Ameren-Labadie Thermal Variance Request
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April 8, 2020

Mr. Chris Wieberg, Program Director
Water Protection
Missouri Department of Natural Resources
PO Box 176
Jefferson City, Mo 65102-1076

RE: NPDES Permit Number MO-0004812
Request for 316(a) Variance
Ameren Missouri's Labadie Energy Center

Dear Mr. Wieberg:

In accordance of the terms of the NPDES Permit MO-0004812 for the Ameren Missouri Labadie Energy Center, we are herein submitting the final document of the 316(a) variance request. Enclosed are multiple reports that support the Final document, as well as an updated Comment-Response document from the previous draft submittal.

Ameren staff is available to discuss any details of this Variance at your convenience. Please do not hesitate to contact Ms. Meghan Kohlbusch at 314-309-8187 or me at 314-315-3035 if you have any questions or comments.

Sincerely,

Craig J. Giesmann

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LABADIE ENERGY CENTER
§316(a) FINAL DEMONSTRATION

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April 2020

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EXECUTIVE SUMMARY

The Labadie Energy Center (LEC) is a steam electric power plant located in Labadie, Missouri on the south bank of the lower Missouri River near River Mile (RM) 57 in Franklin County. The LEC has four generating units and a total net capacity of 2,580 megawatts (MW) and utilizes a once-through cooling water system withdrawing water from the Missouri River. The resulting heated effluent is discharged (via National Pollution Discharge Elimination System (NPDES) Permit MO-0004812, Outfall 001) to a 1,400-foot-long discharge canal and the adjacent navigation channel of the Missouri River.

The current LEC NPDES permit final effluent limitations became effective on August 1, 2018 and are based on a site-specific thermal model that establishes an effluent limitation of 0.95 for the Thermal Discharge Parameter (TDP), a calculated parameter used as an index of compliance with the Missouri Water Quality Standards ($MWQS_{t.}$) for temperature. The model established that an effluent limitation of 0.95 for the TDP value would ensure compliance with the $MWQS_{t.}$. The TDP limit incorporates a 5 percent margin of safety to ensure compliance with the $MWQS_t$ at the edge of the allowable mixing zone. Nevertheless, the potential for occasional, infrequent exceedances (less than one percent of the time on average based on existing data) of the $MWQS_{t.}$ for temperature exists during conditions of extraordinarily high ambient river temperature and/or extraordinarily low river flow leading Ameren to seek alternative thermal effluent limitations (i.e., a thermal variance from the otherwise applicable effluent limit for the receiving water body).

Ameren is proposing the following alternative temperature effluent limit to ensure continued operation of the LEC while, at the same time, assuring the protection and propagation of a balanced indigenous community in the lower Missouri River (LMOR):

- A TDP of greater than 0.95 will be allowed under conditions when the river flow is less than 40,000 cubic feet per second or ambient river temperatures are greater than 87°F;
- A TDP of greater than 0.95 will be allowed in no more than 6 percent of the days in any calendar year; and
- On any day where the TDP is greater than 0.95, the mixing zone must be less than 40 percent of the volume of the river as calculated by the equations in the permit.

This Demonstration uses a retrospective assessment to evaluate whether the LEC past and current operation has resulted in appreciable harm to the aquatic biota in the LMOR near the LEC and a predictive assessment to determine whether the proposed alternative effluent limits for temperature will assure the protection and propagation of the balanced indigenous community (BIC) of the LMOR.

Screening Results for Biotic Categories

Historical biological data collected in the vicinity of the LEC and from the LMOR were evaluated relative to the seven United States Environmental Protection Agency (USEPA) decision criteria and for each of six biotic categories to address the potential for impacts from LEC's thermal discharge. The evaluation indicated that the LMOR within the LEC study area successfully met the USEPA decision criteria for being considered an area of Low Potential Impact (LPI) for four of the six biotic categories, including the shellfish component of the benthic macroinvertebrate category. A summary of the rationale for LPI biotic categories is as follows:

- **Phytoplankton** - the Missouri River food web is detrital based. Phytoplankton have limited exposure to the thermal plume (less than 90 minutes). There is no evidence indicating that the LEC thermal discharge has caused, or has the potential to cause, a shift towards nuisance phytoplankton taxa.

- **Zooplankton and Meroplankton** - The Missouri River has a low standing crop of zooplankton. Zooplankton and meroplankton drifting downstream are exposed to the thermal plume for a limited duration (less than 90 minutes) due to the flow of the river and the thermal plume affects a relatively small proportion of the LMOR near the LEC (discharge flow is typically less than 5 percent of the river flow).
- **Habitat Formers** – The area in the vicinity of the thermal discharge is devoid of habitat formers due to the River's velocity, turbidity, and silty substrate and would remain so even if the LEC thermal discharge were removed.
- **Shellfish** - The shellfish component of the benthic macroinvertebrate assemblage occur only rarely in the vicinity of the LEC thermal discharge and, hence, has little potential for exposure to the thermal plume. During the current study, no live shellfish were observed either upstream or downstream of the discharge during the visual surveys. No threatened or endangered shellfish species were collected in benthic macroinvertebrate samples and no shells of threatened or endangered shellfish were observed in the visual surveys.
- **Other Vertebrates** - Non-fish vertebrate wildlife such as waterfowl have minimal and intermittent exposure to the LEC thermal discharge and are therefore not vulnerable to direct effects from the thermal discharge.

Hence, detailed analysis of prior appreciable harm was limited to the two remaining biotic categories: fish and benthic macroinvertebrates.

Retrospective Assessment

As presented in this Demonstration, the Retrospective Assessment includes a spatial component comparing communities in the area exposed to the thermal discharge with those in a reference area representing the BIC to evaluate whether appreciable harm has occurred to the fish and benthic macroinvertebrate components of the BIC due to the LEC thermal discharge. A temporal component (fish only) is also included to evaluate changes in the BIC over time.

Evaluation of Prior Appreciable Harm to Fish

Spatial analysis of the data collected during the recent two-year biological monitoring program shows that the LEC thermal discharge is not causing appreciable harm to the fish assemblage. Overall, the fish assemblage abundance, composition, diversity, and abundance of heat tolerant species were similar between the Upstream Reference, Thermally Exposed, and Downstream zones. A "standardized difference" analysis of the combined spatial data incorporating all the metrics evaluated was conducted to compare the Upstream Reference zone to Thermally Exposed zone and to the Downstream zone over all seasons. The distributions in all instances were centered near 0 with mean differences smaller than the standard error indicating that the differences are not likely to be biologically meaningful.

The temporal analysis comparing electrofishing data collected during historical and current studies at corresponding sampling sites at the LEC shows that the LEC thermal discharge has not caused appreciable harm to the fish assemblage. Many of the metrics evaluated (e.g., abundance, diversity, community composition) were either similar between historical and present data or demonstrated similar temporal trends in both the Upstream Reference and Thermally Exposed zones indicating that any observed differences are not due to the LEC thermal discharge. A "standardized difference" analysis of the temporal data for the Upstream Reference and Thermally Exposed zones had positive mean differences indicating some improvement in ecological metrics over time in both zones.

Taken together, the results from the spatial, temporal, and "standardized difference" analyses indicate that there has been no appreciable harm to the fish component of the aquatic community resulting from the LEC thermal discharge.

Evaluation of Prior Appreciable Harm to Benthic Macroinvertebrates

Spatial analysis of the data collected during the recent two-year biological monitoring program shows that the LEC thermal discharge is not causing appreciable harm to the benthic macroinvertebrate assemblage. Benthic macroinvertebrate densities were variable between zones, gears, and seasons but did not show patterns consistent with a thermal effect. Overall, the total number, density, diversity, and abundance of sensitive taxa was similar between Upstream Reference, Thermally Exposed, and Downstream zones for both drifting organisms and infaunal organisms. The Discharge Zone, where sampling was conducted within the unmixed thermal effluent and immediately downstream of the confluence with the Missouri River, as would be expected, exhibited lower numbers in all three categories for both collection gears.

A "standardized difference" analysis of the combined spatial data incorporating all the metrics evaluated for each collection gear was conducted to compare the Upstream Reference zone to Thermally Exposed zone and to the Downstream zone over all seasons. The mean differences in both zone comparisons were slightly negative. However, the magnitude of the shifts is small and about the same as the standard errors suggesting the shifts are not large enough to be biologically meaningful.

In addition, if any of the potential adverse effects were due to the thermal discharge, one would expect the shift from the Upstream Reference zone to Thermally Exposed zone comparison to be greater than the shift for the Upstream Reference zone to Downstream zone comparison. Since the values are nearly identical, the analysis suggests that any potential minor adverse effects are not due to the LEC thermal discharge. The spatial and "standardized difference" analyses indicate that there has been no appreciable harm to the benthic macroinvertebrate component of the aquatic community resulting from the LEC thermal discharge.

Overall, the results of the retrospective assessments show that there has been no appreciable harm to the BIC resulting from prior LEC thermal discharges.

Predictive Assessment

The focus of the predictive assessment is on the relatively rare events (<1 percent of the time) when the TDP limit is greater than 0.95 and the $MWQS_{t.}$ for temperature could be exceeded. The potential thermal exposures during these rare events were assessed using three-dimensional hydrodynamic modeling (FLOW-3D) results and data from two days reflecting the most extreme conditions over the 17-year data record during the most biologically active periods of the year. Actual river and discharge flows and temperatures from June 22, 2006 ("June Model') were used in the model reflecting the most extreme conditions during the spring spawning and nursery period. Similarly, actual river and discharge flows and temperatures from July 21, 2006 ("July Model") were used reflecting the most extreme conditions during the high temperature period in summer.

In both cases, the resulting plume hugs the south shore immediately downstream of the discharge with the plume extending only part way across the LMOR. For the June conditions, temperatures above 90°F were limited to areas within one mile of the discharge and were restricted to areas along the south shore of the LMOR. For July, temperatures above 90°F were limited to areas within about 5.5 miles of the discharge and principally in the southern half of the LMOR.

Exposure of Drifting Organisms

In the June 2006 model run, the background temperature was 83.58°F and only 23 percent of virtual particles "released" by the model along a transect upstream of the LEC discharge were exposed to temperatures in excess of the $MOWQS_t$. In the July 2006 model run, the background temperature was higher at 88.88°F but less than 18 percent of the virtual particles were exposed to temperatures in excess of the $MOWQS_t$. The resulting time vs temperature plots reveal a rapid decline in exposure temperatures within the first 20 to 30 minutes after encountering the discharge, due primarily to turbulence and the high volume of river flows compared to plant discharge flows within the LMOR leading to rapid mixing.

Temperature measurements at the downstream end of the Zone of Initial Dilution (ZID) of the discharge plume revealed that most of the time temperatures were 4°F or less above ambient. Further, only 10 percent of the measurements were greater than 6°F above ambient and all of these were during the coldest periods of the year with little biological productivity.

Representative Important Species

Representative Important Species (RIS) were selected to reflect the biotic components of the indigenous community that were not deemed to be low potential for impact. The following RIS were selected for this predictive assessment:

RIS	Rationale
Channel catfish	Recreational species
Emerald shiner	Important food chain species
Gizzard shad	Important food chain species
Pallid sturgeon	Endangered species
Walleye/sauger	Recreational and temperature sensitive species
White crappie	Recreational and temperature sensitive species

Heat Shock

The life-history characteristics of some RIS serve to limit their potential exposure to the LEC thermal discharge. For those early life stages that would be exposed to the thermal discharge while drifting with the current, exposures were shown to be of relatively short duration (e.g., $\leq$80 minutes). Exposure temperatures at, or exceeding, the thermal limits of early RIS life stages were present in only a small proportion of the LMOR (typically less than 1 percent) and for very short durations (typically less than 30 min.). In addition, temperatures above thermal heat shock limits would be experienced less than 25 percent of the time for all RIS under worst-case conditions. Comparison of the model results to the thermal tolerance literature values for the early life stages of the RIS show that there is little likelihood of heat shock mortality to any of the RIS as a result of the LEC thermal discharge.

Cold Shock

Information needed to assess the potential for cold shock associated with the complete shutdown of all units at the LEC was available for three of the six RIS selected for this assessment. In all cases, the lower incipient lethal temperatures (LILT) were less than the temperature exposures that would occur with complete shutdown of all units at the LEC. Further, the likelihood that all units would be simultaneously shut down at the LEC is exceedingly low. Therefore, there does not appear to be any potential for mortality associated with cold shock at LEC.

Indirect Effects on Reproduction and Development

Temperatures to which the RIS could potentially be exposed in the worst-case scenarios were compared to the literature-based thermal tolerance data for growth and reproduction for each RIS. In all cases, reproduction and growth would either not be affected or would be accelerated leading to slightly earlier reproduction and greater growth. Therefore, there are no adverse effects expected due to exposure to the elevated temperatures from the LEC thermal discharge.

Effects on Habitat and Migration

For four of the six RIS (channel catfish, emerald shiner, gizzard shad, and white crappie) the entire cross-section of the water column is available as a zone of passage under typical conditions. Under worst-case conditions the cross-sectional area would be reduced for gizzard shad and white crappie, however approximately half of the cross-sectional area in the vicinity of the LEC would still be available as a zone of passage.

For walleye/sauger, both cool water species, ambient temperatures frequently exceed their avoidance temperatures during summer, however their use of the LEC vicinity at this time of the year is limited. As ambient temperatures approach their avoidance temperatures, these species would be expected move to cooler areas upstream or to other areas of thermal refuge. Their use of areas near the LEC is primarily during spawning migration in late winter and early spring when exposure temperatures should be substantially lower than reported avoidance temperatures indicating no potential for blockage of migration.

While estimates of avoidance temperatures for pallid sturgeon are not available, the fact that this species would most likely be found in deeper channel area with little exposures to elevated temperatures, suggests little potential for migratory blockage

Master Rationale

Under § 316(a) of the Clean Water Act, 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.

Indicators of Appreciable Harm

USEPA's § 316(a) technical guidance provides a number of criteria to evaluate in demonstrating the absence of appreciable harm, as follows:

1. Presence of all trophic levels
2. Presence of necessary food chain species
3. Diversity
4. Capability to sustain itself
5. Lack of domination of pollution (heat) tolerant
6. No increase in nuisance species
7. Increase or decrease of indigenous species
8. No decrease in threatened and/or endangered species
9. No habitat exclusion due to temperature
10. Maintenance of a zone of passage

11. Change in commercial or sport species
12. No habitat former alterations
13. Magnitude and duration of any identifiable thermal effects
14. Sublethal or indirect effects
15. No thermal effects on rare or unique habitats
16. Presence of critical function zones within thermally exposed areas
17. Trends in the aquatic community
18. Interaction of the thermal discharge with other pollutants

These criteria focus the determination on population and community impacts. Still, demonstrating that the BIC is or will be assured in any receiving water body can be problematic since no operational definition of "balanced" is provided by the USEPA, and no quantitative standard for balance has ever been proposed. In this case, a weight-of-evidence approach using multiple lines of evidence for the LEC is used to evaluate the USEPA criteria and determine whether the thermal discharge has caused appreciable harm to the BIC in the receiving waterbody.

Weight of Evidence Rationale for No Prior Appreciable Harm

Each of the appreciable harm criteria are addressed below using the results of the screening analysis and retrospective and predictive assessments conducted as part of this Demonstration.

1. *Presence of all trophic levels*

The composition of the aquatic community in the Thermally Exposed and Downstream zones shows the presence of the necessary trophic levels similar to the Upstream Reference zone indicating that the structure of the community has not been adversely affected by exposure to the LEC thermal discharge.

2. *Presence of necessary food chain species*

The composition of the aquatic community in the Thermally Exposed and Downstream zones shows the presence of the necessary food chain species similar to the Upstream Reference zone indicating that the structure of the community has not been adversely affected by exposure to the LEC thermal discharge.

3. *Diversity*

Diversity profiles for the spatial and temporal (fish only) analyses for the both fish and benthic macroinvertebrates show that diversity profiles for both assemblages were similar to those in the Upstream Reference zone. Thus, the data demonstrate that diversity has been maintained over time and has not been adversely affected as a result of exposure to the LEC thermal discharge.

4. *Capability to sustain itself*

The results of the predictive and retrospective assessments demonstrate that the biological community near the LEC is self-sustaining. The predictive analysis demonstrated the absence of mortality and negative effects on growth and development as a result of exposure to the LEC thermal plume for all life stages of the selected RIS. This is supported by the retrospective analysis which showed the presence of multiple year classes of fish present and no substantial shifts in the fish community over time and no substantial changes in the current fish or benthic macroinvertebrate assemblages between the Upstream Reference and Thermally Exposed zones.

5. *Lack of domination of pollution (heat) tolerant species*

Fish and benthic macroinvertebrate assemblages were dominated by heat tolerant taxa of similar abundance in the Upstream Reference, Thermally Exposed, and Downstream zones. The temporal analysis of the fish data show that heat tolerant taxa have not increased in the Thermally Exposed zone over time and remain at similar proportions as in the Upstream Reference zone. Pollution/heat tolerant taxa have not increased as a result of exposure the LEC thermal discharge.

6. *No increase in nuisance species*

Species of Asian carp, including bighead, silver, and grass carp, are among the most notable non-native, nuisance species now present in the LMOR. The invasive Asian carp have become increasingly abundant in the vicinity of the LEC and the LMOR through a process of range expansion following their accidental escape into the Mississippi River basin and not due to the LEC thermal discharge.

7. *Increase/decrease of indigenous species*

River-wide modifications and loss of the natural riverine flow regime and habitats have greatly influenced the abundance of native species and affected the overall composition of the fish community resulting in the abundance of non-native species becoming greater than that of native species. These changes to native fish populations have occurred in response to irreversible river modifications that are unrelated to the LEC thermal discharge and would have resulted in the absence of the discharge.

The temporal retrospective analysis shows that the fish assemblage represented in electrofishing samples was similar in both the Upstream Reference and Thermally Exposed zones over time demonstrating that the LEC thermal discharge has not resulted in a decrease, locally or in the LMOR, of indigenous species.

8. *Decrease in threatened and/or endangered species*

The pallid sturgeon is the only federally endangered species potentially occurring in the vicinity of the LEC. Available information suggests that this species is declining throughout the Missouri River due to the loss of ecosystem integrity and the loss or alteration of preferred habitat and not due to the LEC's thermal discharge. Further, there are no designated critical habitat areas for pallid sturgeon in the LMOR.

9. *Habitat exclusion due to temperature*

Under typical and maximum plant operation little to no habitat exclusion is expected for any of the RIS. Walleye and sauger are not typically found in the LMOR near the LEC during the summer period since ambient river water temperatures are above their thermal tolerance limits. Any periods of habitat exclusion would be brief and limited to small areas just downstream of the discharge. Ample alternate habitat exists for all potentially affected species. The predictive assessment demonstrates that substantial areas of habitat would not be excluded for any RIS.

10. *Maintenance of zone of passage*

Under typical plant operation, five of the six RIS (channel catfish, emerald shiner, gizzard shad, white crappie, and pallid sturgeon) would have the entire river cross-section available as a zone of passage. Walleye/sauger are not typically found in the area of the LEC discharge during the summer when ambient temperature approach and exceed their avoidance temperatures. At other times of the year, the zone of passage for walleye/sauger would be maintained. Under worst-case conditions, the zone of passage for gizzard shad and white crappie would be reduced but they would still have approximately half of the river cross-section available as a zone of passage.

The predictive assessment demonstrates that a zone of passage would be maintained at all times for all RIS.

11. Change in commercial or sport species

The retrospective spatial analysis shows the abundance of game fish is approximately equal in the Upstream Reference, Thermally Exposed, and Downstream zones over all seasons and gear types. The temporal analysis shows that there was a slightly higher abundance of game fish collected in the historical Thermally Exposed zone electrofishing study than the present study. These analyses demonstrate that the LEC thermal discharge has not resulted in a change or decrease in the number of sport or game fish.

12. No habitat former alterations

The screening analysis concluded that the LMOR near the LEC was found to be an area of LPI for habitat formers due to the river's velocity, turbidity, and silty substrate which were limiting factors to the colonization and development of habitat formers. These conditions, along with physical alterations to the river shorelines and persistently unstable substrate conditions demonstrates that the absence of habitat formers in the vicinity of the LEC is not related to the discharge and, even in the absence of the discharge, habitat formers would not be able to colonize the area.

13. Magnitude and duration of any identifiable thermal effects

The retrospective and predictive assessments show that there are no discernable effects related to the LEC thermal discharge outside of the Discharge zone which is within the allowable mixing zone. At the most upstream end of the Thermally Exposed zone, temperatures within the thermal plume are, at most, 6°F above ambient. In addition, the thermal discharge is typically less than 5 percent of the Missouri River flow and the duration of any exposures are usually brief, transiting through the upper portion of the thermal plume within an hour and a half.

14. Sublethal or indirect effects

The predictive assessment shows all RIS may experience slightly earlier spawning and increased growth rates under the worst-case conditions associated with the LEC thermal discharge. Little to no difference in spawning or growth rates are expected under typical plant operating conditions. These results demonstrate that no adverse effects on reproduction or growth are associated with the LEC thermal discharge.

15. No thermal effects on rare or unique habitats

There are no habitats in the Thermally Exposed or Downstream zones designated as "unique or rare" for this portion of the LMOR.

16. Presence of critical function zones within thermally exposed areas

There are no critical function zones (e.g., critical spawning and nursery areas) present within the Thermally Exposed and Downstream zones for any of the RIS. The predictive assessment also showed that there would only be minor episodic exclusion from a small area of habitat within the Thermally Exposed zone and only under worst-case exposures.

17. Trends in the aquatic community

The retrospective analysis shows the aquatic community was similar over time and between the Upstream Reference and Thermally Exposed zones based on diversity and assemblage composition metrics. A standardized difference test combining the results of multiple community metrics showed that the differences between the zones was inconsequential and demonstrated no appreciable harm to the aquatic community.

18. Interaction of the thermal discharge with other pollutants

In the LMOR, there are no other sources of thermal discharges anywhere near the LEC such that there is no potential for additive or synergistic effects of the LEC's thermal discharges with any other thermal discharges.

The areas of the LMOR exposed to elevated temperatures is relatively small and the water passes through these exposed areas rapidly (< 2 hours). Hence, there is little likelihood that the relatively small increase in temperature will demonstrably increase the rate of algal growth, the rate of contaminant uptake, the rate of bacteria growth, or the rate of oxygen consumption and result in greater adverse impacts to the LMOR.

Overall, the results of this analysis demonstrate that the LEC's thermal discharge will not exacerbate existing environmental issues in the LMOR through additive or synergistic effects of the heat discharged combined with other existing thermal or other pollutants.

Overall Conclusions

Together the results of the screening analysis and the retrospective and predictive assessments demonstrate that no appreciable harm has or will occur to the BIC in the LMOR as a result of the LEC thermal discharge. The results of the screening analysis and the retrospective and predictive assessments were evaluated with respect to 18 decision criteria identified by the USEPA as indicators of appreciable harm. In each case the available data and analyses demonstrate that the decision criteria were satisfied indicating that no prior appreciable harm has occurred as a result of the LEC's ongoing thermal discharge and the requested alternative temperature limitations (§ 316(a) variance) will assure the protection and propagation of the BIC in the LMOR.

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LIST OF ABBREVIATIONS AND ACRONYMS

ATEL	Alternate Thermal Effluent Limitation
BIC	Balanced Indigenous Community
BIP	Balanced Indigenous Population
BSF	Benthic Fishes Study
BTU/hr	British Thermal Units per hour
CFR	Code of Federal Regulations
CFS	Cubic Feet per Second
CPUE	Catch per Unit Effort
CSR	Code of State Regulations
CTM	Critical Thermal Maximum
CWA	Clean Water Act
CWIS	Cooling Water Intake System
CXLD	Channel Cross-Over L-Dike
EAV	Emergent Aquatic Vegetation
EEH	Equitable Environmental Health
EPT	Ephemeroptera, Plecoptera, Trichoptera
FL	Fork Length
FPS	Feet per second
GPM	Gallons per Minute
H-D	Hester-Dendy
km	Kilometers
LEC	Labadie Energy Center
LILT	Lower Incipient Lethal Temperatures
LMOR	Lower Missouri River
LPI	Low Potential Impact
MDNR	Missouri Department of Natural Resources
mg/l	Milligrams per liter

mm	Millimeters
MMR	Middle Mississippi River
MISO	Midwest independent system operator incorporated
MW	Megawatts
$MWQS_t$	Missouri Water Quality Standards
NPAH	No Prior Appreciable Harm
NPDES	National Pollution Discharge Elimination System
OLD	Outside Bend L-Dike
PCB	Polychlorinated biphenyls
RIS	Representative Important Species
RM	River Mile
SAV	Submerged Aquatic Vegetation
T&E	Threatened and Endangered
TDP	Thermal Discharge Parameter
TL	Total Length
UEC	Union Electric Company
UILT	Upper Incipient Lethal Temperature
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
Wood	Wood Environment and Infrastructure, Inc.
ZID	Zone of Initial Dilution

1. INTRODUCTION

Ameren Missouri's (Ameren) Labadie Energy Center (LEC) is a steam electric power plant located in Labadie, Missouri on the south bank of the lower Missouri River (LMOR) near River Mile (RM) 57 in Franklin County, 35 miles west of St. Louis, Missouri (Figure 1-1). The LEC has four generating units, each with two circulating water pumps, and a gross generating capacity of 2,580 megawatts (MW). The LEC utilizes once-through cooling and withdraws water for each unit from the Missouri River via a shoreline intake structure (Figure 1-2). The resulting heated effluent is discharged to a 1,400-foot-long artificial discharge canal and the adjacent navigation channel of the LMOR (Figure 1-2). This discharge of heat is regulated through a National Pollutant Discharge Elimination System (NPDES) permit (MO-0004812) issued by the Missouri Department of Natural Rsources (MDNR).

1.1 LABADIE THERMAL REGULATORY HISTORY

For much of its operating life, the LEC has operated pursuant to variances duly authorized and issued under § 316(a) of the Clean Water Act. Biological studies and hydrothermal modeling were first performed in the mid-1970s as part of the facility's initial NPDES permit application. Those studies concluded that the LEC was a site of low potential impact for all biotic categories (EEH 1976; UEC 1976). An NPDES permit was issued in 1977 which included an approved alternate effluent limitation (§ 316(a) variance). Thereafter, MDNR renewed the § 316(a) variance over several permitting cycles until 2015. Although limited biological studies were periodically conducted, a complete new demonstration study was not performed. In issuing a renewed NPDES permit in 2015, MDNR noted a need for updated biological studies and established an interim thermal limitation substantively equalivent to the prior variance limitation. The MDNR also imposed a water-quality based final thermal effluent limitations and required Ameren to reestablish a biological monitoring program in accordance with 40 Code of Federal Regulations (CFR) 125 Subpart H. Specifically, in Section D.2.h, of the 2015 NPDES permit required:

> *Six months prior to permit expiration, the permittee shall submit a report detailing how the results of the monitoring program and the recommended path forward to achieve compliance. If a recommendation of the report is reissuance of the 316(a) variance, then a request for reissuance of the 316(a) variance must be submitted detailing how the monitoring program supports the requirements of no appreciable harm, specifically:*
>
> 1. *That no appreciable harm has resulted from the normal component of the discharge taking into account the interaction of such thermal component with other pollutants and the additive effect of other thermal sources to a balanced, indigenous community of shellfish and fish and wildlife in and on the body of water into which the discharge has been made; or*
> 2. *If applicable, that dispite the occurrence of such previous harm, the desired alternative efflluent limitations (or appropriate modifications thereof) will nevertheless assure the protection and propagation of a balanced, indigenous community of shellfish, fish and wildlife in and on the body of water into which the discharge is made.*

In 2016, Ameren requested a modifcation to the LEC NPDES permit to allow use of a site-specific model to determine compliance with Missouri Water Quality Standards ($MWQS_t$) using a combination of river flow, river temperature, effluent flow, and effluent temperature. The model established that an effluent limitation of 0.95 for the Thermal Discharge Parameter (TDP) value would ensure compliance with the $MWQS_t$. On May 3, 2017, MDNR issued a modified NPDES permit for the LEC establishing a thermal efflluent limitation of 0.95 for the TDP for both the interim (through July 31, 2020) and final (effective August 1, 2020) thermal effluent limtations, however

allowing the prior interim thermal effluent limitation of 11.16 x 10^9 British Thremal Units per hour (BTU/hr) whenever the river temperature exceeded 87F or if the river flow was less than or eqaul to 24,000 cubic feet per second (cfs).

Via request of Ameren on June 29, 2018 and reply by MDNR on July 11, 2018, the interim thermal effluent limitations in the 2017 permit were terminated, and the final thermal effluent limitations of the permit became effective on August 1, 2018. A subsequent modified permit was issued September 1, 2018, but made no changes to the above permit terms and conditions.

1.2 LABADIE ENERGY CENTER § 316(a) VARIANCE REQUEST

Retrospective application of the site-specific TDP model adopted in the 2017 NPDES permit to the LEC flow and thermal discharge records from 2002 through 2018 shows that the LEC thermal discharge would have had a TDP < 0.95 approximately 99 percent of the time. Therefore, the potential for exceedance of a TDP of 0.95 exists in rare instances when the ambient river temperatures are extraordinarily high, and/or the river flow is extraordinarily low (Kleinfelder 2016).

Section 316(a) of the Clean Water Act (CWA) and the $MWQS_t$ allow a thermal discharger to seek alternative thermal effluent limitations (ATEL) [§ 316(a) variance] through demonstration that the less stringent alternate effluent limitations would be protective of aquatic life in the receiving waterbody as a whole. Ameren is requesting such a variance from the $MWQS_t$ under § 316(a) to account for those limited instances when there is a potential for exceedance of the water quality standards for temperature. Ameren is proposing the following alternative temperature effluent limit to ensure continued operation of the LEC while, at the same time, assuring the protection and propagation of a balanced indigenous community in the LMOR:

- A TDP of greater than 0.95 will be allowed under conditions when the river flow is less than 40,000 cfs or ambient river temperatures are greater than 87°F;
- A TDP of greater than 0.95 will be allowed in no more than 6 percent of the days in any calendar year; and
- On any day where the TDP is greater than 0.95, the mixing zone must be less than 40 percent of the volume of the river as calculated by the equations in the permit.

1.3 PURPOSE OF THIS REPORT

This Labadie Energy Center § 316(a) Final Demonstration (Demonstration) has been prepared to address requirement D.3.b of the LEC's NPDES permit issued by the MDNR on May 3, 2017. More specifically, this Demonstration evaluates whether the LEC past and current operation, which included rare instances when a TDP value of greater than 0.95 would have occurred, has resulted in appreciable harm to the aquatic biota in the LMOR near the LEC. In addition, this Demonstation asseses whether the proposed alternative effluent limits for temperature will assure the protection and propagation of the balanced indigenous community of the LMOR.

1.4 REPORT ORGANIZATION

Section 2 of this Demonstration briefly describes the LEC discharge and the characteristics of the Missouri River in the vicinity of the LEC. It also provides an overview of the applicable $MWQS_t$ and mixing zone criteria and a description of the LEC permit limits and thermal plume. Section 3 provides an overview of § 316(a) of the CWA and relevant concepts that will be addressed later in the Demonstration. Section 4 presents the biotic category rationales including a brief characterization of each biotic community in the vicinity of the LEC and the applicable "area of low potential impact" decision criteria from the 1977 draft United States Environmental Protection Agency (USEPA) Guidance Manual (Guidance Manual). Section 5 presents the retrospective

assessment to address the “no prior appreciable harm” (NPAH) decision criteria for the fish and benthic macroinvertebrate biotic categories. Section 6 presents the predictive assessment to evaluate whether the balanced indigenous population will be protected and maintained in the event the TDP limit is exceeded. The master rationale in Section 7 summarizes the conclusions for each biotic category and whether the no prior appreciable harm criteria have been met. Finally, Section 8 provides a list of references used in preparing this Demonstration. Supporting appendices to this report are provided under separate cover.

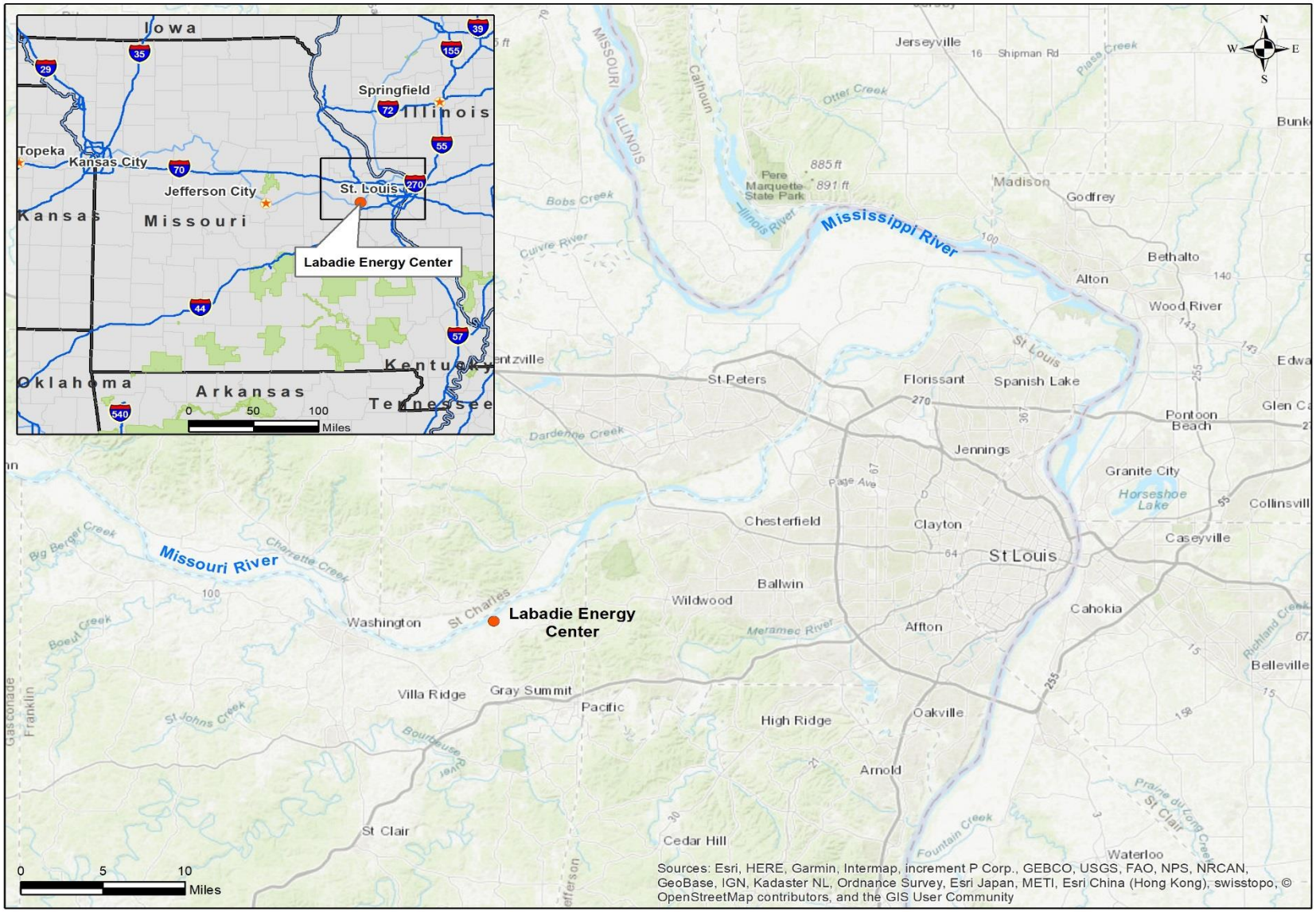


Figure 1-1 General geographical location of the LEC.

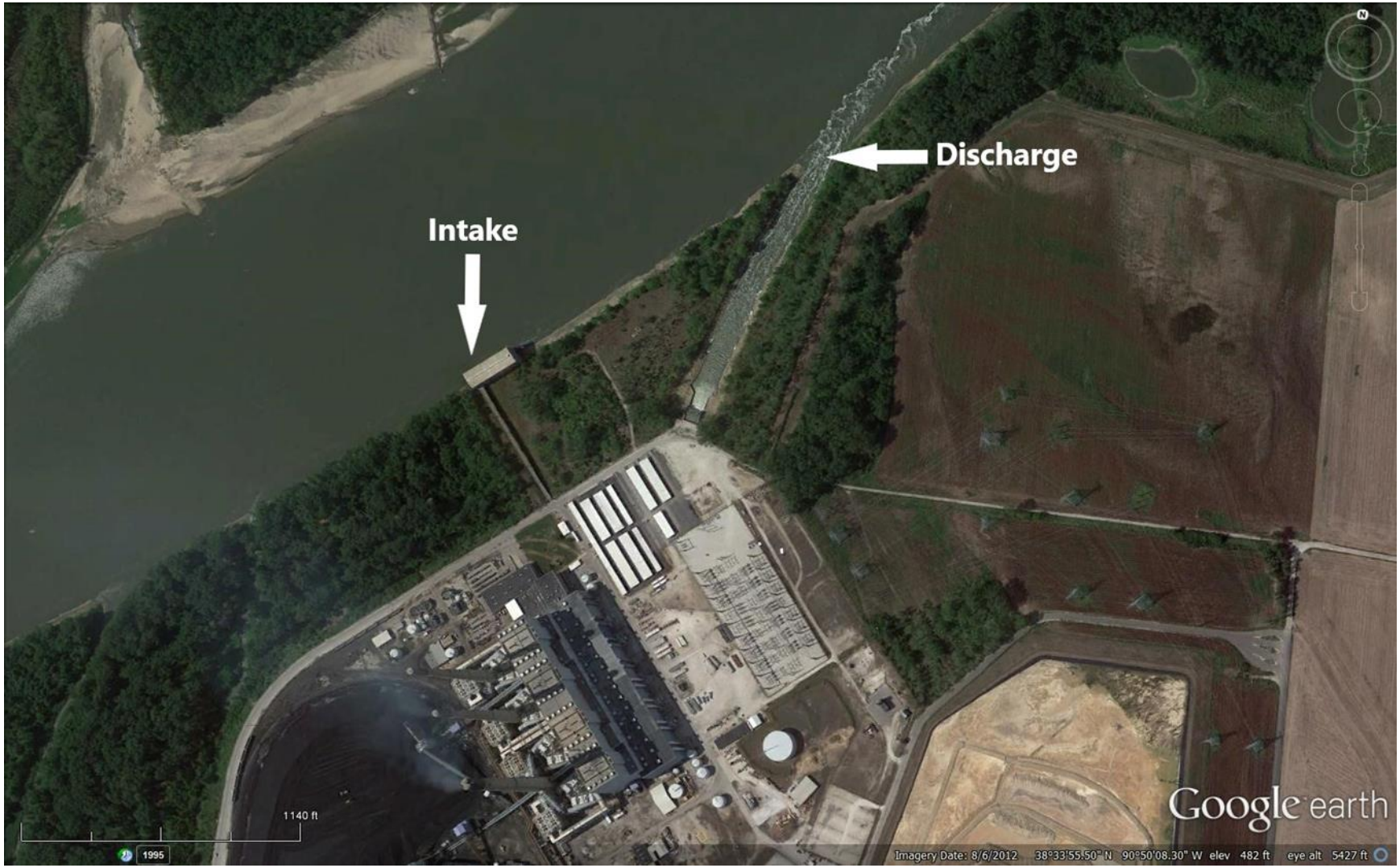


Figure 1-2 Aerial photograph of the LEC showing the cooling water intake and artificial discharge canal.

(Source: Google Earth)

2. LABADIE AND THE ADJACENT MISSOURI RIVER

2.1 CHARACTERISTICS OF THE MISSOURI RIVER IN VICINITY OF LABADIE

The Missouri River is one of the major river systems in the United States, with a 529,350 square mile drainage basin. It flows 2,341 miles from its headwaters at the confluence of the Gallatin, Madison, and Jefferson Rivers near Three Forks, Montana to its confluence with the Mississippi River at St. Louis, Missouri. The Missouri River flows from the Northern Rocky Mountain physiographic province through the glaciated Great Plains and Central Lowlands provinces, and finally through the unglaciated, limestone-dolomite Ozark Plateaus (Galat et al. 2005a, 2005b). Approximately 70 percent of the Missouri River Basin lies within the semi-arid Great Plains, so it is largely a dry-land river.

The geomorphology of the river originally was the product of highly variable daily and seasonal flow rates that carried sediments from the highly erodible soils typical of the Missouri River Basin. The result was a complex, meandering river basin and flood plain that was continually shifting but nevertheless in dynamic equilibrium. The presettlement Missouri River had a wide, highly braided channel with many unconnected islands and was characterized by highly turbid waters, wide fluctuations in temperature (and flow as noted above), and an unstable sand-silt substrate (Pflieger and Grace 1987).

The LMOR has been altered in both its channel form and flow regime by channelization and upstream dams (Johnson et al. 2006). Channel modifications in the LMOR began in the early 1800s with clearing and snagging to improve conditions for steamboat navigation (Chittenden 1903) followed by a focus on channel deepening and bank stabilization efforts (Pflieger and Grace 1987). River modifications have resulted in an estimated loss of up to 50 percent of the original water surface area from Rulo, Nebraska to the mouth (Funk and Robinson 1974). In addition, many of the features that provided habitat diversity to the river were lost.

Flow regulation began on the Missouri River in the late 1930s and was completed with the closure of the Missouri River Reservoir System in 1954 (Ferrell 1993; Galat and Lipkin 2000; Jacobson and Heuser 2001). The system is managed for multiple purposes, including maintenance of commercial navigation flows, flood control, hydropower, public water supply, recreation, and fish and wildlife resources. The U.S. Army Corps of Engineers (USACE) Northwestern Division, Kansas City District, is responsible for maintenance of the federal navigation channel. The USACE Civil Works Division manages 500 miles of the Missouri River, including projects related to habitat restoration and recovery programs, recreation, flood risk management, navigation, riverbed degradation, and dam and levee safety. USACE also reviews and issues permits for commercial dredging operations under the Rivers and Harbors Act and the Clean Water Act to dredge sand and gravel from the Missouri River below Rulo, Nebraska.

Dam construction and channelization along the Missouri River mainstem has fragmented the river into four types of ecological units: a free-flowing reach upstream of the reservoirs, the reservoirs, remnant floodplains between the reservoirs, and a channelized reach below the most downstream reservoir (NRC 2002). The channelized reach, which includes the portion of the river where the LEC is located, extends approximately 735 miles to St. Louis, or about one-third of the total length of the Missouri River. Upstream modifications have reduced or eliminated the river's natural flow regime in which flood pulses in the spring and early summer would create new and productive habitats, cycle organic material and nutrients between the channel and floodplain, replenish water in the floodplain, and serve as cues for spawning of fish and other organisms (USFWS 2003). As a result, the amount of productive, natural habitat has been greatly reduced throughout the system.

The current channel morphology in the LMOR is dominated by rock wing dikes and revetments constructed as part of the Missouri River Bank Stabilization and Navigation Project (Ferrell 1996). These structures stabilized the banks and narrowed and focused the river geometry to help maintain the navigation channel from St. Louis, Missouri to approximately 750 miles upstream at Sioux City, Iowa. The rock structures and revetments (outside of bends) and dikes (inside of bends) force the river into a channel alignment that is self-maintaining.

The typical annual flow cycle in the upstream regulated Missouri River involves peak reservoir storage in July, followed by a gradual decline in storage until late winter (USACE 2006). Flow releases to the LMOR are adjusted according to short-term and annual rainfall amounts and resulting water storage, as well as nesting requirements for the two federally listed bird species (least tern and piping plover) on the storage reservoirs. Targeted flow releases are increased during the navigation period, which normally begins by April 1 near St. Louis and extends until early December. River flow in the LMOR is further supplemented and modulated by tributary inflow.

The Kansas City and Omaha Districts of the USACE, in cooperation with the U.S. Fish and Wildlife Service (USFWS), developed a Draft Missouri River Recovery Management Plan (MRRP) and Draft Environmental Impact Statement (EIS; USACE 2014). The MRRP is an effort to replace lost habitat and avoid a finding of jeopardy to T&E species resulting from USACE projects on the Missouri River related to operation of the mainstem river reservoir system, ongoing navigation, and bank stabilization. Some of the restoration aspects of the program include development of emergent sandbar habitat, shallow water habitat, and wetland and terrestrial habitat. The program also includes ongoing data collection and monitoring to determine if these actions are effective. These actions are being taken pursuant to the 2000 Biological Opinion, amended in 2003 (USFWS 2003).

The changes in flow regimes and destruction of aquatic habitats have greatly influenced the abundance of native species and affected the overall composition of the fish community. Many native fish species are now rare, uncommon, or decreasing in abundance across part or all of their previous range due to the changing ecosystem and habitat losses during recent decades (NRC 2002). Lost also are the flood pulses in the spring and early summer that influenced the river morphology, connected side channels and backwaters to the main channel, created new and productive habitats, cycled organic material and nutrients between the channel and floodplain, replenished water in the floodplain, and served as cues for spawning of fish and other organisms. Productive side channels, chutes, sand bars, islands and backwaters are much reduced. These reductions in ecosystem integrity associated with lost or altered habitat (Hesse and Sheets 1993) likely have contributed to the decline of several native Missouri River fishes, including the federally endangered pallid sturgeon (*Scaphirhynchus albus*) (Dryer and Sandvol 1993). Many of these native fish species are now rare, uncommon, or decreasing in abundance across part or all of their previous range (NRC 2002). In many river reaches, the abundance of non-native species such as Asian carp has become greater than that of native species because of their greater tolerance for the altered temperature regime, flow, turbidity, and habitats.

The presettlement fish community in the Missouri River was characterized by relatively few species adapted to the high turbidity and unstable environment (wide fluctuations in flow, temperature, and shifting substrate) of the river such as the pallid sturgeon, flathead chub, western silvery minnow, plains minnow, and sicklefin chub (Pflieger and Grace 1987). Pflieger and Grace (1987) examined fish survey data collected at approximately 20-year intervals starting around 1940 through the 1980s and noted an increase in the number of species and substantial changes in relative abundance over time. Changes in the river described above led to decreased turbidity and changes in the type and availability of habitat favoring largely pelagic planktivores and sight feeding piscivores such as gizzard shad, skipjack herring, shiners, and sunfish (Funk

and Robinson 1974; Pflieger and Grace 1987). Dominant large fish in surveys from the 1940s included common carp, river carpsucker, channel catfish, and gizzard shad representing 34.9, 18.4, 9.1, and 8.8 percent of the catch, respectively (Pflieger and Grace 1987). Gizzard shad and channel catfish relative abundance increased to 31.8 and 30.8 percent of the catch in the 1980s surveys (respectively), while common carp and river carpsucker declined to represent only 5.9 and 4.8 percent of the catch (respectively) during the same period. In the 1940s surveys small fishes were dominated by plains minnow and flathead chub accounting for 56 and 31 percent of the catch of small fish, respectively (Pflieger and Grace 1987). While plains minnow were still one of the most abundant species during the 1980s surveys, their relative abundance decreased to 36 percent of the catch from 56 percent during the 1940s surveys. Emerald shiner was the second most abundant species in the 1980s surveys representing 28.5 percent of the catch, up from 0.1 percent in the 1940s surveys. The relative abundance of flathead chub decreased markedly to represent only 1.1 percent of the catch during the 1980s surveys. Funk and Robinson (1974) noted a decrease of almost 80 percent in commercial catch, primarily comprised of carp, buffaloes, and catfishes, from 1945 to 1963. They attributed this trend to reduction and deterioration of the Missouri River fish habitat as a result of the navigation and stabilization project.

Pflieger and Grace (1987) noted several factors contributing to the maintenance and increases in the populations of different species within the Missouri River in addition to the changes in flow and habitat. These include escapement from reservoirs (e.g., white bass, bluegill, freshwater drum, emerald shiner, river shiner, and rainbow smelt), accidental and intentional introductions (e.g., rainbow smelt, white bass, and grass carp), and stragglers from tributaries (e.g., spotted bass, longear sunfish, and Ozark minnow). They also postulated that the decrease in common carp between the 1940s to the 1980s surveys resulted from an improvement in water quality. While Pflieger and Grace (1987) suggested that the increase and upriver range expansion of threadfin shad in the Mississippi River may be a result of thermal discharges from power plants, they could not definitely ascribe any changes in the Missouri River fish fauna to thermal discharges. At the time of their paper, Pflieger and Grace (1987) suggested that if the public works projects responsible for the changes in the Missouri River were complete, fish populations would continue to fluctuate but ultimately reach equilibrium. The also postulated that populations of grass, silver, and bighead carp, would likely continue to increase and become well-established in the Missouri River. As has been well-documented, Asian carp have indeed proliferated in the Missouri River and have become a large part of the fish community.

The LEC is located on the south bank (right descending bank) in the channelized reach of the LMOR (Figure 2-1) in an area known as Labadie Bottoms. The Missouri River is approximately 1,300 feet wide and has an approximate average depth in the range of 16 feet in the vicinity of the LEC cooling water intake structure (CWIS) and discharge canal (Kleinfelder 2016). However, depth sounding surveys from 2001 to 2014 in the vicinity of the LEC indicated that the shape of the river bottom changes somewhat with time. Along the lower Missouri River there are numerous wing-, pole-, and L-shaped dikes and shoreline revetment areas, such as downstream of the LEC discharge canal, that have been constructed along the shoreline to improve and maintain the navigability of the river (Figure 2-1). The river depth in the vicinity of the LEC increases sharply because the channel closely approaches the south bank in this area. Sandy beaches are exposed at low water levels. The river currents past the plant are swift, with typical velocities estimated between 2.6 and 4.8 feet per second (fps). Rooted vegetation within the river is lacking and the substrate consists of rock, stone or gravel in areas of current, and silt or clay in depositional areas.

Aquatic habitats in the vicinity of the LEC have also been substantially altered over time by the construction of revetments and dikes and by dredging to maintain a 300-foot wide navigation channel that is at least 9 feet deep. As a result, the channel now is narrower and more uniform than its previous form, with a trapezoidal cross-section resulting in steeper embankments and

faster currents. River meanders have been straightened, natural riparian vegetation has been diminished, variations in river flows and water temperatures are reduced, periodic overbank flow to the floodplain and its nutrient cycling benefits have been eliminated or reduced, sediment transport processes have been altered, and natural processes of cut and fill alleviation have been modified (NRC 2002). In a 32-mile reach of the LMOR from RM 36 to 68 which includes the area where the LEC is located, changes to the river have resulted in the loss of 56 percent of the water surface area between 1879 and 1972 along with a 98 percent reduction in unconnected islands and a 12 percent reduction in channel area from 1879 to 1954 (Funk and Robinson 1974).

In the vicinity of the LEC, river flow follows a typical seasonal pattern with higher flows in late spring and early summer as a result of higher inflows and regulatory releases (Figure 2-2). In general, there is about a three-fold difference in average flows from the highest to the lowest flow period of the year although changes across the years at any point in time can be considerably larger. Median annual flows in recent years (2002 – 2018) exhibited substantial differences from one year to the next, most likely a result in changes in upstream precipitation (Figure 2-3). Flows in relatively high flow years (2008 – 2011) were two to three times higher than those in relatively low flow years (2002 – 2006 and 2012 – 2013). There was no evidence of any long-term trend in river flows across this 17-year period.

Water temperatures in the LMOR followed a seasonal pattern typical of larger mid-Western rivers ranging from less than 40°F in winter to more than 80°F in summer (Figure 2-4). This pattern was fairly consistent across the years although temperatures as high as 87°F were reported approximately one percent of the time. Differences in annual median water temperatures were relatively small in recent years, ranging from just under 55°F to slightly over 63°F (Figure 2-5).

Dissolved oxygen (DO) concentrations in the LMOR followed a seasonal pattern opposite of that of water temperatures ranging from more than 14 milligrams per liter (mg/l) in winter to less than 5 mg/l in summer (Figure 2-6). DO levels, as measured at the Hermann gage, were less than the MO water quality standard of 5 mg/l approximately 5 percent of the time overall and more than 19 percent of the time in July. These low dissolved oxygen levels have been reported to be a result of excess organic materials from wastewater treatment systems, excess animal waste, excess nutrient loads (fertilizer) and excess sedimentation from stream bank and sheet erosion (MDNR 2015). There was no evidence of a long-term trend in DO levels (Figure 2-7).

The LMOR is also affected by sediment, nutrient, and pesticide runoff from agriculture; sediment and metal loadings from mines; urban stormwater discharges; wastewater and industrial plant discharges; septic system leaching; and entrapment of sediments and pollutants behind dams. (USACE 2016). Inputs from these sources include nutrients, toxic chemicals and bacteria, each of which degrade the quality of the aquatic habitats in the LMOR.

Nutrient inputs, principally from agricultural runoff and sewage treatment plan discharges, result in elevated levels of organic nitrogen, nitrate, total phosphorus, and ortho-phosphorus. As a result, approximately 17 and 29 percent of the Missouri River was categorized as being in a most-disturbed condition for total nitrogen and total phosphorus, respectively, with phosphorus concentrations increasing progressively downriver from the Gavins Point Dam (Angradi et al. 2011).

Further, a variety of organic chemicals including organochlorine pesticides, particularly chlordane, heptachlor, and dieldrin along with polyaromatic hydrocarbon compounds (PAH) in the lower river was detected by sampling the water column at Hermann, MO (Petty et al. 1993). The Missouri Department of Health and Senior Services has issued a fish consumption advisory against consumption of shovelnose sturgeon eggs from the Missouri River due to Polychlorinated biphenyls (PCB) and chlordane contamination, and a consumption limit of one meal per month for shovelnose sturgeon flesh and all buffalo species due to PCB, chlordane, methyl mercury

contamination (MDHSS 2018). There is a total ban on consumption of sturgeon roe. There also is a consumption limit of one meal per week for flathead catfish, channel catfish, and blue catfish greater than 17 in. in length and common carp greater than 21 in. from the Missouri River.

Greater than 12 percent of the Missouri River length was determined to have sediments resulting in toxicity to exposed organisms (Angradi et al. 2011) and were concentrated in the Fort Peck Reach and near Kansas City (RM 312-438), or more than 255 RMs upstream of Labadie. Echols et al. (2008), sampling 19 location in the LMOR between Omaha NB and Jefferson City MO, concluded that metal concentrations in the sediments at most of these locations were below probable effects level thresholds (MacDonald et al. 2000), and that they would likely have minimal toxicological effects on biota based on those criteria.

Finally, the lowermost section of the river (St. Charles/St. Lewis Counties), in which the LEC resides, is included in Missouri's § 303(d) 2016 list of impaired waterbodies due to bacteria (*E. coli*), with impaired use for whole body contact recreation (MDNR 2016). This impaired segment was first added to the § 303(d) registry in 2008 and it includes waters that are part of a public water supply.

2.2 LABADIE THERMAL DISCHARGE

The LEC typically operates year-round with only minor seasonal differences as a result of demand changes and maintenance outages (Figure 2-8) and average annual generation has been relatively consistent across the past 17 years (Figure 2-9). Ameren is a member of the Midcontinent Independent System Operator Incorporated (MISO), a regional transmission authority that controls the dispatch of generation assets, including the LEC, within its multi-state regions. MISO operates on a market basis and matches demand and supply on an instantaneous and continuous basis.

The LEC uses water from the LMOR to cool each of its four generating units that is withdrawn through a common shoreline intake structure. Each unit has two circulating water pumps each that are rated at 125,672 gallons per minute (gpm) or 280 cfs at 56 feet of head per pump. At a normal water level of El. 455 feet, the total facility cooling water withdrawal capacity of the LEC is 1,005,378 gpm (2,240 cfs). Except during major outages or intake structure maintenance activities, each unit typically runs both of its two circulating pumps continuously. Hence, there is little seasonal or annual variation in cooling water discharge volumes. The LEC currently does not use chlorination or other biocide applications at its intake.

After water passes through the LEC's steam condensers, the water withdrawn for cooling purposes is discharged back into the river via an open discharge canal that is approximately 1,400 feet long and 100 feet wide. The confluence of the discharge canal with the Missouri River is located approximately 1,500 feet downstream of the intake structure (Figure 1-2). The amount of water discharged is slightly less than the amount withdrawn owing to minor consumptive uses within the facility. Once entering the Missouri River, the heated effluent is dispersed and transported downstream. The temperature of the effluent discharged is dependent on the ambient river water temperature, plant operation, and intake flow.

The LEC's thermal discharge is rapidly and thoroughly mixed throughout the water column and the resulting thermal plume is restricted to the right descending (south) side of the river (Kleinfelder 2016). The downstream distribution of the thermal plume is driven by the river flow, ambient river water temperature, as well as the LEC's discharge temperature and flow.

2.3 APPLICABLE WATER QUALITY STANDARDS AND CRITERIA

$MWQS_t$ for the LMOR in the vicinity of LEC are as follows:

> *For warm water habitats beyond the mixing zone water contaminant sources or physical alteration of the water course shall not raise or lower the temperature of a stream by more than five degrees Fahrenheit (5°F) or two and seven-ninths degrees Celsius (2 7/9°C). Water contaminant sources shall not cause or contribute to stream temperature in excess of ninety degrees Fahrenheit (90°F) or thirty-two and two-ninths degrees Celsius (32 2/9°C). However, site-specific ambient temperature data and requirements of sensitive resident aquatic species will be considered, when data are available, to establish alternative maxima or deviations from ambient temperatures. (*10 Code of State Regulations [CSR] 20-7.031).

The size of an allowable thermal mixing zone is defined in Section 10 CSR 20-7.031 (5)(D)6 as:

> *Thermal mixing zones shall be limited to twenty-five percent (25%) of the cross-sectional area or volume of a river, unless biological surveys performed in response to section 316(a) of the federal Clean Water Act (or equivalent) indicate no significant adverse impact on aquatic life. Thermal plume lengths and widths within rivers, and all plume dimensions within lakes, shall be determined on a case-by-case basis and shall be based on physical and biological surveys when appropriate.*

2.4 LABADIE PERMIT LIMITS

The discharge of heat from the LEC is regulated by a NPDES Permit (MO-0004812) last modified by the MDNR on September 1, 2018. This permit incorporates a daily maximum and monthly average TDP limit of 0.95. Equations to calculate the TDP are provided in the permit while the derivation and validation of these equations for the LEC are described in Kleinfelder (2016). The TDP limit incorporates a 5 percent margin of safety to ensure compliance with the $MWQS_t$ at the edge of the allowable mixing zone as described in the previous section.

In addition to this permit limit, Special Condition #20 in the Labadie NPDES permit requires Ameren to implement an approved monitoring plan to characterize the thermal mixing zone throughout the river downstream from the confluence of the discharge canal and the Missouri River during conditions when the river flow is less than 35,000 cfs and/or the ambient river water temperature is greater than 85°F, as measured at the United States Geological Survey (USGS) Labadie Gage Station (#06935550). Results of the monitoring are to be reported to the MDNR and evaluated to determine whether the measured temperatures are in compliance with the $MWQS_t$ for temperature.

2.5 COMPLIANCE WITH THE LEC THERMAL LIMIT

Since modification of the LEC NPDES permit in 2017, the LEC has not exceeded the applicable TDP permit limit. Further, application of these TDP equations to daily river and plant operational conditions extending over the 17-year period, 2002 – 2018, indicate that the LEC would have met a TDP value of 0.95 (value of 0.95 or less) more than 99 percent of the time (Figure 2-10). The infrequent TDP values greater than 0.95 only occur when river discharge was unusually low and/or water temperatures were well above normal. Seasonally, monthly median TDP values appear to be the inverse of river discharge with highest values in winter and lowest values in late spring (Figure 2-11). Across the 17-year period, the predicted infrequent daily TDP values greater than 0.95 were limited to July, August and, in one case, November (Figure 2-11). Annual median TDP values also were generally inverse of river discharge while not a single predicted daily TDP value of greater than 0.95 was calculated in 12 of the 17 years (>70 percent of the years) (Figure 2-12). Incidents where TDP values greater than 0.95 occur were restricted to those years with especially low river discharge and high water temperatures as discussed in Section 2.1.

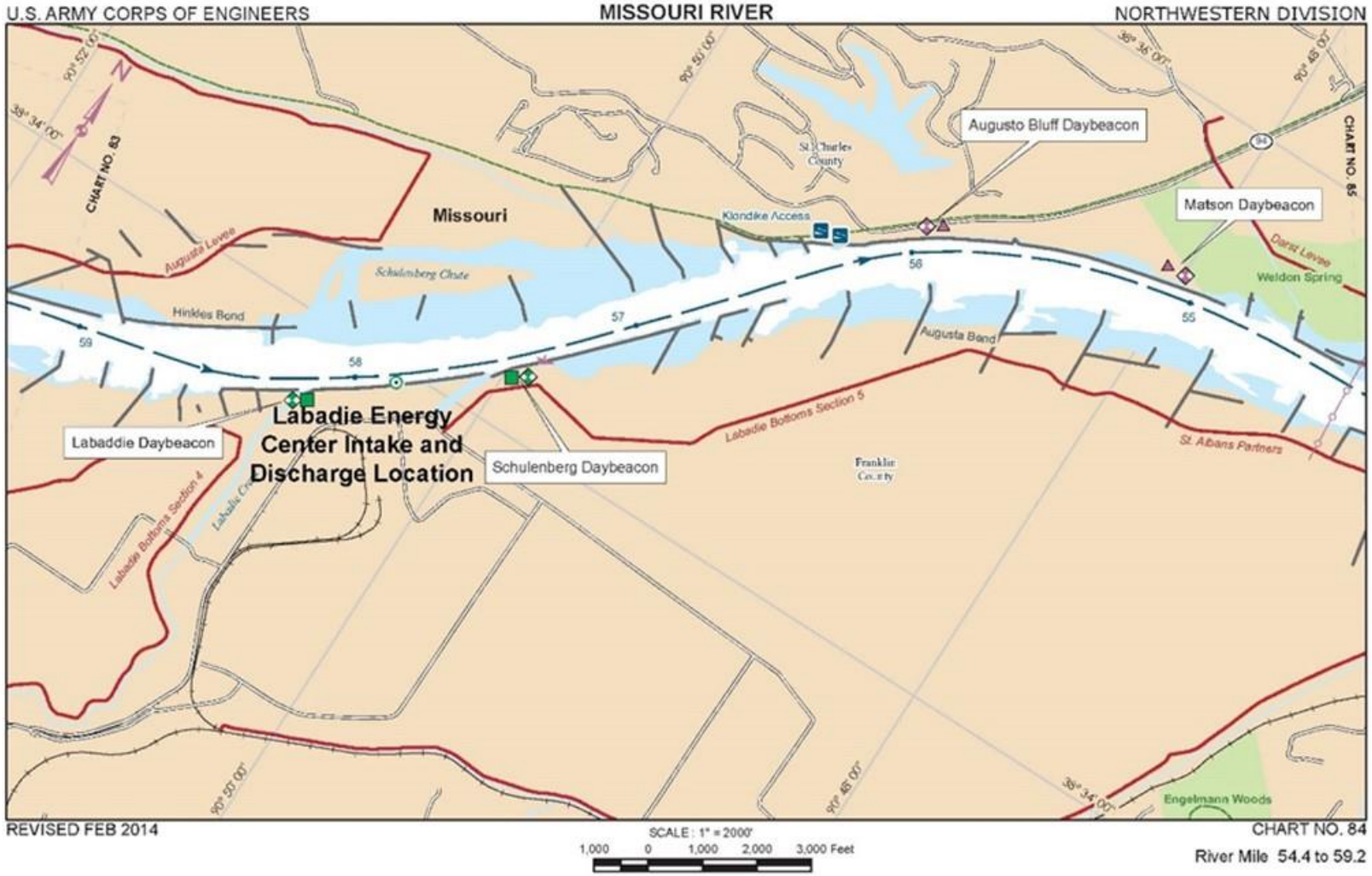


Figure 2-1 United States Army Corps of Engineers navigation chart and levee system near the LEC.

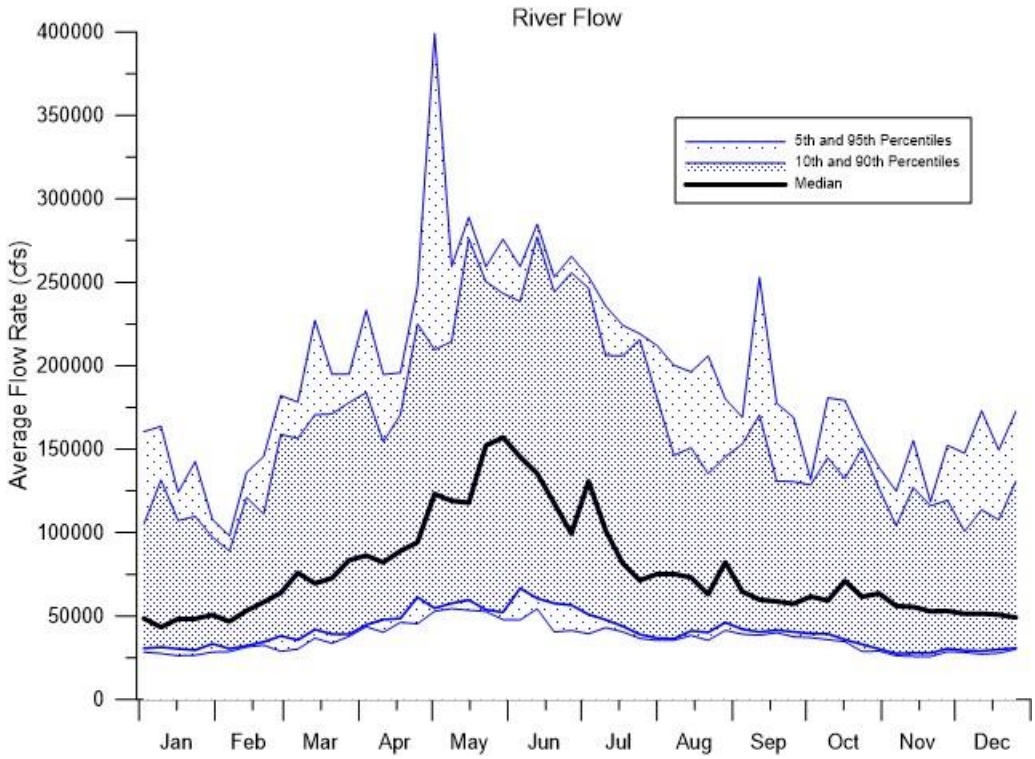


Figure 2-2 Seasonal pattern in river flow in the LMOR as measured at USGS Labadie Gage Station, 2002 - 2018.

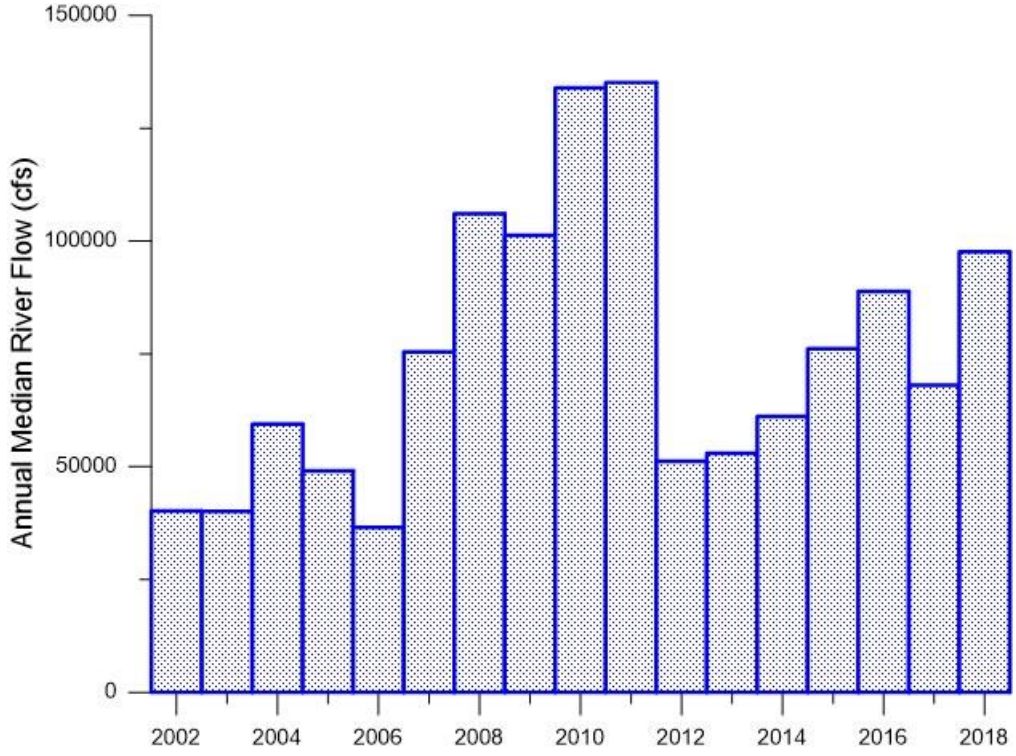


Figure 2-3 Annual median river flow in the LMOR as measured at the USGS Labadie Gage Station, 2002 – 2018.

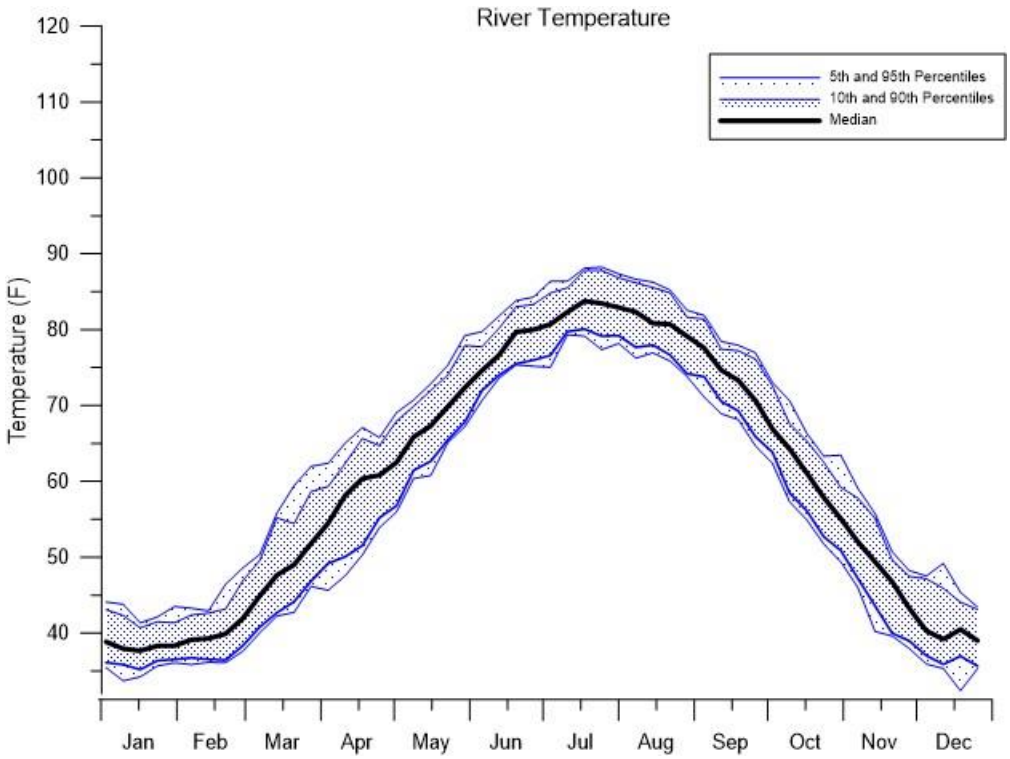


Figure 2-4 Seasonal pattern in river water temperature in the LMOR as measured at LEC intake, 2002 - 2018.

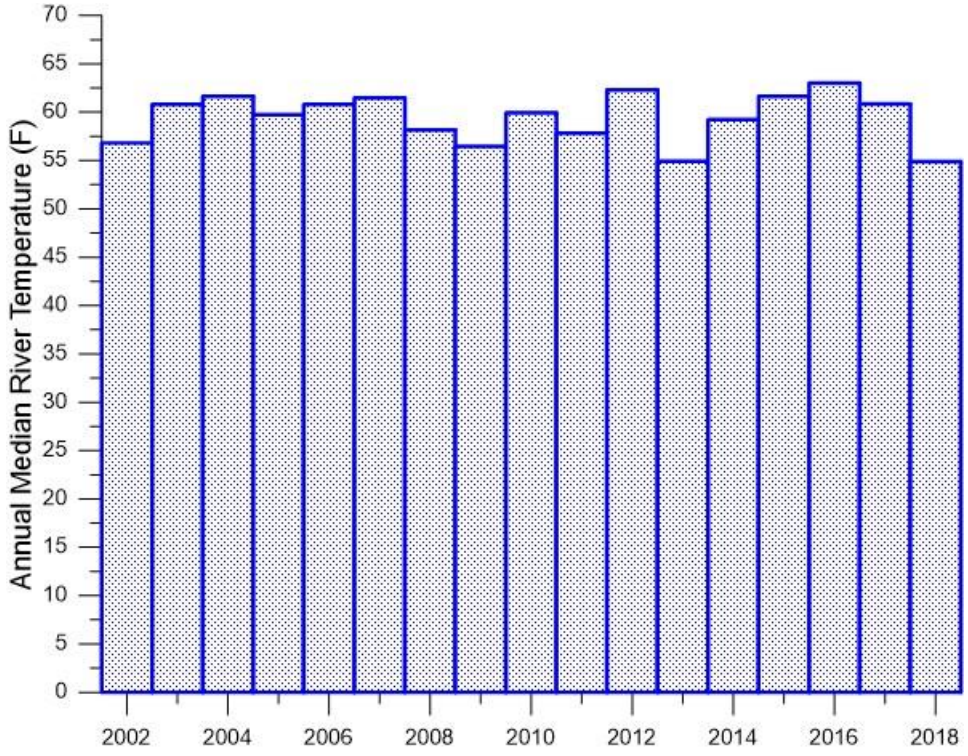


Figure 2-5 Annual median river water temperature in the LMOR as measured at the LEC intake, 2002 - 2018.

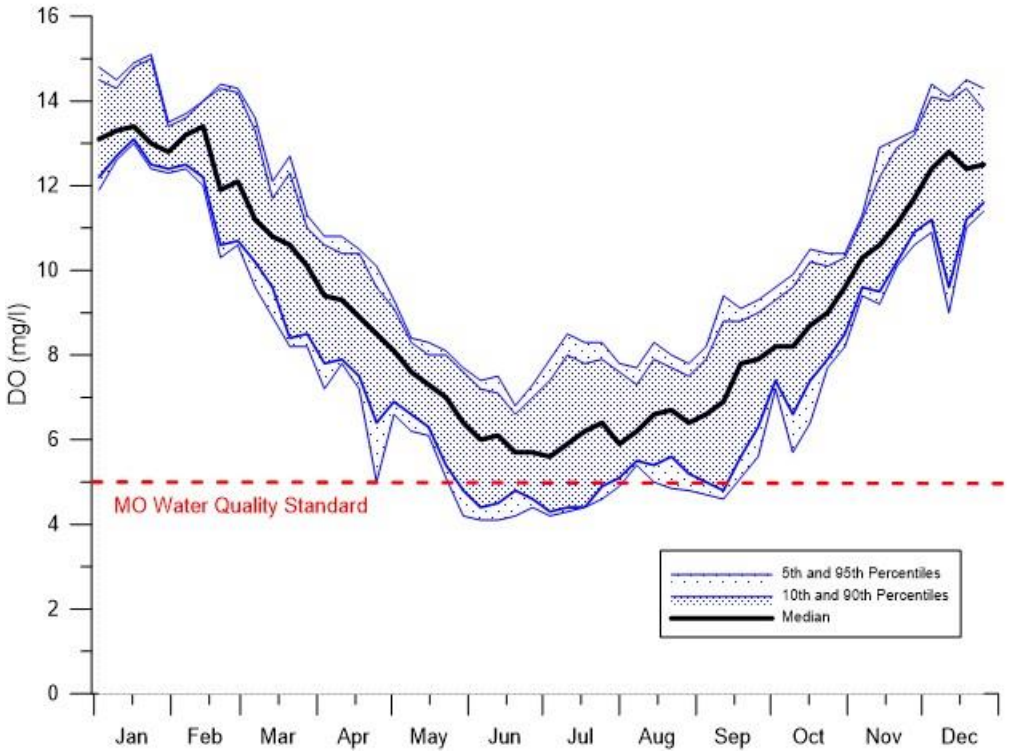


Figure 2-6 Seasonal pattern in river dissolved oxygen in the LMOR as measured at USGS Hermann Gage approximately 40 miles upstream of the LEC, 2007 - 2018.

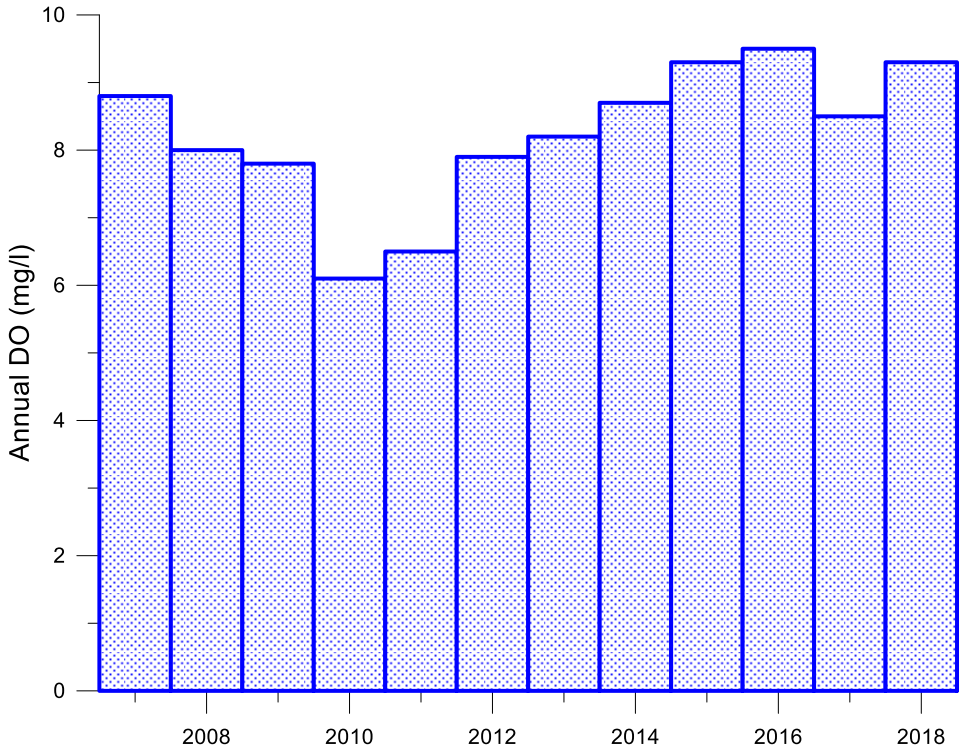


Figure 2-7 Annual trends in river dissolved oxygen in the LMOR as measured at USGS Hermann Gage approximately 40 miles upstream of the LEC, 2007 - 2018.

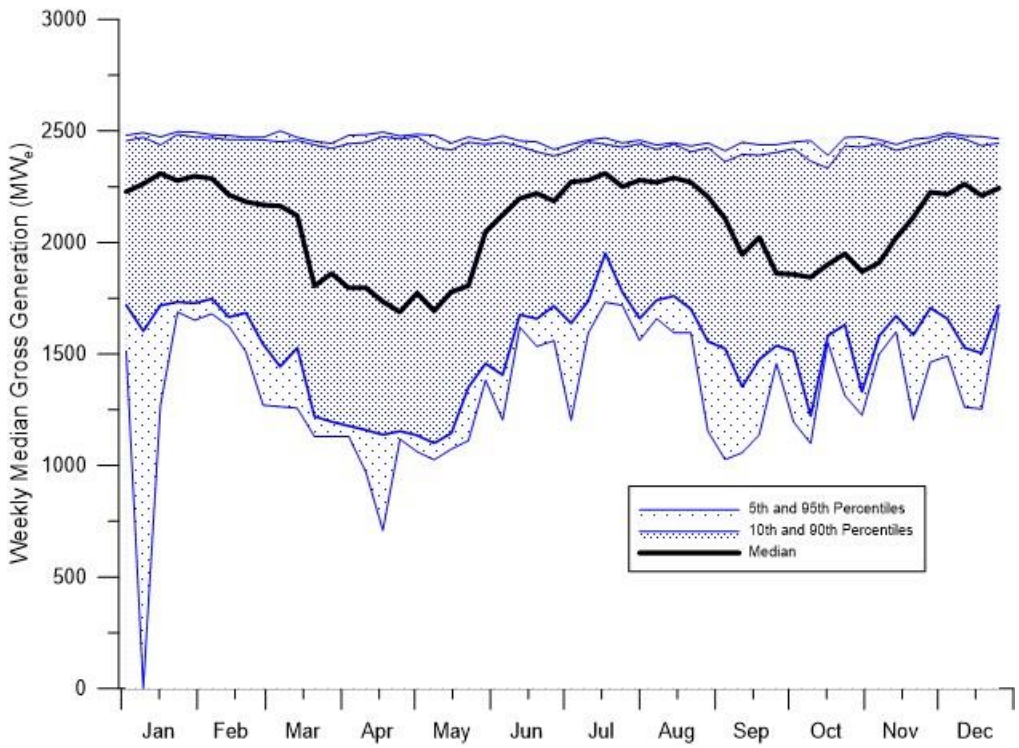


Figure 2-8 Seasonal pattern in gross electrical generation at LEC, 2002 - 2018.

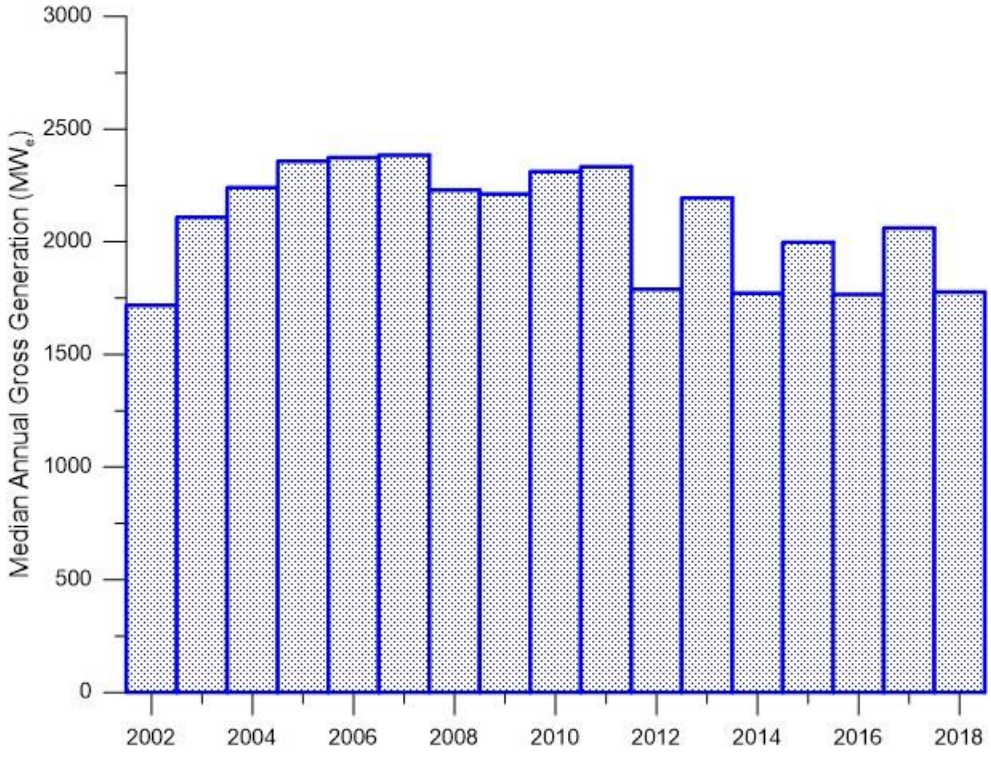


Figure 2-9 Annual median gross electrical generation at LEC, 2002 - 2018.

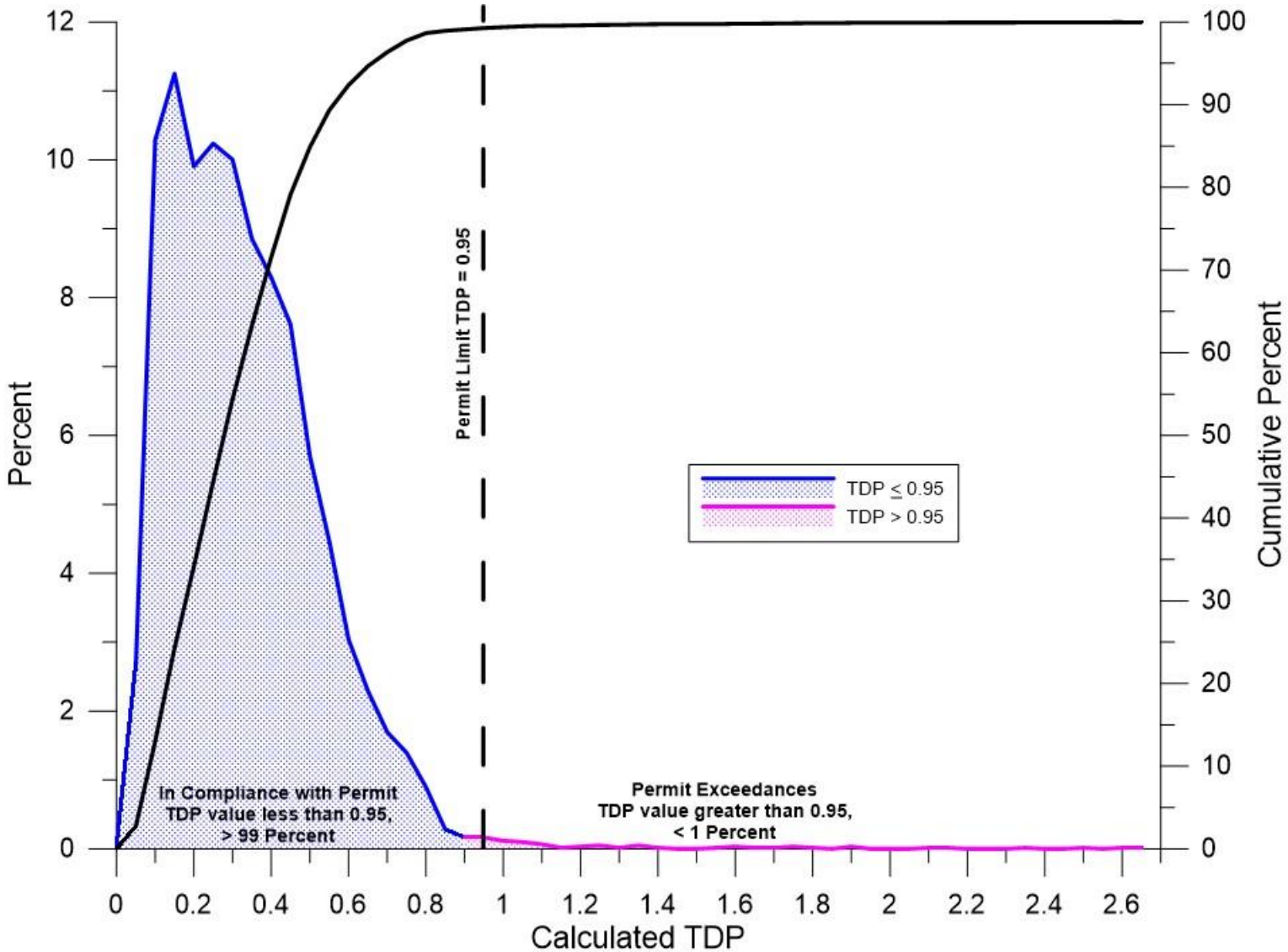


Figure 2-10 Frequency distribution of daily TDP values at LEC over the period 2002 – 2018.

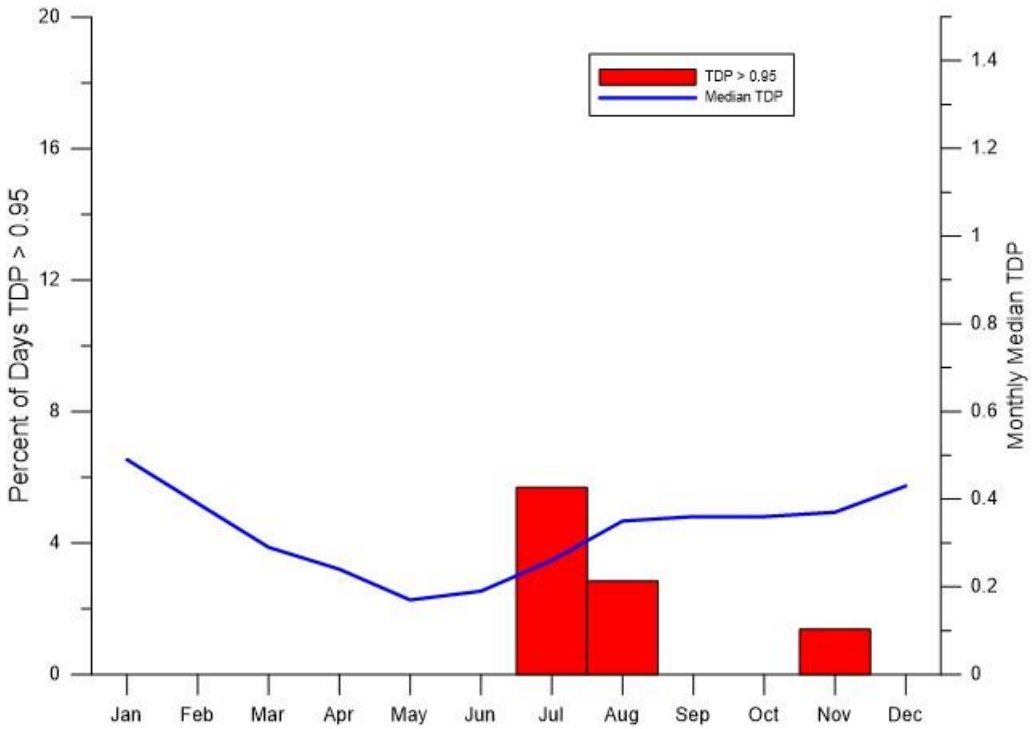


Figure 2-11 Seasonal pattern in TDP values at the LEC from 2002-2018.

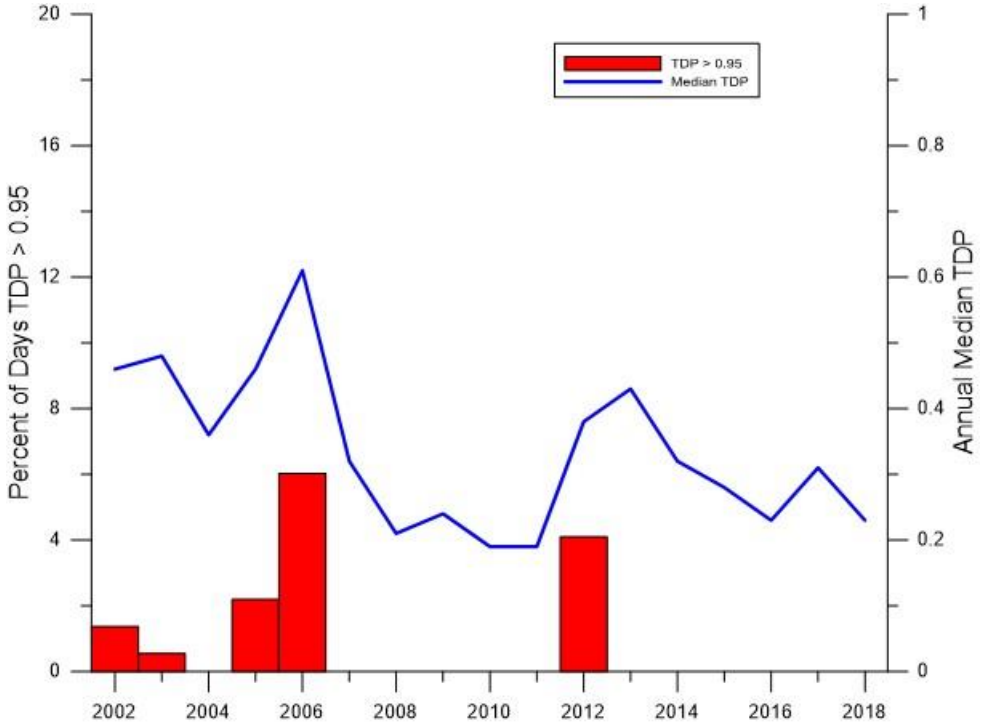


Figure 2-12 Annual trends in TDP values at the LEC from 2002-2018.

3. REGULATORY REQUIREMENTS FOR THERMAL VARIANCE

As demonstrated above, analysis of prior environmental and LEC operational data suggests that there is a potential to exceed the permit thermal limits on a very infrequent basis (< 1 percent of the time). Ameren has evaluated facility operational controls that could reduce that potential even further. However, because the permit thermal limits have the potential to be exceeded, Ameren is requesting a § 316(a) variance for the LEC from the $MWQS_t$ temperature limits that will allow the LEC to continue to operate during periods of discrete yet extreme river conditions.

The MDNR defines a water quality variance as a time-limited designated use and criterion change for a specific pollutant, allowing deviation from meeting a water quality-based effluent limitation for a specific discharger. While MDNR does not provide specific guidance for obtaining a variance from temperature limits, regulations limit the size of the thermal mixing zone to twenty-five percent of the cross-sectional area or volume of a river *"…unless biological studies performed in response to section 316(a) of the federal Clean Water Act (or equivalent) indicate no significant adverse impact on aquatic life. Thermal plume lengths and widths within rivers…shall be determined on a case-by-case basis and shall be based on physical and biological surveys when appropriate.*" (10 CSR 20-7.031(5)(D)6).

Hence, it appears clear that MDNR expects requests for thermal variances to be consistent with the requirements of § 316(a) of the Federal CWA.

3.1 OVERVIEW § 316(a) OF THE CLEAN WATER ACT

While the CWA clearly identified heat as a pollutant, Congress recognized that heat is different from other pollutants in that it:

- Is a natural attribute of all waters;
- Can have both positive and negative effects on aquatic life;
- Does not persist or accumulate in the environment but instead rapidly degrades with time;
- Has effects that are transitory; and,
- Can be detected and avoided by many motile aquatic organisms (Bulleit 2004).

It is for all of the above reasons that Congress included § 316(a) in the CWA. This section applies to point sources with thermal discharges and authorizes the NPDES permitting authority (e.g., State NPDES program Director) to impose alternative effluent limitations for the control of the thermal component of a discharge in lieu of the effluent limits that would otherwise be required.

Regulations implementing § 316(a) are codified at 40 CFR Part 125, Subpart H which identifies the criteria and process for determining whether an alternative effluent limitation (i.e., a thermal variance from the otherwise applicable effluent limit) may be included in a permit. Before a thermal variance can be granted however, 40 CFR § 125.72 and § 125.73 require that the permittee "demonstrate" that the otherwise applicable thermal discharge effluent limit is more stringent than necessary to "*assure the protection and propagation of the waterbody's balanced, indigenous population (BIP) of shellfish, fish and wildlife*". Should the permittee be able to demonstrate, with reasonable assurance and based on the best information reasonably available, that a stable, normally functioning BIP will be able to survive and propagate in the receiving waterbody as a whole, then the alternative temperature limits (i.e., variance) should be granted.

3.2 FEDERAL GUIDANCE

USEPA first issued guidance related to implementing CWA § 316(a) in September 1974 (USEPA 1974). This draft guidance was general in nature, focusing more on process and organization of

the Demonstration but provided a few key definitions described below. Subsequently in 1977, USEPA released a revised draft CWA § 316(a) guidance entitled "Interagency 316(a) Technical Guidance Manual and Guide for Thermal Effects Sections of Nuclear Facilities Environmental Impact Statements" (Guidance Manual). While neither guidance document was ever finalized, this guidance provides valuable technical information on conducting § 316(a) demonstrations, useful to both facilities and permitting authorities.

USEPA imposes specific expectations for granting or renewing a CWA section § 316(a) thermal discharge variance. The burden of proof is on the applicant (permittee) to demonstrate that it is eligible to receive an alternative thermal effluent limit under § 316(a). To do so requires that the permittee demonstrate to the permitting authority that a thermal effluent limit necessary to meet the requirements of § 301 or § 306 of the CWA is more stringent than necessary to assure the protection and propagation of a BIP in and on the body of water into which the discharge is made. (40 CFR § 125.73(a)).

To secure an alternative thermal discharge limit, the permittee must demonstrate that the alternative limit will assure protection of the BIP, considering the "*cumulative impact of its thermal discharge together with all other significant impacts on the species affected*." (40 CFR § 125.73(a)).

When applying for an alternative thermal limit, the permittee must submit the required supporting information and all demonstrations identified and described in 40 CFR § 125.72 and § 125.73. Among other things, the permittee must identify and describe:

1. The requested alternative thermal effluent limitation;
2. The methodology used to support that limitation;
3. The organisms comprising the BIP along with supporting data and information, and;
4. The types of data, studies, experiments and other information the applicant intends to use to demonstrate that the alternative thermal limit assures the protection and propagation of the BIP (40 CFR § 125.72(a) and (b)).

3.3 KEY DEFINITIONS

The significance of effects potentially caused by a thermal discharge, in both an ecological and regulatory sense, can be meaningfully assessed only in the context of established protection objectives, assessment endpoints, and assurance levels (USEPA 1974 and 1977). The following sections summarize the standards and criteria applicable under § 316(a) of the CWA and used in this Demonstration.

3.3.1 Balanced Indigenous Population

The method for evaluating the phrase "balanced indigenous population" or "BIP" is discussed in USEPA regulations, and the meaning of these terms has been further elaborated by the USEPA, Congress and the courts over the last several decades. The meaning of each of these three terms within the context of a § 316(a) Demonstration is discussed below.

Population -The USEPA has consistently recognized that the statutory term "population" which to biologists connotes interacting organisms of a particular species, is appropriately interpreted to mean "community," which connotes assemblages of populations based on ecological function. In promulgating final § 316(a) regulations, USEPA's Administrator stated:

> *The proposed regulations employed the term "balanced, indigenous population," as contained in the statute. Numerous objections were raised to USEPA's use of this phrase. Since the term "population" properly refers only to a single species, it is believed that the term*

> *"community" more accurately reflects the intent of the law. This term has therefore been substituted throughout the regulations. (39 Fed. Reg. 36,178 (8 October 1974)).*

Accordingly, USEPA's regulations provide for issuance of alternative thermal effluent limitations if "*a balanced indigenous community of shellfish, fish, and wildlife*", not necessarily particular populations within the community, will be maintained (40 CFR, 125.73(a); 44 Fed. Reg. 32,952 (7 June 1979)). These regulations define a "Balanced Indigenous Community" or "BIC" as:

> *"…a biotic community typically characterized by diversity, the capacity to sustain itself through cyclic seasonal changes, presence of necessary food chain species and by lack of domination by pollution tolerant species. Such a community 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 Act; and may not include species whose presence or abundance is attributable to alternative effluent limitations imposed pursuant to section 316(a)."*

To demonstrate that a BIC exists requires a case-by-case evaluation in the context of the specific waterbody and its biological community.

Indigenous - The term "indigenous" generally refers to the presence of species that would normally be found in the receiving waterbody; it is not restricted to only truly native species, since managed, introduced species are often included as "indigenous". "Indigenous" can also be interpreted to mean growing or living in the reference (control) body or stretch of water at the time the thermal impact determination is made.

The USEPA has interpreted the term somewhat more restrictively, but also acknowledges that "indigenous" does not mean communities that would exist in a waterbody only if it were in a pristine condition. In the preamble to its proposed § 316(a) rules, USEPA stated:

> *An "indigenous" population may contain species not historically native to the area which have resulted from major irreversible modifications to the water body (such as hydroelectric dams) or to the contiguous land area (such as deforestation attributable to urban or agricultural development) or from deliberate introduction in connection with a program of wildlife management. To qualify for an exemption under Section 316(a), it is therefore not necessary to show that the discharge is compatible with a population which may have existed in a pristine environment, but which has not persisted.* (39 Fed. Reg. 11,435 (28 March 1974); USEPA, Proposed Guidelines for Administration of the 316(a) Regulations (Draft 18 April 1974)).

USEPA thus would make reversibility of environmental modifications the "test" for determining what communities should be considered "indigenous" to the receiving waterbody. If modifications "*cannot reasonably be removed or altered*," then an "indigenous" community will include resulting "*species not historically native to the area*." (USEPA, 316(a) Technical Guidance - Thermal Discharges (Draft 30 September 1974)). On the other hand, "*an altered community which has resulted from pollution that will be corrected by compliance by all sources with Section 301(b)*" *[i.e., effluent limitations and standards] will not be considered "indigenous.*" (39 Fed. Reg. 36,178 (8 October 1974)).

Balanced - The term "balanced" derives from long-standing knowledge that most natural aquatic communities are composed of many species of organisms without an overwhelming number of any one of them. Ecologists have developed several formal indices (i.e., community assessment metrics) to assess the balance and structure of aquatic communities (e.g., indices of diversity, evenness, or richness). To be "balanced", USEPA has indicated that an aquatic community must not be "*dominated by pollution-tolerant species whose dominance is attributable to polluted water*

conditions." (39 Fed. Reg. 11,435 (28 March 1974); 40 CFR 125.71(c), 44 Fed. Reg. 32,951-52 (7 June 1979)).

However, species diversity at each trophic level is not required, and some changes in species composition and abundance are consistent with a balanced community. (39 Fed. Reg. 36,178 (8 October 1974)). According to USEPA, the following are evidence of community imbalance:

- Blocking or reversing short or long-term successional trends of community development.
- A flourishing of heat-tolerant species and an ensuing replacement of other species characteristic of the indigenous community.
- Simplification of the community and the resulting loss of stability.

If a community is stable, not dominated by heat-tolerant species, and follows normal development patterns, it is considered "balanced".

In summary, a BIC is a stable, normally functioning community that is not dominated by heat-tolerant species and is consistent with the reasonably permanent environmental conditions of the waterbody, given potential water quality improvement. An indigenous population of aquatic organisms does not mean that those organisms must be representative of "pristine" conditions in the waterbody. Similarly, a balanced community is one that exhibits structural, functional, and cyclical patterns that are typical for the waterbody and similar waterbodies.

3.3.2 Protection and Propagation

The legislative history of § 316(a) and the subsequent judicial and administrative decisions applying it make clear that the thermal discharge performance standard – the protection and propagation of a BIC – is not to be interpreted as a complete lack of observable effects on that aquatic community. Some effects of added heat to a receiving waterbody are to be expected, especially at the point of discharge and within the designated thermal mixing zone. For example, USEPA has recognized that "*[e]very thermal discharge will have some impact on the biological community of the receiving water," and therefore that "[t]he issue is the magnitude of the impact and its significance in terms of the short-term and long-term stability and productivity of the biological community affected*" (Boston Edison Company (Pilgrim Station Units 1 and 2), NPDES Permit Determination No. MA0025135 (Decision of the Regional Administrator, 11 March 1977)).

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 (USEPA, NRC, and FWS, 316(a) Technical Guidance Manual (Draft 11 December 1975)).

3.3.3 Appreciable Harm

The § 316(a) implementing regulations identified in 40 CFR Part 125, Subpart H, along with administrative and legal precedents, identify the following decision criteria for use in evaluating whether "Appreciable Harm" has occurred and whether a BIC is present in the area receiving the thermal discharge (Coutant 2018).

- Presence of all trophic levels
- Presence of necessary food chain species
- Diversity
- Capability to sustain itself
- Lack of domination of pollution (heat) tolerant

- No increase in nuisance species
- Increase or decrease of indigenous species
- No decrease in threatened and/or endangered species
- No habitat exclusion due to temperature
- Maintenance of a zone of passage
- Change in commercial or sport species
- Biological data on key species
- No habitat former alterations
- Magnitude and duration of any identifiable thermal effects
- Sublethal or indirect effects
- No thermal effects on rare or unique habitats
- Presence of critical function zones within thermally exposed areas
- Trends in the aquatic community
- Interaction of the thermal discharge with other pollutants

Thus, an acceptable ATEL is one that will not result in changes so substantial that would cause community imbalance, elimination, or replacement and thus provides adequate protection against appreciable harm. USEPA has indicated that other relevant factors in determining whether the BIC will be adequately protected include the nature of the waterbody, the risks posed by alternate cooling technologies, the age and remaining useful life of the generating facility, and the nature of the surrounding area (USEPA, 316(a) Technical Guidance - Thermal Discharges Draft 30 September 1974)).

3.3.4 Reasonable Assurance

The standard of proof under § 316(a) is one of "Reasonable Assurance", not scientific certitude, because there are seldom, if ever, cases where such certitude is achievable in the quantification of environmental effects or their significance to biological communities. USEPA has described this standard of proof as follows:

> *The study must provide reasonable assurance of protection and propagation of the indigenous community. Mathematical certainty regarding a dynamic biological situation is impossible to achieve, particularly where desirable information is not obtainable. Accordingly, the Regional Administrator (or Director) must make decisions on the basis of the best information reasonably attainable. At the same time, if he finds that the deficiencies in information are so critical as to preclude reasonable assurance, then alternative effluent limitations should be denied."* (USEPA, 316(a) Technical Guidance - Thermal Discharges (Draft 30 September 1974)).

USEPA has applied the "Reasonable Assurance" standard in numerous decisions implementing § 316(a).[1]

[1] Public Service Company of New Hampshire (Seabrook Station Units 1 and 2), NPDES Appeal No. 76-7 (Decision of the Administrator, 10 June 1977) at 22; Public Service Company of New Hampshire, et al., (Seabrook Station Units 1 and 2), NPDES Appeal No. 76-7 (Decision on Remand, 4 August 1978) at 22; Boston Edison Company (Pilgrim Station Units 1 and 2), NPDES Permit Determination No. MA0025135, Decision of the Regional Administrator, 11 March 1977) at 15-16; Boston Edison Company (Pilgrim Station Units 1 and 2), NPDES Appeal No. 78-7 (Initial Decision, 26 July 1978) at 4-5.

3.4 DEMONSTRATION STRUCTURE AND ORGANIZATION

Demonstrating that the BIC will be protected under the proposed ATEL is typically conducted in four steps:

1. Evaluating each biotic category for low potential impact;
2. Evaluating evidence for prior appreciable harm;
3. Predicting the potential for impact to Representative Important Species (RIS); and,
4. Preparation of a Master Rationale to support the requested alternative thermal limits.

Each of these steps are the focus of the subequent sections of this Demonstration.

4. BIOTIC CATEGORY RATIONALES

In preparing regulatory guidance for § 316(a) variance requests, USEPA recognized that not all components of an aquatic ecosystem are equally vulnerable to the potential effects of thermal discharge. As a result, USEPA included in their draft guidance (USEPA 1977) recommendations for a screening process to identify those components that have a low potential for impact and allow the subsequent analysis to focus on those components of greatest risk. This guidance recommends dividing the biological community into six biotic categories based on the types of organisms, the habitat resource zone they occupy, and their role in the community food web:

- phytoplankton,
- zooplankton (including meroplankton),
- habitat formers,
- benthic macroinvertebrates (including shellfish),
- fish, and
- other vertebrate wildlife.

The Guidance Manual (USEPA 1977) further recommends that facilities conduct pilot field investigations and literature searches to determine if a site is one of low potential impact (LPI) for one or more of the individual biotic categories.

Often these initial investigations will be sufficient to determine if a site is an area of LPI or if additional studies are necessary to respond to the decision criteria presented in Section 3.3 of the Guidance Manual and develop the rationales for the six biotic categories. These rationales evaluate the available scientific information relative to the decision criteria for each biotic category to determine whether a site is an area of LPI. Thermal discharges to sites successfully meeting the area of LPI decision criteria under this early screening process pose little potential threat to the biotic category or categories for which the criteria are met. Those discharges not meeting the decision criteria to qualify as a site of LPI for one or more biotic categories are required to conduct additional studies to determine if the proposed alternative thermal limits will still be protective of the BIC.

For each of the six-biotic categories described in the Guidance Manual, the following sections characterize the community present in the LMOR in the vicinity of the LEC, present the applicable decision criteria for determining an area of LPI, and develop a rationale responsive to these criteria based upon the information presented. More specifically, each element of the biotic category sections includes:

- **Category Characterization**: provides a general description of the biotic category based on available data from the vicinity of the LEC, the LMOR, or another large river with similar characteristics to that of the Missouri River. The information presented is based on available literature and/or prior studies to characterize the major/dominant forms present, fluctuations in population and/or structural dynamics, non-thermal factors affecting the biotic category (e.g., water quality, habitat modifications, introduction of non-native forms), and potential exposure to the thermal plume.
- **Decision Criteria**: identifies and describes the area of LPI decision criteria as it relates to the biotic category in question.
- **Rationale**: provides the justification and basis for whether the LPI criteria are satisfied. For biotic categories that do not meet the LPI criteria, the additional field studies, NPAH decision criteria, and biotic category rationales are presented in Section 5.

4.1 PHYTOPLANKTON

4.1.1 Category Characterization

Phytoplankton are microalgae that inhabit the photic zone (i.e., upper water column) of waterbodies such as rivers, lakes and oceans. Phytoplankton growth is favored in habitats with good light availability, adequate nutrients, and relatively high residence time (Bukaveckas et al. 2011), such as lakes, reservoirs and bays.

Most phytoplankton rely on currents to keep them afloat and carry them through the waterbody and can be the base of some aquatic food webs (NOAA 2017), though food webs in many rivers are detrital based (USACE 1974). Many rivers, such as the Missouri River, exhibit high turbidity levels which decreases light availability and swift water currents that reduce residence time, typically resulting in limited phytoplankton growth (Hesse et al 1982). In addition, the higher water velocities found in many rivers can limit resource utilization efficiency by reducing opportunities for individual phytoplankton cells to utilize growth factors like ambient nutrients (Bukaveckas et al. 2011) leading to reduced overall phytoplankton biomass (Paerl et al. 2006). Due to these habitat attributes, large riverine systems such as the Missouri River have a food web based heavily on detritus, rather than on phytoplankton (Hesse et al 1982). River phytoplankton typically exhibit lower species richness and reduced biomass relative to lake phytoplankton (Rojo et al. 1994).

Equitable Environmental Health (EEH 1976) collected phytoplankton in the vicinity of LEC on five dates in 1974 (July 29, August 29, September 26, October 24 and November 22) and three dates in 1975 (April 22, May 22 and June 19). The following phytoplankton phyla were collected:

- Bacillariophyta (diatoms)
- Chlorophyta (green algae)
- Cyanophyta (blue-green algae)
- Euglenophyta
- Pyrrophyta (dinoflagellates)

The EEH study concluded that the relatively low abundance of phytoplankton in the vicinity of LEC was due to the absence of taxa intolerant of high river flow and turbid water conditions (UEC 1976).

Studies of phytoplankton conducted monthly from 1974 – 1977 in the middle Missouri River (RM 646 – 532.5; the LEC is located near RM 57) by Reetz (1982) observed, in addition to the above, the following two additional phyla:

- Cryptophyta
- Chrysopyhta

Compositional patterns were similar to that observed by EEH (1976). Diatoms dominated the community throughout much of the year (especially in winter and spring). Green algae were usually present in Reetz's sample collections, increasing in number in mid to late summer. Blue-green algae were important components of the community in summer, as cryptophytes were in winter. Chrysophytes, euglenoids, and dinoflagellates were usually present in small to moderate numbers throughout the year. This composition was influenced by discharges of water and associated lentic phytoplankton from Lewis and Clark Lake, an upstream main-stem reservoir and population source for downstream phytoplankton.

Dzialowski et al. (2013) conducted a study comparing phytoplankton in backwater, chute, and mainstem environments in the LMOR (survey range RM 183-660). The sampling station in the study nearest the LEC (RM 57) was at USGS gage 06909000 at RM 197. The study found that diatoms made up the majority of the phytoplankton in all three habitats. Diatoms are more tolerant of the turbid conditions typical of the Missouri River than other phytoplankton taxa. Chlorophyta, cyanobacteria, Cryptophyta, and Euglenophyta were present but decreased in abundance as turbidity increased. The 1974-1975 EEH study similarly found the phytoplankton dominated by diatoms (> 90 percent of the observed biomass) with Chlorophyta, cyanobacteria, Cryptophyta, and Euglenophyta also present in reduced numbers.

The available studies summarized above show that the composition of the phytoplankton component present within the vicinity of the LEC is similar to that found throughout the Missouri River.

4.1.2 Decision Criteria

The USEPA has established criteria to determine if a site is an area of LPI for phytoplankton. Areas of LPI for phytoplankton are defined as systems in which phytoplankton is not the base of the food chain. The Guidance Manual states that most rivers and streams fall into this category (USEPA 1977). An area can be considered LPI if it meets the following criteria:

- Phytoplankton are not the food chain base of the system and do not contribute a substantial amount of the primary photosynthetic activity supporting the community;
- The thermal discharge would not encourage a shift toward nuisance species; and
- Operation of the discharge would not alter the community from a detrital to a phytoplankton-based system (USEPA 1977).

4.1.3 Phytoplankton Rationale

Criterion: *Phytoplankton are not the food base of the river system.*

The Missouri River, like many other lotic systems, is based on detritus, rather than phytoplankton (Hesse 1982).

Criterion: *The thermal discharge would not encourage a shift toward nuisance species.*

Nuisance phytoplankton species are so-called because they can react to stimulants like strong light, high nutrient concentrations, and elevated water temperatures with a sudden, rapid increase in growth called blooms. These blooms can result in unsightly algal mats, unpleasant odors or taste, and in some instances, toxins produced as metabolic by-products of the bloom species. Additionally, as the nuisance species die, the individual organisms sink to the bottom of the water column where they are metabolized by bacteria and micro-organisms. This process consumes ambient dissolved oxygen which can become depleted when large numbers of dead organisms are metabolized after a bloom.

Light availability, reduced by the turbid nature of the Missouri River typically limits the potential for excessive growth of phytoplankton (Hesse et al. 1982; Bukaveckas et al. 2011), including nuisance species. Unlike phytoplankton in lakes and reservoirs, phytoplankton in rivers are constantly transported downstream by the river current; therefore, individual organisms are not resident to the area for a prolonged time and would experience very limited exposure to the LEC thermal discharge. Hydrothermal modeling conducted by Kleinfelder predicts that free-drifting organisms would take approximately an hour and a half to pass through the thermally exposed zone at river flows ranging from 38,000 cfs to 68,000 cfs. If a bloom event does occur in a river, it is typically short in duration, due to dissipation of the phytoplankton by river currents (Marshall, no date).

Due to the transient exposure of phytoplankton to the LEC thermal discharge and lack of a "resident" diverse algal population due to constant downstream transport, the LEC thermal discharge will not result in a shift towards a dominance of nuisance species. In addition, temperatures rapidly decline after the confluence of the LEC discharge canal with the Missouri River. Typically, temperatures within the thermal plume are less than 5°F above ambient by 0.25 miles downstream of the discharge canal and continue to decrease with distance downstream. These moderately elevated temperatures are also not sufficiently high to result in changes in the phytoplankton community.

Criterion: *Operation of the discharge would not alter the food web from a detrital to a phytoplankton-based system.*

The thermal plume would not alter the LMOR from its current detrital-based system to a phytoplankton-based one. Phytoplankton growth in waterbodies is strongly influenced by light availability and residence time (Bukaveckas et al. 2011). Given the limited light availability (resulting from high turbidity), strong water currents prevalent in the LMOR that discourage phytoplankton growth (UEC 1976), and limited exposure that the phytoplankton population has to the thermal plume (due to swift downstream transport), the LEC discharge would not cause a shift in the river from the current detrital-based food web to a phytoplankton-based one.

To summarize, a review of the available studies and literature show that the Missouri River has a detrital-based food web and not one based on phytoplankton productivity primarily due to the high turbidity and flows which limit phytoplankton growth. Further, phytoplankton are exposed to the LEC thermal plume, mostly at temperatures less than 5°F above ambient, for only a short period of time (typically less than 1.5 hours) due to the constant downstream transport. These factors also limit the potential for a shift towards nuisance phytoplankton taxa and the potential for the Missouri River to become a phytoplankton-based food web. Therefore, the area of the Missouri River receiving the LEC thermal discharge satisfy the criteria for classification as an area of LPI for phytoplankton.

4.2 ZOOPLANKTON AND MEROPLANKTON

4.2.1 Category Characterization

Zooplankton are small, common, heterotrophic organisms that inhabit freshwater, brackish, and marine environments and consist of two subgroups: holoplankton and meroplankton. Holoplankton spend their entire lives as plankton. Meroplankton are small, generally early life-stage organisms that only spend this early life-stage in a planktonic form (e.g., shellfish and fish eggs and larvae). Generally, meroplankton will experience similar exposure to a thermal discharge as zooplankton. Zooplankton consume phytoplankton and other organic material, regenerate nutrients, and transfer energy to higher trophic levels in the food web. Freshwater zooplankton are typically composed of rotifers, copepods, and cladocerans (Havel et al. 2009). Rotifers are usually the dominant zooplankton group in rivers. While copepods and cladocerans are present in rivers, they are more abundant in still water environments such as lakes, ponds, and reservoirs (Hynes 1970). Havel et al. (2009) concluded that the lower abundance of copepod and cladocerans in rivers was due in part to reproductive rates too slow to compensate for the mortality these taxa typically experienced in swift river environments.

Zooplankton densities in the LMOR and other rivers are typically low (Dzialowski et al. 2013). Rivers present environmental conditions such as high-water current velocity and elevated ambient levels of suspended particles (i.e. turbidity) that are not conducive to zooplankton growth (Repsys and Rogers 1982). Additionally, most zooplankton have a limited capacity to tolerate the physical buffeting planktonic organisms experience in waterbodies with higher current velocities and turbulence (Repsys and Rogers 1982).

Reservoir discharges are the source of most of the zooplankton found in rivers (Hynes 1970; Havel et al. 2009) and zooplankton abundance typically decreases with distance from these impoundments. Studies by Williams (1971) and Kallemeyen et al. (1977) showed a reduction of 70 percent in zooplankton density 90 miles below the Lewis and Clark Lake (RM 811.1) tailwaters in the Missouri River. While tributaries, backwater areas, and floodplains can also serve as sources of river zooplankton, Dickerson et al. (2009) and Fisher (2011) cited channelization of the LMOR as having largely disconnected the river from floodplains and other backwater areas that previously served as sources of zooplankton to the river. In addition, Havel et al. (2009) found that Missouri River tributaries, on average, contributed little to main stem zooplankton populations. Other potential sources of zooplankton in the Missouri River have been shown to be limited (Havel et al. 2009).

Several zooplankton studies have been conducted within various reaches of the Missouri River and form the basis for characterizing the zooplankton component near the LEC. Consistent with the descriptions of the zooplankton composition discussed above for rivers in general, the Missouri River studies have shown that copepods, cladocerans, and rotifers are the most commonly observed zooplankton taxa. Copepods and cladocerans were more abundant in the upper and middle Missouri River while rotifers were more abundant in the lower, channelized section of the river (Havel et al. 2009; Dickerson et al. 2009; Repsys and Rogers 1982).

As part of the original § 316(a) demonstration studies for the LEC, EEH (1976) collected zooplankton in the Missouri River at the LEC (RM 57.5) in 1974 and 1975. Samples showed zooplankton composition consisted primarily of rotifers, cladocerans, and copepods, similar to the composition found in other Missouri River studies. The overall abundance of zooplankton at the LEC was described as low and the distribution was noted as patchy (UEC 1976).

Zooplankton taxa of commercial importance or rare or endangered zooplankton taxa were not observed or identified in any of the Missouri River studies discussed above and are not known to be present in the river.

4.2.2 Decision Criteria

Areas of LPI for zooplankton are defined as those characterized as having low concentrations of commercially important species, no rare and endangered species and/or those forms that are important components of the food web; or where the thermal discharge will affect a relatively small proportion of the receiving waterbody.

4.2.3 Zooplankton Rationale

The Guidance Manual states that rivers and streams typically have low concentrations of zooplankton, and that most of these waterbodies can be considered areas of LPI (USEPA 1977). Union Electric Company (UEC 1976) found the Missouri River to have a low standing crop of zooplankton. Zooplankton of commercial importance or threatened or endangered zooplankton taxa have not been observed in the studies surveying the LMOR as discussed in Section 4.2.1.

The LEC thermal discharge also affects a relatively small portion of the LMOR, the LEC discharge is typically less than 5 percent of the river flow, and zooplankton and meroplankton drifting downstream would only be exposed to the thermal plume for a brief period of time. Hydrothermal modeling conducted by Kleinfelder predicts that free-drifting organisms would take approximately an hour and a half to pass through the thermally exposed zone at river flows ranging from 38,000 cfs to 68,000 cfs.

For these reasons, the LMOR in the vicinity of the LEC meets the Guidance Manual criteria as an area of LPI for zooplankton and meroplankton. The ichthyoplankton (fish eggs and larvae) component of meroplankton are further addressed in via the predictive assessment in Section 6.

4.3 HABITAT FORMERS

4.3.1 Category Characterization

Habitat formers are any assemblage of plants and animals characterized by a relatively sessile (stationary) life stage with aggregated distribution on which other organisms attach or with which they associate (USEPA 1977). The USEPA (1977) further defines habitat formers as:

1. *"A living and/or formerly living substrate for the attachment of epibiota;*
2. *Either a direct or indirect food source for the production of shellfish, fish, and wildlife;*
3. *A biological mechanism for the stabilization and modification of sediments and contributing to the development of soil;*
4. *A nutrient cycling path or trap; or*
5. *Specific sites for spawning and providing nursery, feeding and cover areas for fish and shellfish."*

Within the Missouri River, habitat formers may include any group of plants or animals which are attached to the river bottom and provide suitable substrate or other critical habitat characteristics for other organisms (UEC 1976). Examples include submerged and emergent aquatic vegetation (SAV and EAV). Surveys conducted as part of the 1976 LEC § 316(a) demonstration (UEC 1976) identified the river's velocity, turbidity, silty substrate, and rip-rap shoreline banks as likely limiting factors to the colonization and development of habitat formers in the vicinity of the LEC discharge (UEC 1976). Silt substrate is unstable and highly susceptible to washout under the high velocity conditions found in the channelized sections of the LMOR (EEH 1976). The surveys found the main channel silty substrate, rip-rap shorelines and low light penetration (i.e. turbidity) did not support the growth of aquatic vegetation (EEH 1976). Angradi et al. (2009) also found that much of the lower river was devoid of submerged aquatic vegetation.

Additionally, due to the historic channelization of the LMOR and the relatively uniform shoreline in the vicinity of the LEC, suitable habitats for spawning or nursery areas for many fish species in the river were not identified (EEH 1976). The current channel morphology of the LMOR in the vicinity of the LEC remains dominated by channelization with rock wing dikes and revetments constructed as part of the Missouri River Bank Stabilization and Navigation Project (Ferrell 1996). These alterations to the channel and flow regime continue to result in changes to the habitat diversity and availability, which has resulted in decreases in fish populations, and native flora and fauna (Johnson et al. 2006; Bryan et al. 2010). Throughout the two years of sample collection under the current Study Plan, no established SAV or EAV communities were observed in any part of the study area.

4.3.2 Decision Criteria

The Guidance Manual provides that areas of LPI for habitat formers are those that are typically devoid of habitat formers. LPI sites may be devoid of habitat formers due to low levels of nutrients, inadequate light penetration, sedimentation, scouring stream velocities, unsuitable substrate character, or the presence of toxic materials (USEPA 1977). Should these factors or physical conditions limiting the habitat formers presence change, the USEPA (1977) defines a site as an area of LPI if the heated discharge would not restrict the reestablishment of habitat formers. LPI sites for habitat formers are also defined as sites that do not pose a danger to threatened or endangered species of other biotic categories from an adverse impact on habitat formers.

4.3.3 Habitat Formers Rationale

The 1976 LEC § 316(a) demonstration (UEC 1976) found that the area within the vicinity of the thermal discharge was devoid of habitat formers due to the river's velocity, turbidity, and silty substrate which were limiting factors to the colonization and development of habitat formers. These limiting environmental conditions are still present today, as is the continued channelization and steep shorelines armored with riprap found throughout the LMOR, which do not support the growth of aquatic vegetation (Ferrell 1996). Based on the physical alterations and persistently unstable substrate conditions of the riverine environment that continue in the LMOR, it is suspected that the absence of habitat formers in the vicinity of the Labadie thermal discharge is unrelated to the discharge and would not change if the discharge were reduced or terminated. The LEC site is devoid of habitat formers and likely to remain so, therefore, the area of the LMOR receiving the LEC thermal discharge satisfies the decision criteria as a site of LPI.

4.4 MACROINVERTEBRATES/SHELLFISH

4.4.1 Category Characterization

Benthic macroinvertebrates are organisms that live in and on the bottom and shoreline substrates of waterbodies where they play an important role in providing food, nutrient cycling, and energy transfer in the food webs of freshwater and marine ecosystems. These organisms may be permanent residents in the substrate or temporary ones such as the larval stages of insects. This biotic category includes shellfish, which in freshwater environments are primarily represented by mussels and clams, but also includes crustaceans such as crayfish.

Substratum-type is the primary factor controlling benthic macroinvertebrate distribution, e.g., chironomids (midgeflies) and oligochaetes (aquatic worms) are commonly found in depositional areas with fine-grained sediments (Hynes 1970; Wolfe et al. 1972). Swift river currents can reduce sediment stability and increase turbidity; conditions which have been shown to limit the development of macroinvertebrate communities and are often associated with low numbers of benthic infauna (Carter et al. 1982; Hynes 1970). Currents and substrate are also known to influence freshwater mussel distribution (Hoke 2009).

As part of the original LEC § 316(a) demonstration studies, EEH conducted surveys of the benthic macroinvertebrate component in the vicinity of the LEC in 1974-1975 using artificial substrate [modified Hester-Dendy (H-D)] samplers, a petite Ponar grab, and a plankton net to collect samples.

Overall, the macroinvertebrate composition varied by substrate type represented by the different collection methods. The macroinvertebrates sampled using the artificial substrate samplers were dominated by caddisflies (order Trichoptera) and midgeflies (order Diptera, family Chironomidae), which together represented approximately 91 percent of the organisms collected (EEH 1976). Drift samples collected 34 macroinvertebrate taxa from two phyla with a genus (*Polypedilum*) of midgefly representing the most prevalent taxa, accounting for approximately 25 percent of the total number of organisms collected. Benthic macroinvertebrates in grab samples were represented by 17 taxa from four phyla. Oligochaetes (aquatic worms) were the most prevalent taxa among the samples.

UEC (1981) conducted a 1-year benthic macroinvertebrate survey in the vicinity of the LEC using a standard Ponar grab sampler. A total of 51 macroinvertebrate taxa were collected with tubificid oligochaetes accounting for approximately 84 percent of the total number of organisms. Chironomidae accounted for only 5 percent of the organisms collected. No commercially important, rare or endangered species were collected during the study. Macroinvertebrates identified were consistent with that expected for a fine sand/silt substrate habitat and were similar to those reported in other Missouri River studies (UEC 1981).

Findings from other studies on the LMOR are consistent with those found in the studies conducted near the LEC showing macroinvertebrate composition influenced primarily by substrate type. Surveys by USGS (2010), Poulton et al. (2002), MDNR (2014), and Carter et al. (1982) all found macroinvertebrates sampled by artificial substrate samplers were dominated by Trichoptera with additional prevalent taxa including mayflies (order Ephemeroptera), stoneflies (order Plecoptera), and Chironomidae. In depositional areas (e.g., dike pool habitats) characterized by fine grained sediments, these studies found the macroinvertebrates were dominated by Oligochaeta and Chironomidae. Poulton and Allert (2012) also found Oligochaeta to be the dominant taxa in petite Ponar samples with substantial contributions from Chironomidae and burrowing Ephemeroptera.

Similar to the sampling conducted in the vicinity of the LEC, none of the studies referenced above collected any macroinvertebrate species of commercial importance or that are threatened or endangered (T&E).

Shellfish are grouped into the benthic macroinvertebrate biotic category by the USEPA. The flow (swift and turbid) and substrate characteristics (hard bottom or silt/clay) of the LMOR do not provide ideal habitat for shellfish. EEH (1976) found that shellfish were not commonly collected and were represented by one gastropod (snail) genus (*Physa* sp.) and one species of fingernail clam (*Sphaerium striatinum*) collected on artificial substrate samplers on one date in the discharge canal. The same clam species was collected in Ponar grab samples in June and October (a total of 9 individuals). During the UEC (1981) survey, no freshwater mussels (Unionidae) were collected, but several species of freshwater fingernail clams and snails were found. The fingernail clam, *Sphaerium striatinum*, was the most abundant shellfish taxon collected representing approximately 2 percent (162 organisms) of the total macroinvertebrates collected. The other LMOR studies reviewed above made no specific mention or discussion of shellfish (mussels and/or clams).

In addition to previous studies, three qualitative visual surveys for shellfish were conducted in 2017 and 2018 to supplement Ponar grab sampling to look for the presence of any T&E shellfish species. No live shellfish were observed or collected during any of the visual surveys conducted for the LEC in 2017 and 2018. The various shells observed and recorded are presented in Table 4-1 for the three individual surveys. No T&E shellfish species were collected in the Ponar samples and no shells of T&E shellfish were observed during the visual surveys.

Shellfish species of commercial importance or that are T&E were not collected during any of the historical sampling conducted in the vicinity of the LEC, the other LMOR studies discussed above, or in the current study.

4.4.2 Decision Criteria

The USEPA (1977) defines an area of LPI for macroinvertebrate/shellfish fauna as one which, within the primary and far-field study areas, can meet the following requirements as specified in the Guidance Manual:

1. Macroinvertebrate/shellfish species of existing or potential commercial value do not occur at the site.
2. Macroinvertebrate/shellfish do not serve as important components of the aquatic community at the site.
3. T&E species of macroinvertebrate and/or shellfish do not occur at the site.
4. The standing crop of macroinvertebrate/shellfish at the time of maximum abundance is less than one-gram ash-free dry weight per square meter.
5. The site does not serve as a spawning or nursery area for the species in 1, 2, or 3 above.

Table 4-1 Result of visual mussel survey on September 15, December 7, 2017 and June 14, 2018.

		Zone 1			Zone 2			Zone 3			Zone 4		
Common Name	***Scientific Name***	**Sep-17**	**Dec-17**	**Jun-18**	**Sep-17**	**Dec-17**	**Jun-18**	**Sep-17**	**Dec-17**	**Jun-18**	**Sep-17**	**Dec-17**	**Jun-18**
Asian Clam	*Corbicula fluminea*	A, C	A	A, C	A		R	A, C	A, C	A, C	C, U	A, C	A, C
Zebra Mussel	*Dreissena polymorpha*		A	C, U				R	U	C, U		U	U, R
Fragile papershell	*Leptodea fragilis*	U	C					U, R	C	U, R		U	
Treehorn Warty back	*Obliquaria reflexa*		U							R			
Round pigtoe	*Pleurobema coccineum*							R					
Mapleleaf	*Quadrula quadrula*										R		
Mucket	*Lampsilis sp.*		U										
Pink heelsplitter	*Potamilus alatus*	U								R	U		R
Giant Floater	*Pyganodon grandis*		U	R						U			U

Relative Abundance Codes: A - Abundant, C - Common, U - Uncommon, R – Rare
Note: No live specimens were encountered. Taxa and relative abundances were based off of observed shells.

4.4.3 Macroinvertebrates/Shellfish Rationale

Criterion: *Macroinvertebrate/shellfish species of existing or potential commercial value do not occur at the site.*

Commercially valuable riverine macroinvertebrates primarily include certain freshwater mussel species and some varieties of snails and crayfish. None of the macroinvertebrates or shellfish collected by EEH (1976) or UEC (1981) in the vicinity of LEC were of commercial importance, and none are otherwise known to exist. Similarly, macroinvertebrate species of commercial importance were not collected in the current study or the other studies reviewed.

Criterion: M*acroinvertebrates/shellfish do not serve as important components of the aquatic community at the site.*

Although benthic invertebrates are typically important components of food webs, the lower, channelized section of the Missouri River supports relatively low numbers of benthic organisms, including the area of the river in the vicinity of LEC (EEH 1976, UEC 1981). Even though macroinvertebrate abundance may be low, they still provide an important food source for fish.

Criterion: *Threatened or endangered species of macroinvertebrate/shellfish do not occur at the site.*

Surveys in the vicinity of the LEC conducted by EEH (1976) and UEC (1981) found no evidence of T&E macroinvertebrate or shellfish species.

Criterion: *The standing crop of macroinvertebrates/shellfish at the time of maximum abundance is less than one-gram ash-free dry weight per square meter.*

Although the abundance of benthic invertebrates in the vicinity of the LEC has been described as low (EEH 1976, UEC 1981), information regarding standing crop is not available. Data from the current two-year study shows that mean seasonal benthic macroinvertebrate densities across all zones ranged from approximately 140 organisms per square meter to 9480 organisms per square meter. These numbers suggest that benthic macroinvertebrate standing crop likely exceeds one-gram ash-free dry weight per square meter.

Criterion: *The site does not serve as a spawning or nursery area for the species that are commercially valuable, rare or endangered, or important components of the food web.*

No commercially valuable or T&E benthic macroinvertebrate or shellfish species have been found in the surveys conducted near the LEC and there is no evidence that these species rely on the area directly exposed to LEC's thermal discharge for reproduction. However, areas behind dike fields downstream of the LEC thermal discharge may contribute to macroinvertebrate/shellfish reproduction and are potentially exposed to the thermal plume.

While the area of the LMOR receiving the LEC thermal discharge meets most criteria for an area of LPI for benthic macroinvertebrates, this subcomponent does represent an important food source for fish and is potentially exposed to the LEC thermal discharge. Therefore, benthic macroinvertebrates are a component of the ongoing biological assessment and addressed in detail relative to the Guidance Manual NPAH decision criteria in Section 5 of this Demonstration report.

On the other hand, shellfish occur only rarely in the vicinity of the LEC thermal discharge and, hence, have little potential for exposure to the thermal plume. Thus, the area of the LMOR receiving the LEC thermal discharge satisfies the decision criteria as a site of LPI for shellfish and therefore shellfish are not addressed further.

4.5 FISH

4.5.1 Category Characterization

Numerous studies of Missouri River fishes have been conducted to determine the long-term effects of river habitat modification on this community component. The most comprehensive study known as the Benthic Fishes Study (BFS) was conducted from 1995–1999 by a consortium consisting of the USGS Cooperative Fishery Units in six states along the Missouri River (Idaho, Montana, South Dakota, Kansas, Iowa, and Missouri), the Columbia Environmental Research Center, and the Montana Department of Fish, Wildlife and Parks (Berry and Young 2001; Galat et al. 2005b; Berry et al. 2004; Pierce et al. 2003). The BFS included the mainstem river from its source to its mouth at the Mississippi River (excluding the mainstem reservoirs). The study area was divided into a total of 27 segments, the last two of which (Segments 25 and 27) bracket the river reach where the LEC is located (RM 57.5). The study features detailed data on distribution, abundance, growth, mortality, recruitment, condition, and population size structure for 26 target benthic fish species.

Under the previous § 316(a) demonstration program, sampling targeting adult fish was conducted near the LEC CWIS and discharge canal (UEC 1976). More recent fisheries surveys (1980–1985 and 1995–2001) have been conducted by Ameren to establish a long-term database on fish composition and abundance in the river near the LEC in order to detect possible changes associated with plant operation or other factors, including river channelization and low flows during the drought of 1988–1992 (Ameren 1998, 2002). Parameters evaluated under this study included species composition, species diversity, species assemblage persistence, relative abundance, catch-per-unit-effort, fish size and condition, Pflieger faunal composition characterization, and individual fish movements through tag recaptures.

The Missouri River fish species composition varies longitudinally from the headwaters to its confluence with the Mississippi River at St. Louis (Berry et al. 2004). Berry and Young (2001) identified 156 fish species occurring in the entire Missouri River Basin and Galat et al. (2005b) found 136 species occurring in the mainstem, floodplains, and reservoirs and of these, 110 species were listed for the LMOR. The changing ecosystem and habitat losses during recent decades has decreased the abundance of many native species to rare or uncommon across part or all of their previous ranges (NRC 2002). It was estimated by Berry and Young (2001) that approximately 35 native species are declining in abundance, while 23 species (14 native and 9 introduced) are increasing.

Important sportfish species within the vicinity of the LEC, include the channel catfish, flathead catfish, blue catfish, sauger, walleye, white bass, striped bass, largemouth bass, smallmouth bass, spotted bass, white crappie, black crappie, and various sunfish species. Commercially exploited species have included common carp, channel catfish, bigmouth buffalo, smallmouth buffalo, flathead catfish, goldeye, and members of the sucker family (Catostomidae). Since July 1992, commercial fishing for catfish species in the Missouri River (flathead catfish, blue catfish, and channel catfish) has been prohibited due to a decline in the number of large fish (Berry and Young 2001).

