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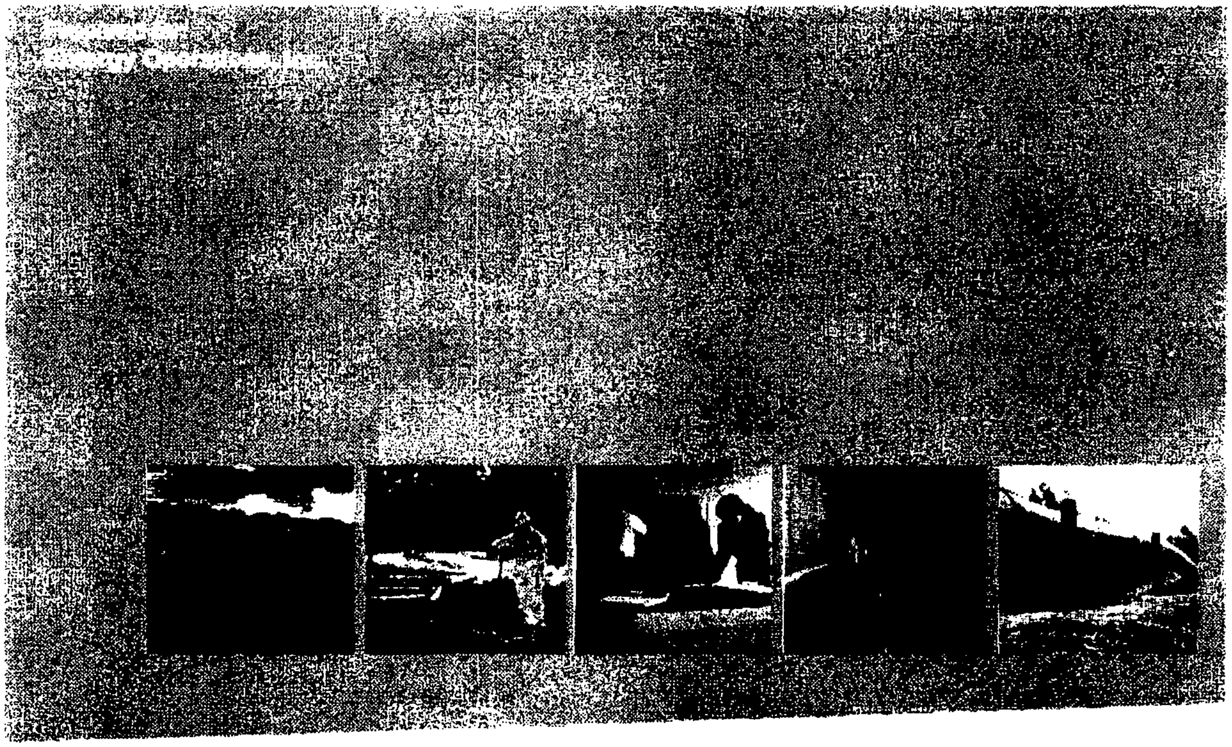

Impingement Mortality and Entrainment Characterization Study (IMECS)
Entergy – Waterford 3

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Prepared for:
Entergy Operations, Inc.

Impingement Mortality and Entrainment Characterization Study (IMECS) Entergy - Louisiana

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Executive Summary

The Impingement Mortality and Entrainment Characterization Study (IMECS) is the primary biological report as part of the Comprehensive Demonstration Study (CDS) required by Section 316(b) of the Clean Water Act (Rule). The IMECS requires three primary items: 1) taxonomic identification of all fish and shellfish with potential to be impinged or entrained; 2) a characterization of the life stages of these species; and 3) an estimate of the current impingement and/or entrainment rates at the plant. Because of the flow in the Mississippi River relative to the amount of intake water withdrawn by Waterford 3, the Waterford 3 plant is not subject to the entrainment performance goals of the Rule. This report focuses on the impingement data at Entergy's Waterford 3 Electric Generating Plant located Killona, Louisiana and demonstrates that the plant is in compliance with the Rule's performance goals.

More specifically, this IMECS will address the following goals:

- Document the results of a one-year impingement field monitoring study to meet the requirements of the IMECS and the Phase II Rule;
- Demonstrate simultaneously the extent to which existing technologies and/or operational measures provide significant reductions in impingement; and
- Document key biological factors that may influence the selection or effectiveness of certain control technologies or operational measures.

One year of impingement sampling was conducted at Entergy's Waterford 1&2 Electric Generating Station (Waterford 1&2) from September 2006 to August 2007. Due to Waterford 1&2's close proximal location to Waterford 3, data collected during this study was utilized to ascertain the current effects of impingement on fish populations in the vicinity of Waterford 3. Further detail describing the sampling methods and study results can be found in the Comparative Analysis of Impingement Mortality Studies document included in Appendix C of this IMECS.

Conformance with IM Performance Goals

On January 25, 2007, the Second Circuit Court of Appeals issued a decision on Riverkeeper, Inc. vs. Environmental Protection Agency (EPA) that remanded much of the substance of the Rule (e.g., the economic tests and the definition of Best Technology Available [BTA]). Since that decision, EPA has suspended the Rule (72 FR: 37107, July 9, 2007) pending further Court action and/or rule-making. Additionally, EPA recommended that best professional judgment (BPJ) is to be used to make 316(b) decisions.

LDEQ staff have indicated that submittal of the IMECS, structured according to guidelines established in the suspended rule, is pertinent to structuring a 316(b) decision based on BPJ. For this reason, Entergy has prepared this IMECS consistent with the requirements of the suspended rule.

Entergy is seeking compliance under Alternative 2 of the Rule, which states that "existing design and construction technologies, operational measures, and/or restoration measures" meet the performance standard in the Rule. In the case of Waterford 3, the current system's performance is based on the location of the intake offshore in the main channel of the river where fish population densities are much lower relative to the Calculation Baseline condition along the shore, primarily because of high current velocities and high suspended solids concentrations in the main channel. Entergy has demonstrated this performance based on a comprehensive evaluation of an extensive body of literature, and interviews with knowledgeable fisheries biologists. All evidence indicates that a significant difference in population density exists between the shoreline and main channel habitats. For these reasons, Entergy believes that it is reasonable to rely on the existing biological data to demonstrate the 316(b) compliance status of the cooling water intake structure (CWIS) at the Waterford 3 plant under Compliance Alternative 2.

In assessing the potential costs of the Phase II Rule, US EPA estimated capital costs and total annualized costs for Waterford 3 to be $27.4M and $7.3M, respectively based on the "addition of a passive fine-mesh screen system (cylindrical wedgewire) near shoreline with mesh width of 1.75 mm." These costs inappropriately cover compliance with both impingement mortality and entrainment performance standards. As Waterford 3 is not subject to the entrainment performance standards of the Rule, adjusted costs to address only the impingement performance standard, using procedures set out in the Rule, are $12.4M and $3.4M respectively for capital and annualized costs. This cost serves as the basis of the Cost-cost test that may be pursued under the Site-Specific Best Technology Available (BTA) compliance approach provided for by the Rule. An alternative approach to the Site-Specific BTA is the showing that the costs of compliance are significantly greater than the monetized benefits of compliance.

Entergy believes that the data available on the fishery of the Mississippi River provides important perspective on the historically observed rates of impingement at Entergy's power plants. Four known sources of information support evaluation of impingement at Entergy's plants and provide an understanding of the Mississippi River fisheries:

- Site-specific data collected by Entergy during the 1970's at several Entergy-owned Mississippi River plants. These data are very consistent with the goals of the Rule. The potential for ecosystem changes to render them unrepresentative of current conditions should be considered; however a preliminary assessment has determined that minimal ecosystem changes have occurred since the data were collected. QA/QC thresholds were properly and adequately established for evaluating the existing data and determining its applicability in today's review process. These include:
    - Duration of Samples Must be Defined;
    - Location of the Samples Must be Defined;
    - The Gear Used for Sample Collection Must Be Described and Appropriate;
    - Samples Must be Collected in a Way to Capture Seasonal and Diel Trends; and
    - All Organisms must be Enumerated and Identified to the Lowest Taxonomic Level.

- Data collected by other, nearby power stations on impingement rates. In some cases, these data sets are both more extensive and more current. The general patterns of impingement (e.g., relative frequency of species) are consistent with those observed from impingement studies conducted at Entergy plants in the 1970s. As importantly, the literature has been relatively consistent over the last few decades suggesting that the impingement data are still representative of current conditions. Additionally, impingement data is currently being collected at the Big Cajun plant located on the LMR. An analysis of this data should confirm the notion that the fishery has changed little since the historic data was collected.

- Current data collected at the Entergy-owned Waterford 1&2 plant. This data provides the most recent impingement characterization at an Entergy plant on the LMR near Waterford 3 conducted during. Comparing the current data with historical studies has yielded a comprehensive analysis of estimated current impingement rates at the Waterford 3 plant.

- The general literature on fisheries of the Mississippi River. This literature base can provide important background regarding the behaviors of important species such as the timing and distribution of their eggs and larvae, their likely survival upon impingement, their habitat preferences, etc. The literature has been supplemented with direct discussions with the leading researchers of the fisheries of the LMR.

These data sources have provided sufficient data to complete this IMECS consistent with the goals of the Rule. The following conclusions relative to impingement have been drawn from this study.

- The assemblage of impinged organisms changes with movement toward the Gulf of Mexico. At the Entergy Baxter Wilson Plant located on the Mississippi River in Mississippi, the impinged organisms are strictly freshwater species. At the Entergy Willow Glen Plant in Louisiana, located 230 miles closer to the Gulf, one estuarine species appears among the ten most commonly impinged species. Seventy miles further downstream, three estuarine species are noted among the most commonly impinged species. At the Entergy Michoud and Paterson plants, located in brackish, tidally-influenced channels adjacent to the Mississippi River, few organisms occur that favor freshwater.
- The fish species that dominated impingement at the Entergy plants are consistent with species documented in surveys performed at similar locations. These include threadfin and gizzard shad, freshwater drum, and river shrimp which account for the vast majority of impinged organisms at the freshwater stations and Atlantic croaker, bay anchovy and blue crab at the brackish water stations. Some species that are abundant in fisheries surveys performed in the LMR (notably catfish, carp) are under represented among impinged fish likely due to their strong swimming ability and/or their avoidance of the habitat near the CWIS.
- While water quality has improved since the 1970's surveys, other factors potentially affecting the fishery have been changed little. Most notably, management of the river for shipping and flood control has been consistent and invasive species have remained well established.
- The species makeup of the fishery of the LMR has been relatively constant over the last several decades. This suggests that improvements in water quality have not greatly changed the types of fish present in the river. This trend is evident in the literature and has been confirmed by direct communication with the relevant authorities.
- The rates of impingement observed at Entergy plants during the 1970's are reasonable estimates of ongoing rates. There has been little or no change in the operation of the CWIS and changes to the river and its fishery appear to be relatively minor. Anecdotal observations by the station operators confirm that the dominant impinged species are the same. Finally, the compliance strategies outlined at each of the stations are insensitive to modest changes in the rates of impingement or, when relevant, entrainment.
- The gizzard shad, threadfin shad, freshwater drum and bay anchovy typically do not tolerate handling well and Atlantic croaker tolerates handling only moderately well. The Electric Power Research Institute (EPRI, 2003) indicated that the median extended survival for freshwater drum and gizzard shad is 20% (8 studies) and 7% (43 studies), respectively. Extended survival rates were not available for threadfin shad but the median initial survival was only 15% (5 studies). The average extended survival rate for bay anchovy is 10% with an average initial survival of 30%. The median extended survival of Atlantic croaker, the most commonly impinged fish at the brackish water stations, was 36%. This suggests that any sort of fish handling and return system is not likely to achieve significant reductions in impingement survival, particularly for these three species that dominate impingement at the Entergy freshwater plants; and bay anchovy, which is common at the Entergy brackish water plants.
- Some other species, notably the crustaceans, survive handling much better. Data summarized by EPRI (2003) suggest that shrimp and crabs survive at rates of approximately 50% or better. Little data are available on river shrimp.
- The Mississippi River's main channel harbors much lower densities of fish than the river's edges and backwaters. Data suggest that population densities in the main channel are less than 5% of what is observed in channel borders (theoretical Calculation Baseline). This trend appears to be a consensus view among fisheries biologists. The relatively low densities are driven by the high velocities and reduced preferred habitat, as well as significant suspended sediment load. This suggests that the current location of the CWIS in the main channel does significantly reduce the rates of impingement relative to placement along the shore or in a backwater.

- Annual variation in the rates of impingement may be significant. A significant change in impingement rate may be associated with the return of juvenile fish to the main channel following inundation of the flood plain. The annual cycle of the fish populations' age structure also may contribute in that juveniles are more susceptible to impingement. While this change in impingement rate was observed in one data set, it is notably absent from two others.
- The typical impinged fish is relatively small. The average fish impinged is on the order of 20 grams in mass (not including carp which average about 1500 grams). This highlights the importance of juveniles in the impinged population, a group subject to high rates of natural mortality.
- State or federally listed species are not likely to be substantially impacted. Young paddlefish, a species of concern to several Louisiana agencies, were impinged in small numbers (historic and current studies). Three pallid sturgeon were impinged at two plants (historic studies). Impacts to other threatened and endangered (T&E) species are not anticipated either in the riverine or estuarine plants.
- Habitats associated with the Waterford 3 Plant are similar to other Entergy Plants on the LWR. Thirteen habitats are documented for the Lower Mississippi River. Habitats at Waterford 3 include: seasonally inundated flood plains; natural steep banks; revetment banking; and channel habitats. These habitats are similar in types and dynamics, and support similar fish communities as those found at Entergy's other plants located on the LWR.

1.0 Introduction

1.1 Statement of IMECS Goals

The Phase II Rule (the Rule) requires that the IMECS is submitted in accordance with §125.95(b)(3). Facilities that have reduced, through-screen intake velocity to less than or equal to 0.5 feet per second (ft/s) are not required to submit the impingement mortality (IM) component of this study ((§125.94(a)(ii)). Facilities whose capacity utilization rate is less than 15 percent, facilities that withdraw cooling water only from a lake or reservoir other than one of the Great Lakes, and those facilities that withdraw less than five percent of the mean annual flow of a freshwater river or stream are not required to submit the entrainment component of this study because no performance standards for entrainment apply. Waterford 3 is only subject to the IM portion of the rule, since less than 5% of the mean annual flow of the Mississippi River is withdrawn for cooling purposes.

1.1.1 Strategy Relative to the 2nd Circuit Court Decision and EPA Suspension of the Rule

On January 25, 2007, the Second Circuit Court of Appeals issued a decision on Riverkeeper, Inc. vs. Environmental Protection Agency (EPA) that remanded much of the substance of the Rule (e.g., the economic tests and the definition of Best Technology Available [BTA]). Since that decision, EPA has suspended the Rule (72 FR:37107, July 9, 2007) pending further Court action and/or rule-making. Additionally, EPA recommended that best professional judgment (BPJ) is to be used to make 316(b) decisions.

The LDEQ staff has indicated that submittal of the IMECS, structured according to guidelines established in the suspended rule, is pertinent to structuring a 316(b) decision based on BPJ. For this reason, Entergy has prepared this IMECS consistent with the requirements of the suspended rule.

1.1.2 Requirements from the Suspended Rule

The requirements for the IMECS are found in Part 125 of the Clean Water Act, Rules 40 CFR Section 125.95(b)(3)(i), (ii), and (iii). The Rule amends 40 CFR to include specific requirements for the IMECS as part of the Comprehensive Demonstration Study. The following is the excerpted portion of the rule (§125.95(b)(3)):

Impingement Mortality and/or Entrainment Characterization Study. You must submit to the Director an Impingement Mortality and/or Entrainment Characterization Study whose purpose is to provide information to support the development of a calculation baseline for evaluating impingement mortality and entrainment and to characterize current impingement mortality and entrainment. The Impingement Mortality and/or Entrainment Characterization Study must include the following, in sufficient detail to support development of the other elements of the Comprehensive Demonstration Study:

(i) "Taxonomic identifications of all life stages of fish, shellfish, and any species protected under Federal, State, or Tribal Law (including threatened or endangered species) that are in the vicinity of the cooling water intake structure(s) and are susceptible to impingement and entrainment;

(ii) A characterization of all life stages of fish, shellfish, and any species protected under Federal, State, or Tribal Law (including threatened or endangered species) identified pursuant to paragraph (b)(3)(i) of this section, including a description of the abundance and temporal and spatial characteristics in the vicinity of the cooling water intake structure(s), based on sufficient data to characterize annual, seasonal, and diel variations in impingement mortality and entrainment (e.g., related to climate and weather differences, spawning, feeding and water column migration). These may include historical data that are representative of the current operation of your facility and of biological conditions at the site;

(iii) Documentation of the current impingement mortality and entrainment of all life stages of fish, shellfish, and any species protected under Federal, State, or Tribal Law (including threatened or endangered species) identified pursuant to paragraph (b)(3)(i) of this section and an estimate of impingement mortality and entrainment to be used as the calculation baseline. The documentation may include historical data that are representative of the current operation of your facility and of biological conditions at the site. Impingement mortality and entrainment samples to support the calculations required in paragraphs (b)(4)(i)(C) and (b)(5)(iii) of this section must be collected during periods of representative operational flows for the cooling water intake structure and the flows associated with the samples must be documented."

1.1.3 Strategy to Address the Rule's Requirements

Entergy believes the three primary requirements of the rule have been met by using the historical dataset. Additionally, we believe that new data collection is not warranted as it will not significantly enhance the existing dataset. By combining the impingement data for five of Entergy's facilities with numerous studies conducted on the LMR an extensive characterization of the river's fisheries has been accomplished. Taxonomic identification and life stages of species with potential for impingement are well understood. Additionally, the impingement rates established in this IMECS were calculated using data collected year-round to account for potential diel and seasonal effects.

1.1.4 Support Issues Specific to Compliance Alternative

Entergy Louisiana, Inc. (Entergy) believes that the information presented in this document indicates that Waterford 3's CWIS is compliant with the Section 316(b) Phase II Rule (the Rule) performance goals for Impingement Mortality. Based on this conclusion, Entergy is seeking compliance under Alternative 2. Alternative 2 requires the submission of a Design and Construction Technology Plan (DCTP) that demonstrates that the current technologies and operational measures meet the applicable performance standards. This document fulfills the Rule's requirements for the DCTP and supports the conclusion that the current configuration and operation of Waterford 3 is compliant with the performance goals of the Rule.

In assessing the potential costs of the Phase II Rule, US EPA estimated capital costs and total annualized costs for Waterford 3 to be $27.4M and $7.3M, respectively based on the "addition of a passive fine-mesh screen system (cylindrical wedgewire) near shoreline with mesh width of 1.75 mm." These costs inappropriately cover compliance with both impingement mortality and entrainment performance standards. Adjusted costs to address only the impingement performance standards, using procedures set out in the rule, are $12.4M and $3.4M respectively for capitalized and annualized costs. Based on impingement data at other like facilities and anecdotal site-specific information, these costs far outweigh the potential benefits of compliance with the Phase II 316(b) rule. Entergy has determined that the installation of 1.75 mm wedgewire screens is not a feasible technology and would very likely be subject to clogging in the river environment.[1]

In addition, this document presents the conclusions of Entergy's assessment of measures to further reduce impingement mortality (IM) beyond the performance required by the Rule. This assessment determined that there are no additional measures available that would significantly reduce IM at the plant that are not significantly more costly than US EPA's estimated costs of compliance. Therefore, Entergy believes that the plant is also compliant under alternative 5 of the Rule (site specific best technology available). Although

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[1] Substantial technical difficulties are associated with installation of potential technologies. These difficulties are partially due to extreme flows found in the Mississippi River. Many of these technologies also rely on screening and will suffer from clogging associated with debris and biological growth. The CWIS at Waterford 3 already experiences clogging by debris; this has been identified as an area of concern by the Institute of Nuclear Power Operators (INPO). Any technology that had the potential to worsen this condition is likely to be unacceptable to INPO. Additional technologies and specific concerns regarding the said technologies are further reviewed in the accompanying DCTP and TIOP documents included in the CDS.

Entergy is seeking compliance under alternative 2, this document also contains the elements necessary to demonstrate compliance under alternative 5.

1.2 Review of Facility and CDS

The purpose of this Impingement Mortality and/or Entrainment Characterization Study (IMECS) as part of the Comprehensive Demonstration Study (CDS) is to evaluate fish and shellfish species that are impinged at the Entergy Louisiana Inc. (Entergy) Waterford 3 electric power generation plant. The plant is located at river mile 129.5, on the west descending bank of the Mississippi River in Killona, Louisiana. The plant consists of a nuclear reactor with a net plant output of 1,165 MW. The cooling water intake structure(s) (CWIS) are not subject to the entrainment performance standards since they withdraw only 0.48% of the source water which is less than the 5% threshold in the regulation.

The Waterford 3 CWIS is located offshore in the main channel of the Mississippi River. The intake canal is formed by a steel sheet piling driven into the river bottom and extends approximately 162 feet out from the face of the structure. The CWIS is also considered submerged since the end of the canal is equipped with a skimmer wall across its entrance which prevents floating debris and surface swimming organisms from entering the system. The offshore location of the CWIS minimizes the fish and shellfish that enter the plant's cooling water system. Most species can not tolerate the harsh conditions of the Mississippi River main channel due to the high velocities, increased debris, a constantly shifting river bed, lack of habitat/vegetation, and a reduction in productivity/food source. Much of this IMECS therefore, focuses on the difference in the aquatic community structure between the shoreline/channel border habitat (which we have defined as the theoretical Calculation Baseline - see Section 4.3) and the main channel.

In the Proposal for Information Collection (PIC) Entergy proposed to pursue Compliance Alternative 2, in part, and demonstrate to the Director that existing design and construction technologies, operational measures, and/or restoration measures meet the "performance standards" in the Rule. The biological assessment in this IMECS is necessary to evaluate the effectiveness of existing controls at the CWIS, and to assist in the evaluation of measures that could potentially be implemented at the plant to reduce IM. The technology assessment is included in the accompanying documents, including the Design, Control and Technology Plan (DCTP) and the Technology Installation and Operation Plan (TIOP).

The Rule allows the use of historical data and data from "like" facilities to meet the objectives of the rule if the data are representative of the current operation of the facility, and of the current biological conditions in the source waterbody. Although rates of impingement have not been evaluated at Waterford 3, impingement has been studied at the Waterford 1& 2 Plant located 2,100 feet upstream. In addition to impingement data collected at the Waterford 1 & 2 Plant, impingement data exist for three other open-cycle power generation plants located on the Lower Mississippi River (LMR) and owned by Entergy. These data are discussed in this report as the data are relevant to the selected compliance approach. The data set reviewed within this IMECS also includes data from numerous Mississippi River studies that focused on fisheries populations and community structure which has allowed us to adequately characterize the source waters.

Through an extensive literature review, Entergy has concluded:

1) There have been no significant changes in the lower Mississippi River fisheries since the historic data were collected; and
2) The historic impingement data are representative of current conditions on the LMR.

A defensible and favorable comparison to the Calculation Baseline is included in this document using the existing dataset which includes historic impingement data collected at Entergy plants and independent fisheries studies performed on the LMR. This dataset is further supported by current data collected at the Waterford 1& 2 plant.

1.3 Document Organization

The remainder of this document is organized as follows.

Section 2 is a presentation of the habitat types in the LMR and the locations of the intake structures for the Entergy Plants on the LMR relative to habitat types.

Section 3 is an overview of the available information reviewed for this report. A short synopsis of each study is provided in Appendix A.

Section 4 provides the major findings of the data assessment focusing on the Waterford 1 & 2 Plant data. This section is organized in accordance with the primary requirements of Rule 125.95(b) focusing on taxonomic identification, life-stage characterization, and current impingement mortality rates.

Section 5 is the list of references used for the IMECS analysis.

Tables, Figures, and Appendices referenced in this document are provided at the end of the document.

2.0 Habitat Review

A review of Mississippi River habitats was performed to document the locations of each plant intake structure in the Mississippi River. The review provides general accounts of the habitats associated with the plants CWIS as it relates to the fish communities in the vicinity of the CWIS and are susceptible to impingement and entrainment. Findings in this review indicate that each of the CWISs associated with Entergy's plants on the LMR are all located in the main channel of the river adjacent to natural steep bank habitats. These habitats are characterized by high current speeds, mobile bed materials, little structure, and do not support substantial fish populations.

The Mississippi River is the largest river system in North America stretching 3,705 km from Minnesota to the Gulf of Mexico in the state of Louisiana. The river is divided into three segments; Headwaters, the Upper Mississippi River, and the Lower Mississippi River. The Headwaters extend from Lake Itasca to St Anthony Falls in Minnesota. The Upper Mississippi River extends from Minnesota to Cairo, Illinois where it meets the Ohio River. The Lower Mississippi River extends approximately 954 river miles from Cairo to the Head-of-Passes in the Gulf of Mexico. The Mississippi River supports high levels of habitat diversity and biological productivity which are associated with the array of wetlands, open-water, and floodplain habitats. The presence of these habitats directly and indirectly influences the occurrence and abundance of fishes that may be found throughout the reaches of the river.

Although the Headwaters and Upper Mississippi River have significant influences on the entire watershed of the Mississippi River, the focus of the habitat review will be associated with the Lower Mississippi River where the Entergy Plants are located.

The Lower Mississippi River is comprised of a vast alluvial valley which directs the Mississippi River and its tributaries to the Gulf of Mexico. The Mississippi Alluvial Plain is a broad, gently sloping floodplain that lies between Cairo, Illinois and Baton Rouge, Louisiana. The Deltaic Plain is a complex system of distributaries and natural levees that extend out from the mainstem Mississippi River and are associated with forested swamps and coastal marshes. Two distinct components of the Lower Mississippi River have been described: 1) the river ecosystem above Baton Rouge is quite variable, the main channel is deep with numerous meanders, and floodplain habitats present. Approximately 55% of the aquatic habitat is deep, swift channels and 45% is slack waters. Dikes and revetments are common: 2) below Baton Rouge the river channel is deeper and narrower with fewer meanders. Approximately 85% of the aquatic habitat is swift, deep channel. Revetments are used extensively in this section of the river to help prevent erosion.

The ecosystem of the river is defined by the area within the river banks (mainstem) and the areas beyond the river banks (floodplain)(Baker et al, 1991). The mainstem includes the main river channel and slackwater areas. The floodplain includes natural levees, forested swamps, swales, ridges, and distributaries. The floodplain along the lower Mississippi River is mostly cutoff from the river due to an extensive levee system that was constructed to reduce flooding to the outlying areas. There is approximately 0.60 million hectares (ha) of natural floodplain remaining within the levees. Numerous habitats exist within the floodplain and the mainstem portion of the river. Terminologies to describe these habitat variations include main channel, steep clay bank, and slackwater areas. However, these descriptions did not take into consideration the biotic communities associated with them. In an effort to account for the different aquatic zones within the river several alterations to these classifications have been established. For the purpose of this section we propose to use the present classification presented by Baker et al. (1991) which accounts for 13 different habitats. Table 1 provides a description for each of the habitats.

The Mississippi River is a highly turbid waterbody with high current velocity. The productivity of the system is limited by light penetration and high suspended solids concentrations, as well as stability and habitability of the available substrate. As a result, the Mississippi River food chain is considered to be detrital-based because phytoplankton occurs in low densities and are not the major energy source. This is typical of larger southeastern and Midwestern Rivers (LL&P 1974).

The flow regime of the LMR is considered to be an important determinant of the fish community. Flow records have been maintained on the LMR since 1900. The flow in the river varies substantially throughout the year and water levels fluctuate at an average of 10 m (Schramm, 2004). For example, at the Waterford 3 facility, located between Baton Rouge and New Orleans, average seasonal flows are estimated to be 580,000, 650,000, 280,000 and 240,000 cfs for winter, spring, summer, and fall, respectively. Average velocity in this portion of the river is as high as 3.9 fps in April and as low as 1.1 fps (39-year avg.) in September (LP&L 1979). In the vicinity of the Baxter Wilson facility, flows as rapid as 8 knots (i.e., in excess of 10 fps) have been observed.

The above referenced Lower Mississippi River habitats are described to help illustrate the variety of riverine habitats associated with the location of the CWISs at Entergy's LMR plants. The CWISs are comprised of onshore and offshore components, which are described in the paragraphs below.

The offshore component of the CWIS is the first set of structures an organism will encounter. The offshore structure includes one or more, large diameter intake pipes (depending on number of units in operation) placed in deep, swift waters associated with the river channel. Each of the pipes is fitted either together or independently (depending on the plant design) with a crib structure (bar rack or intake crib) that houses the opening of the pipe to prevent large debris from entering the CWIS system. The intake pipes carry water to the onshore component of the CWIS. In the case of Waterford 3, the offshore intake structure is comprised of a cofferdam system constructed of steel sheet pile rather than pipes.

The onshore component of the CWIS is constructed of a concrete caisson that houses the intake screens (screenhouse), circulating water pumps, the trash/debris/fish return system, and other screen operating systems.

In this habitat review, the term CWIS is generally used to refer to the offshore intake structure, since it is this structure through which all water and any organisms would be withdrawn from the River. Emphasis has been placed on those habitats in the vicinity of the offshore components of the CWISs because these are the first set of structures an organism would encounter.

2.1 Plant Locations

Entergy currently owns and operates 10 electric generating facilities on the Lower Mississippi River (Figure 1). Eight of the facilities are located along the mainstem channel of the river and two are located on the Mississippi River Estuary. Habitats presented in Table 1 are only applicable to the eight facilities located on the mainstem channel: Waterford 3, Waterford 1 & 2, Ninemile, Little Gypsy, Willow Glen, Baxter Wilson, Gerald Andrus, and Ritchie. Although Baxter Wilson, Gerald Andrus and Richie are not considered in Louisiana, habitat associated with these plants is similar and is important in demonstrating "like facilities." A brief description of each plant and their relative locations is presented below.

The Waterford 3 Plant is located at river mile 129.5 Ahead of the Pass (AHP) along the west bank (right descending) of the Lower Mississippi River. The intake structure for the Waterford 3 Plant is located approximately 162 feet offshore in the main channel of the Mississippi River (Figure 2). The width of the Mississippi River at the Waterford 3 plant is approximately 1,850 feet. Transect data from a hydrographic survey conducted by the USACE in 1992 indicate that average maximum depth is approximately 129 feet[2].

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[2] Transect data for the Lower Mississippi River was taken from the U.S Army Corps of Engineers website: http://www.mvn.usace.army.mil/eng2/edsd/misshyd/misshyd.htm

Waterford 1& 2 is located adjacent to Waterford 3 at river mile 129.9 AHP, Little Gypsy is directly across the river at river mile 129.3 AHP, Ninemile is located downstream at river mile 104 AHP, Willow Glen is upstream at river mile 201 AHP, Baxter Wilson is upstream at river mile 438.7, Gerald Andrus is upstream at river mile 531.5, and Ritchie is upstream at river mile 659.4. Ninemile, Little Gypsy, Waterford 3, Waterford 1 & 2, and Willow Glen are all located within the LDEQ River Segment No. LA070301 and are considered fully supported for primary contact recreation, secondary contact recreation, fish and wildlife propagation and drinking water supply.

2.2 Habitat Summary

Using the habitat data described in Table 1, the following sections provide a qualitative assessment of habitat for each of the Entergy plants located on the mainstem Lower Mississippi River.

2.2.1 Waterford 3

The Entergy Waterford 3 Nuclear Power Plant is located on the right descending bank of the mainstem Mississippi River at river mile 129.5. The intake structure for the plant is located approximately 162 from the main bank along the main channel of the river. The offshore intake component of the CWIS is comprised of a cofferdam type structure constructed of sheet piles which has an unscreened submerged opening and is constrained at its top by a vertical skimmer wall. The cofferdam extends above water surface at an elevation of +15 ft (except during peak flood conditions) and provides a confined/isolated area which separates the cofferdam from the adjacent habitats. A general description of the habitat surrounding the offshore intake structure (based on conditions as determined during mean flow) includes: a small area of seasonally inundated floodplain on the upstream side, revetment banks on the downstream side, and the mainstem river channel. The floodplain area on the upstream side of the plant contains some areas of forested wetland communities. However, this area is adjacent to the Waterford 1 & 2 Plant and is routinely cleared for security reasons.

Aquatic habitats associated with the offshore intake component of the CWIS include: seasonally inundated floodplains along the river levee, revetments, natural steep banks, and channel (Figure 2). The seasonally inundated floodplain area is comprised of a narrow band of sediment along the river bank and levee which supports a few areas of forested wetlands. As previously mentioned this area is currently being managed for security reasons. The floodplain area does not contain any oxbow lakes, sloughs, borrow pits, or ponds. The revetment banks downstream of the CWIS are comprised of crushed concrete rocks and cover a significant portion of the bank above and below the water surface. There is very little vegetation associated with the revetment bank. The natural steep bank habitat is adjacent and parallel to shore (within 100 ft from the main bank) and is crossed by the cofferdam. The opening to the offshore intake structure is estimated to be at least 50 ft out from the natural steep bank and located within the main channel habitat. This habitat is characterized by of high river flows, relatively cool water temperatures, high turbidities, high suspended solids, and mobile bed materials.

Baker (1991) documented a total of 63 species of fish associated with natural steep banks and channels, 55 species for revetments, and 70 species within the seasonally inundated floodplains. The smaller seasonally inundated floodplain areas (flooded areas lacking ponded waters) associated with the Waterford 3 Plant typically supports fewer permanent species. Of the species associated with natural steep banks and revetments, a total of 25 are considered to be common to abundant. Similarly, only 13 are common to abundant in the channel habitats and 24 are common to abundant in the floodplain areas. Review of the data collected for the Waterford 3 Plant Ecological study conducted in 1975 to 1976 suggests that the common to abundant species documented during the study are not significantly different from those characterized by Baker (1991).

2.2.2 Waterford 1 & 2

As described in Section 2.1 of this report, the Entergy Waterford 1 & 2 Plant is located on the right descending bank of the main stem Mississippi River at river mile 129.9. Once through cooling water enters the plant through two separate offshore intake structures for Units 1 and 2. These intakes are located approximately 250 feet offshore at a depth of 41 feet (depth and distance from shore are based on a mean water elevation of 89.7 ft). The intake pipes are bell-mouthed, down-turned, and enclosed by a single rectangular bar rack enclosure composed of 3/8 inch bars with 7 inch center spacing. Cooling water from each offshore intake is carried through 8-ft diameter steel gravity-flow pipes to the screen well located approximately 250-ft inland. The screen well houses the four traveling screens, the screen wash system, and the circulating water pumps. Each screen is 10-ft wide by 50-ft high and is composed of 1/4 inch square mesh.

A general description of the habitat surrounding the offshore intake component (based on conditions as determined during mean flow) includes: large seasonally inundated floodplain area on the upstream side, a small floodplain area on the downstream side, and the mainstem river channel. Both floodplain areas support a significant amount of forested plant communities.

Aquatic habitats associated with the offshore intake component of the CWIS include: seasonally inundated floodplains along the river levee, lotic sandbars, natural steep banks, and channel (Figure 3). The seasonally inundated floodplains are heavily forested, except in those areas immediately adjacent to and in front of the onshore intake screenhouse. This area is mechanically cleared due to safety concerns associated with the fuel dock and the plant. The floodplain habitat upstream of the intake is comprised of forested wetland communities, oxbow lakes, and isolated sloughs which are flooded seasonally. The oxbow lakes and isolated sloughs are located approximately 0.5 miles upstream of the CWIS. The lotic sandbar and natural steep bank habitats are located approximately 200 ft from the main bank just inside of the intake crib which lies on the bottom of the river channel. Although the natural steep bank is present year round, the lotic sandbar habitat is only present seasonally due to the high river flow volumes which continuously moves sediment in and out of the area. The channel habitat is the dominant habitat for the offshore intake structure, consisting of high river flows, relatively cool water temperatures, high turbidities, and high suspended solids.

Baker (1991) documented a total of 63 species of fish associated with natural steep banks and channels, 49 species with sandbars, and 70 species within the seasonally inundated floodplains which include oxbow lakes, sloughs and borrow pits. The smaller seasonally inundated floodplain areas (flooded areas lacking ponds) are similar; however, they commonly support fewer permanent species. Of the 63 species associated with natural steep banks and channels, 25 species appear to be common to abundant in natural steep bank habitat and 13 are common to abundant in the channel habitat. Similarly, only 23 are common to abundant near sandbars and 24 are common to abundant in the floodplain areas. Review of the data collected from the Waterford 1 & 2 Plant intake study conducted in 1976 to 1977 suggests that the common to abundant species collected during the study are not significantly different from those identified by Baker (1991).

2.2.3 Willow Glen

The Entergy Willow Glen Plant is located on the east bank (right descending) of the mainstem Mississippi River at river mile 201 AHP. The offshore intake component of the CWIS for the plant is comprised of multiple pipes that are enclosed within a bar rack crib located approximately 540 ft (Unit 1 and 2) and 410 ft (Units 3, 4, & 5) from the main levee bank. Each of the offshore intake cribs is located off a secondary bank next to the main channel at a mean depth of 37 feet MSL. A general description of the habitat surrounding the offshore intake component (based on conditions as determined during mean flow) includes: seasonally inundated floodplain and the mainstem river channel.

Aquatic habitats associated with the offshore intake component of the CWIS include: seasonally inundated floodplains along the river levee, natural steep banks, and channel (Figure 4). The seasonally inundated floodplains are forested and no oxbow lakes, isolated sloughs or floodplain ponds are present. The natural steep bank habitats are located on the channel side of the offshore intake cribs approximately 500 ft from the main levee. The channel habitat and natural steep bank habitats are the dominant habitats for the offshore intake structure. These habitats are characterized by high river flows, relatively cool water temperatures, high turbidities, high suspended solids, and mobile bed materials.

Baker (1991) documented a total of 63 species of fish associated with natural steep banks and channels and 70 species within the seasonally inundated floodplains. Of the 63 species associated with natural steep banks and channels 25 species appear to be common to abundant near natural steep banks and only 13 are common to abundant in the mainstem channel. Similarly, of the 70 species documented in the seasonally inundated floodplains only 24 species are common to abundant. Site specific biological data collected at the Baxter Wilson Plant from 19 to 19 suggests that the common to abundant species documented during the study period are not significantly different from those characterized by Baker (1991).

2.2.4 Baxter Wilson

The Entergy Baxter Wilson Plant is located on the east bank (left descending) of the mainstem Mississippi River at river mile 439 AHP. Two separate units (Unit 1 and Unit 2) comprise the Baxter Wilson CWISs. While the Unit 2 CWIS is set up in a typical fashion (constructed with both onshore and offshore components, as introduced in Section 2.0), the Unit 1 CWIS is set up entirely offshore. Thus, for Unit 1, those components of the CWIS typically located onshore, (screenhouse, intake pumps, etc.), are fully housed offshore.

The Unit 1 CWIS is located 300 feet from the river bank. Water is pumped into the offshore intake component through two, six-foot diameter pipes. The CWIS is comprised of a 51-foot outer diameter caisson vertically divided into two cells, each with two intake ports leading to a traveling screen (screenhouse) and a pump. The intake ports are approximately ten-feet by ten-feet and covered by bar racks. One set of intake ports are located from 35 to 45 feet MSL while the other set is located from 53 to 63 feet MSL.

Cooling waters for the Unit 2 CWIS are drawn into the plant via an offshore intake component comprised of two 300-foot long, 9-foot diameter intake pipes that extend into the Mississippi River. The onshore intake component is similar in construction to the offshore concrete caisson of Unit 1, as it is also vertically divided into two cells with intake ports leading to the traveling screens and onshore intake pumps. The general description of the habitat surrounding the offshore intake structure (based on conditions as determined during mean flow) consists predominately of seasonally inundated floodplain habitats and the mainstem river channel. The flood plain habitat contains emergent, scrub shrub, and forested communities.

Aquatic habitats associated with the offshore intake component of the CWIS include: seasonally inundated floodplains, natural steep banks, and channel (Figure 5). The seasonally inundated floodplain habitat is present both upstream and downstream of the intake structure. The natural steep bank habitats are present between the existing shoreline and the offshore intake structures. The offshore intake structure for Unit 2 lies on the bottom of the main channel and the intake structure is positioned in the mid-water strata of the main channel. The channel habitat is the dominant habitat for both intake structures. This habitat is characterized by high river flows, relatively cool water temperatures, high turbidities, high suspended solids, and mobile bed materials.

Baker (1991) documented a total of 63 species of fish associated with natural steep banks and channels and 70 species within the seasonally inundated floodplains. Of the 63 species associated with natural steep banks and channels 25 species appear to be common to abundant near natural steep banks and only 13 are common to abundant in the mainstem channel. Similarly, of the 70 species documented in the seasonally inundated floodplains only 24 species are common to abundant. Site specific biological data collected at the Baxter Wilson Plant from 19 to 19 suggests that the common to abundant species documented during the study period are not significantly different from those characterized by Baker (1991).

2.2.5 Ninemile

The Entergy Ninemile Plant is located on the west bank (right descending) of the mainstem Mississippi River at river mile 104 AHP. The offshore intake component of the CWIS for the plant is comprised of four 96" diameter intake pipes which are enclosed by rectangular bar rack structures (intake cribs) submerged approximately 400 feet offshore in the mainstem channel at a mean depth of 30 ft MSL. The general description of the habitat surrounding the offshore intake component (based on conditions as determined during mean flow) consists predominately of seasonally inundated floodplain habitats and the mainstem river channel. The flood plain habitat contains significant forested communities and one floodplain pond.

Aquatic habitats associated with the offshore intake component of the CWIS include: seasonally inundated floodplains, natural steep banks, and channel (Figure 6). The seasonally inundated floodplain extends out approximately 300 ft from the onshore intake structure to within 100 ft of the offshore intake structure (intake crib). The habitat is heavily forested and a small floodplain pond is present approximately 400 ft upstream of the intake structure. The natural steep bank habitats are present along the existing shoreline just inside of the intake cribs which lie on the bottom of the river channel. The channel habitat is the dominant habitat for the intake structure. This habitat is characterized by high river flows, relatively cool water temperatures, high turbidities, high suspended solids, and mobile bed materials. Sedimentation near the intake structure is common and requires frequent dredging to prevent blockage of the intake.

Baker (1991) documented a total of 63 species of fish associated with natural steep banks and channels and 70 species within the seasonally inundated floodplains which include oxbow lakes, sloughs and barrow pits. Of the 63 species associated with natural steep banks and channels 25 species appear to be common to abundant near natural steep banks and only 13 are common to abundant in the mainstem channel. Similarly, of the 70 species documented in the seasonally inundated floodplains only 24 species are common to abundant. No site specific biological data is available from the Ninemile Plant; however, based on the types of habitats identified at Ninemile and those identified at the other plants on the Lower Mississippi River it can be assumed that similar species will be present at the Ninemile Plant.

2.2.6 Little Gypsy

The Entergy Little Gypsy Plant is located on the east bank (left descending bank) of the mainstem Mississippi River at river mile 129.3 AHP. The offshore intake component of the CWIS for the plant is comprised of six large pipes (>116" diameter pipes) which are enclosed within several intake cribs located approximately 540 ft offshore in the mainstem channel at a mean depth of 24 feet MSL. A general description of the habitat surrounding the offshore intake component (based on conditions determined during mean flow) includes: seasonally inundated floodplain habitats and the mainstem river channel. The floodplain area supports forested plant communities.

Aquatic habitats associated with the offshore intake component of the CWIS include: seasonally inundated floodplains, natural steep banks, and channel (Figure 7). The seasonally inundated floodplains are forested and no floodplain ponds, sloughs, and oxbows are present. The natural steep bank habitats are located approximately 50 ft from the main bank (mean depth) just inside of the intake cribs which lie on the bottom of the river channel. The channel habitat is the dominant habitat for the offshore intake structure. This habitat is characterized by high river flows, relatively cool water temperatures, high turbidities, high suspended solids, and mobile bed materials.

Baker (1991) documented a total of 63 species of fish associated with natural steep banks and channels and 70 species within the seasonally inundated floodplains. Of the 63 species associated with natural steep banks and channels 25 species appear to be common to abundant near natural steep banks and only 13 are common to abundant in the mainstem channel. Similarly, of the 70 species documented in the seasonally inundated floodplains only 24 species are common to abundant. No site specific biological data is available for the Little Gypsy Plant; however, based on the types of habitats identified at Little Gypsy and those identified at the other plants on the Lower Mississippi River it can be assumed that similar species will be present at the Little Gypsy Plant.

2.2.7 Gerald Andrus

The Entergy Gerald Andrus Plant is located at the confluence of the Mississippi River and Lake Ferguson along the east bank (left descending bank) at river mile 531. The CWIS for the plant is located within a barge channel at the southern end of Lake Ferguson. This channel is dredged once every four years to maintain clearance for barge traffic and functions as the cooling water intake canal for the plant. The canal is about 1,700 feet long and 450 feet wide with an invert elevation of 67 feet mean sea level (MSL). The canal has 3:1 side slopes and is approximately 20 feet deep. Two submerged offshore intake components are located about 250 feet from the screen housing in the intake canal. The water level around the submerged offshore intake components is approximately 15 feet during low water levels. Each offshore intake structure is surrounded by a crib house made of metal bars similar to a trash rack to prevent large debris from entering the structures. A general description of the habitat surrounding the offshore intake structure (based on conditions during mean flow) includes: floodplain habitats, natural steep banks, and channel habitats. The floodplain area supports emergent and forested plant communities.

Aquatic habitats associated with the offshore components of the CWIS include: natural steep banks and oxbow lakes, and channel habitat (Figure 8). The area is surrounded by significant forested community; however, these habitats are not seasonally inundated. The natural steep bank habitats are associated with the barge channel where the intake structure is located. Lake Ferguson is considered an oxbow lake. Habitats associated with oxbow lakes usually include deep holes, extensive forest communities along the shore, and are less subject to seasonal flooding. Lake Ferguson is not completely isolated from the mainstem river and is subject to seasonal river flows. It supports extensive industrial activities and has numerous barge docking facilities, many of which are routinely dredged. Channel habitat is present in the area of the intake structure; however, this habitat is commands different characteristics from those identified with the mainstem channel in the river including: shallower water, less current and depositional substrate.

Baker (1991) documented a total of 63 species of fish associated with natural steep banks and 70 species within the seasonally inundated floodplains which include: oxbow lakes, borrow pits, and sloughs. Of the 63 species associated with natural steep banks 25 species appear to be common to abundant and for the 70 species associated with the floodplain habitats 24 are common to abundant. No site specific biological data is available for the Gerald Andrus Plant; however, based on the types of habitats associated with the plant and those identified at the other plants on the Lower Mississippi River it can be assumed that similar species will be present at the Gerald Andrus Plant.

2.2.8 Ritchie

The Entergy Ritchie Plant is located on the west bank (right descending bank) of the mainstem Mississippi River at river mile 659. The offshore intake component of the CWIS for the plant is located approximately 40 feet deep and 138 feet from the screen housing and circulator pumps (components of the onshore intake structure) along the levee in the Mississippi River. Breasting dolphins are located north and south of the pipe inlets to prevent damage from river traffic. Both offshore intake pipes share a common crib house structure constructed of alternating metal plates and metal bars to prevent large debris from entering the structures. The top of the crib structure is fabricated out of solid panels, and is considered a velocity cap due to similar function. Two 108" diameter steel gravity-flow pipes supply water to the traveling screen and pump chambers of the onshore intake structure; one pipe for each unit. A general description of the habitat surrounding the offshore intake components (based on conditions during mean flow) includes: seasonally inundated floodplain habitats, revetment banks, and the mainstem river channel. The floodplain area supports forested plant communities.

Aquatic habitats associated with the offshore components of the CWIS include: seasonally inundated floodplains, revetment banks, natural steep banks, and channel (Figure 9). The seasonally inundated floodplains are forested and no floodplain ponds, sloughs, and oxbows are present. The revetment banks are comprised of large concrete mats and rocks and extend above and below the surface. The natural steep bank habitats are located approximately 50 ft from the main bank (mean depth) before the intake crib, which lies on the bottom of the river channel. The channel habitat is the dominant habitat for the intake structure. This habitat consists of high river flows, relatively cool water temperatures, high turbidities, high suspended solids, and mobile bed materials.

Baker (1991) documented a total of 63 species of fish associated with natural steep banks and channels, 55 species with revetment banks, and 70 species within the seasonally inundated floodplains. Of the 63 species associated with natural steep banks and channels, 25 species appear to be common to abundant near natural steep banks and revetments, and only 13 are common to abundant in the mainstem channel. Similarly, of the 70 species documented in the seasonally inundated floodplains, only 24 species are common to abundant. No site specific biological data is available for the Ritchie Plant; however, based on the types of habitats identified at Ritchie and those identified at the other plants on the Lower Mississippi River, it can be assumed that similar species will be present at the Ritchie Plant.

3.0 Review of Data

An extensive literature review was conducted to evaluate the potential impacts of existing intake structures at the Waterford 3 plant. This review included data collected at 5 of Entergy's plants located on the Lower Mississippi River (LMR), and studies conducted by state and federal agencies, academia and other biological groups. Relevant impingement studies conducted at the Entergy stations include: Waterford 1 & 2, the A.B. Paterson and Michoud plants located downstream, and the Baxter Wilson and Willow Glen plants located upstream. Additionally, fisheries data collected for the Waterford 3 Plant (2,100 feet downstream of Waterford 1 & 2) was also reviewed. These studies, as well as other relevant literature used to support the IMECS, are discussed below. In addition to the literature review, experts from several universities, regulatory agencies, and museums were contacted for additional information as well as their professional opinion on the status and trends of the fisheries. The combined data set and the comments from the scientific community to support the requirements of the Phase II Rule are discussed within this document. A short synopsis of each study discussed is presented in Appendices A and C.

