316(b) Sampling Study Final Report-
Lake Catherine Plant

Jones Mill, Arkansas
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<th>Acronym</th>
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<tr>
<td>ADEQ</td>
<td>Arkansas Department of Environmental Quality</td>
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<tr>
<td>AGFC</td>
<td>Arkansas Game and Fish Commission</td>
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<tr>
<td>ANO</td>
<td>Arkansas Nuclear One</td>
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<tr>
<td>BPJ</td>
<td>Best Professional Judgment</td>
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<tr>
<td>BTA</td>
<td>Best Technology Available</td>
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<tr>
<td>CFR</td>
<td>Code of Federal Regulations</td>
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<tr>
<td>CWA</td>
<td>Clean Water Act</td>
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<tr>
<td>CWIS</td>
<td>Cooling Water Intake Structure</td>
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<tr>
<td>EPA</td>
<td>Environmental Protection Agency</td>
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<tr>
<td>IM</td>
<td>Impingement</td>
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<tr>
<td>IMECS</td>
<td>Impingement and Entrainment Characterization Study</td>
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<tr>
<td>MGD</td>
<td>Million Gallons per Day</td>
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<td>PIC</td>
<td>Proposal for Information Collection</td>
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<tr>
<td>QA/QC</td>
<td>Quality Assurance and Quality Control</td>
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<tr>
<td>RIS</td>
<td>Relative Important Species</td>
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<tr>
<td>RM</td>
<td>River Mile</td>
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<tr>
<td>RTE</td>
<td>Rare, Threatened, and Endangered</td>
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<td>USACE</td>
<td>United States Army Corps of Engineers</td>
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<td>USGS</td>
<td>United States Geological Survey</td>
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<td>YOY</td>
<td>Young-of-Year</td>
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Executive Summary

This report characterizes and evaluates those species potentially affected by impingement at the Lake Catherine Electric Generating Plant located in Jones Mill, Arkansas. The facility is located on Lake Catherine, a man made reservoir approximately one mile upstream of Remmel Dam, on the Ouachita River near Jones Mill. Previously documented studies from Lake Dardanelle, Lake Hamilton, De Gray Lake, and Lake Catherine supported an assessment of those species potentially affected by impingement impacts. This study 1) characterizes the fish and shellfish species collected from impingement samples, 2) determines the presence/absence of any rare, threatened or endangered species impinged, 3) notes the presence/absence of commercially or recreationally important species, 4) provides size data on all impinged species, 5) describes diel and seasonal shifts in species composition, and 6) calculates current impingement rates for all species (individually and combined).

Previous fish studies of four Arkansas lakes including Lake Catherine (1997 to 2005) documented the most commonly occurring species to be gizzard shad, threadfin shad, bluegill and longear sunfishes, bluntnose minnow, and largemouth bass. Impingement sampling performed at Arkansas Nuclear One (ANO) from 1974 to 1994 provided a calculation of historical impingement rates. Entergy supports the belief that the sampling subset from 1979-1988 represents the most complete and consistent collection methodology and will therefore serve as a guideline for sampling procedures followed in this study. It will also serve as a benchmark for comparison with currently collected impingement data from Entergy’s Lake Catherine Plant.

The habitats surrounding the Lake Catherine cooling water intake structures as well as the organisms occupying those habitats have been documented extensively as revealed by a thorough data review prior to the initiation of sampling. An extensive summary of supporting documentation utilized to describe the biology of the Ouachita River and surrounding lakes was compiled for use in this study based upon proximity, habitat similarities, and other impingement/entrainment studies (Appendix A).

All field and laboratory personnel followed the developed Quality Assurance Quality Control (QA/QC) protocols at all times. Strict adherence to these guidelines allowed Entergy to accurately record, analyze, and report a realized and true measured characterization of impinged organisms at Entergy’s Lake Catherine Plant.

Based on the findings presented in this study, the overall calculated annual impingement rate at Lake Catherine is 4.22 organisms per 10,000 m³, and impinged species were predominantly threadfin and gizzard shad. This is compared to the estimated rate of 0.74 organisms calculated using the Lake Catherine fish biomass numbers and the 1979-1988 Arkansas Nuclear One studies from Lake Dardanelle in which the impingement rates were calculated to be 1.82 organisms per 10,000 m³. The disparity in impingement rates between the two studies may be attributed to many factors including: differences in the design of the CWIS of the two plants, duration of each study, actual plant operation, and a significant increase in threadfin shad impingement during the current November sampling period that may be considered an outlier. Utilization of strict statistical parameters that allow for removal of outliers in the dataset lowers the impingement rate to 1.21 organisms per 10,000 m³, while adjusting for average yearly plant operation lowers the impingement rate to 0.3 organisms per 10,000 m³.
1.0 Introduction

This report characterizes and evaluates those species potentially affected by impingement at the Lake Catherine Plant located in Jones Mill, Arkansas. The report was created in support of the Lake Catherine Proposal for Information Collection (PIC) and the Impingement Mortality and Entrainment Characterization Study (IMECS) developed for Lake Catherine in accordance with the requirements of the PIC and the IMECS found in 40 CFR Section 125.95(1)(i), (ii), (iii), and (iv), and 125.95(3)(i), (ii), and (iii).

The EPA developed regulations in 40 CFR 125 (SubPart J) in Section 316(b) of the Clean Water Act to manage cooling water intake structures (CWIS). On July 9, 2007, EPA suspended the following sections of the Code of Federal Regulations: 40 CFR 122.21(r)(1)(ii) and (5); 125.90(a), (c), and (d); and 125.91 through 125.99. These portions of the regulations were challenged by industry and environmental stakeholders, and, upon judicial review, the Second Circuit remanded these sections to the EPA for further consideration. However, with this action, 40 CFR 125.90(b) was not suspended. This section allows permitting authorities to develop best professional judgment (BPJ) controls for existing facility CWIS’s that reflect the best technology available (BTA) for minimizing adverse environmental impacts, and directs permitting authorities to establish 316(b) requirements on a BPJ basis.

The sampling program for this study was designed in accordance with requirements outlined in 40 CFR 125.95 (the Rule) prior to its remand in July, 2007. In its previous framework, the Rule allowed for utilization of data from “another facility with comparable design, operational, and environmental conditions” (“like facilities”) in making biological and technical assessments for a power plant. In addition to the Lake Catherine Plant, Entergy currently owns and operates the Arkansas Nuclear One (ANO) Electric Generating Facility on Lake Dardanelle. Entergy chose to utilize data collected at “like facilities” to serve as representative studies for facilities with similar ecological structure. In keeping with this strategy, the current impingement study performed at the Lake Catherine Plant was compared with the historical impingement study at ANO. The ANO facility is located about 60 miles NNW of the Lake Catherine Plant. In addition to proximal location and habitat similarities of the plants, both facilities employ two cooling water intake structures. Entrainment mortality characterization was not required for either facility because they are located on reservoirs. These factors support the Lake Catherine Plant and ANO as “like facilities”, and thus allow Entergy to utilize impingement data collected at ANO in an impingement assessment for the Lake Catherine Plant.

During the development of the PIC and the IMECS, Entergy consulted with the Arkansas Department of Environmental Quality (ADEQ) and Arkansas Game and Fish Commission (AGFC) regarding the abundance of relevant historical data that supported Entergy’s compliance approach and met the requirements of the Rule. The ADEQ and AGFC verbally supported Entergy’s findings of the sufficiency of existing data to support taxonomic identifications and characterizations of life stages listed in the Rule and the use of “like facilities” in a comparison for the development of impingement rates at Entergy’s Lake Catherine Plant. However, based upon the limited extent of current impingement data for facilities in Arkansas (specifically Lake Catherine), the ADEQ and AGFC recommended that additional impingement data would be valuable to validate the existing historical data and determine current impingement mortality (IM) rates. It should be noted that while the language of the rule uses IM (impingement mortality), this study chose to make the distinction that not all organisms “impinged” in a sample were moribund upon capture.

The resulting study at the Lake Catherine Plant included impingement sample collections every 12 hours over a 24-hour period once per month for a one-year period. Note, based on AGFC’s management of Lake Catherine and their input into the proposed sampling strategy the current study was completed after nine months of sampling. Objectives of this study included:

- Characterize fish and shellfish species collected from impingement samples (species composition and relative abundance),
• Note the presence of rare, threatened, or endangered species in impingement samples,
• Note the presence of commercially and recreationally important species,
• Provide size data (length and weight) on all impinged species,
• Characterize diel and seasonal shifts in species composition, and
• Calculate a current impingement rate from the data collected.

These objectives were formulated to assure that all data necessary for a complete analysis of impingement at the Lake Catherine Plant were collected, documented and appropriately reviewed. Sampling, data recording, and data analysis followed pre-established QA/QC procedures to ensure the integrity of the sampling program and information described in this report.
2.0 Historical Review

An extensive literature review was conducted to evaluate the potential impacts of existing intake structures for the Lake Catherine Plant with a focus on developing the data needed to support the IMECS. This review included data collected at two of Entergy's plants located in Arkansas and studies conducted by state and federal agencies, academia and other biological forums on four lakes with similar characteristics in Arkansas.

A relevant historical impingement study conducted at the Entergy ANO station spanned 20 years, and a ten year subset of this data provided the basis for calculating historical impingement rates. The dominant species impinged included gizzard shad, threadfin shad, freshwater drum, blue catfish, common carp, channel catfish, and skipjack herring. Furthermore, the historical impingement rate at ANO was used to calculate an estimate of the current impingement rate at Lake Catherine.

Ambient fisheries and habitat data collected for Lake Catherine, Lake Hamilton, Lake Dardanelle, and De Gray Lake were reviewed. In addition to the literature review, experts from regulatory agencies were contacted for additional information as well as their professional opinion on the status and trends of the fisheries. A short synopsis of each study discussed is presented in Appendix A.

A summary of the supporting documents and studies used in characterizing the biology surrounding the Lake Catherine Plant can be found in Appendix A.
3.0 Description of Study Area

The Lake Catherine Plant is located approximately one mile upstream from Remmel Dam on the eastern bank of the Lake Catherine Reservoir, which is an impoundment of the Ouachita River near Jones Mill, Arkansas. This portion of the Ouachita River is contained within the Ouachita Mountains Ecoregion, as described by the ADEQ (Figure 1).