Gizzard shad were found to be the most abundant species collected in both the BFS and Ameren studies and comprised 42 percent and 55 percent of the total catches, respectively. Almost all minnow, chub, and shiner species collected in the BFS were absent from the Ameren study (Ameren 2002) catches; this includes emerald shiner, which was the second-most frequently caught species in the BFS. This absence was most likely due to the habitats selected for sampling or low sampling efficiency of the electrofishing gear for small species during the Ameren study. In the BFS, many of the small cyprinid species were caught by seines in shallow or backwater areas (Berry et al. 2004). Other common species collected during the BFS and Ameren studies,

in decreasing order of abundance, include river carpsucker, freshwater drum, channel catfish, common carp, shortnose gar, and flathead catfish (ASA 2008). Another recent source (USACE 2006) has identified these species as being dominant, in addition to red shiner and goldeye.

4.5.2 Decision Criteria

The Guidance Manual provides that the fish section of a § 316(a) demonstration will be successful if it can show that the site is an area of LPI for fish. An area receiving a thermal discharge would be determined as a site of LPI if the following conditions within the primary and far-field study area as stated by USEPA (1977) are met:

1. The occurrence of sport and commercial species of fish is marginal;
2. This discharge site is not a spawning or nursery area;
3. The thermal plume (bounded by the 3.6°FC isotherm) will not occupy a large portion of the zone of passage which would block or hinder fish migration under the most conservative environmental conditions (based on 7-day, 10-year low flow or water level and maximum water temperature);
4. The plume configuration will not cause fish to become vulnerable to cold shock or have an adverse impact on threatened or endangered species.

4.5.3 Fish Rationale

In order for the LMOR in the vicinity of the LEC to meet the criteria for an area of LPI, the occurrence of sport and commercial fish species within that area must be minimal along with the presence of spawning and nursery areas. However, important sportfish species were identified within the vicinity of the LEC during several previous studies and include channel catfish, flathead catfish, blue catfish, sauger, walleye, white bass, striped bass, largemouth bass, smallmouth bass, white crappie, black crappie, and sunfish species. Commercially exploited species identified within the vicinity of the LEC include common carp, channel catfish, bigmouth buffalo, smallmouth buffalo, flathead catfish, goldeye, and members of the sucker family, Catostomidae. However, since July 1992, commercial fishing for catfish species in the Missouri River (flathead catfish, blue catfish, and channel catfish) is prohibited due to a decline in the number of large fish (Berry and Young 2001).

Given the above, the LEC thermal discharge does not meet the LPI decision criteria due to the occurrence of sport and commercial fish species within and moving through the thermal discharge area. In addition, some of the potentially thermally exposed areas within this section of the Missouri River contain macrohabitats that may be utilized for spawning (e.g., dike field habitats).

As the LEC thermal discharge area does not meet the decision criteria for LPI, the Guidance Manual presents requirements for additional studies to demonstrate the fish communities will not suffer appreciable harm. The LEC has undertaken the § 316(a) biological monitoring program to collect data sufficient to support water quality and biological assessments to assure the protection and propagation of a BIC of fish in the LMOR in the vicinity of the LEC thermal discharge. The current studies were designed to collect additional information relative to addressing the NPAH criteria for the fish component of the aquatic community in the vicinity of the LEC thermal discharge.

4.6 OTHER VERTEBRATE WILDLIFE

4.6.1 Category Characterization

Vertebrate wildlife other than fish includes waterfowl, turtles, and mammals (USEPA 1977). Much of the vertebrate wildlife in the LMOR such as waterfowl (e.g., herons, ducks, geese), muskrats,

and raccoons will prefer the shore zone and floodplain habitats. However, the channelization of the river, including rip-rap shorelines, has significantly reduced this available habitat and has eliminated much of the shoreline vegetation suitable for wildlife (UEC 1976). Several migratory shorebird species utilize the LMOR as a migration stopover area to rest and forage for food to replenish fat reserves (Lee 2007). Lee (2007) evaluated the available food resources for migrating shorebirds on three sandbar locations (RMs 171, 177, and 213) upstream of LEC (RM 57.5). Shorebirds of primary concern thought to utilize the LMOR sandbars include the endangered piping plover and least tern species (Lee 2007).

4.6.2 Decision Criteria

The Guidance Manual defines sites of LPI for vertebrate wildlife as areas where the thermal discharge does not impact large or unique populations of wildlife or important, threatened, or endangered wildlife. The USEPA (1977) acknowledges that most sites will be considered LPI sites for this biotic category, simply because the thermal discharge will not impact large or unique populations of wildlife. Areas of exception would be cold areas (such as North Central United States) where geese and ducks could be attracted to the thermal discharge and encouraged to stay through the winter (USEPA 1977). Areas not considered sites of LPI for other vertebrate wildlife are defined as sites in which the thermal discharge might pose a danger to threatened or endangered wildlife species.

4.6.3 Other Vertebrate Wildlife Rationale

Non-fish vertebrate wildlife have minimal and intermittent exposure to the LEC's thermal discharge and are therefore not vulnerable to direct effects from the thermal discharge. With the exception of herptiles (i.e., reptiles and amphibians), vertebrate wildlife species are warm-blooded, so their body temperatures are not dependent on their surroundings, even if they are temporarily resident in waters affected by the LEC thermal discharge. Furthermore, the area of the thermal plume is limited in relation to the available foraging and habitat areas in the LMOR near the LEC. Due to this low exposure of populations and the river channelization impacts on food resources and wildlife habitat, the area of the LMOR receiving the LEC thermal discharge satisfies the decision criteria as a site of LPI.

5. RETROSPECTIVE ASSESSMENT

5.1 INTRODUCTION

As articulated in 40 CFR Part 125, Subpart H, § 125.73 (c)(1), existing thermal dischargers seeking a § 316(a) variance may support their variance request by showing that NPAH has resulted from the ongoing thermal discharge. In the Guidance Manual (USEPA 1974, 1977), demonstrations based on showing the absence of appreciable harm are termed Type I demonstrations. These demonstrations are often termed "retrospective assessments" since they rely on evaluations of exposed populations compared to those that would exist in the absence of the thermal discharge or to those that existed prior to thermal exposure to identify potential adverse changes to the ecological communities attributable to the thermal discharge.

A retrospective assessment is generally not concerned with conditions within the permit-allotted mixing zone, in which thermal effects short of acute lethality are to be expected. Retrospective assessments can examine whether the discharge has adversely changed the communities in the area exposed to the thermal plume in comparison to communities in similar habitats outside the influence of the thermal discharge. They may also compare the present ecological conditions in the area exposed to the thermal discharge to conditions existing there prior to the thermal discharge. Because ecological communities seldom remain constant, any changes detected by this type of comparison may not necessarily be attributable to the thermal discharge. However, if current and prior data from a reference area unexposed to the thermal discharge are available, that information can be used to assess whether any changes detected within the area exposed to the thermal plume are due to the discharge, or simply parallel widespread changes in the water body.

This retrospective assessment uses a variety of ecological metrics for the fish and benthic macroinvertebrate biotic categories, deemed not to be LPI, to evaluate whether the decision criteria for demonstrating NPAH identified in Section 3.3.3 are met. Some of the NPAH decision criteria can be addressed using a retrospective assessment while others are addressed via the predictive assessment presented in Section 6. The results of the retrospective and predictive assessments are used to address each of the 18 NPAH decision criteria in the Master Rationale (Section 7). The subset of NPAH decision criteria that are addressed in this retrospective assessment include:

- Presence of all trophic levels
- Presence of necessary food chain species
- Diversity
- Capability to sustain itself
- Lack of domination of pollution (heat) tolerant
- No increase in nuisance species
- Increase or decrease of indigenous species
- No decrease in threatened and/or endangered species
- Change in commercial or sport species
- Magnitude and duration of any identifiable thermal effects
- Trends in the aquatic community

A spatial analysis using data from the recent two-year biological monitoring program was used in evaluating most of these criteria. In the spatial analysis, sampled sites upstream of the influence of the thermal discharge were used as reference areas with the assumption that, other than exposure to the thermal discharge, environmental conditions would be similar to those sites sampled downstream of the discharge. The assemblages of fish and benthic macroinvertebrates in the Upstream Reference zone therefore represent the BIC or the community that would be expected to be present in the Thermally Exposed and Downstream zones in the absence of the thermal discharge. Ecological metrics including community composition, abundance/density, and diversity were compared between the Upstream Reference, Thermally Exposed, and Downstream zones to look for specific differences identified in the NPAH criteria.

In addition to the spatial analysis, a temporal analysis comparing data from available historical studies near the LEC with the recent biological monitoring program data was used to evaluate potential adverse trends in the aquatic community. The results of this temporal analysis were used to supplement the findings of the spatial analysis.

An overview of the study plan for the recent biological monitoring program and the resulting data and the available historical data sets used in the spatial and temporal analyses is presented in the following section.

5.2 LABADIE 316(a) BIOLOGICAL STUDIES

Data from current (2017-2018) studies and available historical data (1980-1985, 1997-2002) were used to evaluate whether spatial and/or temporal adverse changes have occurred, or are occurring, in areas of the LMOR exposed to the LEC thermal discharge. A brief overview of each of these studies is provided below.

5.2.1 Recent Studies

Ameren prepared and submitted a thermal discharge monitoring study plan (hereafter Study Plan) to conduct the two years of biological monitoring required by the NPDES renewal permit issued for the LEC with an effective date of August 1, 2015. The MDNR verbally approved the Study Plan with minor modifications and authorized Ameren to commence data collection beginning in February 2017 while Ameren finalized the Study Plan. The final Study Plan was approved by the MDNR on July 13, 2017. A brief summary of the Study Plan is provided below. The full Study Plan and associated addenda are presented in Appendix A . The studies of this Demonstration consist of two main components:

- Hydrothermal Modeling
- Biological Monitoring Studies

5.2.1.1 Hydrothermal modeling and site selection

A state-of-the-art three-dimensional hydrothermal model (Flow-3D) was used by Kleinfelder to model varying scenarios of river and plant operation conditions to simulate the potential spatial extent of the thermal plume. To facilitate the selection of sampling sites, a predicted water temperature difference (ΔT) of 3°F or more above ambient river temperature was used to define river areas where plume temperatures could exceed natural daily water temperature variations[2], to which resident organisms were presumed to be well adapted. The area encompassing predicted temperatures >3°F was defined as the “Thermally Exposed zone”. A “Downstream zone” was defined as the river reach starting at the downstream end of the Thermally Exposed zone, and an “Upstream Reference zone” was defined as the river reach upstream of the LEC

[2]Conservatively based on a typical daily water temperature range of 1-2°F recorded at USGS gage 06935550, upstream of the LEC cooling water discharge outfall

intake and discharge outfall. In addition, a "Discharge zone" was defined as the area represented by the discharge canal and the area immediately below the canal extending to the first wing dike to be consistent with historical data collection programs. The four sampling zones were:

- An Upstream Reference zone (Zone 1) unexposed by the LEC discharge (RM 58.5 – RM 62);
- A Discharge zone (Zone 2) encompassing the area of highest potential exposure to the thermal discharge (RM 57.5 – RM 57.25);
- A Thermally Exposed zone (Zone 3) where potential effects from thermal discharge would be expected if present (RM 57.25 – RM 52); and
- A Downstream zone (Zone 4) which potentially could experience minor and transient exposure to the thermal discharge (RM 52 – RM 50).

Figure 5-1 shows the delineation of the four sampling zones.

5.2.1.2 Biological monitoring studies

Desktop and field reconnaissance surveys were conducted by Wood Environment and Infrastructure, Inc. (Wood) within each sampling zone to identify habitat types (e.g., inside bend, outside bend, dike fields), select sampling locations, and evaluate the applicability of sampling gears for each habitat type. The sampling plan was designed to ensure that multiple major habitat types were sampled in each zone to give a more complete representation of the fish and benthic macroinvertebrate assemblages.

Specific sampling sites for fish and benthic macroinvertebrate surveys were selected and stratified by habitat. A total of six habitat types (inside bend channel border, inside bend wing-dike pool, inside bend wing-dike, outside bend L-dike pool, main channel cross-over L-dike pool, and main channel cross-over L-dike bar) were selected for sampling within each zone. Sampling sites within the Thermally Exposed zone were identified first, then comparable habitat types and locations were identified in the Upstream Reference and Downstream zones. The locations selected for sample collection by habitat type are shown in the figures presented in Appendix A to Addendum 1 to the Study Plan (Appendix A). Figure 5-2 shows the location of the sampling stations in each zone.

Fish surveys were conducted by Wood using a variety of sampling gears to collect samples from the different habitat types in each of the sampling zones. The use of multiple sampling methods serves to overcome gear bias and ensure a more complete inventory of the species present in the subject receiving water body segment. Sample collection for adult and juvenile fish was conducted monthly during a two-year period (Feb. 2017- Jan. 2019). Ichthyoplankton samples were collected by Wood in inside bend wing-dike and outside bend and main channel cross-over L-dike field habitats were collected biweekly from mid-March through July and monthly during August and September during the two-year period.

Benthic macroinvertebrate and shellfish samples were collected by Wood quarterly from depositional and rock/gravel habitats in the river. Samples from depositional habitats were collected using a standard (9-inch x 9-inch) Ponar grab sampler. Samples from rock/gravel habitats were collected using H-D multi-plate samplers. In addition to noting the presence of and identifying any shellfish collected during the benthic and/or fish sample collections, Wood conducted periodic visual surveys for shellfish and mussel/clam shells to determine whether any T&E shellfish were present in the study area.

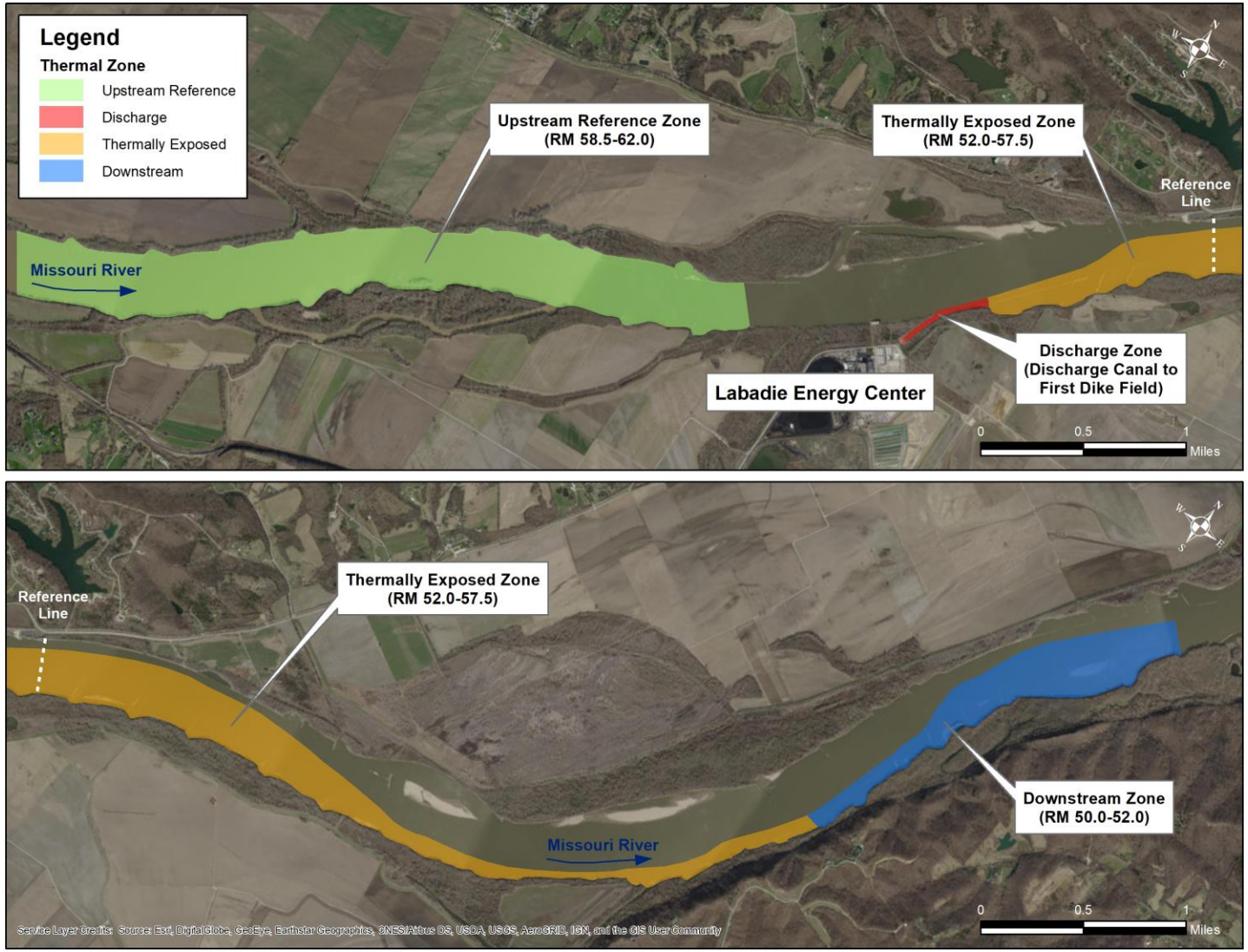


Figure 5-1 Four sampling zones identified within the study area based on thermal plume mapping for the LEC 316(a) thermal demonstration. (Color coding of the zones is continued throughout this section.)

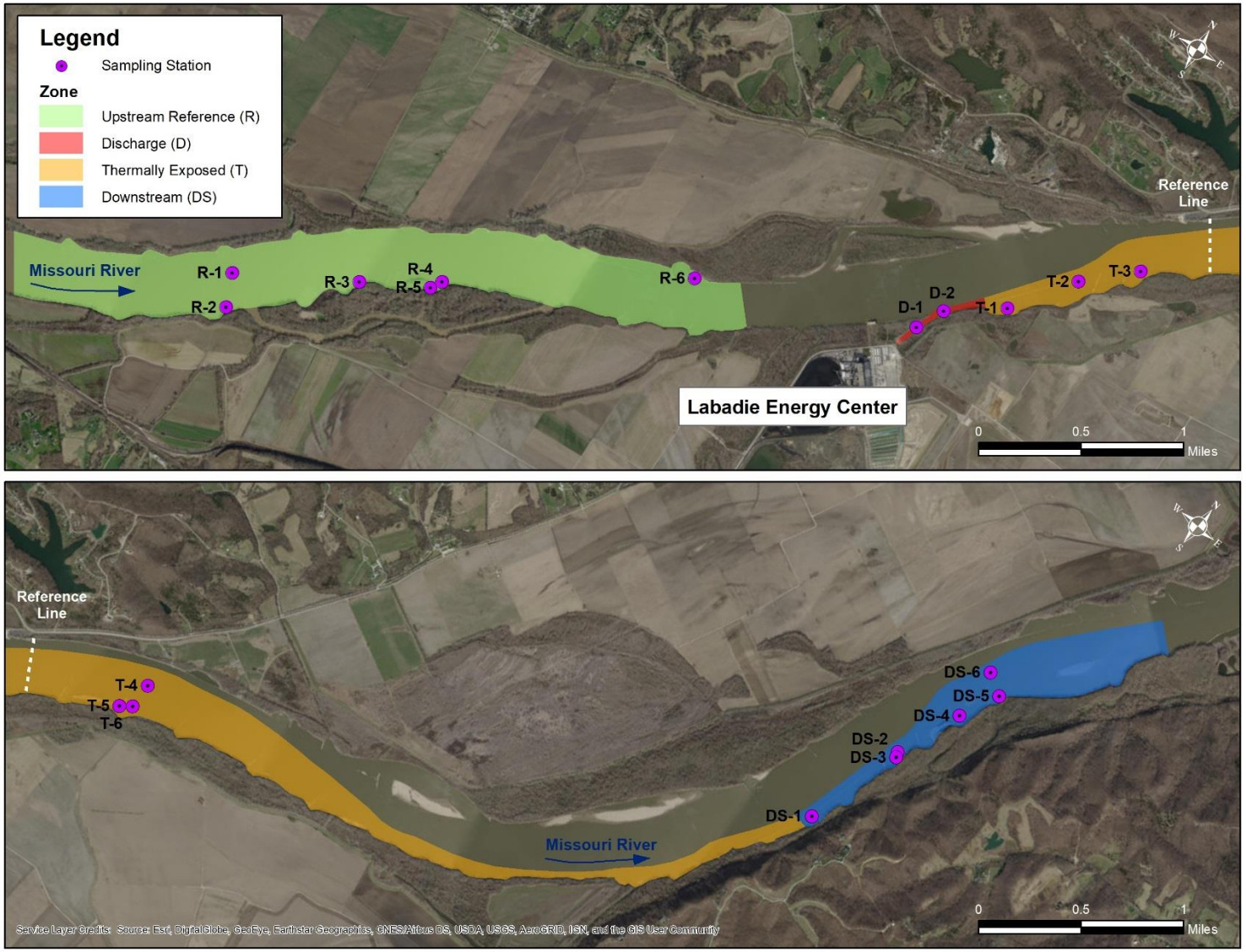


Figure 5-2 Sampling stations for the two-year biological monitoring program at the LEC, 2017-2018..

5.2.2 Historical Studies

Two sets of previous fisheries sampling data were compared to the results of the current study as part of the retrospective assessment. From 1980-1985, monthly electrofishing sampling was performed at four sites along the south shoreline of the Missouri River (Ameren 1998). Site 1 was immediately upstream of the cooling water intake; site 2 was within the discharge canal; site 3 was along the shore and outside of the dike immediately downstream of the discharge canal, and site 4 was within the wing dike downstream of site 3 (Figure 5-3). Additional monthly electrofishing surveys were performed at the same locations from 1997-2002 (Ameren 2002). An additional sampling site, Site 5 was added inshore of the dikes for the 1997-2002 survey. The data for these historical sampling programs will be compared to the recent sampling program (described in Section 5.2.1) for selected habitats.

	Reference Zone		Within Discharge		Thermally Exposed Zone
Past	Site 1		Sites 2 & 3		Site 4 & 5
Present	1-OLD		2-DIS		3-CXLD & 3-OLD

Note: OLD = outside bend L-Dike habitat; DIS = Discharge habitat; CXLD = Channel cross-over L-Dike habitat.

To facilitate the data comparison between historical and recent data sets, sample data were grouped by seasons as Winter: January-March, Spring: April-June, Summer: July-September, and Fall: October-December. Table 5-1 shows the available electrofishing data from both historical and recent studies.

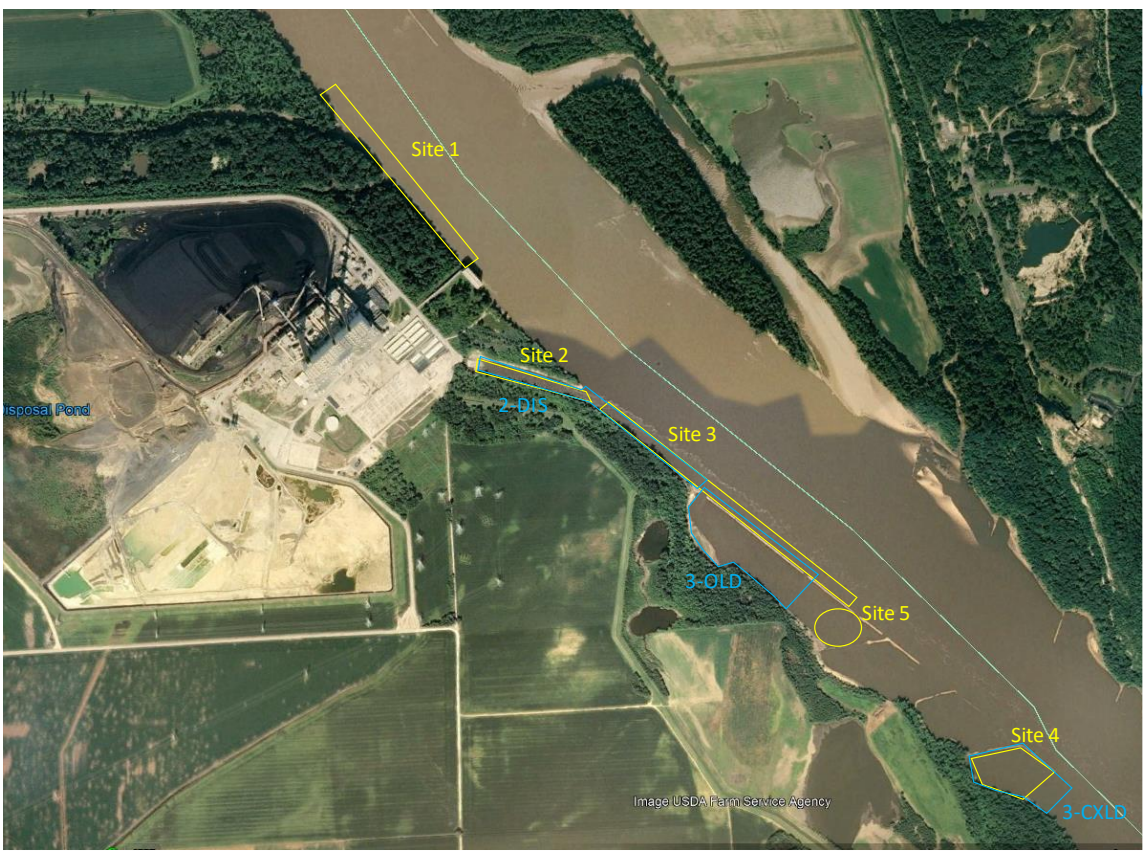


Figure 5-3 Sampling sites used in the 1980-1985 and 1997-2002 electrofishing surveys at the LEC, and corresponding site designations from the 2017-018 survey.

Table 5-1 Number of electrofishing collections conducted in each zone and habitat during the LEC fisheries sampling in 1980-1985, 1997-2002, and 2017-2018. Highlighted cells indicate groups of collections for which temporal questions T1-T4 were examined.

Zone	Habitat	Winter			Spring			Summer			Fall		
		1980-85	1997-02	2017-18	1980-85	1997-02	2017-18	1980-85	1997-02	2017-18	1980-85	1997-02	2017-18
1	CXLD	0	0	6	0	0	6	0	0	6	0	0	6
	IWD	0	0	6	0	0	6	0	0	6	0	0	5
	OLD	1	6	6	5	6	6	6	6	6	7	5	6
2	DIS	1	6	6	5	6	6	6	6	6	7	5	6
3	CXLD	1	6	6	5	6	6	6	6	6	7	5	6
	IWD	0	0	6	0	0	6	0	0	6	0	0	6
	OLD	0	6	6	0	6	6	0	6	6	0	5	6
4	CXLD	0	0	6	0	0	6	0	0	6	0	0	6
	IWD	0	0	6	0	0	6	0	0	6	0	0	6
	OLD	0	0	6	0	0	6	0	0	6	0	0	6

5.3 ENVIRONMENTAL AND OPERATIONAL CONDITIONS CONTEXT

Prior to the analysis of the biological data, environmental and the LEC operation information was summarized to determine if the study years can be considered representative of typical conditions. The results of this summary are presented below.

5.3.1 River temperature and flow

Mean daily Missouri River discharge flows measured at the USGS gage #06935550 at Labadie were generally above historical average flows (measured at the USGS Hermann gage, #06934500) for much of the period from April through August during the first year of study and from September through January during the second year (Figure 5-4). In 2017, flows during the April to August period ranged up to 2.5 times historical average flows and remained well below historical maximums except for May when flows reached the historical maximum of 500,000 cfs. In 2018, flows during the September through January period ranged up to approximately 1.5 times the historical average flows and remained well below historical maximums except for two peaks in early September and October which reached the historical maximum values.

Mean daily water temperatures (measured at the Labadie gage) were close to historical average values (measured at the Hermann gage) throughout the two-year study period 2017-2108 (Figure 5-5). Water temperatures in June and July 2017 were slightly warmer than average, while they were around average values in those months during 2018.

Continuous temperature monitoring data from the surface and bottom recorded by Wood at each sampling station in Discharge, Thermally Exposed, and Downstream zones for the 2017 and 2018 study years were compared to ambient river water temperatures recorded at the Labadie gage (Figure 5-6 through Figure 5-9). For all stations there was little difference between surface and bottom measured temperatures. As expected, Discharge zone water temperatures were well above ambient temperatures throughout each year though temperatures recorded at the Discharge zone station in the river (Dis 2) were typically several degrees cooler than those recorded in the discharge canal (Dis 1). Water temperatures at all other stations were close to or only a few degrees above the recorded ambient river water temperature.

River flow was quite variable during the 2017-2018 study period but with one exception, remained within the observed historical variability. River water temperatures were considered representative of typical conditions as they were close to historical averages. Field measured water temperatures show that the thermal discharge is rapidly attenuated by mixing with the mainstem river by the first downstream dike field.

5.3.2 Plant generation and discharge flow

The LEC operated normally during the first year of study and did not experience periods of outage or non-operation during the summer months. The LEC mean annual capacity factors for 2017 and 2018 were similar to the five-year mean capacity factor of 73 percent (Table 5-2). During the summer months of July and August, the LEC capacity factors for 2017 and 2018 were similar to the mean values for those months during the previous five-year operating period (Table 5-2).

The LEC thermal discharge flows were below historical average discharge flows in March, April, June, late July/early August, and September in 2017 and in late May and September through December in 2018 (Figure 5-10). Plant discharge flows approximated the historical average from late June through late July in both study years. The LEC thermal discharge flows for each of the study years were within historical ranges and are considered representative of typical conditions, particularly during the summer period.

Mean daily discharge temperatures for the LEC in 2017 were below historical mean values for periods from March through early June and again in August and September and at or above

historical mean values for periods in June, July, and late September (Figure 5-11). In 2018, mean daily discharge temperatures for the LEC were above historical mean values in May and June and below the historical mean value in July. All LEC mean daily discharge temperatures were within historical ranges and are considered representative of typical conditions, particularly during the summer period.

Table 5-2 The LEC Capacity factors for 2014 through 2018.

Year	Percentage of Maximum Generation												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2014	86	88	76	49	48	73	87	82	55	64	61	77	71
2015	89	80	77	60	60	81	82	71	76	72	75	71	75
2016	78	75	52	58	44	72	77	82	67	70	77	76	69
2017	80	75	57	65	76	74	83	80	71	79	81	78	75
2018	84	80	73	77	75	75	84	81	62	64	64	62	73
Mean	83	80	67	62	61	75	83	79	66	70	72	73	73

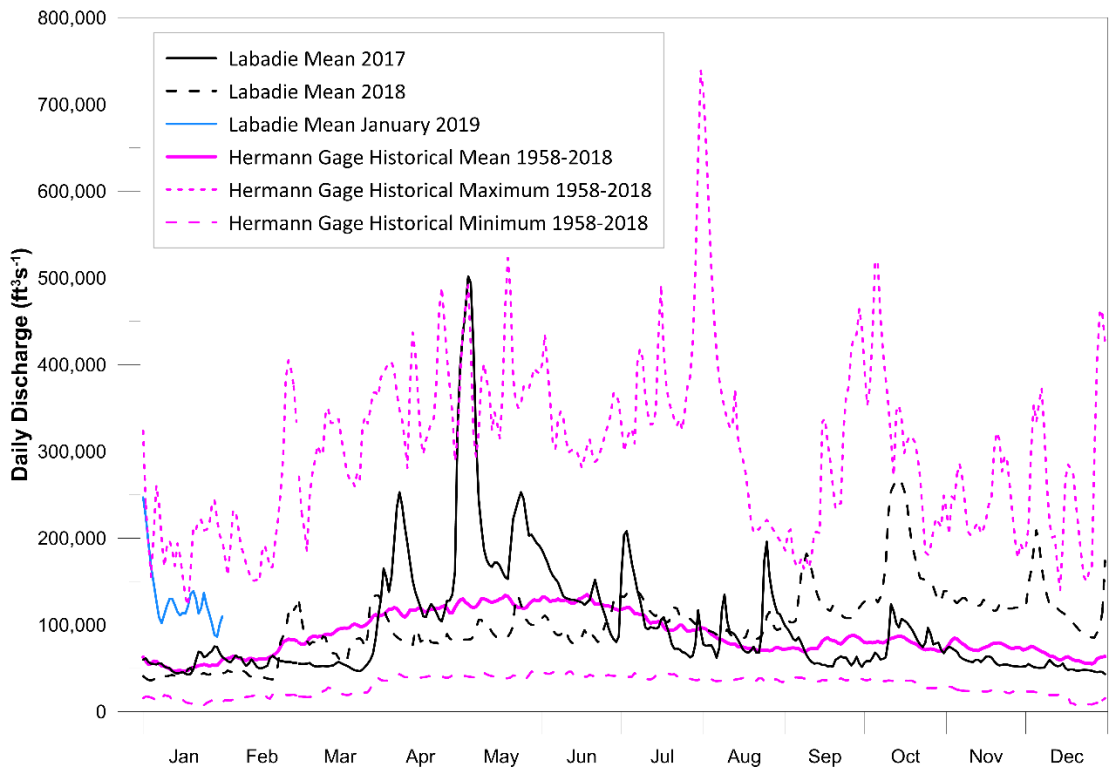


Figure 5-4 Historical and 2017- January 2019 daily mean Missouri River discharge flows measured at the Hermann and Labadie gages, respectively.

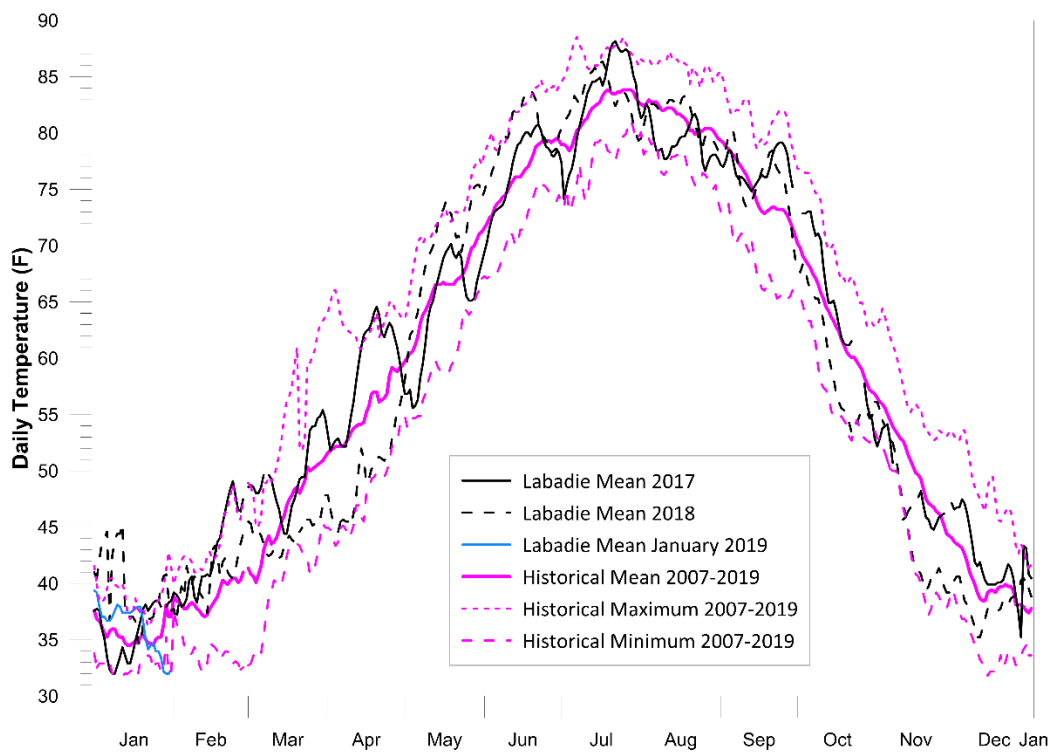


Figure 5-5 Historical and 2017- January 2019 daily mean Missouri River water temperature measured at the Hermann and Labadie gages, respectively.

Figure 5-6 Surface-measured continuous monitoring water temperature data from each sampled site compared to Labadie gage ambient temperatures for 2017.

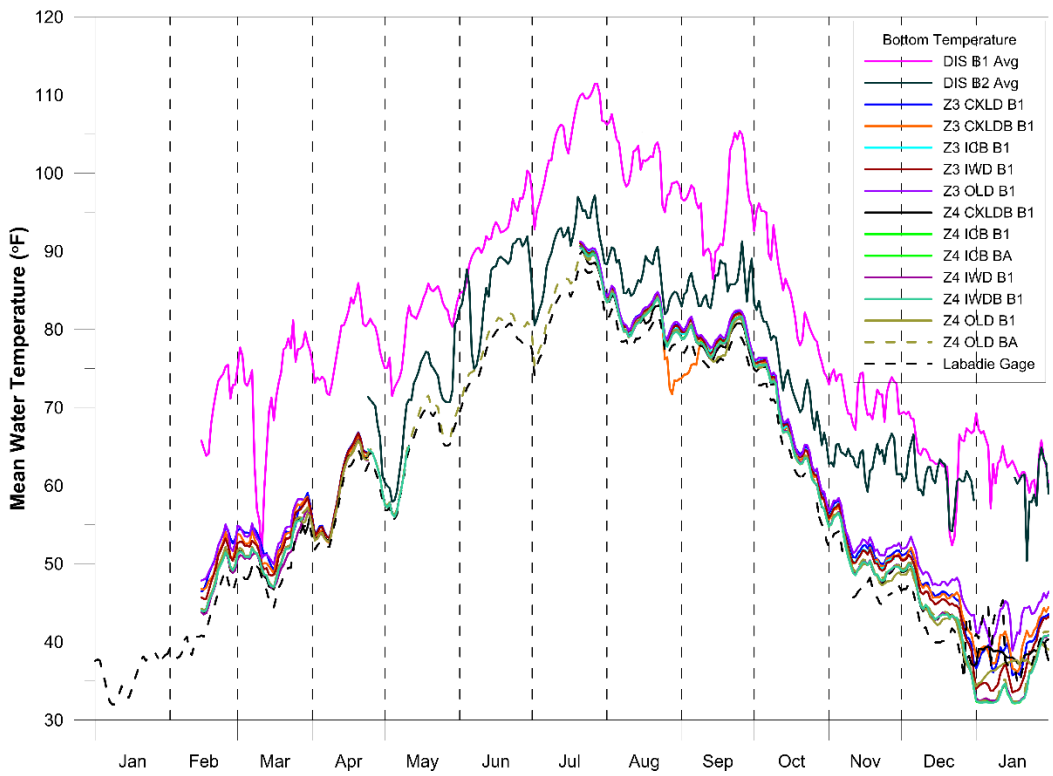


Figure 5-7 Bottom-measured continuous monitoring water temperature data from each sampled site compared to Labadie gage ambient temperatures for 2017.

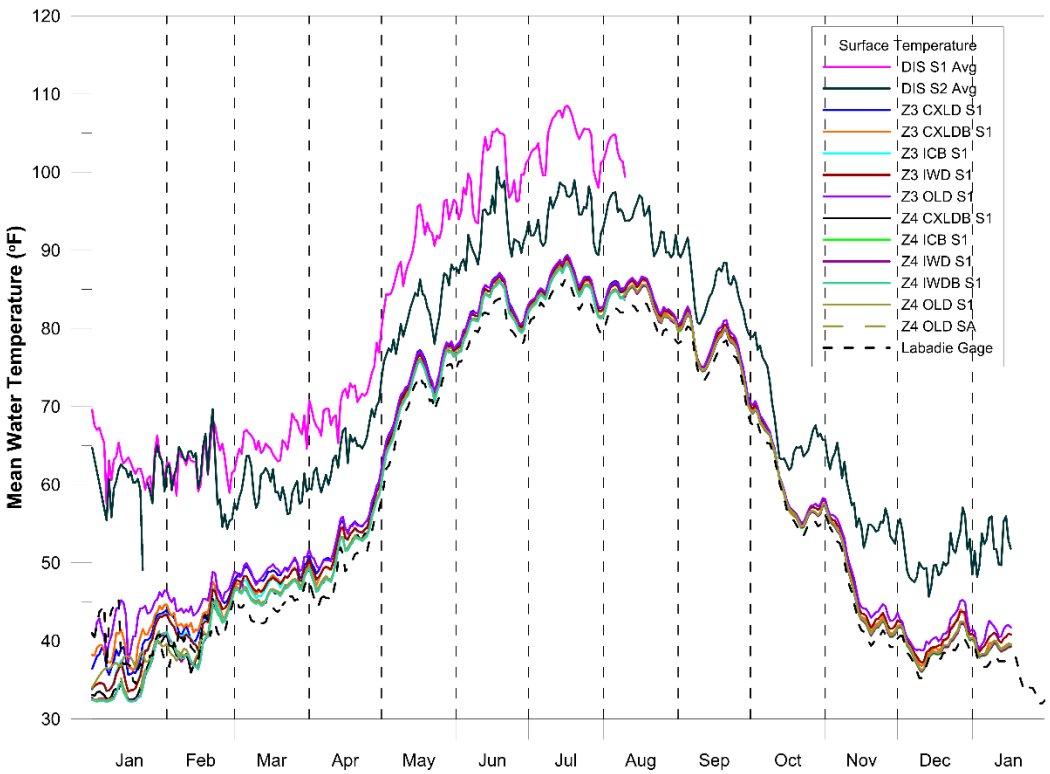


Figure 5-8 Surface measured continuous monitoring water temperature data from each sampled site compared to Labadie gage ambient temperatures for 2018.

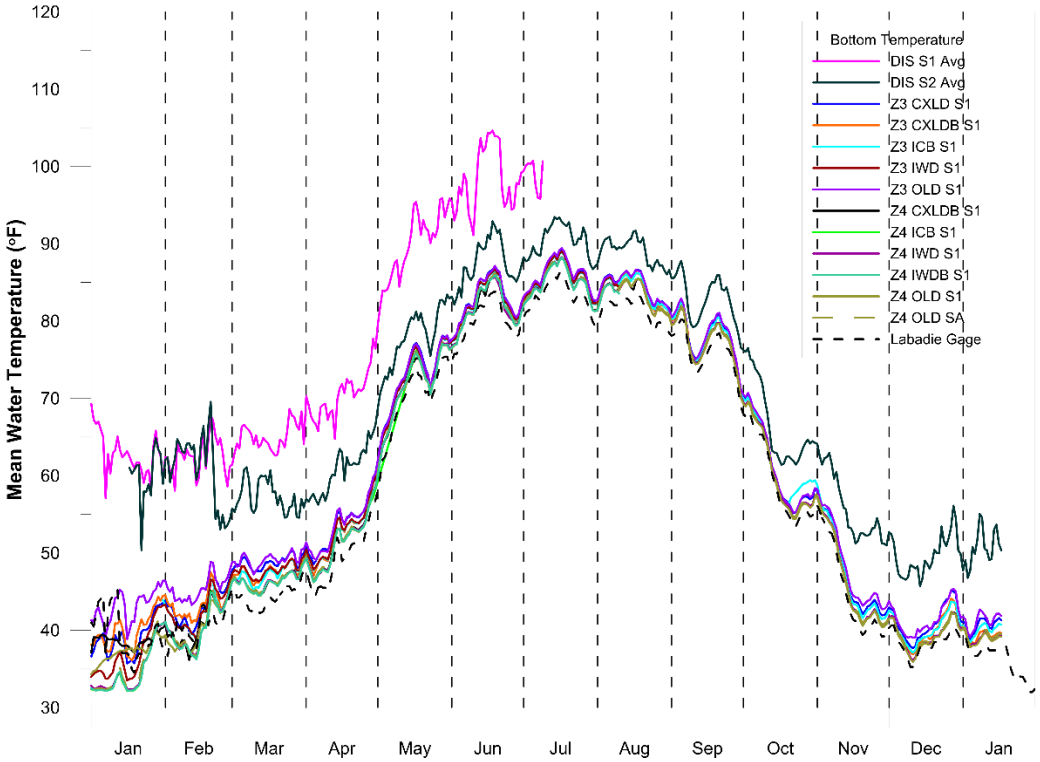


Figure 5-9 Bottom measured continuous monitoring water temperature data from each sampled site compared to Labadie gage ambient temperatures for 2017.

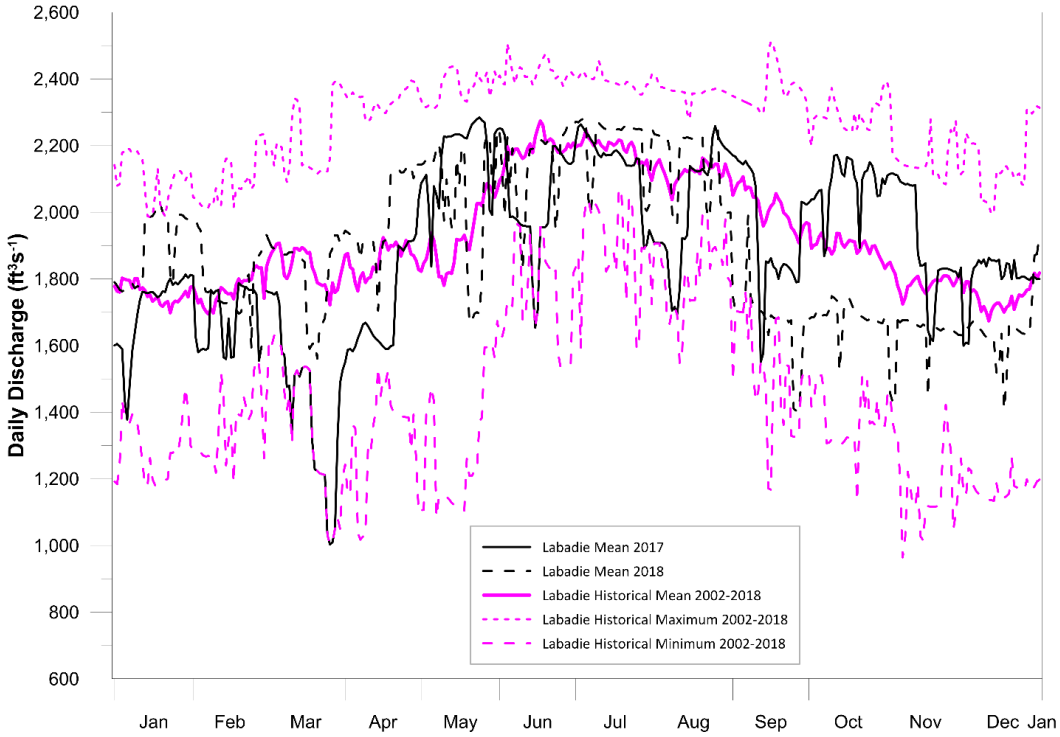


Figure 5-10 Historical and 2017-2018 mean daily thermal discharge flows for the LEC.

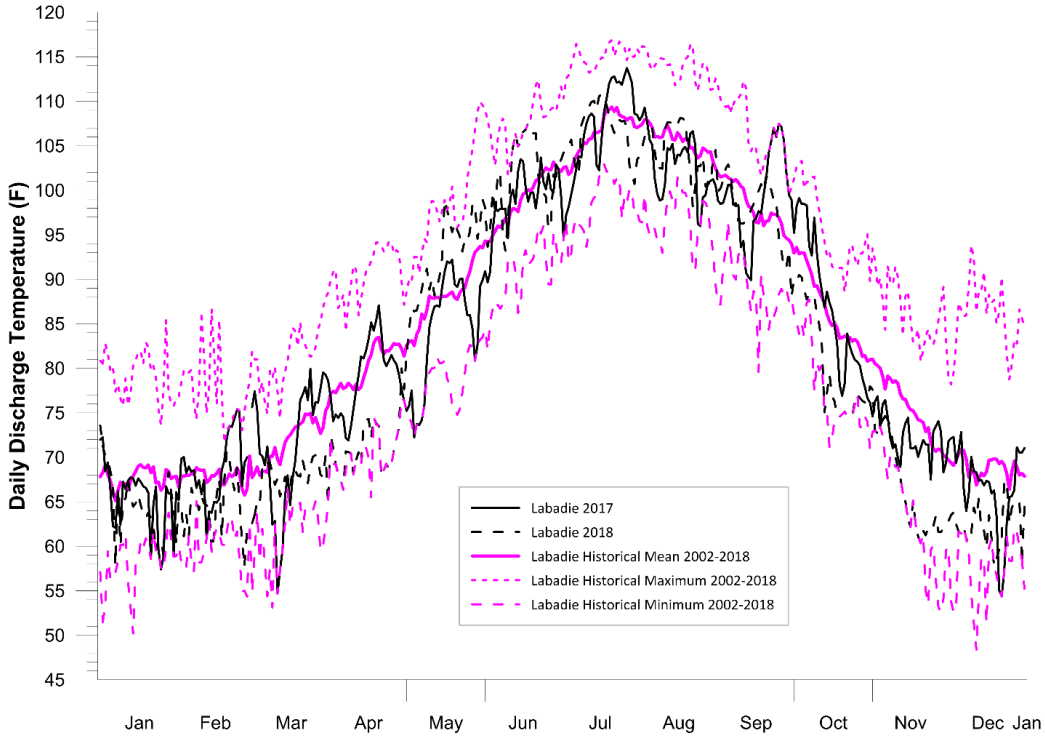


Figure 5-11 Historical and 2017-2018 mean daily discharge temperatures for the LEC.

5.4 SPATIAL ANALYSIS

5.4.1 Fish

The fish assemblage in the LMOR in the vicinity of the LEC was described by the two-year sampling program using bag seines, electrofishing, hoop nets, and Missouri trawls, in selected habitats in the four sampling zones: the Upstream Reference zone, Discharge zone within and immediately downstream of the discharge canal, the Thermally Exposed zone where the excess temperatures are > 3°F, and the Downstream zone. The fish assemblages in all zones were robust, containing many different species, and of a diverse number of ecological and human-use types. Overall, a total of 70 species and two different hybrids were identified.

The total number of fish collected (all gears and both study years combined) from the Upstream Reference, Thermally Exposed, and Downstream zones were similar, at 9,150, 7,104, and 8,063 fish respectively (Table 5-3). The Discharge zone was sampled only with electrofishing gear, which produced a total of 948 fish collected.

Dominant fish species were also similar across zones, with red shiner being ranked first in all zones. Other prominent species found abundantly in all zones, or all zones but the Discharge zone, were gizzard shad, channel shiner, sicklefin chub, shoal chub, and bullhead minnow. Summary tables for all fish data are presented in Appendix B Section B.1.

5.4.1.1 Overall Abundance

The fisheries sampling data collected by Wood in 2017-2018 exhibited differences in “densities” i.e. mean catch from each of the sampling gears standardized to the target level of effort (duration of sampling or area sampled) in terms of both numerical abundance and total fish biomass. The results are summarized for the summer in Figure 5-12 and winter seasons in Figure 5-13. Data from bag seine and electrofishing collections during the summer showed similar densities between the Upstream Reference and Thermally Exposed zones while other gears indicated lower densities in the Thermally Exposed zone. In summer electrofishing samples, fish biomass was greater in the Thermally Exposed zone compared to the Upstream Reference zone. During winter electrofishing sampling, the Discharge zone contained higher densities than the other zones, indicating a degree of attraction to the heated discharge. Spring and fall sampling similarly did not show a consistent pattern of reduced abundance in either the Thermal or Downstream zones (Full tabular results are presented in Appendix B). Overall, there was not a consistent pattern of lower abundance in the Thermally Exposed and Downstream Zones than in the Upstream Reference zone demonstrating no adverse effect of the LEC’s thermal discharge on overall fish abundance.

Table 5-3 Species composition in each zone from fisheries sampling programs near the LEC during 2017-2018.

	Upstream Zone			Discharge Zone			Thermally Exposed Zone			Downstream Zone		
Rank	Taxon	Number	Fraction	Taxon	Number	Fraction	Taxon	Number	Fraction	Taxon	Number	Fraction
1	Red shiner	3,056	0.334	Red shiner	330	0.348	Red shiner	1,291	0.182	Red shiner	1,824	0.226
2	Channel shiner	1,287	0.141	Blue catfish	154	0.162	Emerald shiner	914	0.129	Channel shiner	1,055	0.131
3	Sicklefin chub	568	0.062	River carpsucker	67	0.071	Gizzard shad	757	0.107	Gizzard shad	980	0.122
4	Shoal chub	559	0.061	Emerald shiner	59	0.062	Channel shiner	743	0.105	Emerald shiner	636	0.079
5	Gizzard shad	557	0.061	Gizzard shad	56	0.059	Sicklefin chub	627	0.088	Shoal chub	631	0.078
6	Emerald shiner	495	0.054	Freshwater drum	46	0.049	Shoal chub	607	0.085	Sicklefin chub	472	0.059
7	Freshwater drum	487	0.053	Longnose gar	35	0.037	Freshwater drum	371	0.052	Bullhead minnow	286	0.035
8	Blue catfish	350	0.038	Shortnose gar	31	0.033	Blue catfish	282	0.040	Freshwater drum	275	0.034
9	Channel catfish	279	0.030	Flathead catfish	22	0.023	Channel catfish	242	0.034	Blue catfish	270	0.033
10	Bullhead minnow	255	0.028	Common carp	20	0.021	Silver carp	167	0.024	Channel catfish	256	0.032
11	Sand shiner	205	0.022	Channel catfish	19	0.020	Bullhead minnow	104	0.015	Silver carp	153	0.019
12	Silver carp	155	0.017	Smallmouth buffalo	19	0.020	River carpsucker	100	0.014	Goldeye	141	0.017
13	Goldeye	115	0.013	Silver carp	13	0.014	Goldeye	90	0.013	Blacktail chubs	117	0.015
14	River carpsucker	74	0.008	Striped bass x white bass	12	0.013	Longnose gar	86	0.012	Mosquitofish	105	0.013
15	Longnose gar	66	0.007	Goldeye	11	0.012	Shortnose gar	86	0.012	Sand shiner	85	0.011
>15	56 additional taxa	642	0.072	22 additional taxa	54	0.057	56 additional taxa	637	0.090	53 additional taxa	777	0.096
	Total	9,150	1.000	Total	948	1.000	Total	7,104	1.000	Total	8,063	1.000

5.4.1.2 Capability to Sustain Itself

Length-frequency distribution data shows that multiple size classes and year classes of fish are present in all sampled zones. Figure 5-14 shows example length-frequency distributions for selected large-bodied fishes which would exhibit enough range in lengths to demonstrate the presence of multiple year-classes: gizzard shad, blue catfish, silver carp, channel catfish, freshwater drum, and the sucker family. The distribution of length classes of fish was similar among the Upstream Reference, Thermally Exposed, and Downstream zone, but skewed toward larger fish in the Discharge zone. The presence of multiple size and year classes of fish and the absence of any difference in the length-frequency distributions between Upstream Reference, Thermally Exposed, and Downstream zones indicate that the LEC thermal discharge is not preventing the fish exposed to the discharge from reproducing and sustaining themselves.

5.4.1.3 Community Characteristics

Diversity

Diversity of the community was described based on Hill numbers (Hill 1973), which provide a profile of the community diversity along a spectrum of sensitivity to abundance. Hill numbers are currently the dominant paradigm for describing diversity of ecological communities (Chao et al 2010). The diversity profile includes three special cases, which are the equivalent of three of the previously most commonly used diversity metrics. At the low end of the sensitivity spectrum, (q = 0) the Hill number is completely insensitive to abundance, and the Hill number (^0D) is equivalent to simple species richness. At q =1, the value of the Hill number is equal to the exponential of the Shannon index ($^1D = e^{H'}$) and represents the number of equally abundant species that would constitute a community with the measured level of diversity. At q = 2, the Hill number represents the number of abundant species in the community and is the numerical equivalent of the inverse of the Simpson concentration. At higher values of q, the Hill numbers are increasingly sensitive to abundance so that rare species become less influential and highly abundant species dominate the value of the metric. Because fish vary greatly in individual size (biomass) and therefore dominant species in terms of numerical abundance could be far less significant in terms of community biomass, the profiles were calculated both for numerical abundance and for biomass.

The diversity profiles varied among gear and zones but did not indicate lower diversity in either the Thermally Exposed or Downstream zones compared to the Upstream Reference zone (Figure 5-15). Diversity profiles based on biomass typically declined more steeply as sensitivity to abundance (q) increased than did profiles based on numerical abundance, indicating that biomass is more concentrated in a few species, such as gizzard shad, blue catfish, flathead catfish, bighead carp, than is numerical abundance. There was no observed effect of the LEC's thermal discharge on fish diversity.

Dominance

Although there are many species of fish in the LEC vicinity, the community is dominated by a relatively small number of species. In terms of numbers, the most abundant species comprised 18 percent (Thermally Exposed zone) to 35 percent (Discharge zone) of the total catch, with the top two species contributing 31 to 51 percent, the top 5 species 61 to 70 percent, and the top 10 species 83 to 86 percent across all zones (Figure 5-16). The most abundant species across all zones were red shiner (26 percent), channel shiner (12 percent), gizzard shad (9 percent), emerald shiner (8 percent), and shoal chub (7 percent) (Table 5-4). All of the five most abundant species except gizzard shad are small-bodied forage species.

Community biomass was also dominated by a few species in all zones, however the discharge zone, which was sampled only by electrofishing, was much more dominated by a single species (Table 5-4). The Upstream Reference zone and the Thermally Exposed zone exhibited nearly identical dominance curves (Figure 5-16). The top five species in terms of biomass were blue catfish (25 percent), common carp (12 percent), smallmouth buffalo (11 percent), silver carp (9 percent), and river carpsucker (7 percent). Except for blue catfish and smallmouth buffalo, the dominant species were l in the rough fish category.

The dominant species were very similar among all four sampling zones. For numerical dominance, red shiner and gizzard shad were in the top five in abundance in all four zones, and emerald shiner and channel shiner in three zones. For biomass, common carp, smallmouth buffalo, and blue catfish were in the top five in biomass in all four zones, and silver carp and river carpsucker in three of the four zones. There was no evidence of an effect of the LEC's thermal discharge on the dominant fish species in the area.

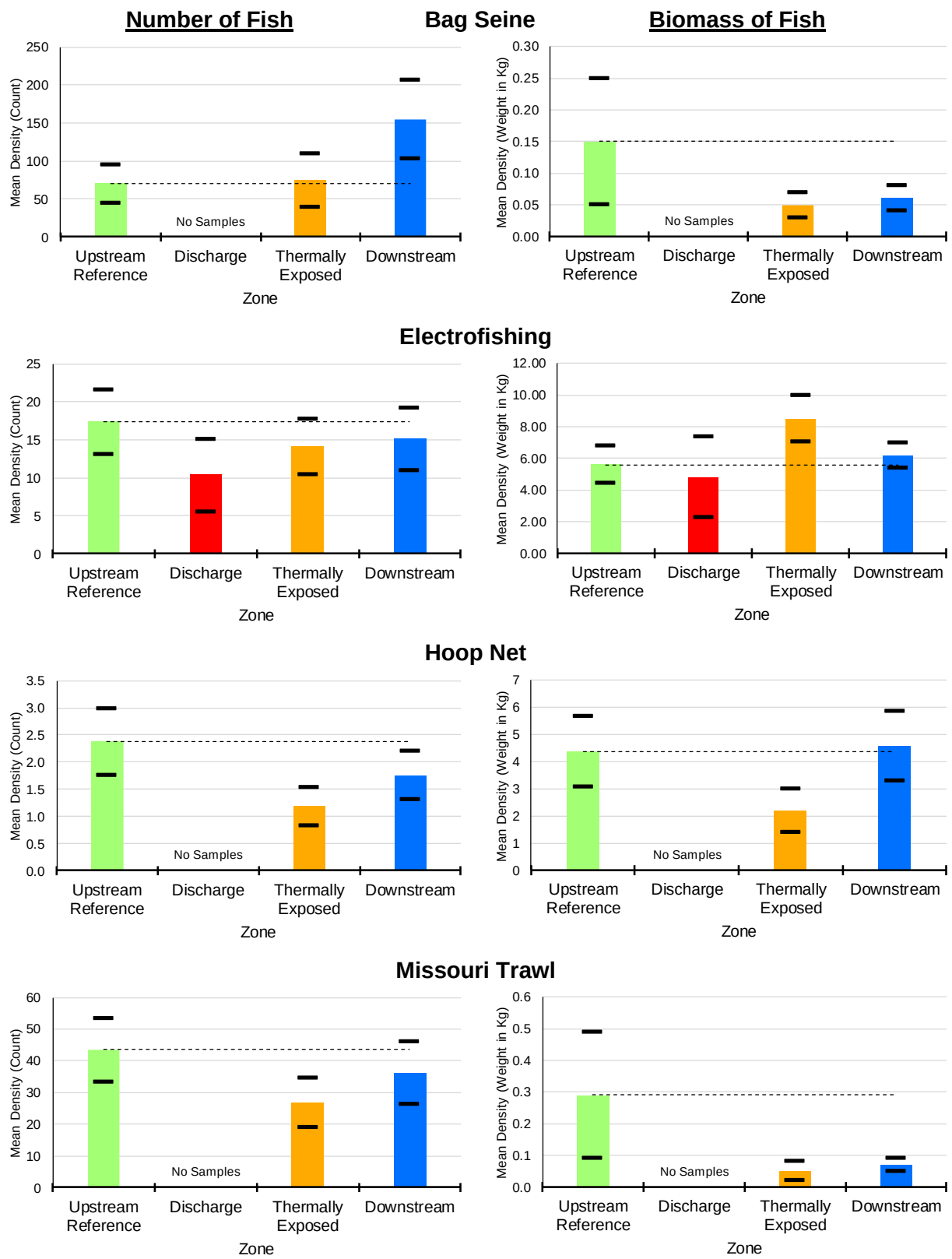


Figure 5-12 Summer mean density in fisheries sampling at the LEC in 2017-2018 for each gear type and zone, based on number of fish (left column) and biomass in Kg (right column). Black bars indicate +/- 1 standard error from mean.

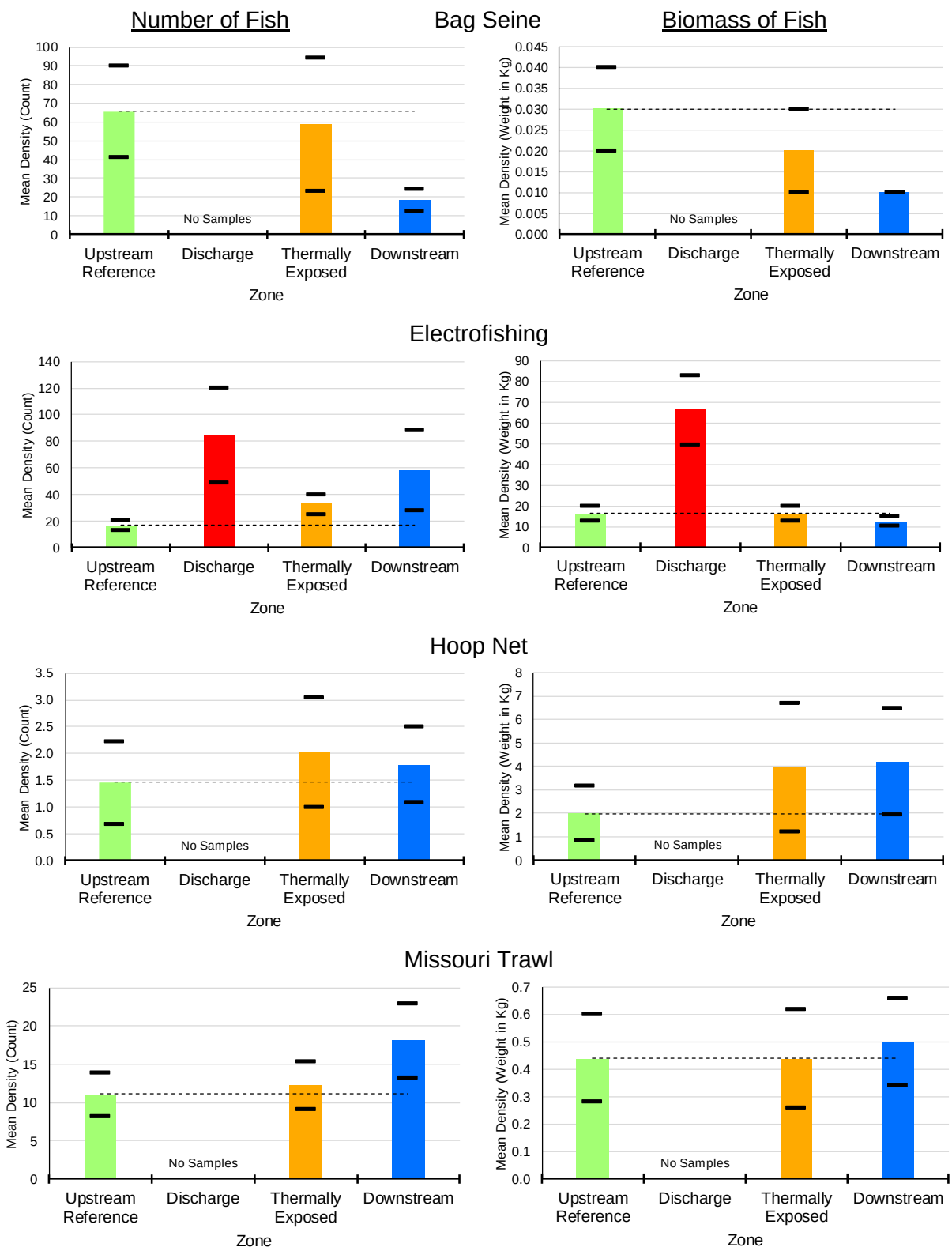


Figure 5-13 Winter mean density of fisheries sampling at the LEC in 2017-2018 for each gear type and zone, based on number of fish (left column) and biomass in Kg (right column). Black bars indicate +/- 1 standard error from mean.

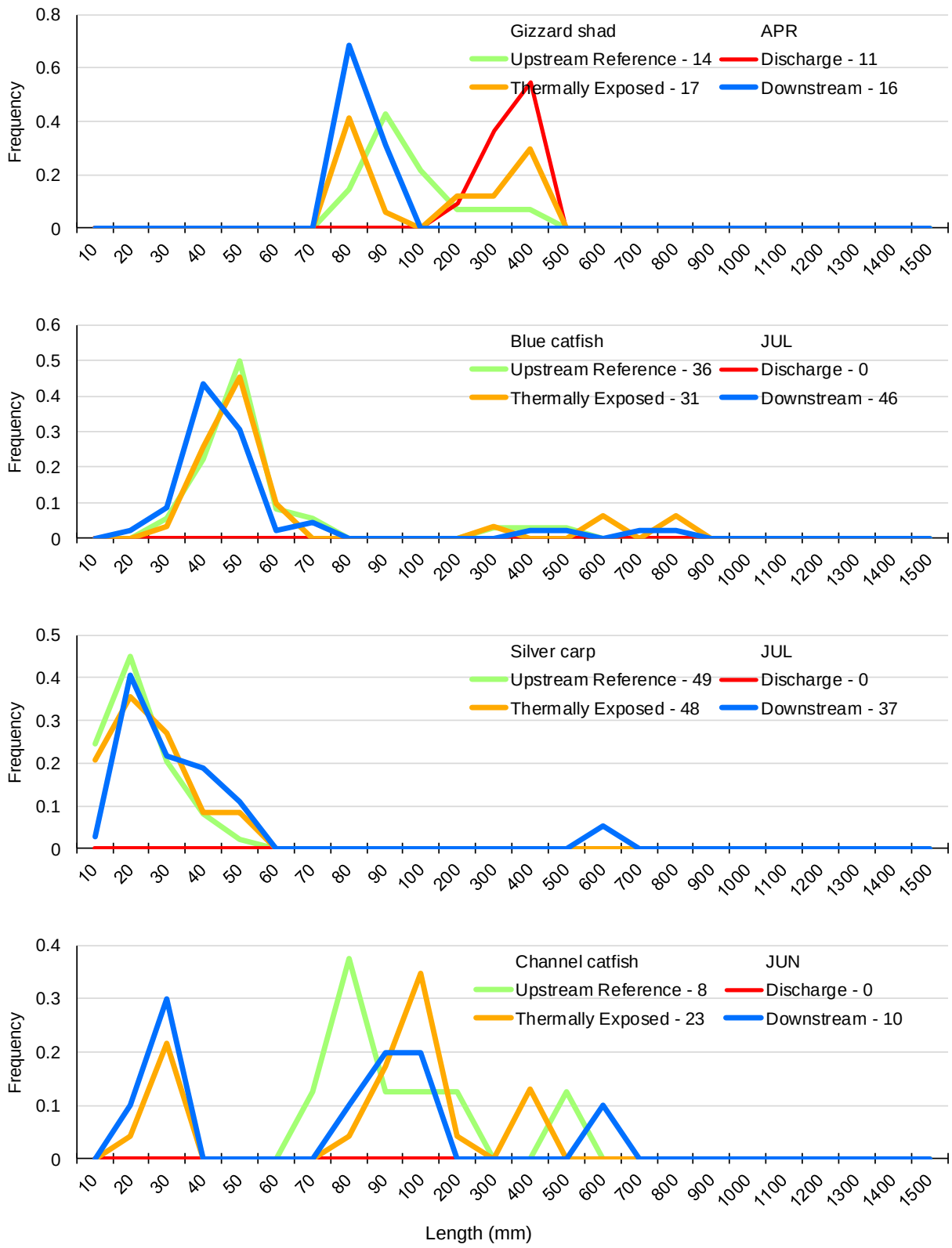


Figure 5-14 Length frequency of selected fish taxa collected in the vicinity of the LEC in 2017-2018 by all sampling gears across all seasons.

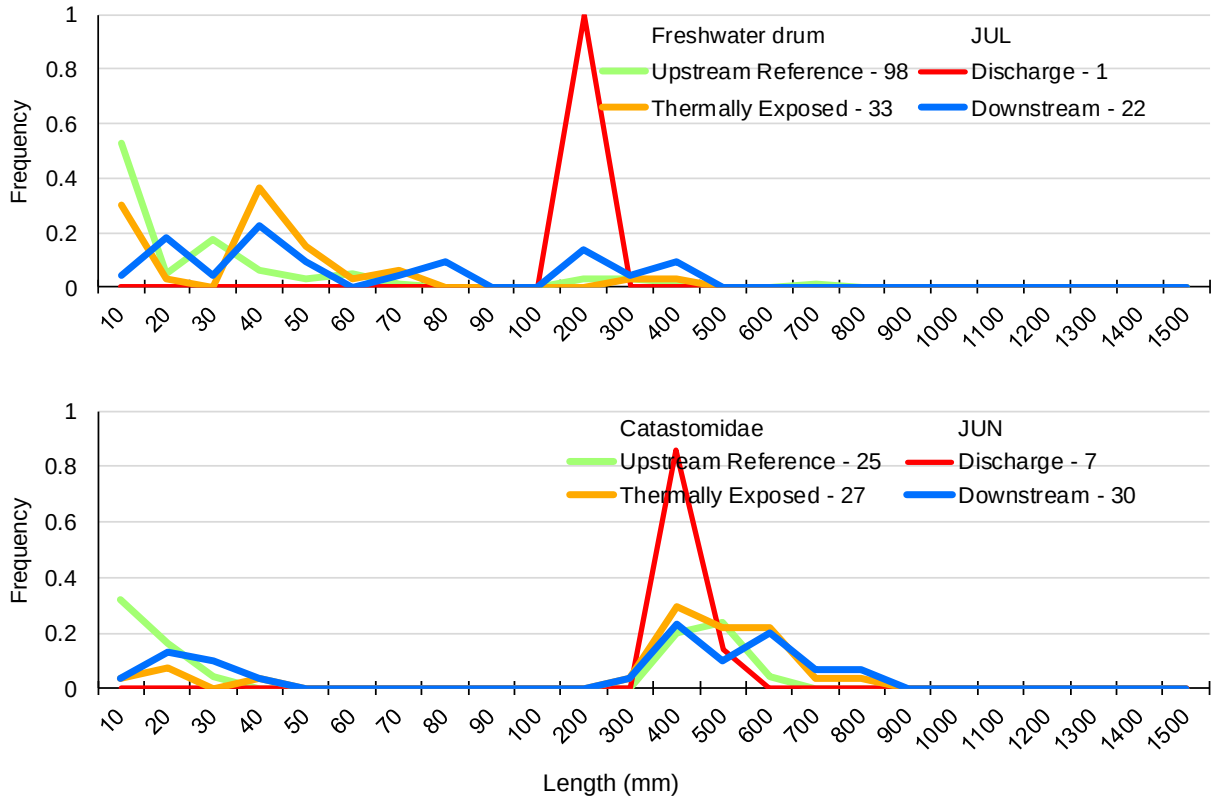


Figure 5-14 Continued.

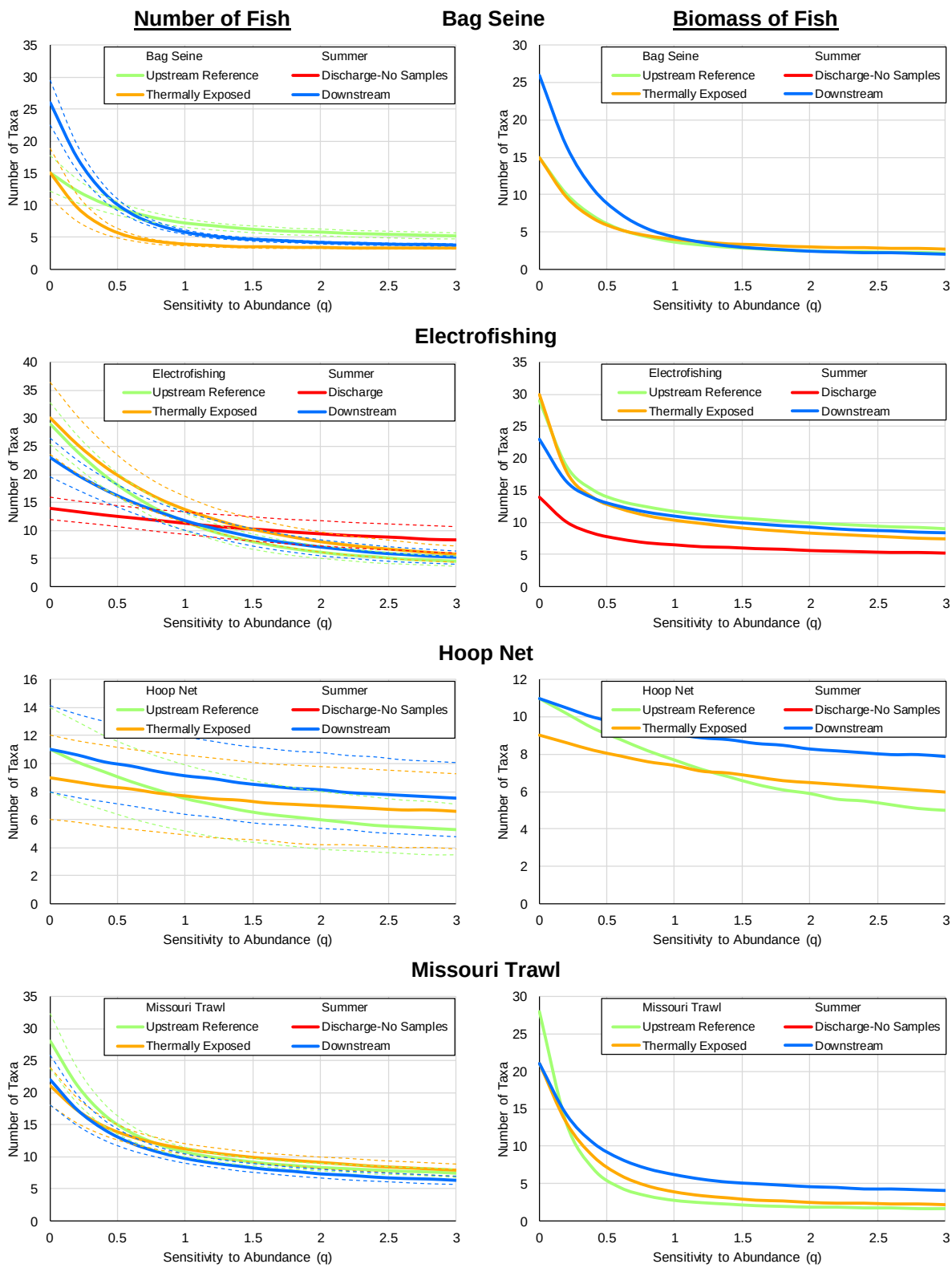


Figure 5-15 Summer diversity profiles of fisheries sampling at the LEC in 2017-2018 for each gear type and zone, based on number of fish (left column) and biomass in Kg (right column). Dashed lines for numerical profiles indicate +/- 1 standard deviation around estimate.

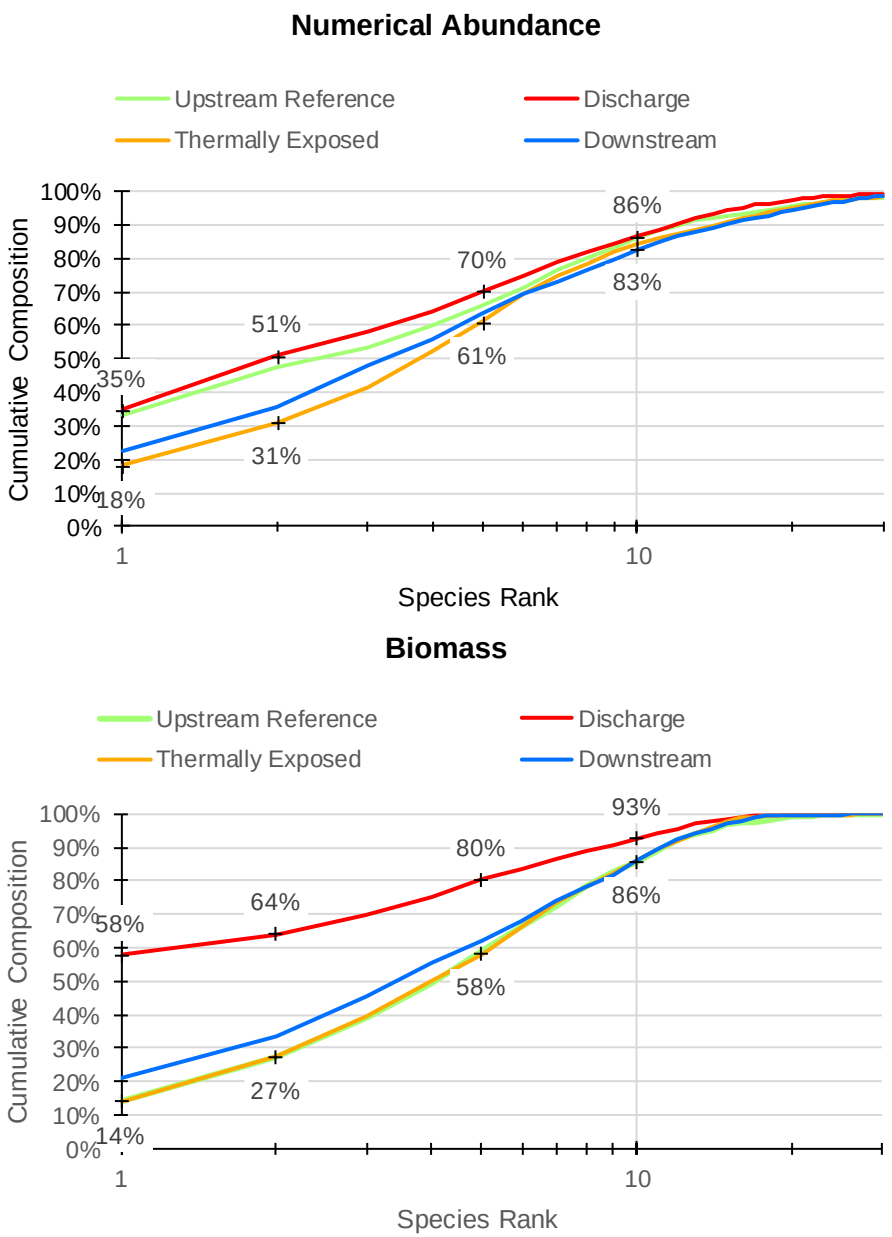


Figure 5-16 Dominance of the fish community in the LEC vicinity based on all sampling gears combined over all seasons, 2017-2018. Top figure is based on numerical abundance and bottom on biomass.

Table 5-4 Dominant fish species collected in the vicinity of the LEC in 2017-2018 from all gears and seasons, in terms of numerical abundance and biomass.

		Upstream Reference		Discharge		Thermally Exposed		Downstream	
Basis	**Rank**	**Species**	**%**	**Species**	**%**	**Species**	**%**	**Species**	**%**
Numbers	1	Red shiner	33%	Red shiner	35%	Red shiner	18%	Red shiner	23%
	2	Channel shiner	14%	Blue catfish	16%	Emerald shiner	13%	Channel shiner	13%
	3	Sicklefin chub	6%	River carpsucker	7%	Gizzard shad	11%	Gizzard shad	12%
	4	Shoal chub	6%	Emerald shiner	6%	Channel shiner	10%	Emerald shiner	8%
	5	Gizzard shad	6%	Gizzard shad	6%	Sicklefin chub	9%	Shoal chub	8%
	Total		66%		70%		61%		64%
Biomass	1	Common carp	14%	Blue catfish	58%	Smallmouth buffalo	14%	Blue catfish	21%
	2	Smallmouth buffalo	13%	Common carp	6%	Common carp	13%	Common carp	12%
	3	Blue catfish	12%	River carpsucker	6%	Silver carp	12%	Silver carp	12%
	4	Silver carp	10%	Flathead catfish	5%	Blue catfish	11%	Smallmouth buffalo	10%
	5	Grass carp	10%	Smallmouth buffalo	5%	River carpsucker	8%	River carpsucker	7%
	Total		59%		80%		58%		62%

Presence of all Trophic Levels

The fish community was separated into trophic categories based on Pearson et al. (2011), which included detritivores, planktivores, herbivores, omnivores, insectivores, carnivores, top predators, and combinations of these categories for species not well-categorized into a single group (Table 5-5). Although the division of the community into the trophic categories varied somewhat whether numbers or biomass was the basis for categorization, the Upstream Reference, Thermally Exposed, and Downstream zones differed little among each other and showed the presence of all trophic levels in each zone (Figure 5-17). The Discharge zone appeared to have an elevated frequency of carnivore and top predator categories compared to the other zones. Hence, the LEC's thermal discharge did not prevent the presence of all appropriate trophic levels.

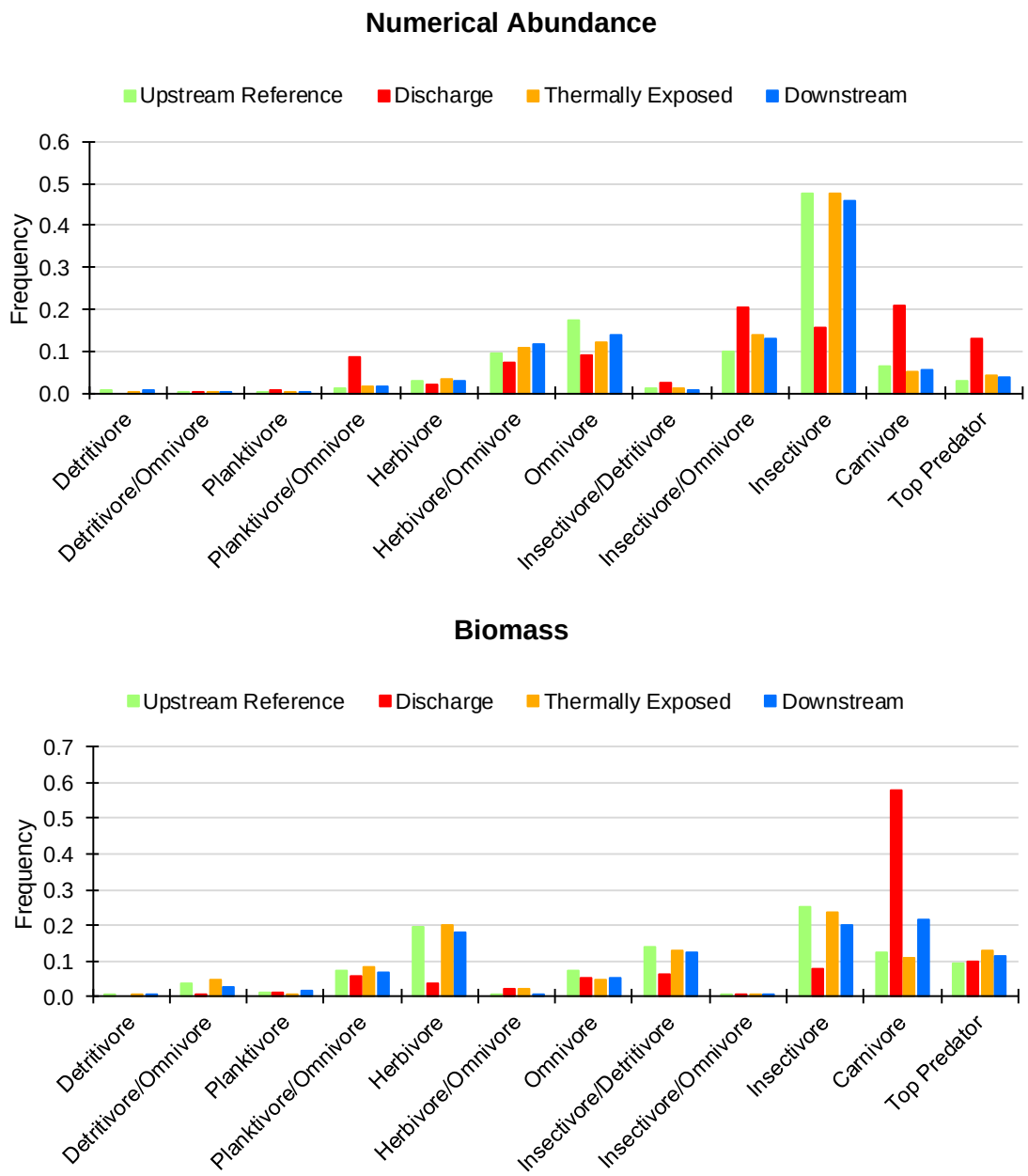


Figure 5-17 Trophic categories of the fish community sampled in the vicinity of the LEC in 2017-2018 based on all sampling gears over all seasons.

Table 5-5 Classification of LMOR fishes collected at LEC 2017-2018 into trophic guilds based on Pearson et al. 2011.

Carnivore	**Herbivore**	**Invertivore**	**Invertivore**	**Top Piscivore**
Rock bass	Stonerollers	Lake sturgeon	Bigeye shiner	Smallmouth bass
Spotted bass	Central stoneroller	Sturgeon - Scaphirhynchus	Ghost shiner	Largemouth bass
White bass	Grass carp	Pallid sturgeon	Rosyface shiner	Striped bass
Chestnut lamprey	Plains minnow	Shovelnose x Pallid	Silverband shiner	Striped bass x white bass
Blue catfish	Silver carp	Shovelnose sturgeon	Sand shiner	Pikeperch
	Minnow Family group 2	Brook silverside	Channel shiner	Sauger
Detritivore	Silver lamprey	Banded killifish	Suckermouth minnow	Sauger x Walleye
Bluntnose minnow		Plains killifish	Creek chub	Walleye
	Omnivore	Quillback carpsucker	Mooneyes	Gar Family
Detritivore-Omnivore	American eel	White sucker	Goldeye	Longnose gar
Bigmouth buffalo	Bullhead minnow	Blue sucker	Mooneye	Shortnose gar
Black buffalo	White crappie	Smallmouth buffalo	Green sunfish	Flathead catfish
Goldfish	Freshwater drum	Spotted sucker	Orangespotted sunfish	
Fathead minnow	Channel catfish	Sucker - Redhorses	Bluegill	
		Silver redhorse	Longear sunfish	
Herbivore-Omnivore	**Planktivore-Omnivore**	Golden redhorse	Black crappie	
Gizzard shad	River carpsucker	Shorthead redhorse	Darter - Etheostoma	
		Gravel chub	Rainbow darter	
Invertivore-Detritivore	**Planktivore**	Blacktail chubs	Johnny darter	
Common carp	Paddlefish	Sturgeon chub	Yellow perch	
	Skipjack herring	Shoal chub	Perches	
Invertivore-Omnivore	Bighead carp	Sicklefin chub	Darter - Percina	
Red shiner		Silver chub	Logperch	
Striped shiner		Shiners - Notropis	Madtoms	
		Emerald shiner	Stonecat madtom	
		River shiner	Freckled madtom	

Necessary Food Chain Species

The make-up of the fish community was classified into informally defined types (Table 5-6) including forage (typically small-bodied when fully grown), rough (large-bodied when fully grown, but generally not desired by anglers), game/commercial (targeted by anglers and/or commercial fishermen, often large-bodied when fully grown), pan (medium-bodied when fully grown and may be targeted or are desirable by-catch for anglers), and special (species of special management interest, in this case sturgeons and paddlefish).

Table 5-6 Classification of Missouri River fishes into forage, rough, game, pan and special categories for purpose of describing the fish community.

Forage	Rough	Game	Pan	Special
Herrings	Gizzard shad	Largemouth bass	Sunfish Family	Sturgeons
Minnows	Common carp	Spotted bass	White bass	Paddlefish
Killifish	Asian carps	Striped bass	Yellow perch	
Lampreys	Gars	Walleye		
Silversides	Suckers (Non-Buffalo)	Sauger		
Madtoms	Goldfish	Blue catfish		
Drums		Flathead catfish		
Mooneyes		Channel catfish		
Livebearers		Buffalos		
Darters				
Stonerollers				

The proportion of these fish types differed little across the four zones, either in terms of numbers or biomass (Figure 5-18), except that in the Discharge zone forage fish were more dominant in terms of numerical abundance than in other zones, and game fish (large catfishes) were more dominant in terms of biomass than in other zones. The data show that the necessary food chain species are present in all zones in similar proportions.

No Increase in Nuisance Species

The rough fish category consists of species that are typically tolerant of poor water quality and/or high temperatures and thus may outcompete less tolerant species under stressful conditions. Generally rough fish, and particularly nuisance species, are less desirable for human uses than are game, pan, or special category fishes. Asian carps, for example are a well-documented nuisance species that can be extremely abundant, alter the trophic structure of a water body, and even pose a danger to recreational boaters due to their escape response. One indication of potential harm from a thermal discharge might be an increased proportion of rough fish in the Thermally Exposed or Downstream zones. The numbers and proportions of rough fish in the Upstream Reference, Thermally Exposed, and Downstream zones are similar as shown in Figure 5-18. The most common species that would be considered a nuisance species, silver carp, showed very slight increases in areas exposed to the thermal discharge. They accounted for 1.7 percent of the catch in the Upstream Reference zone, 2.4 percent in the Thermally Exposed zone, and 1.9 percent in the Downstream zone (Table 5-3). Their contribution to total fish biomass ranged from 10 percent in the Upstream Reference zone to 12 percent in the Thermally Exposed

and Downstream zones (Table 5-4). Another species often considered a nuisance species, common carp, had biomass of 14 percent upstream, but 13 percent and 12 percent in the Thermally Exposed and Downstream zones, respectively. Therefore, nuisance species have not become dominant as a result of the LEC thermal discharge.

Change in Commercial or Sport Species

Based on the classification of fish types in Table 5-6, commercial and/or sport species would be represented by the game and pan fish categories. The proportion of game and pan fish categories was similar among Upstream Reference, Thermally Exposed, and Downstream zones indicating the LEC discharge has not caused a change in the abundance of these species (Figure 5-18). Game and pan fish biomass were also similar between the three zones. The Discharge zone had a higher proportion of game fish (large catfish species) abundance and biomass than the other three zones, suggesting an attraction to the discharge either due directly to a preference for higher water temperatures, or due to the abundance of forage species. This demonstrates that LEC's thermal discharge did not cause a decrease in commercial or sport species.

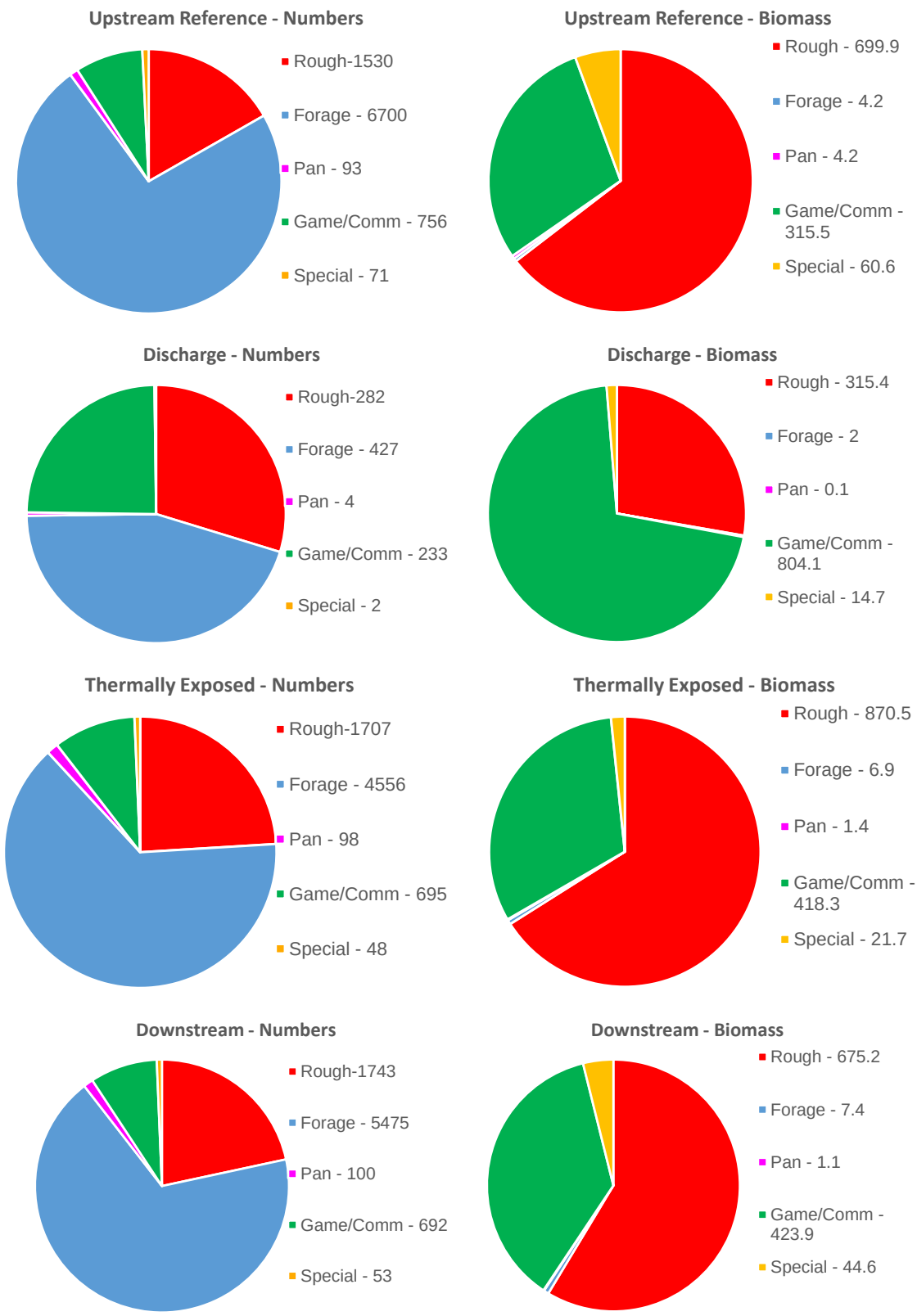


Figure 5-18 Composition of fisheries sampling results in rough, forage, pan, game, and special categories based on numerical abundance (left column) and total biomass in Kg (right) over all seasons and gear types.

Lack of Domination by Heat Tolerant Species

Some of the species in the community could be classified as heat-intolerant (environment in the LEC vicinity would be near their upper thermal tolerance limit) or heat-tolerant (environment in the LEC vicinity is well below their upper thermal tolerance limit). Species considered to be intolerant for the community are sauger, walleye, mooneye, goldeye, and white crappie (Appendix B Section B.2). Species considered to be thermally tolerant are bighead carp, silver carp, bigmouth buffalo, smallmouth buffalo, channel catfish, flathead catfish, emerald shiner, gizzard shad, longnose gar, shortnose gar, and river carpsucker (Appendix B Section B.2).

The abundances of heat intolerant species were similarly low in all zones. Heat tolerant species represented a higher proportion of the community than heat intolerant species in all zones. The proportion of heat tolerant species was slightly higher in the Discharge, Thermally Exposed, and Downstream zones relative to the Upstream Reference zone suggesting a possible effect of LEC thermal discharge on the number of heat tolerant species (Figure 5-19). This was not the case for biomass of heat tolerant species which was lowest in the Discharge zone.

Lack of Domination by Pollution Tolerant Species

Because chemical and organic pollution can be exacerbated by heat, it is also informative to see whether pollution intolerant species may have been replaced by pollution tolerant species in areas affected by a thermal discharge. The LEC community was classified as tolerant or intolerant to pollution based on Pearson et al. (2011), although many of the species are neither distinctly tolerant nor intolerant.

For the LEC discharge, there is no indication of a shift from pollution intolerant or to pollution tolerant species (Figure 5-20). In terms of numerical abundance, pollution intolerant species comprised approximately 2 percent of the community in all zones, and pollution tolerant species were relatively less abundant in the Thermally Exposed (22 percent) and Downstream (26 percent) zones than in the Upstream Reference zone (36 percent). Trends across zones were similar for biomass, with intolerant species ranging from 6 percent to 8 percent, except for the Discharge zone, and pollution tolerant species from 24 percent to 25 percent.

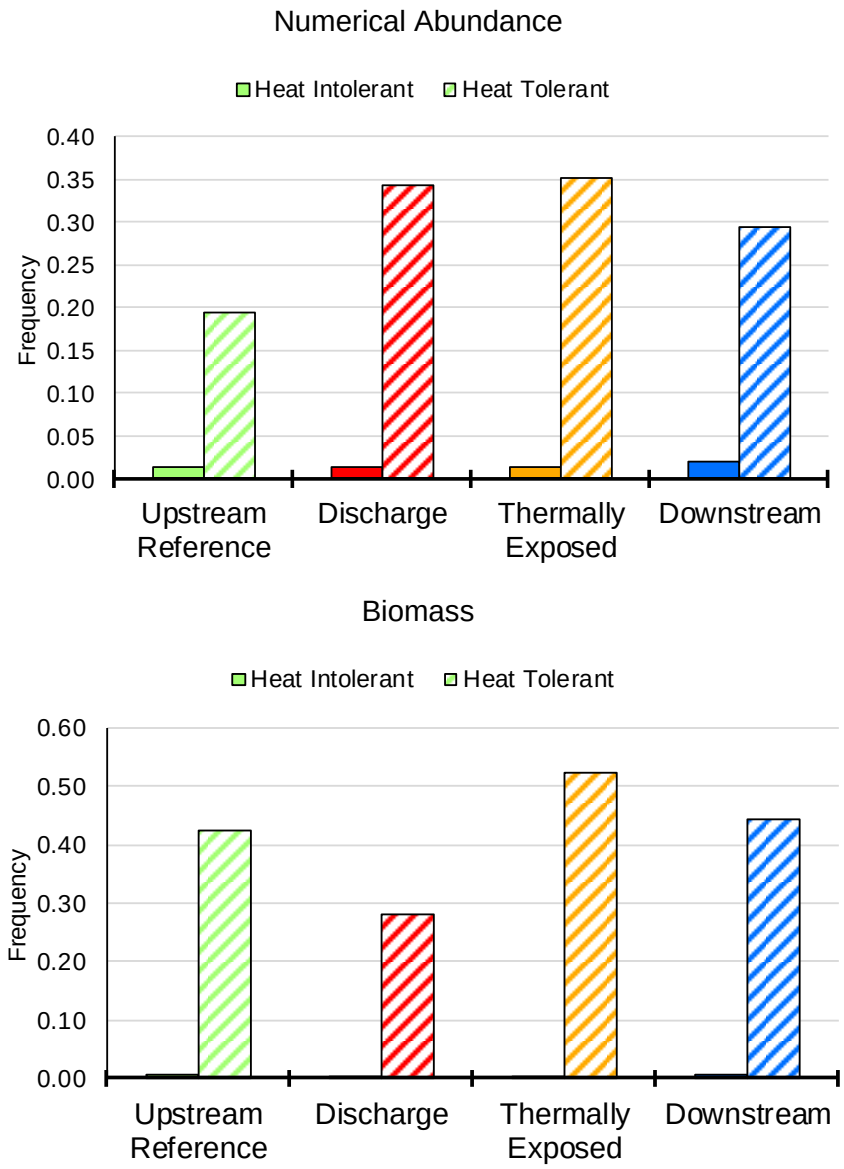


Figure 5-19 Fractions of number of fish (top) and biomass (bottom) comprised of heat-intolerant species (solid) and heat-tolerant species (hatched) in fisheries sampling at the LEC in 2017-2018 for all gear and seasons combined.

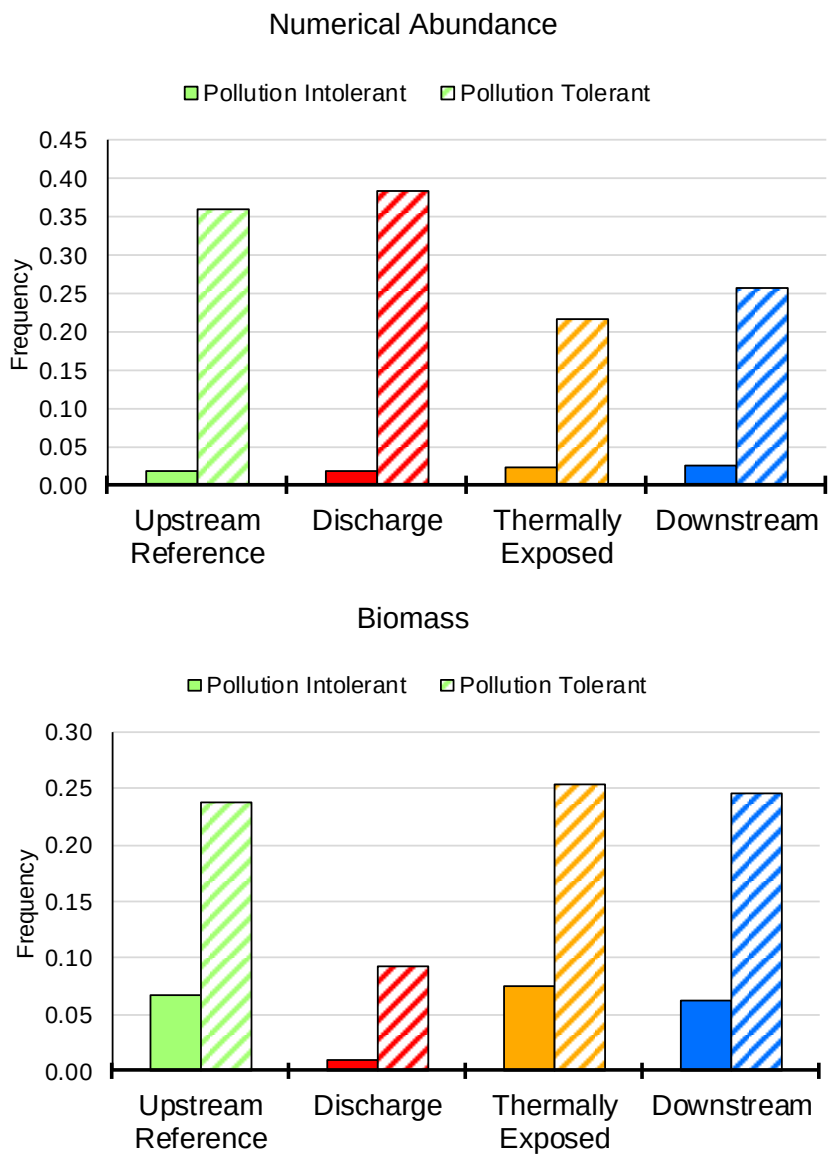


Figure 5-20 Fractions of number of fish (top) and biomass (bottom) comprised of pollution-intolerant species (solid) and pollution-tolerant species (hatched) in fisheries sampling at the LEC in 2017-2018 for all gear and seasons combined.

5.4.1.4 Overall Weight of Evidence

While the evaluation above does not document any clear effect of the LEC's thermal discharge on the individual community metrics, it is also helpful to evaluate patterns across all metrics to see if there are any consistent patterns suggestive of thermal effects. For example, is the Upstream Reference Zone consistently better across all metrics than the thermally exposed zones? This evaluation was done using a quantitative Weight-of-Evidence approach. In this analysis, a "standardized difference", essentially a t-statistic, was calculated for each ecological metric for each combination of sampling gear and season. Each standardized difference was formulated so that it would have a negative value if consistent with harm, and a positive value if inconsistent. Standardized differences were calculated for both numbers of fish and for biomass so that both aspects of the community could be analyzed.

$$Standardized\ Difference = X \frac{V_{TE\ or\ D} - V_{Upstream}}{\sqrt{se(V_{TE\ or\ D})^2 + se(V_{Upstream})^2}}$$

where

X = multiplier set to -1 or +1 so that the difference is negative if the change direction is consistent with harm

V = value of the metric

se(V) = standard error of the metric

Only metrics which had a directional (better vs worse) component were used. Metrics used were:

Metric	Basis	Directional
Abundance	Numbers	High better than low
Abundance	Biomass	High better than low
Diversity ^{0}D (Species Richness)	Numbers	High better than low
Diversity ^{1}D (transform of H')	Numbers	High better than low
Diversity ^{2}D (Inverse Gini-Simpson)	Numbers	High better than low
Diversity ^{3}D (very abundant species)	Numbers	High better than low
Fraction Non-Rough	Numbers	High better than low
Fraction Non-Rough	Biomass	High better than low
Fraction Heat Intolerant	Numbers	High better than low
Fraction Heat Intolerant	Biomass	High better than low
Fraction Heat Tolerant	Numbers	Low better than high
Fraction Heat Tolerant	Biomass	Low better than high
Fraction Pollution Intolerant	Numbers	High better than low
Fraction Pollution Intolerant	Biomass	High better than low
Fraction Pollution Tolerant	Numbers	Low better than high
Fraction Pollution Tolerant	Biomass	Low better than high

In a case where there is no spatial change between zones, these standardized differences would be expected to have a distribution centered at 0, with approximately equal proportions positive and negative (Figure 5-21). If there were prior appreciable harm due to the thermal discharge, the distribution of differences would be shifted toward negative values.

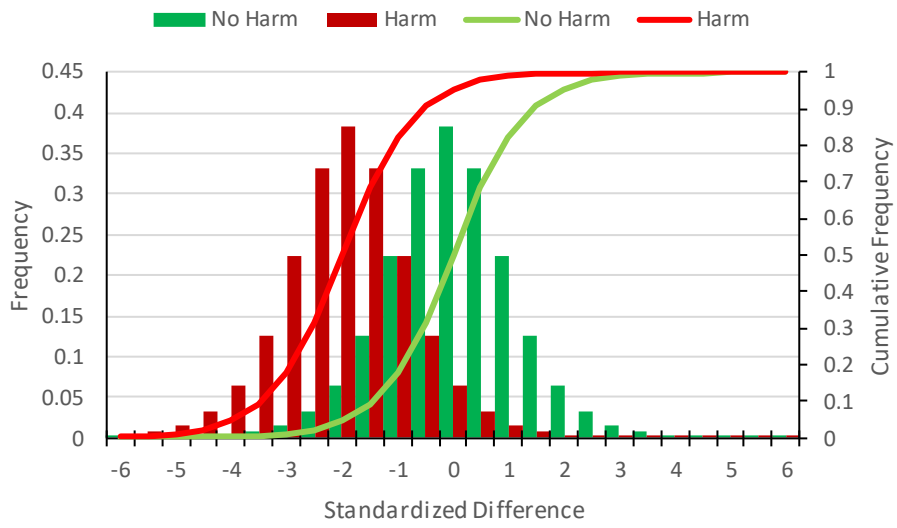


Figure 5-21 Idealized pattern of standardized differences if there were no harm (green) and if there were appreciable harm.

The overall pattern of standardized differences across all the metrics examined in the spatial analysis is not consistent with harm from the thermal discharge (Figure 5-22). Distributions of differences for both the Upstream Reference zone compared to the Thermally Exposed zone and the Upstream Reference zone compared to the Downstream zone were centered near zero and spread nearly equally to positive and negative values. The mean for the Thermally Exposed zone was -0.611, suggesting potentially a slight degradation in the Thermally Exposed zone relative to the Upstream Reference zone, while the mean for the Downstream zone was -0.053, suggestive of conditions similar to those in the Upstream Reference zone. However, the shift in both distributions from the expected value of 0 (for no effect) is within two standard errors, which indicates that observed shifts are not likely biologically meaningful, particularly for the Downstream zone.

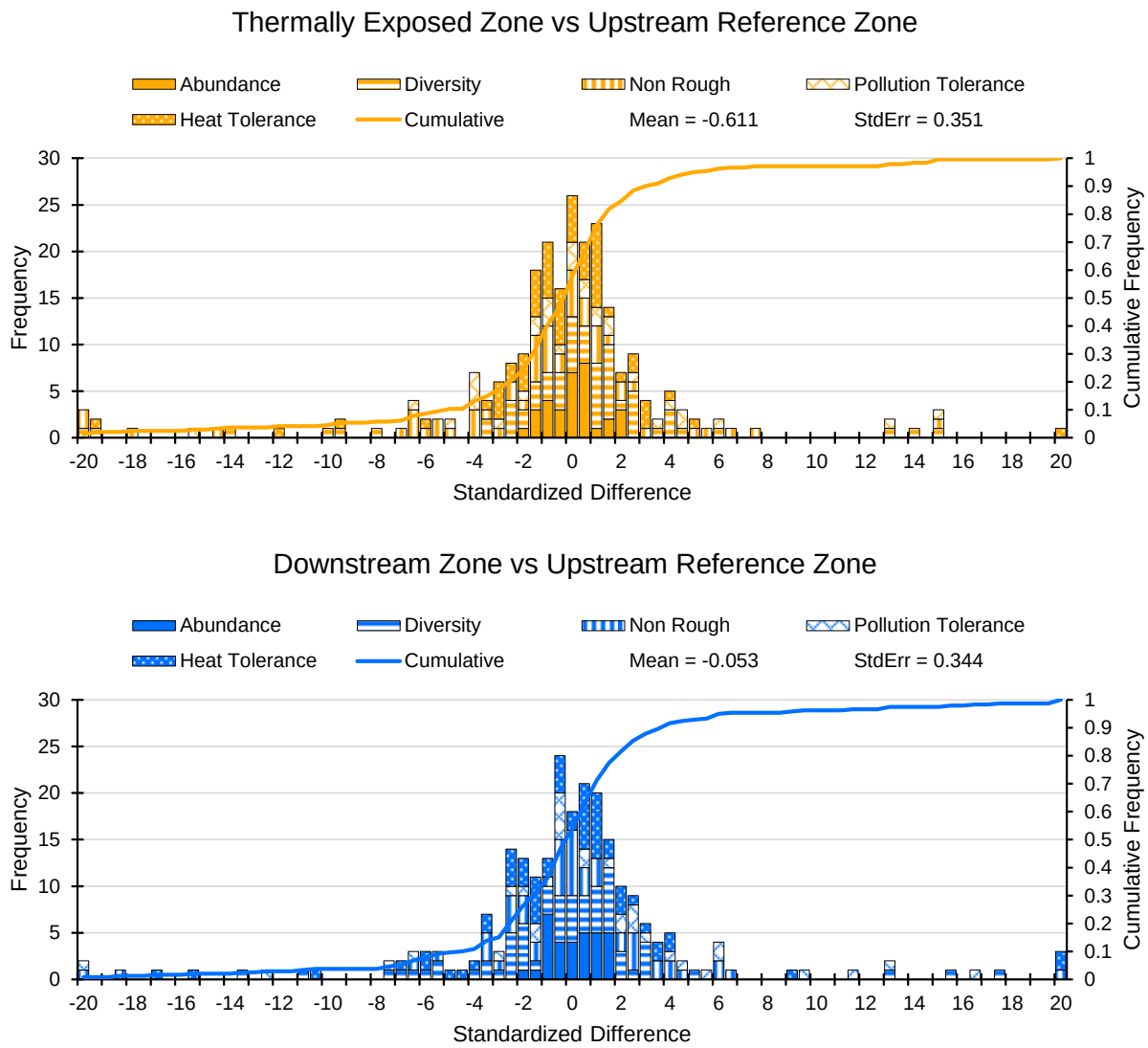


Figure 5-22 Distribution of standardized differences between ecological metrics for the Thermally Exposed Zone and Upstream Refence zone (top) and Downstream zone and Upstream Reference Zone (bottom) over all gear, seasons, and metrics.

5.4.2 Benthic Macroinvertebrate Community

The benthic macroinvertebrate sampling program implemented by Wood in the vicinity of the LEC collected almost 94,000 organisms during 2017-2018 (Table 5-7). The H-D samplers, which tend to collect drifting organisms, collected over 72,000 organisms while the Ponar dredge, which collects benthic infaunal organisms, contained over 21,000 organisms. Abundance in H-D collections were generally similar among the four sampling zones, ranging from approximately 16,000 to 20,000, while abundance in Ponar collections were approximately 600 in the Discharge Zone, but ranged from 5,000 to 9,000 in the other three zones.

The minimum number of families[3] of benthic macroinvertebrates collected in H-D samples was 20 in the Discharge zone, and 29-31 in the other zones. The zonal variation in number of distinct species was similar, with 53 species in the Discharge zone, and 86-88 in the other zones. The number of families in Ponar samples ranged from 10 in the Discharge zone to 25-29in the other zones, while distinct species ranged from 37 in the Discharge zone to 65-79 in the other zones.

Table 5-7 Total organisms collected, and minimum number of families and species for each sampling zone and gear in macroinvertebrate sampling in LEC vicinity in 2017-2018.

Zone	Hester-Dendy			Ponar		
	Count	Minimum Families	Minimum Species	Count	Minimum Families	Minimum Species
Upstream	20,587	29	86	8,765	25	65
Discharge	15,735	20	53	564	10	37
Thermal	20,413	31	92	5,261	29	70
Downstream	15,498	30	88	7,056	27	79
Total	72,233			21,646		

The number of organisms for individual families is provided in Table 5-8 and Table 5-9. Summary table for all benthic macroinvertebrate data are presented in Appendix B Section B.1.

5.4.2.1 Overall Abundance

Sample densities (number per 0.1 m^2) of total macroinvertebrates were calculated for each sampling gear in each season and zone. For both gears, substantial variation occurred among season and zone. For H-D samples, densities in the Discharge zone were distinctly higher than in other zones in all seasons (Figure 5-23). Densities in the Thermally Exposed zone were the same or greater than those in the Upstream Reference zone in all seasons. Downstream zone densities were similar to those in the Upstream Reference zone in all seasons but summer when they were lower. For Ponar samples, the Discharge zone consistently had the lowest densities, and the Upstream Reference Zone the highest, except in winter. Downstream zone densities were higher than in the Thermally Exposed zone. These results demonstrate that the LEC's thermal discharge did not reduce the number of drifting organisms. On the other hand, the reduced abundance of infaunal organisms in the discharge canal could be related to heat, water turbulence or/or sediment instability. Regardless of the cause, there were no effects observed outside the discharge canal.

[3] In determining the minimum number of families collected, organisms identified at higher taxonomic levels, e.g. orders, class, phylum, were considered to be 1 additional family if no organisms within that classification were identified to the level of family. Minimum number of species were determined similarly for organisms identified to genus or higher levels. For example, a genus with no organisms identified to species was considered as 1 additional species.

Table 5-8 Counts of organism by family and minimum number of species in Hester-Dendy sampling in vicinity of the LEC in 2017-2018.

Class	Order	Family	Upstream Reference			Discharge			Thermally Exposed			Downstream		
			Count	Min. Species	Fraction	Count	Min. Species	Fraction	Count	Min. Species	Fraction	Count	Min. Species	Fraction
Arachnida	Trombidiformes	Hydrachnidia	7	1	0.0003	5	1	0.0003	2	1	0.0001	4	1	0.0003
Bivalvia	Veneroida	Corbiculidae	1	1	0.0000	0	0	0	2	1	0.0001	1	1	0.0001
Bivalvia	Veneroida	Dreissenidae	10	1	0.0005	0	0	0	20	1	0.001	6	1	0.0004
Clitellata			0	0	0.0000	1	0	0.0001	3	0	0.0001	2	0	0.0001
Clitellata	Hirudinida	Glossiphoniidae	0	0	0.0000	0	0	0	2	1	0.0001	0	0	0
Clitellata	Tubificida	Naididae	79	7	0.0038	67	4	0.0043	86	9	0.0042	75	7	0.0048
Gastropoda	Basommatophora	Ancylidae	6	1	0.0003	2	1	0.0001	1	1	0	4	1	0.0003
Gastropoda	Basommatophora	Physidae	0	0	0.0000	1	1	0.0001	4	1	0.0002	3	1	0.0002
Hydrozoa	Anthoathecatae	Hydridae	2	1	0.0001	0	0	0	12	1	0.0006	10	1	0.0006
Insecta			172	0	0.0084	42	0	0.0027	250	0	0.0122	403	0	0.026
Insecta	Coleoptera	Elmidae	0	0	0.0000	0	0	0	0	0	0	3	2	0.0002
Insecta	Diptera	Ceratopogonidae	1	1	0.0000	2	2	0.0001	0	0	0	0	0	0
Insecta	Diptera	Chaoboridae	0	0	0.0000	0	0	0	0	0	0	4	1	0.0003
Insecta	Diptera	Chironomidae	8364	34	0.4063	2503	18	0.1591	7559	36	0.3703	5290	35	0.3413
Insecta	Diptera	Empididae	0	0	0.0000	0	0	0	0	0	0	1	1	0.0001
Insecta	Diptera	Simuliidae	0	0	0.0000	3	1	0.0002	1	1	0	0	0	0
Insecta	Diptera	Tabanidae	0	0	0.0000	0	0	0	0	0	0	4	1	0.0003
Insecta	Ephemeroptera		35	0	0.0017	61	0	0.0039	4	0	0.0002	22	0	0.0014
Insecta	Ephemeroptera	Baetidae	1749	1	0.0850	1217	1	0.0773	1030	1	0.0505	1286	1	0.083
Insecta	Ephemeroptera	Caenidae	768	2	0.0373	594	2	0.0378	398	2	0.0195	1144	2	0.0738
Insecta	Ephemeroptera	Ephemeridae	17	1	0.0008	0	0	0	8	1	0.0004	0	0	0
Insecta	Ephemeroptera	Heptageniidae	1759	6	0.0854	493	3	0.0313	1607	5	0.0787	1401	7	0.0904
Insecta	Ephemeroptera	Isonychiidae	399	3	0.0194	98	3	0.0062	288	3	0.0141	114	3	0.0074
Insecta	Ephemeroptera	Leptohyphidae	61	1	0.0030	10	1	0.0006	33	1	0.0016	36	1	0.0023
Insecta	Ephemeroptera	Palingeniidae	1	1	0.0000	0	0	0	1	1	0	0	0	0
Insecta	Ephemeroptera	Polymitarcyidae	3	1	0.0001	0	0	0	1	1	0	0	0	0

Class	Order	Family	Upstream Reference			Discharge			Thermally Exposed			Downstream		
			Count	Min. Species	Fraction	Count	Min. Species	Fraction	Count	Min. Species	Fraction	Count	Min. Species	Fraction
Insecta	Ephemeroptera	Potamanthidae	2	1	0.0001	0	0	0	1	1	0	2	1	0.0001
Insecta	Megaloptera	Corydalidae	37	2	0.0018	10	1	0.0006	16	2	0.0008	13	1	0.0008
Insecta	Odonata		0	0	0.0000	0	0	0	1	0	0	2	0	0.0001
Insecta	Odonata	Coenagrionidae	29	1	0.0014	0	0	0	78	2	0.0038	47	1	0.003
Insecta	Odonata	Corduliidae	38	2	0.0018	0	0	0	18	2	0.0009	27	2	0.0017
Insecta	Odonata	Gomphidae	3	1	0.0001	0	0	0	3	1	0.0001	5	1	0.0003
Insecta	Plecoptera		3	0	0.0001	3	0	0.0002	25	0	0.0012	0	0	0
Insecta	Plecoptera	Perlidae	168	5	0.0082	68	4	0.0043	132	5	0.0065	121	4	0.0078
Insecta	Plecoptera	Perlodidae	31	2	0.0015	32	2	0.002	69	2	0.0034	28	2	0.0018
Insecta	Plecoptera	Taeniopterygidae	2	1	0.0001	2	2	0.0001	2	1	0.0001	4	1	0.0003
Insecta	Trichoptera		15	0	0.0007	10	0	0.0006	3	0	0.0001	6	0	0.0004
Insecta	Trichoptera	Hydropsychidae	6598	3	0.3205	10489	3	0.6666	8560	3	0.4193	5261	3	0.3395
Insecta	Trichoptera	Hydroptilidae	16	1	0.0008	2	1	0.0001	6	1	0.0003	15	1	0.001
Insecta	Trichoptera	Leptoceridae	6	1	0.0003	0	0	0	6	1	0.0003	1	1	0.0001
Insecta	Trichoptera	Polycentropodidae	193	2	0.0094	5	1	0.0003	166	2	0.0081	94	2	0.0061
Trepaxonemata			0	0	0.0000	0	0	0	0	0	0	1	0	0.0001
Trepaxonemata	Neoophora	Planariidae	12	1	0.0006	15	1	0.001	15	1	0.0007	58	1	0.0037
Totals			20587	86		15735	53		20413	92		15498	88	

Table 5-9 Counts of organism by family and minimum number of species in Ponar sampling in vicinity of the LEC in 2017-2018.

Class	Order	Family	Upstream Reference			Discharge			Thermally Exposed			Downstream		
			Count	Minimum Species	Fraction	Count	Minimum Species	Fraction	Count	Minimum Species	Fraction	Count	Minimum Species	Fraction
Arachnida	Trombidiformes	Hydrachnidia	0	0	0.0000	1	1	0.0018	0	0	0	0	0	0
Bivalvia			0	0	0.0000	0	0	0	0	0	0	1	0	0.0001
Bivalvia	Unionoida	Unionidae	0	0	0.0000	0	0	0	0	0	0	1	1	0.0001
Bivalvia	Veneroida	Corbiculidae	16	1	0.0018	8	1	0.0142	7	1	0.0013	6	1	0.0009
Bivalvia	Veneroida	Dreissenidae	7	1	0.0008	0	0	0	1	1	0.0002	14	1	0.002
Clitellata			987	0	0.1126	38	0	0.0674	1169	0	0.2222	1438	0	0.2038
Clitellata	Hirudinida	Glossiphoniidae	1	1	0.0001	0	0	0	1	1	0.0002	2	2	0.0003
Clitellata	Lumbriculida	Lumbriculidae	4	1	0.0005	0	0	0	3	1	0.0006	10	1	0.0014
Clitellata	Tubificida	Naididae	5454	4	0.6222	260	7	0.461	2929	8	0.5567	3968	11	0.5624
Entognatha	Collembola	Isotomidae	45	1	0.0051	0	0	0	3	1	0.0006	7	1	0.001
Gastropoda	Basommatophora	Ancylidae	2	1	0.0002	0	0	0	0	0	0	0	0	0
Gastropoda	Basommatophora	Planorbidae	0	0	0.0000	0	0	0	1	1	0.0002	1	1	0.0001
Insecta			0	0	0.0000	0	0	0	1	0	0.0002	0	0	0
Insecta	Coleoptera		3	0	0.0003	0	0	0	1	0	0.0002	0	0	0
Insecta	Coleoptera	Elmidae	3	1	0.0003	0	0	0	0	0	0	3	2	0.0004
Insecta	Coleoptera	Staphylinidae	0	0	0.0000	0	0	0	1	1	0.0002	0	0	0
Insecta	Diptera		1	0	0.0001	1	0	0.0018	31	0	0.0059	0	0	0
Insecta	Diptera	Ceratopogonidae	7	2	0.0008	3	2	0.0053	4	2	0.0008	8	4	0.0011
Insecta	Diptera	Chaoboridae	2	1	0.0002	0	0	0	11	1	0.0021	7	1	0.001
Insecta	Diptera	Chironomidae	942	34	0.1075	77	20	0.1365	477	29	0.0907	833	33	0.1181
Insecta	Diptera	Dolichopodidae	0	0	0.0000	0	0	0	1	1	0.0002	0	0	0
Insecta	Diptera	Psychodidae	2	1	0.0002	0	0	0	2	1	0.0004	4	1	0.0006
Insecta	Diptera	Simuliidae	1	1	0.0001	0	0	0	0	0	0	0	0	0
Insecta	Ephemeroptera		5	0	0.0006	0	0	0	16	0	0.003	4	0	0.0006
Insecta	Ephemeroptera	Baetidae	1	1	0.0001	1	1	0.0018	0	0	0	3	1	0.0004
Insecta	Ephemeroptera	Caenidae	2	1	0.0002	0	0	0	1	1	0.0002	6	1	0.0009

Class	Order	Family	Upstream Reference			Discharge			Thermally Exposed			Downstream		
			Count	Minimum Species	Fraction	Count	Minimum Species	Fraction	Count	Minimum Species	Fraction	Count	Minimum Species	Fraction
Insecta	Ephemeroptera	Ephemeridae	1017	3	0.1160	3	1	0.0053	409	3	0.0777	430	3	0.0609
Insecta	Ephemeroptera	Heptageniidae	2	1	0.0002	0	0	0	1	1	0.0002	4	1	0.0006
Insecta	Ephemeroptera	Isonychiidae	0	0	0.0000	0	0	0	1	1	0.0002	0	0	0
Insecta	Ephemeroptera	Leptohyphidae	0	0	0.0000	0	0	0	1	1	0.0002	0	0	0
Insecta	Ephemeroptera	Palingeniidae	115	1	0.0131	97	1	0.172	85	1	0.0162	189	1	0.0268
Insecta	Ephemeroptera	Polymitarcyidae	19	1	0.0022	0	0	0	8	2	0.0015	6	2	0.0009
Insecta	Hemiptera		0	0	0.0000	0	0	0	0	0	0	2	1	0.0003
Insecta	Hemiptera	Aphididae	0	0	0.0000	0	0	0	2	1	0.0004	0	0	0
Insecta	Hemiptera	Corixidae	2	1	0.0002	0	0	0	1	1	0.0002	0	0	0
Insecta	Lepidoptera		0	0	0.0000	0	0	0	1	1	0.0002	0	0	0
Insecta	Megaloptera	Corydalidae	0	0	0.0000	0	0	0	1	1	0.0002	0	0	0
Insecta	Odonata	Corduliidae	0	0	0.0000	0	0	0	1	1	0.0002	3	1	0.0004
Insecta	Odonata	Gomphidae	5	1	0.0006	3	1	0.0053	9	2	0.0017	20	2	0.0028
Insecta	Plecoptera		1	0	0.0001	0	0	0	1	0	0.0002	0	0	0
Insecta	Plecoptera	Perlidae	1	1	0.0001	0	0	0	0	0	0	0	0	0
Insecta	Plecoptera	Perlodidae	0	0	0.0000	0	0	0	1	1	0.0002	4	1	0.0006
Insecta	Plecoptera	Taeniopterygidae	0	0	0.0000	0	0	0	0	0	0	1	1	0.0001
Insecta	Trichoptera		0	0	0.0000	0	0	0	0	0	0	2	0	0.0003
Insecta	Trichoptera	Hydropsychidae	116	2	0.0132	72	2	0.1277	77	2	0.0146	76	2	0.0108
Insecta	Trichoptera	Hydroptilidae	0	0	0.0000	0	0	0	0	0	0	1	1	0.0001
Insecta	Trichoptera	Leptoceridae	1	1	0.0001	0	0	0	0	0	0	0	0	0
Insecta	Trichoptera	Polycentropodidae	1	1	0.0001	0	0	0	2	1	0.0004	2	1	0.0003
Totals			8765	65		564	37		5261	70		7056	79	

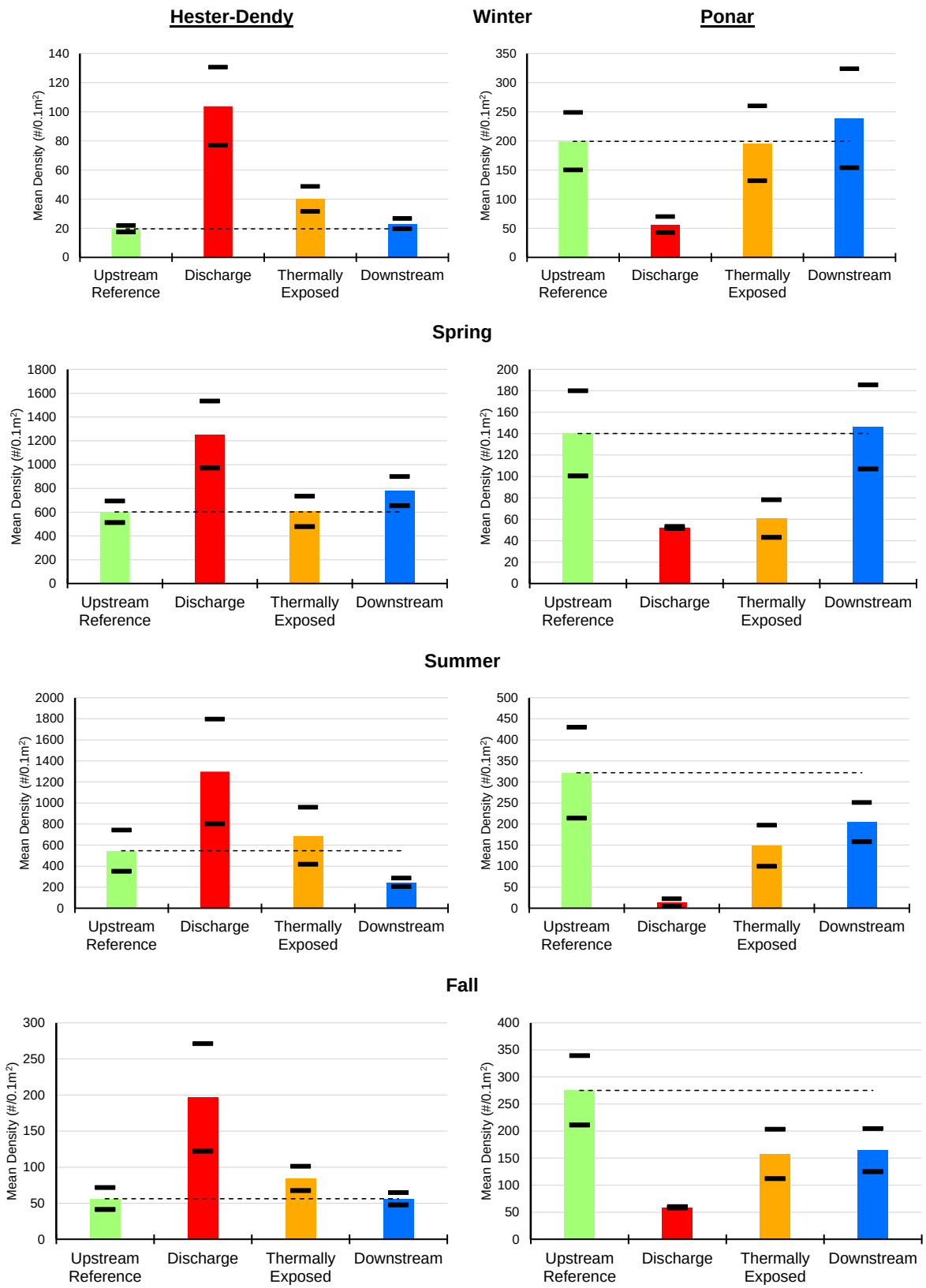


Figure 5-23 Mean density (#/0.1m^2) of macrobenthos in sampling at the LEC in 2017-2018 for each season, gear type, and zone. Back bars indicate +/- 1 standard error from mean.

5.4.2.2 Capability to Sustain Itself

Seasonal density patterns (relative to maximum seasonal density) for the drift component of the macroinvertebrate community sampled with H-D gear were very similar among the four sampling zones (Figure 5-24). The only departure from the pattern of high densities in spring and summer and low densities in winter and fall was that summer densities in the Downstream zone were lower relative to maximum density than in the other zones (Figure 5-24 top). Reasons for this pattern are unknown but are clearly not related to the LEC's thermal discharge.

For the Ponar samples of the benthic infauna, the Upstream Reference zone had winter, summer, and fall densities greater than 90 percent of the maximum, with spring relative density only 55 percent of the maximum (Figure 5-24 bottom). For the Thermally Exposed and Downstream zones, densities were highest in winter and lowest in summer, and well below maximum (43 percent to 64 percent) in summer and fall. The Discharge zone had maximum densities in spring and minimum densities in summer.

Some disturbance, such as earlier maturation and thus drifting, to benthic infauna is suggested by the lower spring, summer, and fall densities in the Thermally Exposed and Downstream zones relative to the Upstream Reference zone. However, both the epifaunal and infaunal macroinvertebrate communities demonstrate the ability to sustain themselves in the Thermally Exposed and Downstream zones.

5.4.2.3 Community Characteristics

Diversity

Due to the differences in taxonomic level (class, order, family, etc.) of identification of the benthic macroinvertebrates, diversity was calculated at the family level because most organisms could be identified to this level. Other than fewer families being observed in Discharge zone samples than in other zones (at q = 0), there was no consistent pattern of differences in diversity among the other zones (Figure 5-25). Diversity was similar between the Upstream Reference, Thermally Exposed, and Downstream zones in all seasons at all levels of q in both the H-D and Ponar samples. Overall, more families were collected in the H-D samples than in the Ponar samples (q = 0), and diversity at higher values of q was also higher in H-D samples, indicating that the drift community is less dominated by a few families than is the in-faunal community. This analysis demonstrates that the LEC thermal discharge has not adversely affected the benthic macroinvertebrate diversity in the Thermally Exposed and Downstream zones.

Dominance

All zones, except for the Discharge zone, had similar proportions comprised of the dominant benthic macroinvertebrate groups (Figure 5-26). For the Upstream Reference, Thermally Exposed, and Downstream zones, H-D samples were dominated by Diptera (flies – 34 percent to 41 percent), Ephemeroptera (mayflies – 17 percent to 26 percent), and Trichoptera (caddisflies – 33 percent to 43 percent) with Plecoptera (stoneflies) and other combined taxa ranging from 3 percent to 5 percent. In the Discharge zone, Tricoptera dominated (67 percent), followed by Diptera (16 percent) and Ephemeroptera (16 percent).

For Ponar samples of the benthic infauna, the composition was also similar among zones, but with the Discharge zone being the most different from the others. For the Upstream Reference, Thermally Exposed, and Downstream zones, Tubificida was the dominant group ranging from 56 percent to 62 percent, followed by Diptera at 10 percent to 12 percent, and Ephemeroptera 9 percent to 13 percent. All other groups were comprised 14 percent to 24 percent, but most of these were undifferentiated Class Clitellata (11 percent to 22 percent). The Discharge zone was only different from the other zones in that Tubificida accounted for only 46 percent of the sampled

organisms, and that Trichoptera were 13% rather than 1-2 percent. While there is some evidence of effects on the macrobenthic component within the Discharge Canal, the LEC thermal discharge has not adversely affected the benthic macroinvertebrate community in the Thermally Exposed and Downstream zones in the main river.

Dominance by Pollution Tolerant Species

Because the Ephemeroptera, Plecoptera, and Trichoptera orders generally require good water and sediment quality and other habitat conditions, the number of species in these orders and fraction of the community comprised of these groups are often used as indicators of habitat quality. In H-D samples the number of Ephemeroptera, Plecoptera, and Trichoptera (EPT) species in the Thermally Exposed and Downstream zones was generally similar (slightly higher or lower) to the Upstream Reference zone while the fraction of EPT species was typically slightly higher in the Upstream Reference zone (Figure 5-27). Ponar samples showed a similar pattern, however the fraction of EPT species was typically lower due to the higher abundance of Tubificida in the sediment. These patterns indicate that the LEC thermal discharge has not caused the areas downstream to be dominated by pollution tolerant species.

Dominance by Heat Tolerant Species

Some EPT taxa are more intolerant of high temperatures than others. A literature search identified the following EPT taxa as having an upper incipient lethal temperature of 86°F (30°C) or less: Baetidae, *Caenis* sp., *Hexagenia limbata*, *Heptagenia* sp., Heptageniiidae, *Stenonema femoratum*, *Acroneuria* sp., Perlidae, Taeniopterygidae, *Taeniopteryx* sp., *Hydroptila* sp., and Hydroptillidae, (Appendix B Table B-29). Overall, these heat-intolerant taxa were approximately 8% of the total EPTorganisms sampled by the Hester-Dendy and 30% of EPT organisms for Ponar samples.