Although many relevant data sources were obtained during the literature review, it should be noted that several sources contacted had limited biological data for the Mississippi River. These sources cited the lack of appropriate sampling equipment and under-sized boats as part of the reason for the lack of sampling effort on the river. High water velocities, heavy boat and barge traffic and the presence of obstacles and debris in the water column and on the bottom are common on the Mississippi River and create safety concerns for routine sampling efforts. This was confirmed by fisheries researchers in both academia and federal resource agencies. The literature review is organized based on the major components of Entergy's case that Waterford 3 is compliant with Alternative 2 of the 316(b) Phase II rule.

3.1 Literature Review

3.1.1 The existing LMR data are sufficient to characterize the aquatic community, impingement mortality (IM) rates and seasonality of impingement.

Studies conducted at Entergy facilities (Figure 1) demonstrate that impingement rates are low at facilities in the LMR, the species impinged are common and that impingement varies seasonally with fish abundance. A number of other studies evaluating impingement or the aquatic community of the LMR are discussed following the discussion of studies at Entergy facilities. A synopsis of recent interviews with plant personnel is presented in Section 3.1.1.3.

3.1.1.1 Studies Conducted at Entergy's Plants

Impingement studies and/or 316(b) Demonstration studies have been conducted at several Entergy facilities on the Lower Mississippi River (Figure 1). These include; Waterford 1 & 2 (ENSR 2007, Espey, Huston and Associates 1977a), Willow Glen (Espey, Huston and Associates 1977b), Baxter Wilson (Mississippi Power and Light (1974), A.B. Paterson (Hollander 1981) and Michoud (Hollander 1981). Each of these studies evaluated impingement for one year and assessed both seasonal and diel variation in impingement. Several of the studies (Mississippi Power and Light 1984, Hollander 1981, Louisiana Power and Light 1979, CK Associates and URS 2002) also provided information on the aquatic community in the vicinity of the plants. A very brief summary of each document's scope and findings is presented below. A more extensive summary of these reports is provided in Appendices A and C.

Comparative Analysis of Impingement Mortality Studies, Waterford 3. 2007. ENSR Prepared for Entergy Louisiana.

Report compares data collected in historic impingement studies conducted at Waterford 1&2 and Waterford 3 with current impingement study data collected at Waterford 1&2. Historically, impingement rate was documented to be 4.22 organisms per 10,000 m^3 of water pumped through the plant for both units combined. The current rate was calculated to be 16.16 organisms per 10,000m^3. This report is presented in Appendix C.

Annual Data Report. Waterford Power Plant Units 1 and 2. Screen Impingement Studies February 1976 Through January 1977. Espey, Huston & Associates, Inc. Prepared for Louisiana Power and Light Company.

Study results show higher impingement rates in winter and spring. The facility is located at Mississippi River mile marker 129.9 AHP. Species composition was dominated by river shrimp (49.6% of the total catch), blue catfish (20.3%), threadfin shad (10.5%), bay anchovy (6.0%), freshwater drum (4.5%), and gizzard shad (2.9%). Total annual impingement rates were estimated to be 336,454 organisms, which equates to 4.22 individuals per 10,000 m^3 of water pumped through the plant for both units combined. Daily impinged biomass ranged from 3.6 kg to 33.6 kg.

Willow Glen Power Station 316(a) and 316(b) Demonstrations Federal Water Pollution Control Act Amendments of 1972 (PL 92-500). 1977. Espey, Huston & Associates, Inc. Prepared for Gulf States Utilities Company.

Impingement and entrainment data were collected from January 1975 through January 1976 at three of the five units (Units 1 & 2 and Unit 4) at Willow Glen Power Plant. Major species were freshwater drum, gizzard shad, threadfin shad, blue catfish, white and black crappie, river shrimp, and crayfish. Impingement rates were relatively low, 1.47 (Units 1 & 2) and 0.13 (Unit 4) organisms per 10,000 m^3. Approximately 126,000 organisms per year were estimated to be impinged with all five units in operation. One pallid sturgeon (T & E species) was impinged over the course of the study.

Baxter Wilson Impingement Study - Mississippi Power & Light (MP&L). 1974. Grand Gulf Nuclear Plant Units 1 & 2. Environmental Report. (Baxter Wilson Impingement Study included within this report).

Impingement data were collected from March 1973 through March 1974. Major species were gizzard shad, threadfin shad, freshwater drum, crappie, and channel catfish. The shad species and freshwater drum represented over 90% of the total catch. Impingement was relatively low and calculated to be 160,730 individual organisms per year. No threatened or endangered species were documented on the revolving screens; however, paddlefish (species of concern) were impinged. Common species were consistent with the literature for the Lower Mississippi River.

Grand Gulf Nuclear Plants 1 & 2 Impingement Study - Mississippi Power & Light (MP&L). 1974. Grand Gulf Nuclear Plant Units 1 & 2. Environmental Report.

Information on Mississippi River flow, velocities, stage with surveys of fish populations in different habitats (e.g., backwaters, tributary and river bank) were presented. Difficulty in sampling the river's main flow was also noted. Gizzard shad contributed 37.4% of the total catch, followed by freshwater drum (10.3%), blue catfish (8.3%), flathead catfish (4.9%), and river carpsucker (4.8%).

Impingement Impact of A.B. Paterson & Michoud Steam Electric Generation Plants of the Biota of the Inner Harbor-Navigation Canal and the Mississippi River-Gulf Outlet, Orleans Parish, Louisiana. Submitted for New Orleans Public Service, Inc. Hollander, E.E. 1981.

Impingement data were collected and the fisheries in adjacent waters were surveyed. Most commonly collected species were estuarine in nature; Atlantic croaker, white shrimp, brown shrimp, bay anchovy, sand trout, blue crab, hardhead catfish, and Gulf menhaden. Annual impingement estimated to be 226,489 organisms at the Paterson Plant and 1,676,726 organisms at the Michoud Plant.

Louisiana Power & Light, April, 1979. Demonstration Under Section 316(b) of the Clean Water Act. Waterford Steam Electric Plant Unit No. 3.

Fisheries data collected in the Mississippi River between Baton Rouge and New Orleans. Common species included gizzard shad, threadfin shad, blue catfish, freshwater drum, striped mullet, skipjack herring, channel catfish, river carpsucker, blue gill, and common carp. The most common species reported were consistent with literature for the Lower Mississippi River.

Application Addendum for a Louisiana Pollutant Discharge Elimination System Permit and Comprehensive Demonstration Study under the 316 (b) Rule for Track II. 2002, for Bonnet Carre Power, LLC LaPlace, Louisiana (Sempra) by CK Associates and URS.

Habitat analysis was conducted at Mississippi River mile marker 132.2 AHP using the 13 distinct LMR habitats developed by Baker et al (1991). Six habitats were identified in the study area and each was reviewed specifically to determine the number of fish species (133 potential species found in the LMR), larval fish and eggs associated with each habitat type. Each of the six habitat types were determined to have a significantly reduced number of aquatic organisms compared to the total potentially found on the river. Of the six habitats reviewed, the researchers concluded that a CWIS located offshore and at middle depth would minimize the number of organisms potentially impinged and/or entrained.

Entergy, 2000. Industry Short Technical Questionnaire: Phase II Cooling Water Intake Structures. A-UT-0156. Waterford 3 Plant.

This provides basic operation information. Actual intake flow rates by cooling water intake structure by month are presented along with a water flow diagram.

3.1.1.2 Other Studies

In addition to the studies conducted at Entergy Plants in the LMR, a number of additional studies and personal communications provide understanding of the aquatic community potentially subject to impingement, impingement rates and the seasonality of impingement in the LMR. Figure 10 illustrates the locations on the Mississippi River where each of the studies were conducted. These studies are summarized in Appendix A. Baker et al (1991) presents a detailed delineation of the habitats of the LMR along with the communities of fish associated with the habitat types. Hartfield and Slack (unpublished 2001-2004), provide summaries of a series of trawls conducted in the LMR in 2001, 2003 and 2004. While these surveys apparently targeted sturgeon, notes on by-catch indicate that the by-catch consisted of shrimp, aquatic insects and species of fish common to the LMR. Data collected upstream of the Willow Glen Plant are summarized in the River Bend Environmental Report (citation). This study included sampling for ichthyoplankton as well as juvenile and adult fish from 1972-1977 using a variety of gear. Inter-annual variability in catches is noted. Schramm (2004) provides a compilation of fisheries data for the Mississippi River from four sources. This study includes biomass estimates by habitat type. A study by the U.S. Army Corps of Engineers (USACE) (1984) evaluated fish in levee borrow pits, while another study (USACE 1987) presented baseline data on the fish and benthic communities of 8 LMR floodplain lakes and a discussion of the movement of fish between different habitats. Schramm (2005), Killgore (2005) and Kelso and Rutherford (2006) all supported Entergy's conclusion that the fisheries of the LMR had likely changed little since the 1970's. Kelso and Rutherford further stated that there is a lack of information on the fisheries and indicated that more data would be needed to infer otherwise.

3.1.1.3 Anecdotal Impingement Observations

Plant operations personnel were interviewed in November 2004 at each of Entergy's plants to determine the current levels of organisms impinged, dominant species impinged, seasonal and diel variations of organism impinged. Information provided for each plant indicates that shad (threadfin and gizzard), freshwater drum, catfish (blue catfish and channel catfish), river shrimp, and crawfish are the most abundant species observed on the screens for the plants in the freshwater regions of the river (including the plant farthest downriver in the non-tidal portion of the river, Ninemile). Species most abundant on the screens in the tidally-influenced segments (i.e., Paterson and Michoud) consisted of croaker, shad (gizzard and menhaden), anchovy, white shrimp, brown shrimp and blue crab. Observed abundances (screens are operated on average twice per day for 10 to 15 minutes each shift) of organisms on the screens were reported to be low. Plant personnel indicate that there appears to be an increase in organisms on the screens as the river begins receding after floods. This is similar to the behavior documented at Baxter Wilson.

Seasonal variations were identified as being relatively low. Shad and catfish species appear to have the greatest fluctuations in abundance with the greatest peaks occurring during the summer and fall months. Diel variations could not be determined due to the operation of the screens at the same time each day (once in the morning and once in the evening).

No threatened and endangered species have been observed by plant operations personnel on the screens.

3.1.2 Life Stage and Taxonomy Data for all Species in the LMR

A significant body of literature related to the fisheries and aquatic life of the LMR was reviewed. This included both life history and taxonomic information. A detailed discussion of the literature is presented in Section 3.3 as well as a summary of personal communications with fisheries experts from academia and government agencies with fisheries responsibilities. The literature review contains information on common as well as rare, threatened and endangered species of the LMR. Detailed species accounts of rare, threatened and endangered species can be found in Appendix B.

3.1.3 Fish and Other Aquatic Species Distribution

As discussed in Section 2.0, the Waterford 3 cooling water intake structure (CWIS) is located in the mid channel habitat. In large rivers, data regarding the aquatic community of the mid-channel habitat are not as common as data from other habitats due to the difficulties in sampling this environment (Baker et al 1991, Koel 2004, Madejeczyk et al 1998, Hartfield 2001-2004) and the lower abundance and diversity of aquatic organisms in the mid channel habitat (Killgore 2005, Kelso and Rutherford 2005, Kelso and Rutherford 2006, CK Associates and URS 2002, Baker et al 1991, Barko 2004, CDM and Limnetics 1976, Eggleton and Schramm 2004, Dettmers et al 2001, Junk and Wantzen 2004, Koel 2004, River Bend Environmental Report 1981, Schramm 2004, Killgore 2005, Kelso and Rutherford 2005, Gutreuter 2005, Schramm 2005, Schramm 2006, Hartfield 2006). Detailed summaries of the above references are presented in Appendix A. A summary of the personal communications are presented in Section 3.3.2.2

3.1.4 Abundance of Species Most Commonly Impinged

Although rates of impingement have not been evaluated at the Waterford 3 Plant, impingement data on the LMR are available for Waterford 1&2 (ENSR 2007, Espey, Huston and Associates 1977a), located 2,100 feet upstream. Impingement data is also available for Willow Glen (Espy Huston and Associates 1977b), Baxter Wilson (Mississippi Power and Light 1974), and A.B. Paterson and Michoud (Hollander 1981). The distribution of these plants along the LMR is presented in Figure 1. Each of these studies details the relative abundance of fish impinged including both common and rare species. Fish impingement is discussed in detail in Section 4.1.2. Results from the LMR are similar to results observed at other plants where common species of fish were the most commonly impinged (LeJeone and Monzingo 2000, McInery and Held 1995, McLaren 2000, Michaud 2000, Richkus and Mclean 2000, Ringger 2000). Detailed summaries of these impingement reports can be found in Appendix A.

3.1.5 Impingement rates at Waterford 3 are estimated to be low and IM will have no long lasting consequences to the populations of impinged fish.

Rates of impingement for Entergy plants are discussed in detail in Section 4.1.3. Data to support the discussion can be found for Waterford 1 & 2 (ENSR 2007, Espey, Huston and Associates 1977a), Willow Glen (Espy Huston and Associates 1977b), Baxter Wilson (Mississippi Power and Light 1974), and A.B. Paterson and Michoud (Hollander 1981). At River Bend upstream of Willow Glen, (excerpts from River Bend Report, 1981) suggests that the magnitude of commercial fisheries catches on the LMR would far exceed impingement losses. Commercial and recreational catches on the LMR are discussed in Section 3.3.1.1. A conclusion that there was no long term change in the fisheries community related to impingement in other systems was reached by Barnthouse 2000, LeJeone and Monzingo 2000, Lewis and Seegert 2000, Richkus and Mclean 2000, Ringger 2000. Killgore (2005) suggested that gizzard shad (a commonly impinged species) were probably the most numerically and biomass dominant fish and that nothing could be done to reduce their impinged numbers.

3.2 General Trends Relevant to Plant, Compliance Strategy

Entergy is pursuing a weight of evidence approach by choosing Compliance Alternatives 2 and 5 simultaneously for the Waterford 3 CWIS. The discussion below presents the case under Alternative 2. Detailed summaries of the reports that support this position can be found in Appendix A. If the permitting agencies do not concur with our findings that the facility is in compliance with the rule using existing control measures, the Cost-Cost Test will be applied. This test will be applied under the provisions for Site-specific Best Technology Available (BTA), according to the procedures defined in the Rule in order to evaluate whether actual costs of compliance are "significantly greater" than the US EPA-estimated costs developed as part of the rule making. The location of the plant, its size, and the nature of the Mississippi River system all affect the feasibility, performance, and cost of potential technologies.

3.2.1 Overall Trends

Several trends are apparent upon reviewing the available impingement data for the LMR. The following summarizes the most important trends and fisheries conclusions.

- When analyzed in comparison with data presented in the most current impingement mortality study conducted by Entergy, the historical studies at five of Entergy's plants represent sound efforts to estimate the annual rates of impingement including consideration of diel and seasonal variation.
- Studies were conducted at different time periods and at different locations on the LMR. Review of the methodologies and quality of data presented indicates that no significant changes occurred between studies on locations. Also, no changes in operation of the plants were reported that would affect data quality. Per the goals of the Rule, samples were collected over a 24 hr period and on a seasonal basis over an entire year.
- There is a strong consensus in the literature and among fisheries experts (Section 3.3.2.1) that the fishery of the LMR has not undergone significant changes since the collection of the impingement data. The dominant species, as well as their population densities, are unlikely to have changed significantly since the 1970s. This is consistent with informal observations by the plants' operators and substantiated by the most current impingement study conducted (2006-2007).

- Entergy believes that available data support the rule's requirements of the IMECS. The available data provide a sound basis for characterizing the three general aspects of impingement mortality and entrainment required as part of the IMECS by 40 CFR 125.95(b)(3): (1) taxonomic identification of fish and shellfish within the zone of influence of the CWIS; (2) assessment of all life stages including temporal variation; and (3) estimation of current rates.
- The species impinged at the five plants change with movement toward the Gulf of Mexico in a logical fashion. As the salinity increases and with closer proximity to the Gulf, estuarine/marine species increase in frequency.
- The wide distribution of plants (RM 93 – RM 433) with impingement data allows for inference of likely rates of impingement at nearby stations that have not rigorously quantified impingement.
- The most commonly impinged fish are also common in the source water. Despite this, several important fish in the source water are under-represented among the impinged organisms (e.g. notably catfish and carp) likely due to their strong swimming ability and/or their avoidance of the habitat near the cooling water intake structure (CWIS).
- The ten most commonly impinged fish constitute 94.4% of the total numbers of fish. Thus, the species of concern at each plant are clear.
- At the plants located on freshwater, the most commonly impinged species are generally forage fish or shellfish with little commercial or recreational value.
- Three young pallid sturgeon were impinged at only two stations (historic studies) and several juvenile paddlefish were impinged at the plants (historic and current studies). Three post-larval shovelnose sturgeon were impinged during the most recent sampling study. While the populations of these fish have generally declined in the LMR, there is a potential for their impingement. These species may benefit from restoration measures.
- Fish and shellfish impinged at the two estuarine plants are of higher commercial and recreational value than the majority of those impinged freshwater plants. Despite this, the annual losses of these organisms are very modest when compared to annual harvest data collected by state wildlife agencies.
- The total numbers and lengths of impinged fish are available in each of the studies with the vast majority of impinged finfish being juveniles.
- Temporal changes in impingement rates are modest. Little change is apparent during the day (diel) and generally rates of impingement are stable throughout the year. The exceptions to this appear to be increases in impingement as young of the year return to the main channel following floods, observed at one station, and with migration of marine species into the estuaries observed at Michoud and Paterson.
- All of the plants have operating fish handling and return systems. Given the sensitivity to handling of many of the impinged species at the fresh water plants, these systems may not contribute significantly to reductions in impingement mortality. The importance of shellfish among impinged organisms at the two estuarine plants, and these organisms' tolerance of handling, suggests that the return systems are likely to contribute to significant reductions in impingement mortality for these species relative to the Calculation Baseline.
- Several of the plants located on the river's main stem (i.e., Waterford 3, Waterford 1 & 2, Little Gypsy, Ninemile, Willow Glen, Baxter Wilson, and Ritchie) have CWIS that draw from deep, fast-moving water located several hundred feet offshore. There is a consensus that the population densities in these areas are far lower than in quieter, shallower water located along shore and in backwaters. This phenomenon contributes to each of these stations having greatly reduced rates of impingement (approximately 95%) relative to the Calculation Baseline condition (i.e., along shore) (see Section 4.2.2).

3.2.2 Timing and Methods

Table 2 summarizes the impingement studies conducted at Entergy's plants located on the LMR. Data collection frequency varied from twice weekly to monthly. Sample duration for all studies was 24 hours, however the frequency that samples were collected within the 24-hour period varied from 10-minutes to 30-minutes. Most important, samples were collected frequently enough to quantify integrated daily rates and seasonal effects.

Sampling methods for each study were similar in that organisms were collected with stationary nets from the screen wash troughs. The revolving screens were typically rotated in advance of the sampling event to remove organisms to enable a more accurate count for the designated sampling period.

3.2.3 Rates of IM

Rates of impingement are discussed in Section 4.1.3. Rates were obtained using historical data from five of Entergy's plants located on the LMR, and current data collected at the Waterford 1& 2 Plant 2,100 feet upstream of Waterford 3. Impingement rates were based on 10,000 m^3 of water flow to allow comparisons between the plants and to enable extrapolation over time. The impingement rate for the Waterford 3 plant was estimated to be 16.16 organisms per 10,000 m^3, based on the current impingement rate documented at Waterford 1&2.

3.3 Characterization of Susceptible Species and Life Stages

40 CFR 125.95(b)(3)(i) sets out the requirements of the IMECS relative to identification of fish and shellfish taxa potentially affected by impingement mortality and entrainment. The goals of this effort are to identify these species that are likely to dominate impingement mortality and entrainment, with a special focus on those that have commercial or recreational importance. In addition, any species subject to special protections (e.g., state- or federally-listed threatened or endangered species) must be noted.

This section will review the available information in order to identify the relevant species and will provide a brief review of the nature of several important species. The discussions rely on station-specific data, industry-generated summaries of the fish populations within the vicinity of the plant, the more general literature, and recent discussions with experts on the fishery of the LMR.

3.3.1 Overview of LMR Fisheries

3.3.1.1 Commercial Fisheries on the LMR

The most commonly impinged species at Entergy's plants located on the fresh water portions of the river have no significant recreational or commercial value. At the two stations located on tidal channels associated with the Mississippi River estuarine system, Paterson and Michoud, commercial species are important. Despite this, adverse impacts to their populations or to the commercial harvest are not expected since the annual impingement rates associated with the CWIS are typically low.

Commercial harvest in the UMR is dominated by four groups of fishes including the common carp, buffalos (bigmouth and smallmouth), catfishes (channel and flathead), and freshwater drum which together represent 95% of the total commercial catch in the UMR and 99% of the monetary value (Fremling et al. 1989). .The common carp has ranked first among species in commercial catch for decades.

The same species harvested in the UMR also dominate the commercial fisheries for the freshwater portions of the LMR. Commercial harvest of fishes in the LMR is difficult to assess because of inconsistencies in methods of gathering and reporting data; however limited information indicates commercial harvest is increasing (Schramm 2004). According to Schramm, neither the commercial nor recreational fisheries appear to be over harvested; however, fisheries for sturgeon and paddlefish should be carefully monitored. He also notes that future fisheries production may be threatened by loss of aquatic habitat, altered spatial and temporal aspects of floodplain inundation and nuisance invasions. In addition, navigation traffic affects fish survival and recruitment via direct impacts and habitat alteration, and is expected to increase in the future (Schramm 2004).

In the LMR, NMFS statistics for 1954-1977 show fish harvest of 6-12 million kg and increasing over time (Risotto and Turner 1985). Self-reported commercial harvests have been collected by the Tennessee Wildlife Resources Agency since 1990 and by the Kentucky Department of Fish and Wildlife resources since 1999. Annual catch for the Mississippi River bordering Tennessee during 1999-2000 varied from 36 to125 tons. Landings of blue catfish and flathead catfish have increased substantially, while harvests of common carp, buffalo fishes, channel catfish and freshwater drum have been highly variable. In Kentucky waters, catch ranged from 18-56 tons between 1999 and 2001, and buffalo and catfishes dominated the catch as well. Schramm (2004) notes that other states on the LMR either do not measure commercial catch or the states do so sporadically. In Louisiana, commercial catch is measured but is not designated as being from specific waters.

In the brackish portions of the LMR the blue crab and penaeid shrimp (white, brown and pink shrimp) are the two most important commercial groups. The blue crab commercial fishery in Louisiana is one of the largest crab fisheries in the U.S. in terms of biomass. A rapid growth in fishing effort occurred in the 1980's but by the mid-1990's the fishery exhibited declining catch rates. Although landings in Louisiana have decreased in recent years, landings averaged 42.9 million pounds during the 1990's. These landings represent 72.7% of the total Gulf of Mexico production. Marsh loss and habitat changes are two of the most important factors associated with the decreased production of blue crabs, excessive fishing effort, various environmental factors (reduced salinities), and illegal and incidental fishing mortality (LBCR 2005).

Commercial species constituted 32% of the species (16 species of fish and 6 species of invertebrates) collected at the Paterson Plant during the 1977-79 impingement study. Commercial fish comprised 57% of the total impingement by number and commercial invertebrates constituted 14% of the total impingement by number. At Michoud, 28% of the species (19 species of fish and 6 species of invertebrates) collected were commercially important species. Commercial fish comprised 31% and commercial invertebrates comprised 39% of the total impingement by number.

Blue crab constituted 9.0% of the impinged organisms at Michoud (1977-79), 10.5% of the total at Paterson and 0.2% at Waterford 1 & 2 (1976-77). Based on estimated annual impingement rates, biomass measurements (from the Waterford 1 & 2 study), and high extended survivability rates, loss of blue crab from these facilities is insignificant, estimated to be much less than 0.1% of the total Louisiana landings.

Louisiana has the nation's most productive commercial shrimp fishery, landing about 100 million pounds a year at a dockside value of $150 million. The white shrimp and brown shrimp constitute the vast majority of the landings. White shrimp constituted 2.4% of the total catch at Paterson and 20.0% of the total catch at Michoud during the impingement studies in 1977-79. Using the estimated annual impingement rate for the Michoud plant, extended survival probability of 50%, and 35 harvested shrimp per pound (LSU 2005); loss of white shrimp at these two plants is insignificant to the fisheries (<<0.1%). Entrainment of white shrimp should also not pose a concern in the LMR as spawning typically occurs as far as 9 km from the shore in water depths of at least 9 meters (Whitaker 1983).

In 1977 and 1978, Gulf menhaden was the leading Louisiana species landed in volume and ranked third in commercial value. In 1978, Gulf menhaden landings were a record 1,508 million pounds (Hollander 1981). In 2003 landings for all species harvested in Louisiana waters was 1.2 billion pounds. Mississippi landings were much less at 212 million pounds (NMFS 2005). Loss of organisms, due to impingement and/or entrainment at CWIS located in the LMR, are insignificant when compared to these figures.

3.3.1.2 Recreational Fisheries on the LMR

The recreational fishery has not been rigorously defined in the LMR. Schramm (2004) states that fresh-water fishing catch rates are relatively high: but efforts are extremely low. Because of the large size, swift and dangerous currents, the presence of large commercial vessels and lack of public access, recreational fishing on these reaches has been largely discouraged. Providing access is difficult due to the large fluctuations in river levels and separation of many of the remaining floodplain lakes from the river during low water stages. Although recreational fishing has been somewhat limited historically on the main channel of the LMR, management agencies have initiated measures to improve access and increase public education regarding the fishing opportunities (Schramm 2004).

According to the literature, the recreational species targeted most often in the freshwater portions of the LMR include the bass, catfish, crappie, gar, and carp species. In the lower portions of the LMR, increased salinity allows estuarine species to be targeted as well. The sand seatrout (white seatrout) for example, a favorite of recreational fisherman, inhabit areas within the tidal channels as demonstrated by the impingement data at the Patterson and Michoud (Mississippi River mile marker 92.6 AHP) plants where this species constituted 12.6% and 4.2% of impingement, respectively. Blue crabs are also targeted by recreational fishermen and have been documented at Entergy's most downstream plants.

3.3.2 Spatial Differences in the LMR Fisheries

In most large rivers, fish species diversity typically increases from headwater to river mouth. Vertical distribution is patchy, with highest numbers at the river surface and at the bottom, with the mid-depth virtually devoid of fish, probably due to very high currents located mid-depth (MP&L 1974). Large floodplain rivers like the Mississippi are dynamic and made up of several diverse ecosystems composed of several habitats, including the main channel, side channel, floodplain, and backwater lakes that allow a diverse assemblage of organisms to persist. One hundred ninety-five (195) species of freshwater fishes have been recorded to occur in the main-stem of the Mississippi and Atchafalaya rivers, representing almost one-third of the freshwater fish species in North America. Sixty-seven (67) species inhabit the headwaters, 132 species inhabit the Upper Mississippi River, and about 150 species inhabit the Lower Mississippi and Atchafalaya Rivers (Fremling et al. 1989). Baker et al. (1991) also estimated that 91 species of freshwater fishes inhabit the LMR, with 30 or more other species present intermittently. The most common freshwater species in the LMR include the gizzard shad, threadfin shad, goldeye, carp, river carpsucker, smallmouth buffalo, blue catfish, channel catfish, flathead catfish, river shiner, and freshwater drum. Bluegill, largemouth bass, and black and white crappie are also fairly common. In addition to the fish, two species of shrimp, (river shrimp and grass shrimp) and a crayfish (Cambarinae) are abundant.

The majority of the LMR is fresh water; however the water becomes brackish near the river mouth and during severe drought periods, the saltwater has been known to extend as far upstream as New Orleans, LA. The water is also brackish in the back channels and backwater lakes near the mouth of the river. Notably the shipping channels on which the Paterson and Michoud Plants are located are brackish in nature and salinity may approach one-third of that of seawater. As the water becomes more brackish, bay anchovy, striped mullet, blue crab, Atlantic croaker, seatrout, gulf menhaden, and penaeid shrimp are found in the lower reaches of the LMR. These species typically utilize the Mississippi River for spawning, as nursery grounds, and for protection.

Thus, we expect that with movement from Entergy's Gerald Andrus, Ritchie, and Baxter Wilson plants to those stations located closer to New Orleans (Little Gypsy, Waterford 1 & 2, Waterford 3, Nine mile, Paterson, and Michoud), more estuarine species will be encountered. This is borne out both in vicinity sampling and impingement records.

The LMR provides plentiful habitat for fishes that thrive in swiftly flowing water but few species can tolerate the high current velocities of the upper and middle water column of the channel (Baker et al. 1991). Most fishes likely inhabit areas near the banks (Pennington et al. 1983) and the channel bottom, where the current is slower (Baker et al. 1991). Several fish species forage in the floodplain of the LMR when it is inundated by high water levels (Baker et al. 1991); these include gars, bowfin, common carp, buffalos, river carpsucker, channel catfish, blue catfish, white bass, crappies, and freshwater drum. Many fishes also use the inundated floodplain for spawning. Densities of larval fishes in the LMR are highest in backwaters, which are important nurseries for fishes and contain a larval fish assemblage differing from that of the main-stem river (Beckett and Pennington 1986).

Spatial differences in population densities are caused by many factors including habitat, water depth and velocity. Most studies show higher fish densities at the channel bank and backwaters compared to the main channel. This is primarily due to increased habitat area, shallow water depths, and reduced river velocities. Most fish species found in the channel prefer the channel bottom where current is slower (Baker et al. 1991). These species are usually represented by larger specimens of these species, such as freshwater drum, buffalo, common carp, and catfish. Most fishes likely inhabit areas near the banks, and most generally prefer the shallow, slower inside edge of a river as opposed to the deeper, faster current of the cut-bank edge (Pennington et al. 1983 and Sempra 2002). Since many fish exhibit specific preference for certain types of habitat, stream or river locations with diverse habitats may be expected to contain more fish species than locations with fewer habitat types (Schlosser 1982; Angermeier and Karr 1984; Reeves et al. 1993). In the Barko and Herzog (2003) study, differences in fish assemblages were also observed between habitat types which they suggest is due, in part, to each species' preference for turbidity and flow.

Since many fish species feed on invertebrates, invertebrate habitat preference is important as well. Rocky substrates associated with dike structures on the LMR support higher total densities of aquatic invertebrates than abandoned channels, natural river banks, dike fields, temporary secondary channels, sandbars, re-vetted banks, main channel, and permanent secondary channels (habitats listed in order of decreasing invertebrate density) (Wright 1982). This apparent habitat preference by invertebrates further substantiates the fact that most fish will be associated with closer inshore (bank) habitats than deeper offshore habitats.

The river shrimp was collected in high abundance during several of the 1970's impingement studies previously discussed, as well as in the most recent study perfomed at Waterford 1&2. The Missouri Department of Conservation conducted a recent study of this species (Barko and Hrabik 2003) in the un-impounded Upper Mississippi River. In this study, four physical habitats were sampled: main channel border, main channel border with wing dike, open side channel, and closed side channel. The objective of the study was to assess the association of river shrimp abundance with environmental factors and habitat types to understand the ecology of this species in a channelized river system. River shrimp were most abundant in the open side channels and no correlation between water velocity and shrimp abundance was found.

3.3.2.1 Review of LMR Habitats and Fisheries Associations

Habitat types were also analyzed in the Sempra (2002) study conducted at Mississippi River mile marker 132.2 AHP as part of the 316(b) demonstration study for a new power plant and CWIS. It was determined that although there are 13 distinct habitat types found in the LMR, only a few dominate the river's landscape in the lower reaches. The researchers used the habitats developed by Baker and his colleagues (Baker et al. 1991) to determine a species' abundance potential in the study area. They defined Baker's 13 habitat zones as Habitat Zone Distribution which is the correlation of a species to their preferred habitat throughout their life cycle. Preferred habitat also includes Habitat Range Distribution, which is the water column distribution most favored by the species throughout their life cycle.

In the Sempra (2002) study, six habitats were reviewed specifically to determine the number of fish species and eggs associated with each type. Each habitat zone was determined to have a reduced number (from 133 potential species found in the LMR) of fish, egg and larval species associated with the habitat. This further validates the fact that proper placement of a CWIS can reduce both impingement mortality and entrainment due to the habitat being poorly utilized by fish and invertebrate species susceptible to impingement.

The Sempra (2002) document listed gizzard shad as abundant (A) or common (C) in all habitat zones except for the channel where they are considered uncommon (U). Threadfin shad are considered abundant or common in most habitats except lotic sandbars where they are considered uncommon. No ranking was given for threadfin shad in the channel. Freshwater drum are considered abundant or common in all habitats except floodplain ponds where they were not given a ranking. Freshwater drum are considered common in the channel. Of the 133 species analyzed in the Sempra document, 48 species (36% of the species) were assigned a ranking for the main channel. Twenty-three (23) species are considered probable (P) and likely to occur but records are lacking or inconclusive; 8 species are considered common; 8 species are considered uncommon; 5 species are considered abundant (shortnose gar, blue sucker, small mouth buffalo, blue catfish and flathead catfish); 3 species are considered rare; and 1 species (striped bass) is considered typical (T) in the channel where it occurs regularly but in low numbers.

No comprehensive ichthyofaunal surveys have been conducted on the LMR in at least the past 30 years (Schramm 2005, personal communication). The most difficult habitat to sample is the main channel, where current velocities and debris loads are highest, and extensive commercial navigation occurs. Because researchers historically could not effectively sample the main channel, relatively little is known about the extent that fish use this habitat (Illinois Natural History Survey-INHS 1997). A current assessment of Mississippi River fishes was compiled from four different sources and reviewed by six ichthyologists familiar with Mississippi River fauna (Schramm 2004). Dr. Schramm notes the lack of standardized habitat classification for Mississippi River fishes. He therefore assigned one or more of three habitat zones to each species: main channel, channel border, and backwater. He defines the habitat zones as follows:

- Main channel - the portion of the river that contains the thalweg and the navigation channel where the water is relatively deep and the current, although varying temporally and spatially, is persistent and relatively strong;
- Channel border - the zone from the main channel to the riverbank. Current velocity and depth will vary, generally decreasing with distance from the main channel, but the channel border is a zone of slower current, more shallow water, and greater habitat heterogeneity. Channel border includes secondary channels and sloughs, islands and their associated sandbars, dikes and dike pools, and natural and re-vetted banks; and
- Backwater zone - includes lentic habitats lateral to the channel border that are connected to the river at least some time in most years. This zone includes abandoned channels (including floodplain lakes) severed from the river at the upstream or both ends, lakes lateral to the channel border, ephemeral ponds, borrow pits created when levees were built, and the floodplain itself during overbank stages.

These habitat zones are extremely relevant when considering species with the most potential for impingement and/or entrainment in the LMR habitat. Additionally, these definitions are significant in our compliance approach comparing the LMR fisheries between the main channel, where many of Entergy's CWIS are located, and the channel border, which is the area representing the theoretical Calculation Baseline (see Section 4.2.2.1).

The definition of the main channel and channel border are slightly different according to the Upper Mississippi River Conservation Committee (UMRCC) (2004). In this document the main channel is defined as habitat that occurs in both pooled and open portions of the Mississippi River and includes only that portion of the river through which large commercial craft can operate. It is defined on its edges by combinations of river regulating structures (wing dikes), riverbanks, islands, buoys and other markers. It has a minimum depth of nine feet and a minimum width of 400 feet. A current always exists varying in velocity with river stages and bottom type is mostly a function of current. Most of the main channel is subject to scouring action during periods of rapid water flow and during passage of tow boats in shallower stretches. The UMRCC defines the channel border as the microhabitat that is between the 9-foot navigation channel and the main river bank.

Of the 137 resident species that Dr. Schramm researched, he was able to assign border habitat to 24 species and backwater habitat to 50 species. No species were expected to reside in main channel habitats throughout their life-cycle. Schramm states that fish are considered backwater dependent if they require conditions such as little or no current, soft-sediment bottom, or aquatic or inundated terrestrial vegetation during at least some portion of their life cycle. Riverine-dependent fishes are those that require flowing water and sand, gravel, or rock substrate during at least some part of their life-cycle; these conditions may be found in the main channel or channel border zones. Schramm considered species peripheral (channel border) to the Mississippi River if available life history information indicated that the species inhabits tributary rivers or streams, prefers small rivers or streams, or avoids or is rare in large rivers.

The following fish species are noted by Schramm as 'backwater dependent' species: gizzard and threadfin shad, common carp, bluegill, largemouth bass, black and white crappie. The following were noted to be 'riverine dependent' species: pallid sturgeon, shovelnose sturgeon, paddlefish, river carpsucker, and freshwater drum. The following species were also noted by the author as species that were abundantly taken in most surveys in the open river segments of the Mississippi River: gizzard and threadfin shad, emerald shiner, river carp sucker, smallmouth buffalo, blue catfish, flathead catfish and freshwater drum. Other species commonly taken in the open river include: longnose and shortnose gar, skipjack herring, red shiner, river shiner, common carp, silver carp, speckled chub, silver chub, bigmouth buffalo, channel catfish, brook silverside, warmouth, bluegill, and largemouth bass.

3.3.2.2 Statements from Fisheries Researchers

Two major conclusions can be drawn from the extensive literature review regarding fisheries in the LMR: (1) population density and diversity are higher in the channel border and backwaters than in the main channel; and (2) the overall fisheries in the LMR have not changed significantly since the 1970's. Several top fisheries researchers were contacted via telephone and in person to verify these conclusions including Dr. Bob Kelso and Dr. Allen Rutherford with Louisiana State University Baton Rouge, LA; Dr. Jack Killgore with the USACE in Vicksburg, MS; Dr. Steve Gutreuter with the United States Geological Service (USGS) in La Crosse, WI, Dr. Hal Schramm with the USGS at the Mississippi Cooperative Fish and Wildlife Research Unit Mississippi State, and Paul Hartfield with the United States Fish and Wildlife Service (USFWS). Together, these statements help to validate existing literature and the conclusions drawn here to. A summary of the conversations is provided below.

Dr. Jack Killgore

Dr. Killgore stated that the fisheries in the Lower Mississippi River have remained relatively consistent since the 1970's, although the Upper Mississippi River (dammed portion) has undergone significant changes. In the LMR, some species have declined including the pallid sturgeon and some of the sucker species; however, the overall community has changed very little. He stated he agreed that the most abundant species impinged in the 1970's studies (i.e., gizzard shad, threadfin shad, and freshwater drum) would be the same dominant species today. He stated gizzard shad is probably the most numerically and biomass dominant species on the river and "nothing can reduce their numbers".

Dr. Killgore also agreed that the density (abundance) and diversity of organisms is higher along the bank and backwaters compared to the main channel. He also agreed that the extension of power plant intake pipes offshore and in deeper waters would reduce the amount of impingement and entrainment. He followed by stating that most larval fishes and juveniles do not utilize the deeper portions of the river (Killgore 2005, personal communication).

Dr. Bob Kelso and Dr. Allen Rutherford

Both professors agreed that the abundance and densities of fish in the river have remained consistent over the last 20 to 30 years. Species Entergy has identified from the literature are consistent with what would be found in the river today. Dr. Rutherford also indicated that there shouldn't be a significant change in fish composition until you get to Mississippi River Mile Marker AHP 90. This is the region of the river where significant mixing of salt water takes place. He did indicate that there would be influxes of estuarine species that are tolerant of fresh water as far upstream as Baton Rouge; however, these numbers are insignificant in comparison to the overall abundance in the river. As noted above, this is very consistent with the observed rates of impingement at the various Entergy plants located along the river.

Dr Kelso indicated that there would be a significant shift in abundance of fish and species diversity moving from the shoreline habitats out to the main channel of the river. Abundance numbers would drop by as much as 95%. Literature on the majority of the fish in the river should indicate that most of these fish are littoral in nature and require a significant level of structure which is not available in the main part of the channel. He further indicated that eggs and larvae associated with these species would also decrease proportionally. He stated most species spawn up near the shoreline habitats where there is structure, cover, and lower flow velocities.

Both indicated that species of fish occurring in the river are adapted to specific conditions occurring in the river. Most species, however, cannot sustain populations out in the main areas of the river due to the high velocities that occur there. Individuals of those few species that do occur in the main channel are usually fairly large in size, live close to the bottom, and are capable of high swimming speeds, sufficient to avoid the intake structures (Kelso and Rutherford 2005, personal communication).

On April 11, 2006 ENSR personnel met with Dr. Kelso and Dr. Rutherford at Louisiana State University (LSU) to further discuss the lower Mississippi River fisheries. After reviewing the impingement rates documented in the historic IM studies, Dr. Kelso indicated that the amount of fish/shellfish historically impinged is "not an issue" due to the magnitude of the river. The low impingement rates did not surprise either professor. They both stated that very few organisms utilize the high velocity waters found in the main channel. Both professors agreed the fisheries were reduced the farther you get from the shoreline; however they did not know the magnitude of the difference.

The professors stated that most species in the LMR spawn in the spring. Due to the harsh conditions in the river and the vast temperature differences between seasons, most organisms grow very quickly to enable their survival. Dr. Kelso stated that most fish reach 100 mm by July.

The implication of the abundance of river shrimp impinged at a couple of the plants in the 1970's was discussed. The professors were not aware of any commercial importance of this species due to its relatively small adult size. They were not aware of a bait fishery for this species. They did state the river shrimp is still very abundant in the LMR.

Regarding long-term changes in the LMR fisheries, the professors stated they were not aware of any significant changes with the fisheries. They further indicated that there is a lack of information on the fisheries and indicated that more data would be needed to infer otherwise. They did state that it appears there has been an increase in grass carp in the river over the years; however this species is rarely impinged. They confirmed that there is not a consensus that the river has changed for the better or worse since the 1970's when the majority of the impingement data were collected.

Regarding the abundance of estuarine species (i.e. striped mullet, anchovy, blue crab) at the downstream plants, the professors informed us that estuarine species usually migrate upstream during low flow periods (late summer and fall) which is consistent with the historical database. They also stated that most of these individuals are brightly colored males; however the reason for this is not known.

Regarding potential impingement of T&E species Dr. Kelso and Dr. Rutherford stated the species most prone to being impinged would be the sturgeon species. They stated there is relatively low risk to paddlefish due to their backwater habitat preference, minimal risk to the smaller dace and shiner species listed, and relatively no risk to mussels since they require attachment sites and are not be found in fast moving waters.

Dr. Steve Gutreuter

Dr. Gutreuter has been involved with several extensive projects involving sampling of the Mississippi River main channel (see Dettmers et al. 2001). He agreed that abundance and diversity was lower in the main channel compared to the side channel and backwaters. He did indicate that more recent studies show higher biomass than previously seen in the main channel primarily due to better gear and calibration. He stated much of this biomass is due to the typically larger fish that inhabit the deeper waters of the main channel. Dr. Gutreuter stated the more recent studies would not be published for at least one year, however he stated he was still comfortable with the general conclusions of the 2001 study (i.e., that population densities decrease sharply with movement into high velocity portions of the river) (Gutreuter 2005, personal communication).

Dr. Hal Schramm - USGS

Dr. Schramm agreed that fish abundance and diversity is typically higher along the shoreline and backwaters as compared to the main channel. He stated the true main channel is primarily a function of depth more so than the distance from the shoreline. He stated the river may be 50 feet deep only 100 feet from shore at some parts of the river and this would be considered mainstem. He did state that a depth of 30 feet would most likely be considered mainstem anywhere along the river (Schramm 2005 and 2006).

Dr. Schramm also stated that several groups are currently conducting fisheries research in the main channel of the LMR and they have been getting interesting results. Specifically, several minnow species apparently utilize the main channel more so than was previously thought. Therefore, Dr. Schramm does have concerns for these smaller species due to their potential for impingement and/or entrainment. (Note: These species were not reported on screens in historic studies at Waterford 1&2 (Espey, Huston and Associates 1977a), Willow Glen (Espy Huston and Associates 1977b), Baxter Wilson (Mississippi Power and Light 1974), or A.B. Paterson and Michoud (Hollander 1981).). He stated additional research is needed to better understand these species as well as the other larger species that utilize the main channel. Dr. Schramm stated that due to the extensive area (habitat) the main channel encompasses, impingement is likely to have only a relatively small effect on the fish populations.

Dr. Schramm stated that the precision of fish abundance values in the LMR is usually very poor primarily due to sampling techniques that are size, and/or species selective. Nevertheless, he agreed that abundance of the primary species observed in the LMR in the 1970's impingement studies (i.e., fresh water drum, gizzard shad, threadfin shad) would probably be the most abundant species impinged today as their numbers have probably changed little over time (Schramm 2005, personal communication).

When questioned whether the fisheries in the LMR had had any significant changes over the past 30 years, Dr. Schramm could not answer either way due to the lack of long-term data on the river. For all intents and purposes, he stated the fisheries were the same since there is no evidence that it has changed. Additionally he stated he was not aware of any changes in the populations of the dominant species impinged over time (i.e. shad, carp, drum, etc.).

Paul Hartfield – USFWS

Mr. Hartfield was contacted (Hartfield 2006) in regards to his trawling efforts on the Mississippi River. Although he has focused most of his efforts on collecting sturgeon species in the vicinity of Vicksburg, MS, additional species were collected as well. In 2001-2002, Mr. Hartfield collected 28 species of fishes, 2 species of freshwater turtles, and freshwater shrimp. He stated that by far the most abundant fishes sampled by trawling (1.5 inch mesh) were juvenile and young of year catfish (blue and channel), and at some sites juvenile drum. Sturgeon were the most abundant large fish collected with trawls (>100 mm). With occasional exceptions (blue suckers, buffalo) trawls were selective for small fish species or small life stages.

Mr. Hartfield agreed that abundance and diversity is higher along the shoreline and backwaters compared to the mainstem portion of the river. He stated that more fish occupy the mainstem during low river stages. Also his research has shown a seasonal migration in the Fall into the mainstem by some species (including several chub species). Mr. Hartfield stated that during high river stages, the Mississippi River mainstem supports reduced fish/shellfish abundance due to the extreme conditions associated with high currents and debris. According to Mr. Hartfield there may be as much as 6-8 feet of sand movement along the bottom during these high stage periods and the offshore habitat changes daily making the environment inhospitable for fish. Apparently during high river stages many of the species that typically inhabit the mainstem (e.g. paddlefish and sturgeon) are caught along the shoreline taking cover in the vegetation, primarily willow trees.

3.3.3 Dominant Species Impinged in the LMR

The following is a brief summary of the dominant species impinged at Entergy's plants located in the lower Mississippi River. Table 3 provides a summary of dominant species identified in historic impingement studies. A biological profile is presented for these dominant species in Appendix A. Table 4 summarizes the length, weight, survival, and swimming speed characteristics for species impinged at Entergy's plants. Handling tolerance and swimming speeds are also discussed.

River shrimp

Ohio River Shrimp (*Macrobrachium ohione*) may grow up to 4 inches long, live in fresh and brackish water along the eastern United States seaboard to the Gulf of Mexico, and are the only species of Macrobrachium found in the Mississippi River. Once common in the Mississippi River below St. Louis, they supported commercial fisheries that once existed near Chester and Cairo, Illinois. Ohio shrimp were thought to be extirpated (locally extinct) in the Mississippi River bordering Missouri and Illinois by 1962. In 1991, however they were rediscovered. The decline in the population of Ohio shrimp is thought to be related to the channelization of the river (Hrabik 1999).

In the LMR, however, this species is still quite abundant. *M. ohione* are the most common freshwater shrimp in Louisiana and can be found in the Atchafalaya and lower Mississippi Rivers, where almost all of the current production is used for bait.

Gizzard Shad

Gizzard shad (*Dorosoma cepedianum*) occur primarily in freshwater and are most abundant in large rivers and reservoirs, avoiding high gradient streams. The species is most often found in large schools. Spawning generally takes place in late spring, usually in shallow protected water. 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. Gizzard shad generally grow to 14 inches and provide forage for most game species (Chilton 1997). Ross (2001) noted that young gizzard shad tend to occur along shorelines in very shallow water, gradually moving offshore into deep water as they grow. Individuals older than age class 3 rarely occur in shallow water (Bodola 1966).

Schramm (2004) stated that this species is abundantly taken in the LMR. He also states that the gizzard shad is a backwater dependent species that may be found in all three main habitat zones; the main channel, channel border and backwaters. Gizzard shad have little commercial or recreational value, although they do serve as forage for game fish.

Threadfin Shad

Like gizzard shad, threadfin shad (*Dorosoma petenense*) 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). The threadfin shad is a pelagic schooling species that primarily occupies the areas between the surface and the thermocline with the greatest densities near the surface (Netsch et al. 1971). Schramm (2004) stated that this species is abundantly taken in all LMR surveys. He also states that the threadfin shad is a backwater dependent species that is most likely to be found in the channel border and backwaters. Threadfin shad serve as forage fish but have little other commercial or recreational value.

Freshwater Drum

Freshwater drum (*Aplodinotus grunniens*) occur in a wide variety of habitats, and is one of the most wide latitudinal-ranging fish in North America. They inhabit deep pools of medium to large rivers and large impoundments spending most of their time at or near the bottom. Young drum feed on small crustaceans and aquatic insect larvae, and adults feed on snails, small clams, crayfish, small fishes, and insect larvae (Swedberg 1968; Robison and Buchanan 1992). They are often found rooting around in the substrate or moving rocks to dislodge their prey (Chilton 1997). The freshwater drum is a pelagic spawner, usually spawning in the spring. The eggs are semi-buoyant and pelagic. In Wisconsin, schools of spawning fish have been observed milling at the surface with backs out of the water (Becker 1983; Chilton 1997). Schramm (2004) stated that this species is taken abundantly in all river surveys in the LMR. He also states that the freshwater drum is a riverine dependent species that is most likely to be found in the channel border and backwaters. Freshwater drum is taken on a commercial basis.