Lake Catherine is an oligotrophic to mesotrophic\(^1\) system supporting 34 fish species as documented by the AGFC. Only one aquatic habitat of this system is associated with the intake structures at Lake Catherine and is defined as “offshore” (Figure 2). Lake habitats are commonly divided into three categories: offshore (limnetic zone), shoreline (littoral zone), and backwater cove (littoral zone).

Offshore habitats tend to be devoid of usable habitat structure and vegetation and as such supports only a limited number of fish species. Of the 34 species documented to occur in Lake Catherine, only 12 are common to offshore habitats. As much as 75% of the species known to occupy offshore habitats are strong, heavy-bodied fishes capable of avoiding intake structures. The majorities of the fishes utilizing the offshore habitat are pelagic, and are thus not as susceptible to impingement as benthic species due to the placement of the CWIS. Additionally, the water level of Lake Catherine is lowered every winter by Entergy to help control nuisance vegetation along the shoreline, as well as provide and opportunity for shoreline maintenance and inspection. This annual drawdown reduces the amount of littoral habitat and concentrates the pelagic species in the limnetic zone nearer to the CWIS, thus impingement rates are expected to increase during this period.

Based on the proximity of the two plants and the similar locations of their CWIS on reservoirs, the rate of impingement observed at ANO was used to estimate the rate at Lake Catherine, as well as serve as a basis of comparison for the current impingement study. A general description of the ANO facility is included below.

The ANO facility is located on a peninsula that extends into the north shore of Lake Dardanelle. There are two cooling water intake structures at the ANO facility, ANO-1 and ANO-2. Although the units share a common intake structure, ANO-2 utilizes closed cycle cooling, and will not be a focus of this study. ANO-1 utilizes open cycle once through cooling. Cooling water for ANO-1 is drawn from Lake Dardanelle through a 4,400-foot long intake canal. Bar racks with three-inch openings prevent large debris from entering the intake structure. Cooling waters are then passed through vertical traveling screens equipped with 3/8" mesh screens. Additionally, a fish barrier net has been deployed in an arc around the mouth of the CWIS in the winter months since 1999. The net is comprised of continuous sections 250 foot-long lengths of 3/8 to 1/2 inch mesh that extend to a depth of 20 feet, and has proven to be very effective in reducing impingement at ANO.

3.1 Source Water Body Information

Lake Catherine is 11.25 miles long with a surface area of approximately 1,940 acres. Lake Catherine is influenced by releases from Carpenter Dam (waters from Lake Hamilton) and is typically characterized as a mesotrophic to oligotrophic water body. Recent increases in fish densities (as indicated by AGFC surveys)

\(^1\) Mesotrophic, oligotrophic, and eutrophic are terms used to describe nutrient load, sedimentation, and productivity of a body of water. Eutrophic environments tend to exhibit extremely high levels of nutrients and productivity, many times resulting in low dissolved oxygen levels, and consequently, mass fish die-offs. Oligotrophic environments tend to be fairly devoid of nutrients, thus lacking vegetation and tending to retain high dissolved oxygen levels. Mesotrophic habitats are middle range habitats; they are not typically prone to one extreme or the other and can be highly productive because nutrient loading cycles are well established.
suggest a tendency towards mesotrophic dynamics within the reservoir. Fish populations within the reservoir follow behavioral patterns of fishes associated with large lake environments (discussions with AGFC on dynamics of Lake Catherine).

### 3.2 In-Place Technology

Cooling water for the Lake Catherine Plant is withdrawn from Lake Catherine through two CWIS at a design flow rate of 94 MGD for CWIS 1 and 360 MGD for CWIS 2 with a combined intake rate of 454 MGD, or 702 cfs (Figure 2). The CWIS was designed for normal operation within river high-water and low-water elevations of +36 feet and +56 feet respectively. The average water flow through Lake Catherine is 2,450 cfs, as measured at the U.S. Geological Survey gaging station located immediately downstream of Remmel Dam (gage 07359002) (Figure 13). Based on this information, it is determined that the Lake Catherine Plant withdraws approximately 29% of the average flow rate through Lake Catherine. Rule 40 CFR 125.93 states that only facilities that withdraw water from a tidal river, estuary, ocean, or one of the Great Lakes are subject to entrainment goals. It also characterizes a lake or reservoir as any inland body of water with a retention time greater than 7 days. The average hydraulic retention time for Lake Catherine is 8 days, thus it is considered a reservoir, and is not subject to entrainment goals (FTN, 2007).

CWIS 1 is comprised of two 8-foot diameter horizontal pipes extending 120 feet into Lake Catherine. These intake pipes empty water into an open cofferdam area prior to entering the fore bay area which consists of four adjacent 37-foot long by 6.2-foot wide by 37-foot deep bays. The intake configuration includes stop logs followed by traveling screens. CWIS 2 provides cooling water for Unit 4, which is considered a “load following unit.” CWIS 2 is comprised of two adjacent 10-foot diameter horizontal pipes extending 160 feet offshore. The mouths of the intake pipes for CWIS 1 and 2 are located in offshore habitats. Cooling water from Units 1-3 is discharged directly to Lake Catherine via two 10-foot by 10-foot tunnels south of the facility. Cooling water from Unit 4 is discharged directly to Lake Catherine through a single 12.5-foot diameter pipe which spits into three bays. Temperature measurements noted in the EPA’s STORET database indicated a lack of intense thermal stratification in the Lake Catherine. Since the area affected by the Lake Catherine intake is relatively small\(^2\) and the reported retention time of the lake is 8 days, Entergy believes that natural lake stratification will not be affected by the cooling water discharge.\(^3\)

Because the Lake Catherine Plant is used as a “peaking reserve/load following” facility it does not typically operate year-round, and thus its respective CWIS do not operate to capacity. At the time of the study, Units 1-3 were not operating and were no longer in service and Unit 4 was considered a reserve unit to be operated on a very limited basis. Sampling during this study was performed exclusively at CWIS 2 to reflect maximum possible impingement rates based on current operation of the plant.

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\(^2\) Zone of hydraulic influence for CWIS 1 is a 25.8-foot radius, and a 50.4-foot radius for CWIS 2.

\(^3\) Measurements listed in the ADEQ database were collected on July 24, 1989 during a period that stratification would be expected to be pronounced. ([www.adeg.state.ar.us/water/waterquality.htm](http://www.adeg.state.ar.us/water/waterquality.htm)) These measurements indicated a lack of intense thermal stratification during hot summer months when any thermal stratification would be expected to be most prominent. Waters were classified as epilimnion (upper portion of the water column with warmer temperatures and higher dissolved oxygen levels) and hypolimnion (lower portion of the water column with cooler temperatures and lower dissolved oxygen levels), however, the relatively small amount of cooling water discharged from the Lake Catherine Plant has been determined to create an insignificant amount of disturbance to the water column and natural stratification.
4.0 Materials and Methods

Based on the proximity of the two plants and their similar lake settings, an initial annual impingement rate for the Lake Catherine Plant was estimated by using ANO’s pre-existing impingement data and comparing the rate with known fish biomass on Lake Catherine as determined by the Arkansas Game and Fish Commission (AGFC). The current impingement rate was determined during the 2006-2007 sampling study conducted at the Lake Catherine Plant based on volume of water pumped at the time of sampling. Details of the current sampling program at Lake Catherine are provided in the following sections.

Impingement sampling was conducted at CWIS 2 within the sluiceway of the debris/fish return system as close to the traveling screens as was safely and logistically manageable. Nets constructed of 3/8” mesh netting attached to a steel-pipe frame were placed into the sluiceway to capture all organisms washed from the screens. Net frames were constructed specifically to the dimension of the sluiceway to prevent organisms from flowing or swimming past the net.

Screens were washed and rotated for 30 minutes prior to each 24-hour sampling event to achieve a standard reference point. Subsequent to the end of each of two, 12-hour sample intervals, screens were washed and rotated for 30 minutes to collect all impinged organisms. Twelve hour intervals were chosen as the most closely represented actual operations of the CWIS and screens. Identification of organisms to the lowest possible taxa level was made and recorded along with the length of each specimen. Taxonomic keys included: Douglas, (1974); Pflieger (1997); Robison & Buchanan (1988); Pennak (1978) and Ross (2001). An average weight for all specimens of a given species was also recorded (batch weight). One representative specimen from each species collected was preserved in a 10 percent formalin solution and retained as a reference. Data analyses examined trends in diel and seasonal species composition and abundance. Current annual impingement rates were subsequently determined for each species.

4.1 Collection of Hydrological Data

Upon arrival at the sampling site, hydrological data was collected from intake waters in front of the rotating screens using a YSI-85 meter. Temperature, dissolved oxygen, and conductivity were measured and recorded on field data sheets and later entered into an Excel spreadsheet. Additional data collected included weather conditions, air temperature, and screen wash time. The status of each pump within the CWIS (i.e., the water flow rate through each screen) was also recorded to adjust volume normalization of impingement data. The recording team member’s initials were placed at the bottom of the field data sheet in accordance with established sampling plan QA/QC procedures. An additional team member reviewed and initialed the recorded data to ensure that all entries were complete.

4.2 Collection of Biological Data

Characterization data associated with the life stages of fish, shellfish, and any species protected under Federal, State, and Tribal Law susceptible to impingement and entrainment at Entergy’s Arkansas plants were reviewed to help determine seasonal and diel fluctuations in impingement and to aid in determination of relative important species. Further detail on the life history of these species and the general diel and seasonal fluctuations of biota of the Arkansas lakes can be found in Appendix C. Based upon this review, samples were collected monthly at 12-hour intervals over a 24-hour period from October 2006 to June 2007.

