemental studies on the three different zones (lower cooling loop, and two zones outside the cooling loop – mid and upper) in the Lake of Egypt in accordance with a Detailed Plan of Study approved by IEPA on March 24, 2016 (“Detailed Plan of Study”):

- “Pilot” studies for the phytoplankton, zooplankton, macroinvertebrate and shellfish, and habitat former biotic categories (as defined in the 1977 USEPA Draft 316(a) Guidance Manual);
- Study of common carp as a nuisance species in LOE; and
- Study of white crappie and black crappie with a focus on their thermal tolerance and available refuge habitat during the summer season.

These studies are intended to supplement existing LOE studies and the previous 316(a) demonstration in support of an updated 316(a) demonstration report.

4 METHODS

4.1 TEMPERATURE AND DISSOLVED OXYGEN

Pursuant to the Detailed Plan of Study, EIU assessed the LOE temperature and dissolved oxygen weekly during June through September 2016 at five sampling locations in each of the three lake zones (Lower-lake, Mid-lake, Upper-lake) (Figure 1). Temperature (°C), DO (mg L^{-1}), and specific conductivity (µS cm^{-1}) was estimated from surface to bottom (0.5-m intervals) using a field multi-probe (YSI Inc., Yellow Springs, OH).

4.2 WATER CHEMISTRY

In accordance with the Detailed Plan of Study, EIU assessed water chemistry once per month during June, July, and August 2016 at three sampling locations in each of the three lake zones (Lower-lake, Mid-lake, Upper-lake). At each sampling location, EIU sampled temperature and dissolved oxygen every 0.5 meters in depth from surface to bottom using a YSI pro water quality meter. A secchi disk was used to assess the depth of the photic zone. EIU collected a water sample at each location for nutrient analysis using a 1L depth-integrated Van Dorn horizontal bottle sampler. To preserve nutrient samples, EIU kept samples on ice until analysis. EIU analyzed nutrients in the laboratory using methods adapted from *Standard Methods for the Examination of Water and Wastewater 22nd Edition* (Way 2012) and the *National Lakes Assessment Laboratory Operations Manual* (USEPA 2012b). Specifically, EIU analyzed, Ammonia (determined using nesslerization); Nitrate (determined using cadmium reduction); Total nitrogen (determined by persulfate digestion); Total phosphorus (determined by persulfate digestion); and Alkalinity (determined by inflection point titration with HCL).

4.3 PHYTOPLANKTON

In compliance with the Detailed Plan of Study, EIU sampled phytoplankton at the same locations as water chemistry once per month during June, July, and August 2016 (Figure 2), using a 1L depth-integrated Van Dorn horizontal bottle sampler. EIU collected three samples from each of the three lake zones during each sampling event (Figure 2). EIU preserved each phytoplankton sample with buffered Lugol's solution. EIU identified phytoplankton using the sedimentation method with an inverted compound microscope (e.g., USEPA 2012b). Sedimentation chambers (5-10 ml) were used in conjunction with a Whipple ocular micrometer for enumeration. Total counts were estimated by extrapolation to total volume of the sample. To assess differences in phytoplankton community structure among zones, EIU researchers used nonmetric multidimensional scaling based on Bray-Curtis dissimilarity coupled with ANOSIM (Analysis of Similarities) using primer version 6.

4.4 ZOOPLANKTON AND MEROPLANKTON

The approved Detailed Plan of Study did not require sampling of the zooplankton biotic category. However, based on further discussion with Illinois Environmental Protection Agency, EIU collected zooplankton samples in concert with water chemistry and phytoplankton once per month during June, July, and August 2016 (Figure 2), using two vertical tows with a Wisconsin plankton net (243 µm mesh) from the bottom of the photic zone to surface. Zooplankton samples were preserved using buffered 4% Lugol's solution. The Illinois Natural History Survey Kaskaskia Biological Station laboratory conducted the zooplankton and meroplankton analysis. Zooplankton were enumerated and identified to the lowest practicable taxonomic level. Enumeration was obtained by placing an entire sample in a specific volume of water and stirring with a magnetic stirrer. A Hansen-Stemple volumetric pipette was used to collect and place a subsample in a Wards zooplankton counting wheel, and the number of each species collected in the subsample were extrapolated according to the dilution and initial volume of water sampled. Differences in the density of zooplankton among lake zones and months were assessed using a two-way ANOVA. Differences in the community of zooplankters was assessed using nonmetric multidimensional scaling based on Bray-Curtis dissimilarity coupled with ANOSIM (Analysis of Similarities) using primer version 6.

4.5 MACROINVERTEBRATES, SHELLFISH, AND SUBSTRATE

Based on the requirements in the Detailed Plan of Study, EIU researchers sampled macroinvertebrates and shellfish once per month during June, July, and August 2016 using a petite ponar dredge (Figure 2). For each zone of the lake, EIU collected three to five duplicate dredge samples along one transect. Additionally, a separate dredge sample was used to characterize the substrate. EIU sieved samples using a 504-micron bucket sieve and preserved the sample in 70% ethanol. A gridded screen was used to sort a randomized 300-organism subsample of the invertebrates collected at each location (*see* USEPA 2012b for specific methods). Macroinvertebrates were viewed under a stereo dissecting microscope and identified to lowest taxon practicable and enumerated (*see* Table 4.1 in USEPA 2012b). To assess differences in community structure among areas EIU conducted nonmetric multidimensional scaling based on Bray-Curtis dissimilarity coupled with ANOSIM using primer version 6. In addition, various indices were estimated including species richness using Margalef's d (d = (Number of species – 1)/Log(total number of indviduals), Shannon-Weiner's diversity (H' = -Σ(pi*ln(pi)), Simpson's Diversity ($\lambda = 1/\Sigma pi^2$), and evenness using pierlou's J' (J' = H'/Log(Number of species).

4.6 HABITAT FORMERS

In accordance with the Detailed Plan of Study, the Illinois Natural History Survey (INHS) assessed the macrophyte community for information on habitat formers during August 2016. The entire main shoreline of the lake was surveyed using a Lowrance HD-10 sidescan sonar with structure scan in the littoral zone at a speed of no greater than 5 mph. Additionally, two randomly selected areas of submerged aquatic vegetation (SAVs) were mapped at a speed no greater than 3 mph to provide a higher resolution map. Within these randomly selected areas, INHS assessed the density and species composition (to the lowest taxonomic level practical) of SAVs at five-0.25 m^2 quadrats along three transects. INHS researchers used the slow speed side-scan imaging in concert with the transect data to draw a vegetation map of the different areas of the Lake. INHS then extrapolated the transect data coupled with the entire lake side-scan profile to estimate the coverage and species composition of SAVs in Lake of Egypt.

4.7 FISH

EIU collected new site-specific information for two additional categories of representative important species (RIS) - nuisance and thermally-sensitive species. EIU sampled fish using three-phased AC electrofishing during October 2016. A total of 15, 15-min shoreline transects were sampled in Lake of Egypt (Figure 3). Seven shoreline samples were conducted in the lower lake with four each in the mid- and upper lake. Most fish sampled were held in an aerated live well identified to species and released unharmed. Common carp (nuisance species) and sportfishes were measured (mm) and weighed (g). EIU euthanized all black crappie sampled for removal of otoliths. To increase sample size for black crappie additional fyke net and DC electrofishing surveys were conducted during November 2016. During the Fyke net samples all fishes sampled were identified, weighed (g), and measured (mm); however, during DC electrofishing sampling only crappie were targeted. For common carp, largemouth bass, and black crappie EIU estimated the condition of individuals using relative weight.

EIU used all black crappie specimens captured during the electrofishing efforts and fyke net efforts for age analysis. Sagittal otoliths were removed by disconnecting the operculum and accessing the cranial chamber anteriorly. Otoliths were cleaned and air dried, then placed in immersion oil and viewed with a stereo microscope under low magnification (7-40x) using reflected light. Age of fish was estimated by counting the number of annuli (visual growth bands) using two independent readers. Growth was modeled from individual lengths at age with a von Bertalanffy model: $L_t = L_\infty(1 - e^{-K(t-t_0)})$, where L_t is the length at time t, L_∞ is the asymptotic length, K is the growth coefficient, and t_0 is the time at which length would theoretically be 0 mm. To assess the proportion of black crappie in LOE that are available to the fishery the proportional size distribution of quality (200 mm) (PSD), preferred (250) (PSD-P), and memorable (300 mm) (PSD-M) crappie was assessed.

5 RESULTS

5.1 TEMPERATURE AND DISSOLVED OXYGEN

Throughout the summer months temperature and dissolved oxygen (DO) were stratified with depth (Figure 4-7). In the lower lake (power plant) zone temperature in the epilimnion peaked during August with surface temperatures exceeding 30 C. At this point EIU also saw the lowest levels of surface DO (Figure 6); however, EIU found the other two zones of the lake to have dissolved oxygen levels greater than 4 mg/L and in the upper zone DO exceeded 6 mg/L during August (Figure 6). Although during September, EIU found the DO in the lower zone to be below 4 mg/L (Figure 7); the surface DO in the middle zone approached 6 mg/L and in the upper zone was greater than 7 mg/L (Figure 7).

5.2 WATER CHEMISTRY

Based on Alkalinity, all zones of the lake were categorized as soft (Table 1). Overall, both the Total N and P (Table 1) were low throughout the lake; however, there was a pulse of total N in the lower lake zone during June (Table 1).

5.3 PHYTOPLANKTON

A total of 46 genera (Appendix 1) from 7 different phyla of phytoplankton were identified in Lake of Egypt. The phytoplankton community in the lake was dominated by genera in the phylum Bacillariophyta (Table 2). Additionally, the relative abundance of the nitrogen fixing phyla Chlorophyta and Cyanobacteria was high (Table 2). EIU found the presence of one phylum that is known to be warm tolerant Dinophyta which occurred in the highest abundance in the upper lake zone (Table 2). Overall, there was no significant difference in the total abundance of phytoplankton among lake regions (ANOVA, $F_{2,24} = 2.39$, $P = 0.11$). Although the relative abundance of phytoplankton was similar among lake zones there were differences in the community structure among lake zones (ANOSIM, $p < 0.05$, Figure 8) and among months (ANOSIM, $p < 0.05$, Figure

8). There was a significant difference in phytoplankton community between the lower and mid zone (ANOSIM, $p < 0.02$) and the lower and upper zone (ANOSIM, $p < 0.001$); however, there was no significant difference in community between the mid and upper zone (ANOSIM, $p > 0.69$). Differences between the lower and mid lake zone were driven by increased abundances of two genera in the phylum Bacillariophyta in the lower lake and increased abundances of phyla Cyanobacteria and Dinophyta in the mid zone (SIPMER). Differences between the lower zone and the upper zone were driven by increased abundance of a genus of Bacillariophyta in the lower lake zone and increased Cyanobacteria and Dinophyta in the upper zone (SIMPER). Over all lake zones, EIU found all months to have significantly different phytoplankton community structures (ANOSIM, $p < 0.02$). The differences among months can be attributed to increased relative abundance of Dinophyta and Cyanobacteria in August compared to June and July (SIMPER), and a changing in the genera of Bacillariophyta between June and July (SIMPER).

5.4 ZOOPLANKTON AND MEROPLANKTON

Although rotifers dominated all regions of Lake of Egypt, EIU identified a total of nine different taxa of zooplankton (Table 3). Both zooplankton density and taxa richness peaked during June and declined through the summer (Table 3, Figure 9). There was no significant interaction between lake zone and month (ANOVA, $F_{4,18} = 1.286$, $p = 0.312$); Since there was no significant interaction between lake zone and month EIU was able to assess the main effects of zone and month independently. There was a significant effect of both lake zone (ANOVA, $F_{2,18} = 4.836$, $p < 0.05$) and month (ANOVA, $F_{2,18} = 6.387$, $p < 0.05$). Although the density of zooplankton was significantly higher in June compared to both July (Tukey HSD, $p = 0.044$, Figure 10) and August (Tukey HSD, $p = 0.008$, Figure 10), there was no difference in density between July and August (Tukey HSD, $p = 0.710$, Figure 10). EIU found significantly higher zooplankton density in the lower lake zone compared to the mid lake zone (Tukey HSD, $p = 0.016$, Figure 11), there was no difference in density between the lower and upper (Tukey HSD, p = 0.370, Figure 11) nor between the upper and mid lake zones (Tukey HSD, p = 0.225, Figure 11). Although there were differences in the zooplankton density among lake zones; there were no differences in community structure among months (ANOSIM, P > 0.05) (Figure 12) or lake zones (ANOSIM, P > 0.05) (Figure 13).

5.5 MACROINVERTEBRATES, SHELLFISH, AND SUBSTRATE

EIU found the macroinvertebrate community to be dominated by bloodworms, midges (Chironomidae), and glassworms (*Chaoborus*) (Table 4). EIU found one taxon of crustacean (Amphipoda) in all regions of the lake and one family of invasive bivalve (Sphaeriidae) was also found throughout the lake (Table 4). Overall, there was no difference in taxa diversity (ANOVA p>0.05), richness (ANOVA p>0.05), or evenness (p>0.05) among lake zones (Table 5). The macroinvertebrate community had relatively low scores based on taxa diversity, richness, and evenness (Table 5). There was no difference in community structure of macroinvertebrates between lake regions (ANOSIM, P >0.05; Figure 14). Based on dredge samples substrate in Lake of Egypt is dominated by fine sediments (silt/muck) with some areas containing larger gravel and cobble substrates (Table 6). There was no difference in the proportional abundance of the different substrate types among lake regions (ANOSIM, P > 0.05; Figure 15)

5.6 HABITAT FORMERS

The community of macrophytes was dominated by water willow in all zones of the lake (Table 7-8, Figure 16). The highest coverage of water willow occurred in the mid zone of Lake of Egypt (Table 7-8). EIU found a small number of submerged aquatic vegetation in every zone of the lake (Table 7-8, Figure 16), with the exotic milfoil being the most abundant in the upper lake zone (Table 7-8, Figure 16), pondweed most abundant in the mid lake zone (Table 7-8, Figure 15), and slender naiad being most abundant in the lower lake zone (Table 7-8, Figure 16).