In H-D samples, the proportion of heat-intolerant EPT organisms was lower in the Thermally Exposed zone than in the Upstream Reference zone, except in the fall (Figure 5-28). Downstream zone values were nearly the same as the Upstream Reference zone in spring and summer, but distinctly greater than Upstream Reference zone values in winter, but lower in the fall. Samples from the Discharge zone exhibited a lower proportion of heat-intolerant relative to other zones in all seasons.

For Ponar samples, heat-intolerant taxa were more prevalent in winter and fall seasons. The Thermally Exposed zone had a lower fraction of heat-intolerant than the Upstream Reference zone in the spring, but similar fractions in all other seasons, while the Downstream zone had a higher fraction in the winter, lower fraction in the fall, and similar fractions in spring and summer.

The heat intolerant EPT taxa comprise a fraction of the EPT organisms and an even smaller fraction of the overall benthic macroinvertebrates sampled. All zones appear to be similarly dominated by heat tolerant taxa, with the exception the benthic infauna sampled by Ponar in the fall, and there is no indication that the proportion of heat intolerant taxa are being reduced in favor of heat tolerant taxa in the Thermally Exposed and Downstream zones.

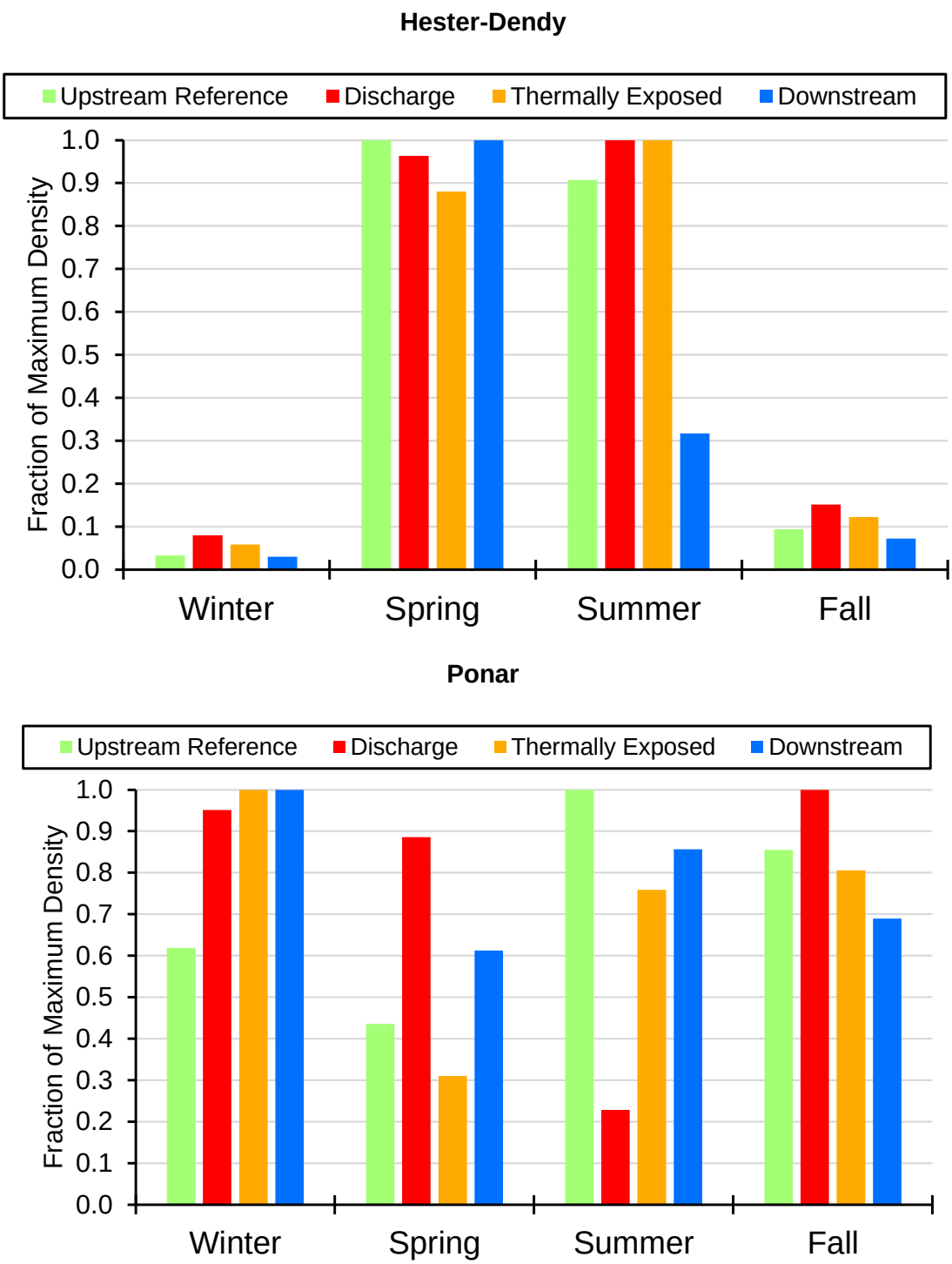


Figure 5-24 Seasonal pattern of variation in relative density of macroinvertebrates of Upstream, Discharge, Thermal, and Downstream zones, in Hester-Dendy samples (top) and Ponar samples (bottom) in the LEC vicinity in 2017-2018.

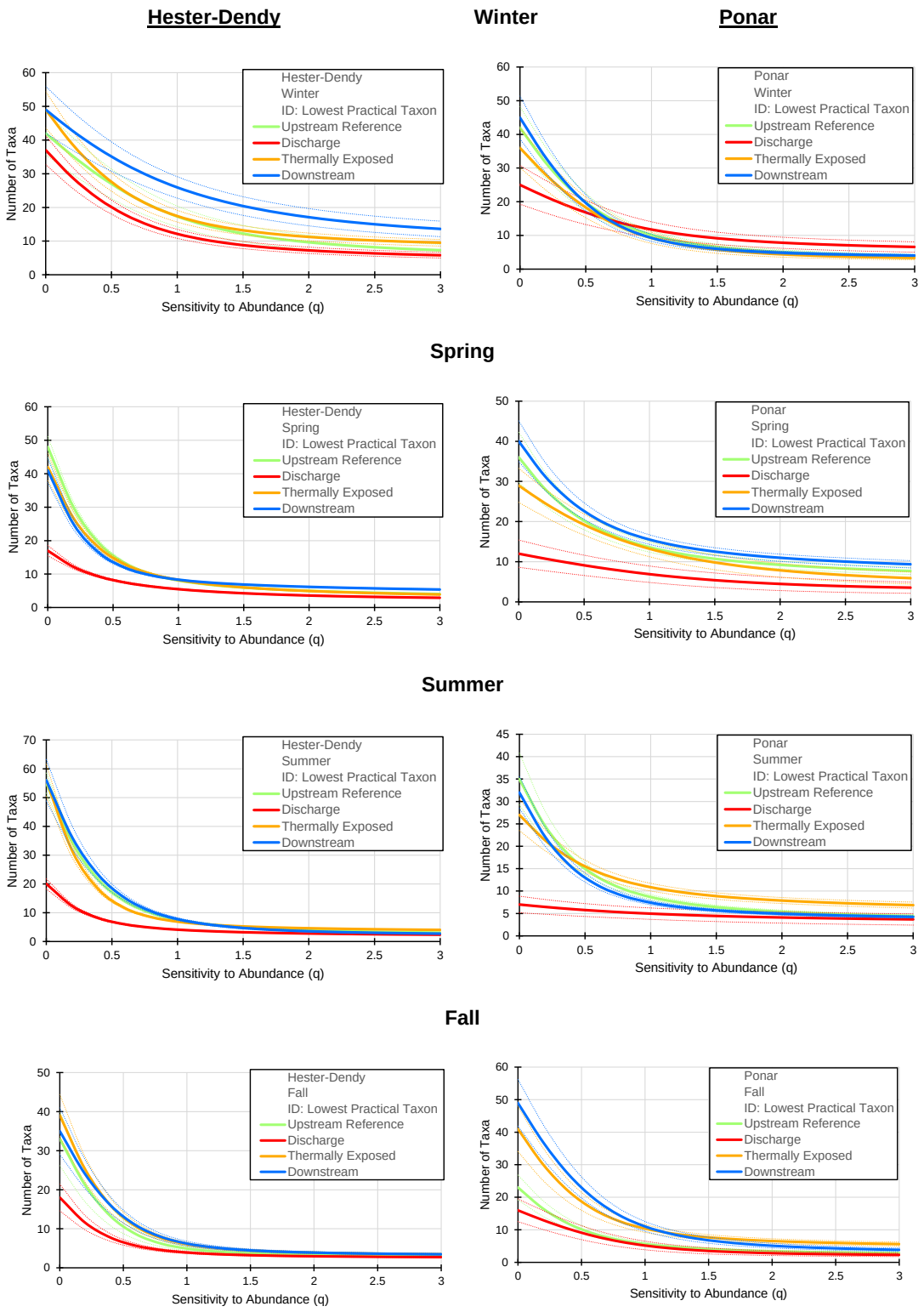


Figure 5-25 Diversity profiles of macrobenthos sampled at the LEC in 2017-2018 for each gear type and season. Dashed lines for numerical profiles indicate +/- 2 standard deviations around estimate.

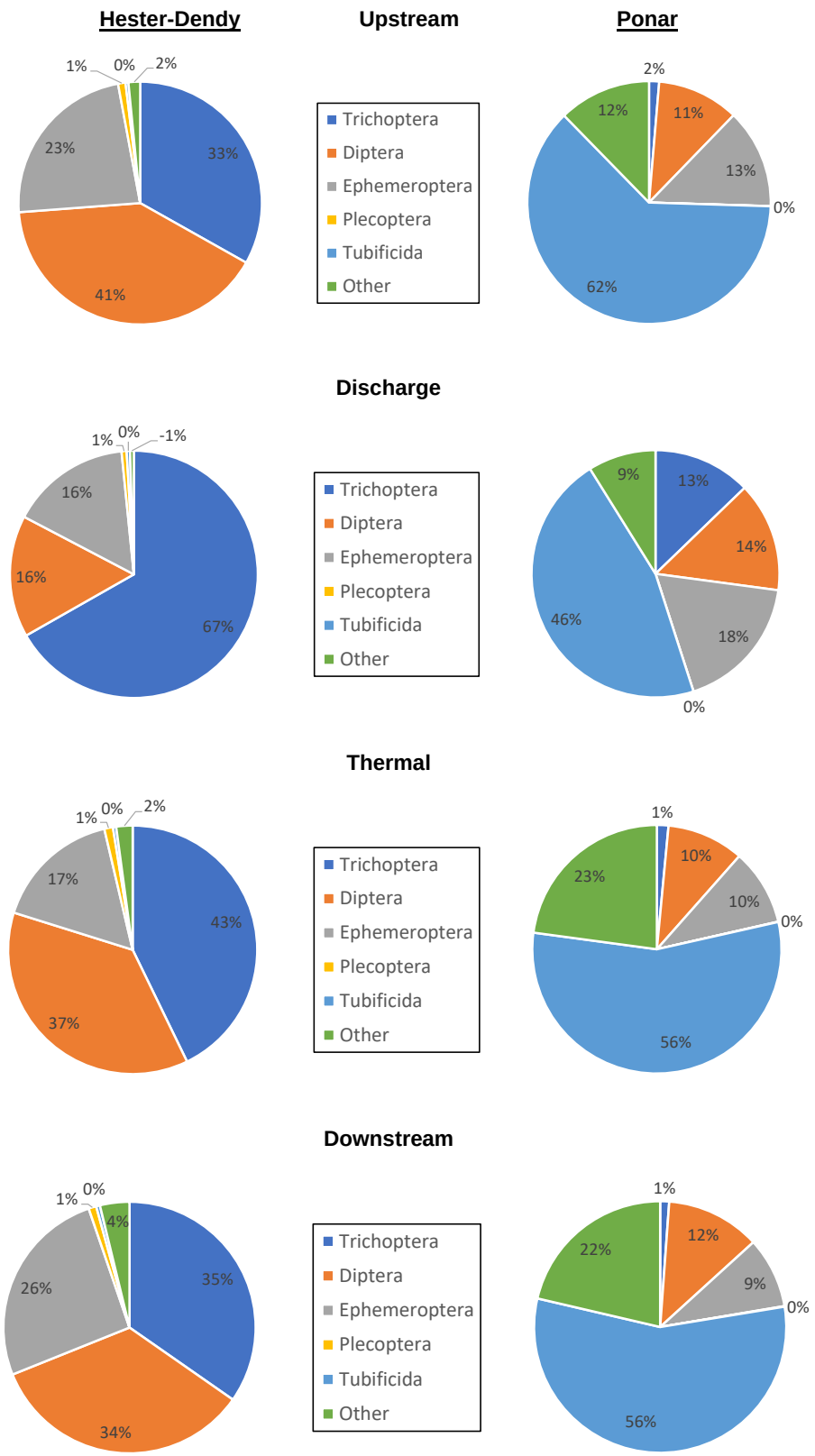


Figure 5-26 Major groups of benthic macroinvertebrates in sampling near the LEC in 2017-2018.

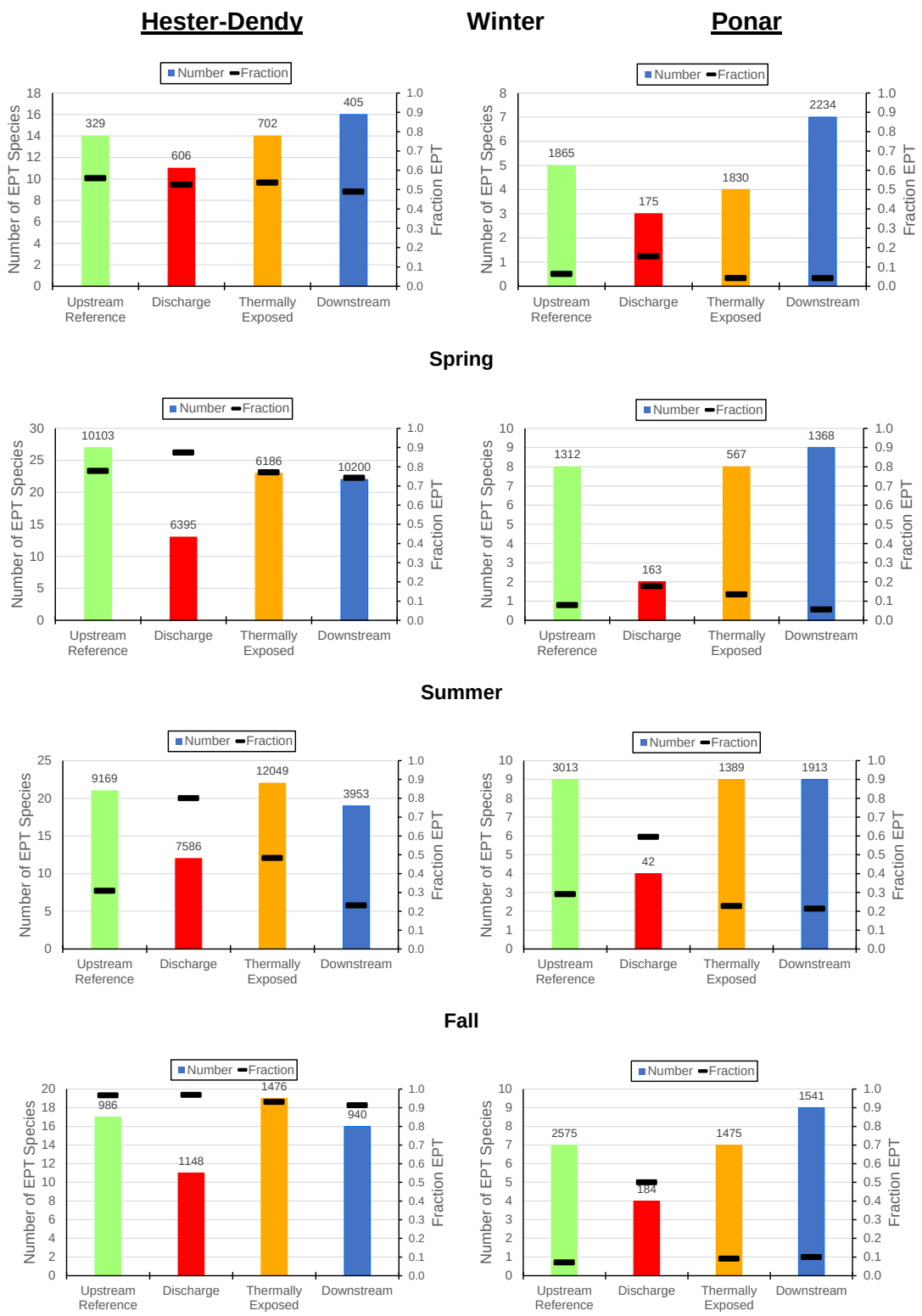


Figure 5-27 Contribution of Ephemeroptera, Plecoptera, and Trichoptera species to the total sample for Hester-Dendy and Ponar samples at the LEC in 2017-2018. Colored columns represent the number of EPT species. Numbers above the column is total number of organisms. Black horizontal bars are the fraction of the community comprised of EPT species.

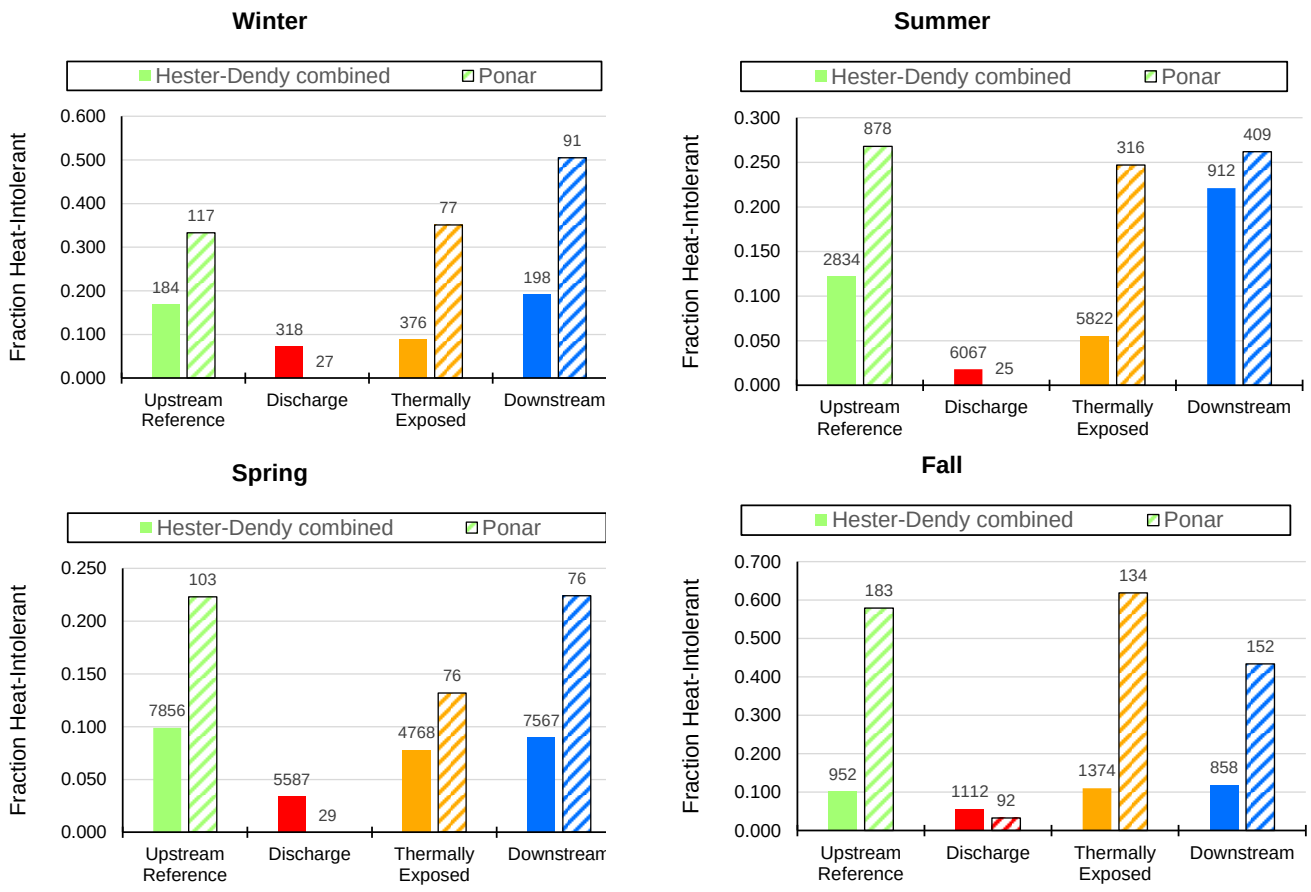


Figure 5-28 Fraction of EPT organisms that are heat-intolerant in Hester-Dendy (solid) and Ponar samples (hatched) in vicinity of the LEC, 2017-2018. Numbers over columns are the number of EPT organisms.

5.4.2.4 Overall Weight of Evidence

As with fish, a quantitative Weight-of-Evidence approach was used to evaluate the overall effects of the LEC's thermal plume on the benthic macroinvertebrate component of the BIC. In this analysis, a "standardized difference", essentially a t-statistic, was calculated for each ecological metric for each combination of gear and season comparing the Upstream Reference zone with the Thermally Exposed zone and with the Downstream zone. Each standardized difference was formulated so that it would have a negative value if consistent with harm, and a positive value if inconsistent.

$$Standardized\ Difference = X\frac{V_{TE\ or\ D} - V_{Upstream}}{\sqrt{se(V_{TE\ or\ D})^2 + se(V_{Upstream})^2}}$$

where

X = multiplier set to -1 or +1 so that the difference is negative if the change direction is consistent with harm

V = value of the metric

se(V) = standard error of the metric

Only metrics which had a directional (better vs worse) component were used. Metrics used were:

Metric	Basis	Directional
Abundance	Numbers	High better than low
Diversity ^{0}D (Family Richness)	Numbers	High better than low
Diversity ^{1}D (transform of H')	Numbers	High better than low
Diversity ^{2}D (Inverse Gini-Simpson)	Numbers	High better than low
Diversity ^{3}D (very abundant species)	Numbers	High better than low
EPT Species	Numbers	High better than low
Fraction EPT	Biomass	High better than low
Fraction EPT Heat Tolerant	Biomass	Low better than high

In a case where there is no effect of the thermal discharge, these standardized differences would be expected to have a distribution centered at 0, with approximately equal proportions positive and negative. If there were prior appreciable harm due to the thermal discharge, the distribution would be shifted toward negative values. In comparing the pattern of differences for the Thermally Exposed zone and the Downstream zone, the Thermally Exposed zone, where some effect of the discharge might be expected, would be more shifted toward the negative.

The overall pattern of differences across all the metrics examined is not consistent with harm from the thermal discharge (Figure 5-29). Distributions for both the Thermally Exposed zone and the Downstream zone compared to the Upstream Reference zone were shifted slightly positively from zero (mean for Thermally Exposed zone = 1.04 and for the Downstream zone mean = 0.55). The magnitude of the shifts were within 2 standard errors from 0, suggesting that the shifts may not be large enough to be biologically important. This is supported by the fact that the magnitude of the positive shift was greater for the Thermally Exposed zone than for the Downstream zone. If the LEC discharge were the primary cause of degraded conditions, any shift toward negative values should be greater in the Thermally Exposed zone than in the Downstream zone.

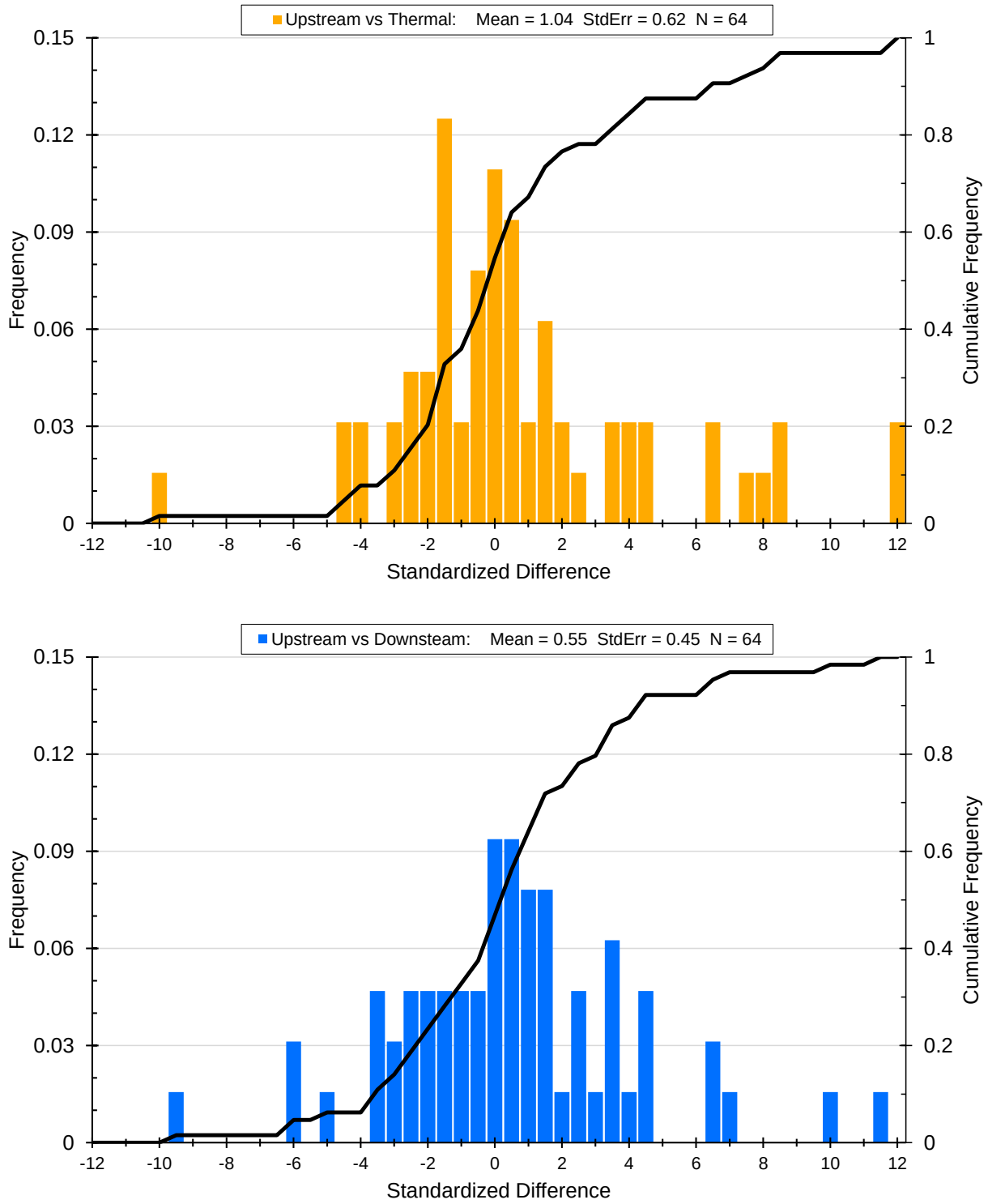


Figure 5-29 Distribution of standardized differences between ecological metrics for Upstream zone and Thermal zone (top) and Upstream zone and Downstream zone (bottom) over all gear and metrics for macroinvertebrate sampling.

5.5 TEMPORAL ANALYSIS

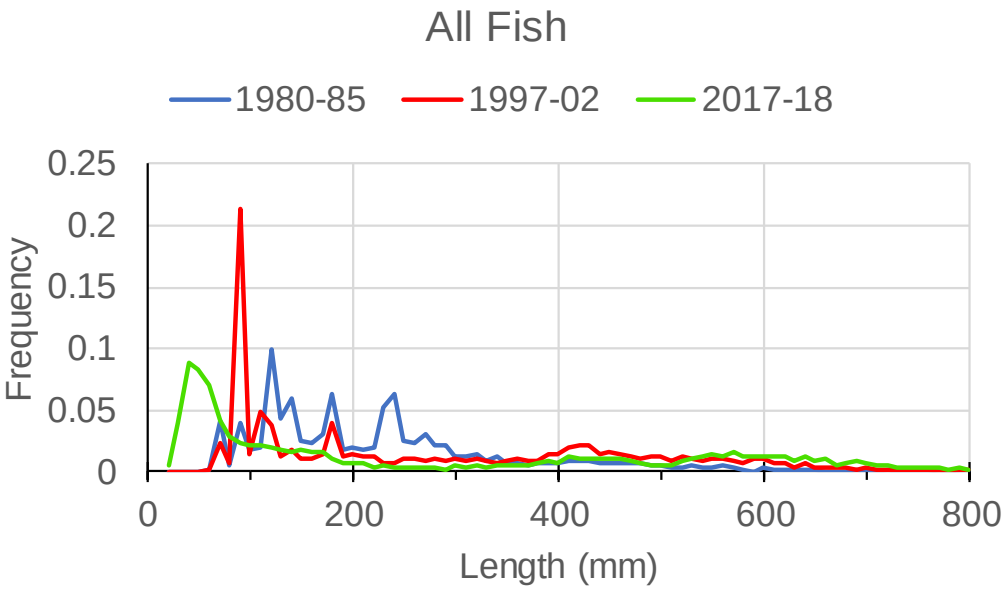
5.5.1 Introduction

Historical and current electrofishing data from corresponding sampling locations (Section 5.2.2) are available to determine whether any adverse trends in the fish assemblage over time exist. The available data were first evaluated for any methodological differences or biases that could affect the data comparison. The adverse effects, or appreciable harm, questions were then addressed using metrics including catch per unit effort (CPUE), biomass, diversity, community composition, and heat sensitive vs heat tolerant species.

5.5.2 Fish

When comparing ecological data collected over a period of nearly 40 years, it is important to assess whether the methodology may have changed in a way that could confound data interpretation. Although the electrofishing methodology was maintained the same in the 1980-1985, 1997-2002, and 2017-2018 surveys to the extent possible, the data suggested that different levels of attention to collecting small fishes occurred, particularly in 2017-2018. Electrofishing is a sampling method for collecting large fish that may be difficult to sample by other methods, and large fish, because they intercept a greater part of the electric field are more susceptible to being immobilized than are small fish. They are also more visible to the collectors and may be subject to a natural human bias to retrieve larger fish. For this reason, electrofishing data on small specimens may be less standardized than data for larger specimens (Reynolds 1984).

The length frequencies of the fish caught by electrofishing in the three surveys suggest differences in the degree of focus on collecting smaller fish (Figure 5-30 top). In the 1980-1985 surveys, relatively few fish less than 100 mm were collected. In contrast, the 1997-2002 surveys collected a large number of fish just less than 100 mm, and the 2017-2018 surveys collected a large number of fish 40-70 mm in length, with 40 percent of fish 100 mm or less (Table 5-10). Another signal that collection methods, with respect to the smaller fishes, is different is seen in the 16 species observed only in the ≤100 mm size class in the 2017-2018 sampling (plus red shiner which had only two individuals observed in the 1997-2002 survey). It is unlikely that these differences are solely due to actual differences in abundance or presence. In order to focus the analysis on fish that are actually the target of the electrofishing sampling effort, fish less than 100 mm in length were eliminated from the analysis.



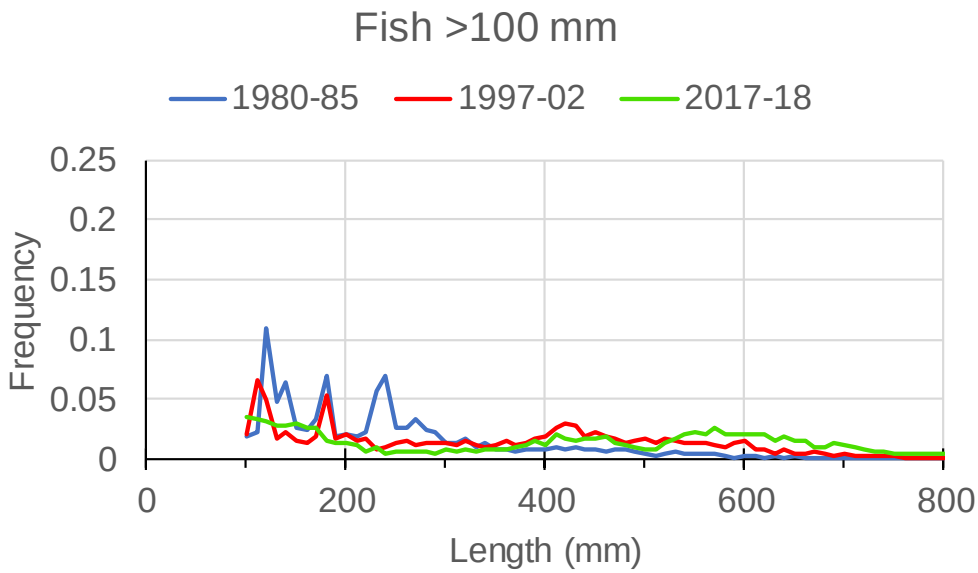


Figure 5-30 Length frequency of fish collected by electrofishing at the LEC in 1980-1985, 1997-2002, and 2017-2018. Top figure is all fish, bottom figure is subset to fish over 100 mm.

Table 5-10 Catch in electrofishing sampling in all seasons and zones combined at the LEC in 1980-1985, 1997-2002, and 2017-2018 of fish ≤100 mm and >100 mm. Highlighted cells indicate species collected only at lengths ≤100 mm and only in 2017-18 survey.

Common Name	1980-85		1997-02		2017-18		Total
	≤100	>100	≤100	>100	≤100	>100	
Gizzard shad	270	1593	975	1036	550	382	4806
Freshwater drum	17	258	7	188	29	418	917
River carpsucker	1	190	1	288	4	281	765
Common carp	0	120	0	473	0	149	742
Red shiner	0	0	2*	0	559	0	561
Blue catfish	0	54	0	133	8	364	559
Shortnose gar	0	121	0	131	3	224	479
Goldeye	4	156	0	103	31	116	410
Emerald shiner	0	0	0	0	408	0	408
Channel catfish	3	65	3	167	39	66	343
Longnose gar	0	40	0	41	1	227	309
Smallmouth buffalo	2	21	0	118	0	160	301
Flathead catfish	4	69	8	76	19	124	300
Silver carp	0	0	0	7	37	207	251
White bass	5	55	0	55	2	8	125
Channel shiner	0	0	0	0	107	0	107
Chestnut lamprey	0	47	0	8	0	2	57
Grass carp	0	1	0	8	0	43	52
Bluegill	5	5	2	4	17	14	47
Blue sucker	0	2	0	11	1	32	46
Bullhead minnow	0	0	0	0	42	0	42
Spotted bass	0	4	0	5	4	29	42
Striped bass x white bass	0	0	0	25	0	17	42
Bigmouth buffalo	0	9	0	15	0	16	40
Black buffalo	0	4	0	5	0	22	31
White crappie	0	18	1	1	0	6	26
Shovelnose sturgeon	0	2	0	1	0	20	23
Sand shiner	0	0	0	0	19	0	19
Brook silverside	0	0	15	0	2	0	17
Orangespotted sunfish	0	0	0	0	17	0	17
Mooneye	2	7	0	1	4	2	16
Shorthead redhorse	0	6	0	2	0	7	15
Skipjack herring	0	6	0	4	0	5	15
Bighead carp	0	0	0	8	0	6	14
Green sunfish	1	1	0	1	10	1	14
Quillback carpsucker	0	3	0	7	0	4	14

Common Name	1980-85		1997-02		2017-18		Total
	≤100	>100	≤100	>100	≤100	>100	
Black crappie	0	10	0	1	1	0	12
Sauger	0	7	0	2	0	3	12
Walleye	0	5	0	0	2	3	10
Largemouth bass	0	5	1	3	0	0	9
Golden redhorse	0	4	0	2	0	2	8
American eel	0	7	0	0	0	0	7
Shoal chub	0	0	0	0	7	0	7
Bluntnose minnow	0	0	0	0	6	0	6
Logperch	0	0	0	0	4	0	4
Longear sunfish	1	1	0	1	0	1	4
White sucker	0	1	0	3	0	0	4
Freckled madtom	0	0	0	0	3	0	3
Paddlefish	0	1	0	2	0	0	3
Smallmouth bass	0	3	0	0	0	0	3
Striped bass	0	2	0	1	0	0	3
Goldfish	0	0	0	0	1	1	2
Lake sturgeon	0	0	0	0	0	2	2
Suckermouth minnow	0	0	0	0	2	0	2
Central stoneroller	0	0	0	0	1	0	1
Fathead minnow	0	0	0	0	1	0	1
Largescale stoneroller	0	0	0	0	1	0	1
River shiner	0	0	0	0	1	0	1
Rock bass	0	1	0	0	0	0	1
Rosyface shiner	0	0	0	0	1	0	1
Sauger x Walleye	0	0	0	0	0	1	1
Silver chub	0	0	0	0	1	0	1
Silver lamprey	0	0	0	0	0	1	1
Silver redhorse	0	0	0	0	0	1	1
Spotted sucker	0	0	0	0	0	1	1
Total Individuals	315	2,904	1,015	2,937	1,945	2,968	12,084
Total Species	12	38	10	37	37	39	65
% ≤100 mm	10%		26%		40%		

* Highlighted even though 2 individuals were collected in 1997-2002 sampling.

5.5.2.1 Overall Abundance

Temporal trends in fish abundance downstream of the LEC thermal discharge must be considered in context of the surrounding area. Summertime (July-Sep) numerical abundance in the Upstream Reference zone in the three surveys shows a declining trend in CPUE over time from 24 fish/20 min, to 19 fish/20 min, to 9 fish/20 min (Figure 5-31). In terms of fish biomass, the 1997-2002 surveys had the highest biomass (14 kg/20 min), with (12 kg/20 min) in the 1980-1985 survey and and later (8 kg/20 min) in the 2017-2018 survey.

In the area immediately downstream of the LEC discharge (Site 4 in early surveys and station 3-CXLD in the 2017-2018), a similar decline in CPUE was observed (Figure 5-32), matching the pattern seen upstream of the discharge. CPUE varied from 23 fish/20 min, to 11 fish/20 min, to 8 fish/20 min in the latest survey. Fish biomass in the three surveys varied from approximately 10 kg/20 min in 1980-1985, to 5 kg/20 min in 1997-2002, to 9 kg/20 min in 2017-2018.

Fish CPUE and biomass data from the Thermally Exposed zone during the summertime exhibit a similar temporal pattern to that from the Upstream Reference zone demonstrating that observed decreases in abundance over time are not the result of exposure to the LEC thermal discharge.

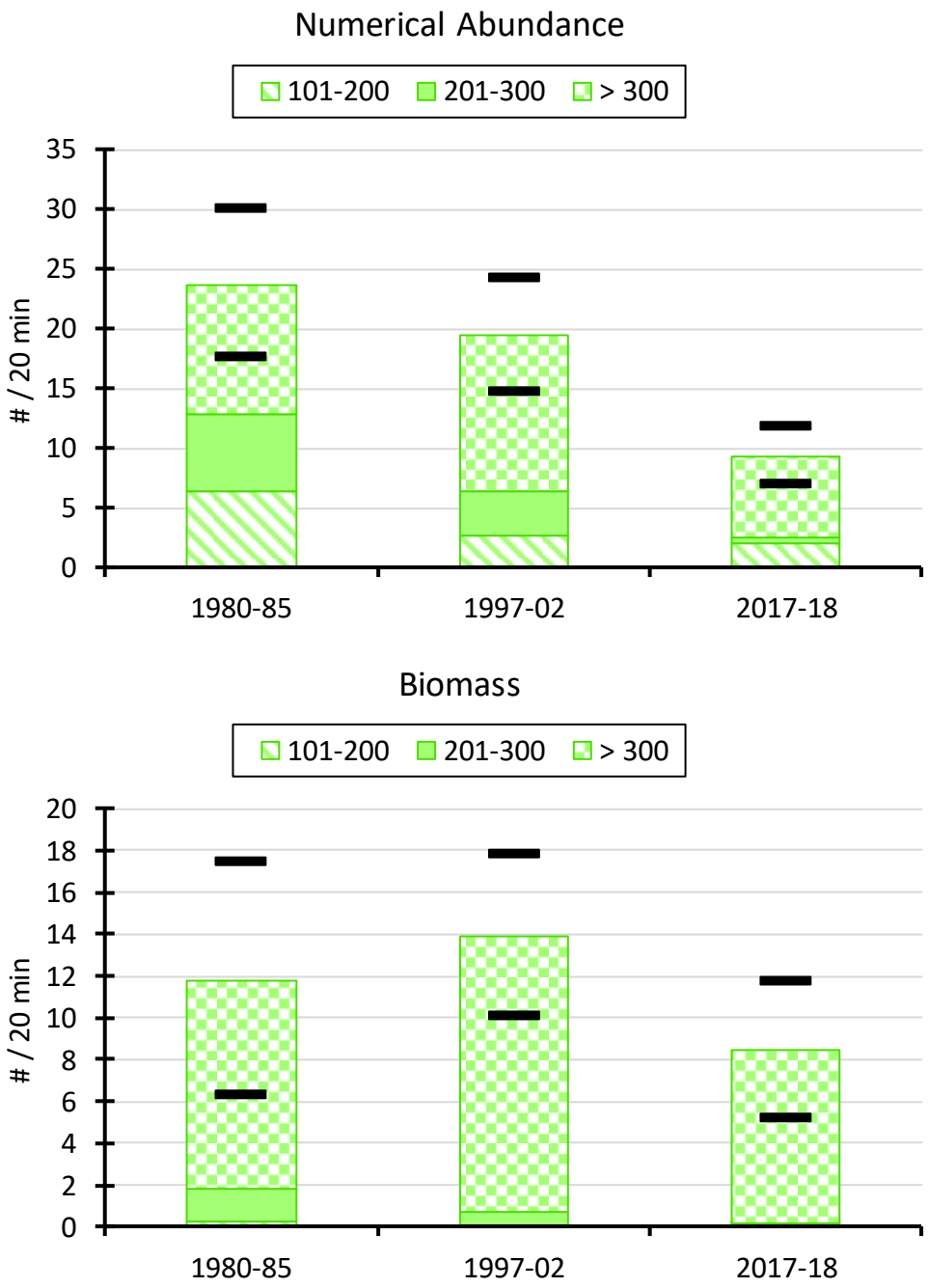


Figure 5-31 Catch per 20 minutes of electrofishing sampling at the LEC in 1980-1985 and 1997-2002 at Site1, and 2017-2018 in Upstream Reference zone (OLD habitat in 2017-2018), in summer (Jul-Sep). Black horizontal bars are +/- one standard error from the total. Top figure is based on number of fish in each length class, bottom figure is based on biomass of fish in each length class (101-200 mm, 201-300 mm, and >300 mm).

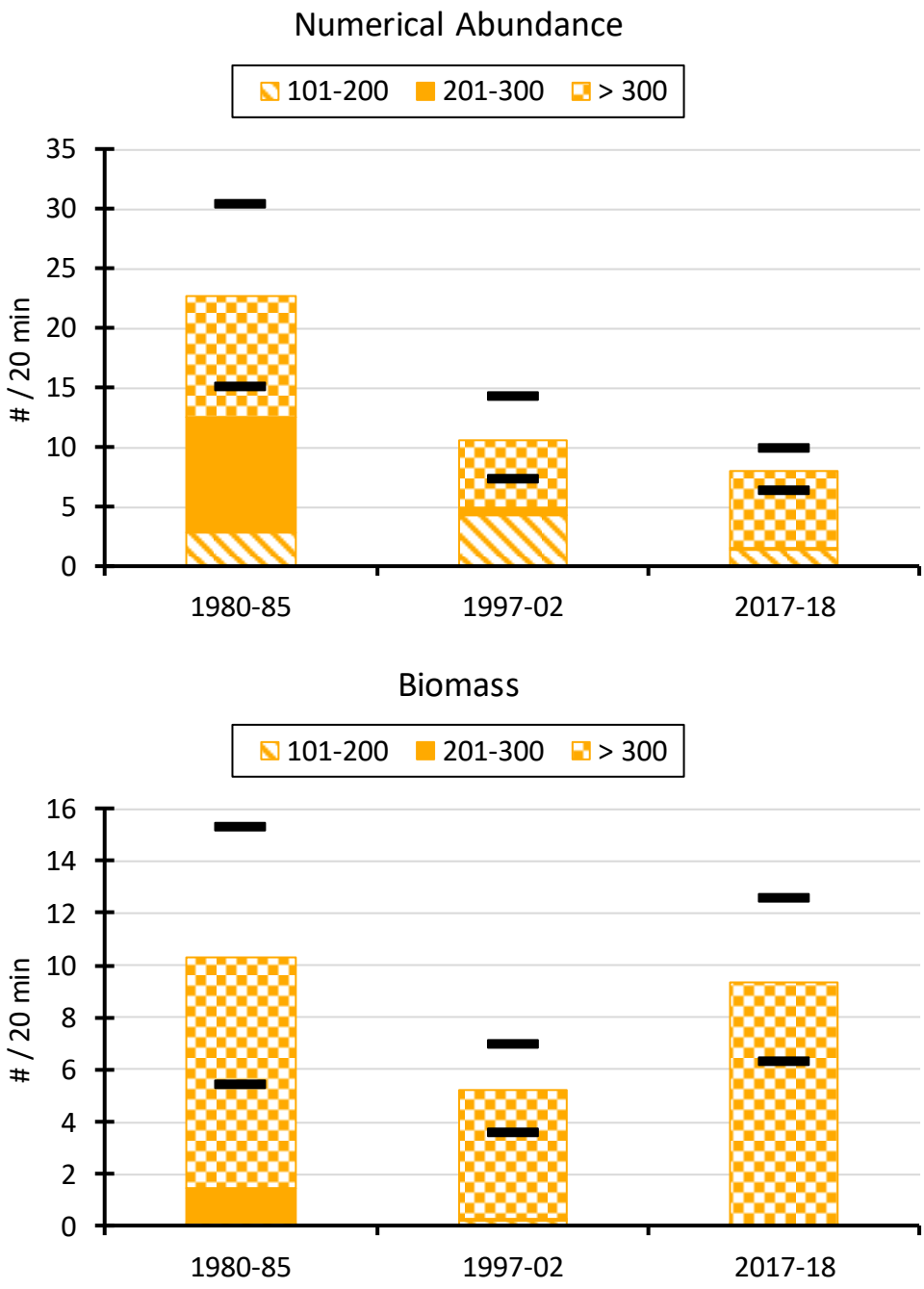


Figure 5-32 Catch per 20 minutes of electrofishing sampling at the LEC in 1980-1985 and 1997-2002 at Site1, and 2017-2018 in Thermally Exposed zone (CXLD habitat in 2017-2018), in summer (Jul-Sep). Black horizontal bars are +/- one standard error from the total. Top figure is based on number of fish in each length class, bottom figure is based on biomass of fish in each length class (101-200 mm, 201-300 mm, and >300 mm).

5.5.2.2 Community Characteristics

Diversity

For upstream reference areas (Site 1 in 1980-1985 and 1997-2002, and OLD habitat in the Upstream Reference zone in 2017-2018, summer) diversity profiles based on Hill numbers (Hill 1973) indicate very similar diversity in the earliest and latest sampling efforts, with reduced diversity in the intermediate survey (Figure 5-33). Species richness (number of species at 0 sensitivity to abundance) was slightly higher, 18 to 14, in the earliest sampling, but as sensitivity to abundance increased ($q > 0.5$), the two surveys were within 1 species. The last survey exhibited a diversity value of 10 equally abundant species (at $q = 1$), while the earliest survey had an equivalent diversity of 9 species. Effective species at $q = 2$ was approximately 8 and 7.5 respectively, and at $q = 3$ approximately 7 and 6.5. Diversity based on biomass exhibited qualitatively the same pattern as numerical diversity, however the number of effective species was slightly lower.

In the Thermally Exposed zone (Site 4 in 1980-1985 and 1997-2002, and CXLD habitat in 2017-2018, summer), species richness (number of species at 0 sensitivity to abundance) was higher, 17 to 13, in the earliest sampling (Figure 5-314). At higher sensitivity to abundance ($q > 0.5$), the most recent survey data had the highest diversity of the three surveys, and the 1997-2002 survey the lowest. Diversity based on biomass exhibited qualitatively the same pattern as numerical diversity, however the number of effective species was slightly lower.

The temporal trend in diversity in both the Upstream Reference and Thermally Exposed zones is similar indicating that exposure to the LEC discharge over time has not caused a decrease in diversity.

Dominance

The composition of the fish community in the Upstream Reference zone indicated domination by fishes classified as “rough” fish (see Table 5-6 for classification) (i.e. species that are not targeted by sport or commercial fishermen, and that as adults are too large for most piscivores to consume) in all three survey periods (Figure 5-35). The common groups in the rough fish category were gars, carp/goldfish, buffalo suckers (subfamily Ictiobinae), gizzard shad, and freshwater drum. Catfishes comprised the only common game fish, and there were few panfish. This community composition is not a representation of the entire fish community but, instead, reflects only larger fishes collected by the electrofishing survey methods. The composition changed little across the three surveys, except that rough fish were relatively more numerically abundant during the 1997-2002 survey (85 percent) than in the earlier (74 percent) or later (70 percent) surveys. Rough fish dominated the biomass in all surveys, ranging from 78 to 84 percent. Game fish were the second most dominant category.

The composition of the fish community in the Thermally Exposed zone, CXLD habitat, was also dominated by rough fish in the first and last surveys, but they generally were not as dominant ranging only from 34 to 72 percent of numerical abundance and 40 to 66 percent of biomass (Figure 5-36). Game/Commercial fish (mostly large catfishes and buffalos) were the other common category, with only small contributions from other categories. In the 1980-1985 and 1997-2002 surveys, the Game/Commercial category was the largest component of biomass (56 and 60 percent) but were only 34 percent of biomass in the 2017-2018 survey.

Based on the numerical diversity profiles and composition of the fish community in electrofishing samples from the Upstream Reference zones and in habitat CXLD in the Thermally Exposed zone in the summer, dominance of the different groups does not appear to have been adversely affected as a result of the LEC thermal discharge.

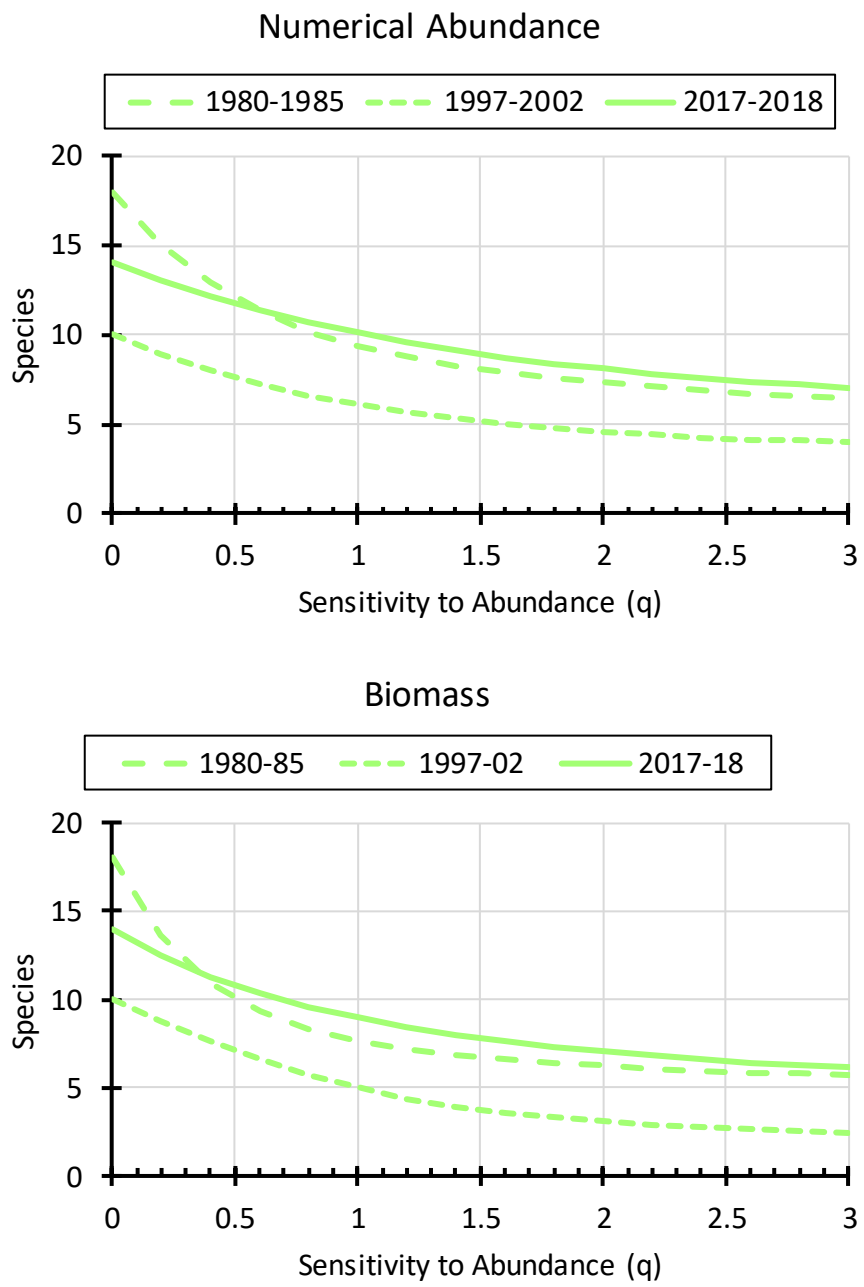
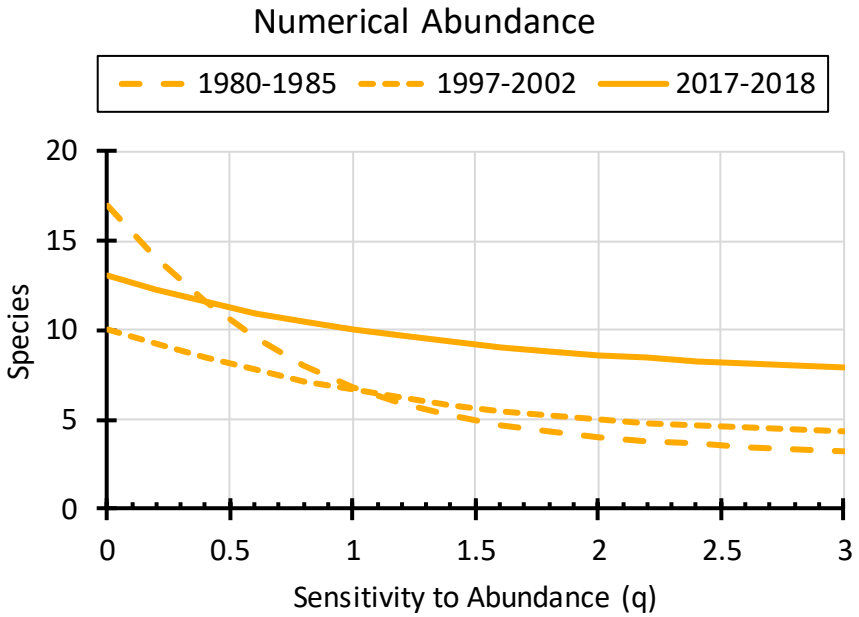


Figure 5-33 Diversity profiles based on Hill numbers for electrofishing sampling at the LEC in 1980-1985, 1997-2002, and 2017-2018 in the Upstream Reference zone (OLD habitat in 2017-2018), in summer (Jul-Sep). Top figure is based on number of fish of each species, bottom figure is based on biomass of each species.



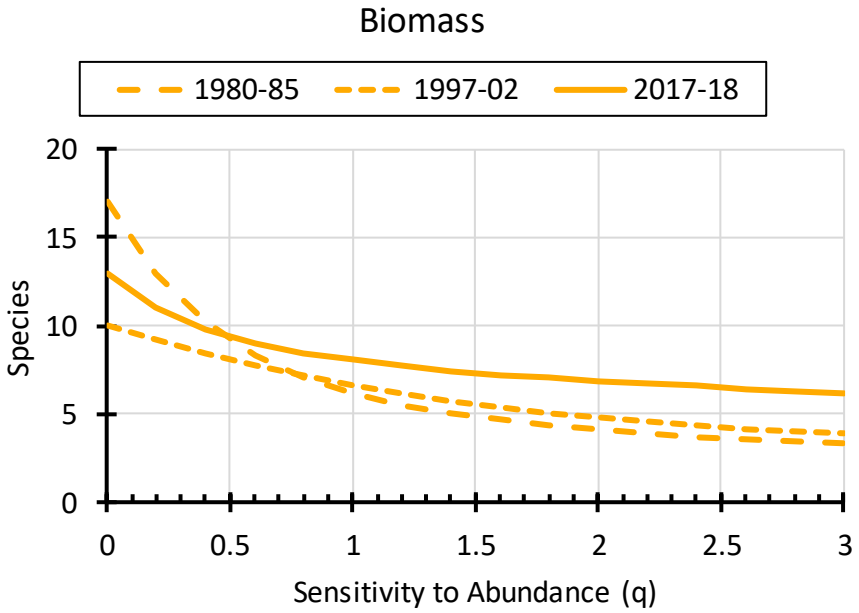


Figure 5-34 Diversity profiles based on Hill numbers for electrofishing sampling at the LEC in 1980-1985, 1997-2002, and 2017-2018 in the Thermally Exposed zone (CXLD habitat in 2017-2018), in summer (Jul-Sep). Top figure is based on number of fish of each species, bottom figure is based on biomass of each species.

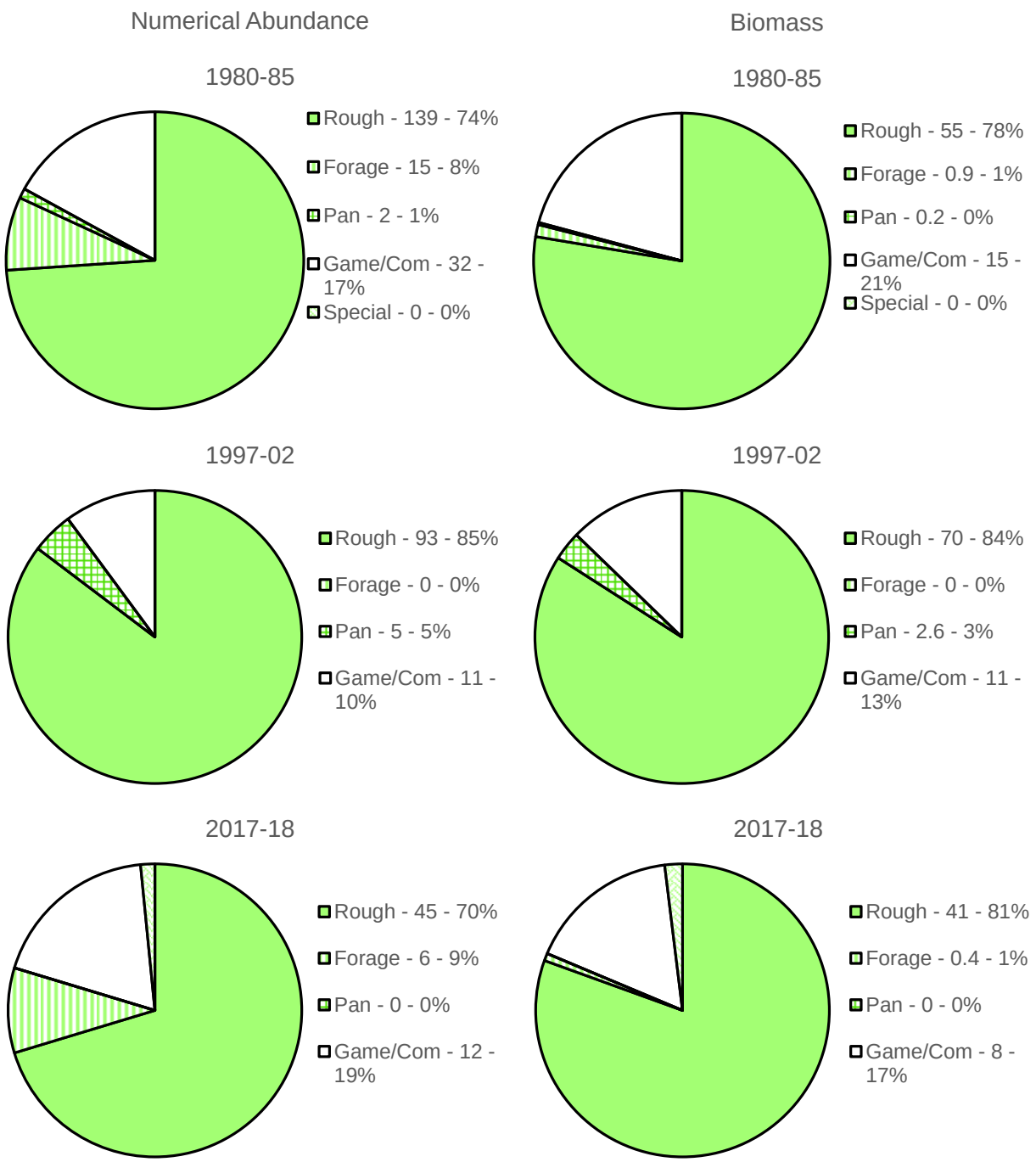


Figure 5-35 Fish community composition for electrofishing sampling at the LEC in 1980-1985, 1997-2002, and 2017-2018 in Upstream Reference zone (OLD habitat in 2017-2018), in summer (Jul-Sep). Left side of figure is based on number of fish of each species, right figure is based on biomass of each species.

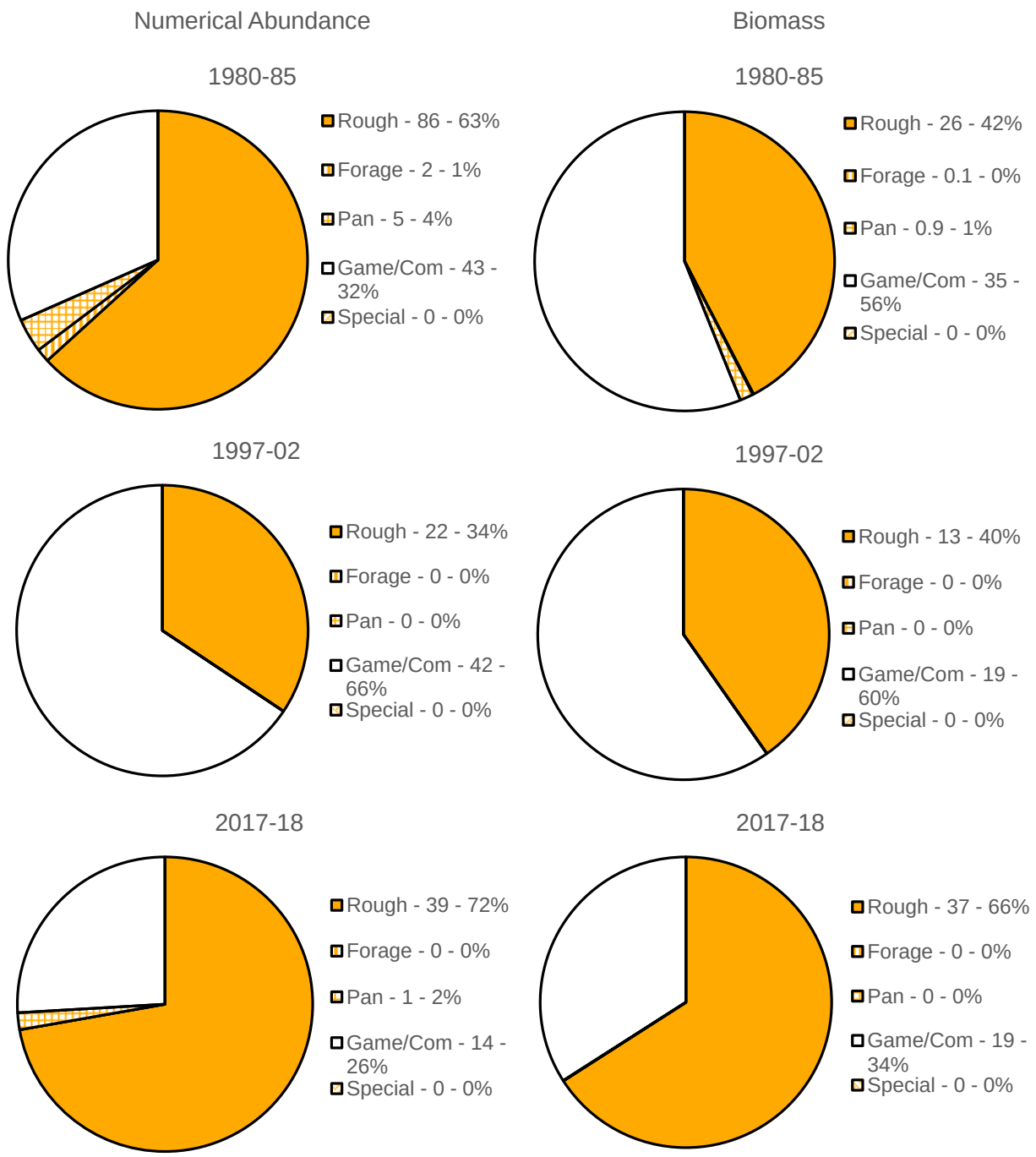


Figure 5-36 Fish community composition for electrofishing sampling at the LEC in 1980-1985, 1997-2002, and 2017-2018 in Thermally Exposed zone (CXLD habitat in 2017-2018), in summer (Jul-Sep). Left side of figure is based on number of fish of each species, right figure is based on biomass of each species.

Dominance by Heat Tolerant Species

A sign that the LEC's thermal discharge is having an adverse effect would be if heat sensitive species would disappear or become less important members of the fish community, while heat tolerant species become more common. For purposes of this analysis, heat sensitive species are

sauger, walleye, and their hybrid, mooneye, goldeye, and white crappie. Heat tolerant species are bighead carp, bigmouth buffalo, channel catfish, emerald shiner, flathead catfish, gizzard shad, longnose gar, river carpsucker, shortnose gar, silver carp, smallmouth buffalo (Appendix B Section B.2). As with the other questions, it is important to understand how this metric may be changing in the ecosystem independent of the thermal discharge.

In the Upstream Reference zone, the community was dominated by heat tolerant species comprising 58 percent to 70 percent of fish abundance and 31 percent to 74 percent of the biomass (Figure 5-37). There was no apparent temporal trend based on numerical abundance, but the fraction of thermally tolerant based on biomass declined from the first survey to the last.

Heat sensitive species comprised 0 percent to 8 percent by numbers, and 0 percent to 2 percent by weight of the fish collected, without any apparent temporal trend.

In the Thermally Exposed zone, the prevalence of heat tolerant species was higher, ranging from 68 percent to 91 percent by numbers, and 37 percent to 78 percent by biomass, without any evident temporal trend (Figure 5-38). Highest prevalence of tolerant species occurred in the 1997-2002 surveys. Heat sensitive species were very scarce in this zone in the summer, with maximum observed prevalence of 2 percent and there is no temporal increase in heat tolerant species, and no observed temporal decline in heat sensitive species. This analysis demonstrates that the LEC's thermal discharge has not caused a change in the relative abundance of heat tolerant or heat sensitive species.

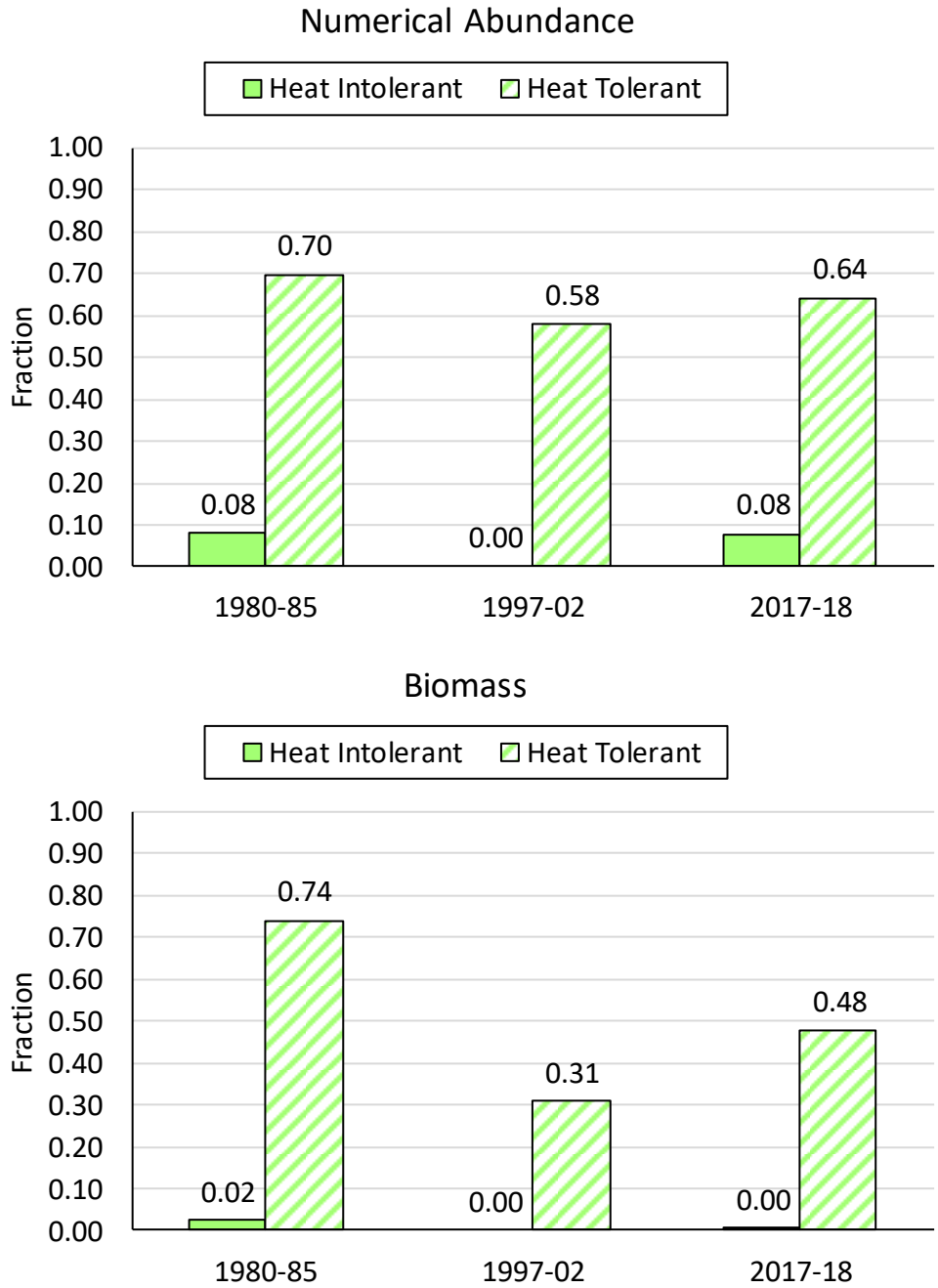


Figure 5-37 Fraction of heat-tolerant and heat-intolerant species for electrofishing sampling at the LEC in 1980-1985, 1997-2002, and 2017-2018 in Upstream Reference zone (OLD habitat in 2017-2018), in summer (Jul-Sep). Top figure is based on numerical abundance, bottom figure is based on biomass.

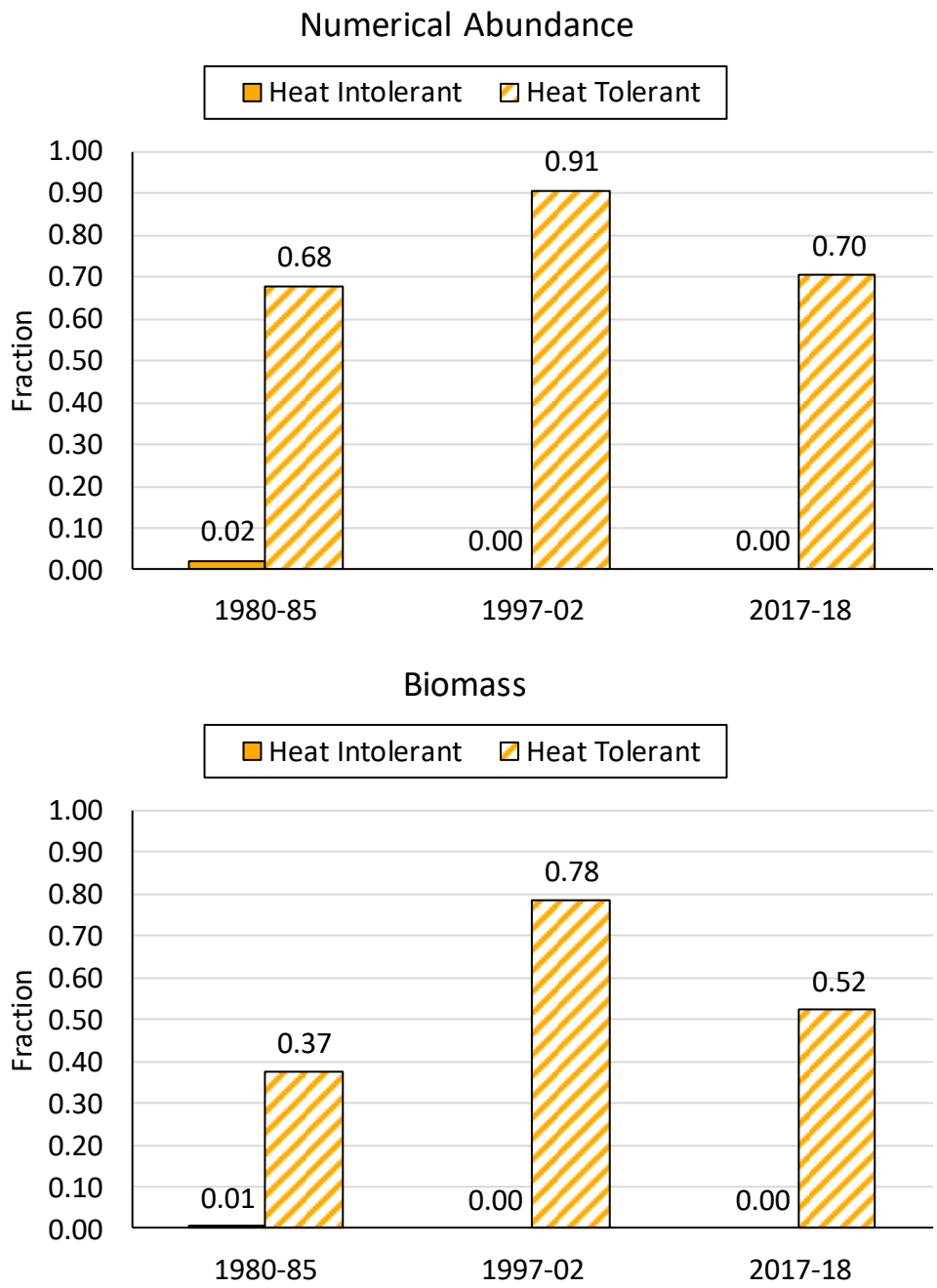


Figure 5-38 Fraction of heat-tolerant and heat-intolerant species for electrofishing sampling at the LEC in 1980-1985, 1997-2002 at Site 4, and 2017-2018 in the Thermally Exposed zone (CXLD habitat in 2017-2018), in summer (Jul-Sep). Top figure is based on numerical abundance, bottom figure is based on biomass.

5.5.2.3 Overall Weight of Evidence

In order to assess the overall weight of evidence in an objective quantitative manner, a "standardized difference", essentially a t-statistic, was calculated for each ecological metric for each combination of season and sampling zone comparing changes between the 1980-1985

survey and the 2017-2018 survey. Each standardized difference was formulated so that it would have a negative value if consistent with harm, and a positive value if inconsistent.

$$Difference = X \frac{V_{2017-18} - V_{1980-85}}{\sqrt{se(V_{2017-18})^2 + se(V_{1980-85})^2}}$$

where

X = multiplier set to -1 or +1 so that the difference is negative if the change direction is consistent with harm

V = value of the metric

se(V) = standard error of the metric

In a case where there is no temporal change between surveys, these standardized differences would be expected to have a distribution centered at 0, with approximately equal proportions positive and negative. If there were prior appreciable harm due to the thermal discharge, the distribution for the Thermally Exposed zone would be shifted toward negative values, in comparison to the distribution for the Upstream Reference zone.

Only metrics which had a directional (better vs worse) component were used. Metrics used were:

Metric	Basis	Directional
Abundance	Numbers	High better than low
Abundance	Biomass	High better than low
Diversity ^{0}D (Species Richness)	Numbers	High better than low
Diversity ^{1}D (transform of H')	Numbers	High better than low
Diversity ^{2}D (Inverse Gini-Simpson)	Numbers	High better than low
Diversity ^{3}D (very abundant species)	Numbers	High better than low
Fraction Non-Rough	Numbers	High better than low
Fraction Non-Rough	Biomass	High better than low
Fraction Heat Intolerant	Numbers	High better than low
Fraction Heat Intolerant	Biomass	High better than low
Fraction Heat Tolerant	Numbers	Low better than high
Fraction Heat Tolerant	Biomass	Low better than high

For the Upstream Reference zone, the distribution of standardized differences had a mean of 1.59, standard error of 0.45, and median of 0.93 (Figure 5-39 top). Differences based on abundance metrics appeared to be more frequently negative, while those based on diversity and composition were more frequently positive. As a whole, the differences suggest an improvement of the fish community between 1980-85 and 2017-18.

The distribution of differences in the Thermally Exposed zone had a mean of 1.12, standard error of 0.47, and median of 0.56 (Figure 5-39 bottom). As in the Upstream Reference zone, abundance metrics were generally negative while diversity and composition metrics were usually positive.

The temporal trend analysis indicates that the fish community in the Thermally Exposed zone changed in ways similar to those in the Upstream Reference zone indicating no adverse effects from exposure to the LEC thermal discharge over time. A Kolmogorov-Smirnov test that the two distributions of standardized differences were different was not significant (KS = 0.087 p = 0.490).

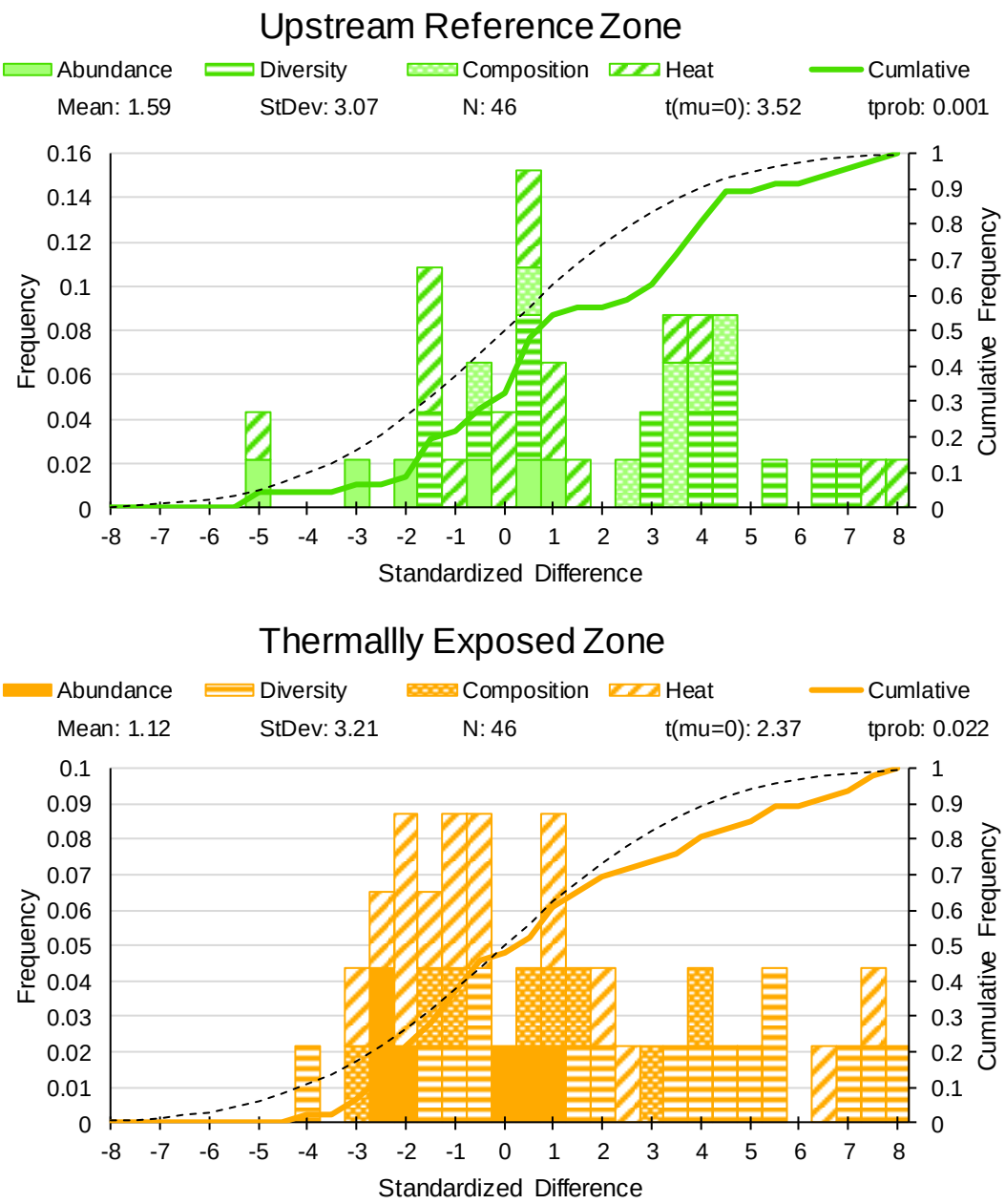


Figure 5-39 Standardized differences of ecological metrics between 1980-1985 and 2017-2018 for the Upstream reference zone (top) and Thermally Exposed zone (bottom) based on electrofishing data. Dashed line indicates cumulative normal distribution with mean = 0.

6. PREDICTIVE ASSESSMENT

A "Predictive Assessment" as part of a § 316(a) Demonstration evaluates potential effects of a thermal discharge using characteristics of the thermal plume, together with reported effects of thermal exposures on the aquatic organisms of interest. In the Guidance Manual (USEPA 1974, 1977), this type of approach falls under the category of a Type II Demonstration. In the overall process of evaluating the BIC protection, a predictive assessment serves as a complement to a "No Prior Appreciable Harm" assessment that was the focus of the previous section in that it allows consideration of:

- Thermal discharge conditions not frequently encountered at the facility;
- Biological functions not directly observed in the field study; and,
- Species not collected in sufficient numbers to permit a retrospective assessment of effects (e.g., rare, threatened or endangered species).

A predictive assessment is typically conducted in three steps:

1. Predicting the likely temperature exposures resulting from the facility's thermal discharge;
2. Selecting RIS that best reflect the biotic components of the aquatic community not determined to be low potential impact (Section 4); and,
3. Determining the potential effects of the predicted thermal exposures to each RIS.

Each of these three steps is discussed with specific reference to the LEC thermal discharge in more detail below.

6.1 THERMAL EXPOSURES FROM LEC DISCHARGE

As noted in Section 2, the LEC thermal discharge has not violated the NPDES permit limit for temperature (TDP $\leq$ 0.95) since this limit was adopted in 2017. Further, retrospective calculation of daily TDP over the 17-year period (2002 – 2018) revealed that the TDP was less than 0.95 more than 99 percent of the time. Hence, it is reasonable to presume that the Designated Uses of the LMOR in the vicinity of the LEC (including Livestock & Wildlife and Warm Water Habitat) are being protected.

6.1.1 Modeling of the LEC Thermal Plume

The focus of this predictive assessment is on the relatively rare events (<1 percent of the time) when the TDP limit is greater than 0.95 necessitating this variance request. The potential thermal exposures during these rare events were assessed using a three-dimensional hydrodynamic model (FLOW-3D) of the LMOR in the vicinity of the LEC (Flow Science 2016). FLOW-3D belongs to a family of models known as Computational Fluid Dynamics (CFD) Models. The system to be simulated posed challenges in that it was necessary to address both the nearfield jet-induced mixing of the discharge in the river, as well as the far-field ambient mixing and heat transport that occurs downstream in the river. CFD represents the state of the art in hydrodynamic simulation.

Application of FLOW-3D to the LMOR involved construction of a computational mesh or grid, which is effectively a numerical description of the actual physical system. Once constructed, the model enables the user to simulate the three-dimensional mixing of the LEC thermal discharge in the Missouri River for particular combinations of flow and temperature in both the river and the discharge. Thus, the inputs to any individual simulation include the LMOR flow rate and temperature as well as the LEC discharge rate and temperature, and the output from the model is the three-dimensional temperature distribution in the river throughout the model domain for a defined distance downstream of the LEC discharge.

A model domain extending from approximately 0.75 river miles upstream of the facility discharge to a point 3.5 river miles downstream of the discharge was selected. Based on evaluation of temperature monitoring data in the river and subsequent model simulations, the spatial extent chosen was more than sufficient to evaluate compliance with the water quality criteria for temperature. In order to examine conditions further downstream in the river, some simulations used a model domain extending 7.65 river miles downstream.

FLOW-3D relies on a detailed description of the physical processes and physical data for the system being simulated. There are no model coefficients that must be calibrated to make the model "fit the data." Other simulation models systematically rely on fine-tuning of model coefficient values to minimize the difference between observed and predicted results. Consequently, there is no need in this instance for a calibration step. FLOW-3D, once constructed for the system under study, can be used to simulate the system, and the FLOW-3D output can be directly compared to known system data as a validation of its ability to simulate the system. Six independent temperature data collection surveys conducted in the river over a 14-year period (years 2003 to 2016) and a wide range of flow and temperature conditions in both the river and the discharge were used to validate the model. Rigorous statistical methods to compare model output against actual data found excellent agreement between the model and the data, demonstrating the model's validity to simulate this system. More information on this model and its application to LEC's thermal discharge are provided in Kleinfelder (2016, 2017a, and 2017b).

The validated model for the LEC's thermal plume provides a valuable tool that can assess system response for any combination of the key system inputs, i.e., flow and temperature in both the river and in the discharge. This model was initially used to develop the TDP-based thermal limit adopted in the LEC's NPDES permit in 2017 as discussed in Section 2.4 and 2.5. This thermal limit assures compliance with $MWQS_t$ at the edge of the allowable mixing zone.

Beyond its use to develop the TDP limit, this validated model provides important information on thermal exposures in the river during actual historic events to be used as part of the predictive biothermal assessment. Specifically, this model provides:

- Estimates of the longitudinal, horizontal, and vertical distribution of elevated water temperatures downstream of the LEC's discharge; and,
- Temperature exposure profiles for organisms that might drift through the thermal plume using FLOW-3D's ability to track flow path for individual particles.

Model results using data from two days reflecting the most extreme conditions over the 17-year data record during the most biologically active periods of the year were selected for this assessment. Actual river and discharge flows and temperatures from June 22, 2006 ("June Model') were used in the model reflecting the most extreme conditions during the spring spawning and nursery period. Similarly, actual river and discharge flows and temperatures from July 21, 2006 ("July Model") were used reflecting the most extreme conditions during the high temperature period in summer. It is helpful to note that the TDP value was calculated to be less than 0.95 on June 22, 2006, while the calculated TDP value on July 21, 2006 was 2.65, the highest daily value calculated across the 17-year data record. These individual dates had the most extreme conditions across the more than 6,000 days of available data and occurred during an exceedingly hot and dry period in the Missouri River valley.

6.1.2 Spatial Distribution in Temperatures

In both cases, the model demonstrated a rapid mixing of the heated effluent with the much larger volume of water coming from upstream (typically 40 to 50 times discharge flow), yielding a rapid decline in temperatures following initial dilution. The resulting plume hugged the south shore immediately downstream of the discharge with the plume extending only part way across the

LMOR (Figure 6-1 and Figure 6-2). For the June Model, temperatures above 90°F were limited to areas along the south shore of the river within 1 mile of the discharge. For the July Model, temperatures above 90°F were limited to areas in the southern half of the river within about 5.5 miles of the discharge. Turbulence within the LMOR results in a high degree of mixing vertically, although plume temperatures and width were slightly lower near the bottom close to the point of discharge owing to plume buoyancy (Figure 6-3 and Figure 6-4).

Analysis of the temperature distributions in areas downstream of the LEC's discharge revealed that the volumes and surface areas of the LMOR encompassing specific temperatures show almost identical patterns on both dates modeled. Based on the June Model, selected to reflect worst-case spawning and nursery conditions, more than 97 percent of the volume and area within the model boundaries experienced temperatures less than or equal to 90°F while less than 1 percent experienced temperatures in excess of 100°F (Figure 6-5 top). Based on the July Model, selected to reflect worst-case summer conditions, temperatures were naturally higher (ambient, background temperature was 88.83°F) with slightly more than 50 percent of the volume and area of the expanded model boundaries experienced temperatures less than or equal to 90°F, but still less than 1 percent experienced temperatures in excess of 100°F (Figure 6-5 bottom).

6.1.3 Exposures of Drifting Organisms

Organisms with no or limited swimming ability can be carried by the river currents into the vicinity of the LEC and potentially exposed to elevated temperatures from the LEC's discharge. Organisms that fall into this category include eggs and larvae of fish that use the river's currents as a natural dispersal mechanism. To address the exposures to elevated temperatures from the LEC's thermal plume for these organisms, the Flow-3D model was used to track individual particles as they transit the section of the LMOR potentially influenced by the thermal discharge. In this modeling effort, hypothetical neutrally buoyant particles were released every 45 feet across the LMOR and at four depths from the bottom to the surface at a point just upstream of the LEC's point of discharge. The model software then tracked each of these particles as they were transported downstream by river currents and calculated the temperatures to which each was exposed every 10 seconds after release. These particles should reflect the transport of passive organisms through the area potentially exposed to the LEC's thermal plume.

In the June Model, the background temperature was 83.58°F and only 13 of the 56 particles released (23 percent) were exposed to temperatures in excess of the $MWQS_t$ for temperature (Figure 6-6). In the July Model, the background temperature was higher at 88.88°F but only 9 of the 51 particles released (<18 percent) were exposed to temperatures in excess of the $MWQS_t$ for temperature. In both models, exposed particles were restricted to those released in areas near the southern shore of the river.

Tracking the elevated temperatures for individual particles through time can provides information on the magnitude and duration of potential exposures experienced by passively drifting organisms on both modeled dates (Figure 6-7). First, the particles released across the cross-section of the river experienced temperature increases of only 2 degrees F or less. Second, only 10 percent of the particles experienced temperature increases of 8 degrees F or more. Finally, maximum temperature elevations rapidly decreased by more than 70 percent within 10 minutes of discharge. This rapid temperature decline can be attributed to turbulence and the high volume of river flows compared to plant discharge flows within the LMOR leading to rapid mixing. This rapid mixing helps to limit exposure of passively transported organisms to elevated temperatures from the LEC's thermal discharge.

Figure 6-1 Spatial distributions of elevated temperatures from LEC's thermal discharge based on modeling of conditions from June 22, 2006.

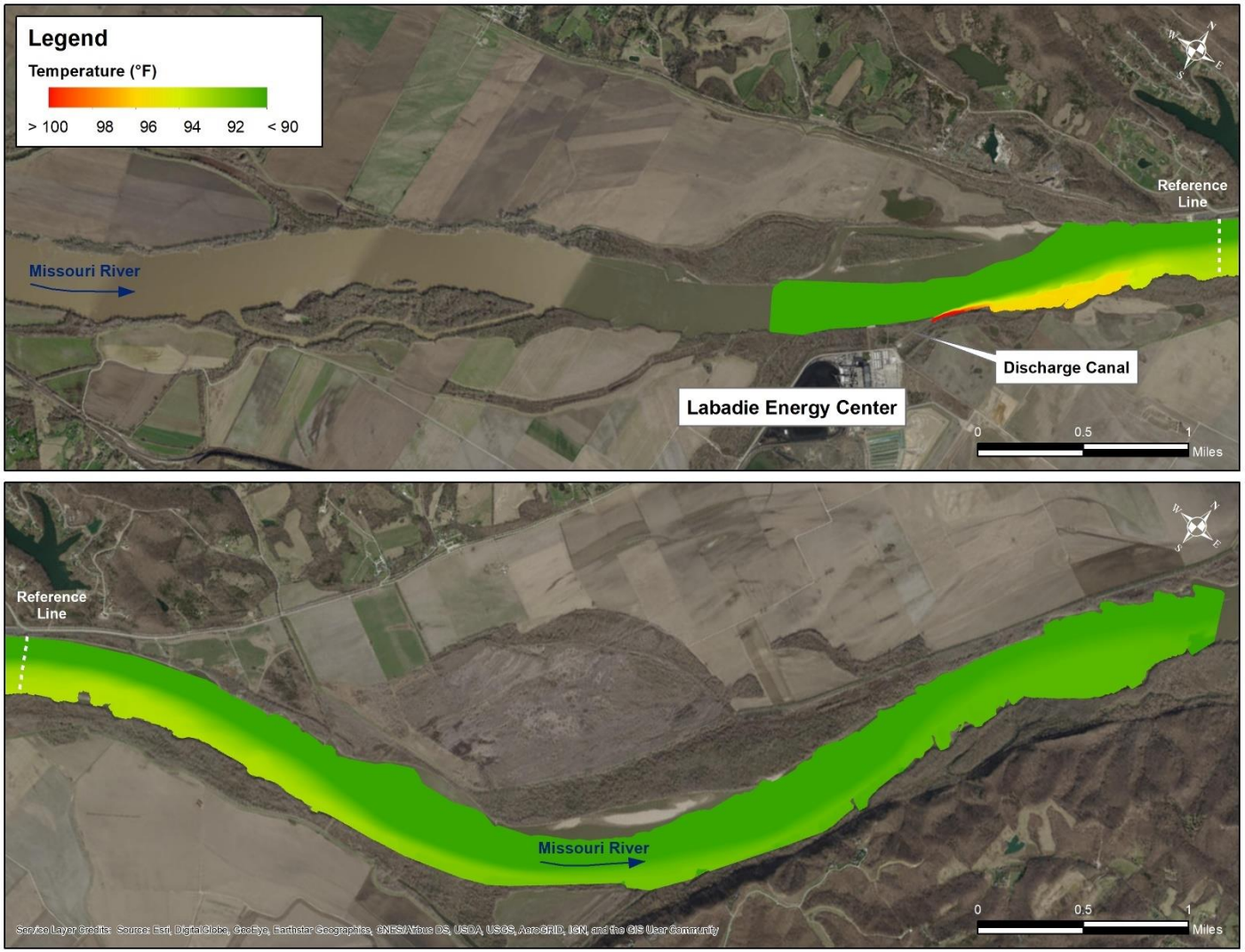


Figure 6-2 Spatial distributions of elevated temperatures from LEC's thermal discharge based on modeling of conditions from July 21, 2006.

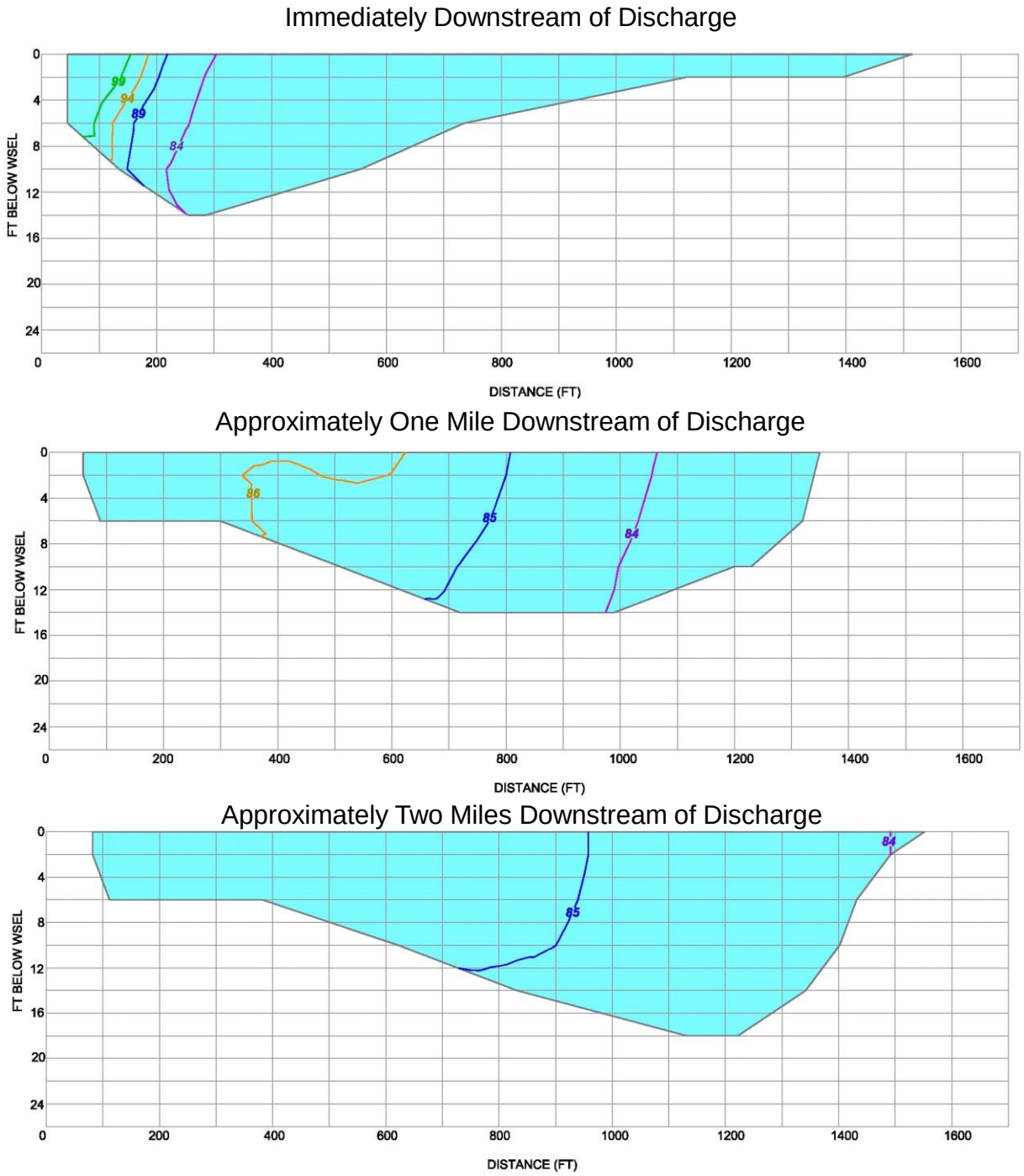


Figure 6-3 Distribution of elevated temperatures from LEC's thermal discharge in cross-section at three separate locations in the LMOR based on modeling of conditions from June 22, 2006.

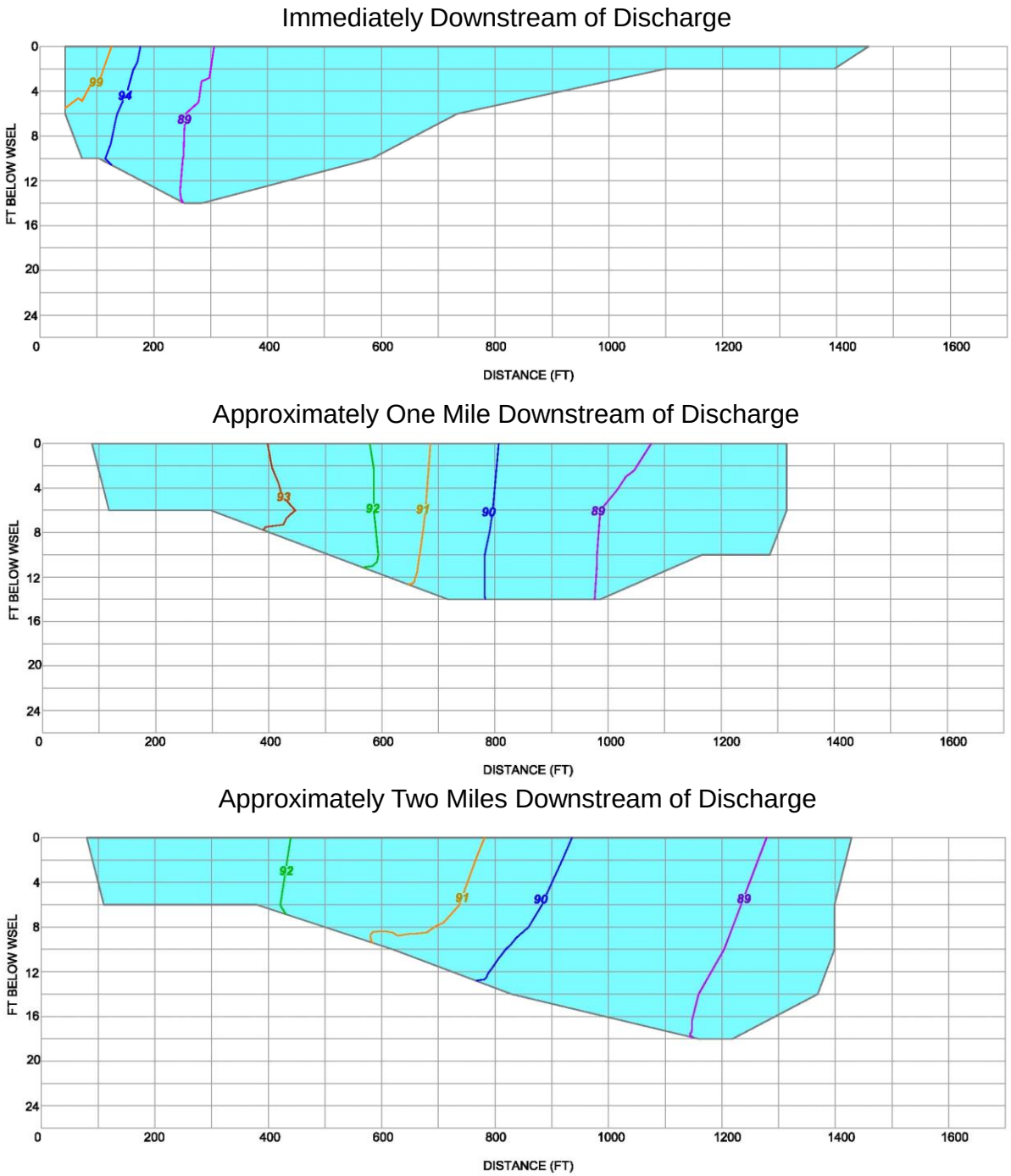


Figure 6-4 Distribution of elevated temperatures from LEC's thermal discharge in cross-section at three separate locations in the LMOR based on modeling of conditions from July 21, 2006.

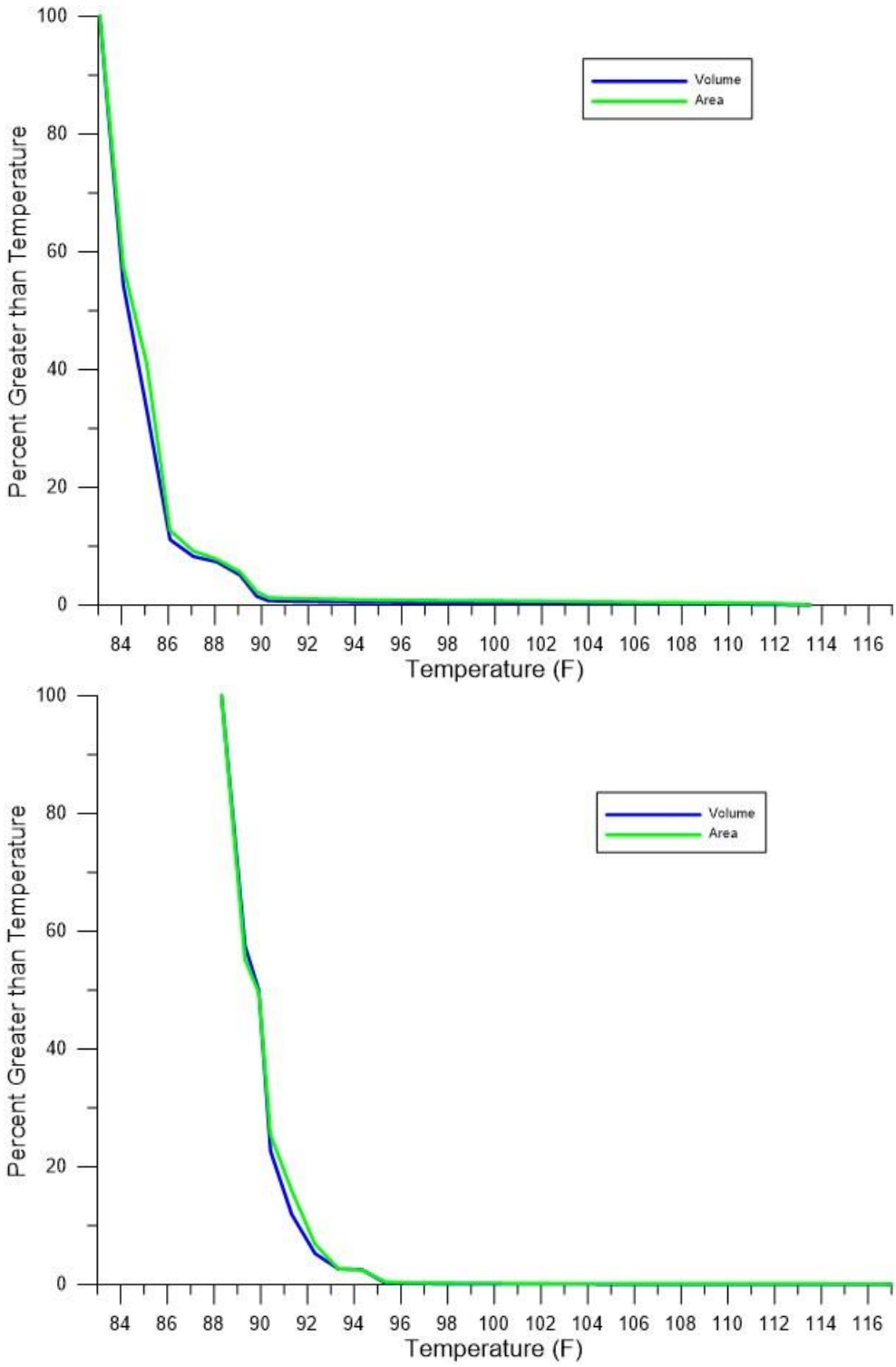


Figure 6-5 Percent of areas and volumes greater than specified temperatures based on modeling of LEC's thermal plume from June 22, 2006 (top panel) and July 21, 2006 (bottom panel).

June 2006 Model

Depth (ft).	Distance Across Model Grid																			
	533[1]	578	623	668	713	758	803	848	893	938	983	1028	1,073	1,118	1,163	1,208	1,253	1,298	1,343	1,388
0	7.3	7.3	9.3	5.7	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	166.8	12.8	11.5	16.5	40.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9		8.7	16.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0								
13				9.5	0.0	0.0	0.0	0.0												

July 2006 Model

Depth (ft).	Distance Across Model Grid																			
	533[1]	578	623	668	713	758	803	848	893	938	983	1,028	1,073	1,118	1,163	1,208	1,253	1,298	1,343	1,388
0	4.2	4.7	11.8	3.8	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	31.8	317.8	48.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8		7.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0									
12					0.0															

Figure 6-6 Number of minutes each particle is exposed to temperatures exceeding MO WQS from LEC's thermal discharge based on modeled conditions on June 22, 2006 and July 21, 2006.

[1] Approximate location of south shore of the LMOR.

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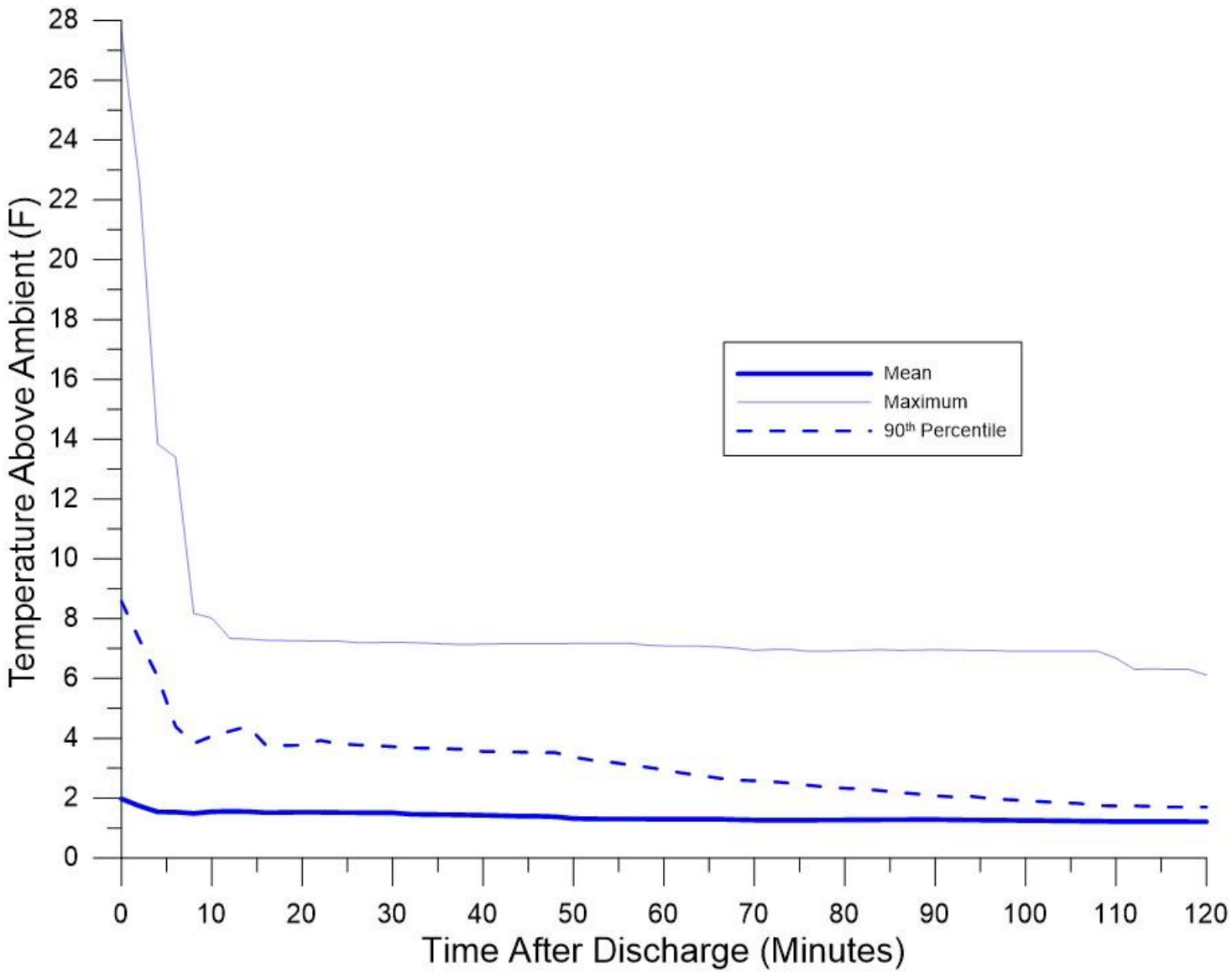

Figure 6-7 Probability distributions of temperature exposures by modeled particles released upstream of LEC's thermal discharge based on modeled conditions on July 21, 2006, the most extreme conditions.

6.1.4 Long Term Exposures to Elevated Temperatures

The previous two subsections described the short-term temperature exposures under observed extreme worst-case conditions. These extreme temperatures are appropriate for evaluating the potential for acute effects resulting from short-term exposures. However, they are not the best measure for evaluating the potential for sublethal effects, such as growth and reproduction, resulting from long-term exposures to elevated temperatures.

Evaluation of long-term temperature exposures for aquatic organisms was based on actual measured temperatures rather that worst-case exposures that occurred on a modeled single day, as used for evaluation of acute mortality. Analysis of actual measurements were made at a location just downstream of the LEC discharge canal, which was assumed to be at the downstream end of the Zone of Initial Dilution (ZID) of the discharge plume by ambient river waters. This analysis revealed that most of the time temperatures were 4°F or less above ambient. Further, only 10 percent of the measurements were greater than 6°F above ambient and all of these were during the coldest periods of the year with little biological productivity. Hence, an assumption of 6°F above ambient is a highly conservative assumption of potential long-term exposure of aquatic organisms to the LEC thermal discharge

6.2 SELECTION OF REPRESENTATIVE IMPORTANT SPECIES

The second step in the predictive assessment for the LEC was to select species to represent the BIC components not deemed to have low potential impact. The Guidance Manual (USEPA 1974 and 1977) recognizes that it is impractical to study and assess in great detail every species at a site, and it is therefore necessary to select a smaller group to be representative of the balanced indigenous community. These selected species are designated as RIS. Generally, five to 15 RIS are chosen to represent the community.

According to the Guidance Manual, criteria for selecting RIS include that the species are:

- Representative, in terms of their biological requirements, of a balanced indigenous community of fish, shellfish, or wildlife;
- Commercially or recreationally valuable;
- Threatened or endangered;
- Critical to the structure and function of the ecosystem (e.g., habitat formers such as submerged aquatic vegetation);
- Potentially capable of becoming localized nuisance species; and
- Necessary in the food chain for the well-being of species determined above.

Other considerations for RIS selection include the extent of the species' seasonal occurrence and abundance within the thermal plume, their thermal sensitivity, and the quantity and quality of information available for the assessment, such as data on thermal tolerance. While many or most fish species in the LMOR may be year-round residents within the area, some are more transient, using the area for adult spawning migrations, dispersal of young to habitats more suitable for the species, or refuge from natural environmental conditions (e.g., high flows or non-preferred water temperatures). For fish species, the results of catch data collected during the monthly surveys for the retrospective assessment provide an additional basis for RIS selection.

Benthic macroinvertebrates as a biotic category was not determined to have a low potential for impact (Section 4). However, they were not included as a RIS in this predictive assessment as they are best addressed in the retrospective assessment (Section 5) for the following reasons:

- The primary purpose of the predictive assessment is to predict under modeled hypothetical conditions the potential effect of an additional heat source on the components of the biotic community that are either mobile or otherwise transient in occurrence. Benthic macroinvertebrates generally are neither.
- There are no documented occurrences of endangered benthic macroinvertebrates or of species having commercial or recreational importance in the study area.
- The availability of results from rigorous lab testing of thermal tolerance for relevant species in the lower Missouri River is limited.
- Being sedentary in nature, benthic macroinvertebrates are recognized as ideal organisms for determining toxicity and pollutant effects, often as indicator species, and thus are ideal for a retrospective assessment of past and present influence of the thermal discharge on the community.

Using the above criteria, the following RIS were selected for this predictive assessment:

RIS	Rationale
Channel catfish	Recreational species
Emerald shiner	Important food chain species
Gizzard shad	Important food chain species
Pallid sturgeon	Endangered species
Walleye/sauger	Recreational and temperature sensitive species
White crappie	Recreational and temperature sensitive species

The expected seasonal occurrence of life stages for these species is shown in Figure 6-8 based on local field studies and available literature. A discussion of life history and distribution of each of these RIS in the LMOR is provided below. Thermal tolerance of each RIS is presented and addressed in Section 6.3.

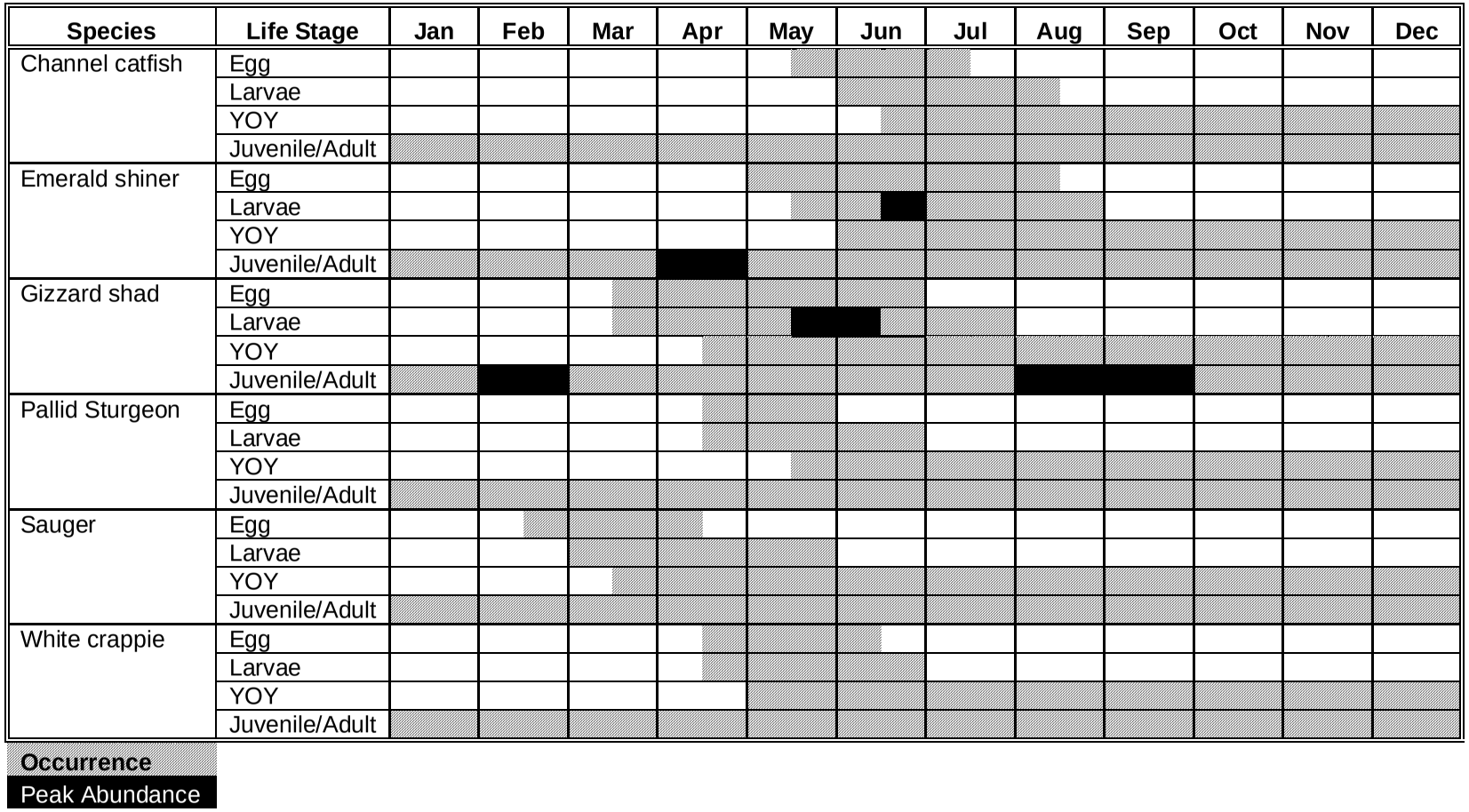

Figure 6-8 Expected seasonal occurrence of RIS life stages in vicinity of LEC based on actual collections and/or available scientific literature.

6.2.1 Channel Catfish

Channel catfish (*Ictalurus punctatus*) was selected as an RIS as it is one of the most popular target species of recreational fishermen in the LMOR (MDOC 2011). Channel catfish is a large, omnivorous riverine catfish species, with the state record catch in Missouri waters is 34.6 lb (Pfleiger 1997). Channel catfish once were a major component of the commercial fishery in the Missouri River, along with flathead catfish and blue catfish. However, the commercial fishery for these three species was closed in July 1992 in response to their declining abundance and population size structure, as well as to reallocate their exploitation to recreational anglers (Mestl 1999, Stanovick 1999, Travnichek and Clemons 2001).

Channel catfish typically spawn in late spring and early summer when water temperatures reach 65°F or more (McMahon and Terrell 1982, Pitlo et al. 2004). Spawning occurs over a range of temperatures from 69.8°F to 84.2°F, with an optimal temperature of 80.6°F (Hubert 1999). Based on water temperatures recorded in the vicinity of the LEC, sustained temperatures in this range (70–84°F) would correspond with the period from late May through June. Often there are two spawning peaks, as apparent from a bimodal size distribution of young catfish, possibly resulting from an interruption by unfavorable conditions such as river discharge or temperature (Pitlo et al. 2004).

Channel catfish eggs are deposited in nests in a gelatinous mass. Incubation lasts for 5.5 to 10 days at 75-82°F (Holland-Bartels and Duval 1988). The male tends the nest while eggs hatch and stays there for about one week after hatching to guard the fry. Fry are less vulnerable to predation in turbid water and aggregate at the edge of the channel over mud or sand bottoms (McMahon and Terrell 1982). Early growth is variable among year classes and apparently is dependent upon existing conditions (Pitlo et al. 2004).

Young channel catfish occupy the main channel or main channel border habitats during their first year (Pitlo et al. 2004). Adults may be found in many habitats including channels and large open areas, but prefer habitat with woody debris, bank cavities, and moderate currents (Koel et al. 1998). Newcomb (1989) found them to be concentrated in deep scour holes in eddy current areas around rock wing dikes at depths >12 ft and velocities <0.9 ft/sec in the Missouri River in Nebraska. In daylight they seek depths with cover and current, while at night or in rising water levels they feed in shallower depths. Most channel catfish do not stray far from their home pool, but some have been shown to make extensive movements (Pitlo et al. 2004). For example, Dames et al. (1989) found that LMOR channel catfish traveled considerably long distances in short time periods and demonstrated changing seasonal patterns in distance and direction. Downstream movements generally occurred during autumn season, while upstream movements and migration from the LMOR into tributaries was more frequent in the spring. Adult channel catfish overwinter in deep water, usually associated with structure such as boulders or debris, and exhibited little movement in the LMOR during the overwinter period (Garrett 2010).

6.2.2 Emerald Shiner

The emerald shiner (*Notropis atherinoides*) was selected as an RIS because of its importance as a prey species in the food chain of the LMOR and the availability of thermal tolerance data derived from controlled laboratory testing. It is one of the most abundant minnows in the Missouri and Mississippi rivers. For example, emerald shiner was the fourth-most abundant species caught in the vicinity of the LEC between 2017and 2018. This species is a common inhabitant of open channels of large river and streams with low to moderate gradient (Pflieger 1997) where it forms large schools in midwater or near-surface depths.

Breeding adults occur throughout the Missouri River from late May through early July during what appears to be a prolonged spawning period (Pflieger 1997). A prolonged spawning period would

allow each fish to spawn more than once per season (Becker 1983). Non-adhesive eggs are broadcast at night in shallow water near the surface where they sink to the bottom over rocky substrate, hard sand, or firm mud. The eggs hatch in 24 to 36 hours and the yolk-sac larvae remain on the bottom for approximately four days before joining large schools near the surface (Becker 1983, Pflieger 1997). In the LMOR, the eggs and fry are not likely subject to drifting downriver and no eggs and only a small number of emerald shiner larvae in ichthyoplankton were collected in the vicinity of the LEC from 2015 to 2018.

Schramm (2004) generally characterized the habitat of juvenile and adult emerald shiners to be channel border and backwater areas, while Schloesser et al. (2011) described emerald shiner as a habitat generalist. Reeves (2006) commonly collected the juveniles and adults in wing-dike and wing-dike sandbar mesohabitats as did Ameren's 2017-2018 survey by electrofishing and seining.

6.2.3 Gizzard Shad

Gizzard shad (*Dorosoma cepediatum*) was selected as an RIS because of its importance as a prey species in the LMOR. Its productivity is linked to its role in the trophic structure of the community, since it feeds on primary producers (phytoplankton and periphyton) and planktonic consumers (zooplankton and some fish eggs and larvae). Gizzard shad occur in every stream basin in Missouri but is most abundant in the Mississippi and Missouri Rivers (Pflieger 1997). Much of the Missouri River population has been associated with the lower channelized river segments, where gizzard shad are able to thrive as prolonged swimmers (Galat et al. 2005b). It is so abundant in some locations that it is sometimes considered a nuisance species, possibly competing with other species for food and space. Gizzard shad are particularly susceptible to mortality resulting from sudden and extreme changes in temperature, with winter die-offs at temperatures below 38° F (Williamson and Nelson 1985).

Gizzard shad have been reported to spawn at temperatures ranging from 50°F to 82°F, depending on location (Heidinger and Brooks 2005), and spawning can be protracted over 3 to 4 months (Tisa and Ney 1991, Michaletz 1997). Based on water temperatures recorded in the vicinity of the LEC, sustained temperatures in this range would correspond with the period from approximately late March to late June. Spawning activity had been correlated with rapidly rising water levels and stimulated at water temperatures over 60 °F (Williamson and Nelson 1985). Aggregations of gizzard shad will migrate upstream to spawn in shallow water, less than 5 ft in relatively protected areas (Pflieger 1997, Williamson and Nelson 1985). Eggs are adhesive, attach to the bottom and hatch in 36 to 95 hours after fertilization in water temperatures ranging from 62 to 80 °F (Heidinger and Brooks 2005). No gizzard shad eggs were collected in ichthyoplankton sampling in the vicinity of the LEC from 2015 to 2018.

In the Missouri River, young gizzard shad are abundant along the shore in late May and June (Pflieger 1997). Young-of-year (YOY) gizzard shad began to appear in the LEC impingement collections during 2005–2006 at lengths of 22–32 millimeters (mm) total length (TL) from mid-May to mid-July. Young gizzard shad grow very quickly (e.g., 0.44–1.33 mm/day as larvae and 0.30–1.0 mm/day as juveniles), reaching 6 to 7 in. by the end of their first year (Tisa and Ney 1991, Michaletz 1997, Heidinger and Brooks 2005). This rapid growth rate limits the period when they are effectively preyed upon to approximately their first 6 months of life. By September they become too large for all but the largest predators and may reach a maximum size of 175 mm TL (6.9 in.) by December.

6.2.4 Pallid Sturgeon

Pallid sturgeon (*Scaphirhynchus albus*) was selected as an RIS based upon its status as a federally listed and state-listed endangered species. Pallid sturgeon was first recognized as a species distinct from the shovelnose sturgeon in 1905 and was listed as endangered on

September 6, 1990 (USFWS 2007). The pallid sturgeon is adapted to live near the bottom of large, free-flowing rivers in turbid waters. It prefers a diversity of water depths and velocities such as typically found in braided channels and around islands and sand bars and flats (USFWS 2007, 2014). It is considered endemic to the Missouri River, as well as the Mississippi River and the lower reaches of the Yellowstone, Platte, and Kansas rivers (Dryer and Sandoval 1993; USFWS 2014).

The pallid sturgeon's current range is fragmented by mainstem dams on the Missouri River and its presence is considered scarce throughout much of its former range (USFWS 2007). Catch rates of pallid sturgeon have been consistently low recently in the most downstream reaches of the LMOR near the LEC (Herman et al. 2014; Herman and Wrasse 2015, 2016), and there is no evidence for increasing relative abundance in the LMOR despite stocking efforts (Wildhaber et al. 2014).

Recent observations have provided evidence of limited recruitment in the LMOR and Mississippi River. Three confirmed larval pallid sturgeon were collected in 2000 from a side channel (Lisbon Chute) at RM 217 (USNRC 2014), approximately 160 miles upstream of the LEC. Two naturally reproduced larval pallid sturgeon were captured in 2014 by the MDC near St. Louis and their identification was confirmed by DNA analysis (Crosby 2015). More recently, additional collections of a small number of wild-spawned pallid sturgeon larvae and suspected wild juvenile pallid sturgeon from the lower Missouri River have been confirmed (Jacobson et al. 2016). Regardless of these observations, the population is considered neither stable nor self-sustaining (Steffenson 2012, USFWS 2014) and it primarily consists of older individuals.

In the lower Missouri River, juvenile and adult pallid sturgeon primarily have been observed in channel border habitats associated with engineered structures but also has been documented inside channels with flowing water (USFWS 2014). In the Middle Mississippi River (MMR) where the river habitat is similar to that of the LMOR, sonic-tagged pallid sturgeon (614-888 mm standard length) occupied the main channel most frequently (39 percent), likely due to the predominance of this habitat type, followed by main-channel border (26 percent) and between wing dikes (14 percent) (Hurley et al. 2004). This pattern was similar across all seasons, regardless of water temperature, except during high spring flows at temperatures between 50°F and 68°F, when they increasingly used areas between wing dikes. Koch et al. (2012) conducted a similar study with sonic-tagged adult pallid sturgeon (>600 mm fork length [FL]) on the MMR that refined data on the selection of specific habitats from which they concluded that wing dike flows and substrates may provide otherwise missing habitat complexity, e.g., scour holes of depths 6-12 meters and sand substrate.

Information on pallid sturgeon reproduction is scarce, although currently there are efforts aimed at improving the understanding of pallid sturgeon reproductive biology and spawning behavior. Pre-spawning pallid sturgeon generally move upstream beginning in the late fall and early spring (DeLonay et al. 2012). Spawning in the LMOR appears to be associated with increasing day length, increasing water temperature, and typically higher river flows and generally occurs from the end of April through May. Over their whole range, spawning has been observed from March to July with fish in the northern part of the range spawning later than those in the southern part (USFWS 2014). While increasingly more information is becoming available on pallid sturgeon spawning habitat preferences, the relative spawning success remains unknown. DeLonay et al. (2012) demonstrated that during the upstream spawning migration, pallid sturgeon preferred the slower currents of the inside channel bends. McElroy et al. (2012), interpreting Delonay et al. (2010) data, hypothesized that the use of slower currents in the inside channel bends of the Missouri River, frequently traversing the river thalweg from inside bend to inside bend, for upstream migration afforded adult pallid sturgeon optimization of their migration through reduced energetic cost and shorter pathways. Wildhaber et al. (2007) assumed that, like other sturgeon

species, spawning occurs over coarse substrate in river currents in or adjacent to the main channel.

Sturgeon eggs are adhesive. Newly hatched larvae are attracted to light and migrate upward into the water column towards the surface to enter the current. Kynard et al. (2002) observed pallid sturgeon larvae swimming off the bottom at day-2, swimming increasingly higher off the substrate and into current at day 4, and actively swimming in circles at the surface on days 7-8. They remain pelagic and may drift downstream for up to 13 days and several hundred kilometers (km) depending on river flow, water temperature, and growth rates (Braaten et al. 2012, USFWS 2014). Unlike other sturgeon species, pallid sturgeon larvae appear to drift during both day and night (Braaten et al. 2012). Braaten et al. (2010) showed that freely drifting pallid sturgeon larvae were most closely associated with the bottom 0.5 meters of the water column. Drifting larvae swimming height within the water column was related to development stage, habitat preference, migratory style and migratory distance (Kynard et al. 2002). In addition, drifting larval distribution was greatest in mid-channel and outside bend habitat locations where currents were highest. Larval sturgeon transition from free drifting to settling into benthic habitats when the larvae reach approximately 18 to 20 mm in length (Braaten et al. 2010).

Little is known regarding habitat preferences for settled larval and young pallid sturgeon, however they are surmised to be similar to those for the closely related shovelnose sturgeon larval and young habitat preferences (USFWS 2014). Based on this premise, larval pallid sturgeon (20-30 mm) would prefer side-channel, low velocity (1.6-2.2 fps) habitats for settling shortly after their drifting period. By the time they would reach 30-40 mm length, Age-0 sturgeon would show a preference for habitats with faster velocity flows (Ridenour et al. 2011).

All species of sturgeon are highly migratory and capable of long-range (> 300 km) movements, often moving freely among multiple large river systems (Tripp et al. 2019). While these movements are known to be triggered by river stage and temperature, they are highly variable among populations (Tripp et al. 2019). For example, shovelnose sturgeon in the northern regions (e.g. RM 595-734) of the Missouri River exhibit only short-range movement patterns while sturgeon in the LMOR (RM 130-150) have migration patterns that include both short and long distances (Wildhaber et al. 2011). Wildhaber et al. (2011) speculates that these differences among populations within the Missouri River maybe a result of nearby tributary use for spawning by northern populations or altered environmental cues from upstream reservoirs with regulated flows. Tripp et al. (2019) found that pallid and other sturgeon species within the Missouri River exhibited seasonal movements out of and back to core areas at different times of the year, with greater movement for pallid sturgeon observed in the summer and fall. Pallid sturgeon seasonal movements within the Missouri River were closely tied to temperature along with movements increasing with rising river water and decreasing with low water levels (Tripp et al. 2019).

6.2.5 Walleye/sauger

Both walleye (*Sander vitreus*) and the closely related sauger (Sander canadensis), were selected as RIS due to its temperature sensitivity and importance as recreational species in parts of the Missouri River. In this study, they are combined together since their temperature sensitivities are similar and the egg and larval stages are exceedingly difficult to distinguish using normal identification methods. Native to freshwater rivers and lakes primarily east of the Rocky Mountains and west of the Appalachians (McMahon et al. 1984), walleye is one of the most widespread fishes in interior North America (Hoagstrom and Berry 2010). Walleye is known to be a migratory species, navigating extensive distances for spawning, suitable foraging or staging areas and returning (homing behavior) to specific area (Haxton et al. 2015). Within large, fragmented rivers such as the Missouri River, walleye movement can be restricted by dams and other barriers that may not be designed to facilitate fish movement. However, Haxton et al. (2015)

found that walleye movement was limited even within contiguous, unimpounded reaches of a large fragmented river, suggesting that dams might not be the barrier to some populations. The limited walleye movement among river reaches, even by only a few individuals, could be necessary to maintain the genetic diversity within a fragmented river population (Haxton et al. 2015).

Spawning of adults typically occurs at night from mid-February through early April in temperatures from 38 to 58°F within flowing water and clean rocky substrate (Auer 1982). Spawning habitats of shallow shoreline areas, shoals, riffles, and the rock substrate at the base of dams are preferred (McMahon et al. 1984). Demersal, adhesive eggs are broadcasted and fertilized during release onto unguarded coarse gravel, boulder, and rock substrate to which the eggs adhere (Auer 1982; Cross and Collins 1995). The 1.5 to 2.1 mm diameter eggs hatch in approximately 14 to 21 days at water temperatures ranging from 46.4 to 59°F and require well-oxygenated water for high survival and growth (Auer 1982; McMahon et al. 1984).

Newly hatched fry will absorb yolk-sac within 3 to 5 days during which point they are transported by water flows to lakes or impounded river areas. Fry begin feeding at 15 to 25 mm in length and remain photopositive until reaching lengths of 25 to 40 mm after which the demersal fry, juveniles and adults seek shelter to avoid periods of intense light (McMahon et al. 1984).

Adult walleyes are often found under cover of boulders, log piles, brush, and submerged vegetation during the day and feed at night after moving inshore (McMahon et al. 1984). They prefer areas of slight currents throughout the year, with the exception of winter periods when they avoid turbulent areas. Optimal growth temperatures and dissolved oxygen range from 68 to 75°F and 3-5 mg/l, respectively (McMahon et al. 1984).

Often confused with the walleye, the sauger (*Sander canadensis*) is less abundant within the Missouri River. The sauger typically is shorter, has a more slender body than walleye, and is identifiable by the larger dark brown saddle blotches, along with spots on its dorsal fin (Tomelleri and Eberle 1990). A white tip on its tail and dark membranes on the posterior end of the dorsal fin can often distinguish the walleye (Tomelleri and Eberle 1990). Sauger has been found to prefer deeper water and are more tolerant of turbid, silted bottomed waters than walleye (Trautman 1981).

6.2.6 White Crappie

White crappie (*Pomoxis annularis*) was selected as an RIS due to its temperature sensitivity and its importance as a recreational sportfish in the LMOR. It is native to freshwater lakes, streams, and rivers from the southern Great Lakes to Texas and Alabama, west to Nebraska, east to North Carolina, then west of Appalachian Mountains to New York (Edwards et al. 1982). Within river systems white crappie are most commonly found in low velocity areas within pools and backwater areas away from the main channel in clearer waters (Edwards et al. 1982). Within Missouri rivers, white crappie prefer locations away from the main channel in sluggish pools or backwater areas of low to zero velocity (Pflieger 1975). Within the Missouri River, fish surveys identified higher abundance of white crappie in mid and upper river segments than those segments within the LMOR (Berry et al. 2004).

Mature males construct and guard nests over at depths of 4 inches to 14 feet near vegetation or other cover (Edwards et al. 1982). Siefert (1968) also found spawning adults selected nesting locations near objects and bottom vegetation but had no strong substrate preference. Spawning occurs from March to July after water temperatures reach 55-57°F peaking at 61-68°F, however spawning has been observed in Missouri at water temperatures as high as 78.8°F (Edwards et al. 1982). Demersal, colorless, adhesive eggs with a diameter of 0.8 to 0.9 mm typically hatch in 27 to 93 hours depending on water temperature (Auer 1982). Newly hatched fry range in length

from 1.2 to 2.6 mm, depart the nest at slightly larger lengths (4.1 to 4.6 mm), and fully absorb the yolk-sac before reaching 5 mm (Auer 1982, Siefert 1968, 1969).