Samples were collected once during the early morning at 0500 and once during the evening at 1700. This sampling regime allowed for characterization of diel migratory patterns, if present. Samples were collected by placing a net constructed of 3/8 inch mesh attached to a steel pipe frame into the debris/fish return sluiceway. Net frames were constructed utilizing measurements of the sluiceway dimensions to ensure a snug fit and prevent organisms from flowing around the collection net. At the end of each respective 12-hour interval the net was set in the sluiceway and the screens rotated and washed for 30 minutes to collect impinged
organisms. If the sample net became full prior to the completion of any scheduled 30 minute wash, a second net was placed behind the first, and the first net removed. This process was repeated as necessary.

The nets of collected organisms were emptied into sorting trays and separated by species. (Experienced field biologists identified each species, however for those species not easily identified organism classification was confirmed using designated species identification guides cited in Appendix D.) Organisms alive upon capture were separated from deceased organisms, enumerated and recorded, then returned to the lake.

If more than 30 organisms of each species were collected, a random subset of 30 specimens was chosen for length measurements. If 30 or less specimens were present, all organisms were measured. Fish total length (TL) was recorded and crayfish were measured from the anterior tip of the rostrum to the posterior edge of the telson. All measurements were recorded to the nearest millimeter. Health condition (living or deceased) and damage sustained to the organism was assessed and recorded.

Total weight for each species was recorded. When more than 30 specimens were present, a batch weight was obtained and applied to all individuals in the sample. In obtaining a batch weight, a random sub-sample of 30 individuals was split from the group, enumerated, and weighed to the nearest tenth of a gram. The number of individuals present in the sample was then estimated through extrapolation of the number of batch weight individuals to the total weight.

A representation of every species documented in the study was preserved in museum quality condition to establish a reference collection to be maintained for the life of the project and made available for examination by outside parties including the regulatory agencies. Specimens selected to be preserved were identified using the designated species identification guides recording both common and scientific names on internal and external sample labels. The labels also recorded collector’s initials, date, and location. The specimens and the internal labels were then placed into the jars and covered with a 10% formalin solution. External labels were fixed to the outside of the sample container with clear tape.

The outer rim of the sample container was wrapped with Teflon plumbing tape to prevent leakage and evaporation and tightly sealed. Reference specimens were stored in a cool, dark room in a designated storage area. In addition to the preserved specimens, a representative photo record of both juvenile and adult fishes was established and maintained in an electronic database. Availability of photographs and key taxonomic characters of species ensures accuracy and consistency in identifications throughout the life of the project.

4.3 Data Management and Analysis

4.3.1 Data Analysis

Upon entering the completed data set into an Excel spreadsheet, data for species comprising greater than 1 percent of the total number captured were analyzed to compute several different comparisons. These comparisons include total number captured, percent of organisms alive upon capture, length-frequency analysis, monthly impingement mortality rate, and average annual impingement rate. Total number of species captured throughout the duration of the study was also calculated. Any data concerning rare, threatened, or endangered species (RTE species) were highlighted and conclusions concerning the effects, if any, to these organisms were determined.

It is important to note that not all impinged invertebrates were utilized in data analyses in the interest of maintaining clarity and to avoid confounding the more relevant data. Only those species representing greater than one percent of the total number of organisms impinged were reviewed in the process of generating many of the figures presented (Figures 8-14); however all impinged organisms were enumerated and recorded for the sake of compiling a biologically complete data record, as well as a total impingement rate.
4.3.2 Impingement Rate

Impingement rate (IMR) is calculated based on the number of organisms captured during a set time period per unit volume of water pumped through the intake screens. Volume of water pumped is based on the number of circulating water pumps operating during each sampling period. This rate is expressed as number of organisms per 10,000 cubic meters of water.

\[
IMR = \left( \frac{\text{# organisms captured}}{\text{volume of water sampled (cubic meters)}} \right) \times 10000
\]

This rate is then annualized to reflect impingement at the facility on a yearly basis. It is important to note that because sampling was performed exclusively at CWIS 2 throughout the study, only the pumping capacity of Unit 4 was used in calculating impingement rates for the Lake Catherine Plant.

4.3.3 Quality Assurance and Quality Control (QA/QC) Measures

All field and laboratory personnel adhered to the basic rules for recording collected data. This ensured that all writing was legible, errors were corrected with a single strike-out line followed by the recorder’s initials and the date (no erasures), and incomplete pages were crossed-out with a diagonal, dated line.

All data was entered on pre-printed, standardized datasheets at the time of sampling. Generic information, such as date, type of sampling, field team members, and weather conditions were included at the top of the form. Site-specific conditions were recorded at the beginning of sample collection. Upon completion of sample collection, any unusual conditions that might have affected the quality of the sample were documented. An explanation was provided for any missing data. The datasheet was then checked for accuracy by a second member of the field team prior to obtaining additional samples or moving to the next station.

Field datasheets and lab bench sheets were placed in labeled folders for input into an electronic database. The database was maintained in Excel with cells for all parameters collected in the field.

Prior to processing the data, the Field Sampling Manager or assignee reviewed the forms for completeness and accuracy. Printouts of entered data were verified against corresponding field datasheets and lab bench sheets to ensure that information has been accurately transferred. For large datasets entered (e.g., more than 100 entries), a subset of 10 data entries were selected at random to be checked. If errors were detected in the subset, then corrections were made, and the entire data set was rechecked. The forms were then initialed and dated by the verifying party. Following data verification, the original data forms were segregated by sampling date and type and archived for the life of the project.

To ensure that sample collection, data entry, and data analysis followed a concise organizational flow, standardized QA/AC measures entailing all steps in the data collection and reporting process were developed. These standards include (but are not limited to):

- Supporting documents and reference literature obtained from reputable academic and scientific publishers or peer-reviewed journals;
- Site-specific impingement data and impingement data obtained from other Entergy-owned power plants utilized only if collected data met the following criteria:
  - Sample duration adequately defined,
  - Sample location adequately defined,
  - Appropriate description of gear used for sample collection, and
  - Enumeration and identification of organisms to the lowest taxonomic level.
• On-site field data recorded on appropriate field data sheets reviewed twice before filing of documents;
• Database entries reviewed three times for accuracy and completeness before data were utilized in any type of analyses;
• Data analyses reviewed three times for accuracy and completeness before conclusions were drawn regarding study results;
• Results reviewed by experienced fisheries biologists and reasonable, well-versed conclusions were drawn from study results; and,
• Reports were twice reviewed in their entirety for accuracy prior to submittal to agencies.

By adhering to previously established guidelines, Entergy was able to accurately record, analyze, and report a true characterization of organisms affected by impingement.
5.0 Results

5.1 Hydrology

Water temperatures exhibited seasonal variations typical for Lake Catherine during the study period (Figure 3 and Appendix C). The highest water temperature (27.0°C) was recorded in June, 2007 and the lowest water temperature (7.4°C) was recorded in February, 2007. Dissolved oxygen (DO) levels were lowest in late summer and early fall (1.62 mg/L, October 2006) when the water was seasonally warm, and highest in the winter and spring (10.78 mg/L, April 2007) when the water was seasonally cool (Figure 4). Water temperature and DO exhibit a characteristic inverse relationship due to physical and chemical properties of water that limit oxygen solubility as temperature increases (see Figures 3 & 4).

River stage data near the Lake Catherine Plant during the study period was not available, as it is pending USGS approval. However, trends may be interpreted from the USACE gages located above and below the plant on the Ouachita River (Figures 5 & 6). Data from both gages indicated that stage varied about 19 feet throughout the study, attaining maximum values in mid-January, and minimum values at the initiation of sampling in October.4

The total surface area of Lake Catherine is about 1,940 acres (84,500 sq ft) with a storage volume of 1.52 billion cubic ft. Based on U.S. Geological Survey Station 07359002 at Remmel Dam, annual discharge is 1,573 MGD (2,434 cfs) (mean discharge 1929-2005). Lake Catherine has a hydraulic retention time of 8.0 days (FTN, 2007) and therefore meets EPA’s definition of a reservoir (see 40 CFR 125.93).

5.2 Impingement Rate

The total number of organisms impinged over the course of sampling at the facility was 3,408 individuals comprising 17 species identified from 9 families (Table 1). It should be noted that no rare, threatened, or endangered (RTE) species were impinged during the sampling period.

The annual impingement rate, as determined in this study, at Entergy’s Lake Catherine Plant was calculated to be 4.22 organisms per 10,000 m³, corresponding to annual impingement of 413,802 organisms (Figure 7 & Table 2). This calculation was based on assumptions that would reflect maximum possible impingement. Other methods of analysis which take into account actual plant operation and removing outliers in the data, yielded different annual impingement rates. For example, utilization of strict statistical parameters that allow for removal of outliers in the dataset lowers the impingement rate to 1.21 organisms per 10,000 m³, while adjusting for average yearly plant operation lowers the impingement rate to 0.3 organisms per 10,000 m³. A more detailed discussion of these different impingement rates is presented in Section 6.

5.2.1 Seasonal Variation

The annual rate of impingement over the course of the sampling study was calculated to be 4.22 organisms per 10,000 m³, and seasonal variations were observed when monthly rates were examined (Figures 5 & 9). At sample initiation in October, 2006, impingement rates were low (0.09 organisms per 10,000 m³). November showed a sharp increase in impingement rate (26.96) which was the highest documented rate recorded in the study (Figure 7). Winter impingement rates ranged from 1.29 in December, 2006 to 3.75 organisms per 10,000 m³ in February, 2007 (Figure 5). As water temperatures increased and seasons began to shift, impingement rates sharply declined through spring and early summer (March 2007 – June 2007) (Figure 7).

4 Stage data for the Ouachita River was obtained from the U.S. Army Corps of Engineers website www.rivergages.com, at the Blakely Mountain Dam (RM 465.3) and Arkadelphia (RM 398.9) stations.
The lowest impingement rate documented during the study occurred in the spring (0.02 organisms per 10,000 m³).

The five months with the highest impingement rates, November, December, January, February, and March accounted for 99.5% of total organisms impinged during the study period. An impingement rate of less than 0.05 organisms per 10,000 m³ was observed throughout the rest of the sampling period (April 2007 – June 2007) (Figure 7).