Blue catfish

The blue catfish (*Ictalurus furcatus*) is primarily a large-river fish, occurring in main channels, tributaries and impoundments of major river systems. They are native to major rivers of the Ohio, Missouri, and Mississippi river basins. They tend to move upstream in summer in search of cooler temperatures, and downstream in winter for warmer temperatures. Blue catfish do not mature until reaching 24-inches. They spawn in late spring or early summer when water temperatures reach 75° F. Males select nest sites which are normally dark secluded areas such as cavities in drift piles, logs, undercut banks, rocks, cans, etc. The blue catfish diet is quite varied but smaller fish tend to eat invertebrates, while larger fish eat fish and large invertebrates (Chilton 1997). They are an important commercial and recreational species throughout its range.

Common Carp

Common carp (*Cyprinus carpio*) were first introduced into North America in 1877 and is now one of the most widely distributed fish in North America. They are primarily a warm-water species, and do very well in warm, muddy, highly productive (eutrophic) waters. Adults are primarily benthic and omnivorous, feeding on both plant and animal material. Common carp may grow as big as 75 pounds and are generally considered a nuisance by North American anglers (Chilton 1997).

Ross (2001) states that carp occur in a variety of habitats but are more common in deep pools of streams or in reservoirs, especially in or near vegetated areas with mud or sand substrata. They are fairly tolerant of poor water quality and can survive low oxygen levels and high turbidity. Schramm (2004) stated that this species is commonly taken in most surveys in the LMR. He also states that the common carp is a backwater dependent species that is most likely to be found in the channel border and backwaters. Schramm notes the importance of invasive species in the Mississippi River and stated the most common invasive species presently established in the river include the common carp, grass carp, silver carp, bighead carp, and zebra mussel. Since the carp is a nuisance, any reduction in their numbers (i.e. impingement mortality) would be a benefit to the aquatic ecosystem as this would allow the proliferation of indigenous, non-invasive species.

Channel Catfish

Channel catfish (*Ictalurus punctatus*) are extremely adaptable and occur in a variety of habitats but are especially characteristic of major rivers and large streams having low or moderate gradients. They prefer to live in cool to warm clear water habitats but will tolerate turbid waters. They are highly active at night from dusk to midnight when they do most of their feeding. Channel catfish spawn during the months of May thru July when water temperatures are above 75 degrees. They prefer overhanging rock ledges, cut banks, and submerged trees and roots systems for their nesting. Females mature at 14 inches and males somewhat smaller. At one year old, channel catfish are about four inches long. By their fourth year they have usually reached 12 inches. The channel catfish is an opportunistic omnivore, feeding on just about any living or dead material. Being primarily a nocturnal animal, channel catfish must rely on its sensory organs, including the well-developed barbels, to find food. Their diet consists of aquatic insects, worms, clams, crayfish, snails, and fish, all of which could be dead or alive. Their stomachs might be packed with vegetable materials dropped into the water or minnows depending on what's available. However, large channel catfish feed almost exclusively on fish.

The channel catfish is an important recreational and commercial fish throughout the state. Natural populations of channel catfish are secure throughout the lower Mississippi River as more than 90% of the commercial harvest is attributed to farm raised stocks.

Skipjack Herring

The skipjack herring (*Alosa chrysochloris*) is a migratory species commonly found in the lower Mississippi River basin. They are commonly found near dams in the rivers where they congregate prior to the spring and summer spawn (April – June). Little documented information is available concerning spawning habitat. They prefer clear waters associated with sand or gravel beds in larger rivers. Skipjacks eat plankton, minnows and larvae of mayflies and caddisflies. They feed in large schools, leaping out of the water while pursuing prey. Adult lengths average 12-16 inches (30.5-40.7cm). Skipjack herring serve as forage fish but have little commercial or recreational importance.

Bay anchovy

The anchovies are the most abundant of the schooling, pelagic fishes. The bay anchovy (*Anchoa mitchilli*) is an extremely common fish, restricted to the bays and close inshore areas. The species ranges from Maine to Florida and also occurs throughout the Gulf of Mexico. Adults usually attain a size of four inches (Hoese and Moore 1977). Bay anchovy are planktonic feeders. Although they are not important commercially, they do serve as a major forage species for many game fish. This species is able to exploit a wide variety of habitats, is known to overpopulate a waterbody, and can be used to indicate poor water quality (Monaco et al. 1989).

Atlantic croaker

The croakers (Family Sciaenidae) are perhaps the most characteristic group of northern Gulf inshore fishes. In numbers of species they exceed all other families, and in numbers of individuals, or biomass, they are among the top three (others being mullet and anchovies) species of fish found in the bay systems throughout the Gulf (Hoese and Moore, 1977) The most abundant species of croakers occurring along the Gulf Coast is the Atlantic Croaker (*Micropogonias undulatus*). They spawn in the shallow Gulf near passes, with the larvae entering the bays, where they spend their first summer in brackish water. Although most croaker are adapted to living on muddy bottoms, a few are found in more sandy habitats, and a few are adapted to rocky habitats.

The Atlantic croaker is one of the most common bottom-dwelling estuarine species, with the young occurring in the deeper parts of the bays in the summer but departing in the fall. Only a few fish live past their first year but very large croaker are found at the mouth of the Mississippi River.

Sand seatrout

The sand seatrout (*Cynoscion arenarius*, croaker family) is a sport fish of some importance and is popular with anglers. These fish spawn in deeper channels of the bays or in the shallow Gulf, the young staying over muddy bottoms. The spawning season typically runs from February to October. This species becomes almost entirely piscivorous at a relatively small size. Adults are mature at 140 to 180 mm in length and are thought to have a life span of 3 years.

White Shrimp and Brown Shrimp

Bay systems serve as a nursery area for several commercially important species of penaeid shrimp, primarily white and brown shrimp. Many estuarine species often migrate upstream in search of food as well. In the upper Gulf of Mexico brown shrimp (*Farfantepenaeus aztecus*) are typically the dominant species from May through July, while white shrimp (*Litopenaeus setiferus*) are dominant from August through April (Baxter et al. 1988). The natural diet of post larval penaeid shrimp includes copepods, amphipods, tanaids, and polychaetes, which account for 53% of their diet, with plankton accounting for the remainder (Minello et al. 1989).

Penaeid shrimp are most active at night, often swimming to the surface in shallow water. White shrimp seldom burrow as brown shrimp do, but they do usually rest on the bottom during the daylight hours. Mating and spawning for penaeid shrimp takes place offshore. Brown shrimp breed year-round at depths of 50-120 meters; individuals in shallower water do not breed in the coldest months, i.e., January and February. White shrimp breed in shallower water (14 to 50 meters) and spawn mostly in the fall. When conditions are suitable the females release between 0.5 and 1 million eggs. Twenty-four hours later the drifting eggs hatch as nauplii and begin a planktonic existence. After five molts the egg yolk is exhausted, and the nauplius transforms into a protozoea, a mysid, and finally a post larva, which enters the bays to become a bottom dweller. They remain in the bays and estuaries until they are nearly mature then they migrate offshore to breed (Fotheringham 1980).

Blue crab

Both species of blue crab, (*Callinectes sapidus*), and (*Callinectes similis*) are common along the northern Gulf of Mexico. Blue crabs are very tolerant and adapt much better to a variety of habitats when compared to other species. A commercial blue crab fishery has existed in the Gulf of Mexico for several decades. The larger *C. sapidus* reaches a maximum carapace width of 21 cm compared to 12 cm for *C. similis*. Berried (egg mass) female *C. sapidus* are found nearly year round with the peak of the breeding season being in June and July. After mating, the female migrates into deeper water where she attaches the fertilized eggs to her pleopods. The eggs hatch in two weeks releasing the young as zoeae which eventually molts into a megalops and then transforms into a diminutive adult form. The crabs mature in one year, begin breeding and live perhaps two more years. Blue crabs are omnivores, feeding on fish, bottom invertebrates, vascular plants, and detritus (Fotheringham 1980).

3.3.3.1 Handling Tolerance

Table 4 presents data summarized by EPRI (2003) on the observed impingement survival of different fish species. This review does not include all species but does summarize an extensive set of studies for many important species. To support the assessment of potential survival upon fish handling and return, the species that are both common in the LMR and commonly impinged were assessed relative to the average and median rate of survival following removal from traveling screens.

EPRI (2003) indicated that the median extended survival for freshwater drum and gizzard shad is 20% (8 studies) and 7% (43 studies), respectively. Extended survival rates were not available for threadfin shad but the median initial survival was only 15% (5 studies). This suggests that any sort of fish handling and return system is not likely to achieve significant reductions in impingement mortality for the three finfish species that dominate impingement at the LMR freshwater plants. Of the two common invertebrate species impinged in CWIS, the initial survival for freshwater shrimp was 50% (1 study). Available data for other relevant taxa (including estuarine species) are also presented in Table 4.

Initial and extended survival rates have also been determined for 15 estuarine species (Table 4). The species with the highest initial and extended survival probabilities include brown shrimp (0.83 mean), white shrimp (0.81), and blue crab (0.66) which are common at the two estuarine plants, Michoud and Paterson. These species are also observed at very low frequencies among impinged organisms at Waterford 1 & 2 and are likely to be occasionally encountered at Ninemile, Waterford 3, and Little Gypsy.

These trends will be evaluated further relative to potential mitigation measures in subsequent portions of the CDS.

3.3.3.2 Swimming Speeds

In the Preamble to the Rule, the US EPA states: "Intake velocity is one of the key factors that can affect the impingement of fish and other aquatic biota". A document produced by Sempra in 2002 also states: "In the immediate area of the intake structure, the velocity of water entering a CWIS exerts a direct physical force against which fish and other organisms must act to avoid impingement and entrainment". In addition, technologies (wedgewire screens and velocity caps) may reduce or change CWIS velocities, and hence impingement. In the LMR the typical high velocities assist in reducing impingement by adding a force larger than the intake structure suction force at a 90° angle to the intake. This reduces the number of fish entering the CWIS. When the ambient water velocity is higher than the intake approach velocity, the major effect is to pull the aquatic organisms downriver and not towards the CWIS intake pipes.

A species' swimming speed is important in determining its ability to avoid the suction force of CWIS intake pipes. Swimming speed information can be useful when considering the application of potential construction technologies, especially if the species in the vicinity of the CWIS are known. Thus, this information may be an important part of the IMECS. Available data for important species are presented in Table 4.

Analysis of the impingement data showed moderate correlations between a species' swimming speed and its potential for impingement. River shrimp swim very slowly; adult males swim on average 7.6 mm/s. This species dominated impingement (as high as 57% of the total abundance) at the Willow Glen and Waterford 1 & 2 impingement studies. These high impingement rates were probably due, in part, to the shrimps' inability to break away from the suction created at the intakes. Alternatively, gizzard shad and threadfin shad both have moderate swimming speeds when compared to other finfish (optimum of 23 cm/s for fish 25-50 mm) and were two of the most abundantly impinged fish in the impingement studies. Larger freshwater drum are able to swim relatively fast (optimum speed of 90 cm/s for 300 mm fish), however this species was the most abundantly impinged fish at Baxter Wilson, Willow Glen 1 & 2 and Willow Glen 4. Carp (optimum speed of 166 cm/s for 36-77 mm fish) and bluegill (critical speed of 101 cm/s for 64 mm fish) are able to swim relatively fast and were impinged in low numbers, likely due to their ability to swim faster than the approach velocity at the intakes.

Spotted seatrout (cruising speed of 81 cm/s for 300 mm fish) swim at moderate speeds and were impinged in small numbers at the Michoud and Paterson plants. Bay anchovy (cruising speed of 21 cm/s for 90 mm fish) swim relatively slowly and were impinged in higher abundance at these same two plants (Table 3). Although swimming speeds are not available for blue crab, white shrimp, and brown shrimp, these species are relatively slow swimmers and were impinged in moderate abundance (up to 20% total abundance) at Paterson and Michoud. These results suggest a connection between impingement rates and escape potential, with stronger swimming species capable of escaping the flow field of the intake and vice versa.

Although a species' swimming speed is likely a key element in determining its impingement potential, there are many factors that are important including individual size, behavioral cues, feeding habits, preferred location within the water column and physical habitat preference relative to the CWIS location, and the tendency to school.

3.3.4 Threatened and Endangered Species

Louisiana, Arkansas, and Mississippi rare, threatened, and endangered species lists were reviewed for the counties or parishes where Entergy's Baxter Wilson, Gerald Andrus, Ritchie, A.B. Paterson, Michoud, Little

Gypsy, Waterford 1 & 2, Ninemile, and Willow Glen plants are located. If the river marks a county boundary, the lists for counties on both sides of the river were reviewed for that facility. Species that were listed (Federal or state) as endangered, threatened, or candidate for one or more of the counties/parishes reviewed are included in the T&E Species list summarized in Table 5. Species listed as "prohibited" and "restricted harvest" by Louisiana are also included. Detailed species accounts for threatened and endangered species can be found in Appendix B.

Dr. Todd Slack with the Mississippi Museum of Natural Science provided lists of species in the general area of Entergy's facilities located on the LMR. The list was compiled from the Museum's current database and the Inland Fishes of Mississippi, authored by Dr. Stephen Ross (Ross 2001). Dr. Slack stated that the list is extensive and should include all common fish in the area. This information was used primarily to determine potential occurrence of T&E species and to help characterize the source waters.

The databases used to develop the T&E list include:

- Louisiana Natural Heritage Program lists by parish (last updated December 2004);
- 2005-2006 Implementation Strategy for Louisiana Department of Environmental Quality and the United States Fish and Wildlife Service Memorandum of Understanding (MOU);
- Mississippi Museum of Natural Science Natural Heritage Inventory: Search Animal Database by County (Species of Special Concern);
- Endangered Species of Mississippi List, Mississippi Natural Heritage Program (last updated 2002); and
- Arkansas Heritage Program Rare Species Search Engine by County.

The 2005-2006 Implementation Strategy for Louisiana Department of Environmental Quality and the United States Fish and Wildlife Service Memorandum of Understanding (LDEQ and USFWS MOU) lists all federally listed threatened and endangered species in Louisiana that are dependant on aquatic habitat. Listed species are associated with Louisiana water body sub-segment numbers. The LDEQ/USFWS MOU was reviewed for the segments associated with the plants (if applicable – not applicable for Gerald Andrus and Ritchie). No species are listed for A.B. Paterson (Segment No. LA041501) or Michoud (Segment No. LA041901). Ninemile, Little Gypsy, Waterford 1 & 2, and Willow Glen source water is obtained from Segment No. LA070301. The pallid sturgeon is listed for Segment No. LA070301. Baxter Wilson is located in Mississippi across the Mississippi River from Louisiana. The segment number assigned by Louisiana to the Mississippi River where Baxter Wilson is located is Segment No. LA070101. The fat pocketbook mussel is listed for Segment No. LA070101.

The following species on the Mississippi River T&E Species List are included in the MOU, but are not listed for the segments where Entergy's facilities are located:

- Inflated heelsplitter mussel; and
- Gulf sturgeon.

The following threatened and endangered (T&E) species discussion focuses on federal and/or state listed species in Arkansas, Louisiana and Mississippi that have the potential to be impinged or entrained in the LMR. The federal T&E list (USFWS) and state lists (Louisiana, Mississippi, and Arkansas) were reviewed and those species with any potential for impingement and/or entrainment are provided in Table 5.

As a result of the literature review and a review of historical impingement and entrainment data, few T&E species appear to have any potential to be impinged and/or entrained in the LMR. T&E species suspected to inhabit, or have been documented in the literature in, the general vicinity of Entergy's LMR plants were selected for further consideration. Most species were eliminated based on minimal potential to be found in the LMR, or due to their large size or non-aquatic nature (i.e., birds, whales, manatee, etc). The Cumberlandian combshell (a freshwater mussel), for example, has only been documented in Tishomingo County (northeast corner of Mississippi), therefore is not expected to inhabit the LMR. The Ozark cavefish listed in Arkansas, only inhabits underground caves, therefore should not be found in the LMR. Other species including the bayou darter was eliminated as a species of concern even though it has been documented in a county bordering the LMR. This species has been documented near the Mississippi River in both Claiborne and Lincoln counties, however it is apparently restricted to Bayou Pierre and the lower reaches of its tributaries: White Oak Creek, Foster Creek, and Turkey Creek in Mississippi (Ross 2001). Due to this species' apparent restriction to Pierre Bayou, and its habitat preference for shallow riffles and runs over coarse gravel or pebbles, it was not given further consideration since it has minimal potential for impingement and/or entrainment in the LMR. Other species eliminated from consideration were done so based on similar reasoning.

During the one year study conducted at the Waterford 1 & 2 plant from 1976 to 1977, only two occurrences of an impinged state or federally listed species was documented, which included two small pallid sturgeon, (*Scaphirhynchus albus*) measuring 283 and 420 mm TL. Based on the small number of reported incidences of impingement during this study, as well as anecdotal information provided by the operations manager, it is evident that this species or other state or federally listed species will not be significantly impacted by impingement at the Waterford 1 & 2 plant. Additionally, trawling efforts conducted by the USFWS (see Hartfield summary Section 2.2.2) have shown that the pallid sturgeon is not very common. For example, in 2001 trawling resulted in the collection of 615 shovelnose sturgeon, 9 pallid sturgeon, 7 intermediates that were tentatively identified as pallid sturgeon, and 6 intermediates that were more similar to shovelnose.

3.3.5 Other Considerations that Might Drive Additional Concerns

There are no additional concerns related to the operation and/or location of the Waterford 3 CWIS on the LMR. Impingement losses are estimated to be modest and are unlikely to adversely affect the fisheries on a river the size of the Mississippi River. The intakes are not located in any areas that appear to be used as primary nursery habitat or designated habitat that would raise additional concern. Potential adverse impact to T&E species or other species of concern appear minimal based on an extensive literature search and the historic database.

3.4 Methods of Extrapolation from Historical Data

3.4.1 Review of Data Relevance

The relevance of historical data is addressed in this section considering potential fisheries trends in the LMR and whether the impingement data were collected under normal operating conditions. Available data were analyzed to determine their sufficiency to estimate the Calculation Baseline. Conclusions formed based on historic data were then proofed against current impingement data collected at the Waterford 1&2 plant, as presented in the Comparative Analysis of Impingement Mortality Studies document (see Appendix C). The sufficiency of the data is also discussed as it pertains to supporting the other goals of the CDS. Table 6 is a combined list of species impinged at Waterford 1 & 2, Willow Glen, Baxter Wilson plants.

Biological data used to address current impingement mortality rates for the plants located on the Mississippi River are derived from a series of impingement studies conducted at the identified power plants (Waterford 1 & 2, Willow Glen, Baxter Wilson, A. B. Paterson, and Michoud). In general, these studies were conducted to evaluate and characterize the organisms impinged and entrained during the operation of each of these plants. Each of the studies was designed to quantify the number, species, rate, seasonality, and diel variations of impingement and entrainment occurring at each of the plants.

- The relevancy of the existing historical data can be shown to be representative of the species and relative abundances present in current conditions. The temporal data gap has been bridged by consulting with several leading authorities from the universities and the agencies concerning the relevance of the historical data. QA/QC thresholds were established for evaluating the existing data and determining its applicability. These include:
  - Duration of Samples Must be Defined. A set time was established for operation of pumps and screen rotation;
  - Location of the Samples Must be Defined. Samples were collected for impinged and entrained organisms;
  - The Gear Used for Sample Collection Must Be Described and Appropriate, samples were collected from the rotating screens;
  - Samples Must be Collected in a Way to Capture Seasonal and Diel Trends. ' All samples were collected over a 24 hour period for one year; and,
  - All Organisms must be Enumerated and Identified to the Lowest Taxonomic Level.

A complete and thorough review of current and historical data was performed to assess the quantitative value of existing data and to determine if the basis of the data were sufficient to support estimating calculation baselines for the plants identified in this review. Current data available in the literature suggests that existing research provides an adequate quantitative assessment of the existing fisheries in the river. Most of the studies conducted were designed to sample specific regions of the river, such as backwater areas and littoral zones, and to study specific species, such as the pallid sturgeon and paddle fish. Independently, these data may only provide a small subset of information on the overall fishery in the river. However, when looked at cumulatively, the extent of this data, combined with all the available data from the impingement and entrainment studies conducted at the plants, does provide a good qualitative assessment of the fish diversity and relative abundance in the river. Our findings have been corroborated by leading fishery biologists from LSU, the United States Army Corps of Engineers (USACE), U.S. Fish and Wildlife Service, and the U.S.G.S, and are further supported by data collected in the most recent impingement mortality study conducted at the Waterford 1&2 plant (see Appendix C).

3.4.1.1 No Significant Long-Term Changes in the LMR

The riverine ecosystem of the Mississippi River has undergone many changes. Most of the natural changes have occurred gradually over hundreds of thousands of years, whereas human-induced changes have occurred rapidly and recently. Several factors have apparently contributed to the recent declines in the river's flora and fauna, including habitat loss and degradation, point and non-point pollution, toxic substances, commercial and recreational fishing and navigation, deterioration of water quality during drought periods, reduced availability of key plant and invertebrate food sources, and invasion of non-indigenous species (Bhowmik and Adams 1989). Many of the biological changes observed in the Mississippi River have occurred over the past century and not just the last several decades. Johnson (1987), for example noted that many fish species such as the river sucker and blue catfish have declined in the UMR due to dredging extending back 150 years, and dam construction during the 1930's, which both had a dramatic effect on the availability of fast-flowing water and rock-bottom habitats. Although several key native organisms including submerged plants, native pearlymussels, fingernail clams, and certain fishes have decreased along substantial reaches of the river in recent years or decades, most species have changed little over time.

At present, the Mississippi River's native fish assemblage appears intact (Fremling et al. 1989; Gutreuter 1997; Weiner at al. 1998). Schramm (2004) also states that although some species are considered rare, with the exception of sturgeon, sport and commercial fisheries show no signs of over fishing and may even support increased effort in harvest.

Schramm (2004) compiled four current studies dated 1989, 1991, 1995, and 2000, and reported the abundance category of the fish species inhabiting the Lower Mississippi River. The most dominant fish in the river, according to these four studies, were gizzard shad, threadfin shad, freshwater drum, and blue catfish. These species were abundantly taken in all river surveys. Carp, white crappie, skipjack herring, and bluegill were categorized as species that were commonly taken in most surveys. These same species dominated the impingement studies in the 1970's; therefore we can conclude there have been no significant changes in the LMR fisheries since the historical impingement data were collected.

Estuarine species and invertebrates were not analyzed in Schramm's study so abundance values could not be obtained for these species. The most common estuarine species collected in the Michoud and Paterson impingement studies included white shrimp, Atlantic croaker, bay anchovy, sand seatrout, blue crab, Gulf menhaden, sea catfish, and striped mullet. These species are very typical of upper Gulf of Mexico estuaries and tidal river systems. Overall community structure does not appear to have changed the past several decades although saltwater commercial fishing harvest in Louisiana has declined somewhat. According to National Marine Fisheries Service (NMFS) statistics, finfish landings have declined between 1984 and present day, however shellfish landings have remained relatively steady. The long-term decline in fin-fish harvest is primarily due to the corresponding decline in wetland habitat.

The river shrimp was collected in high abundance in both the historic and current impingement studies previously discussed. Present day abundance in the LMR is not well known since most river studies have primarily focused on fish. The Missouri Department of Conservation conducted a recent study of this species (Barko and Hrabik 2003) in the un-impounded Upper Mississippi River. Although the focus of the study was to assess the association of river shrimp abundance with environmental factors and habitat types, the study showed a healthy shrimp population in the upper Mississippi River.

Consultation with several leading authorities from the universities and the agencies concerning historical patterns of fish populations in the LMR has been conducted. Dr. Rutherford and Dr. Kelso of LSU, Dr. Killgore of the USACE, and Hal Schramm with the USGS each indicated that the species characterization in the river has remained fairly consistent over the last 20 to 30 years and they would not anticipate a significant change in species for much of the river from well above the state of Mississippi down to Mississippi River mile marker 90 AHP. Furthermore, they indicated that estimates of population densities (relative abundance) for the major species occurring in the river have remained relatively stable during the same time period. In addition, each mentioned the lack of quantitative data to fully assess the fishery in the Mississippi River.

Long-term studies were not conducted at any of Entergy's plants; however, impingement data were collected at the Quad Cities Station located on the upper Mississippi River between 1973 and 1996 (LeJeone, 2000). Although this plant is located on the upper Mississippi River, similar species dominated the impingement collections compared to Entergy's LMR plants. In the Quad Cities Station study, gizzard shad constituted 66% of the samples followed by freshwater drum (21%), bluegill (5%), channel catfish (2%), and white bass (2%). These five species represented 96% of the total collections over the 23-year period (Figure 13). During the length of the study the relative abundance of the dominant species changed very little as depicted in Figure 13 where gizzard shad and freshwater drum were by far the most dominant species impinged every year. Significant inter-annual variation was observed in the impingement rates. For example in 1987 approximately 232,000 organisms were impinged and in 1989 an estimated 3 million organisms were impinged. A sudden increase in impingement rate was observed in 1984, but this can be explained by the conversion of the plant from closed to open cycle.

Significant inter-annual variation was also observed at the Waterford 3 plant water study (Figures 22 and 23). Between 1973 and 1974, nearly 2,500 gizzard shad were collected and the following year less than 1,000 were collected. Over 400 threadfin shad were collected between 1977 and 1978, and between 1979 and 1980, only a few individuals were collected.

In a comparative analysis of the historic and current impingement data collected at the Waterford 1&2 plant, significant inter-annual variation was again noted (documented historic impingement rate of 4.22 organisms per 10,000 m^3, documented current impingement rate of 16.16 organisms per 10,000m^3).

The lack of data collected on the Mississippi River is primarily due to the lack of a safe and effective design and coordination of a sampling program to fully assess the fishery. It is therefore, our opinion and the opinion expressed by Dr. Kelso, Dr. Rutherford, Dr. Killgore, and Dr. Schramm that the existing data reviewed for the development of this document is the most current and applicable dataset available and the data presented in these studies is in fact relevant to current and existing conditions at each of the plants. Furthermore, it is our opinion that data from these plants can be used to support, supplement, and be used in lieu of data for other plants located on the river.

3.4.2 Method of Extrapolation

Impingement data collected at Entergy's plants are summarized in Table 2 and Figures 14-21. Impingement rates were calculated based on effort and flow. Impingement rates calculated based on effort resulted in an estimate of the number of organisms impinged per sampling event (typically 24 hours in duration) that was then extrapolated to an annual rate. The impingement rates calculated based on flow resulted in an estimate of the number of organisms impinged per volume of water sampled during the study, which was standardized to 10,000 cubic meters. Impingement rates based on effort were also extrapolated to 10,000 cubic meters using the design capacity of the plant, or the rate at the time of the sampling. Calculated impingement rates for Waterford 3 were based on known impingement data collected at other Entergy plants, including Waterford 1& 2, located 2,100 feet upstream.

3.4.3 Discussion of Uncertainty

Data collected in the impingement studies were initially evaluated based on operating condition at the time the study was conducted. These operating conditions are estimated to be at or near maximum operating capacity. Evaluating this data and applying it to current operating conditions requires several assumptions:

- Approach velocities and through screen velocities are assumed to be the same;
- Intake structures have not undergone any type of retrofit or substantial change in operation; and
- Densities of fish and shellfish and their diversity have not changed.

Based on the available information, we believe that each of these assumptions is valid.

Data reviewed in the literature and from existing impingement studies provide a qualitative assessment of the fisheries in the Mississippi River and at the plants. These data provide a comprehensive analysis of the fish assemblages, specifically juvenile and adult fish, occurring in different habitat zones associated with the river.

Although we believe the fish community structure of the LMR fisheries has not significantly changed since the historical data were collected, it should be noted that most of the studies reviewed and analyzed for this IMECS were short-term studies (1-2 years). Significant inter-annual variation occurs in many biological systems and is represented in several impingement studies including the LeJeone and Monzingo (2000) study. If the historical impingement data were collected during a 'non-typical' year, the data may not have been representative of conditions at the plants then, and therefore would not be representative of the current conditions. However, the potential for non-representative data has been reduced in this IMECS by analyzing the combined historic dataset for five of Entergy's plants located on the LMR that were collected over a span of seven years (1973-1979). This dataset was then compared to the most current impingement study performed at the Waterford 1&2 plant to corroborate conclusions made based on the historic data. Speciation of organisms collected in the both historic and current studies is similar, and relative abundance of the dominant species observed in the ambient waters is similar to those documented in the impingement data. However, impingement rates documented historically are much lower than the current documented rate. This same inter-annual variation was represented in the large-scale LeJeone and Monzingo (2000) study, and lends credence to viewing the LMR as a highly variable body of water subject to significant inter-annual fluctuations. Since the general trends in impingement rates are similar between all studies reviewed, we conclude the data are representative of typical biological parameters on the river. This also suggests that the impingement data are representative (see Section 3.2.1).

4.0 Data Interpretation

Although various impingement studies performed at several different facilities were reviewed in preparation of this IMECS, data interpretation and comparisons were most heavily weighted upon the current study at the Waterford 1&2 Plant. Details of the data compiled from this study in comparison with relevant historic studies are presented in the following section.

4.1 Current Impingement Study Performed at the Waterford 1&2 Plant

Impingement analysis at the Waterford 3 Electric Generating Station was determined from sampling data at Waterford 1&2, another Entergy-owned plant, in accordance with the "like facilities" clause of the recently remanded section 40 CFR 125.95 of the EPA's Clean Water Act. Evaluation of historical studies of impingement, an extensive document review, and a current impingement study were used in conjunction to obtain a comprehensive analysis of impingement potential at Waterford 3.

Impingement sampling was conducted within the sluiceway of the fish return systems at 12-hour intervals over a 24-hour period, monthly for one year, beginning in September 2006. In addition to the biological data, hydrological parameters such as water temperature, dissolved oxygen, and conductivity were also recorded.

All field and laboratory personnel adhered to all Quality Assurance Quality Control (QA/QC) measures at all times. By adhering to the guidelines outlined in this document, Entergy was able to accurately record, analyze, and report a true characterization of impinged organisms.

The current impingement rate at the Waterford 1&2 plant was calculated to be 16.16 organisms per 10,000 m^3, while the historic study obtained a rate of 4.22 organisms per 10,000 m^3. The disparity between the current and historical impingement rates at the site is attributable to inter-annual variations documented in the Mississippi River. Such variations can be correlated with the magnitude of spring flooding and summer drought events, which may alter river flows, water temperature, and suitable reproductive habitat, among other conditions. Based on these calculations and the proximity and habitat similarity of the plants, the current impingement rate at Waterford 3 is also estimated to be 16.16 organisms per 10,000 m^3. However, due to the differences in intake capacity of the two plants, the estimated number of organisms impinged annually at Waterford 3 differs from that of Waterford 1&2. When the rate of 16.16 and the annual design intake capacity of the Waterford 3 CWIS are incorporated into the impingement formula, the number of organisms estimated to be impinged at Waterford 3 is 3,472,951. This corresponds to about 2.5 times the number of organisms estimated to be impinged annually at Waterford 1&2 (1,379,533). A detailed discussion of this impingement study is available in Appendix C.

4.2 Overview of Relevant Studies

4.2.1 Taxonomic Identifications

A list of the impinged species at the Waterford 1&2 Plant, the Willow Glen Plant and the Baxter Wilson Plant is provided in Table 6. The species for each respective plant was combined with the species list created by Dr. Hal Schramm (2004) to create a comprehensive list of all species with "potential to occur" in the vicinity of the respective plant (Appendix C). Relative abundance of fish/shellfish impinged at the above mentioned plants and collected in the vicinity of the Waterford 3 Plant is presented in Figures 22 through 29.

The dominant species impinged at Entergy's above referenced facilities are similar to those species endemic to the Mississippi River as demonstrated by the following studies.

Fish characterization studies performed on the LMR near Waterford 3 from 1977 to 1979 documented the most common species to be gizzard shad, threadfin shad, blue catfish, freshwater drum, striped mullet, skipjack herring, channel catfish, river carpsucker, blue gill, and common carp.

Similar species were collected by Barko et al. (2004) in the Upper Mississippi River where the numerically dominant component of the adult fish assemblage was comprised of only three species: gizzard shad; common carp; and channel catfish. Gizzard shad were impinged frequently at all of Entergy's freshwater plants, as were channel catfish. Common carp were impinged but was rarely a dominant species. At Baxter Wilson common carp represented 3% of the total impinged organisms.

In the current impingement study (2006-2007) conducted at Waterford 1&2, most commonly collected fish species included threadfin shad, blue and channel catfish, freshwater drum, and bay anchovy. River and grass shrimp were also collected, comprising over 60% of the number of organisms documented.

The most commonly collected fish in CDM and Limnetics (1976) study on the LMR included gizzard shad, threadfin shad, goldeye, carp, river carpsucker, smallmouth buffalo, blue catfish, channel catfish, flathead catfish, river shiner, and freshwater drum. In addition to the fish, river shrimp, grass shrimp, and a crayfish (Cambarinae) were collected.

In the LeJeone and Monzingo (2000) study on the Upper Mississippi River, freshwater drum and gizzard shad accounted for approximately 90% of the fish impinged at the Quad Cities Station.

McInery and Held (1995) collected fish in Pool 9 of the Upper Mississippi River and determined the most dominant species was the freshwater drum followed by gizzard shad, channel catfish, black crappie, flathead catfish, white bass and mooneye.

Miranda (2005) conducted a study of Mississippi River oxbow lakes. Fish abundance was dominated by blue gill (28.5%), gizzard shad (19.4%), threadfin shad (11.9%), longear sunfish (8.0%), largemouth bass (7.6%), silverside (3.6%), common carp (2.7%), orangespotted sunfish (2.7%), white bass (2.0%), smallmouth buffalo (1.8%), black crappie (1.6%), white crappie (1.5%), and catfishes (1.4%).

In another ambient characterization study (Koel, 2004), the most common species collected in the Upper Mississippi River were gizzard shad (29%), emerald shiner (22%), bluegill (8%), freshwater drum (6%), and spotfin shiner (5%).

Although many of the species observed in the historic impingement samples are similar in composition and relative abundance to the species found in the LMR itself, some species are noticeably absent or under-represented from the impingement samples. For example, some of the most common fish in the LMR, shiners and smallmouth buffalo were rarely observed in the impingement samples. Skipjack herring, while common in the LMR, only account for a small percentage of the total number of fish impinged (generally less than 1%). This is confirmed by two surveys conducted on the LMR by Entergy at the Waterford 3 and Grand Gulf plants (see Table 7). While quantitative comparisons are difficult, it is apparent that several species that dominate the ambient samples are poorly represented in impingement samples collected at near by stations. The differences in composition and frequency of fish known to be common in the LMR and those observed in the impingement samples is likely to due to habitat preferences and/or escape potential. The ambient river studies utilized different gear which has the potential to bias the results of the sampling event making inter-survey comparisons difficult.

4.2.2 Characterization of Life Stages

The rule calls for the characterization of all stages that might be subject to impingement and, if appropriate, entrainment. This characterization is necessary to ensure the full scope of any potential impact is understood and that any implications for selection of mitigation measures are known. Entergy believes that the general literature supports understanding of the potential impacts to all life stages. Equally as important, the impingement studies that are available were designed to facilitate understanding of diel and annual variations.

Life stages subject to entrainment are determined primarily by intake screen mesh size which is typically ⅜". Most of Entergy's plants on the LMR, including the Waterford 3 and Waterford 1&2 Plants, are only subject to performance goals for impingement mortality due to the low proportion of average annual river discharge used by the plant. Only Entergy's Michoud and A.B. Paterson plants are also subject to entrainment, therefore only life stages subject to impingement at the Waterford 3 plant are discussed in this IMECS.

4.2.2.1 Size of Impinged Organisms

Life stages subject to impingement include all stages greater than the intake screen mesh size. Impingement varies with species but young of the year (YOY) individuals dominated historical LMR impingement studies (based on length and weight data and observations). Exceptions were smaller species that typically do not exceed several inches in length even as adults. Current anecdotal observations also indicate that YOY currently dominate impingement at LMR CWIS. Impingement data from other water bodies also show a dominance of YOY on traveling water screens compared to adult organisms. Due to the placement of trash racks and debris screens on intake pipes, and due to their ability to out-swim intake approach velocities, larger organisms are not typically subject to impingement. Some exceptions include invertebrates (e.g., shrimp, crayfish, blue crab) which are generally smaller than fin-fish and have reduced swimming abilities. Adults of these species may become impinged in addition to juveniles.

Length data collected in the aforementioned impingement studies demonstrate that YOY or juveniles typically dominate impingement (Table 8). Lengths for all of these species, except the common carp, are more typical of younger individuals than for adults.

4.2.2.2 Temporal Variations in IM

Temporal variations in IM and E are the result of both biological factors (e.g., spawning season, migrations, etc.) and non-biological factors (e.g., river stage, plant operational status, etc.). Due to the multitude of factors that can potentially affect impingement mortality and entrainment at a given location, temporal variations are difficult to ascertain. Specific knowledge of the waterbody, plant CWIS, and the dominant species in the area can allow temporal variations to be estimated. Much of this information is available from the literature. One obvious factor that can affect impingement mortality and entrainment, and which takes precedent over biological factors is the operational status of a plant. Many plants operate on a "peaking reserve" status and only operate on a limited basis when energy production is needed. Typically power demand increases in summer, thus increasing impingement mortality and entrainment rates during the warmer months due to the increase in water withdrawal and the fact that the biomass of YOY fish is typically high during the summer. As noted above, none of the Entergy plants can commit to such seasonal reductions in capacity. It should also be noted that the data available from the plants were collected during normal operating conditions and, therefore, do not reflect any bias associated with differential plant operation.

Understanding of the temporal variations in impingement and entrainment is important for two potential reasons:

- In order to accurately characterize impacts of impingement mortality and entrainment. For example, if impingement events were more significantly common during the night, failure to sample during both day and night would bias the daily estimates of impingement. Entergy believes that the existing data sets address this issue by inclusion of sampling throughout the year as well as both day and night conditions.
- In order to assess whether periodic flow reduction might serve as a mitigation measure. For example, if it can be demonstrated that impingement mortality occurs during a specific season and the plant can

be idled or run with reduced cooling water flow during that period, this might present an effective mitigation strategy. At this point, Entergy is not able to commit to such operational measures.

4.2.2.3 Seasonal Variation

Spawning season is one of the most important biological factors affecting impingement mortality and entrainment rates. The primary period of reproduction and peak abundance of most LMR taxa is during the months of spring (typically March through May). 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 in the LMR in regards to entrainment as this is the time eggs and larval organisms are most abundant. Many of these organisms will be able to avoid entrainment later in the year as they grow larger, and increase their swimming ability.

Upon reaching a size greater than ⅜-inch (approximately 10mm), the organisms are subject to impingement. Time necessary to attain this size varies per species and individual but appears to occur quickly in the Mississippi River. According to LSU professors, Drs. Kelso and Rutherford, most fish species must grow very quickly to enable their survival and most species reach 100 mm by July. A fish of this size would be subject to impingement. According to the professors, this quick growth is required primarily due to the harsh conditions in the river and the vast temperature differences between seasons.

It is interesting to note that the spawning period in the LMR correlates to the seasonal flooding/high water period. At the Waterford Unit 3 Plant, seasonal average flows have been calculated to be 580,000, 650,000, 280,000 and 240,000 cfs for winter, spring, summer, and fall, respectively. Elevated flows most likely push the eggs and larval fish past the CWIS more so than the rest of the year due to increased velocities.

Data collected in both studies (1976-1977 and 2006-2007, see Appendix C for more detail) conducted at Waterford 1 & 2 Plant were evaluated to determine seasonal variations in impingement rates (Figure 28). Both studies exhibit similar seasonal variation, although the 2006-2007 study exhibits a much larger spread between its maximum and minimum impingement rates over the course of the year. Speciation of impingement samples was also similar, with 7 of the 9 species historically recorded to comprise greater than 1% of the impingement sample also comprising greater than 1% of the impingement sample in the 2006-2007 study. River shrimp were documented as the most frequently impinged species both historically and currently, comprising at least half of the number of organisms impinged. River shrimp are reported to receive reproductive cues from spring flood spates and use flooded terrestrial habitat for reproduction. This coincides with the observed decrease in river shrimp impingement throughout early spring as the shrimp had largely vacated the main river to reproduce. Body lengths recorded during the June sampling event in the 2006-2007 study indicate that the majority of river shrimp captured ranged from 36 to 50 mm in length, indicating juvenile (post-spawning) shrimp. Historic plankton studies performed at the Waterford 3 plant indicate that river shrimp egg densities also peak in June. Average monthly impingement rates documented for threadfin shad, channel catfish, freshwater drum, and bay anchovy from 2006-2007 closely mirrored historic monthly impingement rates, with impingement being highest in summer and fall months (79% of total organisms impinged accounted for during this period) and lowest during winter and spring months (total impingement rate of less than 7 organisms per 10,000 m^3 observed during these months). Blue catfish exhibited little seasonal variation both studies. A complete copy of the Comparative Analysis of Impingement Studies report is available in Appendix C of this document.

In the Baxter Wilson impingement study previously discussed, it was observed that daily impingement was relatively low from March through June, with a sharp increase in late June peaking in mid-July. The increased rate of impingement in mid-July was likely precipitated by the reduction in river volume and the growth of juvenile fish. The reduction in impingement after mid-July was most likely caused by high natural mortality associated with most species, and an increase in swimming ability.

Biomass and total abundance were analyzed for seasonal differences at the Willow Glen Plant as well (Unit 1 & 2, and Unit 4). Biomass was variable, however higher values were observed in spring and early summer (mid-March through early July) compared to the rest of the year. Total abundance showed similar trends with higher rates in the summer (mid-June through early August). River shrimp and crayfish contributed much to this apparent peak in the warmer months of the year.

Potential temporal (seasonal) variations were also analyzed at the Paterson Plant and it was determined that the impingement rates were higher January through March in 1978 and in January in 1979. Seasonal variations at the Michoud plant showed higher impingement rates in April, August and September in 1978, and in February and May in 1979. Both of these plants are in estuarine environments.

4.2.2.4 Diel Variation

Most of the historical impingement data were collected during both the day and night to enable an accurate assessment of the species and true impingement rates. However, much of the data was summarized on a daily 24-hour basis.

Data were collected every 12 hours during the 2006-2007 study conducted at Waterford 1&2 and every four hours at Paterson and Michoud and recorded as such. Although impingement rates were variable, minimum impingement rates were typically observed during daytime samples (collected from 0400 hours to 1600 hours). The nighttime samples (collected from 1600 hours to 0400 hours) exhibited the highest impingement rates both studies conducted.

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 was demonstrated at the Waterford 1&2, Paterson and Michoud plants.

4.2.3 Documentations of Current IM and E Rates

Rates of impingement on the LMR varied between 0.7 organisms impinged per 10,000 m^3 to 16.16 organisms impinged per 10,000 m^3 for the Entergy plants with impingement data. Impingement rates for all plants are depicted in Figures 14 through 21. Impingement rates were lowest for the Willow Glen plant where rates ranged from 0.13 to 1.47 organisms per 10,000 m^3 depending upon the units sampled. The impingement rate at the Baxter Wilson Plant was 1.96 organisms impinged per 10,000 m^3. Impingement at the Waterford 1& 2 Plant was averaged to be 10.19 organisms per 10,000 m^3 (average of historic and current impingement rates)[3]. Impingement rate at the Michoud Plant was 9.41 organisms per 10,000 m^3 and impingement at the Paterson Plant was calculated to be 5.42 organisms per 10,000 m^3. It should be noted that these two plants also do not have CWIS that are located in the LMR main channel.

Impingement rates were estimated based on flow rate recorded during the study or by assuming the flow rate was at maximum plant capacity when flow rates were not available. Flow rates were standardized to 10,000 m^3 of water flow to allow extrapolation over time and to allow plant comparisons. These rates appear reasonable when compared to other impingement studies on large river systems. Between 1973 and 1996 an extensive impingement monitoring effort was conducted at the Quad Cities Plants located on the upper Mississippi River (LeJeone and Monzingo, 2001) (see Figures 31-33). Mean annual impingement for those years that employed open cycle cooling (1984-1996) was 952,000 organisms which are in the same order of magnitude as Entergy's plants. Annual impingement at the Waterford 1 & 2 Plant for example is estimated at

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[3] Historic and current documented impingement rates were averaged to assimilate a normalized impingement rate for this report. Riverine systems are highly variable, as evident by the Mississippi River. The fluctuating dynamics of this type of system naturally deters stabilization of impingement rates over time, as presented in the 2001 LeJeone and Monzingo study.

858,000 organisms and annual impingement at the Michoud Plant is estimated at 1,677,000 organisms (Table 2).

Using the above referenced figures it is also possible to estimate annual biomass loss due to impingement mortality. Using biomass data collected during the Waterford 1 & 2 study it was determined that 35 impinged organisms are equivalent to one pound. By extrapolating the above referenced averaged annual impingement estimates, annual impingement losses at Waterford 3 are estimated to be approximately 24.514 pounds. Potential impact to the LMR fisheries based on these rates is likely insignificant.

4.3 Definition of Performance Basis

The 316 (b) Rule is specific in that it requires an 80% reduction in IM from the Calculation Baseline. In this IMECS we have defined the Calculation Baseline (see Section 4.2.2.1) and estimated reduction in accordance with the rule. The most accurate way to accomplish this would be to measure the fish and shellfish inhabiting the theoretical Calculation Baseline, the CWIS zone of influence, and the revolving screens, all three simultaneously. This is not feasible on the Mississippi River due to safety concerns. We have taken a different approach as discussed below that meets the objectives of the Rule.

Although the rule is specific in that it established a quantitative reduction in IM, it should be noted that many NPDES permittees and regulatory agencies have historically taken more of an ecological approach in assessing performance basis as it relates to potential impact from CWIS.

Barnthouse (2004) for example, estimated that annual reductions in year class abundance for the principal Hudson River fish populations ranged from <5% to >35%. The author emphasize that the impact predictions refer to short-term reductions in abundance and he states there is no evidence that any of the species investigated have experienced any long-term declines.

In the Lewis and Seegert (2000) study conducted on the Wabush River in Indiana, it was determined the low entrainment and impingement rates indicated the stations were not adversely affecting the fish community.

In another impingement/entrainment study conducted in the mid-west by Michaud (2000), impact was deemed inconsequential and 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.

Upon review of the data collected at a power plant located on Chesapeake Bay (Ringger, 2000), the Maryland DNR concluded that the impingement losses were small and did not represent a significant impact to fish populations.

It is demonstrated in this IMECS that the Waterford 3 CWIS is in compliance with the rule based primarily on the location of the cooling water intake structures. Since the calculated impingement rates are very low, we also believe there are no short-term or long-term impacts to the fisheries due to the magnitude of the Mississippi River and the standing crop that far exceeds impingement losses.

4.3.1 Target Species

Some species have greater importance than others based on commercial/recreational importance, ecological importance, and protected status. T&E species were given extra attention in this IMECS due to their regulatory protection. After reviewing all the data, we do not believe that any other species warranted special attention at the Waterford 3 Plant. Several commercially important species impinged at Entergy's estuarine plants (e.g. blue crab, white and brown shrimp) will be focused on in their respective IMECS submittals. Likewise no specific species has been focused on in the technology assessment for the Waterford 3 Plant.

It is interesting to note that some species such as gizzard shad are often looked upon by the public and sometimes the scientific community as having limited value due to their ubiquitous nature. Although this species has ecological value and is a component to the food chain, population control of this species often occurs. Haines (2000), for example suggested biological control of gizzard shad by using predator fish species to manage and reduce impingement on cooling water intake screens. Similarly gizzard shad are often targeted in freshwater lakes/reservoirs across the United States by fisheries agencies (via lake drawdown) to manage their populations.

For the purpose of this IMECS, however, all species were treated equally important estimating the performance basis.

4.3.2 Numbers vs. Biomass

The 316(b) rule does not specify whether compliance with the IM performance standard should be based on a reduction in fish/shellfish abundance or biomass. For this reason both were evaluated. Species richness is also discussed below as a means of estimating the reduction of organisms in the main channel of the LMR compared to the channel border.

4.3.2.1 Calculation Baseline - Biomass

Calculation Baseline - Biomass

Calculation baseline is defined in Section 125.93 as "an estimate of impingement mortality and entrainment that would occur at your site assuming that: the cooling water system has been designed as a once through system; the opening of the cooling water intake structure is located at, and the face of the standard ⅜-inch mesh traveling screen is oriented parallel to, the shoreline near the surface of the source waterbody; and the baseline practices, procedures, and structural configuration are those that your facility would maintain in the absence of any structural or operational controls, including flow or velocity reductions, implemented in whole or in part for the purpose of reducing impingement mortality and entrainment". This is considered to be the worst-case for both impingement mortality and entrainment. Therefore, a CWIS located along the shoreline or in a back-water will be much more likely to be in habitat with increased populations of fish relative to those in the main channel. Using the reasoning for the Phase I rule and the Phase II Calculation Baseline, the location of existing intake structures (away from shoreline and in high velocity waters) could be used to "claim" credit for the reduction of impingement mortality and entrainment.

A similar stance was taken by a plant located in Texas (Spicer, 2000) where the design specifications developed to ensure reliability and safety also helped minimize adverse environmental impact by locating the intake zone of "low biological value" relative to alternative areas. In another analysis conducted for the construction of a new CWIS on the Mississippi River (Sempra, 2002) the company proposed to locate the new CWIS away from the shoreline and at depth to reduce environmental impact.