Adult white crappie populations can be highly dependent on cover availability. Adults are found to congregate around submerged trees, stumps, brush, aquatic vegetation, and boulders (Edwards et al. 1982). Other limitations on population abundance include hydraulic conditions, predation, and the availability of type and size of food especially at critical stages in the life cycle (McDonough and Buchanon 1991). In the Wabash River in Indiana, adult white crappie showed preference to temperatures of 80 to 80.6°F near a thermal effluent but were not found in heated discharge above 87.8°F (Edwards et al. 1982).

6.3 ASSESSMENT OF POTENTIAL BIOTHERMAL EFFECTS

The response of the RIS to the LEC's thermal plume was evaluated using thermal response data obtained in laboratory studies (Appendix C Table C-1). This laboratory data was supplemented by data collected during field studies (EPRI 2013) on maximum temperatures at which the RIS were found to occur and potentially survive, at least over a short term (Appendix C Table C-2). Most of the available data evaluated response to rapid changes in temperature, as would commonly be experienced with exposure to a thermal plume and conventionally defined as the incipient lethal temperature method (Brungs and Jones 1977). Use of these laboratory data tends to be conservatively protective since organisms can acclimate and adapt, both physiologically and genetically, to changed temperature regimes, recover from short-term thermal stress and utilize lower temperature areas of the waterbody as refuge from stressful temperatures when necessary (Bevelheimer and Coutant 2004, Reash 2008, Bevelheimer 2008).

Using these laboratory data, this predictive assessment focuses on addressing the following four questions with regard to the magnitude, areal extent and frequency of occurrence of elevated temperature exposures from the LEC's thermal discharge and the effects that such exposures could have on the fish community components in the LMOR:

- Are the areal extent and probability of occurrence of mortality resulting from thermal exposures sufficiently large to adversely affect the populations of planktonic individuals, including the egg and larval stages of fish, as they drift past the LEC facility?
- Are rapid temperature declines during winter if the LEC abruptly ceases discharging heat sufficient to adversely affect the populations of fish in the LMOR from mortality associated with cold shock?
- Are the effects of long-term exposures to elevated temperatures from the LEC's thermal discharge of sufficient intensity, magnitude and frequency of occurrence so as to adversely affect the reproduction and development of fish in the LMOR?
- Are the cross-sectional areas from which motile individuals are excluded as a result of thermal avoidance sufficiently large and likely to occur frequently enough so as to block migratory pathways for fish in the LMOR?

These questions were addressed in this predictive assessment by comparing seasonal occurrence of the RIS in the LMOR in the vicinity of the discharge and biothermal response information for these species obtained in laboratory studies to the predicted seasonal ambient and plume temperatures to which the organisms may be exposed. As previously noted, temperature exposures were estimated from plume modeling of extreme conditions in late spring and summer.

For each question, the potential for the LEC's thermal discharge to have an appreciable impact on the populations of the RIS was assessed by evaluating the thermal effects predictions in the context of:

- Species life-cycle requirements and characteristics;
- Species ranges and distributions;
- The relative amount of available habitat in the LMOR; and
- Potential for reversal of effects.

6.3.1 Potential Effects from Increased Mortality

Aquatic organisms can adjust to the thermal environment physiologically, thereby shifting their tolerance range, but this acclimation has limits and ultimately a water temperature may be reached that would be lethal (Figure 6-9). The upper and lower lethal limits of thermal tolerance are typically determined by laboratory experiments and are defined as the temperature resulting in death of 5, 50, or 95 percent of the test organisms (TL5, TL50, TL95). Immobilization or death resulting from sudden increases or decreases in water temperature beyond an organism's upper or lower incipient tolerance limit (LILT) is often referred to as "heat shock" or "cold shock," respectively.

The tolerance of organisms to extremes of temperature change is influenced by three factors: 1) their genetic ability to adapt to thermal changes within their characteristic temperature range; 2) the acclimation temperature prior to exposure to a change; and 3) the duration of exposure to the elevated or lowered temperature (Coutant 1972). The first factor, genetic ability to adapt to

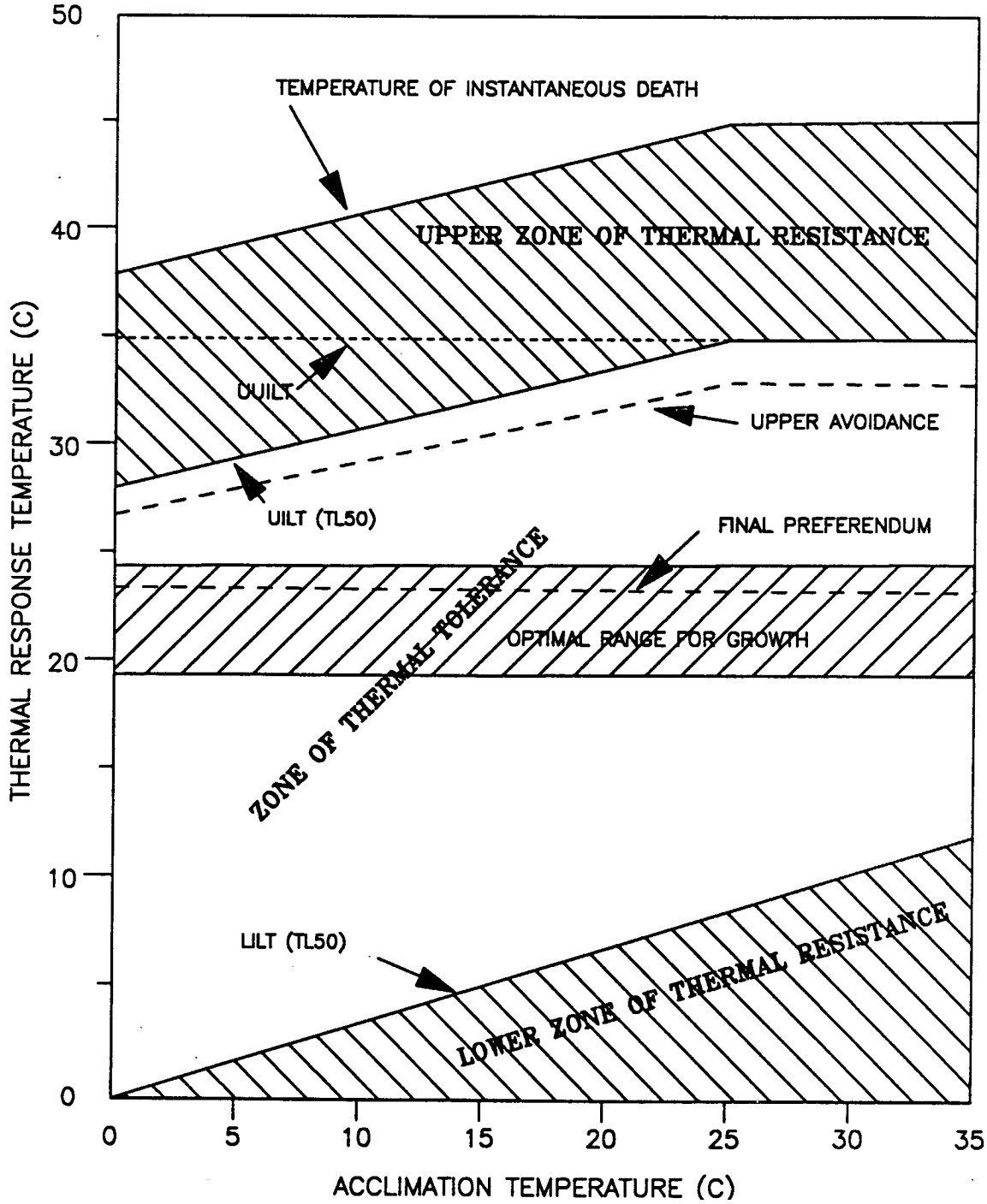

Figure 6-9 Interrelationship of various thermal effect parameters and acclimation temperature.

temperature changes, differs among species and among developmental stages within a particular species (Hochachka and Somero 1971). For example, striped bass tolerate higher temperatures than salmon, and juvenile striped bass have higher tolerances than adult striped bass (EA 1978a, Coutant 1970).

The second factor, the temperature to which an organism has become physiologically adapted (acclimation temperature), affects aquatic organisms' upper and lower temperature tolerance to long- and short-term periods of exposure (Brett 1956; Coutant 1972; Lauer et al. 1974; Figure 6-9). True acclimation to changed temperature requires several days to more than a week (Brett 1941; Fry 1971; Hochachka and Somero 1971). For long-term exposure, the upper incipient lethal temperature (UILT), which is the highest temperature at which 50 percent (TL50) of a sample of organisms can survive long-term exposure (24 hours to one week), is determined for each organism at the highest sustainable acclimation temperature. The lowest temperature at which 50 percent (TL50) of the warm acclimated organisms can survive long-term exposure is the LILT.

Tolerance to short-term (seconds to hours) exposures to temperature changes also depends on the organism's acclimation temperature (Lauer et al. 1974; EA 1978 a,b; IA 1978a,b,c,d; IA 1979; Greges and Schubel 1979). A sample of organisms acclimated to temperatures at the low end of their range of tolerance typically can tolerate larger increases in temperature than a sample of the same organisms acclimated to temperatures near the high end of their range of tolerance (Lauer et al. 1974). For example, striped bass post yolk-sac larvae acclimated to 68°F tolerated a 23.4°F temperature rise (equal to an exposure temperature of 91.4°F) for 5 minutes, whereas the same species life stage acclimated to 78.8°F tolerated only a 19.1°F rise (equal to an exposure temperature of 97.9°F) for the same exposure time (EA 1978a). Nonetheless, organisms acclimated to warmer temperatures generally can tolerate higher maximum temperatures than if they were acclimated to lower temperatures, as illustrated by temperatures reported by EPRI (2013).

The third factor crucial to tolerance of temperature change is duration of exposure (Coutant 1972). The tolerance of an organism to temperature changes is a direct function of exposure time. Organisms tolerate exposure to greater changes in temperature if the exposure is for a short period (Brett 1952). For example, striped bass acclimated to approximately 77°F survive an increase in temperature of 29°F (equal to an exposure temperature of 106°F) for 10 seconds, but tolerate an increase in temperature of only 18°F (equal to an exposure temperature of 95°F) for 60 minutes (EA 1979). This time-temperature aspect of tolerance of temperature change is crucial to an accurate and scientifically valid assessment of the potential for organisms to tolerate heat shock from potential exposure to the LEC's thermal plume.

6.3.1.1 Heat Shock

Thermal discharges, like that from the LEC, could theoretically cause mortality through exposures of aquatic organisms to temperatures exceeding their thermal tolerance resulting in heat shock. However, in the LMOR, the potential for heat shock from exposure to the LEC's thermal plume is limited to those life stages of the RIS that lack sufficient swimming ability to avoid lethal temperatures. This would include the very early life stages, such as eggs and larvae, that could drift into the thermal plume from river currents. The extensive literature on the effects of thermal plumes on fish demonstrate larger more motile life stages (juveniles and adults) will actively avoid temperatures outside their preferred ranges (Environment Canada 2014) and, hence, have virtually no potential of being subject to heat shock.

Data relevant to short-term temperature exposures for the early life stages of fish was available for only two of the RIS used in this assessment, emerald shiner and pallid sturgeon. These two species have relatively low thermal tolerances compared to other species found in the LMOR. Thus, the results based on these species can be used as conservative indicators of potential

thermal effects on the other RIS species. These data were then compared to the thermal exposures based on particle tracking in the Flow-3D model described in Section 6.1.3 and illustrated in Figure 6-7 to assess the potential that the early life stages of these two species could potentially experience lethal temperatures. This particle tracking model documented that any exposures to elevated temperatures resulting from drifting into the LEC's thermal plume would be relatively short-term (e.g., ≤80 minutes). The potential for heat shock mortality to the other RIS was addressed qualitatively by comparing temperature exposures to information from long-term exposures such as UILT and Critical Thermal Maxima (CTM) (Beitinger et al. 2000). Available literature demonstrates that the heat tolerance from short-term exposures, such as through drift, will be much higher than either UILTs or CTMs. Hence, any evaluation using long-term thermal tolerance data can be considered very conservative. The results of these comparisons are presented for each of the RIS below.

Channel catfish

In the vicinity of the LEC, channel catfish spawn from late May through June. Eggs are deposited in nests in a gelatinous mass. Incubation typically lasts for 5.5 to 10 days. The male tends the nest while eggs hatch and stays there for about 1 week after hatching to guard the fry. Fry aggregate at the edge of the channel over mud or sand bottoms and have only limited vulnerability to the currents. This low vulnerability to drifting is reflected in the fact that no channel catfish eggs or larvae were collected during ichthyoplankton sampling in the vicinity of the LEC.

Channel catfish have wide geographic range including areas well south of the LEC it is reasonable to expect that they are tolerant of temperatures much higher than that observed in the LMOR. UILT values reported for larvae of this species acclimated to temperatures similar to that occurring in the LMOR was 95.90°F (Table 6-1). These temperatures encompassed less than 0.5 percent of the LMOR volume in the vicinity of the LEC (Figure 6-5). Drifting larvae would encounter these temperatures less that 10 percent of the time during the worst-case spring larval nursery period and none would be exposed to these temperatures for more than 16 minutes (Figure 6-6). Hence, there appears little likelihood that channel catfish larvae would experience exposures to lethal temperatures during drift.

Table 6-1 Thermal mortality temperatures used in this assessment of potential effects of the LEC's thermal plume to RIS in the LMOR.

Species	Life Stage	Thermal Effect Description	Acclimated Temperature (F)	Effect Temperature (F)	Reference Number[1]
Channel catfish	Larvae	Upper Incipient Lethal Temperature	84.20	95.90	191
Gizzard shad	YOY		86.00	96.80	172
Sauger	Juvenile	Upper Incipient Lethal Temperature	50.18	79.88	175
			53.60	80.06	175
			57.02	83.12	175
			60.80	83.48	175
			64.94	83.66	175
			67.82	85.10	175
			71.60	85.82	175
White crappie	Juvenile	Upper Incipient Lethal Temperature	80.60	91.40	184
			89.60	91.40	184

[1]**Reference citations in Appendix Table C-1.**

Emerald shiner

Emerald shiners have a prolonged spawning period in the LMOR extending from late May through early July. The prolonged spawning period would allow each fish to spawn more than once per season. Non-adhesive eggs are broadcast at night in shallow water near the surface where they sink to the bottom over rocky substrate, hard sand, or firm mud. The eggs hatch in 24 to 36 hours and the yolk-sac larvae remain on the bottom for approximately 4 days. Hence, both eggs and yolk-sac larvae should experience minimal exposure to the LEC's thermal plume. Thereafter, the developing larvae and juveniles swim up to join large schools near the surface and are subject to drifting downriver from river currents. In the two years of ichthyoplankton sampling in the vicinity of the LEC, no eggs and only 212 larvae of any minnow species were collected and only 15 of the larvae were identified as emerald shiner. These results support the assumption that most of the early life stages of this species occur in areas where they would not be exposed to the LEC's thermal plume.

While there are no short-term thermal tolerance data available for emerald shiner, there are for juveniles of a related species, spottail shiner (*Notropis hudsonius*). These data indicate that there might be very short-term exceedances of safe temperatures for juveniles of this species (Figure 6-10)[4]. However, these exceedances are of short duration (<10 min.) and occupy 1 percent or less of the surface area and volume in the vicinity of the LEC (Figure 6-5). Further, these measures of safe temperatures were developed using acclimation temperatures (79°F) less than that observed on the two dates modeled, representing extreme case (<1 percent) conditions of low river flow and high ambient temperature. Given the influence of acclimation temperatures on thermal tolerance, it is likely that the actual safe temperature might be higher than shown as illustrated in Figure 6-10.

Pallid sturgeon

While information on pallid sturgeon reproduction is scarce, spawning in the LMOR appears to generally occur from the end of April through May and likely over coarse substrate in river currents in or adjacent to the main channel. Sturgeon eggs are adhesive and should not be part of the drift and, hence, should experience minimal potential for exposure to the LEC's thermal plume. Newly hatched larvae migrate upward into the water column and enter the current. They remain pelagic and may drift downstream for up to 13 days and several hundred km depending on river flow, water temperature, and growth rates. However, when drifting they were most closely associated with the bottom 0.5 meters of the water column and larval abundance was greatest in mid-channel and outside-bend habitat locations where currents were highest. Larval sturgeon transition from free drifting to settling into benthic habitats when the larvae reach approximately 18 to 20 mm in length when they are approximately 30 days old and no longer part of the drift. In the two years of ichthyoplankton sampling in the vicinity of the LEC, no eggs and only one larvae of any sturgeon species were collected. This larva could have been either the more common shovelnose sturgeon or the rare pallid sturgeon but most likely the former owing to the relative abundance of each species.

The only short-term temperature tolerance data for pallid sturgeon were developed using an acclimation temperature of 72°F, more than 10°F less than observed in late spring of 2006. These data indicate that there might be very short-term exceedances of both safe temperatures and UILT for larvae of this species a (Figure 6-11)[3]. However, these exceedances are of short duration (<5 min. for UILT and <50 min. for safe temperatures) and occupy a small portion (<10 percent for safe temperatures and <1 percent for UILT) of the surface area and volume in the vicinity of LEC (Figure 6-5).

[4] See Appendix C Table C-1 for reference citations.

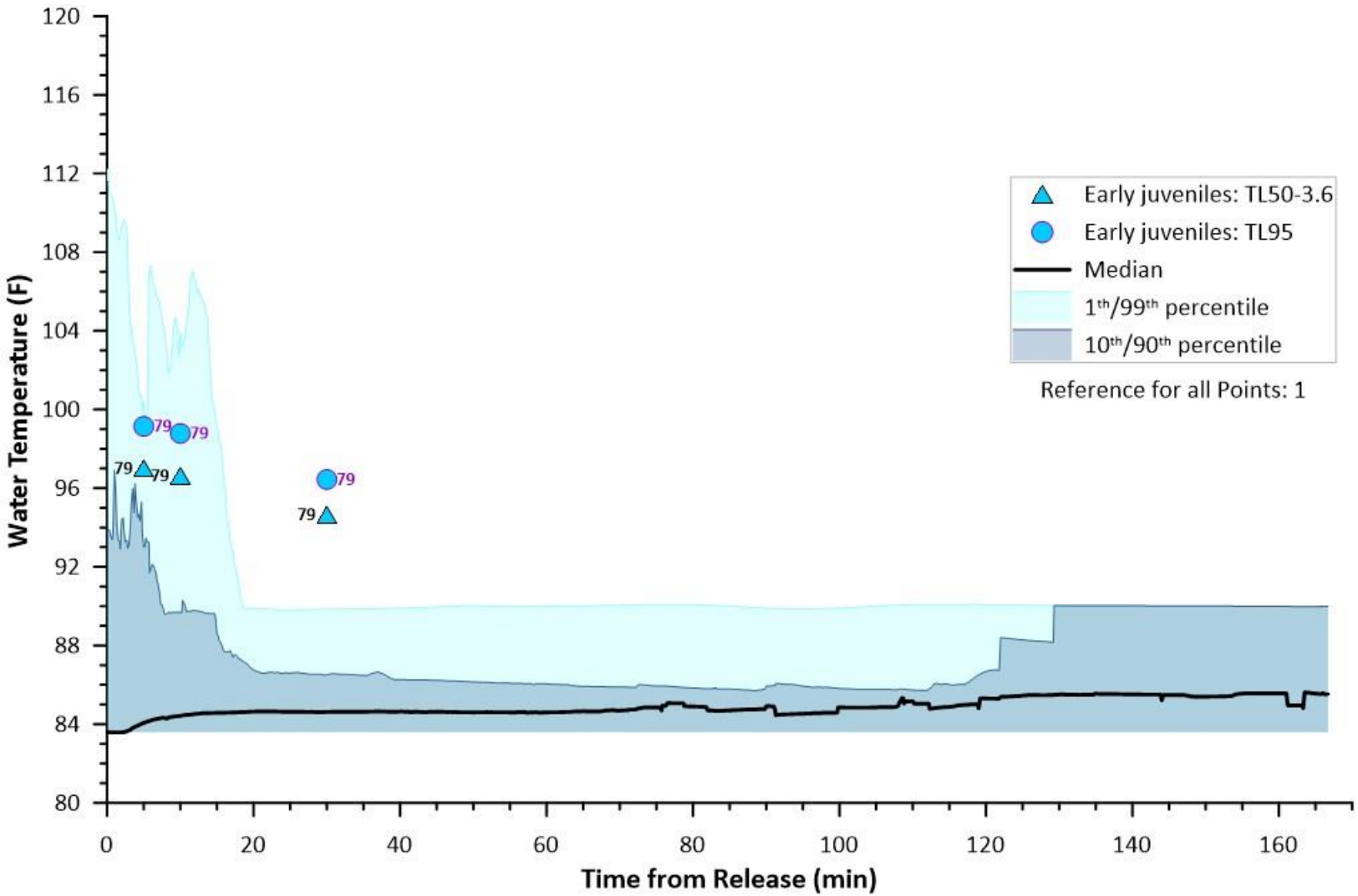

Figure 6-10 Short-term thermal tolerance of spottail shiner juveniles relative to temperature exposures based on particle tracking in the June 2006 model run. (Delta-T tolerance data are safe temperatures (TL50-3.6F). (Data labels indicate test acclimation temperature).

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Further, these biothermal measures for pallid sturgeon larvae were developed using acclimation temperatures substantially less than that observed on the June date modeled, representing extreme case (<1 percent) conditions of low river flow and high ambient temperature. Given the influence of acclimation temperatures on thermal tolerance, it is likely that the actual safe temperature might be higher than listed in this figure. Finally, most of these exceedances occur near the discharge and up in the water column whereas pallid sturgeon larvae are most commonly found closer to the bottom

Gizzard shad

Gizzard shad appear to spawn in the vicinity of the LEC from approximately late March to late June. Spawning occurs in shallow water in relatively protected areas. The eggs are adhesive and attach to the bottom. These two characteristics indicate that eggs should not be carried by currents and accounts for the fact that no gizzard shad eggs were collected in the two years of ichthyoplankton sampling in the vicinity of the LEC. Larval gizzard shad are more commonly found up in the water column and this species accounted for just under 1 percent of the larvae collected in the 2-year sampling effort.

Unfortunately, there are no thermal tolerance data for gizzard shad larvae. However, the UILT for young of year (i.e., post larval) gizzard shad acclimated to temperatures comparable to those observed in the LMOR was 96.8°F (Table 6-1). Temperatures at or above 96.8°F encompassed less than 0.5 percent of the LMOR volume in the vicinity of the LEC (Figure 6-5). Drifting larvae would encounter these temperatures less that 10 percent of the time during the worst-case spring larval nursery period and none were exposed to these temperatures for more than 16 minutes (Figure 6-6). Hence, there appears little likelihood that gizzard shad larvae would experience exposures to lethal temperatures during drift.

Walleye/sauger

Spawning of the two closely related species, walleye and sauger, typically occurs during February and March in shallow shoreline areas, shoals, riffles, and the rock substrate at the base of dams. The demersal, adhesive eggs are broadcasted and fertilized during release onto unguarded coarse gravel, boulder, and rock substrate where the eggs adhere. Given their adhesive nature, eggs should not normally be part of the drift and none were collected in the two-year sampling effort in the vicinity of the LEC. Eggs hatch in approximately 14 to 21 days and the newly hatched fry absorb yolk-sac within 3 to 5 days. At that point, they are transported by water flows to lakes or impounded river areas. Fry begin feeding at 15 to 25 mm in length and remain photopositive until reaching lengths of 25 to 40 mm in a couple of months after which they become demersal and are no longer carried by the currents. Only a total of 20 larvae of these two species were collected in the two-year sampling effort in the vicinity of the LEC indicating that areas near the facility are not critical spawning and nursery habitat for this species. It is likely that the few larvae collected were transported into the area from upstream cool water spawning habitats by high spring flows.

Walleye and sauger are most commonly found in the vicinity of the LEC during April and early May when water temperatures typically range from 50 to 70°F. At these acclimation temperatures, the UILT for sauger ranges from just under 80°F to more than 85°F (Table 6-1). These temperatures would rarely, if ever, be encountered in the vicinity of the LEC's thermal discharge at times of the year when walleye and sauger would likely be present. Hence, there appears little likelihood that walleye or sauger larvae would experience exposures to lethal temperatures during drift.

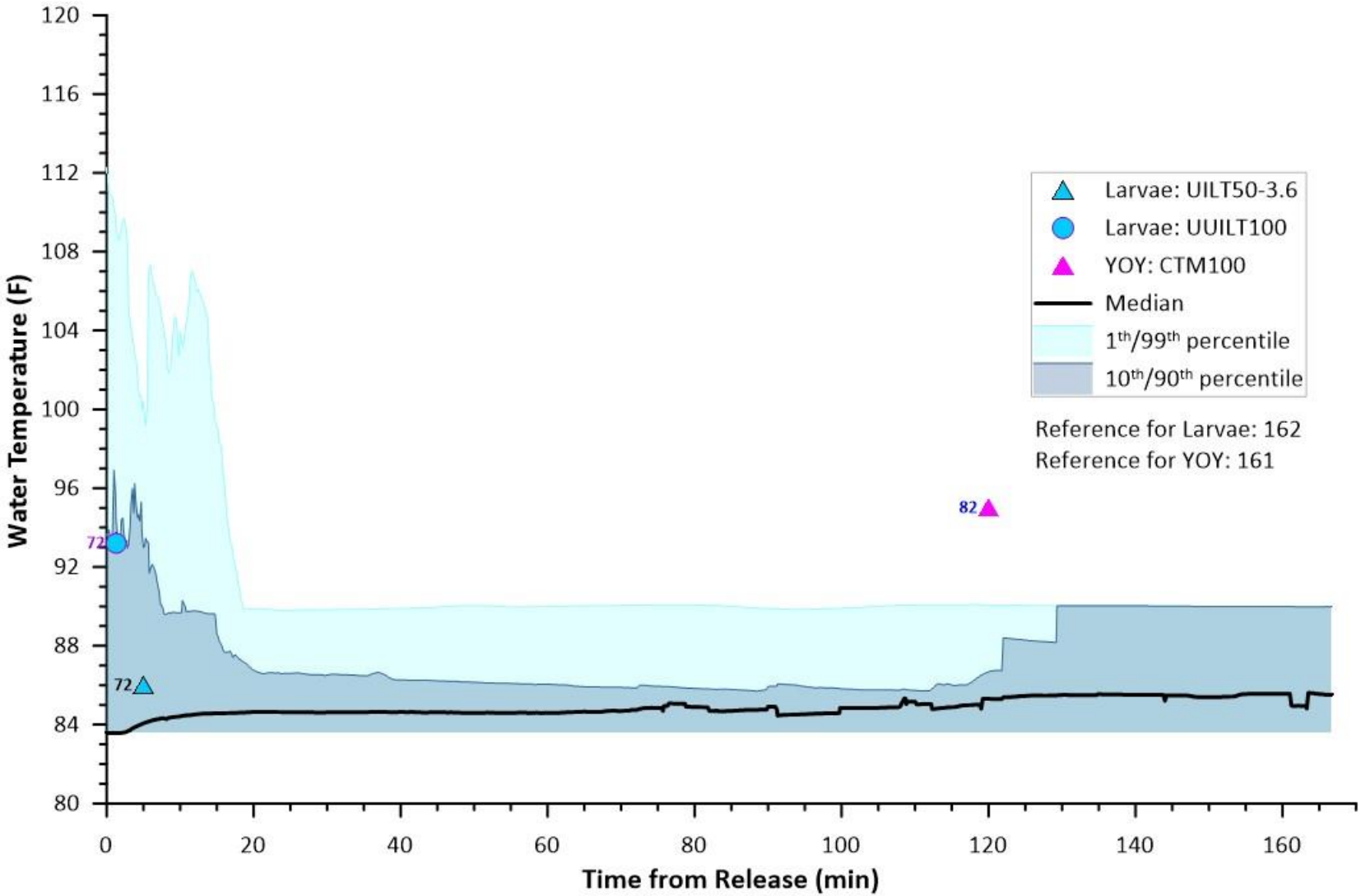

Figure 6-11 Short-term thermal tolerance of pallid sturgeon larvae and Upper thermal tolerance of YOY relative to temperature exposure based on particle tracking in the June 2006 model run. (Delta-T tolerance data are safe temperatures (TL50-3.6F). Data labels indicate test acclimation temperature).

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White crappie

Spawning of white crappie occurs over an extended period from March to July. The eggs are demersal, colorless and adhesive and typically hatch in 27 to 93 hours depending on water temperature. Given their adhesive nature, eggs should not normally be part of the drift. The newly hatched fry begin to leave the nest after a few days where they are transported about by water currents. After approximately one month, the now juveniles retreat to the backwater nursery areas to avoid currents and actively feed and grow. No eggs and only 61 crappie larvae were collected in the two-year sampling effort in the vicinity of the LEC indicating that this area is not important spawning or nursery habitat for this species, or that spawning and nursery occurs in backwater areas away from the main channel. In either case, eggs and larvae of this species should have little potential for exposure to the LEC's thermal plume.

Unfortunately, there are no thermal tolerance data for white crappie larvae. However, the UILT for juvenile white crappie acclimated to temperatures comparable to those observed in the LMOR was 94.1°F (Table 6-1). These temperatures encompassed less than 1.0 percent of the LMOR volume in the vicinity of LEC (Figure 6-5) while drifting larvae would encounter these temperatures less that 25 percent of the time during the worst-case spring larval nursery period and none were exposed to these temperatures for more than 18 minutes (Figure 6-7). Hence, there appears little likelihood that white crappie larvae would experience exposures to lethal temperatures during drift.

6.3.1.2 Cold Shock

When exposed to a temperature gradient, juvenile and adult fish and other mobile organisms will tend to move to, and stay within, a preferred temperature range. The preferred temperature first selected by an organism depends on the initial acclimation temperature. Organisms continue to select progressively higher or lower temperatures until they reach their ultimate preferred temperature. This behavior provides a thermal environment, which approximates the optimal available temperatures for many physiological functions, including growth (Neill and Magnuson 1974). A species' ultimate preferred temperature (final preferendum) is usually near the upper end of its optimum range for growth (Brett 1971; Coutant 1975; Figure 6-9).

A consequence of thermal preference behavior is that fish in temperate and colder climates usually are attracted to heated water, such as may be caused by industrial discharges, during the fall, winter, and spring. When they are able to stay long enough to become acclimated to the warmer temperatures of the plume, there is potential for cold shock (i.e., a sudden decrease in temperature sufficient to cause severe thermal stress to aquatic organisms).

Information needed to assess the potential for cold shock associated with the complete shutdown of all units at the LEC was available for three of the six RIS selected for this assessment. In all cases, the LILT were less than the temperature exposures that would occur with complete shutdown of all units at the LEC (Figure 6-12 through Figure 6-15)[5]. Hence, there does not appear to be any potential for mortality associated with cold shock at LEC. Further, the likelihood that all units would be simultaneously shut down at the LEC is exceedingly low. For example, this never occurred over the 17-year period, 2002 – 2018; therefore, it does not appear that mortality from cold shock will be an issue at the LEC in the future.

[5] Guidance for interpreting Figures 6-16 through 6-22 is provided in Appendix C.

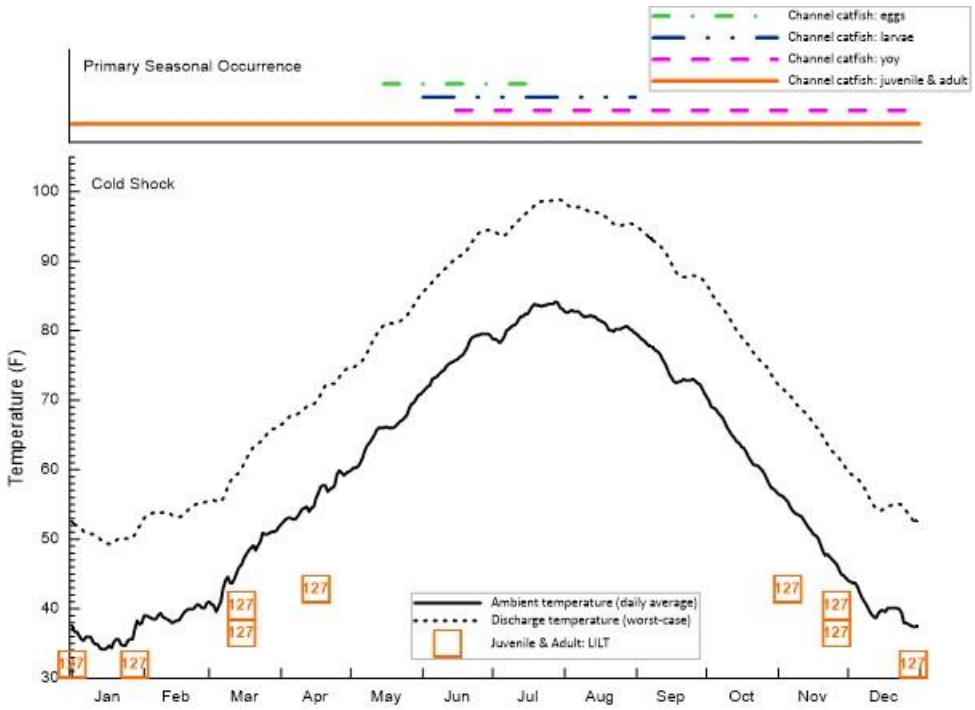

Figure 6-12 Thermal effects diagram relating to potential cold shock for channel catfish acclimated to maximum discharge temperatures and suddenly exposed to lower, ambient temperatures due to total instantaneous shutdown of all LEC generating units (numbers within thermal tolerance symbols are literature source codes).

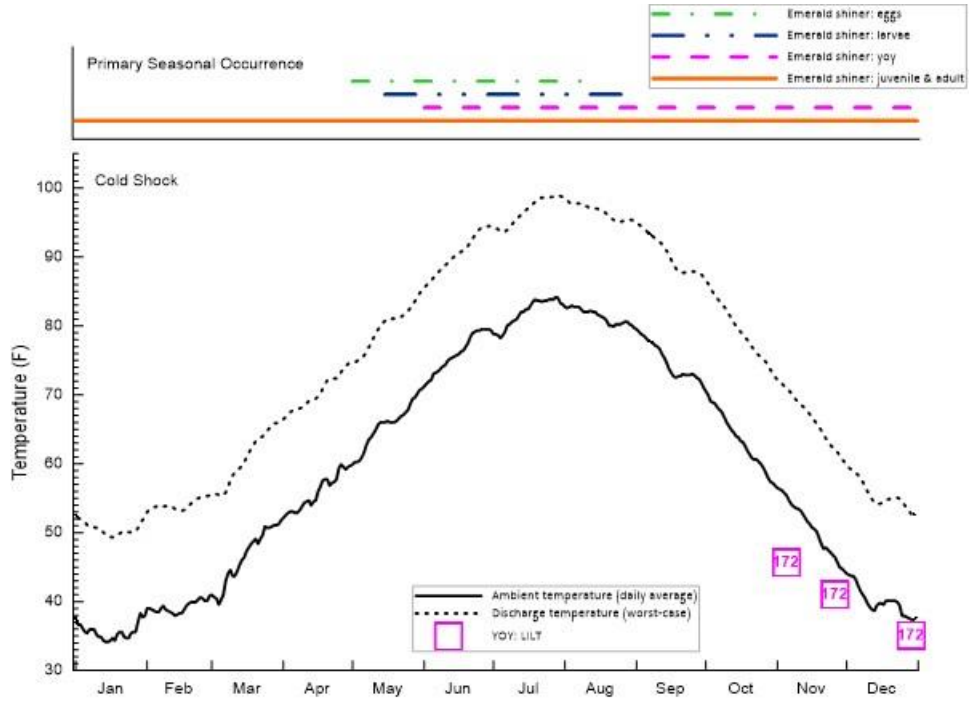

Figure 6-13 Thermal effects diagram relating to potential cold shock for emerald shiner acclimated to maximum discharge temperatures and suddenly exposed to lower, ambient temperatures due to total instantaneous shutdown of all LEC generating units (numbers within thermal tolerance symbols are literature source codes).

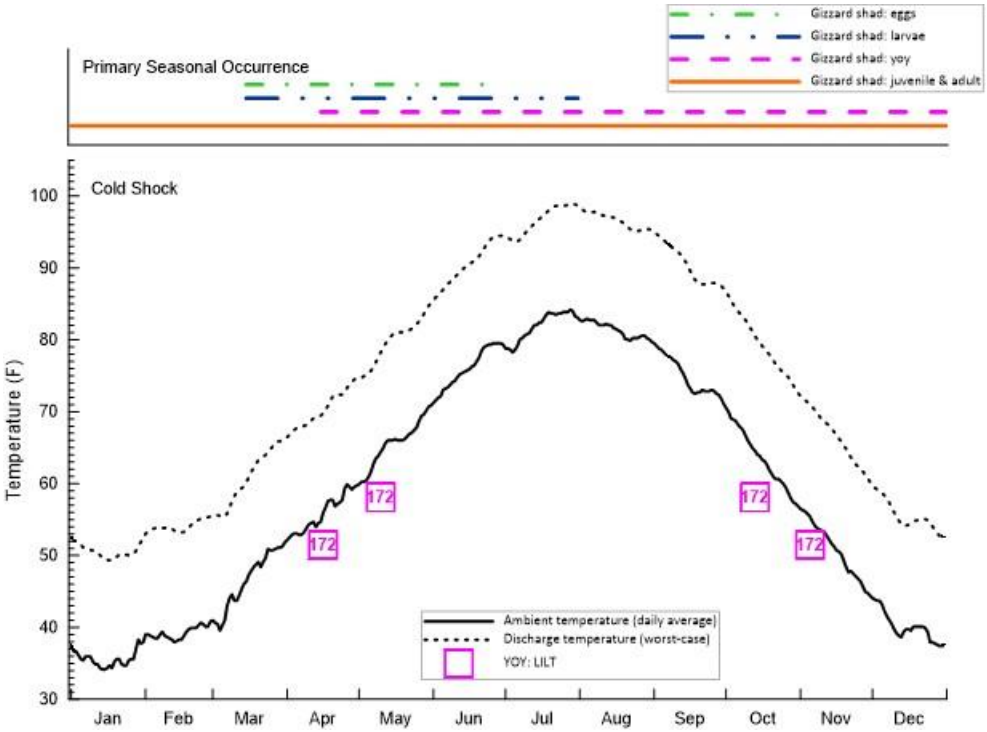

Figure 6-14 Thermal effects diagram relating to potential cold shock for gizzard shad acclimated to maximum discharge temperatures and suddenly exposed to lower, ambient temperatures due to total instantaneous shutdown of all LEC generating units (numbers within thermal tolerance symbols are literature source codes).

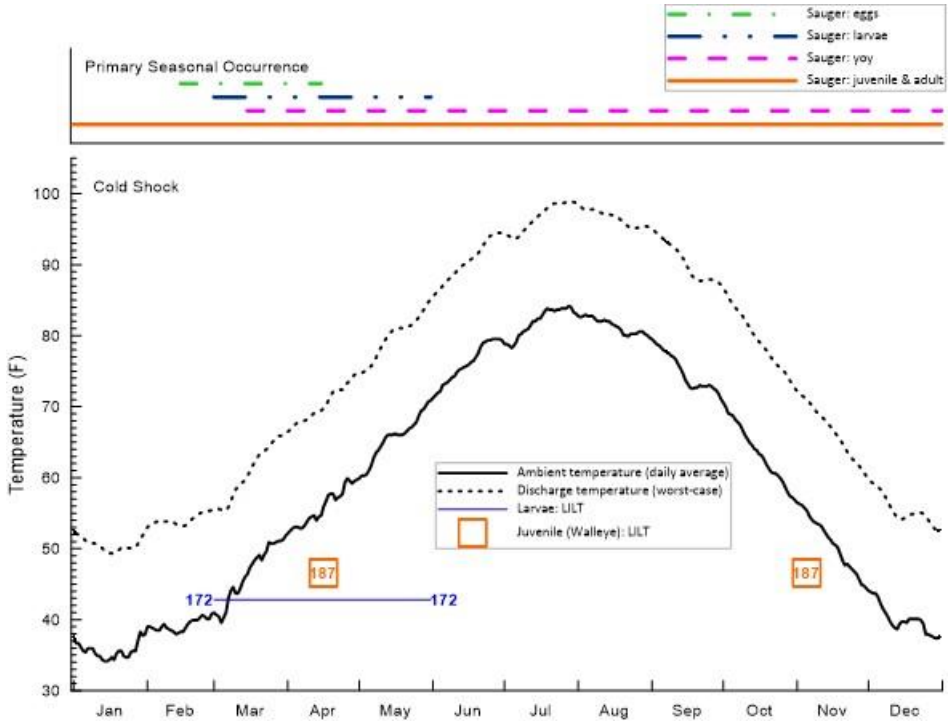

Figure 6-15 Thermal effects diagram relating to potential cold shock for sauger acclimated to maximum discharge temperatures and suddenly exposed to lower, ambient temperatures due to total instantaneous shutdown of all LEC generating units (numbers within thermal tolerance symbols are literature source codes).

6.3.2 Potential Effects Through Changes in Reproduction and Development

Thermal discharges can theoretically reduce reproductive success of species exposed to the plume by causing excessive shifts in the seasonal onset of spawning, disrupting normal egg development and hatch or reducing their growth and development. The potential for harm from such effects is a function of the spatial dimension of the habitat affected and the extent to which the affected zone is critical to the reproduction of the population. Since metabolic processes, such as body growth and egg maturation, are optimized for a limited range of temperatures, elevated plume temperatures can cause both increases and decreases in rates at which such processes occur.

Within the range of thermal tolerance there are temperature optima for metabolism controlling essential functions like growth and reproduction. Species are adapted to a range of temperatures in their environment over which they function at close to maximum physiological performance. As water temperatures increase above or below this range, physiological performance rapidly degrades. The optimum temperature range for growth is different for cold, cool, and warm water species, and also varies among developmental life stages of particular species. For example, the optimum temperature range for growth of most salmonids is between 54.5 °F and 61°F (NAS/NAE 1973); for American shad it is between 64°F and 75°F (Leggett and Whitney 1972; EA 1978a; IA 1978c), whereas the optimum temperature for growth of small juvenile striped bass is approximately 80°- 86.5°F (Kellogg and Gift 1983; Meldrim et al. 1974; Holland et al. 1971). The maximum value in a species' temperature range for optimal growth typically coincides with the organism's final temperature preference (Brett 1971; Coutant 1975).

Thus, there is a potential for thermal discharges to either increase or decrease an exposed organism’s physiological performance and growth by shifting water temperatures toward or away from its optimum temperature range. Changes in physiological performance, in turn, have the potential to directly affect growth and reproduction, and indirectly alter the competitive ability of species and change community composition. Spawning can be influenced by an array of factors varying among species, including lunar cycles, photoperiod (i.e., duration of daylight), and water currents in addition to water temperature (Hoar 1969; Hardy 1978; Middaugh 1981; Conover and Ross 1982; Conover and Kynard 1984; Tewksbury and Conover 1987). The act of spawning may be relatively instantaneous for an individual organism and may coincide with a relatively narrow range of water temperatures. However, the conditioning that precedes the event and assures that mature individuals are at the appropriate stage of reproductive development when spawning temperatures occur can be a period of weeks or months (Hoar 1969; Hokanson 1977; Jones et al. 1976). Thus, reproductive condition in fish may represent a biological response to the range and average of environmental factors experienced during an extended period. Temperature is but one factor in a complex interrelationship of conditions conducive to spawning. These factors interact to assure that the time of spawning usually coincides with conditions (e.g., temperatures, food availability) conducive to development and survival of embryo and larval stages.

In temperate zone waterbodies, such as the LMOR, inter-annual variations in temperature can occur at any given date, especially during the period of rapid warming in spring. These variations may advance or delay the seasonal timing of spawning during warm and cool years, respectively. In addition, the rate of development and growth of eggs and larvae is, in part, dependent on water temperatures. In relatively warm springs, the effect of early spawning and accelerated development tends to result in a relatively early peak egg and larval season.

The assessment of the potential for the LEC’s thermal discharge to adversely affect growth and development of each of the RIS is discussed in the following sections. Relevant life history information for each species summarized below is discussed in more detail in Section 6.2.

Channel catfish

Channel catfish spawn in nests most commonly between mid-May and mid-July in the LMOR (Figure 6-8). As the eggs are deposited in nests, eggs and the newly hatched larvae should experience very limited portion of the locally spawned individuals would be exposed to elevated temperatures from the LEC's thermal plume. For those individuals exposed, exposures to elevated temperatures could slightly advance spawning times and development rates yielding individuals slightly larger than those only exposed to ambient temperatures (Figure 6-16).

Emerald shiner

Emerald shiners have a prolonged spawning period in the LMOR extending from late May through early July (Figure 6-8). Non-adhesive eggs are broadcast at night in shallow water near the surface where they sink to the bottom over rocky substrate, hard sand, or firm mud. Hence, eggs and the newly hatched larvae of this RIS should experience very limited exposures to elevated temperatures from the LEC's thermal plume. For those individuals exposed, exposures to elevated temperatures could slightly advance spawning times and development rates yielding individuals slightly larger than those only exposed to ambient temperatures (Figure 6-17).

Gizzard shad

Gizzard shad appear to spawn in the vicinity of the LEC from approximately late March to late June (Figure 6-8). Spawning occurs in shallow water in relatively protected areas and eggs are adhesive and attach to the bottom. Hence, eggs and the newly hatched larvae of this RIS should experience very limited exposures to elevated temperatures from the LEC's thermal plume. For those individuals exposed, exposures to elevated temperatures could slightly advance spawning times and development rates yielding individuals slightly larger than those only exposed to ambient temperatures (Figure 6-18).

Pallid sturgeon

Pallid sturgeon spawning in the LMOR generally should occurs from the end of April through May, based largely on observed spawning of shovelnose sturgeon (Figure 6-8). Preferred spawning habitat includes coarse substrate in the river currents in or adjacent to the main channel near wing dikes. Sturgeon eggs are adhesive and should not be exposure exposed to LEC's thermal plume. Newly hatched larvae migrate up into the water column and drift downstream for up to 13 days. After a few weeks, juvenile sturgeon settle into benthic habitats and are no longer part of the drift. For those rare individuals exposed, exposures to elevated temperatures could slightly advance development rates (Figure 6-19). The optimum temperature for growth of pallid sturgeon estimated from laboratory test data is about 72.3°F which is higher than ambient temperatures.

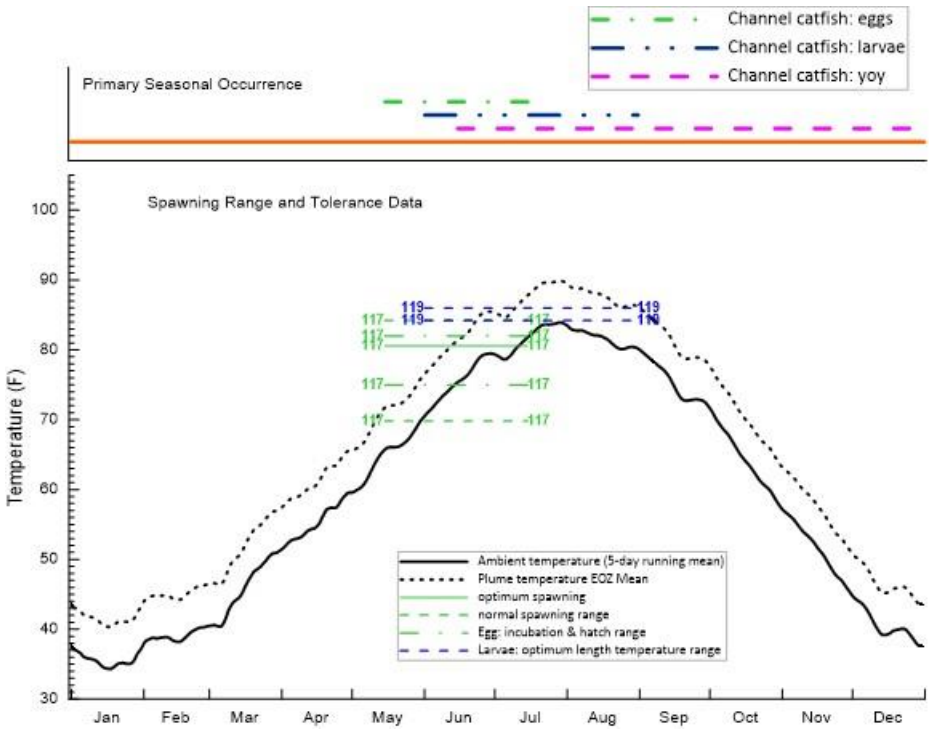

Figure 6-16 Reproductive success and growth data for channel catfish relative to their primary seasonal occurrence near LEC and to ambient temperatures and corresponding surface mean temperatures at the edge of the ZID.

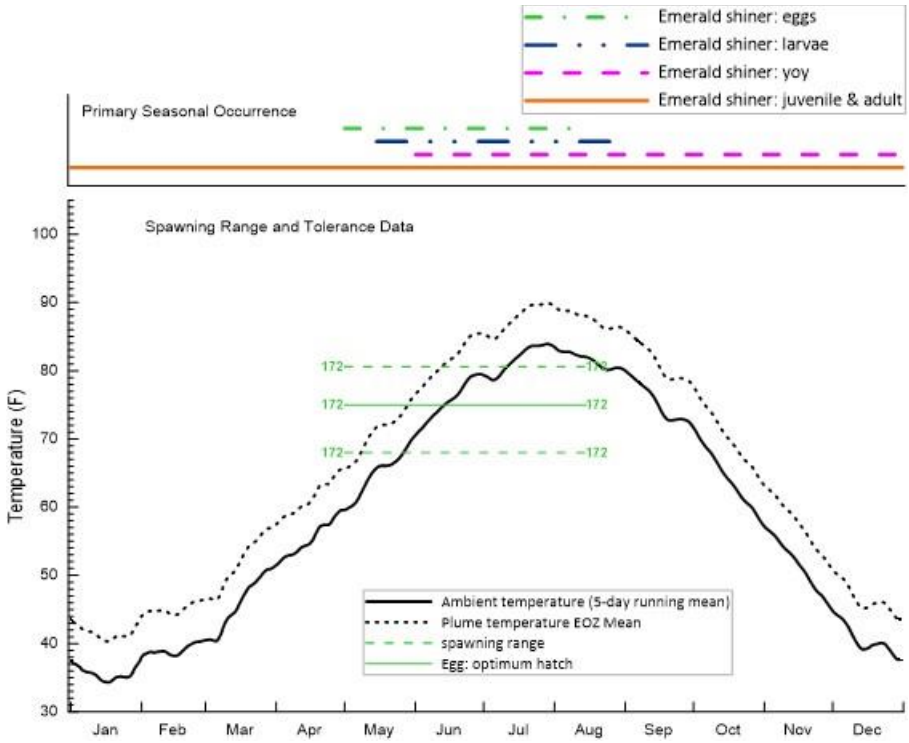

Figure 6-17 Reproductive success and growth data for emerald shiner relative to their primary seasonal occurrence near LEC and to ambient temperatures and corresponding surface mean temperatures at the edge of the ZID.

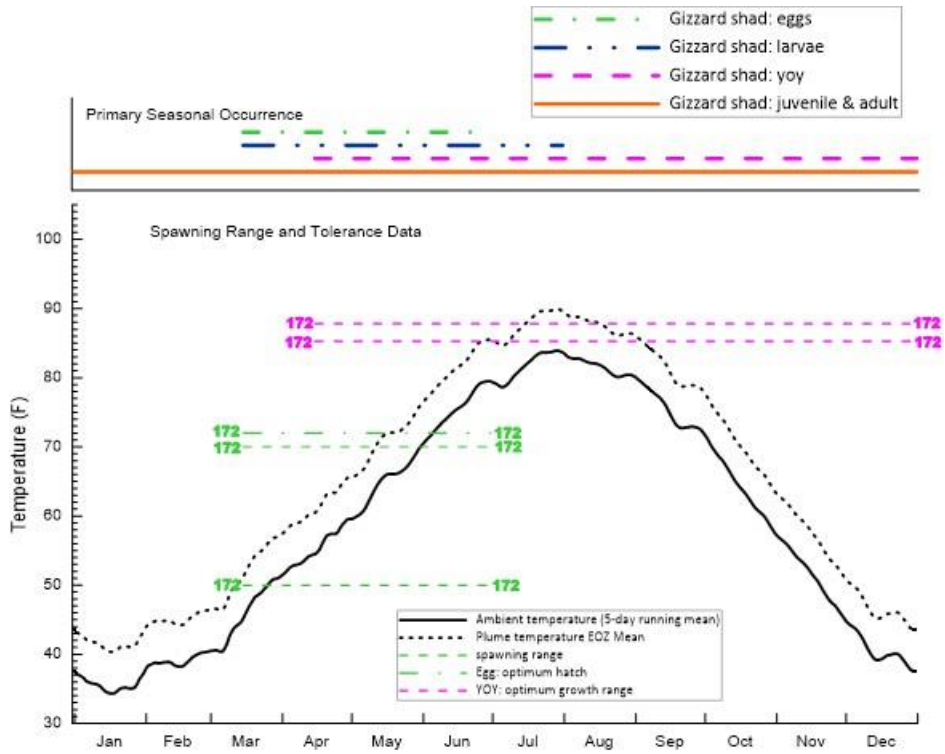

Figure 6-18 Reproductive success and growth data for gizzard shad relative to their primary seasonal occurrence near LEC and to ambient temperatures and corresponding surface mean temperatures at the edge of the ZID.

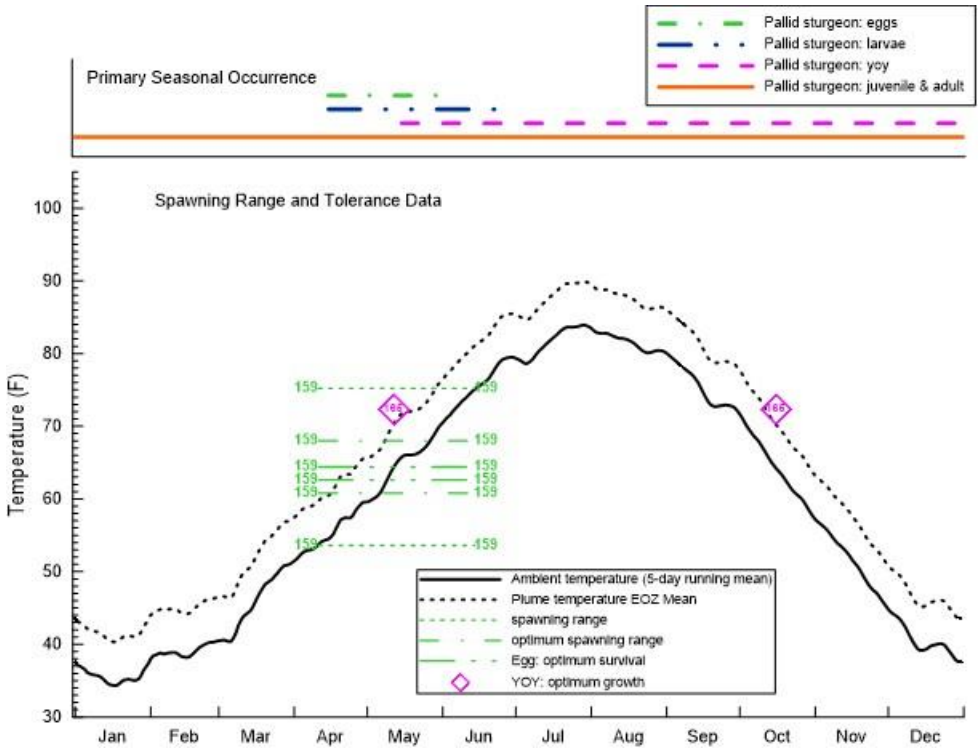

Figure 6-19 Reproductive success and growth data for pallid sturgeon relative to their primary seasonal occurrence near LEC and to ambient temperatures and corresponding surface mean temperatures at the edge of the ZID.

Walleye/sauger

Spawning of the two closely related species, walleye and sauger, typically occurs during February and March (Figure 6-8) in shallow shoreline areas, shoals, riffles, and the rock substrate at the base of dams. The demersal, adhesive eggs adhere to the substrate and should have minimal exposure to the LEC's thermal plume. A few days after hatch, the larvae swim up into the water column where they are transported by water flows to lakes or impounded river areas. For the later larval stages individuals exposed, exposures to elevated temperatures could slightly advance spawning times and development rates yielding individuals slightly larger than those only exposed to ambient temperatures (Figure 6-20).

White crappie

White crappie spawning occurs from March to July (6-8). The demersal, adhesive eggs should not normally be exposed to elevated temperatures from the LEC's thermal plume. A few days after hatch the larvae swim up into the water column where they are transported about by water currents. After approximately one month, the now juveniles retreat to the backwater nursery areas to avoid currents and actively feed and grow where they should experience minimal exposure to elevated temperatures. For those few individuals exposed, exposures to elevated temperatures could slightly advance spawning times and development rates yielding individuals slightly larger than those only exposed to ambient temperatures (Figure 6-21).

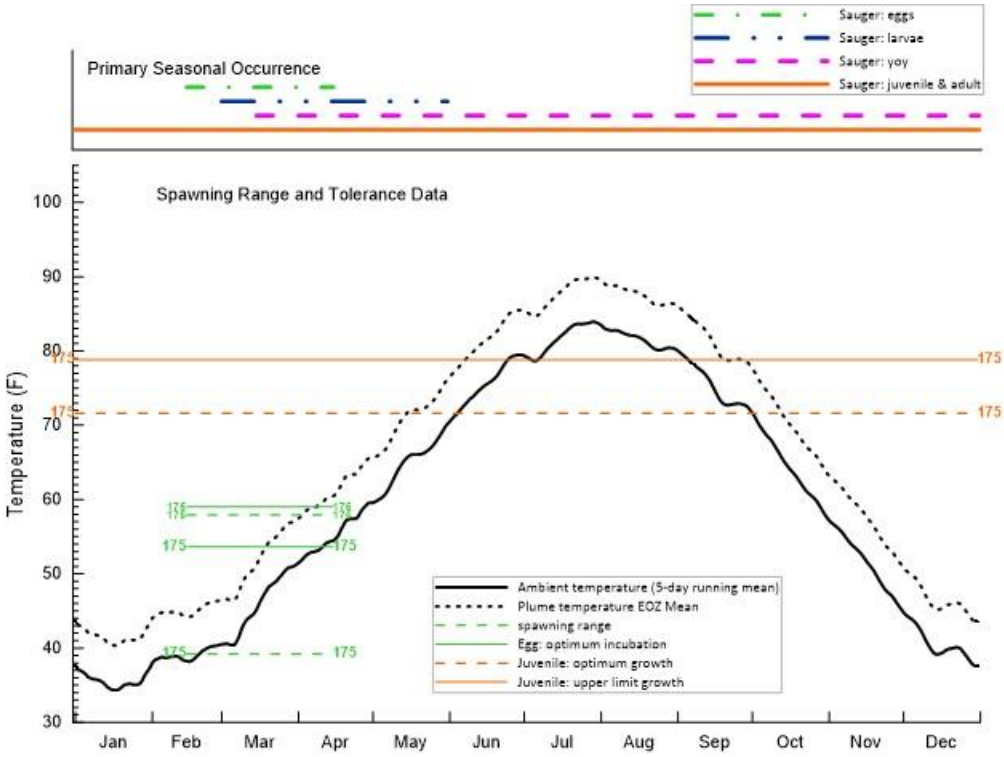

Figure 6-20 Reproductive success and growth data for sauger relative to their primary seasonal occurrence near LEC and to ambient temperatures and corresponding surface mean temperatures at the edge of the ZID.

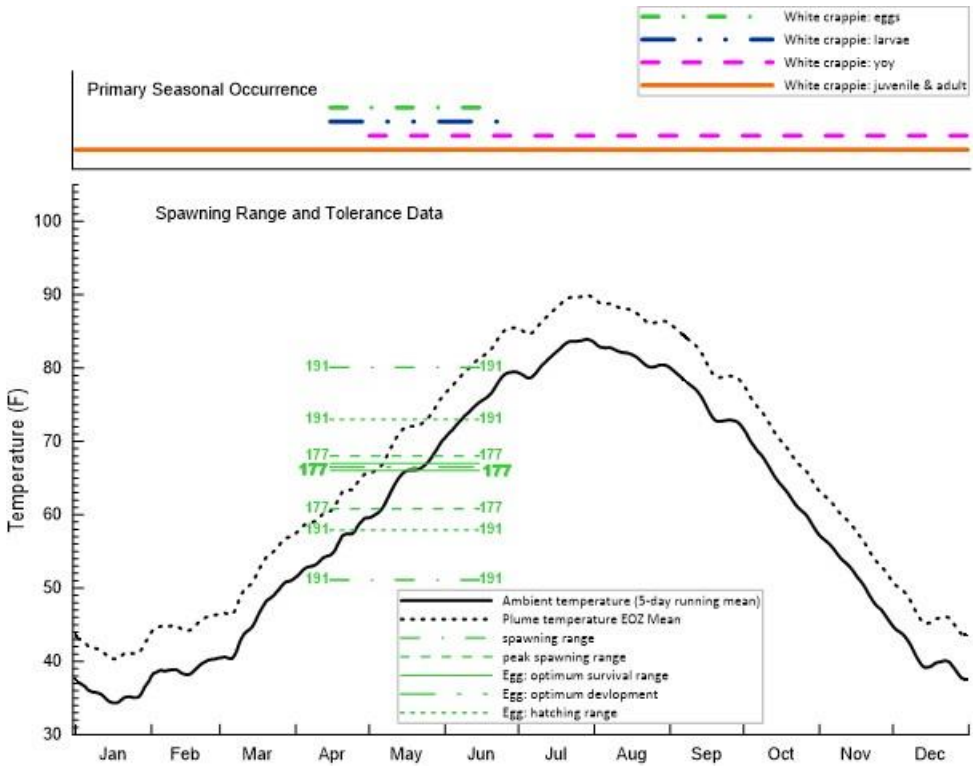

Figure 6-21 Reproductive success and growth data for white crappie relative to their primary seasonal occurrence near LEC and to ambient temperatures and corresponding surface mean temperatures at the edge of the ZID.

6.3.3 Potential Effects on Habitat Utilization and Migration

In the case of mobile species, organisms may adjust to their thermal environment behaviorally by movement along existing temperature gradients. When exposed to a temperature gradient, free-swimming juvenile and adult fish and other mobile organisms avoid stressful high temperature by moving through the gradient to water having lower temperatures (Meldrim et al. 1974; Neill and Magnuson 1974; TI 1976; EA 1978a). This is known as “temperature avoidance.”

Avoidance temperatures generally are close to, but slightly less than, the species UILT (Figure 6-9). The avoidance response precludes problems of heat stress from a thermal discharge for juvenile and adult fishes and other mobile organisms in open water systems such as the LMOR (USEPA 1976). The effect of localized elevations in temperature that approach thermal tolerance limits for such species is therefore generally limited to exclusion from otherwise usable habitat. Avoidance responses measured in the laboratory generally overestimate potential habitat exclusion in nature, because they do not account for long-term acclimation to elevated temperatures, or for other biological imperatives (e.g., feeding, migratory behavior) that may cause organisms to occupy areas at temperatures they might otherwise avoid. The focus of this assessment is on the potential for the LEC’s thermal plume to yield temperatures in excess of avoidances temperatures and, hence, block critical migratory pathways in the vicinity of the LEC.

For two of the RIS, channel catfish and emerald shiner, avoidance temperatures (Table 6-2) were higher than the temperatures observed in the vicinity of the LEC. Hence, the entire cross-section of the water column is available as a zone of passage for these species. For two other RIS, gizzard shad and white crappie, avoidance temperatures (Table 6-2) were occasionally exceeded as a result of the LEC’s thermal discharge. However, for both of these species, approximately half of the cross-sectional area in the vicinity of the LEC would still be available as a zone of

passage under the worst-case conditions. Under more typical operations, no blockage would be expected for these species. Walleye and sauger are both cool water species and ambient temperatures frequently exceed their avoidance temperatures during summer (Table 6-2). At these times, these species would be expected move to cooler areas upstream or thermal refugia. Their use of areas near the LEC are limited to spawning migration during late winter and early spring when ambient temperatures average 40 to 50°F. At these times, exposure temperatures should be substantially lower than reported avoidance temperatures indicating no potential for blockage of migration. While estimates of avoidance temperatures for pallid sturgeon are not available, studies on mortality from thermal exposures suggest this may be more heat tolerant than originally thought species (Chipps et. al., 2010; 96-hour CTM of 91.4°F). This heat tolerance coupled with the fact that this species would most likely be found in deeper channel areas, suggests little potential for migratory blockage.

6.4 ASSSESSMENT SUMMARY

A Predictive Assessment is a process in which potential effects of the thermal discharge are calculated using information on the known characteristics of the thermal plume, together with a detailed three-dimensional hydrological model of worst-case conditions during the late spring spawning and nursery period and during the worst-case conditions during the summer. These two modeled scenarios demonstrated that, under worst-case conditions, the LEC's thermal plume quickly mixed with water in the LMOR causing temperatures to decline rapidly within 20 to 30 minutes and to approach ambient conditions within a few miles of the discharge. Elevated temperatures were largely restricted to areas along the southern shore of the LMOR and highest temperatures were found near the surface.

Table 6-2 Estimates of cross-sectional areas available for fish passage in the LMOR in the vicinity of the LEC's thermal discharge based on the July 2006 worst-case model.

RIS	Stage	Upper Avoidance Temperature (°F)	Acclimation Temperature (°F)	Percent of Cross-Section Available for Passage	References
Channel catfish	Juvenile & Adult	95	86	100.0	Cherry, D.S., K.L. Dickson, & J. Cairns, Jr. (1975)
Emerald shiner	Juvenile	107.6	NA	100.0	Ellis (1984) in: Wismer and Christie (1987)
Gizzard shad	Adult	93.2	80.6-86	52.3	Yoder and Emery (2003)
Pallid sturgeon		NA		NA	
Sauger	All	82	NA	0.0	Coutant (1977a) in: Wismer and Christie (1987)
White crappie	All	89.6	80.6-86	47.7	Yoder and Emery (2003)

The potential biological effects resulting from exposures to the worst-case thermal exposures was assessed on the following RIS:

RIS	Rationale
Channel catfish	Recreational species
Emerald shiner	Important food chain species
Gizzard shad	Important food chain species
Pallid sturgeon	Endangered species
Walleye/sauger	Recreational and temperature sensitive species
White crappie	Recreational and temperature sensitive species

These RIS were selected to reflect the biotic components of the indigenous community that were not deemed to be low potential for impact.

The magnitude of biological effects of elevated temperatures from the LEC's thermal plume was evaluated through four modes of potential effect. The results of these evaluations are discussed below.

Potential for Heat-Related Mortality

The potential for direct mortality from exposures to elevated temperatures was limited to eggs and larvae that could be carried into the LEC's thermal plume by river currents. Older, more motile stages, of each of the RIS can detect, and actively avoid, temperatures lower than those known to cause mortality. For most of the RIS, the egg and early larval stages are predominantly in areas where exposures to elevated temperatures from the LEC's thermal plume are limited rendering little likelihood of thermal mortality in these stages. Older larval stages could be exposed to elevated temperatures owing to their presences in the water column. To evaluate the potential for heat-related mortality for these life stages, temperature exposures were compared to reported lethal temperatures based on laboratory studies for each RIS. For most of the RIS, this comparison revealed little chance for lethal effects from the LEC's thermal discharge. For those RIS with reported lethal temperatures lower than exposure temperatures, exposures are of short durations and are limited to a small portion of the cross-section very near the LEC's discharge. Hence, mortality, if any, from LEC's thermal discharge is likely to be very small and occur very infrequently.

Potential for Cold-Shock Mortality

Cold shock can occur when fish, acclimated to the warmer temperatures of the plume, experience a sudden decrease in temperature associated with the cessation of generation at the LEC. Such cold shock can cause mortality if the temperature drop is sufficiently large. Evaluation of lower temperature tolerances of the RIS compared to potential for temperature drops in the vicinity of LEC revealed virtually no potential for cold shock from winter shut down. Further, analysis of the LEC operation over the past 17 years did not find a single instance where all four units at the LEC were simultaneously shut down.

Potential for Growth and Development Effects

The potential for sublethal effects through changes in growth and development was evaluated by comparing long-term temperature exposures at the edge of the ZID to optimal temperatures for spawning and growth. This evaluation revealed no evidence of negative effects on growth and development to any of the RIS from continual exposure to the LEC's thermal plume. In fact, such exposures are more likely to advance development and increase growth of the RIS leading to larger individuals at the end of the growing season.

Potential for Blockage of Migration

The potential for the LEC's thermal plume to block migratory pathways was evaluated by comparing temperature exposures to avoidance temperatures based on laboratory studies. This evaluation is based on the conservative assumption that the RIS will not pass through water at temperatures greater than reported avoidance temperatures. This evaluation documented that avoidance temperatures were higher than exposure temperatures for four of the six RIS indicating no potential for migratory blockage. For the remaining two RIS with some potential for migratory blockage under worst-case conditions, approximately half of the cross-sectional area in downstream of the LEC's discharge remained available as a migratory pathway.

Overall, the results of this predictive assessment provide evidence that the LEC's thermal discharge has little potential to result in an imbalanced indigenous community in the LMOR for two reasons. First, LEC's thermal discharge results in a calculated TDP value of less than 0.95 more than 99 percent of the time (indicating compliance with the current permit temperature limit). Such compliance assures protection of designated uses in the LMOR, including fish propagation. Second, potential effects under worst-case conditions appear to be small, of limited duration, and not likely to adversely affect the populations of RIS. None of these effects are of sufficient magnitude to jeopardize the continued protection of a BIC in the LMOR.

7. MASTER RATIONALE

This Demonstration for the LEC was prepared to address requirement D.3.b of the LEC's NPDES permit issued by the MDNR on May 3, 2017. More specifically, this Demonstration evaluates whether the LEC past and current operation has resulted in appreciable harm to the aquatic biota in the LMOR near the LEC. In addition, this Demonstation asseses whether the proposed alternative effluent limits for temperature will assure the protection and propagation of the BIC of the LMOR.

Ameren is requesting the following alternative temperature effluent limit for those rare instances (less than 1 percent of the time based on historical records) when there is a potential for exceedance of the water quality standards for temperature as a result of the LEC's thermal discharge. This alternative limit is designed to allow for the continued operation of the LEC while, at the same time, assuring the protection and propagation of a balanced indigenous community (BIC) in the LMOR:

- A TDP of greater than 0.95 will be allowed under conditions when the river flow is less than 40,000 cfs or ambient river temperatures are greater than 87°F;
- A TDP of greater than 0.95 will be allowed in no more than 6 percent of the days in any calendar year; and
- On any day where the TDP is greater than 0.95, the mixing zone must be less than 40 percent of the volume of the river as calculated by the equations in the permit.

Under § 316(a) of the CWA, a permittee may obtain a § 316(a) variance 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.

The Guidance Manual describes a BIC as one that is typically characterized by diversity, the capacity to sustain itself through cyclic seasonal changes, and the presence of necessary food chain species. That is, the structure, function, and cyclical patterns typical of the waterbody's aquatic community should be maintained in the presence of the thermal discharge. The regulations also state that the BIC should not be simplified in structure or function and should not be dominated by pollution-tolerant species such as those tolerant of high temperatures or low dissolved oxygen. An "indigenous" community may contain species not historically native to the waterbody if they are present because of major irreversible modifications to the system or were deliberately introduced in wildlife management programs.

The purpose of this Master Rationale is to address whether the results of this Demonstration show that the LEC thermal discharge and requested § 316(a) variance meet the USEPA § 316(a) criteria for assessing appreciable harm.

7.1 INDICATORS OF APPRECIABLE HARM

The USEPA has determined that a community generally does not need to be protected from mere "disturbance," but rather that communities will be adequately protected if "appreciable harm" is avoided. The protection objective is typically to assure the sustainability of an indigenous community and protect its beneficial uses. In the terminology of Guidance Manual, this objective is prevention of "appreciable harm" which will assure the protection, propagation, and maintenance of the BIC. The criteria for evaluating appreciable harm include:

1. Presence of all trophic levels
2. Presence of necessary food chain species

3. Diversity
4. Capability to sustain itself
5. Lack of domination of pollution (heat) tolerant
6. No increase in nuisance species
7. Increase or decrease of indigenous species
8. No decrease in threatened and/or endangered species
9. No habitat exclusion due to temperature
10. Maintenance of a zone of passage
11. Change in commercial or sport species
12. No habitat former alterations
13. Magnitude and duration of any identifiable thermal effects
14. Sublethal or indirect effects
15. No thermal effects on rare or unique habitats
16. Presence of critical function zones within thermally exposed areas
17. Trends in the aquatic community
18. Interaction of the thermal discharge with other pollutants

These criteria focus the determination on population and community impacts. Still, demonstrating that the BIC is or will be assured in any receiving water body can be problematic since no operational definition of "balanced" is provided by the USEPA, and no quantitative standard for balance has ever been proposed. In this case, a weight-of-evidence approach using multiple lines of evidence for the LEC is used to evaluate the USEPA criteria and determine whether the thermal discharge has caused appreciable harm to the BIC in the receiving waterbody.

7.2 WEIGHT OF EVIDENCE RATIONALE FOR NO PRIOR APPRECIABLE HARM

Each of the appreciable harm criteria identified in Section 7.1 are addressed below using the results of the screening analysis and retrospective and predictive assessments conducted as part of this Demonstration.

1. Presence of all trophic levels

The area in the vicinity of the LEC thermal discharge was considered an area of LPI for phytoplankton, zooplankton, and habitat formers which are components of the lower trophic levels of the food chain. Benthic macroinvertebrate data showed they were equally abundant in the Upstream Reference and Thermally Exposed zones during all seasons of the year. Forage fish were abundant and comprised a large and similar portion of the fish assemblages in both the Upstream Reference and Thermally Exposed zones. Benthic feeders and top predators, while less abundant than forage species, similarly showed no difference between Upstream Reference and Thermally Exposed zones. The composition of the aquatic community in the Thermally Exposed zone shows the presence of the necessary trophic levels similar to the Upstream Reference zone, indicating that the structure of the community has not been adversely impacted by exposure to the LEC thermal discharge.

2. Presence of necessary food chain species

The fish collected during the current biological monitoring program represented feeding guilds from planktivores through top predators. Fish in each feeding guild were similarly abundant in the Upstream Reference, Thermally Exposed, and Downstream zones. As described above, forage fish and top predators comprised similar proportions of the fish community in all three zones. All the necessary food chain species are found in the Thermally Exposed and Downstream zones at the LEC.

3. Diversity

Diversity profiles for the both fish and benthic macroinvertebrates show that diversity in both assemblages was similar among the Upstream Reference, Thermally Exposed, and Downstream zones across gears and seasons. In the fish assemblage, forage and rough fish were the primary groups comprising the assemblages in the each of the three zones. Total fish abundance and dominant fish species were also similar across zones. In addition, the temporal analysis of the electrofishing data showed that fish assemblage diversity and composition has remained similar in both the Upstream Reference and Thermally Exposed zones over time. Thus, the evidence shows that diversity is being maintained and has not been adversely impacted as a result of exposure to the LEC thermal discharge.

4. Capability to sustain itself

The results of the predictive and retrospective assessments provide evidence that the biological community near the LEC is self-sustaining. The predictive analysis demonstrated the absence of significant mortality as a result of exposure to the LEC thermal plume for all life stages of the selected RIS, even under worst-case exposures. Similarly, RIS growth and development would not be negatively affected by the LEC thermal discharge. As a result, no adverse effects on the ability of the populations exposed to the LEC thermal discharge to sustain themselves are expected. This conclusion is supported by the retrospective analysis which showed multiple year classes and life stages evident in fish assemblage in the current study, no substantial shifts in the fish community over time, and no substantial changes in the current fish or benthic macroinvertebrate assemblages between the Upstream Reference and Thermally Exposed zones.

5. Lack of domination of pollution (heat) tolerant

Both fish and benthic macroinvertebrate assemblages were dominated by heat tolerant taxa in both the Upstream Reference, Thermally Exposed, and Downstream zones and the abundance of heat tolerant taxa was similar between zones. In general, heat sensitive taxa comprised only small proportions of the assemblages in each zone. The temporal analysis of the fish data show that heat tolerant taxa have not increased in the Thermally Exposed zone over time and remain at the similar proportions as in the Upstream Reference zone.

The temporal and spatial retrospective analyses provide evidence that pollution/heat tolerant and nuisance species have not become a dominant part of the fish or benthic macroinvertebrate assemblages due to the LEC thermal discharge.

6. No increase in nuisance species

Species of Asian carp, including bighead, silver, and grass carp, are among the most notable non-native, nuisance species now present in the LMOR. The invasive Asian carp have become increasingly abundant throughout the entire LMOR through a process of range expansion following their accidental escape into the Mississippi River basin, which is clearly not due to the LEC thermal discharge. Many of the fish classified as rough fish, including the Asian carps, common carp, and possibly gizzard shad can be considered nuisance species. The proportion

of rough fish in the Upstream Reference, Thermally Exposed, and Downstream zones was shown to be similar. The proportion of rough fish in the Upstream Reference and Thermally Exposed zones has also remained similar over time. Hence, the LEC thermal discharge has not caused an increase in nuisance species.

7. Increase or decrease of indigenous species

The bed, banks, and flow regime of the Missouri River have been modified and managed for navigation and flood control over many decades prior to the start of the LEC thermal discharge. Such river-wide modifications and loss of the natural riverine flow regime and habitats have greatly influenced the abundance of native species and affected the overall composition of the fish community. It has been reported that many native fish species are now rare, uncommon, or decreasing in abundance across part or all of their previous range as a result of this extensive habitat modification (NRC 2002). In many reaches of the river, the abundance of non-native species has become greater than that of native species because of their greater tolerance for river-wide changes, modifications and loss of the natural riverine flow regime and habitats. These changes to native fish populations have occurred in response to irreversible river modifications that are unrelated to the LEC thermal discharge and would have resulted in the absence of the discharge altogether.

The temporal retrospective analysis shows that the fish assemblage represented in electrofishing samples was comprised primarily of rough fish in both the Reference and Thermally Exposed zones both in the historical as well as recent studies. The overall composition of the electrofishing assemblages was similar between zones and over time. These results demonstrate that the LEC thermal discharge has not resulted in a decrease, locally or in the LMOR, of indigenous species.

8. No decrease in threatened and/or endangered species

The pallid sturgeon is the only federally endangered species potentially occurring in the vicinity of the LEC. Available information suggests that this species is declining throughout the Missouri River due to the loss of ecosystem integrity and the loss or alteration of preferred habitat and not due to the LEC's thermal discharge. Further, there are no designated critical habitat areas for pallid sturgeon in the LMOR.

9. No habitat exclusion due to temperature

Under typical plant operation, four of the six RIS would experience no habitat exclusion. Walleye and sauger are not typically abundant in the LMOR near the LEC during the summer period, since ambient river water temperatures are above their thermal tolerance limits. Under worst-case conditions, both gizzard shad and white crappie may experience some habitat exclusion along the southern shoreline just downstream of the LEC. Ample alternate habitat exists for gizzard shad and white crappie in the vicinity of the LEC that would offer temporary refuge from the elevated temperatures. For pallid sturgeon, little to no habitat exclusion is expected due to their expected heat tolerance. The predictive assessment demonstrates that substantial areas of habitat would not be excluded for all RIS.

10. Maintenance of a zone of passage

Under typical plant operation, four of the six RIS would have the entire river cross-section available as a zone of passage. Under worst-case conditions, gizzard shad and white crappie would have approximately half of the river cross-section available as a zone of passage. Walleye and sauger are only expected to be in the vicinity of the LEC during spawning migrations which occurs during cooler times of the year. At these times, no blockage of passage is expected for these species. The predictive assessment demonstrates that a zone of passage would be maintained at all times for all RIS.

11. Change in commercial or sport species

The retrospective spatial analysis shows the abundance of game fish is approximately equal in the Reference, Thermally Exposed, and Downstream zones, combining all seasons and gear types. Game fish also comprise approximately equal percentages of all fish in each of the three zones. The temporal analysis shows that there was a slightly higher abundance of game fish collected in the historical Thermally Exposed zone electrofishing study than the present study. These analyses provide no evidence that the LEC thermal discharge has resulted in a change or decrease in the number of sport or game fish.

12. No habitat former alterations

The screening analysis concluded that the LMOR near the LEC was found to be an area of LPI for habitat formers due to the river's velocity, turbidity, and silty substrate which were limiting factors to the colonization and development of habitat formers. These conditions, along with physical alterations to the river shorelines and persistently unstable substrate conditions demonstrates that the absence of habitat formers in the vicinity of the LEC is not related to the discharge and, even in the absence of the discharge, habitat formers would not be able to colonize the area.

13. Magnitude and duration of any identifiable thermal effects

The retrospective and predictive assessments show that there are no discernable effects related to the LEC thermal discharge outside of the Discharge zone, which is within the allowable mixing zone. The hydrodynamic modeling of various scenarios, including the most extreme discharge scenario over the last 17 years of LEC operation, shows that the elevated temperatures in the thermal discharge are rapidly attenuated after the confluence of the discharge with the Missouri River. At the most upstream end of the Thermally Exposed zone, mean daily temperatures within the thermal plume are, at most, 6°F above ambient. In addition, the thermal discharge is typically less than 5 percent of the Missouri River flow and the duration of any exposures are usually brief, transiting through the upper portion of the thermal plume within an hour and a half.

14. Sublethal or indirect effects

These types of effects are primarily related to reproduction and growth and may be experienced should the river temperatures fall outside of the range of optimum spawning and growth temperatures for individual species. The predictive assessment shows all RIS may experience slightly earlier spawning and increased growth rates under the worst-case conditions associated with the LEC thermal discharge. Little to no difference in spawning or growth rates are expected under typical plant operating conditions. These results demonstrate that no adverse effects on reproduction or growth are associated with the LEC thermal discharge.

15. No thermal effects on rare or unique habitats

There are no habitats in the Thermally Exposed or Downstream zones designated as "unique or rare" for this portion of the LMOR.

16. Presence of critical function zones within thermally exposed areas

There are no critical function zones (e.g., critical spawning and nursery areas) present within the Thermally Exposed and Downstream zones for any RIS. The predictive assessment also showed that there would only be minor episodic exclusion from a small area of habitat within the Thermally Exposed zone and only under worst-case exposures.

17. Trends in the aquatic community

The retrospective analysis shows diversity was similar over time and between the Upstream Reference and Thermally Exposed zones. Both Upstream Reference and Thermally Exposed

zones showed similar composition over time with the community being dominated by rough fish (e.g., Asian carp, common carp, gizzard shad) with game fish representing the next most dominant group. Most of the fish assemblage in the Upstream Reference and Thermally Exposed zones were heat tolerant and they comprised a similar percentage of the assemblage over time and among zones. A standardized difference test combining the results of multiple community metrics showed that the differences between the zones was inconsequential and demonstrating no appreciable harm to the aquatic community.

18. Interaction of the thermal discharge with other pollutants

In addition to the direct effects on the aquatic organisms, heat added to aquatic environments has the potential to impact the BIC through the additive or synergistic effects of heat combined with other existing thermal or other pollutants in the receiving waters. In the LMOR, there are no other sources of thermal discharges anywhere near the LEC such that there would be any overlaps of thermal plumes or their effects. Hence, there is no potential for additive or synergistic effects of the LEC's thermal discharges with any other thermal discharges.

Thermal discharges, alone, have the potential to interact with other pollutants and other water quality parameters through various physical, chemical and biological processes to increase their negative effects on aquatic ecosystems. The existence and magnitude of such effects will depend on site-specific conductions, including the magnitude of pollutant concentrations and degraded water quality conditions as well as the magnitude, spatial extent and frequency of occurrence of elevated temperature exposures.

The area of the LMOR near the LEC is considered degraded as a result of nutrient loadings, toxic chemical contamination, bacterial contamination and low dissolved oxygen concentrations (Section 2.1). The potential for the LEC's thermal plume to exacerbate each of these known problems is discussed below.

<u>Nutrients</u>

The LMOR near the LEC is known to contain elevated levels of nutrients, including organic nitrogen, nitrate, total phosphorus, and ortho-phosphorus, principally from upstream non-point source agricultural runoff. These nutrients can result in excessive algal growth leading to wide swings in dissolved oxygen levels and reductions in SAV through increased turbidity.

The areas of the LMOR exposed to elevated temperatures is relatively small and the water containing these nutrients pass through these areas rapidly (< 2 hours). Hence, there is little likelihood that the relatively small increase in temperature will demonstrably increase the rate of algal growth and result in greater adverse impacts to the LMOR.

<u>Chemical Contaminants</u>

The LMOR near the LEC is known to contain elevated levels of pesticides, PCBs and mercury. The first contaminant is most likely from upstream non-point source agricultural runoff whereas the latter two contaminants are most likely from industrial discharges to the LMOR. Each of these contaminant categories tend to accumulate in sediments.

The sediment areas of the LMOR exposed to elevated temperatures are relatively small and exposure temperatures are reduced owing to dilution. Hence, there is little likelihood that the relatively small increase in temperature will demonstrably increase the rate of contaminant uptake and result in greater adverse impacts to the LMOR.

<u>Bacterial Contaminants</u>

The LMOR near the LEC is known to contain elevated levels of bacteria from human sources including *Escherichia coli*. These anthropogenic bacteria most likely come from sewage

treatment facilities and urban runoff in the area. Currently, the MDNR lists the LMOR in the vicinity of the LEC as impaired as a result of *E. coli* contamination.

As with nutrients, the areas of the LMOR exposed to elevated temperatures is relatively small and the water containing these bacteria pass through these areas rapidly (< 2 hours). Hence, there is little likelihood that the relatively small increase in temperature will demonstrably increase the rate of bacteria growth and result in greater adverse impacts to the LMOR.

Dissolved Oxygen Concentration

The LMOR near the LEC is known to occasionally have dissolved oxygen (DO) concentrations less than the MO Water Quality Standard of 5 mg/l. These low DO concentrations can be attributed to loadings of nutrients and other organic materials from a variety of sources and most commonly occur during the warmer months of the year.

Elevated temperatures can yield lower DO levels through one of two processes. First, the solubility of oxygen in water is inversely related to water temperature. Hence, increases in temperature can result in off gassing of oxygen when DO concentrations are at saturation levels. However, since DO levels in the LMOR are rarely at saturation levels, this process is not likely to have any effect on DO levels in and adjacent to the LEC's thermal discharge. Second, elevated temperatures can increase the chemical and biological processes that require oxygen and result in lower DO levels in the water. However, as is the case with nutrients and bacteria, the area of the LMOR exposed to elevated temperatures is relatively small and the water containing the oxygen passes through these areas rapidly (< 2 hours). Hence, there is little likelihood that the relatively small increase in temperature will demonstrably increase the rate of oxygen consumption and result in greater adverse impacts to the LMOR.

These conclusions regarding the effects of the LEC's thermal discharge on DO levels in the LMOR are supported by the results of DO monitoring conducted in the vicinity of the LEC as part of the biological monitoring studies. Cumulative percent plots of the DO measurements collected during July and August, when water temperatures are highest, reveal no demonstrable differences in the distribution of DO levels across the zones of thermal exposure (Figure 7-1). This further supports the conclusion that the LEC's thermal discharge is not resulting in lower DO levels in the LMOR.

Overall, the results of this analysis demonstrate that the LEC's thermal discharge will not exacerbate existing environmental issues in the LMOR through additive or synergistic effects of the heat discharged combined with other existing thermal or other pollutants.

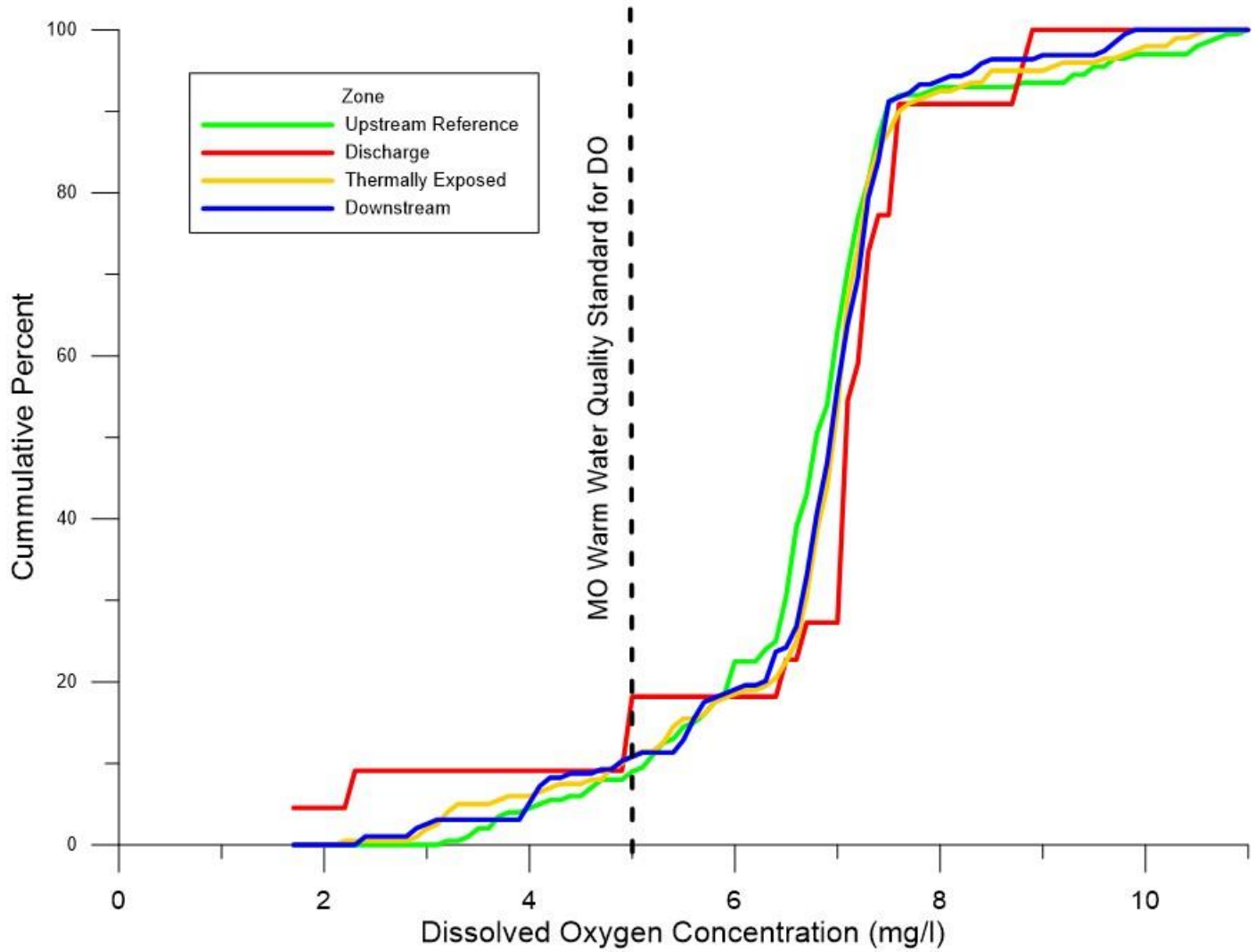

Figure 7-1 Cumulative percent of measured dissolved oxygen concentrations from July and August above and below the MO water quality standard for dissolved oxygen.

7.3 OVERALL CONCLUSIONS

The screening analysis and the retrospective and predictive assessments were used to evaluate 18 decision criteria for assessing appreciable harm identified by the USEPA. In each case the available data and analyses demonstrate that the decision criteria were satisfied indicating that no prior appreciable harm has occurred as a result of the LEC's ongoing thermal discharge and the requested alternative temperature effluent limitation (§ 316(a) variance) will assure the protection and propagation of the BIC in the LMOR.

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APPENDIX A
LABADIE ENERGY CENTER § 316(a) STUDY PLAN AND ADDENDA

APPENDIX B
RETROSPECTIVE ASSESSMENT TABLES

APPENDIX C
RIS PREDICTIVE EVALUATION METHODS

LABADIE ENERGY CENTER
§316(a) FINAL DEMONSTRATION

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APPENDIX A
LABADIE ENERGY CENTER § 316(a) STUDY PLAN AND ADDENDA

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1. INTRODUCTION

The Labadie Energy Center (LEC) is a steam electric power plant located in Labadie, Missouri on the south bank of the lower Missouri River near River Mile (RM) 57 in Franklin County, 35 miles west of St. Louis, Missouri (Figure 1). The Center has four generating units, each with two circulating water pumps, and a total net capacity of 2,407 megawatts (MW). The LEC utilizes once-through cooling. Cooling water for each unit is withdrawn from the Missouri River via a shoreline intake structure (Figure 2). The resulting heated effluent is discharged (via National Pollution Discharge Elimination System (NPDES) Permit MO-0004812, Outfall 001) to a 1,400-foot-long discharge canal and the adjacent navigation channel of the Missouri River (Figure 2).

Permitting history

The LEC's first unit came online in 1970 and the facility became fully operational in 1973. The LEC was issued an initial NPDES permit in 1975 that specified an effluent temperature limit of 118° F and a schedule for conversion to off-stream cooling by 1981. A 316(a) variance was approved and a new, revised permit issued in 1977 based upon the results of a comprehensive biological and hydrothermal modeling study. The new permit contained an alternate effluent limitation of 10.63 x 10^9 British thermal units (BTU)/hr and removed the prior limit of 118°F and the off-stream conversion requirement.

The LEC applied to renew the 316(a) variance over the next two permit cycles and the renewed variance was granted for the 1982 and 1987 NPDES permits. An application for permit renewal and request for a renewed variance and revised heat rejection limit of 11.16 x 10^9 BTU/hr was submitted along with supporting thermal plume and biological monitoring information in 1992. The new heat rejection limit was based on a revised calculation and represented no additional heat output. The permit was approved in 1994.

An application for the renewal of the LEC NPDES permit and 316(a) variance was submitted in 1998. The permit was not reissued at that time and the department requested a revised renewal application in 2011. The LEC NPDES permit was granted and reissued as the current permit effective August 2015. The current NPDES permit has an interim heat rejection limit of 11.16 x 10^9 BTU/hour with a 10-year compliance schedule to meet the water temperature criteria in the Missouri Water Quality Standards of 90° F and a change in temperature of +/- 5° F. In addition, the LEC is required to reestablish a biological monitoring program to evaluate the potential impacts on aquatic communities.

Missouri River

The Missouri River has changed dramatically over the past century as the result of man's efforts to manage the river for navigation and flood control. Modifications to the river and its floodplain began in the late 1800s simply with removal of snags to permit navigation (NRC 2002). Channel enhancements began in the early 1900s, and damming and flow regulation began in the 1930s. The river modifications culminated in the construction of five US Army Corps of Engineers (USACE) dams on the upper mainstem of the river in the 1950s and 1960s and the completion of the Missouri River Bank Stabilization and Navigation Project in the lower, unimpounded river in 1981. These modifications have reduced or eliminated the river's natural flow regime in which flood pulses in the spring and early summer would create new and productive habitats, cycle organic material and nutrients between the channel and floodplain, replenish water in the floodplain, and serve as cues for spawning of fish and other organisms. As a result, the amount

of productive, natural habitat has been greatly reduced. To mitigate the loss of riverine habitat and the natural flow regime, the USACE has instituted the Missouri River Recovery Program.

The LEC is located on the south bank in the channelized reach of the lower Missouri River. The river in this section has also been substantially altered over time by the construction of revetments and dikes and by dredging to maintain a 300-ft wide navigation channel that is at least 9 ft deep. As a result, the channel now is narrower and more uniform than its previous form, with a trapezoidal cross-section resulting in steeper embankments and faster currents. River meanders have been straightened, natural riparian vegetation has been lost, variations in river flows and water temperatures are reduced, periodic overbank flow to the floodplains and its nutrient cycling benefits have been eliminated or reduced, sediment transport is reduced, and natural processes of cut and fill alleviation have been modified.

The modifications and reduction and/or loss of the natural riverine flow regime and habitats has greatly influenced the abundance of native species and affected the overall composition of the fish community. Many native fish species are now rare, uncommon, or decreasing in abundance across part or all of their previous range due to the changing ecosystem and habitat losses during recent decades (NRC 2002). Berry and Young (2001) estimate that approximately 35 native species are declining in abundance while 23 species are increasing. In many river reaches, the abundance of non-native species has become greater than that of native species because of their greater tolerance for the altered temperature regime, flow, turbidity, and habitats. Some of the native species most affected include the pallid sturgeon, plains minnow, sauger, sturgeon chub, and sicklefin chub (NRC 2002).

Historical thermal and biological studies

The LEC conducted a comprehensive biological study and hydrothermal modeling effort as part of the initial NPDES permit application from 1974 to 1975. Hydrothermal modeling delineated the thermal plume under various river flow and temperature scenarios and evaluated the potential for compliance with the Missouri water quality standards outside the mixing zone (Edinger and Buchak 1976). Biological studies included data collection on fish (electrofishing and seining), benthic macroinvertebrates, periphyton, phytoplankton, and zooplankton. Samples for fish, benthic macroinvertebrates, and periphyton were generally collected from both sides of the river upstream of the discharge, just below the discharge, in the discharge canal, and approximately 2 miles below the discharge. Samples for phytoplankton and zooplankton community composition analysis were collected from the intake and discharge areas. The study concluded that the LEC was a site of low potential impact (LPI) for all biotic categories (EEH 1976; Union Electric Company 1976).

Routine biological monitoring of the fish community in the vicinity of the LEC was conducted by Ameren from 1980-1985 and from 1996-2001 (Ameren 2002). Fish were sampled quarterly by electrofishing at five sites in the vicinity of the LEC during the period of each study. Analyses were conducted to compare various metrics, including catch per unit effort (CPUE), diversity/species richness, relative abundance, biomass, and condition factor, between the two sampling periods and with the original 1975-76 study. The studies concluded that the fish community in the vicinity of the LEC was healthy, self-sustaining, and show no adverse impacts from the LEC thermal discharge (Ameren 2002).

In conjunction with the most recent LEC NPDES permit renewal, the Department requested that the United States Fish and Wildlife Service (USFWS) provide fisheries data on the lower Missouri river. The USFWS provided data collected from 2003 to 2011 on a 20-mile segment of the

Missouri river bracketing the LEC. A brief analysis of the data is presented in the 2015 NPDES permit fact sheet. Fish were collected using four gear types – mini-fyke nets, push trawls, otter trawls, and trammel nets. Comparison of the total number of fish, average number of fish per set, and species richness data between stations upstream of the LEC to stations downstream of the LEC showed no significant differences.

The current LEC NPDES permit (MO-0004812) requires that Ameren reestablish a biological monitoring program in accordance with 40 CFR 125 Subpart H to evaluate the potential impact of the thermal discharge. The biological monitoring program must collect data sufficient to support water quality and biological assessments to assure the protection and propagation of a balanced indigenous community (BIC) of fish, shellfish, and macroinvertebrates in the Missouri River in the vicinity of the LEC's thermal discharge.

This study plan outlines the anticipated approach for conducting the required water quality and biological data collection and a biothermal assessment.

2. 316(a) APPROACH OVERVIEW

The 316(a) studies will have three main components:

- Hydrothermal modeling;
- Biological monitoring studies; and
- Biothermal assessment.

A state-of-the-art three-dimensional hydrothermal model will be applied to assist in the delineation of the thermal plume for sampling site selection. The biological monitoring studies will provide the abundance and spatial and temporal distribution information for a retrospective biothermal assessment to evaluate whether the BIC in the Missouri River is being protected. It is anticipated that data collection for the biological monitoring studies will be initiated in early 2017 and continue for a period of 2 years (i.e., through the end of 2018). The remainder of this section provides an overview of the approach for the hydrothermal modeling, biological monitoring studies and the biothermal assessment.

2.1 HYDROTHERMAL MODELING

A state-of-the-art three-dimensional hydrothermal model (Flow 3D, RMA-10, or similar model) will be applied using available bathymetry, field temperature measurements, meteorological data, river flow, and plant operational data. The hydrothermal model application and the selection of sample collection locations will consider and account for the salient features of the river downstream of the LEC discharge such as wing dikes that affect the river flow, habitat type, and distribution of water temperature. The selected hydrothermal model will be used to characterize the LEC's thermal plume over a range of environmental and LEC operational conditions.

The hydrothermal modeling will assist in the design of a biological monitoring program within the area of the lower Missouri River adjacent to the LEC. Information on the thermal plume distribution will be used to delineate thermally exposed and downstream sampling zones.

2.2 BIOLOGICAL MONITORING STUDIES APPROACH

The biological monitoring studies proposed in this study plan will employ a spatially-stratified sampling scheme to account for factors such as habitat type and degree of exposure to the LEC's thermal plume. Samples will be collected within a thermally-exposed zone, an upstream control zone, and a downstream zone. The proposed studies will be conducted using a phased approach

that will result in a robust data collection program. First, habitats within the sampling zones delineated as part of the hydrothermal modeling will be mapped and potential sampling locations identified. Second, the biological sample collections will be conducted.

Phase I of the study plan will consist of:

- Habitat characterization/mapping.

Using the delineated sampling zones, areas of available and similar habitats within each zone will be identified for biological sampling using a combination of existing maps, charts, and other available information. A preliminary habitat map showing the basic habitat types within each zone will be prepared. A field survey will be conducted to evaluate the accuracy of the habitat type map by qualitatively assessing various habitat parameters such as, but not limited to, shoreline type, substrate type, water depth, and current velocity.

The combination of hydrothermal modeling to delineate the sampling zones and habitat characterization to identify the habitat types present will provide the basis for selecting the sampling locations for the fish and benthic macroinvertebrate and shellfish collection programs.

Phase II of the study plan will consist of the biological data collection programs:

- Fish; and
- Benthic macroinvertebrates and shellfish.

Fish surveys will be conducted using a variety of sampling gears to collect samples for all substantively present habitat types in each of the sampling zones. The use of multiple sampling methods will serve to avoid gear bias and ensure a more complete inventory of the species present in the subject receiving stream segment. Sample collection for adult and juvenile fish will be conducted monthly during a two-year period. Ichthyoplankton samples in wing-dike and/or L-dike field habitats will be collected biweekly from mid-March through July and monthly during August and September during a two-year period. Ichthyoplankton data from ongoing entrainment sampling at the LEC will be used as an additional source of information to fully characterize the ichthyoplankton community and drift composition.

Benthic macroinvertebrate and shellfish samples will be collected from depositional and rock/gravel habitats quarterly during a two-year period. Samples from depositional habitats will be collected using a standard (9-inch x 9-inch) ponar dredge. Samples from rock/gravel habitats will be collected using Hester-Dendy (H-D) multi-plate samplers.

These biological data collection programs will form the basis for the biothermal assessment.

2.3 BIOTHERMAL ASSESSMENT APPROACH

A biothermal assessment of LEC's thermal discharge will be conducted using a well-established retrospective impact assessment approach. The results of this approach will constitute a line of evidence in an overall impact assessment.

The retrospective assessment will use the results of the two-year biological monitoring program in the vicinity of the LEC, as described in this study plan, and historical data to determine whether there is evidence of prior appreciable harm to the BIC from the LEC thermal discharge. For this evaluation, data characterizing communities in the thermally exposed zone, upstream control, and downstream zones, as well as historical community data, will be carefully analyzed to determine whether there is evidence that LEC's thermal plume has caused appreciable harm to

the BIC over the full term of the LEC's operations. The results of the retrospective evaluation will then be compared to phenomena identified by USEPA as evidence of appreciable harm to biological communities. The potential for the LEC's thermal discharge to be the cause of observed changes at the population or community level will be assessed in light of the nature and magnitude of predicted thermal effects and potential interactions with other known stressors.

Depending upon the results of the biological studies, retrospective biothermal assessment, and the need to compile a comprehensive variance request, a predictive biothermal assessment may also be conducted. The predictive biothermal assessment would utilize hydrothermal modeling to estimate exposure temperatures and durations. These would be compared to literature-based thermal tolerance limits for selected species to determine the likelihood and magnitude of biothermal responses elicited by temperatures in LEC's thermal discharge to assess their significance in the context of the regulatory standards and requirements, i.e., the protection and propagation of a Balanced Indigenous Community (BIC).

The significance of biothermal effects will equate to their potential for causing "appreciable harm," according to 40 CFR 125 Subpart H and guidance provided by USEPA's *Draft Interagency 316(a) Technical Guidance Manual and Guide for Thermal Effects Sections of Nuclear Facilities Environmental Impact Statements.*[1]

3. HYDROTHERMAL MODELING

Objective(s)

To characterize the extent of the LEC's thermal plume across and downstream from the discharge under varying combinations of meteorological, river flow, river temperature, and plant operating conditions. Delineation of the thermal plume and the ability to model seasonal thermal discharge and river flow scenarios will assist in the selection of biological sampling locations.

Model Inputs

A state-of-the-art three-dimensional hydrothermal model (Flow 3D, RMA-10, or similar model) suitable for achieving the present study objectives will be selected and adapted to the adjacent Missouri River.

Available shoreline and bathymetric data will be used to apply a computational mesh over the model domain. Bathymetric data will be obtained from United States Army Corps of Engineers (USACOE) surveys conducted in 2001, 2007, 2009, 2013, and 2014. The computational mesh contains discrete points (nodes) where initial condition and depth data are input to the model. In this case, the river model domain will start upstream of LEC's intake and extend several miles downstream. The mesh will include the discharge canal, and mesh spacing will be refined locally in the canal and adjacent receiving waters.

Available United States Geological Survey (USGS) gage data and LEC operational data will be used to identify the historical range of values for model input variables including river flow, river water temperature, plant intake and discharge flows, plant load, and plant discharge temperatures. Understanding the range of values for these input parameters will allow the selection of the most appropriate combinations of variables for model runs to evaluate the across and downstream extent of the thermal plume.

[1] *U.S. Environmental Protection Agency, Office of Water Enforcement, Permits Division, Industrial Permits Branch (May 1, 1977).*

Field collected water temperature data will be used to validate the hydrothermal model. The available field collected data include discrete plume temperature measurements that were collected on four separate days (one day each in July 2003, August 2003, January 2004, and April 2016).

Biological sampling program support
The selected three-dimensional hydrothermal model will be run under various environmental and operational scenarios to delineate the thermal plume extent/characteristics. This will include a model projection of the downstream and across-river extent of the thermal plume to locate boundaries of potential thermally exposed and downstream sampling zones.

4. BIOLOGICAL MONITORING STUDY PLAN

This study plan is designed to be responsive to the requirements outlined in Section D Schedule of Compliance – Thermal Discharges of the Labadie NPDES permit including:

- Collecting water quality and biological data to demonstrate the protection and propagation of a balanced indigenous community of fish, shellfish, and benthic macroinvertebrates in the Missouri River in the vicinity of the plant's thermal discharge;
- Providing information on the diversity of the aquatic community and the presence of the necessary food chain species;
- Collecting data to demonstrate the non-dominance of pollution-tolerant species;
- Showing the community can sustain itself through cyclic seasonal changes; and
- Upstream and downstream biological reference areas.

4.1 PHASE I

The information and data compiled in this first phase of study will be used to design a sample collection program for fish and benthic macroinvertebrates and shellfish that is stratified by habitat type and degree of exposure to the thermal discharge.

4.1.1 Habitat Survey and Characterization

Objective(s)
To identify dominant habitat types within the thermally exposed, upstream control, and downstream zones so that sample collection may be stratified by habitat type and that all substantially present habitat types are sampled. Habitat type will also dictate, in part, the selection of sampling gear.

Habitat characterization
A preliminary, desktop characterization of the potential habitat types in the thermally exposed, upstream control, and downstream zones will be conducted by reviewing existing sources of data and information on the Missouri River in the vicinity of the LEC. These sources will include, but may not be limited to, bathymetric data, aerial photography, and navigational charts. A preliminary map will be developed to denote the areas of habitat identified.

Habitat survey
A field survey will be conducted to evaluate the accuracy of the preliminary habitat map, fill in any data gaps identified in the initial habitat characterization, and identify potential sampling locations. During the survey, a qualitative evaluation of habitat identifying parameters will be conducted in

areas for which the preliminary habitat identification cannot be clearly confirmed. These parameters may include, but may not be limited to:

- Shoreline type
- Geomorphological features
- Water depth
- Flow
- Substrate type

In addition, any data collection necessary to fill in data gaps identified during the initial habitat characterization will be conducted during the habitat surveys. In particular, if the existing bathymetric data are lacking the necessary detail or spatial coverage for the habitat characterization, new bathymetric surveys may be conducted. New bathymetry surveys may cover the entire anticipated range of the biological survey area or be used to fill in areas with insufficient coverage. If a new survey is needed, a detailed methodology will be developed.

4.2 PHASE II

Based upon the information collected in Phase I, specific sampling sites will be selected to account for differences in habitat type and thermal exposure. This will provide a valid basis for statistical analysis of the data. While the exact sampling sites will be identified subsequent to the thermal plume delineation and habitat characterization, this section presents some anticipated sites and details on the other aspects of the fish and benthic macroinvertebrate surveys.

4.2.1 Fish Surveys

Objective(s)

To document and compare the presence, characteristics, and relative abundance of fish species in thermally exposed, upstream control, and downstream sampling zones. Data from the current study, in conjunction with historical data, will be used to evaluate whether a BIC, as defined in 40 CFR Part 125 Subpart H, is present and has been maintained within the study area.

Site selection

The study design includes three sampling zones: upstream control, thermally exposed, and downstream. The upstream control zone will include habitats upstream of the discharge that are comparable to the habitats selected for sampling in the thermally exposed zone. The thermally exposed zone will be the zone of greatest thermal exposure (e.g., > 5° F above ambient) and will begin at the discharge and extend downstream. The downstream zone will include habitats downstream of the thermally exposed zone that are comparable to the habitats selected for sampling in the thermally exposed zone. The delineation of the thermally exposed and downstream zones will be re-evaluated after conducting the preliminary hydrothermal modeling and habitat characterization and in consultation with the Missouri Department of Natural Resources (MDNR).

Habitat selection for sampling will depend on the results of the Phase I hydrothermal modeling and habitat characterization/mapping. Habitats to be sampled within the thermally exposed zone will be identified first, then comparable habitats will be selected for sampling in the upstream control and downstream zones. Factors that will be considered in selecting habitat types for sampling will include, but may not be limited to, the amount of the habitat type within the thermally exposed zone, the overall level of sampling effort, uniqueness of a habitat type and importance to productivity, and the potential to yield additional species to the inventory. Once habitat types

have been selected for sampling, they will be identified using the nomenclature convention from Welker and Drobish (2012).

Each discrete area of a particular habitat type within a zone will be identified as a potential sampling site (e.g., three discrete areas of wing dike pool habitat within the thermally exposed zone will imply that there are three potential sampling sites within that zone for wing dike pool habitat). If more than one discrete sample is collected from within a sampling site, then the area from which the sample was collected will be termed the sample location. Sampling sites/locations will be selected using a stratified random design prior to the first sample collection effort. Once selected, the sites will be documented by GPS and will remain fixed for the duration of the study. The final number of sampling locations will depend on the availability of habitats and sites within the three zones with comparable physical features. Additional sites (e.g., discharge canal) may be selected to allow comparisons with historical data but not necessarily with upstream control and/or downstream sites.

As an example for this plan, the following habitat types are anticipated to be encountered and sampled. Actual habitat types for sampling will be selected after the completion of Phase I as described above.

- channel border
- wing-dike or L-dike field
- main-channel/thalweg (inside bend or outside bend)

Sample Collection

The sampling gear utilized will depend on the habitat type sampled. Multiple gears may be used for a particular habitat type to avoid gear bias and ensure a more complete inventory of the species present. Where possible, the gear specifications will either match or be close to matching those of gear used by other researchers on the lower Missouri River for data comparability. Alternatively, gear will be selected that has currently been shown to be most effective for the river conditions. Tentatively, these sampling gears by habitat type will include:

- Channel border (depths <12 ft)
    - 240-volt boat mounted pulsed-DC electrofisher[2] (for large-bodied fishes and historical data comparability)
    - 8-ft (2.44-m) head rope mini-Missouri trawl (Herzog et al. 2014) for small-bodied juvenile and adult benthic fishes

- Wing dike or L-dike field
    - 240-volt boat-mounted pulsed-DC electrofisher (for large-bodied fishes and historical data comparability)
    - 1-m towed conical plankton net with 500-µm mesh (for eggs, larvae, or early juveniles)[3]
    - 8-ft (2.44-m) head rope mini-Missouri trawl (Herzog et al. 2014) for small-bodied juvenile and adult benthic fishes

[2] Both AC and, most recently, pulsed-DC electrofishers have been used for Labadie biomonitoring programs in the past.

[3] Ichthyoplankton sampling will be limited to off-channel areas where drifting eggs and larvae may have settled, or for species that do not rely on drift and would not appear in entrainment collections

    - 30-ft x 6-ft bag seine

- Main-channel/thalweg (inside bend or outside bend)
    - 8-ft (2.44-m) head rope mini-Missouri trawl (Herzog et al. 2014) for small-bodied juvenile and adult benthic fishes

In addition, the discharge canal will be sampled using electrofishing for comparability to historical data.

The biological sample collection program for fish will be conducted over a two-year period. The frequency and duration of sample collection and the number of samples collected will depend on gear type. After each sample is collected, water depth, water temperature, dissolved oxygen, turbidity, and conductivity will be recorded at the surface and bottom using a field multi-probe (YSI meter or similar). In addition, relevant meteorological variables (e.g., air temperature, cloud cover, relative humidity, wind speed, etc.) will be obtained from the National Oceanographic and Atmospheric Administration (NOAA)/National Weather Service (NWS) Washington, MO Regional Airport station for the period of study.

Electrofishing samples will be collected once per month for 24 consecutive months, river and weather conditions permitting. One electrofishing sample of approximately 20-minute duration will be collected in each habitat type in each zone per month during the day and at night.

Trawl samples will be collected once per month for 24 consecutive months, river and weather conditions permitting. One trawl sample of approximately 3-5 minute duration over a standardized distance will be collected in each habitat type in each zone per month during the day and at night.

Seining will be conducted once per month for 24 consecutive months, river and weather conditions permitting. Two seine hauls will be conducted in the dike field habitat type in each zone per month during the day and at night.

Ichthyoplankton sampling will be conducted biweekly from mid-March through July and once per month during August and September for two years, river and weather conditions permitting. Samples will be collected by towing a 1-m conical plankton such that the entire water column will be sampled. Two, 3-5 minute duration samples will be collected in the dike field habitat type in each zone per sampling effort during the day and at night.

Sample processing

Fish collected by electrofishing, trawling, and seining will be processed in the field and returned to the river alive. All fish will be identified to species and up to 30 individuals per species will be measured and weighed. Voucher specimens for all species/taxa collected will be preserved, returned to the laboratory, and retained for a period of five years. Fish abnormalities using the deformities, erosion, lesions, and tumors (DELT) method will be noted and recorded. Any endangered species encountered (e.g., pallid and lake sturgeon) will be reported and handled per standard USFWS methods/directions.

Ichthyoplankton (eggs, larvae, and early juveniles) will be preserved in the field with a 10% formalin/rose bengal solution and returned to the laboratory for taxonomic analysis.

Data analysis
All data collected during the fish surveys will be entered into a Microsoft Access or similar database. The fish community will be characterized by zone and habitat type. In addition, it is anticipated that the following or similar metrics will be reported:

- Catch-per-unit-effort (number and biomass)
- Community metrics such as species richness, species diversity, species dominance
- Percent pollution tolerant species
- Length-frequency distributions for selected species
- Mean relative weight for game and protected species

Detailed methods for each sample collection gear type as well as sample processing and sample analysis (e.g., taxonomic) methods are provided in the Standard Operating Procedures (SOPs) and Quality Assurance Project Plan (QAPP) that accompany this study plan.

4.2.2 Benthic Macroinvertebrate and Shellfish Surveys

Objective(s)
To document and compare the presence and relative abundance of the benthic macroinvertebrate taxa in the thermally exposed, upstream control, and downstream zones. The data from the current study, in conjunction with historical data, will be used to evaluate whether a BIC, as defined in 40 CFR Part 125 Subpart H, is present within the study area.

Site selection
The study design is based upon the same three sampling zones (i.e., upstream control, thermally exposed, and downstream zones) and habitat type and sampling site identification and selection methods used for the fish sampling. Up to three sampling sites will be selected within each habitat type within each zone prior to the first sample collection effort. Once selected, the sites will be documented by GPS and will remain fixed for the duration of the study. The final number of sampling locations will depend on the availability of habitats and sites within the three zones with comparable physical features. The discharge canal will also be sampled for comparability to historical data.

As an example in this plan, the following habitat types are anticipated to be encountered and sampled. Actual habitat types for sampling will be selected after the completion of Phase I as described above.

- Depositional; and
- Rock/gravel (primarily expected to be associated with wing dikes and revetments).

Sample Collection
The biological sample collection program for benthic macroinvertebrates and shellfish will be conducted quarterly for a period of 2 years.

For depositional habitats, samples will be collected using a standard ponar dredge from three randomly selected locations within each site and composited for analysis. An additional sample will be collected from each site for qualitative grain size analysis.

Rock/gravel habitats will be sampled using H-D sampling arrays. Each array will consist of two samplers. At each of three selected locations within each sampling site, one H-D array will be

deployed for benthic sample collection and one array will be set for mid-water column sample collection. This will yield a total of six H-D sampling arrays deployed within each sampling site. Samplers will remain deployed for a period of six weeks during each quarter. After the first year of sampling is complete, the H-D data will be evaluated to determine whether to continue the dual deployment or to continue with either the benthic or mid-water deployment.

At each sampling site, each sample and the surrounding area will be visually inspected for the presence of native mussels/mussel shells. In addition, native mussel shells found in trawls will be noted. Any native mussels/mussel shells found will be identified to species to determine whether any threatened and endangered species are present.

At each sample collection location, water depth, water temperature, dissolved oxygen, turbidity, and conductivity will be recorded at the surface and bottom using a field multi-probe (YSI meter or similar). In addition, relevant meteorological variables (e.g., air temperature, cloud cover, relative humidity, wind speed, etc.) will be obtained from the National Oceanographic and Atmospheric Administration (NOAA)/National Weather Service (NWS) Washington, MO Regional Airport station for the period of study.

Sample processing

Standard ponar dredge samples will be sieved in the field using a 0.5-mm mesh bucket sieve. All organisms, detritus, debris, and sediments from the sieve bucket will be carefully removed from the sieve into a sample container and preserved with a 10% formalin/rose bengal solution. All samples will be returned to the laboratory for taxonomic analysis.

Hester-Dendy samplers will be retrieved and placed in individual sample containers containing a 10% formalin solution with Rose Bengal stain and transported back to the laboratory for processing. In the laboratory, sampler plates will be removed and carefully scraped to remove all organisms. The remaining contents of the sample container will be sieved using a 0.5-mm mesh sieve to collect any organisms dislodged during transport. Samplers and each sample location within a site will be processed separately.

In the laboratory, samples will be subsampled to a minimum quota of 200 organisms as described in the SOP. Organisms will be identified to the lowest practicable taxonomic level. Voucher specimens will be retained for all species/taxa collected and will be retained for a period of 5 years.

Data analysis

All data collected during the benthic macroinvertebrate and shellfish surveys will be entered into a Microsoft Access or similar database. The benthic macroinvertebrate community will be characterized by zone and habitat type. Benthic macroinvertebrate habitat and community analysis will include, but may not be limited to, the following metrics:

- density (#/m^2)
- taxa richness
- dominant taxa
- EPT index
- Biotic index
- Shannon diversity index
- qualitative sediment characterization (percent abundance of particle types, Wentworth scale)

Detailed methods for each sample collection gear type as well as sample processing and sample analysis (i.e., taxonomic) methods are provided in the SOP and QAPP documents that accompany this study plan.

5. BIOTHERMAL ASSESSMENT

A retrospective biothermal assessment will be conducted to evaluate whether the thermal discharge is preventing the protection and propagation of the BIC in the Missouri River in the vicinity of the LEC. Because there are no State criteria for evaluating whether a thermal discharge threatens the protection and propagation of a BIC, the following sources of guidance will be used:

- USEPA draft guidance manuals (Draft 316(a) Guidance) issued for the implementation of Section 316(a) of the Clean Water Act (CWA) in 1974, 1975, and 1977 (USEPA 1974, 1975, 1977);
- 40 CFR Part 125 Subpart H;
- Professional practice in prior Section 316(a) assessments at other generating stations; and
- Guidelines for Ecological Risk Assessment (ERA Guidance) recommending approaches and criteria for assessing impacts from chemical, physical, or biological stressors (USEPA 1998a)

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 of any nuisance species or heat-tolerant community not representative of the highest community development in the lower Missouri River;
- A decrease in indigenous species of the lower Missouri River;
- Changes in community structure of the lower Missouri River to resemble a simpler successional stage;
- A substantial reduction in community heterogeneity or trophic structure;
- Reduction of successful completion of life cycles of indigenous species;
- Impairment of a zone of passage to the extent that it will not provide for the normal movement of populations of RIS, dominant species of fish, and economically important species of fish, shellfish, and wildlife;
- Adverse impact on threatened or endangered species; or
- The elimination of an established or potential economic or recreational use of the lower Missouri River.

The biothermal assessment process will consist of three sequential steps:

- Evaluation of Biotic Category vulnerability;
- Retrospective ["No Prior Appreciable Harm (NPAH)] evaluation of biothermal impact; and
- Evaluation of Balanced Indigenous Community (BIC) protection and propagation.

5.1 BIOTIC CATEGORY VULNERABILITY

Biotic category vulnerability will be assessed using the Critical Function Zone (CFZ) and Biotic Category (BC) methods recommended by the USEPA Draft 316(a) Guidance. The vulnerability

evaluation screens out those biotic categories that have low potential for impacts from LEC's thermal plume (LPI categories), and focuses the retrospective, no prior appreciable harm (NPAH), assessment on the remaining biotic categories.

5.2 RETROSPECTIVE ASSESSMENT

Whether the LEC's operations and thermal discharge has caused appreciable harm to fish and macroinvertebrate and shellfish communities will be evaluated using a retrospective biothermal assessment.

Methods for the retrospective evaluation will include:

- Comparison of species/taxa composition and abundance among samples from the three zones (thermally exposed, upstream control, downstream) in the planned biological studies;
- Comparison of the species/taxa composition and abundance observed in the present study to that reported in historical studies; and
- Review of existing information on the status of, and trends in, the biological community and water quality in the lower Missouri River.

Differences among the three zones will be examined for evidence of exposure and response relationships and the potential influences of other ecological factors to the extent possible.

5.3 PREDICTIVE BIOTHERMAL ASSESSMENT

As discussed in Section 2.3, a predictive biothermal assessment may be conducted depending on the results of the biological monitoring, retrospective assessment, and the need for a comprehensive variance. The following section provides an overview of the anticipated predictive biothermal assessment approach, if it is performed. In the event a predictive biothermal assessment will be conducted, a more detailed methodology will be developed and presented for MDNR review.

5.3.1 Representative Important Species

USEPA's 1977 Draft 316(a) Guidance recognizes that it is impractical to study and assess in great detail every species at a site, and it is therefore necessary to select a smaller group to be representative of the balanced indigenous community. These selected species are designated as representative important species (RIS). Generally, five to 15 RIS are selected to represent the community. According to the Draft 316(a) Guidance, RIS are to include species that are:

- Representative, in terms of their biological requirements, of a balanced indigenous community of fish, shellfish, and wildlife;
- Commercially and recreationally valuable;
- Threatened or endangered;
- Critical to the structure and function of the ecosystem (e.g., habitat formers);
- Potentially capable of becoming localized nuisance species; and
- Necessary in the food chain for the well-being of species determined above.

Other considerations for RIS selection include the extent of the species involvement with the thermal plume, the species thermal sensitivity, and the quantity and quality of information available for the assessment.

The selection of RIS will include consultation with, and input from, the MDNR.

5.3.2 Predictive Assessment

The potential for impact would be evaluated by predicting the nature and likelihood of potential thermal effects on individual organisms, and then assessing the significance of those effects on the RIS populations. In the language of USEPA Draft Section 316(a) Guidance, the significance of effects equates to their potential for causing “Appreciable Harm”. The nature and likelihood of thermal effects will be characterized by comparing the habitat preferences, seasonal occurrence, and temperature requirements or limits of each species to thermal exposures that could potentially occur as a result of the LEC’s operations.

A thorough review of the literature on thermal response temperatures, life history information, and seasonal occurrence in the vicinity of the LEC would be conducted. The results of the biological monitoring studies would also be used as a component of the predictive assessment.

A state-of-the-art hydrothermal model would be selected and used to estimate exposure temperatures and durations of exposure under a variety of river flow, meteorological, river temperature, and plant operating condition scenarios. The resulting exposure scenarios would be compared to the biological and thermal response information obtained from the biological monitoring studies and the scientific literature to evaluate whether biological effects of LEC’s thermal discharge are sufficiently large to jeopardize the health of six trophic level components (biotic categories) and RIS populations selected to represent the BIC.

6. REPORTING

As specified in the LEC NPDES permit, annual progress reports will be submitted to the MDNR by February 28 of each year. In the event that modifications are necessary to the sampling plan to address unforeseen circumstances, the MDNR will be notified of the potential change(s) as early as possible in the process to solicit comments/feedback.

A final report detailing the results and conclusions of the biological monitoring study and, if necessary, a renewed 316(a) demonstration will be submitted with the permit renewal application six months prior to the existing permit expiration.

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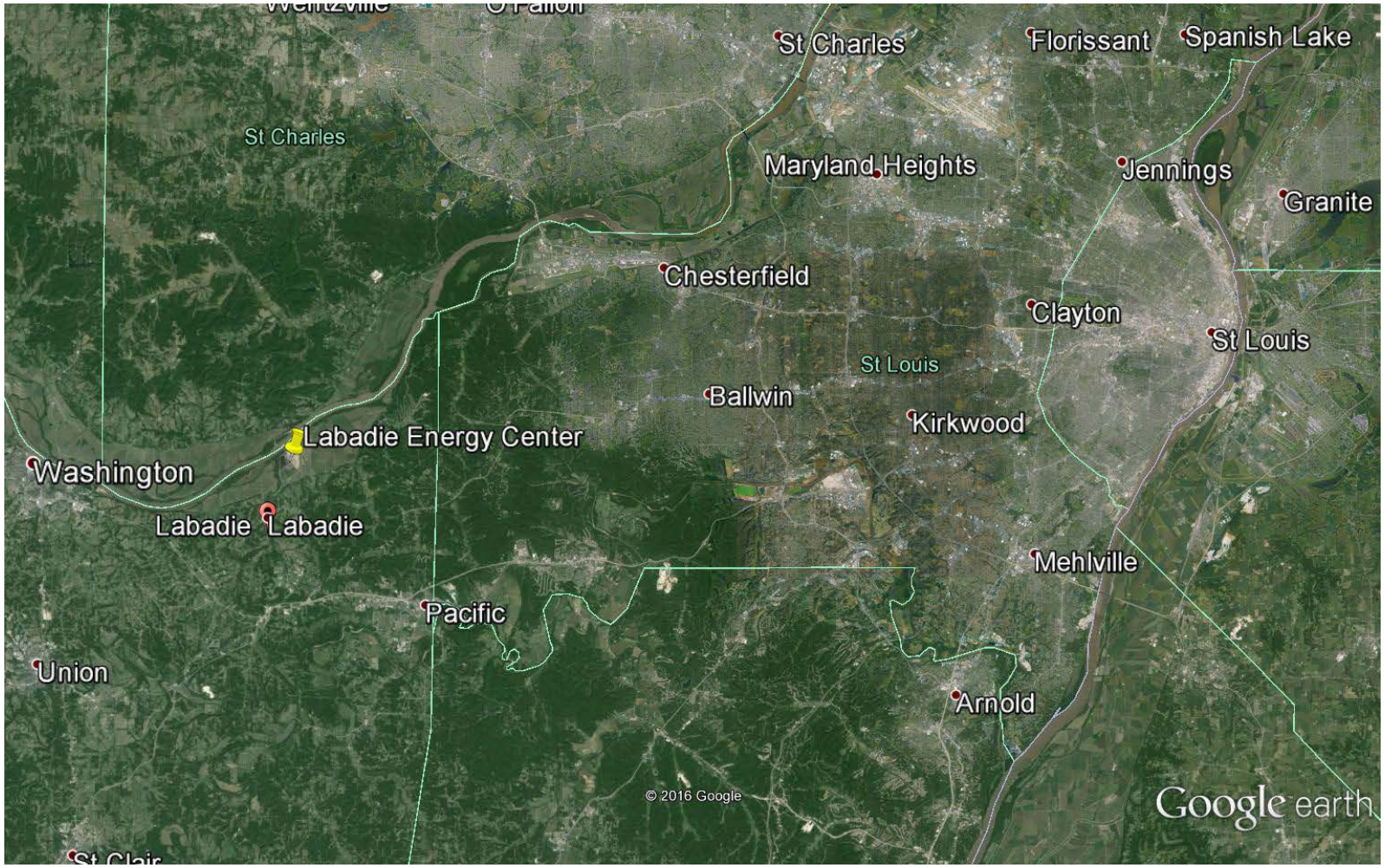

Figure 1 Aerial photograph showing the general geographical location of the LEC (Source: Google Earth)

Figure 2. Aerial photograph of the LEC showing the cooling water intake and discharge canal (Source: Google Earth)

AMEREN MISSOURI LABADIE ENERGY CENTER
316(A) STUDY PLAN

ADDENDUM 1
HABITAT CHARACTERIZATION AND SAMPLING SITE SELECTION

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1 INTRODUCTION AND PURPOSE

This addendum summarizes refinements to the Labadie Energy Center (LEC) 316(a) Study Plan resulting from work performed on hydrothermal modeling (Section 3 in the Study Plan), habitat characterization (Section 4.1), and site selection (Sections 4.2.1 and 4.2.2), which has been completed subsequent to the initial preparation of the Study Plan.

As outlined in the Study Plan, hydrothermal modeling was performed to predict the spatial extent of the thermal plume under varying environmental and station operating conditions. A desktop habitat mapping exercise was then conducted using existing information to identify the riverine habitat types within the study area. After completion of a preliminary habitat map, site selection included a field reconnaissance trip to evaluate the accuracy of the habitat map and identify other potential riverine habitat features that may influence the selection of the sample collection locations. Finally, a “ground-truthing” effort was conducted to further evaluate the conditions of specific sampling sites and confirm the feasibility of access and sample collection.

The addendum is organized into three main sections that summarize the results of the work performed. These sections are:

- Section 2: Hydrothermal Modeling
- Section 3: Habitat Characterization
- Section 4: Site Selection

2 HYDROTHERMAL MODELING

2.1 INTRODUCTION

A state-of-the-art hydrothermal model was used to conduct preliminary hydrothermal modeling under varying scenarios of river and plant operation conditions to simulate the potential spatial extent of the thermal plume. To facilitate the selection of sampling sites, a predicted water temperature difference (ΔT) of 3°F or more above ambient river temperature was used to define river areas where plume temperatures could exceed natural daily water temperature variations[1], to which resident organisms were presumed to be well adapted. This area encompassing predicted temperatures ≥3°F was defined as the "thermally exposed zone". A "downstream zone" was defined as the river reach starting at the downstream end of the thermally exposed zone, and an "upstream control zone" was defined as the river reach upstream of the LEC intake and discharge outfall. These three primary zones comprised the study area for the initial Labadie 316(a) study plan (Section 2.2 of the Study Plan). Ameren subsequently identified a fourth zone—the "discharge zone"—that had been previously included in historical sampling programs. This zone is represented by the discharge canal and the area immediately below the canal extending to the first wing dike (see Section 2.3, below). The discharge zone will be sampled using electrofishing for fish and a Ponar dredge and Hester-Dendy samplers for benthic macroinvertebrate sampling to allow a comparison with historical data collected using the same methods.

2.2 MODEL SELECTION AND SCENARIO OVERVIEW

The FLOW-3D computational fluid dynamics model (Flow Science, 2016) was selected for modeling three-dimensional mixing of the LEC thermal discharge with the Missouri River. This model was deemed appropriate for this application because of its ability to simulate both near-field and far-field mixing and to accommodate complex river features such as variable bathymetry, bars, islands, and dikes that are present in the Missouri River. As described in Section 3 of the Study Plan, available bathymetric data from the U.S. Army Corps of Engineers collected in 2001, 2007, 2009, 2013, and 2014 were used to adapt the model to the Missouri River in the vicinity of the LEC.

Available field-collected water temperature measurements from July and August 2003, January 2004, and January and April 2016 were used to validate the hydrothermal model. For each survey, either nine or 10 transects were sampled from the discharge canal to approximately 1 mile downstream. Transects were spaced approximately 500 yards apart in the downstream direction. Temperature measurements were collected every 100 feet across each transect and every 2 feet vertically from the surface to the bottom.

Available river flow and river temperature data from USGS Hermann gage 06934500 and LEC operating (discharge flow and temperature) data from 2002-2015 were used to develop model scenarios that would encompass a potential range of conditions that could influence the downstream and cross-river extent of the thermal discharge. Combinations of high and low river flows and temperatures and full-load plant operating conditions (discharge flow and temperature) were modeled to evaluate changes in the predicted extent of the thermal plume. As would be expected, model simulations generally showed that the predicted thermal plume reached farther downstream at lower river flows regardless of the water temperature.

[1]Conservatively based on a typical daily water temperature range of 1-2°F recorded at USGS gage 06935550, upstream of the LEC cooling water discharge outfall

2.3 SAMPLING ZONE DELINEATION

Sampling zones were delineated to facilitate the selection of the biological sample collection locations by dividing the study area based on the expected degree of exposure to excess temperature (i.e., temperatures above ambient river water temperature) from the LEC thermal discharge. The division of the study area into sampling zones helps to account for the variable nature of the thermal plume over space and time.

A general review of the thermal plume maps produced by the preliminary modeling showed that excess river temperatures predominantly stayed associated with the right descending river bank and extended furthest downstream under low flow conditions. Excess temperatures were highest and most consistently present in the discharge canal and just downstream of the confluence with the Missouri River to the first dike, located at approximately river mile (RM) 57.25. Based on the latter observation, and considering the discharge area would experience an exposure scenario different from habitats further downstream and had been sampled historically, it was determined this area should constitute an additional sampling zone. This additional sampling zone, the discharge zone, was delineated to include the discharge canal and the outer bend habitat along the right descending bank (from the thalweg to the bank) downstream to the first dike.

A more detailed evaluation of the preliminary modeling of the thermal plume was conducted to determine the appropriate downstream extent for the thermally exposed sampling zone. The first step was to identify the excess temperature isotherm that would guide the downstream extent decision. An excess temperature of 3°F (i.e., 3°F above the ambient river water temperature) was selected as the most representative isotherm to delineate the downstream extent of the thermally exposed zone. The 3°F excess temperature isotherm was selected for the reasons described above in Section 2.1. In addition, at the highest modeled ambient water temperature of 87° F, the 3° F excess temperature isotherm corresponds to the 90° F isotherm (the Missouri water quality standard for maximum temperature). The 87° F ambient water temperature represents the upper 99th percentile of the daily averaged water temperature data from 2002 through 2015.

This evaluation showed that under river flow conditions of approximately 31,000 cfs, the 3°F excess temperature isotherm was present downstream to approximately RM 52. Based on river discharge data for 2002 to 2015 from the USGS Hermann gage 06934500, flows of 31,000 cfs or less occurred about 5% of the time. Based on these observations, the thermally exposed zone for sample collection was determined to extend from the start of the first dike (approximately RM 57.25) downstream of the discharge canal downstream to approximately RM 52 (Figure 2-1).

The downstream zone was defined as the zone downstream of approximately RM 52 to approximately RM 50. The upstream control zone was selected to be between approximately RM 58.5 and RM 62, well upstream of any potential influence from the LEC intake and discharge. Both zones contain habitat types comparable to those found in the thermally exposed zone, as described in detail below in Sections 3 and 4.

The following revised four sampling zones comprise the LEC 316(a) study area:

- An upstream control zone unaffected by the LEC intake or discharge (RM 58.5 – RM 62),
- A discharge zone encompassing the area of highest potential exposure to the thermal discharge (RM 57.5 – RM 57.25)

- A thermally exposed zone where any potential effects from thermal discharge would be expected if present (RM 57.25 – RM 52), and
- A downstream zone which potentially could experience minor and transient exposure to the thermal discharge (RM 52 – RM 50).