5.2.2 Diel Variation

Average daytime impingement rates were lower than the nighttime impingement rates (6.34 at night and 1.26 during daytime collections), and species comprising >1% of all organisms impinged were mostly consistent (Figures 8 & 9). Gizzard shad and threadfin shad were the only species that comprised >1% of the organisms impinged during both the daytime and nighttime samples. While daytime samples yielded a higher percentage of gizzard shad, nighttime samples were dominated by threadfin shad. (Figures 8 & 9 and Table 3).

5.2.3 Aquatic Organisms

This section details abundance and distribution of impingement by species documented in the impingement samples. Specific details regarding the life histories of these organisms can be found in Appendix C.

5.2.3.1 Species Comprising > 1%

Species comprising greater than 1% of all organisms impinged during the 2006-2007 study include threadfin shad and gizzard shad, which represented 83% and 17% respectively (Figure 10). Nearly all impingement recorded for these species occurred from November to March (Figure 11). A more specific discussion of impingement by species is included below.

**Threadfin Shad (Dorosoma petenense)**

The average annual impingement rate for threadfin shad was calculated to be 3.43 organisms per 10,000 m³, with threadfin comprising over 81% of all organisms impinged. The vast majority (2410) of these individuals were collected in the November sample, in which threadfin shad exhibited a monthly impingement rate of 26.8 organisms per 10,000 m³. (Figure 12). The average length of threadfin shad impinged at Lake Catherine was 75 mm.

**Gizzard Shad (Dorosoma cepedianum)**

The average annual impingement rate for gizzard shad was calculated to be 0.69 organisms per 10,000 m³, with gizzard shad comprising approximately 16% of all organisms impinged. Gizzard shad impingement rate peaked in February and March, with the highest monthly impingement rate of 3.49 occurring during February (Figure 13). The average length of gizzard shad impinged at Lake Catherine was 168 mm.

**Freshwater Drum (Aplodinotus grunniens)**

The average annual impingement rate for freshwater drum was calculated to be only 0.004 organisms per 10,000 m³, comprising only 0.1% of all the organisms impinged. The average length of freshwater drum impinged at Lake Catherine was 382 mm. Although freshwater drum were not well represented in the current sampling study, they did represent 1.1% of the historical study, and are presented here for comparative purposes.
6.0 Summary and Conclusions

The initial impingement analysis for the Lake Catherine Plant was performed in accordance with the “like facilities” clause of the recently remanded section 40 CFR 125.95 of the EPA’s Clean Water Act using data from nearby systems Lake Hamilton, Lake Dardanelle, and De Gray Lake. Evaluation of the historical studies of impingement at Arkansas Nuclear One (ANO), an extensive document review of the ambient fisheries data, and the current impingement study were used in conjunction to obtain a comprehensive analysis of potential impingement at Lake Catherine. However, due to the lack of historic impingement data at the Lake Catherine and based on meetings with the ADEQ and the AGFC it was determined that additional data would be needed to establish a baseline for impacts at the Lake Catherine Plant.

The current impingement study performed from 2006-2007 provided data on species richness, abundance, and impingement potential at the Lake Catherine Plant. In order to present concise results, only species comprising greater than 1% of the total number of impinged organisms were utilized in analyses. The dominance of threadfin and gizzard shad in the impingement samples is analogous to the species compositions of the area lakes outlined in the document review. The historic impingement studies at ANO from 1979-1988 also exhibited samples dominated by these two species (Figure 14).

The impingement potential of threatened and endangered species is a major concern that must be addressed in the data analysis of any impingement study. Thirteen “endangered” or “threatened” aquatic species have been documented by the USFWS (2007) and the AGFC (2007) to occur in regions of Arkansas. This list includes the Ozark cavefish (Amblyopsis rosae), Cave crayfish (Cambarus aculabrum), (Cambarus zophonastes), Leopard darter (Percina pantherina), Arkansas Fatmucket (Lampsilis powelli), Pink mucket (Lampsilis abrupta), Scaleshell mussel (Lepotdea leptodon), Curtis pearlymussel (Epioblasma florentina curtisi), Fat pocketbook (Potamilus capax), Ouachita rock pocketbook (Arkansa wheeleri), Speckled pocketbook (Lampsilis streckeri), Pallid sturgeon (Scaphirhynchus albus), and Arkansas River shiner (Notropis girardi). No threatened or endangered species were impinged at the Lake Catherine CWIS during the course of this study.

Blue catfish, channel catfish, freshwater drum, and common carp were the species of greatest commercial and recreational value with impingement potential, but IM rates for these species were relatively low. Although threadfin and gizzard shad exhibited the highest impingement potential, these species have only indirect value as bait and forage species. Additionally, gizzard shad exhibit such high abundance that annual winter drawdowns of Lake Catherine are designed in part to control their population, thus impingement of this species is considered to have minimal impact upon the fishery. Threadfin shad are stocked in Lake Catherine by the AGFC, effectively negating any population impacts resulting from impingement.

Seasonal variation in species richness, abundance, and impingement rate was exhibited in the current Lake Catherine and historic ANO impingement studies. Greatest species richness and abundance was observed in the cooler winter months (November through March). Migration of fish to deeper waters in winter in search of warmer water conditions is expected to increase fish abundance near intake pipes, which in turn should result in an increase in impingement rates. The annual winter drawdown of Lake Catherine concentrates aquatic organisms near the intake structure as well. Accordingly, the highest impingement rates at Lake Catherine were also observed from November to March. Another seasonal factor affecting impingement potential is the “cold shock” mortality of gizzard and threadfin shad resulting from these species’ inability to adjust to rapidly decreasing winter water temperatures. The associated die-off creates an abundance of deceased shad that cannot attempt to avoid the intake structure, resulting in higher rates of shad impingement. As the lake levels begin to rise in the spring, many fish species exhibit seasonal migratory shifts to near shore habitat and away from the hydraulic influence of intake structures, thus contributing to reduced impingement. Similar seasonal trends are also apparent at the ANO facility, where the highest recorded impingement rates were during
winter, and the lowest rates were observed in the summer (Figure 15). Additionally, 94% of impingement at the ANO facility has been shown to occur between November 1 and April 1, which is similar to the current study.

Diel variation was not as pronounced in the study, but species richness, abundance, and impingement potential were each slightly greater during the nighttime samples. Diel variations observed are most likely associated with species-specific daily patterns of rest and feeding periods (Appendix B & C). Some aquatic species become more active at night and migrate offshore to feed, possibly leading to a slight increase in the number of organisms near the intake structure. Diel variation was not addressed in the ANO study.

The annual impingement rate at Entergy’s Lake Catherine Plant was calculated to be 4.22 organisms per 10,000 m³, corresponding to annual impingement of 413,802 organisms (Figure 7 & Table 2). This is a sizable increase from the estimated rate of 0.74 organisms calculated using the Lake Catherine fish biomass numbers and the 1974-1994 ANO study that yielded an average annual impingement rate of 1.82 organisms per 10,000 m³ (Table 2). The calculated rate was obtained assuming continuous yearly operation of the intake structure at full pumping capacity to reflect maximum possible impingement. More detailed analyses of impingement taking additional factors into account were also performed, and each yielded lower impingement rates, as discussed below.

A common practice in basic statistical analysis is the rejection of data considered to be an “outlier” in order to concentrate numbers around a central mean. The “outlier” designation is generally obtained by using mathematical rules incorporating quartiles. An “extreme” outlier is an observation beyond the fence defined by >Q₃ + 3*IQR, where Q₃ is the third quartile, and IQR is the interquartile range (Q₃-Q₁). Using this method the high number of shad impinged in the November sample is considered a chance occurrence and is not utilized in calculating the impingement rate. Data analysis with such strict statistical parameters yields an impingement rate of 1.21 organisms per 10,000 m³ (Rao)(Table 2).

Although the impingement rate of 4.22 was based on design capacity, the Lake Catherine Plant does not normally operate year-round. Because it is used as a “peaking reserve/load following” facility, it generally does not operate during the winter months when demand decreases. With the months of November through February removed from statistical analysis, an impingement rate of 0.3 organisms per 10,000 m³ is calculated. This rate most likely predicts the realized impingement potential at the Lake Catherine Plant during normal operating conditions, and is in fact more analogous to the rate estimated from the ANO study (Table 2).

Although the current November impingement rate (26.96) appears high, the ANO study exhibited a similar maximum monthly impingement rate (36.45) in February of 1979. The high historical rate was due to impingement of large numbers of gizzard shad at the ANO facility. The aforementioned “cold shock” mortality of gizzard and threadfin shad may be attributed to both of these values. It should be noted that such elevated monthly impingement rates were not recorded in any other months of the ten years of the historical study, lending credence to perceiving them as outlier values.

Another possible factor affecting impingement comparisons between the Lake Catherine Plant and ANO is a difference in the design of their respective CWIS. ANO employs a 4,400-foot intake canal, while the Lake Catherine Plant draws its cooling water directly from the lake using large-diameter pipes. Abundance and speciation of organisms that utilize the intake canal as habitat may not be exactly representative of the aquatic communities of the lake.

In conclusion, the disparity between the impingement rates is attributable to several factors, notably the significant increase in threadfin shad impingement during the current November sampling period. Although winter impingement was expected to be higher in regards to threadfin and gizzard shad, the high numbers encountered at the Lake Catherine Plant in November are considered an outlier possibly attributed to cold shock mortality. Despite the large November sample, impingement rates at the Lake Catherine Plant are considered relatively low. Multiple years of sampling by the AGFC have determined healthy and abundant
stocks of threadfin and gizzard shad in Lake Catherine that rebound to normal abundance after each spawning season. Therefore, no measured negative impact exists for the ichthyofauna of Lake Catherine resulting from Entergy's CWIS. Additionally, species composition and relative abundance of dominant species in historic and current studies are similar in both the ambient waters and those represented from impingement. Since the general trends in impingement rates are similar with the ANO study and species composition of all studies reviewed, we conclude the data are representative of typical biological parameters of the lake (Appendices A, B & C).
7.0 References


FTN Association Ltd. (FTN). 2007. Analysis of temperature and dissolved oxygen n the Ouachita River and Lake Catherine before and after inlet plating and establishment of minimum flows at Remmel Dam. Prepared for Entergy Arkansas, Inc.