5.7 FISH

Using electrofishing EIU collected a total of 1234 fishes from 17 different species and one hybrid species (Table 9). The most common fish species sampled were bluegill, longear sunfish, redear sunfish, and largemouth bass (Table 9). There was a significant effect of lake zone on the relative density of fishes (ANOVA, $F_{2,12} = 10.042$, $p = 0.003$). There was a significantly higher relative density of fishes in the lower lake zone compared to either the mid (Tukey HSD, $p = 0.006$) or upper (Tukey HSD, $p = 0.010$) lake zones (Figure 16); however, there was no difference in fish relative density between the mid and upper (Tukey HSD, $p = 0.976$) lake zones (Figure 17). EIU sampled a total of 14 black Crappie using AC electrofishing (Table 9). Overall condition of largemouth bass, as estimated by relative weight, was high (Wr = 88 +/- 1) (Table 11).

Using Trap nets EIU sampled 124 individuals from nine species and one hybrid (Table 10). Only one species, the yellow bass, was sampled using trap nets that was not part of the electrofishing samples (Table 10). As with electrofishing, the most prevalent species were sunfish (Table 9-10). Although EIU sampled no common carp using trap nets, EIU sampled 11 black crappie using nets.

Nuisance Species

EIU sampled two individual common carp during AC electrofishing (Table 9). The overall CPUE of common carp was 0.53 fish/hr. No other common carp were sampled in Lake of Egypt. Both carp were in excellent condition with relative weight greater than 120 (Table 11).

Thermally-sensitive species

During electrofishing, trap netting, and additional targeted collections, we sampled a total of 46 black crappie and no white crappie. black crappie average length was 278 +/- 6.7 mm and ranged between 173 and 366 mm (Figure 18). The size structure of crappie was skewed towards larger fish (Figure 18) with 91% of crappie being greater than or equal to quality (200 mm) length, 78% of crappie being greater than or equal to preferred (250 mm) length, and 28% of crappie being greater than or equal to memorable (300 mm) length. We found black crappie to be in excellent condition with a relative weight of 100 +/- 2 (Table 11). Based on otolith age estimates black crappie ranged in age from 1 – 5 years with the dominant age class being age 2 (Figure 19). The age structure sampled during this study was similar to the study conducted in 2007 by Heidinger (Table 11). Black crappie growth fit a Von Bertalanffy model well (R^2 = 0.996) with the maximum length of the average fish reaching 381 mm (Figure 20). EIU found black crappie to be growing faster than previously reported for this population (Figure 20).

6 DISCUSSION

As expected for a temperate reservoir, the thermal profiles of Lake of Egypt were stratified in both temperature and dissolved oxygen during summer 2016. The thermal profiles of LOE were similar to other power cooling lakes which have areas that are outside of the cooling loop. Comparable to LOE, Coffeen Lake showed high summer temperatures within the cooling loop coupled with large thermal refuge areas in adjacent basins (Porreca 2010). Areas outside the cooling loop in LOE, specifically in the upper zone, contained areas that had both moderate summer temperatures and sufficient DO throughout the summer for temperate aquatic flora and fauna. The lower cooling loop zone of the lake did experience low DO and high temperature at the peak of the summer that would cause avoidance by thermally sensitive species such as crappie sp. (Edwards et al. 1982). However, sampling revealed this low DO high temperature combination only occurred during the months of August and September in the lower lake zone and during August in the mid lake zone. The upper zone of the lake had temperature and DO conditions suitable for black crappie growth and survival throughout the summer (Edwards et al. 1982).

Based on the assessment of nutrients in Lake of Egypt, there is relatively low input of nitrogen species and phosphorous. This relatively low level of nutrients is explained by the relatively small contributions from the surrounding landscape. Historically, LOE had a larger input of nitrogen from the septic systems of adjacent homes; however, the removal of septic systems for sewers has significantly reduced nitrogen and phosphorus inputs (Heidinger 2007). EIU found only one elevated nitrogen reading in LOE during summer 2016 which occurred during June in the lower lake zone potentially attributable to runoff from adjacent lawn fertilizer. All other readings of nitrogen and phosphorus were lower than Illinois standards for an oligotrophic system like Lake Michigan.

Overall the community of phytoplankton was dominated by diatoms (Bacillariophyta), as this is among the most common type of freshwater phytoplankton, their dominance would be expected in any midwestern lake. Due to the relatively low amount of nutrients in LOE, the phytoplankton community contained an abundance of species that could fix nitrogen (i.e. *Anabena* and *Aphizomenon*). The abundance of blue-green algae (Cyanobacteria) in the lake is directly attributable to the low nutrients in the system. Because of the low amount of nitrogen contributed to the lake from the surrounding watershed the species that can fix atmospheric nitrogen as with the bluegreen algae are favored.

As expected, the phytoplankton community changed throughout the summer; however, EIU also saw a difference in community structure between lake zones (Bush et al 1974). Much of this difference can be attributed to higher proportions of cyanobacteria in the more nitrogen deficient mid and upper lake zones. Although, EIU did sample one defined bloom (i.e., a rapid increase in a species density) of thermally tolerant (Dinophyta) phytoplankton in LOE; however, the bloom occurred in the upper zone of the lake and not in the lower cooling loop zone. Additionally, this increase in dinoflagellates was most apparent in the August sample at the warmest lake temperature.

In contrast to other cooling lake studies, the zooplankton and meroplankton community abundance was highest in June and dropped quickly throughout the summer months (Mulhollem et al. 2015). In a sample of three Illinois cooling lakes, Mulhollem et al. (2015) found highest zooplankton densities during May in cooling lakes whereas in ambient control lakes zooplankton communities peaked during June. A major difference with this study was EIU did not begin zooplankton sampling until June which may have led to the missing of the highest abundance. Although EIU may have missed the peak density of zooplankton the results showed similar species composition to other Illinois cooling and ambient reservoirs with the most dominant macro-zooplankters being Calanoida and Cyclopoida, and the dominant micro-zooplankter being rotifers (Mulhollem et al. 2015). The earlier peak density of zooplankters in power cooling lakes is also coupled with earlier spawning of fishes allowing for a match of larval fishes with their main food source (Mulhollem et al. 2015). Overall, EIU found the zooplankton abundance to be highest in the lower cooling loop zone of the lake and there was no difference in the zooplankton community among lake zones.

Similar to other reservoirs in Southern Illinois, the majority of the substrate in LOE was comprised of silt/muck based on dredge samples. The lack of substrate heterogeneity led to a relatively poor community of macroinvertebrates. Although the macroinvertebrate community was relatively low in diversity there were no differences in the community assemblage nor species diversity or richness measures among lake regions. Macroinvertebrate abundance and diversity is often driven by habitat (e.g., substrate type, depth) and are not as affected by thermal effluent as the vertebrate fauna may be.

The macrophyte community of Lake of Egypt was dominated by water willow which is common in Illinois around lake margins. There was little submerged aquatic vegetation in Lake of Egypt due in large order to the rapid increase in water depth adjacent to the shoreline. Where habitat was suitable in embayments, EIU found stands of naiad, pond weed, and the exotic milfoil. EIU found submerged aquatic vegetation throughout all lake zones in habitats that were conducive to plant growth. Therefore, the heated effluent of Lake of Egypt does not seem to be impacting the aquatic plant community.

The fish assemblage in Lake of Egypt was similar to other Illinois cooling (Porreca 2010) and ambient reservoirs (Mullholem et al 2015). As expected bluegill sunfish dominated the fish community in Lake of Egypt. There was no impact of heated effluent on the distribution of fishes in the lake. Density of fishes was higher in the heated portion of the lake compared to either the mid or upper lake sections. In Lake Coffeen, another Illinois power cooling lake, fish density was higher outside the cooling loop during the late summer and fall; however, the fish density was the highest in the cooling loop during winter and spring (Porreca 2010).

Nuisance species

EIU sampled a total of two common carp in the extensive electrofishing and trapnet surveys, suggesting a small population of nuisance species in the lake.

Thermally-sensitive species

The population of crappie in Lake of Egypt has shifted in the past two decades. Historically, white crappie dominated the lake (Heidinger 2009). White crappie tend to be more successful in more turbid systems due to high young of the year mortality from predation in clear lakes. The more turbid water conditions that were present when residences around the lake relied on septic systems rather than a sewer system allowed the successful recruitment of white crappie. The change in nutrients has drastically limited the amount of nutrients in to the lake thereby leading to a less turbid system preferred by black crappie. The previous fish survey conducted by Heidinger (2009) found only one white crappie leading to the implementation of a stocking program for black crappie. During the surveys, EIU sampled only black crappie. The population demographics of crappie suggests a short-lived, fast-growing population of fishes that are in excellent condition. The size structure of crappie in the lake was comprised of a large proportion of relatively large fish.

Although supported by stocking, EIU found evidence of natural reproduction of crappie in the lake. The age structure suggested a large recruitment class of age two individuals and some individuals age three - five that were produced previous to the last stocking event (2015). Although the temperature and DO in the cooling loop section was inhospitable to crappie during the peak of the summer; there was adequate thermal refuge in the upper lake zone. As evident by the age structure crappie are surviving and thriving in the lake.

Conclusions

Overall, the biotic communities in Lake of Egypt were typical of an oligotrophic (low nutrient) Midwestern system. Based on EIU's assessment, the relatively low nutrient availability in Lake of Egypt is driving the phytoplankton, zooplankton, and SAV communities. During all sampling EIU found an abundance of one taxon (Dinoflagellates) that are heat tolerant. This taxon was present in all lake zones and was most abundant in the upper lake zone. The presence of this taxon is common in many reservoirs in Southern Illinois during the peak of the summer (Heidinger *personal communication*). Although, the community of fishes in Lake of Egypt is similar to many reservoirs in the State of Illinois; the size structure and condition of sportfish is better than many ambient systems.

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Table 2. Mean water chemistry values (S.E. = standard error) for each zone of Lake of Egypt collected during summer 2016. All values except alkalinity are in mg L^{-1}. Alkalinity values are in mg L^{-1} $CaCO_3$.

	Zone	Alkalinity	S.E.	NH_3	S.E.	NO_3	S.E.	Total N	S.E.	Total P	S.E.
June											
	Lower Lake (Power plant)	21.57	2.26	0.012	0.001	0.105	0.002	1.473	0.097	0.013	0.001
	Mid Lake	27.87	4.21	0.011	0.002	0.331	0.230	0.853	0.056	0.014	0.002
	Upper Lake	25.90	4.19	0.010	0.003	0.064	0.012	0.892	0.014	0.015	0.002
July											
	Lower Lake (Power plant)	31.83	1.82	0.028	0.008	0.098	0.017	0.326	0.074	0.047	0.005
	Mid Lake	39.67	5.63	0.006	0.001	0.046	0.009	0.651	0.007	0.030	0.002
	Upper Lake	39.10	2.46	0.003	0.001	0.069	0.020	0.567	0.008	0.034	0.002
August											
	Lower Lake (Power plant)	27.67	1.09	0.006	0.002	0.118	0.023	0.364	0.041	0.045	0.007
	Mid Lake	25.67	1.16	0.002	0.001	0.067	0.007	0.548	0.057	0.043	0.005
	Upper Lake	20.80	4.14	0.001	0.000	0.100	0.004	0.367	0.051	0.089	0.024

Table 3. Abundance of the phytoplankton phyla sampled from the three zones of Lake of Egypt during summer 2016.

Phylum	Lower	Mid	Upper	Total
Bacillariophyta	9920	6544	8809	25273
Chlorophyta	7675	8845	8067	24588
Cyanobacteria	5042	7136	10600	22778
Cryptophyta	3950	3341	4334	11625
Dinophyta	466	2611	5207	8284
Euglenophyta	1541	2027	1666	5233
Chrysophycea	110	64	127	301

Table 4. Mean +/- Standard Error of zooplankton density (Number/L) sampled from three different areas of Lake of Egypt collected during summer 2016.

Taxa	Lower Lake	Mid Lake	Upper Lake
06/02/2016			
Daphnia			
Cyclopoida	0.49±0.34	0.13±0.23	
Calanoida	0.18±0.31		
Nauplii	0.09±0.16	0.04±0.08	0.09±0.16
Rotifers	148.44±44.13	21.75±37.67	62.96±16.05
D. lumholtzi			0.09±0.16
Bosminidae	0.04±0.08	0.04±0.08	0.36±0.41
Chydoridae			
Ceriodaphnia	0.09±0.16		
07/07/2016			
Daphnia			0.28±0.48
Cyclopoida			
Calanoida			
Nauplii	0.28±0.48	0.28±0.48	
Rotifers	6.56±0.97	1.95±0.87	4.74±2.56
D. lumholtzi		0.56±0.97	
Bosminidae			
Chydoridae		0.14±0.24	
Ceriodaphnia			
08/05/2016			
Daphnia			
Cyclopoida			0.25±0.43
Calanoida	0.13±0.22		0.13±0.22
Nauplii	5.27±6.98		1.88±3.26
Rotifers	3.64±2.65	1.32±1.42	1±1.09
D. lumholtzi			
Bosminidae	0.25±0.43		
Chydoridae			
Ceriodaphnia			

Table 5. Abundance of macroinvertebrates sampled from the three lake zones of Lake of Egypt during summer 2016.