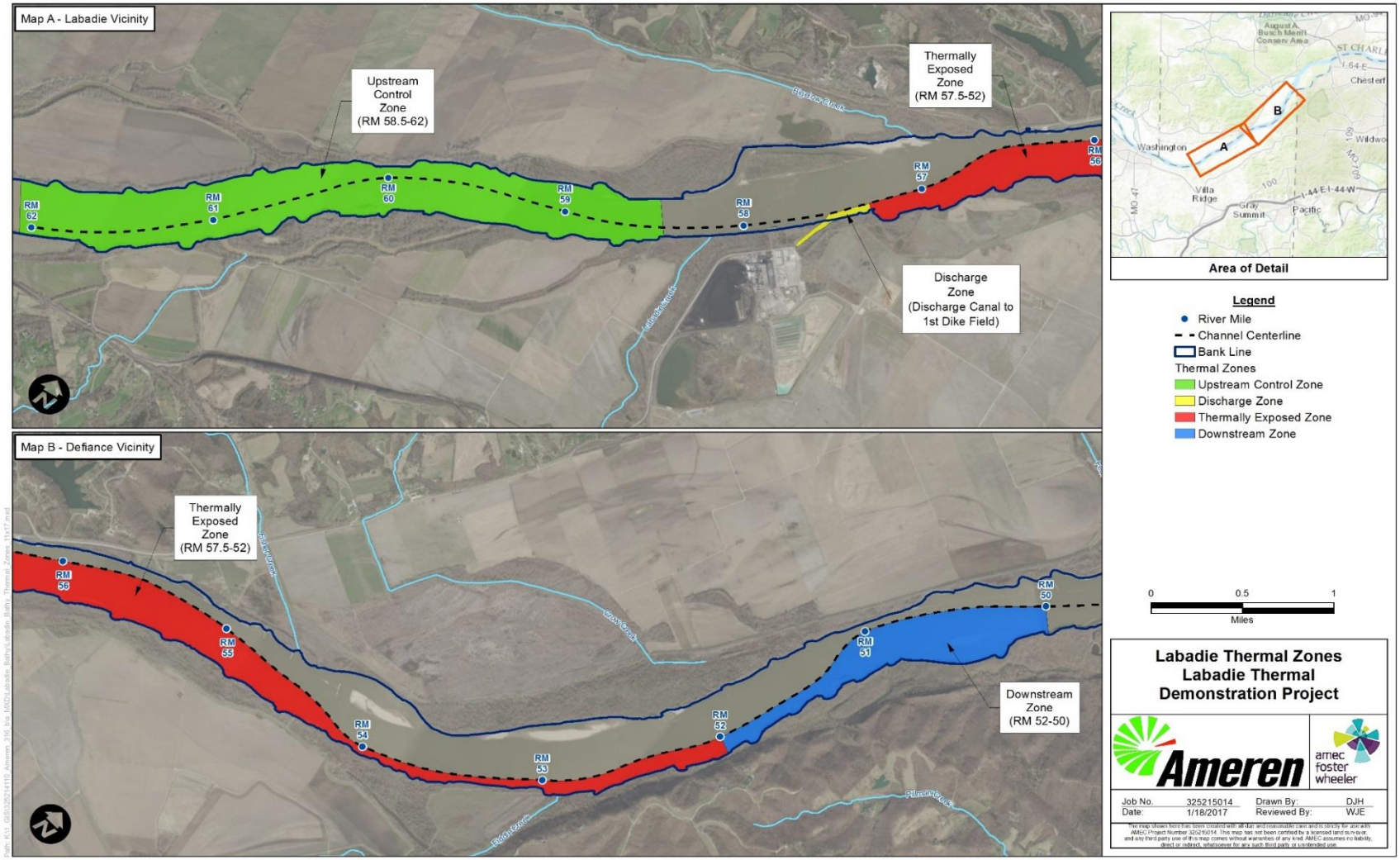

Figure 2-1. **Four Sampling Zones Identified within the Primary Study Area Based on Thermal Plume Mapping for Labadie Energy Center 316(a) Thermal Demonstration**

3 HABITAT CHARACTERIZATION AND PRELIMINARY SITE SELECTION

3.1 INTRODUCTION

Once the sampling zones were approximated, a desktop habitat characterization mapping was conducted using available data to identify the habitats within each of the sampling zones. The habitat characterization map was used to identify the key habitat types that were substantively present in the thermally exposed zone and that would be the focus of the biological sample collection program. After identifying the preliminary habitat types for sampling in the thermally exposed zone, the habitat characterization map was used to identify similar habitats in the upstream control and downstream zones.

3.2 METHODS

The desktop characterization of the potential habitat types in the sampling zones was conducted by reviewing existing sources of data and information on the Missouri River in the vicinity of the LEC. These sources included bathymetric data, river morphometry, aerial photography, and navigational charts. National Wetland Inventory maps were also added to the habitat characterization for reference, as many of the palustrine wetlands associated with riverine environments are periodically flooded during high river stage and provide important functions related to life cycles of aquatic biota. Coverages of NWI wetlands, however, were modified at the boundary of the Missouri River to eliminate gross inaccuracies of NWI mapping (e.g., mapping of forested wetlands within the river area).

Habitats were classified using the hierarchical system described by Welker and Drobish (2010) as a guide. Their system consists of macrohabitats, mesohabitats, and microhabitats which allows for both general and specific categorization for sampling to serve the needs for biological and physical data collection efforts.

The preliminary habitat characterization mapping effort was conducted for the entire anticipated reach of the study area from approximately RM 62 downstream to approximately RM 50 and included both right and left descending banks.

3.3 APPLICATION OF THE CLASSIFICATION SYSTEM TO THE STUDY AREA

Welker and Drobish (2010) identified three tiers of habitats: macrohabitats, mesohabitats, and microhabitats. During the desktop habitat characterization effort, macrohabitats were identified and mapped first (Figure 3-1). A more detailed evaluation of the information was then conducted to identify the key mesohabitats and microhabitats present in the study area. These are shown in the figures in Appendix A.

3.3.1 Macrohabitats

Delineation of macrohabitats was undertaken in a step-wise fashion. Close examination of bathymetric data was undertaken to identify the location of the main channel center within the LEC reach. Cross sections were then “cut” every one-half mile to assist in delineation of the main channel and its location within the broader river valley. Finally, general river morphology was examined along with noting the occurrence of side channels, secondary channels, and tributary

mouths. Using this information, the general limits of the macrohabitats were approximated longitudinally within the LEC reach. The macrohabitats identified within the LEC reach included:

- Main Channel Crossover (CHXO)
- Main Channel Outside Bend (OSB)
- Main Channel Inside Bend (ISB)
- Secondary Channel-Connected (Large) (SCCL)
- Secondary Channel-Connected (Small) (SCCS)
- Tributary Small Mouth (TRMS)

Only Secondary Channel-Connected (Large and Small) macrohabitat types did not occur in the thermally exposed zone (i.e., river mid-line to right descending bank from approximately RM 57.25 to RM 52) and were, therefore, not identified for potential sample collection. The locations of the macrohabitats within the study area are shown in Figure 3-1.

3.3.2 Mesohabitats

Mesohabitats within the LEC reach occur within the identified macrohabitats and are shown in the figures presented in Appendix A. Mesohabitats present in the study area include:

- Thalweg
- Channel Border
- Pools
- Bars
- Island Tips

Thalweg and channel border habitats are ubiquitous within the study area and account for most available habitat. Pool habitats are primarily represented in association with identified dike fields. Bars and island tips, while present, were less common.

3.3.3 Microhabitats

Microhabitats are also identified within the LEC reach and are shown in the figures presented in Appendix A. The entire LEC reach is variously composed of dikes that are river training structures that function to maintain the navigation channel. While Welker and Drobish (2010) identified several different types of dike microhabitat, the current habitat characterization only differentiated between wing dikes and L-dikes. The following microhabitats were identified within the study area:

- Wing Dikes
- L-Dikes
- Channel Sand Bar
- Bank Line
- Chute

3.3.4 Observed Data Gaps

Several data gaps were identified during the desktop habitat characterization mapping effort. These data gaps include the following:

1. *Channel border and side channel depths*. Several channel border and side channel areas (SCCS and SCCL) lack sufficient bathymetric information to confirm water depth and habitat characteristics. Such areas are expected to be inundated during high water levels and would be expected to support aquatic biota of varying life stages. However, insufficient information is available to fully understand water depth and relative use by aquatic biota during periods of low flow and potentially elevated thermal conditions.
2. *Aberrant bathymetric readings*. In selected locations detailed bathymetric data suggested the presence of bottom elevations that were suspect. For example, in several locations higher elevations suggested the presence of a “shallow” or bar within a portion of an area expected to be the thalweg. Such readings may be aberrant and should be verified and corrected, as appropriate.
3. *Main channel connectivity*. Based on aerial photo review, several existing and relict side channels were identified. Several side channels were identified that clearly connect to the main channel. In contrast, the connectivity of other selected relict channels could not be verified using office-level information.
4. *Dike field characteristics*. Limited work was previously performed in the dike field immediately downstream of LEC (right descending bank) in support of hydrothermal modeling efforts. Using aerial photographs the limits and configuration of other dike structures in the LEC have been identified in Appendix A. These preliminary configurations and the particular type of dike should be field verified to more fully understand the potential characteristics of these microhabitats and their associated pool mesohabitats.
5. *Pool Definition.* The criteria for delineation of pools indicates that pool mesohabitats are areas immediately downstream from sandbars, dikes, snag-piles, or other obstructions that have formed a scour hole >1.2 meters deep. Pool habitats identified in Appendix A require refinement to confirm water depths at each location and refine limits of pools.

An attempt was made to collect the appropriate data to fill these data gaps during the field reconnaissance and ground-truthing efforts (Sections 4.2 and 4.4 below).

3.4 PRELIMINARY HABITAT TYPES IDENTIFIED FOR SAMPLING

Based upon the desktop habitat characterization mapping, six macro/meso/microhabitat combinations were identified as potential sampling sites pending the outcome of the field reconnaissance and ground-truthing surveys. The habitat types selected for sampling in the upstream control, thermally exposed, and downstream zones and the number of discrete locations for each habitat type are presented in Table 3-1. Because data collected from the discharge zone is intended only for comparison with historical studies, the discharge zone is not included in Table 3-1.

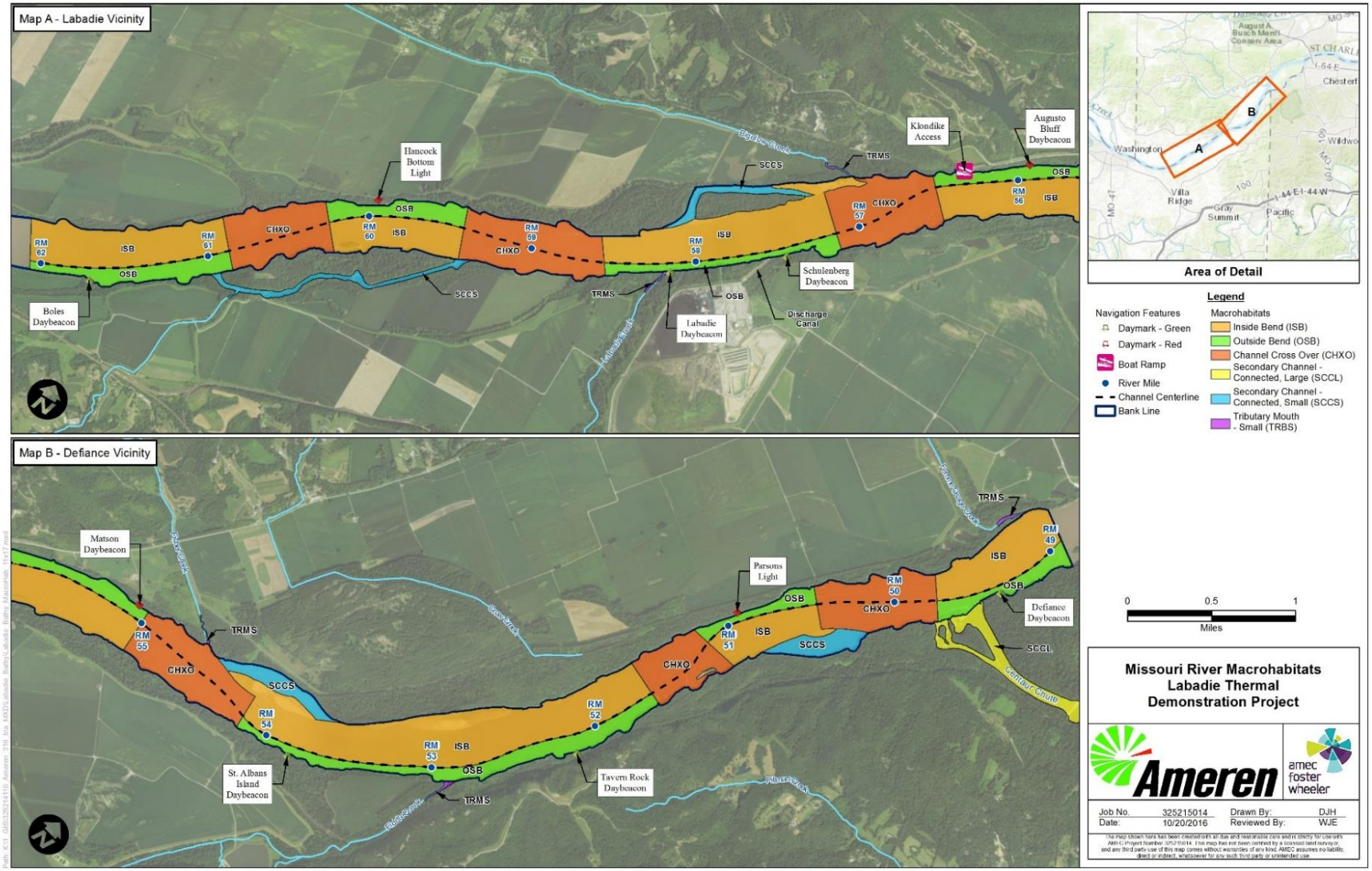

Figure 3-1. **Macrohabitats Identified within the LEC Study Area**

Table 3-1. **Number of Macrohabitat and Mesohabitat Types Present within the Upstream Control, Thermally Exposed, and Downstream Zones.**

Sampling Zone	Macrohabitat	Mesohabitat	Number of Habitats Present
Upstream Zone	Outside Bend	L-dike/Pool	6
	Main Channel Crossover	L-dike/Pool	4
	Main Channel Crossover	L-dike/Bar	1
	Inside Bend	W-dike/Pool	5
	Inside Bend	W-dike/Bar	2
	Inside Bend	Channel Border	~ 2.25 miles
Thermally Exposed Zone	Outside Bend	L-dike/Pool	9
	Main Channel Crossover	L-dike/Pool	3
	Main Channel Crossover	L-dike/Bar	1
	Inside Bend	W-dike/Pool	4
	Inside Bend	W-dike/Bar	2
	Inside Bend	Channel Border	~ 1.5 miles
Downstream Zone	Outside Bend	L-dike/Pool	2
	Main Channel Crossover	L-dike/Pool	2
	Main Channel Crossover	L-dike/Bar	2
	Inside Bend	W-dike/Pool	1
	Inside Bend	W-dike/Bar	2
	Inside Bend	Channel Border	~ 0.75 miles

4 FIELD RECONNAISSANCE AND SAMPLING SITE SELECTION

4.1 INTRODUCTION

During the site selection process, the habitat types initially identified for sample collection using desktop habitat characterization mapping were evaluated in the field during reconnaissance and ground-truthing trips. These trips also were used to collect data to fill data gaps identified by the desktop exercise (Section 3.3.4 above). The combination of desktop habitat characterization mapping and field reconnaissance information was then used to select specific sample collection locations for each habitat type in each sampling zone. The more detailed data collected during the ground-truthing survey were used in the development of the sample collection standard operating procedures.

4.2 FIELD RECONNAISSANCE

A field reconnaissance survey was conducted on October 26, 2016 to identify features associated with each habitat including, but not limited to, shoreline type, geomorphological features, water depth, flow, and substrate type. The field reconnaissance also allowed the identification of specific features of mesohabitats (e.g., bars, collapsed dikes, notches in dikes, etc.) that were not observed from available aerial photography data used as part of the habitat characterization study. In addition, the applicability of sampling gears for each substantially present habitat type was assessed.

The information collected during the reconnaissance survey supported the macrohabitat classification performed during the desktop mapping and no changes to the mapped macrohabitat types were necessary. Several newly formed sand bar mesohabitats (e.g., bars at RM 58.75, RM 56.8, RM 55.6 and RM 51.5) were identified and recorded as potential sampling locations. Substrate types of these sand bars were dominated by sand and gravel. Other sand bars identified by the desktop habitat characterization consisted of compacted clay and silt.

While no new microhabitat types were identified during the reconnaissance survey, several key observations were made regarding the condition of many of the dikes. Notches or openings in dikes were noted and their respective GPS coordinates taken. Flow characteristics (e.g., back eddy flow) immediately behind dikes created by notch openings were also noted. Recently collapsed dike tips (e.g., wing dikes from RM 61 to 62) not previously observed from available aerial photography data were documented. The observations regarding the condition of the dikes was used in the selection of specific sampling locations as described in Section 4.3.

General depth profiles around dikes and bars were recorded to guide sample site selection and assess the potential applicability of sampling gear types. On the day of the reconnaissance survey when depth profiles were recorded, the river gage height was 5.81 feet and river discharge was approximately 66,000 cfs. While depth profiles varied slightly, the depth immediately off dike fields generally ranged from 6 to 8 feet, providing an ideal habitat type for electrofishing. Depths surrounding sand bar habitats varied substantially depending on the slope of banks, ranging from 1 to 13 feet. Bars ideal for bag seining had surrounding depths of 1-3 feet and were mostly composed of sand substrate. Dikes predominantly were composed of boulders, large cobble, and wood pilings. Shoreline substrate within the study area was predominantly compacted clay and silt, with sporadic fallen trees and woody debris providing potential habitat structure for fish.

Maps showing the mesohabitat and microhabitat types identified through the desktop mapping and the reconnaissance survey are presented in Appendix A. Photographs of representative

mesohabitats and microhabitats substantially present within the 13-mile study reach are presented in Appendix B.

4.3 SITE SELECTION RATIONALE

Specific sampling sites for fish and benthic macroinvertebrate surveys were selected based on the results of the habitat characterization study and field reconnaissance surveys, which aided in determining dominant habitat types present within the study area and their comparability among thermally exposed and non-exposed sections of the river. As described in the study plan (Sections 4.2.1 and 4.2.2), sample collection locations within the thermally exposed zone were identified first, then comparable habitat types and locations were identified in the upstream control and downstream zones. Based on the results of the hydrothermal modeling, the habitat types identified for sampling in the thermally exposed zone were limited to the area from the river center-line to the right descending bank. The reconnaissance field survey provided information with which to evaluate the suitability of each area of a particular habitat type for sampling and to identify the preferred representative sample location for that habitat type. The locations selected for sample collection by habitat type are shown in the figures presented in Appendix A. The number of habitat types per zone and the anticipated sample collection gears for each habitat type are shown in Table 4-1.

The initial study plan (Section 4.2 in the Study Plan) tentatively identified three basic habitat types that were expected to be encountered in the study area pending the completion of Phase I – Habitat Survey and Characterization of the Study Plan (Section 4.1 in the Study Plan). Based on the completion of the desktop habitat mapping and the field reconnaissance survey described in this addendum, a total of six unique habitat types were identified for sample collection in the thermally exposed zone (Table 4-1). Outside Bend–L-dike/Pool habitats were the most abundant habitat type within the thermally exposed zone.

Identification of representative sample locations for each habitat type were dependent on the suitability of each specific location for sampling and comparability with sampling locations identified in the thermally exposed zone. In some cases, Outside bend–L-dike/Pool fields did not have notches, preventing access to sampling locations (e.g., upstream control field at RM 61.5, downstream L-dike/Pool at RM 51.75). In other cases, Inside bend–Wing-dikes were partially or fully collapsed (e.g., upstream control field at RM 61 to 62). Sampling locations identified for bag seining included two bars within each major zone, located on inside bends behind or in front of wing-dikes and behind main channel crossover L-dikes. Each of these locations had a mostly sand/gravel substrate and gradual drop-off with sufficient area present for several seine hauls. Other bars initially identified from aerial photography within each sampling zone were not selected because they were found to be unsuitable for bag seining (i.e., substrate composed of mud/clay and steep drop-offs).

In total, 19 discrete sampling locations were identified: six in each of the three major sampling zones and one for the discharge zone (Table 4-1).

4.4 GROUND-TRUTHING SURVEYS

Detailed ground-truthing surveys were completed on November 17 and November 29, 2016 to fill data gaps identified by initial habitat characterization and the field reconnaissance survey. Bathymetric surveys were conducted in areas with insufficient bathymetric data for each sampling location identified during the field reconnaissance survey. Potential locations for each collection method and gear type were mapped using GPS for each sampling location. Sediment

composition was documented for locations selected for macroinvertebrate sampling. The extent of each L-dike and wing-dike proposed for sample collection also was documented, including their upstream and downstream limits, horizontal limits, and height to determine when that dike may become submerged, as well as the location and flow velocity through notches or openings. These data were used in the development of more detailed Standard Operating Procedures, including updated maps of each sampling location, to be used by field crews during sampling.

Table 4-1. **Proposed Sampling Locations and Gear Types for Macrohabitats and Mesohabitats within each Sampling Zone**

Sampling Zone	Macrohabitat	Mesohabitat	Approximate River Mile	Electrofishing	IP Tows	Bag Seine	Benthos*	Hoop Net	MO-trawl
Upstream Control Zone	Inside Bend	Channel Border	61.5						✓
	Outside Bend	L-dike/Pool	61.2	✓	✓		✓	✓	✓
	Main Channel Crossover	L-dike/Pool	60.5	✓	✓		✓	✓	✓
	Inside Bend	W-dike/Pool	60	✓	✓		✓	✓	✓
	Inside Bend	W-dike/Bar	60			✓			
	Main Channel Crossover	L-dike/Bar	58.75			✓			
Discharge Zone	NA	NA	57.5	✓			✓		
Thermally Exposed Zone	Outside Bend	L-dike/Pool	57.25	✓	✓		✓	✓	✓
	Main Channel Crossover	L-dike/Bar	56.8			✓			
	Main Channel Crossover	L-dike/Pool	56.6	✓	✓		✓	✓	✓
	Inside Bend	Channel Border	56.25						✓
	Inside Bend	W-dike/Bar	55.6			✓			
	Inside Bend	W-dike/Pool	55.6	✓	✓		✓	✓	✓
Downstream Zone	Outside Bend	L-dike/Pool	52.25	✓	✓		✓	✓	✓
	Main Channel Crossover	L-dike/Pool	51.5	✓	✓		✓	✓	✓
	Main Channel Crossover	L-dike/Bar	51.5			✓			
	Inside Bend	W-dike/Bar	51			✓			
	Inside Bend	W-dike/Pool	50.9	✓	✓		✓	✓	✓
	Inside Bend	Channel Border	50.75						✓

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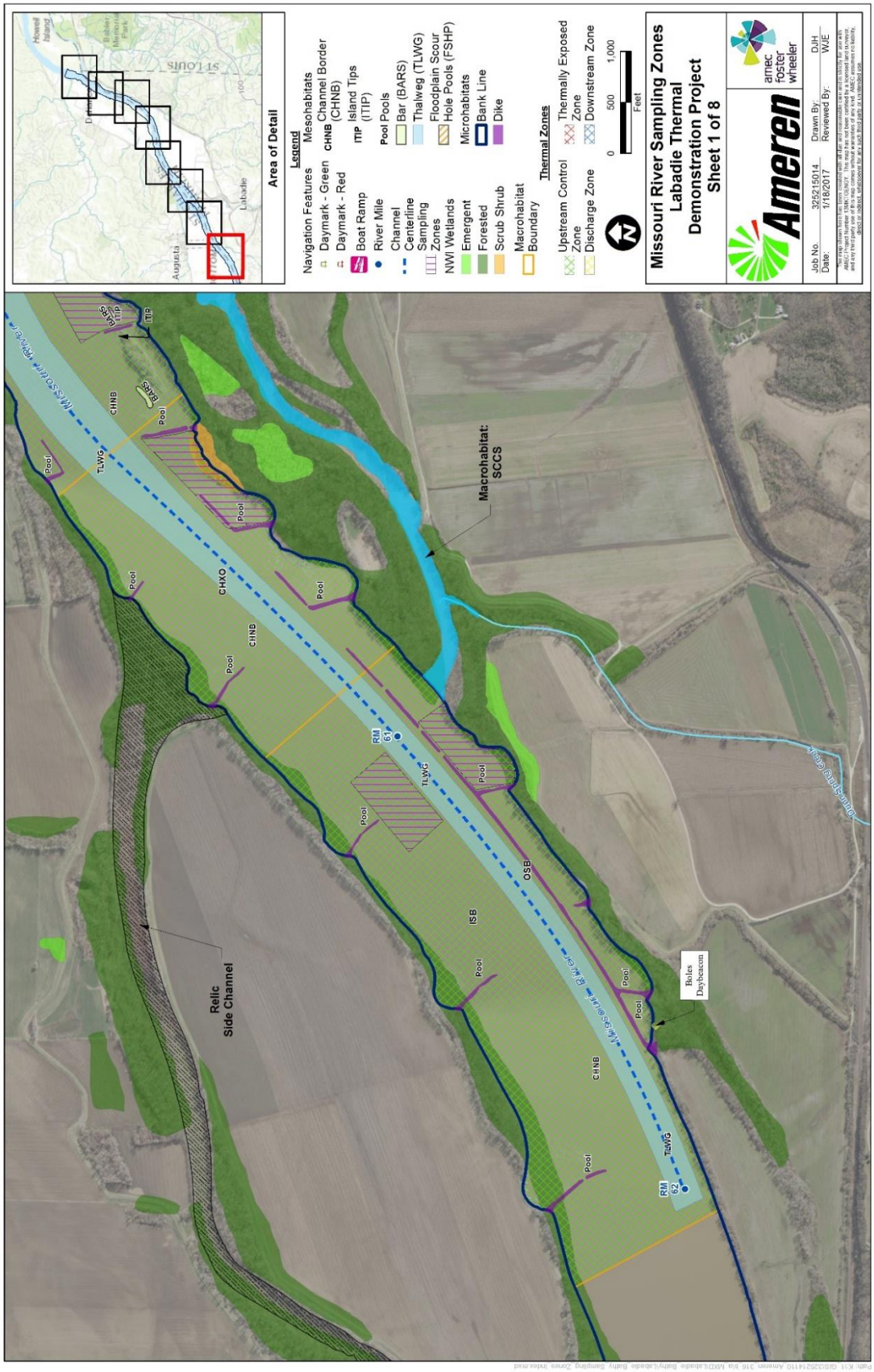
APPENDIX A
Mesohabitats, Microhabitats, and Sampling Locations Identified within the LEC Study Area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Thalweg (TLWG)
Floodplain Scour
Hole Pools (FSHP)
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Discharge Zone
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Missouri River Sampling Zones
Labadie Thermal
Demonstration Project
Sheet 1 of 8
Ameren
amec foster wheeler
Job No. 325215014
Date: 1/18/2017
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Reviewed By: WJE
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Macrohabitat: SCCS
Boles Daybacon
RM 61
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ISB
OSB
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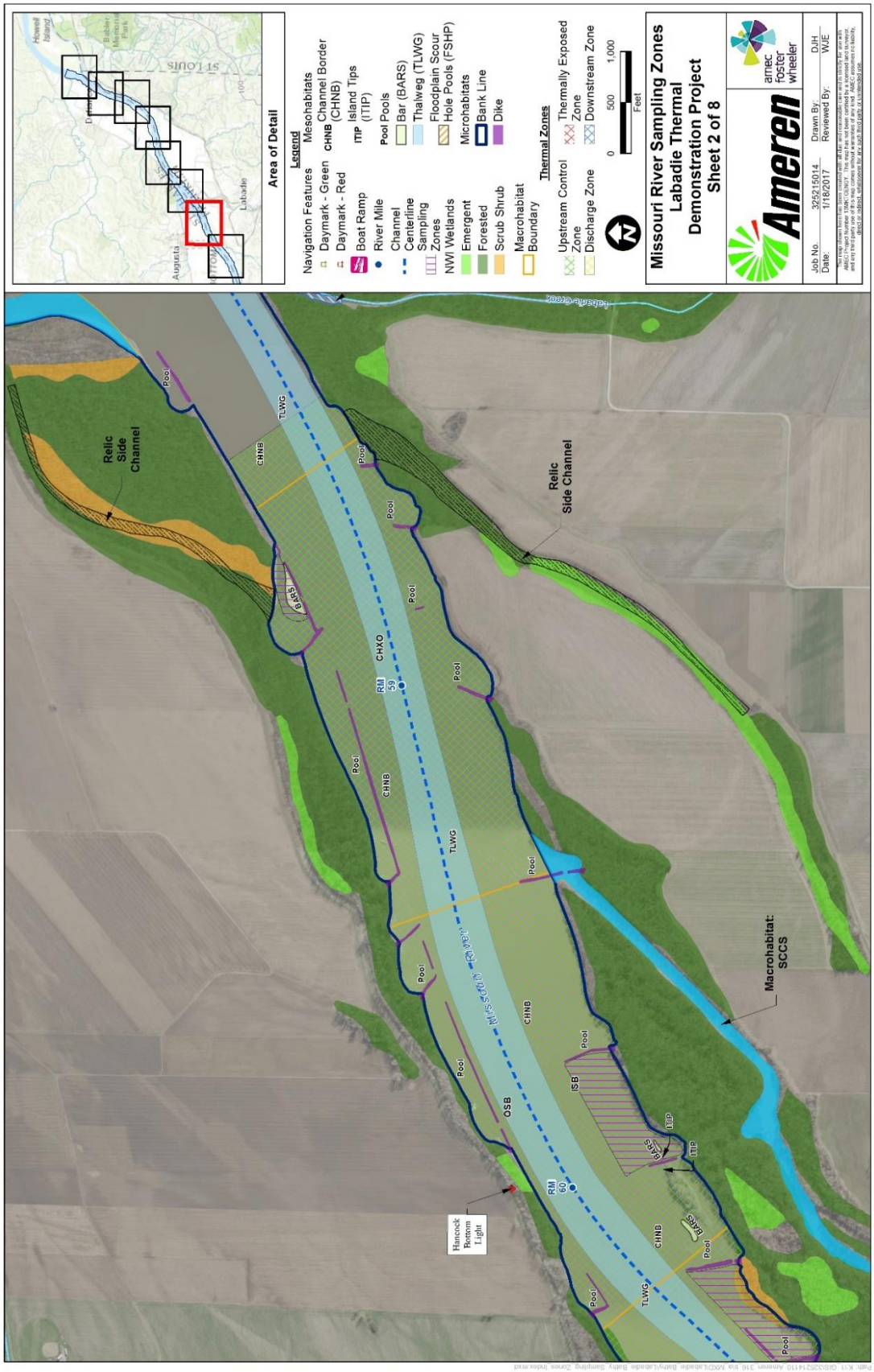
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Sheet 2 of 8
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Job No. 32521501 4
Date: 1/18/2017
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Reviewed By: WJE
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RM 59
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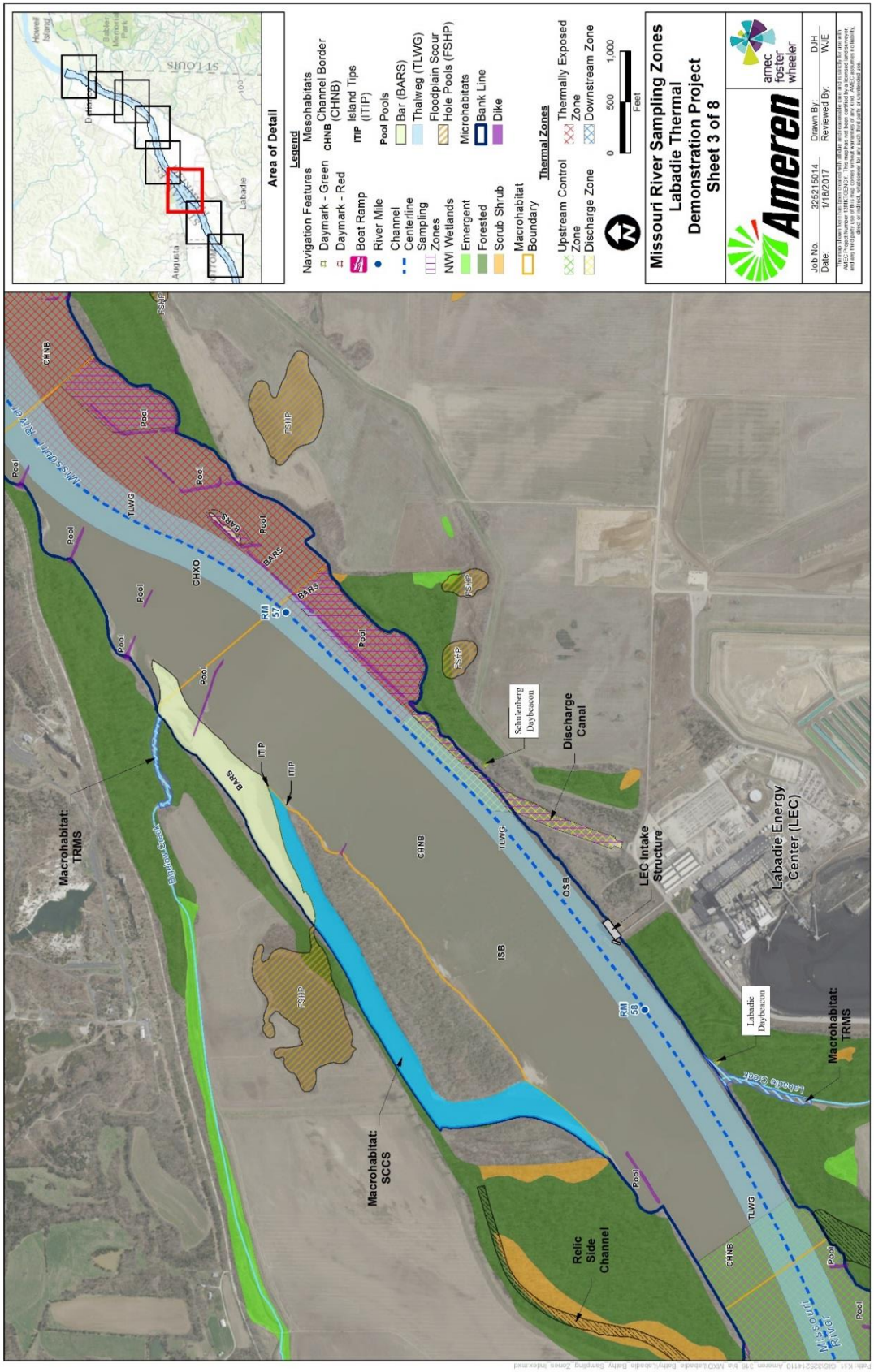
Pool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Discharge Canal
LEC Intake Structure
Labadie Energy Center (LEC)
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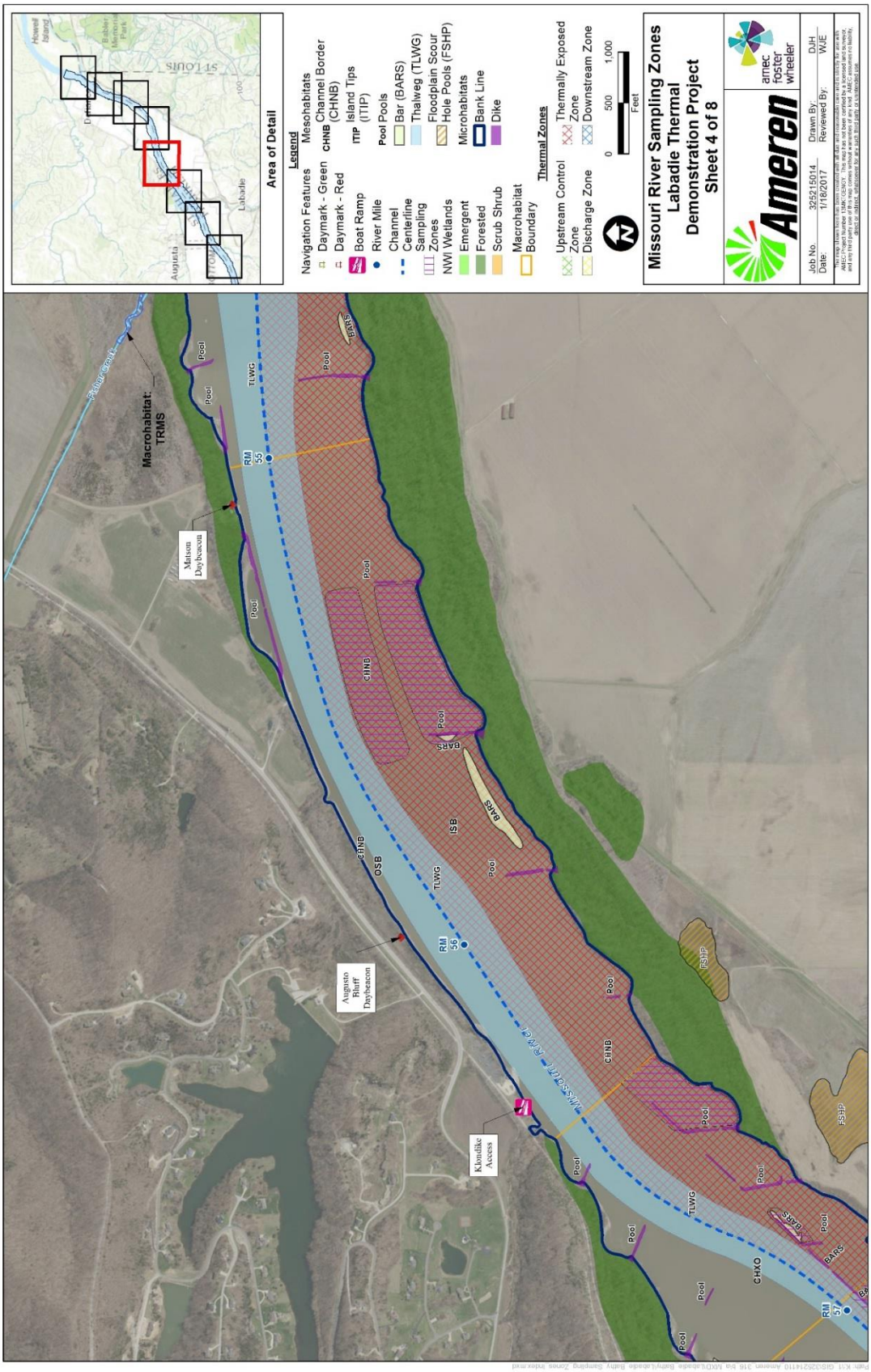
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Sheet 4 of 8
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Reviewed By: WJE
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Augusto Bluff Daybeacon
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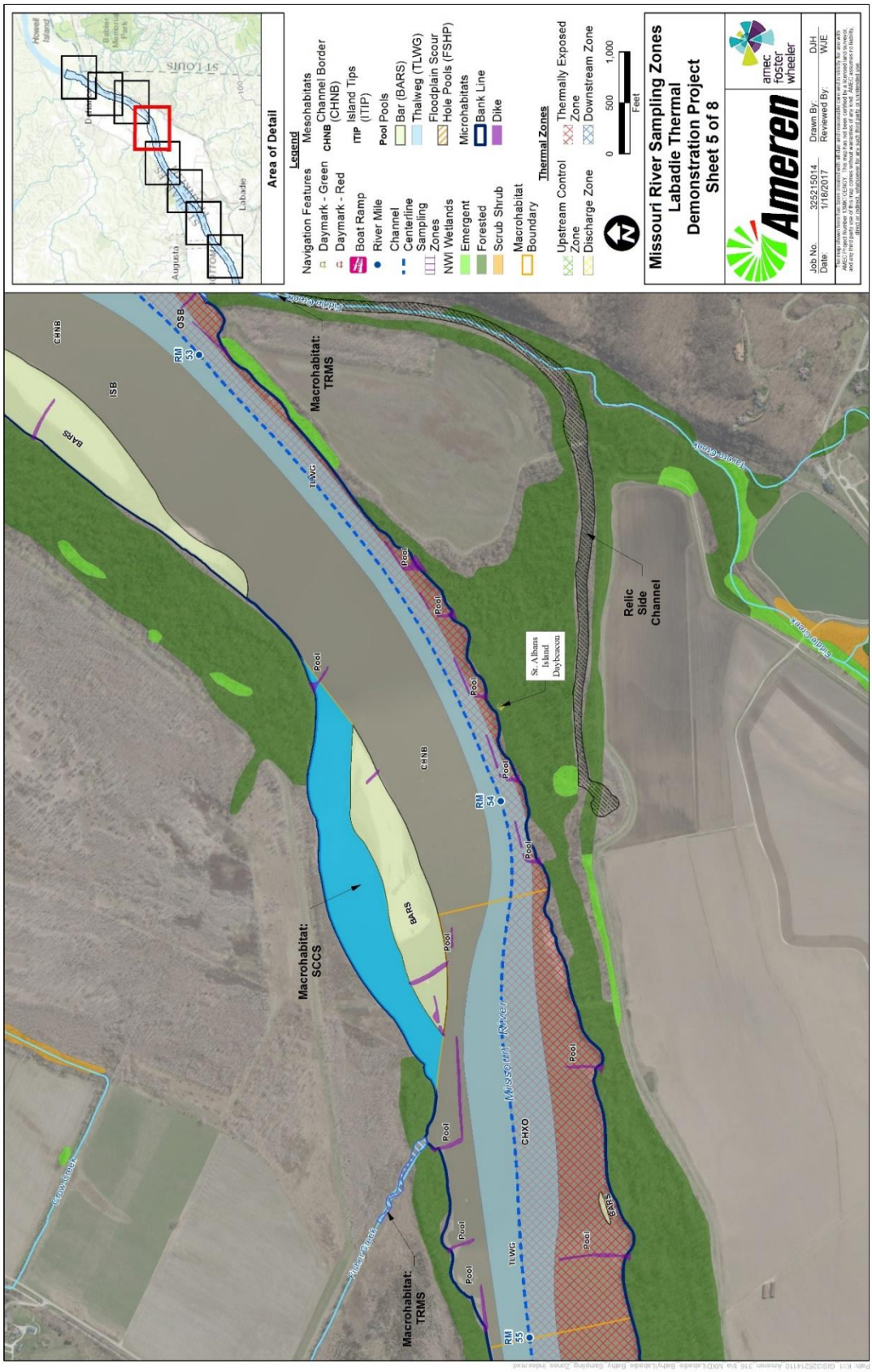
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Labadie Thermal
Demonstration Project
Sheet 5 of 8
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Reviewed By: WJE
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Macrohabitat: SCCS
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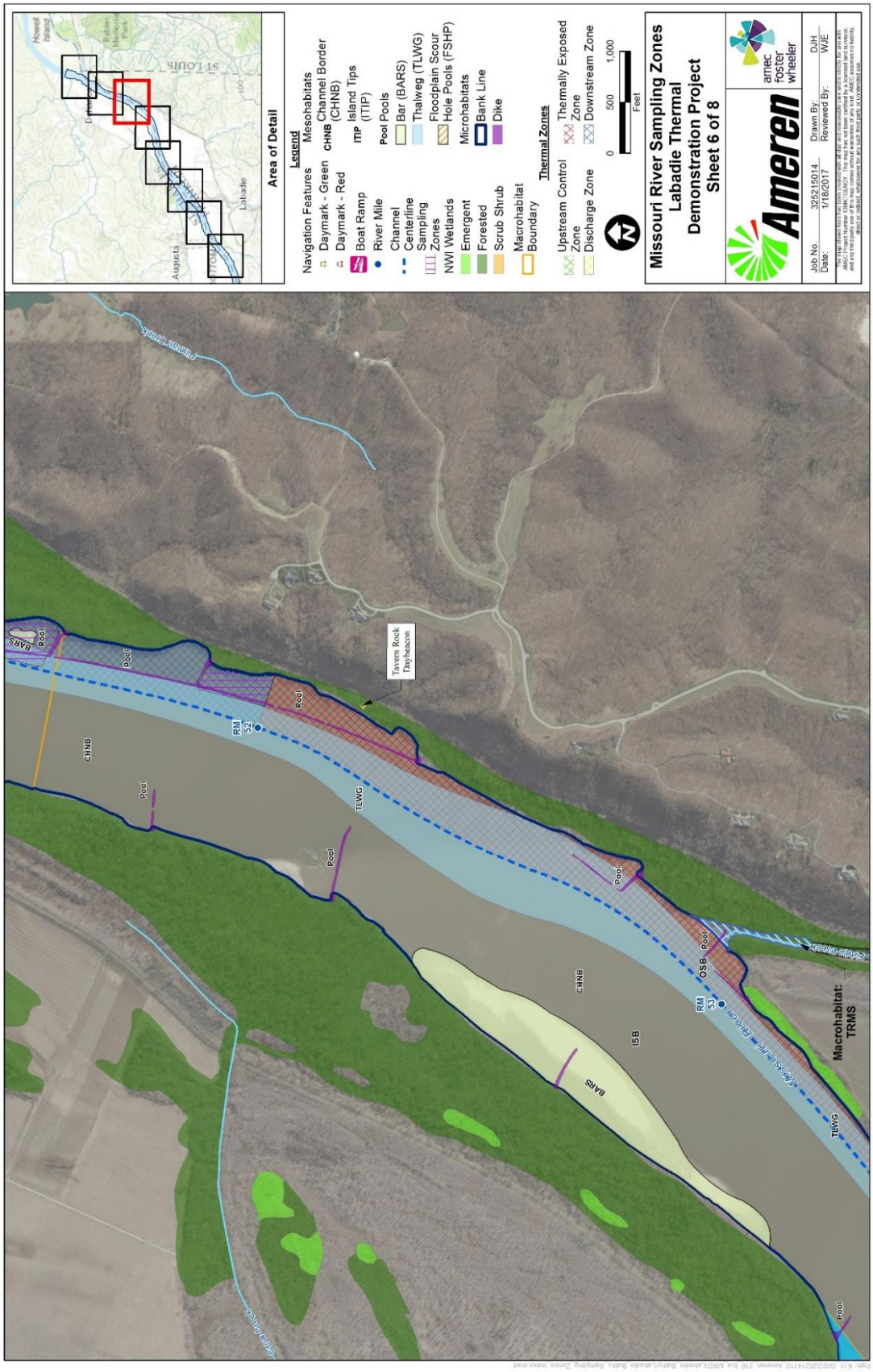
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ITIP Island Tips (ITIP)
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Microhabitats
Bank Line
Dike
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Discharge Zone
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Downstream Zone
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Feet
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Labadie Thermal
Demonstration Project
Sheet 6 of 8
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Job No. 325215014
Date: 1/18/2017
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Reviewed By: WJE
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RM 53
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OSB
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Augusta
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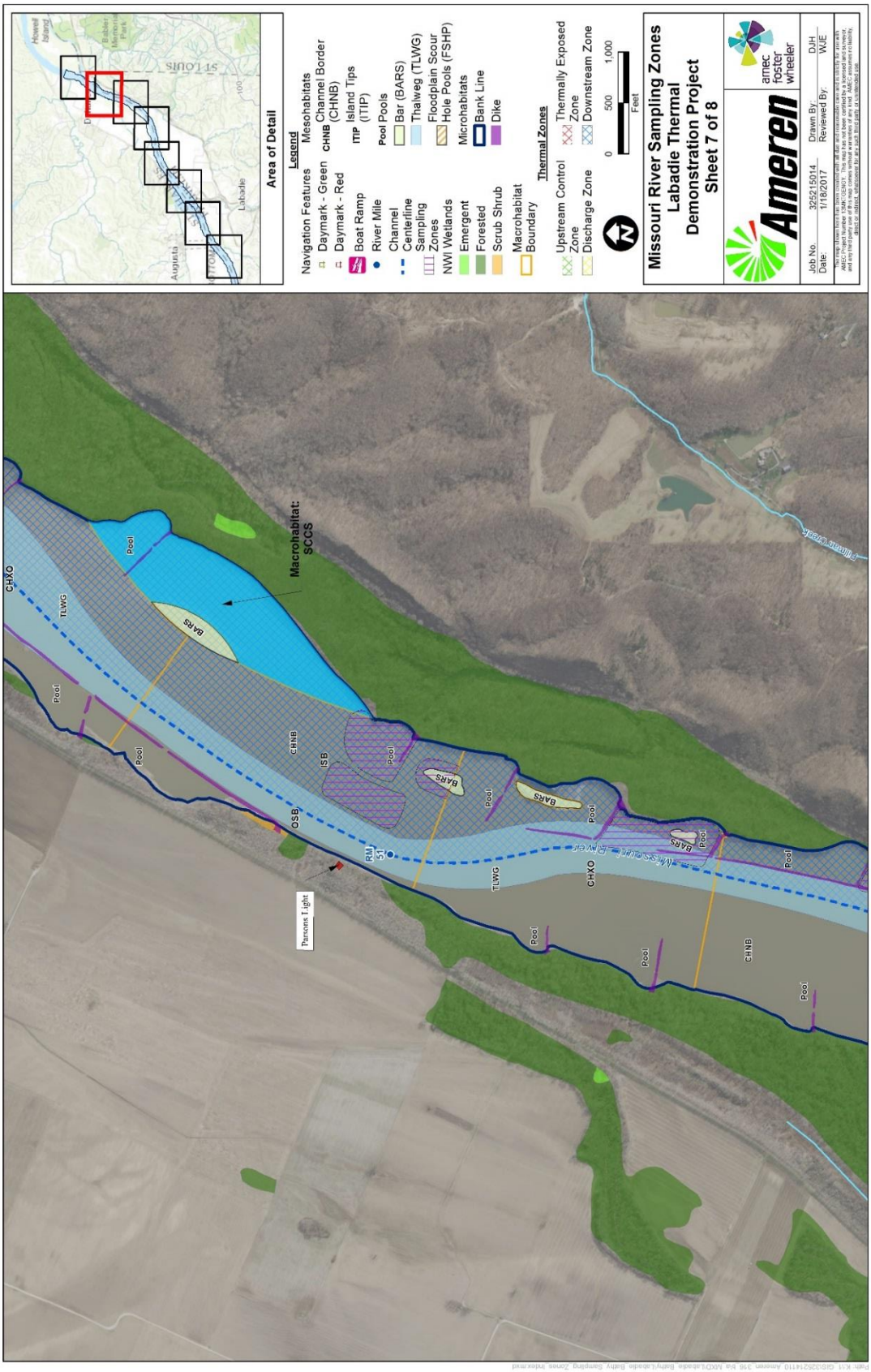
St. Louis
Howell Island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Upstream Control Zone
Discharge Zone
Thermally Exposed Zone
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Missouri River Sampling Zones
Labadie Thermal Demonstration Project
Sheet 7 of 8
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amec foster wheeler
Job No. 325215014
Date: 1/18/2017
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Reviewed By: WJE
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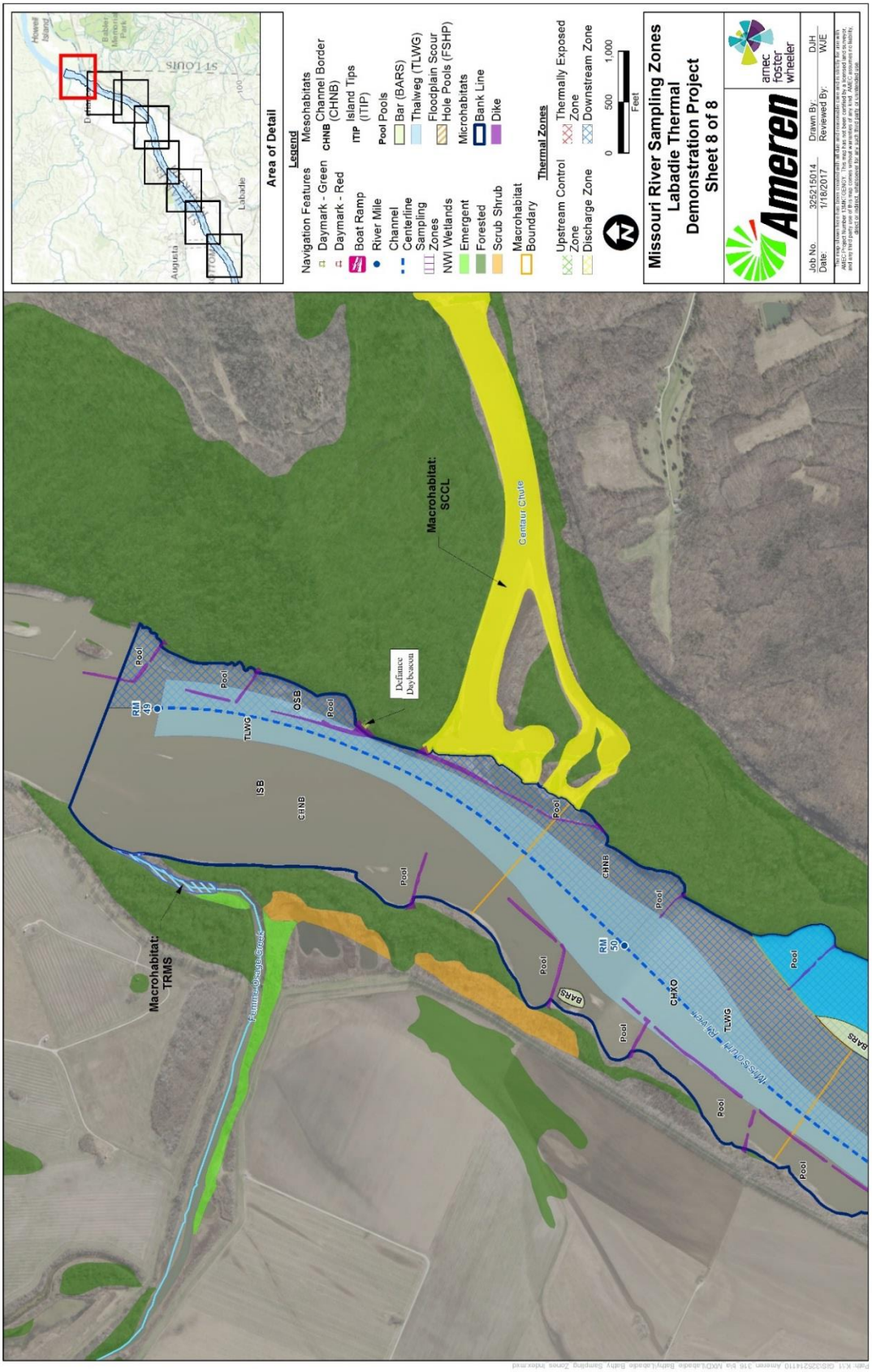
RM 51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Defiance Daybosecu
Pool
RM 49
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MISSOURI RIVER
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Pool Pools
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Thermal Zones
Upstream Control Zone
Discharge Zone
Thermally Exposed Zone
Downstream Zone
0 500 1,000
Feet
Missouri River Sampling Zones
Labadie Thermal Demonstration Project
Sheet 8 of 8
Ameren
amec foster wheeler
Job No. 325215014
Date: 1/18/2017
Drawn By: DJH
Reviewed By: WJE

APPENDIX B
Reconnaissance Survey Photo Log

Upstream Control Zone

1. View upstream of inside of second L-dike on outside bend within Upstream Control Zone (approximately RM 61.2).

2. Close-up view of second L-dike on outside bend within Upstream Control Zone (approximately RM 61.2).

3. Downstream view of shoreline downstream of second L-dike on outside bend within Upstream Control Zone (approximately RM 61.2).

4. View upstream of second L-dike in main channel crossover within Upstream Control Zone (approximately RM 60.5).

5. Close-up view of wing-dike on inside bend within Upstream Control Zone (approximately RM 60).

6. View of sand bar on inside of second L-dike on main channel crossover within Upstream Control Zone (approximately RM 58.75).

Discharge Zone

7. View of Labadie Energy Center discharge canal and western point of discharge canal mouth with the Missouri River (mix of mud/clay/rock substrate).

8. Eastern stretch of discharge canal near mouth with the Missouri River (mud/clay substrate).

Thermally Exposed Zone

9. First L-dike on outside bend within Thermally Exposed Zone with view of notch.

10. Sand bar on inside corner of second L-dike in main channel crossover within Thermally Exposed Zone.

11. View downstream of bar habitat composed of mud/clay within Thermally Exposed Zone (approximately RM 55.8).

12. View sand bar on upstream side of wing-dike within Thermally Exposed Zone (approximately RM 55.6).

13. Second wing-dike on inside bend within Thermally Exposed Zone (approximately RM 55.6).

14. View of shoreline downstream of second wing-dike on inside bend within Thermally Exposed Zone (approximately RM 55.5).

Downstream Zone

15. View upstream of inside of first L-dike on outside bend within Downstream Zone (approximately RM 52.25).

16. View upstream of first L-dike in channel crossover within Downstream Zone (approximately RM 51.5).

17. View of shoreline downstream of first L-dike in channel crossover within Downstream Zone (approximately RM 51.5).

18. View of bar composed of mud/sand within first L-dike in channel crossover of Downstream Zone (approximately RM 51.5).

19. Downstream view of bar composed of mud/sand downstream of first wing-dike in channel crossover within Downstream Zone (approximately RM 51).

20. View upstream of first wing-dike on inside bend within Downstream Zone (approximately RM 50.9).

21. Close-up view of first wing-dike on inside bend within Downstream Zone (approximately RM 50.9).

AMEREN MISSOURI LABADIE ENERGY CENTER
316(A) STUDY PLAN

ADDENDUM 2
PREDICTIVE BIOTHERMAL ASSESSMENT

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Washingtonville, New York 10992

May 2017

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1 INTRODUCTION AND PURPOSE

This Addendum 2 summarizes proposed methodology for conducting a predictive biothermal assessment for the Labadie Energy Center (LEC) Thermal Study. It supplements a general description presented in Section 5.3 of the LEC 316(a) Study Plan dated August 18, 2016. The predictive biothermal assessment, together with the retrospective assessment described in Section 5.2 of Study Plan, will provide a comprehensive assessment of the potential biological effects of exposure on a seasonal basis to the LEC thermal plume, as related to the protection and propagation of a balanced indigenous community (BIC) in the lower Missouri River.

Together, the predictive and retrospective assessments will form a weight-of-evidence approach using several sources of guidance, including:

- USEPA draft guidance manuals (Draft 316(a) Guidance) issued for the implementation of Section 316(a) of the Clean Water Act (CWA) in 1974, 1975, and 1977 (USEPA 1974, 1975, 1977);
- 40 CFR Part 125 Subpart H;
- Professional practice in prior Section 316(a) assessments at other generating stations; and
- Guidelines for Ecological Risk Assessment (ERA Guidance) recommending approaches and criteria for assessing impacts from chemical, physical, or biological stressors (USEPA 1998).

The LEC has been continuously operating since its four generating units were placed in service between 1970 and 1973. The continuous operation of LEC over the past 46+ years would suggest that a Type I, retrospective demonstration of No Prior Appreciable Harm (NPAH), as described in Section 5.2 of the Study Plan, will constitute the best evidence of thermal effects of the LEC discharge on the aquatic community in its vicinity and ultimately the lower Missouri River.

The greatest utility of a Type II predictive assessment, including the assessment of the relative vulnerability of biotic categories (Section 5.1 of the Study Plan), is its application to facilities in the planning stage or at sites where there is an insufficient period of operation to manifest all thermal effects. However, a predictive assessment may provide information and insight into the population and community dynamics underlying the data collected from field surveys (Section 4 of the plan) or on species and life stages not collected but suspected to be present in the study area.

The LEC 316(a) studies will utilize a retrospective assessment to evaluate the endpoint of NPAH for both benthic macroinvertebrates and fish. The predictive assessment outlined in this addendum will be conducted to supplement the retrospective assessment for selected representative important species (RIS) of fish.

The predictive assessment will utilize information derived from modeling of the LEC thermal plume, available literature on the thermal tolerance of selected species, and the seasonality of occurrence by life stage as demonstrated by catch statistics from the field sampling and pertinent literature sources or other surveys of the lower Missouri River. Section 2 below briefly describes the mathematical model selected to simulate the spatial characteristics of the LEC thermal plume under varying environmental and operational scenarios. Section 3 proposes the elements of an assessment of potential thermal effects on individual fish species and their life stages residing

within the influence of the modeled thermal plume. Section 4 states where the predictive assessment results will be reported and interpreted.

2 HYDROTHERMAL MODELING

2.1 MODEL SELECTION

In support of the predictive biothermal assessment, a state-of-the-art, dynamic hydrothermal model will be used to simulate the spatial extent of the LEC's thermal plume, depicted as an equilibrium state under a specified scenario of river and plant operation conditions. The FLOW-3D computational fluid dynamics model (Flow Science 2016) was selected for modeling the three-dimensional mixing of the LEC thermal discharge with the Missouri River. This model was deemed appropriate for this application because of its ability to simulate both near-field and far-field mixing and to accommodate complex river features such as variable bathymetry, bars, islands, and dikes that are present in the Missouri River. It previously has been used in evaluating compliance with Missouri thermal water quality standards (Kleinfelder 2016) where it is described in more detail, including validation procedures. It also has been used to support the selection of sampling sites for annual biological monitoring for the retrospective biothermal assessment, as described in the Study Plan and its Addendum 1, Habitat Characterization and Sampling Site Selection.

For the predictive assessment, the model domain (spatial extent of the computational grid) will extend from approximately 0.75 river miles upstream of the facility discharge to a point approximately 8 river miles downstream of the discharge. Two overlapping numerical meshes with different resolutions will be used: a nested grid mesh with fine spacing (15 feet by 15 feet) for higher resolution near the discharge outfall and a coarser mesh (30 feet by 30 feet) away from the discharge outfall. The vertical resolution will be 4 feet for both grid meshes.

2.2 MODEL SCENARIOS

Multiple scenarios representing varying inputs of boundary conditions (i.e., river flow rate and river temperature) and plant operating conditions (i.e., discharge flow rate and discharge temperature) will be modeled to characterize plume temperatures to which resident organisms would be exposed. The scenarios will be selected with the objective of representing reasonable "worst case" (maximum temperature elevation) and typical conditions on a seasonal basis, relying on statistical analysis of historical records of the LEC operation and river flow and temperature.

Preliminary modeling (Kleinfelder 2016) has indicated that plume temperature exposure likely would be greatest during periods of low river discharge, most importantly during summer and winter months. These two seasons are expected to be targeted by the predictive biothermal assessment. Besides river flow and temperature, the model input variables of plant discharge temperature and discharge flow rate will be evaluated to determine operating conditions that most effect elevated plume temperatures.

3 ASSESSMENT METHODS

3.1 REPRESENTATIVE IMPORTANT SPECIES

USEPA's 1977 Draft 316(a) Guidance recognizes that it is impractical to study and assess in detail every species at a site. Therefore, it is necessary to select a smaller group designated as RIS to be representative of the balanced indigenous community. As stated in USEPA's 1977 Draft 316(a) Guidance, RIS would include species that are:

- representative, in terms of their biological requirements, of a balanced indigenous community of fish, shellfish, and wildlife;
- commercially and recreationally valuable;
- threatened or endangered;
- critical to the structure and function of the ecosystem (e.g., habitat formers);
- potentially capable of becoming localized nuisance species; and
- necessary in the food chain for the well-being of species determined above.

Other considerations for RIS selection include the extent of the species' involvement with the thermal plume, their thermal sensitivity, and the quantity and quality of information available for the assessment, such as data on thermal tolerance.

Another consideration is the seasonal occurrence and abundance of prospective species within the area potentially influenced by the LEC thermal plume. While many or most fish species in the lower Missouri River may be year-round residents within the area, some are more transient, using the area for adult spawning migrations, dispersal of young to habitats more suitable for the species, or refuge from natural environmental conditions (e.g., high flows or non-preferred water temperatures). For fish species, the results of catch data collected during the monthly surveys for the retrospective assessment will provide an additional basis for RIS selection.

The final selection of RIS for the predictive biothermal assessment will be made in consultation with the MDNR. To the extent that thermal tolerance data are available and seasonal presence in the study area is indicated, all life stages for the RIS (embryonic, larval, juvenile, and adult) will be included in the analysis. A preliminary list of RIS and the reason for inclusion is as follows.

Species	**Reason for Inclusion**
Pallid sturgeon *Scaphirhynchus albus*	endangered species
Bighead/silver carp *Hypophthalmichthys* sp.	nuisance species
Gizzard shad *Dorosoma cepedianum*	food chain species
Walleye/sauger *Sander* sp.	thermally sensitive recreational species
Channel catfish *Ictalurus punctatus*	commercial/recreational species
Emerald shiner *Notropis atherinoides*	food chain species
White crappie *Pomoxis annularis*	thermally sensitive recreational species
Largemouth bass *Micropterus salmoides*	commercial/recreational species
Shorthead redhorse *Moxostoma macrolepidotum*	thermally sensitive species

3.2 RIS EVALUATION

As recommended in the USEPA Draft 316(a) Guidance, the potential effects of the thermal discharge on RIS to be evaluated will include:

- mortality from excess heat,
- mortality from cold shock,
- habitat exclusion,
- blockage of migration, and
- reduced growth or reproductive success.

The nature and likelihood of thermal effects will be characterized by evaluating the habitat preferences, seasonal occurrence, and temperature requirements or limits of each species and life stage to thermal exposures potentially resulting from the LEC's operations, as determined from the hydrothermal modeling.

River temperature sampling surveys and preliminary model runs have indicated that the thermal plume becomes entrained along the right descending shoreline, which in the study area includes wing dikes and L-dikes, as well as open shoreline (see Addendum 1). With this in mind, the evaluation will include fish species that utilize channel margin and nearshore habitats (particularly dike fields) in addition to the river's main channel.

The predictive analyses will identify the nature and seasonal timing of potential thermal effects on each RIS and life stage. The spatial extent of these potential effects will be characterized by estimating the dimensions of the water body (e.g., volume, cross-sectional area) occupied by temperatures that might limit important biological activities.

Mortality from excess heat (heat shock) could include all life stages whose presence in the area would be expected. The elapsed time of exposure to potentially lethal temperatures will be evaluated for RIS whose eggs and larvae freely drift in the river current and for RIS that depend on habitat more protected from the river currents for spawning and early life stage development.

The potential for mortality from cold shock will be evaluated for species utilizing the thermal plume to achieve their preferred temperatures but could suffer acute mortality if the thermal plume were dissipated by abrupt cessation of thermal discharge from the LEC operating units. Laboratory-derived data for cold shock is sparse for the RIS but will be used for this evaluation as available.

Juvenile and adult fish, with their greater mobility than earlier life stages, may vacate water temperatures exceeding their preference and thus be excluded temporarily from the otherwise suitable habitat. Laboratory-derived avoidance and preference temperatures available in the literature will be used to quantify the amount of excluded habitat.

Some fish species utilize the lower Missouri River for seasonal migrations to and from spawning areas or areas on which they rely for forage or optimal habitat. The predictive assessment will evaluate the possibility of blockage of these migrations by thermal plume temperatures equaling or exceeding available laboratory-derived avoidance temperature data for the species. To this end, the minimum cross-sectional area providing passage for the migrating species will be quantified as a percentage of the river's overall cross-section along a transect corresponding to the greatest influence of the plume.

Lastly, elevated plume temperatures have the potential of affecting the location and possibly the timing of fish spawning, as well as the survival, development, and growth of their spawn. The potential for these thermal effects will be evaluated to the extent that required thermal tolerance data are available for individual species and early life stages. Emphasis will be placed on riverine habitats that are utilized as spawning and rearing areas, including shallow water habitats and those with shoreline structures such as dikes or natural cover types. The season, location, and size of potentially affected habitat areas will be described.

4 REPORTING

The results of the predictive biothermal assessment will be incorporated into the §316(a) variance demonstration and will be combined and interpreted along with the results of the retrospective assessment described in Section 5.2 of Study Plan. Together, these two assessments will be the basis for a master rationale determining whether the LEC thermal discharge is protective of a balanced indigenous community in the lower Missouri River.

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AMEREN MISSOURI LABADIE ENERGY CENTER
316(a) STUDY PLAN

ADDENDUM 3
SUMMARY OF REVISIONS TO THE INITIAL STUDY PLAN

DRAFT

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Prepared by:
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May 2017

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1 INTRODUCTION AND PURPOSE

This addendum summarizes changes and adjustments to the original Labadie Energy Center (LEC) 316(a) Study Plan (the plan) resulting from work conducted subsequent to the initial plan submittal. Phase I of the plan that included the preliminary hydrothermal modeling, habitat characterization, and sample site selection has been completed and is presented in Addendum 1 to the Labadie 316(a) Study Plan. While the results of this work did not require major changes to the study approach or the main components of the plan (i.e., hydrothermal modeling, biological monitoring studies), they did necessitate revisions to some of the details associated with the biological monitoring studies. The revisions to the biological monitoring studies include:

- the number of sampling zones,
- the number of riverine habitat types present in the study area,
- types of gear proposed for sample collection, and
- number of samples per gear type and habitat type.

There were no revisions to Sections 1, 3, and 6 of the Study Plan. Section 2 presented an overview of the study and sampling approach. Therefore, the changes described below would also apply to the corresponding sections of Section 2. The only change to Section 5 of the original Study Plan, which presented the biothermal assessments, is that Ameren has decided to proceed with conducting the predictive assessment (Addendum 2 to the Labadie 316(a) study plan).

The remainder of this addendum highlights the changes made to the original Labadie 316(a) Study Plan that was submitted to the MDNR on August 22, 2016 and provides a brief rationale for each change.

2 REVISIONS TO THE ORIGINAL LABADIE 316(A) STUDY PLAN

Subsequent to the submittal of the initial Labadie 316(a) Study Plan, Ameren completed work on the Phase I studies described in Section 4.1, Phase I of the plan. Phase I studies included preliminary hydrothermal modeling and habitat characterization for the anticipated study area and resulted in the selection of sample collection sites for the biological monitoring studies. The sampling zones, riverine habitat types, sampling gear, and sampling sites described in the original study plan were based on anticipated thermal plume distribution and habitat types. The completion of Phase I resulted in a more accurate description of the expected thermal plume distribution and habitat types within the study area, thus allowing refinements to the fish and benthic macroinvertebrate surveys which are described below.

In addition to the refinements for the fish and benthic macroinvertebrate surveys, continuous temperature monitoring has been added to the study plan for sampling locations in the discharge, thermally exposed, and downstream zones. Continuous temperature monitoring will provide data with which to evaluate the short-term changes in temperature regime within each habitat type and zone. ONSET HOBO continuous temperature monitors will be set 1 foot below the surface and 1 foot above the bottom in each habitat type (except channel border habitats due to the swift current) in each zone. Temperature monitors will be set at 2 locations within the discharge zone – one in the discharge canal and one along the bank downstream of the mouth of the discharge canal. Temperature will be recorded every 15 minutes and temperature monitors will be checked and data downloaded monthly. During periods of high river flow and debris loading, monitors may be removed until river conditions allow the monitors to be reset.

2.1 FISH SURVEYS – SITE SELECTION

The following describes revisions to survey details in Section 4.2.1, Fish Surveys of the original Study Plan for sample site selection.

Addition of fourth sampling zone

A discharge zone was added to the study area and includes the discharge canal downstream to the first wing dike. This area has been sampled historically and, based on the preliminary hydrothermal modeling, experiences a thermal exposure distinct from other zones. The four sampling zones that comprise the LEC 316(a) study area are now:

1. An upstream control zone unaffected by the LEC intake or discharge (RM 58.5 – RM 62),
2. A discharge zone encompassing the area of highest potential exposure to the thermal discharge (RM 57.5 – RM 57.25)
3. A thermally exposed zone where any potential effects from thermal discharge would be expected if present (RM 57.25 – RM 52), and
4. A downstream zone which potentially could experience minor and transient exposure to the thermal discharge (RM 52 – RM 50).

Data collected from the discharge zone will be compared to available historical data for the same area. Therefore, fish and benthic macroinvertebrate sampling will be conducted using only the same sampling methods as historical studies – electrofishing for fish and a Ponar dredge and Hester-Dendy samplers for benthic macroinvertebrates. Sampling in the other three zones will be stratified by habitat and use multiple gear types to allow a comparison of fish and benthic macroinvertebrate communities among the upstream control, thermally exposed, and downstream zones.

Temperature defining extent of thermally exposed zone

A temperature 5°F above the ambient river water temperature was used to define the thermally exposed zone in the original plan. The thermally exposed zone is now based upon a temperature 3°F above the ambient temperature. A temperature of 3°F above ambient is considered to exceed natural daily water temperature variations[1] and would approximate the 90°F isotherm (the Missouri water quality standard for maximum temperature) at the highest modeled temperature of 87°F.

Habitat types sampled within each zone

The original plan assumed there would be three primary habitat types sampled within each sampling zone —- channel border, wing-dike or L-dike field, and main-channel/thalweg (inside bend or outside bend). Based upon the preliminary hydrothermal modeling and habitat characterization conducted in Phase I studies, the following six habitat types will be sampled in each of the three primary zones (upstream control, thermally exposed, and downstream):

1. Inside bend channel border;
2. Outside bend L-dike/pool
3. Channel crossover L-dike/pool
4. Inside bend W-dike/pool
5. Inside bend W-dike/bar
6. Channel crossover L-dike/bar

2.2 FISH SURVEYS – SAMPLE COLLECTION

The following describes revisions to survey details in Section 4.2.1, Fish Surveys of the original Study Plan for sample collection methods.

Addition of hoop nets

The original plan specified the use of four gear types for conducting the fisheries sampling — electrofishing, mini-Missouri trawl, seine, and plankton net. Hoop nets are added as a fifth sampling gear type. One hoop net will be deployed per habitat type per zone (Table 2-1) for a total duration of 48 hours per event. Nets will be checked and reset after 24 hours.

Specification of sampling gear by habitat type

Based on the three habitat types presumed to be present in the original plan, channel border habitats were to be sampled using the mini-Missouri trawl and electrofishing; dike field habitats were to be sampled using the same two gears plus a plankton net and bag seine; and the channel/thalweg habitat would be sampled using the mini-Missouri trawl. Table 2-1 lists the revised habitat types and sampling gear that will be used to sample each habitat type.

Night sampling eliminated

Day and night sampling was proposed for all gear types in the original plan. Night sampling was eliminated in the revised plan primarily because of crew safety concerns. Hoop nets will be sampled using an overnight set in lieu of mini-Missouri trawl night sampling.

Number of mini-Missouri trawls per habitat type

The original plan specified that one trawl sample of an approximate duration of 3 to 5 minutes would be collected in each habitat type in each zone. The plan was revised to include three trawls

[1]Conservatively based on a typical daily water temperature range of 1-2°F recorded at USGS gage 06935550, upstream of the LEC cooling water discharge outfall

each of an approximate duration of 2 to 5 minutes in each habitat type in each zone. The 3 trawls will be composited to yield one trawl sample per habitat type per zone.

Number of ichthyoplankton tows per habitat type

The original study plan stated that two ichthyoplankton tows would be collected in each of three habitat types in each primary sampling zone during each sampling event. The number of ichthyoplankton tows per habitat type per sampling zone (upstream control, thermally exposed, and downstream) per event has been revised to one tow in each of the six habitat types listed above in Section 2.1.

Ichthyoplankton net and tow duration

A 1-meter plankton net was specified for ichthyoplankton sampled collection in the original plan and tow duration was estimated between 3 and 5 minutes each. A one-half meter plankton net with 500-micron mesh will now be used in lieu of the 1-meter net. As a result of the smaller diameter net being used, the tow duration will be extended to between 5 and 10 minutes to yield a 50-cubic meter sample.

Number of seine hauls per habitat type

Two seine hauls in a single habitat type (dike field) per zone were specified in the original plan. The number of seine hauls has been revised to one to two per habitat type per zone (upstream control, thermally exposed, and downstream) per event. In addition, seining will now be conducted in two habitat types per zone (Table 2-1).

2.3 BENTHIC MACROINVERTEBRATE AND SHELLFISH SURVEYS – SITE SELECTION

The revisions that were made to the fish surveys site selection section in the original plan regarding the number of sampling zones and the temperature used to delineate the thermally exposed zone described in Section 2.1 above also were made to the corresponding sections of the benthic macroinvertebrate and shellfish surveys section of the original plan.

Selection of habitat types for sampling

Three habitat types have been selected for benthic macroinvertebrate and shellfish sampling in each of the three primary sampling zones (upstream control, thermally exposed, and downstream):

- Outside bend L-dike/pool
- Channel crossover L-dike/pool
- Inside bend W-dike/pool

In addition, benthic macroinvertebrate samples will be collected from the discharge zone.

2.4 BENTHIC MACROINVERTEBRATE AND SHELLFISH SURVEYS – SAMPLE COLLECTION

The following describes revisions to benthic macroinvertebrate and shellfish survey details in Section 4.2.2 of the original Study Plan for sample collection methods.

Grain size samples

The original plan specified that a separate ponar grab sample would be collected from each sample site for a qualitative grain size analysis. In the revised study plan, the qualitative grain size analysis will be conducted on the composite sample comprised of the three ponar grabs in each habitat type in each zone.

Hester-Dendy sampler array placement

In the original plan, Hester-Dendy sampler arrays were to be placed at three locations within each sample site in each zone. Based on the additional habitat types identified, Hester-Dendy arrays will be placed at two locations within each habitat type in each zone.

Table 2-1. Proposed Sampling Locations and Gear Types for Macrohabitats and Mesohabitats within each Sampling Zone

Sampling Zone	Macrohabitat	Mesohabitat	Approximate River Mile	Electrofishing	IP Tows	Bag Seine	Benthos*	Hoop Net	MO-trawl
Upstream Control Zone	Inside Bend	Channel Border	61.5						✓
	Outside Bend	L-dike/Pool	61.2	✓	✓		✓	✓	✓
	Main Channel Crossover	L-dike/Pool	60.5	✓	✓		✓	✓	✓
	Inside Bend	W-dike/Pool	60	✓	✓		✓	✓	✓
	Inside Bend	W-dike/Bar	60			✓			
	Main Channel Crossover	L-dike/Bar	58.75			✓			
Discharge Zone	NA	NA	57.5	✓			✓		
Thermally Exposed Zone	Outside Bend	L-dike/Pool	57.25	✓	✓		✓	✓	✓
	Main Channel Crossover	L-dike/Bar	56.8			✓			
	Main Channel Crossover	L-dike/Pool	56.6	✓	✓		✓	✓	✓
	Inside Bend	Channel Border	56.25						✓
	Inside Bend	W-dike/Bar	55.6			✓			
	Inside Bend	W-dike/Pool	55.6	✓	✓		✓	✓	✓
Downstream Zone	Outside Bend	L-dike/Pool	52.25	✓	✓		✓	✓	✓
	Main Channel Crossover	L-dike/Pool	51.5	✓	✓		✓	✓	✓
	Main Channel Crossover	L-dike/Bar	51.5			✓			
	Inside Bend	W-dike/Bar	51			✓			
	Inside Bend	W-dike/Pool	50.9	✓	✓		✓	✓	✓
	Inside Bend	Channel Border	50.75						✓

Note: Benthos sampling includes Ponar and Hester-Dendy samplers

3 PREDICTIVE BIOTHERMAL ASSESSMENT

In the original study plan, conducting a predictive biothermal assessment was presented as a potential option pending the outcome of the biological monitoring studies, retrospective assessment, and need for a 316(a) variance request. A predictive biothermal assessment will be conducted to supplement the retrospective assessment and support a request for a 316(a) variance. The predictive biothermal assessment approach is described in Addendum 2 to the Labadie 316(a) Study Plan.

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B. RETROSPECTIVE ASSESSEMENT SUPPORTIVE MATERIAL

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Table B-1 Species composition (numbers caught and weight in kg) of fish sampled with bag seine at the LEC in 2017-2018, by zone.

Rank	Upstream			Discharge			Thermally Exposed			Downstream		
	Taxon	Count	Weight	Taxon	Count	Weight	Taxon	Count	Weight	Taxon	Count	Weight
1	Red shiner	2972	0.281	NS	NS	NS	Red shiner	1092	0.367	Red shiner	1155	0.351
2	Channel shiner	848	0.162	NS	NS	NS	Emerald shiner	666	0.600	Channel shiner	602	0.096
3	Emerald shiner	418	0.080	NS	NS	NS	Gizzard shad	348	0.649	Gizzard shad	556	0.583
4	Sand shiner	200	0.038	NS	NS	NS	Channel shiner	263	0.130	Emerald shiner	462	0.179
5	Bullhead minnow	198	0.038	NS	NS	NS	Sicklefin chub	116	0.014	Bullhead minnow	177	0.140
6	Shoal chub	195	0.037	NS	NS	NS	Shoal chub	98	0.030	Shoal chub	141	0.024
7	Gizzard shad	170	0.033	NS	NS	NS	Bullhead minnow	35	0.037	Mosquitofish	104	0.015
8	Bluntnose minnow	35	0.007	NS	NS	NS	Sand shiner	30	0.010	Sicklefin chub	78	0.019
9	Mosquitofish	34	0.007	NS	NS	NS	Freshwater drum	19	0.031	Sand shiner	69	0.025
10	Freshwater drum	28	0.005	NS	NS	NS	Channel catfish	16	0.036	Blacktail chubs	49	0.005
11	Sicklefin chub	27	0.005	NS	NS	NS	Sturgeon chub	13	0.002	Bluntnose minnow	44	0.038
12	Orangespotted sunfish	18	0.003	NS	NS	NS	Bluntnose minnow	12	0.006	Freshwater drum	28	0.084
13	Goldeye	12	0.002	NS	NS	NS	Goldeye	10	0.022	Orangespotted sunfish	25	0.047
14	Bluegill	11	0.002	NS	NS	NS	White bass	7	0.005	Bluegill	20	0.016
15	Smallmouth buffalo	8	0.002	NS	NS	NS	Minnow Family	6	0.001	Goldeye	15	0.007
16	Sunfish - Lepomis	6	0.001	NS	NS	NS	Silver chub	4	0.001	Silver carp	15	0.007
17	Plains minnow	4	0.001	NS	NS	NS	Bluegill	3	0.005	Smallmouth buffalo	13	0.014
18	River carpsucker	4	0.001	NS	NS	NS	Silver carp	3	0.004	Channel catfish	11	0.023
19	River shiner	4	0.001	NS	NS	NS	Smallmouth buffalo	3	0.005	Pikeperch	10	0.010
20	Silver chub	4	0.001	NS	NS	NS	Blacktail chubs	2	0.000	River shiner	7	0.003
21	Rosyface shiner	3	0.001	NS	NS	NS	Buffalofish	2	0.001	Sturgeon chub	7	0.002
22	Sturgeon chub	3	0.001	NS	NS	NS	Golden redhorse	2	0.013	White bass	6	0.005
23	Bigeye shiner	2	0.000	NS	NS	NS	Largemouth bass	2	0.004	Carpsuckers	5	0.001
24	Brook silverside	2	0.000	NS	NS	NS	Pikeperch	2	0.002	Ghost shiner	5	0.001
25	Channel catfish	2	0.000	NS	NS	NS	River shiner	2	0.002	Buffalofish	4	0.000
26	Longnose gar	2	0.000	NS	NS	NS	Striped bass x white bass	2	0.027	Golden redhorse	3	0.001
27	Silver carp	2	0.000	NS	NS	NS	Banded killifish	1	0.027	Minnow Family	3	0.000
28	Blacktail chubs	1	0.000	NS	NS	NS	Blue catfish	1	0.027	River carpsucker	3	1.182
29	Blue catfish	1	0.000	NS	NS	NS	Flathead catfish	1	0.179	Common carp	2	0.006
30	Grass carp	1	0.000	NS	NS	NS	Plains killifish	1	0.000	Grass carp	2	0.000
31	Ghost shiner	1	0.000	NS	NS	NS	Rosyface shiner	1	0.001	Green sunfish	2	0.004
32	Largemouth bass	1	0.000	NS	NS	NS	Shiners - Notropis	1	0.000	Plains minnow	2	0.001
33	Sauger x Walley	1	0.000	NS	NS	NS	Spotted bass	1	0.001	Silver chub	2	0.000

Rank	Upstream			Discharge			Thermally Exposed			Downstream		
	Taxon	Count	Weight	Taxon	Count	Weight	Taxon	Count	Weight	Taxon	Count	Weight
34	Spotted bass	1	0.000	NS	NS	NS	Suckermouth minnow	1	0.005	Spotted bass	2	0.001
35	Stonerollers	1	0.000	NS	NS	NS				Bigeye shiner	1	0.000
36	Temperate basses	1	0.000	NS	NS	NS				Brook silverside	1	0.001
37				NS	NS	NS				Creek chub	1	0.001
38				NS	NS	NS				Johnny darter	1	0.000
39				NS	NS	NS				Logperch	1	0.001
40				NS	NS	NS				Rosyface shiner	1	0.001
41				NS	NS	NS				Sunfish - Lepomis	1	0.000
Total	**Taxa**	**Count**	**Weight**	**Taxa**	**Count**	**Weight**	**Taxa**	**Count**	**Weight**	**Taxa**	**Count**	**Weight**
	36	**5221**	**0.71**	**0**	**0**	**0**	**34**	**2766**	**2.22**	**41**	**3636**	**2.89**

Table B-2 Species composition (numbers caught and weight in kg) of fish sampled with electrofishing at the LEC in 2017-2018, by zone.

Rank	Upstream			Discharge			Thermally Exposed			Downstream		
	Taxon	Count	Weight	Taxon	Count	Weight	Taxon	Count	Weight	Taxon	Count	Weight
1	Gizzard shad	192	6.116	Red shiner	330	0.162	Gizzard shad	346	24.950	Red shiner	659	0.143
2	Freshwater drum	173	0.150	Blue catfish	154	657.399	Emerald shiner	190	0.343	Gizzard shad	347	7.521
3	Blue catfish	81	0.070	River carpsucker	67	66.947	Red shiner	177	0.177	Emerald shiner	172	0.076
4	Longnose gar	62	0.054	Emerald shiner	59	0.094	Freshwater drum	99	35.768	Freshwater drum	129	25.817
5	River carpsucker	60	0.052	Gizzard shad	56	22.438	River carpsucker	92	98.209	Silver carp	97	130.312
6	Emerald shiner	59	0.051	Freshwater drum	46	39.517	Longnose gar	81	54.133	Shortnose gar	71	44.918
7	Red shiner	58	0.050	Longnose gar	35	23.762	Silver carp	79	144.381	River carpsucker	66	68.449
8	Silver carp	55	0.048	Shortnose gar	31	20.663	Shortnose gar	75	49.828	Blue catfish	65	129.927
9	Goldeye	52	0.045	Flathead catfish	22	57.945	Blue catfish	72	131.030	Flathead catfish	53	5.441
10	Shortnose gar	50	0.043	Common carp	20	71.394	Smallmouth buffalo	62	139.388	Longnose gar	50	32.564
11	Smallmouth buffalo	44	0.038	Channel catfish	19	21.036	Common carp	45	151.600	Goldeye	43	1.875
12	Channel catfish	43	0.037	Smallmouth buffalo	19	57.661	Goldeye	41	2.110	Common carp	41	121.116
13	Common carp	43	0.037	Silver carp	13	33.663	Flathead catfish	40	22.857	Channel shiner	38	0.029
14	Channel shiner	39	0.034	Striped bass x white bass	12	9.347	Channel catfish	25	11.916	Smallmouth buffalo	35	81.179
15	Flathead catfish	28	0.024	Goldeye	11	1.648	Channel shiner	20	0.017	Channel catfish	18	11.357
16	Grass carp	16	0.014	Channel shiner	10	0.007	Grass carp	14	90.115	Sand shiner	14	0.005
17	Bullhead minnow	15	0.013	Spotted bass	6	0.595	Blue sucker	13	20.138	Bullhead minnow	12	0.019
18	Black buffalo	9	0.008	Bullhead minnow	5	0.007	Bluegill	12	0.180	Grass carp	12	61.833
19	Bluegill	9	0.008	Shoal chub	5	0.003	Bullhead minnow	10	0.020	Blue sucker	11	13.126
20	Shovelnose sturgeon	9	0.008	Bighead carp	4	14.443	Spotted bass	10	0.848	Spotted bass	10	1.177
21	Orangespotted sunfish	8	0.007	Blue sucker	4	8.580	Black buffalo	8	27.658	Bluegill	9	0.258
22	Spotted bass	7	0.006	Sand shiner	4	0.003	Bigmouth buffalo	7	23.205	Bigmouth buffalo	7	11.161
23	Blue sucker	5	0.004	Quillback carpsucker	2	2.814	Green sunfish	6	0.052	Orangespotted sunfish	6	0.027
24	Green sunfish	4	0.003	Black buffalo	1	4.216	Mooneye	4	0.013	Shovelnose sturgeon	6	4.208
25	Walleye	4	0.003	Bluegill	1	0.068	Shovelnose sturgeon	4	2.734	Black buffalo	4	16.999
26	White bass	4	0.003	Chestnut lamprey	1	0.084	Shorthead redhorse	3	0.214	Bluntnose minnow	3	0.001
27	Logperch	3	0.003	Fathead minnow	1	0.002	Striped bass x white bass	3	1.521	Shorthead redhorse	2	0.736
28	Skipjack herring	3	0.003	Golden redhorse	1	0.128	White bass	3	0.728	Striped bass x white bass	2	0.103
29	White crappie	3	0.003	Grass carp	1	6.420	Freckled madtom	2	0.003	White bass	2	0.530
30	Bighead carp	2	0.002	Green sunfish	1	0.020	Orangespotted sunfish	2	0.013	Brook silverside	1	0.000
31	Bigmouth buffalo	2	0.002	Lake sturgeon	1	14.262	Quillback carpsucker	2	1.177	Chestnut lamprey	1	0.049
32	Bluntnose minnow	2	0.002	Orangespotted sunfish	1	0.009	White crappie	2	0.381	Goldfish	1	0.054

Rank	Upstream			Discharge			Thermally Exposed			Downstream		
	Taxon	**Count**	**Weight**	**Taxon**	**Count**	**Weight**	**Taxon**	**Count**	**Weight**	**Taxon**	**Count**	**Weight**
33	Brook silverside	1	0.001	Sauger	1	0.074	Black crappie	1	0.000	Logperch	1	0.003
34	Central stoneroller	1	0.001	Shorthead redhorse	1	0.392	Bluntnose minnow	1	0.001	Longear sunfish	1	0.065
35	Freckled madtom	1	0.001	Shovelnose sturgeon	1	0.430	Golden redhorse	1	0.212	Mooneye	1	0.018
36	Lake sturgeon	1	0.001	Suckermouth minnow	1	0.008	Goldfish	1	0.013	Rosyface shiner	1	0.002
37	Largescale stoneroller	1	0.001	White bass	1	0.000	Sand shiner	1	0.001	Skipjack herring	1	0.170
38	Mooneye	1	0.001				Sauger	1	0.733	Walleye	1	0.372
39	River shiner	1	0.001				Sauger x Walleye	1	0.135	White crappie	1	0.104
40	Sauger	1	0.001				Shoal chub	1	0.001			
41	Shoal chub	1	0.001				Silver lamprey	1	0.060			
42	Shorthead redhorse	1	0.001				Silver redhorse	1	0.018			
43	Silver chub	1	0.001				Skipjack herring	1	0.661			
44	Suckermouth minnow	1	0.001				Spotted sucker	1	0.190			
Total	Taxa	Count	Weight	Taxa	Count	Weight	Taxa	Count	Weight	Taxa	Count	Weight
	44	1156	6.95	37	948	1136.24	44	1561	1037.73	39	1994	771.74

Table B-3 Species composition (numbers caught and weight in kg) of fish sampled with hoop net at the LEC in 2017-2018, by zone. NS indicated no sampling in the zone.

Rank	Upstream			Discharge			Thermally Exposed			Downstream		
	Taxon	Count	Weight	Taxon	Count	Weight	Taxon	Count	Weight	Taxon	Count	Weight
1	Shovelnose sturgeon	41	25.597	NS	NS	NS	Blue sucker	29	74.455	Shovelnose sturgeon	35	38.291
2	Blue sucker	30	0.199	NS	NS	NS	Smallmouth buffalo	19	47.619	Blue sucker	23	51.735
3	Blue catfish	16	0.106	NS	NS	NS	Freshwater drum	14	11.086	Blue catfish	22	111.945
4	Freshwater drum	16	0.106	NS	NS	NS	Shovelnose sturgeon	14	9.611	Freshwater drum	14	14.412
5	Smallmouth buffalo	11	0.073	NS	NS	NS	River carpsucker	8	8.824	Goldeye	12	3.396
6	River carpsucker	10	0.066	NS	NS	NS	Flathead catfish	7	22.736	Smallmouth buffalo	12	29.384
7	Common carp	8	0.053	NS	NS	NS	Blue catfish	6	6.154	Flathead catfish	10	28.133
8	Flathead catfish	4	0.026	NS	NS	NS	Common carp	5	21.054	River carpsucker	8	10.468
9	Silver carp	3	0.020	NS	NS	NS	Goldeye	5	1.642	Common carp	5	21.806
10	Channel catfish	2	0.013	NS	NS	NS	Silver carp	5	13.002	Silver carp	4	7.180
11	Longnose gar	2	0.013	NS	NS	NS	Longnose gar	3	8.120	Channel catfish	3	6.250
12	Shorthead redhorse	2	0.013	NS	NS	NS	Shorthead redhorse	3	1.264	Longnose gar	3	10.890
13	Bighead carp	1	0.007	NS	NS	NS	Bigmouth buffalo	2	5.178	Bighead carp	2	18.220
14	Goldeye	1	0.007	NS	NS	NS	Channel catfish	2	1.079	Striped bass x white bass	2	0.880
15	Lake sturgeon	1	0.007	NS	NS	NS	Grass carp	2	13.575	Gizzard shad	1	0.850
16	Paddlefish	1	0.007	NS	NS	NS	Black buffalo	1	4.430	Grass carp	1	6.200
17	Sauger	1	0.007	NS	NS	NS	Sauger x Walleye	1	0.600	Mooneye	1	0.220
18	White bass	1	0.007	NS	NS	NS	Striped bass x white bass	1	0.390	Sauger x Walleye	1	1.930
Total	Taxa	Count	Weight	Taxa	Count	Weight	Taxa	Count	Weight	Taxa	Count	Weight
	18	151	26.33	0	0	0	18	127	250.82	18	159	362.19

Table B-4 Species composition (numbers caught and weight in kg) of fish sampled with Missouri mini-trawl at the LEC in 2017-2018, by zone. NS indicated no sampling in the zone.

Rank	Upstream			Discharge			Thermally Exposed			Downstream		
	Taxon	Count	Weight	Taxon	Count	Weight	Taxon	Count	Weight	Taxon	Count	Weight
1	Sicklefin chub	541	0.143	NS	NS	NS	Sicklefin chub	511	0.156	Shoal chub	490	0.099
2	Channel shiner	400	0.152	NS	NS	NS	Shoal chub	508	0.120	Channel shiner	412	0.126
3	Shoal chub	363	0.138	NS	NS	NS	Channel shiner	460	0.138	Sicklefin chub	394	0.112
4	Freshwater drum	270	0.103	NS	NS	NS	Freshwater drum	239	2.571	Channel catfish	224	0.573
5	Blue catfish	252	0.096	NS	NS	NS	Blue catfish	203	1.374	Blue catfish	183	2.710
6	Channel catfish	232	0.088	NS	NS	NS	Channel catfish	199	0.743	Freshwater drum	104	3.223
7	Gizzard shad	195	0.074	NS	NS	NS	Silver carp	80	4.539	Bullhead minnow	97	0.045
8	Silver carp	95	0.036	NS	NS	NS	Gizzard shad	63	0.088	Gizzard shad	76	0.092
9	Goldeye	50	0.019	NS	NS	NS	Bullhead minnow	59	0.024	Goldeye	71	0.055
10	Bullhead minnow	42	0.016	NS	NS	NS	Emerald shiner	58	0.091	Blacktail chubs	68	0.005
11	Red shiner	26	0.010	NS	NS	NS	Blacktail chubs	47	0.005	Silver carp	37	1.376
12	Emerald shiner	18	0.007	NS	NS	NS	Orangespotted sunfish	44	0.007	Sturgeon chub	25	0.012
13	Blacktail chubs	13	0.005	NS	NS	NS	Goldeye	34	0.072	White bass	14	0.004
14	Silver chub	13	0.005	NS	NS	NS	Sturgeon chub	23	0.008	Red shiner	10	0.003
15	Shovelnose sturgeon	12	0.005	NS	NS	NS	Red shiner	22	0.015	Shovelnose sturgeon	7	2.080
16	White bass	11	0.004	NS	NS	NS	Shovelnose sturgeon	19	9.337	Silver/bighead carp	6	0.003
17	Sucker - Ictiobinae	10	0.004	NS	NS	NS	Shortnose gar	11	6.491	Paddlefish	5	0.001
18	Minnow Family	8	0.003	NS	NS	NS	Paddlefish	10	0.004	Silver chub	5	0.001
19	Sunfish - Lepomis	8	0.003	NS	NS	NS	White bass	10	0.002	Sunfish - Lepomis	5	0.001
20	Pikeperch	7	0.003	NS	NS	NS	Sand shiner	6	0.002	Orangespotted sunfish	4	0.001
21	Sturgeon chub	7	0.003	NS	NS	NS	Common carp	5	0.002	Blue sucker	3	1.290
22	Sunfish - Pomoxis	6	0.002	NS	NS	NS	Silver chub	5	0.002	Bluegill	3	0.002
23	Paddlefish	5	0.002	NS	NS	NS	Bluegill	3	0.001	Common carp	3	0.008
24	Sand shiner	5	0.002	NS	NS	NS	Mooneyes	3	0.000	Longnose gar	3	2.092
25	Buffalofish	4	0.002	NS	NS	NS	Sunfish - Lepomis	3	0.000	Bluntnose minnow	2	0.001
26	Minnow Family group 2	4	0.002	NS	NS	NS	Flathead catfish	2	0.484	Emerald shiner	2	0.003
27	Silver/bighead carp	4	0.002	NS	NS	NS	Grass carp	2	0.005	Flathead catfish	2	0.004
28	Common carp	3	0.001	NS	NS	NS	Gravel chub	2	0.010	Golden redhorse	2	0.000
29	Orangespotted sunfish	2	0.001	NS	NS	NS	Logperch	2	0.000	Minnow Family	2	0.000
30	Shortnose gar	2	0.001	NS	NS	NS	Longnose gar	2	1.700	Mooneye	2	0.000
31	Spotted bass	2	0.001	NS	NS	NS	Minnow Family group 2	2	0.000	Mooneyes	2	0.000
32	Bluegill	1	0.000	NS	NS	NS	Sauger x Walleye	2	0.001	Buffalofish	1	0.000
33	Bluntnose minnow	1	0.000	NS	NS	NS	Sucker - Ictiobinae	2	0.000	Ghost shiner	1	0.000
34	Flathead catfish	1	0.000	NS	NS	NS	Sunfish – Pomoxis	2	0.000	Grass carp	1	0.003
35	Golden redhorse	1	0.000	NS	NS	NS	Bluntnose minnow	1	0.000	Mosquitofish	1	0.000

Rank	Upstream			Discharge			Thermally Exposed			Downstream		
	Taxon	**Count**	**Weight**	**Taxon**	**Count**	**Weight**	**Taxon**	**Count**	**Weight**	**Taxon**	**Count**	**Weight**
36	Grass carp	1	0.000	NS	NS	NS	Catfish (Ictalurus)	1	0.000	Sand shiner	1	0.000
37	Mooneyes	1	0.000	NS	NS	NS	Madtoms	1	0.000	Shiners - Notropis	1	0.000
38	Mosquitofish	1	0.000	NS	NS	NS	Shiners – Notropis	1	0.000	Smallmouth buffalo	1	1.280
39	River shiner	1	0.000	NS	NS	NS	Silverband shiner	1	0.001	Sucker - Ictiobinae	1	0.000
40	Shiners - Notropis	1	0.000	NS	NS	NS	Sturgeon – Scaphirhynchus	1	0.000	Sucker - Redhorses	1	0.000
41	Sturgeon - Scaphirhynchus	1	0.000	NS	NS	NS	Unidentifiedr	1	0.000	Temperate basses	1	0.000
42	Sucker - Catostominae	1	0.000	NS	NS	NS				Unidentified	1	0.000
43	Sucker - Catostomus	1	0.000	NS	NS	NS						
Total	Taxa	Count	Weight	Taxa	Count	Weight	Taxa	Count	Weight	Taxa	Count	Weight
	44	2622	0.94	0	0	0	41	2650	27.99	42	2274	15.20

Table B-5 Sampling statistics for fish monitoring program at LEC in 2017-2018 by gear, zone, and season. NS indicated no sampling in the zone.

Gear	Statistic	Upstream				Discharge				Thermally Exposed				Downstream			
		Win	Spr	Sum	Fal	Win	Spr	Sum	Fal	Win	Spr	Sum	Fal	Win	Spr	Sum	Fal
Bag Seine	Samples	10	6	8	8	NS	NS	NS	NS	10	6	8	8	10	6	8	8
	Count	745	248	445	3782	NS	NS	NS	NS	847	306	900	712	273	998	1463	902
	Weight (kg)	0.32	0.38	0.92	1.63	NS	NS	NS	NS	0.28	0.52	0.68	0.74	0.15	1.68	0.63	0.44
	Mn ct density	65.62	25.57	70.61	250.49	NS	NS	NS	NS	58.86	26.58	74.97	63.84	18.45	136.66	155.06	121.46
	se ct density	24.45	12.97	25.49	100.04	NS	NS	NS	NS	35.56	3.43	35.24	22.78	5.83	79.08	51.87	68.44
	Mn wt density	0.03	0.03	0.15	0.14	NS	NS	NS	NS	0.02	0.04	0.05	0.06	0.01	0.22	0.06	0.06
	se wt density	0.01	0.01	0.1	0.08	NS	NS	NS	NS	0.01	0.01	0.02	0.02	0	0.17	0.02	0.03
Electro-fishing	Samples	18	18	18	17	6	6	6	6	18	18	18	18	18	18	18	18
	Count	319	327	368	142	558	177	67	146	654	332	273	302	1140	287	285	282
	Weight (kg)	305.01	258.57	117.29	136.73	449.8	235.97	32.05	418.43	324.24	278.32	174.62	260.56	257.57	214.86	120.72	178.59
	Mn ct density	17	15.94	17.4	8.08	84.91	26.52	10.39	22.46	32.7	16.46	14.16	15.72	58.33	14.89	15.15	14.45
	se ct density	3.9	1.77	4.28	1.53	35.64	3.92	4.8	5.56	7.08	2.98	3.61	3.28	30.2	2.8	4.09	3.61
	Mn wt density	16.39	12.56	5.58	7.98	66.22	35.95	4.8	64.55	16.38	13.65	8.5	13.58	12.52	11.07	6.2	9.31
	se wt density	3.52	1.23	1.18	1.43	16.8	12.17	2.55	19	3.5	2.83	1.44	3.15	2.49	1.68	0.8	2.73
Hoop Net	Samples	18	18	18	18	NS	NS	NS	NS	18	18	18	18	18	18	18	18
	Count	28	51	42	30	NS	NS	NS	NS	36	36	21	34	32	57	31	39
	Weight (kg)	38.29	82.36	77.72	43.42	NS	NS	NS	NS	70.3	81.4	38.76	60.36	74.43	147.99	80.82	58.96
	Mn ct density	1.46	2.86	2.38	1.68	NS	NS	NS	NS	2.02	2.03	1.19	1.9	1.8	3.2	1.76	2.31
	se ct density	0.77	0.6	0.62	0.58	NS	NS	NS	NS	1.02	0.48	0.35	0.65	0.7	1.42	0.45	0.49
	Mn wt density	1.99	4.61	4.38	2.42	NS	NS	NS	NS	3.94	4.58	2.2	3.38	4.22	8.29	4.57	3.45
	se wt density	1.17	1.24	1.3	1.06	NS	NS	NS	NS	2.73	1.37	0.79	1.66	2.27	3.77	1.28	0.98
Missouri mini-trawl	Samples	24	24	24	24	NS	NS	NS	NS	24	24	24	24	24	24	24	24
	Count	247	613	1011	753	NS	NS	NS	NS	325	575	665	1087	371	475	784	645
	Weight (kg)	10.01	0.93	6.9	3.78	NS	NS	NS	NS	10.38	7.07	1.44	9.11	9.21	2.75	1.4	1.84
	Mn ct density	11.11	25	43.6	32.09	NS	NS	NS	NS	12.32	20.61	26.84	42.26	18.09	22.73	36.29	32.15
	se ct density	2.86	7.22	10.07	13.84	NS	NS	NS	NS	3.11	6.26	7.79	19.09	4.88	5.83	10.01	19.88
	Mn wt density	0.44	0.04	0.29	0.15	NS	NS	NS	NS	0.44	0.28	0.05	0.36	0.5	0.13	0.07	0.07
	se wt density	0.16	0.02	0.2	0.05	NS	NS	NS	NS	0.18	0.12	0.03	0.18	0.16	0.07	0.02	0.05

Table B-6 Sample size, estimated diversity and standard deviation at q = 0, 1, 2, and 3 for fish sampled with bag seine at the LEC in 2017-2018, by season, and zone. NS indicated no sampling in the zone.

Season	Statistic	Upstream			Discharge			Thermally Exposed			Downstream		
		Count		Weight	Count		Weight	Count		Weight	Count		Weight
		Estimate	StdDev	Estimate	Estimate	StdDev	Estimate	Estimate	StdDev	Estimate	Estimate	StdDev	Estimate
Winter	N	745	-	-	NS	-	-	847	-	-	273	-	-
	^{0}D	18	1.02	18	NS	NS	NS	16	2.33	15	15	1.05	15
	^{1}D	7.3	0.25	8.4	NS	NS	NS	3.2	0.15	5.3	4.8	0.37	5.1
	^{2}D	5.8	0.18	6.3	NS	NS	NS	2	0.08	4	2.7	0.22	3.4
	^{3}D	5.3	0.16	5.5	NS	NS	NS	1.8	0.06	3.5	2.3	0.16	2.9
Spring	N	248	-	-	NS	-	-	306	-	-	998	-	-
	^{0}D	20	1.73	20	NS	NS	NS	23	1.5	23	28	1.9	28
	^{1}D	7.6	0.62	7.9	NS	NS	NS	10.9	0.62	8	5.8	0.26	3.4
	^{2}D	5.2	0.41	5.7	NS	NS	NS	8	0.49	5.4	3.7	0.12	2
	^{3}D	4.5	0.34	4.8	NS	NS	NS	7	0.46	4.5	3.3	0.09	1.7
Summer	N	445	-	-	NS	-	-	900	-	-	1463	-	-
	^{0}D	15	1.41	15	NS	NS	NS	15	1.93	15	26	1.74	26
	^{1}D	7.2	0.32	3.6	NS	NS	NS	3.9	0.11	4	5.8	0.18	4.3
	^{2}D	5.8	0.25	2.4	NS	NS	NS	3.4	0.05	3	4.2	0.1	2.4
	^{3}D	5.2	0.25	2.1	NS	NS	NS	3.3	0.04	2.7	3.8	0.09	2
Fall	N	3782	-	-	NS	-	-	712	-	-	902	-	-
	^{0}D	22	1.81	22	NS	NS	NS	18	1.61	18	20	1.33	20
	^{1}D	3	0.06	5.6	NS	NS	NS	6.1	0.23	5.8	7.8	0.27	11.1
	^{2}D	1.9	0.03	4	NS	NS	NS	4.5	0.17	4.2	5.6	0.23	8.8
	^{3}D	1.7	0.02	3.4	NS	NS	NS	4	0.16	3.8	4.7	0.24	7.9

Table B-7 Sample size, estimated diversity and standard deviation at q = 0, 1, 2, and 3 for fish sampled with electrofishing at the LEC in 2017-2018, by season, and zone. NS indicated no sampling in the zone.

Season	Statistic	Upstream			Discharge			Thermally Exposed			Downstream		
		Count		Weight	Count		Weight	Count		Weight	Count		Weight
		Estimate	StdDev	Estimate	Estimate	StdDev	Estimate	Estimate	StdDev	Estimate	Estimate	StdDev	Estimate
Winter	N	319	-	-	558	-	-	654	-	-	1140	-	-
	^{0}D	28	2.49	28	29	3.18	29	30	3.44	30	31	2.84	31
	^{1}D	12.6	0.87	8.8	6.4	0.48	5.3	10.5	0.56	9	6.2	0.3	8.6
	^{2}D	8.7	0.69	7.3	3.1	0.2	3	7.1	0.33	7.1	3.4	0.16	6.7
	^{3}D	7.1	0.68	6.6	2.5	0.14	2.4	6.1	0.28	6.5	2.7	0.12	5.9
Spring	N	327	-	-	177	-	-	332	-	-	287	-	-
	^{0}D	33	2.36	33	22	1.62	22	27	1.23	27	30	2.87	30
	^{1}D	17.2	1.08	10.6	12.8	0.97	8.2	16.3	0.85	12.1	17.1	1.19	10.5
	^{2}D	12.9	0.83	8.3	10	0.77	5	11.8	0.91	9.8	12.5	1.1	8
	^{3}D	11.2	0.79	7.4	8.9	0.69	3.8	9.5	0.93	8.5	10.3	1.17	7
Summer	N	368	-	-	67	-	-	273	-	-	285	-	-
	^{0}D	29	1.82	29	14	0.98	14	30	3.18	30	23	1.75	23
	^{1}D	11.6	0.78	11.7	11.3	1	6.5	13.7	1.17	10.4	11.7	0.82	11
	^{2}D	6.2	0.57	9.9	9.4	1.12	5.6	8	0.9	8.4	7	0.73	9.3
	^{3}D	4.6	0.44	9	8.3	1.16	5.2	5.8	0.72	7.5	5.2	0.6	8.4
Fall	N	142	-	-	146	-	-	302	-	-	282	-	-
	^{0}D	23	2.17	23	18	1.6	18	24	2.02	24	22	1.31	22
	^{1}D	11.7	1.45	10.4	7.3	0.85	3.1	11.6	0.82	9.9	9	0.69	10.6
	^{2}D	6.6	1.15	8.3	4	0.55	1.8	7.7	0.68	7.9	5.2	0.49	9.1
	^{3}D	4.8	0.87	7.2	3.2	0.43	1.6	6.1	0.62	7.1	4.1	0.39	8.3

Table B-8 Sample size, estimated diversity and standard deviation at q = 0, 1, 2, and 3 for fish sampled with hoop net at the LEC in 2017-2018, by season, and zone. NS indicated no sampling in the zone.

Season	Statistic	Upstream			Discharge			Thermally Exposed			Downstream		
		Count		Weight	Count		Weight	Count		Weight	Count		Weight
		Estimate	StdDev	Estimate	Estimate	StdDev	Estimate	Estimate	StdDev	Estimate	Estimate	StdDev	Estimate
Winter	N	28	-	-	NS	-	-	36	-	-	32	-	-
	^{0}D	8	1.87	8	NS	NS	NS	7	1.07	7	10	1.77	10
	^{1}D	3.7	1.24	2.3	NS	NS	NS	3.7	0.69	1.8	6.5	1.52	3.6
	^{2}D	2.3	0.69	1.5	NS	NS	NS	2.5	0.49	1.3	4.8	1.3	2.7
	^{3}D	1.9	0.49	1.4	NS	NS	NS	2.1	0.38	1.2	4	1.13	2.5
Spring	N	51	-	-	NS	-	-	36	-	-	57	-	-
	^{0}D	8	0.72	8	NS	NS	NS	11	1.47	10	11	1.32	11
	^{1}D	6.6	0.58	6.5	NS	NS	NS	8.9	1.35	6.8	5.9	0.96	6
	^{2}D	5.8	0.62	5.3	NS	NS	NS	7.8	1.36	5.7	3.7	0.72	4.1
	^{3}D	5.3	0.64	4.5	NS	NS	NS	7.1	1.37	5.2	3	0.58	3.4
Summer	N	42	-	-	NS	-	-	21	-	-	31	-	-
	^{0}D	11	1.51	11	NS	NS	NS	9	1.48	9	11	1.53	11
	^{1}D	7.5	1.18	7.7	NS	NS	NS	7.7	1.41	7.4	9.1	1.37	9.1
	^{2}D	6	1.02	5.9	NS	NS	NS	7	1.38	6.5	8.1	1.34	8.3
	^{3}D	5.3	0.92	5	NS	NS	NS	6.6	1.35	6	7.5	1.31	7.9
Fall	N	30	-	-	NS	-	-	34	-	-	39	-	-
	^{0}D	8	1.43	8	NS	NS	NS	13	1.63	13	11	1.37	11
	^{1}D	4.9	1.03	5.5	NS	NS	NS	9.4	1.54	7.7	8.8	1.13	8.8
	^{2}D	3.5	0.82	4.7	NS	NS	NS	7.4	1.44	6	7.6	1.09	7.8
	^{3}D	3	0.7	4.4	NS	NS	NS	6.5	1.32	5.2	6.9	1.08	7.2

Table B-9 Sample size, estimated diversity and standard deviation at q = 0, 1, 2, and 3 for fish sampled with Missouri mini-trawl at the LEC in 2017-2018, by season, and zone. NS indicated no sampling in the zone.

Season	Statistic	Upstream			Discharge			Thermally Exposed			Downstream		
		Count		Weight	Count		Weight	Count		Weight	Count		Weight
		Estimate	StdDev	Estimate	Estimate	StdDev	Estimate	Estimate	StdDev	Estimate	Estimate	StdDev	Estimate
Winter	N	247	-	-	NS	-	-	325	-	-	371	-	-
	^{0}D	16	1.45	16	NS	NS	NS	19	1.22	19	22	2.35	21
	^{1}D	8.2	0.53	4.3	NS	NS	NS	7.7	0.52	4.2	7.8	0.52	6.3
	^{2}D	6.4	0.37	3.2	NS	NS	NS	5	0.37	3.5	5.3	0.32	5.4
	^{3}D	5.8	0.33	2.8	NS	NS	NS	4.2	0.31	3.2	4.6	0.27	5
Spring	N	613	-	-	NS	-	-	575	-	-	475	-	-
	^{0}D	28	3.41	28	NS	NS	NS	31	1.76	31	28	2.46	27
	^{1}D	10.6	0.54	5.9	NS	NS	NS	10.4	0.59	2.8	11	0.57	4.9
	^{2}D	8	0.37	4.2	NS	NS	NS	6.5	0.41	1.9	8.2	0.39	3.4
	^{3}D	7	0.4	3.7	NS	NS	NS	5.2	0.37	1.7	7.2	0.41	2.9
Summer	N	1011	-	-	NS	-	-	665	-	-	784	-	-
	^{0}D	28	2.12	28	NS	NS	NS	21	1.48	21	22	1.94	21
	^{1}D	10.7	0.35	2.7	NS	NS	NS	11.2	0.39	3.9	9.7	0.35	6.2
	^{2}D	8.3	0.27	1.8	NS	NS	NS	9.1	0.42	2.5	7.3	0.32	4.6
	^{3}D	7.4	0.3	1.6	NS	NS	NS	7.9	0.46	2.2	6.3	0.32	4.1
Fall	N	753	-	-	NS	-	-	1087	-	-	645	-	-
	^{0}D	15	1.03	15	NS	NS	NS	22	1.69	22	18	1.42	16
	^{1}D	5.4	0.22	2.8	NS	NS	NS	6.2	0.22	5.1	5.7	0.26	2.6
	^{2}D	3.7	0.16	1.8	NS	NS	NS	4.6	0.13	3.4	4.1	0.15	1.8
	^{3}D	3.2	0.14	1.6	NS	NS	NS	4.2	0.1	2.9	3.8	0.13	1.6

Table B-10 Count and weight (kg) by fish type for fish sampled with bag seine at the LEC in 2017-2018, by season, and zone. R = Rough, F = Forage, P = Panfish, G = Gamefish, and S = Special Interest. NS indicated no sampling in the zone.

Season	Statistic	Upstream					Discharge					Thermally Exposed					Downstream				
		R	F	P	G	S	R	F	P	G	S	R	F	P	G	S	R	F	P	G	S
Winter	Count	9	732	4	0		NS	NS	NS	NS	NS	5	842	0	1		10	257	6	0	
	Fraction	0.012	0.983	0.005	0		NS	NS	NS	NS	NS	0.006	0.993	0	0.001		0.037	0.941	0.022	0	
	Weight	0.030	0.286	0.005	0		NS	NS	NS	NS	NS	0.024	0.238	0	0.013		0.042	0.102	0.006	0	
	Fraction	0.093	0.891	0.017	0		NS	NS	NS	NS	NS	0.088	0.863	0	0.049		0.280	0.680	0.041	0	
	Total Ct	745					NS					848					273				
	Total Wt	0.322					NS					0.276					0.15				
Spring	Count	26	212	5	6		NS	NS	NS	NS	NS	54	223	8	21		54	907	20	19	
	Fraction	0.104	0.851	0.020	0.024		NS	NS	NS	NS	NS	0.176	0.729	0.026	0.069		0.052	0.909	0.020	0.019	
	Weight	0.129	0.172	0.031	0.050		NS	NS	NS	NS	NS	0.058	0.240	0.008	0.217		1.263	0.376	0.021	0.020	
	Fraction	0.338	0.450	0.082	0.130		NS	NS	NS	NS	NS	0.110	0.460	0.015	0.415		0.752	0.224	0.013	0.012	
	Total Ct	249					NS					306					998				
	Total Wt	0.383					NS					0.521					1.681				
Summer	Count	89	338	18	0		NS	NS	NS	NS	NS	2690	628	0	3		531	899	17	16	
	Fraction	0.200	0.760	0.040	0		NS	NS	NS	NS	NS	0.299	0.698	0	0.003		0.363	0.614	0.012	0.011	
	Weight	0.790	0.116	0.014	0		NS	NS	NS	NS	NS	0.341	0.309	0	0.028		0.413	0.178	0.028	0.007	
	Fraction	0.858	0.126	0.015	0		NS	NS	NS	NS	NS	0.503	0.456	0	0.041		0.660	0.285	0.045	0.010	
	Total Ct	445					NS					900					1463				
	Total Wt	0.92					NS					0.677					0.626				
Fall	Count	83	3682	9	8		NS	NS	NS	NS	NS	44	661	2	5		21	865	11	5	
	Fraction	0.022	0.974	0.002	0.002		NS	NS	NS	NS	NS	0.062	0.928	0.003	0.007		0.023	0.959	0.012	0.006	
	Weight	1.019	0.595	0.008	0.009		NS	NS	NS	NS	NS	0.275	0.441	0.002	0.024		0.145	0.252	0.017	0.022	
	Fraction	0.625	0.365	0.005	0.005		NS	NS	NS	NS	NS	0.370	0.594	0.003	0.033		0.333	0.580	0.038	0.049	
	Total Ct	3782					NS					712					902				
	Total Wt	1.630					NS					0.742					0.435				

Table B-11 Count and weight (kg) by fish type for fish sampled with electrofishing at the LEC in 2017-2018, by season, and zone. R = Rough, F = Forage, P = Panfish, G = Gamefish, and S = Special Interest. NS indicated no sampling in the zone.

Season	Statistic	Upstream					Discharge					Thermally Exposed					Downstream				
		R	F	P	G	S	R	F	P	G	S	R	F	P	G	S	R	F	P	G	S
Winter	Count	192	69	5	51	2	126	337	1	93	1	317	270	12	55	0	296	788	6	49	1
	Fraction	0.602	0.216	0.016	0.160	0.006	0.226	0.604	0.002	0.167	0.002	0.485	0.413	0.018	0.084	0.000	0.260	0.691	0.005	0.043	0.001
	Weight	216.651	0.410	0.572	86.017	1.360	127.958	1.686	0.020	319.704	0.430	238.305	2.386	0.603	82.945	0.000	164.609	0.327	0.212	91.395	1.030
	Fraction	0.710	0.001	0.002	0.282	0.004	0.284	0.004	0.000	0.711	0.001	0.735	0.007	0.002	0.256	0.000	0.639	0.001	0.001	0.355	0.004
	Total Ct	319					558					654					1140				
	Total Wt	305.01					449.80					324.24					257.57				
Spring	Count	161	71	16	77	2	89	44	3	40	1	173	92	9	56	2	141	83	10	52	1
	Fraction	0.492	0.217	0.049	0.235	0.006	0.503	0.249	0.017	0.226	0.006	0.521	0.277	0.027	0.169	0.006	0.491	0.289	0.035	0.181	0.003
	Weight	167.700	0.305	2.823	80.171	7.567	92.601	0.066	0.077	128.960	14.262	204.332	0.137	0.691	72.227	0.934	163.358	0.627	0.759	49.147	0.970
	Fraction	0.649	0.001	0.011	0.310	0.029	0.392	0.000	0.000	0.547	0.060	0.734	0.000	0.002	0.260	0.003	0.760	0.003	0.004	0.229	0.005
	Total Ct	327					177					332					327				
	Total Wt	258.565					235.966					278.321					258.57				
Summer	Count	218	84	5	56	5	20	26	0	21	0	162	51	4	56	0	170	52	1	58	4
	Fraction	0.592	0.228	0.014	0.152	0.014	0.299	0.388	0.000	0.313	0.000	0.593	0.187	0.015	0.205	0.000	0.596	0.182	0.004	0.204	0.014
	Weight	88.455	0.685	0.119	24.576	3.459	20.834	0.208	0.000	11.009	0.000	89.624	0.149	0.040	84.803	0.000	76.779	0.614	0.005	41.119	2.208
	Fraction	0.754	0.006	0.001	0.210	0.029	0.650	0.006	0.000	0.343	0.000	0.513	0.001	0.000	0.486	0.000	0.636	0.005	0.000	0.341	0.018
	Total Ct	368					67					273					368				
	Total Wt	117.295					32.051					174.616					117.29				
Fall	Count	97	16	2	26	1	47	20	0	79	0	209	36	1	54	2	224	24	2	32	0
	Fraction	0.683	0.113	0.014	0.183	0.007	0.322	0.137	0.000	0.541	0.000	0.692	0.119	0.003	0.179	0.007	0.794	0.085	0.007	0.113	0.000
	Weight	83.529	0.600	0.078	52.028	0.490	73.984	0.058	0.000	344.384	0.000	166.344	0.735	0.020	91.658	1.800	118.700	0.823	0.008	59.056	0.000
	Fraction	0.611	0.004	0.001	0.381	0.004	0.177	0.000	0.000	0.823	0.000	0.638	0.003	0.000	0.352	0.007	0.665	0.005	0.000	0.331	0.000
	Total Ct	142					146					302					282				
	Total Wt	136.73					418.43					260.56					178.59				

Table B-12 Count and weight (kg) by fish type for fish sampled with hoop net at the LEC in 2017-2018, by season, and zone. R = Rough, F = Forage, P = Panfish, G = Gamefish, and S = Special Interest. NS indicated no sampling in the zone.

Season	Statistic	Upstream					Discharge					Thermally Exposed					Downstream				
		R	F	P	G	S	R	F	P	G	S	R	F	P	G	S	R	F	P	G	S
Winter	Count	22	0	0	3	3	NS	NS	NS	NS	NS	25	4	0	4	3	16	7	0	8	1
	Fraction	0.786	0.000	0.000	0.107	0.107	NS	NS	NS	NS	NS	0.694	0.111	0.000	0.111	0.083	0.500	0.219	0.000	0.250	0.031
	Weight	34.178	0.000	0.000	1.930	2.177	NS	NS	NS	NS	NS	62.520	1.332	0.000	4.238	2.206	32.540	1.872	0.000	39.410	0.610
	Fraction	0.893	0.000	0.000	0.050	0.057	NS	NS	NS	NS	NS	0.889	0.019	0.000	0.060	0.031	0.437	0.025	0.000	0.529	0.008
	Total Ct	28					NS					36					32				
	Total Wt	38.29					NS					70.30					74.432				
Spring	Count	24	0	0	14	13	NS	NS	NS	NS	NS	17	0	0	14	5	13	0	0	17	27
	Fraction	0.471	0.000	0.000	0.275	0.255	NS	NS	NS	NS	NS	0.472	0.000	0.000	0.389	0.139	0.228	0.000	0.000	0.298	0.474
	Weight	43.151	0.000	0.000	32.550	6.662	NS	NS	NS	NS	NS	39.160	0.000	0.000	38.731	3.513	29.362	0.000	0.000	86.136	32.487
	Fraction	0.524	0.000	0.000	0.395	0.081	NS	NS	NS	NS	NS	0.481	0.000	0.000	0.476	0.043	0.198	0.000	0.000	0.582	0.220
	Total Ct	51					NS					36					57				
	Total Wt	82.36					NS					81.40					147.99				
Summer	Count	17	0	0	13	12	NS	NS	NS	NS	NS	11	0	0	6	4	15	0	0	15	1
	Fraction	0.405	0.000	0.000	0.310	0.286	NS	NS	NS	NS	NS	0.524	0.000	0.000	0.286	0.190	0.484	0.000	0.000	0.484	0.032
	Weight	35.962	0.000	0.000	30.220	11.542	NS	NS	NS	NS	NS	24.246	0.000	0.000	11.748	2.761	51.428	0.000	0.000	28.150	1.240
	Fraction	0.463	0.000	0.000	0.389	0.148	NS	NS	NS	NS	NS	0.626	0.000	0.000	0.303	0.071	0.636	0.000	0.000	0.348	0.015
	Total Ct	42					NS					21					31				
	Total Wt	77.72					NS					38.76					80.82				
Fall	Count	9	1	1	4	15	NS	NS	NS	NS	NS	17	1	0	14	2	17	6	0	10	6
	Fraction	0.300	0.033	0.033	0.133	0.500	NS	NS	NS	NS	NS	0.500	0.029	0.000	0.412	0.059	0.436	0.154	0.000	0.256	0.154
	Weight	15.104	0.471	0.501	5.381	21.964	NS	NS	NS	NS	NS	29.884	0.310	0.000	29.039	1.131	28.431	1.744	0.000	24.826	3.954
	Fraction	0.348	0.011	0.012	0.124	0.506	NS	NS	NS	NS	NS	0.495	0.005	0.000	0.481	0.019	0.482	0.030	0.000	0.421	0.067
	Total Ct	30					NS					34					39				
	Total Wt	43.42					NS					60.36					58.96				

Table B-13 Count and weight (kg) by fish type for fish sampled with Missouri mini-trawl at the LEC in 2017-2018, by season, and zone. R = Rough, F = Forage, P = Panfish, G = Gamefish, and S = Special Interest. NS indicated no sampling in the zone.

Season	Statistic	Upstream					Discharge					Thermally Exposed					Downstream				
		R	F	P	G	S	R	F	P	G	S	R	F	P	G	S	R	F	P	G	S
Winter	Count	26	120	2	95	4	NS	NS	NS	NS	NS	31	243	1	50	0	19	273	2	74	3
	Fraction	0.105	0.486	0.008	0.385	0.016	NS	NS	NS	NS	NS	0.095	0.748	0.003	0.154	0.000	0.051	0.736	0.005	0.199	0.008
	Weight	7.488	0.057	0.001	0.604	1.863	NS	NS	NS	NS	NS	9.846	0.084	0.000	0.446	0.000	5.121	0.083	0.001	3.368	0.640
	Fraction	0.748	0.006	0.000	0.060	0.186	NS	NS	NS	NS	NS	0.949	0.008	0.000	0.043	0.000	0.556	0.009	0.000	0.366	0.069
	Total Ct	247					NS					325					371				
	Total Wt	10.01					NS					10.38					9.21				
Spring	Count	247	251	17	89	7	NS	NS	NS	NS	NS	213	256	14	71	19	57	317	16	78	7
	Fraction	0.404	0.411	0.028	0.146	0.011	NS	NS	NS	NS	NS	0.372	0.447	0.024	0.124	0.033	0.120	0.667	0.034	0.164	0.015
	Weight	0.136	0.132	0.002	0.609	0.053	NS	NS	NS	NS	NS	1.091	0.190	0.003	0.827	4.960	1.990	0.158	0.004	0.495	0.106
	Fraction	0.146	0.142	0.002	0.653	0.057	NS	NS	NS	NS	NS	0.154	0.027	0.000	0.117	0.701	0.723	0.058	0.001	0.180	0.038
	Total Ct	611					NS					573					475				
	Total Wt	0.93					NS					7.07					2.75				
Summer	Count	263	473	9	264	2	NS	NS	NS	NS	NS	119	298	45	200	3	115	425	8	236	0
	Fraction	0.260	0.468	0.009	0.261	0.002	NS	NS	NS	NS	NS	0.179	0.448	0.068	0.301	0.005	0.147	0.542	0.010	0.301	0.000
	Weight	5.154	0.092	0.002	0.960	0.691	NS	NS	NS	NS	NS	0.957	0.076	0.006	0.399	0.000	0.923	0.133	0.001	0.348	0.000
	Fraction	0.747	0.013	0.000	0.139	0.100	NS	NS	NS	NS	NS	0.665	0.053	0.004	0.277	0.000	0.657	0.095	0.001	0.248	0.000
	Total Ct	1011					NS					665					784				
	Total Wt	6.90					NS					1.44					1.40				
Fall	Count	47	651	0	50	5	NS	NS	NS	NS	NS	41	951	2	85	8	46	572	1	23	2
	Fraction	0.062	0.865	0.000	0.066	0.007	NS	NS	NS	NS	NS	0.038	0.875	0.002	0.078	0.007	0.071	0.888	0.002	0.036	0.003
	Weight	0.391	0.231	0.000	0.379	2.784	NS	NS	NS	NS	NS	3.502	0.293	0.001	0.929	4.381	0.056	0.090	0.001	0.356	1.335
	Fraction	0.103	0.061	0.000	0.100	0.736	NS	NS	NS	NS	NS	0.385	0.032	0.000	0.102	0.481	0.030	0.049	0.001	0.194	0.727
	Total Ct	753					NS					1087					644				
	Total Wt	3.78					NS					9.11					1.84				

Table B-14 Count and weight (kg) by fish type for heat and pollution tolerant and intolerant fish sampled with bag seine at the LEC in 2017-2018, by season, and zone. NS indicated no sampling in the zone.

Season	Statistic	Upstream				Discharge				Thermally Exposed				Downstream			
		Heat		Pollution		Heat		Pollution		Heat		Pollution		Heat		Pollution	
		Tolerant	Intolerant	Tolerant	Intolerant	Tolerant	Intolerant	Tolerant	Intolerant	Tolerant	Intolerant	Tolerant	Intolerant	Tolerant	Intolerant	Tolerant	Intolerant
Winter	Count	85	0	188	0	NS	NS	NS	NS	73	0	584	0	18	0	165	0
	Fraction	0.114	0	0.252	0	NS	NS	NS	NS	0.086	0	0.689	0	0.066	0	0.604	0
	Weight	0.1055	0	0.0786	0	NS	NS	NS	NS	0.1358	0	0.0659	0	0.0479	0	0.0719	0
	Fraction	0.328	0	0.244	0	NS	NS	NS	NS	0.492	0	0.239	0	0.32	0	0.481	0
	Total Ct	745				NS				847				273			
	Total Wt	0.3216				NS				0.2761				0.1495			
Spring	Count	43	12	12	12	NS	NS	NS	NS	112	6	36	6	60	15	394	18
	Fraction	0.173	0.048	0.048	0.048	NS	NS	NS	NS	0.366	0.02	0.118	0.02	0.06	0.015	0.395	0.018
	Weight	0.0671	0.0114	0.0106	0.0114	NS	NS	NS	NS	0.3597	0.0049	0.0434	0.0049	1.2895	0.007	0.1985	0.0079
	Fraction	0.176	0.03	0.028	0.03	NS	NS	NS	NS	0.69	0.009	0.083	0.009	0.767	0.004	0.118	0.005
	Total Ct	248				NS				306				998			
	Total Wt	0.3823				NS				0.5212				1.6809			
Summer	Count	192	0	112	1	NS	NS	NS	NS	558	4	298	5	893	0	353	0
	Fraction	0.431	0	0.252	0.002	NS	NS	NS	NS	0.62	0.004	0.331	0.006	0.61	0	0.241	0
	Weight	0.8178	0	0.03191	0.0003	NS	NS	NS	NS	0.4936	0.0175	0.1214	0.0195	0.481	0	0.0678	0
	Fraction	0.889	0	0.035	0	NS	NS	NS	NS	0.729	0.026	0.179	0.029	0.768	0	0.108	0
	Total Ct	445				NS				900				1463			
	Total Wt	0.920311905				NS				0.6772				0.626			
Fall	Count	286	0	2695	1	NS	NS	NS	NS	294	0	188	1	89	0	307	1
	Fraction	0.076	0	0.713	0	NS	NS	NS	NS	0.413	0	0.264	0.001	0.099	0	0.34	0.001
	Weight	1.2608	0	0.1734	0.0011	NS	NS	NS	NS	0.4839	0	0.146	0.0114	0.1703	0	0.0682	0.0013
	Fraction	0.773	0	0.106	0.001	NS	NS	NS	NS	0.653	0	0.197	0.015	0.391	0	0.157	0.003
	Total Ct	3782				NS				712				902			
	Total Wt	1.6304				NS				0.7415				0.4353			

Table B-15 Count and weight (kg) by fish type for heat and pollution tolerant and intolerant fish sampled with electrofishing at the LEC in 2017-2018, by season, and zone. NS indicated no sampling in the zone.

Season	Statistic	Upstream				Discharge				Thermally Exposed				Downstream			
		Heat		Pollution		Heat		Pollution		Heat		Pollution		Heat		Pollution	
		Tolerant	Intolerant	Tolerant	Intolerant	Tolerant	Intolerant	Tolerant	Intolerant	Tolerant	Intolerant	Tolerant	Intolerant	Tolerant	Intolerant	Tolerant	Intolerant
Winter	Count	130	14	55	10	120	6	315	6	418	16	164	14	395	6	654	5
	Fraction	0.408	0.044	0.172	0.031	0.215	0.011	0.565	0.011	0.639	0.024	0.251	0.021	0.346	0.005	0.574	0.004
	Weight	143.674	4.841	104.65	0.333	133.732	1.5193	28.3706	1.5193	198.935	2.2476	126.16	1.38	123.805	0.6985	84.1013	0.2231
	Fraction	0.471	0.016	0.343	0.001	0.297	0.003	0.063	0.003	0.614	0.007	0.389	0.004	0.481	0.003	0.327	0.001
	Total Ct	319				558				654				1140			
	Total Wt	305.01				449.80				324.24				257.57			
Spring	Count	144	6	74	8	109	0	32	0	190	2	105	8	155	9	85	14
	Fraction	0.44	0.018	0.226	0.024	0.616	0	0.181	0	0.572	0.006	0.316	0.024	0.54	0.031	0.296	0.049
	Weight	116.204	0.3734	55.756	3.0137	105.841	0	35.0145	0	170.268	0.381	93.4924	14.692	123.247	0.352	86.391	8.133
	Fraction	0.449	0.001	0.216	0.012	0.449	0	0.148	0	0.612	0.001	0.336	0.053	0.574	0.002	0.402	0.038
	Total Ct	327				177				332				287			
	Total Wt	258.57				235.97				278.32				214.86			
Summer	Count	270	29	16	29	44	5	9	5	199	15	21	20	185	20	41	26
	Fraction	0.734	0.079	0.043	0.079	0.657	0.075	0.134	0.075	0.729	0.055	0.077	0.073	0.649	0.07	0.144	0.091
	Weight	59.0207	0.5297	24.2537	4.1308	19.134	0.183	6.979	0.183	92.2269	0.1061	34.2578	5.5521	57.964	0.571	34.113	4.721
	Fraction	0.503	0.005	0.207	0.035	0.597	0.006	0.218	0.006	0.528	0.001	0.196	0.032	0.48	0.005	0.283	0.039
	Total Ct	368				67				273				285			
	Total Wt	117.29				32.05				174.62				120.72			
Fall	Count	53	12	17	12	52	1	9	1	190	16	19	17	181	11	21	12
	Fraction	0.373	0.085	0.12	0.085	0.356	0.007	0.062	0.007	0.629	0.053	0.063	0.056	0.642	0.039	0.074	0.043
	Weight	67.476	0.591	31.714	0.591	59.945	0.02	34.877	0.02	107.78	0.637	42.314	0.849	87.9635	0.747	47.021	2.007
	Fraction	0.494	0.004	0.232	0.004	0.143	0	0.083	0	0.414	0.002	0.162	0.003	0.493	0.004	0.263	0.011
	Total Ct	142				146				302				282			
	Total Wt	136.73				418.43				260.56				178.59			

Table B-16 Count and weight (kg) by fish type for heat and pollution tolerant and intolerant fish sampled with hoop net at the LEC in 2017-2018, by season, and zone. NS indicated no sampling in the zone.