Tables
Table 1. Phylogenetic Distribution of Species Impinged at the Lake Catherine Plant, 2006 - 2007.

<table>
<thead>
<tr>
<th>Family</th>
<th>Common Name</th>
<th>Scientific Name</th>
<th>Total Number Impinged</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cambaridae</td>
<td>Crayfish</td>
<td>Procambarus sp.</td>
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<tr>
<td>Clupeidae</td>
<td>Threadfin shad</td>
<td>Dorosoma petenense</td>
<td>2773</td>
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<tr>
<td></td>
<td>Gizzard shad</td>
<td>Dorosoma cepedianum</td>
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<td>Unidentified shad</td>
<td>Dorosoma sp.</td>
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<td>Ictaluridae</td>
<td>Channel catfish</td>
<td>Ictalurus punctatus</td>
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<tr>
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<td>Flathead catfish</td>
<td>Pylodictis olivaris</td>
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<tr>
<td></td>
<td>Yellow bullhead</td>
<td>Ameiurus natalis</td>
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<tr>
<td>Moronidae</td>
<td>White bass</td>
<td>Morone chrysops</td>
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<td>Percidae</td>
<td>Logperch</td>
<td>Percina caprodes</td>
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<td>Walleye</td>
<td>Sander vitreus</td>
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<td>Atherinopsidae</td>
<td>Brook silverside</td>
<td>Labidesthes sicculus</td>
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<td>Centrarchidae</td>
<td>White crappie</td>
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<td>Longear sunfish</td>
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<td>Sciaenidae</td>
<td>Freshwater drum</td>
<td>Aplodinotus grunniens</td>
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<td>Catostomidae</td>
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<td>Spotted sucker</td>
<td>Minytrema melanops</td>
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<td>Total</td>
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Table 2. Calculated Impingement Rates for the Arkansas Nuclear One and Lake Catherine Plants.

Table 2a: Impingement Calculations - Original Estimates

<table>
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<tr>
<th></th>
<th>Fish Productivity (Kg/Ha)</th>
<th>Productivity Divisor</th>
<th>Total Annual Fish Standing Crop (Kg)</th>
<th>Annual Impingement Rate (# org / 10000m³)</th>
<th>Annual # of Organisms Impinged</th>
<th>Annual Loss of Biomass (Kgs)</th>
<th>Annual Percent Biomass Lost to Impingement</th>
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</thead>
<tbody>
<tr>
<td>Lake Dardanelle</td>
<td>1139.58 (Known)</td>
<td>2.46 (1139.58/2.46=462.33)</td>
<td>15,910,593.74 (Known)</td>
<td>1.82 (Known)</td>
<td>1,900,000 (Known)</td>
<td>24,643.46 (Known)</td>
<td>0.15% (Calculated)</td>
</tr>
<tr>
<td>Lake Catherine</td>
<td>462.33 (Known)</td>
<td></td>
<td>307,218.74</td>
<td>0.74 (Estimated)*</td>
<td>46,000 (Estimated)</td>
<td>599.88 (Calculated)</td>
<td>0.2% (Calculated)</td>
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Table 2b: Impingement Calculations - Actual

<table>
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<th></th>
<th>Fish Productivity (Kg/Ha)</th>
<th>Total Annual Fish Standing Crop (Kg)</th>
<th>Annual Impingement Rate (# org / 10000m³)</th>
<th>Annual # of Organisms Impinged**</th>
<th>Annual Loss of Biomass (Kgs)</th>
<th>Annual Percent Biomass Lost to Impingement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lake Dardanelle</td>
<td>1139.58</td>
<td>15,910,593.74</td>
<td>1.82</td>
<td>1,900,000</td>
<td>24,623.46</td>
<td>0.15%</td>
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<tr>
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<td></td>
<td>(70 organisms = 1lb = 0.45Kg)</td>
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<td>Lake Catherine</td>
<td>462.33</td>
<td>307,218.74</td>
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<td>2,681.38</td>
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*70 organisms = 1lb = 0.45Kg

Entergy (ANO), 1979-1988
Entergy (LC), 2006-2007
316(b) Impingement Sampling
Table 2c: Impingement Calculations - November Sample Removed

<table>
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<tr>
<th></th>
<th>Fish Productivity (Kg/Ha)</th>
<th>Total Annual Fish Standing Crop (Kg)</th>
<th>Annual Impingement Rate (# org / 10000m³)</th>
<th>Annual # of Organisms Impinged</th>
<th>Annual Loss of Biomass (Kgs)</th>
<th>Annual Percent Biomass Lost to Impingement</th>
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<tbody>
<tr>
<td>Lake Dardanelle</td>
<td>1139.58</td>
<td>15,910,593.74</td>
<td>1.82</td>
<td>1,900,000</td>
<td>24,623.46</td>
<td>0.15%</td>
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<td>(70 organisms = 1lb = 0.45Kg)</td>
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<td>Lake Catherine</td>
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Table 2d: Impingement Calculations - Winter Months (Nov, Dec, Jan, Feb) Removed

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<th>Fish Productivity (Kg/Ha)</th>
<th>Total Annual Fish Standing Crop (Kg)</th>
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<th>Annual # of Organisms Impinged</th>
<th>Annual Loss of Biomass (Kgs)</th>
<th>Annual Percent Biomass Lost to Impingement</th>
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<td>(70 organisms = 1lb = 0.45Kg)</td>
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Table 3: Diel Enumeration of Species Impinged at Lake Catherine, 2006-2007.

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Lake Catherine Site and Aquatic Habitat Map
Entergy Arkansas – Lake Catherine Plant
Jones Mill, Arkansas

Figure 2
November 2007
Figure 3. Water Temperatures Recorded at Time of Sampling, 2006-2007.
Figure 4. Dissolved Oxygen Concentrations Recorded at Time of Sampling, 2006-2007.
Figure 5. Ouachita River Stage Data at Arkadelphia, AR during Sampling Period, 2006-2007.
Figure 6. Ouachita River Stage Data at Blakely Mountain Dam, AR during Sampling Period, 2006 -2007.
Figure 7. Average Monthly Impingement Rates at Lake Catherine, 2006 - 2007.
Figure 8. Composition of Impinged Species Comprising >1% of Daytime Samples at Laje Catherine, 2006 -2007.

- Gizzard shad: 74%
- Threadfin shad: 24%
- Logperch: 2%
Figure 9. Composition of Impinged Species Comprising >1% of Nighttime Samples at Lake Catherine, 2006 -2007.
Figure 10. Composition of Impinged Species Comprising >1% of Total Catch at Lake Catherine, 2006-2007.
Figure 11. Impingement Rates for Dominant Species at Lake Catherine, 2006 - 2007.
Figure 12. Threadfin Shad Monthly Impingement Rates at Lake Catherine, 2006 -2007.
Figure 13. Gizzard Shad Average Monthly Impingement Rates at Lake Catherine, 2006 -2007.
Figure 14. Composition of Impinged Species Comprising >1% of Total Catch at Arkansas Nuclear One, 1979 to 1988.
Figure 15. Average Monthly Impingement Rates: Lake Catherine vs. Arkansas Nuclear One.
Appendix A

Summary of Supporting Impingement/Biological Studies

Lake Catherine rotenone sampling was conducted from 2001-2003 and 2005 in Tigre Bay. Individuals per hectare was recorded and kilograms/ha were calculated. All data was composited to give an average total of all abundance and biomass figures.

Thirty-four species were collected. Of those, gizzard shad, threadfin shad, black crappie, largemouth bass, spotted bass, white crappie, common carp, yellow bullhead, channel catfish, walleye, freshwater drum, white bass and yellow bass were considered to be offshore species of concern (OSC).

Approximately 62% of all species abundance was of OSC. Twenty nine percent of OSC individuals collected were gizzard shad, averaging 9265/ha and 68.9% of OSC biomass at a mean of 191.74 kg/ha. Threadfin shad had an abundance of 26.8% at 8431/ha and made up 8.5% of OSC biomass at 18kg/ha. Largemouth bass made up 2% of the OSC and black crappie made up 1.7%. Gizzard shad also made up 41% of the entire lake’s biomass. Longear sunfish made up 8%, bluegill sunfish at 6% and threadfin shad at 5%. The total average biomass for the entire system was 462 kg/ha.


The author proposes that judgments of adverse environmental impact from cooling water intake structures need to be preceded by an appreciation of what is normal. With this perspective, the sum of the best scientific understanding of how organisms and aquatic ecosystems function should be the norm or standard of measure for how we judge the effects of human activities on aquatic systems. For the best likelihood of recovery, key aspects of altered systems should be brought back toward normative, although not necessarily back to the historical or pristine state. New alterations should be judged for adversity by how much they move key attributes away from what might be considered normal. The author suggests that if a water intake does not move the aquatic ecosystem outside the ‘normative’ range, then no adverse impact has occurred.


This document includes fisheries data collected at the Arkansas Nuclear One (ANO) Cooling Water Intake Structure (CWIS) located at Lake Dardenelle, Arkansas. Common species included gizzard shad, threadfin shad, blue catfish, freshwater drum, skipjack herring, channel catfish, blue gill, and common carp.

Entergy conducted impingement studies on Lake Dardanelle between 1977 and 1988 at ANO Unit 1 CWIS. Monitoring efforts were to characterize impingement conditions and to determine a calculation baseline. ANO is located on a peninsula formed by Lake Dardanelle, near the town of London. Water is brought in through a 4000 foot intake canal and released via a 520 foot discharge canal.

Fish assemblages vary within the system. Flathead catfish, channel catfish, and blue catfish are present in areas of current. Largemouth bass, spotted bass, green sunfish, bluegill sunfish, black and white crappie, and warmouth occupy slack water areas. Common carp, black, bighorn and smallmouth buffalo, carp suckers, freshwater drum, and redhorse comprise the rough fish. Striped bass and white bass are present in the spring. Gizzard shad and threadfin shad are considered the most important forage species.