	June			July			August		
Lowest Identification	Lower	Mid	Upper	Lower	Mid	Upper	Lower	Mid	Upper
AMPHIPODA	1	2	3	0	0	0	0	0	0
ANNELIDA	3	3	3	3	3	4	2	4	4
BLOODWORM	24	9	60	16	3	46	14	4	20
CAENIDAE	0	0	0	0	0	2	0	0	0
CERATOPOGONIDAE	0	0	1	0	0	0	0	0	0
CHAOBORIDAE	8	10	10	5	5	21	0	7	34
CHIRONOMIDAE	6	21	36	14	11	41	11	4	11
DIPTERA PUPA	1	2	0	1	0	1	0	3	3
EPHEMERIDAE	0	0	1	1	1	0	0	0	0
HIRUDINEA	0	0	3	0	0	2	0	1	2
HYDROPSYCHIDAE	0	0	0	0	2	0	0	0	0
SPHAERIIDAE	13	31	10	6	1	0	1	0	0
Total	**56**	**78**	**127**	**46**	**26**	**117**	**28**	**23**	**74**

Table 6. Indices of taxa richness, evenness, and diversity for macroinvertebrates sampled from Lake of Egypt during summer 2016. S = number of taxa, N = number of individuals, Margalef’s d = taxa richness, J’ = eveness, H’ = Shannon-Weiner Diversity, Simpson’s = Simpson’s Diversity.

	June			July			August		
Index	Lower	Mid	Upper	Lower	Mid	Upper	Lower	Mid	Upper
S	7	7	9	7	7	7	4	6	6
N	56	78	127	46	26	117	28	23	74
Margalef's d	1.49	1.38	1.65	1.57	1.84	1.26	0.90	1.59	1.16
J'	0.78	0.79	0.66	0.81	0.84	0.69	0.74	0.94	0.77
H'	1.52	1.55	1.45	1.58	1.63	1.34	1.02	1.68	1.38
Simpson's	0.74	0.75	0.69	0.77	0.78	0.69	0.61	0.83	0.70

Table 7. Abundance of substrates sampled from Lake of Egypt during summer 2016.

Date	Zone	Site	site code	%silt/muck	%sand	%gravel	%cobble
6/2/2016	Lower	1	D1.1	10	0	10	80
6/2/2016	Lower	2	D1.2	100	0	0	0
6/2/2016	Lower	3	D1.3	95	5	0	0
6/2/2016	Lower	4	D1.4	50	50	0	0
6/2/2016	Mid	1	D2.1	0	60	20	20
6/2/2016	Mid	2	D2.2	90	10	0	0
6/2/2016	Mid	3	D2.3	90	10	0	0
6/2/2016	Mid	4	D2.4	0	33	33	33
6/2/2016	Upper	1	D3.1	0	0	10	90
6/2/2016	Upper	2	D3.2	90	10	0	0
6/2/2016	Upper	3	D3.3	90	10	0	0
6/2/2016	Upper	4	D3.4	90	10	0	0
6/2/2016	Upper	5	D3.5	0	33	33	33
7/7/2016	Lower	1	D1.1	60	10	10	20
7/7/2016	Lower	2	D1.2	100	0	0	0
7/7/2016	Lower	3	D1.3	90	10	0	0
7/7/2016	Lower	4	D1.4	10	70	20	0
7/7/2016	Mid	1	D2.1	0	90	10	0
7/7/2016	Mid	2	D2.2	90	10	0	0
7/7/2016	Mid	3	D2.3	90	10	0	0
7/7/2016	Mid	4	D2.4	0	10	60	30
7/7/2016	Upper	1	D3.1	40	20	20	20
7/7/2016	Upper	2	D3.2	80	20	0	0
7/7/2016	Upper	3	D3.3	80	20	0	0
7/7/2016	Upper	4	D3.4	60	30	10	0
7/7/2016	Upper	5	D3.5	0	20	30	50
8/5/2016	Lower	1	D1.1	0	60	30	10
8/5/2016	Lower	2	D1.2	90	10	0	0
8/5/2016	Lower	3	D1.3	90	10	0	0
8/5/2016	Lower	4	D1.4	10	50	40	10
8/5/2016	Mid	1	D2.1	0	60	20	20
8/5/2016	Mid	2	D2.2	80	10	10	0
8/5/2016	Mid	3	D2.3	80	10	10	0
8/5/2016	Mid	4	D2.4	0	70	20	10
8/5/2016	Upper	1	D3.1	50	40	10	0
8/5/2016	Upper	2	D3.2	80	20	0	0
8/5/2016	Upper	3	D3.3	80	20	0	0
8/5/2016	Upper	4	D3.4	80	20	0	0
8/5/2016	Upper	5	D3.5	10	50	30	10

Table 8. Summary of macrophyte density in Lake of Egypt on 31 August 2016. Percentages are greater than 100% because of overlap in vegetated zones

	Water willow	Milfoil	Filamentous algae	Pondweed	Slender naiad	No vegetation
% perimeter coverage	81%	8%	1%	7%	6%	18%
Mean width of coverage (m^2)	1.4	2401.9	0.2	0.0	0.0	
SD of width coverage	0.8	4073.8	1.0	0.0	0.0	

Table 9. Proportion of shoreline with different macrophytes in Lake of Egypt on 31 August 2017.

Zone	Water willow	Milfoil	Filamentous algae	Pondweed	Slender naiad
Lower	0.661	0.00	0.00	0.00	0.44
Mid	0.902	0.14	0.00	0.21	0.00
Upper	0.800	0.06	0.02	0.00	0.00

Table 10. Abundance (Number) and Catch per Effort (Fish/hr) of fishes sampled with AC electrofishing from the three zones of Lake of Egypt during fall 2016.

	Lower Lake		Mid Lake		Upper Lake		Total	
Species	Number	CPE	Number	CPE	Number	CPE	Number	CPE
Black Crappie	4	2.29	6	6	4	4	14	3.73
Bluegill	488	278.86	114	114	137	137	739	197.07
Bluntnose Minnow			1	1			1	0.27
Blackstripe Topminnow	4	2.29	1	1	1	1	6	1.60
Brown Bullhead	11	6.29			1	1	12	3.20
Brook Silverside	9	5.14	18	18			27	7.20
Common Carp	2	1.14					2	0.53
Channel Catfish			2	2	1	1	3	0.80
Golden Shiner	2	1.14					2	0.53
Green Sunfish	1	0.57	3	3	3	3	7	1.87
Gizzard Shad	13	7.43			3	3	16	4.27
Lepomis hybrid	10	5.71			5	5	15	4.00
Largemouth Bass	51	29.14	36	36	13	13	100	26.67
Longear Sunfish	67	38.29	14	14	42	42	123	32.80
Redear Sunfish	74	42.29	22	22	14	14	110	29.33
Spotted Sucker	3	1.71					3	0.80
Threadfin Shad	44	25.14	4	4			48	12.80
Warmouth	5	2.86			1	1	6	1.60
Total	**788**	**450.29**	**221**	**221**	**225**	**225**	**1234**	**329.07**

Table 11. Abundance of fishes sampled with trap nets in the three zones of Lake of Egypt during fall 2016.

Species	Lower Lake	Mid Lake	Upper Lake	Total
Black Crappie	7	1	3	12
Bluegill	8		20	28
Lepomis hybrid	3		1	4
Largemouth Bass	2	1	2	5
Longear Sunfish	4		23	27
Orangespotted Sunfish	1			1
Readear Sunfish	15		13	28
Threadfin Shad		2		2
Warmouth	3		1	4
Yellow Bass	6	4	4	14
Total	49	8	67	125

Table 11. Fish condition as estimated by mean relative weight (+/- S.E.) of Largemouth Bass, Common Carp (nuisance species), and Black Crappie (thermally sensitive)

		Relative Weight	
Species	N	This Study	Heidinger
Largemouth Bass	105	88 +/- 1	95
Common Carp	2	124	n/a
Black Crappie	45	100 +/- 2	98

Table 12. Age structure of Black Crappie sampled during 2007 (Heidinger) and during 2016 (EIU).

Age	2007	2016
1	15	7
2	19	25
3	1	9
4	7	3
5	1	1

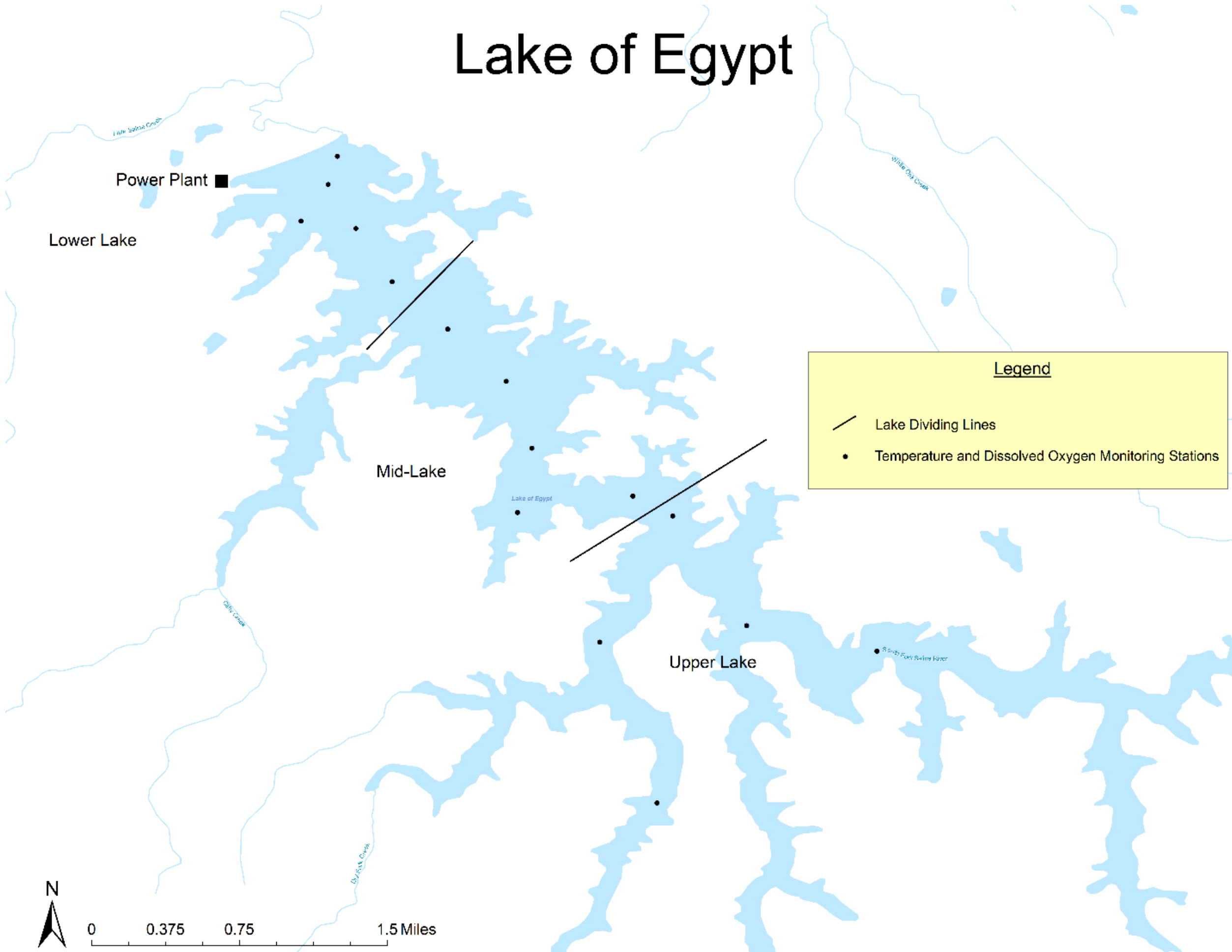

Figure 1. Locations of Temperature and Dissolved Oxygen sampling sites from the three zones of Lake of Egypt.