There is a strong consensus within the scientific community that abundance, biomass, and species richness are much lower in the mainstem (main channel) portion of the Lower Mississippi River compared to the shoreline. Fisheries data from the LMR as well as anecdotal information such as researcher knowledge are used in this IMECS to support this concept, and demonstrate compliance with the compliance standard (i.e. >80% reduction in impingement mortality) based on CWIS location.

The Calculation Baseline for Waterford 3 was estimated using historical biomass estimates for the upper and lower Mississippi River as well as estimates from other rivers around the world (see Table 9). Data collected from shoreline/backwater habitats is summarized below.

Baker et al. (1991) referenced several studies that provided fish production/biomass estimates in the Mississippi River. Fish biomass in pools averaged 153 kg/ha and ranged from 16 to 625 kg/ha. Other studies have indicated that biomass may average over 2065 kg/ha and can reach over 3860 kg/ha (Baker et al. 1988; Holland and Cobb 1989). In isolated sloughs standing stocks ranged from 145 to 939 kg/ha and averaged 510 kg/ha. According to Baker, biomass in lower Mississippi River oxbow lakes range from 162 to 1023 kg/ha with a mean of 535 kg/ha. Oxbows on tributaries average 250 kg/ha while standing crops in burrow pits average 678 kg/ha in one study.

According to Schramm (2004), fish production on the LMR has not been estimated and biomass estimates are highly variable but tend to range from 300-900 kg/ha-1. He reviewed biomass results from 5 studies (including the aforementioned Baker et al. 1991 study) that sampled, in a consistent and comparable fashion, 13 different habitats and noted the following:

- Biomass in the backwaters, burrow pits, and dyke pools averaged 671 kg/ha (Pilto, 1987, Baker et al. 1991, Cobb et al. 1984 and Lowery et al. 1987).
- Biomass in the channel border averaged 469 kg/ha (Pilto 1987).
- Biomass in the main channel averaged 21 kg/ha (Dettmers et al. 2001 – see discussion below).

We believe the density associated with the channel border is most appropriate to use as the Waterford 1&2 Calculation Baseline. The Calculation Baseline (based on biomass), therefore for the Waterford 1&2 Plant CWIS is 469 kg/ha. This is the theoretical biomass proximal to the CWIS if they were located on channel border, opposed to the main channel.

Our biomass estimate and Calculation Baseline is consistent with biomass estimates for other river systems across the world. Randall et al. (1995) summarized fish production estimates from 142 fresh water rivers across the world. Average biomass for all rivers was determined to be 146 kg/ha. Average biomass for North American Rivers was determined to be 137 kg/ha (Table 6).

Reduction from Baseline - Biomass

Data availability in the Mississippi River is more extensive along shoreline and backwater habitats compared to the mainstem and navigable portions of the river. This is primarily due to sampling obstacles associated with the open river including floating debris, barge traffic, significant depths, high currents, and the constantly changing river bed (sand dunes). Although difficult to sample, an extensive sampling effort was conducted on the upper Mississippi River (UMR – Pool 26) and lower Illinois River by Dettmers et al. (2001). A total of 151 bottom trawls, 114 were from the Mississippi River, were collected from the main channel trough (navigation channel). Total biomass density averaged 21 kg/ha for the upper Mississippi River and 29 kg/ha for the lower Illinois River. Although the biomass estimate is for the upper Mississippi River, there is no reason to believe the biomass estimate for the LMR main channel would be significantly different based on similar species and relative abundance of those species found in both systems.

The biomass estimate for the main channel (21 kg/ha) represents a 95% reduction when compared to the above referenced Calculation Baseline (channel border biomass) of 469 kg/ha. Since the biomass associated with an offshore intake is 95% less than the biomass associated with a channel border intake, it is likely that there is a corresponding reduction in impingement mortality of 95% relative to baseline. Therefore the simple location of the Waterford 3 CWIS enables the IM performance standard (>80% reduction) to be met (Figure 34).

Additionally, the literature shows that the many fish associated with the main channel are adults, and have a reduced risk for being impinged based upon their increased swimming ability and larger size.

Furthermore, the biomass comparison between shoreline and main channel assumes mortality of all organisms that are impinged at the Waterford 3 CWIS, which is not the case. The CWIS is equipped with a fish return system which enables a percentage of the organisms to return alive to the source waterbody.

Although survivability of the species impinged at the Waterford 3 Plant has not been studied, studies at other plants show some survival (see Section 4.3.2).

These biomass estimates are based on an extensive literature review and over three- hundred worldwide fish collections, approximately half associated with the Mississippi River system. We acknowledge that there is uncertainty associated with any sampling effort and that there is the potential that biomass is higher than the literature shows in the main channel due to sampling bias and inefficiencies in gear. However, anecdotal information (researcher opinions), and additional literature focused on abundance/species diversity discussed below, supports the premise that the fisheries are much reduced in the main channel compared to the shoreline.

4.3.2.2 Calculation Baseline - Abundance

Calculation Baseline - Abundance

Randall et al. (1995) summarized numeric density for 143 rivers around the world. Mean density was determined to be 75,665 fish per hectare for all rivers combined and 132,247 fish per hectare for North American rivers.

Numeric density data for channel border habitats on the LMR is not available. Although there are vast differences between river systems across the world, LMR density is not expected to be significantly different than Randall's density estimates. For this reason, the density for North American Rivers (132,000 organisms per hectare) was selected as the Calculation Baseline (based on abundance) for the Waterford 3 Plant.

Reduction from Baseline - Abundance

Dettmers et al. (2001) calculated numeric density (abundance) in Pool 26 of the Mississippi River as well as the Lower Illinois River. Numeric density in the main channel Mississippi River was calculated to be 86 fish per hectare (no./ha) and density in the Illinois River was calculated to be 166 fish per hectare. Although this study only assessed finfish (no shellfish), the abundance values are significantly smaller than that found in other riverine systems. A reduction in abundance between a CWIS located in the main channel and one located along the shoreline appears far greater than the 80% required by the rule (i.e., (132,000-166)/132,000) = 99.9%). The highest percentage of shellfish impinged at any of Entergy's plants was at Waterford 1&2 (59% of total) during the 2006-2007 study. Even if shellfish had been included in the Dettmers study (and assuming a consistent relative abundance factor) the plant would still meet the 80% reduction required by the rule (99.7% reduction).

4.3.2.3 Calculation Baseline - Species Richness

Calculation Baseline – Species Richness

Of the 137 resident species assigned habitat zones by Schramm (2004), none are expected to reside in main channel habitats throughout their life cycle, 24 are expected to occupy one or more channel border habitats throughout their life cycle and 50 species are expected to reside in one or more backwater habitats throughout their life cycle. Schramm defines the probable zone as the area of the river from which the fish have been or are likely to be collected. Channel border is listed as the probable zone for 108 species; backwater is listed as the probable zone for 107 species; and the main channel is listed as the probable zone for only 31 of the 137 species listed. This reduction in species richness corresponds similarly to the reduction in biomass and abundance between the LMR channel border and the mainstem as discussed previously.

The reduction in species in the main channel s due to several factors including the lack of suitable habitat, a vast increase in water velocity, turbidity and depth, and a reduction in nutrients and food supply for most species. According to Schramm, the 31 species thought to inhabit the main channel include lamprey, sturgeon, paddlefish, gar, shad/herring, central stoneroller, grass carp, plains minnow, pearl dace, shiners, creek chub, suckers, smallmouth buffalo, redhorse, catfish, brook stickleback, and striped bass.

A comprehensive list of species that may potentially be impinged at Entergy's power plants was compiled by combining Schramm's main channel species that are likely to occur in the LMR, with documented impinged species. A list of all species impinged at the Waterford 1 & 2 Plant, Baxter Wilson and the Willow Glen Plant is shown in Table 6. The compilation of the historic impingement list with Schramm's list is depicted in Appendix C. As noted in Appendix B, there are 42 species listed with the potential to occur in the main channel of the LMR. It should be noted that this list includes all species that were impinged regardless of their impingement rate. Many of these individuals were probably only incidentally impinged due to limited use of main channel habitat, or may have been dead prior to being impinged. Most importantly, there are only nine species that were determined by Schramm as species that inhabit the LMR which were also documented as being impinged at the aforementioned power plants.

Baker et al. (1991) compiled a similar species list to Dr. Schramm's. A total of 91 Lower Mississippi River fish species were identified and studied. Of these species Baker and his colleagues found that only five species were considered abundant (usually found in high numbers) in the main channel and only eight species were considered common (usually found in moderate numbers) in the main channel. In all, the authors state that channel habitat in the lower Mississippi River may be inhabited by only 30 or more fish species out of the 91 species that maintain reproducing populations in the river.

The Calculation Baseline (based on species richness) for the Waterford 3 Plant is 137 species based on the maximum number of species that could potentially inhabit the shoreline or channel border of the LMR.

Reduction from Baseline – Species Richness

In their study of the upper Mississippi River main channel, Dettmers et al. (2001) determined the habitat was dominated by gizzard shad and freshwater drum (each represented 30% of the total), smallmouth buffalo (10%), channel catfish (9%), shovelnose sturgeon (5%), mooneye (4%) and common carp (3%)(Figures 32 and 33). These seven species account for over 90% of the fish in the Mississippi River main channel. With the exception of the shovelnose sturgeon, these same species dominated the Illinois River main channel as well. Dominance by relatively few species in the main channel is consistent with the literature previously discussed and further illustrates the harsh environment in the main channel and the unsuitability of the habitat for most species.

Illinois Natural Heritage Survey (INHS) scientists, in collaboration with the USGS and the USACE, sampled the fishes in the main channel of the Mississippi River near Grafton, Illinois in 1996 with a specialized trawling vessel, collecting a total of 24 fish species (INHS 1997). Abundant species included freshwater drum, channel catfish, gizzard shad, smallmouth buffalo, and carp. Other fishes caught less frequently in the main channel included the shovelnose sturgeon, lake sturgeon, and blue sucker. These researchers note that many of the fish (gizzard shad, channel catfish, and smallmouth buffalo) use the main channel during the entire year as they are suited for life in fast-flowing river conditions. Many other fishes use the main channel only seasonally. The study's most diverse catches occurred in September and October when the river was at its lowest and temperatures were moderate. In these conditions, fish common to backwaters (e.g., bigmouth buffalo, shortnose gar, and black crappie) were found in the main channel. Although this study focused on the fishes in the UMR main channel, the species are similar to those documented on the lower portions of the river.

At the Waterford 1 & 2 plant, seven species represented over 96% of the organisms impinged in the 2006-2007 study. Only nine species represented 98% of the organisms impinged 1976 to 1977. These studies suggest a significant reduction in species richness in the main channel compared to the 137 (Calculation Baseline) potential species that inhabit the LMR.

As stated previously, a reduction in the fisheries in the LMR main channel is due to several factors, most importantly increased velocities, debris, and the lack of suitable habitat. Additionally, a lack of a food source could also play a factor in the spatial differences observed between habitats. Eggleton and Schramm (2004) compared feeding ecology and energetic relationships with habitat of blue catfish and flathead catfish. They concluded that caloric densities of consumed foods for both species are generally greatest in floodplain, intermediate in secondary river channels, and least in the main river channel.

Similar findings were observed by Junk and Wantzen (2004) who noted that primary production in the floodplain is much higher than in the main channel. These factors help to further explain why there is a significant difference in fish/shellfish abundance, biomass, and species between the main channel and shoreline/channel border.

4.4 Estimation of Current Performance Relative to the Calculation Baseline

The rule is not explicit in how to define the theoretical Calculation Baseline and also how to measure IM reductions against the baseline. As demonstrated in Section 4.2 we have taken a broad approach and compared three biological measurements between the main channel and channel border: biomass; abundance and species richness. The data show that there is at least an 80% reduction in all three measurements due to the main channel location of the CWIS at Waterford 3.

Additionally, the Calculation Baseline assumes there are no technologies installed that return fish/shellfish back to the source waters. The Waterford 3 Plant is equipped with a debris handling system and associated enhanced ditch that returns debris and organisms back to the Mississippi River outside of the CWIS zone of influence. The current configuration of the debris handling and return system is only effective when the river is at moderate to high stages to allow the organisms to be discharged directly into the river. Based on best professional judgment (BPJ) the reduction in IM associated with the fish return system is estimated conservatively at 10% based on extended survivability studies at other plants.

We believe the combination of "credit" for the fish return system, and the reduction in biomass and abundance in the main channel compared to the channel border is will in excess of the 80% IM reduction required by the rule, see Table 4-1 of the DCPT Document.

4.4.1 Review of CWIS Structure and Operation

The Waterford 3 Plant consists of a nuclear generating unit which employs open cycle cooling. The intake structure is situated 162 feet offshore in approximately 40 feet of water. The unit obtains water directly from the non-tidal portion of the Mississippi River, see Habitat Review Section 2.0.

The CWIS is equipped with eight sets of traveling screens, 90% of which are equipped with 1/4" mesh; the remaining 10% utilize 3/8" mesh screening. Each screen is cleaned by a high pressure spray was from two parallel headers located on the inside of the ascending side of the screen. The spray system can be operated manually or automatically at either high or low speeds. Impinged organisms are returned via a combined sluiceway system which discharges organisms into a common ditch that flows directly to the Mississippi River. All organisms are returned away from the influence of the intake pipes and cooling water discharge zone. Frequency of screen rotation and washing is entirely dependent on debris load and may occur on an hourly basis (high load) or on a daily basis (low load). See the Design and Construction Technology Plan (DCTP) and 40 CFR Section 122.21 submittals for an in-depth analysis of the CWIS structure and operation.

4.4.2 Impingement Mortality

Impingement mortality survival studies have only been conducted at Entergy's Paterson Plant. Weighted extended survival of the primary species impinged at the facility show that 37% of the organisms will survive impingement which significantly reduces any potential adverse impact created by the plant. Initial and extended survival rates were also calculated by EPRI (2003). Mean extended survival rates for fresh water species ranged from 11% for black crappie to 93% for blue gill. Survival of estuarine organisms ranged from 0% for spotted seatrout to 83% for brown shrimp (see Table 4).

These data demonstrate that a portion of the organisms that are impinged survive and are returned to the river alive. This is important as it relates to the compliance strategy for the Waterford 3 Plant. As stated in the PIC document, Entergy believes the existing fish return system should be credited 10% towards the Calculation Baseline.

5.0 Summary and Conclusions

Entergy has carefully reviewed the various studies supported on the LMR at and near several Entergy-owned power plants located on the shores of the river relative to impingement on the CWIS's intake screens as part of its effort to comply with the Rule relative to impingement and entrainment losses at these plants. In addition, to the "in-house" studies, Entergy has carefully reviewed numerous extant published studies pertaining to the ichthyofauna of the LMR, as well as some of the studies on the Upper Mississippi River, in an effort to determine the species composition, abundance and distribution along the river. This review has addressed all of the various aquatic habitats that have been identified as being associated with the river and its fishery populations, including the near shore, open water, side channels and depths within the river. Finally, Entergy has initiated personal communications with both the various recognized agencies and individuals who are generally considered to be the authorities on the status of the fish abundance, their distribution and habitat preferences for the river and its associated waters for the purpose of getting their opinion on the current status of the river associated fish populations. These reviews have placed emphasis on the Threatened and Endangered species that might occur in the river and therefore, be susceptible to impingement and/or entrainment by the power plants located along the LMR.

The data presented in the Entergy studies typically shows very low numbers of organisms being impinged on the screens of the plants studied as compared to fisheries data for onshore or nearshore. This is not an unexpected finding given that the intake structures typically consist of large pipes located on or near the river bottom at some distance from the shoreline and are located in the main channel of the river through whence water is pumped to the screens and then into the units themselves. This type of intake design complies with the previous EPA 316(b) Guidelines. The thinking of the day, confirmed by both the literature and the resources that were personally contacted as part of this work, was that population densities of the most vulnerable life stages to impingement would be at their lowest in the main channel of the river. Thus, such an intake system would greatly reduce impingement on the screens. At the time of the installation of these intakes, this system was generally considered to reflect Best Technology Available (BTA).

Based on the evidence presented in this document, Entergy concludes that the location of the existing intake structure results in a 95% reduction in IM relative to the calculation baseline condition. The substantial body of literature reviewed and interviews with recognized fisheries experts all indicated that fish populations are significantly lower in the main channel of the River where the intake structure is located. The reduction due to this location is sufficient to achieve the Rule's performance goals for IM (80-95% reduction relative to the Calculation Baseline). Therefore, Entergy believes Waterford 3 is in compliance with Alternative 2 of the Rule.

This finding is based on a review of an extensive body of literature on fish population distributions in the LMR and interviews with recognized experts. In addition, impingement studies conducted at Waterford 1&2 have found that relatively low numbers of fish are impinged, supporting the notion that the location of this intake structure results in reduced impingement relative to the calculation baseline. In combination, Entergy believes this information is sufficient to demonstrate the performance of the intake structure and meet the Rule's requirements for the IMECS.

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Tables

Table 1. Description of Aquatic Habitats in the Lower Mississippi River.

River Habitat[1]	Features	Description	Location
Channel	Main channel & Secondary Channel	Channel habitat is characterized by those portions of the river with continuous flowing water. Habitats change little from season or river stage. Microhabitats associated with shifting sediments are common and change on a daily basis. Sediment loads vary by location on the river.	Channel habitats are present throughout the entire reach of the river. Channel steepness and depth are dependent upon sediment types in the substrate.
Natural Steep Bank	Steep slopes or cut banks	Occur on the concave sides of river bends. Steep banks typically adjoin channel habitats. Highly subject to erosion.	More common in portions of the river north of Baton Rouge where sediments are comprised of sand and gravel, mud and point bar deposits.
Revetment	Protective materials usually consisting of man-made materials such as concrete, tires, rip rap etc.	Usually associated with the concave side of bends. Commonly used throughout the lower Mississippi River along the steep banks.	Due to increased erosion revetments are commonly used in the lower Mississippi River.
Lotic Sandbar	Shallow sloping habitats	Habitats located along point bars, borders of islands, middle bars, and dike systems. Moderate to swift currents, coarse sand or sand-gravel substrate. Conditions are similar to the channel habitats.	Materials from these habitats typically create dunes on the river bottom. Usually occurs a few meters from shore.

Table 1. Description of Aquatic Habitats In the Lower Mississippi River.

River Habitat[1]	Features	Description	Location
Pool	Slack or slow water areas	Slow or no current areas associated with downstream sides of dikes, islands, middle bars, and point bars. They are typically deep and have fine sediments and do not support substantial amounts of brush or debris.	Pools are more common during low flow conditions and can be found along the entire reach of the river. However, most pools are associated with dike systems which are common in portions of the river north of Baton Rouge.
Lentic Sandbar	Shallow sloping habitats	Usually associated with low currents, fine sediments and shallower depths. These habitats are ephemeral and are more common during constant river stage.	Usually occurs near the shoreline.
Contiguous slough	Slackwater, flood plain habitats. Connected to the main channel during most river stages	Usually remnants from abandoned river channels however they are usually quite narrow and closer to the mainstem river.	Typically found in those portions of the river where substantial river meanders occur. Also present throughout the river during low flow conditions.
Isolated Slough	Slackwater, flood plain habitats.	Usually remnants from abandoned river channels however they are usually quite narrow and closer to the mainstem river.	Typically found in those portions of the river where substantial river meanders occur.

Table 1. Description of Aquatic Habitats in the Lower Mississippi River.

River Habitat[1]	Features	Description	Location
Oxbow Lake	Former river channels	Remnant portions of the river which were cut off from the main river channel. They are fairly deep and fairly large (200 to > 1600ha). Shorelines associated with oxbows are usually wooded and heavily vegetated.	Located along meandering sections of the river. The greatest number of Oxbow lakes appear north of Baton Rouge.
Levee Borrow Pit	Manmade floodplain habitats	These habitats are formed by the removal of fill materials for levee construction. They vary in size, time period in which they are flooded, and habitats associated with them.	Located in those reaches of the river that have high sediment deposits in the floodplain and are typically above river flood stage.
Floodplain Ponds	Permanent, small, shallow ponds	These ponds are located in the alluvial river swamps. They are similar to isolated sloughs and oxbow lakes; however, much smaller. They form indepressional areas and tributaries to the river and are associated with Tupelo-Cypress wetlands.	Typically found in those portions of the river where substantial river meanders occur.

Table 1. Description of Aquatic Habitats in the Lower Mississippi River.

River Habitat[1]	Features	Description	Location
Seasonally Inundated Floodplain	High river stages over low-lying lands	Areas used to include lands well outside the main river. However, construction of the levee system has separated those floodplain areas and isolated those within the river channel areas. Some of the outlying areas still receive flood waters associated with tributary flooding. The river floodplain within the levees is inundated during peak flood periods. Habitats in these areas are associated with swift currents to slack areas near the periphery.	Located in those areas near old river meanders and around sandbar deposits. Found throughout the entire reach of the river except where revetments occur.
Tributary	Downstream portion of tributary where it meets the mainstem river.	Habitats are associated with the backwater flooding of the tributaries. Usually low flowing areas with sand-silt to mud bottoms. Have areas of significant brush and debris accumulation.	There are no significant tributaries to the Mississippi River below Baton Rouge.

[1] Habitats presented in this table are derived from Baker et al. (1991).

Table 2. Summary of Historical Impingement Studies at Entergy's Power Plants on the Lower Mississippi River

Location	Study Title	River Mile	Period of Sampling	Sampling Frequency	Sampling Duration	Sampling Location	Estimated Annual Impingement Rate (organisms/yr)[a]	Plant Capacity (gpm)	Estimated Annual Impingement per 10,000 m^{3} [b]	Ten Most Common Species
Baxter Wilson	Baxter Wilson Impingement Study	433.2	March 12, 1973 - August 20, 1973	March 12 - May 11, 1973: Daily, May 12 - August 20, 1973 : *Twice per week*; August 31, 1973 - March 1, 1974: Once per week for 24 hours	24 hours	Screen wash trough	160,730	412,000	1.96c	**Total 97.1%** - Freshwater drum (31.7%), Gizzard shad (30.8%), Shad *spp. (22.2%). Threadfin shad (3.3%)*, Carp (2.7%), River shrimp (2.6%),White crappie (1.5%), Sucker (1.3%), Channel catfish (0.7%), Skipjack herring (0.4%)
Willow Glen Units 1 & 2	Willow Glen 316(a) and 316(b) Demonstration	201.6	January 1975 - January 1976	April - July. 4 times per month; 2 times per month remainder of year. 30 minute samples collected 4 times over 24 hours	24 hours	Sluiceway	26,210	171,000	1.47d	**Total 97.4 %** - River shrimp (57.3%), Freshwater drum (22.1%), Gizzard shad (5.7%), Threadfin shad (5.1%), Crayfish (2.6%), Blue catfish (2.4%), Black crappie (0.7%), Skipjack herring (0.6%), Bluegill (0.6%), White crappie (9 5%)
Willow Glen Unit 4	Willow Glen 316(a) and 316(b) Demonstration	201.6	January 1975 - January 1976	April - July; 4 times per month; 2 times per month remainder of year. 30 minute samples collected 4 times per day	24 hours	Sluiceway	5,037	228,000	0.13d	**Total 94.5%** - River shrimp (27.5%), Crayfish (27.0%). Freshwater drum (12.5%). Gizzard shad (9.3%), Threadfin shad (7.5%). Blue catfish (5 8%), Bluegill (1 4%) White crappie (1.4%), Channel catfish (1.2%). Skipjack herring (0.9%)
	Willow Glen Plant						Weighted-average	902,400	0.70	
Waterford 1 & 2	Screen Impingement Studies	129 7	February 1976 - January 1977	24 samples; 4 times per month	24 hours	Screen wash trough	336,454	429 000	4.22d	**Total 98.7%** - River shrimp (49.7%), Blue catfish (20.3%). Threadfin shad (10.5%). Bay anchovy (6 0%), Freshwater drum (4.5%), Gizzard shad (2 9%), Skipjack herring (2.4%). Channel catfish (2 1%), Striped mullet (0.3%), Blue crab (0.2%)
Waterford 1 & 2	Current Impingement Study	129.7	September 2006-August 2007	Once per month, two 12-hour samples in 24 hours	24 hours	Screen wash trough	1,379,533	429,000	16.16d	**Total 98.1%** - River shrimp (55.5%), Threadfin shad (13.4%), Blue catfish (11.1%). Grass shrimp (8 0%), Channel catfish (4.4%), Freshwater drum (3.2%), Bay anchovy (1.2%), Hogchoker (0.5%), Silverband shiner (0 4%), and Paddlefish (0.4%).
	Waterford 1 & 2 Plant					Average	857,994		10.19d	
Paterson	*Impingement Impact* of A.B. Paterson & Michoud Stations	*branches off at* RM 92.6	*August 1977 -* December 1979	*Every other Thursday 10-*minute samples collected every 4 hours for 24 hours	*24 hours*	*Sluiceway*	226,489	149,581	*5.42d*	**Total 90.7%** - *Atlantic croaker* (32.2%), Bay anchovy (17.1%), White seatrout (12.6%). Blue crab (10.5%), Gulf menhaden (6 6%), Sea catfish (4.5%), *White shrimp (2.4%), Spot* croaker (1.9%), Spotted seatrout (1.8%), Hogchoker (1.1%)
Michoud	Impingement Impact of A.B. Paterson & Michoud Stations	branches off at RM 92 6	August 1977 - December 1979	Every other Thursday. 10-minute samples collected every 4 hours for 24 hours	24 hours	Sluiceway	1,676,726	529,750	9.41d	**Total 91.2%** - Atlantic croaker (21.5%), White shrimp (20.0%), Bay anchovy (13.5%), Brown shrimp (10.5%), Blue crab (9.0%), Sea catfish (7.8%). White seatrout (4.2%), Gafftopsail catfish (1.8%), Least puffer (1 6%), Blackcheek tonguefish(1.4%)

a - Impingement rate estimated based on sampling effort

b - Impingement rate estimated based on flow rate recorded during study

c - Flow rate used to calculate impingement rate were assumed to be at maximum plant capacity

d - Flow rates were recorded during impingement study and used to calculate impingement rate

Table 3:
Summary of Species Dominating Historic Impingement at Entergy Plants on the Lower Mississippi River

Mississippi River Mainstem (4 units)				Estuary (2 plants)			
Species	Average	Min	max	Species	Average	Min	max
River Shrimp	34.3%	2.6%	57.3%	Atlantic Croaker	26.9%	21.5%	32.2%
Freshwater Drum	17.7%	4.5%	31.7%	Bay Anchovy	15.3%	13.5%	17.1%
Gizzard Shad	12.2%	2.9%	30.8%	White Shrimp	11.2%	2.4%	20.0%
Crayfish	7.4%	2.6%	27.0%	Blue Crab	9.8%	9.0%	10.5%
Blue Catfish	7.1%	0.0%	20.3%	White Seatrout	8.4%	4.2%	12.6%
Threadfin Shad	6.6%	3.3%	10.5%	Sea Catfish	6.2%	4.5%	7.8%
Shad Sp.	5.6%	0.0%	22.2%	Brown Shrimp	5.3%	10.5%	10.5%
Bay Anchovy	1.5%	0.0%	6.0%	Gulf Menhaden	3.3%	6.6%	6.6%
Skipjack Herring	1.1%	0.4%	2.4%	Spot Croaker	1.0%	1.9%	1.9%
Channel Catfish	1.0%	0.0%	2.1%	Spotted Seatrout	0.9%	1.8%	1.8%
Carp	0.7%	0.0%	2.7%	Gafftopsail Catfish	0.9%	1.8%	1.8%
White Crappie	0.5%	0.0%	1.5%	Least Puffer	0.8%	1.6%	1.6%
Bluegill	0.5%	0.0%	1.4%	Blackcheek Tonguefish	0.7%	1.4%	1.4%
Sucker	0.3%	0.0%	1.3%	Hogchoker	0.6%	1.1%	1.1%
Black Crappie	0.2%	0.0%	0.7%	Total	91.0%		
Stipped Mullet	0.1%	0.0%	0.3%				
Blue Crab	0.1%	0.0%	0.2%				
Total	96.7%						

Table 4. Length, Weight, Survival, and Swimming Speed Characteristics for Species Impinged at Entergy's Power Plants

		Length (mm)[1]		Weight (g)[2]		Initial Survival[3]		Extended Survival[4]		Swimming Speeds (cm/s)	
Common Name	**Scientific Name**	**Average**	**Median**	**Average**	**Median**	**Average**	**Median**	**Average**	**Median**	**Median/Mean**	**Critical/Optimum**
Freshwater Species											
Freshwater Drum	*Aplodinotus grunniens*	86.4	64.8	41.9	4.5	0.545	0.528	0.227	0.204	90 d	NA
Ohio river shrimp	*Macrobrachium ohione*	55.5	55.8	3.0	3.6	0.500	0.500	NA	NA	0.76 e	NA
Gizzard Shad	*Dorosoma cepedianum*	115.2	109.5	66.0	2.4	0.693	0.884	0.284	0.070	2 - 4 a	10 a
Threadfin Shad	*Dorosoma petenense*	63.3	53.5	4.7	1.5	0.325	0.153	NA	NA	2 - 4 a	10 a
Common carp	*Cyprinus carpio*	398.0	398.0	1545.3	1984.2	0.595	0.630	0.469	0.472	NA	166 h
Black crappie	*Pomoxis nigromaculatus*	NA	NA	NA	NA	0.624	0.607	0.119	0.014	NA	NA
Crappies	*Pomoxis* sp.	NA	NA	NA	NA	0.493	0.493	0.290	0.290	NA	NA
Channel Catfish	*Ictalurus punctatus*	71.8	62.8	18.6	2.6	0.843	0.800	0.697	0.588	50 f	55.2 g
Bluegill	*Lepomis macrochirus*	46.3	44.8	8.6	4.0	0.905	1.000	0.926	0.971	NA	101 - 130 j
Sucker family	Catostomidae	NA	NA	NA	NA	0.562	0.538	0.480	0.436	NA	169 - 259 k
Smallmouth buffalo	*Ictiobus bubalus*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bigmouth buffalo	*Ictiobus cyprinellus*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Skipjack herring	*Alosa chrysochloris*	119.4	112.0	42.8	8.1	NA	NA	NA	NA	NA	NA
Alosa species	*Alosa* sp.	NA	NA	NA	NA	0.736	0.839	0.206	0.061	NA	NA
Blue catfish	*Ictalurus furcatus*	86.8	83.8	22.4	12.1	NA	NA	NA	NA	30 b	NA
Brackish Species											
White shrimp	*Penaeus setiferus*	NA	NA	NA	NA	0.689	0.706	0.806	0.806	NA	NA
Brown shrimp	*Penaeus aztecus*	NA	NA	NA	NA	0.815	0.907	0.830	0.850	NA	NA
Bay anchovy	*Anchoa mitchilli*	NA	NA	NA	NA	0.295	0.178	0.100	0.000	21.1 i	NA
Gulf menhaden	*Brevoortia patronus*	NA	NA	NA	NA	0.249	0.251	0.136	0.136	NA	NA
Blue Crab	*Callinectes sapidus*	NA	NA	NA	NA	0.858	0.921	0.664	0.735	NA	NA
Hardhead sea catfish	*Arius felis*	NA	NA	NA	NA	0.434	0.277	0.710	0.703	NA	NA
Sand weakfish	*Cynoscion arenarius*	NA	NA	NA	NA	0.239	0.194	0.265	0.265	NA	NA
Spotted seatrout	*Cynoscion nebulosus*	NA	NA	NA	NA	0.544	0.400	0.000	0.000	81 l	NA
Sea trouts, Weakfishes	*Cynoscion* sp.	NA	NA	NA	NA	0.157	0.157	0.579	0.579	NA	NA
Striped mullet	*Mugil cephalus*	NA	NA	NA	NA	0.599	0.574	0.428	0.396	32 - 83 c	50 - 130 c
Atlantic croaker	*Micropogon undulatus*	NA	NA	NA	NA	0.669	0.827	0.416	0.357	NA	NA
Spot	*Leiostomus xanthurus*	NA	NA	NA	NA	0.622	0.718	0.410	0.332	NA	NA
American Shad	*Alosa sapidissima*	NA	NA	NA	NA	0.658	0.870	0.067	0.001	NA	NA
Least puffer	*Sphoeroides parvus*	NA	NA	NA	NA	0.738	0.729	0.610	0.610	NA	NA
Blackcheek tonguefish	*Symphurus plagiusa*	NA	NA	NA	NA	0.778	0.770	0.796	0.796	NA	NA

Notes:
NA - Data not available
1 Average and median length of impinged organisms from Waterford 1 & 2 and Willow Glen 4
2 Average and median weight of impinged organisms from Waterford 1 & 2, Willow Glen 1 & 2 and Willow Glen 4
3 Initial Survival. EPRI 2003.
4 Extended Survival (24 - 120 hours after impingement) EPRI 2003.
a Median and optimum swimming speeds. Barnes, J. 1977.
b Mean sustained speed. Venn Beecham et al., 2003.
c Median and optimum swimming speeds for fish 2.5-6.5 cm. Rulifson, R.A. 1977.
d Mean cruising speed for red drum. Wakeman and Wohlschlag. 1982
e Mean speed for freshwater shrimp. Medland, et al., 2000
f Mean sustained speed. Venn Beecham et al. 2003.
g Critical speed. Sylvester 1992.
h Optimum speed. Wolter and Arlinghaus. 2003
i Cruising speed for Northern anchovy. Huntley and Zhou. 2004.
j Critical speed. Wolter and Arlinghaus. 2003.
k Critical speed for white sucker. Wolter and Arlinghaus. 2003
l Mean cruising speed. Huntley and Zhou. 2004.

Table 5. Potential Threatened Endangered Species to Inhabit Waters in Vicinity of Entergy's Power Plants located on the Lower Mississippi River

Mississippi River T&E Species				Baxter Wilson LA070101	AB Paterson LA041501 Michoud LA041901	Ninemile LA070301	Little Gypsy Waterford 1&2 LA070301		Willow Glen LA070301
Scientific Name	Common Name	Federal Status	Louisiana Status	Madison Parish	Orleans Parish	Jefferson Parish	St. Charles Parish	St. John the Baptist Parish	East Baton Rouge Parish
<u>Bivalvia</u>									
Pleurobema rubrum	Pyramid pigtoe	Unlisted	Unlisted	X					
Actinonaias ligamentina	Mucket	Unlisted	Unlisted	X					
Elliptio dilatata	Spike	Unlisted	Unlisted	X					
Potamilus inflatus	Inflated heelsplitter	T	T						X
<u>Osteichthyes</u>									
Polyodon spathula	Paddlefish	Unlisted	Prohibited				X		
Scaphirhynchus albus	Pallid sturgeon	E	E		X		X		X
Acipenser oxyrinchus desotoi	Gulf sturgeon	T	T		X				
Alosa alabamae	Alabama shad	C	Unlisted						X
<u>Reptillia (Snakes not included)</u>									
Macrochelys temminckii	Alligator snapping turtle	Unlisted	Restricted Harvest	X				X	
Malaclemys terrapin	Diamondback terrapin	Unlisted	Restricted Harvest		X	X			

E = Endangered, T = Threatened, C = Candidate

Table 6. Combined List of Species Impinged at Waterford 1&2, Willow Glen, and Baxter Wilson

	Common Name	Scientific Name
1	Skipjack herring	*Alosa chrysochloris*
2	Black bullhead	*Ameiurus melas*
3	Yellow bullhead	*Ameiurus natalis*
4	Bowfin	*Amia calva*
5	Bay anchovy	*Anchoa mitchilli*
6	American eel	*Anguilla rostrata*
7	Pirate Perch	*Aphredoderus sayanus*
8	Freshwater drum	*Aplodinotus grunniens*
9	Sheepshead	*Archosargus probatocephalus*
10	Gulf menhaden	*Brevoortia patronus*
11	Blue crab	*Callinectes sapidus*
12	Goldfish	*Carassius auratus*
13	River carpsucker	*Carpioides carpio*
14	Sucker	Catostomidae
15	Flier	*Centrarchus macropterus*
16	Asian clam	*Corbicula* spp.
17	Blue Sucker	*Cycleptus elongatus*
18	Minnow	Cypinidae
19	Chub	Cyprinidae
20	Carp	Cyprinidae
21	Common carp	*Cyprinus carpio*
22	Atlantic stingray	*Dasyatis sabina*
23	Gizzard shad	*Dorosoma cepedianum*
24	Threadfin shad	*Dorosoma petenense*
25	Shad	*Dorosoma sp.*
26	Ladyfish	*Elops saurus*
27	Pickerel	*Esox sp.*
28	Goldeye	*Hiodon alossoides*
29	Mooneyes	*Hiodon sp.*
30	Mooneye	*Hiodon tergisus*
31	Cypress minnow	*Hybognathus hayi*
32	(Mississippi) Silvery minnow	*Hybognathus nuchalis*
33	Minnow	*Hybognathus sp.*
34	Silver chub	*Hybopsis storeriana*
35	Bighead carp	*Hypophthalmichthys nobilis*
36	Chestnut lamprey	*Ichthyomyzon castaneus*
37	Catfishes	Ictaluridae (catfishes)
38	Blue catfish	*Ictalurus furcatus*
39	Channel catfish	*Ictalurus punctatus*
40	Smallmouth buffalo	*Ictiobus bubalus*
41	Bigmouth buffalo	*Ictiobus cyprinellus*
42	Buffalo spp.	*Ictiobus sp.*
43	Lampsilis clam	*Lampsilis* spp.
44	Longnose gar	*Lepisosteus osseus*
45	Shortnose gar	*Lepisosteus platostomus*
46	Green sunfish	*Lepomis cyanellus*
47	Warmouth	*Lepomis gulosus*

Table 6 (continued). Combined List of Species Impinged at Waterford 1&2, Willow Glen, and Baxter Wilson

	Common Name	Scientific Name
48	Orangespotted sunfish	*Lepomis humilis*
49	Bluegill	*Lepomis macrochirus*
50	Longear sunfish	*Lepomis megalotis*
51	Redear sunfish	*Lepomis microlophus*
52	Spotted sunfish	*Lepomis punctatus*
53	Sunfish	*Lepomis sp.*
54	Bantam sunfish	*Lepomis symmetricus*
55	River shrimp	*Macrobrachium ohione*
56	Sicklefin shiner (Chub)	*Macrohybopsis meeki*
57	Silver chub	*Macrohybopsis storeriana*
58	Speckled chub	*Macrohyobopsis aestivalis*
59	Spotted bass	*Micropterus punctulatus*
60	Largemouth Bass	*Micropterus salmoides*
61	Spotted sucker	*Minytrema melanops*
62	White bass	*Morone chrysops*
63	Yellow bass	*Morone mississippiensis*
64	Striped bass	*Morone saxatilis*
65	Striped mullet	*Mugil cephalus*
66	Golden shiner	*Notemigonus crysoleucas*
67	Emerald shiner	*Notropis atherinoides*
68	Pugnose minnow	*Notropis emiliae*
69	Silverband shiner	*Notropis shumardi*
70	Minnow	*Notropis sp.*
71	Weed shiner	*Notropis texanus*
72	Mimic shiner	*Notropis volucellus*
73	Stonecat madtom	*Noturus flavus*
74	Tadpole madtom	*Noturus gyrinus*
75	Speckled madtom	*Noturus leptacanthus*
76	Madtom	*Noturus sp.*
77	Rainbow trout	*Oncorhynchus mykiss*
78	Worm Eel	*Ophichthidae spp.*
79	Grass Shrimp	*Paleomonetes kadiakensis*
80	Southern flounder	*Paralichthys lethostigma*
81	Perch	Percidae
82	Suckermouth minnow	*Phenacobius mirabilis*
83	Bullhead minnow	*Pimephales vigilax*
84	Paddlefish	*Polyodon spathula*
85	White crappie	*Pomoxis annularis*
86	Black crappie	*Pomoxis nigromaculatus*
87	Crappie	*Pomoxis sp.*
88	Crayfish	*Procambarus* spp.
89	Flathead catfish	*Pylodictis olivaris*
90	Pallid sturgeon	*Scaphirhynchus albus*
91	Shovelnose sturgeon	*Scaphirhynchus platorhynchus*
92	Sauger	*Stizostedion canadense*
93	Walleye	*Stizostedion vitreum*
94	Hogchoker	*Trinectes maculatus*

Table 7. Results of Ambient Fisheries Assessments from Grand Gulf and Waterford 3 Studies

Study Title	Location	River Mile	Period of Sampling	Sampling Frequency	Sampling Duration	Sampling Location		Six Most Common Species
Environmental Field Measurements Program	Grand Gulf Units 1 & 2	400 - 410	June 1972 - August 1973	Monthly		Main River - Stations 1, 3, 5, 6, 8 & 10		**Total 69.7%** - Gizzard shad (37.4%) freshwater drum (10.3%), blue catfish (8.3%), flathead catfish (4.9%), river carpsucker (4.8%) smallmouth bufallo (4.0%)
Environmental Field Measurements Program	Grand Gulf Units 1 & 2	400 - 408	June 1972 - August 1973	Monthly		Near Shore - Stations 1 & 8		**Total 91.8%** - Threadfin shad (30.8%) emeral shiner (25.5%), river shiner (14.1%), silvery minnow (11.6%), shiner spp. (6.9%), cypress minnow (2.9%)
Environmental Field Measurements Program	Grand Gulf Units 1 & 2	400 - 408	August 1973	Once		Near Shore - No current - Station 1		**Total 97.1%** - Threadfin shad (36.2%), gizzard shad (31.5%), silvery minnow (23 6%), red shiner (2.6%), cypress minnow (2.3%), shiner spp. (0.9%)
Environmental Field Measurements Program	Grand Gulf Units 1 & 2	400 - 408	August 1973	Once		Near Shore - Moderate current - Station 1		**Total 79.0%** - Channel catfish (22.8%), silver chub (20.8%), mooneye (15.0%), freshwater drum (8.8%), shiner spp. (6.2%), silvery minnow (5.4%)
Environmental Field Measurements Program	Grand Gulf Units 1 & 2	400 - 408	August & September 1973	5 trawl efforts conducted in August. 3 trawl efforts in September	15 minute tow (trawling)	Mississippi River Channel - Stations 3 & 6	Average Number of fish caught per hour: 37.07	**Total 91.7%** - Bluecatfish (29.2%), River shrimp (13.9%), shovelnose sturgeon (13.9%), Silver chub (12.5%), gizzard shad (5.6%), speckled chub (5.6%), grass shrimp (5.6%), channel catfish (5.6%)
Environmental Field Measurements Program	Grand Gulf Units 1 & 2	400 - 410	September 1972 - August 1973	Dominant fish species in 3 macrohabitats		Backwater: Station 1		**Total 66.3%** - gizzard shad (30.2%), blue catfish (10.0%), river carpsucker (7.8%), freshwater drum (6.5%), Shovelnose sturgeon (6.0%), White crappie (5.8%)
Environmental Field Measurements Program	Grand Gulf Units 1 & 2	400 - 410	September 1972 - August 1973	Dominant fish species in 3 macrohabitats		River Bank: Stations 3,5, 6, 8		**Total 86.3%** - gizzard shad (52.3%), freshwater drum (15.5%), silver chub (5.6%), flathead catfish (5.2%), blue catfish (4.9%), river carpsucker (2.8%)
Environmental Field Measurements Program	Grand Gulf Units 1 & 2	400 - 410	September 1972 - August 1973	Dominant fish species in 3 macrohabitats		Tributary: Station 10		**Total 68.3%** - gizzard shad (18.4%), shortnose gar (13.3%), blue catfish (12.4%), freshwater drum (11.0%), smallmouth buffalo (6.9%), Bowfin (6.3%)
Environmental Field Measurements Program	Grand Gulf Units 1 & 2		August 1973	Electrofishing	1.8 hours of effort	Hamilton & Gin Lakes	Average number of fish collected per hour: 275.3	**Total 94.3%** - bluegill (35.5%), threadfin shad (27.2%), gizzard shad (21.9%), sunfish sp. (3.8%), black crappie (3.1%), largemouth bass (3.1%)
Environmental Field Measurements Program - Larval fish	Grand Gulf Units 1 & 2	400 - 408	July 1973	Ichthyoplankton - Three replicate samples collected from surface using 0.505 mm mesh plankton net, twice per month	15 minute tow	Mississippi River Channel - Diurnal - Stations 3 & 6	Density of fish: 0.5415 per m3	**Total 92.4%** - Shad (42.0%), minnows (30.1%), drum (17.1%), crapple (2.6%), sunfish. (0.4%), sucker (0.2%)

Table 7. Results of Ambient Fisheries Assessments from Grand Gulf and Waterford 3 Studies

Study Title	Location	River Mile	Period of Sampling	Sampling Frequency	Sampling Duration	Sampling Location		Six Most Common Species
Evaluation of the Waterford 3 Generating Station - Surveillance Program	Waterford 3	129.5	April 1973 - September 1976	Intermittently using a combination of gear types: surface trawls, otter trawls, gill nets and electronshockers		Vicinity of Waterford 3		Total 90.1% - Gizzard shad (38.0%), blue catfish (18.1%), threadfin shad (14.5%), striped mullet (10.4%), freshwater drum (6.9%), skipjack herring (2.2%)
Louisiana Pwer and Light 316(b) Demonstration	Waterford 3	129.5	April 1973 - September 1976	Three years using gill nets and electroshocking	48 hour gillnetting & 2 hr electroshicking	RM 126 - 132	Average Number of fish caught per hour: 1.22	Total 90.1% - Gizzard shad (38.0%), blue catfish (18.1%), threadfin shad (14.5%), striped mullet (10.4%), freshwater drum (6.9%), skipjack herring (2.2%)
Louisiana Pwer and Light 316(b) Demonstration	Waterford 3	129 5	April 1973 - September 1976	Three years using gill nets and electroshocking	48 hour gillnetting & 2 hr electroshicking	RM 126 - 132 - shallow stations	Average Number of fish caught per hour: 0.77	
Louisiana Pwer and Light 316(b) Demonstration	Waterford 3	129.5	April 1973 - September 1976	Three years using gill nets and electroshocking	48 hour gillnetting & 2 hr electroshicking	RM 126 - 132 - deep stations	Average Number of fish caught per hour: 1.04	
Louisiana Pwer and Light 316(b) Demonstration	Waterford 3	129.5	April 1973 - September 1976	Three years using gill nets and electroshocking	48 hour gillnetting & 2 hr electroshicking	RM 126 - 132	Minimum and Maximum Length of Fish (mm)	Gizzard shad (25 - 341), blue catfish (17 - 655), threadfin shad (17 - 190), striped mullet (68 - 397), freshwater drum (13 - 306), skipjack herring (20 - 325)

Table 8. Mean Sizes of Fish Impinged at Power Plants Located on the Lower Mississippi River.