Historical impingement data was conducted from 1974-1994, however Entergy determined from 1977-1988 to be the most complete and was therefore utilized. Impingement monitoring involved total counts of fish that accumulated on screens during 24 hour periods. Fish counts were conducted up to 5 consecutive days depending on the season. All fish were identified to species and lengths and weights were recorded. Impingement samples were collected 805 days during the sampling period. Additional information recorded included inlet water temperature, traveling screens being washed, and number of pumps in operation. Only
Unit 1 traveling screens were sampled. Fish counts were compiled into consecutive 10-day averages for the period of record.

14.9% of all impingement occurred during the 10-day period of mid-February in the aggregated annual data. An average of 120,000 impinged individuals was documented during this period. Approximately 94% of all impingements occurred during the winter months from November 1 and April 1. Over 96% of fish impinged annually was composed of threadfin shad (51%), gizzard shad (38%) and freshwater drum (7%). The remaining 4% consisted of skipjack herring, silversides, catfish and several other species. The major cause of fish impingement mortalities was the result of ambient cold stresses of threadfin and gizzard shad. Many were observed to be already dead or moribund during impingement.

Impingement mortality had no significant effect on the standing crop of fish populations during the study. Although threadfin and gizzard shad comprise the majority of impinged organisms, populations reestablish themselves each year.


Biological control of gizzard shad using predator fish species was used to reduce impingement on cooling water intake screens at Coffey County Lake, Kansas. Comparisons were completed between the lake’s primary productivity (chlorophyll a), catch-per-unit-effort of young-of-year and adult gizzard shad, and body conditions of predator species. No relationships were found between the lake’s productivity and gizzard shad densities indicating that other mechanisms control shad numbers, likely predation. It is believed that the predator species present played a significant role in reducing YOY shad densities each year. The author states that it would be an obvious advantage in a power plant cooling lake to have predator species reduce gizzard shad YOY abundance to densities low enough to prevent excessive impingement.


Fish entrainment and impingement studies were conducted at Cayuga and Wabash River generating stations in 1987 and 1988 (35 miles apart). Concurrent river samplings were conducted upstream from the stations to assess adult fish and ichthyoplankton populations. The original 316(b) studies were conducted in 1976-77 and concluded the stations were having minimal impact. The six month impingement estimates for Cayuga and Wabush were 15,086 and 11,401 fish, respectively. Impingement at both plants was dominated by YOY channel catfish and gizzard shad. In addition small minnows (primarily bullhead minnow and emerald shiner) were also dominant species in the river sampling upstream from the stations. Unusually low river flows during the spring and summer of 1987 and 1988 provided worst-case conditions for entrainment and impingement; however, the low entrainment and impingement rates indicated the stations were not adversely affecting the Wabash River fish community.


The survival of fish impinged on 1-mm mesh Ristroph-type screens was evaluated at Somerset Station, a coal-fired electric generating station located on the south shore of Lake Ontario. Survival testing was conducted over a 4-year period that included all four seasons. Test fish were diverted from the fish return and held for 96-h for observation. Twenty-eight species were tested and collections were dominated by alewife, emerald shiner, gizzard shad, rainbow smelt, and spottail shiner. Survival rates commonly approached or exceeded 80%, and were influenced by species, fish size or life stage, season and fish condition.

Since 1975 Wisconsin Electric has conducted impingement and entrainment studies at seven steam-electric, once through cooling power plants, as well as one closed-cycle plant. All plants are located on the Great Lakes or tributaries to them. The studies concluded that since the vast majority of the fish impinged during the 1975-1976 period were alewife and rainbow smelt (the then most abundant species in lakes Michigan and Superior) and since the historic commercial harvests of these two species greatly exceeded the annual impingement estimates, impact was deemed inconsequential. With respect to the entrainment results, the studies detected few fish eggs or larvae that were not alewife or smelt. As a consequence of these findings, the company did not believe that any structural modifications to the intakes were necessary, since any of the feasible alternatives would have been very costly. The state agencies concurred with these findings.


The Comanche Peak Steam Electric Station (CPSES) is a once-through two-unit nuclear power station located 65 miles southwest of Dallas. Both units were on-line by 1993 and the NRC required a 316(b) demonstration study. Units 1 and 2 share a common intake structure located flush on the shore of an excavated recess of Squaw Creek Reservoir. This recess is 50 ft. deep at the trash racks. It was determined that total plant impingement (including threadfin shad) is very low for a plant of this size (2300 MWe), and entrainment is dominated by forage species with high fecundity and pelagic spawning habits. Impingement and entrainment of gamefish is extremely low. The paper describes how the design specifications were developed to ensure reliability and safety also helped minimize adverse environmental impact by locating the intake in a zone of “low biological value” relative to alternative areas.


Texas Instruments Incorporated conducted the effects of air bubble curtains on fish impingement at ANO’s Unit 1 CWIS on Lake Dardanelle during 1974-1975. Objectives included the characterization of species composition and biomass, length frequency distributions of fish impingements during 4 seasonal air curtain test periods, and an examination of causal relationships between impingement, air-bubble curtain status, and selected biological parameters during testing.

ANO is located on Lake Dardanelle, an impounded system of the Arkansas River. Cooling water is taken in from a 1.2 km intake canal to 8 fore bays at Unit 1. Velocities of 0.46m/s are present at the intake screens. The air curtain screen is located across the mouth of the intake canal approximately 121.9 meters long at a depth of 4.6 meters. Fiberglass pipes lying side by side at lengths of 121.9 m, 91.4 m, 54.9 m, and 24.4 m at the bottom of the canal provide the air curtain via 0.2 cm air holes situated along the upper surface of the pipes. Holes are situated only at the end of the pipes to provide a uniform curtain across the canal.

Seasonal tests were conducted October-November, January-February, April-May, and July-August, consisting of 6 consecutive weekly periods of 3 days of curtain operation and 3 days off curtain operation with 1 day in between of no sampling.

38 species of fish were identified during the study with a total of 9,571,922 total individuals comprising a biomass of 78,762 kg. Impingement rates rose during late October 1974 and persisted through the remainder of the fall and winter sampling period. As temperatures increased through spring, impingement decreased. No correlation of biomass impingement and air curtain operation could be determined. Species occurring most during tests included the threadfin shad, gizzard shad, blue catfish, channel catfish, white bass, white crappie and freshwater drum. 95% of all impingements were of threadfin shad and gizzard shad. Of these two species,
threadfin shad dominated both total numbers (91%) and total biomass (88%). Impingement rates for all species combined were significantly correlated to decreased water temperature in the winter.
Appendix B

Biological Profile of Lake Catherine
Life Histories of Relative Important Species (RIS)

The following section provides an overview of the relative important species subject to impingement mortality at the Lake Catherine Plant. These species include any threatened or endangered species as well as any commercially or recreationally important species.

Gizzard shad (*Dorosoma cepedianum*)

Gizzard shad occur primarily in freshwater and are most abundant in large rivers and reservoirs, avoiding high gradient streams. Spawning generally takes place in late spring, usually in shallow protected water or near shore (Chilton, 1997 and Robison and Buchanan, 1988). Gizzard shad are planktivorous. The young feed on microscopic animals and plants, as well as small insect larvae, while adults feed by filtering small food items from the water using their long gill rakers. The gizzard shad is primarily a pelagic species, usually traveling in large schools in the open waters. This species generally grow to 14 inches and provide forage for most game species (Chilton, 1997). Ross (2001) stated that young gizzard shad tend to occur along shorelines in very shallow water, gradually moving offshore into deep water as they grow. Cross (1967) also noted that gizzard shad occupy progressively deeper water as they grow older and tend to increasingly consume organisms associated with the bottom sediments rather than those found near the surface. Bodola (1966) found that individuals older than age class 3 rarely occur in shallow water.

The AGFC employs various management techniques, such as winter drawdowns and selective shad kills with rotenone, to control their populations in certain impoundments. Another attempted shad control measure in reservoirs has been stocking of large predatory species such as striped bass, northern pike, muskellunge, and walleye (Robison and Buchanan, 1988). The authors also note that the gizzard shad is a fragile species that dies quickly after handling. Adult gizzard shad have a potential for impingement at the Lake Catherine Plant due to their preference for deeper waters and its schooling behavior as well as historical observations by plant personnel.

Threadfin shad (*Dorosoma petenense*)

Like gizzard shad, threadfin shad are most commonly found in large rivers and reservoirs. However, threadfin shad are most likely to be found in waters with a noticeable current and are usually found in the upper five feet of water. Spawning begins in the spring and continues through summer. Adults are considerably smaller than gizzard shad and rarely exceed 6 inches in length (Chilton, 1997). This species is a pelagic schooling species that primarily occupy the areas between the surface and the thermocline with the greatest densities near the surface (Netsch et al. 1971). Houser and Dunn (1967) also found that during most of the year in Bull Shoals Reservoir (Arkansas) threadfin shad occupied a sharply limited layer of water between the surface and the thermocline. The authors also note that the shad density decreased with increasing depth. Compared to gizzard shad, threadfin shad are expected to have a much reduced potential for impingement at the Lake Catherine Plant.

Longear sunfish (*Lepomis megalotis*)

Longear sunfish occur in a variety of habitats and is most abundant in small, clear, upland streams with rocky bottoms and permanent or semi-permanent flow. They are typically found in pools and do well in reservoirs. This species feeds primarily on aquatic and terrestrial insects as well as small fish. The species is a colonial nester and in Arkansas spawning occurs from May through August (Robison and Buchanan, 1988). Boyer and Vogele (1971) reported that in reservoirs the species typically spawn in brush-free areas having a gradually sloping gravel substance. The authors note that most nests were between 0.7 and 11.2-feet with an average depth of 4.9-feet. Due to the species’ preference for more shallow waters, the potential for impingement is minimal.
Bluegill sunfish (*Lepomis macrochirus*)

Bluegills begin spawning when water temperatures reach 70 F peaking in May or June. Nests are created in shallow water, one or two feet in depth usually on a gravel substrate (Chilton, 1997). The bluegill is a generalized sight feeder. It is a gregarious species, often moving in loose schools, and it feeds at various depths depending on food availability (Robison and Buchanan, 1992). Young fish feed on plankton, but as they grow the diet shifts to aquatic insects and their larvae. Up to 50% of their diet may consist of midge larvae (Chilton, 1997). Since bluegill may be found at various depths in the water column, its potential for impingement at the Lake Catherine Plant is likely greater than some of the other sunfish species.