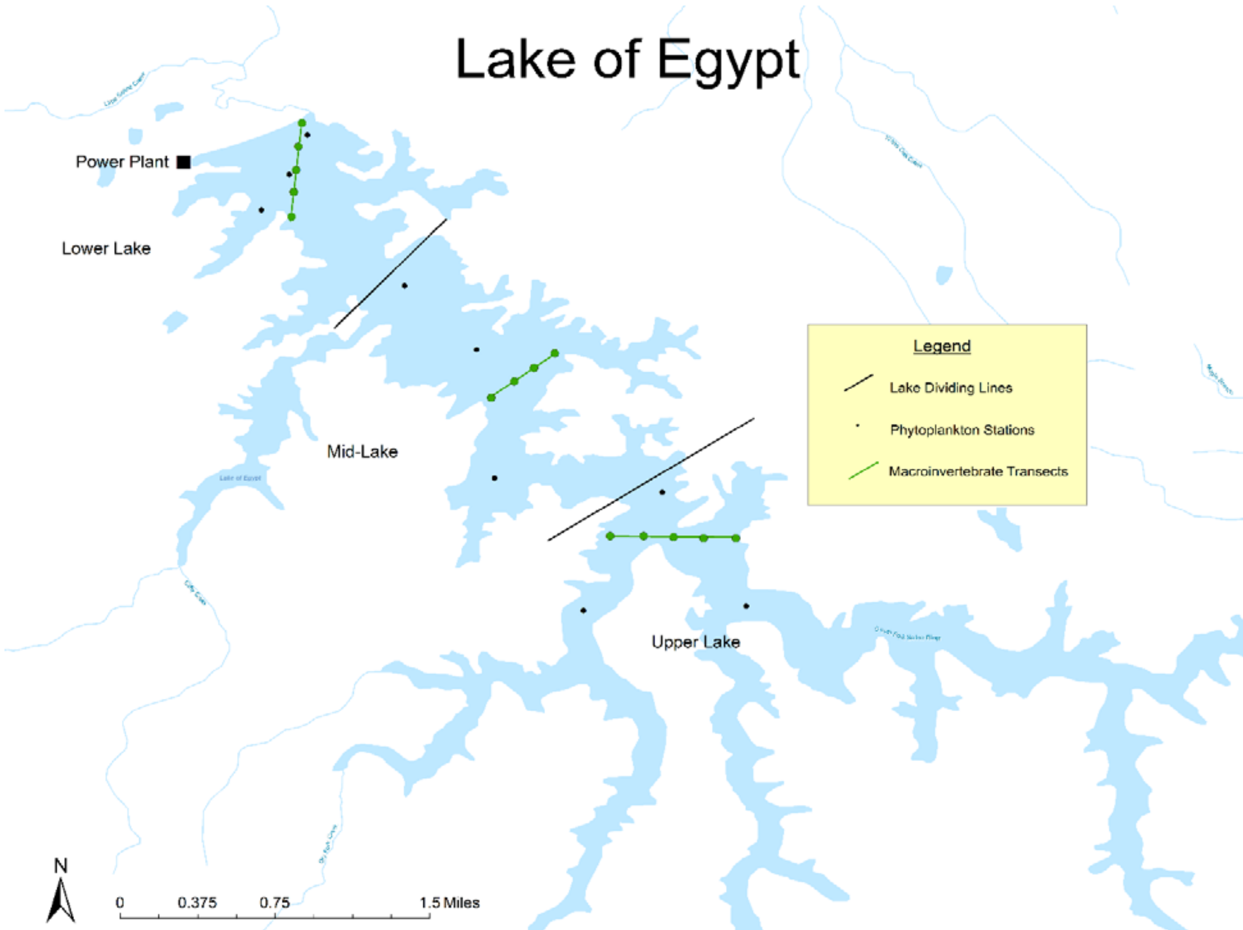

Figure 7-1. Locations phytoplankton and macroinvertebrates samples conducted in the three zones of Lake of Egypt during summer 2016.

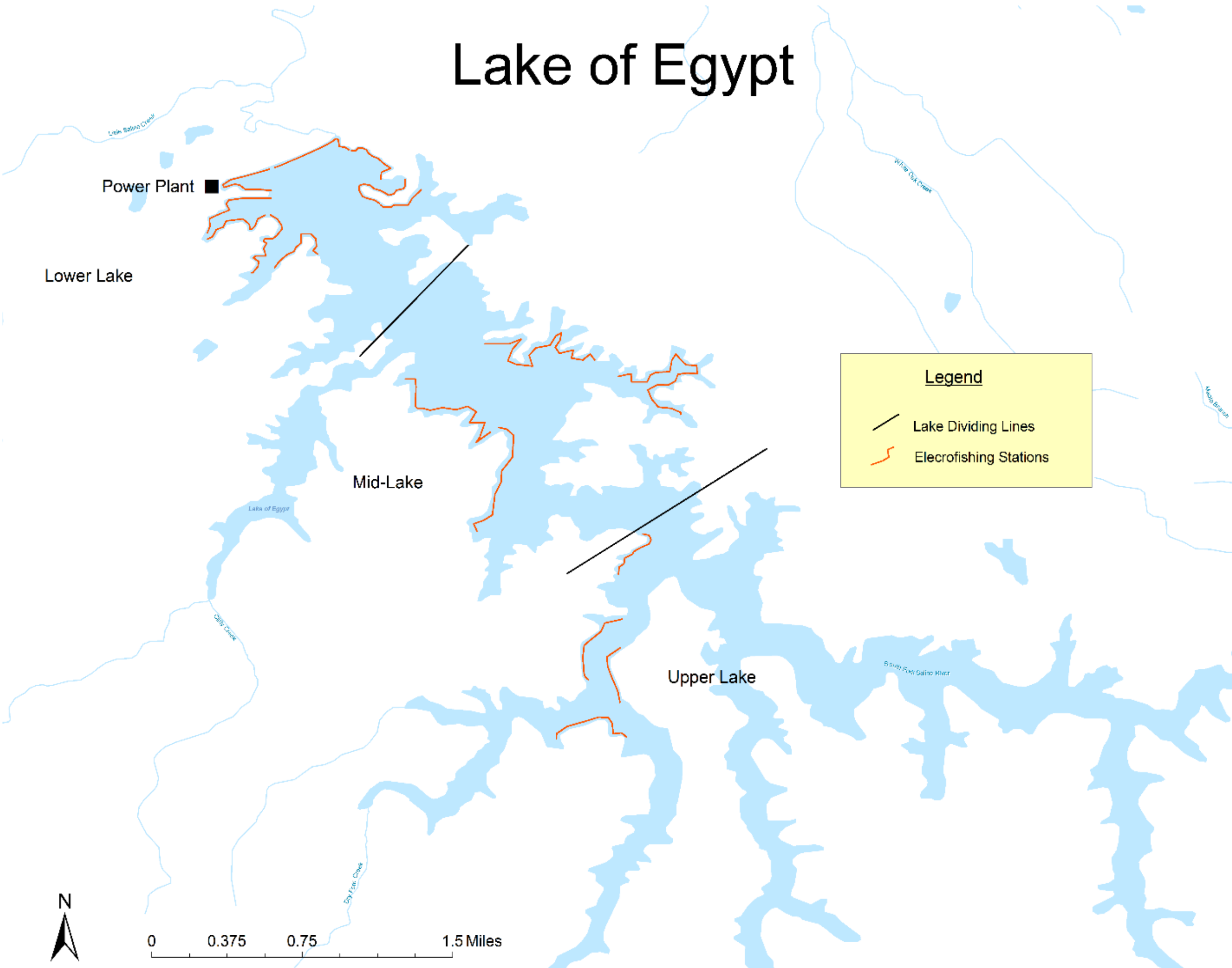

Figure 7-2. Locations of AC electrofishing transects sampled from the three zones of Lake of Egypt during fall 2016.

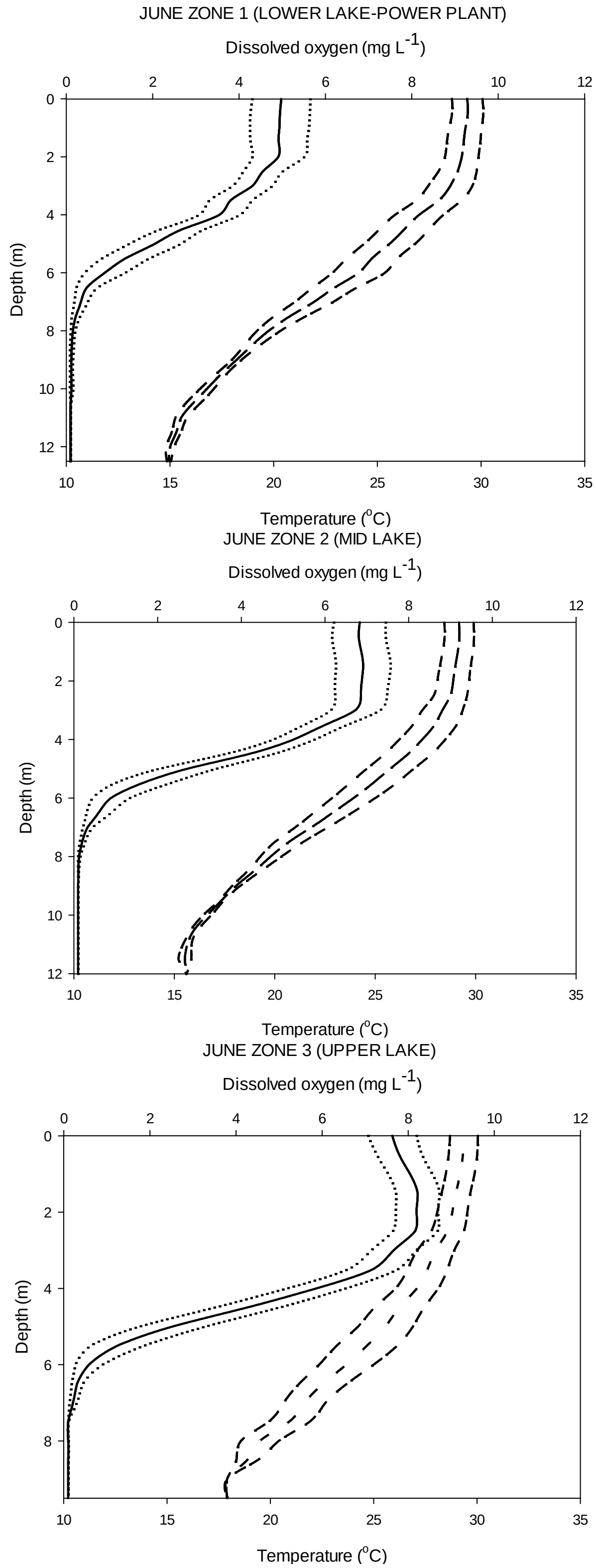

Figure 7-3. Average +/- 95% confidence intervals for temperature (dashed) and DO (solid and dotted) from the upper (top), mid (middle), and upper (bottom) during June 2016.

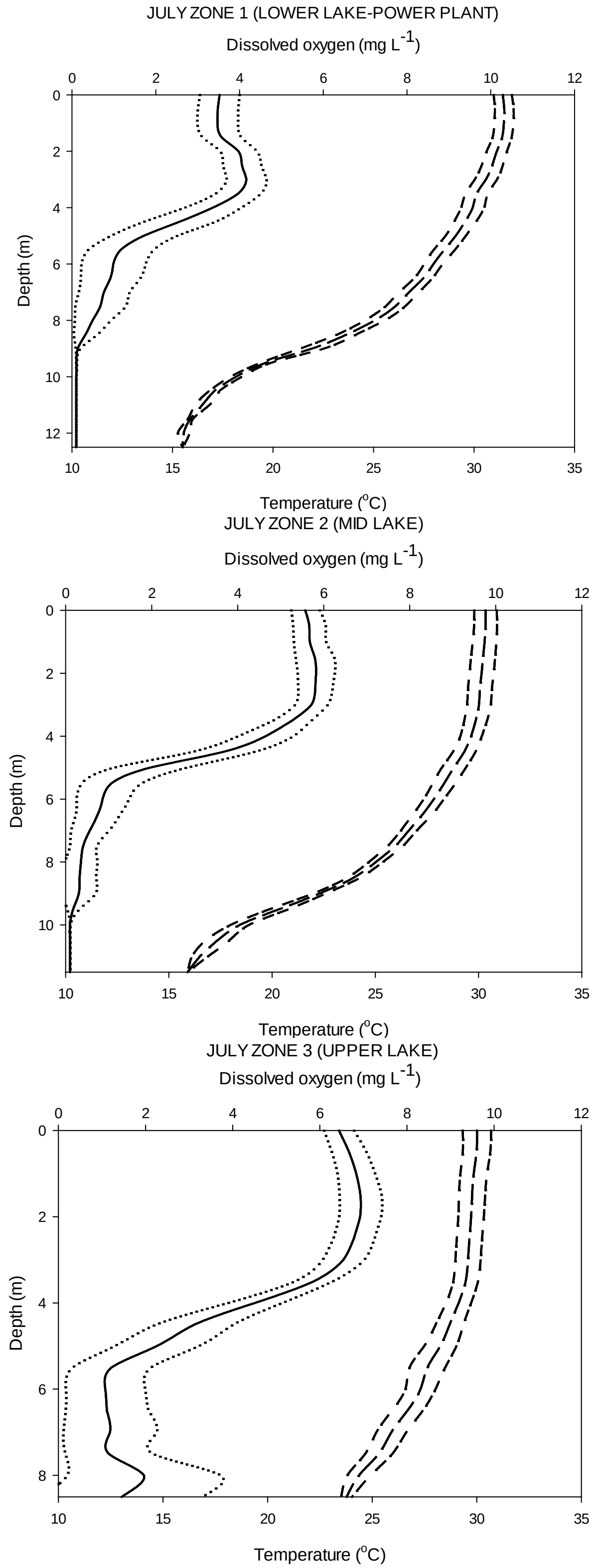

Figure 7-4. Average +/- 95% confidence intervals for temperature (dashed) and DO (solid and dotted) from the upper (top), mid (middle), and upper (bottom) during July 2016.