Species	Historical Length	Current Length
gizzard shad	11.5 cm	8.0 cm
threadfin shad	6.3 cm	6.4 cm
freshwater drum	8.6 cm	7.7 cm
blue catfish	8.7 cm	13.1 cm
channel catfish	7.2 cm	7.3 cm
bluegill	4.6 cm	10.0 cm
skipjack herring	11.9 cm	6.6 cm
common carp	39.9 cm	24.2 cm
river shrimp	5.6 cm	5.1 cm

Table 9. *Fish Production in Rivers (only rivers with biomass and/or density data are presented below),* see article for complete list

River	Biomass (kg per ha)	Density (no. per ha)	References
Amazon, Venezuala	1600		Bayley 1983; Welcomme 1985
Bere. England	161.2	130000	Mean of 3 sites; Mann 1971
Tarrant, England	198	778000	Mann 1971
Devil's, England	95	64000	Mann 1971
Docken's, England	75	25000	Mann 1971
Black Brows, England	59	24000	Le Cren 1969
Kingswell, England	51	9000	Le Cren 1969
Hall, England	129	7000	Le Cren 1969
Appletreeworth, England	62	4000	Le Cren 1969
Swan, Canada	124.4	50206	Mahon and Balon 1985; Watson and Balon 1984
Carroll, Canada	274.8	115125	Mahon and Balon 1985; Watson and Balon 1984
Hopewell, Canada	228.4	154163	Mahon and Balon 1985; Watson and Balon 1984
Irvine, Canada	149.9	208253	Mahon and Balon 1985; Watson and Balon 1984
Ellis, Canada	376	100036	Mahon and Balon 1985; Watson and Balon 1984
Upper Carol, Canada	278.7	205183	Mahon and Balon 1985
Mud CK, Canada	127.5	61667	Mean of 3 sites; Portt 1980 (as cited in Mahon and Balon 1985)
North Branch, Canada	217.5	131000	Mahon and Balon 1985
Irvine2, Canada	187.2	283537	Halyk and Balon 1983; Mahon and Balon 1985
Struga, Poland	111.2	39247	Mahon and Balon 1985; Watson and Balon 1984
Lubrzanka, Poland	241	17230	Mahon and Balon 1985; Watson and Balon 1984
Warkocz, Poland	307.5	50058	Mahon and Balon 1985; Watson and Balon 1984
Bobraz, Poland	50.2	23698	Mahon and Balon 1985; Watson and Balon 1984
Utrata1, Poland	310.5	33370	Penczak 1981; Mahon and Balon 1985
Utrata2, Poland	142.5	33559	Penczak 1981; Mahon and Balon 1985
Utrata3, Poland	86.6	19595	Penczak 1981; Mahon and Balon 1985
Utrata4, Poland	45.6	93200	Penczak 1981; Mahon and Balon 1985
Utrata5, Poland	10.8	6581	Penczak 1981; Mahon and Balon 1985
Utrata6, Poland	40.9	46055	Penczak 1981; Mahon and Balon 1985
Zalewka1, Poland	49.8	6230	Penczak 1981; Mahon and Balon 1985
Zalewka2. Poland	42.5	46327	Penczak 1981; Mahon and Balon 1985
Zalewka3, Poland	38.4	6484	Penczak 1981; Mahon and Balon 1985
Wolborka, Poland	37.4	3714	Penczak 1981; Mahon and Balon 1985
Kejin1, Malaysia	173.1	206021	Watson and Balon 1984
Kejin2, Malaysia	71	53873	Watson and Balon 1984
Lawa1, Malaysia	30.5	15866	Watson and Balon 1984
Lawa2, Malaysia	21.3	9789	Watson and Balon 1984
Kaha, Malaysia	38.5	11389	Watson and Balon 1984
Bulu, Malaysia	21.5	8262	Watson and Balon 1984
Payau, Malaysia	27.1	7282	Watson and Balon 1984
Philip, Canada	36	13300	Randall et al. 1989; R.G. Randall pers. comm.
Jaruma, Spain	233.4	45458	Mean of 3 sites; Lobon-Cervia and Penczak 1984
Big Springs, USA	84.2		Goodnight and Bjornn 1971; Welcomme 1985
Lemhi, USA	212		Goodnight and Bjornn 1971; Welcomme 1985
Mesta, Bulgaria	80.2	6638	Mean of 5 sites; Penczak et al. 1985
Speed, Canada	15.4	24547	Mean of 3 sites; Mahon et al. 1979
Kafue, Zambia	520		Kapetsky 1974; cited in Welcomme 1985
Deer, USA	84.7		Chapman 1965; Welcomme 1985
Needle Branch, USA	45.9		Chapman 1965; Welcomme 1985
Clemons Fork 1, USA	54.9		Lotrich 1973, Welcomme 1985
Clemons Fork 2, USA	63.6		Lotrich 1973, Welcomme 1985
Clemons Fork 3, USA	71.5		Lotrich 1973, Welcomme 1985
15, Florida, USA	95.1		Hoyer and Canfield 1991 (biomass averaged for the number of rivers indicated)
19, Vermont, USA	7.4		Hoyer and Canfield 1991 (biomass averaged for the number of rivers indicated)
2, Washington, USA	52		Hoyer and Canfield 1991 (biomass averaged for the number of rivers indicated)
10, Ontario, Canada	104.2		Hoyer and Canfield 1991 (biomass averaged for the number of rivers indicated)
20, Wyoming, USA	110.8		Hoyer and Canfield 1991 (biomass averaged for the number of rivers indicated)
1, Missouri, USA	57		Hoyer and Canfield 1991 (biomass averaged for the number of rivers indicated)
12, Iowa, USA	251		Hoyer and Canfield 1991 (biomass averaged for the number of rivers indicated)
Average	148.1	75665	
North America Average	137.3	132247	

Randall, R.G. J.R.M. Kelso and C.K. Minns. 1995. Fish production in freshwaters: Are rivers more productive than lakes? Canadian Journal of Fisheries and Aquatic Sciences 52: 631-643

Figures

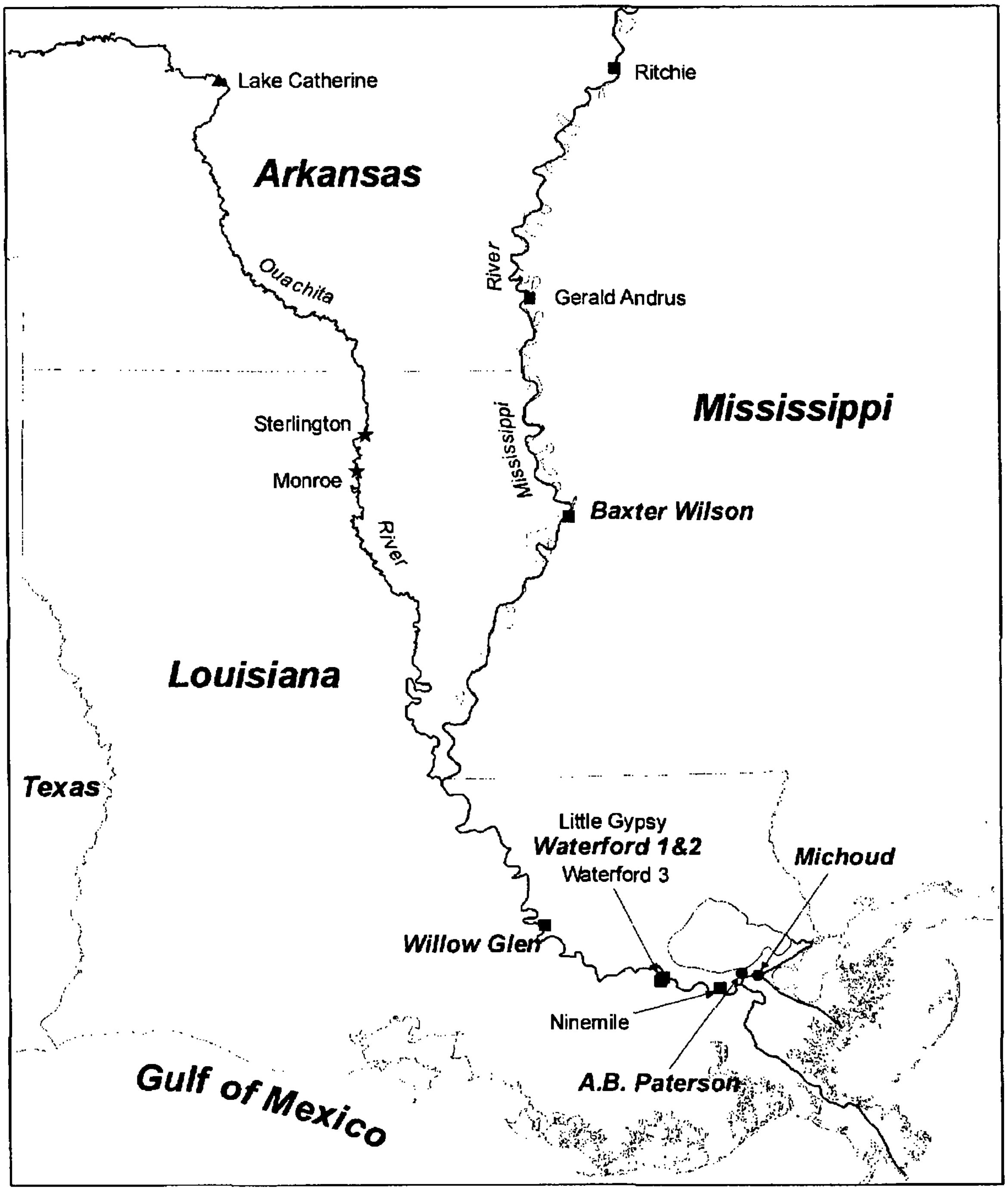

Figure 1:
Location Map for Entergy Plants in Louisiana, Arkansas, Mississippi, and Texas

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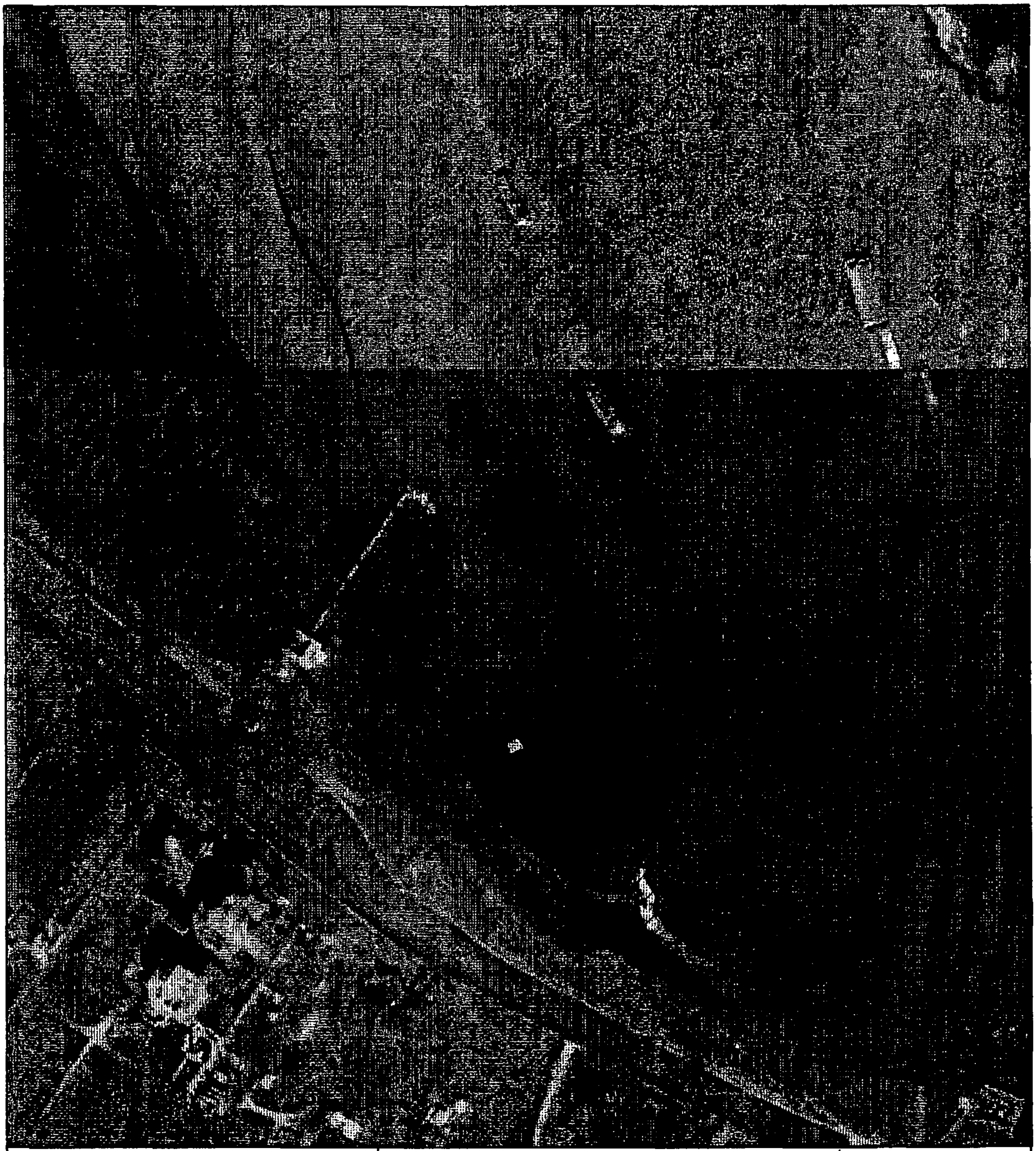

LEGEND

Location of Intake

Habitat Interpretation from Baker et al. 1991.
Orthophoto taken 2004 at 1 meter resolution.

Figure 2:
Aquatic Habitat Map
for Waterford 1&2 Plant

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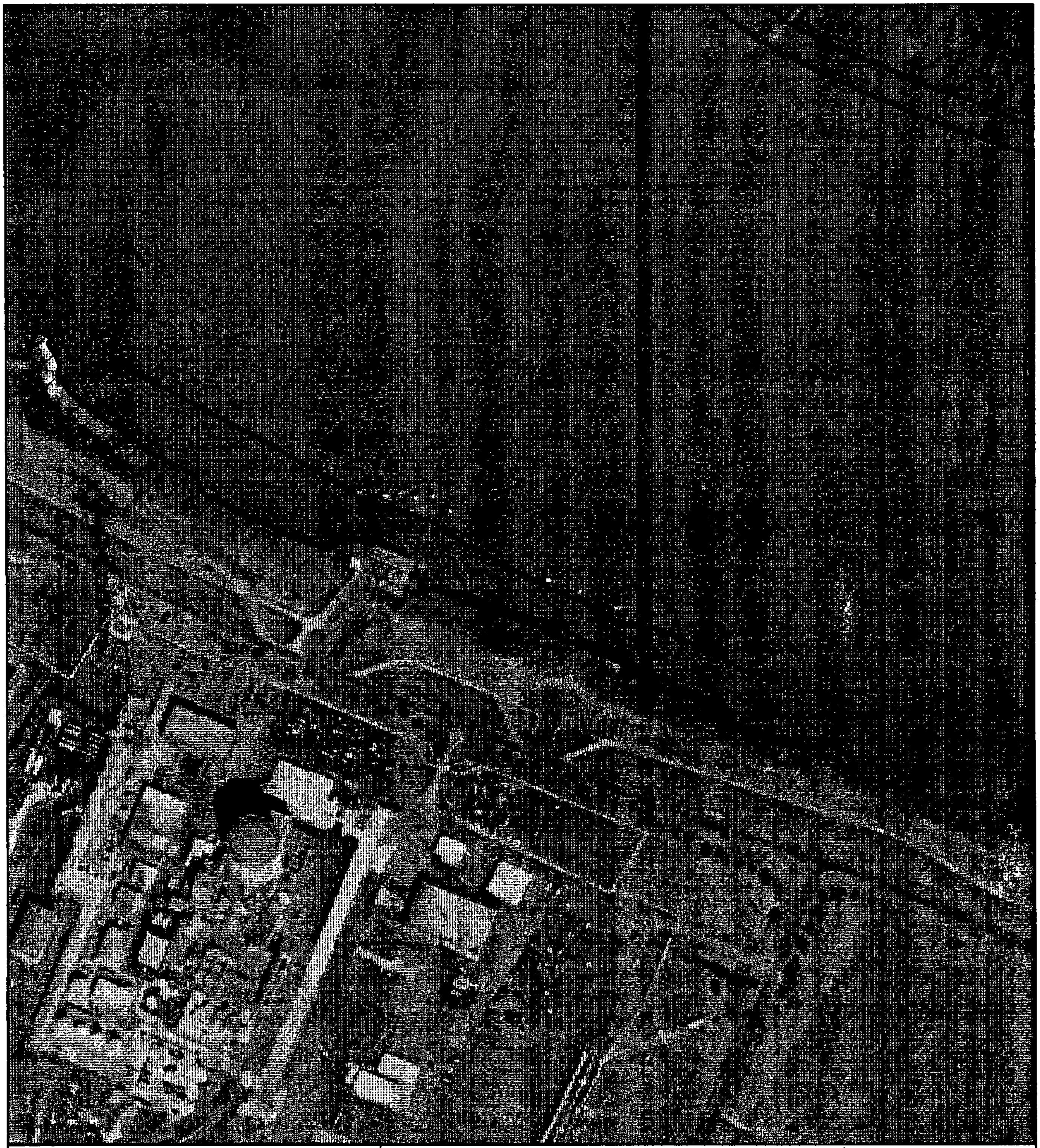

LEGEND

Location of Intake

Habitat Interpretation from Baker et al. 1991.
Orthophoto taken 2004 at 1 meter resolution.

Figure 3:
Aquatic Habitat Map
for Waterford 3 Plant

ENSR

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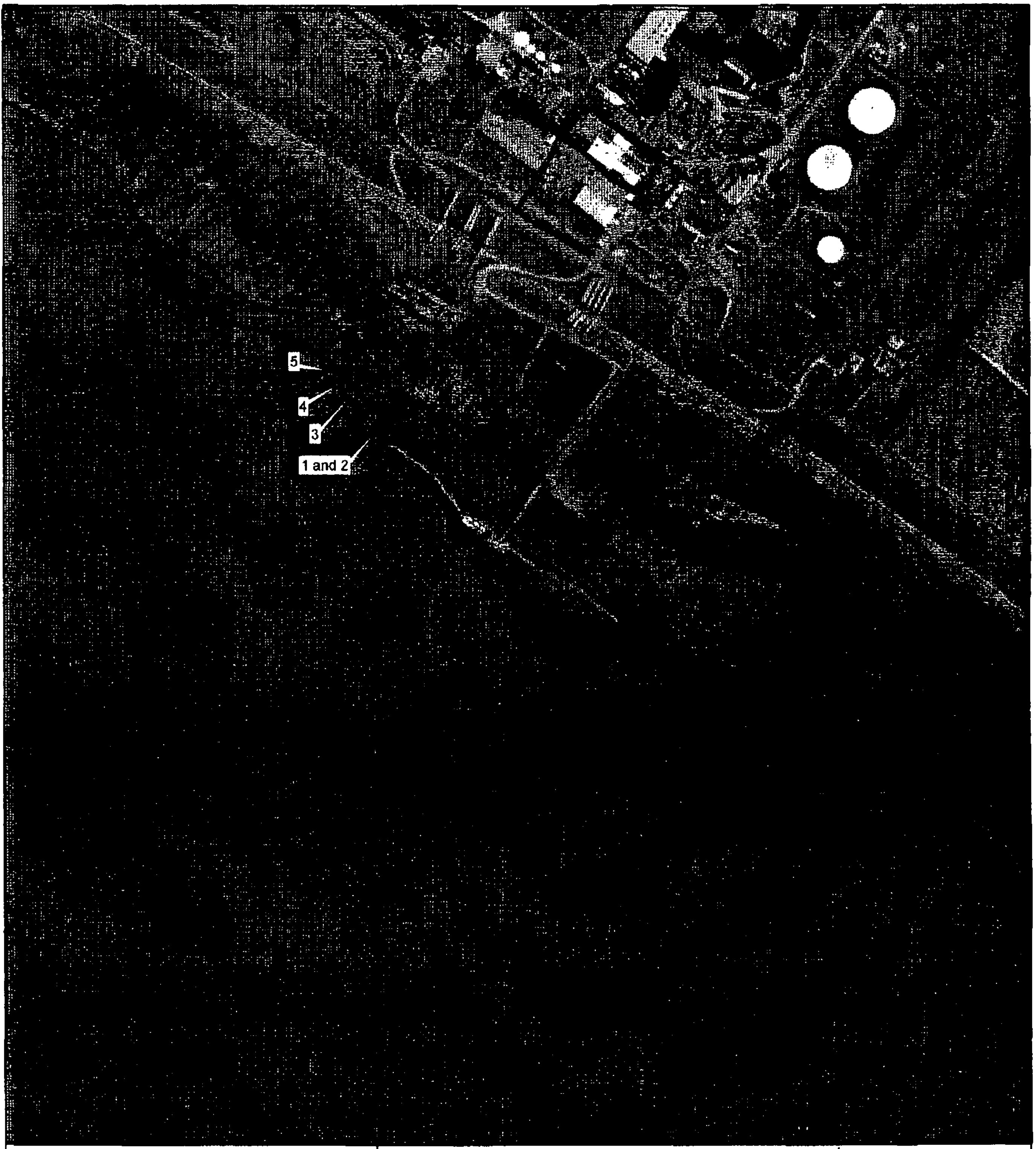

LEGEND

Location of Intake

Habitat Interpretation from Baker et al. 1991.
Orthophoto taken 2004 at 1 meter resolution.

Figure 4:
Aquatic Habitat Map for Willow Glen Plant

ENSR

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LEGEND

Location of Intake

Habitat Interpretation from Baker et al. 1991.
Orthophoto taken 2004 at 1 meter resolution.

Figure 5:
Aquatic Habitat Map for
Baxter Wilson Plant

ENSR

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Habitat Interpretation from Baker et al. 1991.
Orthophoto taken 2004 at 1 meter resolution.

Figure 6:
Aquatic Habitat Map
for Ninemile Plant

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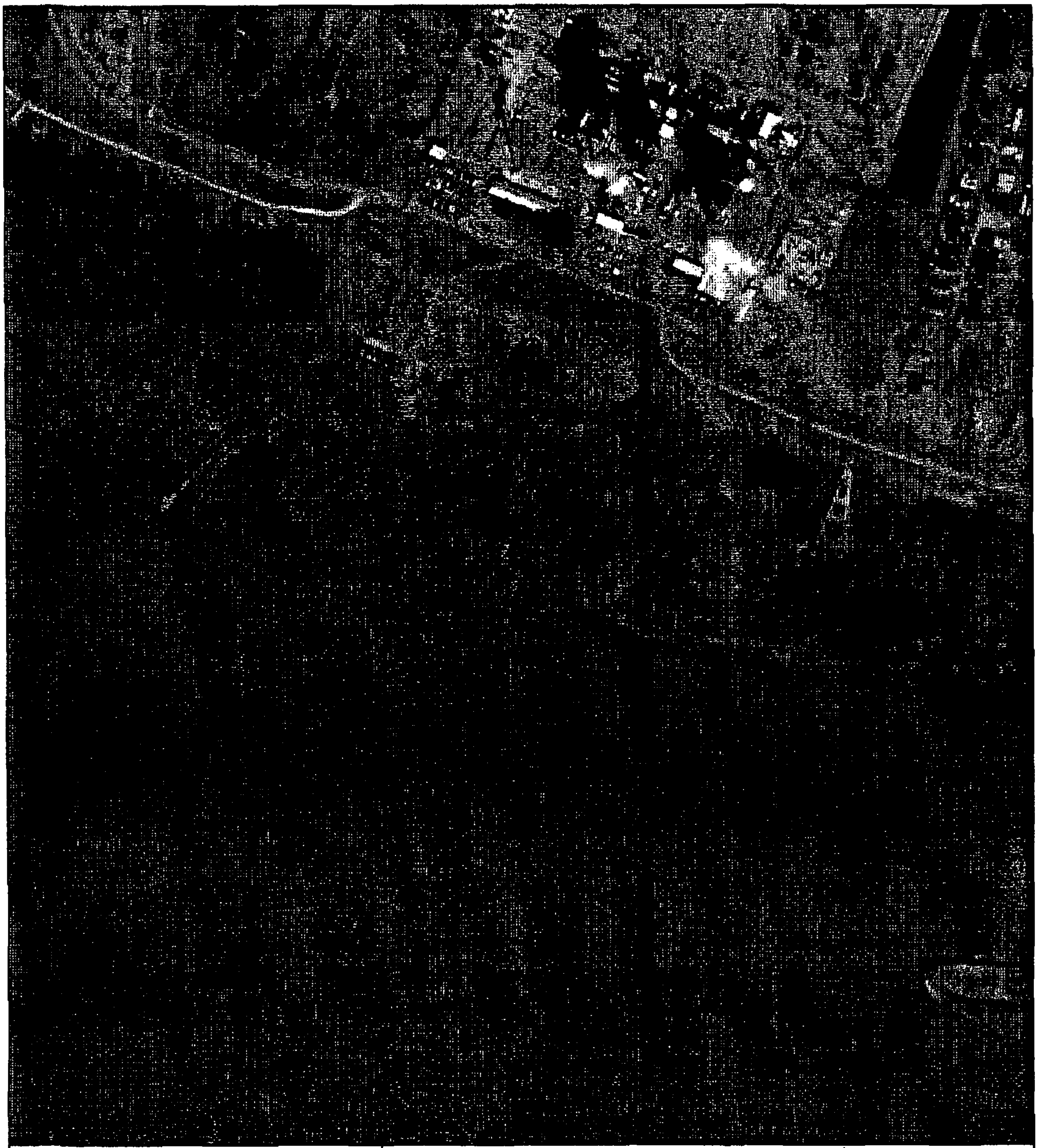

Habitat Interpretation from Baker et al. 1991.
Orthophoto taken 2004 at 1 meter resolution.

Figure 7:
Aquatic Habitat Map
for Little Gypsy Plant

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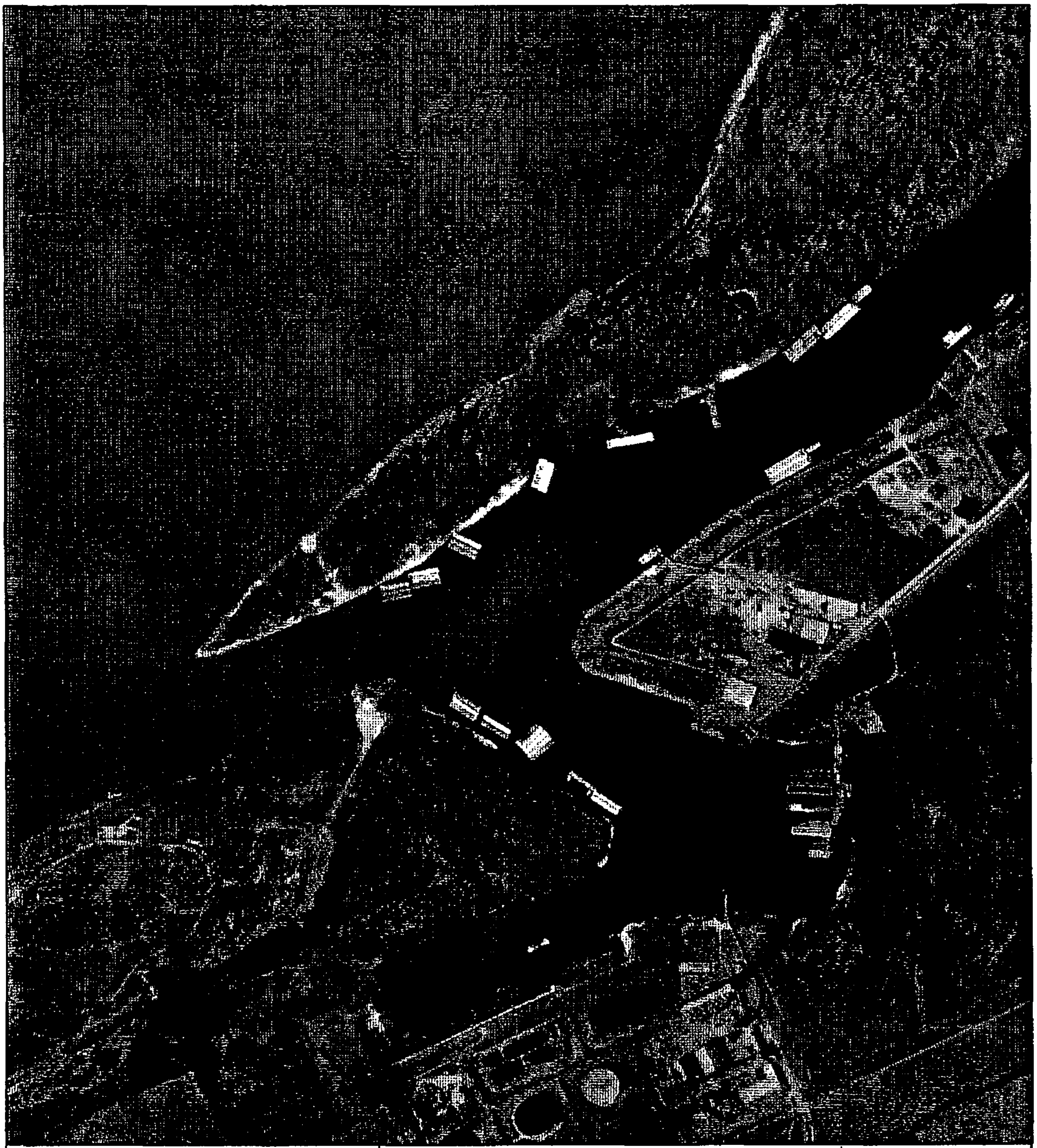

LEGEND

Location of Intake

Habitat Interpretation from Baker et al. 1991.
Orthophoto taken 2004 at 1 meter resolution.

Figure 8:
Aquatic Habitat Map for
Gerald Andrus Plant

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LEGEND

Location of Intake

Habitat Interpretation from Baker et al. 1991.
Orthophoto taken 2004 at 1 meter resolution.

Figure 9:
Aquatic Habitat Map for Ritchie Plant

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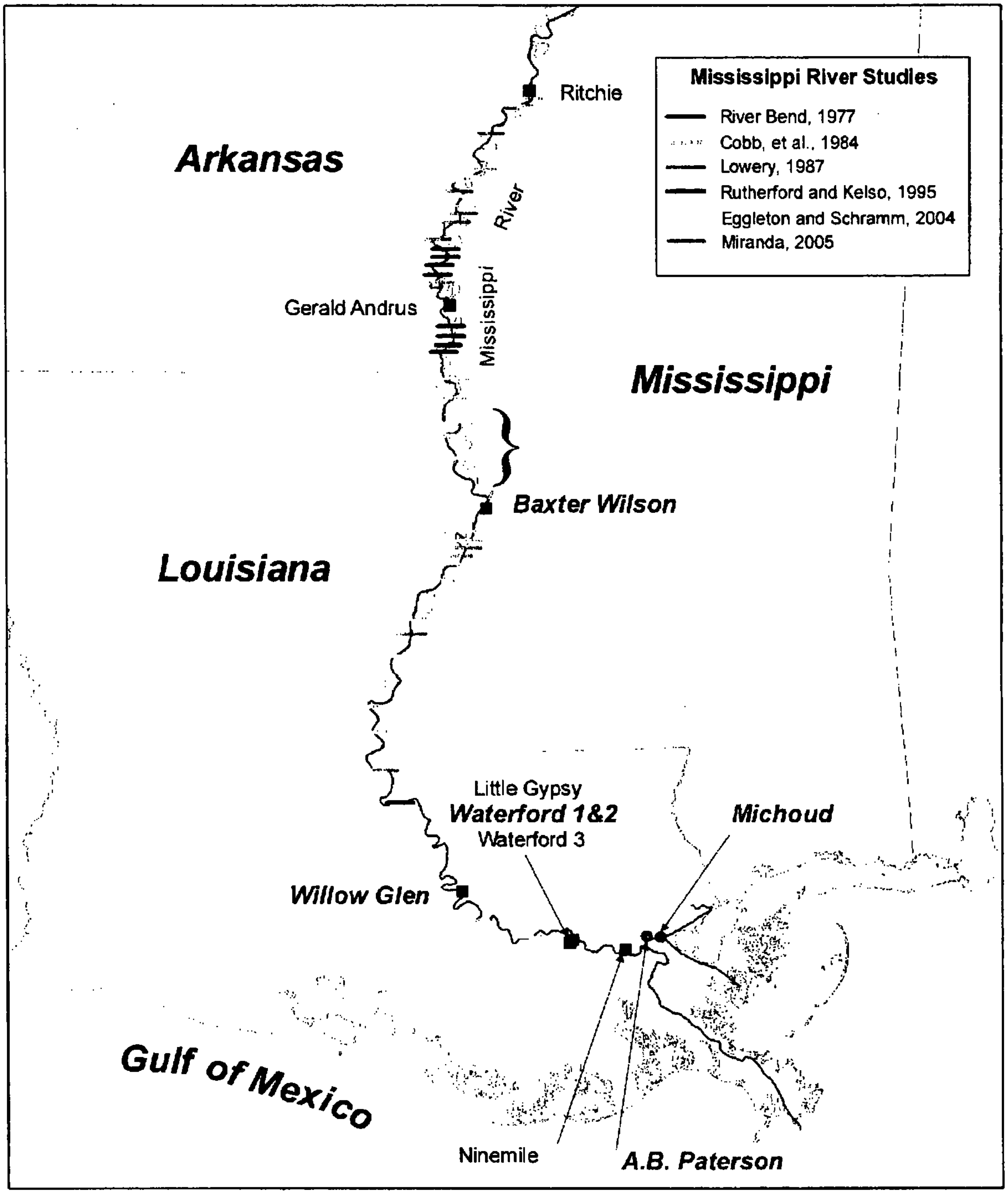

Ritchie	Plants without Impingement Data
Michoud	Plants with Impingement Data
■	Mississippi River Plants
●	Mississippi River Estuary Plants

Figure 10:
Location Map for Ambient Sampling on the Mississippi River

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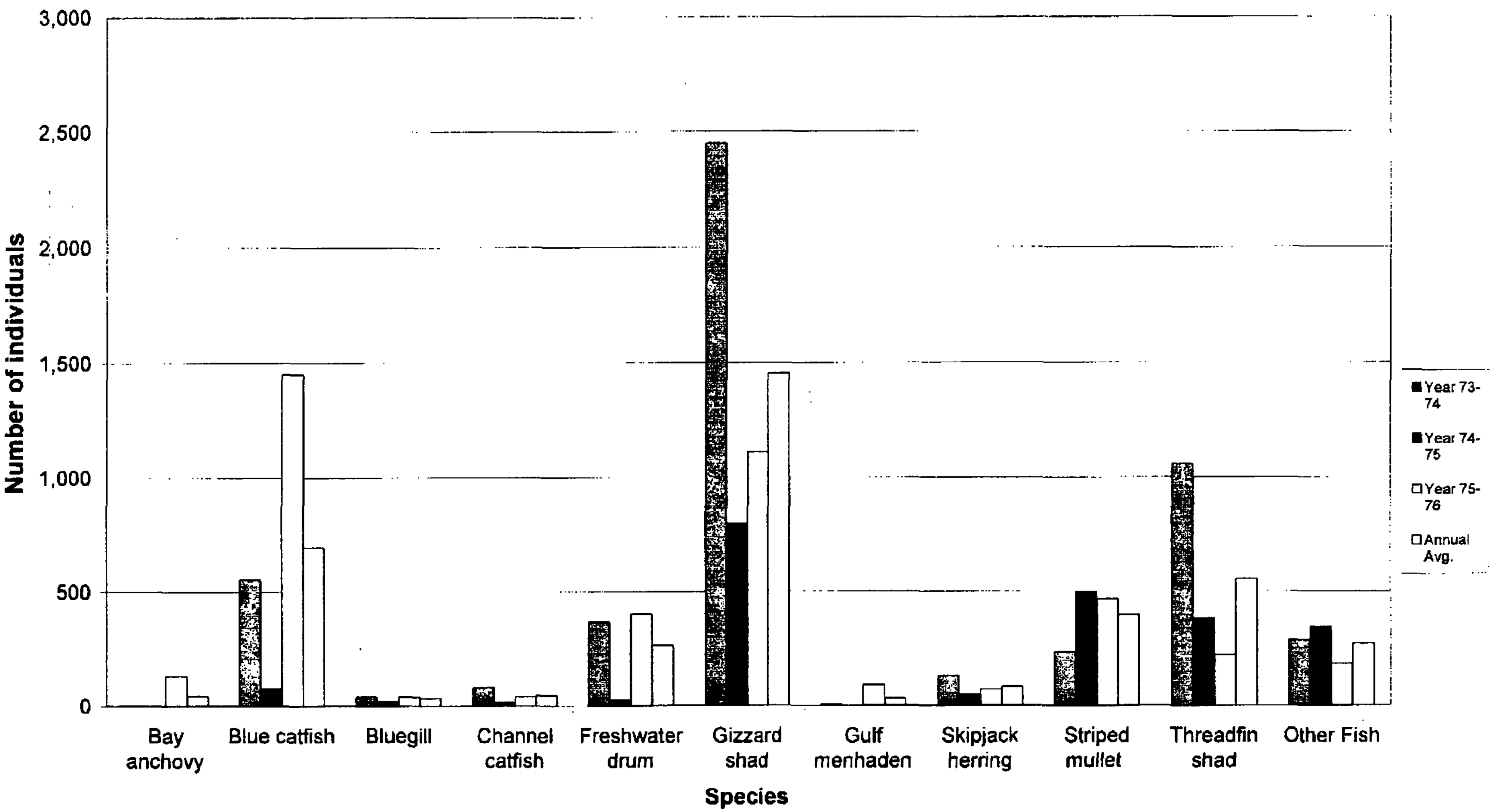


Figure 11. Abundance of Organisms Collected in Vicinity of the Waterford 3 Plant (1973-76)

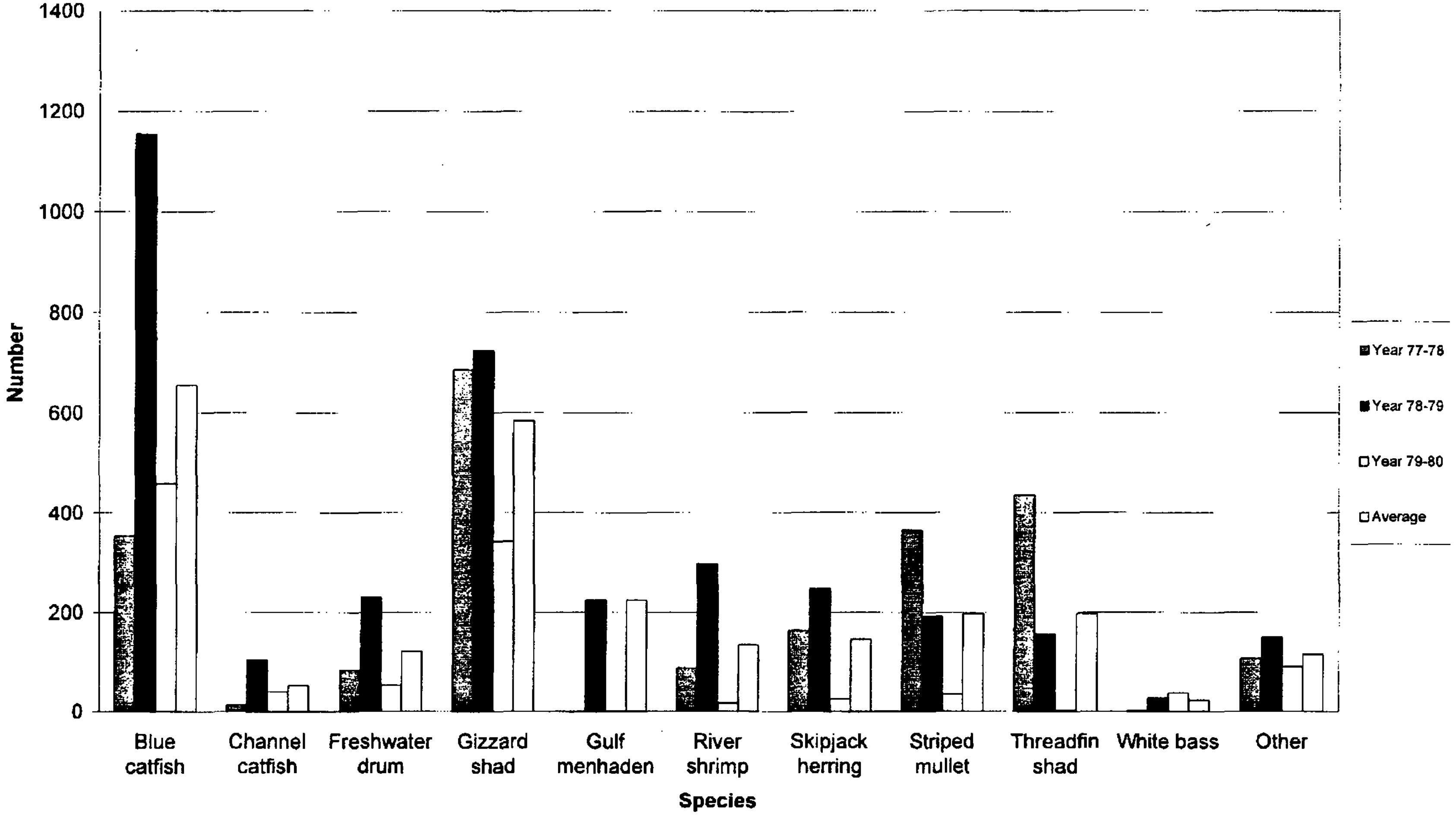


Figure 12. Abundance of Organisms Collected in Vicinity of the Waterford 3 Plant (1977-1980)

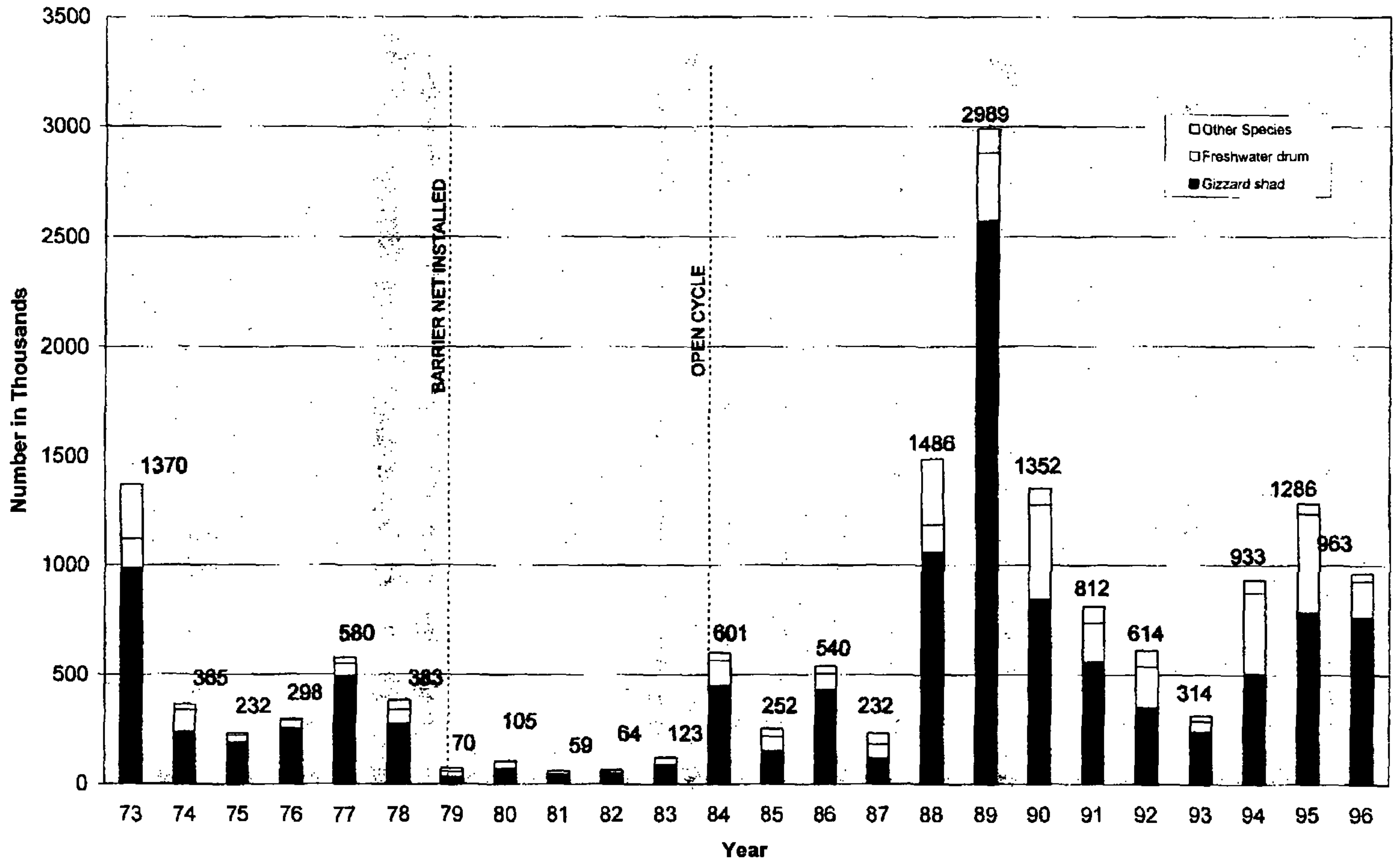


Figure 13. Estimated Number of Fish Impinged at Quad Cities Station (1973-1996; LeJeone Study)

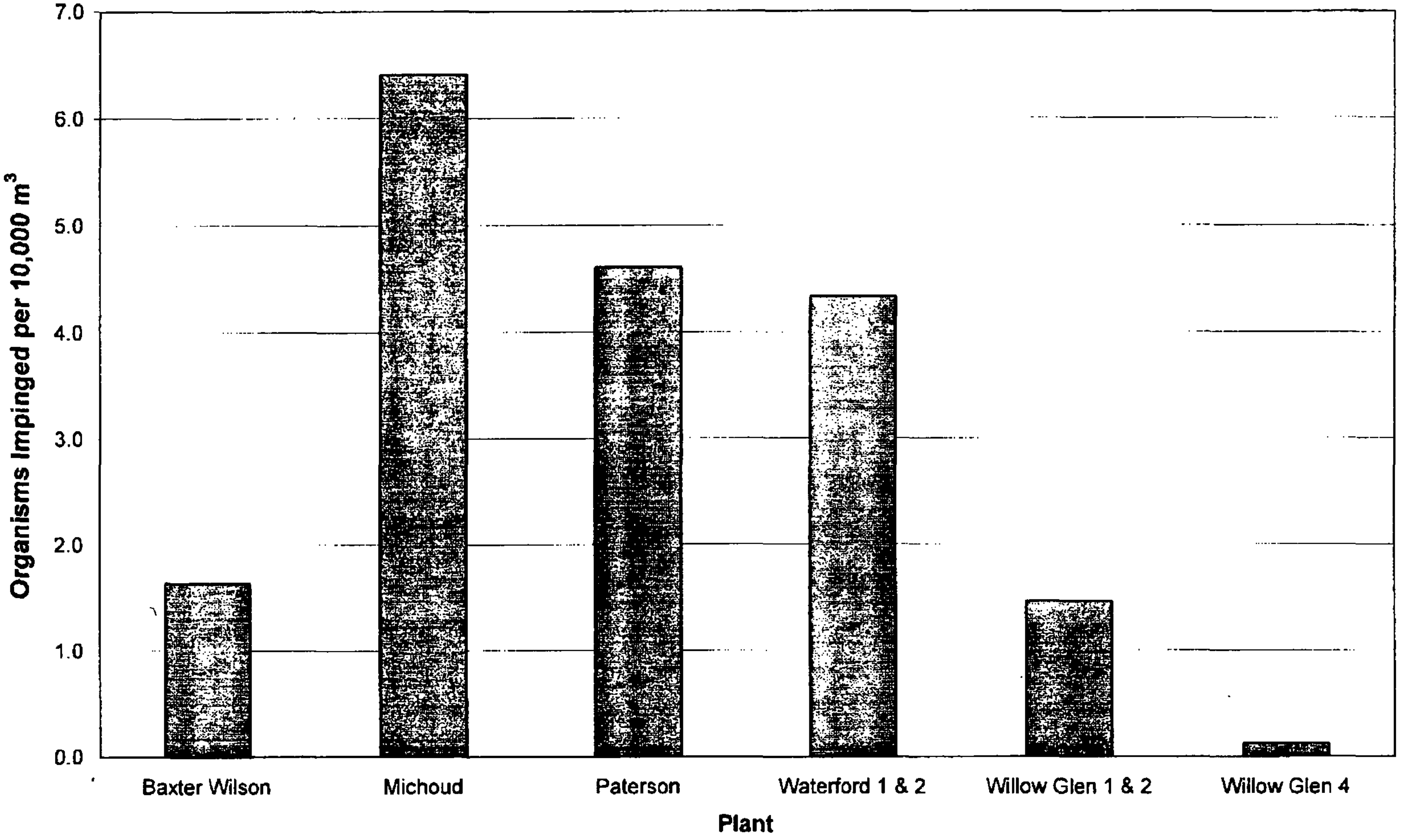


Figure 14. Mean Impingement Rate Per Plant

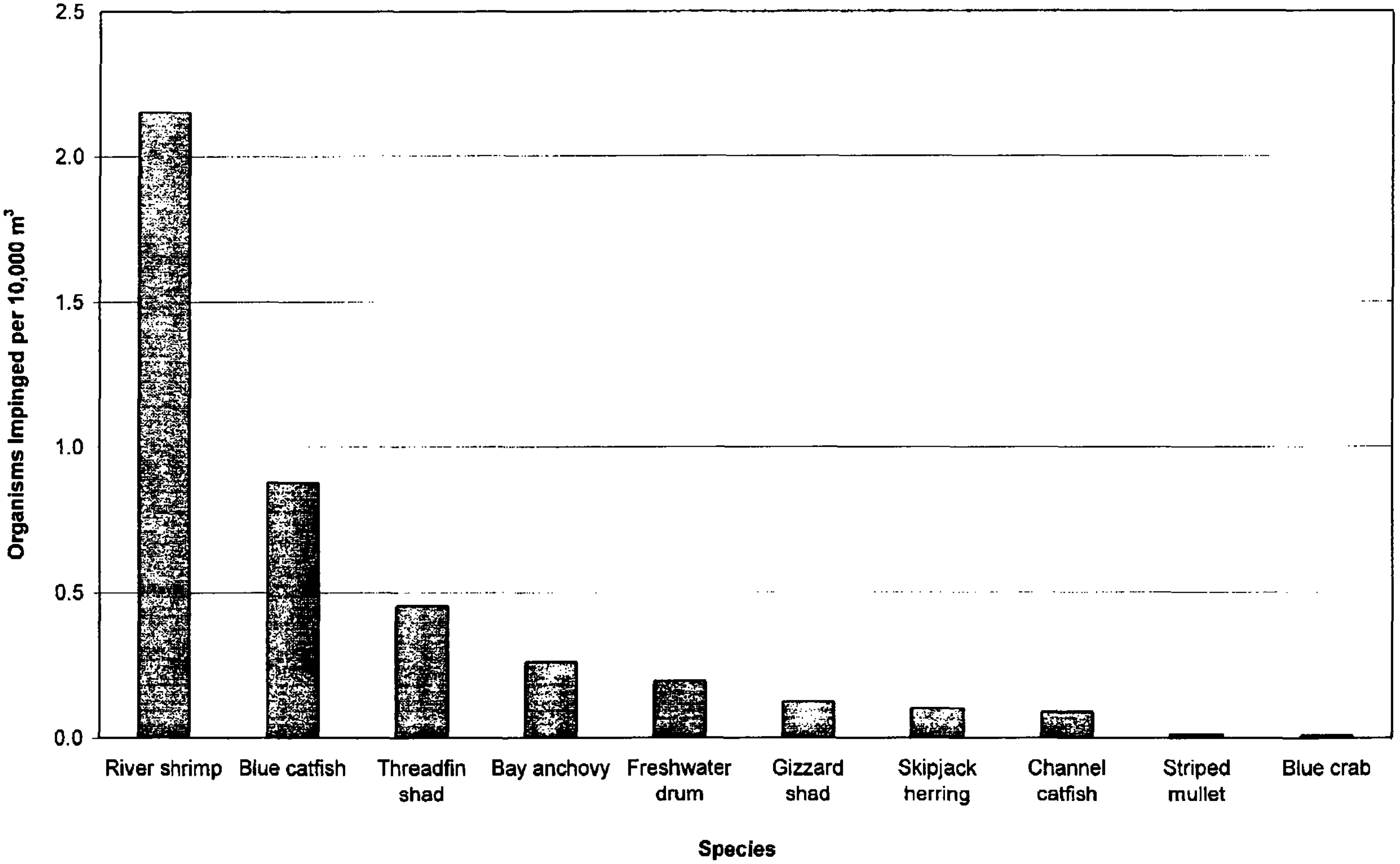


Figure 15. Impingement Rates at Waterford 1 & 2 (1976-1977)