Season	Statistic	Upstream				Discharge				Thermally Exposed				Downstream			
		Heat		Pollution		Heat		Pollution		Heat		Pollution		Heat		Pollution	
		Tolerant	Intolerant	Tolerant	Intolerant	Tolerant	Intolerant	Tolerant	Intolerant	Tolerant	Intolerant	Tolerant	Intolerant	Tolerant	Intolerant	Tolerant	Intolerant
Winter	Count	2	1	1	18	NS	NS	NS	NS	1	4	0	26	5	8	0	19
	Fraction	0.071	0.036	0.036	0.643	NS	NS	NS	NS	0.028	0.111	0	0.722	0.156	0.25	0	0.594
	Weight	2.24	0.59	1.84	30.858	NS	NS	NS	NS	0.549	1.332	0	62.485	6.198	3.802	0	29.222
	Fraction	0.059	0.015	0.048	0.806	NS	NS	NS	NS	0.008	0.019	0	0.889	0.083	0.051	0	0.393
	Total Ct	28				NS				36				32			
	Total Wt	38.29				NS				70.30				74.43			
Spring	Count	11	0	6	4	NS	NS	NS	NS	18	0	8	3	15	0	1	5
	Fraction	0.216	0	0.118	0.078	NS	NS	NS	NS	0.5	0	0.222	0.083	0.263	0	0.018	0.088
	Weight	17.423	0	19.273	10.49	NS	NS	NS	NS	49.223	0	27.215	5.572	40.068	0	1.65	10.147
	Fraction	0.212	0	0.234	0.127	NS	NS	NS	NS	0.605	0	0.334	0.068	0.271	0	0.011	0.069
	Total Ct	51				NS				36				57			
	Total Wt	82.36				NS				81.40				147.99			
Summer	Count	19	0	1	9	NS	NS	NS	NS	8	0	1	3	15	0	3	3
	Fraction	0.452	0	0.024	0.214	NS	NS	NS	NS	0.381	0	0.048	0.143	0.484	0	0.097	0.097
	Weight	41.232	0	4.39	23.155	NS	NS	NS	NS	19.33	0	4.58	5.25	42.025	0	14.02	7.908
	Fraction	0.53	0	0.056	0.298	NS	NS	NS	NS	0.499	0	0.118	0.135	0.52	0	0.173	0.098
	Total Ct	42				NS				21				31			
	Total Wt	77.72				NS				38.76				80.82			
Fall	Count	1	1	3	1	NS	NS	NS	NS	19	2	1	2	8	6	5	9
	Fraction	0.033	0.033	0.1	0.033	NS	NS	NS	NS	0.559	0.059	0.029	0.059	0.205	0.154	0.128	0.231
	Weight	3.43	0.471	11.254	0.471	NS	NS	NS	NS	37.456	0.91	2.261	2.79	23.084	1.744	13.316	8.074
	Fraction	0.079	0.011	0.259	0.011	NS	NS	NS	NS	0.621	0.015	0.037	0.046	0.392	0.03	0.226	0.137
	Total Ct	30				NS				34				39			
	Total Wt	43.42				NS				60.36				58.96			

Table B-17 Count and weight (kg) by fish type for heat and pollution tolerant and intolerant fish sampled with Missouri mini-trawl at the LEC in 2017-2018, by season, and zone. NS indicated no sampling in the zone.

Season	Statistic	Upstream				Discharge				Thermally Exposed				Downstream			
		Heat		Pollution		Heat		Pollution		Heat		Pollution		Heat		Pollution	
		Tolerant	Intolerant	Tolerant	Intolerant	Tolerant	Intolerant	Tolerant	Intolerant	Tolerant	Intolerant	Tolerant	Intolerant	Tolerant	Intolerant	Tolerant	Intolerant
Winter	Count	55	0	4	0	NS	NS	NS	NS	59	0	14	0	38	0	5	0
	Fraction	0.223	0	0.016	0	NS	NS	NS	NS	0.182	0	0.043	0	0.102	0	0.013	0
	Weight	6.6586	0	4.881	0	NS	NS	NS	NS	9.2915	0	3.3295	0	3.9863	0	1.3635	0
	Fraction	0.665	0	0.487	0	NS	NS	NS	NS	0.895	0	0.321	0	0.433	0	0.148	0
	Total Ct	247				NS				325				371			
	Total Wt	10.01				NS				10.38				9.21			
Spring	Count	147	41	2	46	NS	NS	NS	NS	66	29	4	40	49	64	2	74
	Fraction	0.24	0.067	0.003	0.075	NS	NS	NS	NS	0.115	0.05	0.007	0.07	0.103	0.135	0.004	0.156
	Weight	0.333	0.0055	0.0019	0.0071	NS	NS	NS	NS	0.2867	0.0072	0.0024	0.0164	0.7896	0.0171	0.0005	1.3082
	Fraction	0.357	0.006	0.002	0.008	NS	NS	NS	NS	0.041	0.001	0	0.002	0.287	0.006	0	0.475
	Total Ct	613				NS				575				475			
	Total Wt	0.93				NS				7.07				2.75			
Summer	Count	277	8	73	9	NS	NS	NS	NS	149	7	53	7	241	11	33	11
	Fraction	0.274	0.008	0.072	0.009	NS	NS	NS	NS	0.224	0.011	0.08	0.011	0.307	0.014	0.042	0.014
	Weight	0.4563	0.0379	0.0171	0.041	NS	NS	NS	NS	0.9641	0.036	0.0135	0.036	0.6001	0.0387	0.017	0.0387
	Fraction	0.066	0.005	0.002	0.006	NS	NS	NS	NS	0.67	0.025	0.009	0.025	0.427	0.028	0.012	0.028
	Total Ct	1011				NS				665				784			
	Total Wt	6.90				NS				1.44				1.40			
Fall	Count	68	2	46	2	NS	NS	NS	NS	141	1	37	2	23	0	12	0
	Fraction	0.09	0.003	0.061	0.003	NS	NS	NS	NS	0.13	0.001	0.034	0.002	0.036	0	0.019	0
	Weight	0.0898	0.055	0.024	0.055	NS	NS	NS	NS	3.5932	0.029	1.211	0.0329	0.0481	0	0.007	0
	Fraction	0.024	0.015	0.006	0.015	NS	NS	NS	NS	0.395	0.003	0.133	0.004	0.026	0	0.004	0
	Total Ct	753				NS				1087				645			
	Total Wt	3.78				NS				9.11				1.84			

Table B-18 Means and standard errors for individual metrics, and standardized differences for winter fish sampling at the LEC in 2017-2018.

Gear	Type	Metric	Upstream Reference			Thermally Exposed				Downstream			
			Mean	Std Err	N	Mean	Std Err	N	Std Diff	Mean	Std Err	N	Std Diff
Bag Seine	Density	Count	65.617	24.45	10	58.859	35.561	10	-0.157	18.447	5.833	10	-1.876
		Weight	0.026	0.009	10	0.017	0.009	10	-0.712	0.009	0.003	10	-1.704
	Diversity	^{0}D Ct	18	1.02	745	16	2.326	847	-0.788	15	1.049	273	-2.051
		^{1}D Ct	7.301	0.253	745	3.208	0.146	847	14.020	4.805	0.371	273	-5.568
		^{2}D Ct	5.779	0.176	745	2.03	0.077	847	-19.522	2.739	0.217	273	-10.873
		^{3}D Ct	5.316	0.162	745	1.759	0.058	847	-20.725	2.254	0.161	273	-13.404
	Heat Tolerance	Fraction Ct Intolerant	0	0	745	0	0	847		0	0	273	
		Fraction Wt Intolerant	0	0	745	0	0	847		0	0	273	
		Fraction Ct Tolerant	0.114	0.012	745	0.086	0.01	847	1.853	0.066	0.015	273	2.525
		Fraction Wt Tolerant	0.328	0.017	745	0.492	0.017	847	-6.746	0.32	0.028	273	0.242
	Composition	Fraction Ct Non-R	0.988	0.004	745	0.994	0.003	847	1.252	0.963	0.011	273	-2.066
		Fraction Wt Non-R	0.907	0.011	745	0.912	0.01	847	0.347	0.72	0.027	273	-6.408
	Pollution Tolerance	Fraction Ct Tolerant	0.252	0.016	745	0.689	0.016	847	-19.427	0.604	0.03	273	-10.475
		Fraction Wt Tolerant	0.244	0.016	745	0.239	0.015	847	0.233	0.481	0.03	273	-6.952
		Fraction Ct Intolerant	0	0	745	0	0	847		0	0	273	
		Fraction Wt Intolerant	0	0	745	0	0	847		0	0	273	
Electrofishing	Density	Count	17.003	3.899	18	32.697	7.083	18	1.941	58.332	30.2	18	1.357
		Weight	16.387	3.517	18	16.377	3.501	18	-0.002	12.524	2.49	18	-0.896
	Diversity	^{0}D Ct	28	2.486	319	30	3.441	654	0.471	31	2.842	1140	0.794
		^{1}D Ct	12.64	0.865	319	10.474	0.557	654	-2.104	6.237	0.304	1140	-6.982
		^{2}D Ct	8.676	0.691	319	7.129	0.333	654	-2.017	3.387	0.156	1140	-7.467
		^{3}D Ct	7.084	0.681	319	6.095	0.285	654	-1.340	2.721	0.117	1140	-6.314
	Heat Tolerance	Fraction Ct Intolerant	0.044	0.011	319	0.024	0.006	654	-1.545	0.005	0.002	1140	-3.341
		Fraction Wt Intolerant	0.016	0.007	319	0.007	0.003	654	-1.162	0.003	0.002	1140	-1.803
		Fraction Ct Tolerant	0.408	0.028	319	0.639	0.019	654	-6.934	0.346	0.014	1140	2.006
		Fraction Wt Tolerant	0.471	0.028	319	0.614	0.019	654	-4.229	0.481	0.015	1140	-0.316
	Composition	Fraction Ct Non-R	0.348	0.027	319	0.489	0.02	654	4.264	0.732	0.013	1140	12.920
		Fraction Wt Non-R	0.132	0.019	319	0.129	0.013	654	-0.130	0.273	0.013	1140	6.106
	Pollution Tolerance	Fraction Ct Tolerant	0.172	0.021	319	0.251	0.017	654	-2.916	0.574	0.015	1140	-15.637
		Fraction Wt Tolerant	0.343	0.027	319	0.389	0.019	654	-1.406	0.327	0.014	1140	0.533
		Fraction Ct Intolerant	0.031	0.01	319	0.021	0.006	654	-0.892	0.004	0.002	1140	-2.732
		Fraction Wt Intolerant	0.001	0.002	319	0.004	0.002	654	0.988	0.001	0.001	1140	0.000
Hoop net	Density	Count	1.459	0.766	18	2.021	1.015	18	0.442	1.803	0.697	18	0.332
		Weight	1.993	1.166	18	3.941	2.733	18	0.656	4.215	2.267	18	0.872
	Diversity	^{0}D Ct	8	1.87	28	7	1.067	36	-0.465	10	1.769	32	0.777
		^{1}D Ct	3.695	1.239	28	3.739	0.691	36	0.031	6.543	1.522	32	1.451
		^{2}D Ct	2.292	0.693	28	2.473	0.491	36	0.213	4.785	1.303	32	1.689
		^{3}D Ct	1.933	0.489	28	2.081	0.382	36	0.237	4	1.134	32	1.673
	Heat Tolerance	Fraction Ct Intolerant	0.036	0.035	28	0.111	0.052	36	1.189	0.25	0.077	32	2.540
		Fraction Wt Intolerant	0.015	0.023	28	0.019	0.023	36	0.124	0.051	0.039	32	0.797
		Fraction Ct Tolerant	0.071	0.049	28	0.028	0.027	36	0.771	0.156	0.064	32	-1.057
		Fraction Wt Tolerant	0.059	0.045	28	0.008	0.015	36	1.087	0.083	0.049	32	-0.363
	Composition	Fraction Ct Non-R	0.214	0.078	28	0.306	0.077	36	0.843	0.5	0.088	32	2.433
		Fraction Wt Non-R	0.107	0.058	28	0.111	0.052	36	0.051	0.563	0.088	32	4.328
	Pollution Tolerance	Fraction Ct Tolerant	0.036	0.035	28	0	0	36	1.023	0	0	32	1.023
		Fraction Wt Tolerant	0.048	0.04	28	0	0	36	1.188	0	0	32	1.188
		Fraction Ct Intolerant	0.643	0.091	28	0.722	0.075	36	0.673	0.594	0.087	32	-0.391
		Fraction Wt Intolerant	0.806	0.075	28	0.889	0.052	36	0.910	0.393	0.086	32	-3.617

Gear	Type	Metric	Upstream Reference			Thermally Exposed				Downstream			
			Mean	Std Err	N	Mean	Std Err	N	Std Diff	Mean	Std Err	N	Std Diff
Missouri mini-trawl	Density	Count	11.109	2.859	24	12.315	3.113	24	0.285	18.091	4.884	24	1.234
		Weight	0.435	0.159	24	0.441	0.184	24	0.022	0.502	0.156	24	0.300
	Diversity	^{0}D Ct	16	1.449	247	19	1.22	325	1.584	22	2.346	371	2.176
		^{1}D Ct	8.237	0.525	247	7.688	0.523	325	-0.741	7.762	0.517	371	-0.646
		^{2}D Ct	6.386	0.373	247	5	0.369	325	-2.642	5.318	0.317	371	-2.183
		^{3}D Ct	5.78	0.333	247	4.197	0.314	325	-3.460	4.575	0.266	371	-2.828
	Heat Tolerance	Fraction Ct Intolerant	0	0	247	0	0	325		0	0	371	
		Fraction Wt Intolerant	0	0	247	0	0	325		0	0	371	
		Fraction Ct Tolerant	0.223	0.026	247	0.182	0.021	325	1.204	0.102	0.016	371	3.929
		Fraction Wt Tolerant	0.665	0.03	247	0.895	0.017	325	-6.664	0.433	0.026	371	5.867
	Composition	Fraction Ct Non-R	0.895	0.02	247	0.905	0.016	325	0.394	0.946	0.012	371	2.240
		Fraction Wt Non-R	0.252	0.028	247	0.051	0.012	325	-6.656	0.305	0.024	371	1.451
	Pollution Tolerance	Fraction Ct Tolerant	0.016	0.008	247	0.043	0.011	325	-1.957	0.013	0.006	371	0.303
		Fraction Wt Tolerant	0.487	0.032	247	0.321	0.026	325	4.047	0.148	0.018	371	9.222
		Fraction Ct Intolerant	0	0	247	0	0	325		0	0	371	
		Fraction Wt Intolerant	0	0	247	0	0	325		0	0	371	

Table B-19 Means and standard errors for individual metrics, and standardized differences for spring fish sampling at the LEC in 2017-2018.

Gear	Type	Metric	Upstream Reference			Thermally Exposed				Downstream			
			Mean	Std Err	N	Mean	Std Err	N	Std Diff	Mean	Std Err	N	Std Diff
Bag Seine	Density	Count	25.575	12.97	6	26.577	3.428	6	0.075	136.66	79.08	6	1.386
		Weight	0.028	0.01	6	0.037	0.012	6	0.591	0.223	0.174	6	1.124
	Diversity	^{0}D Ct	20	1.731	248	23	1.503	306	1.309	28	1.903	998	3.110
		^{1}D Ct	7.595	0.62	248	10.897	0.622	306	3.761	5.775	0.258	998	-2.712
		^{2}D Ct	5.24	0.407	248	7.974	0.491	306	4.287	3.686	0.118	998	-3.666
		^{3}D Ct	4.546	0.343	248	6.954	0.461	306	4.193	3.268	0.091	998	-3.605
	Heat Tolerance	Fraction Ct Intolerant	0.048	0.014	248	0.02	0.008	306	-1.777	0.015	0.004	998	-2.339
		Fraction Wt Intolerant	0.03	0.011	248	0.009	0.005	306	-1.735	0.004	0.002	998	-2.360
		Fraction Ct Tolerant	0.173	0.024	248	0.366	0.028	306	-5.282	0.06	0.008	998	4.490
		Fraction Wt Tolerant	0.176	0.024	248	0.69	0.026	306	-14.345	0.767	0.013	998	-21.384
	Composition	Fraction Ct Non-R	0.895	0.019	248	0.81	0.022	306	-2.862	0.946	0.007	998	2.459
		Fraction Wt Non-R	0.662	0.03	248	0.879	0.019	306	6.138	0.245	0.014	998	-12.645
	Pollution Tolerance	Fraction Ct Tolerant	0.048	0.014	248	0.118	0.018	306	-3.057	0.395	0.015	998	-16.858
		Fraction Wt Tolerant	0.028	0.01	248	0.083	0.016	306	-2.905	0.118	0.01	998	-6.152
		Fraction Ct Intolerant	0.048	0.014	248	0.02	0.008	306	-1.777	0.018	0.004	998	-2.111
		Fraction Wt Intolerant	0.03	0.011	248	0.009	0.005	306	-1.735	0.005	0.002	998	-2.260
Electrofishing	Density	Count	15.945	1.772	18	16.461	2.983	18	0.149	14.891	2.799	18	-0.318
		Weight	12.555	1.23	18	13.655	2.832	18	0.356	11.068	1.677	18	-0.715
	Diversity	^{0}D Ct	33	2.362	327	27	1.227	332	-2.254	30	2.867	287	-0.808
		^{1}D Ct	17.23	1.08	327	16.325	0.854	332	-0.657	17.111	1.193	287	-0.074
		^{2}D Ct	12.863	0.83	327	11.776	0.913	332	-0.881	12.52	1.103	287	-0.248
		^{3}D Ct	11.202	0.793	327	9.506	0.931	332	-1.387	10.262	1.167	287	-0.667
	Heat Tolerance	Fraction Ct Intolerant	0.018	0.007	327	0.006	0.004	332	-1.414	0.031	0.01	287	1.032
		Fraction Wt Intolerant	0.001	0.002	327	0.001	0.002	332	0.000	0.002	0.003	287	0.316
		Fraction Ct Tolerant	0.44	0.027	327	0.572	0.027	332	-3.419	0.54	0.029	287	-2.485
		Fraction Wt Tolerant	0.449	0.028	327	0.612	0.027	332	-4.249	0.574	0.029	287	-3.117
	Composition	Fraction Ct Non-R	0.465	0.028	327	0.416	0.027	332	-1.268	0.484	0.029	287	0.470
		Fraction Wt Non-R	0.241	0.024	327	0.119	0.018	332	-4.124	0.146	0.021	287	-3.013
	Pollution Tolerance	Fraction Ct Tolerant	0.226	0.023	327	0.316	0.026	332	-2.613	0.296	0.027	287	-1.971
		Fraction Wt Tolerant	0.216	0.023	327	0.336	0.026	332	-3.479	0.402	0.029	287	-5.052
		Fraction Ct Intolerant	0.024	0.008	327	0.024	0.008	332	0.000	0.049	0.013	287	1.634
		Fraction Wt Intolerant	0.012	0.006	327	0.053	0.012	332	2.995	0.038	0.011	287	2.033
Hoop net	Density	Count	2.859	0.603	18	2.028	0.475	18	-1.081	3.204	1.424	18	0.223
		Weight	4.61	1.24	18	4.579	1.373	18	-0.017	8.292	3.775	18	0.927
	Diversity	^{0}D Ct	8	0.72	51	11	1.475	36	1.828	11	1.319	57	1.996
		^{1}D Ct	6.602	0.581	51	8.937	1.345	36	1.594	5.911	0.956	57	-0.617
		^{2}D Ct	5.767	0.624	51	7.807	1.359	36	1.364	3.747	0.723	57	-2.115
		^{3}D Ct	5.282	0.639	51	7.106	1.368	36	1.208	3.006	0.582	57	-2.634
	Heat Tolerance	Fraction Ct Intolerant	0	0	51	0	0	36		0	0	57	
		Fraction Wt Intolerant	0	0	51	0	0	36		0	0	57	
		Fraction Ct Tolerant	0.216	0.058	51	0.5	0.083	36	-2.803	0.263	0.058	57	-0.573
		Fraction Wt Tolerant	0.212	0.057	51	0.605	0.081	36	-3.947	0.271	0.059	57	-0.719
	Composition	Fraction Ct Non-R	0.49	0.07	51	0.306	0.077	36	-1.771	0.684	0.062	57	2.081
		Fraction Wt Non-R	0.422	0.069	51	0.25	0.072	36	-1.721	0.707	0.06	57	3.106
	Pollution Tolerance	Fraction Ct Tolerant	0.118	0.045	51	0.222	0.069	36	-1.258	0.018	0.018	57	2.062
		Fraction Wt Tolerant	0.234	0.059	51	0.334	0.079	36	-1.016	0.011	0.014	57	3.663
		Fraction Ct Intolerant	0.078	0.038	51	0.083	0.046	36	0.084	0.088	0.038	57	0.188
		Fraction Wt Intolerant	0.127	0.047	51	0.068	0.042	36	-0.941	0.069	0.034	57	-1.010

Gear	Type	Metric	Upstream Reference			Thermally Exposed				Downstream			
			Mean	Std Err	N	Mean	Std Err	N	Std Diff	Mean	Std Err	N	Std Diff
Missouri mini-trawl	Density	Count	25.002	7.217	24	20.608	6.262	24	-0.460	22.727	5.832	24	-0.245
		Weight	0.04	0.017	24	0.277	0.117	24	2.008	0.133	0.069	24	1.304
	Diversity	^{0}D Ct	28	3.414	613	31	1.762	575	0.781	28	2.463	475	0.000
		^{1}D Ct	10.629	0.536	613	10.371	0.588	575	-0.324	11.041	0.573	475	0.525
		^{2}D Ct	8.006	0.373	613	6.504	0.412	575	-2.703	8.224	0.391	475	0.403
		^{3}D Ct	7.01	0.399	613	5.181	0.365	575	-3.381	7.237	0.409	475	0.396
	Heat Tolerance	Fraction Ct Intolerant	0.067	0.01	613	0.05	0.009	575	-1.251	0.135	0.016	475	3.646
		Fraction Wt Intolerant	0.006	0.003	613	0.001	0.001	575	-1.477	0.006	0.004	475	0.000
		Fraction Ct Tolerant	0.24	0.017	613	0.115	0.013	575	5.738	0.103	0.014	475	6.176
		Fraction Wt Tolerant	0.357	0.019	613	0.041	0.008	575	15.016	0.287	0.021	475	2.467
	Composition	Fraction Ct Non-R	0.597	0.02	613	0.63	0.02	575	1.168	0.878	0.015	475	11.304
		Fraction Wt Non-R	0.854	0.014	613	0.846	0.015	575	-0.386	0.277	0.021	475	-23.080
	Pollution Tolerance	Fraction Ct Tolerant	0.003	0.002	613	0.007	0.003	575	-0.971	0.004	0.003	475	-0.275
		Fraction Wt Tolerant	0.002	0.002	613	0	0	575	1.108	0	0	475	1.108
		Fraction Ct Intolerant	0.075	0.011	613	0.07	0.011	575	-0.332	0.156	0.017	475	4.100
		Fraction Wt Intolerant	0.008	0.004	613	0.002	0.002	575	-1.481	0.475	0.023	475	20.135

Table B-20 Means and standard errors for individual metrics, and standardized differences for summer fish sampling at the LEC in 2017-2018.

Gear	Type	Metric	Upstream Reference			Thermally Exposed				Downstream			
			Mean	Std Err	N	Mean	Std Err	N	Std Diff	Mean	Std Err	N	Std Diff
Bag Seine	Density	Count	70.61	25.49	8	74.97	35.238	8	0.100	155.06	51.87	8	1.461
		Weight	0.152	0.096	8	0.053	0.019	8	-1.008	0.057	0.016	8	-0.972
	Diversity	^{0}D Ct	15	1.41	445	15	1.932	900	0.000	26	1.738	1463	4.915
		^{1}D Ct	7.246	0.32	445	3.883	0.114	900	-9.903	5.842	0.182	1463	-3.815
		^{2}D Ct	5.754	0.246	445	3.356	0.05	900	-9.553	4.219	0.099	1463	-5.791
		^{3}D Ct	5.246	0.246	445	3.265	0.04	900	-7.956	3.837	0.09	1463	-5.389
	Heat Tolerance	Fraction Ct Intolerant	0	0	445	0.004	0.002	900	1.901	0	0	1463	
		Fraction Wt Intolerant	0	0	445	0.026	0.005	900	4.901	0	0	1463	
		Fraction Ct Tolerant	0.431	0.023	445	0.62	0.016	900	-6.629	0.61	0.013	1463	-6.700
		Fraction Wt Tolerant	0.889	0.015	445	0.729	0.015	900	7.617	0.768	0.011	1463	6.528
	Composition	Fraction Ct Non-R	0.8	0.019	445	0.7	0.015	900	-4.107	0.629	0.013	1463	-7.506
		Fraction Wt Non-R	0.142	0.017	445	0.497	0.017	900	15.116	0.333	0.012	1463	9.258
	Pollution Tolerance	Fraction Ct Tolerant	0.252	0.021	445	0.331	0.016	900	-3.053	0.241	0.011	1463	0.470
		Fraction Wt Tolerant	0.035	0.009	445	0.179	0.013	900	-9.311	0.108	0.008	1463	-6.131
		Fraction Ct Intolerant	0.002	0.002	445	0.006	0.003	900	1.200	0	0	1463	-0.944
		Fraction Wt Intolerant	0	0	445	0.029	0.006	900	5.185	0	0	1463	
Electrofishing	Density	Count	17.396	4.278	18	14.163	3.611	18	-0.577	15.146	4.092	18	-0.380
		Weight	5.584	1.184	18	8.501	1.441	18	1.564	6.198	0.795	18	0.431
	Diversity	^{0}D Ct	29	1.824	368	30	3.183	273	0.273	23	1.753	285	-2.372
		^{1}D Ct	11.579	0.781	368	13.721	1.166	273	1.526	11.685	0.821	285	0.093
		^{2}D Ct	6.214	0.57	368	8.011	0.904	273	1.682	6.972	0.734	285	0.815
		^{3}D Ct	4.586	0.437	368	5.849	0.717	273	1.505	5.174	0.598	285	0.793
	Heat Tolerance	Fraction Ct Intolerant	0.079	0.014	368	0.055	0.014	273	-1.218	0.07	0.015	285	-0.436
		Fraction Wt Intolerant	0.005	0.004	368	0.001	0.002	273	-0.965	0.005	0.004	285	0.000
		Fraction Ct Tolerant	0.734	0.023	368	0.729	0.027	273	0.141	0.649	0.028	285	2.331
		Fraction Wt Tolerant	0.503	0.026	368	0.528	0.03	273	-0.627	0.48	0.03	285	0.583
	Composition	Fraction Ct Non-R	0.391	0.025	368	0.359	0.029	273	-0.829	0.375	0.029	285	-0.417
		Fraction Wt Non-R	0.157	0.019	368	0.306	0.028	273	4.418	0.244	0.025	285	2.742
	Pollution Tolerance	Fraction Ct Tolerant	0.043	0.011	368	0.077	0.016	273	-1.762	0.144	0.021	285	-4.329
		Fraction Wt Tolerant	0.207	0.021	368	0.196	0.024	273	0.344	0.283	0.027	285	-2.233
		Fraction Ct Intolerant	0.079	0.014	368	0.073	0.016	273	-0.284	0.091	0.017	285	0.543
		Fraction Wt Intolerant	0.035	0.01	368	0.032	0.011	273	-0.209	0.039	0.011	285	0.268
Hoop net	Density	Count	2.379	0.621	18	1.193	0.351	18	-1.663	1.759	0.447	18	-0.810
		Weight	4.376	1.303	18	2.204	0.788	18	-1.426	4.57	1.28	18	0.106
	Diversity	^{0}D Ct	11	1.515	42	9	1.48	21	-0.944	11	1.525	31	0.000
		^{1}D Ct	7.537	1.181	42	7.734	1.414	21	0.107	9.139	1.372	31	0.885
		^{2}D Ct	5.959	1.017	42	7	1.382	21	0.606	8.076	1.338	31	1.259
		^{3}D Ct	5.292	0.916	42	6.594	1.349	21	0.799	7.462	1.31	31	1.358
	Heat Tolerance	Fraction Ct Intolerant	0	0	42	0	0	21		0	0	31	
		Fraction Wt Intolerant	0	0	42	0	0	21		0	0	31	
		Fraction Ct Tolerant	0.452	0.077	42	0.381	0.106	21	0.543	0.484	0.09	31	-0.271
		Fraction Wt Tolerant	0.53	0.077	42	0.499	0.109	21	0.232	0.52	0.09	31	0.085
	Composition	Fraction Ct Non-R	0.381	0.075	42	0.286	0.099	21	-0.767	0.323	0.084	31	-0.515
		Fraction Wt Non-R	0.245	0.066	42	0.143	0.076	21	-1.008	0.212	0.073	31	-0.333
	Pollution Tolerance	Fraction Ct Tolerant	0.024	0.024	42	0.048	0.047	21	-0.459	0.097	0.053	31	-1.255
		Fraction Wt Tolerant	0.056	0.035	42	0.118	0.07	21	-0.786	0.173	0.068	31	-1.527
		Fraction Ct Intolerant	0.214	0.063	42	0.143	0.076	21	-0.716	0.097	0.053	31	-1.416
		Fraction Wt Intolerant	0.298	0.071	42	0.135	0.075	21	-1.588	0.098	0.053	31	-2.260

Gear	Type	Metric	Upstream Reference			Thermally Exposed				Downstream			
			Mean	Std Err	N	Mean	Std Err	N	Std Diff	Mean	Std Err	N	Std Diff
Missouri mini-trawl	Density	Count	43.595	10.07	24	26.836	7.79	24	-1.317	36.29	10.01	24	-0.515
		Weight	0.286	0.198	24	0.054	0.028	24	-1.158	0.065	0.023	24	-1.106
	Diversity	^{0}D Ct	28	2.125	1011	21	1.483	665	-2.701	22	1.935	784	-2.088
		^{1}D Ct	10.711	0.345	1011	11.189	0.392	665	0.916	9.737	0.354	784	-1.971
		^{2}D Ct	8.337	0.267	1011	9.064	0.419	665	1.465	7.34	0.318	784	-2.403
		^{3}D Ct	7.411	0.303	1011	7.922	0.461	665	0.927	6.299	0.316	784	-2.541
	Heat Tolerance	Fraction Ct Intolerant	0.008	0.003	1011	0.011	0.004	665	0.610	0.014	0.004	784	1.189
		Fraction Wt Intolerant	0.005	0.002	1011	0.025	0.006	665	3.102	0.028	0.006	784	3.653
		Fraction Ct Tolerant	0.274	0.014	1011	0.224	0.016	665	2.336	0.307	0.016	784	-1.525
		Fraction Wt Tolerant	0.066	0.008	1011	0.67	0.018	665	-30.450	0.427	0.018	784	-18.691
	Composition	Fraction Ct Non-R	0.736	0.014	1011	0.821	0.015	665	4.182	0.853	0.013	784	6.235
		Fraction Wt Non-R	0.253	0.014	1011	0.335	0.018	665	3.589	0.343	0.017	784	4.132
	Pollution Tolerance	Fraction Ct Tolerant	0.072	0.008	1011	0.08	0.011	665	-0.602	0.042	0.007	784	2.769
		Fraction Wt Tolerant	0.002	0.001	1011	0.009	0.004	665	-1.785	0.012	0.004	784	-2.418
		Fraction Ct Intolerant	0.009	0.003	1011	0.011	0.004	665	0.399	0.014	0.004	784	0.973
		Fraction Wt Intolerant	0.006	0.002	1011	0.025	0.006	665	2.913	0.028	0.006	784	3.452

Table B-21 Means and standard errors for individual metrics, and standardized differences for fall fish sampling at the LEC in 2017-2018.

Gear	Type	Metric	Upstream Reference			Thermally Exposed				Downstream			
			Mean	Std Err	N	Mean	Std Err	N	Std Diff	Mean	Std Err	N	Std Diff
Bag Seine	Density	Count	250.49	100	8	63.844	22.776	8	-1.819	121.46	68.44	8	-1.064
		Weight	0.143	0.077	8	0.063	0.018	8	-1.006	0.059	0.028	8	-1.017
	Diversity	^{0}D Ct	22	1.812	3782	18	1.607	712	-1.651	20	1.33	902	-0.890
		^{1}D Ct	2.971	0.06	3782	6.139	0.232	712	13.223	7.78	0.268	902	17.479
		^{2}D Ct	1.899	0.031	3782	4.505	0.173	712	14.799	5.592	0.235	902	15.580
		^{3}D Ct	1.673	0.024	3782	3.961	0.164	712	13.797	4.723	0.236	902	12.884
	Heat Tolerance	Fraction Ct Intolerant	0	0	3782	0	0	712		0	0	902	
		Fraction Wt Intolerant	0	0	3782	0	0	712		0	0	902	
		Fraction Ct Tolerant	0.076	0.004	3782	0.413	0.018	712	-17.785	0.099	0.01	902	-2.122
		Fraction Wt Tolerant	0.773	0.007	3782	0.653	0.018	712	6.284	0.391	0.016	902	21.683
	Composition	Fraction Ct Non-R	0.976	0.002	3782	0.938	0.009	712	-4.054	0.973	0.005	902	-0.505
		Fraction Wt Non-R	0.37	0.008	3782	0.63	0.018	712	13.182	0.657	0.016	902	16.262
	Pollution Tolerance	Fraction Ct Tolerant	0.713	0.007	3782	0.264	0.017	712	24.830	0.34	0.016	902	21.432
		Fraction Wt Tolerant	0.106	0.005	3782	0.197	0.015	712	-5.787	0.157	0.012	902	-3.891
		Fraction Ct Intolerant	0	0	3782	0.001	0.001	712	0.844	0.001	0.001	902	0.950
		Fraction Wt Intolerant	0.001	0.001	3782	0.015	0.005	712	3.054	0.003	0.002	902	1.057
Electrofishing	Density	Count	8.079	1.526	17	15.72	3.28	18	2.112	14.455	3.614	18	1.625
		Weight	7.977	1.428	17	13.58	3.15	18	1.620	9.312	2.725	18	0.434
	Diversity	^{0}D Ct	23	2.165	142	24	2.025	302	0.337	22	1.314	282	-0.395
		^{1}D Ct	11.75	1.454	142	11.634	0.823	302	-0.069	9.008	0.694	282	-1.702
		^{2}D Ct	6.642	1.149	142	7.699	0.683	302	0.791	5.23	0.491	282	-1.129
		^{3}D Ct	4.829	0.873	142	6.116	0.621	302	1.202	4.113	0.391	282	-0.749
	Heat Tolerance	Fraction Ct Intolerant	0.085	0.023	142	0.053	0.013	302	-1.198	0.039	0.012	282	-1.763
		Fraction Wt Intolerant	0.004	0.005	142	0.002	0.003	302	-0.340	0.004	0.004	282	0.000
		Fraction Ct Tolerant	0.373	0.041	142	0.629	0.028	302	-5.204	0.642	0.029	282	-5.421
		Fraction Wt Tolerant	0.494	0.042	142	0.414	0.028	302	1.580	0.493	0.03	282	0.019
	Composition	Fraction Ct Non-R	0.246	0.036	142	0.248	0.025	302	0.046	0.145	0.021	282	-2.417
		Fraction Wt Non-R	0.131	0.028	142	0.185	0.022	302	1.497	0.14	0.021	282	0.257
	Pollution Tolerance	Fraction Ct Tolerant	0.12	0.027	142	0.063	0.014	302	1.860	0.074	0.016	282	1.464
		Fraction Wt Tolerant	0.232	0.035	142	0.162	0.021	302	1.696	0.263	0.026	282	-0.703
		Fraction Ct Intolerant	0.085	0.023	142	0.056	0.013	302	-1.079	0.043	0.012	282	-1.595
		Fraction Wt Intolerant	0.004	0.005	142	0.003	0.003	302	-0.162	0.011	0.006	282	0.858
Hoop net	Density	Count	1.678	0.579	18	1.904	0.647	18	0.261	2.313	0.491	18	0.837
		Weight	2.423	1.055	18	3.377	1.661	18	0.485	3.451	0.978	18	0.715
	Diversity	^{0}D Ct	8	1.43	30	13	1.626	34	2.309	11	1.369	39	1.516
		^{1}D Ct	4.911	1.029	30	9.448	1.539	34	2.451	8.758	1.125	39	2.523
		^{2}D Ct	3.543	0.817	30	7.41	1.437	34	2.339	7.567	1.089	39	2.956
		^{3}D Ct	2.991	0.697	30	6.466	1.319	34	2.330	6.936	1.078	39	3.074
	Heat Tolerance	Fraction Ct Intolerant	0.033	0.033	30	0.059	0.04	34	0.501	0.154	0.058	39	1.823
		Fraction Wt Intolerant	0.011	0.019	30	0.015	0.021	34	0.142	0.03	0.027	39	0.571
		Fraction Ct Tolerant	0.033	0.033	30	0.559	0.085	34	-5.769	0.205	0.065	39	-2.376
		Fraction Wt Tolerant	0.079	0.049	30	0.621	0.083	34	-5.606	0.392	0.078	39	-3.388
	Composition	Fraction Ct Non-R	0.7	0.084	30	0.235	0.073	34	-4.195	0.538	0.08	39	-1.401
		Fraction Wt Non-R	0.652	0.087	30	0.142	0.06	34	-4.831	0.464	0.08	39	-1.592
	Pollution Tolerance	Fraction Ct Tolerant	0.1	0.055	30	0.029	0.029	34	1.148	0.128	0.053	39	-0.366
		Fraction Wt Tolerant	0.259	0.08	30	0.037	0.032	34	2.573	0.226	0.067	39	0.316
		Fraction Ct Intolerant	0.033	0.033	30	0.059	0.04	34	0.501	0.231	0.067	39	2.642
		Fraction Wt Intolerant	0.011	0.019	30	0.046	0.036	34	0.861	0.137	0.055	39	2.163

Gear	Type	Metric	Upstream Reference			Thermally Exposed				Downstream			
			Mean	Std Err	N	Mean	Std Err	N	Std Diff	Mean	Std Err	N	Std Diff
Missouri mini-trawl	Density	Count	32.089	13.85	24	42.259	19.095	24	0.431	32.149	19.89	24	0.002
		Weight	0.147	0.054	24	0.363	0.183	24	1.127	0.07	0.049	24	-1.061
	Diversity	^{0}D Ct	15	1.026	753	22	1.692	1087	3.538	18	1.418	645	1.714
		^{1}D Ct	5.439	0.222	753	6.194	0.223	1087	2.395	5.664	0.256	645	0.662
		^{2}D Ct	3.718	0.156	753	4.574	0.129	1087	4.238	4.129	0.149	645	1.905
		^{3}D Ct	3.192	0.139	753	4.196	0.101	1087	5.839	3.755	0.13	645	2.957
	Heat Tolerance	Fraction Ct Intolerant	0.003	0.002	753	0.001	0.001	1087	-0.904	0	0	645	-1.505
		Fraction Wt Intolerant	0.015	0.004	753	0.003	0.002	1087	-2.537	0	0	645	-3.386
		Fraction Ct Tolerant	0.09	0.01	753	0.13	0.01	1087	-2.742	0.036	0.007	645	4.235
		Fraction Wt Tolerant	0.024	0.006	753	0.395	0.015	1087	-23.419	0.026	0.006	645	-0.238
	Composition	Fraction Ct Non-R	0.938	0.009	753	0.962	0.006	1087	2.279	0.929	0.01	645	-0.672
		Fraction Wt Non-R	0.897	0.011	753	0.615	0.015	1087	-15.282	0.97	0.007	645	5.635
	Pollution Tolerance	Fraction Ct Tolerant	0.061	0.009	753	0.034	0.005	1087	2.619	0.019	0.005	645	4.099
		Fraction Wt Tolerant	0.006	0.003	753	0.133	0.01	1087	-11.895	0.004	0.002	645	0.533
		Fraction Ct Intolerant	0.003	0.002	753	0.002	0.001	1087	-0.415	0	0	645	-1.505
		Fraction Wt Intolerant	0.015	0.004	753	0.004	0.002	1087	-2.279	0	0	645	-3.386

Table B-22 Summary of benthic invertebrates collected in Hester-Dendy bottom samples at the LEC during 2017-2018 sampling, by season and zone.

Class-Order-Family	Name	Winter				Spring				Summer				Fall			
		Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4
Cli-Tubi-Naididae	Stylaria lacustris	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Cli-Tubi-Naididae	Slavina appendiculata	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Cli-Tubi-Naididae	Pristina longiseta	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Cli-Tubi-Naididae	Piguetiella sp.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cli-Tubi-Naididae	Paranais sp.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cli-Tubi-Naididae	Nais pardalis	1	5	4	7	0	0	0	0	0	0	0	0	1	0	0	0
Cli-Tubi-Naididae	Nais communis/variabilis complex	0	4	6	8	0	0	0	0	1	0	0	0	0	0	2	0
Cli-Tubi-Naididae	Nais behningi	0	16	4	0	2	0	1	12	0	0	0	0	0	0	0	0
Cli-Tubi-Naididae	Nais sp.	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Cli-Tubi-Naididae	Limnodrilus claparedianus/cervix	1	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0
Cli-Tubi-Naididae	Dero digitata	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1	2
Cli-Tubi-Naididae	Naidinae	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Cli-Tubi-Naididae	Tubificinae	32	0	7	2	2	0	2	0	0	0	1	0	0	0	0	0
Cli-Hiru-Glossiphoniidae	Helobdella austinensis	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Cli- -	Clitellata	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0
Ins-Tric-Polycentropodidae	Neureclipsis sp.	1	2	2	0	60	0	49	38	23	0	16	3	8	0	18	2
Ins-Tric-Polycentropodidae	Cyrnellus fraternus	0	0	0	0	0	0	1	0	23	0	4	12	0	0	1	0
Ins-Tric-Polycentropodidae	Polycentropodidae	0	1	0	0	7	0	1	0	1	0	2	1	0	0	1	0
Ins-Tric-Leptoceridae	Nectopsyche sp.	0	0	0	0	0	0	1	0	2	0	1	0	0	0	1	0
Ins-Tric-Leptoceridae	Leptoceridae	0	0	0	0	1	0	0	0	3	0	1	0	0	0	0	0
Ins-Tric-Hydroptilidae	Mayatrichia sp.	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0
Ins-Tric-Hydroptilidae	Hydroptilidae	0	0	0	1	0	0	0	0	0	2	1	0	0	0	0	0
Ins-Tric-Hydropsychidae	Potamyia flava	10	46	57	20	388	222	327	691	344	690	705	64	104	344	186	75
Ins-Tric-Hydropsychidae	Hydropsyche sp.	14	67	34	16	925	754	890	1119	400	1619	1750	24	30	188	85	33
Ins-Tric-Hydropsychidae	Cheumatopsyche sp.	1	0	0	0	8	0	14	2	0	0	0	0	0	0	0	0
Ins-Tric-Hydropsychidae	Hydropsychidae	2	7	7	7	640	792	129	308	78	229	163	20	38	44	42	12
Ins-Tric-	Trichoptera	0	0	0	0	11	8	0	0	2	0	2	1	0	0	0	0
Ins-Plec-Taeniopterygidae	Taeniopteryx sp.	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Ins-Plec-Taeniopterygidae	Taeniopterygidae	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Plec-Perlodidae	Isoperla sp.	2	2	0	2	0	0	0	0	0	0	0	0	0	0	1	0
Ins-Plec-Perlodidae	Hydroperla sp.	3	3	6	1	0	0	0	0	0	0	0	0	3	8	6	1
Ins-Plec-Perlodidae	Perlodidae	0	0	0	0	0	0	0	0	0	0	0	0	1	5	0	1
Ins-Plec-Perlidae	Perlinella sp.	0	0	1	0	3	0	0	0	0	0	0	0	0	0	0	0
Ins-Plec-Perlidae	Perlesta sp.	0	2	0	0	11	4	14	18	0	0	1	0	0	0	0	0
Ins-Plec-Perlidae	Neoperla sp.	1	1	3	2	2	0	2	6	9	0	20	5	8	1	11	3

Class-Order-Family	Name	Winter				Spring				Summer				Fall			
		Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4
Ins-Plec-Perlidae	Attaneuria sp.	0	0	0	0	0	0	0	0	18	0	0	0	0	0	0	1
Ins-Plec-Perlidae	Acroneuria sp.	2	0	1	6	5	0	2	1	21	8	6	6	2	0	2	1
Ins-Plec-Perlidae	Perlidae	0	4	0	1	4	0	4	1	0	0	2	1	0	0	0	0
Ins-Plec-	Plecoptera	0	1	0	0	1	0	0	0	0	0	16	0	1	1	4	0
Ins-Odon-Gomphidae	Gomphus sp.	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Ins-Odon-Gomphidae	Dromogomphus sp.	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
Ins-Odon-Gomphidae	Gomphidae	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0
Ins-Odon-Corduliidae	Neurocordulia molesta	1	0	0	2	0	0	0	0	15	0	5	4	0	0	6	4
Ins-Odon-Corduliidae	Didymops transversa	0	0	0	0	0	0	0	0	4	0	0	0	1	0	0	0
Ins-Odon-Coenagrionidae	Argia sp.	0	0	0	2	1	0	4	0	15	0	38	19	1	0	12	6
Ins-Odon-	Zygoptera	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Mega-Corydalidae	Corydalus sp.	0	0	0	2	0	0	0	0	27	10	2	2	1	0	0	0
Ins-Mega-Corydalidae	Chauliodes sp.	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Ins-Ephe-Potamanthidae	Anthopotamus sp.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Ins-Ephe-Polymitarcyidae	Ephoron album	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0
Ins-Ephe-Polymitarcyidae	Ephoron sp.	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Ins-Ephe-Palingeniidae	Pentagenia vittigera	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
Ins-Ephe-Leptohyphidae	Tricorythodes sp.	0	0	1	0	15	2	10	12	7	2	4	3	0	2	0	0
Ins-Ephe-Isonychiidae	Isonychia sicca	0	0	0	0	11	0	13	0	0	0	2	0	0	0	0	0
Ins-Ephe-Isonychiidae	Isonychia rufa	0	0	0	0	7	6	26	0	11	0	1	2	0	4	0	0
Ins-Ephe-Isonychiidae	Isonychia bicolor	0	0	0	0	1	6	18	0	16	0	16	1	0	0	0	0
Ins-Ephe-Isonychiidae	Isonychia sp.	0	0	0	0	133	14	116	29	18	0	1	2	0	0	0	0
Ins-Ephe-Heptageniidae	Stenacron sp.	0	0	0	1	2	0	0	0	4	0	1	1	0	0	1	2
Ins-Ephe-Heptageniidae	Maccaffertium terminatum	0	2	1	1	4	0	0	4	2	0	1	0	0	0	0	0
Ins-Ephe-Heptageniidae	Maccaffertium mexicanum integrum	11	9	23	10	99	22	71	76	119	30	154	77	131	54	157	93
Ins-Ephe-Heptageniidae	Maccaffertium sp.	2	0	4	2	8	0	1	5	2	0	0	2	7	2	3	0
Ins-Ephe-Heptageniidae	Heptagenia sp.	0	4	4	0	43	0	22	15	0	5	17	1	7	23	6	7
Ins-Ephe-Heptageniidae	Heptageniidae	8	2	7	8	122	20	48	95	53	27	95	25	27	3	39	12
Ins-Ephe-Ephemeridae	Hexagenia sp.	0	0	0	0	0	0	0	0	1	0	4	0	0	0	1	0
Ins-Ephe-Ephemeridae	Ephemeridae	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Ins-Ephe-Caenidae	Caenis sp.	0	0	0	0	22	0	21	27	28	2	36	14	1	0	0	0
Ins-Ephe-Caenidae	Amercaenis sp.	0	0	0	0	224	180	47	525	46	8	19	18	0	0	0	0
Ins-Ephe-Caenidae	Caenidae	0	0	0	1	0	0	0	4	0	0	0	0	0	0	0	0
Ins-Ephe-Baetidae	Pseudocloeon sp.	0	0	0	0	469	262	281	346	93	159	86	31	0	0	0	0
Ins-Ephe-Baetidae	Baetidae	0	0	0	0	150	40	55	119	2	2	3	35	0	0	0	0
Ins-Ephe-	Ephemeroptera	0	1	0	0	21	4	3	8	0	0	0	2	1	0	0	0
Ins-Dipt-Tabanidae	Tabanidae	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0

Class-Order-Family	Name	Winter				Spring				Summer				Fall			
		Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4
Ins-Dipt-Chironomidae	Tvetenia vitracies	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Tribelos fuscicorne	0	0	0	0	0	0	0	0	7	0	2	10	0	0	0	0
Ins-Dipt-Chironomidae	Tribelos sp.	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0
Ins-Dipt-Chironomidae	Thienemannimyia sp. group	0	2	0	2	3	0	7	4	5	0	15	14	5	0	13	4
Ins-Dipt-Chironomidae	Thienemanniella xena	2	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Thienemanniella lobapodema	0	0	0	0	8	0	2	0	2	0	0	0	0	0	1	0
Ins-Dipt-Chironomidae	Thienemanniella sp.	0	2	4	1	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Telopelopia okoboji	7	6	13	5	22	0	22	8	7	0	28	0	1	0	2	0
Ins-Dipt-Chironomidae	Tanytarsus sepp	0	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Tanytarsus glabrescens group	0	3	1	2	5	0	2	8	9	0	6	6	0	1	1	0
Ins-Dipt-Chironomidae	Tanytarsus sp.	3	4	1	4	0	0	0	0	4	0	1	0	0	0	0	0
Ins-Dipt-Chironomidae	Stenochironomus sp.	0	0	0	0	255	92	134	148	616	76	683	813	0	0	0	0
Ins-Dipt-Chironomidae	Robackia claviger	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Rheotanytarsus exiguus group	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Rheotanytarsus sp.	0	30	49	8	523	116	246	664	1749	524	1193	99	1	1	6	4
Ins-Dipt-Chironomidae	Procladius (Psilotanypus) sp.	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Procladius sp.	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Ins-Dipt-Chironomidae	Polypedilum scalaenum group	0	2	0	0	6	0	14	8	77	0	50	58	0	0	0	1
Ins-Dipt-Chironomidae	Polypedilum illinoense group	0	0	1	2	0	0	0	0	16	0	10	0	0	0	0	0
Ins-Dipt-Chironomidae	Polypedilum halterale group	0	0	0	0	0	0	0	0	1	0	16	1	0	0	0	0
Ins-Dipt-Chironomidae	Polypedilum flavum	0	22	22	7	239	104	235	429	67	145	94	83	4	3	9	6
Ins-Dipt-Chironomidae	Polypedilum sp.	0	2	1	1	1	4	0	0	195	4	21	13	0	2	0	0
Ins-Dipt-Chironomidae	Phaenopsectra obediens group	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Ins-Dipt-Chironomidae	Paralauterborniella nigrohaltera	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Paracladopelma sp.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Parachironomus frequens	0	0	0	0	0	0	0	0	13	0	0	5	0	0	0	0
Ins-Dipt-Chironomidae	Orthocladius sp.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Nanocladius minimus	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Nanocladius distinctus	0	7	8	16	0	0	0	0	0	0	0	2	0	0	0	0
Ins-Dipt-Chironomidae	Nanocladius crassicornus/rectine	0	1	0	3	0	0	0	0	2	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Nanocladius alternantherae	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Nanocladius sp.	0	6	0	4	0	0	0	0	0	0	0	1	0	0	1	1
Ins-Dipt-Chironomidae	Labrundinia pilosella	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Kribiodorum perpulchrum	0	0	0	0	8	0	4	4	14	4	11	24	0	0	0	0
Ins-Dipt-Chironomidae	Hydrobaenus sp.	2	1	0	1	0	0	0	0	0	0	0	0	1	0	0	2
Ins-Dipt-Chironomidae	Harnischia sp.	1	0	0	0	6	0	2	0	7	0	12	3	0	0	0	0
Ins-Dipt-Chironomidae	Glyptotendipes sp.	0	0	4	0	0	0	0	0	0	0	4	1	0	0	0	1

Class-Order-Family	Name	Winter				Spring				Summer				Fall			
		Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4
Ins-Dipt-Chironomidae	Dicrotendipes neomodestus	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Dicrotendipes sp.	2	2	0	0	4	0	0	0	5	0	1	4	0	0	0	0
Ins-Dipt-Chironomidae	Cryptotendipes sp.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Cryptochironomus sp.	0	0	0	0	7	0	0	0	2	0	1	1	0	0	6	0
Ins-Dipt-Chironomidae	Cricotopus/Orthocladius sp.	0	0	2	4	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Corynoneura lobata	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Corynoneura floridaensis	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Cladotanytarsus sp. group A	0	0	0	0	4	0	0	0	2	0	1	0	0	0	0	0
Ins-Dipt-Chironomidae	Chironomus decorus group	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Chironomus sp.	0	0	0	0	0	0	0	0	9	0	0	2	0	0	5	1
Ins-Dipt-Chironomidae	Axarus sp.	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Ins-Dipt-Chironomidae	Ablabesmyia mallochi	2	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0
Ins-Dipt-Chironomidae	Ablabesmyia (Ablabesmyia)	0	0	0	0	0	0	0	0	74	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Ablabesmyia (Karelia) sp.	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Ablabesmyia sp.	0	0	1	0	0	0	0	0	0	0	1	1	0	0	0	0
Ins-Dipt-Chironomidae	Chironomidae	0	1	7	4	18	0	32	40	136	20	45	217	0	1	1	3
Ins-Dipt-Chironomidae	Chironominae	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Chironominae (Chironomini)	0	0	0	0	8	0	2	0	68	0	2	8	0	0	0	0
Ins-Dipt-Chironomidae	Chironominae (Tanytarsini)	0	0	1	0	0	4	7	18	64	16	0	2	0	0	0	0
Ins-Dipt-Chironomidae	Orthocladiinae	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Tanypodinae	0	1	0	0	4	0	0	0	0	0	0	4	0	0	1	0
Ins-Dipt-Chaoboridae	Chaoborus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Ins- -	Insecta	0	0	0	0	0	0	0	195	65	0	138	90	0	0	0	0
Ara-Trom-Hydrachnidia	Hydracarina	0	0	0	0	2	0	0	0	0	2	0	1	0	1	0	1
Hyd-Anth-Hydridae	Hydra sp.	1	0	5	7	0	0	0	0	0	0	2	0	1	0	0	0
Gas-Baso-Physidae	Physa sp.	0	0	2	2	0	0	0	0	0	0	0	1	0	0	2	0
Gas-Baso-Ancylidae	Ferrissia sp.	5	2	0	3	0	0	0	0	0	0	1	0	0	0	0	0
Biv-Vene-Dreissenidae	Dreissena polymorpha	0	0	0	0	0	0	0	0	4	0	15	3	0	0	1	1
Biv-Vene-Corbiculidae	Corbicula fluminea	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	1
Tre-Neoo-Planariidae	Planariidae	0	1	0	0	0	0	2	0	6	0	7	43	0	2	1	1
Tre- -	Trepaxonemata	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0

Table B-23 Summary of benthic invertebrates collected in Hester-Dendy mid-depth samples at the LEC during 2017-2018 sampling, by season and zone.

Class-Order-Family	Name	Winter				Spring				Summer				Fall			
		Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4
Cli-Tubi-Naididae	Stylaria lacustris	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cli-Tubi-Naididae	Slavina appendiculata	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Cli-Tubi-Naididae	Piguetiella sp.	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cli-Tubi-Naididae	Paranais sp.	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Cli-Tubi-Naididae	Nais pardalis	0	5	0	2	0	0	0	0	0	0	0	1	0	0	0	0
Cli-Tubi-Naididae	Nais communis/variabilis complex	3	6	18	4	0	0	0	0	0	0	1	0	0	0	0	0
Cli-Tubi-Naididae	Nais behningi	0	28	5	0	5	0	8	8	0	0	0	0	0	0	0	0
Cli-Tubi-Naididae	Nais sp.	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Cli-Tubi-Naididae	Limnodrilus udekemianus	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0
Cli-Tubi-Naididae	Limnodrilus claparedianus/cervix	0	0	0	2	0	0	0	0	0	0	0	2	3	0	0	0
Cli-Tubi-Naididae	Dero digitata	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0
Cli-Tubi-Naididae	Aulodrilus pluriseta	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Cli-Tubi-Naididae	Tubificinae	8	0	11	9	0	0	0	0	0	0	0	11	2	1	0	0
Cli- -	Clitellata	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Ins-Tric-Polycentropodidae	Neureclipsis sp.	1	0	5	1	31	2	21	26	16	0	9	0	12	0	27	1
Ins-Tric-Polycentropodidae	Cyrnellus fraternus	0	0	0	0	3	0	0	0	3	0	2	3	0	0	2	6
Ins-Tric-Polycentropodidae	Polycentropodidae	0	0	0	0	0	0	2	0	4	0	3	1	0	0	0	0
Ins-Tric-Leptoceridae	Nectopsyche sp.	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Ins-Tric-Leptoceridae	Leptoceridae	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Ins-Tric-Hydroptilidae	Mayatrichia sp.	0	0	0	0	11	0	2	11	2	0	0	2	0	0	0	0
Ins-Tric-Hydroptilidae	Hydroptilidae	0	0	0	0	2	0	2	1	0	0	0	0	0	0	0	0
Ins-Tric-Hydropsychidae	Potamyia flava	8	37	38	23	446	253	230	631	202	391	458	41	149	65	277	211
Ins-Tric-Hydropsychidae	Hydropsyche sp.	18	91	38	16	1673	1674	1187	1356	398	2228	1372	16	72	254	115	93
Ins-Tric-Hydropsychidae	Cheumatopsyche sp.	0	0	0	0	17	4	3	8	0	0	0	0	1	0	2	1
Ins-Tric-Hydropsychidae	Hydropsychidae	4	8	4	8	497	258	251	435	61	210	190	23	70	14	6	8
Ins-Tric-	Trichoptera	0	0	0	0	2	0	0	4	0	2	1	1	0	0	0	0
Ins-Plec-Taeniopterygidae	Taeniopteryx sp.	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	3
Ins-Plec-Taeniopterygidae	Strophopteryx sp.	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Plec-Perlodidae	Isoperla sp.	17	1	20	10	0	0	0	0	0	0	0	0	2	1	0	0
Ins-Plec-Perlodidae	Hydroperla sp.	1	4	28	5	0	0	0	0	0	0	0	0	0	7	5	7
Ins-Plec-Perlodidae	Perlodidae	0	0	1	0	0	0	0	0	0	0	0	0	2	1	2	1
Ins-Plec-Perlidae	Perlesta sp.	0	0	0	0	34	34	17	36	0	0	0	0	0	0	0	0
Ins-Plec-Perlidae	Neoperla sp.	0	0	0	0	4	0	0	2	10	0	4	9	3	1	9	9
Ins-Plec-Perlidae	Attaneuria sp.	0	0	1	0	1	0	0	3	1	8	6	1	1	0	1	2
Ins-Plec-Perlidae	Acroneuria sp.	4	0	1	1	4	0	5	1	15	0	10	1	1	1	3	3

Class-Order-Family	Name	Winter				Spring				Summer				Fall			
		Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4
Ins-Plec-Perlidae	Perlidae	0	1	0	0	4	2	2	0	0	0	2	0	0	1	2	1
Ins-Plec-	Plecoptera	0	0	1	0	1	0	0	0	0	0	0	0	0	1	4	0
Ins-Odon-Gomphidae	Dromogomphus sp.	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Ins-Odon-Gomphidae	Gomphidae	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Ins-Odon-Corduliidae	Neurocordulia molesta	0	0	1	1	3	0	0	3	12	0	4	7	1	0	1	4
Ins-Odon-Corduliidae	Didymops transversa	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Ins-Odon-Corduliidae	Didymops sp.	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
Ins-Odon-Corduliidae	Macromiinae	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Ins-Odon-Coenagrionidae	Coenagrion/Enallagma sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Ins-Odon-Coenagrionidae	Argia sp.	1	0	0	3	2	0	3	0	9	0	11	10	0	0	8	7
Ins-Odon-Coenagrionidae	Coenagrionidae	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Ins-Odon-	Zygoptera	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
Ins-Mega-Corydalidae	Corydalus sp.	0	0	0	0	0	0	0	4	8	0	12	5	0	0	1	0
Ins-Mega-Corydalidae	Chauliodes sp.	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Ins-Ephe-Potamanthidae	Anthopotamus sp.	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Ephe-Leptohyphidae	Tricorythodes sp.	0	0	0	0	15	2	2	12	23	2	15	8	0	0	1	1
Ins-Ephe-Leptohyphidae	Leptohyphidae	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Ins-Ephe-Isonychiidae	Isonychia sicca	0	0	0	0	3	14	5	8	0	0	1	0	0	0	0	0
Ins-Ephe-Isonychiidae	Isonychia rufa	0	0	0	0	43	10	17	13	4	0	1	2	1	0	0	0
Ins-Ephe-Isonychiidae	Isonychia bicolor	0	0	0	0	22	0	13	1	2	10	1	0	0	0	0	0
Ins-Ephe-Isonychiidae	Isonychia sp.	0	0	0	0	116	32	53	55	11	2	2	1	0	0	2	0
Ins-Ephe-Heptageniidae	Stenonema femoratum	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Ins-Ephe-Heptageniidae	Stenacron sp.	1	0	0	4	0	0	1	0	7	0	0	2	2	0	2	1
Ins-Ephe-Heptageniidae	Spinadis simplex	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Ins-Ephe-Heptageniidae	Raptoheptagenia cruentata	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Ins-Ephe-Heptageniidae	Maccaffertium terminatum	1	0	4	0	0	0	1	6	1	0	1	1	0	0	0	0
Ins-Ephe-Heptageniidae	Maccaffertium mexicanum integrum	50	7	58	25	185	26	87	111	238	55	213	225	206	52	245	190
Ins-Ephe-Heptageniidae	Maccaffertium exiguum	0	0	0	0	2	0	1	4	1	0	0	0	0	0	0	0
Ins-Ephe-Heptageniidae	Maccaffertium sp.	1	2	5	4	0	0	5	2	4	0	19	0	1	0	4	2
Ins-Ephe-Heptageniidae	Heptagenia sp.	7	10	7	6	39	34	27	62	4	20	0	0	6	16	17	10
Ins-Ephe-Heptageniidae	Heptageniidae	10	2	13	13	138	26	80	152	154	22	82	79	48	18	80	63
Ins-Ephe-Ephemeridae	Hexagenia limbata	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Ins-Ephe-Ephemeridae	Hexagenia sp.	2	0	0	0	12	0	0	0	1	0	1	0	0	0	0	0
Ins-Ephe-Caenidae	Caenis sp.	0	0	0	0	9	0	12	42	59	4	30	18	2	0	0	1
Ins-Ephe-Caenidae	Amercaenis sp.	0	0	0	0	354	388	212	483	22	12	21	11	0	0	0	0
Ins-Ephe-Caenidae	Caenidae	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Ins-Ephe-Baetidae	Pseudocloeon sp.	0	0	0	0	536	372	272	474	252	294	206	94	0	0	0	0

Class-Order-Family	Name	Winter				Spring				Summer				Fall			
		Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4
Ins-Ephe-Baetidae	Baetidae	0	0	0	1	236	68	90	165	11	20	37	21	0	0	0	0
Ins-Ephe-	Ephemeroptera	0	0	0	0	11	52	1	12	2	4	0	0	0	0	0	0
Ins-Dipt-Simuliidae	Simulium sp.	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Empididae	Hemerodromia sp.	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Tribelos fuscicorne	0	0	0	0	0	0	0	0	12	0	0	4	0	0	0	0
Ins-Dipt-Chironomidae	Thienemannimyia sp. group	2	0	2	5	10	0	11	6	11	0	5	16	2	0	1	5
Ins-Dipt-Chironomidae	Thienemanniella xena	0	0	2	4	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Thienemanniella lobapodema	0	0	0	0	4	0	0	0	4	0	0	2	0	0	1	0
Ins-Dipt-Chironomidae	Telopelopia okoboji	16	5	11	4	2	0	2	2	25	1	38	1	0	0	0	0
Ins-Dipt-Chironomidae	Tanytarsus sepp	0	0	0	0	0	0	2	0	8	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Tanytarsus glabrescens group	1	0	0	0	2	0	1	1	6	0	10	6	0	1	0	0
Ins-Dipt-Chironomidae	Tanytarsus sp.	5	0	8	5	4	0	0	0	0	0	8	2	0	0	0	0
Ins-Dipt-Chironomidae	Stenochironomus sp.	0	0	0	0	176	54	112	138	395	26	664	738	0	0	0	0
Ins-Dipt-Chironomidae	Rheotanytarsus sp.	0	44	31	11	557	184	363	578	1930	481	2413	166	1	9	3	4
Ins-Dipt-Chironomidae	Polypedilum scalaenum group	0	0	1	0	12	0	0	4	85	0	53	74	0	0	0	0
Ins-Dipt-Chironomidae	Polypedilum illinoense group	0	7	1	5	0	0	0	0	5	0	16	15	0	0	0	1
Ins-Dipt-Chironomidae	Polypedilum halterale group	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Polypedilum flavum	3	24	16	10	294	228	158	297	234	136	354	72	2	9	6	8
Ins-Dipt-Chironomidae	Polypedilum sp.	0	0	0	0	0	0	1	0	32	0	3	19	0	0	0	0
Ins-Dipt-Chironomidae	Phaenopsectra obediens	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Paratanytarsus sp.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0
Ins-Dipt-Chironomidae	Paralauterborniella nigrohaltera	4	0	3	0	0	0	0	0	0	0	0	1	0	0	0	0
Ins-Dipt-Chironomidae	Parachironomus frequens	0	0	0	0	0	0	0	0	0	0	4	17	0	0	0	0
Ins-Dipt-Chironomidae	Orthocladius (Orthocladius)	1	4	4	2	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Orthocladius sp.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Nanocladius distinctus	8	12	10	4	0	0	0	0	0	0	12	2	0	0	0	0
Ins-Dipt-Chironomidae	Nanocladius crassicornus/rectine	0	0	5	1	0	0	1	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Nanocladius alternantherae	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Nanocladius sp.	0	0	7	2	0	0	0	0	0	0	0	0	0	0	0	2
Ins-Dipt-Chironomidae	Micropsectra sp.	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Kribiodorum perpulchrum	0	0	0	0	8	0	0	2	7	0	9	17	0	0	0	0
Ins-Dipt-Chironomidae	Hydrobaenus sp.	3	0	4	3	0	0	0	0	0	0	0	0	0	0	0	2
Ins-Dipt-Chironomidae	Harnischia sp.	0	0	1	3	0	0	1	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Glyptotendipes sp.	0	0	0	0	0	0	0	0	2	0	21	3	0	0	0	0
Ins-Dipt-Chironomidae	Eukiefferiella claripennis group	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Dicrotendipes neomodestus	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Dicrotendipes sp.	0	2	0	0	0	0	0	0	9	0	1	3	0	0	0	0

Class-Order-Family	Name	Winter				Spring				Summer				Fall			
		Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4
Ins-Dipt-Chironomidae	Cryptochironomus sp.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Cricotopus/Orthocladius sp.	1	1	1	1	0	0	0	0	0	0	0	0	1	1	0	0
Ins-Dipt-Chironomidae	Cricotopus sylvestris group	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Cricotopus bicinctus	0	13	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Cricotopus sp.	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Corynoneura lobata	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Corynoneura sp.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Cladotanytarsus sp. group A	0	0	0	0	0	0	0	0	2	0	2	2	0	0	0	0
Ins-Dipt-Chironomidae	Chironomus decorus group	0	0	1	0	0	0	0	8	0	0	0	2	0	0	0	0
Ins-Dipt-Chironomidae	Chironomus sp.	0	0	0	1	0	0	0	0	4	0	0	1	0	0	0	2
Ins-Dipt-Chironomidae	Ablabesmyia mallochi	1	0	0	0	0	0	0	0	1	0	8	0	0	0	0	0
Ins-Dipt-Chironomidae	Ablabesmyia annulata	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	1
Ins-Dipt-Chironomidae	Ablabesmyia (Ablabesmyia)	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Ablabesmyia (Karelia) sp.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Chironomidae	1	0	4	1	22	8	6	16	78	24	39	151	0	0	2	1
Ins-Dipt-Chironomidae	Chironominae	0	0	0	0	2	0	5	0	0	0	0	1	0	0	0	0
Ins-Dipt-Chironomidae	Chironominae (Chironomini)	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
Ins-Dipt-Chironomidae	Chironominae (Tanytarsini)	0	0	0	0	2	12	11	13	17	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Orthocladiinae	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Ins-Dipt-Chironomidae	Tanypodinae	0	0	0	1	0	0	0	0	8	0	0	0	0	0	2	0
Ins-Dipt-Chaoboridae	Chaoborus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Ins-Dipt-Ceratopogonidae	Sphaeromias sp.	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Ceratopogonidae	Bezzia/Palpomyia sp.	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Cole-Elmidae	Macronychus glabratus	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Ins-Cole-Elmidae	Ancyronyx variegatus	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Ins- -	Insecta	0	0	0	0	0	0	0	0	107	42	112	118	0	0	0	0
Ara-Trom-Hydrachnidia	Hydracarina	0	0	2	0	4	2	0	2	0	0	0	0	1	0	0	0
Hyd-Anth-Hydridae	Hydra sp.	0	0	4	2	0	0	0	0	0	0	0	0	0	0	1	1
Gas-Baso-Physidae	Physa sp.	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gas-Baso-Ancylidae	Ferrissia sp.	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Biv-Vene-Dreissenidae	Dreissena polymorpha	1	0	0	0	0	0	0	0	5	0	4	2	0	0	0	0
Biv-Vene-Corbiculidae	Corbicula fluminea	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Tre-Neoo-Planariidae	Planariidae	0	0	0	1	0	0	0	0	5	8	4	13	1	4	1	0

Table B-24 Summary of benthic invertebrates collected in Ponar samples at the LEC during 2017-2018 sampling, by season and zone.

Class-Order-Family	Name	Winter				Spring				Summer				Fall			
		Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4
Cli-Tubi-Naididae	Quistadrilus multisetosus	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Cli-Tubi-Naididae	Pristina synclites	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Cli-Tubi-Naididae	Piguetiella sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Cli-Tubi-Naididae	Paranais sp.	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Cli-Tubi-Naididae	Nais pardalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Cli-Tubi-Naididae	Nais communis/variabilis complex	0	0	0	208	0	0	0	0	0	0	0	0	0	0	0	2
Cli-Tubi-Naididae	Nais behningi	0	20	16	1	0	0	0	0	0	0	0	0	0	0	0	0
Cli-Tubi-Naididae	Limnodrilus udekemianus	4	0	2	6	0	0	0	15	71	0	2	68	10	5	2	1
Cli-Tubi-Naididae	Limnodrilus hoffmeisteri	18	1	15	37	0	0	2	9	4	0	5	2	11	1	10	8
Cli-Tubi-Naididae	Limnodrilus hoffmeisteri complex	56	8	0	16	64	0	14	60	0	0	96	72	0	1	16	0
Cli-Tubi-Naididae	Limnodrilus claparedianus/cervix	224	1	147	249	38	5	11	110	527	0	111	438	28	1	131	56
Cli-Tubi-Naididae	Limnodrilus sp.	4	0	3	5	0	0	1	2	5	0	1	1	8	3	9	15
Cli-Tubi-Naididae	Dero digitata	0	1	0	0	0	0	0	1	0	0	0	1	0	0	1	4
Cli-Tubi-Naididae	Dero sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
Cli-Tubi-Naididae	Branchiura sowerbyi	29	1	42	25	83	8	21	55	264	1	160	333	352	9	111	226
Cli-Tubi-Naididae	Aulodrilus pluriseta	0	0	1	0	0	0	0	4	0	0	0	0	0	0	0	16
Cli-Tubi-Naididae	Naididae	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	8
Cli-Tubi-Naididae	Naidinae	1	0	3	2	0	0	0	0	0	0	0	0	0	0	0	0
Cli-Tubi-Naididae	Tubificinae	871	56	669	564	488	87	196	376	891	9	432	319	1403	41	691	648
Cli-Lumb-Lumbriculidae	Lumbriculidae	0	0	0	0	3	0	2	6	0	0	0	0	1	0	1	4
Cli-Hiru-Glossiphoniidae	Helobdella papillata	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Cli-Hiru-Glossiphoniidae	Helobdella sp.	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Cli-Hiru-Glossiphoniidae	Actinobdella inequiannulata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Cli-Hiru-Glossiphoniidae	Actinobdella sp.	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Cli- -	Clitellata	334	6	773	883	40	14	79	171	209	0	85	128	404	18	232	256
Ins-Tric-Polycentropodidae	Neureclipsis sp.	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0
Ins-Tric-Polycentropodidae	Cyrnellus fraternus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Ins-Tric-Leptoceridae	Oecetis sp.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Tric-Hydroptilidae	Hydroptila sp.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Tric-Hydropsychidae	Potamyia flava	1	1	0	4	2	4	1	1	14	6	10	3	6	3	10	21
Ins-Tric-Hydropsychidae	Hydropsyche sp.	0	1	4	6	36	25	28	21	45	12	4	5	3	16	8	11
Ins-Tric-Hydropsychidae	Hydropsychidae	0	0	0	0	2	0	8	2	6	2	3	0	1	2	1	2
Ins-Tric-	Trichoptera	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Ins-Plec-Taeniopterygidae	Taeniopteryx sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Ins-Plec-Perlodidae	Isoperla sp.	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0

Class-Order-Family	Name	Winter				Spring				Summer				Fall			
		Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4
Ins-Plec-Perlodidae	Perlodidae	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Ins-Plec-Perlidae	Neoperla sp.	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Ins-Plec-	Plecoptera	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0
Ins-Odon-Gomphidae	Gomphus sp.	0	0	0	1	1	1	1	3	1	0	0	2	3	1	5	3
Ins-Odon-Gomphidae	Dromogomphus sp.	0	0	2	4	0	0	0	1	0	0	0	0	0	0	0	0
Ins-Odon-Gomphidae	Gomphidae	0	0	1	2	0	1	0	0	0	0	0	4	0	0	0	0
Ins-Odon-Corduliidae	Neurocordulia molesta	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0
Ins-Odon-Corduliidae	Didymops transversa	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Ins-Mega-Corydalidae	Corydalus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Ins-Lepi-	Lepidoptera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Ins-Hemi-Corixidae	Corixidae	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Hemi-Aphididae	Aphididae	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Ins-Hemi-	Hemiptera	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0
Ins-Ephe-Polymitarcyidae	Tortopus primus	0	0	0	0	19	0	6	2	0	0	0	0	0	0	0	0
Ins-Ephe-Polymitarcyidae	Ephoron album	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Ins-Ephe-Polymitarcyidae	Ephoron sp.	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Ins-Ephe-Polymitarcyidae	Polymitarcidae	0	0	0	0	0	0	1	3	0	0	0	0	0	0	0	0
Ins-Ephe-Palingeniidae	Pentagenia vittigera	3	25	7	1	1	0	10	2	89	4	67	163	22	68	1	23
Ins-Ephe-Leptohyphidae	Tricorythodes sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Ins-Ephe-Isonychiidae	Isonychia sp.	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Ins-Ephe-Heptageniidae	Maccaffertium mexicanum integrum	0	0	0	0	0	0	0	0	2	0	0	2	0	0	0	1
Ins-Ephe-Heptageniidae	Heptageniidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Ins-Ephe-Ephemeridae	Hexagenia limbata	39	0	27	45	23	0	10	16	234	0	78	105	105	3	82	64
Ins-Ephe-Ephemeridae	Hexagenia bilineata	0	0	0	0	13	0	4	18	71	0	10	13	0	0	0	0
Ins-Ephe-Ephemeridae	Hexagenia atrocaudata	1	0	0	1	0	0	0	0	29	0	2	2	2	0	6	1
Ins-Ephe-Ephemeridae	Hexagenia sp.	59	0	21	14	3	0	0	0	374	0	106	99	38	0	22	24
Ins-Ephe-Ephemeridae	Ephemeridae	8	0	8	14	2	0	0	2	12	0	31	12	4	0	2	0
Ins-Ephe-Caenidae	Caenis sp.	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Ins-Ephe-Caenidae	Amercaenis sp.	0	0	0	0	0	0	0	3	0	0	1	1	0	0	0	0
Ins-Ephe-Caenidae	Caenidae	0	0	0	0	1	0	0	2	0	0	0	0	0	0	0	0
Ins-Ephe-Baetidae	Pseudocloeon sp.	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Ins-Ephe-Baetidae	Baetidae	0	0	0	0	0	0	0	1	0	0	0	2	1	0	0	0
Ins-Ephe-	Ephemeroptera	5	0	9	2	0	0	5	2	0	0	2	0	0	0	0	0
Ins-Dipt-Simuliidae	Simuliidae	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Psychodidae	Psychoda sp.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Ins-Dipt-Psychodidae	Psychodidae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	3
Ins-Dipt-Dolichopodidae	Dolichopodidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0

Class-Order-Family	Name	Winter				Spring				Summer				Fall			
		Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4
Ins-Dipt-Chironomidae	Tribelos jucundus	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Tribelos fuscicorne	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Tribelos ater	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Thienemannimyia sp. group	0	0	0	2	0	0	0	4	2	0	0	0	0	0	0	3
Ins-Dipt-Chironomidae	Telopelopia okoboji	0	0	1	0	1	0	0	32	1	0	1	5	0	0	0	3
Ins-Dipt-Chironomidae	Tanytarsus sepp	0	0	1	2	5	0	0	2	0	0	0	0	0	0	0	2
Ins-Dipt-Chironomidae	Tanytarsus sp.	3	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Tanypus neopunctipennis	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Stictochironomus caffrarius grou	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Ins-Dipt-Chironomidae	Stictochironomus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Ins-Dipt-Chironomidae	Stenochironomus sp.	0	0	0	0	2	0	2	0	6	0	0	0	0	0	0	1
Ins-Dipt-Chironomidae	Stempellinella leptocelloides	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Robackia claviger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Ins-Dipt-Chironomidae	Rheotanytarsus sp.	0	1	0	0	17	1	1	52	41	6	9	13	0	0	1	1
Ins-Dipt-Chironomidae	Rheosmittia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Ins-Dipt-Chironomidae	Procladius (Psilotanypus) sp.	19	0	13	17	4	0	5	8	4	0	0	0	0	3	0	8
Ins-Dipt-Chironomidae	Procladius (Holotanypus) sp.	20	0	8	7	8	0	2	2	0	0	0	0	0	0	3	6
Ins-Dipt-Chironomidae	Procladius sp.	9	0	4	0	0	0	0	2	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Polypedilum trigonus	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Ins-Dipt-Chironomidae	Polypedilum scalaenum group	0	0	0	0	0	1	0	0	9	0	48	2	0	0	2	1
Ins-Dipt-Chironomidae	Polypedilum nubifer	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Polypedilum illinoense group	0	1	0	18	16	0	1	0	3	0	4	0	0	0	1	2
Ins-Dipt-Chironomidae	Polypedilum halterale group	1	15	1	5	3	5	1	36	4	0	5	1	0	0	0	1
Ins-Dipt-Chironomidae	Polypedilum flavum	2	0	0	4	1	3	6	6	32	0	8	4	0	0	1	0
Ins-Dipt-Chironomidae	Polypedilum sp.	0	2	0	0	0	1	0	0	1	0	4	0	0	0	0	0
Ins-Dipt-Chironomidae	Paratendipes basidens	0	0	0	0	0	0	0	0	0	0	0	0	3	0	2	3
Ins-Dipt-Chironomidae	Paralauterborniella nigrohaltera	4	7	1	0	0	1	0	0	0	0	0	0	0	0	2	0
Ins-Dipt-Chironomidae	Paracladopelma undine	3	0	1	4	1	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Paracladopelma nereis	1	1	1	5	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Paracladopelma sp.	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Parachironomus frequens	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Ins-Dipt-Chironomidae	Orthocladius (Orthocladius)	1	1	2	10	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Orthocladius sp.	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Nilotanypus sp.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Kribiodorum perpulchrum	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Hydrobaenus sp.	18	0	3	7	0	0	0	0	0	0	0	0	0	0	1	5
Ins-Dipt-Chironomidae	Harnischia sp.	1	5	1	0	100	2	14	70	4	0	17	4	2	0	0	0

Class-Order-Family	Name	Winter				Spring				Summer				Fall			
		Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4
Ins-Dipt-Chironomidae	Glyptotendipes sp.	1	0	1	0	4	0	0	0	0	0	0	0	0	0	1	0
Ins-Dipt-Chironomidae	Epoicocladius sp.	2	0	1	1	0	0	1	5	1	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Dicrotendipes sp.	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Demicryptochironomus sp.	6	1	0	2	0	0	0	1	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Cryptotendipes sp.	0	1	0	1	20	0	7	7	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Cryptochironomus sp.	15	3	8	4	30	3	6	58	25	0	27	21	120	2	36	44
Ins-Dipt-Chironomidae	Cricotopus/Orthocladius sp.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Ins-Dipt-Chironomidae	Cricotopus sp.	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	1
Ins-Dipt-Chironomidae	Coelotanypus sp.	0	1	1	3	0	0	0	0	0	0	0	1	0	0	2	2
Ins-Dipt-Chironomidae	Chironomus decorus group	7	0	6	13	139	0	68	135	0	0	10	30	18	0	0	1
Ins-Dipt-Chironomidae	Chironomus sp.	0	0	3	3	106	0	10	29	3	0	12	28	0	0	38	14
Ins-Dipt-Chironomidae	Chernovskiia sp.	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
Ins-Dipt-Chironomidae	Axarus sp.	0	0	0	0	1	0	0	0	6	0	0	3	6	0	0	0
Ins-Dipt-Chironomidae	Ablabesmyia mallochi	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Ablabesmyia annulata	2	0	1	2	7	0	2	8	1	0	21	5	18	0	15	8
Ins-Dipt-Chironomidae	Ablabesmyia (Karelia) sp.	2	0	2	1	0	0	0	8	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Ablabesmyia sp.	1	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Ins-Dipt-Chironomidae	Chironomidae	14	0	4	2	15	1	3	4	0	0	3	0	0	0	0	3
Ins-Dipt-Chironomidae	Chironominae	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Chironominae (Chironomini)	3	3	1	2	3	0	0	1	1	0	0	0	0	0	0	2
Ins-Dipt-Chironomidae	Orthocladiinae	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Tanypodinae	1	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0
Ins-Dipt-Chironomidae	Tanypus sp.	1	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Ins-Dipt-Chaoboridae	Chaoborus sp.	1	0	0	1	0	0	0	0	1	0	0	0	0	0	9	6
Ins-Dipt-Chaoboridae	Chaoboridae	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
Ins-Dipt-Ceratopogonidae	Stilobezzia sp.	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
Ins-Dipt-Ceratopogonidae	Sphaeromias sp.	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	1
Ins-Dipt-Ceratopogonidae	Probezzia sp.	1	0	0	0	1	0	0	1	0	0	0	0	0	0	0	1
Ins-Dipt-Ceratopogonidae	Culicoides sp.	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	2
Ins-Dipt-Ceratopogonidae	Ceratopogon sp.	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Ceratopogonidae	Bezzia/Palpomyia sp.	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ins-Dipt-Ceratopogonidae	Ceratopogonidae	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0
Ins-Dipt-	Diptera	0	0	0	0	0	0	30	0	1	0	1	0	0	1	0	0
Ins-Cole-Staphylinidae	Staphylinidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Ins-Cole-Elmidae	Stenelmis sp.	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Ins-Cole-Elmidae	Dubiraphia sp.	1	0	0	1	1	0	0	0	0	0	0	0	1	0	0	1
Ins-Cole-	Coleoptera	2	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0

Class-Order-Family	Name	Winter				Spring				Summer				Fall			
		Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4	Zone 1	Zone 2	Zone 3	Zone 4
Ins- -	Insecta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Ent-Coll-Isotomidae	Isotomidae	44	0	2	1	0	0	0	0	1	0	0	0	0	0	1	6
Ara-Trom-Hydrachnidia	Hydracarina	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Gas-Baso-Planorbidae	Planorbidae	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0
Gas-Baso-Ancylidae	Ancylidae	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Biv-Vene-Dreissenidae	Dreissena polymorpha	4	0	0	5	0	0	0	0	1	0	0	8	2	0	1	1
Biv-Vene-Corbiculidae	Corbicula fluminea	2	6	2	2	1	0	1	0	13	0	3	2	0	2	1	2
Biv-Unio-Unionidae	Leptodea fragilis	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Biv- -	Bivalvia	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0

Table B-25 Mean density, standard error, and sample size for benthic inverebrate sampline at the LEC in 2017-2018, by gear, season and zone.

Gear	Season	Statistic	Zone			
			Upstream Reference	Discharge	Thermally Exposed	Downstream
Hester-Dendy	Winter	Mean	19.59	103.77	40.07	23.12
		Std Err	2.24	26.79	8.57	3.54
		N	23	8	24	24
	Spring	Mean	601.73	1251.47	605.28	776.26
		Std Err	90.27	281.60	128.19	122.51
		N	23	7	14	18
	Summer	Mean	546.10	1298.97	687.73	246.14
		Std Err	195.54	496.67	271.02	40.49
		N	23	8	24	22
	Fall	Mean	56.28	196.58	84.25	55.99
		Std Err	15.19	74.48	16.84	8.52
		N	24	8	24	23
Ponar	Winter	Mean	199.25	56.09	195.51	238.68
		Std Err	49.39	13.78	64.23	84.92
		N	6	2	6	6
	Spring	Mean	140.17	52.24	60.58	146.15
		Std Err	39.81	0.96	17.49	39.25
		N	6	2	6	6
	Summer	Mean	321.90	13.46	148.40	204.38
		Std Err	107.99	8.97	48.76	46.63
		N	6	2	6	6
	Fall	Mean	275.11	58.97	157.59	164.64
		Std Err	64.00	1.28	45.56	39.81
		N	6	2	6	6

Table B-26 Sample size, estimated diversity and standard deviation at q = 0, 1, 2, and 3 for benthic invertebrate sampling at the LEC in 2017-2018, by gear, season, and zone.

Gear	Season	Statistic	Upstream		Discharge		Thermally Exposed		Downstream	
			Estimate	StdDev	Estimate	StdDev	Estimate	StdDev	Estimate	StdDev
Hester-Dendy	Winter	N	248	-	558	-	602	-	324	-
		^{0}D	42	3.16	37	2.14	49	2.7	49	3.47
		^{1}D	17.32	1.54	12.15	0.67	17.41	0.88	25.94	1.59
		^{2}D	9.64	1.04	7.26	0.46	11.23	0.59	17.1	1.28
		^{3}D	7.29	0.89	5.82	0.42	9.51	0.5	13.63	1.16
	Spring	N	6853	-	5051	-	5275	-	8523	-
		^{0}D	48	1.55	17	0.76	42	2.05	41	1.83
		^{1}D	8.1	0.12	5.5	0.09	8.24	0.15	8.32	0.09
		^{2}D	5.01	0.09	3.61	0.07	4.95	0.1	6.17	0.07
		^{3}D	4.05	0.08	2.94	0.06	3.91	0.09	5.38	0.08
	Summer	N	7900	-	6962	-	11048	-	3085	-
		^{0}D	55	1.76	20	0.86	56	2.78	56	3.62
		^{1}D	7.58	0.13	4.13	0.05	6.92	0.09	7.81	0.23
		^{2}D	3.93	0.07	2.8	0.04	4.63	0.05	3.6	0.11
		^{3}D	3.09	0.05	2.38	0.03	4.07	0.04	2.78	0.07
	Fall	N	788	-	1055	-	1281	-	835	-
		^{0}D	33	3.43	18	1.71	39	2.69	35	2.99
		^{1}D	4.93	0.25	3.92	0.13	6.06	0.24	6.22	0.31
		^{2}D	3.29	0.11	2.96	0.07	3.91	0.11	3.9	0.14
		^{3}D	2.97	0.09	2.74	0.06	3.49	0.09	3.48	0.11
Ponar	Winter	N	556	-	107	-	330	-	738	-
		^{0}D	42	3.13	25	2.87	36	2.91	45	3.19
		^{1}D	10.14	0.63	11.73	1.15	9.25	0.82	9.27	0.52
		^{2}D	5.02	0.35	7.8	0.82	4.35	0.41	4.86	0.23
		^{3}D	3.81	0.26	6.56	0.76	3.31	0.29	4.03	0.17
	Spring	N	653	-	59	-	232	-	763	-
		^{0}D	36	3.12	12	1.7	29	2.11	40	2.54
		^{1}D	13.63	0.62	6.89	1.02	13.24	1	15.52	0.6
		^{2}D	9.23	0.48	4.46	0.81	7.86	0.85	10.98	0.46
		^{3}D	7.71	0.44	3.53	0.69	5.91	0.74	9.36	0.46
	Summer	N	1513	-	31	-	705	-	1318	-
		^{0}D	35	2.88	7	0.93	27	1.76	32	1.77
		^{1}D	8.66	0.27	4.95	0.64	10.87	0.43	7.42	0.23
		^{2}D	5.36	0.19	4.09	0.63	7.89	0.33	4.93	0.15
		^{3}D	4.4	0.17	3.66	0.63	6.87	0.33	4.24	0.13
	Fall	N	717	-	119	-	514	-	563	-
		^{0}D	23	1.91	16	1.74	41	3.5	49	3.58
		^{1}D	5.61	0.27	5.17	0.65	10.39	0.6	11.03	0.75
		^{2}D	3.39	0.17	2.81	0.35	6.57	0.35	5.11	0.36
		^{3}D	2.81	0.14	2.3	0.26	5.62	0.3	3.84	0.26

Table B-27 Fraction of organisms in major groups during benthic sampling at the LEC in 2017-2018, by gear and zone.

Gear	Major Group	Zone			
		Upstream Reference	Discharge	Thermally Exposed	Downstream
Hester-Dendy	Trichoptera	0.3317	0.6676	0.4281	0.3471
	Diptera	0.4063	0.1594	0.3703	0.3420
	Ephemeroptera	0.2328	0.1571	0.1650	0.2584
	Plecoptera	0.0099	0.0066	0.0112	0.0099
	Tubificida	0.0038	0.0043	0.0042	0.0048
	Other	0.0084	0.0027	0.0122	0.0260
Ponar	Trichoptera	0.0134	0.1277	0.0150	0.0115
	Diptera	0.1089	0.1436	0.1001	0.1208
	Ephemeroptera	0.1324	0.1791	0.0992	0.0911
	Plecoptera	0.0002	0.0000	0.0004	0.0007
	Tubificida	0.6222	0.4610	0.5567	0.5624
	Other	0.1126	0.0674	0.2222	0.2038

Table B-28 Number of species and fraction of organism in EPT orders during benthic sampling at the LEC in 2017-2018 by gear, season, and zone.

Gear	Season	Statistic	Zone			
			Upstream Reference	Discharge	Thermally Exposed	Downstream
Hester-Dendy	Winter	# Species	14	11	14	16
		Fraction	0.559	0.525	0.536	0.489
		N	329	606	702	405
	Spring	# Species	27	13	23	22
		Fraction	0.778	0.874	0.771	0.742
		N	10103	6395	6186	10200
	Summer	# Species	21	12	22	19
		Fraction	0.309	0.8	0.483	0.231
		N	9169	7586	12049	3953
	Fall	# Species	17	11	19	16
		Fraction	0.966	0.969	0.931	0.913
		N	986	1148	1476	940
Ponar	Winter	# Species	5	3	4	7
		Fraction	0.063	0.154	0.042	0.041
		N	1865	175	1830	2234
	Spring	# Species	8	2	8	9
		Fraction	0.079	0.178	0.134	0.056
		N	1312	163	567	1368
	Summer	# Species	9	4	9	9
		Fraction	0.291	0.595	0.228	0.214
		N	3013	42	1389	1913
	Fall	# Species	7	4	7	9
		Fraction	0.071	0.5	0.091	0.099
		N	2575	184	1475	1541

Table B-29 Upper incipient lethal temperature (UILT) for EPT taxa from literature. Heat intolerant are those with UILT ≤ 30 in bold font.

Order	Family	Scientific Name	UILT*
Ephemeroptera	**Baetidae**	**Baetidae**	**26.1**
	Baetidae	Pseudocloeon sp.	41.1
	Caenidae	**Caenis sp.**	**26.7**
	Ephemeridae	Hexagenia bilineata	>30
	Ephemeridae	**Hexagenia limbata**	**26.6**
	Heptageniidae	**Heptagenia sp.**	**28.3**
	Heptageniidae	**Heptageniidae**	**22**
	Heptageniidae	**Stenonema femoratum**	**25.5**
Plecoptera	**Perlidae**	**Acroneuria sp.**	**30**
	Perlidae	**Perlidae**	**24.1**
	Taeniopterygidae	**Taeniopterygidae**	**29.5, 21**
	Taeniopterygidae	**Taeniopteryx sp.**	**29.5, 21**
Trichoptera	Hydropsychidae	Hydropsyche sp.	>35
	Hydroptilidae	**Hydroptila sp.**	**30-41.1**
	Hydroptilidae	**Hydroptilidae**	**30-41.1**
	Polycentropodidae	Neureclipsis sp.	>35

*Dallas and Ross-Gillespie 2015; Environmental Canada 2014; Nebeker and Lemke 1968; Stewart et al. 2013; Yoder and Rankin 2005

Table B-30 Number of organisms in EPT orders, number and fraction in heat-intolerant groups during benthic sampling at the LEC in 2017-2018 by gear, season, and zone.

Gear	Season	Statistic	Zone			
			Upstream Reference	Discharge	Thermally Exposed	Downstream
Hester-Dendy	Winter	Total EPT	184	318	376	198
		# Intolerant	31	23	33	38
		Fraction	0.168	0.072	0.088	0.192
	Spring	Total EPT	7856	5587	4768	7567
		# Intolerant	778	190	370	681
		Fraction	0.099	0.034	0.078	0.09
	Summer	Total EPT	2834	6067	5822	912
		# Intolerant	347	112	321	202
		Fraction	0.122	0.018	0.055	0.221
	Fall	Total EPT	952	1112	1374	858
		# Intolerant	97	63	151	101
		Fraction	0.102	0.057	0.11	0.118
Ponar	Winter	Total EPT	117	27	77	91
		# Intolerant	39	0	27	46
		Fraction	0.333	0	0.351	0.505
	Spring	Total EPT	103	29	76	76
		# Intolerant	23	0	10	17
		Fraction	0.223	0	0.132	0.224
	Summer	Total EPT	878	25	316	409
		# Intolerant	235	0	78	107
		Fraction	0.268	0	0.247	0.262
	Fall	Total EPT	183	92	134	152
		# Intolerant	106	3	83	66
		Fraction	0.579	0.033	0.619	0.434

Table B-31 Means and standard errors for individual metrics, and standardized differences for benthic invertebrates collected during winter sampling at the LEC in 2017-2018.

Season	Gear	Type	Metric	Upstream Reference			Thermally Exposed				Downstream			
				Mean	Std Err	N	Mean	Std Err	N	Std Diff	Mean	Std Err	N	Std Diff
Winter	Hester-Dendy	Composition	Fraction EPT	0.559	0.027	329	0.536	0.019	702	-0.692	0.489	0.025	405	-1.894
			EPT Species	14	1	329	14	1	702	0	16	1	405	1.414
		Density	Mean Countt	19.595	2.242	23	40.07	8.566	24	2.312	23.116	3.537	24	0.841
		Diversity	^{0}D	42	3.158	248	49	2.7	602	1.685	49	3.473	324	1.491
			^{1}D	17.32	1.54	248	17.41	0.88	602	0.052	25.945	1.593	324	3.893
			^{2}D	9.64	1.045	248	11.23	0.585	602	1.331	17.097	1.283	324	4.508
			^{3}D	7.288	0.894	248	9.506	0.499	602	2.166	13.633	1.155	324	4.344
		Thermal Tolerance	Fraction EPT Intolerant	0.168	0.028	184	0.088	0.015	376	-2.565	0.192	0.028	198	0.611
	Ponar	Composition	Fraction EPT	0.063	0.006	1865	0.042	0.005	1830	-2.867	0.041	0.004	2234	-3.135
			EPT Species	5	1	1865	4	1	1830	-0.707	7	1	2234	1.414
		Density	Mean Count	199.25	49.389	6	195.5	64.232	6	-0.046	238.68	84.919	6	0.401
		Diversity	^{0}D	42	3.13	556	36	2.911	330	-1.404	45	3.187	738	0.672
			^{1}D	10.136	0.631	556	9.249	0.821	330	-0.857	9.27	0.52	738	-1.058
			^{2}D	5.023	0.347	556	4.347	0.406	330	-1.265	4.861	0.228	738	-0.390
			^{3}D	3.81	0.26	556	3.309	0.289	330	-1.288	4.033	0.169	738	0.720
		Thermal Tolerance	Fraction EPT Intolerant	0.333	0.044	117	0.351	0.054	77	0.258	0.505	0.052	91	2.524

Table B-32 Means and standard errors for individual metrics, and standardized differences for benthic invertebrates collected during spring sampling at the LEC in 2017-2018.

Season	Gear	Type	Metric	Upstream Reference			Thermally Exposed				Downstream			
				Mean	Std Err	N	Mean	Std Err	N	Std Diff	Mean	Std Err	N	Std Diff
Spring	Hester-Dendy	Composition	Fraction EPT	0.778	0.004	10103	0.771	0.005	6186	-1.036	0.742	0.004	10200	-6.011
			EPT Species	27	1	10103	23	1	6186	-2.828	22	1	10200	-3.536
		Density	Mean Countt	601.73	90.27	23	605.3	128.19	14	0.023	776.26	122.51	18	1.147
		Diversity	^{0}D	48	1.552	6853	42	2.054	5275	-2.331	41	1.834	8523	-2.914
			^{1}D	8.099	0.121	6853	8.242	0.147	5275	0.751	8.32	0.092	8523	1.455
			^{2}D	5.015	0.088	6853	4.949	0.104	5275	-0.483	6.173	0.075	8523	10.031
			^{3}D	4.054	0.079	6853	3.905	0.086	5275	-1.275	5.382	0.083	8523	11.543
		Thermal Tolerance	Fraction EPT Intolerant	0.099	0.003	7856	0.078	0.004	4768	-4.084	0.09	0.003	7567	-1.911
	Ponar	Composition	Fraction EPT	0.079	0.007	1312	0.134	0.014	567	3.41	0.056	0.006	1368	-2.371
			EPT Species	8	1	1312	8	1	567	0	9	1	1368	0.707
		Density	Mean Count	140.17	39.812	6	60.58	17.486	6	-1.83	146.15	39.254	6	0.107
		Diversity	^{0}D	36	3.124	653	29	2.109	232	-1.857	40	2.544	763	0.993
			^{1}D	13.628	0.62	653	13.24	1	232	-0.328	15.518	0.604	763	2.183
			^{2}D	9.235	0.481	653	7.858	0.853	232	-1.407	10.984	0.462	763	2.624
			^{3}D	7.707	0.445	653	5.914	0.738	232	-2.081	9.361	0.463	763	2.576
		Thermal Tolerance	Fraction EPT Intolerant	0.223	0.041	103	0.132	0.039	76	-1.611	0.224	0.048	76	0.016

Table B-33 Means and standard errors for individual metrics, and standardized differences for benthic invertebrates collected during summer sampling at the LEC in 2017-2018.

Season	Gear	Type	Metric	Upstream Reference			Thermally Exposed				Downstream			
				Mean	Std Err	N	Mean	Std Err	N	Std Diff	Mean	Std Err	N	Std Diff
Summer	Hester-Dendy	Composition	Fraction EPT	0.309	0.005	9169	0.483	0.005	12049	26.23	0.231	0.007	3953	-9.443
			EPT Species	21	1	9169	22	1	12049	0.707	19	1	3953	-1.414
		Density	Mean Countt	546.1	195.54	23	687.7	271.02	24	0.424	246.14	40.486	22	-1.502
		Diversity	^{0}D	55	1.757	7900	56	2.784	11048	0.304	56	3.615	3085	0.249
			^{1}D	7.583	0.129	7900	6.915	0.089	11048	-4.258	7.814	0.23	3085	0.875
			^{2}D	3.93	0.066	7900	4.629	0.05	11048	8.443	3.595	0.106	3085	-2.681
			^{3}D	3.091	0.049	7900	4.068	0.044	11048	14.8	2.784	0.073	3085	-3.466
		Thermal Tolerance	Fraction EPT Intolerant	0.122	0.006	2834	0.055	0.003	5822	-9.802	0.221	0.014	912	6.577
	Ponar	Composition	Fraction EPT	0.291	0.008	3013	0.228	0.011	1389	-4.509	0.214	0.009	1913	-6.157
			EPT Species	9	1	3013	9	1	1389	0	9	1	1913	0.000
		Density	Mean Count	321.9	107.99	6	148.4	48.755	6	-1.464	204.38	46.634	6	-0.999
		Diversity	^{0}D	35	2.885	1513	27	1.76	705	-2.367	32	1.771	1318	-0.886
			^{1}D	8.66	0.272	1513	10.87	0.43	705	4.343	7.421	0.233	1318	-3.458
			^{2}D	5.361	0.188	1513	7.891	0.334	705	6.597	4.93	0.15	1318	-1.794
			^{3}D	4.396	0.168	1513	6.873	0.332	705	6.653	4.243	0.133	1318	-0.715
		Thermal Tolerance	Fraction EPT Intolerant	0.268	0.015	878	0.247	0.024	316	-0.737	0.262	0.022	409	-0.227

Table B-34 Means and standard errors for individual metrics, and standardized differences for benthic invertebrates collected during fall sampling at the LEC in 2017-2018.

Season	Gear	Type	Metric	Upstream Reference			Thermally Exposed				Downstream			
				Mean	Std Err	N	Mean	Std Err	N	Std Diff	Mean	Std Err	N	Std Diff
Fall	Hester-Dendy	Composition	Fraction EPT	0.966	0.006	986	0.931	0.007	1476	-3.993	0.913	0.009	940	-4.883
			EPT Species	17	1	986	19	1	1476	1.414	16	1	940	-0.707
		Density	Mean Countt	56.279	15.192	24	84.25	16.836	24	1.233	55.986	8.522	23	-0.017
		Diversity	^{0}D	33	3.427	788	39	2.693	1281	1.377	35	2.992	835	0.440
			^{1}D	4.926	0.247	788	6.065	0.236	1281	3.336	6.221	0.308	835	3.283
			^{2}D	3.288	0.109	788	3.906	0.109	1281	3.991	3.895	0.138	835	3.442
			^{3}D	2.968	0.095	788	3.492	0.091	1281	3.988	3.48	0.111	835	3.508
		Thermal Tolerance	Fraction EPT Intolerant	0.102	0.01	952	0.11	0.008	1374	0.618	0.118	0.011	858	1.085
	Ponar	Composition	Fraction EPT	0.071	0.005	2575	0.091	0.007	1475	2.213	0.099	0.008	1541	3.064
			EPT Species	7	1	2575	7	1	1475	0	9	1	1541	1.414
		Density	Mean Count	275.11	63.998	6	157.6	45.557	6	-1.496	164.64	39.814	6	-1.466
		Diversity	^{0}D	23	1.911	717	41	3.495	514	4.518	49	3.58	563	6.407
			^{1}D	5.613	0.27	717	10.39	0.601	514	7.257	11.03	0.75	563	6.795
			^{2}D	3.391	0.168	717	6.571	0.348	514	8.231	5.11	0.361	563	4.318
			^{3}D	2.814	0.143	717	5.625	0.303	514	8.385	3.841	0.262	563	3.444
		Thermal Tolerance	Fraction EPT Intolerant	0.579	0.036	183	0.619	0.042	134	0.719	0.434	0.04	152	-2.671

Table B-35 Sampling statistics for electrofishing sampling at LEC in 1980-1985, 1997-2002, and 2018-2018, by zone, habitat, and season. Only fish > 100 mm total length are included.

Zone	Habitat	Season	Survey	Number of Samples	Number of Fish	Biomass (Kg)	Mean N. Fish per 20 min	StdErr (Mean Mean N. Fish)	Mean Biomass (Kg per 20 min)	StdErr (Mean Biomass)
Upstream Reference	OLD	Winter	1980-1985	1	85	16.31	65.38		16.31	
			1997-2002	6	460	58.51	77.75	41.46	9.75	5.05
			2017-2018	6	95	109.23	15.48	5.74	18.21	7.73
		Spring	1980-1985	5	204	50.83	35.32	4.22	10.17	2.57
			1997-2002	6	229	271.6	33.02	6.72	45.27	9.77
			2017-2018	6	91	93.89	13.39	0.9	15.65	3.56
		Summer	1980-1985	6	188	70.72	23.74	6.21	11.79	5.58
			1997-2002	6	109	83.43	19.42	4.7	13.91	3.85
			2017-2018	6	64	50.48	9.27	2.41	8.41	3.24
		Fall	1980-1985	7	480	45.06	57.63	17.01	6.44	1.53
			1997-2002	5	120	97.38	28.1	10.29	19.48	8.65
			2017-2018	6	61	45.09	9.63	3.24	7.51	3.12
Discharge	DIS	Winter	1980-1985	1	36	14.13	32.73		14.13	
			1997-2002	6	454	430.49	76.32	10.06	71.75	13.21
			2017-2018	6	223	449.62	33.86	4.29	74.94	23.29
		Spring	1980-1985	5	277	112.97	55.45	15.69	22.59	5.15
			1997-2002	6	302	395.63	52.51	13.35	65.94	20.83
			2017-2018	6	129	235.88	19.43	3.67	39.31	12.46
		Summer	1980-1985	6	67	42.01	11.28	2.73	7	2.67
			1997-2002	6	113	133.11	18.83	5.34	22.19	4.81
			2017-2018	6	36	32	5.47	1.43	5.33	2.89
		Fall	1980-1985	7	456	176.4	64.3	29.52	25.2	10.63
			1997-2002	5	325	289.82	66.56	9.59	57.96	6.15
			2017-2018	6	127	418.39	19.47	4.67	69.73	20.58
Thermally Exposed	CXLD	Winter	1980-1985	1	25	8.35	20.83		8.35	
			1997-2002	6	90	90.75	15	4.2	15.12	2.02
			2017-2018	6	100	75.21	14.49	6.3	12.53	4.46
		Spring	1980-1985	5	237	52.65	47.4	15.09	10.53	1.92
			1997-2002	6	144	92.45	24	7.33	15.41	3.95
			2017-2018	6	82	95.18	12.09	1.7	15.86	3.82

Zone	Habitat	Season	Survey	Number of Samples	Number of Fish	Biomass (Kg)	Mean N. Fish per 20 min	StdErr (Mean Mean N. Fish)	Mean Biomass (Kg per 20 min)	StdErr (Mean Biomass)
Thermally Exposed	CXLD	Summer	1980-1985	6	136	61.68	22.67	7.64	10.28	4.94
			1997-2002	6	64	31.26	10.67	3.41	5.21	1.67
			2017-2018	6	54	56.14	8.01	1.8	9.36	3.14
		Fall	1980-1985	7	713	106.24	100.19	36.5	15.18	3.05
			1997-2002	5	48	73.09	9.6	3.23	14.62	2.37
			2017-2018	6	76	107.3	11.78	3.02	17.88	5.28
	OLD	Winter	1997-2002	6	106	136.96	17.54	3.32	22.83	6.95
			2017-2018	6	167	175.38	26.04	6.17	29.23	9.31
		Spring	1997-2002	6	136	163.26	22.52	7.24	27.21	4.47
			2017-2018	6	93	143.87	13.63	3.96	23.98	7.31
		Summer	1997-2002	6	114	117.25	20.24	5.45	19.54	4.59
			2017-2018	6	48	72.49	6.84	2.27	12.08	4.4
		Fall	1997-2002	5	123	180.42	24.04	3.87	36.08	6.87
			2017-2018	6	81	98.71	12.04	3.29	16.45	7.39

Table B-36 Diversity statistics of fish community in electrofishing sampling by zone and season during 1980-1985, 1997-2002, and 2017-2018 LEC studies based on numerical count and total biomass. Only fish > 100 mm total length are included.

Zone	Habitat	Season	Survey	Number of Fish	$^{0}D_{Count}$	$^{0}D_{Count}$ Standard Deviation	$^{1}D_{Count}$	$^{1}D_{Count}$ Standard Deviation	$^{2}D_{Count}$	$^{2}D_{Count}$ Standard Deviation	$^{0}D_{weight}$	$^{1}D_{weight}$	$^{2}D_{weight}$
Upstream Reference	OLD	Winter	1980-1985	57	9	1.32	3.33	0.49	2.11	0.27	9	4.63	3.76
			1997-2002	397	14	1.99	1.96	0.14	1.34	0.05	14	6.41	5.02
			2017-2018	29	17	2.16	9.06	1.25	6.22	0.92	17	7.43	5.57
		Spring	1980-1985	102	17	2.68	5.83	0.68	3.42	0.36	17	7.74	6.03
			1997-2002	83	19	1.04	8.95	0.73	5.52	0.6	19	8.33	5.39
			2017-2018	14	16	1.77	11.62	1.11	10.09	0.94	16	8.65	7.3
		Summer	1980-1985	47	18	2.16	9.37	0.74	7.34	0.59	18	7.66	6.25
			1997-2002	36	10	0.81	6.1	0.57	4.58	0.51	10	5.01	3.08
			2017-2018	14	14	1.22	10.13	1.07	8.09	1.1	14	8.97	7.08
		Fall	1980-1985	308	20	1.4	4.08	0.26	2.3	0.13	20	7.38	4.63
			1997-2002	46	13	1.48	6.37	0.65	4.39	0.47	13	4.97	3.26
			2017-2018	18	17	1.4	11.49	1.36	7.74	1.44	17	10.61	9.25
	DIS	Winter	1980-1985	9	10	1.38	7.9	1.16	6.75	1.1	10	6.7	5.73
			1997-2002	203	21	1.64	7.24	0.45	4.17	0.31	21	8.32	5.65
			2017-2018	55	22	3.1	9.56	0.91	6.78	0.52	22	5.31	2.98
		Spring	1980-1985	136	16	1.34	6.26	0.51	3.62	0.34	16	6.09	4.09
			1997-2002	130	15	1.49	6.99	0.48	4.38	0.39	15	4.19	2.3
			2017-2018	26	16	1.25	9.72	0.84	7.45	0.7	16	8.16	4.97
		Summer	1980-1985	10	12	1.05	10.07	0.8	9.18	0.82	12	6.33	4.17
			1997-2002	45	12	1.54	6.42	0.71	4.51	0.59	12	3.69	2.35
			2017-2018	10	10	0.98	7.95	0.95	6.61	1.04	10	6.43	5.61
		Fall	1980-1985	199	21	2.03	7.88	0.52	4.43	0.36	21	10.76	7.36
			1997-2002	160	21	2.25	7.23	0.63	3.72	0.34	21	9.94	7.03
			2017-2018	67	16	1.48	5.89	0.75	3.21	0.42	16	3.1	1.82

Zone	Habitat	Season	Survey	Number of Fish	$^{0}D_{Count}$	$^{0}D_{Count}$ Standard Deviation	$^{1}D_{Count}$	$^{1}D_{Count}$ Standard Deviation	$^{2}D_{Count}$	$^{2}D_{Count}$ Standard Deviation	$^{0}D_{weight}$	$^{1}D_{weight}$	$^{2}D_{weight}$
Thermally Exposed	CXLD	Winter	1980-1985	6	6	0.73	5.38	0.59	5.08	0.61	6	3.87	3.09
			1997-2002	23	14	1.93	8.75	1.02	6.82	0.85	14	8.28	5.6
			2017-2018	37	15	1.87	7.22	0.91	4.85	0.63	15	7.33	5.39
		Spring	1980-1985	162	20	2.7	4.2	0.51	2.09	0.17	20	7.9	5.67
			1997-2002	46	19	1.73	9.8	0.96	6.46	0.77	19	8.34	5.84
			2017-2018	10	18	1.73	13.9	1.33	12.05	1.27	18	10.23	8.31
		Summer	1980-1985	60	17	2.49	6.81	0.92	4.06	0.52	17	6.2	4.09
			1997-2002	21	10	0.88	6.66	0.78	5.01	0.73	10	6.64	4.78
			2017-2018	10	13	1.55	10.04	1.21	8.63	1.12	13	8.05	6.87
		Fall	1980-1985	504	25	2.04	3.75	0.24	1.96	0.09	25	8.71	5.94
			1997-2002	10	10	0.88	8.13	0.72	7.16	0.75	10	5.06	3.93
			2017-2018	18	15	1.47	10.42	1.16	8.11	1.13	15	7.05	5.84
	OLD	Winter	1997-2002	27	14	1.31	8.92	0.83	6.98	0.75	14	5.66	3.79
			2017-2018	58	19	2.45	8.42	0.91	5.51	0.61	19	8.43	7.07
		Spring	1997-2002	36	12	1.79	6.91	0.62	5.78	0.44	12	5.05	3.83
			2017-2018	23	17	1.98	10.92	1.26	8.26	1.16	17	10	8.07
		Summer	1997-2002	35	13	2.08	7.28	0.8	5.66	0.63	13	5.57	4.33
			2017-2018	11	11	0.97	8.74	0.84	7.38	0.9	11	8.29	7.14
		Fall	1997-2002	28	14	1.62	7.52	0.71	6.04	0.5	14	5.31	3.88
			2017-2018	15	17	1.67	11.51	1.27	9.1	1.14	17	8.83	7.09

Table B-37 Fish community in electrofishing sampling by zone, season, habitat, and type during 1980-1985, 1997-2002, and 2017-2018 LEC studies based on numerical count and total biomass. Only fish > 100 mm total length are included.

Zone	Habitat	Survey	Season	Number of Fish					Biomass (Kg)				
				Rough	Forage	Pan	Game	Special	Rough	Forage	Pan	Game	Special
Upstream Reference	OLD	1980-1985	Winter	77	5	1	2	0	15.04	0.752	0.39	0.132	0
			Spring	167	10	3	23	1	41.373	1.195	0.89	6.71	0.657
			Summer	140	15	2	31	0	55.957	0.934	0.162	13.667	0
			Fall	402	46	16	16	0	34.461	3.878	1.126	5.59	0
		1997-2002	Winter	444	13	2	1	0	55.475	2.531	0.142	0.365	0
			Spring	195	5	5	23	1	241.344	0.751	1.669	25.683	2.15
			Summer	97	0	5	7	0	72.026	0	2.647	8.757	0
			Fall	97	7	0	16	0	83.533	0.298	0	13.548	0
		2017-2018	Winter	69	8	1	17	0	80.797	0.289	0.48	27.665	0
			Spring	65	3	2	21	0	73.442	0.171	0.386	19.89	0
			Summer	48	6	0	9	1	43.082	0.409	0	6.009	0.98
			Fall	47	6	1	6	1	37.894	0.231	0.076	6.397	0.49
Discharge	DIS	1980-1985	Winter	14	17	2	3	0	9.852	0.755	0.456	3.064	0
			Spring	233	27	4	12	1	99.714	2.654	0.783	9.473	0.345
			Summer	42	4	0	21	0	30.323	0.668	0	11.021	0
			Fall	344	61	24	27	0	113.717	7.804	5.435	49.443	0
		1997-2002	Winter	365	37	16	36	0	216.668	5.461	6.509	201.853	0
			Spring	247	1	7	45	2	330.465	0.051	2.046	58.814	4.25
			Summer	99	1	0	13	0	127.116	0.088	0	5.908	0
			Fall	256	18	17	34	0	191.872	2.913	7.265	87.77	0
		2017-2018	Winter	135	6	1	80	1	167.3787	1.529	0.02	280.258	0.43
			Spring	94	0	1	33	1	101.602	0	0.068	119.946	14.262
			Summer	16	4	0	16	0	23.029	0.177	0	8.789	0
			Fall	49	1	0	77	0	81.004	0.02	0	337.364	0

Zone	Habitat	Survey	Season	Number of Fish					Biomass (Kg)				
				Rough	Forage	Pan	Game	Special	Rough	Forage	Pan	Game	Special
Thermally Exposed	CXLD	1980-1985	Winter	18	3	0	4	0	6.144	0.176	0	2.025	0
			Spring	205	9	10	13	0	43.14	0.565	1.316	7.633	0
			Summer	88	2	5	41	0	27.609	0.058	0.892	33.119	0
			Fall	643	17	31	21	1	79.832	1.971	3.941	17.892	2.6
		1997-2002	Winter	64	18	1	7	0	68.528	2.206	0.533	19.478	0
			Spring	115	4	4	21	0	78.678	0.728	1.229	11.811	0
			Summer	40	0	0	24	0	27.489	0	0	3.768	0
			Fall	36	6	1	5	0	64.276	2.074	0.069	6.675	0
		2017-2018	Winter	90	4	0	6	0	70.7296	0.465	0	4.0136	0
			Spring	64	0	2	15	1	84.489	0	0.278	9.875	0.54
			Summer	43	0	1	10	0	49.365	0	0.0233	6.7548	0
			Fall	56	5	0	14	1	84.003	0.167	0	22.383	0.75
	OLD	1997-2002	Winter	74	5	0	27	0	65.188	0.486	0	71.289	0
			Spring	88	0	1	47	0	77.158	0	0.225	85.88	0
			Summer	51	0	1	62	0	27.344	0	0.033	89.875	0
			Fall	75	1	3	44	0	91.525	0.162	0.585	88.147	0
		2017-2018	Winter	141	6	2	18	0	149.7344	0.722	0.489	24.435	0
			Spring	81	0	1	11	0	125.385	0	0.323	18.157	0
			Summer	36	2	0	10	0	52.354	0.044	0	20.092	0
			Fall	63	4	1	13	0	82.537	0.063	0.02	16.085	0

Table B-38 Heat tolerance of fish community in electrofishing sampling by zone, season, and habitat during 1980-1985, 1997-2002, and 2017-2018 LEC studies based on numerical count and total biomass. Only fish > 100 mm total length are included.

Zone	Habitat	Survey	Season	Number of Fish			Biomass (Kg)		
				Intolerant	Neutral	Tolerant	Intolerant	Neutral	Tolerant
Upstream Reference	OLD	1980-1985	Winter	6	7	72	1.142	3.48	11.692
			Spring	10	55	139	1.196	23.098	26.531
			Summer	15	42	131	1.713	16.737	52.27
			Fall	51	81	348	4.635	12.777	27.643
		1997-2002	Winter	12	23	425	2.451	13.694	42.368
			Spring	6	59	164	0.842	98.228	172.527
			Summer	0	46	63	0	57.728	25.702
			Fall	4	41	75	0.154	65.792	31.433
		2017-2018	Winter	11	51	33	2.007	82.993	24.231
			Spring	2	31	58	0.343	46.957	46.589
			Summer	5	18	41	0.198	26.179	24.103
			Fall	6	28	27	0.231	21.439	23.418
Discharge	DIS	1980-1985	Winter	8	18	10	0.584	8.906	4.637
			Spring	16	68	193	1.988	59.215	51.766
			Summer	4	26	37	0.668	28.691	12.653
			Fall	47	125	284	7.534	87.973	80.892
		1997-2002	Winter	36	96	322	5.363	251.609	173.519
			Spring	0	178	124	0	295.581	100.045
			Summer	1	61	51	0.088	96.177	36.847
			Fall	15	98	212	2.37	175.583	111.867
		2017-2018	Winter	6	110	107	1.5193	314.4014	133.695
			Spring	0	42	87	0	130.066	105.812
			Summer	4	8	24	0.177	12.718	19.1
			Fall	1	90	36	0.02	358.458	59.91

Zone	Habitat	Survey	Season	Number of Fish			Biomass (Kg)		
				Intolerant	Neutral	Tolerant	Intolerant	Neutral	Tolerant
Thermally Exposed	CXLD	1980-1985	Winter	7	5	13	2.201	0.897	5.247
			Spring	7	33	197	1.135	13.36	38.159
			Summer	3	41	92	0.34	38.238	23.1
			Fall	19	102	592	2.766	38.847	64.623
		1997-2002	Winter	18	39	33	2.206	61.219	27.32
			Spring	2	43	99	0.332	37.655	54.459
			Summer	0	6	58	0	6.745	24.512
			Fall	6	15	27	2.074	30.902	40.118
		2017-2018	Winter	5	32	63	0.5996	34.666	39.9426
			Spring	0	26	56	0	39.336	55.846
			Summer	0	16	38	0	26.8083	29.3348
			Fall	4	42	30	0.107	78.611	28.585
	OLD	1997-2002	Winter	5	49	52	0.486	103.704	32.773
			Spring	0	76	60	0	116.359	46.904
			Summer	1	52	61	0.18	59.835	57.237
			Fall	1	61	61	0.162	128.855	51.402
		2017-2018	Winter	6	38	123	0.722	64.4444	110.214
			Spring	1	27	65	0.323	62.43	81.112
			Summer	2	9	37	0.044	27.917	44.529
			Fall	4	26	51	0.063	60.145	38.497

Table B-39 Standardized differences of ecological metrics between survey 1 (1980-1985) and survey 3 (2017-2018) in Upstream Reference zone, OLD habitat.

Metric	Season	Mean value of metric in Survey 1	Standard Error of Metric	Number of Samples	Mean value of metric in Survey 3	Standard Error of Metric	Number of Samples	Difference of Metric Values	Pooled Standard Deviation	Standardized Difference
Abundance Count	Spring	35.32	4.22	5	13.39	0.90	6	-21.93	4.32	-5.08
	Summer	23.74	6.21	6	9.27	2.41	6	-14.47	6.66	-2.17
	Fall	57.63	17.01	7	9.63	3.24	6	-48.00	17.32	-2.77
Abundance (Kg)	Spring	10.17	2.57	5	15.65	3.56	6	5.48	4.39	1.25
	Summer	11.79	5.58	6	8.41	3.24	6	-3.38	6.45	-0.52
	Fall	6.44	1.53	7	7.51	3.12	6	1.07	3.48	0.31
Diversity ^{0}D	Winter	9	1.32	57	17.00	2.16	29	8.00	2.53	3.16
	Spring	17	2.68	102	16.00	1.77	14	-1.00	3.21	-0.31
	Summer	18	2.16	47	14.00	1.22	14	-4.00	2.48	-1.61
	Fall	20	1.40	308	17.00	1.40	18	-3.00	1.98	-1.52
Diversity ^{1}D	Winter	3.33	0.49	57	9.06	1.25	29	5.73	1.34	4.27
	Spring	5.83	0.68	102	11.62	1.11	14	5.79	1.30	4.45
	Summer	9.37	0.74	47	10.13	1.07	14	0.76	1.30	0.58
	Fall	4.08	0.26	308	11.49	1.36	18	7.41	1.39	5.35
Diversity ^{2}D	Winter	2.11	0.27	57	6.22	0.92	29	4.11	0.96	4.29
	Spring	3.42	0.36	102	10.09	0.94	14	6.67	1.01	6.63
	Summer	7.34	0.59	47	8.09	1.10	14	0.75	1.25	0.60
	Fall	2.30	0.13	308	7.74	1.44	18	5.44	1.45	3.76
Diversity ^{3}D	Winter	1.81	0.20	57	5.15	0.79	29	3.34	0.82	4.10
	Spring	2.77	0.27	102	9.38	0.94	14	6.61	0.98	6.76
	Summer	6.42	0.62	47	7.06	1.08	14	0.64	1.25	0.51
	Fall	1.94	0.09	308	5.90	1.32	18	3.96	1.32	2.99
	Winter	0.07	0.03	85	0.12	0.03	95	0.05	0.04	1.05

Metric	Season	Mean value of metric in Survey 1	Standard Error of Metric	Number of Samples	Mean value of metric in Survey 3	Standard Error of Metric	Number of Samples	Difference of Metric Values	Pooled Standard Deviation	Standardized Difference
Heat Intolerant Count	Spring	0.05	0.02	204	0.02	0.02	91	-0.03	0.02	-1.25
	Summer	0.08	0.02	188	0.08	0.03	64	0.00	0.04	-0.04
	Fall	0.11	0.01	480	0.10	0.04	61	-0.01	0.04	-0.19
Heat Intolerant (Kg)	Winter	0.07	0.03	85	0.02	0.01	95	-0.05	0.03	-1.67
	Spring	0.02	0.01	204	0.00	0.01	91	-0.02	0.02	-1.34
	Summer	0.02	0.01	188	0.00	0.01	64	-0.02	0.02	-1.21
	Fall	0.10	0.01	480	0.01	0.01	61	-0.10	0.02	-5.19
Heat Tolerant Count	Winter	0.85	0.04	85	0.35	0.05	95	0.50	0.06	7.99
	Spring	0.68	0.03	204	0.64	0.05	91	0.04	0.06	0.73
	Summer	0.70	0.03	188	0.64	0.06	64	0.06	0.07	0.82
	Fall	0.73	0.02	480	0.44	0.06	61	0.28	0.07	4.23
Heat Tolerant (Kg)	Winter	0.72	0.05	85	0.22	0.04	95	0.50	0.07	7.63
	Spring	0.52	0.04	204	0.50	0.05	91	0.03	0.06	0.41
	Summer	0.74	0.03	188	0.48	0.06	64	0.26	0.07	3.73
	Fall	0.61	0.02	480	0.52	0.06	61	0.09	0.07	1.39
Non-Rough Count	Winter	0.13	0.04	85	0.34	0.05	95	0.21	0.06	3.42
	Spring	0.19	0.03	204	0.37	0.05	91	0.19	0.06	3.25
	Summer	0.26	0.03	188	0.30	0.06	64	0.04	0.07	0.55
	Fall	0.17	0.02	480	0.33	0.06	61	0.16	0.06	2.58
Non-Rough (Kg)	Winter	0.13	0.04	85	0.39	0.05	95	0.26	0.06	4.16
	Spring	0.19	0.03	204	0.39	0.05	91	0.20	0.06	3.39
	Summer	0.22	0.03	188	0.20	0.05	64	-0.03	0.06	-0.50
	Fall	0.24	0.02	480	0.52	0.06	61	0.29	0.07	4.29

Table B-40 Standardized differences of ecological metrics between survey 1 (1980-1985) and survey 3 (2017-2018) in Thermally Exposed zone, CXLD habitat.

Metric	Season	Mean value of metric in Survey 1	Standard Error of Metric	Number of Samples	Mean value of metric in Survey 3	Standard Error of Metric	Number of Samples	Difference of Metric Values	Pooled Standard Deviation	Standardized Difference
Abundance Count	Spring	47.40	15.09	5	12.09	1.70	6	-35.31	15.19	-2.33
	Summer	22.67	7.64	6	8.01	1.80	6	-14.66	7.85	-1.87
	Fall	100.19	36.50	7	11.78	3.02	6	-88.41	36.63	-2.41
Abundance (Kg)	Spring	10.53	1.92	5	15.86	3.82	6	5.33	4.28	1.25
	Summer	10.28	4.94	6	9.36	3.14	6	-0.92	5.85	-0.16
	Fall	15.18	3.05	7	17.88	5.28	6	2.70	6.10	0.44
Diversity ^{0}D	Winter	6	0.73	6	15.00	1.87	37	9.00	2.01	4.48
	Spring	20	2.70	162	18.00	1.73	10	-2.00	3.21	-0.62
	Summer	17	2.49	60	13.00	1.55	10	-4.00	2.93	-1.36
	Fall	25	2.04	504	15.00	1.47	18	-10.00	2.51	-3.98
Diversity ^{1}D	Winter	5.38	0.59	6	7.22	0.91	37	1.84	1.09	1.70
	Spring	4.20	0.51	162	13.90	1.33	10	9.70	1.42	6.81
	Summer	6.81	0.92	60	10.04	1.21	10	3.23	1.52	2.13
	Fall	3.75	0.24	504	10.42	1.16	18	6.67	1.19	5.63
Diversity ^{2}D	Winter	5.08	0.61	6	4.85	0.63	37	-0.23	0.88	-0.26
	Spring	2.09	0.17	162	12.05	1.27	10	9.96	1.28	7.77
	Summer	4.06	0.52	60	8.63	1.12	10	4.57	1.24	3.70
	Fall	1.96	0.09	504	8.11	1.13	18	6.15	1.13	5.43
Diversity ^{3}D	Winter	4.91	0.62	6	4.03	0.54	37	-0.88	0.82	-1.07
	Spring	1.77	0.12	162	11.11	1.28	10	9.34	1.29	7.27
	Summer	3.27	0.40	60	7.90	1.09	10	4.63	1.16	3.99
	Fall	1.68	0.06	504	6.92	1.08	18	5.24	1.08	4.84
	Winter	0.28	0.09	25	0.05	0.02	100	-0.23	0.09	-2.49

Metric	Season	Mean value of metric in Survey 1	Standard Error of Metric	Number of Samples	Mean value of metric in Survey 3	Standard Error of Metric	Number of Samples	Difference of Metric Values	Pooled Standard Deviation	Standardized Difference
Heat Intolerant Count	Spring	0.03	0.01	237	0.00	0.01	82	-0.03	0.02	-1.90
	Summer	0.02	0.01	136	0.00	0.01	54	-0.02	0.02	-1.19
	Fall	0.03	0.01	713	0.05	0.03	76	0.03	0.03	0.99
Heat Intolerant (Kg)	Winter	0.26	0.09	25	0.01	0.01	100	-0.26	0.09	-2.88
	Spring	0.02	0.01	237	0.00	0.01	82	-0.02	0.01	-1.49
	Summer	0.01	0.01	136	0.00	0.01	54	-0.01	0.02	-0.34
	Fall	0.03	0.01	713	0.00	0.01	76	-0.03	0.01	-1.94
Heat Tolerant Count	Winter	0.52	0.10	25	0.63	0.05	100	-0.11	0.11	-0.99
	Spring	0.83	0.02	237	0.68	0.05	82	0.15	0.06	2.61
	Summer	0.68	0.04	136	0.70	0.06	54	-0.03	0.07	-0.37
	Fall	0.83	0.01	713	0.40	0.06	76	0.44	0.06	7.54
Heat Tolerant (Kg)	Winter	0.63	0.10	25	0.53	0.05	100	0.10	0.11	0.90
	Spring	0.73	0.03	237	0.59	0.05	82	0.14	0.06	2.24
	Summer	0.38	0.04	136	0.52	0.07	54	-0.15	0.08	-1.86
	Fall	0.61	0.02	713	0.27	0.05	76	0.34	0.05	6.34
Non-Rough Count	Winter	0.32	0.09	25	0.18	0.04	100	-0.14	0.10	-1.39
	Spring	0.16	0.02	237	0.34	0.05	82	0.19	0.06	3.23
	Summer	0.37	0.04	136	0.28	0.06	54	-0.09	0.07	-1.22
	Fall	0.11	0.01	713	0.34	0.05	76	0.24	0.06	4.23
Non-Rough (Kg)	Winter	0.29	0.09	25	0.36	0.05	100	0.07	0.10	0.68
	Spring	0.26	0.03	237	0.33	0.05	82	0.07	0.06	1.16
	Summer	0.58	0.04	136	0.34	0.07	54	-0.24	0.08	-3.05
	Fall	0.27	0.02	713	0.35	0.06	76	0.08	0.06	1.46

B.2 DERIVATION OF HEAT SENSITIVE FISH SPECIES

Heat tolerance data available in the literature from laboratory tests were used to categorize heat sensitive or intolerant species versus more heat tolerant species for several fish species that reside in the lower Missouri River. Although heat tolerance data are limited for some of these species (and nonexistent for several other species), the existing data were used to differentiate species less tolerant of the naturally high ambient temperatures in the river, according to the laboratory testing results. Temperatures greater than approximately 90-91°F (adjusted to 93-94°F as appearing in Table B-54) were used to differentiate heat tolerant fish species from more heat sensitive species.

The Table B-54 and Table B-55 present the tolerance limits for species of adult or juvenile fish commonly found in the vicinity of the LEC and the literature sources from which they originated. These data represent the temperatures at which acute mortality (typically for 50 percent of the test subjects when held for 24 or 48 hours) or active avoidance can occur. Test results were selected for the highest acclimation temperature available from the testing to best represent the actual ambient temperature to which the fish would be acclimated in the river.

The lab testing results are considered to be conservative in that the tests were conducted under controlled laboratory conditions, usually under temperature held constant for 24-48 hours or more, rather than under diel or spatial temperature fluctuations typically occurring in the river. Tests usually were conducted with fish specimens from locales other than the river, thus the test fish were not subjected to the lower Missouri River's thermal regime to which they could be adapted. Evidence is provided by collections of species from temperatures in the wild exceeding the supposed maximum temperature tolerated under lab conditions, such as documented in the Ohio River (EPRI 2013).

Table B-41 Upper temperature tolerance values (°F) at high acclimation temperature—adult & juvenile heat shock

Species	Value	Acclimation	Parameter	Comments	Source(s)
Pallid sturgeon	91.4, 95 92.1-95.9	82.4 75.2	CTM17%, CTM100% LTM(CTM)	Small sample size (6 fish) 20-203 mm fish	Chipps et al. 2010 Deslaurieres et al. 2016
Bighead carp	96.1	86.0	UILT50	103-134 mm fish	Sheng and Xu 2008
Silver carp	98.8	86.0	UILT50	103-134 mm fish	Sheng and Xu 2008
Gizzard shad	96.8 97.7	80.6-86 95.0	UILT50 24 h TL50	Ohio River Knoxville , TN	Yoder and Emery 2003 Hart 1952
Walleye	93.4 94.6 88.9	78.8-82.1 73.4 78.4	UUILT CTM UILT	Slow heating <1C/day Mean CTM for Iowa fish	Hokanson and Koenst 1986 Peterson 1993 Smith and Koenst 1975
Sauger	86.7	75.0	UILT50		Smith and Koenst 1975
Channel catfish	100.0 107.8	86.0 95	UILT CTM	Texas	Allen and Strawn 1967 Bennett, McCauley, and Beitinger 1998
Emerald shiner	100.1 95.4	77.0 66.2-77.0	CTM 7-day TL50 and UUILT	St. Louis Bay, L. Superior	Matthews and Maness 1979 McCormick and Kleiner 1976
White crappie	91.4 91.0	84.2 75.9	UILT >96 h TL50	Lake Erie	Brungs and Jones 1977 Reutter and Herdendorf 1976
Shorthead redhorse	95.2 91.9	69.1-74.8 69.1-74.8	CTM mean UUILT	Muskingham R. Ohio Muskingham R. Ohio	Reash 2000 et al. Reash 2000 et al.
River carpsucker	95.4 102.2	N/A 80.6-86.0	UILT UILT	Does not cite original source Ohio R.	Hasnian 2012 Yoder and Emery 2003
Freshwater drum	93.2 91.0	N/A 82.4-95.0	CTM UILT	Lake Erie Same UILT as Jinks 1981	Reutter and Herdendorf 1976 Houston 1982
Mooneye	90.7	80.6-86.0	UILT	Ohio R.	Yoder and Emery 2003
Goldeye	90.7	80.6-86.0	UILT	Ohio R.	Yoder and Emery 2003
Flathead catfish	100.0	80.6-86.0	UILT	Ohio R.	Yoder and Emery 2003
Longnose gar	100.9	80.6-86.0	UILT	Ohio R.	Yoder and Emery 2003
Shortnose gar	100.9	80.6-86.0	UILT	Ohio R.	Yoder and Emery 2003
Smallmouth buffalo	102.7	80.6-86.0	UILT	Ohio R.	Yoder and Emery 2003
Bigmouth buffalo	100.9	80.6-86.0	UILT	Ohio R.	Yoder and Emery 2003

Table B-42 Temperature tolerance values (°F) at high acclimation temperature—adult & juvenile avoidance

Species	Value	Acclimation	Parameter	Comments	Source(s)
Pallid sturgeon	N/A				
Bighead carp	94.1 91.4	86.0 77.0	Upper avoidance		Sheng and Xu 2008
Silver carp	96.8 91.6	86.0 77.0	Upper avoidance		Sheng and Xu 2008
Gizzard shad	93.2 93.0-93.9	80.6-86.0 N/A	Upper avoidance	Ohio R.	Yoder and Emery 2003 Churchill and Wojtalik 1969
Walleye	69.8 84.2	N/A 80.6-86.0	Upper avoidance	WI lake fish Ohio R.	Inskip and Magnuson 1983 Yoder and Emery 2003
Sauger	82.4	N/A	Upper avoidance		Coutant 1977
Channel catfish	95.0 93.2	86.0 80.6	Upper avoidance		Cherry et al. 1977
Emerald shiner	107.6 88.0	N/A 80.6-86.0	Upper avoidance Upper avoidance		Ellis 1984 Yoder and Emery 2003
White crappie	87.8 89.6	N/A	Upper avoidance Upper avoidance	thermal effluent IN	Proffit and Benda 1971 Yoder and Emery 2003
Shorthead redhorse	78.8 80.2	N/A	Upper avoidance Final preferendum	Should be <preference No original source cited	Coutant 1977 Hasnian 2012
River carpsucker	96.6	80.6-86.0	Upper avoidance	Ohio River	Yoder and Emery 2003
Freshwater drum	86	N/A 80.6-86.0	Upper avoidance	Wabash River, IN	Coutant 1977 Yoder and Emery 2003
Mooneye	84.2	80.6-86.0	Upper avoidance	Ohio River	Yoder and Emery 2003
Goldeye	84.2	80.6-86.0	Upper avoidance	Ohio River	Yoder and Emery 2003
Flathead catfish	94.1	80.6-86.0	Upper avoidance	Ohio River	Yoder and Emery 2003
Longnose gar	95.0	80.6-86.0	Upper avoidance	Ohio River	Yoder and Emery 2003
Shortnose gar	95.0	80.6-86.0	Upper avoidance	Ohio River	Yoder and Emery 2003
Smallmouth buffalo	96.8	80.6-86.0	Upper avoidance	Ohio River	Yoder and Emery 2003
Bigmouth buffalo	95.0	80.6-86.0	Upper avoidance	Ohio River	Yoder and Emery 2003

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APPENDIX C
RIS PREDICTIVE EVALUATION METHODS

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C. PREDICTIVE EVALUATION DATA AND METHODS

This appendix discusses the types of biothermal data and their use in evaluating the potential for thermal impacts on the RIS. It also provides a reference list of literature sources from which biothermal data was obtained.