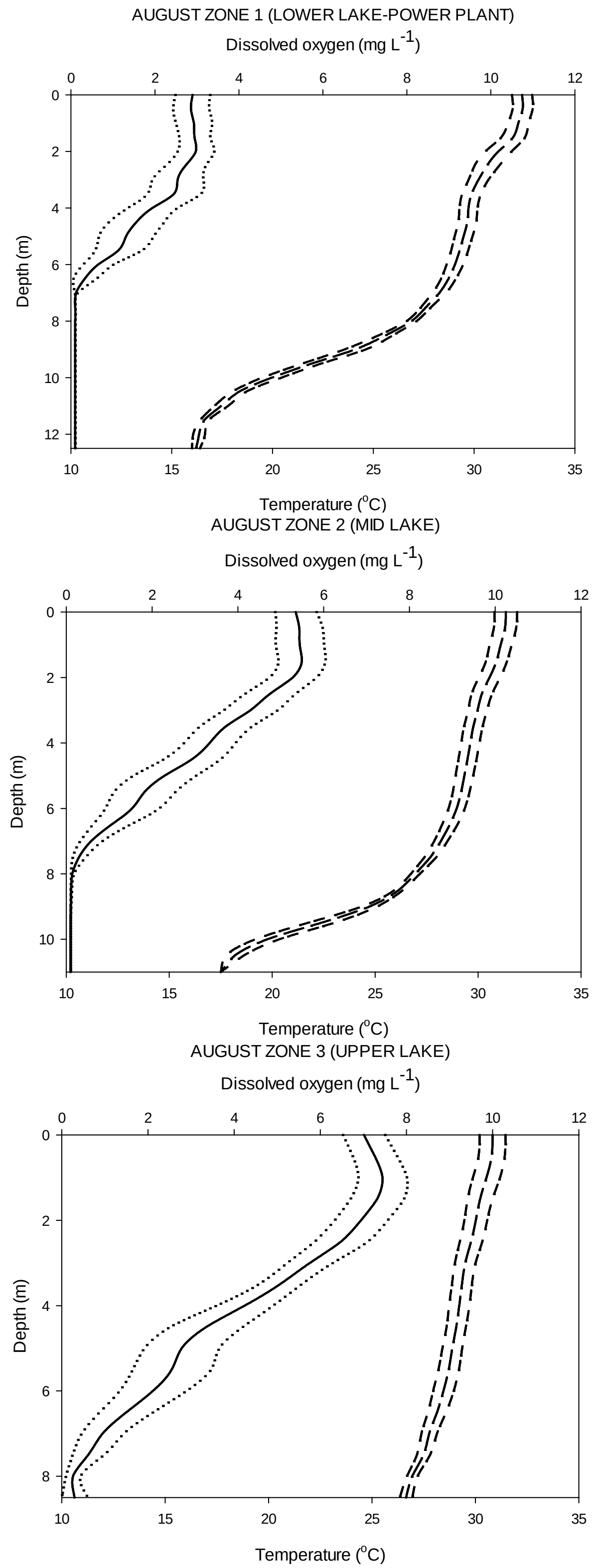

Figure 7-5 Average +/- 95% confidence intervals for temperature (dashed) and DO (solid and dotted) from the upper (top), mid (middle), and upper (bottom) during August 2016.

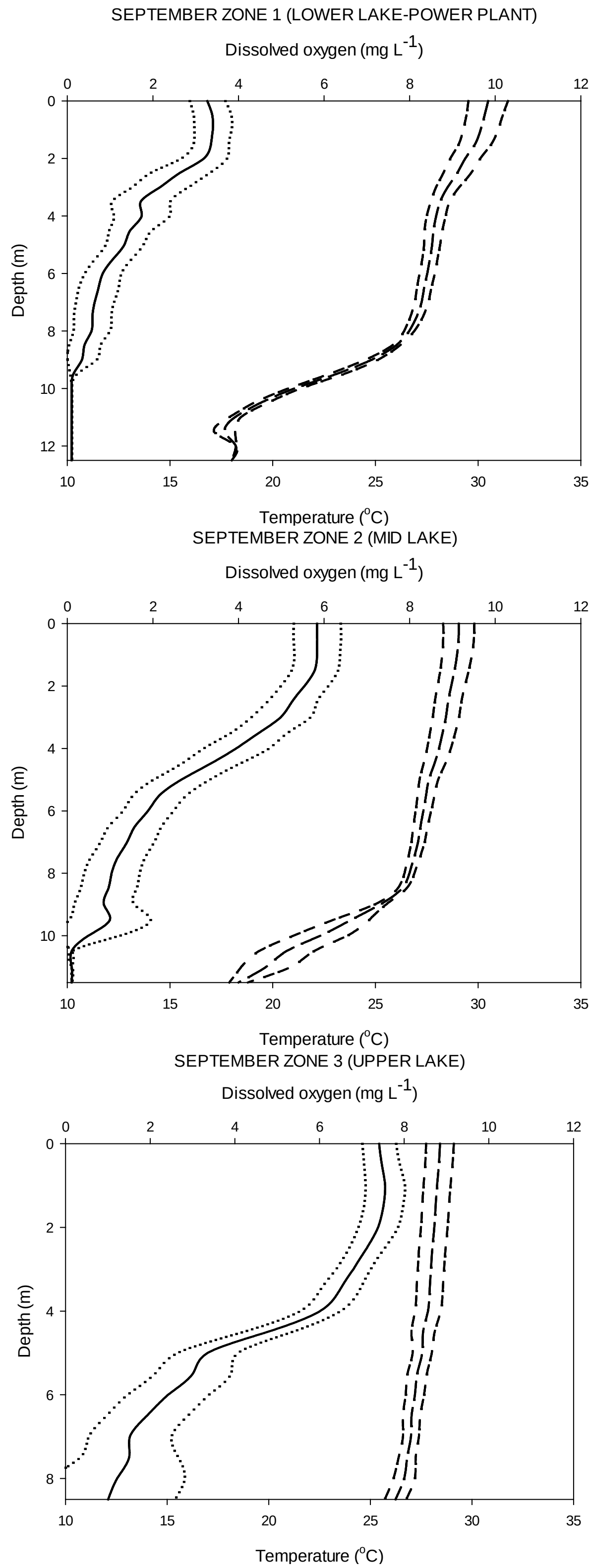

Figure 7-6. Average +/- 95% confidence intervals for temperature (dashed) and DO (solid and dotted) from the upper (top), mid (middle), and upper (bottom) during September 2016.

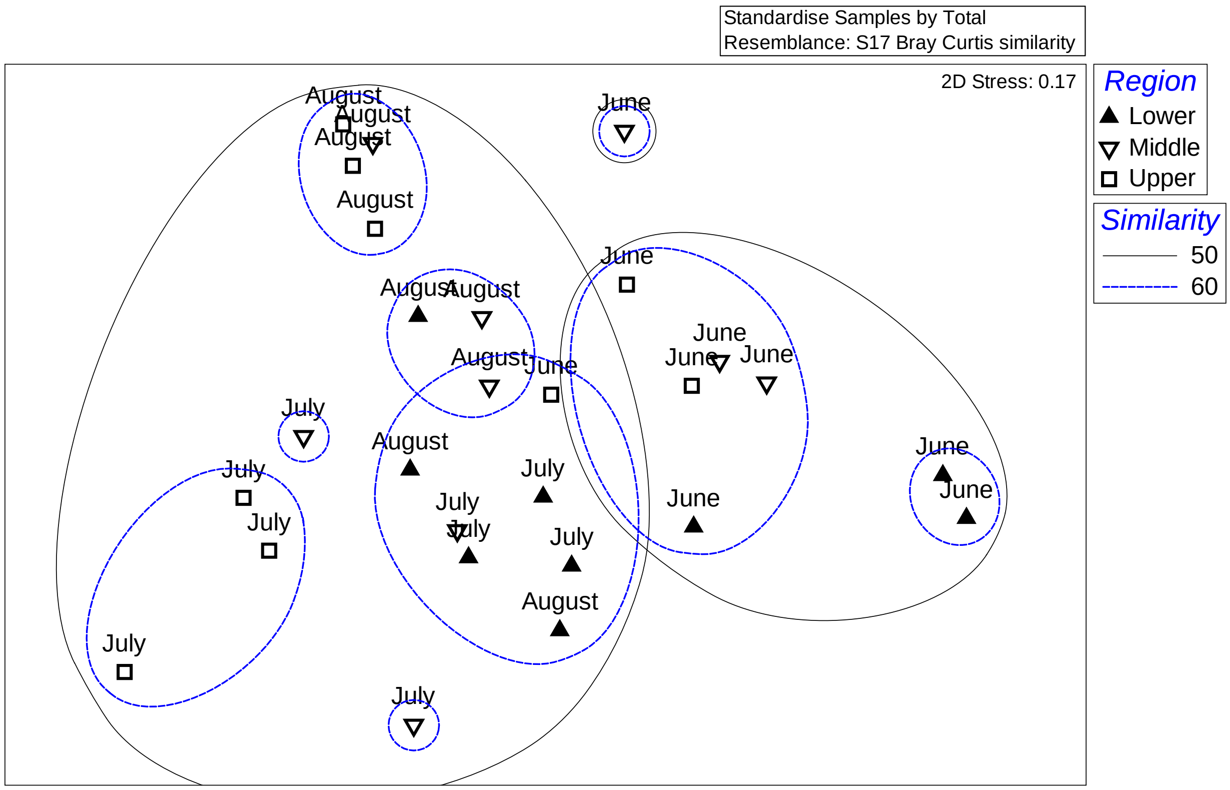

Figure 7-7. Non-metric multidimensional scaling plot for the phytoplankton community sampled from the lower (filled triangles), mid (open inverted triangles), and upper (open squares) zones of Lake of Egypt during summer 2016. The blue ellipses represent 60% community similarity among sites and black ellipses represent 50% community similarity among sites. Points close in space represent high community similarity between sites based on 1 – Bray-Curtis dissimilarity index. Points far apart represent low community similarity between sites based on 1 – Bray-Curtis dissimilarity index.

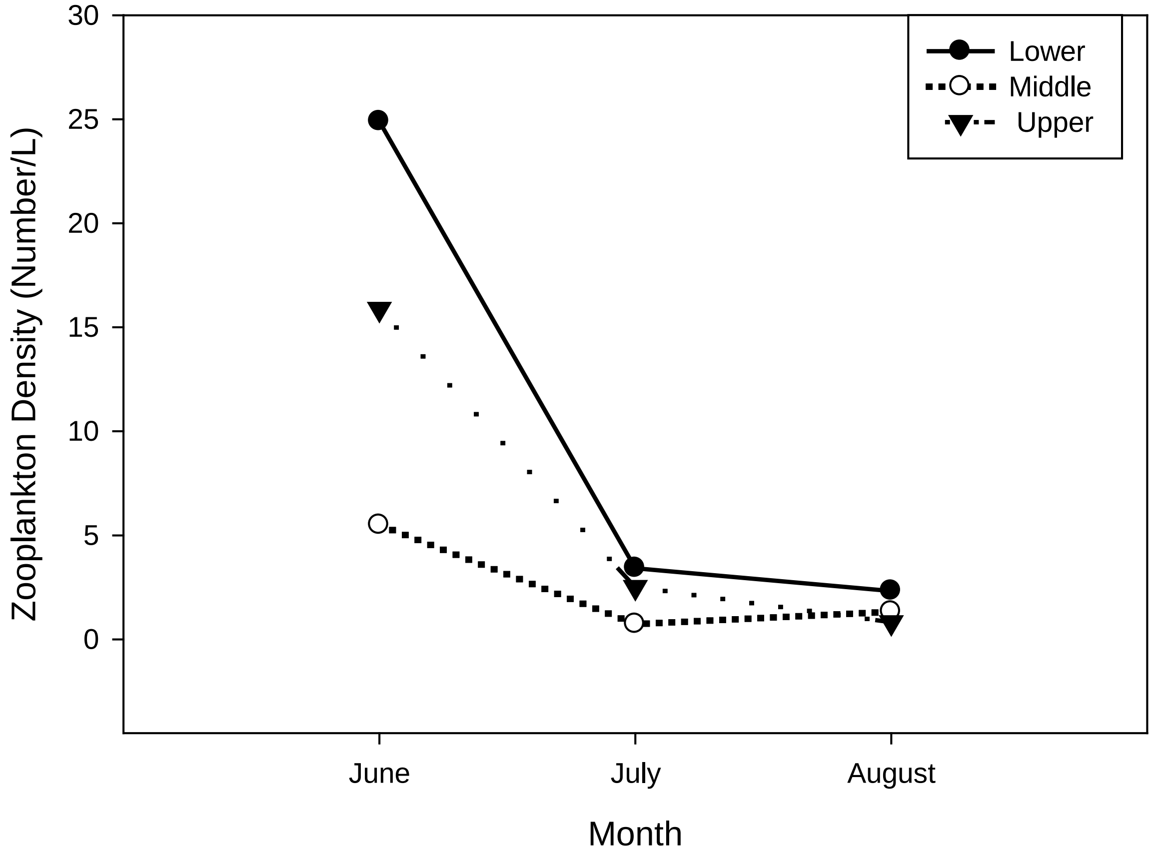

Figure 7-8 Average zooplankton density sampled from the lower (filled circles and solid line), mid (open circles and dotted line), and upper (filled triangles and dashed line) zones of Lake of Egypt by month.