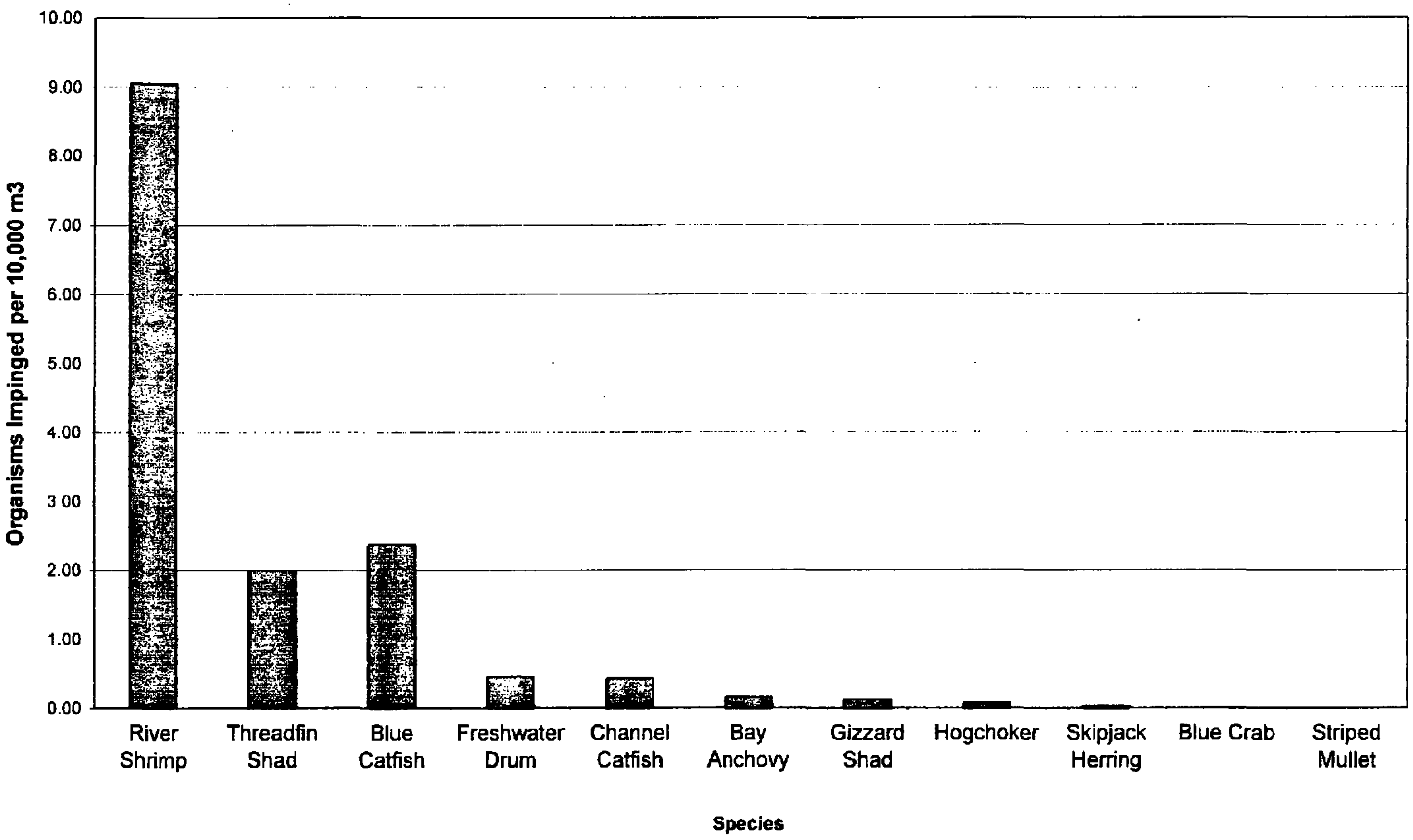


Figure 16. Impingement Rates at Waterford 1&2 (2006-2007)

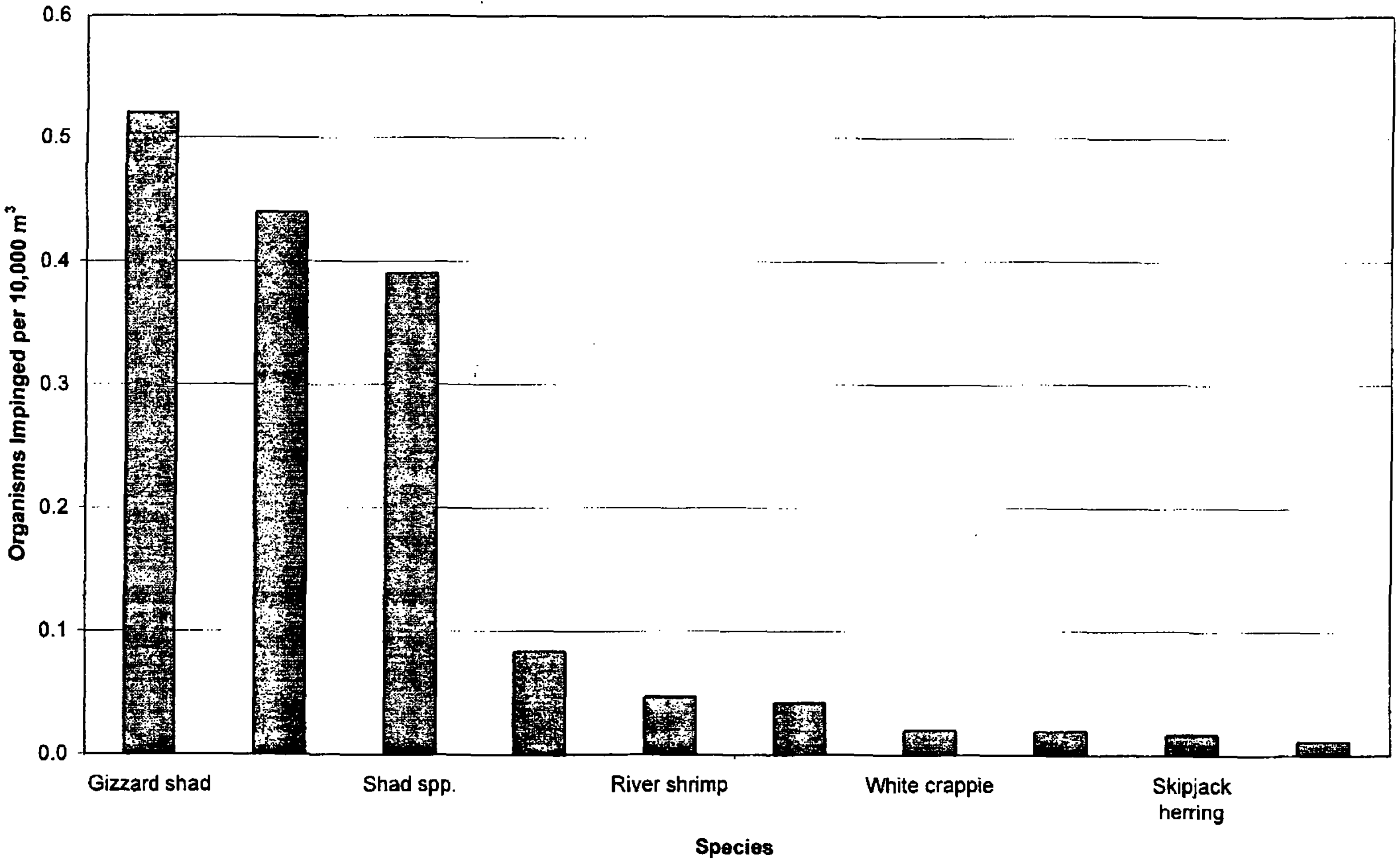


Figure 17. Impingement Rates at Baxter Wilson

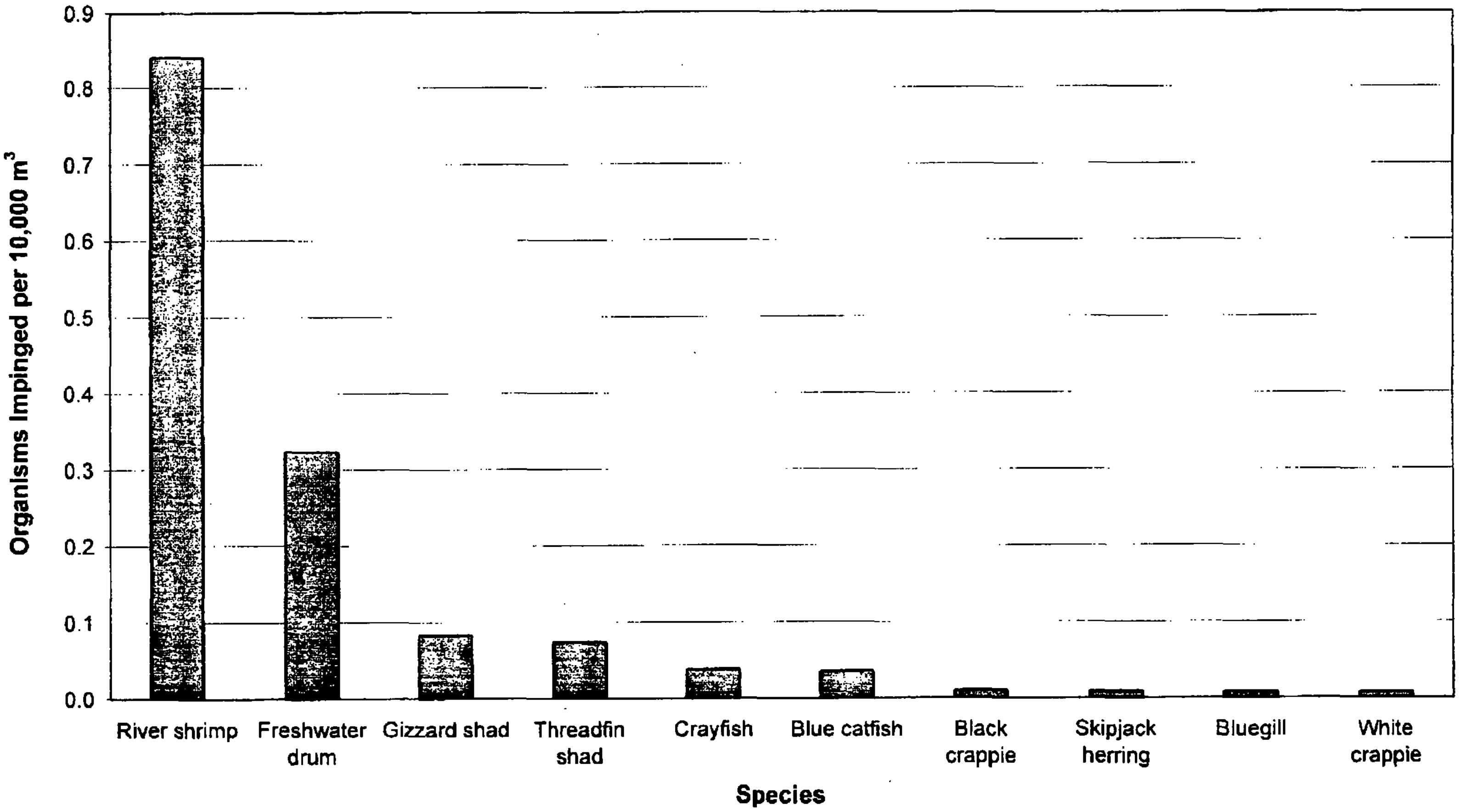


Figure 18. Impingement Rates at Willow Glen 1 & 2

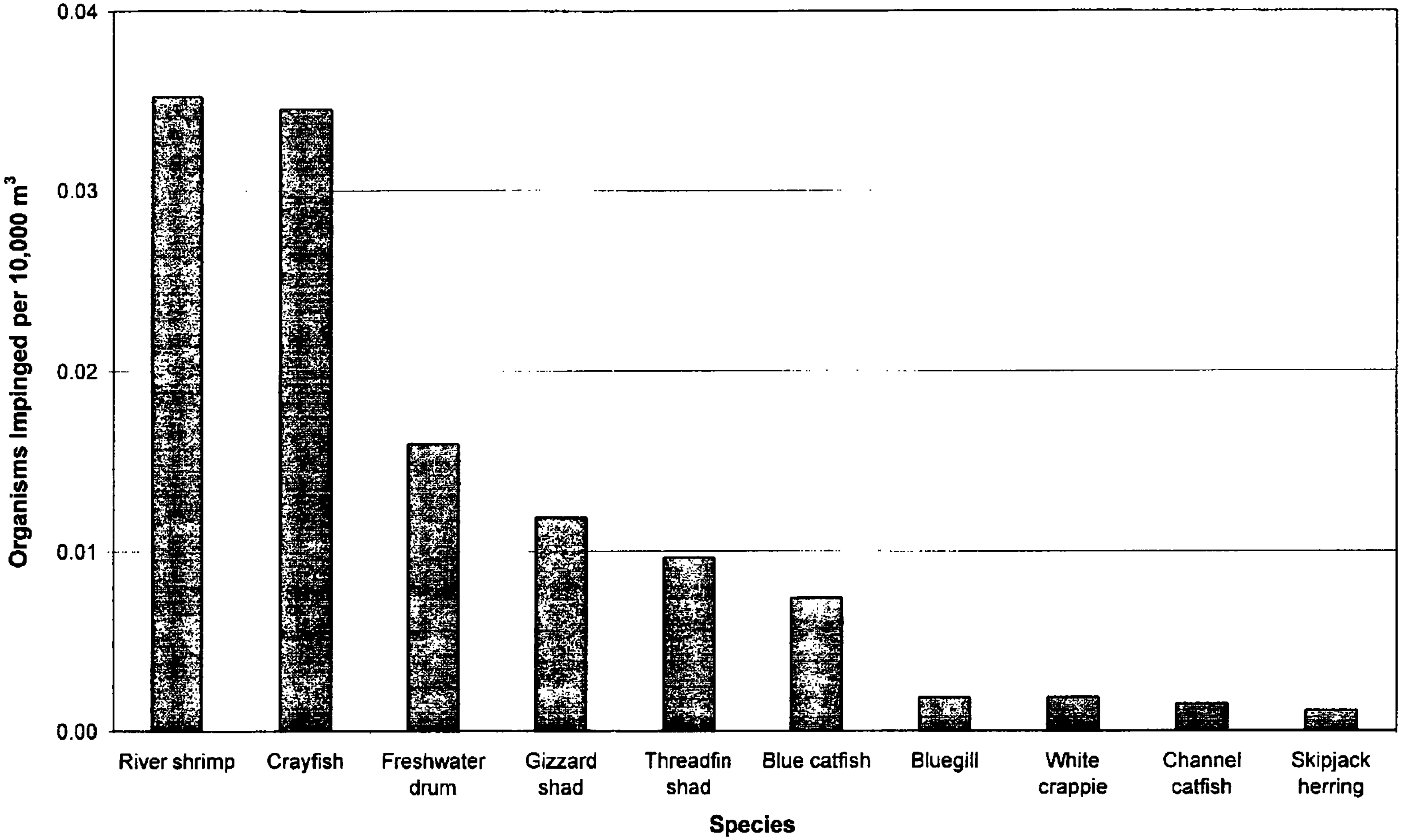


Figure 19. Impingement Rates at Willow Glen 4

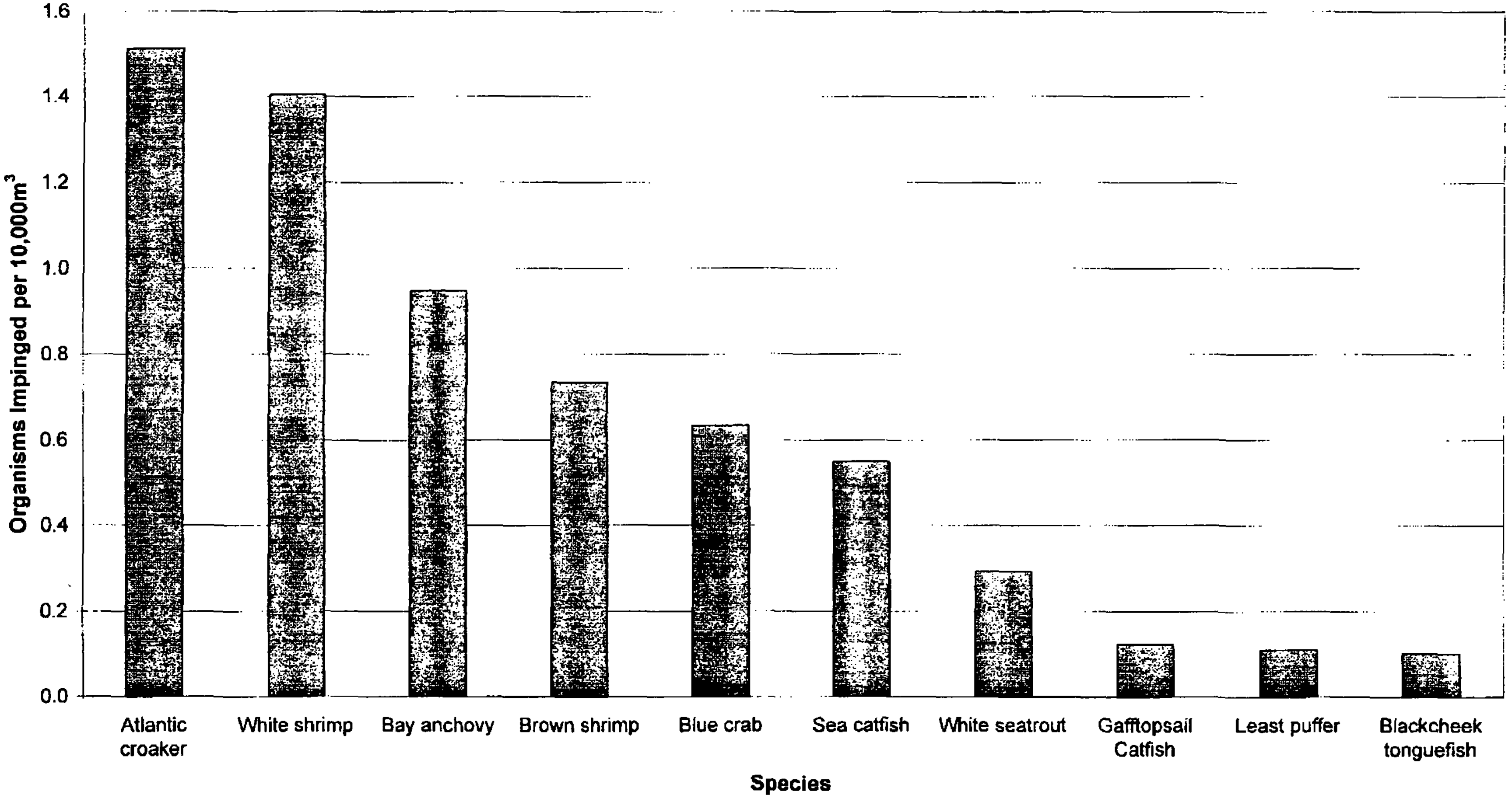


Figure 20. Impingement Rates at Michoud Plant

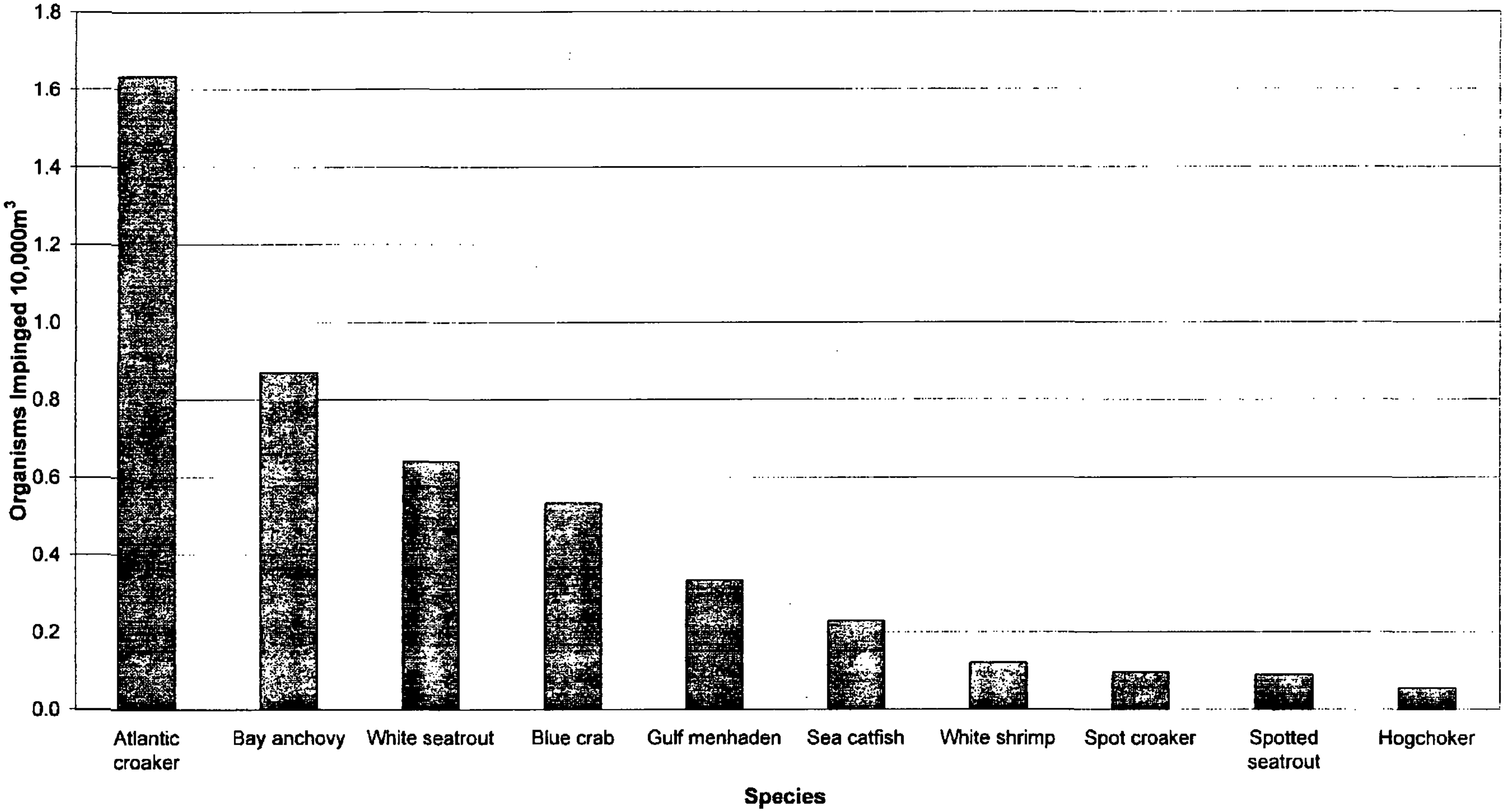


Figure 21. Impingement Rates at Paterson Plant

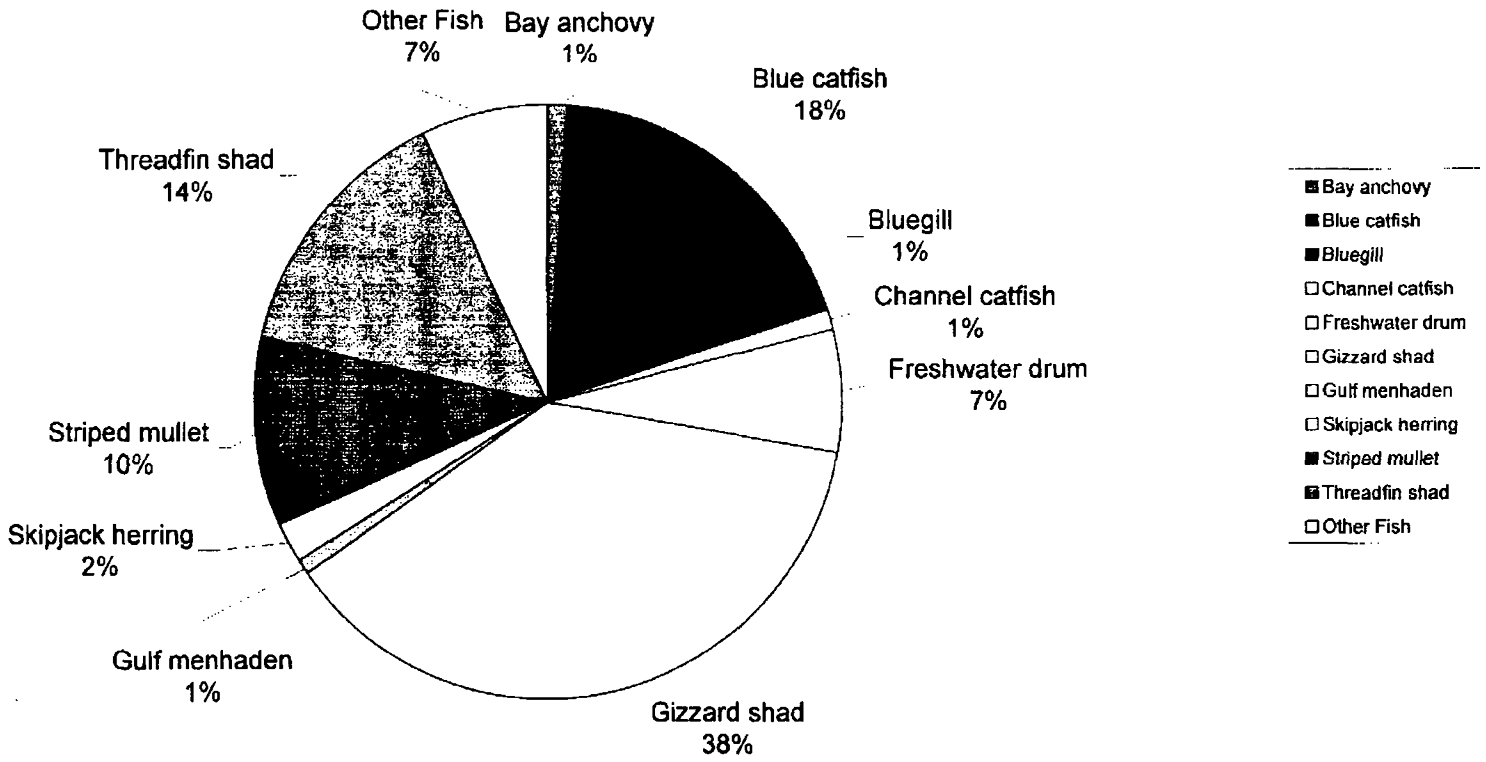


Figure 22. Relative Abundance of the Dominant Species Collected in the Vicinity of the Waterford 3 Plant (1973 to 1976)

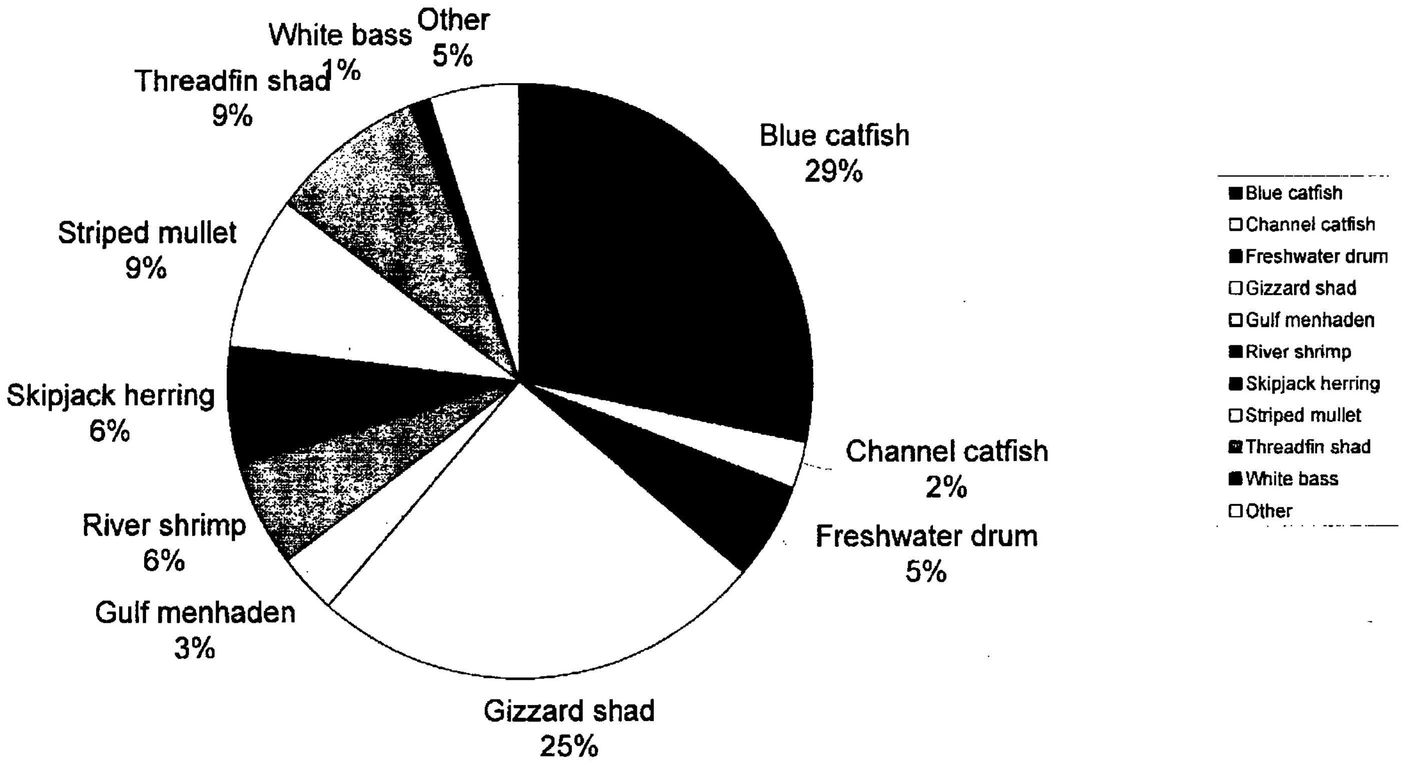


Figure 23. Relative Abundance of the Dominant Species Collected in the Vicinity of the Waterford 3 Plant (1977-1980)

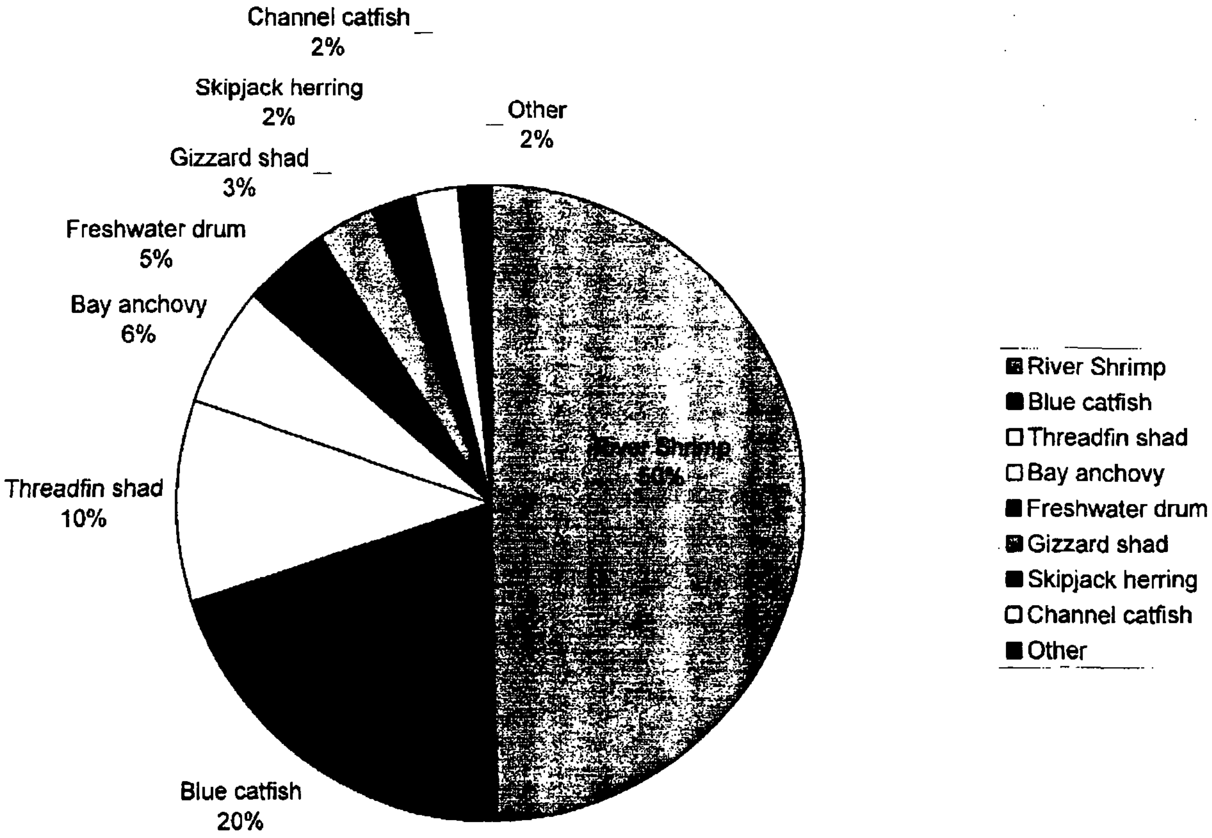


Figure 24. Relative Abundance of Selected Organisms (>1%) Impinged at the Waterford 1&2 Plant (1976-1977)

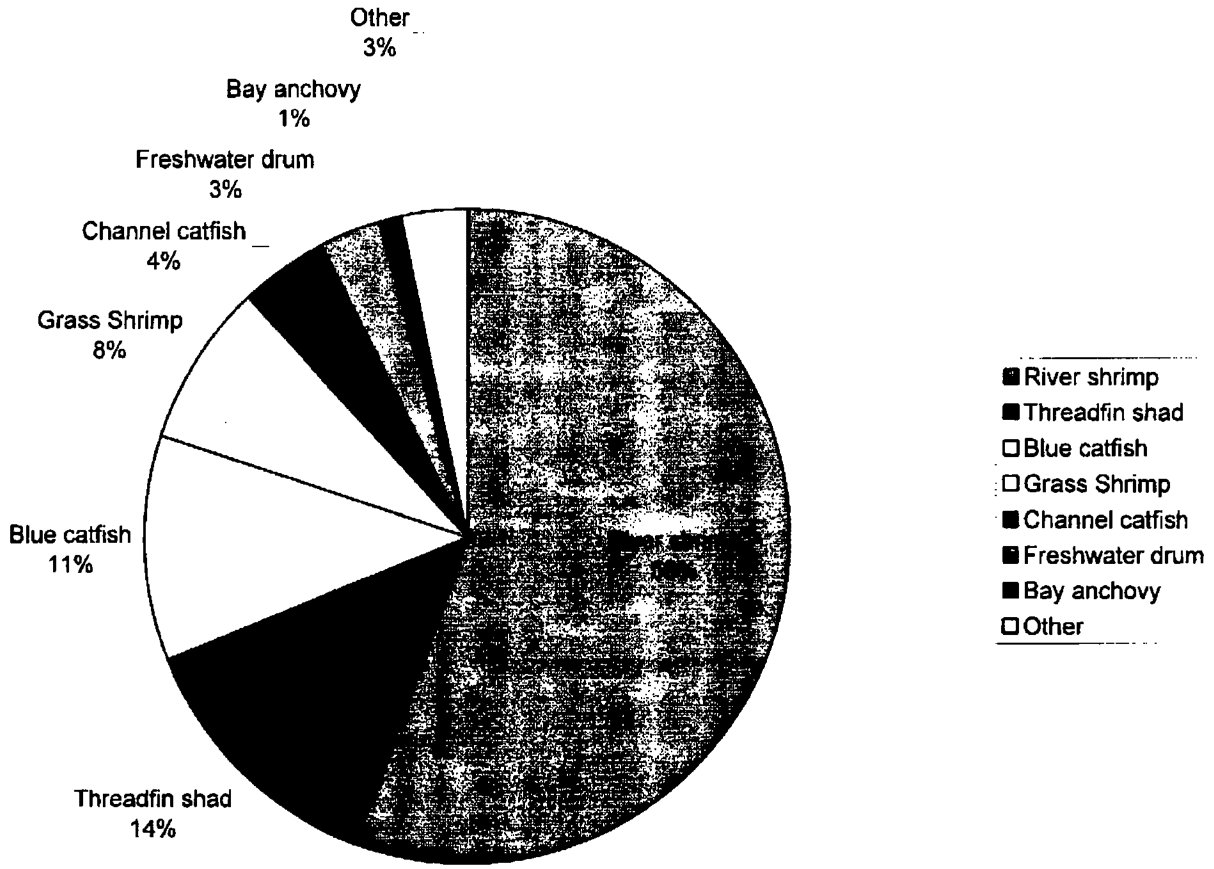


Figure 25. Relative Abundance of Selected Organisms (>1%) Impinged at the Waterford 1&2 Plant (2006-2007)

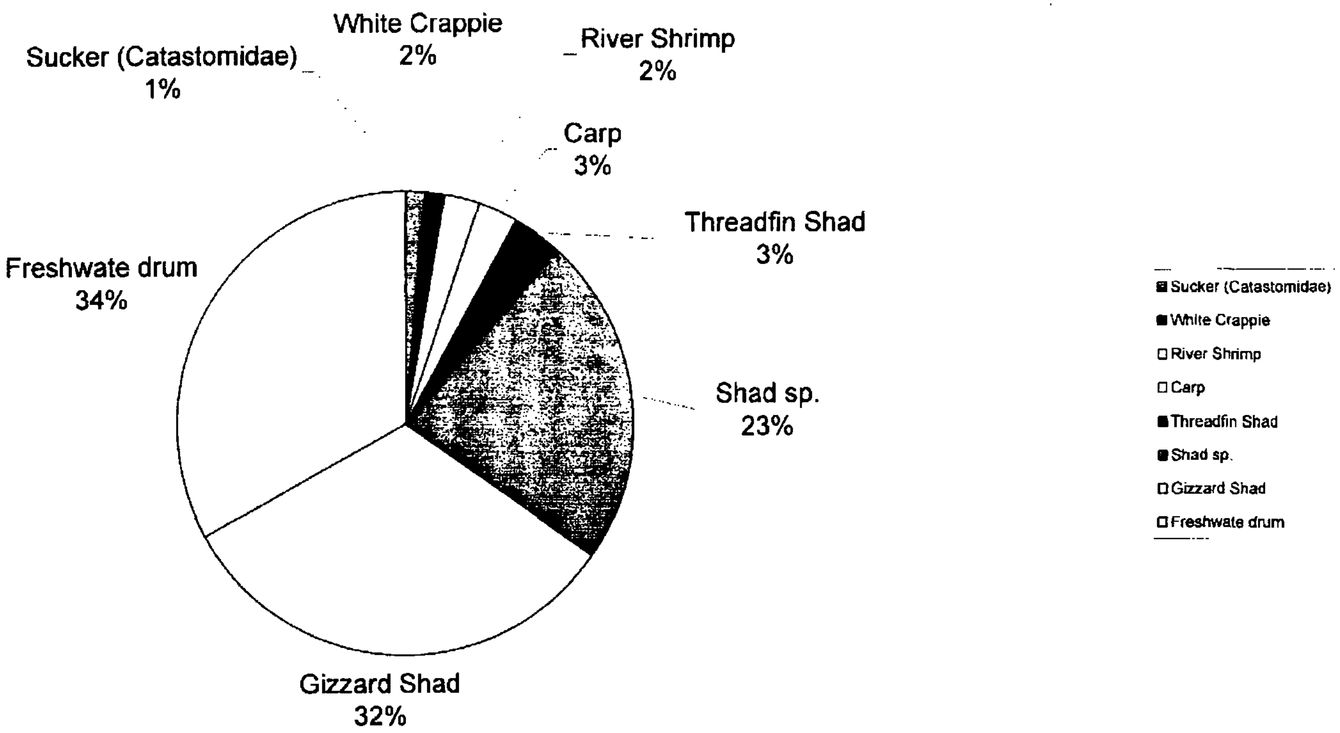


Figure 26. Relative Abundance of Selected Organisms (>1%) Impinged at the Baxter Wilson Plant (August 1973 to August 1974)

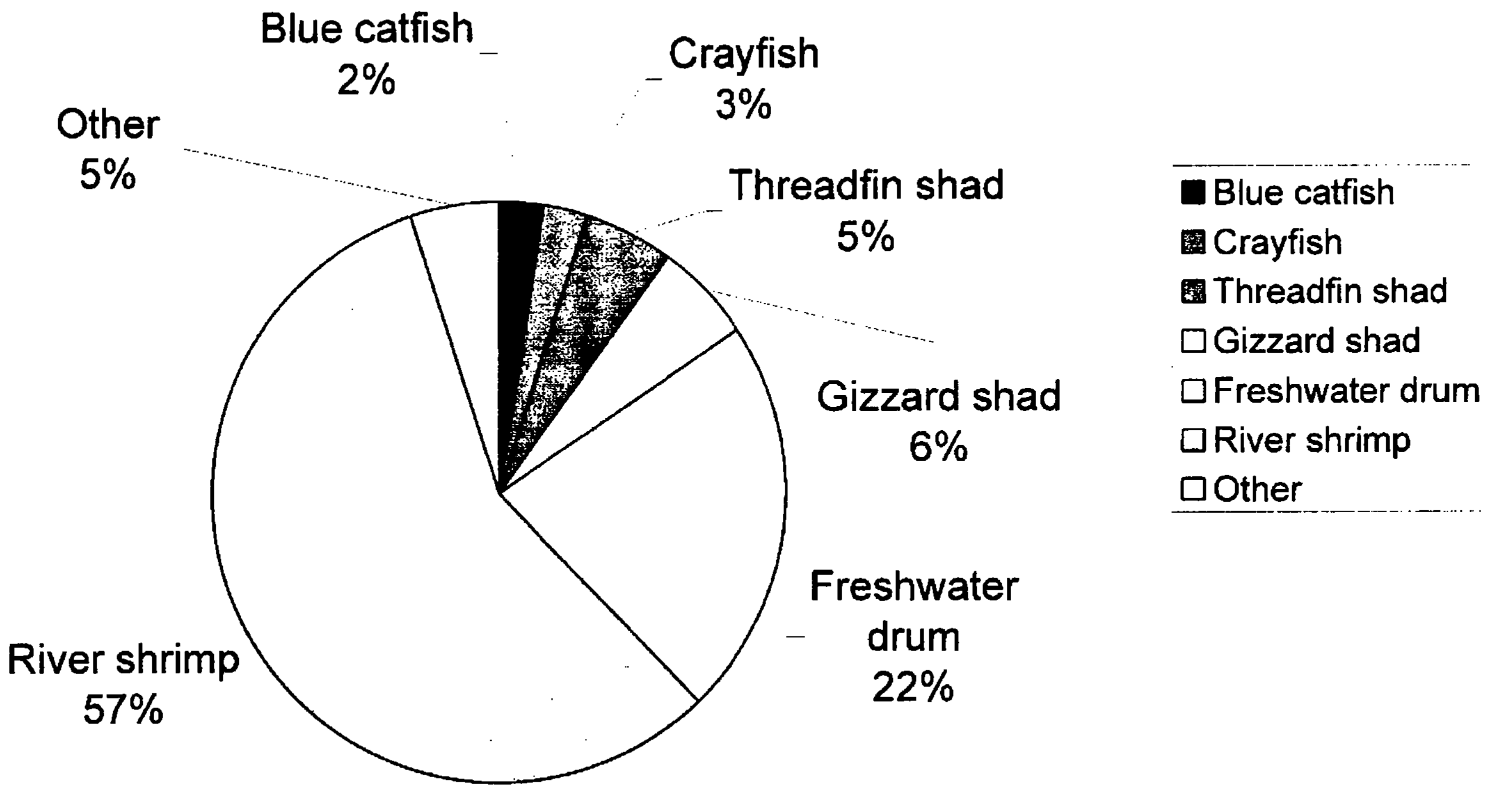


Figure 27a. Relative Abundance of Selected Fishes (>1%) Impinged at Willow Glen Power Station (Units 1 & 2 combined) from (1975-1976)

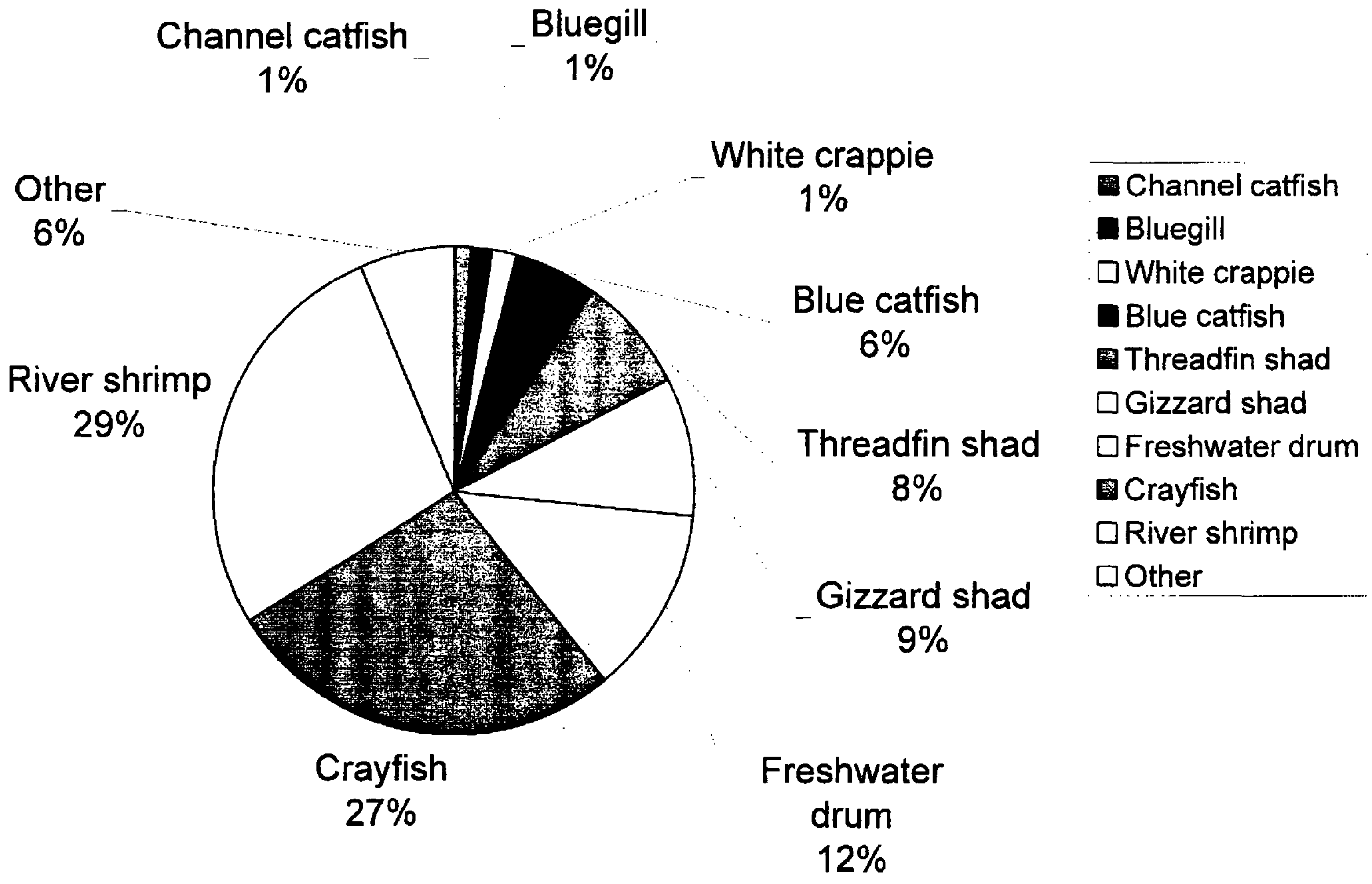


Figure 27b. Relative Abundance of Selected Fishes (>1%) Impinged at Willow Glen Power Station (Unit 4) (1975-1976)