C.1 BIOTHERMAL RESPONSE MEASURES

Thorough review and evaluation of all reasonably available information from the literature provided biothermal data for the RIS. The biothermal data were used to quantify the following temperature responses of the RIS.

C.1.1. Survival of juveniles and adults

Aquatic organisms can adjust to the thermal environment physiologically, thereby shifting their tolerance range, but this acclimation has limits and ultimately a water temperature may be reached that would be lethal. The upper and lower lethal limits of thermal tolerance are defined as the temperature resulting in survival of 50 or 95 percent of the test organisms (TL50, TL95). The tolerance of organisms to extremes of temperature change is influenced by three factors: (1) their genetic ability to adapt to thermal changes within their characteristic temperature range; (2) the acclimation temperature prior to exposure to a change; and (3) the duration of exposure to the elevated temperature (Coutant 1972).

The upper incipient lethal temperature (UILT) can be defined as the highest temperature at which 50 percent (TL50) of a sample of organisms can survive long-term exposure (24 hours to one week) and is determined for each organism at the highest sustainable acclimation temperature. The lowest temperature at which 50 percent (TL50) of the warm acclimated organisms can survive long-term exposure is the lower incipient lethal temperature (LILT). UUILT is the ultimate upper temperature limit if gradual acclimation is allowed to continue (Fry et al. 1946).

C.1.2. Heat shock and cold shock

Immobilization or death resulting from sudden increases or decreases in water temperature beyond an organism's upper or lower tolerance limit is often referred to as "heat shock" or "cold shock", respectively. Short-term limits of tolerance to heat shock are estimated by TL95s or TL50s for exposures of seconds to a few hours. Tolerance to short-term (seconds to hours) exposures to temperature changes also depends on the acclimation temperature (Lauer et al. 1974; EA 1978; IA 1978; Greges and Schubel 1979). A sample of organisms acclimated to low temperatures typically can tolerate larger increases in temperature than a sample of the same organisms acclimated to temperatures near the high end of their range of tolerance (Lauer et al. 1974). "Cold-shock" relates to a sudden, sustained decrease in the temperature environment and is estimated by 24-hr or longer TL95s and TL50s.

C.1.3. Avoidance

In the case of mobile species, organisms may adjust to their thermal environment behaviorally by movement along existing temperature gradients. When exposed to a temperature gradient, unconfined, free-swimming juvenile and adult fish and other mobile organisms avoid stressful high temperature by moving through the gradient to water having lower temperatures (Meldrim et al. 1974; Neill and Magnuson 1974; TI 1976; EA 1978). Avoidance will typically occur as

water temperature exceeds the species' preferred temperature by more than 3.6–9.0°F. Temperatures eliciting this avoidance response are called "avoidance temperatures" and are determined in the laboratory by observation of the positions of organisms maintained in a gradient of temperatures. Avoidance temperature is dependent on the temperature of prior acclimation; the temperature eliciting an avoidance response will generally increase as the acclimation temperatures increases, up to limits imposed by the UUILT.

C.1.4. Spawning and early development

The spawning temperature range is one measure of the suitability of the thermal environment for spawning and early development. The act of spawning may be relatively instantaneous for any individual and may coincide with a relatively narrow range of water temperatures. However, the conditioning that precedes the event and assures that mature individuals are at the appropriate stage of reproductive development when spawning temperatures occur can be a period of weeks or months (Hoar 1969; Hokanson 1977; Jones et al. 1976). Thus, reproductive condition in fish may represent a biological response to the range and average of environmental factors experienced during an extended period. Temperature is only one factor in a complex interrelationship of conditions conducive to spawning. These factors interact to assure that the time of spawning usually coincides with conditions (e.g., temperatures, food availability, salinity) conducive to development and survival of embryo and larval stages. The upper tolerance limits for hatching of eggs and for survival of larvae are also measures of the suitability of the thermal environment for spawning and early development of the RIS.

C.1.5. Optimum temperature for physiological performance

Within the range of thermal tolerance, there are temperature optima for metabolism controlling essential functions like growth and reproduction. Species are adapted to a range of temperatures in their environment over which they function at close to maximum physiological performance. As water temperatures increase above or below this range, physiological performance degrades.

The most sensitive indicator of the optimum temperature for performance is growth rate (Coutant 1972), and most of the thermal effects data on physiological functions reported in the literature are for growth. The optimum range for growth is defined as the range of temperature at which growth is not significantly different from the temperature supporting maximum growth. The maximum value in a species' temperature range for optimal growth typically coincides with the organism's final temperature preference (Brett 1971; Coutant 1975) and is often within 5.0-9.0°F of its maximum temperature tolerance for survival.

C.2 EVALUATION OF BIOTHERMAL RESPONSE

Sources of the biothermal response data used in the predictive RIS biothermal assessment are identified in the graphical analyses (thermal effect diagrams) presented in Section 6. The application of these data to the biothermal impact assessment is discussed below.

C.2.1. Thermal Shock Tolerance (Plume Entrainment)

The potential for mortality of planktonic organisms and life-stages during plume entrainment (heat shock) was predicted based on laboratory-determined TL50s for exposure durations ranging from 1 minute to 2 hours. Safe-temperature limits were calculated from TL50 data by subtracting 3.6°F. Although the 50 percent mortality endpoint is statistically the most precise measure of thermal tolerance, the use of safe-temperature estimates provides a higher level of

protection for assessing the potential for acute effects. It has been shown for long term exposures (24 hours or more) that a 3.6°F safety factor is sufficient to adjust TL50 temperatures to temperatures at which essentially no mortality would occur (NAS/NAE 1973).

Safe-temperature limits were expressed as ΔT and compared graphically to ΔT exposures that could be experienced by a planktonic organism drifting through the LEC's thermal plume. The potential for mortality from excess temperature exposure was conservatively evaluated by comparing the safe-ΔT limits to the ΔTs experienced by an organism passing through the thermal plume. Sources of heat shock temperatures for the RIS are provided in Table B-1.

C.2.2. Mortality from Cold Shock

Thermal mortality can occur by cold shock, where aquatic organisms residing in elevated temperatures within the thermal plume are subject to temperatures below their thermal tolerance limits in the event of a plant shutdown. Cold shocks have the potential to cause mortality if the change in temperature exceeds the tolerance of the species.

The extent of the thermal impact due to cold shock depends on the magnitude and rate of the decrease in the discharge temperature as well as the actual discharge temperature at the time of the outage. The potential for cold shock was addressed using cold-shock data (24-hr to 96-hr TL50s or LILT) on each species as available. These lower temperature tolerance data were graphically compared to the maximum temperature drops that would occur in the event that the LEC was to suddenly shutdown. The thermal impact diagram used to make this comparison is explained in Section C.2.6. Sources of cold shock temperatures for the RIS are provided in Table C-1.

Table C-1 Literature Source and Assigned Codes for Thermal Response Data Used in the Biothermal Assessment

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C.2.3. Upper Avoidance Temperatures

Avoidance temperatures were used to define areas of a thermal plume that potentially may be temporarily excluded as a zone of passage because of elevated temperatures. Avoidance temperatures were also used as a conservative estimate of the potential for the plume to exclude habitat from long-term occupation.

Avoidance temperatures are typically derived in a laboratory where observations are made on fish behavior in a thermal gradient. Most of the avoidance temperature data reported in the literature are measured during a relatively short exposure interval (e.g., 1-4 hours) and consequently are dependent upon acclimation temperature in the same manner as the UILT. Exclusion areas or restricted zones of passage based on these acute avoidance temperatures are best interpreted as temporary conditions since fish in a natural setting eventually would be able to acclimate to higher temperatures and thus be able to utilize portions of the “excluded” area. A more relevant avoidance parameter would be a chronic, or long-term upper avoidance temperature, but data on this parameter are rarely available. As a substitute for a chronic upper avoidance temperature, avoidance temperatures determined at high acclimation temperatures are often used. This chronic avoidance temperature generally would be expected to approach the UUILT for a species. Therefore, use of acute avoidance temperatures to evaluate the potential for habitat exclusion and blockage of fish movements is very protectively conservative.

The temperature elevation that elicits an avoidance response (i.e., avoidance temperature) depends on the temperature to which the organism is physiologically acclimated as it encounters a temperature gradient. Sources of upper avoidance temperatures for the RIS are provided in Table C-1.

Estimation of exclusion areas based on avoidance temperatures might suggest that the actual presence or absence of fish could be predicted. However, the actual presence or absence of organisms in a thermally altered area also is influenced by non-thermal factors, such as availability of food, cover, velocities, and substrate type. These non-thermal factors can override the temperature-avoidance response, thereby optimizing the overall survival of the organism (Brett 1971; Coutant 1970, 1975; Reynolds 1977, Spaulding 2014).

C.2.4. Optimum Temperatures for Growth

The optimum temperature and the upper end of the optimum temperature range for growth were used to evaluate the potential for the thermal plume to reduce growth of the RIS. These two measures of growth response to temperature are illustrated in the growth rate curve for striped bass post yolk-sac larvae and juveniles (EA 1978, Figure C-1). Maximum growth took place at 81.1 °F, while growth at 77.2 °F and 85.3 °F was not significantly less than at 81.1 °F. Thus, the range of temperatures for optimal growth is determined to be 77.2-85.3 °F, and the optimum temperature for growth in this example is the same as the upper end of the optimum range for growth, namely 85.3 °F. It is also apparent from the figure (Figure C-1) that growth continues at a high rate to a temperature of about 90 °F.

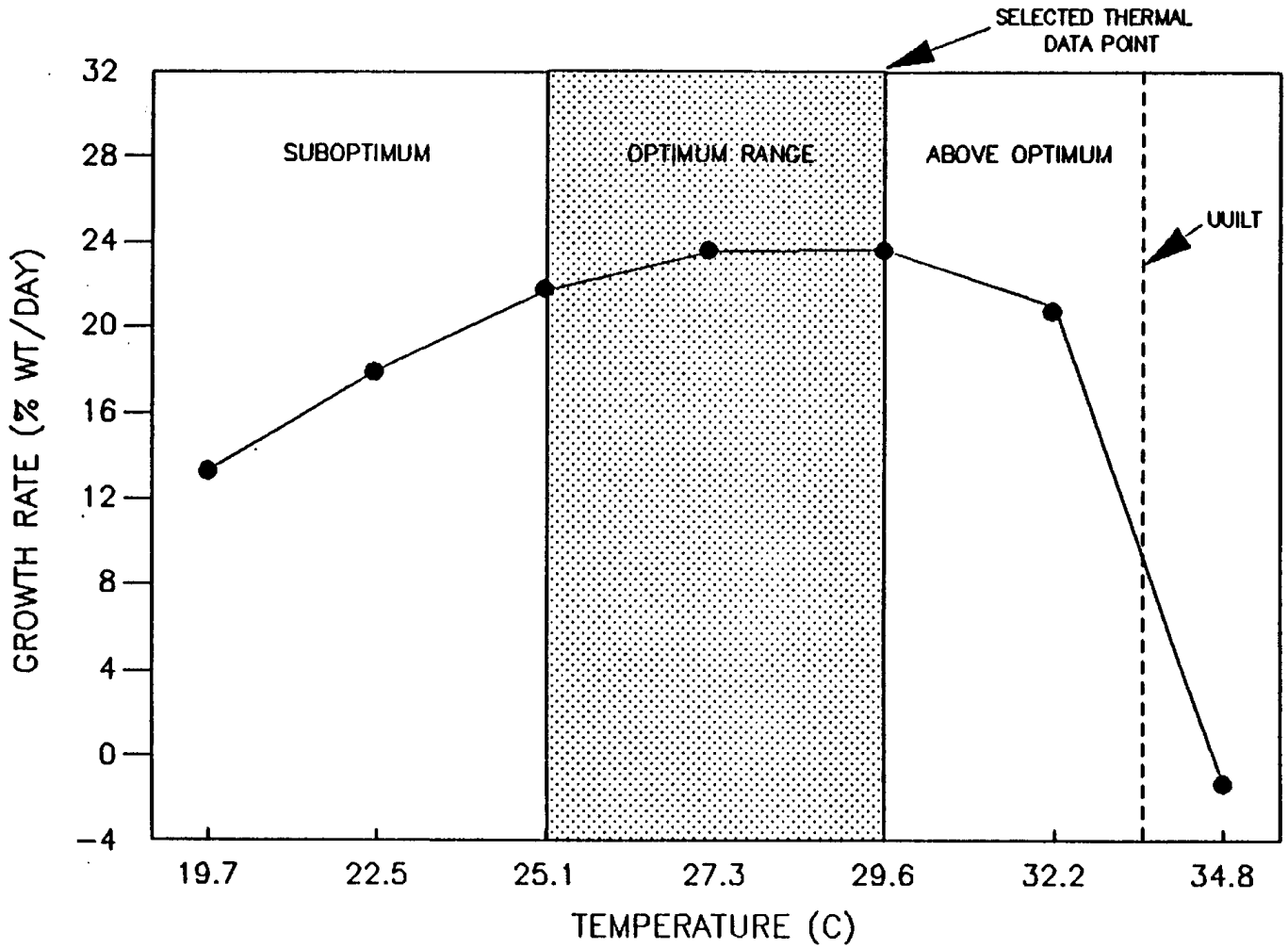


Figure C-1 Example of relationship among water temperature, growth, the optimum range for growth, and thermal tolerance (UUILT) for striped bass (adapted from EA 1978).

Thus, the upper limit of the temperature range optimal for growth was used whenever possible to estimate the maximum temperature permitting optimum or near-optimum growth. Extended exposure to temperatures above this limit (but below UUILT) do not necessarily contribute to thermal mortality or prohibit growth, but are higher than documented for optimal growth. Other factors being equal, plume temperatures above the upper limit of the optimum temperature range for growth would therefore reduce growth rate. Comparable estimates of this limiting growth temperature are the maximum weekly average temperatures (MWAT) for growth derived by Brungs and Jones (1977) (one-third of the range between a species' optimum growth temperature and its UUILT). The MWAT was used to define the maximum plume temperature allowing optimum growth and performance if the upper temperature limit of the optimal range for growth was not reported in the literature.

When plume temperatures are equal to, or less than, the optimum temperature for growth, they are more favorable for growth than are ambient temperatures. Other factors being equal, plume temperatures below the optimum temperature for growth would increase growth rate relative to ambient temperature. The optimum growth temperature was therefore used to estimate the maximum plume temperature resulting in enhancement of growth rates.

When data on optimum temperatures were not available, final thermal preferenda (preferred temperatures) were used as an estimate of the optimum temperature. The final preferendum is generally accepted as an estimator of the optimum temperature for growth (Brett 1971; Coutant 1975).

Growth response parameters are applicable for prolonged exposures (e.g., several days or weeks), and thus, is not relevant for estimating effects from short-term plume exposures. Furthermore, temperatures in excess of the upper limits of the optimum temperature range for growth would not necessarily exclude fish from an area, but merely indicate that growth and other physiological functions may not be functioning optimally. As noted by the NAS/NAE (1972), "optimum temperatures (such as those producing fastest growth rates) are not generally necessary at all times to maintain thriving populations and are often exceeded in nature during summer months." Although laboratory evidence indicates that fish tend to respond predictably to temperature, factors such as habitat type, food availability, and others can influence the thermal distribution of a fish species in the field (Reynolds 1977). Sources of optimal growth temperatures for the RIS are provided in Table C-1.

C.2.5. Spawning and Early Development

Temperature requirements for early development were used to define zones of the thermal plume that may have been suitable habitat for spawning and early development but may not be available for these activities because of the change in temperatures. The life stages addressed (when appropriate thermal effect data are available) are eggs, larvae, and early juveniles. The principal thermal response parameters are:

- successful spawning temperature range;
- upper end of the optimum temperature range for egg hatch; and
- thermal tolerance limits for larvae and early juveniles.

The upper limit of the optimum temperature range for hatch was used, whenever available, to identify areas of the thermal plume that may be unfavorable for egg incubation because of temperature. The maximum temperature for embryo survival also was used for this purpose

when available. These thermal response parameters usually are determined from laboratory studies on hatching success. When this type of data was not available for a species, the upper limit of the temperature range for successful spawning was used to identify areas of the plume that may be unfavorable for spawning.

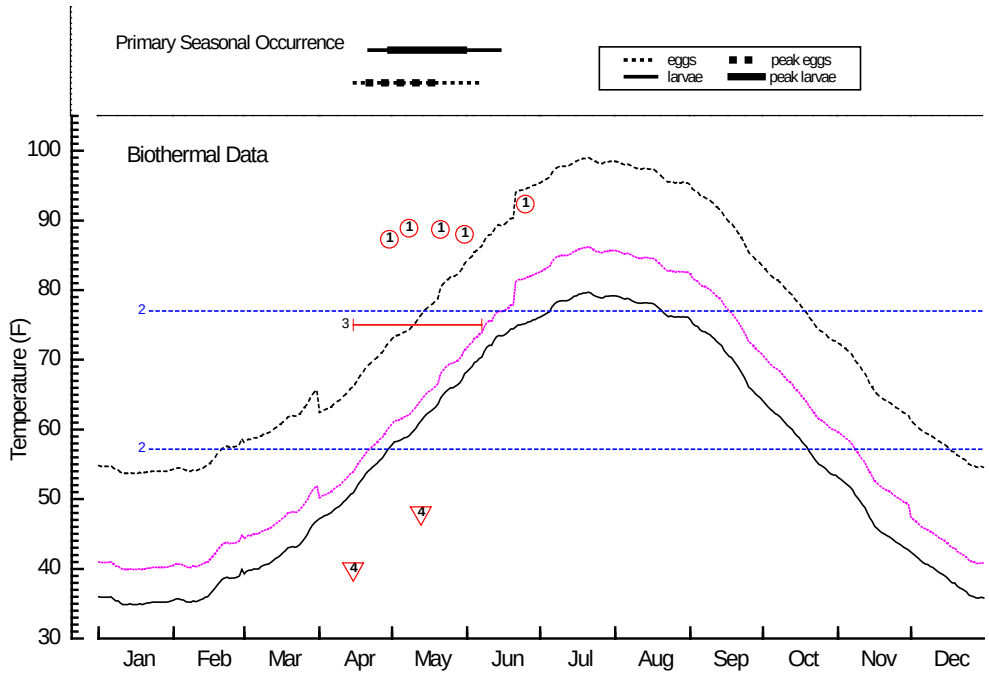
Tolerance limits, determined in the laboratory for larvae and early juveniles, were used to identify areas of the thermal plume that are potentially unsuitable as nursery areas. TL50s (24-hr to 96-hr), the UUILT and UILT were used.

Laboratory determined incipient-lethal temperatures are based on fairly rapid (sometimes instantaneous) temperature increases and are conditional on the acclimation state of the fish (i.e., the temperature at which the fish's physiological and biochemical functions are equilibrated). If given the opportunity to acclimate slowly to higher temperatures (a condition that usually exists in the natural setting), young fish would be able to utilize warmer zones within the thermal plume than would be predicted on the basis of incipient-lethal temperatures alone. The ultimate incipient-lethal temperature is not constrained by acclimation temperature, and, although rarely available for early life stages, is therefore a better indicator of the long-term thermal suitability of the plume as nursery habitat. Sources of optimal temperatures for spawning and development for the RIS are provided in Table C-1.

C.2.6. Thermal Effects Diagrams and Effects Frequency Diagrams

Thermal effect diagrams were used to compare biothermal response data for cold-shock and spawning/early development to plume temperatures at the edge of the zone of initial mixing throughout the year. A hypothetical example and explanation of the basic elements of a thermal effect diagram is shown in Figure C-2 Thermal effect diagrams were constructed for each of the RIS by plotting biothermal response data in relation to the prevailing acclimation temperature of the organisms (i.e., ambient temperatures in the case spawning/early development and plume temperatures in the case of cold shock). However, for predicted effects to be meaningful, they must be considered in light of the occurrence and distribution of each selected species or life stage within the vicinity of the plume. For example, if a life stage is not in the vicinity of the LEC when plume temperatures exceed its thermal requirements, then in reality no effect is possible.

The thermal effect diagrams were used primarily to identify the likelihood of cold-shock or reduced reproductive success for each of the RIS, as well as the periods of time when the potential effect might occur. The temperature profile, thermal response, and seasonal occurrence elements included in the thermal effect diagrams are illustrated in the hypothetical example shown in Figure C-2.



The thermal impact diagram was used to graphically examine the potential for cold-shock and effects on reproduction.

Hydrothermal Parameters

The temperature profile consists of curves for ambient temperature and approximate maximum temperature in the discharge channel (for cold-shock) or at the edge of the zone of initial dilution (ZID)(for spawning/early development). The ambient temperature curve was based on the 5-day mean ambient temperatures at the LEC. Since the maximum temperatures at the ZID occupy a relatively small area of potential habitat for aquatic organisms, this temperature is shown to provide perspective on the relative potential for more spatially extensive effects.

Biothermal Effect Parameters

Biothermal effects data were plotted above (spawning/early development) or below (cold-shock) the appropriate acclimation temperature for the period of time when the applicable life stage occurs in the vicinity of the LEC. The line marked "2" represents the spawning temperature range for the species and identifies the normal temperature conditions for peak spawning. The line marked "3" represents the maximum temperature compatible with optimum hatching success of eggs and is plotted as a line spanning the seasonal occurrence of eggs. The points marked "1" represent upper tolerance limits estimated by 24-hr to 96-hr TL50s. They are plotted directly above the point on the ambient temperature profile equivalent to the acclimation temperature at which the TL50 was determined. When the acclimation temperature exceeds the high ambient temperature, the TL50 is plotted directly above the highest ambient temperature. The points marked "4" indicate lower tolerance limits and are plotted directly below the point on the discharge channel or plume temperature equivalent to the acclimation temperature at which the lower tolerance limit (LILT) was determined. In the example, all lower tolerance limits lie below the ambient temperature; thus, there is no potential for cold shock mortality to organisms acclimated to the thermal plume if they were returned rapidly to ambient conditions during a plant shutdown.

Primary Seasonal Distribution

Above each biothermal effect diagram, the period of occurrence for applicable life stages was plotted as a series of bars. The bars indicate the primary season of occurrence based on life history information and densities measured in the field and impingement and entrainment sampling conducted during 1976, 2003 and 2007.

Figure C-2 Hypothetical example of the biothermal effect diagrams with explanation.

Table C-2 Maximum Temperatures at which RIS caught in three regions of the Ohio River (EPRI 2013).

Species	Lower River		Middle River		Upper River	
	°F	N	°F	N	°F	N
Bighead carp	88.7	12	81.1*	2	-	0
Channel catfish	96.8	494	113.5	1,332	101.1	1,586
Emerald shiner	96.8	473	108.0	1,434	101.1	1,738
Gizzard shad	96.8	550	115.3	1,556	101.1	1,918
Sauger	95.9	482	115.3	1,515	99.3	1,888
Silver carp	89.6	49	84.9	11	-	0
Walleye	89.4	12	89.2	85	88.2	442
White crappie	91.4	72	88.7	101	88.2	82

N = total sample size

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1. INTRODUCTION

Ameren Missouri submitted a draft 316(a) demonstration to Missouri Department of Natural Resources (MDNR) in August, 2019. Ameren subsequently received joint comments from MDNR and from the Missouri Department of Conservation (MDC), and also included feedback from Region VII of the United States Environmental Protection Agency (USEPA) and the United States Fish and Wildlife Service (USFWS). Ameren responses to the comments are provided in a separate response document (Response to Agency Preliminary Comments on Labadie Energy Center §316(a) Draft Demonstration dated 1/31/2020). This document provides supplementary materials directly requested in those comments or in response to the agency comments.

The document is organized around major themes in the comments, in particular

- Removal of Asian carp from data analysis
- Seasonal Trends in Heat-Intolerant Species
- Diversity calculations
- Effect of Family-level identifications in macrobenthos diversity analysis
- Use of Hester-Dendy (H-D) macrobenthos data combined across depths
- Use of Biotic Index in Analysis

2. REMOVAL OF ASIAN CARPS FROM DATA ANALYSIS

Several of the agency comments requested that statistical analysis of the fish data collected in 2017-2018 be redone after removal of Asian carps. The concern was that the ability to detect harm caused by the LEC thermal discharge would be masked by the presence of these invasive, and relatively heat-tolerant, species. Although guidance from USEPA on how community analysis for prior appreciable harm is to be conducted would not suggest that these species be removed, to accommodate the agency comments, the analyses in section 5.4.1 have been redone after removal of the Asian carp species (grass carp, bighead carp, and silver carp). Graphical analyses of individual metrics, along with the original result, are presented below. In addition, the distributions of the standardized differences based on all metrics across gear and seasons are also provided.

The analyses without Asian carps were consistently similar to those including Asian carps, leading to similar conclusions that the LEC thermal discharge has not caused prior appreciable harm to the community.

2.1 RELATIVE ABUNDANCE OF ASIAN CARPS

Despite the abundance of larval Asian carps in ichthyoplankton and entrainment collection, Asian carps comprised only a fraction of the fish community collected by fisheries sampling methods. In numerical abundance they comprised only 2% to 3% of the fish collected in each zone (Table 2-1). Because the grow rapidly and reach large sizes, the contribution to fish biomass was higher, but still only 5% in the discharge zone and 20% in the other zones.

Asians carp species individually were also not generally among the more common species. Table 2-2 below is a revised version of Table 5-3 of the demonstration, illustrating the 15 most common taxa in each zone. Silver carp are the only Asian carp species that was in the top 15 species, ranging from 10th most common in the Thermally Exposed zone to 13th most abundant in the Discharge zone. As indicated in Table 2-1, total abundance would only decline 2% to 3% with removal of Asian carps.

Table 2-1 Number and biomass of Asian carp species in each zone from fisheries sampling programs near the LEC during 2017-2018.

Taxon	Number of Fish				Biomass (kg)			
	Upstream Zone	Discharge Zone	Thermally Exposed Zone	Downstream Zone	Upstream Zone	Discharge Zone	Thermally Exposed Zone	Downstream Zone
Bighead carp	3	4	0	2	5.2	14.4	0.0	18.2
Silver carp	155	13	167	153	106.1	33.7	161.9	138.9
Grass carp	18	1	18	16	105.8	6.4	103.7	68.0
Asian carp Total	176	18	185	171	217.2	54.5	265.6	225.1
Total	9151	948	7105	8064	1084.3	1136.2	1318.8	1152.0
% Asian carp	2%	2%	3%	2%	20%	5%	20%	20%

Table 2-2 Species composition in each zone from fisheries sampling programs near the LEC during 2017-2018, as presented in draft Demonstration, and after removal of Asian carps. Differences noted by highlight or footnotes.

	Upstream Zone			Discharge Zone			Thermally Exposed Zone			Downstream Zone		
Rank	Taxon	Number	Fraction	Taxon	Number	Fraction	Taxon	Number	Fraction	Taxon	Number	Fraction
1	Red shiner	3,056a	0.334	Red shiner	330	0.348	Red shiner	1,291	0.182	Red shiner	1,824	0.226
2	Channel shiner	1,287	0.141	Blue catfish	154	0.162	Emerald shiner	914	0.129	Channel shiner	1,055c	0.130
3	Sicklefin chub	568	0.062	River carpsucker	67	0.071	Gizzard shad	757	0.107	Gizzard shad	980	0.122
4	Shoal chub	559	0.061	Emerald shiner	59	0.062	Channel shiner	743	0.105	Emerald shiner	636	0.079
5	Gizzard shad	557	0.061	Gizzard shad	56	0.059	Sicklefin chub	627	0.088	Shoal chub	631	0.078
6	Emerald shiner	495	0.054	Freshwater drum	46	0.049	Shoal chub	607	0.085	Sicklefin chub	472	0.059
7	Freshwater drum	487	0.053	Longnose gar	35	0.037	Freshwater drum	371	0.052	Bullhead minnow	286	0.035
8	Blue catfish	350	0.038	Shortnose gar	31	0.033	Blue catfish	282	0.040	Freshwater drum	275	0.034
9	Channel catfish	279	0.030	Flathead catfish	22	0.023	Channel catfish	242	0.034	Blue catfish	270	0.033
10	Bullhead minnow	255	0.028	Common carp	20	0.021	Silver carp	167	0.024	Channel catfish	256	0.032
11	Sand shiner	205b	0.021	Channel catfish	19	0.020	Bullhead minnow	104	0.015	Silver carp	153	0.019
12	Silver carp	155	0.017	Smallmouth buffalo	19	0.020	River carpsucker	100	0.014	Goldeye	141	0.017
13	Goldeye	115	0.013	Silver carp	13	0.014	Goldeye	90	0.013	Blacktail chubs	117	0.015
14	River carpsucker	74	0.008	Striped bass x white bass	12	0.013	Longnose gar	86	0.012	Mosquitofish	105	0.013
15	Longnose gar	66	0.007	Goldeye	11	0.012	Shortnose gar	86	0.012	Sand shiner	85d	0.010
New 15	Smallmouth buffalo	63		Channel shiner	10		Smallmouth buffalo	84		River carpsucker	77	
>15	56 additional taxa	662	0.072	22 additional taxa	54	0.057	56 additional taxa	638	0.090	53 additional taxa	782	0.097
	Total	9,151	1.000	Total	948	1.000	Total	7,105	1.000	Total	8,064	1.000
	Total without Asian carps	8,970		Total without Asian carps	930		Total without Asian carps	6,919		Total without Asian carps	7,886	

a Original total was 3,054; b Original total was 188; c Original total was 1,052; d Original total was 84

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2.2 OVERALL ABUNDANCE

Abundance of fishes within seasons and zones, and for each gear, were provided in the demonstration in Figures 5-12 (winter) and 5-13 (summer). Those figures are modified below to examine the effect of removal of Asian carps from the analysis. In both seasons, only Missouri Trawl catches exhibited a noticable change in numerical abundance (Figure 2-1 and Figure 2-2). Biomass was noticably reduced in at least one of the season in all gear except the bag seine, however the critical point is that the pattern of relative abundance among the four zones, and particularly for the Upstream Reference zone and the Downsteam zone remains the same, with or without Asian carps.

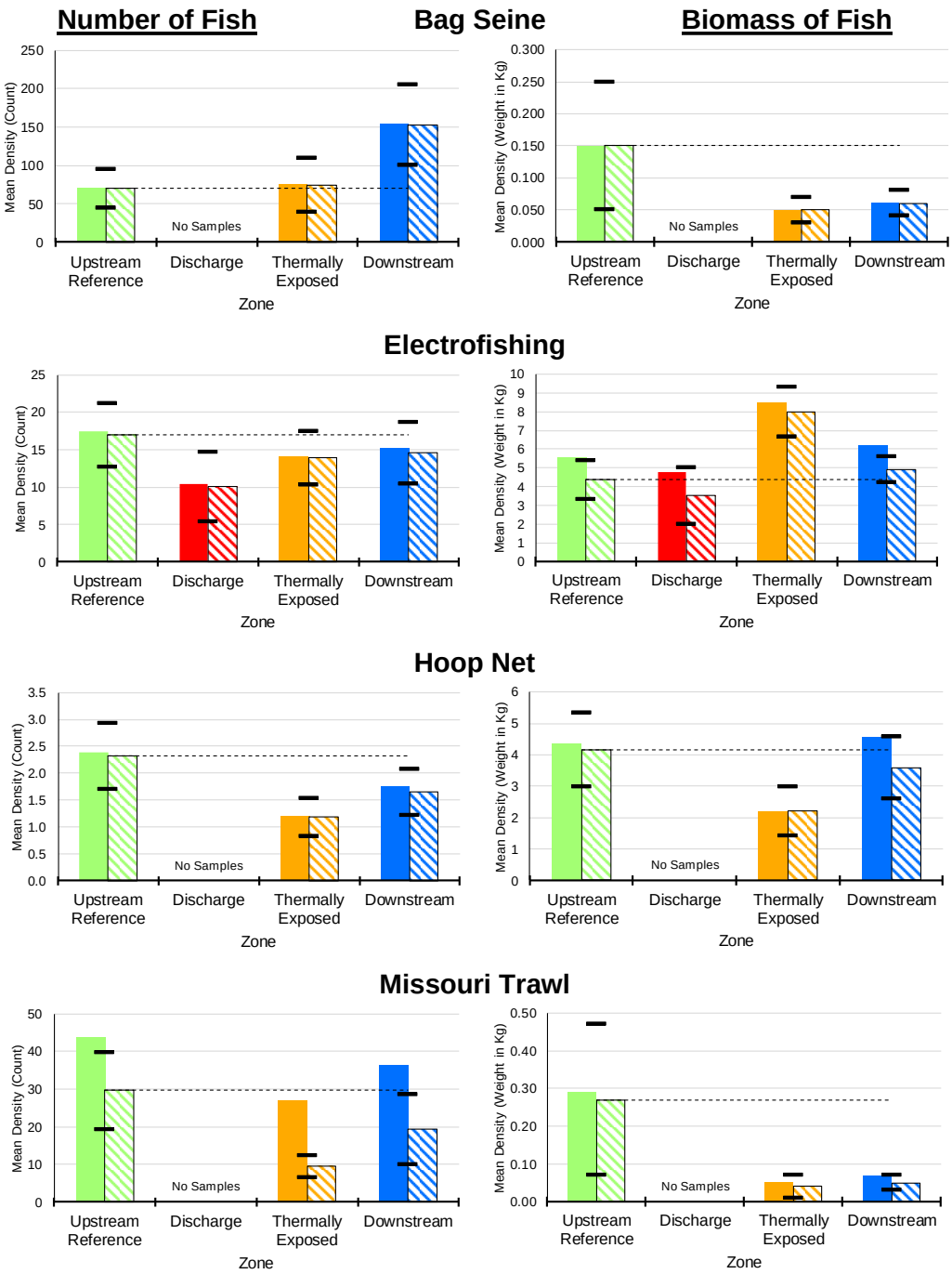


Figure 2-1 Summer mean density in fisheries sampling at the LEC in 2017-2018 for each gear type and zone, based on number of fish (left column) and biomass in Kg (right column). Solid color bars include Asian carps. Hatched bars exclude Asian carps. Black horizontal bars are +/- 1 standard error for mean without Asian carps.

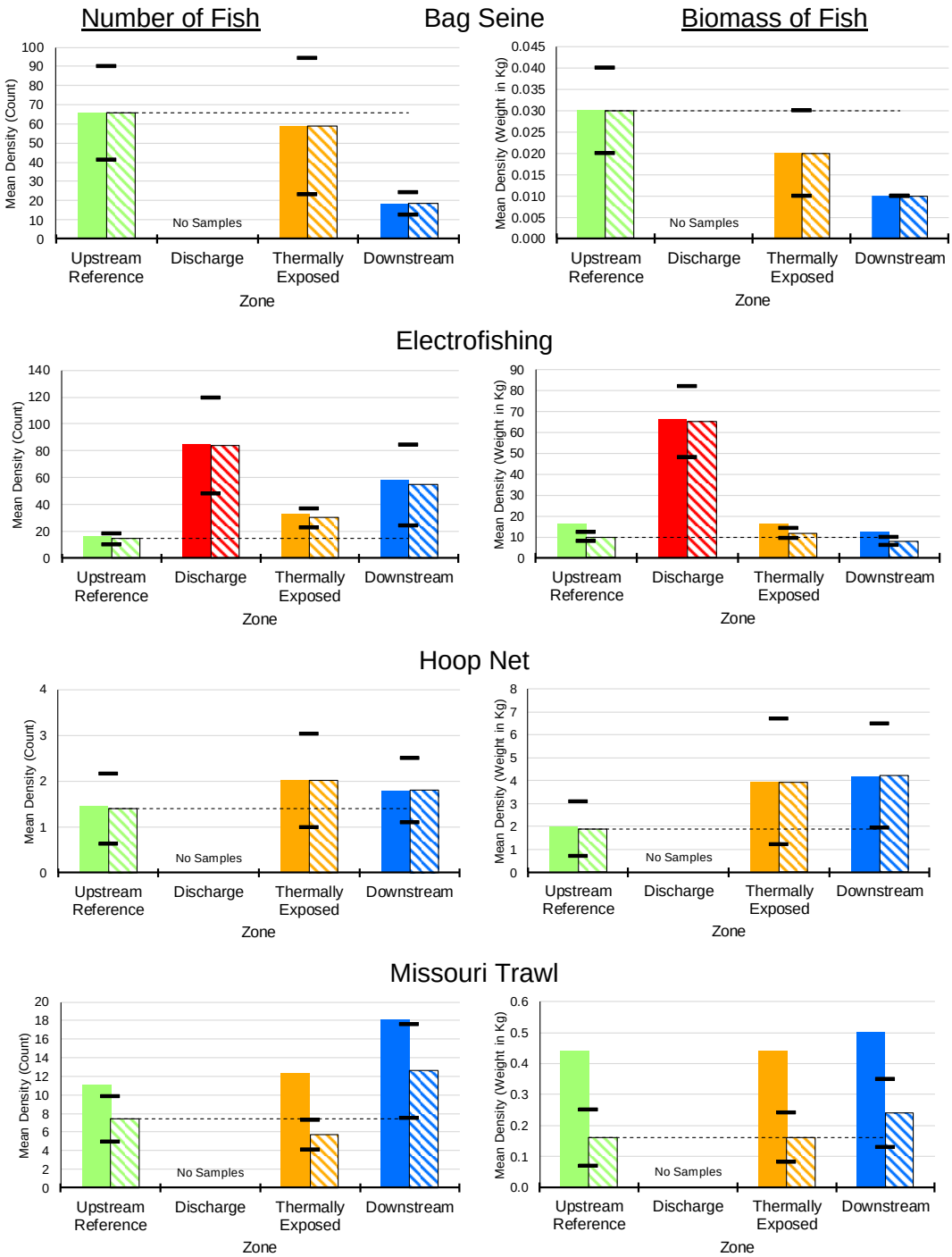


Figure 2-2 Winter mean density of fisheries sampling at the LEC in 2017-2018 for each gear type and zone, based on number of fish (left column) and biomass in Kg (right column). Solid color bars include Asian carps. Hatched bars exclude Asian carps. Black horizontal bars are +/- 1 standard error for mean without Asian carps.

2.3 COMMUNITY CHARACTERISTICS

2.3.1 Diversity

Diversity profiles were provided in the draft demonstration in Figure 5-15. The profiles are changed very little by removal of the three Asian carp species from the calculation (Figure 2-3), an unsurprising result since these species were only 2% to 3% of total numerical abundance and 5% to 20% of biomass. As with previous figures, the key comparison is not the change in any zonal profile, but the relationships among the profiles for each of the zones. Diversity relationships across zones do not change with or without Asian carps.

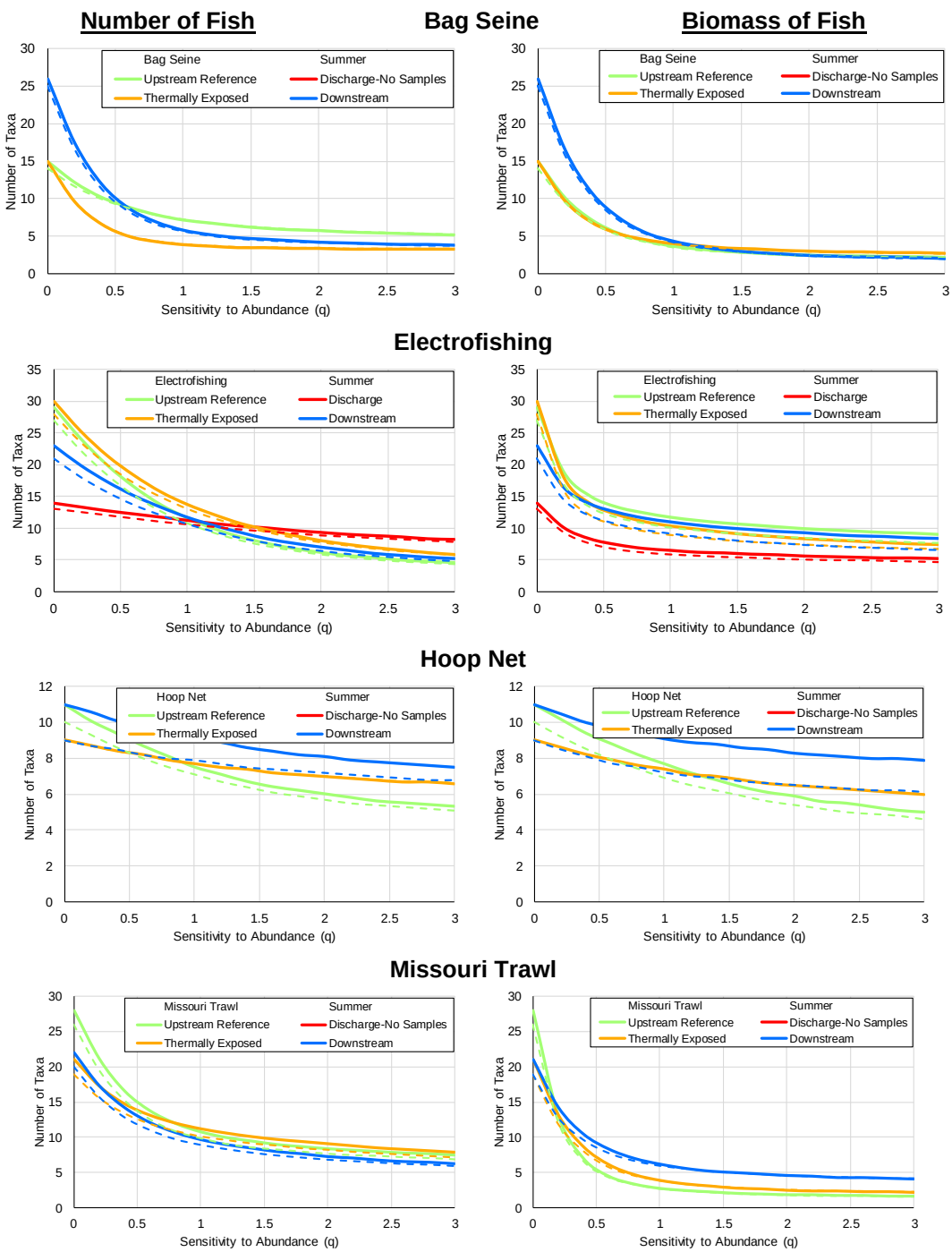
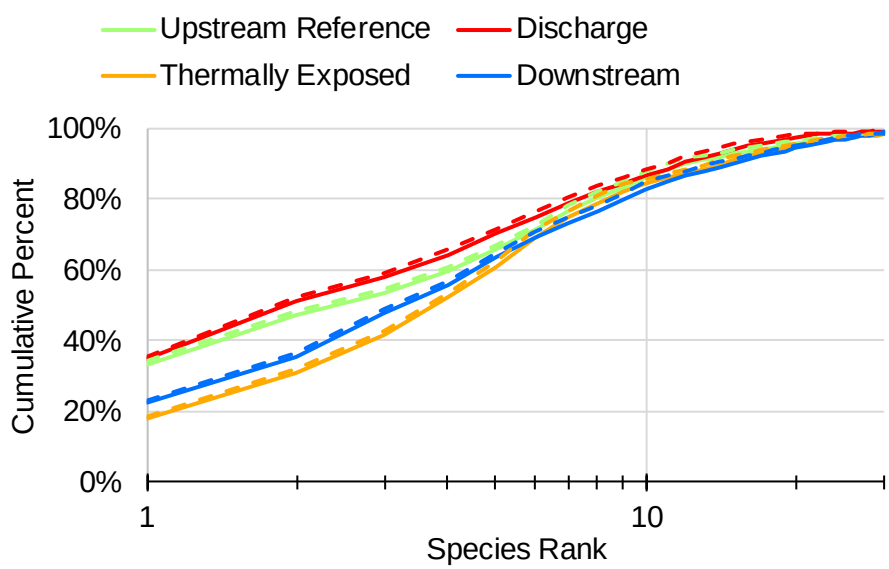


Figure 2-3 Summer diversity profiles of fisheries sampling at the LEC in 2017-2018 for each gear type and zone, based on number of fish (left column) and biomass in Kg (right column). Solid lines depict results including Asian carps. Dashed lines depict results without Asian carps.

2.3.2 Dominance

Dominance of the fish community was described in the demonstration in Figure 5-16. The figure was modified to examine dominance profiles with and without Asian carps (Figure 2-4). Dominance curves for numerical abundance changed very little when Asian carps were omitted. Biomass dominance was modified somewhat, but the relationships of dominance among the zones was the same.

Numerical Abundance



Biomass

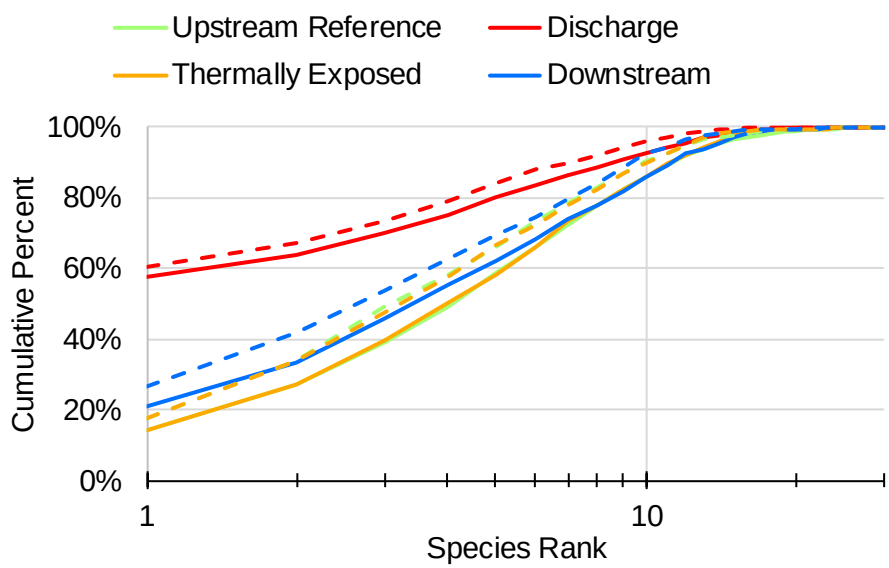


Figure 2-4 Dominance of the fish community in the LEC vicinity based on all sampling gears combined over all seasons, 2017-2018. Top figure is based on numerical abundance and bottom on biomass. Solid lines depict results including Asian carps. Dashed lines depict results without Asian carps.

2.4 COMMUNITY COMPOSITION

Composition of the fish community with respect to different fish categories (Rough, Forage, Panfish, Game, and Special Concern) was provided in Figure 5-18 of the demonstration. Forage and rough fish were the most prevalent numerically, and rough and game fish were most prevalent in terms of biomass. As a result of an agency comment, the analysis was redone after moving the buffalo species (subfamily Ictiobinae) to a Game/Commercial category. Figure 5-18 is revised to reflect this change in the demonstration. Figure 2-5 provides an alternative way to examine the breakdown of the community into these categories in terms of numbers and biomass, with and without the inclusion of Asian carps. It is apparent that the Asian carps have little effect on the community composition, or the differences in composition across zones.

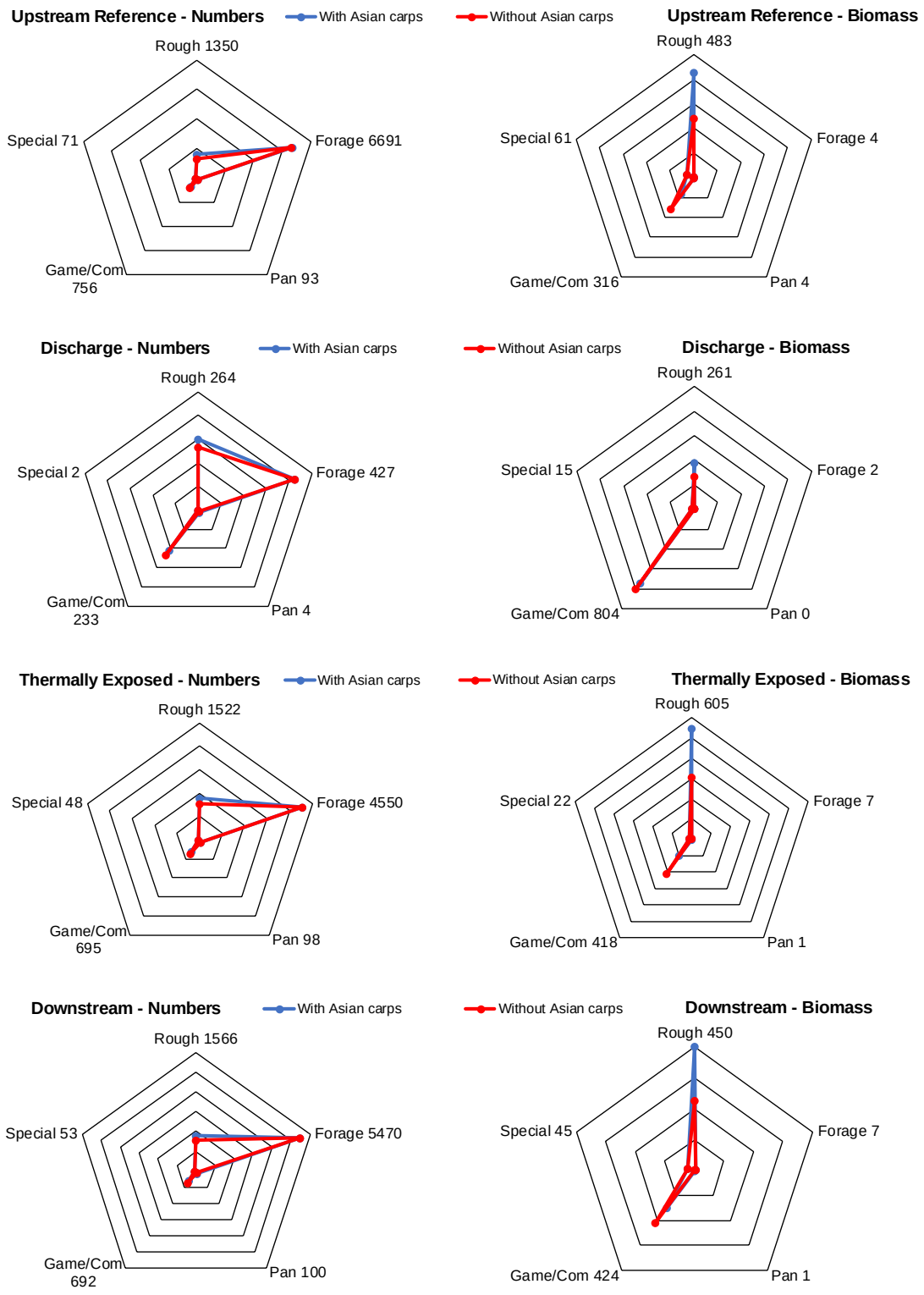


Figure 2-5 Composition of fisheries sampling results in rough, forage, pan, game/commercial, and special categories based on numerical abundance (left column) and total biomass in Kg (right) over all seasons and gear types.

2.4.1 Presence of all Trophic Levels

The breakdown of the community into trophic strategies was provided in Figure 5-17 of the demonstration. The relative frequencies of the different strategies changes little when Asian carps are removed from the analysis (Figure 2-6).

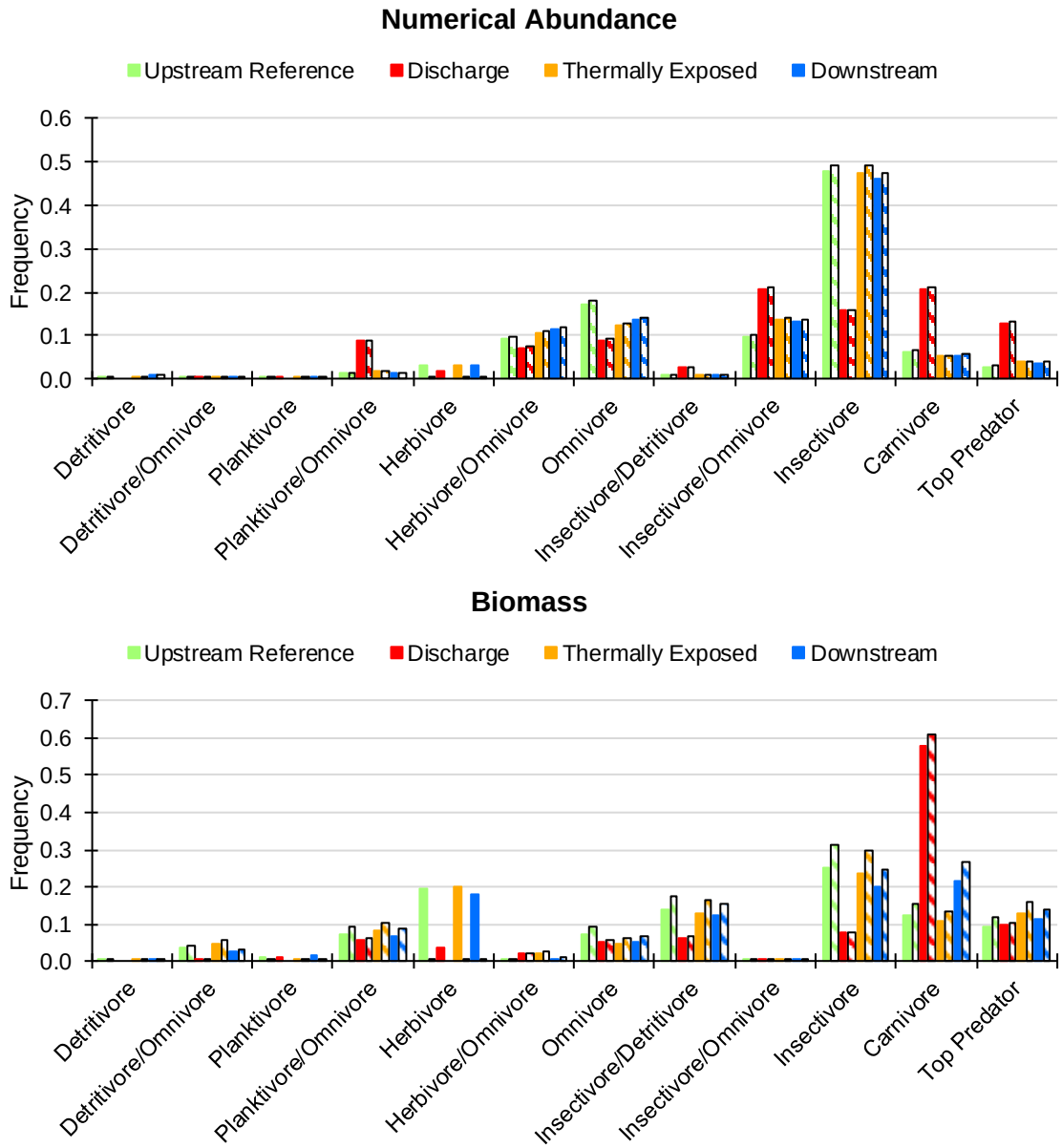


Figure 2-6 Trophic categories of the fish community sampled in the vicinity of the LEC in 2017-2018 based on all sampling gears over all seasons. Solid color bars include Asian carps. Hatched bars exclude Asian carps.

2.4.2 Heat Tolerance

The relative abundance of heat-intolerant and heat-tolerant species across the sampling zones was presented in Figure 5-19. Silver carp and bighead carp were included in the heat-tolerant species. The relative frequencies of heat-intolerant and heat-tolerant species changes little if Asian carps are removed (Figure 2-7), and in particular the patterns among the zones remain the same.

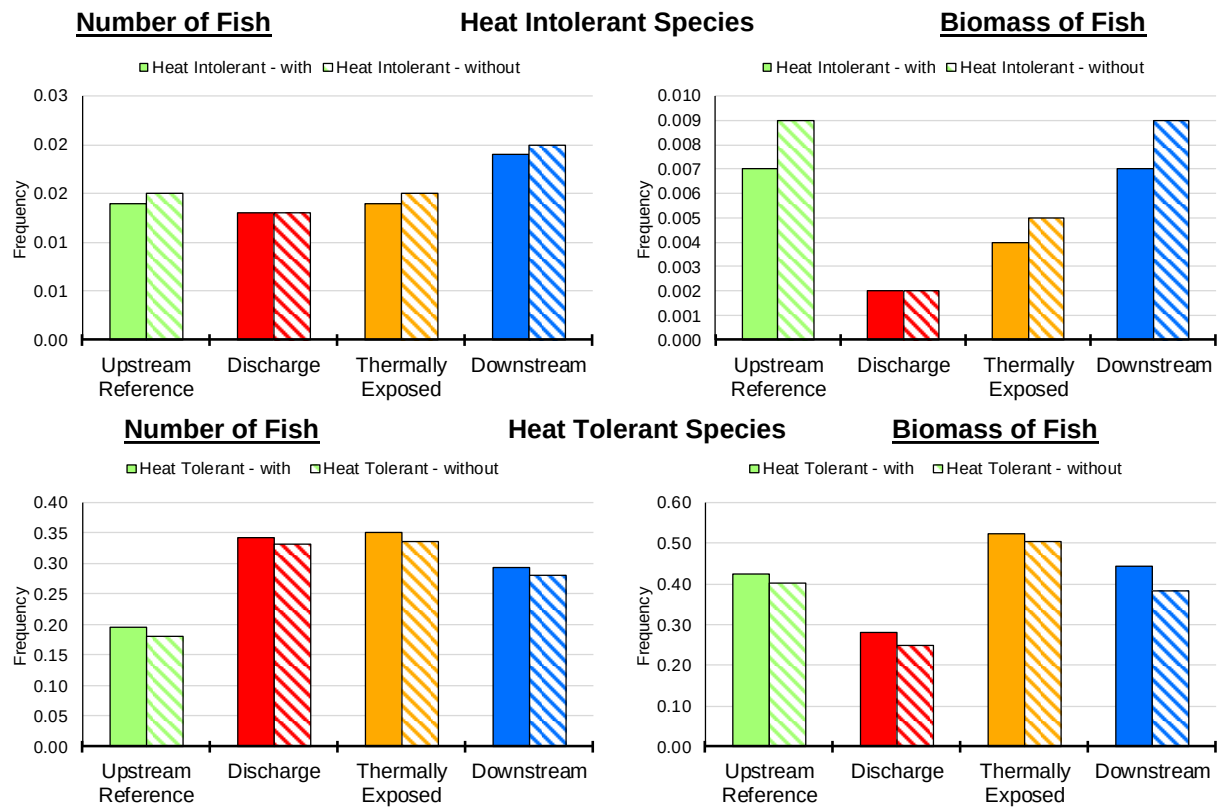


Figure 2-7 Fraction of the fish community in the vicinity of the LEC in 2017-2018 comprised of heat intolerant (top) and heat tolerant (bottom) species based on all sampling gears over all seasons. Solid color bars include Asian carps. Hatched bars exclude Asian carps.

2.4.3 Pollution Tolerance

The relative abundance of pollution-intolerant and pollution-tolerant species across the sampling zones was presented in Figure 5-20. According to Pearson et al. (2011), silver carp were included in the pollution-tolerant species. The relative frequencies of pollution-intolerant and pollution-tolerant species changes little if Asian carps are removed (Figure 2-8), and in particular the patterns among the zones remain the same.

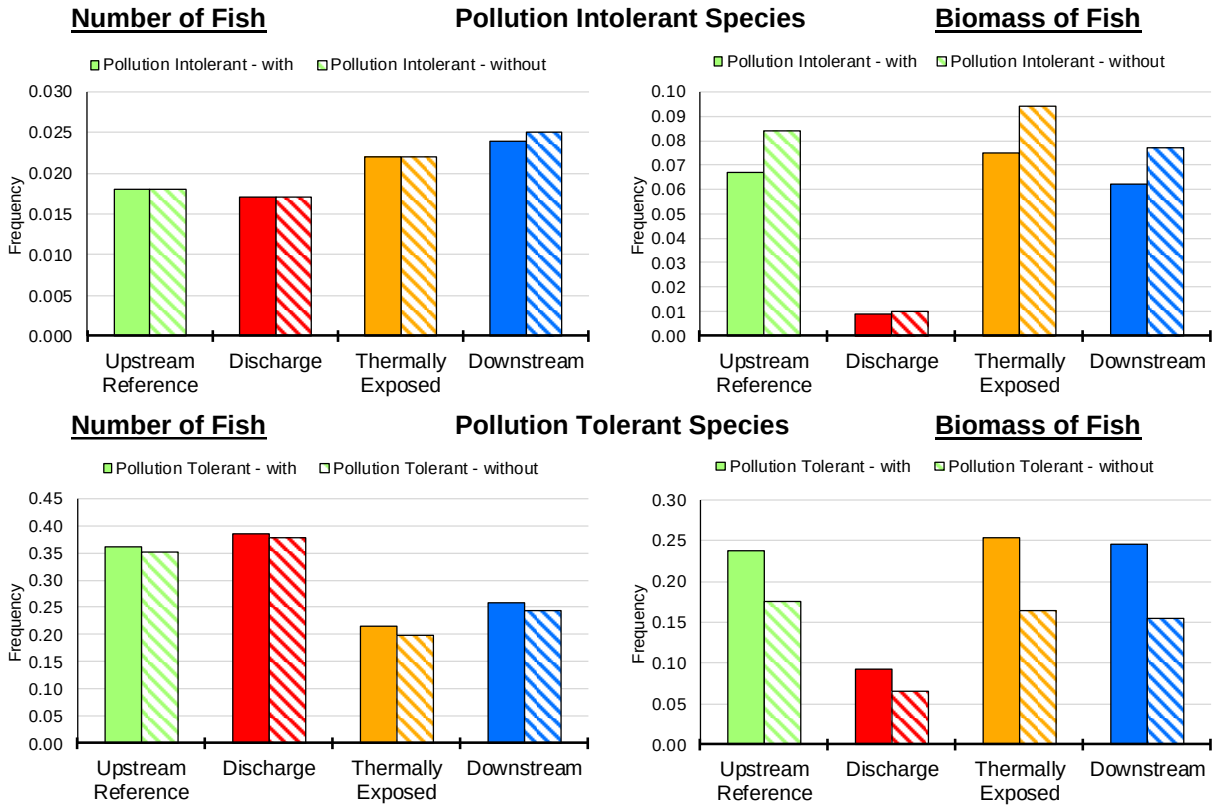


Figure 2-8 Fraction of the fish community in the vicinity of the LEC in 2017-2018 comprised of pollution intolerant (top) and pollution tolerant (bottom) species based on all sampling gears over all seasons. Solid color bars include Asian carps. Hatched bars exclude Asian carps.

2.5 OVERALL WEIGHT OF EVIDENCE

Due to the changes to the some of the individual metrics due to other agency comments (such as adding subfamily Ictiobinae to a Game/Commercial category) appropriate metrics were recalculated for the "with Asian carps" case, and Figure 5-22 of the demonstration has been updated in the revised demonstration. The recalculated standardized differences with and without Asian carps for zones 1 and 3 (Figure 2-9) and zones 1 and 4 (Figure 2-10) show little effect of Asian carp removal. For the zone 1 to 3 comparison, the mean is slightly less negative (-0.611 with Asian carp and -0.547 without), and for the zone 1 to 4 comparison, slightly more negative (-0.053 with Asian carp and -0.148 without). compare and all metrics were recalculated without Asian carps. However, in both cases, the means with or without Asian carps are close enough to zero that actual biological effects of the discharge, if any, are small.

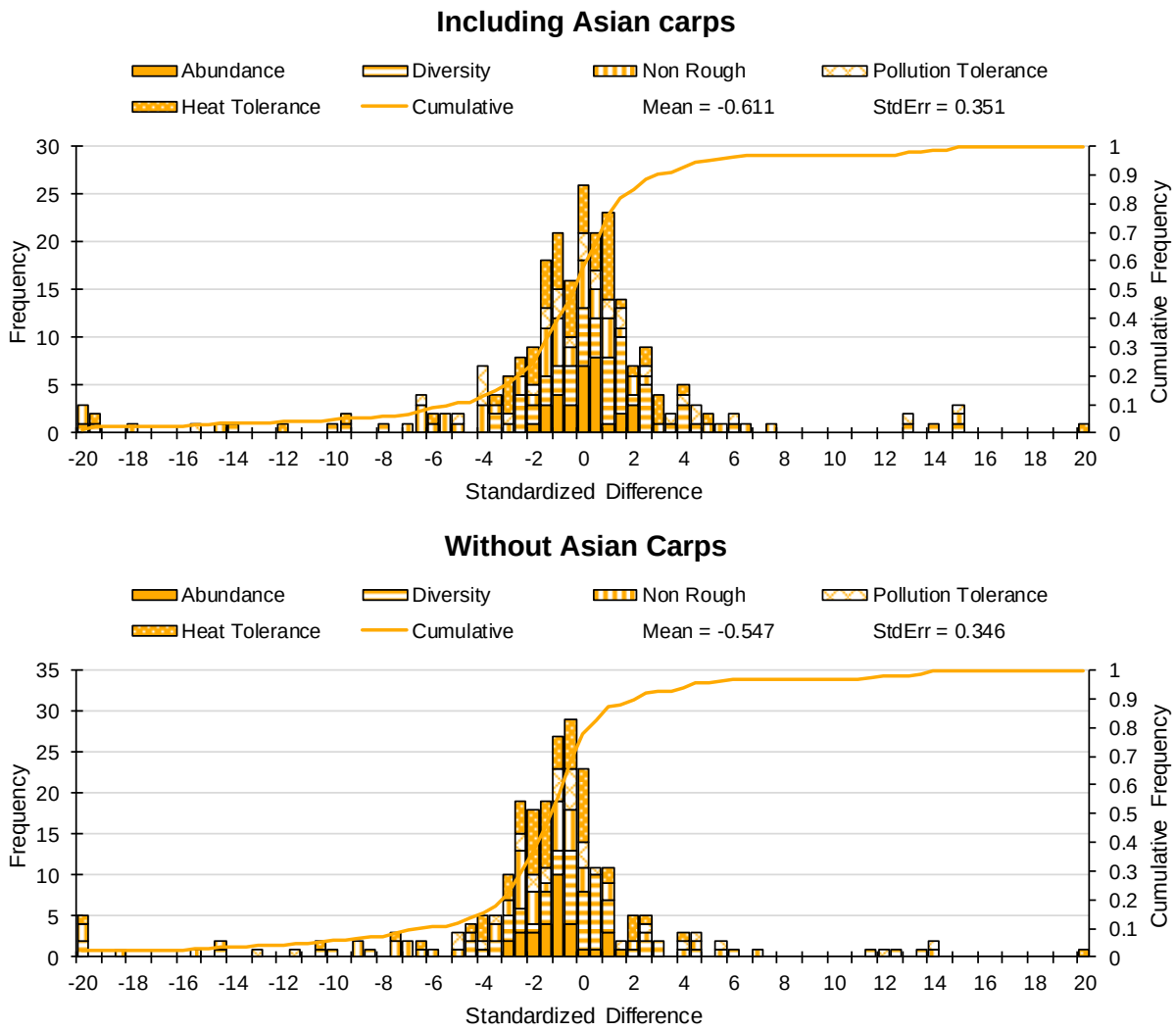


Figure 2-9 Distribution of standardized differences between ecological metrics for the Thermally Exposed Zone and Upstream Refence zone, including Asia carps (top) and without Asian carps (bottom) over all gear, seasons, and metrics.

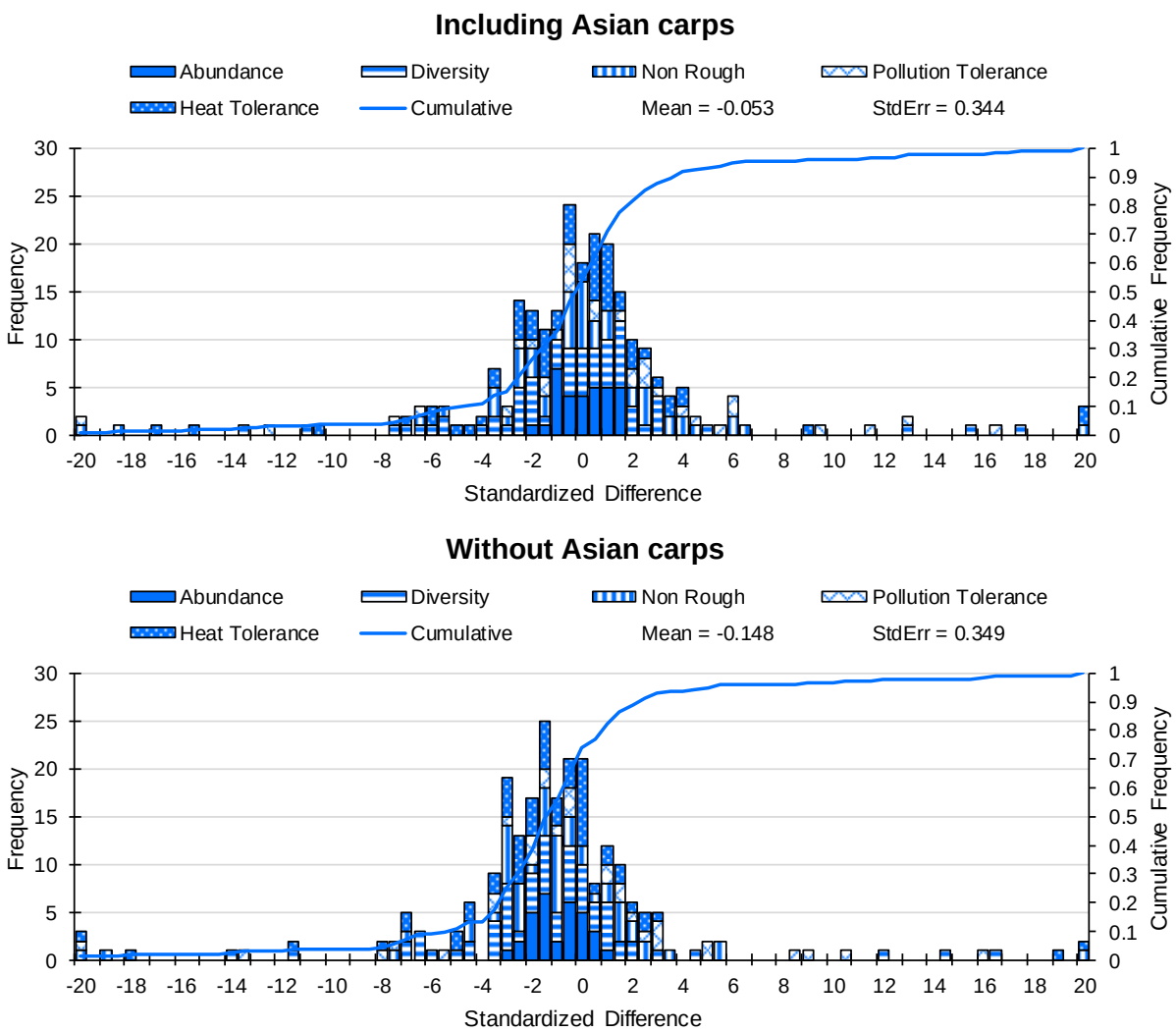


Figure 2-10 Distribution of standardized differences between ecological metrics for the Downstream Zone and Upstream Reference zone, including Asia carps (top) and without Asian carps (bottom) over all gear, seasons, and metrics.

3. SEASONAL TRENDS IN HEAT-INTOLERANT SPECIES

Commentors requested a graphical presentation that would demonstrate seasonal trends in heat-intolerant species. Figure 3-1 indicates that seasonal aspects of the abundance of heat-intolerant species is similar among the zones.

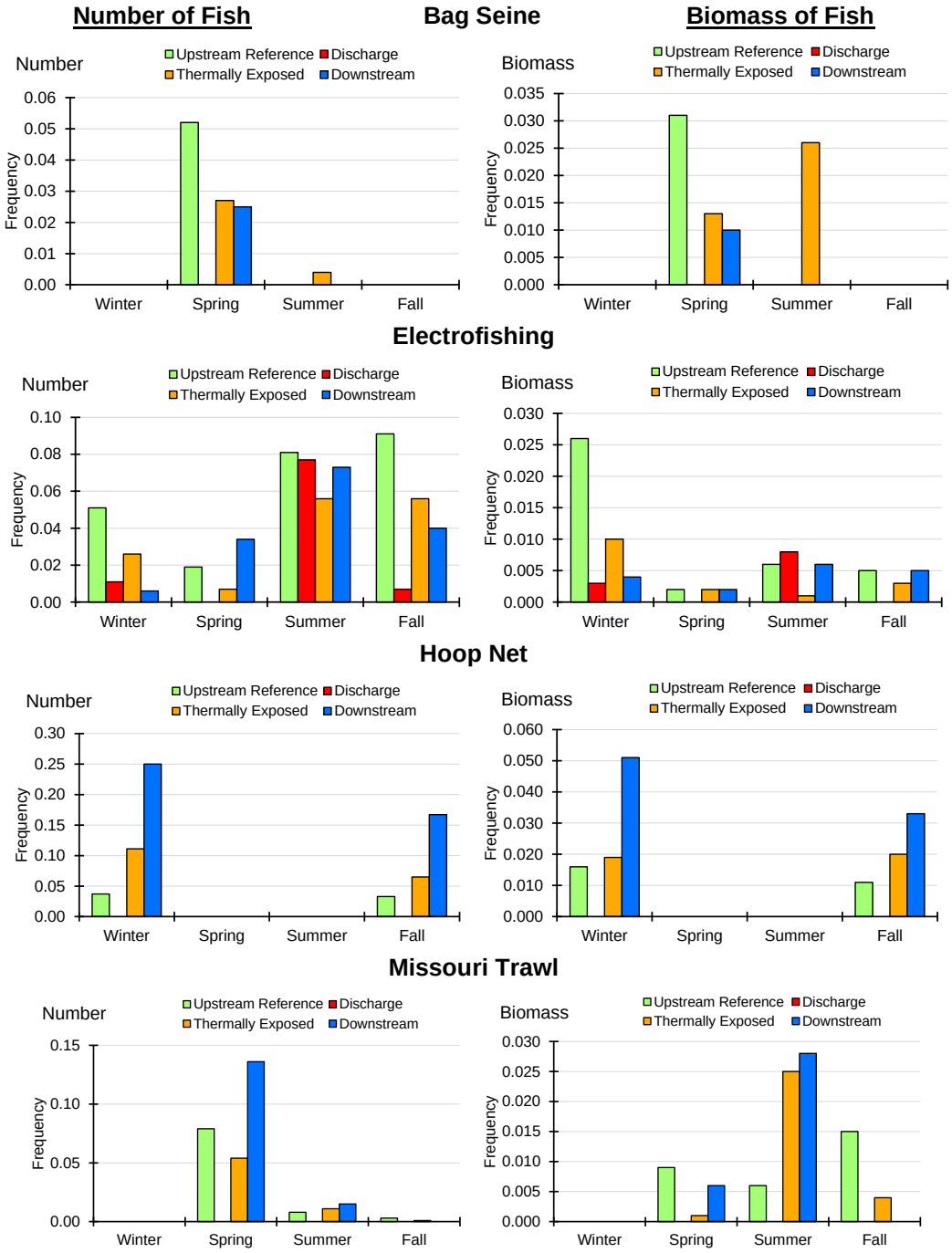


Figure 3-1 Seasonal fraction of the fish community comprised of heat-intolerant species as numbers (left) and biomass (right) in the vicinity of the LEC in 2017-2018.

4. DIVERSITY CALCULATIONS

Assume that a community consisting of S species with numbers of individual species denoted as $N_1, N_2, N_3, \ldots . N_S$ and N is the total number of organisms. The proportion of the community due to each species i is $\mathrm{p_i} = \frac{\mathrm{N_i}}{\sum_{\mathrm{i=1}}^{\mathrm{S}} \mathrm{N_i}}$.

Hill numbers (Hill 1973) of order q, where q is a measure of the sensitivity of diversity to species abundance, denoted as ${}^{\mathrm{q}}\mathrm{D}$, are calculated as:

$${}^{\mathrm{q}}\mathrm{D} = \left(\sum_{\mathrm{i=1}}^{\mathrm{S}} \mathrm{p_i^q}\right)^{\frac{1}{1-\mathrm{q}}} \quad \text{where } q \geq 0, \text{ but } q \neq 1 \ldots\ldots \qquad [1]$$

Because the exponent $\frac{1}{1-\mathrm{q}}$ would be undefined at q = 1, the limiting value as q→1 is substituted for equation [1]:

$${}^{\mathrm{q}}\mathrm{D} = \exp\left(-\sum_{\mathrm{i=1}}^{\mathrm{S}} \mathrm{p_i} \log \mathrm{p_i}\right) \quad \text{where } q = 1 \qquad [2]$$

The calculations describe a continuous smooth relationship between ${}^{\mathrm{q}}\mathrm{D}$ and q, given the particular values of $\mathrm{p_i}$. When most of the organisms captured belong to just a few taxa, the curve declines sharply from its maximum value (S) at q = 0. If the community is more evenly dispersed among many taxa, the curve declines gradually. The diversity profile is interpretable as the number of equally abundant taxa that would be required to produce the same level of diversity at any particular level of sensitivity to abundance.

At q = 0, the diversity metric is completely insensitive to the relative abundance, and as would be expected, ${}^{0}\mathrm{D}$ is equal to the species richness (S). When q = 1, the diversity metric is equivalent to exp(H´) where H´ is the Shannon-Weiner diversity. When q = 2, the diversity metric is equivalent to the inverse Simpson index.

q	Special Cases of Hill Numbers at q = 0, 1, 2	Corresponding Metric
0	${}^{0}\mathrm{D} = \left(\sum_{\mathrm{i=1}}^{\mathrm{S}} \mathrm{p_i^0}\right)^{\frac{1}{1-0}} = \left(\sum_{\mathrm{i=1}}^{\mathrm{S}} 1\right)^{1} = \mathrm{S}$	Species Richness
1	${}^{1}\mathrm{D} = \exp\left(-\sum_{\mathrm{i=1}}^{\mathrm{S}} \mathrm{p_i} \log \mathrm{p_i}\right) = \exp\,(\mathrm{H'})$	exponential of Shannon Diversity
2	${}^{2}\mathrm{D} = \left(\sum_{\mathrm{i=1}}^{\mathrm{S}} \mathrm{p_i^2}\right)^{\frac{1}{1-2}} = \frac{1}{\sum_{\mathrm{i=1}}^{\mathrm{S}} \mathrm{p_i^2}}$	inverse Simpson Diversity

For a sample of the community the calculated ${}^{\mathrm{q}}\mathrm{D}$ values are biased low in comparison to the true community values because some species that are present in the community may not be collected in the sample. This bias decreases with increasing sampling effort. As effort increases, more species are observed and therefore diversity could be expected to increase. Chao et al. (2014) provide the theoretical basis for estimating the asymptotic diversity if the habitat was completely sampled. For q = 0:

$${}^{0}\widehat{\mathrm{D}} = \mathrm{S_{obs}} + \hat{\mathrm{f}}_0 \qquad [3]$$

where S_{obs} is the number of species appearing at least once, and $\hat{f}_0$ is the estimated number of species present but not observed in the sample.

Uncertainty around the diversity profiles was assessed though a procedure, in which 1) the number of unsampled species is estimated; 2) the sampling probabilities of Sobs detected and $\hat{f}_0$ undetected species are estimated; 3) a bootstrap sample of the combined detected and undetected species of the original size n is taken; 4) the diversity profile is calculated from the bootstrap sample; 5) steps 3) and 4) are repeated 500 times; and 6) dispersion statistics are calculated for the 500 diversity profiles.

1) Chao et al. (2014) suggested the Chao1 estimator of $\hat{f}_0$:

$\hat{f}_0 = (n-1)f_1^2/(2nf_2)$, if $f_2 > 0$ [4a]

$\hat{f}_0 = \frac{(n-1)f_1(f_1-1)}{2n}$, if $f_2 = 0$, [4b]

where f_x is the number of species with exactly x organisms in the sample, and n is the total number of organisms sampled.

The sample coverage $\hat{C}$, is calculated as:

$\hat{C} = 1 - \frac{f_1}{n}\left[\frac{(n-1)f_1}{(n-1)f_1+2f_2}\right]$, if $f_2 > 0$ [5a]

$\hat{C} = 1 - \frac{f_1}{n}\left[\frac{(n-1)(f_1-1)}{(n-1)(f_1-1)+2}\right]$, if $f_2 = 0$ [5b]

If $\hat{C}$ = 1, then an alternative estimator was used (Gotelli and Colwell 2010) which divides the observed species into rare (S_{rare}) and abundant (S_{abund}) groups, based on ≤ 10 or > 10 organisms in the sample, and n_{rare} is the number of individuals of rare species:

$S_{rare} = \sum_{x=1}^{10} f_x$ [6a]

$S_{abund} = \sum_{x>10} f_x$ [6b]

$n_{rare} = \sum_{x=1}^{10} xf_x$ [6c]

In this case, the coverage and $\hat{f}_0$ are estimated as:

$\hat{C}_{ACE} = 1 - \frac{f_1}{n_{rare}}$ [7]

$\hat{\gamma}^2_{rare} = \max\left\{\frac{S_{rare}}{\hat{C}_{ACE}}\frac{\sum_{x=1}^{10} x(x-1)f_x}{(n_{rare}-1)n_{rare}} - 1,0\right\}$ [8]

$\hat{S} = S_{abund} + \frac{S_{rare}}{\hat{C}_{ACE}} + \frac{f_1}{\hat{C}_{ACE}}\hat{\gamma}^2_{rare}$ [9]

$\hat{f}_0 = \hat{S} - S_{abund} - S_{rare}$ rounded up to the next integer value [10]

2) The adjusted capture probabilities for the S_{obs} are

$$\hat{p}_i = \frac{x_i}{n}\left[1 - \hat{\lambda}\left(1 - \frac{x_i}{n}\right)^n\right]$$

where

$$\hat{\lambda} = \frac{1 - \hat{C}}{\sum_{x_i \geq 1} \frac{x_i}{n}\left(1 - \frac{x_i}{n}\right)^n}$$

and for the $\hat{f}_0$ unseen species are

$$\hat{p}_i = \frac{1 - \hat{C}}{\hat{f}_0}$$

3) A random sample of size n is drawn with replacement from the S_{obs} with probabilities $\hat{p}_1, \hat{p}_2, \hat{p}_3, \ldots\ldots \hat{p}_{S_{obs}}$, and from the $\hat{f}_0$ unseen species with probabilities $\hat{p}_{S_{obs+1}}, \hat{p}_{S_{obs+2}}, \hat{p}_{S_{obs+3}} \quad \ldots\ldots \hat{p}_{S_{obs+\hat{f}_0}}$.

4) The diversity profile is computed for the sample using equations [1] and [2].

5) Steps 3) and 4) are repeated.

6) The standard deviations of the profiles are calculated at values of q at 0.1 intervals, and used to set approximate bounds (${}^{q}D$ +/ 2 standard deviations) for the profiles.

5. EFFECT OF FAMILY-LEVEL IDENTIFICATION ON MACROBENTHOS DIVERSITY ANALYSIS

Several comments questioned whether the use of family-level identification for the diversity analysis, rather than the lowest practical taxon, was potentially masking differences between zones. Although biotic indices, which use the same type of data to assess water quality within streams, often successfully use a higher level taxonomic specificity (Hilsenhoff 1987, Huggins and Moffet 1988), the original analyses have been replaced by analyses using the lowest practical taxon in the revised demonstration document. In addition, other analyses that tallied the number of taxa at particular levels of identification in the macrobenthic section (5.4.2) were also revised as described below.

The number of species observed was adjusted to include higher taxonomic categories if they did not include any organisms identified to species. For example, in Sample A in Table 5-1, the organisms identified only to family or genus are considered a species if there were no identified species within the classification (e.g. Family Hydrachnida, and genera *Chaoborus* and *Orthocladius*), while the genus *Nanocladius* does not represent a species in Sample A. In Sample B, the genus *Chaoborus* is not a species because *Chaoborus punctipennis* was present, but *Nanocladius* is considered a species because none of the genus were identified to a lower level. Because this method assigns only a single species to the higher taxonomic level, the number of species can be considered the minimum number of species. Similar considerations were applied to determine the number of genera, families, orders, etc.

Table 5-1 Example of species designations when organisms are identified to lowest practical taxon.

Identification as: Family – *Genus species*	Sample A		Sample B	
	Count	Considered as Species	Count	Considered as Species
Hydrachnida -	7	Yes	7	Yes
Chaoboridae – *Chaoborus sp.*	2	Yes	2	No
Chaoboridae – *Chaoborus punctipennis.*	0	-	2	Yes
Chironomidae - *Nanocladius*	13	No	20	Yes
Chironomidae - *Nanocladius alternantherae*	2	Yes	0	-
Chironomidae - *Nanocladius crassicornus*	6	Yes	0	-
Chironomidae - *Nanocladius distinctus*	33	Yes	0	-
Chironomidae - *Nanocladius minimus*	1	Yes	0	-
Chironomidae - *Orthocladius sp.*	1	Yes	1	Yes
Total Species in Sample		7		4

Using this procedure, the number of species increased from the prior draft which provided only the number of “identified species”, i.e. number of taxa for which genus and species could both be determined.

Because the analyses in 5.4.2 have all been revised to address the comment, detailed comparisons of the prior results with results based on lowest practical taxon are not provided here, except for an illustrative example of the diversity profiles (Figure 5-1). The number of taxa was increased, i.e. the diversity profile curves were shifted upward, but relationships among the four sampling zones was not substantially affected.

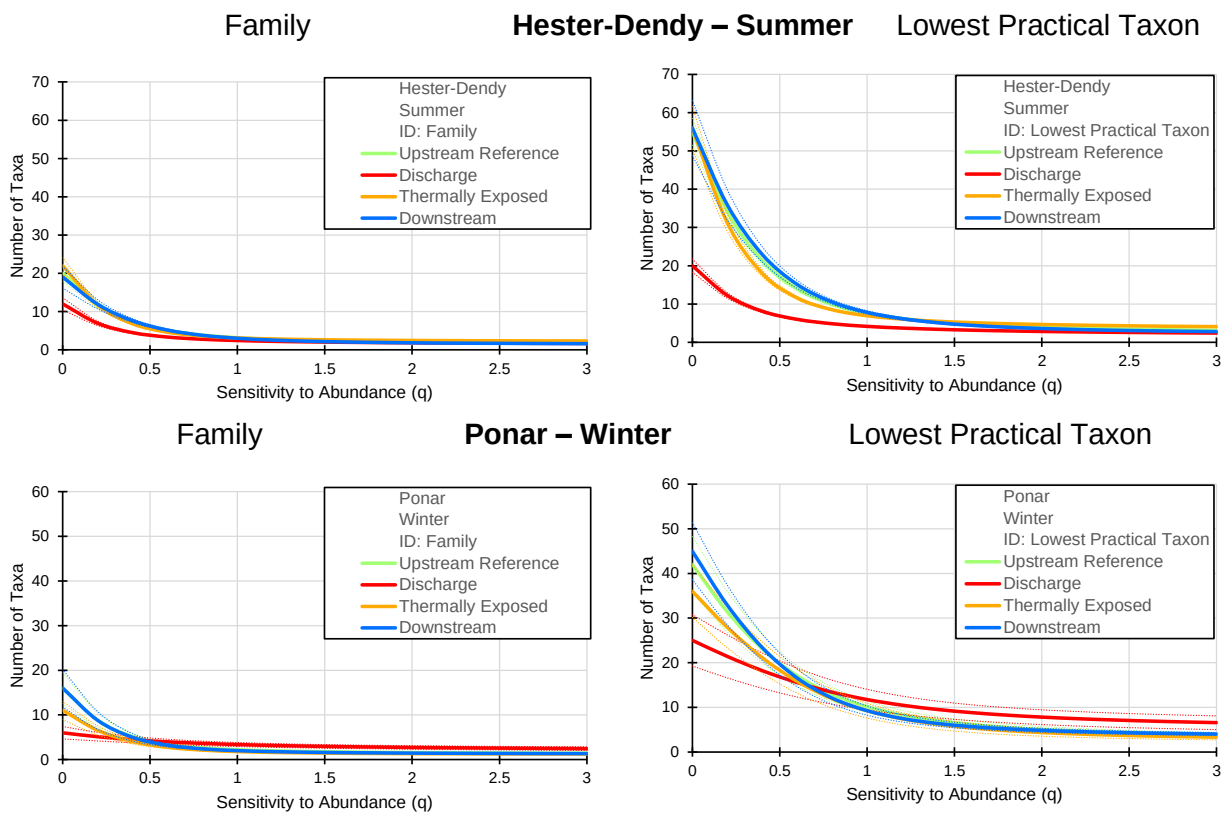


Figure 5-1 Diversity profiles of macrobenthos sampled at the LEC in 2017-2018 for Hester-Dendy sampling in summer (top) and Ponar sampling in winter (bottom). Level of taxonomic specificity is Family (left) and lowest practical taxon (right). Dashed lines for numerical profiles indicate +/- 2 standard deviations around estimate.

6. USE OF HESTER-DENDY MACROBENTHOS DATA COMBINED ACROSS DEPTHS

The following figures demonstrate the relative similarity between mean density among the mid-depth and bottom macrobenthic collecitons on a seasonal basis. Figures are also presented that illustrate the relative similarity among the dominant taxonomic orders. Additionally, Attachment A provides more detail regarding the taxonomic composition and the relative similarity between these two groups of macrobenthic data. Results in Figure 6-1 and Figure 6-2 indicate that a high degree of similarity among data collections from the mid-depth and the benthic H-D macrobenthic samples, thereby supporting the aggregation of these data sets as part of the thermal demonstration analysis.

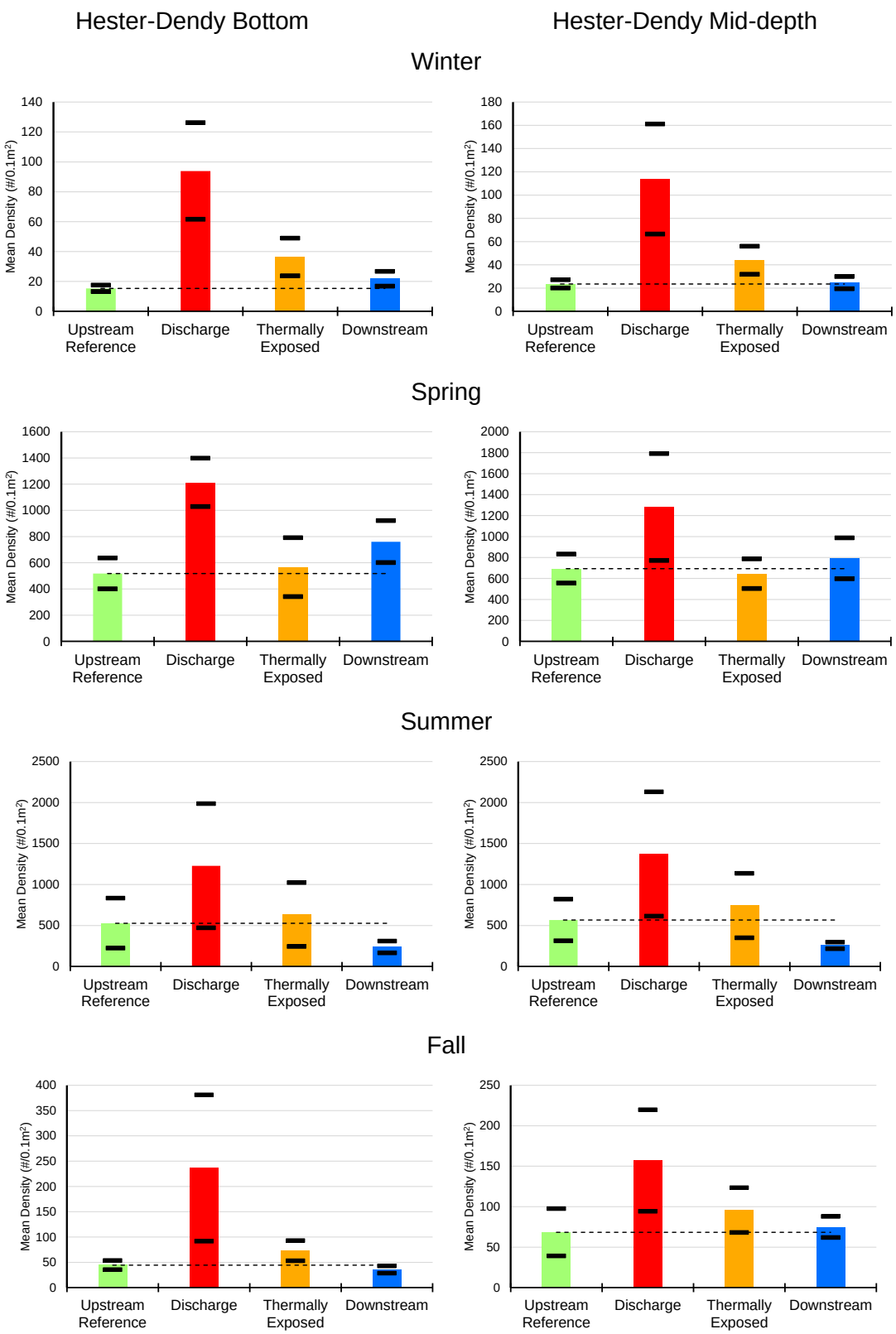


Figure 6-1 Mean density (#/0.1m²) of Hester-Dendy sampling of macrobenthos at the LEC in 2017-2018 for each season, and zone. Bottom and mid-depth samples shown separately. Back bars indicate +/- 1 standard error from mean.

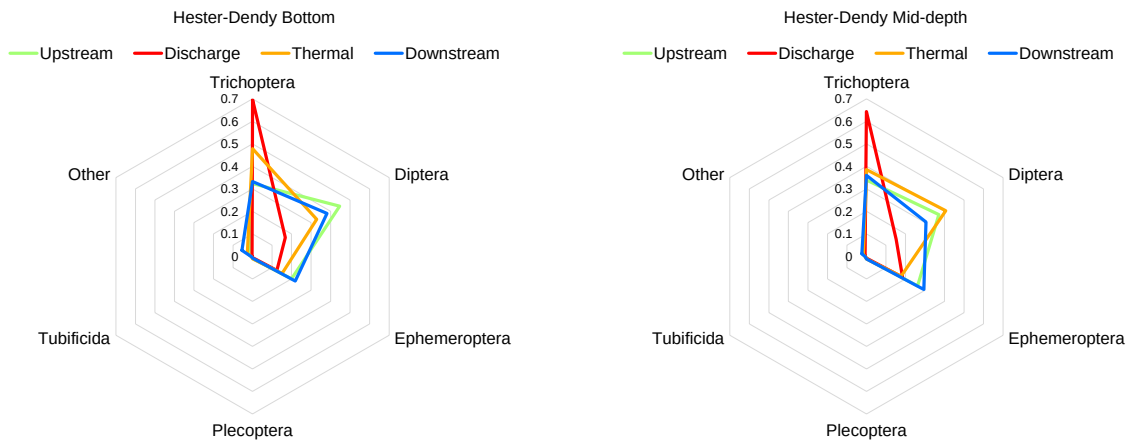


Figure 6-2 Contribution of major orders to the macrobenthos sampled by Hester-Dendy samplers on the bottom (left) and at mid-depth (right).

7. BIOTIC INDEX

The Biotic Index (BI) of mid-depth and bottom-depth H-D samplers was also similar among each of the sampling zones during each season (see Attachment A, Table A-7). While slightly lower BI values were observed in the spring for each of the sampling zones, the BI values were relatively consistent, ranging from 4.22 in the discharge zone in spring to 5.51 for the upstream reference zone in summer (Figure 7-1, Table A-7). Overall, no statistically significant differences were observed among BI values for mid-depth and bottom-depth H-D samplers (t-stat = -0.47, df = 30, p-value = 0.64).

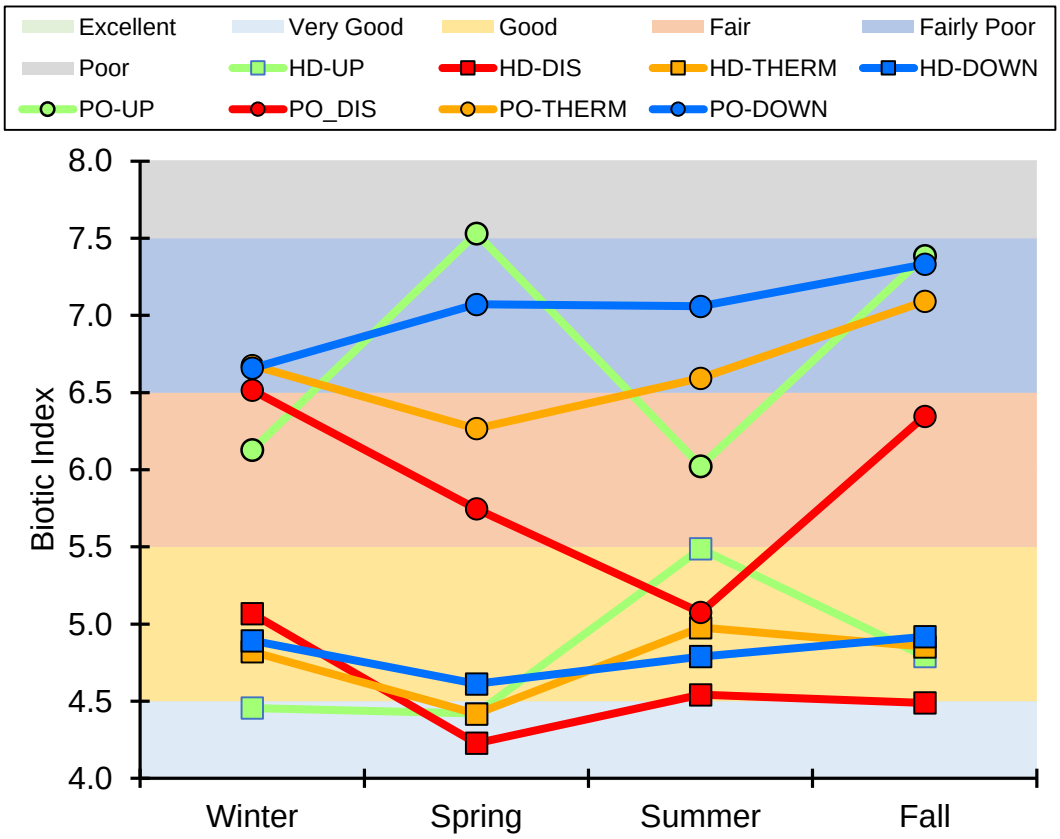


Figure 7-1 Biotic index for Hester-Dendy (squares) and Ponar (circles) sampling at LEC 2017-2018, by season and zone

8. BENTHIC INVERTEBRATE SAMPLE PROCESSING AND QA/QC

Benthic Macroinvertebrate Sample Processing

Standard ponar dredge samples were sieved in the field using a 0.5-mm mesh bucket sieve. The remaining organisms, detritus, debris, and sediments from the sieve bucket were carefully removed from the sieve and placed into a sample container and preserved in 10 percent formalin solution with Rose Bengal stain.

Hester-Dendy samplers were retrieved and placed in individual sample containers containing 10 percent formalin solution with Rose Bengal stain and transported back to Wood's Ecology Laboratory for processing. In the laboratory, sampler plates were removed and carefully scraped to remove all organisms. Each sample container was also sieved using a No. 35 (0.5- mm mesh) sieve to collect any organisms dislodged during transport.

All ponar and H-D samples were returned to Wood's Ecology Laboratory and processed according to procedures set forth for Laboratory Sample Processing in the "*Standard Operating Procedures for the Ameren Missouri Labadie Energy Center 316(a) Program Field Sampling and Analysis*" (AmecFW 2018).

Invertebrates were sorted following the same sorting procedures as ichthyoplankton except invertebrates were split into three different vials to facilitate the identification process. The three vials contained the following taxonomic "processing groups": (1) Oligochaeta; (2) Chironomidae; and (3) other taxa (e.g., crustaceans, other insects, mollusks). Contents of each sample were thoroughly rinsed into a No. 35 size sieve having 500-µm mesh. All invertebrates were sorted from the sample using a 10X magnifying lamp and submitted for taxonomic analysis. If H-D and Ponar samples contained a large number of specimens then samples were split using a Folsom plankton splitter. Sub-samples were then processed until a minimum of 200 specimens were found. Counts for individual sub-samples were maintained in the event that multiple sub-samples were required to reach a total of 200 specimens or in the event that an initial sub-sample containing more than 200 specimens was split a second time. The identifications of specimens in the sub-sample that contained a minimum of 200 specimens was multiplied by the appropriate split factor (2^x, where x = the number of times the sample was split) to obtain the total number of individuals in the sample. The remainder of the sub-samples were also examined for the presence of potential large and rare taxa. These specimens, if present, were not included in the split factor calculation.

All taxonomic identifications were done using stereoscopes with a polarized light set-up. For organisms mounted on slides (midges and worms) a compound microscope was used with phase contrast. If the numbers of organisms in samples were high from the sorting process (> 400 organisms) appropriate actions were taken to split the sample. A target of 200 (- 10 percent) identified organisms was established across all taxonomic processing groups for the entire sample. If a sample was dominated by Oligochaeta or Chironomidae (> 100 organisms in each group) appropriate actions were taken to split the individual vials. To ensure that the target number of identified organisms was achieved, the Laboratory Manager or their designee verified that the total count was achieved across all taxonomic processing groups (i.e., Others, chironomids, oligochaetes). Based on this review the Laboratory Manager or their designee allowed the splitting of discrete taxonomic processing groups such that the sum of all organisms identified from all groups achieved the target value. Prior to identification, midges and worms were mounted on slides using PVA or CMCP-10, depending on availability. All identifications were made to the lowest practical taxonomic level, usually genus or species. Damaged or partial specimens were counted as part of the sample, using the convention of counting heads or bodies, ensuring an individual was not counted twice. Macroinvertebrate exuviae were not counted. A reference collection of each taxon was maintained.

Quality Assurance/Quality Control

A detailed description of the Quality Assurance Project Plan (QAPP) that addresses quality assurance and quality control (QA/QC) requirements for the biological monitoring program and environmental measurements and information that was collected can be found in the "*Quality Assurance Project Plan for the Ameren Labadie Energy Center 316(a) Program*" (AmecFW 2016).

The SOP and QAAP were prepared prior to the start of sampling and were followed throughout the study to ensure that the data generated met specified quality standards that include precision, accuracy, completeness, representativeness, and comparability. All project staff were highly qualified for their tasks and trained specifically for adherence to the SOPs and any additional aspects of the program, such as equipment operation, site security, and safety procedures as described in the Health and Safety Plan (HASP) (AmecFW 2017). In addition, periodic auditing of data collection activities performed in the field and laboratory were conducted by senior personnel from Wood and ASA to ensure that the protocols and procedures were being followed correctly. Systematic QC procedures were also instituted to verify recorded data. The primary areas where these QC procedures were employed was during calibration of instruments and for sample processing (e.g., sample sorting, species identification, and length measurements). A Continuous Sampling Plan, Type-1 (CSP-1) was implemented under these procedures that had a specified average outgoing quality limit (AOQL) of 5 percent, which represents the maximum fraction of all items (e.g., taxonomic identifications, measurements) or lots (e.g., whole samples) that could be defective as a worst case (i.e., no more than 5 percent of samples could fail to meet acceptance criteria). Samples that did not achieve the specified 95 percent acceptance criteria were rejected and reprocessed according to prescribed CSP-1 procedures. A 10 percent identification check was followed for the QA/QC assessment of macroinvertebrate specimen identification. Ten percent of samples that were identified by each taxonomist were processed for a QA/QC check by a second qualified taxonomist. Subsets of ten samples were designated for the QA/QC check, with one of the ten samples randomly picked to be the QA/QC sample. The original taxonomist must correctly identify 95 percent of the organisms comprising the sample in order to pass the QA/QC check. If a taxonomist fails a QC inspection, then the remaining samples within that subset of ten samples will be re-examined by the original taxonomist and also undergo another QA/QC check by a second qualified taxonomist. If these samples continue to fail inspection, then previous samples identified by the original taxonomist will undergo QC checks until 95 percent accuracy is achieved. A reference collection of voucher specimens was also maintained and independently verified by another taxonomist, with outside verification by a third party as needed. Any rare specimens or specimens of threatened or endangered species required additional verification and were sent to an outside recognized taxonomic expert for confirmation.

Data verification and validation of field data was conducted by qualified biologists (e.g., QA manager or field/lab supervisors) during the course of the project to ensure that the resulting data was suitable for use as intended. Project records, including field sampling logs, raw data sheets, sample COC forms and instrument calibration logs, were reviewed to verify that data were collected according to the QAPP. Data was validated first by a review of datasheets and data files to find whether data were incomplete or appeared to be inappropriate or out of a reasonable range of values. The field data were initially entered into a project developed Access database and were reviewed by a second individual for accuracy and completeness. Data entry into the database underwent a 100 percent visual QC comparison to the data on the corresponding data sheets. Finally, data files were subjected to error checking programs to detect outlying values either to investigate further or to eliminate if shown to be spurious. This investigation required tracing the data to raw data sheets and consulting with field or lab personnel who recorded the data. All raw data sheets, log books, and data files were maintained for future reference. All

computer files were backed up on a daily basis while any data entry or editing procedures were ongoing. Reports were generated from the database and/or from database information exported into Excel for reporting or calculation/statistical purposes. The data reports generated from the database were checked at a 20 percent frequency to ensure that the programs were performing correctly. Similarly, statistical analysis performed on the data from the database were checked by verification of calculations to ensure validity of the analysis findings. All electronic files (data, database, reports, etc.) were stored on the office local area network under the project number in an appropriately named subdirectory. Original field logbooks and any additional raw data were maintained in the project files located in the office central files under the project number.

References

Amec Foster Wheeler Environment & Infrastructure, Inc. (AmecFW). 2016. Quality Assurance Project Plan for the Ameren Missouri Labadie Energy Center 316(a) Program. Prepared for Ameren Missouri, St. Louis, MO. Prepared by AmecFW. August 2016.

Amec Foster Wheeler Environment & Infrastructure, Inc. (AmecFW). 2017. Health and Safety Plan for the Ameren Labadie 316(a) Program. Prepared for Ameren Missouri, St. Louis, MO. Prepared by AmecFW. January 2017.

Amec Foster Wheeler Environment & Infrastructure, Inc. (AmecFW). 2018. Standard Operating Procedure for the Ameren Missouri Labadie Energy Center 316(a) Program Field Sampling and Analysis. Prepared for Ameren Missouri St. Louis, MO. Prepared by AmecFW. April 2018. Revision 3.

9. SEDIMENT GRAIN SIZE

In conjunction with the response to MDNR Comment 29.a, qualitative sediment characterization (percent abundance of particle types) of individual macroinvertebrate samples collected by ponar grab as per the study plan are included below.

Labadie Energy Center
316(a) Thermal Demonstration

Sampling Method: Ponar

Sample ID	Date	Total Effort	Surface Temp	Bottom Temp	Surface DO	Bottom DO	Surface Turbidity	Bottom Turbidity	Depth	Grain Size
LAB-PN-1-IWD-0-01	3/28/2107	0.156	12.7	12.4	10.4	9.6	32.3	50.6	4	80% fine silt, 20% clay
LAB-PN-1-IWD-0-02	6/27/2017	0.156	25.5	25.5	5.94	5.71	171	178		30% fine silt, 55% medium silt, 10% fine sand, 5% clay
LAB-PN-1-IWD-0-03	9/19/2017	0.156	24.3	24	9.7	9	24	48.2		95% fine sand, 4% medium snad, 1% clay
LAB-PN-1-IWD-0-04	11/14/2017	0.156	8.5	8.3	14.01	13.8	13.01	20.1		5% clay, 25% fine silt, 70% medium silt
LAB-PN-1-IWD-0-05	3/13/2018	0.156	5.6	5.5	11.09	10.98	98.9	119	3.5	60% clay, 20% fine silt, 20% medium silt
LAB-PN-1-IWD-0-06	6/4/2018	0.156	24.8	24.8	6.85	6.75	68.3	66.7	4	15% fine sand, 40% medium silt, 45% clay
LAB-PN-1-IWD-0-07	8/29/2018	0.156	26	26.2	7.21	6.74	227	264	3	10% clay, 90% fine silt
LAB-PN-1-IWD-0-08	12/10/2018	0.156	1.7	1.7	15.83	15.49	308	323	4	50% fine sand, 40% fine silt, 10% clay
LAB-PN-1-OLD-0-01	3/28/2017	0.156	12.4	12.5	10.4	9.9	47.7	48.1	5	5% fine sand, 35% clay, 60% medium silt
LAB-PN-1-OLD-0-02	6/27/2017	0.156	25.3	25.3	6.51	6.49	195	204		80% clay, 19% fine silt, 1% fine sand
LAB-PN-1-OLD-0-03	9/19/2017	0.156	24.1	24.1	9.2	8.64	24.1	35.2		45% fine sand, 45% silt, 10% gravel
LAB-PN-1-OLD-0-04	11/14/2017	0.156	8.2	8.2	14.04	14.1	23.5	26.3		2% gravel, 3% course sand, 30% clay, 65% fine silt
LAB-PN-1-OLD-0-05	3/13/2018	0.156	5.5	5.5	11.46	11.07	77.8	72.5	4.5	5% clay, 5% coasre gravel, 20% coarse sand, 70% fine silt
LAB-PN-1-OLD-0-06	6/4/2018	0.156	24.6	24.6	6.68	6.57	66.9	69.6	2.5	30% fine silt, 70% clay
LAB-PN-1-OLD-0-07	8/29/2018	0.156	26.2	26.3	6.8	6.75	165	220	3	15% fine sand, 15% clay, 70% fine silt
LAB-PN-1-OLD-0-08	12/10/2018	0.156	1.7	1.7	15.65	15.46	330	312	5	60% clay, 30% medium silt, 10% fine sand
LAB-PN-1-CXLD-0-01	3/28/2017	0.156	12.5	10.8	10.4	8.8	40.1	53.6	6	1% medium sand, 60% clay, 39% fine silt
LAB-PN-1-CXLD-0-02	6/27/2017	0.156	25.4	25.4	5.72	5.98	182	210		60% clay, 38% fine silt, 2% fine sand
LAB-PN-1-CXLD-0-03	9/19/2017	0.156	24.2	24.1	9.51	8.96	35.5	123		60% clay, 30% fine silt, 10% fine sand
LAB-PN-1-CXLD-0-04	11/14/2017	0.156	8.2	8.4	12.9	12.9	20.1	24.9		20% clay, 5% fine silt, 75% medium silt
LAB-PN-1-CXLD-0-05	3/13/2018	0.156	5.6	5.5	11.28	10.28	88.6	100	3.5	40% clay, 30% fine silt, 30% silt
LAB-PN-1-CXLD-0-06	6/4/2018	0.156	24.7	24.7	6.85	6.68	66.4	72.9	3	20% fine sand, 15% fine silt, 65% clay
LAB-PN-1-CXLD-0-07	8/29/2018	0.156	26.2	26.2	7.08	6.63	116	187	3	5% find sand, 25% clay, 70% fine silt
LAB-PN-1-CXLD-0-08	12/10/2018	0.156	1.7	1.7	15.77	15.41	318	310	4	40% clay, 20% fine sand, 40% fine silt
LAB-PN-2-DIS-0-01	3/28/2017	0.156	18.9	18.8	10.3	10.1	60.6	58.4	6	20% medium silt, 80% clay
LAB-PN-2-DIS-0-02	6/27/2017	0.156	34.1	34	5.32	5.12	286	252		10% clay, 5% fine silt, 84% medium silt, 1% fine sand
LAB-PN-2-DIS-0-03	9/19/2017	0.156	33	32.9	9.7	9.68	42.5	44.9		80% medium silt, 20% clay
LAB-PN-2-DIS-0-04	11/14/2017	0.156	23	22.4	11.6	11.8	29.7	31.1		40% clay, 60% medium lilt
LAB-PN-2-DIS-0-05	3/13/2018	0.156	19.6	19.6	9.36	9.36	137	137	3	2% fine sand, 58% medium silt, 40% clay
LAB-PN-2-DIS-0-06	6/4/2018	0.156	32.8	32.7	6.21	6.19	77.1	77	2.5	40% clay, 60% medium silt
LAB-PN-2-DIS-0-07	8/29/2018	0.156	37	36.9	7.09	7.07	270	291	2	70% clay, 30% fine silt
LAB-PN-2-DIS-0-08	12/10/2018	0.156	16.2	16.2	13.98	12.82	315	333	5	60% fine sand, 35% fine silt, 5% clay

Sample ID	Date	Total Effort	Surface Temp	Bottom Temp	Surface DO	Bottom DO	Surface Turbidity	Bottom Turbidity	Depth	Grain Size
LAB-PN-3-IWD-0-02	6/28/2017	0.156	26.4	26.4	5.99	5.61	168	190		80% clay, 19% fine silt, 1% fine sand
LAB-PN-3-IWD-0-03	9/20/2017	0.156	25.6	25.5	9.21	9.02	25.6	39		50% silt, 40% clay, 10% fine sand
LAB-PN-3-IWD-0-04	11/15/2017	0.156	11	10.9	13.5	13.5	18.9	22.1		3% fine sand, 27% clay, 70% fine silt
LAB-PN-3-IWD-0-05	3/14/2018	0.156	7.8	7.9	10.74	10.59	146	172	3.5	85% clay, 1% fine sand, 14% fine silt
LAB-PN-3-IWD-0-06	6/5/2018	0.156	26.1	26	7.05	6.85	80.8	89.9	2.5	20% clay, 80% fine silt
LAB-PN-3-IWD-0-07	8/30/2018	0.156	27.4	27.4	7.05	6.88	176	212	2	10% clay, 25% fine sand, 65% fine silt
LAB-PN-3-IWD-0-08	12/11/2018	0.156	2.7	2.7	17.32	15.49	238	244	4	40% clay, 55% fine silt, 5% fine sand
LAB-PN-3-OLD-0-01	3/28/2017	0.156	14.6	14.6	10.4	10.4	52.5	51.7	4	10% coarse sand, 1% pebbles, 60% clay, 29% medium silt
LAB-PN-3-OLD-0-02	6/27/2017	0.156	27.3	27.3	5.8	5.5	265	246		5% clay, 55% medium silt, 40% fine sand
LAB-PN-3-OLD-0-03	9/19/2017	0.156	26.1	26	9.73	9.68	37.9	39.8		84% silt, 10% medium sand, 5% coarse sand, 1% clay
LAB-PN-3-OLD-0-04	11/14/2017	0.156	11.4	11.5	13.8	13.7	27.9	28.7		10% clay, 3% fine sand, 20% medium silt, 67% fine silt
LAB-PN-3-OLD-0-05	3/13/2018	0.156	9.5	9.5	10.92	10.55	115	128	3.5	80% clay, 20% medium silt
LAB-PN-3-OLD-0-06	6/4/2018	0.156	26.9	26.9	6.8	6.72	70.3	78.3	3.5	30% medium silt, 70% clay
LAB-PN-3-OLD-0-07	8/29/2018	0.156	28.1	28.1	7.28	7.13	271	288	2	15% clay, 85% fine silt
LAB-PN-3-OLD-0-08	12/10/2018	0.156	3.8	3.8	14.89	14.9	325	327	4	80% fine silt, 15% fine sand, 5% clay
LAB-PN-3-CXLD-0-01	3/28/2017	0.156	14.4	14.3	10.1	7.7	40.3	54.6	4	40% clay, 60% fine silt
LAB-PN-3-CXLD-0-02	6/27/2017	0.156	27.4	27.3	4.97	5.01	148	162		70% clay, 15% medium silt, 14% fine silt, 1% fine sand
LAB-PN-3-CXLD-0-03	9/19/2017	0.156	26.4	26.3	10.1	9.99	18.8	25.9		84% fine silt, 15% clay, 1% fine sand
LAB-PN-3-CXLD-0-04	11/14/2017	0.156	11	11	13.6	13.7	22.9	21.2		10% fine silt, 90% medium silt
LAB-PN-3-CXLD-0-05	3/14/2018	0.156	8.4	8.4	10.45	10.48	96.1	113	3.5	10% clay, 20% medium silt, 70% fine silt
LAB-PN-3-CXLD-0-06	6/4/2018	0.156	26.6	26.6	6.77	6.67	49	67	3	30% clay, 70% fine silt
LAB-PN-3-CXLD-0-07	8/29/2018	0.156	27.6	27.6	7.2	6.83	162	209	3	30% clay, 70% fine silt
LAB-PN-3-CXLD-0-08	12/10/2018	0.156	3	3	13.65	13.47	239	215	4	50% clay, 45% fine silt, 5% fine sand
LAB-PN-4-IWD-0-01	3/29/2017	0.156	13.6	13.6	10.4	10.3	59	59.8	4	80% fine silt, 20% clay
LAB-PN-4-IWD-0-02	6/28/2017	0.156	26.2	26.2	5.97	5.62	171	196		5% clay, 10% fine sand, 70% medium silt, 15% fine silt
LAB-PN-4-IWD-0-03	9/20/2017	0.156	26	25.7	10.41	10.28	21	37.4		99% silt, 1% clay
LAB-PN-4-IWD-0-04	11/15/2017	0.156	9.9	9.8	13.9	13.7	13.9	20.6		5% clay, 25% medium silt, 70% fine silt
LAB-PN-4-IWD-0-05	3/14/2018	0.156	7.2	6.9	10.92	10.77	116	111	3.5	50% clay, 50% fine silt
LAB-PN-4-IWD-0-06	6/5/2018	0.156	25.8	25.6	6.96	6.48	56.5	63.8	3	2% fine sand, 18% clay, 80% fine silt
LAB-PN-4-IWD-0-07	8/30/2018	0.156	26.9	26.9	6.93	6.62	147	172	2	20% fine sand, 80% fine silt
LAB-PN-4-IWD-0-08	12/11/2018	0.156	2.2	2.2	17.2	15.6	228	227	3	60% medium silt, 30% clay, 10% fine silt
LAB-PN-4-OLD-0-01	3/29/2017	0.156	13.6	13.6	10.2	9.9	54.6	56.1	4	60% silt, 25% clay, 10% sand, 5% fine/medium pebbles
LAB-PN-4-OLD-0-02	6/28/2017	0.156	26	26	5.45	5.28	161	175		85% clay, 14% fine silt, 1% sand
LAB-PN-4-OLD-0-03	9/20/2017	0.156	25.1	25	10.17	10.11	19.8	20.9		50% fine silt, 49% clay, 1% medium sand
LAB-PN-4-OLD-0-04	11/15/2017	0.156	9.9	9.9	13.8	13.6	14.4	17		5 % fine sand, 10% clay, 20% fine silt, 65% medium silt
LAB-PN-4-OLD-0-05	3/14/2018	0.156	7.1	7.1	10.87	10.74	182	186	2.5	60% clay, 40% fine silt
LAB-PN-4-OLD-0-06	6/5/2018	0.156	25.7	25.7	6.97	6.93	64.7	95.4	4	10% fine sand, 10% clay, 80% fine silt
LAB-PN-4-OLD-0-07	8/30/2018	0.156	27	27	7.14	6.75	162	211	3.5	15% fine sand, 85% fine silt
LAB-PN-4-OLD-0-08	12/11/2018	0.156	2.2	2.2	15.82	14.98	251	248	5	45% clay, 45% fine sand, 10% fine silt
LAB-PN-4-CXLD-0-01	3/29/2017	0.156	13.4	13.4	10.2	9.9	56	54.3	4	94% fine silt, 5% fine sand, 1% clay
LAB-PN-4-CXLD-0-02	6/28/2017	0.156	26.1	26	5.21	4.98	139	168		85% coarse silt, 5% fine sand, 9% fine silt, 1% clay
LAB-PN-4-CXLD-0-03	9/20/2017	0.156	25.4	25.2	10.01	9.89	23.5	29.6		69% medium silt, 20% fine silt, 10% fine sand, 1% clay

Sample ID	Date	Total Effort	Surface Temp	Bottom Temp	Surface DO	Bottom DO	Surface Turbidity	Bottom Turbidity	Depth	Grain Size
LAB-PN-4-CXLD-0-05	3/14/2018	0.156	7.1	7.1	10.94	10.84	123	151	2.5	40% clay, 60% fine silt
LAB-PN-4-CXLD-0-06	6/5/2018	0.156	25.7	25.7	6.7	6.83	53.2	74.9	2.5	5% fine sand, 15% clay, 80% fine silt
LAB-PN-4-CXLD-0-07	8/30/2018	0.156	27	27	7.15	6.78	149	188	4	10% fine sand, 40% fine silt, 50% clay
LAB-PN-4-CXLD-0-08	12/11/2018	0.156	2.2	2.2	16.95	16.03	239	245	3	90% fine sand, 10% fine silt

Units for Water Quality Measurements: Temperature (°C), Dissolved Oxygen (mg/L), Turbidity (NTU), Depth (ft)
Total effort for Ponar samples were calculated in area sampled (m^2).

10. TOLERANCE

In MDNR Comment 9.d., data on heat-tolerant and heat-intolerant fish species were requested. Table 2-1Table 10-1 provides the data.

Table 10-1 Counts and weights of heat-intolerant, heat-tolerant, and heat-neutral (not in tolerant or intolerant categories) fishes for each combination of gear, zone, and season. Tolerant and intolerant species are listed individually. Neutral species are combined.