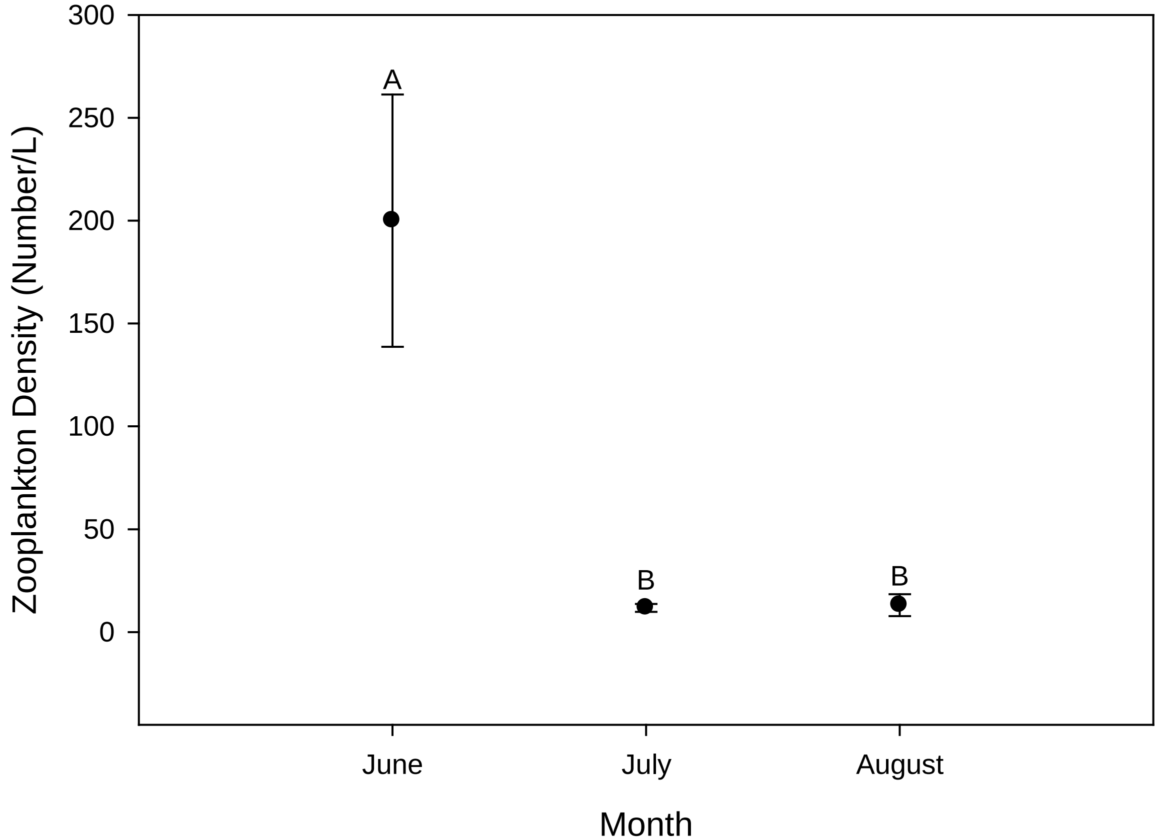

Figure 7-9. Average zooplankton density +/- S.E. sampled by month from Lake of Egypt. Different letters represent statistical differences at $p < 0.05$.

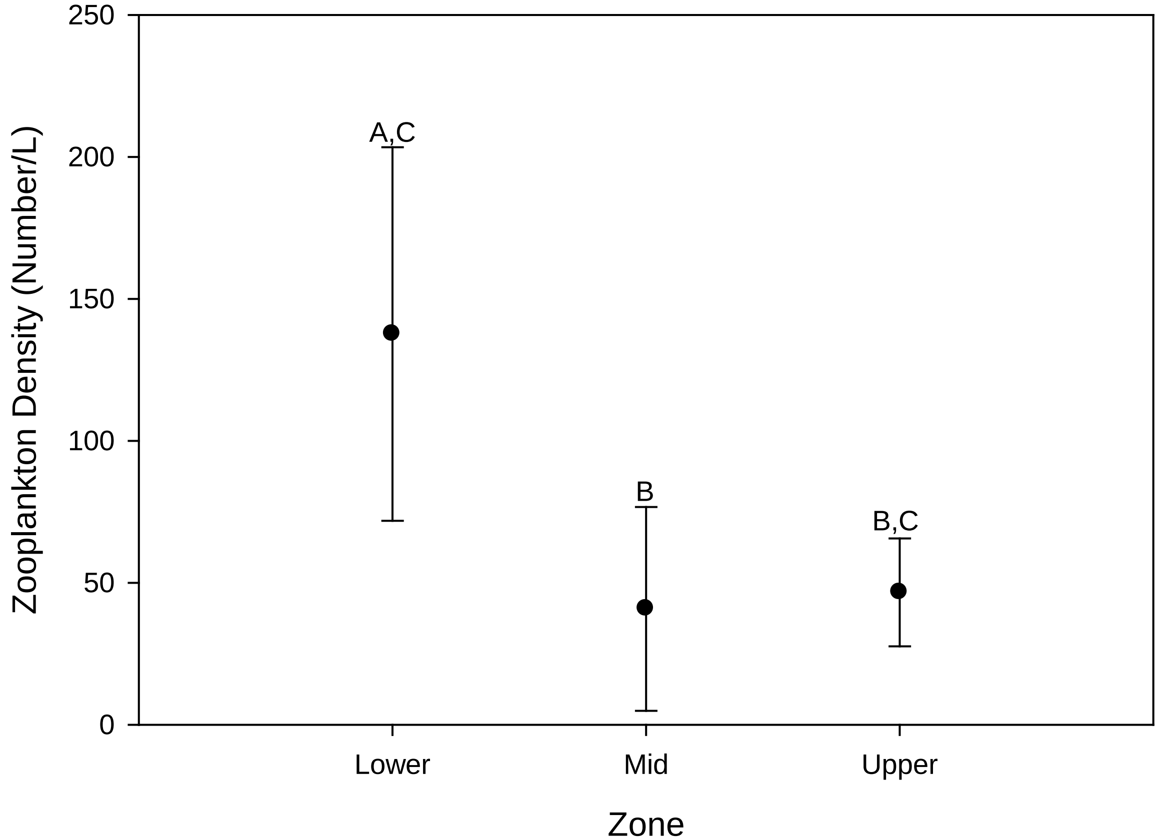

Figure 7-10. Average zooplankton density +/- S.E. sampled by lake zone from Lake of Egypt. Different letters represent statistical differences at $p < 0.05$.

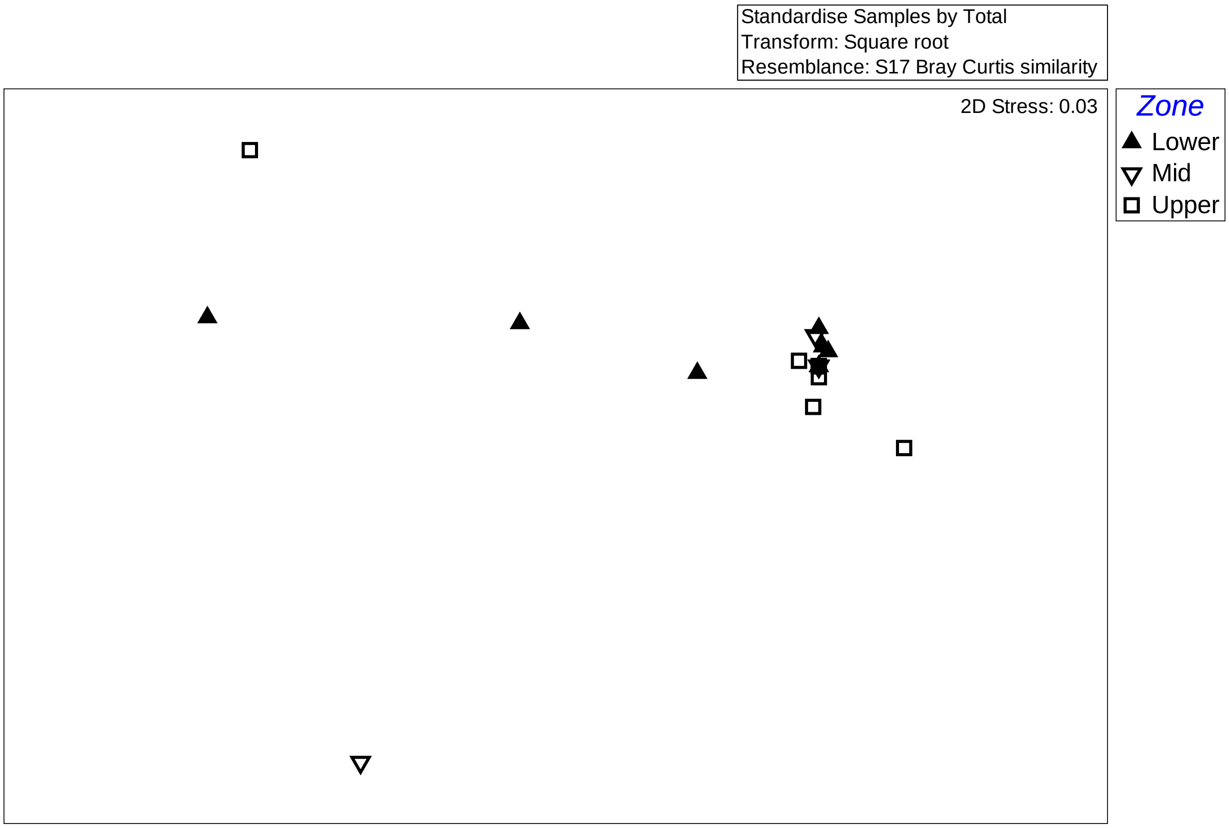

Figure 7-11. Non-metric multidimensional scaling plot for the zooplankton community assemblage sampled from the lower (filled triangles), mid (inverted open triangles), and upper (open squares) zones of Lake of Egypt during summer 2016. Points close in space represent high community similarity between sites based on 1 – Bray-Curtis dissimilarity index. Points far apart represent low community similarity between sites based on 1 – Bray-Curtis dissimilarity index.

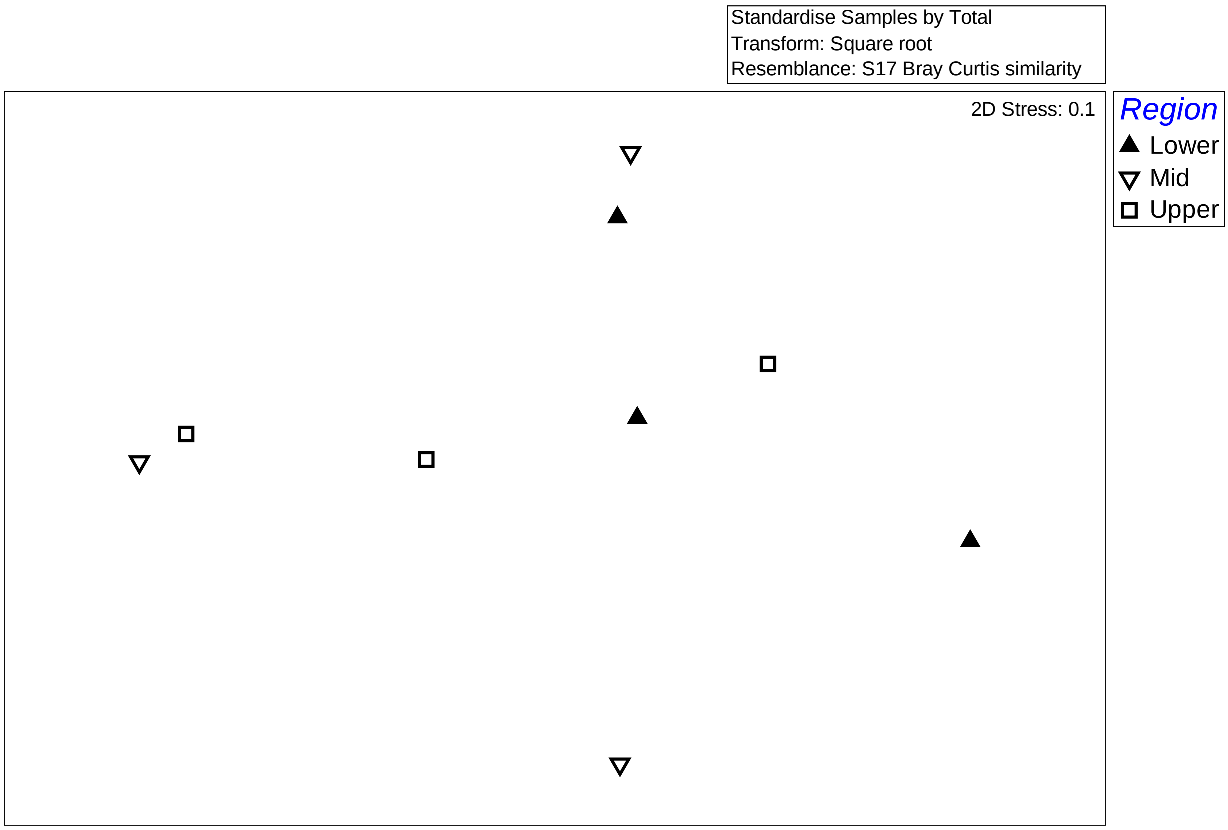

Figure 7-12. Non-metric multidimensional scaling plot for the macroinvertebrate community assemblage sampled from the lower (filled triangles), mid (inverted open triangles), and upper (open squares) zones of Lake of Egypt during summer 2016. Points close in space represent high community similarity between sites based on 1 – Bray-Curtis dissimilarity index. Points far apart represent low community similarity between sites based on 1 – Bray-Curtis dissimilarity index.