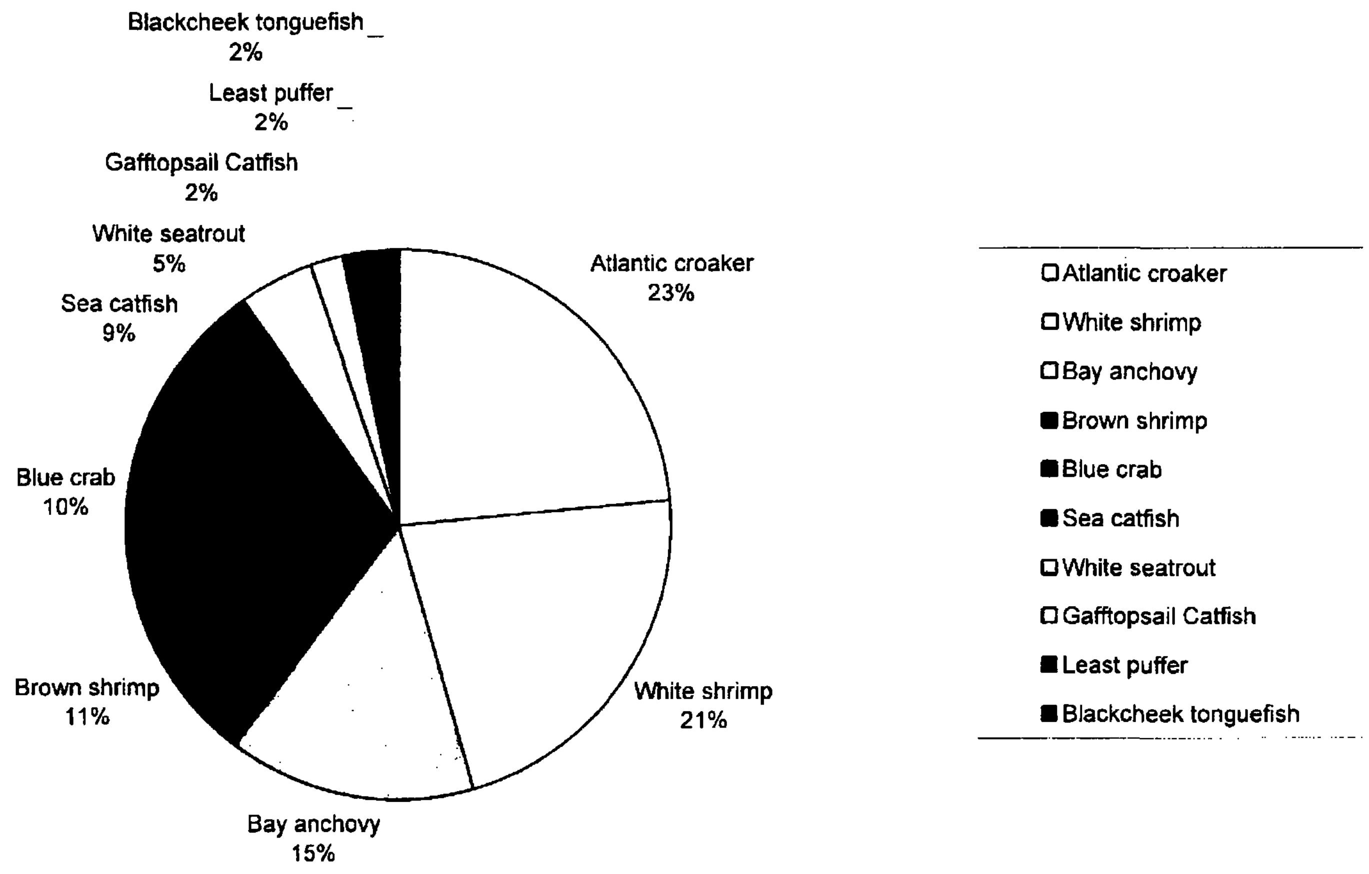


Figure 28. Relative Abundance of Selected Organisms Impinged at the Michoud Plant (1977-1979)

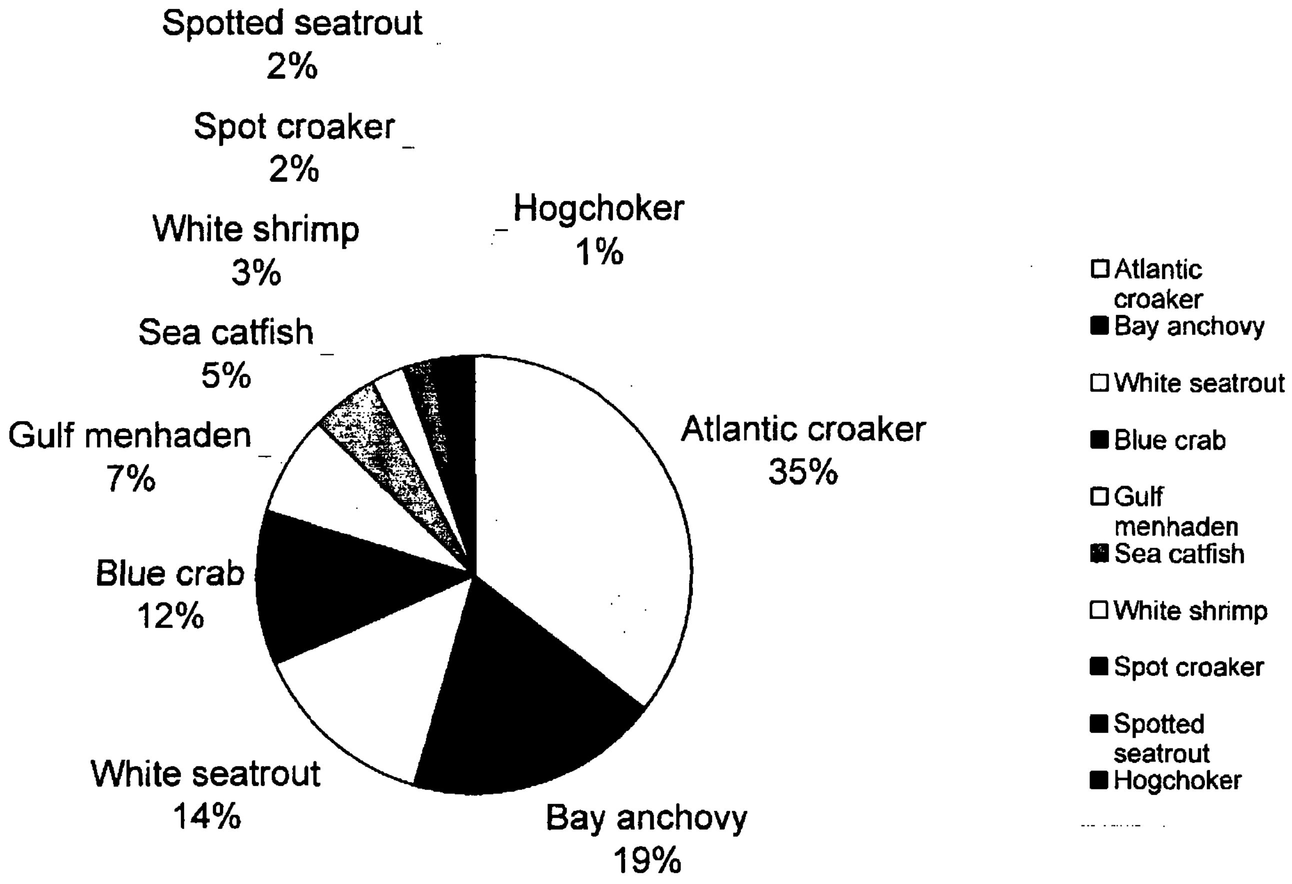


Figure 29. Relative Abundance of Selected Organisms Impinged at the Paterson Plant (1977-1979)

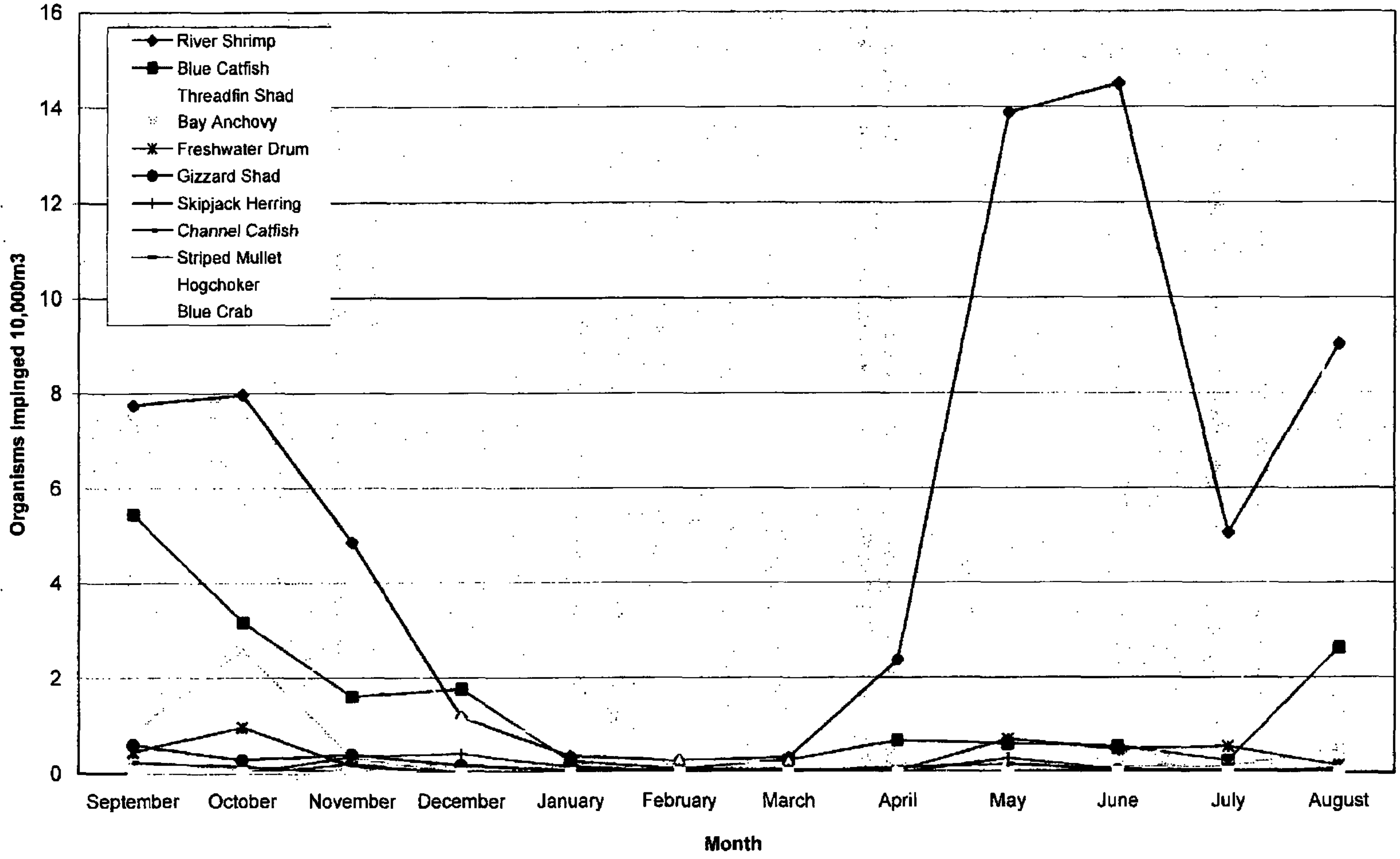


Figure 30. Seasonal Trends in Impingement at Waterford 1&2 (1976-1977, 2006-2007)

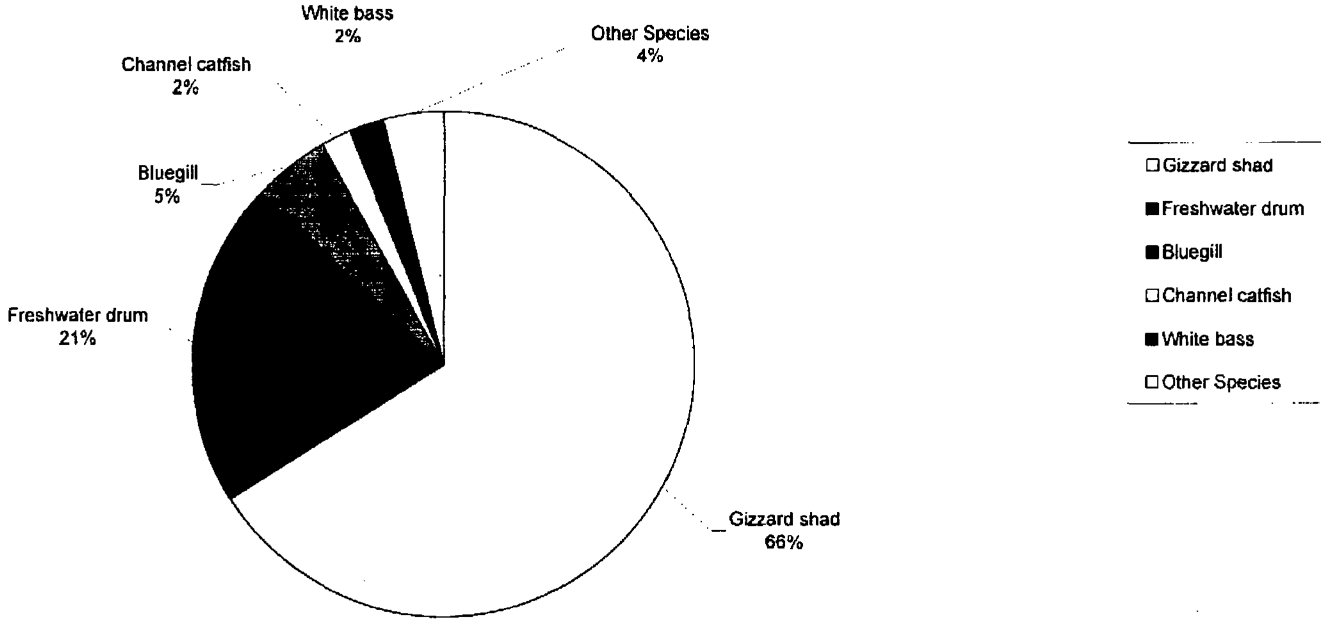


Figure 31. Mean Annual Abundance for Top Five Species Impinged at the Quad Cities Station Located on the Upper Mississippi River (1984-1994)

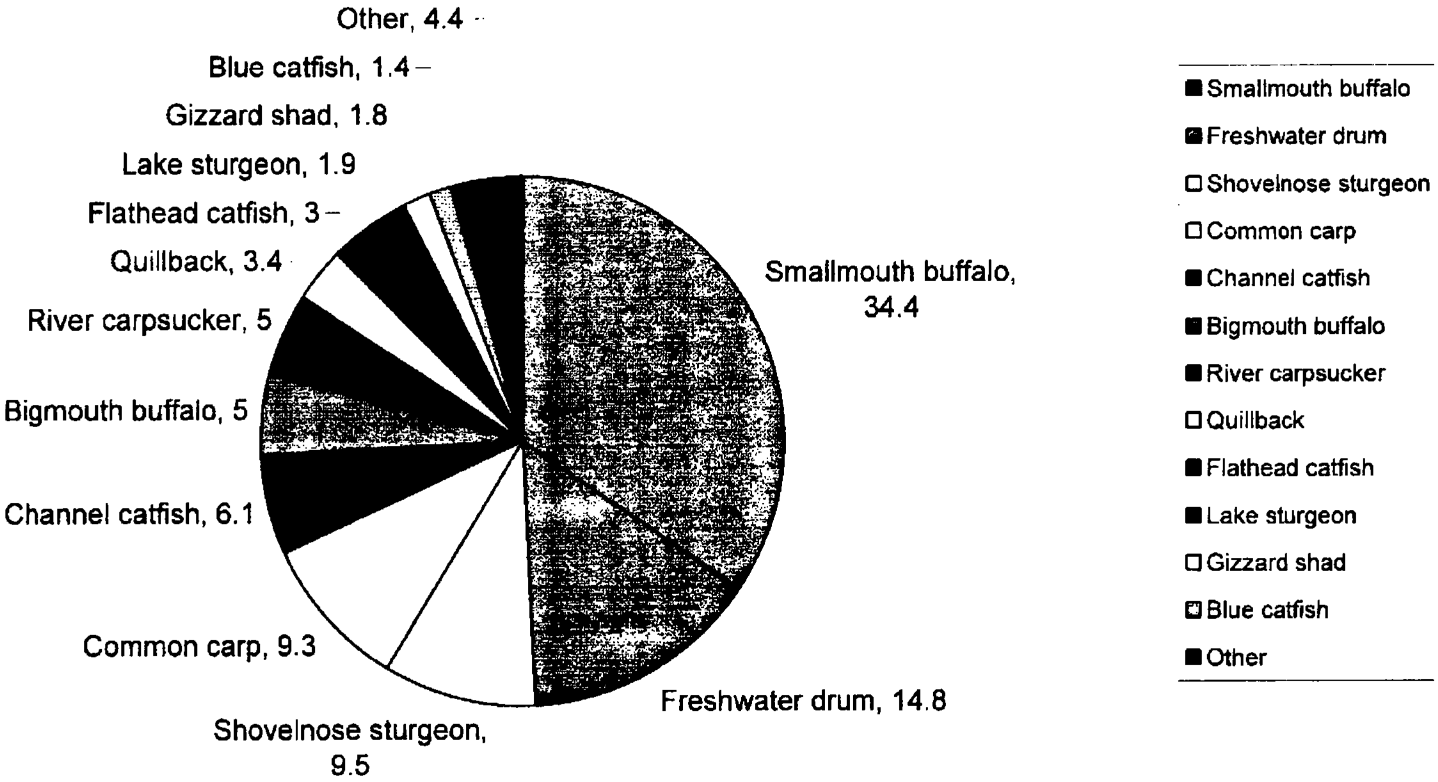


Figure 32. Fish Density (% of Total Biomass) Collected by Benthic Trawl from the Main Channel (Pool 26) of the Upper Mississippi River (2000)

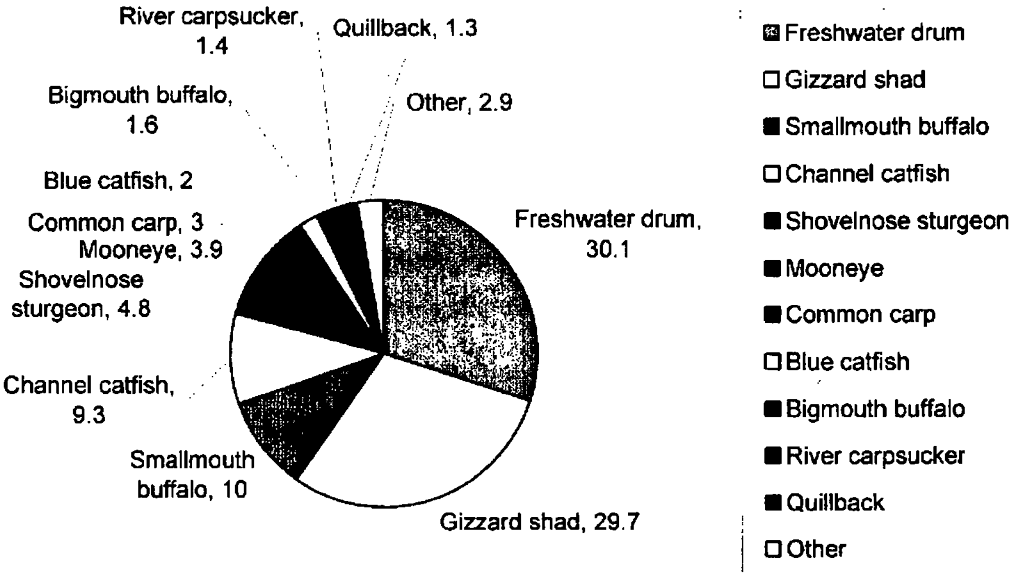
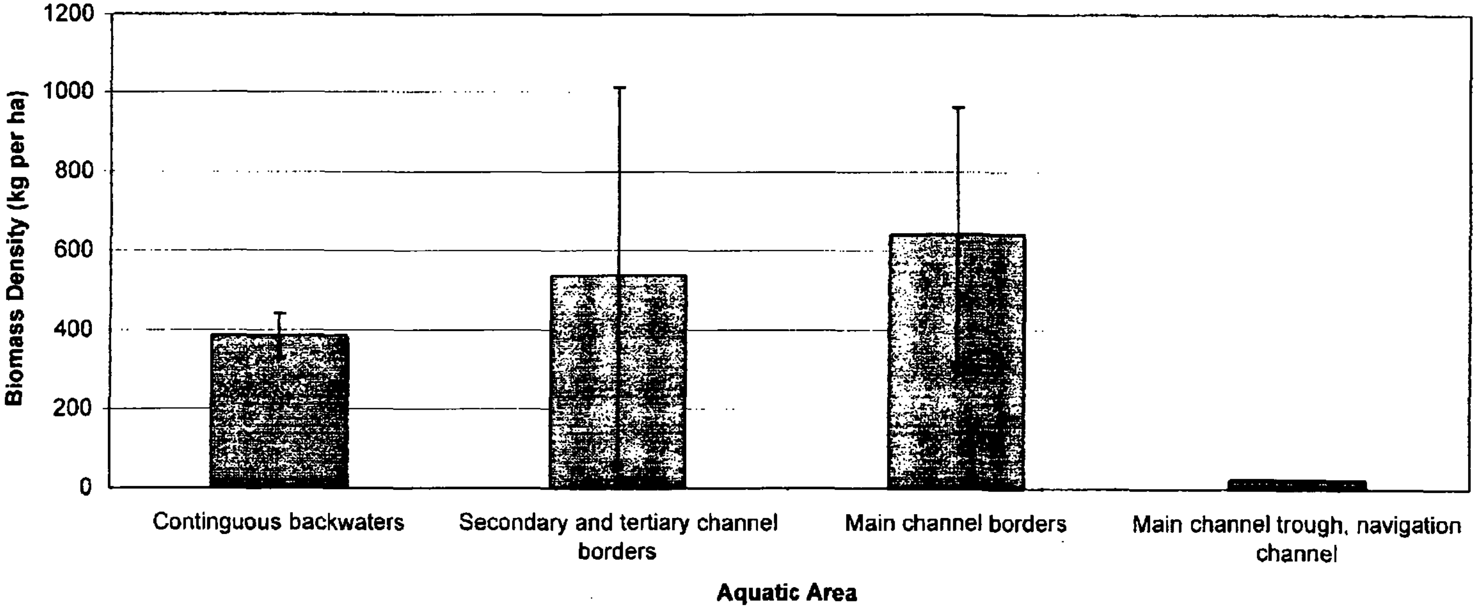


Figure 33. Fish Denisty (% of Total Abundance) Collected by Benthic Trawl from the Main Channel (Pool 26) of the Upper Mississippi River

Figure 34. Biomass Density Estimates - Upper Misssippi River System



Appendix A

Literature Review

Appendix A

Literature Review

Summary of Impingement Studies at Entergy Plants

The following studies were conducted at Entergy plants on the Lower Mississippi River. These projects characterize impingement and, in several cases, the ambient aquatic community.

Summary of the Waterford 1&2 Impingement Study

Espey, Huston and Associates, Inc. (1977a) conducted a study between February 1976 and January 1977 at Entergy's Waterford Unit 1 and 2 CWIS. The purpose of the investigation was to evaluate the impact of the existing intake structures on the biota of the Mississippi River. The facility is located at Mississippi River mile marker 129.9 on the west descending bank of the Mississippi River in Killona, Louisiana.

Impingement sampling was conducted bi-weekly for 24 hours durations for one year for a total of 26 samples. Samples were collected in the sluiceway with three baskets; two constructed of ¼" expanded metal, framed with angle iron and the third basket of ½" hardware cloth framed with angle iron. Weights of captured organisms were measured on an O haus Dial-O-Gram balance, sensitive to ± 0.1 gram. Lengths were measure to the nearest millimeter. Standard length was measured for finfish. Shrimp were measured from the tip of the rostrum to the tip of the telson, while the carapace width of the blue crab was measured. A 24-hour time unit was designated with the screens being run, washed, and cleared at the outset of the period. Baskets were then set in a series in the sluiceway. The two ¼" expanded metal baskets were placed closest to the screens with the ½" hardware cloth basket last as the backup. Collections were made when one or more of the screens operated during the 24-hour sampling period. For the final 30 minutes, all screens were run, washed and simultaneously stopped at the end of the 24th hour. All organisms collected during each diurnal period were identified to species, except when precluded by physical condition. Physical injuries were noted. All fish and crustaceans were individually weighed and measured except for large collection events. These samples were sub-sampled such that all measurements were taken on 25 randomly selected individuals. The number of circulators operating per each unit was recorded, as well as other physical parameters, including temperature, dissolved oxygen, conductivity and pH.

Results of this study show that an equal number of both fish and invertebrates were impinged, however, the overall species richness was greater for fish (46 species) as compared to invertebrates (3 species). Total sample weight for each 24-hour sample ranged from 3,593 grams to 33,560 grams. Impinged organisms were primarily juveniles (>25mm); however, larger organisms (375 mm) were also impinged including the American eel and common carp. River shrimp dominated numerically and constituted 49.7% of the total catch, followed by blue catfish (20.3%), threadfin shad (10.5%), bay anchovy (6.0%), freshwater drum (4.5%), gizzard shad (2.9%), skipjack herring (2.4%), channel catfish (2.1%), striped mullet (0.3%), and blue crab (0.2%). These ten species represented 98.7% of the total biomass. Annual impingement was estimated to be 336,454 individuals, equating to a rate of 4.22 individuals per 10,000 m^3 of water pumped through the plant for both units combined.

Of the top ten species comprising 98.7% of the total "catch" in the impingement study, only the blue catfish, threadfin shad, gizzard shad, freshwater drum, skipjack herring, channel catfish, and river shrimp are considered common throughout the Lower Mississippi River range. The presence of bay anchovy, blue crab, and striped mullet is attributed the Plant's proximity to the Gulf of Mexico. These species are considered estuarine species but are commonly associated with brackish to freshwater areas of rivers and tributaries. The Waterford 1 & 2 Plant is considered to be located in a non-estuarine segment of the river, as the documented salt wedge for the LMR is typically found at a considerable distance downstream (River Mile 90). In all as many as 46 species of saltwater fishes have been documented as far north as St. Francisville, Louisiana. This occurrence is usually associated with extreme low-flow periods when saltwater intrudes into the river.

A-2 Summary of the Baxter Wilson Impingement Study

Between March 12, 1973 and August 20, 1973, and between August 31, 1973 and March 1, 1974, an impingement study was conducted at Entergy's Baxter Wilson plant (Mississippi River mile marker 433.2 AHP) (MP&L 1974). The study was conducted to verify estimates of fish impingement for the Grand Gulf Nuclear Station. The data from this study were compiled and submitted to the Mississippi Department of Environmental Quality (MDEQ) in two separate documents. Samples for the spring through summer 1973 were collected daily for the first two months and thereafter twice a week for either 24 or 48 hours and resulted in the collection of 36,326 fish and 1,186 invertebrates (37,512 total). Fifty-four fish species and twelve species of invertebrates were collected in the study. The samples for the August 1973 through March 1974 collection period consisted of a total of 18 sample days at Unit 1 and 14 sample days at Unit 2. A combined total of 40,025 organisms (fish and invertebrates) were collected in the 1973 to 1974 studies.

Mean lengths of fish and invertebrates were measured to the nearest 0.01 millimeter. Mean weight was recorded to the nearest 0.01 gram and was estimated from length-weight regressions derived from specimens collected at the Grand Gulf Nuclear Station also located on the lower Mississippi River. Rates of impingement were based on the rated capacity of the intake water pumps. Information regarding mesh size of the collection baskets is not available however ¼" mesh baskets were utilized for the other Entergy plant studies.

A total of twenty-five species of fish and eight invertebrate species were collected (2,517 total individuals). With few exceptions, all of the fish were juveniles. The exceptions were the minnows, threadfin shad, bullheads and an occasional mature species of a larger fish such as gar or suckers. The majority of the river shrimp, however, were mature adults (MP&L 1974).

The shad species (gizzard, threadfin, and shad *spp.*) dominated impingement samples, contributing 56.3% of the total catch, followed by freshwater drum (31.7%), carp (2.7%), river shrimp (2.6%), white crappie (1.5%), sucker (1.3%), channel catfish (0.7%) and skipjack herring (0.4%). Annual impingement was estimated to be 160,730 individuals, equating to a rate of 1.96 individuals per 10,000 m^3 of water pumped through the plant.

Impingement rates were higher for Unit 2 by a ratio of 3.5 to 1 prior to July and 1.3 to 1 after July (March through July 1973). The differences observed in impingement rates between Unit 1 and Unit 2 were explained by two factors: (1) differences in design between the CWIS; and (2) differences in intake velocities (Unit 2 was higher) (MP&L 1974).

From March through June, average daily impingement was relatively low (average of 25.6 organisms per day at the combined units). A sharp increase began in late June and peaked in mid-July reaching 3,916 organisms per day at Unit 1 and 4,952 organisms per day at Unit 2. By the end of August, rates returned to pre-July values. The increased rate of impingement in mid-July was likely caused by two factors: (1) river stage decreased below flood stage, resulting in increased fish density in the river's main channel; (2) the abundance of juveniles in the population. One of the effects of flooding is decreased fish density in the river proper, particularly during the reproductive period, as fish disperse into flooded backwaters. When the river returns within its banks, fish densities increase again. (MP&L, 1974). Another factor contributing to the increased impingement in July is that larval fish, which previously were entrained in the spring, had grown significantly and were now susceptible to becoming impinged. In addition, these juvenile fish were more susceptible to impingement than adult fish because of reduced swimming capabilities.

The decline in impingement after the mid-July peak was probably caused by the following two factors. Young-of-the-year (YOY) fish typically have an annual mortality rate of 95 to 99% and many of the fish died; and as the fish grow their swimming ability increases and they can avoid being impinged (MP&L 1974).

Summary of the Willow Glen Impingement Study

The Willow Glen Plant is located on the Mississippi River near mile marker 201.6 AHP. Units 1 & 2 and Unit 4 were sampled individually (Espey Huston and Associates 1977b). The sluiceways were sampled for thirty-minutes four times per day (1600, 1200, 1800 and 2400), and four times per month (April-July) or two times per month (remainder of the year) between January 1975 and January 1976. The screens were rotated just prior to each sampling and, taken together; these samples represent a complete characterization of impingement over the relevant 24-hour period. Organisms were collected in each operable sluiceway with baskets constructed of ¼" expanded metal, framed with angle iron. The baskets were approximately 30" long, 24" deep and 24" wide. The screens were cleaned six hours previous to the first sample time by screen washing for thirty minutes. Upon completion of the screen run, all fish and invertebrates collected in the baskets were removed and preserved in 10% formalin. The organisms were later identified to the lowest possible taxa, weighed to the nearest 0.1g, and measured (standard length) to the nearest mm. Concurrent with these collections, dissolved oxygen, water temperature, pH, conductivity and turbidity were measured in the screen wells of the operating units. Impingement rates based on flow were calculated individually for Units 1 & 2 and Unit 4 and then weighted to estimate the annual impingement when all five units were in operation. The annual weighted impingement was estimated to be 126,449 organisms per year, assuming maximum operation of all five units.

At Unit 1 and 2 river shrimp represented 57.3% of the total "catch", followed by freshwater drum (22.1%), gizzard shad (5.7%), threadfin shad (5.1%), crayfish, (*Procambarus* spp.) (2.6%), blue catfish (2.4%), black crappie (0.7%), skipjack herring (0.6%), bluegill (0.6%), and white crappie (0.5%). These top ten species represented 97.4% of the total abundance. Using the figures from this study, annual impingement at Units 1 and 2 was estimated to be 26,210 organisms, based on effort. Using the flow information recorded during the study, the impingement rate was 1.47 individuals per 10,000 m^3 of water pumped through the two units or 50,013 organisms per year.

Biomass and total abundance were analyzed for seasonal differences at Unit 1 and 2. Biomass varied somewhat throughout the year; however, it was much higher in the spring and early summer (mid-March through early July) than the rest of the year. Total abundance showed similar trends with much higher rates in the summer (mid-June through early August). River shrimp contributed much of the observed seasonal difference observed.

At Willow Glen Unit 4, river shrimp dominated the collections and comprised 27.5% of the total abundance followed by crayfish (27.0%), freshwater drum (12.5%), gizzard shad (9.3%), threadfin shad (7.5%), blue catfish (5.8%), bluegill (1.4%), white crappie (1.4%), channel catfish (1,2%) and skipjack herring (0.9%). These ten species constituted 95.4% of the total abundance. Based on effort the annual impingement at Unit 4 is estimated to be 5,037 organisms. Using the flow information recorded during the study, the impingement rate was 0.13 individuals per 10,000 m^3 of water pumped through the Unit or 5,897organsims per year.

Total abundance showed similar trends observed at Unit 1 and 2 with higher rates in the summer (mid-June through early August). River shrimp and crayfish contributed significantly to this apparent peak in the warmer months of the year.

Summary of the A.B. Paterson Plant Impingement Study (Estuarine)

The A.B. Paterson (Paterson) Plant is located in the New Orleans Parish on the Inner Harbor Navigational Canal (IHNC) just south of Lake Pontchartrain. The IHNC splits from the Mississippi River near mile marker 92.6 AHP. A total of 523 samples were collected every other Thursday from September 1977 through December 1979 (Hollander 1981). For each 24-hour time unit, screens were run, washed and cleaned at the outset of the period. A 10-minute sample was taken every 4 hours at 0800, 1200, 1600, 2000 and 2400. Stainless steel mesh baskets (⅜" mesh) were placed into the sluice so that all organisms that were washed off the screens were retained in the baskets. Organisms were identified to species, counted, weighed and measured. Representatives of each species size grouping collected in the sample were measured and a count of the remainder was made. Sex and breeding condition of crabs were noted for all collected organisms. Total length was measured for the finfish (tip of snout to the tip of the compressed caudal fin). Shrimp were measured in centimeters from the anterior tip of the rostral spine to the posterior edge of the telson. Crabs were measured to the nearest ½", across the tips of the lateral spines (carapace width). Catches were never large enough to necessitate sub-sampling.

A total of 68 species were collected from the sluiceway during the study. Atlantic croaker comprised 32.3% of the impinged organisms followed by bay anchovy (17.1%), white (sand) seatrout (12.6%), blue crab (10.5%), Gulf menhaden (6.6%), sea catfish (4.5%), white shrimp (2.4%), spot croaker (1.9%), spotted seatrout (1.8%) and hogchoker (1.1%). These ten species comprised 90.7% of the total catch during this study.

Using the figures from this study, annual impingement is estimated to be 226,489 organisms which equates to 5.42 individuals per 10,000 m^3 of water pumped through the plant. Weighted extended survival of the primary species impinged at the facility show that 37% of the organisms will survive impingement, which significantly reduces any potential adverse impact created by the plant. Results of this study showed that "during 1978-1979 estimated impingement impact for both stations (Patterson and Michoud) was less than the estimated impact of one local commercial fisherman operating half the time during the shrimping season". Estimated impingement impact of the Paterson Plant was equivalent to 2.5% (1978) and 0.5% (1979) of 1 commercial fishing boat.

Since samples were collected every four hours, potential daily (diel) impingement fluctuations were analyzed. Minimum impingement rates were observed at 0400 and 2400 at Unit 1; 0400 and 1600 at Unit 3 and 0400 and 2000 at Unit 4. Maximum impingement rates were observed at 0800 at Unit 1; 2000 at Unit 2; 0800 and Unit 3; and 0800 at Unit 4. Although impingement rates were somewhat variable depending upon the unit, the very early hours of the day (0400) showed the lowest impingement rates, and the mid-morning hours (0800) had the highest impingement rates. Potential seasonal variations were also analyzed at the plant and it was determined that the impingement rates were higher January through March in 1978 and in January in 1979.

Summary of the Michoud Plant Impingement Study (Estuarine)

The Michoud Plant is also located in the New Orleans Parish on the Intercoastal Waterway (ICWW) which splits from the Mississippi River near mile marker 92.6 AHP. A total of 666 samples were collected at this plant between August 1977 and December 1979 (Hollander 1981). This study was conducted concurrently with the Paterson study and sampling procedures were the same (10-minute samples collected every 4-hours every other Thursday). A total of 91 species were collected from the sluiceway during the study. Atlantic croaker made up 21.5% of the organisms collected, followed by white shrimp (20.0%), bay anchovy (13.5%), brown shrimp (10.5%), blue crab (9.0%), sea catfish (7.8%), white seatrout (4.2%), gaff-topsail catfish (1.8%), least puffer (1.6%) and blackcheek tonguefish (1.4%). These ten species comprised 91.2% of the total catch in the study.

Using the figures from this study, annual impingement is estimated to be 1,676,726 organisms which equates to 9.41 individuals per 10,000 m^3 of water pumped through the plant. Weighted extended survival of the primary species impinged at the facility show that 57% of the organisms will survive impingement which significantly reduces any potential adverse impact of the plant. Results of this study were the same as the Patterson Plant study that showed "during 1978-1979 estimated impingement impact for both stations (Patterson and Michoud) is less than the estimated impact of one local commercial fisherman operating half the time during the shrimping season". Estimated impingement impact of the Michoud Plant was 12.7% (1978) and 2.2% (1979) of 1 commercial fishing boat.

Since samples were collected every four hours, potential daily (diel) impingement fluctuations were also analyzed at the Michoud plant. Minimum impingement rates were observed at 0400 and 1600 at Unit 1; 0400 and 1600 at Unit 2 and 1600 at Unit 3. Maximum impingement rates were observed at 0800 at Unit 1, 2, and 3. Although impingement rates were somewhat variable depending upon the unit, the very early hours of the day (0400) and mid-day (1600) showed the lowest impingement rates, and the mid-morning hours (0800) showed the highest impingement rates, consistent with the Paterson data.

Seasonal variations were also analyzed in this study and it was determined that impingement rates were highest in April, August and September in 1978, and in February and May in 1979.

Other Supporting Studies

Although Entergy's power plants are not the focus of the following studies, the information is very useful in validating Entergy's historic impingement dataset and supporting key concepts stated in this document. The following studies also enable a more complete characterization of the Mississippi River and the habitats associated with Entergy's CWISs on the lower Mississippi River (LMR).

Baker J.A., K.J. Killgore, and R.L. Kasul. 1991. Aquatic habitats and fish communities in the lower Mississippi River. *Aquatic Sciences*, Volume 3, Issue 4, Pages 313-356.

This study delineates the aquatic habitats of the river and describes the communities of fish associated with them. Thirteen distinct habitats are recognized by the authors: channel, natural steep bank, revetment, sandbar (lotic and lentic), pool, slough (contiguous and isolated), oxbow lake, borrow pit, seasonal inundated floodplain, pond, and tributary. Habitat distribution and relative abundance for 91 Lower Mississippi River fish species are discussed. Five species were considered abundant (usually found in high numbers) in the main channel and eight species were considered common (usually found in moderate numbers) in the main channel. Fish biomass estimates are provided for several habitats but not for the main channel. Typical physical conditions (depth, current, and substrate) are provided for 13 habitats. Current in the main channel ranged from 1-3 m/s (low stage) to 2-5 m/s (high stage). Currents were much lower in the other habitats.

It is noted in the study that: "the lower Mississippi River has been sampled relatively poorly because of its great size, depth and strong currents. Until the 1970s there had been almost no large-scale fish studies of the river. Not surprisingly, habitats have been studied in inverse proportion to the difficulty in sampling them, so that only a few have been relatively well sampled (e.g., lentic sandbars, borrow pits, pools) while others (e.g., channel and lotic sandbars) remain virtually unknown".

The report states: "Fish collections from main channel habitat in the lower Mississippi River are essentially nonexistent. From what is known of its physical attributes, few species probably could regularly inhabit the upper and middle water column in this habitat. Some larger fishes such as paddlefish, white bass, and striped bass, and smaller actively swimming fishes such as skipjack herring and goldeye may occupy this area for feeding or for moving among other habitats. Even these species presumably spend considerable time in habitats having lower current speed".

Current speeds are considerably diminished at and very near the river bottom, and enormous sand dunes probably produce rather large, relatively slow-current eddies. Species such as sturgeons, common carp, buffalofishes, carp suckers, blue sucker, catfishes, sauger and freshwater drum could inhabit these areas in the channel habitat, as they do in small rivers. The authors also note that it is also possible that relatively small species such as the central silvery minnow, several chubs (genus *Hybopsis*), and the river darter could inhabit the channel due to their bottom-dwelling habits and streamlined forms. In all, the main channel habitat in the lower Mississippi River may be inhabited by 30 or more fish species out of the 91 species that maintain reproducing populations in the river.

Fish biomass in pools averaged 153 kg/ha and ranged from 16 to 625 kg/ha. Other studies have indicated that biomass may average over 2065 kg/ha and can reach over 3860 kg/ha.

In isolated sloughs, standing stocks ranged from 145 to 939 kg/ha and averaged 510 kg/ha. Biomass in lower Mississippi River oxbow lakes appear to range from 162 to 1023 kg/ha with a mean of 535 kg/ha. Oxbows on tributaries average 250 kg/ha. Standing crops in borrow pits averaged 678 kg/ha in one study. The biomass estimates in this report are referenced from other studies.

The authors note that hydroacoustics in 1988 indicated that fish abundances in both lotic sandbar and main channel habitats may be underestimated by traditional fish collecting techniques. Densities appear to be lower, on average, than pool, lentic sandbar, and natural steep bank habitats; however, during summer and early fall the channel and lotic sandbar habitats have rather surprising numbers of fish. Biomass estimates for the main channel are not presented.

Barko, V.A., D.P. Herzog, R.A. Hrabik, and J.S. Scheibe. 2004. Relationships among fish assemblages in the main-channel border physical habitats in the unimpounded Upper Mississippi River. *Transactions of the American Fisheries Society* 133: 371-384.

This study used Long-Term Resource Monitoring Program (LTRMP) data on fish assemblages in main-channel border habitat (naturally occurring but altered by channelization maintenance) and wing dike habitat (artificial rock structure) to investigate the impact of wing dikes on fishes. Fishes were sampled from 1994 to 2000 during three annual sampling periods; 301 samples were collected in wing dike habitat and 341 samples were collected in main channel border habitat. Four sampling methods, day electro fishing, large hoop net, small hoop net, and mini-fyke net, were included in the analysis. Age-0 fishes were separated from adult fishes for analysis by using reported lengths for each species.

In wing dike habitats, 5,949 adult fishes representing 59 species and 4,855 age-0 fishes representing 47 species were collected. In main channel borders, 5,971 adult fishes representing 54 species and 19,769 age-0 fishes representing 51 species were collected. Cyprinidae (minnows), Clupeidae (herrings), and Centrarchidae (sunfishes) were more abundant in wing dike habitat, and Catostomidae (suckers) and Ictaluridae (catfishes) were more abundant in main-channel border habitat. Smallmouth buffalo, river carpsucker, and channel catfish occurred in high numbers in main-channel border habitat. Flathead catfish and freckled madtom were relatively more abundant in wing dike habitat. Blue sucker was relatively more abundant at wing dikes. The most abundant families of age-0 fishes at wing dikes were Clupeidae and Cyprinidae, and the most abundant families of age-0 fishes at main channel borders were Sciaenidae (drums).

Barko, V.A., M.W. Palmer and D. P. Herzog. 2004. Influential Environmental Gradients and Spatiotemporal Patterns of Fish Assemblages in the Unimpounded Upper Mississippi River. *American Midland Naturalist*. Vol. 152:296-310.

This study investigated the variation of fish assemblages in response to selected environmental factors. Data were collected from 1993 to 2000 from five physical habitats in the un-impounded upper Mississippi River. Eighty-nine species representing 18 families were captured. Of those, 26% were fluvial specialists, 25% were fluvial dependent and 49% were generalist. The numerically dominant component of the adult fish assemblage (those species accounting for >10% of the total catch) accounted for 50% of the total and was comprised of only three species: gizzard shad (*Dorosoma cepedianum*, 25%), common carp, (*Cyprinus carpio*, 15%) and channel catfish (*Ictalurus punctatus*, 10%). The dominant component of the YOY (young of year) fish assemblage was comprised of only two species, accounting for 76% of the total catch. These included freshwater drum (*Aplodinotus grunniens*, 39%) and gizzard shad (37%). Physical habitat effects differed between YOY and adult fishes. The four main environmental gradients influencing overall assemblage structure for both age groups were river elevation, water velocity, conductivity and depth of gear deployment. Adult assemblage structure was similar over time, while YOY assemblage present in 1995 was dissimilar from assemblages present during the other years. The 500 year flood event in 1993 was speculated as contributing to a lag effect from the backwater spawning episodes as a result of the flood pulse. Diversity and evenness indices were low but stable across years for the adult assemblage but varied across years for the YOY assemblage. This study suggests that YOY and adult fish of some species may be using different physical habitats and environmental cues. Adults of many species were associated with wing dikes, closed side channels and tributary physical habitat, which tend to have lower velocities when compared to main channel borders and open side channels. Although patterns were not strong for many YOY fishes, the study suggested that several species associated more with main channel borders, tributaries and closed side channel types of physical habitats.

Barko, V.A. and D.P. Herzog. Relationship among side channels, fish assemblages, and environmental gradients in the unimpounded upper Mississippi River. *Journal of Freshwater Ecology*, Volume 18, Number 3. September 2003.

Fish abundance and environmental data were collected between 1993 and 2001 from six side channels (open and closed) between River km 46.7 and 128.7 in an effort to determine if the fish assemblages differ among the channels. Six sampling methods were used; electrofishing; fyke netting; mini-fyke netting; gill netting; large and small hoop netting. Five hundred seventy-one samples were taken within closed side channels and 224 from the open side channels. There were 11,287 fish representing 18 families collected from the open side channels and 31,282 fish representing 19 families collected from the closed side channels. Differences in fish assemblages were observed between the open and closed side channels. Species that were more abundant in the open side channels were species more tolerant of currents and/or turbidity, including channel catfish, channel shiner, emerald shiner, sauger, river carpsucker, goldeye, and common carp. Species collected more frequently from moderate to low turbidity and/or current included red shiner, orange spotted sunfish, green sunfish, silver band shiner, and white crappie. Pool-dwellers and schooling species, both of which seek cover and prefer little or no current, were common in the closed side channels and included smallmouth buffalo, black buffalo, bigmouth buffalo, black crappie and white crappie.

Barnthouse, L.W. Impacts of power-plant cooling systems on estuarine fish populations: the Hudson River after 25 years. *Environmental Science & Policy* 3 (2000) S341-S348.

In the 1970's the most thoroughly studied and controversial plants were the Indian Point, Bowline, and Roseton generating stations on the Hudson River. A settlement agreement in 1981 led to the establishment of a long-term monitoring program. Estimates of annual reductions in year class abundance for the principal Hudson River fish populations ranged from <5% to >35%. For those species for which the most credible data were available, the striped bass reductions were highest at 20%. The authors emphasize that the impact predictions refer to short-term reductions in abundance. They note there is no evidence that any of the species investigated have experienced any long-term population declines.

Camp, Dresser & McKee, Inc. (CDM) and Limnetics (1976). An Ecological Study of the Lower Mississippi River. Report to Middle South Services, Inc. New Orleans, Louisiana.

An ecological study of the LMR was conducted to determine the species composition, abundance, and biomass of the biological communities in the river. Six sites were selected for fish collections near Mississippi River mile marker 786, 730, 665, 522, 301 and 175 AHP (Ahead of Pass) (with focus on the river near 522, 730 and 785 AHP). At each of the sites three habitats were sampled; (1) river channel; (2) clay-bank area; and (3) backwater area. A total of 65 species were collected during the study; 46 species at Mississippi River mile marker 785 AHP, 49 species at mile marker 730 AHP, and 57 at mile marker 522 AHP. The most commonly captured fish included the gizzard shad, threadfin shad, goldeye, carp, river carpsucker, smallmouth buffalo, blue catfish, channel catfish, flathead catfish, river shiner, and freshwater drum. In addition to the fish, two species of shrimp (*Macrobrachium ohione* and *Palaemonetes kadiakensis*) and a crayfish (Cambarinae) were collected. The "greatest abundance of ichthyoplankton were generally collected at the claybank stations with the lowest numbers generally captured at the midchannel stations".

Coutant, C.C. What is 'normative' at cooling water intakes? Defining normalcy before judging adverse. *Environmental Science & Policy* 3 (2000) S37-S42.

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.

Dettmers, J.M., S. Gutreuter, D.H. Wahl, and D.A. Soluk. 2001. Patterns in abundance of fishes in main channels of the upper Mississippi River system. *Canadian Journal of Fisheries and Aquatic Sciences* 58: 933–942.

Dettmers et al. (2001) used a bottom trawl to sample the navigation channels of Pool 26 of the Mississippi River (114 trawl hauls) and the lower Illinois River (37 trawl hauls). Average total biomass density in the navigation channels of Pool 26 was 21 kg per ha, and average total biomass density in the lower Illinois River was 29 kg per ha. Average numeric density was 86 fish per ha in Pool 26 and 166 fish per ha in the lower Illinois River. The authors note that these densities may be underestimates, as trawl avoidance and escapement could not be estimated during the study. The biomass dominants, defined as those with densities approximately 10% or more of total community density, in the navigation channel of Pool 26 were smallmouth buffalo, freshwater drum, and shovelnose sturgeon. The biomass dominants in the lower Illinois River were freshwater drum, smallmouth buffalo, and common carp. Numeric dominants in Pool 26 were freshwater drum, gizzard shad, and smallmouth buffalo. Numeric dominants in the lower Illinois River were freshwater drum and gizzard shad.

Estimates of biomass density in the main channel were far less than values recorded in other aquatic areas of the upper Mississippi River system. The largest recorded biomass estimates are from main channel borders and side channels. Biomass estimates in backwaters were intermediate, and the lowest estimates are from the main channel.

Eggleton, M.A. and H. L. Schramm, Jr. 2004. Feeding Ecology and energetic relationships with habitat of blue catfish, *Ictalurus furcatus*, and flathead catfish, *Pylodictis olivaris*, in the lower Mississippi River, U.S.A. *Environmental Biology of Fishes* 70: 107-121.