Bluntnose minnow (*Pimephales notatus*)

The bluntnose minnow generally inhabits medium-sized to large, clear, permanent streams with gravel bottoms and aquatic vegetation, but can be found in a variety of stream and lake habitats throughout Arkansas. Quite pools and backwater habitat areas are favored habitats. Food consists primarily of plankton, algae, insect larvae, and small aquatic invertebrates (Robison and Buchanan, 1988). In lakes, bluntnose minnows are often associated with mimic shiners. Usually a school of 10-15 bluntnose minnows follows immediately behind and beneath a school of shiners (Moyle, 1969). Moyle also stated that bluntnose minnows are primarily browsers of organic detritus, algae, and midge larvae or pupae from the bottom or surfaces of aquatic plants. Due to this species preference for more shallow waters and aquatic vegetation, the potential for impingement is minimal.

Largemouth bass (*Micropterus salmoides*)

Largemouth bass are most commonly found in clear, quite waters in natural and man-made lakes and ponds, and in back waters and pools of streams and rivers. The species is intolerant of high turbidity and siltation and is often found during most parts of the day near logs or other cover in deep water (Robison and Buchanan, 1988). Largemouth bass prefer to nest in quite, more vegetated water compared to other black bass, but will use any substrate besides soft mud, including submerged logs. Nests are usually built in two to eight feet of water. Fry feed primarily on zooplankton and insect larvae while adults feed extensively on other fish and large invertebrates such as crayfish (Chilton, 1997). Since largemouth bass often seek deeper waters, there is some potential for impingement at the Lake Catherine Plant.

Black crappie (*Pomoxis nigromaculatus*)

Like other members of the sunfish family, crappie are nest builders and tend to build relatively large "beds" in the spring. Although fry do not appear to school, fingerlings do. They grow three to five inches the first year and mature in three years. Black crappie feed on less fish than white crappie, but more insects and crustaceans (Chilton, 1997).

Crappie occur in a variety of habitats but are more common in oxbow lakes, pools of larger rivers, and reservoirs. Black crappie are most active at night or in the early morning, and at least in reservoirs, tend to move from open waters during the day to closer to shore at night (Guy et al. 1992).

Black crappie are almost always found near fallen treetops, standing timber, logs or other cover. At most locations they are less abundant than white crappie as they are less tolerant of turbidity and siltation. Black crappie prefer cooler, deeper waters and they do best in clear lakes with abundant aquatic vegetation (Robison and Buchanan, 1988). Except for the breeding season, black crappie form loose schools near submerged treetops or other cover 3-10-feet deep. At night the schools often move out over deep water.
(Moyle, 1969). The black crappie likely has a moderate potential for becoming impinged due to their preference for deeper waters at night and the tendency for fingerlings to school.

**Spotted bass (Micropterus punctulatus)**

Spotted bass are especially abundant in the mountainous regions of Arkansas and has adapted well to impoundments of various sizes. Although common in reservoirs, the spotted bass is usually outnumbered by largemouth bass in reservoirs (Robison and Buchanan, 1988). This was observed in the AGFC collections (2001-2003) from Lake Catherine. As young fish grow, their diet shifts from zooplankton to insects, and finally to fish and crayfish (Chilton, 1997). The spotted bass exhibited the greatest preference of any of the black basses in Bull Shoals Lake (Arkansas) for manmade brush shelters as nesting sites. Nests were found at water depths of 3 and 18-feet and located just downstream from a boulder, log or other cover (Robison and Buchanan, 1988). Although spotted bass do not appear to seek deeper water as much as largemouth bass do, they likely have a moderate potential for impingement.

**White crappie (Pomoxis annularis)**

The white crappie has wide ecological tolerances but prefers quiet waters and is almost always found near brush piles, the tops of fallen trees, or standing timber. It is not a strongly schooling species but tends to congregate in loose aggregations near suitable cover (Robison and Buchanan, 1988). In reservoirs, white crappie occur in open areas and may show a pattern of vertical migration at night (Funk, 1955). Crappie spawn in Arkansas from early April to the middle of June. The nests may be located from less than 1-foot to 20-feet deep in silt-free substrates near a log, stump, or aquatic vegetation (Robison and Buchanan, 1988). Since this species tends to migrate vertically in the water column, it has some potential to be found in deeper waters and therefore potential for impingement. Since white crappie do not typically school, impingement potential is most likely minimal.

**Logperch (Percina caprodes)**

The logperch is Arkansas’ most abundant and widely distributed darter and is most abundant in streams of the Ozark and Ouachita Uplands. It is also common in Arkansas reservoirs. This species feeds primarily on insect larvae and other small invertebrates (Robison and Buchanan, 1988). Mullan et al. (1968) found the logperch to be a sedentary littoral (area along the shore) bottom forager in two Arkansas reservoirs. Winn (1958) stated that in lakes and streams male logperch form schools above an area of sand or gravel parallel to the shoreline. The females feed in deeper water beyond the male school until ready to spawn. In general this species prefers more shoreline habitat and has low potential for impingement, although the potential is greater for females during spawning season.

Using the AGFC data for Lake Catherine, in conjunction with known recreational species in the lake, the following species are considered/discussed as species with potential for impingement at the Lake Catherine Plant. Those species with greater preference for deeper habitats most likely will have a greater chance of being impinged. Many of the species collected in the shallows of Tigre Bay by the AGFC have minimal impingement potential as they are almost always found at the surface including the blackspotted topminnow (*Fundulus olivaceus*), brook silverside (*Labidethes sicculus*) and mosquitofish (*Gambusia affinis*).
Catfish Species (*Ictalurus spp.*)

Although the channel catfish is basically a stream fish, it is extremely adaptable and does equally well in reservoirs. Adults seek out deep pools, submerged logs, and overhanging banks by day and at night feed in riffles and shallow pools. Channel catfish feed on a variety of foods, ranging from fish, insects, mollusks, and crayfish to occasional plant material and detritus (Robison and Buchanan, 1988). Since it is a bottom dwelling species this does have some potential for being impinged at the Lake Catherine Plant. The blue catfish (*Ictalurus furcatus*) is most often found in deeper waters. They feed mainly near the bottom on fish, crayfish, aquatic insects, fingernail clams, and freshwater mussels (Brown and Dendy, 1961), and would also have some potential for becoming impinged. The bottom dwelling nature of the flathead catfish (*Pylodictis olivaris*), which is more common in deep waters, also puts this species at risk for impingement. None of these species tend to school so an abundance of them would not be expected near the intakes.

Striped Bass (*Morone saxatilis*)

In Arkansas reservoirs, striped bass (*Morone saxatilis*) live in moving schools similar to those of the white bass, feeding primarily on the abundant threadfin and gizzard shad (Robison and Buchanan, 1988). Since striped bass prey on shad, and anecdotal information suggests that shad are the most commonly impinged species at the Lake Catherine Plant, this species has some potential for impingement. The larger specimen chasing shad in deeper waters, however, would probably have the ability to swim against the intake velocities or be too big to pass through the intake bars.

Walleye (*Stizostedion vitreum*)

Walleye (*Stizostedion vireum*) are very sensitive to strong light and avoids it by seeking deeper water and sheltered areas in the day. At night the species moves inshore to shoal areas to feed. Adults feed on fish, fry feed on small crustaceans and insects, and larger young feed on a mixture (Robison and Buchanan, 1988). Due to their sensitivity to light and preference for darker waters, this species has some potential for impingement.

Freshwater drum (*Apolodonotus grunniens*)

In Arkansas, freshwater drum (*Aplodinotus grunniens*) inhabit deep pools of medium to large rivers and large impoundments. This bottom dwelling species feeds on mollusks, small fish, chironomids, small crustaceans, and other aquatic macroinvertebrates (Robison and Buchanan, 1988). This species has some potential for impingement at the Lake Catherine Plant as it is a common bottom-dweller.

Grass Carp (*Ctenopharyngodon idella*)

Robison and Buchanan (1988) state that grass carp (*Ctenopharyngodon idella*) have been introduced into Arkansas waters since the mid-1960's to control unwanted plant material. Once they reach approximately 3-inches in length they become nearly 100% herbivorous. Their herbivorous feeding habits make them ideal as vegetation control agents since they are capable of consuming 40-300% of their body weight per day in plant material (Chilton, 1997). Since this species feeds primarily on larger plant material, they are not expected in deeper waters where productivity is limited, therefore the potential for impingement at Lake Catherine is minimal.
Spotted gar (*Lepisosteus oculatus*)

According to Chilton (1997) and Robison and Buchanan (1988), spotted gar (*Lepisosteus oculatus*) are usually associated with aquatic vegetation, or standing timber, in clear water, therefore are not expected to be found in the deeper waters of Lake Catherine.

Sunfish Species (*Lepomis spp.*)

Warmouth (*Lepomis gulosus*) and Green sunfish (*Lepomis cyanellus*) also prefer complex habitat with aquatic vegetation, sunken logs, stumps, cypress knees, etc (Chilton, 1997). The green sunfish is much more tolerant of a wide range of ecological conditions, particularly to extremes in turbidity, dissolved oxygen, temperature and flow (Robison and Buchanan, 1988) and are therefore likely to have a greater tendency to inhabit the deeper waters of the lake compared to the warmouth.

Threatened and Endangered Fish and Shellfish in Arkansas

Thirteen “endangered” or “threatened” aquatic species have been documented by the USFWS (2007) and the AGFC (2007) to occur in regions of Arkansas. This list include the Ozark cavefish (*Amblyopsis rosae*), Cave crayfish (*Cambarus aculabrum*, *Cambarus zophonastes*), Leopard darter (*Percina pantherina*), Arkansas Fatmucket (*Lampsilis powelli*), Pink mucket (*Lampsilis abrupta*), Scaleshell mussel (*Lepotdea leptodon*), Curtis pearlymussel (*Epioblasma florentina curtisi*), Fat pocketbook (*Potamilus capax*), Ouachita rock pocketbook (*Arkansia wheeleri*), Speckled pocketbook (*Lamsilis streckeri*), Pallid sturgeon (*Scaphirhynchus albus*), and Arkansas River shiner (*Notropis girardi*). No threatened or endangered species were impinged during the course of this study.