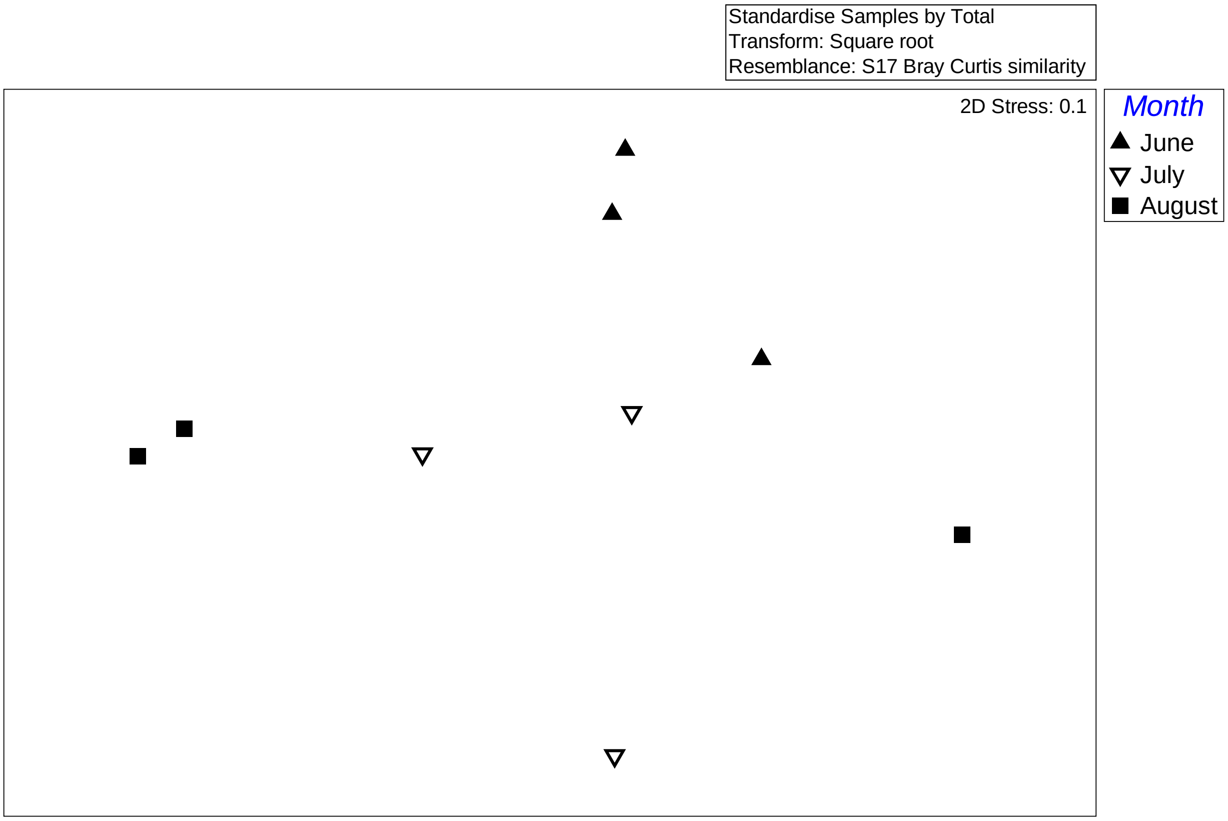

Figure 7-13. Non-metric multidimensional scaling plot for the macroinvertebrate community assemblage sampled during June (filled triangles), July (inverted open triangles), and August (Filled squares) in Lake of Egypt during summer 2016. Points close in space represent high community similarity between sites based on 1 – Bray-Curtis dissimilarity index. Points far apart represent low community similarity between sites based on 1 – Bray-Curtis dissimilarity index.

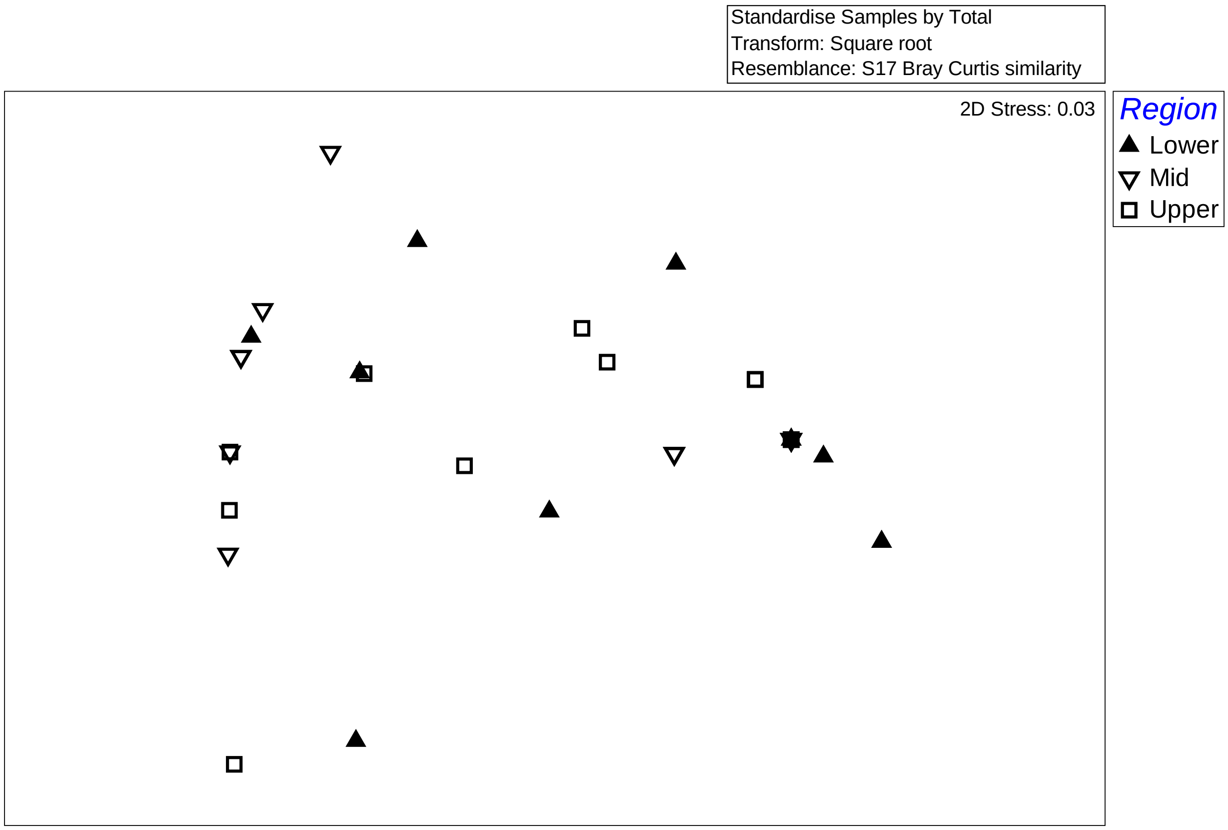

Figure 7-14. Non-metric multidimensional scaling plot for the substrate sampled from the lower (filled triangles), mid (inverted open triangles), and upper (open squares) zones of Lake of Egypt during summer 2016. Points close in space represent high community similarity between sites based on 1 – Bray-Curtis dissimilarity index. Points far apart represent low community similarity between sites based on 1 – Bray-Curtis dissimilarity index.

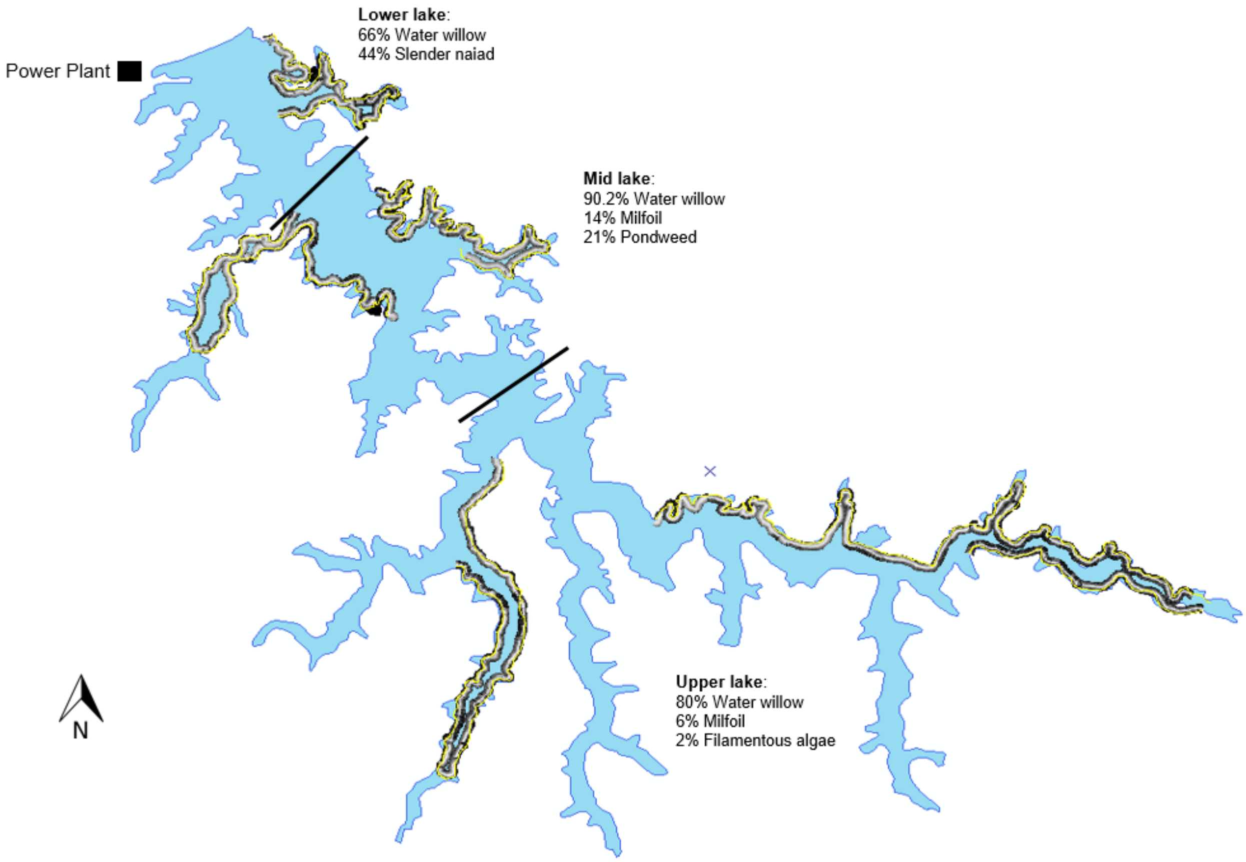

Figure 7-15. Vegetation map of physical transects coupled with slow speed (<3 mph) side-scan sonar transects completed during August 2016. Values of coverage are extrapolated to entire section.

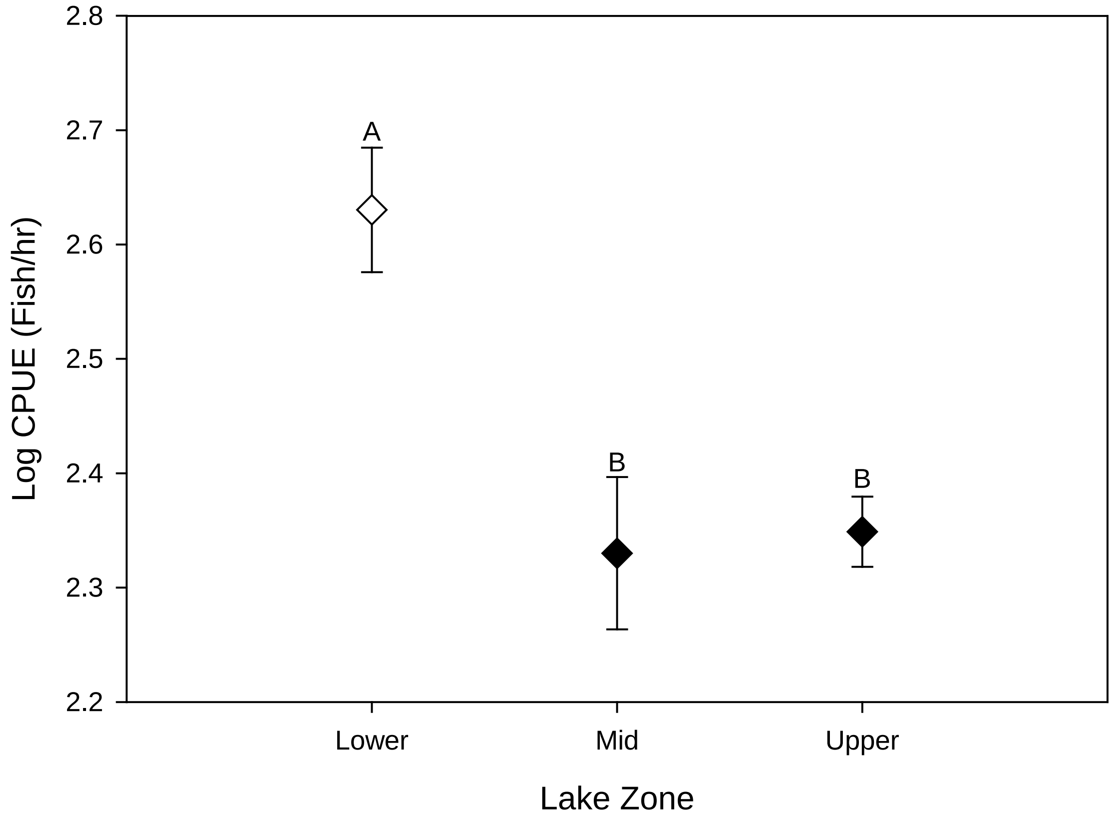

Figure 7-16. Average +/- S.E. relative density (Fish/hr) of fishes sampled using AC electrofishing from the three lake zones of Lake of Egypt during fall 2017. Different letters represent statistical differences at $p < 0.05$.