Gear	Zone	Season	Heat-Tolerance	Taxon	Total Count	Total Weight (kg)
BS	1	Winter	Neutral		660	0.2161
BS	1	Winter	Tolerant	Emerald shiner	76	0.0757
BS	1	Winter	Tolerant	Gizzard shad	5	0.0165
BS	1	Winter	Tolerant	River carpsucker	4	0.0133
BS	1	Spring	Intolerant	Goldeye	12	0.0114
BS	1	Spring	Intolerant	Sauger x Walleye	1	0.0005
BS	1	Spring	Neutral		193	0.3038
BS	1	Spring	Tolerant	Channel catfish	2	0.012
BS	1	Spring	Tolerant	Emerald shiner	34	0.0514
BS	1	Spring	Tolerant	Gizzard shad	7	0.0037
BS	1	Summer	Neutral		253	0.1022
BS	1	Summer	Tolerant	Emerald shiner	113	0.0539
BS	1	Summer	Tolerant	Gizzard shad	78	0.2219
BS	1	Summer	Tolerant	Longnose gar	1	0.542
BS	1	Fall	Neutral		3496	0.3696
BS	1	Fall	Tolerant	Emerald shiner	195	0.2331
BS	1	Fall	Tolerant	Gizzard shad	80	0.3421
BS	1	Fall	Tolerant	Longnose gar	1	0.675
BS	1	Fall	Tolerant	Silver carp	2	0.0021
BS	1	Fall	Tolerant	Smallmouth buffalo	8	0.0085
BS	3	Winter	Neutral		775	0.1404
BS	3	Winter	Tolerant	Emerald shiner	68	0.1114
BS	3	Winter	Tolerant	Gizzard shad	5	0.0244
BS	3	Spring	Intolerant	Goldeye	6	0.0049
BS	3	Spring	Intolerant	Sauger x Walleye	2	0.0021
BS	3	Spring	Neutral		184	0.1538
BS	3	Spring	Tolerant	Buffalofish	2	0.0007
BS	3	Spring	Tolerant	Channel catfish	11	0.0252
BS	3	Spring	Tolerant	Emerald shiner	58	0.101
BS	3	Spring	Tolerant	Flathead catfish	1	0.179
BS	3	Spring	Tolerant	Gizzard shad	40	0.0496
BS	3	Spring	Tolerant	Smallmouth buffalo	2	0.0049
BS	3	Summer	Intolerant	Goldeye	4	0.0175
BS	3	Summer	Neutral		338	0.1661

Gear	Zone	Season	Heat-Tolerance	Taxon	Total Count	Total Weight (kg)
BS	3	Summer	Tolerant	Channel catfish	1	0.0009
BS	3	Summer	Tolerant	Emerald shiner	290	0.161
BS	3	Summer	Tolerant	Gizzard shad	266	0.3316
BS	3	Summer	Tolerant	Smallmouth buffalo	1	0.0001
BS	3	Fall	Neutral		418	0.2576
BS	3	Fall	Tolerant	Channel catfish	4	0.0103
BS	3	Fall	Tolerant	Emerald shiner	250	0.2268
BS	3	Fall	Tolerant	Gizzard shad	37	0.2429
BS	3	Fall	Tolerant	Silver carp	3	0.0039
BS	4	Winter	Neutral		255	0.1016
BS	4	Winter	Tolerant	Emerald shiner	8	0.0061
BS	4	Winter	Tolerant	Gizzard shad	10	0.0418
BS	4	Spring	Intolerant	Goldeye	15	0.007
BS	4	Spring	Intolerant	Sauger x Walleye	10	0.0095
BS	4	Spring	Neutral		912	0.3748
BS	4	Spring	Tolerant	Buffalofish	1	0.0001
BS	4	Spring	Tolerant	Channel catfish	5	0.0039
BS	4	Spring	Tolerant	Emerald shiner	24	0.0288
BS	4	Spring	Tolerant	Gizzard shad	28	0.0703
BS	4	Spring	Tolerant	River carpsucker	2	1.181
BS	4	Spring	Tolerant	Smallmouth buffalo	1	0.0055
BS	4	Summer	Neutral		567	0.1447
BS	4	Summer	Tolerant	Buffalofish	3	0.0003
BS	4	Summer	Tolerant	Channel catfish	4	0.0021
BS	4	Summer	Tolerant	Emerald shiner	365	0.0844
BS	4	Summer	Tolerant	Gizzard shad	503	0.3865
BS	4	Summer	Tolerant	River carpsucker	1	0.0013
BS	4	Summer	Tolerant	Silver carp	11	0.0026
BS	4	Summer	Tolerant	Smallmouth buffalo	9	0.0041
BS	4	Fall	Neutral		813	0.265
BS	4	Fall	Tolerant	Channel catfish	2	0.017
BS	4	Fall	Tolerant	Emerald shiner	65	0.0599
BS	4	Fall	Tolerant	Gizzard shad	15	0.0843
BS	4	Fall	Tolerant	Silver carp	4	0.0046
BS	4	Fall	Tolerant	Smallmouth buffalo	3	0.0045
EF	1	Winter	Intolerant	Goldeye	10	0.333
EF	1	Winter	Intolerant	Sauger	1	0.7
EF	1	Winter	Intolerant	Walleye	2	3.328
EF	1	Winter	Intolerant	White crappie	1	0.48
EF	1	Winter	Neutral		175	156.4952

Gear	Zone	Season	Heat-Tolerance	Taxon	Total Count	Total Weight (kg)
EF	1	Winter	Tolerant	Bigmouth buffalo	1	1.77
EF	1	Winter	Tolerant	Channel catfish	5	2.76
EF	1	Winter	Tolerant	Emerald shiner	16	0.0274
EF	1	Winter	Tolerant	Gizzard shad	35	1.884
EF	1	Winter	Tolerant	Longnose gar	1	0.39
EF	1	Winter	Tolerant	River carpsucker	17	20.858
EF	1	Winter	Tolerant	Shortnose gar	1	0.81
EF	1	Winter	Tolerant	Silver carp	39	68.917
EF	1	Winter	Tolerant	Smallmouth buffalo	15	46.258
EF	1	Spring	Intolerant	Goldeye	5	0.0634
EF	1	Spring	Intolerant	White crappie	1	0.31
EF	1	Spring	Neutral		177	141.9878
EF	1	Spring	Tolerant	Bighead carp	2	1.31
EF	1	Spring	Tolerant	Channel catfish	9	4.921
EF	1	Spring	Tolerant	Emerald shiner	3	0.003
EF	1	Spring	Tolerant	Flathead catfish	11	2.678
EF	1	Spring	Tolerant	Gizzard shad	19	1.253
EF	1	Spring	Tolerant	Longnose gar	28	20.287
EF	1	Spring	Tolerant	River carpsucker	33	37.043
EF	1	Spring	Tolerant	Shortnose gar	22	14.3152
EF	1	Spring	Tolerant	Silver carp	3	5.717
EF	1	Spring	Tolerant	Smallmouth buffalo	14	28.677
EF	1	Summer	Intolerant	Goldeye	26	0.4158
EF	1	Summer	Intolerant	Walleye	2	0.0119
EF	1	Summer	Intolerant	White crappie	1	0.102
EF	1	Summer	Neutral		69	57.7442
EF	1	Summer	Tolerant	Channel catfish	24	4.1271
EF	1	Summer	Tolerant	Emerald shiner	37	0.037
EF	1	Summer	Tolerant	Flathead catfish	16	1.312
EF	1	Summer	Tolerant	Gizzard shad	131	2.7886
EF	1	Summer	Tolerant	Longnose gar	27	16.221
EF	1	Summer	Tolerant	River carpsucker	6	4.128
EF	1	Summer	Tolerant	Shortnose gar	18	11.744
EF	1	Summer	Tolerant	Silver carp	5	8.253
EF	1	Summer	Tolerant	Smallmouth buffalo	6	10.41
EF	1	Fall	Intolerant	Goldeye	11	0.573
EF	1	Fall	Intolerant	Mooneye	1	0.018
EF	1	Fall	Neutral		77	68.658
EF	1	Fall	Tolerant	Bigmouth buffalo	1	3.52
EF	1	Fall	Tolerant	Channel catfish	5	2.502

Gear	Zone	Season	Heat-Tolerance	Taxon	Total Count	Total Weight (kg)
EF	1	Fall	Tolerant	Emerald shiner	3	0.008
EF	1	Fall	Tolerant	Flathead catfish	1	0.2
EF	1	Fall	Tolerant	Gizzard shad	7	0.19
EF	1	Fall	Tolerant	Longnose gar	6	3.62
EF	1	Fall	Tolerant	River carpsucker	4	6.534
EF	1	Fall	Tolerant	Shortnose gar	9	7.53
EF	1	Fall	Tolerant	Silver carp	8	11.669
EF	1	Fall	Tolerant	Smallmouth buffalo	9	31.703
EF	2	Winter	Intolerant	Goldeye	5	1.445
EF	2	Winter	Intolerant	Sauger	1	0.0743
EF	2	Winter	Neutral		432	314.5466
EF	2	Winter	Tolerant	Channel catfish	12	13.9861
EF	2	Winter	Tolerant	Emerald shiner	10	0.0208
EF	2	Winter	Tolerant	Flathead catfish	5	14.691
EF	2	Winter	Tolerant	Gizzard shad	37	16.575
EF	2	Winter	Tolerant	Longnose gar	1	0.621
EF	2	Winter	Tolerant	River carpsucker	41	41.092
EF	2	Winter	Tolerant	Silver carp	4	7.316
EF	2	Winter	Tolerant	Smallmouth buffalo	10	39.43
EF	2	Spring	Neutral		68	130.1247
EF	2	Spring	Tolerant	Bighead carp	2	5.922
EF	2	Spring	Tolerant	Channel catfish	3	2.472
EF	2	Spring	Tolerant	Emerald shiner	21	0.024
EF	2	Spring	Tolerant	Flathead catfish	3	19.09
EF	2	Spring	Tolerant	Gizzard shad	11	4.203
EF	2	Spring	Tolerant	Longnose gar	25	16.94
EF	2	Spring	Tolerant	River carpsucker	7	6.385
EF	2	Spring	Tolerant	Shortnose gar	24	16.977
EF	2	Spring	Tolerant	Silver carp	8	24.827
EF	2	Spring	Tolerant	Smallmouth buffalo	5	9.001
EF	2	Summer	Intolerant	Goldeye	5	0.183
EF	2	Summer	Neutral		18	12.734
EF	2	Summer	Tolerant	Bighead carp	2	8.521
EF	2	Summer	Tolerant	Channel catfish	2	0.078
EF	2	Summer	Tolerant	Emerald shiner	12	0.014
EF	2	Summer	Tolerant	Flathead catfish	12	3.064
EF	2	Summer	Tolerant	Gizzard shad	5	0.01
EF	2	Summer	Tolerant	Longnose gar	5	3.411
EF	2	Summer	Tolerant	Shortnose gar	4	1.826
EF	2	Summer	Tolerant	Smallmouth buffalo	2	2.21

Gear	Zone	Season	Heat-Tolerance	Taxon	Total Count	Total Weight (kg)
EF	2	Fall	Intolerant	Goldeye	1	0.02
EF	2	Fall	Neutral		93	358.461
EF	2	Fall	Tolerant	Channel catfish	2	4.5
EF	2	Fall	Tolerant	Emerald shiner	16	0.035
EF	2	Fall	Tolerant	Flathead catfish	2	21.1
EF	2	Fall	Tolerant	Gizzard shad	3	1.65
EF	2	Fall	Tolerant	Longnose gar	4	2.79
EF	2	Fall	Tolerant	River carpsucker	19	19.47
EF	2	Fall	Tolerant	Shortnose gar	3	1.86
EF	2	Fall	Tolerant	Silver carp	1	1.52
EF	2	Fall	Tolerant	Smallmouth buffalo	2	7.02
EF	3	Winter	Intolerant	Goldeye	14	1.38
EF	3	Winter	Intolerant	Sauger	1	0.733
EF	3	Winter	Intolerant	Sauger x Walleye	1	0.1346
EF	3	Winter	Neutral		220	123.0555
EF	3	Winter	Tolerant	Bigmouth buffalo	1	1.599
EF	3	Winter	Tolerant	Channel catfish	7	2.85
EF	3	Winter	Tolerant	Emerald shiner	137	0.262
EF	3	Winter	Tolerant	Gizzard shad	154	16.0258
EF	3	Winter	Tolerant	Longnose gar	7	7.353
EF	3	Winter	Tolerant	River carpsucker	50	54.0144
EF	3	Winter	Tolerant	Shortnose gar	4	2.232
EF	3	Winter	Tolerant	Silver carp	42	72.054
EF	3	Winter	Tolerant	Smallmouth buffalo	16	42.545
EF	3	Spring	Intolerant	White crappie	2	0.381
EF	3	Spring	Neutral		140	107.6723
EF	3	Spring	Tolerant	Bigmouth buffalo	4	11.494
EF	3	Spring	Tolerant	Channel catfish	8	7.078
EF	3	Spring	Tolerant	Emerald shiner	16	0.0277
EF	3	Spring	Tolerant	Flathead catfish	12	3.881
EF	3	Spring	Tolerant	Gizzard shad	26	3.8384
EF	3	Spring	Tolerant	Longnose gar	39	21.013
EF	3	Spring	Tolerant	River carpsucker	23	25.023
EF	3	Spring	Tolerant	Shortnose gar	20	13.175
EF	3	Spring	Tolerant	Silver carp	25	55.381
EF	3	Spring	Tolerant	Smallmouth buffalo	17	29.357
EF	3	Summer	Intolerant	Goldeye	11	0.0931
EF	3	Summer	Intolerant	Mooneye	4	0.013
EF	3	Summer	Neutral		59	82.2826
EF	3	Summer	Tolerant	Bigmouth buffalo	1	4.422

Gear	Zone	Season	Heat-Tolerance	Taxon	Total Count	Total Weight (kg)
EF	3	Summer	Tolerant	Channel catfish	7	0.5334
EF	3	Summer	Tolerant	Emerald shiner	21	0.021
EF	3	Summer	Tolerant	Flathead catfish	23	18.3138
EF	3	Summer	Tolerant	Gizzard shad	82	0.2677
EF	3	Summer	Tolerant	Longnose gar	18	11.142
EF	3	Summer	Tolerant	River carpsucker	13	12.325
EF	3	Summer	Tolerant	Shortnose gar	18	11.921
EF	3	Summer	Tolerant	Silver carp	4	6.173
EF	3	Summer	Tolerant	Smallmouth buffalo	12	27.108
EF	3	Fall	Intolerant	Goldeye	16	0.637
EF	3	Fall	Neutral		96	152.14
EF	3	Fall	Tolerant	Bigmouth buffalo	1	5.69
EF	3	Fall	Tolerant	Channel catfish	3	1.455
EF	3	Fall	Tolerant	Emerald shiner	16	0.032
EF	3	Fall	Tolerant	Flathead catfish	5	0.662
EF	3	Fall	Tolerant	Gizzard shad	84	4.818
EF	3	Fall	Tolerant	Longnose gar	17	14.625
EF	3	Fall	Tolerant	River carpsucker	6	6.847
EF	3	Fall	Tolerant	Shortnose gar	33	22.5
EF	3	Fall	Tolerant	Silver carp	8	10.773
EF	3	Fall	Tolerant	Smallmouth buffalo	17	40.378
EF	4	Winter	Intolerant	Goldeye	4	0.223
EF	4	Winter	Intolerant	Walleye	1	0.372
EF	4	Winter	Intolerant	White crappie	1	0.1035
EF	4	Winter	Neutral		739	133.0696
EF	4	Winter	Tolerant	Bigmouth buffalo	1	1.437
EF	4	Winter	Tolerant	Channel catfish	1	4.63
EF	4	Winter	Tolerant	Emerald shiner	152	0.0428
EF	4	Winter	Tolerant	Flathead catfish	3	2.1
EF	4	Winter	Tolerant	Gizzard shad	128	2.4833
EF	4	Winter	Tolerant	Longnose gar	6	5.233
EF	4	Winter	Tolerant	River carpsucker	24	23.4284
EF	4	Winter	Tolerant	Shortnose gar	10	6.186
EF	4	Winter	Tolerant	Silver carp	61	56.95
EF	4	Winter	Tolerant	Smallmouth buffalo	9	21.314
EF	4	Spring	Intolerant	Goldeye	9	0.352
EF	4	Spring	Neutral		123	91.262
EF	4	Spring	Tolerant	Bigmouth buffalo	3	4.434
EF	4	Spring	Tolerant	Channel catfish	5	2.787
EF	4	Spring	Tolerant	Emerald shiner	10	0.0135

Gear	Zone	Season	Heat-Tolerance	Taxon	Total Count	Total Weight (kg)
EF	4	Spring	Tolerant	Flathead catfish	21	1.274
EF	4	Spring	Tolerant	Gizzard shad	21	1.415
EF	4	Spring	Tolerant	Longnose gar	23	14.321
EF	4	Spring	Tolerant	River carpsucker	22	23.967
EF	4	Spring	Tolerant	Shortnose gar	27	17.085
EF	4	Spring	Tolerant	Silver carp	19	42.155
EF	4	Spring	Tolerant	Smallmouth buffalo	4	15.795
EF	4	Summer	Intolerant	Goldeye	20	0.571
EF	4	Summer	Neutral		80	62.1898
EF	4	Summer	Tolerant	Channel catfish	10	3.902
EF	4	Summer	Tolerant	Emerald shiner	5	0.006
EF	4	Summer	Tolerant	Flathead catfish	29	2.067
EF	4	Summer	Tolerant	Gizzard shad	93	0.41
EF	4	Summer	Tolerant	Longnose gar	10	5.53
EF	4	Summer	Tolerant	River carpsucker	8	7.352
EF	4	Summer	Tolerant	Shortnose gar	13	9.21
EF	4	Summer	Tolerant	Silver carp	9	14.987
EF	4	Summer	Tolerant	Smallmouth buffalo	8	14.5
EF	4	Fall	Intolerant	Goldeye	10	0.729
EF	4	Fall	Intolerant	Mooneye	1	0.018
EF	4	Fall	Neutral		90	89.876
EF	4	Fall	Tolerant	Bigmouth buffalo	3	5.29
EF	4	Fall	Tolerant	Channel catfish	2	0.038
EF	4	Fall	Tolerant	Emerald shiner	5	0.0135
EF	4	Fall	Tolerant	Gizzard shad	105	3.213
EF	4	Fall	Tolerant	Longnose gar	11	7.48
EF	4	Fall	Tolerant	River carpsucker	12	13.702
EF	4	Fall	Tolerant	Shortnose gar	21	12.437
EF	4	Fall	Tolerant	Silver carp	8	16.22
EF	4	Fall	Tolerant	Smallmouth buffalo	14	29.57
HN	1	Winter	Intolerant	Sauger	1	0.59
HN	1	Winter	Neutral		25	35.455
HN	1	Winter	Tolerant	Channel catfish	1	0.4
HN	1	Winter	Tolerant	Silver carp	1	1.84
HN	1	Spring	Neutral		40	64.94
HN	1	Spring	Tolerant	River carpsucker	7	8.173
HN	1	Spring	Tolerant	Silver carp	2	4.8
HN	1	Spring	Tolerant	Smallmouth buffalo	2	4.45
HN	1	Summer	Neutral		23	36.492
HN	1	Summer	Tolerant	Bighead carp	1	3.922

Gear	Zone	Season	Heat-Tolerance	Taxon	Total Count	Total Weight (kg)
HN	1	Summer	Tolerant	Channel catfish	1	0.59
HN	1	Summer	Tolerant	Flathead catfish	3	6.94
HN	1	Summer	Tolerant	Longnose gar	2	3.82
HN	1	Summer	Tolerant	River carpsucker	3	3.27
HN	1	Summer	Tolerant	Smallmouth buffalo	9	22.69
HN	1	Fall	Intolerant	Goldeye	1	0.471
HN	1	Fall	Neutral		28	39.52
HN	1	Fall	Tolerant	Flathead catfish	1	3.43
HN	3	Winter	Intolerant	Goldeye	4	1.332
HN	3	Winter	Neutral		31	68.415
HN	3	Winter	Tolerant	Channel catfish	1	0.549
HN	3	Spring	Neutral		18	32.181
HN	3	Spring	Tolerant	Channel catfish	1	0.53
HN	3	Spring	Tolerant	Flathead catfish	4	14.82
HN	3	Spring	Tolerant	River carpsucker	1	1.203
HN	3	Spring	Tolerant	Silver carp	4	10.741
HN	3	Spring	Tolerant	Smallmouth buffalo	8	21.929
HN	3	Summer	Neutral		13	19.425
HN	3	Summer	Tolerant	Flathead catfish	1	2.25
HN	3	Summer	Tolerant	Longnose gar	3	8.12
HN	3	Summer	Tolerant	Smallmouth buffalo	4	8.96
HN	3	Fall	Intolerant	Goldeye	1	0.31
HN	3	Fall	Intolerant	Sauger x Walleye	1	0.6
HN	3	Fall	Neutral		13	21.998
HN	3	Fall	Tolerant	Bigmouth buffalo	2	5.178
HN	3	Fall	Tolerant	Flathead catfish	2	5.666
HN	3	Fall	Tolerant	River carpsucker	7	7.621
HN	3	Fall	Tolerant	Silver carp	1	2.261
HN	3	Fall	Tolerant	Smallmouth buffalo	7	16.73
HN	4	Winter	Intolerant	Goldeye	6	1.652
HN	4	Winter	Intolerant	Mooneye	1	0.22
HN	4	Winter	Intolerant	Sauger x Walleye	1	1.93
HN	4	Winter	Neutral		19	64.432
HN	4	Winter	Tolerant	Flathead catfish	1	1.008
HN	4	Winter	Tolerant	Gizzard shad	1	0.85
HN	4	Winter	Tolerant	River carpsucker	3	4.34
HN	4	Spring	Neutral		42	107.917
HN	4	Spring	Tolerant	Bighead carp	1	6.8
HN	4	Spring	Tolerant	Channel catfish	2	5.18
HN	4	Spring	Tolerant	Flathead catfish	2	4.614

Gear	Zone	Season	Heat-Tolerance	Taxon	Total Count	Total Weight (kg)
HN	4	Spring	Tolerant	Longnose gar	1	3.62
HN	4	Spring	Tolerant	River carpsucker	3	4.278
HN	4	Spring	Tolerant	Silver carp	1	1.65
HN	4	Spring	Tolerant	Smallmouth buffalo	5	13.926
HN	4	Summer	Neutral		16	38.793
HN	4	Summer	Tolerant	Bighead carp	1	11.42
HN	4	Summer	Tolerant	Flathead catfish	5	10.135
HN	4	Summer	Tolerant	Longnose gar	2	7.27
HN	4	Summer	Tolerant	River carpsucker	1	0.93
HN	4	Summer	Tolerant	Smallmouth buffalo	6	12.27
HN	4	Fall	Intolerant	Goldeye	6	1.744
HN	4	Fall	Neutral		25	34.127
HN	4	Fall	Tolerant	Channel catfish	1	1.07
HN	4	Fall	Tolerant	Flathead catfish	2	12.376
HN	4	Fall	Tolerant	River carpsucker	1	0.92
HN	4	Fall	Tolerant	Silver carp	3	5.53
HN	4	Fall	Tolerant	Smallmouth buffalo	1	3.188
MT	1	Winter	Neutral		192	3.3546
MT	1	Winter	Tolerant	Channel catfish	45	0.1758
MT	1	Winter	Tolerant	Gizzard shad	4	0.0338
MT	1	Winter	Tolerant	Shortnose gar	2	1.568
MT	1	Winter	Tolerant	Silver carp	4	4.881
MT	1	Spring	Intolerant	Goldeye	40	0.0054
MT	1	Spring	Intolerant	Mooneyes	1	0.0001
MT	1	Spring	Intolerant	Sauger x Walleye	7	0.0028
MT	1	Spring	Neutral		416	0.5909
MT	1	Spring	Tolerant	Channel catfish	54	0.3237
MT	1	Spring	Tolerant	Gizzard shad	89	0.0089
MT	1	Spring	Tolerant	Silver/bighead carp	4	0.0004
MT	1	Summer	Intolerant	Goldeye	8	0.0379
MT	1	Summer	Neutral		722	6.4016
MT	1	Summer	Tolerant	Buffalofish	4	0.0024
MT	1	Summer	Tolerant	Channel catfish	120	0.3347
MT	1	Summer	Tolerant	Flathead catfish	1	0.0001
MT	1	Summer	Tolerant	Gizzard shad	102	0.112
MT	1	Summer	Tolerant	Silver carp	54	0.0095
MT	1	Fall	Intolerant	Goldeye	2	0.055
MT	1	Fall	Neutral		683	3.6399
MT	1	Fall	Tolerant	Channel catfish	13	0.043
MT	1	Fall	Tolerant	Emerald shiner	18	0.0282

Gear	Zone	Season	Heat-Tolerance	Taxon	Total Count	Total Weight (kg)
MT	1	Fall	Tolerant	Silver carp	37	0.0186
MT	3	Winter	Neutral		266	1.0844
MT	3	Winter	Tolerant	Channel catfish	38	0.2291
MT	3	Winter	Tolerant	Emerald shiner	9	0.0114
MT	3	Winter	Tolerant	Gizzard shad	1	0.005
MT	3	Winter	Tolerant	Longnose gar	2	1.7
MT	3	Winter	Tolerant	Shortnose gar	6	4.024
MT	3	Winter	Tolerant	Silver carp	3	3.322
MT	3	Spring	Intolerant	Goldeye	26	0.0068
MT	3	Spring	Intolerant	Mooneyes	3	0.0004
MT	3	Spring	Intolerant	Sauger x Walleye	2	0.0006
MT	3	Spring	Neutral		476	6.7766
MT	3	Spring	Tolerant	Channel catfish	38	0.278
MT	3	Spring	Tolerant	Flathead catfish	1	0.006
MT	3	Spring	Tolerant	Gizzard shad	27	0.0027
MT	3	Summer	Intolerant	Goldeye	7	0.036
MT	3	Summer	Neutral		509	0.4387
MT	3	Summer	Tolerant	Channel catfish	65	0.0536
MT	3	Summer	Tolerant	Emerald shiner	2	0.002
MT	3	Summer	Tolerant	Gizzard shad	32	0.0716
MT	3	Summer	Tolerant	Shortnose gar	2	0.827
MT	3	Summer	Tolerant	Silver carp	48	0.0099
MT	3	Fall	Intolerant	Goldeye	1	0.029
MT	3	Fall	Neutral		945	5.4838
MT	3	Fall	Tolerant	Channel catfish	58	0.182
MT	3	Fall	Tolerant	Emerald shiner	47	0.0776
MT	3	Fall	Tolerant	Flathead catfish	1	0.478
MT	3	Fall	Tolerant	Gizzard shad	3	0.0085
MT	3	Fall	Tolerant	Shortnose gar	3	1.64
MT	3	Fall	Tolerant	Silver carp	29	1.2071
MT	4	Winter	Neutral		333	5.2265
MT	4	Winter	Tolerant	Channel catfish	32	0.2907
MT	4	Winter	Tolerant	Flathead catfish	1	0.004
MT	4	Winter	Tolerant	Gizzard shad	2	0.0146
MT	4	Winter	Tolerant	Longnose gar	1	1.035
MT	4	Winter	Tolerant	Silver carp	1	1.362
MT	4	Winter	Tolerant	Smallmouth buffalo	1	1.28
MT	4	Spring	Intolerant	Goldeye	60	0.0166
MT	4	Spring	Intolerant	Mooneye	2	0.0002
MT	4	Spring	Intolerant	Mooneyes	2	0.0003

Gear	Zone	Season	Heat-Tolerance	Taxon	Total Count	Total Weight (kg)
MT	4	Spring	Neutral		361	1.9461
MT	4	Spring	Tolerant	Buffalofish	1	0.0001
MT	4	Spring	Tolerant	Channel catfish	31	0.1385
MT	4	Spring	Tolerant	Emerald shiner	1	0.0025
MT	4	Spring	Tolerant	Gizzard shad	12	0.0012
MT	4	Spring	Tolerant	Longnose gar	1	0.647
MT	4	Spring	Tolerant	Silver/bighead carp	4	0.0004
MT	4	Summer	Intolerant	Goldeye	11	0.0387
MT	4	Summer	Neutral		532	0.7655
MT	4	Summer	Tolerant	Channel catfish	151	0.1176
MT	4	Summer	Tolerant	Flathead catfish	1	0.0001
MT	4	Summer	Tolerant	Gizzard shad	57	0.0609
MT	4	Summer	Tolerant	Longnose gar	1	0.41
MT	4	Summer	Tolerant	Silver carp	29	0.0085
MT	4	Summer	Tolerant	Silver/bighead carp	2	0.003
MT	4	Fall	Neutral		621	1.7891
MT	4	Fall	Tolerant	Channel catfish	10	0.026
MT	4	Fall	Tolerant	Emerald shiner	1	0.0007
MT	4	Fall	Tolerant	Gizzard shad	5	0.0156
MT	4	Fall	Tolerant	Silver carp	7	0.0058

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ATTACHMENT A: Evaluation of Dual Deployment of Hester Dendy Samplers

Evaluation of Dual Deployment of Hester Dendy Samplers

A total of 72,233 macroinvertebrates were collected from 298 Hester Dendy (H-D) samples over the two year sampling period from February 2017 through January 2018. Similar numbers of macroinvertebrates were collected in samplers suspended at mid-depth (n = 38,597 individuals; 53.4 percent of total) compared with bottom-depth (n = 33,636 individuals; 46.6 percent of total) (Table A-1). Mean densities of mid-depth and bottom-depth H-D samplers by season were similar among each sampling zone (Table A-2). While there was variability among seasons with higher densities in spring and summer, mid-depth H-D samplers typically had higher densities than bottom-depth samplers (Figure A-1). However, differences in mean densities observed among mid-depth and bottom-depth H-D samplers were not statistically significant (t-stat = -0.29, df = 30, p-value = 0.77). Despite differences in depth profile and the possibility for suspended H-D samplers to collect only drifting organisms versus those associated with the community that lives in the benthos, the overall taxonomic composition of H-D samplers was also very similar among depths (Table A-1). A Quantitative Similarity Index for Taxa (QSIT) value was calculated to compare the mid-depth and bottom-depth H-D samplers in terms of presence or absence of taxa, while also taking relative abundance (percent composition) into account (Shackleford 1988). The QSIT value was 87.14 for all locations combined over the two year sampling period, indicating that collections from mid-depth and bottom-depth samplers were essentially equal and representative of the same community (e.g. duplicate samples are expected to have a QSIT of 70 or greater, as determined in Rabeni et al. 1999). The QSIT value was also high when comparing mid-depth and bottom-depth samplers across sampling zones (upstream reference zone = 84.05; discharge zone = 77.91; thermally exposed zone = 83.07; downstream zone = 85.73). Consequently, the Final Demonstration results relied on a combined mid-depth and bottom-depth analysis of the H-D samplers, which accounts for the entire macroinvertebrate community (i.e. drift and benthos).

The top three most abundant taxa at both mid-depth and bottom-depth H-D samplers included the caddisfly genus *Hydropsyche* (27.5 and 23.6 percent of respective totals), the true fly genus *Rheotanytarsus* (17.6 and 15.5 percent, respectively), and the caddisfly *Potamyia flava* (8.9 and 12.7 percent, respectively) (Table A-1). Collectively, these three taxa accounted for 54 and 52 percent of the mid-depth and bottom-depth collections, respectively (Table A-1). These taxa also represented the top three taxa within each sampling zone for both mid-depth and bottom-depths (Table A-3 and C2-4). *Hydropsyche* spp. and *Potamyia flava* are filter feeders belonging to Hydropyschidae, the family of net-spinning caddisflies, and are often associated with big rivers having high silt loads and high concentrations of suspended organic substances (Wiggins 1998). Given their ability to tolerate heavy siltation and suspended materials, it is reasonable to expect high numbers would have been collected at both bottom and mid-depths, as was observed (Table A-1). Similarly, the non-biting midges (e.g. *Rheotanytarsus* spp.), which belong to the tribe Tanytarsini within the family Chironomidae, are also filter feeders that build their own cases. The high abundances of these species at both bottom and mid-depths is likely a result of the conditions present within the lower Missouri River (LMOR) including an increased amount of suspended particulates throughout the water column and bottom substrates ranging from fine silt to course sand with an abundant supply of material (i.e. fine sand) for larvae to build their cases.

Taxa that might be expected to comprise a major component of the LMOR drift (i.e. community sampled by mid-depth H-D samplers) included mayflies belonging to Baetidae (e.g.

Pseudocloeon spp.). These taxa frequently exhibit "fishlike" swimming behavior and use the main drift as a means to move to more optimal habitats and for the colonization of new habitats (Cummings et al. 2008; Thorp and Covich 2015). However, these taxa are primarily associated with the benthos and with fine sediments in depositional habitats where they feed. Based on bottom and mid-depth H-D collections made over the two year sampling period, slightly more individuals of Baetidae including *Pseudocloeon* spp. were collected in mid-depth (n = 3,149; 8.2 percent) than bottom-depth (n = 2,133; 6.3 percent) H-D samplers (Table A-1). This pattern was also maintained across each of the sampling zones (Table A-3 and C2-4).

Other mayflies belonging to the family Heptageniidae, the flat-headed mayflies, including *Maccaffertium mexicanum integrum* and *Heptagenia* spp., have behavioral and morphological adaptations for attachment to rocky surfaces and are known as clingers (Cummings et al. 2008). Based on these behaviors it might be expected for these taxa to exhibit a greater component of the benthic community than the main drift community potentially represented by the mid-depth H-D samplers. However, more individuals of these taxa were observed in mid-depth (n = 3,218; 8.3 percent) than bottom-depth (n = 1,881; 5.6 percent) H-D samplers (Table A-1). This pattern was also consistent across sampling zones (Table A-3 and C2-4). The placement of H-D arrays in close proximity to rock dike structures may provide a possible explanation for the increased occurrence of these taxa in mid-depth samplers. Other taxa that display similar clinging behavior and are also characterized as crawlers (i.e. these taxa main means of locomotion is moving slowly along the bottom) include members of the family Perlidae (e.g. *Acroneuria* spp., *Perlesta* spp., *Neoperla* spp.) (Cummings et al. 2008). These taxa might be expected to represent a larger component of the benthic community (i.e. bottom H-D samplers) than the drift community based on their behavior and morphological adaptations. However, the data show a nearly equal component of these taxa combined in mid-depth (n = 222; 0.6 percent) and bottom-depth (n = 187; 0.6 percent) H-D samplers (Table A-1). Individually, *Perlesta* spp. were more abundant in mid-depth H-D samplers, while *Acroneuria* spp. and *Neoperla* spp. were slightly more abundant in bottom H-D samplers (Table A-1). This pattern was also generally consistent across sampling zones for these taxa (Table A-3 and C2-4).

There were several taxa that were only collected in mid-depth H-D samplers over the two year sampling period, though they occurred in very low abundance (<0.2 percent of mid-depth samples for all taxa combined; Table A-5). Similarly, there were some taxa occasionally collected only in bottom-depth H-D samplers (<0.1 percent of bottom-depth samples for all taxa combined; Table A-6). Thus, all of these occurrences reflect taxa that were infrequently collected during the two year sampling period and not taxa that may be preferential to either the benthic community or the drift community.

Diversity metrics including taxa richness (^{0}D), Shannon diversity (^{1}D), and Simpson diversity (^{2}D) were also similar among mid-depth and bottom-depth H-D samplers by season among each of the sampling zones (Winter – Figure A-2; Summer – Figure A-3). Slight differences in diversity metrics were observed for individual sampling zones (e.g. the upstream reference zone in winter and the thermally exposed zone in summer); however, overall, they showed a very similar pattern as the sensitivity to abundance (q) increased (Figures C2-2 and C2-3). The Biotic Index (BI) of mid-depth and bottom-depth H-D samplers was also similar among each of the sampling zones during each season (Table A-7). While slightly lower BI values were observed in the spring for each of the sampling zones, the BI values were relatively consistent, ranging from 4.22 in the

discharge zone in spring to 5.51 for the upstream reference zone in summer (Table A-7). Overall, no statistically significant differences were observed among BI values for mid-depth and bottom-depth H-D samplers (t-stat = -0.47, df = 30, p-value = 0.64)

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Table A-1. Number of each Species Collected by Mid-Depth and Bottom-Depth Hester Dendy Samplers during 2017-2018 Surveys near Labadie Energy Center

Taxonomic Group	Scientific Name	Mid-Depth		Bottom-Depth		Combined Total	Percent of Combined Total
		Total Number Collected	Percent of Total	Total Number Collected	Percent of Total		
TR	*Hydropsyche* spp.	10,601	27.47	7,948	23.63	18,549	25.68
DI	*Rheotanytarsus* spp.	6,775	17.55	5,213	15.50	11,988	16.60
TR	*Potamyia flava*	3,460	8.96	4,273	12.70	7,733	10.71
DI	*Stenochironomus* spp.	2,303	5.97	2,817	8.37	5,120	7.09
TR	Hydropsychidae	2,047	5.30	2,518	7.49	4,565	6.32
EP	*Pseudocloeon* spp.	2,500	6.48	1,727	5.13	4,227	5.85
DI	*Polypedilum flavum*	1,851	4.80	1,469	4.37	3,320	4.60
EP	*Maccaffertium mexicanum integrum*	1,973	5.11	1,136	3.38	3,109	4.30
EP	*Amercaenis* spp.	1,503	3.89	1,067	3.17	2,570	3.56
EP	Heptageniidae	980	2.54	591	1.76	1,571	2.17
EP	Baetidae	649	1.68	406	1.21	1,055	1.46
DI	Chironomidae	353	0.91	525	1.56	878	1.22
IN	Insecta*	379	0.98	488	1.45	867	1.20
EP	*Isonychia* spp.	274	0.71	313	0.93	587	0.81
DI	*Polypedilum scalaenum* group	229	0.59	216	0.64	445	0.62
EP	*Heptagenia* spp.	265	0.69	154	0.46	419	0.58
TR	*Neureclipsis* spp.	152	0.39	222	0.66	374	0.52
EP	*Caenis* spp.	177	0.46	151	0.45	328	0.45
DI	*Polypedilum* spp.	55	0.14	244	0.73	299	0.41
DI	*Telopelopia okoboji*	107	0.28	121	0.36	228	0.32
PL	*Perlesta* spp.	121	0.31	50	0.15	171	0.24
DI	*Tanytarsini*	55	0.14	112	0.33	167	0.23
OD	*Argia* spp.	54	0.14	98	0.29	152	0.21

Table A-1 (cont.). Number of each Species Collected by Mid-Depth and Bottom-Depth Hester Dendy Samplers during 2017-2018 Surveys near Labadie Energy Center

Taxonomic Group	Scientific Name	Mid-Depth		Bottom-Depth		Combined Total	Percent of Combined Total
		Total Number Collected	Percent of Total	Total Number Collected	Percent of Total		
DI	*Thienemannimyia* sp. group	76	0.20	74	0.22	150	0.21
EP	*Isonychia rufa*	91	0.24	57	0.17	148	0.20
EP	*Tricorythodes* spp.	81	0.21	58	0.17	139	0.19
PL	*Neoperla* spp.	51	0.13	74	0.22	125	0.17
EP	Ephemeroptera	82	0.21	40	0.12	122	0.17
PL	*Acroneuria* spp.	50	0.13	63	0.19	113	0.16
DI	*Kribiodorum perpulchrum*	43	0.11	69	0.21	112	0.16
NA	All Other Non-Dominant Taxa	1,260	3.26	1,342	3.99	2,602	3.60
Totals		**38,597**	**53.43**	**33,636**	**46.57**	**72,233**	**100.00**

* Insect group comprised mostly of unknown insect eggs

Table A-2. Mean Density of Hester Dendy Samplers by Depth by Season in each Sampling Zone during 2017-2018 Surveys near Labadie Energy Center

Gear Type	Season	Statistic*	Sampling Zone			
			Upstream Reference	Discharge	Thermally Exposed	Downstream
Hester Dendy Bottom-Depth	Winter	Mean	15.32	93.84	36.30	21.69
		Std Err	2.16	32.28	12.61	4.96
		N	11	4	12	12
	Spring	Mean	517.6	1212.7	565.7	760.4
		Std Err	117.8	184.72	225.1	160.0
		N	12	3	7	9
	Summer	Mean	527.7	1227.4	632.9	236.6
		Std Err	304.1	757.51	389.9	72.55
		N	12	4	12	11
	Fall	Mean	44.29	236.30	72.83	35.49
		Std Err	9.00	144.59	19.88	7.15
		N	12	4	12	11
Hester Dendy Mid-Depth	Winter	Mean	23.52	113.70	43.84	24.54
		Std Err	3.53	47.35	12.05	5.23
		N	12	4	12	12
	Spring	Mean	693.4	1280.4	644.8	792.0
		Std Err	138.5	509.74	141.3	195.2
		N	11	4	7	9
	Summer	Mean	566.1	1370.5	742.4	255.6
		Std Err	254.4	757.59	393.1	40.02
		N	11	4	12	11
	Fall	Mean	68.26	156.85	95.66	74.77
		Std Err	29.29	62.72	27.69	12.99
		N	12	4	12	12

* Mean density = number of organisms/0.1 m^2, Std Err = standard error of mean, N = number of samples

Table A-3. Number of each Species Collected by Mid-Depth Hester Dendy Samplers in each Sampling Zone during 2017-2018 Surveys near Labadie Energy Center

Taxonomic Group	Scientific Name	Upstream Zone		Discharge Zone		Thermally Exposed Zone		Downstream Zone	
		Total Number Collected	Percent of Total	Total Number Collected	Percent of Total	Total Number Collected	Percent of Total	Total Number Collected	Percent of Total
TR	*Hydropsyche* spp.	2,161	19.79	4,247	49.78	2,712	24.61	1,481	18.22
DI	*Rheotanytarsus* spp.	2,488	22.79	718	8.42	2,810	25.50	759	9.34
TR	*Potamyia flava*	805	7.37	746	8.74	1,003	9.10	906	11.15
DI	*Stenochironomus* spp.	571	5.23	80	0.94	776	7.04	876	10.78
TR	Hydropsychidae	632	5.79	490	5.74	451	4.09	474	5.83
EP	*Pseudocloeon* spp.	788	7.22	666	7.81	478	4.34	568	6.99
DI	*Polypedilum flavum*	533	4.88	397	4.65	534	4.85	387	4.76
EP	*Maccaffertium mexicanum integrum*	679	6.22	140	1.64	603	5.47	551	6.78
EP	*Amercaenis* spp.	376	3.44	400	4.69	233	2.11	494	6.08
EP	Heptageniidae	350	3.21	68	0.80	255	2.31	307	3.78
EP	Baetidae	247	2.26	88	1.03	127	1.15	187	2.30
DI	Chironomidae	101	0.93	32	0.38	51	0.46	169	2.08
IN	Insecta*	107	0.98	42	0.49	112	1.02	118	1.45
EP	*Isonychia* spp.	127	1.16	34	0.40	57	0.52	56	0.69
DI	*Polypedilum scalaenum* group	97	0.89	0	0.00	54	0.49	78	0.96
EP	*Heptagenia* spp.	56	0.51	80	0.94	51	0.46	78	0.96
TR	*Neureclipsis* spp.	60	0.55	2	0.02	62	0.56	28	0.34
EP	*Caenis* spp.	70	0.64	4	0.05	42	0.38	61	0.75
DI	*Polypedilum* spp.	32	0.29	0	0.00	4	0.04	19	0.23
DI	*Telopelopia okoboji*	43	0.39	6	0.07	51	0.46	7	0.09
PL	*Perlesta* spp.	34	0.31	34	0.40	17	0.15	36	0.44
DI	*Tanytarsini*	19	0.17	12	0.14	11	0.10	13	0.16
OD	*Argia* spp.	12	0.11	0	0.00	22	0.20	20	0.25

Table A-3 (cont.). Number of each Species Collected by Mid-Depth Hester Dendy Samplers in each Sampling Zone during 2017-2018 Surveys near Labadie Energy Center

Taxonomic Group	Scientific Name	Upstream Zone		Discharge Zone		Thermally Exposed Zone		Downstream Zone	
		Total Number Collected	Percent of Total	Total Number Collected	Percent of Total	Total Number Collected	Percent of Total	Total Number Collected	Percent of Total
DI	*Thienemannimyia* sp. group	25	0.23	0	0.00	19	0.17	32	0.39
EP	*Isonychia rufa*	48	0.44	10	0.12	18	0.16	15	0.18
EP	*Tricorythodes* spp.	38	0.35	4	0.05	18	0.16	21	0.26
PL	*Neoperla* spp.	17	0.16	1	0.01	13	0.12	20	0.25
EP	Ephemeroptera	13	0.12	56	0.66	1	0.01	12	0.15
PL	*Acroneuria* spp.	24	0.22	1	0.01	19	0.17	6	0.07
DI	*Kribiodorum perpulchrum*	15	0.14	0	0.00	9	0.08	19	0.23
NA	All Other Non-Dominant Taxa	350	3.21	173	2.03	408	3.70	329	4.05
Totals		**10,918**	**100**	**8,531**	**100**	**11,021**	**100**	**8,127**	**100**

* Insect group comprised mostly of unknown insect eggs

Table A-4. Number of each Species Collected by Bottom-Depth Hester Dendy Samplers in each Sampling Zone during 2017-2018 Surveys near Labadie Energy Center

Taxonomic Group	Scientific Name	Upstream Zone		Discharge Zone		Thermally Exposed Zone		Downstream Zone	
		Total Number Collected	Percent of Total	Total Number Collected	Percent of Total	Total Number Collected	Percent of Total	Total Number Collected	Percent of Total
TR	*Hydropsyche* spp.	1,369	14.16	2,628	36.48	2,759	29.38	1,192	16.17
DI	*Rheotanytarsus* spp.	2,273	23.51	671	9.31	1,494	15.91	775	10.51
TR	*Potamyia flava*	846	8.75	1,302	18.07	1,275	13.58	850	11.53
DI	*Stenochironomus* spp.	871	9.01	168	2.33	817	8.70	961	13.04
TR	Hydropsychidae	758	7.84	1,072	14.88	341	3.63	347	4.71
EP	*Pseudocloeon* spp.	562	5.81	421	5.84	367	3.91	377	5.11
DI	*Polypedilum flavum*	310	3.21	274	3.80	360	3.83	525	7.12
EP	*Maccaffertium mexicanum integrum*	360	3.72	115	1.60	405	4.31	256	3.47
EP	*Amercaenis* spp.	270	2.79	188	2.61	66	0.70	543	7.37
EP	Heptageniidae	210	2.17	52	0.72	189	2.01	140	1.90
EP	Baetidae	152	1.57	42	0.58	58	0.62	154	2.09
DI	Chironomidae	154	1.59	22	0.31	85	0.91	264	3.58
IN	Insecta*	65	0.67	0	0.00	138	1.47	285	3.87
EP	*Isonychia* spp.	151	1.56	14	0.19	117	1.25	31	0.42
DI	*Polypedilum scalaenum* group	83	0.86	2	0.03	64	0.68	67	0.91
EP	*Heptagenia* spp.	50	0.52	32	0.44	49	0.52	23	0.31
TR	*Neureclipsis* spp.	92	0.95	2	0.03	85	0.91	43	0.58
EP	*Caenis* spp.	51	0.53	2	0.03	57	0.61	41	0.56
DI	*Polypedilum* spp.	196	2.03	12	0.17	22	0.23	14	0.19
DI	*Telopelopia okoboji*	37	0.38	6	0.08	65	0.69	13	0.18
PL	*Perlesta* spp.	11	0.11	6	0.08	15	0.16	18	0.24
DI	*Tanytarsini*	64	0.66	20	0.28	8	0.09	20	0.27

Table A-4 (cont.). Number of each Species Collected by Bottom-Depth Hester Dendy Samplers in each Sampling Zone during 2017-2018 Surveys near Labadie Energy Center

Taxonomic Group	Scientific Name	Upstream Zone		Discharge Zone		Thermally Exposed Zone		Downstream Zone	
		Total Number Collected	Percent of Total	Total Number Collected	Percent of Total	Total Number Collected	Percent of Total	Total Number Collected	Percent of Total
OD	*Argia* spp.	17	0.18	0	0.00	54	0.57	27	0.37
DI	*Thienemannimyia* sp. group	13	0.13	2	0.03	35	0.37	24	0.33
EP	*Isonychia rufa*	18	0.19	10	0.14	27	0.29	2	0.03
EP	*Tricorythodes* spp.	22	0.23	6	0.08	15	0.16	15	0.20
PL	*Neoperla* spp.	20	0.21	2	0.03	36	0.38	16	0.22
EP	Ephemeroptera	22	0.23	5	0.07	3	0.03	10	0.14
PL	*Acroneuria* spp.	30	0.31	8	0.11	11	0.12	14	0.19
DI	*Kribiodorum perpulchrum*	22	0.23	4	0.06	15	0.16	28	0.38
NA	All Other Non-Dominant Taxa	570	5.90	116	1.61	360	3.83	296	4.02
Totals		**9,669**	**100**	**7,204**	**100**	**9,392**	**100**	**7,371**	**100**

* Insect group comprised mostly of unknown insect eggs

Table A-5. Species Collected only by Mid-Depth Hester Dendy Samplers during 2017-2018 Surveys near Labadie Energy Center

Taxonomic Group	Scientific Name	Total Number Collected	Percent of Mid-Depth	Overall Percent of Total
OL	*Aulodrilus pluriseta*	1	0.003	0.001
OL	*Limnodrilus udekemianus*	3	0.008	0.004
CO	*Ancyronyx variegata*	2	0.005	0.003
CO	*Macronychus glabratus*	1	0.003	0.001
DI	*Bezzia/Palpomyia* spp.	2	0.005	0.003
DI	*Sphaeromias* sp.	1	0.003	0.001
DI	*Hemerodromia* sp.	1	0.003	0.001
DI	*Simulium* spp.	4	0.010	0.006
DI	*Ablabesmyia annulata*	5	0.013	0.007
DI	*Cricotopus* spp.	4	0.010	0.006
DI	*Cricotopus bicinctus*	15	0.039	0.021
DI	*Cricotopus sylvestris* group	4	0.010	0.006
DI	*Eukiefferiella claripennis* group	1	0.003	0.001
DI	*Micropsectra* spp.	8	0.021	0.011
DI	*Paratanytarsus* spp.	2	0.005	0.003
EP	*Hexagenia limbata*	1	0.003	0.001
EP	*Maccaffertium exiguum*	8	0.021	0.011
EP	*Raptoheptagenia cruentata*	1	0.003	0.001
EP	*Spinadis simplex*	2	0.005	0.003
EP	*Stenonema femoratum*	1	0.003	0.001
OD	*Didymops* spp.	2	0.005	0.003
OD	*Coenagrion/Enallagma* sp.	1	0.003	0.001

Table A-6. Species Collected only by Bottom-Depth Hester Dendy Samplers during 2017-2018 Surveys near Labadie Energy Center

Taxonomic Group	Scientific Name	Total Number Collected	Percent of Bottom-Depth	Overall Percent of Total
TU	Trepaxonemata	1	0.003	0.001
HI	*Helobdella austinensis*	2	0.006	0.003
OL	*Pristina longiseta*	1	0.003	0.001
DI	Tabanidae	4	0.012	0.006
DI	*Labrundinia pilosella*	4	0.012	0.006
DI	*Procladius (Psilotanypus)* sp.	1	0.003	0.001
DI	*Corynoneura floridaensis*	1	0.003	0.001
DI	*Nanocladius minimus*	1	0.003	0.001
DI	*Tvetenia vitracies*	2	0.006	0.003
DI	*Axarus* sp.	1	0.003	0.001
DI	*Cryptotendipes* sp.	1	0.003	0.001
DI	*Robackia claviger*	1	0.003	0.001
DI	*Rheotanytarsus exigus* group	1	0.003	0.001
EP	*Pentagenia vittigera*	2	0.006	0.003
EP	*Ephoron album*	3	0.009	0.004

Table A-7. Biotic Index of Hester Dendy Samplers by Depth by Season in each Sampling Zone during 2017-2018 Surveys near Labadie Energy Center

Gear Type	Season	Statistic	Sampling Zone			
			Upstream Reference	Discharge	Thermally Exposed	Downstream
Hester-Dendy Mid-Depth	Winter	Biotic Index	4.38	5.16	4.61	4.95
	Spring	Biotic Index	4.41	4.24	4.40	4.52
	Summer	Biotic Index	5.46	4.47	5.13	4.79
	Fall	Biotic Index	4.82	4.35	4.82	4.87
Hester-Dendy Bottom-Depth	Winter	Biotic Index	4.62	4.95	5.07	4.82
	Spring	Biotic Index	4.43	4.22	4.43	4.72
	Summer	Biotic Index	5.51	4.62	4.79	4.79
	Fall	Biotic Index	4.75	4.58	4.90	5.03

Note: Biotic Index values from 3.51-4.50 indicate very good water quality with possible slight organic pollution. Biotic index values from 4.51-5.50 indicate good water quality with some organic pollution.

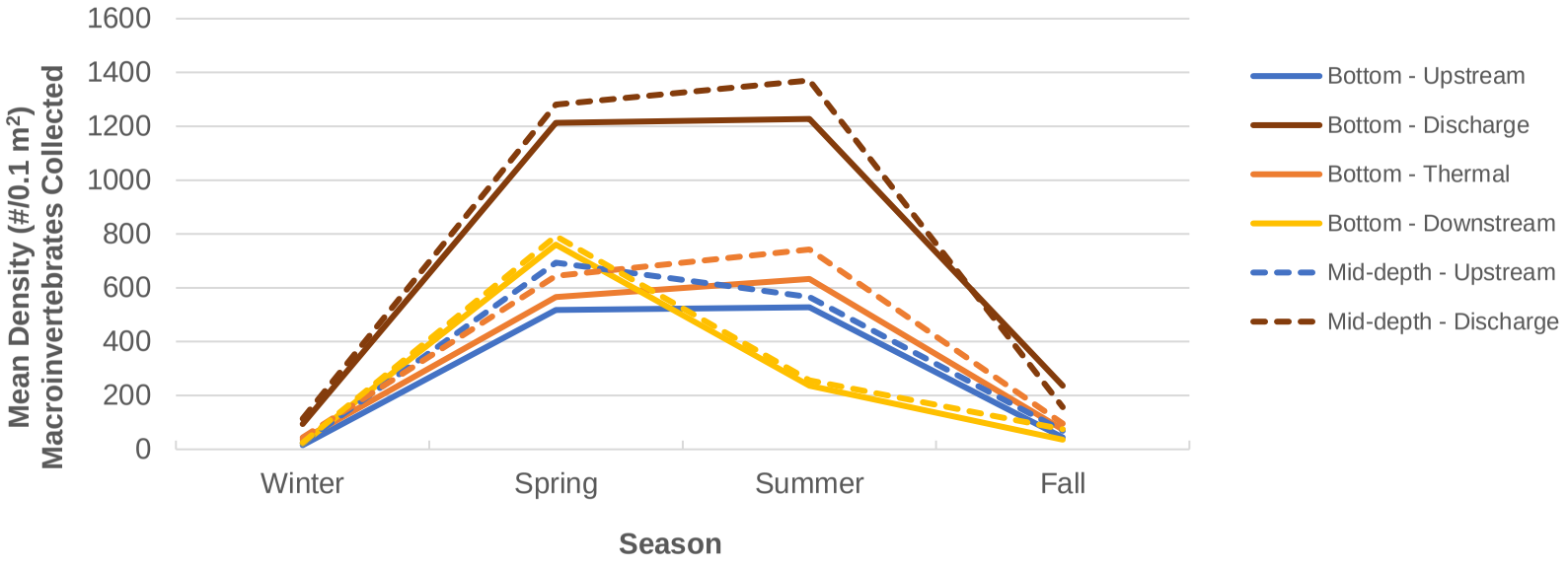

Figure A-1. Mean Density of Hester Dendy Samplers by Depth by Season in each Sampling Zone during 2017-2018 Surveys near Labadie Energy Center

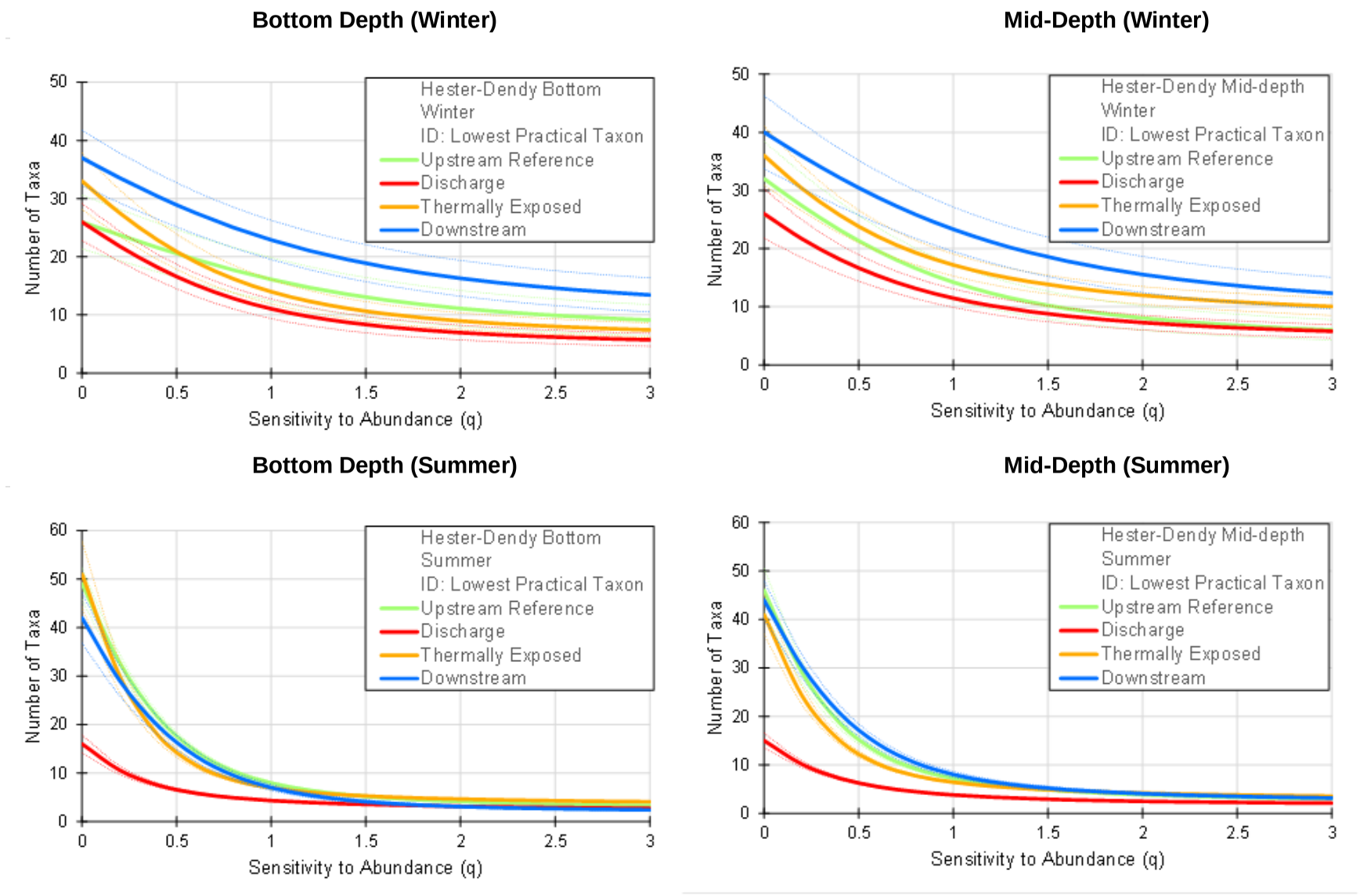

Figure A-2. Diversity Profiles of Hester Dendy Samplers by Depth in each Sampling Zone during Winter (Top Panels) and Summer (Bottom Panels) during 2017-2018 Surveys near Labadie Energy Center

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Response to Agency Preliminary Comments on Labadie Energy Center §316(a) Draft Demonstration Study Report

This document provides responses to comments received from agencies in conjunction with Ameren's submittal of the Labadie Energy Center §316(a) Draft Demonstration Study Report. Ameren Missouri has reviewed the comments provided by the Missouri Department of Natural Resources (MDNR) on behalf of the Agency and the Missouri Department of Conservation (MDC). Ameren also received comments from the Region VII of the United States Environmental Protection Agency (EPA) and the United States Fish and Wildlife Service (USFWS) via email from MDNR on December 4, 2019 and March 18, 2020, respectively. Ameren's responses to these comments are provided below. Some comments have also resulted in revisions to the Draft Demonstration Study Report and supporting materials (i.e., *Supplement to Labadie Energy Center Draft 316(a) Demonstration in Response to Agency Comments,* the "Supplement") which are referenced in the responses below.

MDNR/MDC Comments

Overarching Comment – Removal of Asian Carp from Analysis

The primary concern is the chosen Representative Important Species (RIS). The Asian Carp species should be removed from the RIS assessment, and the statistical analysis re-run. Significant changes will need to occur throughout the 316(a) document but this revision is essential for the final submittal. Rationale for this decision is provided below.

Also, the commenting entities are concerned with the statistical analysis, choice of data exclusions, and sampling methods, including but not limited to not following the sampling plan and requested revisions to the sampling plan. The commenting entities have reason to believe all of these questions can be cogently answered by Ameren prior to (or with) the submission of the 316(a) report.

RESPONSE: Asian carps (collectively "Asian carp") were selected as an RIS because they are a common nuisance species. One of the EPA criteria for selecting RIS (cited in Section 6.2 of the Demonstration) is "capable of becoming a localized nuisance species" (EPA 1974 and 1977). While we believe that Asian carp is an appropriate RIS for the LEC, we will remove Asian carp as an RIS in the predictive assessment (Section 6).

Commenters also requested that the statistical analyses in the retrospective assessment (Section 5) be redone without Asian carp. We do not believe that removing Asian carp is appropriate as they are now an established part of the fish community in the Lower

Missouri River (LMOR). Both the EPA guidance for 316(a) demonstrations (EPA 1974 and 1977) and EPA regulations (40 CFR, 125.73(a); 44 Fed. Reg. 32,952 (7 June 1979)) explicitly state that the indigenous community may contain non-native species so long as their presence is not due to the pollutant being addressed (in this case the thermal discharge) (this is also described in 3.3.1 of the Demonstration). Asian carp are now resident in the LMOR due to range expansion and not as a result of the LEC discharge and, therefore, should be considered part of the balanced indigenous community (BIC). Per EPA guidance, the 316(a) Demonstration is based on showing a balanced community and not a selected portion of that community. Therefore, removing a species that is part of that community would not be consistent with the objective of the Demonstration.

Further, because Asian carp comprised only a small fraction of the catch used in the retrospective analysis, its removal would not be expected to substantively alter any of the conclusions. Table 5-3 shows that silver carp, the most abundant of the Asian carp species, accounted for 1.7%, 1.4%, 2.4%, and 1.9% of the numerical abundance in the Upstream, Discharge, Thermally Exposed, and Downstream zones, respectively. Overall, the three Asian carp species accounted for only 2.2% of numerical abundance in the 2017-2018 sampling, and 16.3% of the biomass in the combined collection. However, to address agency concerns about potential bias to the analytical results, we provide supplemental material comparing community analyses with and without the Asian carp (see the Supplement).

Group I Comments (Operating Permits)

1. Page VII, zone of passage. The Department is asking Ameren to better evaluate the zone of passage. Provide data or references showing the zone of passage area is actually used by fish avoiding the thermally affected zone.

   RESPONSE: The EPA guidance for 316(a) Demonstrations requires that a zone of passage (region of temperatures less than avoidance temperatures that fish may use to traverse up or downstream past a thermal discharge) be maintained (EPA 1974 and 1977). We believe that the availability of a zone of passage has been successfully demonstrated (Section 6.3.3, Table 6-2). Studies to demonstrate that fish were using the zone of passage were not part of the approved Study Plan.

   The scientific literature demonstrates that fishes can avoid higher temperatures or other unfavorable environmental conditions and use alternate areas of the river. For example, a gravid female pallid sturgeon, tracked by telemetry in the LMOR near Boonville in late April 2010, was observed to select an upstream migration pathway that would minimize energy expenditure by repeatedly crossing the river to select slower velocities, while avoiding the higher current in the thalweg (*McElroy et al. 2012. Optimum spawning migration pathways.*

Ecology Vol. 93, No. 1). Because LEC's plume is restricted largely to the area of the thalweg, this fish would likely have avoided the plume due to its higher current velocities and sought the lower velocities, as well as the lower temperatures across the river. Furthermore, temperature sensitive species such as blue sucker tend to complete spawning migrations in fall and early spring prior to the occurrence of high summer plume temperatures (*Neely et al. 2009. Seasonal use distributions and migrations of blue sucker in the Middle Missouri River. Ecology of Freshwater Fish 2009: 18: 437–444*).

2. Section 1.2. The request is explained as requesting a 6% time of deviation from the Thermal Discharge Parameter (TDP) of 0.95 under the following circumstances: river flow is less than 40,000 cfs or ambient river is greater than 87°F. If either of these conditions occur, then the facility may be permitted to exceed the 0.95 TOP 6% of the time.

    a. How does the facility suggest these conditions be monitored; will data be obtained on an hourly or by minute basis?

    b. How will the facility determine the discharge is less than 40% of the river volume? And at what frequency? How will the area of zone of passage be calculated; how does the percentage of river used for mixing compare numerically to the zone of passage?

RESPONSE: Based on the 316(a) study data and associated analyses, Ameren has proposed a modification to the current NPDES permit effluent limitations in Table A-2 as follows:

A Thermal Discharge Parameter (TDP) value greater than 0.95 is permitted when upstream river flow is less than 40,000 cfs, or background river temperature is greater than 87°F. The size of the Mixing Zone shall be less than 40% during these conditions as calculated by the equation in Note 5. This exception shall not occur for more than 6% of the days in a calendar year.

As noted, the TDP permit limit exception could potentially be invoked on up to 6% of the days in a calendar year (i.e., 22 days), but only on days when background river temperature is significantly elevated (i.e., above 87°F), or when low flow is occurring in the river (i.e., upstream river flow is less than 40,000 cfs). For 94% or more of the days in any calendar year, the TDP permit effluent limitation of 0.95 must be met. It is anticipated that, based on historical data, in many years the requested 316(a) exception will never be invoked, and the TDP effluent limitation of 0.95 will be satisfied on all days in such years. Furthermore, whenever the exception is invoked, the allowable mixing zone would still be limited to a maximum of 40% of the river as compared to the standard allowable regulatory mixing zone of 25% of the river. At least, 60% of the river will still be outside the mixing zone providing a substantial zone of passage not dramatically different from the 75% normally required.

2a. The NPDES permit TDP effluent limitation is a daily average limitation. Compliance is measured and determined on a daily basis. Consistent with that, Ameren has proposed that the alternative 316(a) effluent limitation also be measured and determined on a daily basis, i.e., as noted above, the alternative 316(a) effluent limitation cannot be invoked on more than 6% of the ***days*** in a calendar year. While Ameren may collect data on a more frequent basis (e.g., hourly), permit compliance in this regard is based on daily average conditions. As noted in Ameren's 316(a) variance permit modification request, the alternate effluent limitation proposed by Ameren is substantively similar to the water-quality based final thermal effluent limitation in the permit. It would be inconsistent to introduce a time frame different from the current effluent limitation as it would no longer relate to the current effluent limitation from which relief is needed during extreme river conditions. The TDP would continue to be calculated every day of every year, and Ameren would be permitted to exceed the TDP effluent limitation of 0.95 on up to 22 days per calendar year, but only on days when the extreme specified river temperature and flow conditions are encountered. Furthermore, on those days, the size of the mixing zone as calculated by the approved equation in Note 5 of Table A-2 in the permit, must not exceed 40% of the river. Therefore, even on the days when a TDP greater than 0.95 is permitted, at least 60% of the river will be in compliance with Missouri's water quality standards for temperature.

2b. The equation in Note 5 of Table A-2 of the permit specifies how the size of the mixing zone is determined for any combination of river flow, river temperature, discharge flow and discharge temperature. The determination is completed on a daily basis along with the determination of the TDP. If we define the zone of passage as the portion of the river outside of the mixing zone, then it would be 100% minus the percentage of the river in the mixing zone as calculated by the equation in Note 5 of the permit's Table A-2.

3. Section 2-1 page 2-2, 4th full paragraph; the text references "MDNR 2015" however this reference is not found in Section 8. Please provide the corrected reference either to the text or added to the reference section.

   RESPONSE: The MDNR 2015 reference is correct. The date of the 2014 document in the reference section was incorrect and has been changed to 2015.

4. Section 3.3.3 last paragraph; the author indicated the remaining life of the plant was a consideration when assessing thermal discharge consequences.

   What is the remaining useful life of the plant? Is the plant expected to be retired sooner for any reason?

   RESPONSE: Section 3 solely provides the regulatory background and indicates that useful plant life can be a consideration according to the EPA guidance (EPA 1974 and 1977). In our analysis we did not use plant life as a consideration.

5. Section 5.4.1.1. The conclusion was made that winter abundance in the thermally affected zone indicated this zone attracted certain aquatic species and this conclusion also indicated there was no adverse effect. This statement may need additional citations or data showing how attracting species is not an adverse effect.

   RESPONSE: Fish attracted to the thermally exposed zone and discharge may have increased growth rates due to higher temperatures and higher densities of forage fish. Potential adverse effects of these fish being attracted to the discharge and thermally exposed zone are related to cold shock (i.e., a sudden decrease in temperature sufficient to cause severe thermal stress to aquatic organisms) associated with a complete shutdown of all units operating at the LEC. Section 6.3.1.2 of the Demonstration assessed the risk of cold shock for four of the seven RIS species with available information. In all cases, the lower incipient lethal temperatures (LILT) were less than the temperature exposures that would occur with complete shutdown of all units at the LEC (see Figures 6-12 through 6-15 of the Demonstration). These results indicate that there does not appear to be any potential for mortality associated with cold shock at LEC in the event of a shutdown of all operating units. Furthermore, the likelihood that all units would be simultaneously shut down at the LEC is exceedingly low. For these reasons, attracting fish to the thermally exposed zone and discharge during winter months is not considered an adverse effect.

6. Section 5.4.1.3 "Diversity". The first paragraph explains the metrics used to elucidate species indices from the raw data obtained in the LEC studies. A sufficient explanation was provided for Hill numbers and the Shannon index, but was not numerically explained for the Simpson concentration. Please explain how each of the indices were used in the following tables (pages 5-18 to 5-23) and how the tables are representative of the study. Additionally, please provide the equations showing the relationship between the Ho (number of species per Hill number); H1 (exponent of Shannon index); and H2 (inverse of Simpson index) used for this study.

   RESPONSE: The calculations of diversity used here are derived from the abundance-based analytics of Chao and Jost 2015. Assume that a collection consisting of S species with numbers of individual species denoted as n_1, n_2, n_3,....n_S. The proportion of the catch due to each species *i* is

$$p_i = \frac{n_i}{\sum_{i=1}^{S} n_i}.$$

   Hill numbers of order *q*, where *q* is a measure of the sensitivity of diversity to species abundance, denoted as ${}^{q}\mathrm{D}$, are calculated as:

$${}^{q}\mathrm{D} = \left(\sum_{i=1}^{S} p_i^{q}\right)^{\frac{1}{1-q}} \qquad \text{where } q \geq 0, \text{ but } q \neq 1$$

Because the exponent $\frac{1}{1-q}$ would be undefined at q = 1, the limiting value as q→1 is substituted for equation [1]:

$^{q}\mathrm{D} = exp\left(-\sum_{i=1}^{S} p_i \log p_i\right)$ where q = 1

The calculations describe a continuous smooth relationship between $^{q}\mathrm{D}$ and q, given the particular values of p_i derived from the data. When most of the organisms captured belong to just a few taxa, the curve declines sharply from its maximum value (S) at q = 0. If the collection is more evenly dispersed among many taxa, the curve declines gradually. The diversity profile is interpretable as the number of equally abundant taxa that would be required to produce the same level of diversity at any particular level of sensitivity to abundance.

At *q* = 0, the diversity metric is completely insensitive to the relative abundance, and as would be expected, $^{0}\mathrm{D}$ is equal to the observed species richness (S_{obs}). When *q* = 1, the diversity metric is equivalent to exp(H') where H' is the Shannon-Weiner diversity. When *q = 2*, the diversity metric is equivalent to the inverse Simpson index.

q	Special Cases of Hill Numbers at q = 0, 1, 2	Corresponding Metric
0	$^{0}\mathrm{D} = \left(\sum_{i=1}^{S} p_i^0\right)^{\frac{1}{1-0}} = \left(\sum_{i=1}^{S} 1\right)^{1} = S_{obs}$	Species Richness
1	$^{1}\mathrm{D} = exp\left(-\sum_{i=1}^{S} p_i \log p_i\right) = \exp(H')$	exponential of Shannon Diversity
2	$^{2}\mathrm{D} = \left(\sum_{i=1}^{S} p_i^2\right)^{\frac{1}{1-2}} = \frac{1}{\sum_{i=1}^{S} p_i^2}$	inverse Simpson Diversity

The referenced indices were only used in Figure 5-15 on page 5-22. These historical diversity indices (species richness, Shannon, Simpson) are represented in Figure 5-15 (page 5-22) as points on the continuum of the diversity profiles at q = 0, 1, and 2 respectively. Additional tables of diversity indices are provided in Appendix B of the Demonstration Study report (Tables B-6 through B-9).

7. Figure 5-14. Please provide the units for fish length.

RESPONSE: The units (mm) have been added to the figure.

8. Section 5.4.1.3 "Presence of all Trophic Levels". It would be helpful to provide a table (such as was provided in 5-5) of the species and which categories they occur (herbivore, omnivore, planktivore, etc.).

   RESPONSE: A table showing the categorization of species into trophic levels has been inserted into Section 5.4.1.3. The categorization is based on Appendix A in Pearson et al. 2011. Multimetric Fish Indices for Midcontinent (USA) Great Rivers, Transactions of the American Fisheries Society, 140:6, 1547-1564.

9. Section 5.4.1.3 "Lack of Domination by Heat Tolerant Species".

   a. Please provide the rationale for accepting biomass data preferentially to numeric quantities of heat tolerant species. In preferring biomass, the study may be preferring a small subset of large individuals which generally have greater tolerance to changes in heat and may mask the differences in feeding behavior within the different sections in the river.

   b. According to the text, there were no heat intolerant species counted in the discharge and thermally exposed areas, but Figure 5-19 appears to show the opposite.

   c. In addition to this, please graph these by season as Section 6.3.3 indicates certain intolerant species will be completely absent if the river exceeds certain temperatures. Seasonal density graphs were completed for the macroinvertebrate community in Figure 5-24.

   d. Please provide the raw data of the heat intolerant and tolerant species for this section so further statistical analysis can be completed.

   e. Similarly, to assure population skewedness is not a factor, removing all data associated with Asian carp will better show how non-invasive species are distributed in the LEC's region of the LMOR. This is true for all data and graphs; however, as Section 6.2 suggests, Asian carp is a Representative Important Species (RIS), but in fact, an RIS should not be based simply upon abundance or universal presence. The EPA's 1977 316(a) Technical Guidance does not appear to address invasive species, or ecosystems dominated by a class of invasive species (such as the two identified species of carp). Please provide another reference or rationale showing an invasive species could be classified as one of importance.

   RESPONSE:

   a. Biomass was not preferentially used. The sentence has been revised to clarify.

   b. We have reviewed the text and cannot find the statement that there were no heat intolerant species counted in the discharge and thermally exposed areas. On page

5-29, the second paragraph under the sub-section "Lack of Domination by Heat Tolerant Species" starts "The abundances of heat intolerant species were similarly low in all zones."

c. Graphs in Section 5 were selected to illustrate patterns in the data, without overwhelming the reader with more graphics than can be assimilated. The seasonal aspect of the prevalence of heat tolerant and intolerant species was incorporated into the analysis. The data for tolerant and intolerant species, segregated by gear and season, are provided in Appendix B Tables B-14 through B-17. The standardized differences between Upstream and either Thermally Exposed or Downstream zones, based on each of these combinations for fraction intolerant species are provided in Appendix B Tables B-18 through B-21. All of the standardized differences for each combination of gear x season, for both numerical abundance and biomass (without preference) were included in the overall weight of evidence, along with differences based on other metrics, in Figure 5-22.

To satisfy the request, figures similar to Figure 1 are provided in the Supplement (Section 3) to demonstrate the seasonal component of heat-intolerant species as it relates to numerical abundance and biomass.

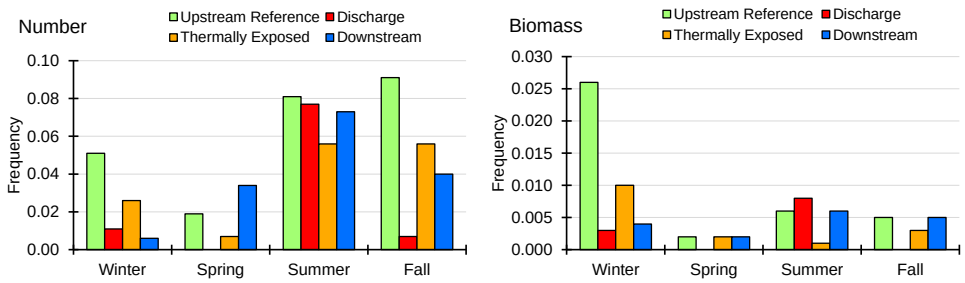

Figure 1. Seasonal fraction of the fish community comprised of heat intolerant species as numbers (left) and biomass (right) in the vicinity of the LEC in 2017-2018.

d. Heat intolerant species included sauger, walleye, mooneye, goldeye, and white crappie. Heat tolerant species included bighead carp, silver carp, bigmouth buffalo, smallmouth buffalo, channel catfish, flathead catfish, emerald shiner, gizzard shad, longnose gar, shortnose gar, and river carpsucker. As indicated in the response to 9(c), the data are summarized in Appendix Tables B-14 through B-17 of the Demonstration Study. Data for individual heat-tolerant and heat-intolerant species, are provided in the Supplement Table 10-1.

e. This question is relevant to two different analyses – the retrospective and the predictive. The removal of Asian carp from the retrospective analysis is addressed in response to the overarching comment (page 2). As indicated in the response, analyses were re-run by removing Asian carp. Results of the

analyses with Asian carp removed (see Section 2 of the Supplement) indicate that community composition is not notably altered from that described in the retrospective analysis of the Demonstration Study. As such, the agency's concern that the inclusion of Asian carp in the analysis would result in a skewing or masking of trends among other non-invasive taxa is not warranted.

Regarding the selection of Asian carp as a RIS, they have been removed from the predictive analysis in Section 6 as requested (see the response to the overarching comment on page 2),

10. Section 5.4.1.4 provides a plethora of data manipulations and graphs showing a standardized difference between the upstream reference section and the thermally exposed and downstream areas. This data should be presented with the removal of invasive carp species. Just as it is important to use sufficiently sensitive analytical methods to detect specific pollutants, species known to be affected by thermal pollution should be used to show if thermal pollution is a factor at this facility. Invasive carp are not effective detectors of thermal pollution, and given they are an invasive species, these data should be removed from all datasets as they appear to be positively skewing the standardized differences. Several assumptions are required when standardized difference is used to show population dynamics. These assumptions must be met for these statistics to be used. Please provide the assumptions met or not met when using the standardized difference test.

RESPONSE: As described in the response to the overarching comment (page 2), Asian carp is now part of the indigenous population of the LMOR and should be included in any community-based evaluation of the LMOR. However, in response to the Agency's request, the retrospective analyses without Asian carp are provided in Section 2 of the Supplement.

Standardized differences were used as part of a weight-of-evidence summary of the results of a great many individual analyses conducted as part of this Demonstration. The only "assumption" used in the analysis of the standardized differences is that the values being calculated (e.g. mean abundance, biomass, diversity, etc.) would adhere to the Central Limit Theorem and have a distribution that is asymptotically Normal. The use of this theorem is essentially universal in parametric statistical analysis and does not depend on the distribution of the underlying data.

We chose not to conduct hypothesis tests for either the individual metrics or for the combination of standardized differences across all of the gear and seasonal metrics. Our principal reason for not doing hypothesis tests was that statistical significance is an arbitrary concept, typically but not always set to use a probability of falsely rejecting a true null hypothesis of no difference (Type 1 error, or "α") of 0.05, which does not necessarily

correspond closely with biological significance, i.e. a biologically meaningful difference in the communities (also see response to Comment #11).

Instead, we presented a graphical summary of the data so that the reader can observe the totality of the information, and hopefully form an opinion about the ecological effect of thermal discharge. If the discharge had a biologically meaningful adverse effect, then the distribution of differences should be visibly shifted toward lower values, regardless of whether the distributions are appropriately described by a t-distribution, Normal distribution, or some other distribution.

Although a non-parametric test (Kolmogorov-Smirnov) is available to compare distributions without making assumptions about the particular distributions, we feel the most appropriate test for this situation, to the extent one may wish to do one (but see also response to comment 11), is to use the Mathews test (Mathews, G. V. T. 1974. On Bird Navigation, with Some Statistical Undertones. Journal of the Royal Statistical Society. Series B 36(3): 349-364). The test has three levels of "significance": 1) not obvious; 2) obvious; and 3) bloody obvious. The comparisons of the standardized differences appear to be level 1.

11. Section 5.5.2.2 narratively explains the community characteristics for diversity and dominance. However, the sections do not effectively compare the interrelationships between the upstream and thermally exposed zone, only the differences between the three different sampling events. Using an analysis of covariance, such as ANCOVA or another similar statistical method, should occur to compare the difference between and within the two groups. Page 5-62 describes the differences found in the upstream reference and the thermally exposed zones for heat tolerant species, again, it appears invasive species are dominating the data therefore small changes in resident non-invasive species cannot be shown graphically.

    RESPONSE: The comparison between the upstream reference zone and other zones (thermally exposed and downstream) was conducted using the most recent data and was the focus of the spatial analysis in the retrospective assessment. Only the most recent data on fish and benthic macroinvertebrate assemblages were used for this comparison as these data would inherently reflect any historical changes that may have occurred within the larger aquatic community as a result of broad/regional trends in the Missouri River, while also allowing for a defensible basis for spatial analysis of the effects of the thermal discharge. The temporal analysis discussed in Section 5.5.2.2 focused on changes that may have occurred within each zone over time. If any such changes occurred similarly in the Upstream Reference Zone and the Thermally Exposed Zone, then those changes would not be attributable to the thermal discharge.

Regarding statistical analyses, we considered a number of statistical approaches to examine these trends. ANCOVA may be considered as one approach. However, EPA (2000) does not support use of statistical hypothesis tests in stressor identification, stating:

> "However, the use of statistical hypothesis tests is problematic. Statistical hypothesis testing was designed for analyzing data from experiments, where treatments are replicated and randomly assigned to experimental units that are isolated from one another. The application of these tests to data from observational studies can result in erroneous conclusions." (EPA 2000, page 3-7)

As such, in our approach we followed EPA's guidance. The approach we used, while non-statistical, provides a thorough and robust analysis of the data that is sufficient to support our conclusions. The historical data (data prior to 2017-2018) are based on sampling in the Upstream Reference, Discharge, and Thermally Exposed zones. The Thermally Exposed zone is conceptually equivalent to the "mixing zone", where temperature criteria may be periodically exceeded, and some response of the fish community would be expected. However, without comparable data in the Downstream zone, i.e. outside the mixing zone, temporal analysis of harm of the LEC discharge is not possible.

As explained in the response to the overarching comment (page 2), we do not believe that removal of invasive species from the analysis is appropriate. However, analyses without Asian carp are provide in Section 2 of the Supplement.

12. Section 5.5.2.3 weighs the evidence of the data. Again, invasive carp are not an effectual tool to measure differences in the heat tolerant vs. intolerant species as they appear ubiquitously at the site. Temporal changes are not necessarily a good measure of differences in community although it is important to show if temporal variability is occurring over discrete periods of time, a comparison should occur between the two groups, upstream and the thermally exposed zone within each study. Again, an ANCOVA could be an appropriate measure of these differences.

    RESPONSE: As discussed in the response to the overarching comment ((page 2), we believe that Asian carp should not be removed from the retrospective analysis as it is part of the LMOR community, and its presence is not a result of the Labadie thermal discharge.

    For the same reasons provided in response to comment #11, we do not believe the use of ANCOVA is useful for this purpose.

13. Section 6 provides the overall assessment of the study. Due to the factors above, these summarized facts may no longer be relevant after the data has been revised and recalculated to show adjusted population indices. The study plan indicated Ameren would consult with the Department over which species should be chosen for RIS. Did this occur? We were in receipt of Addendum 2 dated May 2017 with Section 3.2 highlighted as "RIS

Evaluation". This appears to not be a final selection but instead was prefaced as "The final selection of RIS for the predictive biothermal assessment will be made in consultation with the MDNR." A response was not provided by the Department to Ameren for the specified document as a request was not made at the time. The DNR and MDC would have not selected Asian carp as a RIS.

RESPONSE: We believe this comment was meant to apply to Section 7 which is the Master Rationale and provides the overall assessment of the study (Section 6 is the predictive assessment). The results of the reanalysis without Asian carp are provided in Section 2 of the Supplement; the summarized facts and conclusions are still relevant and applicable.

Conferring with the MDNR was not conducted due to an oversight. We have provided our rationale for selecting Asian carp as an RIS in our response to the overarching comment (page 2). We understand the Agency's position and have removed the Asian carp from the predictive analysis in Section 6.

14. Page 6-12 provides the primary purpose of the predictive assessment as being able to predict the effect on a biotic community from additional heat sources. In the table for representative important species for the predictive assessment, Asian carp was chosen. The rationale provided was simply that is it a nuisance species. The author seems to be comparing their importance based on entrainment sampling at the LEC, however, again, abundance does not necessarily correlate to importance. It appears a more appropriate representative species should be based on the actual importance to Missourians who use the river for sport fishing or food sources; or as a prey base. Additionally, to provide comment as to whether this study provides for a balanced community, food chain species should also be considered; and lastly, appropriate inclusion of endangered species and species known to be temperature sensitive. Channel catfish, emerald shiner, gizzard shad, pallid sturgeon, walleye, sauger, and white crappie are all appropriate RIS. 40 CFR 125.72(b) indicates the facility should choose species used to develop water quality standards; Asian carp are not a species which has associated in-stream numeric standard protections in Missouri.

    RESPONSE: As described in the response to the overarching comment (page 2), Asian carp have been removed from the predictive analysis in Section 6, The other selected RIS meet the criteria of food chain species, endangered species, and temperature sensitive species as well as recreationally important species.

15. Section 6.3.2. Please provide references for assessments made and assumptions provided in this section for each species. How does the author conclude larger individuals are better for the balanced community when exposed to thermal pollution?

    RESPONSE: Citations for life history information provided in this section are provided in Section 6.2 where this information is discussed in more detail. Only information relevant

to the discussion of growth effects is summarized here. The conclusion was not that larger individuals are better, but that slightly earlier spawning and higher growth rates for some individuals would not represent an adverse effect.

16. Section 6.3.3. Sampling did not occur in the zone of passage. Does the author have any comment regarding the lack of sampling in this area? Can any data obtained in the study show the zone of passage is being utilized effectively by heat intolerant species and they are realistically avoiding the thermally exposed zone?

    RESPONSE: The approved study plan did not plan for sampling in the zone of passage. There were no data collected during the study to show the zone of passage being used. However, as discussed in Section 6.3.3, the whole cross-section of the river is available as a zone of passage for all RIS under typical conditions. Even during the worst-case modeled scenario in July, which occurred less than 1 percent of the time over the period of record, approximately 50 percent of the river cross-section would be available to all RIS as a zone of passage (Section 6.1.2, Figure 6-5). In addition, as discussed in the response to Comment 1, fish have been shown to avoid unfavorable temperatures and utilize alternate areas of a waterbody. The similarity in fish assemblages upstream and downstream of the LEC discharge also suggests that fish freely move throughout the river. Therefore, even in the absence of sampling data from the zone of passage, it is reasonable to conclude that even during the infrequent worst-case conditions, fish will use the zone of passage and other available areas of habitat for refuge.

17. Section 7, Rationales 9 and 10 have not been substantiated appropriately. Sampling in the zone of passage did not occur to assure these heat intolerant species can use these areas outside of the thermally exposed area as an avoidance area. The assumption needs to be quantified appropriately.

    RESPONSE: We believe that Rationales 9 and 10 have been substantiated appropriately. For Rationale 9, Section 6.1.2 and Figures 6-4 and 6-5 show that for the June model scenario, 3 percent or less of the modeled area could potentially experience temperatures of 90°F or higher. For the July model scenario, approximately 50 percent of the modeled area could potentially experience temperatures of 90°F or higher. All RIS avoidance temperatures (Table 6-2) are approximately 90°F or higher except for sauger which would not be present in the study area during the summertime. It is important to note that the percentages do not account for all the available habitats near the LEC. Consequently, the percentage of areas potentially experiencing temperatures above 90°F would be substantially less than the above values. In addition, the July model scenario represents potential conditions that may be experienced less than 1 percent of the time over the 17-year period of record. Based on this information, the area of potential habitat exclusion was not considered to be unacceptably large.

For Rationale 10, Section 6.3.3 demonstrates that under typical conditions, the entire river cross-section is available as a zone of passage for all RIS. Table 6-2 shows quantitatively the amount of cross-sectional area available for each of the RIS species (Section 7 is meant as a summary only) under the worst case scenario (July modeled scenario) which occurred less than 1 percent of the time of the 17-year period of record. Even during a worst-case scenario, approximately 50 percent of the river cross-section would be available as a zone of passage for all RIS. Consequently, because the percentage of areas potentially experiencing temperatures above 90°F are either absent or are shown to be extremely limited both spatially and temporally, Rationales 9 and 10 are substantiated.

18. Section 7, Rationale 18. In the nutrients, bacterial contaminants, and dissolved oxygen concentrations, a statement was provided saying "there is little likelihood the relatively small increase in temperature will demonstrably increase the rate of' those enumerated contaminants. Can the author provide a calculation of the assessment to show numerically these are relatively small increases?

    RESPONSE: Figure 7-1 addresses the dissolved oxygen concentrations within the thermally exposed zone relative to the upstream reference zone. As noted in Section 7, there is no reason to expect the LEC's thermal discharge will have any effect on nutrients and bacterial contaminants in the LMOR owing to the small size of the area affected by significantly elevated temperatures and the strong currents sweeping bacteria and nutrients through the thermally exposed zones. There should be no exposure to elevated temperatures for the majority of the bacteria and nutrients passing by the LEC. Therefore, there is no potential for temperature-related effects. Further, most of any exposures that do occur will be in the order of minutes and unlikely to be of sufficient duration to elicit any effects.

19. Section 8. Please provide the following references digitally:

    a. Bevelheimer, 2008
    b. Bevelheimer and Coutant, 2004
    c. Bulleit, 2004
    d. Coutant, 1972
    e. DeLonay et al, 2012
    f. EPRI 2013
    g. Galat et al, 2005a
    h. Galat et al, 2005b
    i. McElroy et al, 2012

j. Mestil, 1999

k. Neill and Magnuson, 1974

l. Schramm, 2004 in Welcomme 2004

m. Stanovick, 1999

n. Tripp et al, 2019

o. Union Electric Company, 1976 and 1977

p. Wismer and Christie, 1987

q. Yoder and Emery, 2004 Group 2 Comments (Engineering)

RESPONSE: The requested references have been provided as part of this response to comments.

Group 2 Comments (Engineering)

20. Table 5-9 is electrofishing sampling from 1980-1985, 1997-2002, and in 2017-2018. Please address why the electrofishing results from Tables 24 & 28 from Volume 2, Attachment K from 1976 Labadie Thermal Discharge Effects on Biological Populations of the Missouri River were not included.

    RESPONSE: The early data were not used because we only had the reference tables which did not provide enough data for our analyses.

21. Section 2, it may be beneficial to include more description on the changes in the Missouri River over time and how the river is being used. See Volume 6 Attachment O and Volume 8 Attachments Q & R from 1976 Labadie Thermal Discharge Effects on Biological Populations of the Missouri River.

    RESPONSE: Additional description of the changes in the Missouri River over time and how it is being used has been incorporated into Section 2.1 of the revised draft Demonstration document.

22. Section 5.4, while the pallid sturgeon are specifically referenced as the only federally listed endangered species, Ameren should provide a discussion on any possible presence of state listed threatened or endangered species. The 2019 list from MDC is available at

    https://nature.mdc.mo.gov/sites/default/files/downloads/2019_SOCC.pdf

    RESPONSE: No federally listed endangered or threatened species were collected over the two-year survey period from 2017-2018. However, three state-endangered lake sturgeon (*Acipenser fluvescens*) were collected. One lake sturgeon was collected from the discharge in April 2018 and one individual was collected from the inside bend wing-dike habitat in

the upstream zone in both May and November 2018. In addition to these individuals several species having S2 "imperiled" or S3 "vulnerable" rankings of conservation concern in Missouri were collected including the plains minnow (*Hybognathus placitus*; S2; n = 6 individuals), sturgeon chub (*Macrhybopsis gelida*; S3; n = 78 individuals) and ghost shiner (*Notropis buchanani*; S2; n= 3 individuals) (Table 1). Five skipjack herring were also collected that have a Missouri ranking of SU "unrankable" due to lack of information or due to substantially conflicting information about status or trends (Table 1).

Table 1. Missouri Species of Conservation Concern Collected from each Sampling Zone and Habitat Type by all Gear Types in 2017-2018

Species	State Rank	Upstream Zone	Discharge Zone	Thermally Exposed Zone	Downstream Zone	Overall Total	Overall Percent
Sturgeon chub	S3	10		36	32	78	0.31
Plains minnow	S2	4			2	6	0.02
Lake sturgeon	S1	2	1			3	0.01
Ghost shiner	S2	1			2	3	0.01
Skipjack herring	SU	3		1	1	5	0.02

S1 - critically imperiled; S2 - imperiled; S3 - vulnerable; SU - currently not rankable due to lack of information

23. Provide justification on why the sampling plan was not followed.

RESPONSE: Ameren implemented the sampling plan as developed and collected all prescribed fisheries, benthic macroinvertebrate, water quality and sediment characteristic data as specified. We infer that this comment may refer to the other comments made by the Bioassessment Group regarding the macroinvertebrate taxonomy, subsampling, deployment of mid-depth and bottom-depth H-D samplers, and the calculation of benthic macroinvertebrate metrics. All of these comments are directly addressed below in detail for each comment.

The only area of the sampling plan that we have identified as not being followed is the coordination with the MDNR on the final selection of RIS which was an inadvertent oversight.

Group 3 Comments (Bioassessment)

24. The study plans reviewed by the Bioassessment Unit all have language indicating that final selection of representative important species (RIS) will be made in consultation with DNR. However, this unit has not been contacted regarding the Labadie project since our joint meeting with Ameren and Amec Foster Wheeler (AFW) in November 2016. The other two DNR people in that meeting were Jake Faulkner and Sam McCord; I do not know whether

they were consulted on the RIS topic after the November 2016 meeting, but the Bioassessment Unit has not been involved since then.

RESPONSE: We apologize for the oversight of not conducting the final step to have the final selection of RIS approved by the MDNR. As indicated in other responses, Asian carp has been removed as an RIS in the predictive analysis in Section 6 of the revised draft Demonstration.

25. Section 8. Please provide determination of relevance for the following references:
    a. Holland et al, 1971; how do blue crabs relate to species found in Missouri?
    b. Meldrim et al, 1974; how do the noted estuarine species compare to freshwater riverine species found in Missouri?

RESPONSE: These were among a group of references cited on the effects of temperature generally on thermal tolerance and metabolism and were not used in any analysis or tolerance value related to the Missouri River.

26. On page 5-41 Section 5.4.2.3 "Community Characteristics: Diversity," it states, "Due to the differences in taxonomic level (class, order, family, etc.) of identification of the benthic macroinvertebrates, diversity was calculated at the family level because most organisms could be identified to this level." This section goes on to describe differences in macroinvertebrate diversity among sampling zones, ultimately determining in the last sentence of the paragraph, "This analysis demonstrates that the LEC thermal discharge has not adversely affected the benthic macroinvertebrate diversity in the Thermally Exposed and Downstream zones."
    a. Basing diversity on family level identification can mask differences among stations, and this measure, as presented, lacks the precision to say definitively whether or not the macroinvertebrate community is affected by thermal discharge. It has been our experience that genera within a given family respond differently to pollutants. For example, some genera of mayflies are highly sensitive to heavy metals, whereas others are less so. In that scenario, the family is still represented, but there is no measure of the overall community being altered. Their study plan (Appendix A, page 11) and SOP (separate document) both state that identifications will be taken to the lowest practicable taxonomic level. If this level of effort was spent, why not base diversity measures on that? DNR protocols also require lowest practicable taxonomic level, but our biological metrics and criteria thresholds are not limited to the family level.
    b. Please provide the rationale for only identifying to the Family level.

RESPONSE:

a. As specified in the study plan, taxonomic identification was conducted to the lowest practicable taxonomic level. In response to this and other related comments regarding the benthic invertebrate analyses, we have included additional data and related analyses in the Supplement.

   Overall, for Hester-Dendy samples, 22% of organisms were identified to species, 65% to genus, and 12% to Family. For ponar samples, 16% were identified to species, 10% to genus, and 44% to family. ASA chose to analyze diversity at the family level as a compromise between being inclusive of as many organisms as possible and being able to do the analysis at a consistent level of taxonomic specificity.

   As a result of the comment, ASA has reconsidered this decision and has revised the diversity analysis to the lowest practical taxon level. This revision has allowed more individual organisms to be included and provided a minimum estimate of the total number of species. The revised analyses have been incorporated the revised draft Demonstration document.

b. Taxonomic identifications were made to the lowest taxonomic level based on the guidance provided in the SOP document by Sarver 2016 (MDNR-ESP-209) entitled "Taxonomic Levels for Macroinvertebrate Identifications". A summary of the macroinvertebrate data with identifications to family level by gear type and by sampling zone is provided in tables 5-8 and 5-9 of the Demonstration, and to the species level in Appendix Tables B-22 through B-24.

27. The study plan (Appendix A) says on page 11 that samples will be subsampled to 200 specimens. The Bioassessment unit could not tell whether they subsampled Hester-Dendy and ponar samples to 200 specimens, but Table 5-6 shows a total of 71,594 individuals identified from Hester-Dendy samplers and 23,115 from ponar samples in 2017-2018. This table also has macroinvertebrate taxa presented both at the family and species level, which suggests that they may have identified specimens to the lowest practicable level, but did not present the data. The heading of "species" in Table 5-6 should be reconsidered, given that relatively few macroinvertebrates can be taken to the species level, especially as larvae. Please supply a response.

    RESPONSE: Consistent with the study plan, if Hester-Dendy and Ponar samples contained a large number of specimens then samples were split using a Folsom plankton splitter. Sub-samples were then processed until a minimum of 200 specimens were found. Counts for individual sub-samples were maintained in the event that multiple sub-samples were required to reach a total of 200 specimens or in the event that an initial sub-sample containing more than 200 specimens was split a second time. The identifications of

specimens in the sub-sample that contained a minimum of 200 specimens was multiplied by the appropriate split factor (2^x, where x = the number of times the sample was split) to obtain the total number of individuals in the sample and species composition.

Captions for Table 5-7 and 5-8 are revised to ""Minimum species", consistent with the identification to the lowest practical taxon. Within a family, the minimum number of species would include each identified species, plus one for each observed genus with no identified species. Use of "0" has been standardized.

28. DNR suggested Hester-Dendy (H-D) samplers be deployed on the bottom of the river as well as suspended in the water column (AFW initially proposed to deploy H-D arrays only at mid-column). Our rationale was that this dual deployment would determine whether suspended H-D arrays only sample the drift, rather than the community that actually lives in the benthos at each station. At the November 2016 meeting, Bill Elzinga (AFW) agreed to this dual deployment, and it was written into the Study Plan. Pages 10-11 of the study plan (Appendix A: Labadie Energy Center§ 316(a) Study Plan and Addenda in the August 8, 2019, Final Demonstration) state that one H-D array would be deployed for benthic sample collection, and one array would be set for mid-water column sample collection. At the end of one year, the two sets would be evaluated to determine whether to continue with the dual deployment.

    The Bioassessment Unit did not see in any of the reports that this was carried out, nor did we read anywhere in Addendum 3: Summary of Revisions to the Initial Study Plan an explanation for why it was not. Please address the topic and provide an explanation for why this revision was made.

    RESPONSE: Consistent with the study plan, both mid-water and bottom H-D arrays were deployed for the full two years of the study. The data were combined because there was no temperature stratification observed in the water column and the decision was made to combine the data to provide a better overall picture of the macroinvertebrate community at the sampling location.

    An analysis of macroinvertebrates collected separately from mid-depth and bottom-depth samplers is provided in the Supplement. Despite differences in depth profile and the possibility for suspended HD samplers to collect only drifting organisms versus those associated with the community that lives in the benthos, the overall taxonomic composition of HD samplers was very similar among depths (overall QSIT value = 87.14) for all locations combined over the two year sampling period. These results indicate that collections from mid-depth and bottom-depth samplers were essentially equal and representative of the same community.

Consequently, the Demonstration results relied on a combined mid-depth and bottom-depth analysis of the HD samplers, which accounts for the entire macroinvertebrate community (i.e. drift and benthos).

29. Also on page 11 of the study plan it says, "Benthic macroinvertebrate habitat and community analysis will include, but may not be limited to the following metrics: density (#/m^2), taxa richness, dominant taxa, EPT index, Biotic index, Shannon diversity index, qualitative sediment characterization (percent abundance of particle types, Wentworth scale). The study plan goes on to say on page 12 that detailed information regarding sample processing and analysis can be found in the SOP and QAPP documents that accompanied the study plan.

    a. Density, "EPT Species," and "EPT Intolerant" are presented in Appendix B, Tables B-46 through B-49. The remaining biological metrics (taxa richness, dominant taxa, biotic index, and Shannon diversity index) are not presented in the report. Based on the study plan, we expected to see more biological metrics provided and discussed. Tables B-37 through B-49 present a great deal of information, but biological metric trends among stations is notably lacking. Please provide the trend analysis.

    b. The SOP concurs with the study plan in that specimens will be identified to the lowest practicable taxon. The QAPP has a section that discusses fish identification, but there is no such discussion for macroinvertebrate identification. Please supply a discussion for the macroinvertebrate discussion.

RESPONSE:

a. Calculations of most of the metrics identified in the study plan were included. However, it was considered inappropriate to discuss each metric individually for our analysis. Rather, we combined them into the standardized difference analysis as part of a Weight-of-Evidence evaluation of thermal effects. The trend analysis for the metrics combined is included in Figure 5-29. We did not initially calculate a biotic index because we did not think that metric was particularly appropriate to evaluate thermal exposure (i.e., tolerance values as originally developed were more an indicator of organic pollution and not thermal conditions). Additionally, after evaluating the sediment composition in the interim report, we did not believe that the analysis provided any useful information to the assessment, so we did not include it in the final report.

   In response to this comment we offer the following:

   - The specific metrics and standardized differences derived from them are presented in the following locations in the revised demonstration:

- Density — Table B-25
- Diversity — Table B-26
- Proportion in Major Groups — Table B-27
- EPT Species and Fraction — Table B-28
- Heat-Intolerance — Table B-30

Seasonal summary of metrics above used to calculate standardized differences

- Winter — Table B-31
- Spring — Table B-32
- Summer — Table B-33
- Fall — Table B-34

- In the revised Demonstration, the diversity metrics and standardized differences are recalculated at lowest practical taxon. Similarly, the biotic index values are presented in the attached the Supplement, Section 7.
- A qualitative sediment characterization (percent abundance of particle types) of individual macroinvertebrate samples collected by ponar grab as per the study plan are also included in the Supplement, Section 9.

b. A detailed discussion of the macroinvertebrate identification and QA/QC procedures followed can be found in the Supplement, Section 8. A brief summary of these procedures is provided below. A 10% identification check was followed for the QA/QC assessment of macroinvertebrate specimen identification. Ten percent of samples that were identified by each taxonomist were processed for a QA/QC check by a second qualified taxonomist. Subsets of ten samples were designated for the QA/QC check, with one of the ten samples randomly picked to be the QA/QC sample. The original taxonomist must correctly identify 95% of the organisms comprising the sample in order to pass the QA/QC check. If a taxonomist fails a QC inspection, then the remaining samples within that subset of ten samples will be re-examined by the original taxonomist and also undergo another QA/QC check by a second qualified taxonomist. If these samples continue to fail inspection, then previous samples identified by the original taxonomist will undergo QC checks until 95% accuracy is achieved. A reference collection of voucher specimens was also maintained and independently verified by another taxonomist, with outside verification by a third party as needed. Any rare specimens or specimens of threatened or endangered species required additional verification and were sent to an outside recognized taxonomic expert for confirmation.

30. This is a minor point, but in Appendix B, the List of Tables needs to be corrected. For example, the List of Tables shows macroinvertebrate data beginning with Table 8-31 (Abundance statistics for benthic macroinvertebrate community sampling for 2017-2018 LEC study by zone, and season). However, macroinvertebrate data are presented in Tables 8-37 through 8-49. There may be other errors, but we verified only the macroinvertebrate tables.

    RESPONSE: A careful review of the Demonstration report has been conducted to identify and correct this and other similar editorial errors.

Group 4 Comments (MDC)

31. The Demonstration is intended to determine whether the alternative effluent limits for temperature will assure the protection and propagation of the balanced indigenous community (page I). According to page V of the report, EPA's indicators of Appreciable Harm include no increase in nuisance species." Indigenous species are described on page 3-3, and seem to include those endemic to a waterbody, but also those specifically managed (such as intentional stocking of sport fish). Per MDC's comment, the DNR is requesting a summary of the temporal aquatic community and how populations have changed over time.

    RESPONSE: Table 5-10 in the Demonstration provides a summary of the fish collected by electrofishing over all seasons and zones for the three study periods. The objective of the included temporal analysis was to evaluate whether changes that may have occurred over time in the thermally exposed and downstream zones also occurred in the upstream reference zone. If such changes have occurred, it could reasonably be concluded that those changes are not a result of exposure to the thermal discharge. As summarized in Section 5.5.2.3 the temporal trend analysis indicates that the fish community in the Thermally Exposed zone changed in ways similar to those in the Upstream Reference zone indicating no adverse effects from exposure to the LEC thermal discharge over time.

32. The Demonstration evaluated data collected on two dates (June 22, 2006 and July 21, 2006) over a 17-year period of record. The rationale described for these dates was they occurred during the most extreme conditions during the "most biologically active period"(page 6-2). June and July are the most biologically active periods but spawning can occur earlier. Please comment as to why spawning months were not included.

    RESPONSE: We selected these dates because they represented the highest TDP values (i.e., worst case) and would have been permit limit exceedances if the current permit had been in place. As such, they represent conditions during which there is the greatest possibility for a biological effect to occur. At other times and other spawning months, the thermal plume temperatures were within acceptable ranges due to a combination of

ambient water temperatures and plant operation and did not approach thermal tolerance limits.

33. The report notes the "avoidance temperatures" of pallid sturgeon are "not known" (page V). Please establish if the avoidance temperatures of pallid sturgeon can be determined, either through literature search or other assessment.

    RESPONSE: After a thorough literature search, no additional references were found providing avoidance temperatures for pallid sturgeon.

34. As acknowledged in Table 2-11, the previous thermal exceedances occur in July, August, and November. The documented previous thermal exceedance months (July, August, November) are not aligned with the selected ·most biologically active period" demonstration dates (in June and July, referenced Page 6-2). By selecting demonstration dates in June and July, potentially important data would be excluded {August, November). Excluding these data might result in inaccurate conclusions. Consider evaluating for the months of previous thermal exceedance or justify more fully why August/November data were excluded.

    RESPONSE: The selection of those June and July dates applies only to the predictive assessment. Those dates were selected as they represented the most extreme high temperature scenarios during the spawning season (June) and throughout the season (July). With the exception of a single year, the historical record indicated that there were no exceedances of current thermal permit limits estimated in November. In months with no exceedances, no thermal effects are expected. At times in which temperature exceedances were predicted in November values were sufficiently low so as to not yield thermal effects.

35. A thermal variance for six percent of the year represents 22 days. If these days were consecutive, it could have a cumulative negative effect for fishery resources. Please provide the rationale for allowing 22 consecutive days of exceeding normal river thermal limits.

    RESPONSE: The need and request for an alternative 316(a) effluent limitation is based, at least in part, on study of the historical database between January 2002 and September 2017. Table 2 illustrates the dates on which a TDP greater than 0.95 was retrospectively calculated to have occurred. (Note that the TDP effluent limitation was not in effect during this period and the facility was in compliance with its then existing thermal effluent limitation.)

Table 2. Consecutive Periods with Retrospectively Calculated TDP > 0.95

Start Date	End Date	Number of Consecutive Days
8/1/2002	8/5/2002	5
8/21/2003	8/22/2003	2
7/19/2005	7/26/2005	8
7/18/2006	7/21/2006	4
7/29/2006	8/4/2006	7
8/8/2006	8/11/2006	4
11/17/2006	11/17/2006	1
11/20/2006	11/20/2006	1
11/25/2006	11/29/2006	5
7/6/2012	7/10/2012	5
7/17/2012	7/20/2012	4
7/23/2012	7/28/2012	6

Note that the challenging conditions typically occur in July and August when high river temperatures can occur. But they did not occur in every year. In year 2006, very low flow in November posed a challenge. As a result, there were a total of 22 days in 2006 (6% of the days in the year). This served as the basis for requesting an alternative 316(a) effluent limitation for up to 6% of the days in any calendar year.

The largest number of consecutive days that posed a challenge was 8 in July of 2005. In July 2012, fifteen days, though not consecutive, would have had TDP greater than 0.95. In the period July 17 through July 28 of 2012, 10 out of 12 days would have had TDP greater than 0.95, and July 21 and 22 would have had TDP values of 0.8 and 0.9, respectively, clearly close to 0.95. So, a potential to have more than 8 consecutive days (i.e., the maximum observed) with TDP greater than 0.95 exists. While Ameren does not expect to experience 22 consecutive days with TDP greater than 0.95, there is concern that the number of consecutive days will exceed the maximum observed in the data record (i.e., 8 consecutive days).

Whether 22 consecutive days with the Ameren discharge TDP greater than 0.95 will pose a detrimental stress on fishery resources is certainly not demonstrated. Even under the

worst-case condition, 60% of the river will still be in compliance with the thermal criteria in Missouri's water quality standards. More typically the portion in compliance will be in the range of 65% to 75%. Without the variance, 75% will be in compliance. Consequently, there is not a dramatic difference in the amount of the river that will be in compliance when the variance limits are invoked versus the normal limits. A substantial zone of passage (i.e., greater than 60% of the river) will be available even under worst case conditions.

Furthermore, 22 consecutive days under the variance is substantially less than that which would be allowed under a provisional variance. The Missouri legislature has provided the Director of Missouri DNR the authority to grant a provisional variance from compliance in appropriate circumstances. Provisional variances can be granted for an initial period not to exceed 45 days. Thus, the State of Missouri already has a mechanism in place to allow a variance to extend more than twice as long as Ameren's 316(a) request.

We reiterate that the variance is a reasonable mechanism for extreme conditions when strict compliance with the thermal criteria in Missouri's water quality standards are not achievable without severe curtailment of electricity production, and the demands for electricity are such that reduction in the generating capacity of the Ameren Labadie facility would pose an unacceptable societal hardship. Therefore, Ameren respectfully requests that there not be a restriction on the number of consecutive days when the 316(a) variance can be invoked.

36. Information about the thermal limits of other sturgeon species included Age-0/1 lake and shortnose sturgeon that showed limits of 31-35 degrees C (87.8 - 95 degrees F). At the low end of the temperature ranges feeding behavior is impacted negatively and at the upper end can be lethal depending on previous acclimation temperatures and duration. In the fish hatchery setting, it has been reported that developmental issues among immature sturgeon may occur over 26 degrees C. Please provide an assessment of this consideration.

RESPONSE: The data and information cited in comment #36 will not affect the interpretation or conclusion of the Demonstration study. Studies have shown that every species, including sturgeons, has their own thermal limits, which also are affected by acclimation temperature, geographic location adaptations, and experimental procedures. Kappenman et. al. (2013) concluded that their experiments showed that pallid and shovelnose sturgeon have a higher thermal tolerance limit, higher thermal optima, and a wider range for embryo to larval development than other sturgeon species.

In addition, recent studies (Delonay et al. 2009; Braaten et al. 2010, 2012) indicate that the area of influence from the LEC thermal plume is well upstream of the most probable settling areas for pallid sturgeon in the lower Missouri River, and possibly well downstream

from prime spawning areas and early embryo development. The following references are provided in addition to the list contained in Comment 19.

Kappenman, K.M., M. A. H. Webb and M. Greenwood. 2013. he effect of temperature on embryo survival and development in pallid sturgeon *Scaphirhynchus albus* (Forbes & Richardson 1905) and shovelnose sturgeon *S. platorynchus* (Rafinesque, 1820). J. Appl. Ichthyol. 29 (2013), 1193–1203

Braaten, P.J., D.B. Fuller, R.D. Lott, M.P. Rugge;s. T.F. Brandt, R.G. Lagaer, and R.J. Holm. 2012. An experimental test and models of drift and dispersal processes of pallid sturgeon (*Scaphirhynchus albus*) free embryos in the Missouri River. Environ. Biol. Fish 93:377-392.

Braaten, P.J., D.B. Fuller, R.D. Lott, M.D. Ruggles, and R.J. Holm. 2010. Spatial distribution of drifting pallid sturgeon larvae in the Missouri River inferred from two net designs and multiple sampling locations. N. Amer. J. Fish. Mgmt. 30(4):1062-1074.

DeLonay, A.J., R.B. Jacobson, D.M. Papoulias, M.L. Wildhaber, K.A. Chojnacki, E.K. Pherigo, J.D. Hass, and G.E. Mestl. 2012. Ecological requirements for pallid sturgeon reproduction and recruitment in the Lower Missouri River. Annual Report 2010. U.S. Geological Survey Open-File Report 2012-1009, 51 pp.

37. An added challenge for fishery resources is the higher the water temperature, the lower the natural concentration of dissolved oxygen gas in the water at standard pressure. For example, at 35 degrees C, the 100% saturation point is around 7 mg/L; it is below 6 mg/L at 45 degrees C. Dissolved oxygen is needed for fish respiration. Also, as temperatures increase, fish respiration increases and consumes more dissolved oxygen. Please provide assurances the LEC discharge is not reducing the DO of the stream to levels which would injure fish, and how will this be monitored/reported.

    RESPONSE: We provided an analysis for DO concentrations within the plume in Section 7, Figure 7-1. The analysis shows that during the study's hottest months, the thermally exposed and downstream zones contained similar (and slightly higher) DO than the upstream zone. Further, DO concentrations in the LMOR are rarely at or near saturation levels. Hence, reductions in saturation levels related to temperature will not cause any loss of DO in the water.

38. Hydrographs for both the Hermann Gage and the Labadie Gage provide water temps that usually peaked in July-August around 30-32 degrees C. Ambient water temperatures naturally reach the feeding impact temperatures. Please comment how this will impact this study overall.

RESPONSE: The fact that ambient temperatures may reach feeding impact temperatures will not have any impact on the interpretations or conclusions of the Demonstration. Ambient water temperatures may reach 30-32°C during some summer months and thus meet or exceed optimum temperatures for feeding and growth for some species, particularly less thermally tolerant species. This naturally occurs for many wild fish populations. The typical response will include a temporarily reduced or zero growth rate until ambient temperatures fall once again within the optimal range. In cases of prolonged high temperatures that could influence survival as well, motile life stages such as juvenile and adult fish will seek available thermal refuge areas, as observed by Ameren studies of Coffeen Lake (ESE 1995). Ambient temperatures in these refuge areas may fall within or closer to the species' range for feeding and growth.

Environmental Science & Engineering, Inc. (ES&E). 1995. Coffeen Lake 1995 aquatic biota and water quality surveys. Prepared for Central Illinois Public Service. November 13, 1995. ES&E Project No. 5195-125-0400.

39. The Demonstration describes that pallid sturgeon would avoid the thermal discharge zone at Labadie, and would not use shoreline habitat most affected by thermal events. It should be noted that Labadie Plant is located on the outside bend of the Missouri River, where the thalweg occurs. As noted in page 6-39, the species is known to use deeper channel areas (a.k.a. the thalweg). Drifting larval pallid sturgeon would not have adequate motility to avoid thermal mixing zones, and this life stage of the pallid sturgeon is known to be carried in the thalweg. Please describe how pallid sturgeon larvae drifting in the thalweg/outside bend where Labadie discharges will be addressed.

RESPONSE: Most drifting sturgeon larvae would not be exposed to potentially lethal temperatures long enough to be affected, particularly during the high river flows and current velocities in the thalweg during their prime spawning months. Transit times are addressed for all RIS in Section 6.3.1.1, including pallid sturgeon.

40. The Demonstration describes not increasing the prevalence of additional invasive species {p. 6-7) as evidence that the demonstration period with thermal variances successfully operates without detriment to the fishery. We consider Asian carp an invasive species and do not stock them as a sport fish. They could be considered a nuisance species.

    a. Please provide the rationale for classifying Asian Carp fish species as native/indigenous.

    b. How would the analysis and conclusions change if the Asian carp were included in the nuisance species- fish group?

RESPONSE: We are not sure which section of the report is being referenced here. Page 6-7 is Figure 6-4 and has no discussion of invasive species. We believe we did classify the

Asian carp as an invasive, nuisance species and they were selected as an RIS based on that criterion in the EPA guidance (see response to overarching comment on page 2). If the MDNR/MDC can clarify exactly which section of the report they are referencing here, we may be able to better address this question.

41. If MDC had been consulted about this study, MDC would have recommended including commercial fish (bigmouth buffalo, etc.) since other groups were included (invasive, game fish, prey fish, endangered, etc.).

RESPONSE: The availability of sufficient thermal tolerance data for bigmouth buffalo has been investigated to determine whether or not bigmouth buffalo could be added as an RIS. A single relevant reference (Yoder and Emery 2003) was found. This reference provided thermal effects temperatures for adult bigmouth buffalo acclimated to 80 to 86 °F as listed in Table 3.

Table 3. Thermal effects temperatures for adult bigmouth buffalo acclimated to 80 to 86 °F

Factor	Temperature (°F)
UILT50	100.9
Upper Avoidance	95.0
Maximum Temperature for Acceptable Growth	93.4
Preferendum	91.2

The thermal effects temperatures provided in this study are generally equal to or higher than the thermal effects temperatures of the other RIS suggesting little if any potential for thermal effects to this species by the LEC's thermal plume.

COMMENTS FROM EPA REGION VII

Comments from John Dunn:

1. The limit of 0.95 TDP, defining a 5°F temperature increase with a 5% safety factor, is technically correct, but does not provide transparent information to the lay public. Permit limits and the variance request should be based on temperatures expressed as degrees °F as set in MDNR criteria.

   RESPONSE: This NPDES permit used an innovative approach in setting thermal effluent limitations. It specifies a daily average thermal effluent limitation of 0.95 for the Thermal Discharge Parameter (TDP). That includes a specific margin of safety of 5% (i.e., the limit could be 1.0 and still be protective of water quality), as well as other inherent conservative factors that were built into the effluent limitations derivation process that afford an even greater, although not specifically quantifiable, margin of safety.

   This effluent limitation is not expressed as a specific temperature in degrees Fahrenheit for the discharge. (In fact, prior versions of this permit also had an effluent limitation expressed in BTUs not temperature. For example, see the permit issued November 24, 2015.) In fact, a single temperature effluent limitation is not adequate to ensure compliance with the receiving water quality standards for temperature. The effluent limitations derivation process for this permit has demonstrated that it is not just the effluent temperature that is critical to maintain acceptable receiving water quality, but it is the combined effect of effluent temperature, effluent flow, upstream temperature and upstream flow that together determine compliance with the water quality standards. The TDP limits the combined effect of these four aspects of the discharge and the river on any given day. As such, compliance with the TDP effluent limitation ensures that the numeric receiving water quality criteria at the edge of the mixing zone for temperature (no greater than 90°F) and increase in temperature above background river temperature (no greater than 5°F above background) are met day in and day out. (Indeed, requiring compliance with the water quality standards is exactly how the final effluent limitations were written in prior versions of this permit. For example, see the permit issued November 24, 2015.) In lay terms, the TDP limits the discharge so that whatever conditions occur in the river on any given day, the river temperature at the edge of the mixing zone will not exceed 90°F or be more than 5°F above background. This is far superior to limiting the discharge to the same specific temperature every day because even if that temperature limitation was derived for some critical condition, there can always be a more critical condition and under that more critical condition, by definition, the river will not be in compliance with the 90°F or delta T of 5°F criterion.

So, the best way to explain the effluent limitation to the lay public is to say that it ensures, for all conditions, that the river will not exceed 90°F or delta T of 5°F at the edge of the mixing zone, i.e., it provides for complete compliance with the water quality standards and also includes safety factors. A static temperature effluent limitation can never do that.

2. Equations for deriving TDP are calculated to many significant digits but monitoring in the current permit is only required once daily. During heat events, stream temperature can vary by up to 1.5°F in a given day.

   RESPONSE: The equations for the TDP have coefficients with several significant digits, but the TDP effluent limitation itself is expressed to only two decimal places (i.e., 0.95). The number of significant digits for the equation coefficients is needed to ensure precision in the calculation. However, the final calculation of the TDP (TDP = M1/M2) should be conducted to only two decimal places consistent with the effluent limitation.

   The effluent limitation is indeed a daily maximum limitation, not an hourly or any other temporal limitation, and compliance is measured (calculated) on a daily basis. While measured temperature may vary by 1.5°F at a point in the river over the course of a 24 hour period, temperature spatially across the river can vary by more even without the Ameren discharge. Such fluctuations are a natural phenomenon. The interim and final effluent limitations have always been expressed as daily maximum limitations as noted above in the referenced permits. Shorter time frames would be impractical, and the daily average TDP effluent limitation ensures compliance with the water quality standards.

3. The permit should assure that monitoring precision matches up with the detailed nature of the modeling. It should be noted that the USGS gage at Hermann, the data source for the permit, monitors Flow and Temperature every 15 minutes. Temperature can be measured inexpensively by calibrated thermistors feeding data to a computer that calculates TDP and estimated temperature at the edge of the RMZ. Continuous monitoring at this frequency would generate unneeded data, but high frequency monitoring when variance conditions are approached could create important data sets for future consideration. In any case, all data used in the model equations should be time synchronized.

   RESPONSE: While the USGS gage at Hermann may provide useful additional information, the USGS gage at Labadie (as required by Notes 2 and 3 to Table A-2 of the permit) is used for specifying background river temperature and flow in this instance. Consistent with the permit requirements and the modeling which served as the basis for the permit, the TDP is calculated and reported on a daily basis using the daily flow and daily temperature measured at the Labadie gauge. This is consistent with the temporal specification of the effluent limitation as discussed above (i.e., it is a daily limitation and compliance is determined only on a daily basis). Shorter time frames (e.g., 15-minute or

hourly) may be considered for operational purposes, and Ameren does use its own flow and temperature instrumentation and statistical relationships in real time to check on how the TDP is trending throughout the course of each individual day. Ameren does not have access in real time to the 15-minute data collected at either USGS station (Hermann or Labadie). However, as the comment suggests, such data can be subsequently obtained and considered by Ameren, after QA/QC by USGS, for future consideration in assessing system response during critical conditions when variance conditions are approached.

4. Ameren has requested a temperature variance for up to 6% of days each year. In keeping with the precision of the model and the ability to collect data, the time of the variance should be measured in the unit of hours. The MDNR criteria for increased temperature in the Mississippi River are based on a percentage of time in the calendar year and would allow this unit of measure. This would avoid the judgement call of how to count fractional days when river temperatures are rapidly changing. Other states, such as Iowa, use this approach.

   RESPONSE: While different approaches may be used in different states, the specific approach for this permit is a daily effluent limitation, not an hourly limitation, and hence the 316(a) variance should be expressed in terms of daily discharge not hourly discharge. If the 316(a) variance is expressed in a time frame other than daily, then it would not be consistent with the effluent limitation. Indeed, it would not be a variance from the current effluent limitation, but rather a whole new effluent limitation. The permit's effluent limitation and any accompanying 316(a) variance must be applied on a consistent time frame, i.e., daily in this instance. Therefore, the request for the 316(a) variance is as stated in the comment, i.e., "up to 6% of the days each year". This will be consistent with the time frame over which the effluent limitation is applied and compliance with that effluent limitation is reported. Introducing a separate time frame for the 316(a) variance may be possible, but it certainly would be cumbersome and confusing and will not be consistent with the way in which the effluent limitation was derived. Therefore, it must also be expressed and reported on a daily basis.

5. Is the calculation for the 40% Mixing Zone the same as for 25% Mixing Zone as defined in Note 5 in the current permit? Would cold temperature/low water events change this calculation? **Note 5: Mixing Zone (As Percent of Total River Flow) shall be calculated using the following equation: Mixing Zone = [0.1857 ln (M1 / M2) + 0.234] * 100**

   RESPONSE: The equation in Note 5 to Table A-2 of the permit (and as cited in the comment) is applicable to the calculation of the size of the mixing zone on any given day. It was derived from a series of model simulations with mixing zones ranging from 11.5% up to 45.7%. So, caution is suggested if applying the equation outside of that range. The equation was first presented in Figure 5 of *Supplemental Report Thermal Plume Modeling and NPDES Permit Effluent Limitations for the Ameren Labadie Energy Center Missouri State*

Operating Permit No. MO-0004812 prepared by Kleinfelder, February 10, 2017. In the current permit, the size of the mixing zone is implicitly limited to 25% of the river flow (see Note 4 to Table A-2). Calculation of the size of the mixing zone on a daily basis with the equation in Note 5 of Table A-2 is a monitoring requirement only. If compliance with the TDP effluent limitation of 0.95 is achieved on any given day, then compliance with a 25% mixing zone will also be achieved on that same day and will be demonstrated by the mixing zone equation in Note 5.

Based on the data record and potential extreme conditions in the river, there will be days when compliance with the TDP effluent limitation, and hence the 25% mixing zone requirement, cannot be achieved short of shutting down the facility. Consequently, Ameren is requesting a 316(a) variance for these extreme conditions. The request seeks relief from the TDP effluent limitation on up to 6% of the days in any calendar year. On those days, Ameren is willing to restrict the size of the mixing zone to 40% of the river flow, thereby leaving 60% of the river flow in compliance with the thermal water quality standards. The size of the mixing zone during those days can be calculated with the equation in Note 5. As derived, the equation is applicable on a year-round basis regardless of temperature or flow in the river or the discharge.

6. The MO Water Quality Criteria for the Missouri River do not allow for any exceedance of temperatures above 90 degrees F instream: 10 CSR20-7.020(4)(D)(1). Criteria for lower sections of the Mississippi River, 10 CSR20-7.020(4)(D)(5), also require a 90 degrees F maximum, but do allow for a 5% time of exceedance and a maximum exceedance temperature of an additional 3 degrees F (93 degrees F at the edge of the RMZ). Mixing zones are set for both rivers at 25% at 10 CSR20-7.020(4)(D)(6).

   RESPONSE: Ameren's request for a 316(a) variance would allow a mixing zone up to 40% of the river flow on up to 6% of the days in a calendar year. The 90°F maximum temperature and delta T less than 5°F would be met at the edge of this mixing zone. Consequently, at least 40% of the river will have temperature less than 90°F and delta T less than 5°F. This is slightly different from although similar to the exception for the Mississippi River currently in Missouri's water quality standards.

7. The Ameren variance request appears to be based on the logic of the Mississippi River criteria and this seems appropriate. The questions/comments below are based on that approach. While variable with river temperature, what is the more elevated temperature (>5°F) at the edge of the 25% mixing zone when the RMZ is expanded to 40% of the river? Does this equate to an additional 3°F increase above 90°F? Is the 40% value based on a calculated zone of passage or a maximum temperature at the higher RMZ? Ameren's variance request should define the increase in temperature above 90°F when the larger RMZ is allowed.

RESPONSE: On days when the 316(a) variance is invoked, the 90°F and delta T less than 5°F requirements will always be met within a 40% mixing zone, but on those days the temperature will be either be (a) above 90°F or (b) more than 5°F above background in a 25% mixing zone. Hence the need for the 316(a) variance.

In response to this comment, we analyzed the model output from a subset of the previously conducted simulations that were run to develop the effluent limitation equations in Tables A-1 and A-2 of the NPDES permit. For each simulation, we determined the location along the river where the maximum temperature occurs after mixing with only 25% of the river flow. At all other locations, the temperature would of course be less than the maximum. The simulations analyzed represent a range of river and discharge temperatures and flows.

The results for the maximum temperature at the edge of the 25% mixing zone for each simulation are provided in the attached Figure. As expected, the Figure demonstrates that the maximum temperature is a function of the TDP. (Recall that the TDP is a composite measure of the combined effect of river and discharge flows and temperatures.) As can be seen, the maximum temperature at the edge of the 25% mixing zone will exceed 90°F at TDP values above 1, again as expected and as we have previously demonstrated. Nonetheless, the Figure further demonstrates that maximum temperature at the edge of the 25% mixing zone will always be below 94°F even for a simulation with TDP as high as 2.87. Analysis of the historical database (January 2002 – December 2018) indicates that TDP never would have exceeded 2.65. So, even when the variance may be invoked allowing temperature in the river to exceed 90°F in up to 40% of the river, the temperature will still be below 94°F in 75% of the river (i.e., be above 94°F in only 25% or less of the river), and will be below 90°F in 60% of the river (i.e., above 90°F in only 40% or less of the river). Furthermore, these maximum percentages will occur for only a small segment of the river and will be less at all other locations in the river.

For most instances during which the variance may be invoked the maximum temperature at the edge of the 25% mixing zone will only be one or two degrees above 90°F. For example, as shown in Figure 2, for a TDP value of 2.3, the maximum temperature at the edge of the 25% mixing zone will still only be about 92°F. And, TDP values at or above 2.3 would be extremely rare. The historical record shows that such has occurred on only 4 days out of 6018 days (less than 0.1% of the time). So, on days when the variance will be invoked, the maximum river temperature at the edge of the 25% mixing zone will typically be around one and almost always less than two degrees above 90°F, but never above 94°F.

The size of the mixing zone can be calculated on any day via the equation already in Note 5 to Tables A-1 and A-2 of the NPDES permit. Using this equation, a 40% mixing zone is needed when the TDP value exceeds approximately 2.5. Based on the historical data record cited above, the maximum TDP that would have ever occurred is 2.65. Values above

2.5 have occurred only twice, and Ameren is willing to accept a 40% limitation on the extent of the mixing zone for any day during which the variance may be needed. For most days when the variance will be needed, the size of the required mixing zone will be less than 40% and much closer to 25%. So, the 40% value is based on the historical record and represents the maximum size of the mixing zone needed. Typically, and throughout all of most years, a 25% mixing zone will be sufficient. But even during those times when a variance is needed, the mixing zone will not be much greater than 25% and never greater than 40% for only a limited segment of the river.

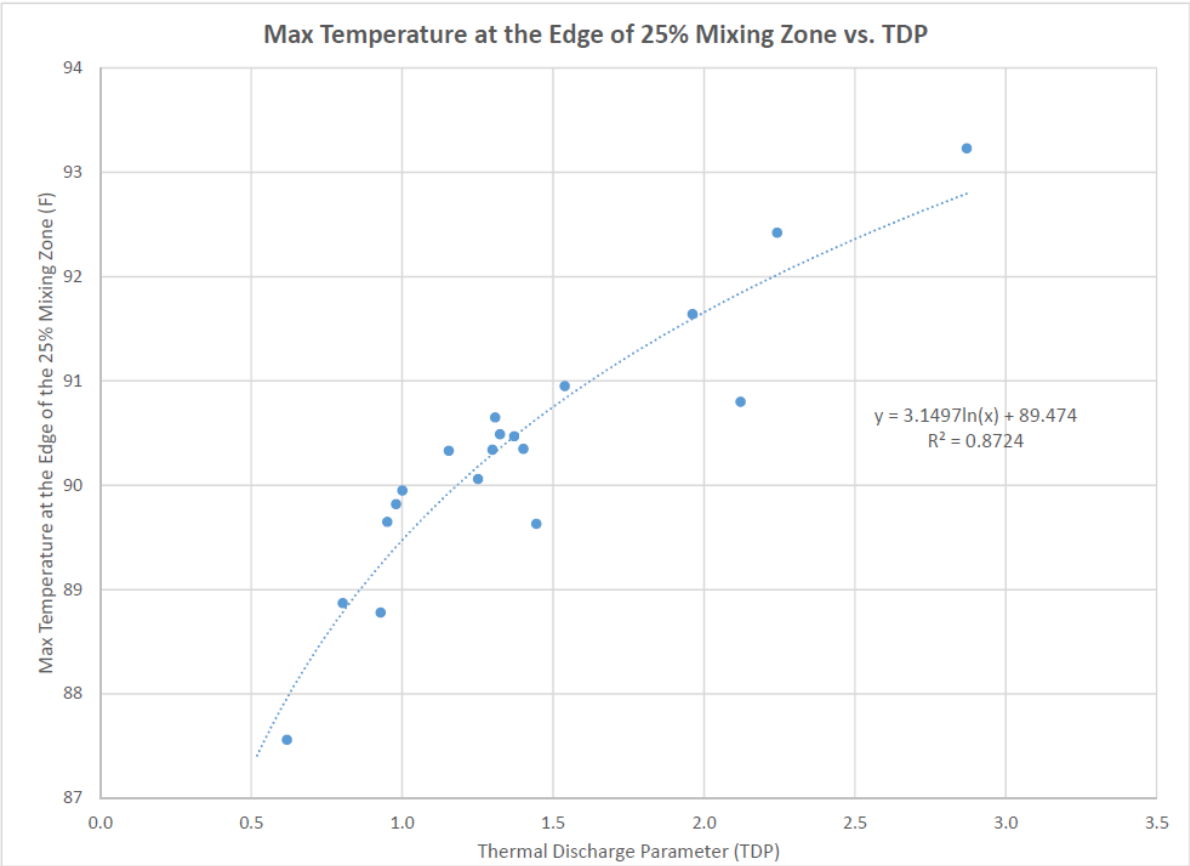

Figure 2. Maximum temperature at the edge of the 25% Mixing Zone vs. TDP

8. Ameren requests that the size of the RMZ be increased when river flows are less than 40,000 CFS. Based in 62 years of USGS data, the 25%-tile of flow at the Hermann gage is 39,200 CFS. Ameren has requested a 6% time of exceedance. It is not clear to EPA why the 40,000 CFS flow was chosen as a cut-off when this is a fairly common condition.

   RESPONSE: The request for a 316(a) variance on up to 6% of the days in any calendar year is based on retrospective analysis of actual conditions. For example, in the year 2006, a TDP of 0.95 would have been exceeded on 6% of the days. The extensive study that

Ameren has conducted in connection with this request has demonstrated that there has been no appreciable harm to the balanced indigenous biological community due to historic discharges from the Facility. Therefore, allowing a variance frequency consistent with the historical data is supported and will ensure the protection of a balanced indigenous community in the lower Missouri River. In other words, continued discharge from the facility at the same level as that which has historically occurred will not result in future appreciable harm to the balanced indigenous community.

If river flow goes below 40,000 cfs and river temperatures are near but below 87°F, a TDP greater than 0.95 will occur with all electric generating units operating at the Ameren Labadie facility. The same will be true if river flow is above 40,000 cfs and river temperature is above 87°F. Hence, the request for a variance when either of these conditions occur.

Regarding the frequency at which a flow less than 40,000 cfs will occur, any statistical analysis should be based on flows at Labadie not at Hermann. Furthermore, historical flow gauge data at Hermann are impacted by upstream reservoir regulation at least since 1958, and gauge data before then should not be used to calculate conditions representative of the present. River flows at Labadie have been reconstructed by Ameren since 2002, the point in time at which detailed information has been collected by Ameren at the location of the current Labadie gauge. Considering those data, a flow of 40,000 cfs is exceeded approximately 14% of the time. It makes sense that the percent frequency for a 40,000 cfs flow should be less at Labadie than at Hermann since Labadie is downstream and would have higher flows than at Hermann on corresponding days. But regardless of the frequency of the flow, the request for variance is still for only a maximum of 6% of the days in a calendar year. In nearly all years the number of days for which a variance will be needed will be less than 6% and for many years there will be no need for a variance. The 6% variance is requested to cover the worst-case condition based on the historical data since 2002.

9. How would MDNR assess compliance with the variance-based limit? If limits and the variance are based on the Mississippi River model, there are other examples of permit approaches in other states.

   RESPONSE: We do not specifically know which permit approaches in other states the commenter is referring to. The Ameren permit has a somewhat novel approach with the TDP effluent limitation. We do not think that should be changed or compromised to accommodate approaches in other states. However, if there is something applicable that the commenter thinks we should consider, we are willing to do that. But, the current permit construct is very amendable to assessing compliance with the variance based limitation. During almost all days (at least 94% of the time), Ameren will comply with the TDP effluent limitation of 0.95. When a TDP of 0.95 is exceeded, as long as river flow is less than 40,000 cfs or background river temperature is greater than 87°F, the variance

based limitation will become effective. On those days, the TDP limitation will be ineffective and the permit limitation will be that the mixing zone shall not exceed 40% as calculated by the equation in Note 5 of Table A-2. The total number of days on which the variance based limitation can be effective is limited to no more than 6% of the days in a calendar year.

10. EPA suggests annual reports with electronic spreadsheets providing the raw data and calculations of TDP and temperature at the edge of the RMZ when the variance is utilized. These detailed data sets could be of long-term use as the variance is renewed over future permit cycles.

    RESPONSE: Ameren is amenable to the preparation of annual reports pending details. Ameren already provides spreadsheets with the raw data and calculated daily TDP when submitting its monthly DMR. Ameren will continue to do so for all days including those when the variance is utilized. The spreadsheet could be expanded to include a calculation of the temperature at the edge of the RMZ when the variance is utilized based on the equation cited above in the response to Comment 7.

Comments from Vanessa Madden:

General Comment

The fish assemblage in the LMOR in the vicinity of the LEC were sampled during the two-year sampling program using bag seines, electrofishing, hoop nets, and Missouri trawls. Macroinvertebrates were sampled using Hester-Dendy samplers which collect drifting organisms, and a Ponar dredge, which collects benthic infaunal organisms. This overall sampling approach for fish and macroinvertebrate monitoring appears to be adequate to provide an overall assessment of the biological community in the vicinity of the LEC.

RESPONSE: Acknowledged

Specific Comments

1. **Table 5-3**. In addition to the graphical representations of the total abundance of fish, a more detailed evaluation would include the pattern of dominant and important species across the four zones.

   RESPONSE: In addition to the listing of the top 15 most abundant species in each zone in Table 5-3, Table 5-4 presents the top 5 most abundant numerically and by weight for each zone. Catch data are broken down by sampling gear in Figure 5-12 (summer) and 5-13 (winter), by length in Figure 5-14, diversity (summer) by zone and gear in Figure 5-15, dominance by zone in Figure 5-16, fish trophic levels by zone in Figure 5-17, major fish

types by zone in Figure 5-18, fractions of heat-tolerant and intolerant in Figure 5-19, and fractions pollution-tolerant and intolerant in Figure 5-20. Additional quantitative information, including for combinations of season, gear, and zone not presented in figures, is is provided in Appendix B of the Demonstration report.

2. **Section 5.4.1.3**. This section addresses the Asian carp with respect to increases in nuisance species. Silver (Asian) carp accounted for 1.7 percent of the catch in the Upstream Reference zone, 2.4 percent in the Thermally Exposed zone, and 1.9 percent in the Downstream zone (Table 5-3). Their contribution to total fish biomass ranged from 10 percent in the Upstream Reference zone to 12 percent in the Thermally Exposed and Downstream zones (Table 5-4). Although the differences are slight, there does appear to be an increase in Asian carp in areas affected by the LEC. An additional sentence should be added stating that slight increases in the number and biomass of Asian carp were observed in areas impacted by the LEC.

   RESPONSE: A sentence has been added on page 5-26 to note the small differences though we do not believe those differences to be biological meaningful (they are likely within the range of natural variability), nor would they be considered to constitute an adverse effect.

3. **Section 5.4.1.4**. The §316(a) demonstration is a weight of evidence approach that uses an overall pattern of standardized differences (similar to a t-statistic) across all the metrics to determine if there are any overall thermal effects. For fish and macroinvertebrates, they compared the thermally-influenced zone to the upstream zone and the downstream zone to the upstream zone. For fish, slight degradation was found in the comparison between the thermally-influenced zone and the upstream zone; whereas, a slight improvement was found between downstream and upstream zones. For macroinvertebrates, a slight degradation was found in comparison between the thermally-influenced zone and upstream as well as the downstream and upstream zones. It would be informative to see individual t-tests for some of the metrics, including abundance (numbers), diversity (numbers), fraction non-rough (numbers), and fraction heat tolerant (numbers). Heat tolerance is more important than pollution tolerance in relation to the impacts from the LEC. Moreover, combining numbers and biomass can mask some of the specific community level effects.

   RESPONSE: The individual metric comparisons (standardized differences) are essentially t-statistics and are presented in the appendix tables. Although each value could of course be compared to a critical value for a t-statistic with the appropriate degrees of freedom, we don't feel it is desirable to do hypothesis tests at this level of analysis. The EPA, in its 2000 Stressor Identification Guidance Document, specifically cautions against using statistical hypothesis testing in this context. One reason is that there are so many metrics that consideration of multiple testing and false significance rapidly arises. On a more

fundamental level, the relevance to any conclusion about the state of the biological community on the basis of statistical significance of any specific metric is dubious. We feel it is more appropriate to look at the whole distribution of the standardized differences, as was done in the weight of evidence sections, to assess whether harm is being caused by the thermal discharge.

4. **Section 5.4.2.** The Ponar and H-D macroinvertebrate sampling methods provided very different results. Similar to the fish results (which are based on combined sampling gears), an evaluation of the combined macroinvertebrate data from the Ponar and H-D samplers is recommended to gain a better overall picture of the macroinvertebrate community in each zone.

   RESPONSE: The fish results were combined across sampling gears for some of the data presentations, but analyses leading to the standardized differences were conducted separately for each gear. As with the fisheries sampling gears, Ponar and H-D sampling methods show different results because they are sampling different components of the macroinvertebrate community, but results from both gear are included in the weight of evidence approach taken to determine if the LEC thermal discharge resulted in adverse effects to the community. The Ponar and H-D based metrics in Appendix B Tables B-31 through B-34 (of the revised demonstration) were included in the overall analysis in Figure 5-29.

5. **Section 6.3.3**. Based on avoidance temperatures, the entire cross-section of the water column is available for passage for Asian carp, channel catfish and emerald shiner. For gizzard shad and white crappie, approximately half of the cross-sectional area in the vicinity of the LEC would still be available for passage under the worst-case conditions. Under more typical operations, no blockage would be expected for these species. To fully characterize the zone of passage, any future monitoring within the zone is recommended. For the more heat tolerant species, monitoring should occur when the zone is expected to be most limited.

   RESPONSE: This comment is acknowledged.

6. For walleye and sauger, use of areas near the LEC are limited to spawning migration during late winter and early spring. Blockage of migration in the zone of passage is not expected to occur. Similarly, for pallid sturgeon migratory blockage is not expected. To fully characterize the zone of passage with regard to the more heat intolerant species, any future monitoring within the zone during migratory periods is recommended.

   RESPONSE: This comment is acknowledged.

COMMENTS FROM USFWS

Comments from Valerie Hentges:

COMMENTS:
The U.S. Fish and Wildlife Service (Service) has briefly reviewed, due to the time limitation, the information provided in the February 27, 2020, email regarding the Labadie Energy Center, Franklin County, Missouri, Clean Water Act Section 316(a) draft final demonstration report and offers the following comments at this time based on the current information provided, pursuant to the Fish and Wildlife Coordination Act (16 U.S.C. 661 et seq.) and the Endangered Species Act of 1973, as amended (16 U.S.C. 1531-1544).

1. The Service has a concern with the certainty of a statement under the heading of "Weight of Evidence Rationale for No Prior Appreciable Harm" on page VII – PDF page 9: "#8 Decrease in threatened and/or endangered species: The data demonstrates that the river-wide decline of pallid sturgeon has nothing to do with LEC's thermal discharge." It is unknown what dataset or document this sentence is referencing for the river-wide decline of pallid sturgeons. The Service is concerned with LEC's thermal discharge due to the potential increase of water temperature that also correlates with low dissolved oxygen levels which would adding to the stressors of pallid sturgeons in this section of the Missouri River. As noted previously in other agency's comments (August 8, 2019), an outside bend of the Missouri River is the location for Labadie. These outside bends can provide habitat, e.g., via the thalweg, are unavoidable to developing pallid sturgeons. Please provide further information specific to the area of influence, not river-wide, for LEC's thermal discharge for the pallid sturgeon.

   RESPONSE:

   This comment has several components, each of which are addressed separately below.

   Certainty of statement for criteria #8

   The language in both the executive summary and master rationale sections of the Demonstration report will be revised as shown below. The documents cited in Section 2.1, paragraph 9 (Hesse and Sheets 1993 and Dryer and Sandvol 1993) provided the basis for identifying ecosystem alteration and changes to river habitat and flow as likely factors responsible for the decline of pallid sturgeon and many other species native to the Missouri River. Additional support for the decline of pallid sturgeon being primarily driven by these factors is found in USFWS (2007) which identifies the conversion of the Missouri River from a turbid river with a diversity of features, depths, and velocities to a more channelized river with little variation in habitat types resulting in a loss of the preferred

habitat of the pallid sturgeon as the primary reason for the decline of the species. Finally, no pallid sturgeon critical habitat exists in the vicinity of the LEC (USFWS 2014).

For clarification, the Executive Summary and Master Rationale criterion #8 will be revised as follows:

> "The pallid sturgeon is the only federally endangered species potentially ocurring in the vicinity of the LEC. Available ~~data~~information suggests that this species is declining throughout the Missouri River due to the loss of ecosystem integrity and the loss or alteration of preferred habitat and not due to the LEC's thermal discharge. ~~factors such as upstream dam and reservoir construction, reduced river water velocities and low bottom dissolved-oxygen levels. The data demonstrate that the river-wide decline of pallid sturgeon has nothing to do with LEC's thermal discharge.~~ Further, there ~~is~~ are no ~~evidence that LEC's thermal discharge has eliminated~~ designated critical habitat areas for pallid sturgeon in the LMOR."

Lower DO due to increased temperature

The potential effects of the LEC's thermal discharge on dissolved oxygen concentrations in the LMOR is addressed in Section 7.2, criterion #18 and in the response to comment #37 in the prior set of Agency comments. The analysis shows that during the study's hottest months, the thermally exposed and downstream zones contained similar (and occasionally slightly higher) DO than the upstream zone, thereby demonstrating no effect from the LEC's thermal plume. Further, DO concentrations in the LMOR are rarely at or near saturation levels. Hence, reductions in saturation levels related to temperature will not cause any loss of DO in the water.

Outside bend habitat near the LEC

As indicated, this topic was raised in previous Agency comments, specifically comment #39. The response to comment #39 indicated that most drifting pallid sturgeon larvae would not be exposed long enough or to high enough temperatures during their development season to experience any detectable effects from exposure to the thermal plume. The response to the earlier Agency comment #36 cited conclusions from Kappenman et. al. (2013) which suggested that pallid and shovelnose sturgeon have a higher thermal tolerance limit, higher thermal optima, and a wider range for embryo to larval development than other sturgeon species.

Pallid sturgeon exposure to the LEC thermal plume is addressed in the predictive assessment section (Section 6) of the Demonstration report, specifically Section 6.1.3 which generally addresses exposure of drifting organisms, Section 6.3.1.1 heat shock, and Section 6.3.2 (and Figure 6-20) effects on reproduction and development.

USFWS. 2007. Species profile, pallid sturgeon, *Scaphirhynchus albus*. Available on-line at: http://www.fws.gov/moriver/PSPROFILE.htm. Last accessed 17 May 2018.

USFWS. 2014. Endangered Species Act Section 7 Consultation. Programmatic Biological Opinion on the U.S. Environmental Protection Agency's Issuance and Implementation of the Final Regulations Section 316(b) of the Clean Water Act. 19 May 2014.

2. The Draft Final Demonstration report could elaborate more in regards to fish, shellfish, macroinvertebrates and larval drift as it references relatively old documents and surveys (the latest being 2008 with multiple references to 1976 and 1981 studies with two additional fish surveys completed from 1980-1985 and 1995-2001). Although the provided Draft Supplement produced by ASA is a rather extensive and thorough study completed in 2017-2018.

   RESPONSE:

   The 2019 Labadie 316(a) Demonstration is based primarily on the 2017-2018 sampling, which was designed to make the appropriate comparisons among the different zones (upstream, thermally exposed, and downstream). Reference to the older studies was made to demonstrate that zonal differences, or similarities, have been consistent through time.

3. The Service is concerned with the lack of capture of benthic species in the ASA 2017-2018 Study (most importantly Shovelnose Sturgeon and Blue Suckers). This study did not include bottom gear sampling equipment, e.g., trammel or gillnets, which would have allowed for the characterization of benthic species. The Service understands the previous dataset did not include these types of sampling gear making it hard to compare data between the older and newer studies.

   RESPONSE:

   Two gear types were selected in the 2017-2018 Study, hoop nets and the mini-Missouri trawl, to specifically target benthic species. The mini-Missouri trawl was specifically designed to collect small-bodied fish species in large rivers and streams that are often difficult to sample with other methods because of water depths and/or velocities (Herzog et al. 2009). The study plan for the 2017-2018 studies, including the use of these gear types, was approved by the MDNR. Use of gill nets and trammel nets was considered in the initially planning phases but due to the high debris loads evident in this reach of the river, these gear types were eliminated from further consideration. Both blue sucker and shovelnose sturgeon were well represented in the hoop net collections accounting for approximately 40 percent of the overall catch. The composition of collections from the mini-Missouri trawl was dominated by small-bodied fishes, mostly benthic minnows and

YOY catfish, freshwater drum and gizzard shad. Overall, a total of 7,551 specimens representing 37 species were collected from mini-Missouri trawling surveys over the two year sampling period, with the top three most abundant species including sicklefin chub (19.2 percent of total), shoal chub (18.0 percent), and channel shiner (16.9 percent). Hoop nets were also deployed during the 2017-2018 Study to specifically target large-bodied benthic fishes. Overall, the composition of hoop net collections was dominated by shovelnose sturgeon and blue sucker which represented 20.6 and 18.8 percent of the total hoop net catch, respectively. Thus, both hoop nets and mini-Missouri trawls were used to effectively sample both small and large-bodied benthic species, including blue sucker and shovelnose sturgeon

4. An overall concern is the possible delayed mortality of fish impacted by the thermal flume and appreciates the comprehensive study in regards to the impact on the local fish populations. One suggestion that may help lessen the thermal flume at the Labadie Energy Center is in the creation of a wetland-type complex or meandering discharge channel allowing for a greater temperature reduction of the discharge water prior to the water mixing back into the Missouri River.

RESPONSE:

Delayed mortality is considered in the sections on potential effects from increased mortality (Section 6.3.1) and heat shock (Section 6.3.1.1) through the use of upper incipient lethal temperature limits and critical thermal maxima values. In all cases, little to no effect is expected due to the relatively limited area influenced by the highest thermal plume temperatures and the short duration of exposure.