Pallid sturgeon (*Scaphirhynchus albus*)

The Pallid sturgeon is listed endangered by the USFWS. This species is essentially restricted to the main channels of the Missouri and Mississippi Rivers. The principal habitat of the pallid sturgeon is the main channel of large, turbid rivers, although some have been captured from mainstem reservoirs on the Missouri River. Very little is known about the reproductive biology of this species. Age and size at maturity for male pallid sturgeon have been estimated at three to four years and 530-580 mm, and five to seven years. Females apparently do not spawn until they are 15-20 years old. Spawning coincides with spring runoff, and occurs between March and June throughout the species' range (Ross, 2001).

In Arkansas there have been only two specimens collected, one in the Mississippi River and one from the St. Francis River in northeastern Arkansas (Robison and Buchanan, 1988). Therefore, the Pallid sturgeon is not expected to inhabit Lake Catherine.

Ozark cavefish (*Amblyopsis rosae*)

The Ozark cavefish is listed endangered by the USFWS. This species is limited in range to caves of the Springfield Plateau physiographic region of Arkansas (northwest corner), Oklahoma, and Missouri. This Ozark endemic species is found today in Arkansas in only seven caves in Benton County (Brown, 1985). The species is never found in surface water, but inhabits the permanently dark, constant temperature of underground passageways (Robison and Buchanan, 1988). Therefore, the Ozark cavefish is not expected to inhabit Lake Catherine.

Leopard darter (*Percina pantherina*)
The Leopard darter is listed threatened by both the USFWS. The species is endemic to the Little River system in Arkansas and Oklahoma. According to Robison and Buchanan (1988) it is a rare species in Arkansas found only in the Mountain Fork and Cossatot rivers in southwestern Arkansas. Therefore, the Leopard darter is not expected to inhabit Lake Catherine.

**Arkansas River shiner (*Notropis giardi*)**

The Arkansas River shiner is listed threatened by the USFWS (USFWS, 2005a) but is not listed by the AGFC. The species is an Arkansas River drainage endemic, but is extremely rare in Arkansas. It has been taken only once in the state at the mouth of Piney Creek, Logan County in 1939 (Black, 1940). Robison and Buchanan (1988) state that numerous fish collections from the Arkansas River at Fort Smith during the last 16 years have failed to produce any specimens and conclude that the species has most likely been extirpated from the state. Therefore, the Arkansas River shiner is not expected to inhabit Lake Catherine.

**Fisheries on Lake Catherine**

**Recreational Fisheries**

Lake Catherine is an extremely important recreational lake in Arkansas. The combination of Lake’s Catherine, Hamilton and Ouachita have given the area its nickname of the “Tri-Lakes Region” and helped transform the counties around Hot Springs National park into one of mid-America’s favorite vacation/retirement areas (US Lakes, 2005).

Trout, crappie, catfish, black bass, striped bass and hybrid bass are popular recreational fish species sought after in Lake Catherine. Trout are stocked into Lake Catherine annually by the AGFC as there is no established trout fishery in the lake (AGFC, 2007). Additional species with recreational importance in Lake Catherine include the spotted, white and smallmouth basses, walleye, flathead, blue, channel, and bullhead catfish, rainbow trout and black and white crappie (AGFC, 2007).

**Andrew Hulsey Fish Hatchery**

The Andrew Hulsey Fish Hatchery provides around three million fingerlings annually to both the Lake Hamilton and Lake Catherine areas, making it one of the most successful sport fish hatcheries in the nation. Sportfishes found in these two lakes include the black, spotted, white and smallmouth basses; walleye; flathead, blue, channel, and bullhead catfish; rainbow trout and black and white crappie among others (U.S. Lakes, 2005). Lake Hamilton (10 miles upstream of Lake Catherine) has been stocked regularly with striped bass (striper) since the 1970s. Lake Hamilton has a large threadfin and gizzard shad population, the stripers’s favorite food, that ensures a healthy population (LHSG, 2005). In 2002 the major species cultured and stocked (including Lake Catherine) at the hatchery were: Florida largemouth bass (350,000), blue catfish (240,000), striped bass (175,000), channel catfish (120,000), Saugeye (100,000), and walleye (25,000) (LHSG, 2005).

**Commercial Fisheries**

There are no established commercial fisheries on Lake Catherine. The state’s wild commercial fishery is confined to the larger lowland lakes and streams of the Arkansas, White, Red, and Mississippi River systems. On rare occasions, commercial fishing is permitted in a few reservoirs (Robison and Buchanan, 1988).
Appendix C

Lake Catherine Ecosystem Dynamics
Hydrology

Lake Catherine was ranked in the lower 50% of Arkansas lakes for trophic status (57% of lakes had higher trophic indices), which indicates that its nutrient load and productivity are fairly average for Arkansas. This is reflected by the fact that Lake Catherine meets all of its designated uses. Historical exceedances of established water quality standards are limited in the historical or present studies (FTN, 1999a).

Lake Catherine is a relatively small impoundment with a short hydraulic residence time of the order of eight days. Lake Catherine is cooler than the nearby Lake Hamilton because it receives cooler water from Lake Hamilton’s hypolimnion (layer under the thermocline where temperature is relatively uniform) and has a short hydraulic residence time. Water released from Lake Hamilton is withdrawn from the lower depths of the lake (about 80 feet) and, as discussed above, is cool and frequently contains higher than expected concentrations of DO. Since water residence time in Lake Catherine is relatively short, the water quality changes little as it moves downstream through the lake. Water quality in Lake Catherine is affected by point sources and upstream dam releases to a greater extent than Lake Hamilton (FTN, 1999a).

Lake DO levels typically remain above 7.0 mg/L near the surface dropping to near 5.0 mg/L throughout the metalimnion to near 1.0 mg/L in the lower extent of the hypolimnion. The lowest hypolimnetic and metalimnetic values occur during late summer (FTN, 1999a and 1999b).

Lake Catherine water temperatures are fairly uniform during the winter months, ranging from 40 to 50 degrees Fahrenheit. As the lake begins to warm in the spring months, the lake becomes stratified into a warmer upper layer (epilimnion) with temperatures from 60 to 70 degrees F and a colder lower layer (hypolimnion) with temperatures from 50 to 55 degrees F. This stratification becomes more distinct as the epilimnion warms even more during the summer months (70 to 75 degrees F) and the hypolimnion remains fairly cool (60 to 65 degrees F). As the surface waters of the lake begin to cool in the fall, the stratification breaks down and the lake temperatures become more uniform from top to bottom (FERC, 2001).

The LCP warm water discharge influences water temperature and flow patterns in the downstream portion of Lake Catherine. The LCP draws in cooling water from the deeper, cooler portions of Lake Catherine and discharges the warmed waters back into the Remmel Dam forebay. Thermal mixing does occur in the surface layers of the lake resulting in warmer surface water near and upstream of the Remmel Dam forebay area.

In 1990, the ADPCE (now ADEQ) prepared a study entitled “A Survey of Bioaccumulative Pollutants in Lake Catherine” (Price, 1990). In this study, sediment and fish samples were collected from Lake Catherine coves receiving effluent from streams that flow past the Garland County Industrial Park and Landfill (GCIP&L). Sediment samples are good indicators of water body effects – both past and present. Two pesticides and Aroclor 1260 were detected in sediments collected primarily from coves in the lower half of the reservoir. None of the constituents were at levels that posed an immediate threat. All concentrations of pesticides and polychlorobiphenyls (PCBs) found in edible portions of the fish were lower than FDA established limits indicating no problems.

Seasonal Variation

Spawning activities are one of the greater biological factors affecting seasonal trends in impingement mortality and entrainment rates. Spring months are characterized by lengthening days, warming waters, increase rainfall, and increased river flows, all of which are conducive to spawning and other reproductive activities. The peak time of egg recruitment is during early spring, while larval recruitment is primarily late spring and early summer. Spring and summer therefore appear to be the most important seasons at Lake Catherine as this is the time eggs and larval organisms are most abundant.

Upon reaching a size greater than ⅜-inch (approximately 10 mm), the organisms are subject to impingement. Time necessary to attain this size varies per species and individual increase in swimming ability. It is important
to note that while many juvenile fishes are present during summer months, highest impingement mortality occurs during winter months when threadfin and gizzard shad become sluggish and experience high natural mortality rates due to sensitivity to cold temperatures. Lethal temperature thresholds for threadfin and gizzard shads are 41 F and 34 F, respectively (Ross, 2001). Die-offs of shad populations, particularly the threadfin shad, occur during the winter, leading to high impingement rates at both Lake Catherine (as confirmed by plant personnel) and ANO. Most impingement mortality losses within any of the years studied occurred during the late fall and winter months. Approximately 94% of all fish impingement occurred during the 5-month period from November through March, and impingement rates extrapolated on an annual basis indicated that the majority (68.7%) of fish impinged at ANO were impinged from January to March. During spring, summer, and early fall months, little to no impingement occurred.

Diel Variation

Diel variations observed are most likely caused by species-specific daily patterns associated with rest and feeding periods. Organisms are much more active and mobile when feeding, and therefore have a higher chance of becoming impinged during these periods. In general most aquatic organisms are more active in the morning hours at daybreak, which is associated with increased feeding activities and motility. Additionally, gizzard and threadfin shad are known to exhibit vertical migration behavior within the water column, following planktonic movement towards the water’s surface to feed at night and remaining in the mid-portion of the water column during the day.
Appendix D

Species Identification Guides
Field Species Identification Guides

The following titles are reference used in the field for identification of collected species:


These guides were chosen based on their adherence to guidelines established by the International Commission of Zoological Nomenclature for identification of species. Common and scientific names of fish utilized have been established by the American Fisheries Society.