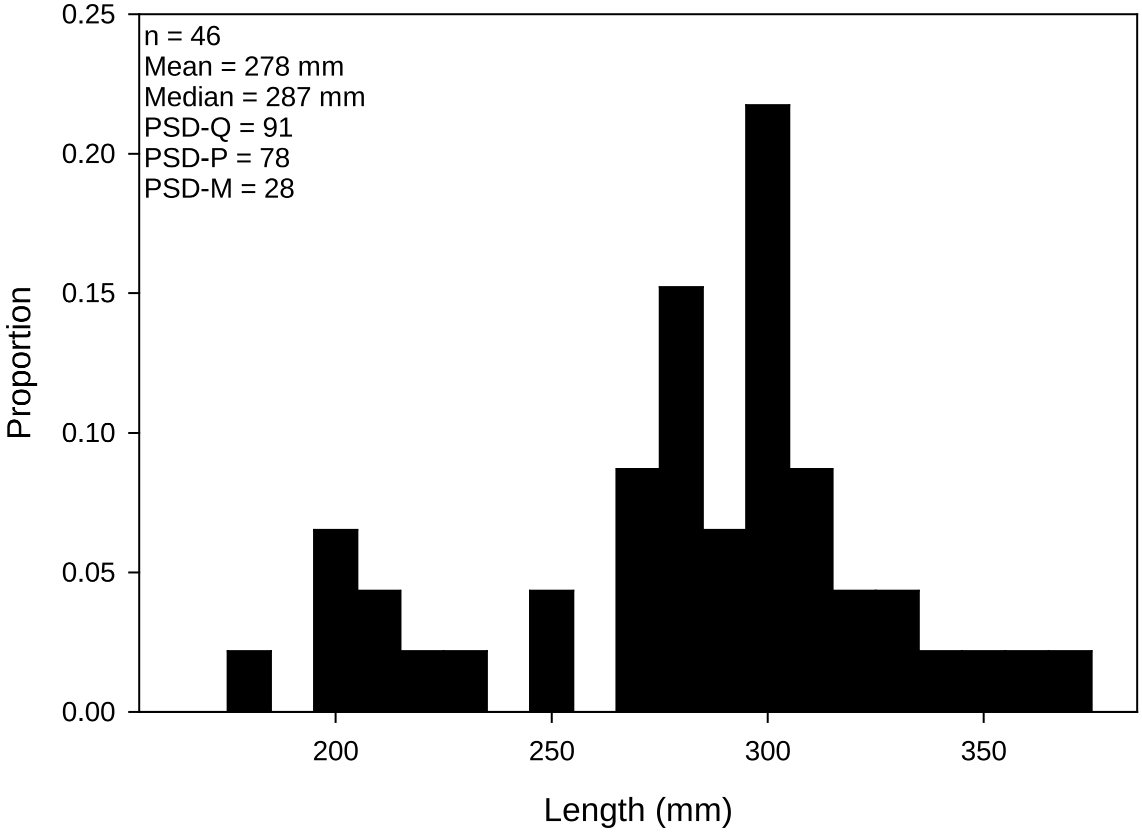

Figure 7-17. Length frequency distribution of black crappie sampled from Lake of Egypt during fall 2016 using both AC electrofishing and trap nets. PSD-Q (proportion of fish greater than quality length, 200 mm), PSD-P (proportion of fish greater than preferred length, 250 mm), PSD-M (proportion of fish greater than memorable, 300 mm).

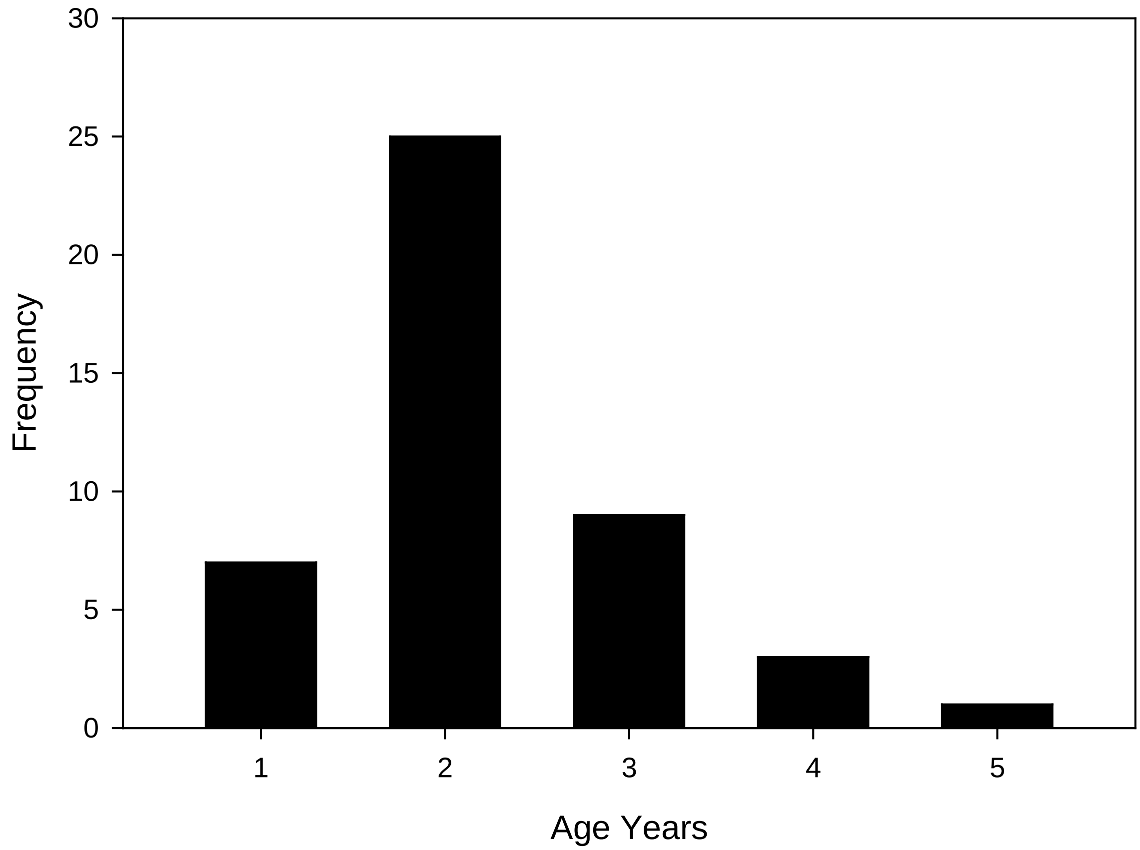

Figure 7-18. Age structure of black crappie sampled from Lake of Egypt during fall 2016 using both AC electrofishing and trap nets.

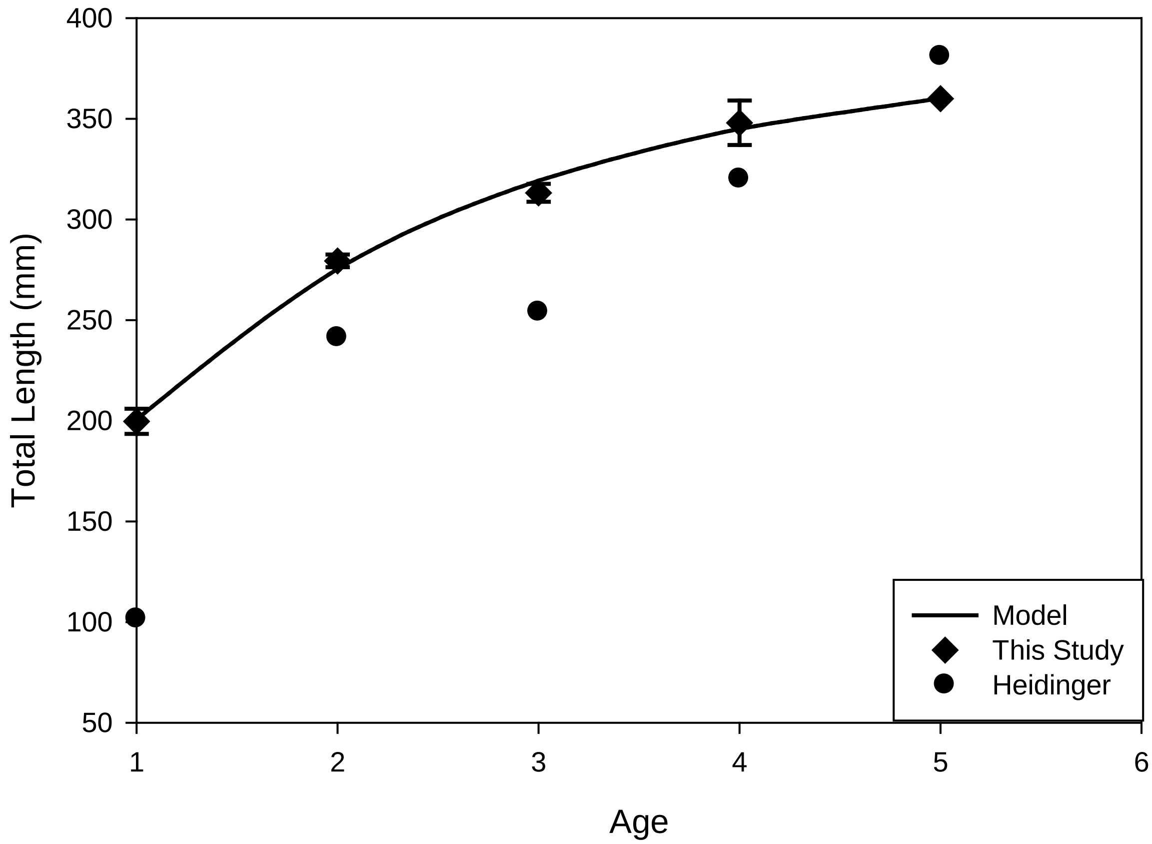

Figure 20. Mean length at age for black crappie sampled during by EIU fall 2016 (triangles) and Heidinger fall 2007 (circles). Solid line represents the von Bertalanffy growth model for crappie sampled during fall 2017 ($Lt = 381*(1 – e^{(-0.532*(t-0))})$).

Appendix: Abundance of Phytoplankton genera by lake zone and month.

PHYLUM	GENERA	Lower			Mid			Upper		
		June	July	August	June	July	August	June	July	August
Bacillariophyta										
	Asterionella	0	0	0	53	0	0	32	0	0
	Fragilaria	201	928	480	379	837	488	457	3664	387
	Synedra	306	320	192	352	104	112	181	280	240
	Acanthoceras	270	0	0	187	112	0	32	0	0
	Cyclotella	192	128	224	160	248	160	46	320	160
	Stephanodiscus	78	672	736	288	520	408	184	80	627
	Aulacoseira	2889	704	96	464	117	568	918	200	0
	Achnanthes	0	32	352	64	0	232	32	0	253
	Navicula	32	64	320	59	99	184	0	176	133
	Nitzschia	224	320	160	0	269	80	0	168	240
Chlorophyta										
	Elakatothrix	0	32	0	0	0	0	23	32	0
	Actinastrum	0	0	0	0	0	0	0	40	40
	Ankistrodesmus	421	64	192	443	40	120	278	72	80
	Chodatella	119	32	64	155	64	40	150	0	133
	Coelastrum	0	0	32	27	0	0	64	0	0
	Crucigenia	0	224	96	0	176	80	0	72	160
	Dictyosphaerium	32	96	288	80	224	184	0	80	187
	Golenkinia	151	0	32	315	67	176	310	120	467
	Oocystis	0	32	64	59	72	0	32	0	80
	Pediastrum	32	192	64	187	53	0	158	32	0
	Polyedriopsis	0	32	32	0	59	0	0	40	200
	Scenedesmus	187	320	288	213	235	752	184	176	613
	Selenastrum	590	832	576	907	597	584	719	264	587
	Tetraedron	64	160	128	64	53	72	104	112	227
	Tetrastrum	23	32	64	27	0	72	32	40	80
	Treubaria	160	96	96	171	93	72	280	120	53
	Euastrum	0	32	64	32	0	40	0	0	0

		Lower			Mid			Upper		
PHYLUM	GENERA	June	July	August	June	July	August	June	July	August
Chlorophyta										
	Staurastrum	0	0	32	112	96	0	40	40	40
	Chlamydomonas	329	640	384	912	339	480	616	296	493
	Chlorogonium	32	32	32	0	0	40	0	0	0
	Gonium	0	0	96	0	0	200	0	0	80
	Phacotus	0	32	32	64	0	0	23	0	0
Chrysophycea										
	Dinobryon	110	0	0	64	0	0	127	0	0
Cryptophyta										
	Chroomonas	512	1760	1344	336	1355	1024	661	1472	1587
	Cryptomonas	78	160	96	59	400	168	95	440	80
Cyanobacteria										
	Anabaena$	261	160	128	277	349	256	258	600	893
	Aphanizomenon$	416	1120	992	1264	1104	1784	1215	1472	2640
	Chroococcus	0	0	0	0	0	152	0	40	0
	Merismopedia	64	32	64	0	0	80	0	32	120
	Microcystis	544	352	800	555	355	512	586	408	933
	Spirulina	46	32	32	0	240	208	87	848	467
Dinophyta										
	Ceratium*	187	0	0	117	40	0	40	0	40
	Peridinium*	87	96	96	635	147	1672	357	264	4507
Euglenophyta										
	Euglena	251	224	416	208	677	328	86	912	173
	Lepocinclis	0	0	0	0	72	0	72	0	0
	Trachelomonas	329	192	128	427	91	224	287	136	0

$ = Low Nutrient Specialist
* = Thermally Tolerant species