These authors examined the feeding habits of blue catfish, *Ictalurus furcatus*, and flathead catfish, *Pylodictis olivaris* collected from floodplain lake, secondary (side) river channel, and main river channel habitats in the lower Mississippi River (LMR). The feeding ecology of these two large river species was described within the context of whether or not off-channel habitats in the LMR (i.e., floodplain lakes and secondary channels) potentially provided energetic benefits to these fishes as purported in contemporary theory of large rivers. Diet composition of prey and associated caloric densities were utilized as indicators. Differences in diet among habitats were strong for blue catfish, but weak for flathead. Consumed foods generally differed among habitats in caloric (energy) content. Caloric densities of consumed foods were generally greatest in floodplain lakes, least in the main river channel and intermediate in secondary river channels. Strong between-year variation in diet was observed for blue catfish. Blue catfish fed disproportionately on lower-energy zebra mussels in the main river channel during 1997 and higher-energy chironomids and oligochaetes in floodplain lakes during 1998. Results suggested that although off-channel habitats potentially provided greater energetic return to catfishes in terms of foods consumed, patterns of feeding and subsequent energy intake may vary annually. Energetic benefits associated with off-channel habitats as purported under contemporary theory (e.g., the "flood-pulse concept") may not be accrued by catfishes every year in the LMR. The LMR drains 41% of the contiguous United States. As such, this study provides information specific to the LMR by relating off-channel habitat-dependent composition of consumed species. This study represents a more mechanistic approach in assessing fish relationships with the main channel, side channel and floodplain lake habitats. Seasonal variations were also noted.

Haines, D.E. Biological control of gizzard shad impingement at a nuclear power plant. *Environmental Science & Policy* 3 (2000) S275-S281.

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.

Hartfield, P. (USFWS) and T. Slack (Mississippi Museum of Natural Science). Unpublished data. 2001-2004.

The following are trawl summaries provided by Paul Hartfield.

2004

Extended high water and other complications limited our sampling to 5 days during 2004. River stages ranged from 12-33 ft. No pallid sturgeon were collected. A total of 37 shovelnose were collected, ranging from 45-819 mm in total length. One larval sturgeon was also collected. By-catch was similar to previous years, including channel, flathead and blue catfish, drum, crappie, speckled and silver chubs, sauger, paddlefish, shad, and shrimp. An interesting note is that all of the smallest sturgeon (45-100+ mm) were collected during September and October. The larval sturgeon was collected in late September. This seems to imply a summer and/or early fall spawn for shovelnose. Although data is limited, it suggests fairly strong recruitment occurred during the summer of 2004.

2003

Sampling was only conducted for 9 days during 2003 due to extended high water stage and other complications. Of these, 8 days were at river stages ranging from 15-25 ft; the lowest stage sampled was 9 ft. We made 54 trawl pulls above Vicksburg, Mississippi at RM 439, 444, 446, 456,471, and 478. A total of 78 shovelnose sturgeon, 5 pallid, and one intermediate were collected. Pallids were taken at approximately RM 478, 456, and 444, and ranged from 439-739 mm fork length (FL). Shovelnose were collected at all sites and ranged from 76-656 mm FL. Young of year shovelnose sturgeon (<140 mmFL) were more common in shallow (<9 ft), sand/gravel areas below gravel bars. One shovelnose tagged on 8/12/02 was captured, released, and reported by a commercial fisherman on 1/6/03. This fish had moved approximately 40 miles downstream.

By-catch consisted of shrimp, various aquatic insects, one softshell turtle, and 11 species of fish, including blue cat, channel cat, flathead, striped bass, paddlefish, drum, speckled chub, silver chub, shad, sauger, and blue sucker. An interesting side note was the discovery of the endangered fat pocketbook mussel (*Potamilus capax*) inhabiting the bases of Ajax and Ben Lomond dikes in secondary channels between RM 481- 489.

2001

The U.S. Fish and Wildlife Service, Mississippi Museum of Natural Science, and Lower Mississippi River Conservation Committee, initiated trawl surveys for pallid sturgeon in the Mississippi River on September 5, 2001. The collection effort was focused in the vicinity of Vicksburg, MS, from Delta Point (~RM 436) to Marshall Cutoff (~RM 452). This area contains a variety of channel habitat types, including islands, dikes, a closed secondary channel, a partially closed secondary channel, point bars, buckshot bank, revetted bank, deep bends, and a shallow crossover. Trawling in large rivers is not a standardized collecting technique. One of the objectives of this study was to determine the value and efficiency of this technique for sampling sturgeon and other big river fishes.

Trawling was conducted for 20 days in 2001 using standard 16 foot, 1.5 inch mesh trawls, and 11 days in 2002, using custom made16 ft., 1.5 in. mesh trawls with 1/4-1/2 in. Cod socks, and 14 ft., 2 in. mesh trawls. Extended high spring and early summer river stages limited sampling in 2002. The trawls collected 28 species of fishes, 2 species of turtles, and freshwater shrimp. By far the most abundant fishes sampled by trawling were juvenile and young of year catfish (blue and channel), and at some sites juvenile drum. Sturgeon were the most abundant large fish collected with trawls (>100 mm). With occasional exceptions (blue suckers, buffalo, et al.), trawls were selective for small fish species or small life stages. Sturgeon were the most abundant large fish collected in the trawl.

Trawling resulted in the collection of 615 shovelnose sturgeon, 9 pallid sturgeon, 7 intermediates that were tentatively identified as pallid sturgeon, and 6 intermediates that were more similar to shovelnose. Sturgeon were collected at virtually all river stages (3.7-34 ft.), but were collected in greater numbers at low to moderate stages. There were 3 recaptures of shovelnose sturgeon that showed a growth of 10-50 mm over 4-9 months, and no recaptures of pallid. Trawls captured shovelnose sturgeon 65-870 mm TL, and pallid 360-816 TL.

Trawling is effective for sampling shovelnose and pallid sturgeon in the Mississippi River, particularly at low to moderate river stages. It also appears to be somewhat selective for sturgeon, probably due to their behavior when disturbed and the presence of spines along their scutes. Trawling is limited by depth, it seems to be less effective at depths greater than 40 ft. This is probably due to the effect of strong currents on the long trawl lines required at these depths. It is also limited by structure. There is an abundance of habitat along revetted banks, but broken revetment, rip-rap, and wire tend to snag and destroy the trawls.

All sturgeon captures were associated with moderate to strong currents, sand and sand/gravel substrates, 12-40 ft. depths, and usually some type of "structure" such as "reefs", dropoffs, secondary channels. Pallids were usually collected in the deeper portions of these habitats, 20-40 ft.

Johnson, B.L., W.B. Richardson, and T.J. Naimo. 1995. Past, present, and future concepts in large river ecology. *Bioscience* 45(3): 134-141.

Johnson et al. (1995) review the concepts of how lotic systems function and suggest ways to expand these concepts to increase understanding of large river ecosystems. There are two primary hypotheses of how lotic systems function: the river continuum concept and its corollaries and the flood pulse concept. The river continuum concept identifies three energy sources that differ in importance along the longitudinal continuum of a river: allochthonous inputs, autochthonous production, and transport of organic material from upstream. In large rivers, the large volume of water is thought to have a buffering effect that reduces variation in temperature and flows. Primary production is reduced due to turbidity. The main energy source is particulate organic matter transported downstream. Because the river continuum concept assumes a longitudinal structure for rivers, the predictions relate only to main channels of rivers and omit backwaters, marshes, and floodplain lakes. Data from large rivers suggest that the river continuum concept holds for large rivers confined to their channels but not for large floodplain channels.

The second primary hypothesis of how lotic systems function is the flood pulse concept, which applies to large floodplain rivers in temperate and tropical areas. This concept identifies the annual flood pulse that extends the river onto the floodplain as the most important hydrologic feature of large rivers. Floodplains are highly productive and usually contain a variety of aquatic habitats, including backwaters, marshes, and lakes. During flooding aquatic organisms leave the channel and utilize the floodplain resources and habitats. As waters recede, nutrients and organic matter flow back into the main channel, side channels, and backwaters. Organic matter from upstream areas is predicted to have negligible effects on production at higher trophic levels compared to organic matter from the floodplain.

Rivers with more diverse habitat, in both the channel and floodplain are likely to be more productive. Damming, irrigation withdrawals, dikes, channelization, and floodplain modifications are likely to reduce habitat diversity, and therefore, productivity.

Junk, W.J. and K.M. Wantzen. 2004. The Flood Pulse Concept: New aspects, approaches and applications – an update. In Proceedings of the Second International Symposium on the Management of Large Rivers for Fisheries Volume II. Welcomme, R. and T. Petr, Eds., FAO Regional Office for Asia and the Pacific, Bangkok, Thailand. RAP Publication 2004/17, pp. 117-139.

This study summarized the predictions of the flood pulse concept and evaluated them in the light of recent data and new concepts. Further developments in floodplain theory are discussed. The flood pulse concept (FPC) focuses on productivity in floodplain areas, in contrast to the river continuum concept (RCC), which focuses on the importance of allochthonous matter from upriver. An additional concept, the riverine productivity model (RPM) predicts that autochthonous production in the river channel and allochthonous inputs in the lower reaches provide a substantial portion of the organic matter used by river organisms.

In rivers where conditions are beneficial for algae growth and where conditions for production in the floodplain are restricted by turbidity and river regulation, in-channel production can be substantially higher than floodplain production. The authors state that "River channels can support diverse and productive fish communities under these conditions", however, they also note that "This is not the case in very large and turbid lowland rivers with a sandy, permanently moving bed load." In rivers that experience a predictable, sufficiently long and timely inundation, such as the Mississippi River, use of floodplain resources provides a "flood pulse advantage" for floodplain fishes compared to riverine species. The authors also state that "In most river-floodplain systems, primary production in the floodplain is much higher than in the channel".

Koel, T.M. Spatial variation in fish species richness of the upper Mississippi River System. *Transactions of the American Fisheries Society* 133:984-1003, 2004.

The objectives of this study were to describe patterns of fish species richness, evenness, and diversity among representative habitats and river reaches and to examine the relationship between fish species richness and habitat diversity. Between 1994 and 1999 fish communities of main channel borders, side channel borders, and contiguous backwater shorelines were sampled using boat-mounted electrofishing gear, mini-fyke nets, fyke nets, hoop nets, and seines. A total of 650,000 fish were collected representing 106 species from UMR pools 4, 8, 13, and 26, the open un-impounded river reach and the La Grange Reach of the Illinois River. The most common species included gizzard shad (29%), emerald shiner (22%), bluegill (8%), freshwater drum (6%), and spot fin shiner (5%).

Within pools, species richness differed significantly among habitats and was highest in back water shorelines and lowest in main channel borders. At the reach scale, Pools 4, 8, and 13 consistently had the highest species richness and pool 26, the open-river reach, and the La Grange reach were significantly lower. Species evenness and diversity showed similar trends. The relationship between native fish species richness and habitat diversity was highly significant. These results support efforts aimed at the conservation and enhancement of connected side channels and backwaters.

LeJeone, J. and R. Monzingo. 316(b) and Quad Cities Station, Commonwealth Edison Company. *Environmental Science & Policy 3* (2000) S313-S322

Quad Cities Station is located approximately 30 miles north of Davenport, Iowa on the Upper Mississippi River. The station uses open cycle cooling and has an intake rate of 2270 cfs. During average river flow, the velocity at the intake is less than 1.0 fps. The relative abundance and impingement of fish at the intake were surveyed from 1973 to 1996. The purpose of the surveys was to determine the impact of the Quad Cities Station on the fish population in the river. Analysis of the surveys has yielded a conclusion that the station has not caused a measurable change in the local fishery. The surveys primarily focused on the freshwater drum, which was chosen as an indicator species.

The cooling water system was operated as a partial-closed system from 1973 to 1983. A barrier net was installed and operated from 1979 to 1983. The station employed open cycle cooling from 1984 to 1996. Inter-annual impingement rates varied greatly (between 1 and 35 fish per 10,000 m^3 water flow) over the study period (1973 to 1996); however, the relative abundance of the dominant species remained relatively unchanged over time. The authors claim the variation in impingement rate was due to changes in the mode of operation, natural fluctuations in fish populations and other environmental variations. An increase in impingement rate was observed over time, but can be explained by the conversion of the plant from closed cycle to open cycle in 1984. Freshwater drum and gizzard shad accounted for approximately 90% of the fish impinged.

Lewis, R. B. and G. Seegert. Entrainment and impingement studies at two power plants on the Wabash River in Indiana. *Environmental Science & Policy* 3 (2000) S303-S312.

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 were 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.

Madejczyk, J.C., N.D. Mundahl and R.M. Lehtinen. 1998. Fish assemblages of natural and artificial habitats within the channel border of the upper Mississippi River. *American Midland Naturalist*. Vol. 139, No.2. pp. 296-310.

This study determined whether fish assemblages differed among various artificial (rip rap, wing dikes, closing dikes and bridge pilings) and natural habitats (woody snags, sandy and or grassy shoreline) within the main channel border (shallow, near shore areas) of the upper Mississippi River (Pool 6 between River Km 1,157 and 1,171). Collections were not conducted in the main channel. Sampling was conducted during the day in August and October 1994 via electrofishing from a boat. A total of 31 fish taxa were collected and catch per unit effort was based on time (fish/min). Fish abundance and diversity measures differed little among habitat types, but significantly larger fish were present at locations with structure (wing dikes and woody snags) than at sites without (bare shore).

During August, emerald shiners dominated collections (all channel border habitats) representing 68% of the total catch (1,743 fish) by number, followed by redhorses (9.1%), gizzard shad (7.3%), smallmouth bass (2.2%), white bass (2.0%), common carp (2.0%), logperch (1.6%), spotfin shiner (1.4%) and freshwater drum (1.2%). Percent of total biomass was dominated by redhorses (49.1%), common carp (31.2%), bigmouth buffalo (4.5%), smallmouth buffalo (1.8%), freshwater drum (1.5%), quillback (1.5%), channel catfish (1.3%), blue sucker (1.2%), and white sucker (1.0%). Only 215 fish were collected in October with similar dominant species.

McInerny, M.C. and J.W. Held. First-year growth of seven co-occurring fish species of Navigation Pool 9 of the Mississippi River. Journal of Freshwater Ecology, Volume 10, Number 1 – March, 1995.

First-year growth patterns of seven fish species (species in which the sample sizes were sufficient to describe growth patterns) were determined with weekly or monthly samples (May 1 – May 31, 1979) taken from water intake screens of a power plant (Dairyland Power Cooperative Genoa Plant) located along Navigation Pool 9 of the Mississippi River (River Mile 679). Mean total lengths of mooneye, gizzard shad, freshwater drum and white bass were at least 110 mm by winter (November through March), while mean lengths of black crappie, channel catfish and flathead catfish were 67 to 74 mm by winter. Mean total lengths at capture of all species except channel catfish increased significantly with time until September or October, after which lengths did not change.

The numbers of fish impinged and spawning periods (ascertained from the literature) for the seven species are as follows: mooneye (May, 51); gizzard shad (May-July, 554); channel catfish (June – August, 480); flathead catfish (June-July, 147); white bass (June, 130); black crappie (May-June, 299); freshwater drum (June – July, 1,123). It was determined that first-year growth among these species appeared strongly associated with water temperature.

McLaren, J.B. Fish survival on fine mesh traveling screens. *Environmental Science & Policy* 3 (2000) S369-S376.

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.

Michaud, D.T. Wisconsin Electric's experience with fish impingement and entrainment studies. *Environmental Science & Policy* 3 (2000) S333-S340.

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.

Miranda, L.E. 2005. (USGS, Mississippi Cooperative Fish and Wildlife Research Unit). Fish assemblages in oxbow lakes relative to connectivity with the Mississippi River. *Transactions of the American Fisheries Society*. 134:1480-1489.

To help design plans to restore and preserve fish assemblages in Mississippi Rive fluvial lakes, this study tested whether predictable patterns in lake fish assemblages were linked to the level of connectivity with the river. Results suggested that connectivity played an important role in structuring fish assemblages and that it was correlated with variables such as lake size, depth, distance from the river, and age. Annual floods homogenize the floodplain and promote connectivity to various degrees, allowing for fish exchanges between river and floodplain that directly affect fish assemblages. Eleven oxbow lakes between River Km 700 and 1,200 (between Memphis, TN and Vicksburg, MS) were included in this study.

Species composition exhibited predictable patterns relative to connectivity. Lakes with higher connectivity had higher representation of rheophilic species such as skipjack herring, river carpsuckers, gars and white bass. These species require the flow, or simply the flooding, afforded by large tributaries to complete their life cycle in lacustrine systems. In contrast, lakes with reduced or no connectivity with the Mississippi River tended to have higher proportion of lacustrine species, such as most of the centrarchids, yellow bass and clupeids. These taxa are adapted to lacustrine environments by completing their life cycle within a lake.

Collections were made during the day between September and November (low water period) via boat electroshocking along the lake shorelines. A total of 48,320 fish were collected representing 31 taxa. Relative abundance of the dominant species were blue gill (28.5%) gizzard shad (19.4%), threadfin shad (11.9%), longear sunfish (8.0%), largemouth bass (7.6%), silverside (3.6%), common carp (2.7%), orangespotted sunfish (2.7%), white bass (2.0%), smallmouth buffalo (1.8%), black crappie (1.6%), white crappie (1.5%), and catfishes (1.4%).

Randall, R.G., J.R.M. Kelso, and C.K. Minns. 1995. Fish production in freshwaters: Are rivers more productive than lakes? *Canadian Journal of Fisheries and Aquatic Sciences* 52: 631-643.

Randall et al. (1995) summarized community fish production data from the literature to test the hypothesis that production is higher in rivers than in lakes. Average community production at 142 river sites was 273 kg per ha per year (range 26 – 2,800 kg per ha per year), and average community production at 22 lakes was 82 kg per ha per year (range 2 – 398 kg per ha per year). The higher production found in rivers was a result of higher densities (14 times) and greater biomass (about 2 times). Fish production and phosphorus were positively correlated in both lakes and rivers. Mean density in rivers was 75,665 fish per ha, and mean biomass in rivers was 146.1 kg per ha (n = 58). Mean density in lakes was 5,577 fish per ha, and mean biomass in lakes was 83.8 kg per ha. Regression equations relating production to fish density, biomass, body size and body mass, and specific production to fish weight are presented.

River Bend Environmental Report

The River bend site is located on the eastern shore of the Mississippi River near St. Francisville, Louisiana. The site is separated from the river by a natural levee formed above the river bank and by the lower floodplain area, which is crossed and drained by Alligator Bayou and its tributaries. The report summarizes aquatic data specific to the site that were gathered by Louisiana State University (LSU) researchers between 1972 and 1977.

Ichthyoplankton were sampled in the river near the site between 1973 and 1977. Surface tows using meter nets (0.505-mm mesh) were conducted monthly or semi-monthly depending upon the season. In addition, a more intensive study and analysis of ichthyoplankton distribution was conducted by Gallagher during 1976-77 and included several 24-hr series of collections to evaluate diel distribution. Forty-five taxa, representing 13 families of fish were identified. Four families, Sciaenidae (drums), Clupeidae (herrings), Cyprinidae (minnows), and Catostomidae (suckers) accounted for between 93 and 98 percent of the ichthyoplankton collected from 1974-77. The freshwater drum dominated the ichthyoplankton and represented 43% (by number) of the total. The Clupeidae were almost entirely represented by the gizzard shad and threadfin shad. While young larvae of these species could not be distinguished, combined, they made up approximately 26% of the total ichthyoplankton collected.

A considerable difference in the composition of ichthyoplankton was noted between 1974 and 1975 (high water years) and in 1976 to 1977 (low water years). Clupeids predominated in high water years (42.5%), while the freshwater drum comprised only 23 percent. In low water years, clupeids represented only 10 percent of the total, while drums were more numerous with 63 percent. No species listed as threatened or endangered were collected during the course of the study.

Total ichthyoplankton density was greatest from May through early July during 1976 and 1977, due mainly to the preponderance of drum. The greatest diversity of taxa was noted in late April and early May.

The spatial distribution of ichthyoplankton in the river at the site was evaluated and abundance tended to be greater at the shoreline stations than in the mid-river samples. Diel distribution of ichthyoplankton showed no significant day-night differences in the total fish larval density, but certain taxa did exhibit periodicity. Suckers and threadfin shad were more abundant at night, while gizzard shad and drum were more abundant during the day.

Juvenile and adult fish were collected from the river near the site between 1972-77 with trammel nets, seines, and hoop nets. Eighty-eight species representing 23 families were collected during the course of the study. Seine collections were generally dominated by Cyprinidae (river shiner, emerald shiner, silverband shiner, and silvery minnow). The threadfin shad was also occasionally numerous in these collections. Gizzard shad and freshwater drum were the most numerous species in the trammel net samples. Also abundant were blue catfish, white bass, bowfin, carp, and flathead catfish. Hoop net collections were dominated primarily by freshwater drum, gizzard shad, and flathead catfish. In general, the number of fish collected was greatest in the summer, with the greatest number of species being present during the spring and summer. High waters tended to produce more diverse catches than low water years, partly due to an influx of extra riverine species.

Populations of fish in the Mississippi River exhibited considerable variation during the course of the studies. This variation was due to both intrinsic factors, such as migrations and spawning behavior and success (resulting in varying strength year classes), and extrinsic factors such as food availability, river flooding, turbidity, currents, and temperature.

Several hundred thousand pounds of finfishes were landed annually from the Mississippi River in Louisiana at the time of the study. Between 1,000 and 2,000 full-time and part-time fishermen contributed to those landings. The areas of the river near the River Bend site, however accounted for only a small portion of the landings (approximately 6%). The principal commercial fish in the area were stated to be shad, buffalo, and catfish.

Schramm, H.L. Jr. 2004. Status and Management of Mississippi River Fisheries. Pages 301-303 in Proceedings of the Second International Symposium on the Management of Large Rivers for Fisheries. Volume 1. FAO regional Office for Asia and the Pacific, Bangkok, Thailand. RAP Publication 2004/16.

This study compiled fisheries data from four sources: Fremling *et al.* (1989); Baker *et al.* (1991); Pilto *et al.* (1995), and Warren *et al.* (2000). Schramm notes the lack of standardized habitat classification for Mississippi River fishes. He assigned one of three habitat zones to each species: main channel, channel border, and backwater. Of the 137 resident species assigned habitat zones, none are expected to reside in main channel habitats throughout their life cycle, 24 are expected to occupy one or more channel border habitats throughout their life cycle and 50 species are expected to reside in one or more backwater habitats throughout their life cycle.

Provided in this report is a list of the preferred habitat for each species, excluding marine species collected in the lower 150 km of the river. The probable zone is the area of the river from which the fish have been or are likely to be collected. Channel border is listed as the probable zone for 108 species. Backwater is listed as the probable zone for 107 species. The main channel is listed as the probable zone for 31 of the 137 species listed. The 31 species thought to inhabit the main channel include three lamprey species, four sturgeon species, paddlefish, two gars species, three shad/herring species, central stoneroller, grass carp, plains minnow, pearl dace, three shiner species, creek chub, two sucker species, smallmouth buffalo, three redhorse species, two catfish species, brook stickleback, and striped bass.

Biomass estimates are provided in this study from five other studies conducted on the UMR and LMR between 1947 and 1997 (Pilto, 1987; Dettmers *et al.* 2001; Lowery et *al.* 1987; Cobb *et al.* 1984; and Baker *et al.* 1991). Biomass (kg/ha) in the backwaters and borrow pits were 361, 596, 558, 741, 34, 911, 687 with a mean of 555 kg/ha. Biomass estimates in the channel border and dyke pools were 333, 327, 748, 153, and 2,065 with a mean of 725 kg/ha. Biomass in the main channel is available for only one study (Dettmers *et al.* 2001) and was 21 kg/ha. Sample size for this study was 114.

Although biomass estimates are low in the main channel (Dettmers *et al.* 2001), trawling resulted in a wide variety of species and sizes. Schramm noted that hydroacoustic sampling indicated moderate to high densities in LMR main channel and channel border habitats in the Baker et al. 1987, 1988a, and 1988b studies, with densities in the main channel lower than along banks or in dike pools.

In the LMR backwaters, gizzard shad made up 44% of the biomass, common carp 15%, freshwater drum 7%, bigmouth buffalo 6% and threadfin shad 5% of the total biomass. Collectively, commercial species were 34% of the total biomass and sport fishes were 10%. Shads and buffalo dominated levee borrow bits. The biomass in lentic dike pools was dominated by shads, buffalo fishes, catfishes, crappies, gars, and white bass. The total biomass of the channel border habitats was dominated by non-ictalurid commercial fishes (73%), catfishes 20% and gizzard shad 6%.

Spicer, G., T. O'Shea and G. Piehler. Entrainment, impingement and BTA evaluation for an intake located on a cooling water reservoir in the southwest. *Environmental Science & Policy* 3 (2000) S323-S331.

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.

U.S. Army Corps of Engineers. Mississippi River Commission. Fishery and Ecological Investigations of Main Stem Levee Borrow Pits Along the Lower Mississippi River. Lower Mississippi River Environmental Program. Report 1. December 1984.

Twenty-five borrow pits along the main stem levee system of the Lower Mississippi River were investigated with regard to aquatic resources as part of the Lower Mississippi River Environmental Program. Objectives of the study were to develop an inventory of environmental resources of the borrow pits and to develop environmental design criteria for borrow pits to be used for levee construction. The 25 borrow pits sampled were distributed along the Mississippi River from New Madrid, Missouri, to Lutcher, Louisiana.

Results of the study indicated that main stem levee borrow pits along the Lower Mississippi River support abundant and moderately diverse fish and macroinvertebrate populations. Total fish standing stock averaged 595 lb/acre. Gizzard shad (34.8% of total), threadfin shad (19.5%), *Lepomis* spp. (17.5%), common carp (2.7%), and smallmouth buffalo (2.7%) were the most abundant fishes, but significant numbers of white crappie and catfishes were also present. The duration of annual borrow pit flooding by Mississippi River waters was the single most important positive factor affecting fish and macrobenthos abundance in the borrow pits.

Two 1-acre plots per borrow pit were sampled for fishes with rotenone. Block nets 3.1 m deep and 192 m long with 12.7-mm stretched mesh were used to delimit each plot. For each borrow pit, one plot was located on the riverward side and one was located on the leeward side. To minimize incidental fish kills, potassium permanganate was applied around the outside perimeter of the net at each plot to detoxify any rotenone that might have passed through the net. Fish were collected for 48 hours following application of rotenone using 0.6 - and 1.9-cm-square mesh dip nets. Fish from each plot were individually measured and collectively weighed by species. A total of 514,430 fish that weighed 29,768 pounds were collected; 58 species and 18 families were identified in the study. The number of fish collected averaged 10,288 individuals per surface acre.

U.S. Army Corps of Engineers. Mississippi River Commission. Fish and Benthic Communities of Eight Lower Mississippi River Floodplain Lakes. Lower Mississippi River Environmental Program. Report 6. February 1987.

The purpose of this study was to obtain baseline data on the fish and benthic communities of eight Lower Mississippi flood plain lakes, including abandoned channels and Oxbow lakes. Fish communities were sampled and evaluated using electrofishing, experimental gill netting, and rotenone in 1984. The comparison of fish populations of oxbow lakes and abandoned channel type II lakes illustrates similarity in species composition, species occurrence, relative abundance, and length frequency. Abandoned channel type I fish populations were not similar to those of the oxbow lakes and type II channels. Fish and population data showed that although fish are transient among main channel and floodplain habitats during high water periods, there are particular habitat types that provide important spawning and nursery areas, forage availability and cover for the majority of the lower Mississippi River fishes when river flow is within the channel top banks. Length frequency analysis showed similarities in size categories of fish from all habitats sampled. Year class strength coincides with changing hydrology, and it is therefore impossible to characterize fish standing stocks from each specific habitat.

A total of 69 fish species representing 18 families were collected from eight floodplain lakes on the Lower Mississippi River. Threadfin shad comprised the dominant forage base (by number) at all but three lakes, where either gizzard shad or orangespotted sunfish was the dominant forage species. Other dominant species included bullhead minnow, bluegill, longear sunfish, and inland silverside

Appendix B

Detailed Rare, Threatened and Endangered Species Information

Sea Turtles (Endangered/Threatened)

Five species of sea turtles are federally listed as endangered or threatened. These same species are also listed as endangered or threatened by the states of Louisiana and Mississippi. These include the loggerhead sea turtle, green sea turtle, leatherback sea turtle, hawksbill sea turtle, and Kemp's or Atlantic Ridley sea turtle. Bob Hoffman with the National Oceanic and Atmospheric Administration (NOAA) was contacted to determine the potential for sea turtles to inhabit the lower reaches of the LMR and tidal channels near the Michoud and Patterson Plant's (Hoffman 2005). Mr. Hoffman indicated that the loggerhead sea turtle is sometimes caught in commercial shrimp trawls in Lake Pontchartrain which is just north of these two plants. He stated the numbers in this area were fairly low. Two additional sea turtle species, the Kemp's Ridley and green, also inhabit the lower reaches of the LMR; however, Mr. Hoffman stated they would be rare this far up the river. He also stated that few sea turtles should be found above Mississippi River mile marker 90 AHP. According to Mr. Hoffman, the average size of most sea turtles in the area is between 1 and 2 feet in diameter (carapace size). Based on the use of intake racks, relatively low intake velocities, and the size of sea turtles in the area, he believes that potential impact to sea turtles associated with CWIS would be almost nonexistent. Based on this information, sea turtles were determined to have no impingement potential in the LMR.

Alligator Snapping Turtle (Restricted Harvest – Louisiana)

The alligator snapping turtle is included on the Madison Parish, LA, Warren County, MS, (Baxter Wilson), Washington County, MS (Gerald Andrus) and St. John the Baptist Parish (Little Gypsy, Waterford 1&2) lists. According to the USFWS, the alligator snapping turtle inhabits most river systems emptying into the Gulf of Mexico, including the Mississippi River as far north as Illinois. It also makes use of bodies of still water associated with river systems. According to the Center for Reptile and Amphibian Conservation and Management, they prefer large slow-flowing streams or tributaries with large holes and mud at the bottom. They are also found in canals, lakes, oxbows, swamps, ponds and bayous. The primary agents of population decline appear to be degradation and damming of river systems and widespread commercial harvest for its meat. A review of studies conducted at Entergy's plants on the Lower Mississippi River found no records of impingement. Based on this information and preferred habitat, it appears the potential for impingement is minimal.

Diamondback Terrapin (Restricted Harvest – Louisiana)

The diamondback terrapin is included on the Orleans (A.B. Paterson and Michoud) and Jefferson (Ninemile) parish lists. According to the Louisiana Department of Wildlife and Fisheries, the diamondback terrapin prefers brackish water habitats, especially coastal marshes including tidal flats, coves, estuaries, and lagoons behind barrier beaches. Its range is along the Atlantic and Gulf coasts from Cape Cod, Massachusetts, to Corpus Christi, Texas. A review of studies conducted at Entergy's plants on the Lower Mississippi River found no records of impingement. Based on this information and the species preferred habitat, it appears the potential for impingement is minimal.

Pyramid Pigtoe (Endangered – Mississippi)

The endangered pyramid pigtoe mussel is listed only by the state of Mississippi. It has been documented in several counties including two counties that border the Mississippi River: Washington (Gerald Andrus) and Warren (Baxter Wilson) counties. According to the USFWS, the pyramid pigtoe occurs in medium to large rivers in sand or gravel in areas with a good current. This species has not been documented in any of the impingement studies reviewed; therefore, their potential for impingement and/or entrainment appears minimal. This species was reviewed as a species of concern due to their historical presence near the above mentioned two plants.

Mucket (Endangered - Mississippi)

The endangered mucket mussel is listed only by the state of Mississippi. Mucket is included on the Louisiana parish list for Madison Parish (Baxter Wilson); however, it is not a listed T&E species in Louisiana. Mucket is not included on any of the Mississippi county lists associated with Entergy plants, including Warren County, where Baxter Wilson is located. According to the USFWS, mucket can be found in gravel or a mixture of gravel and sand in medium to larger rivers such as the Mississippi River. Mucket prefers stable gravel substrates in flowing waters (Oesch 1995). Based on a review of impingement records and their habitat preference, their potential for impingement appears minimal.

Spike (Endangered – Mississippi)

The endangered spike mussel is listed only by the state of Mississippi. Spike is included on the Louisiana parish list for Madison Parish (Baxter Wilson); however, it is not a listed T&E species in Louisiana. Spike is not included on any of the Mississippi county lists associated with Entergy plants, including Warren County, where Baxter Wilson is located. The spike may be found on most substrates except for shifting sand, but is usually found in rivers with a sand-gravel or mud-gravel bottom (Oesch 1995). Based on a review of impingement records and their habitat preference, their potential for impingement appears minimal.

Inflated Heelsplitter (Threatened/Endangered)

The inflated heelsplitter mussel is included on the East Baton Rouge Parish (Willow Glen) list. However, it is not listed on the LDEQ and USFWS MOU for the segment number (LA070301) associated with Willow Glen's source water. According to the USFWS, the inflated heelsplitter was known historically from the Amite and Tangipahoa Rivers, Louisiana; the Pearl River, Mississippi; and the Tombigbee, Black Warrior, Alabama, and Coosa Rivers, Alabama. The presently known distribution is limited to the Amite River, Louisiana, and the Tombigbee and Black Warrior Rivers, Alabama.

The inflated heelsplitter prefers a soft, stable substrate in slow to moderate currents. It has been found in sand, mud, silt, and sandy-gravel. The occurrence of the inflated heelsplitter in silt may be because it was established prior to deposition of the silt. Adults may survive limited amounts of silt where juveniles would suffocate. The inflated heelsplitter is usually collected on the protected side of bars and may occur in depths over 20 feet.

Due to the limited distribution of the inflated heelsplitter in the Amite River in Louisiana and its habitat preferences, it appears there is no potential for impingement and/or entrainment at Entergy's Mississippi River plants.

Fat Pocketbook (Endangered)

The endangered fat pocketbook mussel is listed statewide for both Arkansas and Mississippi and federally. According to the USFWS (1997), today the fat pocketbook is found only in the lower Wabash and Ohio rivers, and in the lower Cumberland River. Impoundments and dredging for navigation, irrigation and flood control have altered or destroyed much of this mussel's habitat, silting up its gravel and sand habitat and probably affecting the distribution of its fish hosts. Recent sampling in 2003 also documented this species in the LMR inhabiting the bases of Ajax and Ben Lomond dikes in secondary channels between RM 481-489 (Hartfield, 2006).

This mussel prefers sand, mud, and fine gravel bottoms of large rivers. It buries itself in these substrates in water ranging in depth from a few inches to eight feet, with only the edge of its shell and its feeding siphons exposed (USFWS 1997).

Reproduction requires a stable, undisturbed habitat and a sufficient population of fish hosts to complete the mussel's larval development. When the male discharges sperm into the current, the females downstream siphon in the sperm in order to fertilize their eggs, which they store in their gill pouches until the larvae hatch. The females then expel the larvae. Those larvae that manage to find a host fish to clamp onto by means of tiny clasping valves, grow into juveniles with shells of their own. At that point they detach from the host fish and settle into the streambed, ready for a long (possibly up to 50 years) life as an adult mussel (USFWS 1997).

The fat pocketbook is listed for Phillips County, AR (Ritchie). This species has not been documented in any of the impingement studies reviewed; therefore, their potential for impingement appears minimal.

Pallid Sturgeon (Endangered)

The pallid sturgeon is listed federally and by Mississippi and Louisiana as endangered. This species can weigh up to 80 pounds and reach lengths of 6 feet, whereas the closely related shovelnose sturgeon rarely weighs more than 8 pounds.

Pallid sturgeons evolved and adapted to living close to the bottom of large, silty rivers with an undisturbed hydrograph. Ross (2001) also states that this species is essentially restricted to the main channels of the Missouri and Mississippi Rivers. He states 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. Schramm (2004) stated that this species is considered rare in the UMR and occasionally collected in the LMR. He also states that the pallid sturgeon is a riverine dependent species that is most likely to be found in the main channel or channel border.

Sexual maturity for males is estimated to be 7-9 years, with 2-3 year intervals between spawning. Females are not expected to reach sexual maturity until 7-15 years, with up to 10-year intervals between spawning. Pallid sturgeons are long lived, with individuals perhaps reaching 50 years of age (USFWS 1998). According to Ross (2001) spawning coincides with spring runoff, and occurs between March and June throughout the species' range. Fishes in Louisiana and Mississippi begin spawning earlier than those in more northern areas.

Today, pallid sturgeons are scarce in the upper Missouri River above Ft. Peck Reservoir; scarce in the Missouri and lower Yellowstone Rivers between Ft. Peck Dam and Lake Sakakawea; very scarce in the other Missouri River reservoir reaches; scarce in the Missouri River downstream of Gavins Point Dam; scarce but slightly more common in the Mississippi and Atchafalaya Rivers; and absent from other tributaries (USFWS 1998).

All of the 3,350 miles of riverine habitat within the pallid sturgeons range have been adversely affected by man. Approximately 28% has been impounded, which has created unsuitable lake-like habitat; 51% has been channelized into deep, uniform channels; the remaining 21% is downstream of dams which have altered the river's hydrograph, temperature, and turbidity. Commercial fishing and environmental contaminants may have also played a role in the pallid sturgeon's decline (USFWS 1998).

Jack Killgore with the USACE in Vicksburg was contacted for further information related to the pallid sturgeon (Killgore 2005, personal communication). He stated they have conducted species-specific sampling in the LMR and have not collected pallid sturgeon below Mississippi river mile marker 180 AHP. He stated the young of the year (YOY) fish <120 mm only swim 50 cm/sec., therefore would be of some concern at CWIS. Larger fish swim >3.0 fps and can out-swim typical intake velocities. Dr. Killgore stated that the pallid sturgeon almost always swims against the current and often employs a tactic called "hunkering" or substrate oppression. This is where the fish extends the pectoral fins and uses available substrate to hold on to. Doing this allows fish to alternately swim and rest when in strong currents.

In a more recent correspondence with Dr. Killgore (2006 personal communication), he stated more recent sampling efforts have collected nine pallid sturgeon in the vicinity of Lake Maurepas, which is just west of Lake Pontchartrain. The diversion for the Lake is near Gramercy, LA (RM 145), therefore Dr. Killgore stated he was going to extend the range for the pallid Sturgeon to at least RM 145. He also stated that it is likely they occur down to New Orleans; however they have not sampled this reach.

Pallid sturgeon are included on the Louisiana parish lists for East Baton Rouge Parish (Willow Glen), St. Charles Parish (Waterford 1&2), and Orleans Parish (Paterson and Michoud), and on the Phillips County, AR list (Ritchie). Pallid sturgeon is included on the LDEQ and USFWS MOU for the segment number (LA070301) associated with the source water for Willow Glen, Waterford 1 & 2, Little Gypsy, and Ninemile.

Paul Hartfield with the USFWS (Hartfield, 2006) and Dr. Todd Slack with the Mississippi Museum of Natural Science conducted trawl sampling in the Mississippi River in 2001-2002, 2003 and 2004 near Vicksburg, MS. The purpose of the sampling was to estimate sturgeon abundance in the river. The river channel edge, point bars and cross overs were sampled, and most sampling was conducted in depths less than 30 feet. Only shovelnose sturgeon were collected in 2004. In 2003, 54 trawls were conducted and a total of 78 shovelnose sturgeon, 5 pallid sturgeon and one intermediate were collected. The pallid sturgeon were collected at approximately RM 478, 456 and 444 and ranged from 439 – 739 mm FL. Trawling was conducted for 20 days in 2001 and 11 days in 2002 using 1.5 in. mesh trawls. A total of 615 shovelnose sturgeon were collected, 9 pallid sturgeon, 7 intermediates that were tentatively identified as pallid sturgeon, and 6 intermediates that were more similar to shovelnose. Sturgeon were collected at virtually all river stages (3.7-34 feet), but were collected in greater numbers at low to moderate stages. The pallid sturgeon collected ranged from 360-816 mm total length. All sturgeon captures were associated with moderate to strong currents, sand and gravel substrates, 12-40 ft. depths, and usually some type of "structure" such as "reefs", drop-offs, and secondary channels. Pallids were usually collected in the deeper portions of these habitats, 20-40 ft. (Hartfield, 2006).

Pallid sturgeon were impinged at the Waterford 1 & 2 plant in 1976 (2 juveniles) and at the Willow Glen plant (1 juvenile) in 1975.

Gulf Sturgeon (Threatened/Endangered)

The USFWS (2003) provides the following summary of the Gulf sturgeon, *Acipenser oxyrinchus*. This species is an anadromous fish (breeding in freshwater after migrating up rivers from marine and estuarine environments), inhabiting coastal rivers from Louisiana to Florida during the warmer months and overwintering in estuaries, bays, and the Gulf of Mexico.

Gulf sturgeon feeding habits in freshwater vary depending on the fish's life history stage (i.e., young-of-the-year, juvenile, sub-adult, adult). Young-of-the-year Gulf sturgeon remain in freshwater feeding on aquatic invertebrates and detritus approximately 10 to 12 months after spawning occurs. Juveniles less than 5 kg (11 lbs) are believed to forage extensively and exploit scarce food resources throughout the river, including aquatic insects (e.g., mayflies and caddisflies), worms (oligochaetes), and bivalve molluscs. Sub-adult (age 6 to sexual maturity) and adult (sexually mature) Gulf sturgeon do not feed in freshwater.

Gulf sturgeon are long-lived, with some individuals reaching at least 42 years in age. Age at sexual maturity for females ranges from 8 to 17 years, and for males from 7 to 21 years. Gulf sturgeon eggs are demersal (they are heavy and sink to the bottom), adhesive, and vary in color from gray to brown to black. Mature female Gulf sturgeon weighing between 29 and 51 kg (64 and 112 lb) produce an average of 400,000 eggs. Habitat at egg collection sites consists of one or more of the following: limestone bluffs and outcroppings, cobble, limestone bedrock covered with gravel and small cobble, gravel, and sand (USFWS 2003).

Historically, the Gulf sturgeon occurred from the Mississippi River east to Tampa Bay. Its present range extends from Lake Pontchartrain and the Pearl River system in Louisiana and Mississippi east to the Suwannee River in Florida. Sporadic occurrences have been recorded as far west as the Rio Grande River between Texas and Mexico, and as far east and south as Florida Bay. Due to its present range, the Paterson and Michoud plants are the only two plants of concern. Gulf sturgeon are included on the Louisiana parish lists for Orleans Parish (Paterson and Michoud), but are not listed for the sub-segments (LA041501 and LA041901, respectively) associated with the plants in the LDEQ and USFWS MOU.

The Gulf sturgeon has been documented in the LMR and Lake Pontchartrain; however, there is no record of Gulf sturgeon impingement at any of the Entergy plants.

Southern Redbelly Dace (Endangered – Mississippi)

The endangered southern redbelly dace is only listed by the state of Mississippi. It is a slender minnow, ranging from 1.6 to 2.8 inches in length, with extremely small scales and two narrow dusky stripes along its side. This species prefers permanent brooks of clear unpolluted water which flow between wooded banks and contain long pools of moving water (ODNR 2005). According to Ross (2001) this species occurs in upland streams of the Great Lakes and the Mississippi River Basins from Minnesota into the lower Tennessee River drainage of Tennessee, Alabama, and Mississippi. He also states the fish are typical of small, cool, clear streams with gravel, rubble, silt, and sand substrata. Dace are quite habitat specific, so they are highly susceptible to localized environmental disturbance. Sites where they have disappeared are characterized by erosion and loss of forest canopy cover, often associated with increased urban development.

The southern redbelly dace feeds in groups along the bottom on herbaceous material (ODNR 2005). Based on studies conducted in Minnesota and Kentucky, southern redbelly dace consume bottom sediments, including large quantities of sand, silt, and organic detritus and lesser amounts of aquatic insects (Ross 2001).

In Kentucky, southern redbelly dace spawn from late March to July. Total ova range from 5,708 to 18,887 in fish of 70-78 mm total length. Southern redbelly dace are nest associates, spawning over nests or mounds of *Semotilus*, *Campostoma*, and *Nocomis*. As a consequence hybrids are common with other nest building fish. The total life span of the southern redbelly dace is approximately 3-4 years (Ross 2001).

According to Ross (2001) southern red-bellied dace is known in three drainages and four river systems in Mississippi: the lower Mississippi River South (Clark Creek, Hatcher Bayou), the Tennessee River (Clear Creek and an unnamed tributary to Indian Creek), the Tallahatchie River (Murphy Branch), and the Yazoo River (Bliss Creek and Skillikalia Bayou and tributaries. Ross notes that recent attempts to collect the species in the vicinity of Vicksburg indicate that populations still remain in portions of Bliss Creek and Skillikalia Bayou in Warren County (Yazoo River system), and in Murphy Branch, Tallahatchie County (Tallahatchie River system). Compared to historical data, populations in Bliss Creek and Skillikalia Bayou have declined and Southern redbelly dace are apparently extirpated from Hatcher Bayou (lower Mississippi River South system) in Warren County.

In Arkansas, southern redbelly dace have been documented primarily in the northwestern portion of the state. A few individuals have been documented in the northeastern portion of the state inland from the Mississippi River (Robison and Buchanan 1992). Schramm (2004) stated that this species has been collected in the Mississippi River but there have been no records of collection since 1978. The southern redbelly dace has been reported in backwaters but is most likely to be found at the channel border in the Mississippi River.

The southern redbelly dace is listed in Warren County, MS (Gerald Andrus). This species has not been documented in any of the impingement studies reviewed. The habitat encountered at most of Entergy's CWIS is poorly suited to this species, therefore, their potential for impingement appears very minimal.

Paddlefish (Louisiana – Possession Prohibited)

Paddlefish, which were once prevalent in all of the tributaries of the Mississippi River, have been in decline due to habitat destruction and river modification, and were proposed for listing under the Endangered Species Act (ESA) in the 1990s. Although they were not listed under the ESA, trade in paddlefish became regulated under the CITES Convention on International Trade in Endangered Species of Wild Fauna and Flora in 1992.

Fish and Wildlife studies and state reviews caused several states to list and protect paddlefish, while adjacent states continued to maintain sport and commercial fisheries. This interstate problem was addressed in the 1991 founding of the Mississippi Interstate Cooperative Resource Association (MICRA) and its development of regional plans and research projects. MICRA continues to address the issues of inter-jurisdictional problems posed by the migratory paddlefish (Rasmussen and Graham 1998).

In Louisiana and Mississippi, the paddlefish is given an S3 ranking (National Heritage Ranking System) which means it is rare and local throughout the state, or found locally (even abundantly at some of its locations) in a restricted region of the state, or because of other factors making it vulnerable to extirpation (21 to 100 known extant populations). In Louisiana, paddlefish are prohibited from harvest year-round. In Mississippi, paddlefish are prohibited from harvest from May 1 through October 31.

Populations still occur in 22 states. Fourteen states allow sport fishing for paddlefish while only six states allow commercial harvesting. Ten states currently stock paddlefish to supplement natural populations or re-establish paddlefish in areas where they had formerly occurred (Graham 1997). Schramm (2004) stated that this species is occasionally taken in the LMR. He also states that the paddlefish is a riverine dependent species that is most likely to be found in all three major habitat zones (river channel, channel bank, and backwaters).

Paddlefish spawn in the spring and usually require fast flowing water (floods which lasts several days), and clean sand or gravel bottoms for successful spawning. During spawning, paddlefish gather in schools. Young fish grow quickly, as much as six inches in a few months. Fish generally become mature at 5-10 years and may live to be 20-30 years old. Paddlefish are plankton feeders inhabiting open waters where they can filter large quantities of water (Chilton 1997).

Paddlefish are included on the St. Charles Parish list (Little Gypsy and Waterford 1&2) and the Phillips County, AR and Tunica County, MS (Ritchie) lists. Paddlefish are also included on the Mississippi county lists for Washington and Chicot (Gerald Andrus), and Warren (Baxter Wilson) counties.

Paddlefish have been documented in several of the LMR impingement studies reviewed in this IMECS. At Waterford 1 & 2 four paddlefish were impinged in June/July 1976; at Willow Glen (Unit 1 & 2) 7 individuals were impinged in June/July 1975; at Willow Glen (Unit 4) 2 individuals were impinged in July and December 1976; and at Baxter Wilson 104 individuals were impinged in 1973/1974 throughout the year. As paddlefish numbers have declined the past several decades, potential impingement rates today are not expected to be at the same level previously discussed due to reduced CWIS withdraws and a decline in the population. The data indicate paddlefish have utilized habitats near intake screens in the LMR; therefore, they are a species of concern.

Alabama Shad (Candidate)

The Alabama shad is included on the East Baton Rouge Parish (Willow Glen) list. It is listed federally as a candidate species and is not listed in Louisiana. It occurs in major rivers draining into the Gulf of Mexico, from the Suwannee River westward to the Mississippi River (Ross 2001). They are anadromous, most of their adult lives are spent in the ocean and they migrate inland when ready to spawn. Several surveys in the 1980s did not find any Alabama shad in the Mississippi River (Robison and Buchanan 1992). This species has not been documented in any of the impingement studies reviewed; therefore, their potential for impingement and/or entrainment appears minimal.

Crystal darter

The endangered crystal darter is listed only by the state of Mississippi. The species prefers clean sand and gravel raceways of large rivers (Ross 2001). The crystal darter buries itself, leaving only the eyes protruding, as it lies in wait for passing prey. Spawning likely occurs in early spring in Mississippi, based on development of breeding tubercles in males (Collette 1965) and on the January-April spawning season documented for crystal darters in Arkansas. The presence of several size classes of oocytes suggests that this species produces multiple egg clutches. Mature or ripening eggs are 1.0 – 1.2 mm in diameter, and clutch sizes vary from 106 to 576 in fish of 62-87 mm standard length (SL). In Arkansas, mature male crystal darters averaged 76 mm SL and mature females averaged 66 mm SL. Both sexes reach maturity after their first year. The life span of this species is between 2.5 and 4 years (George et al. 1996).

In Mississippi, the crystal darter has been documented in several locations including Claiborne County, which borders the Mississippi River south of the Baxter Wilson Plant; however, it appears limited to Bayou Pierre (Ross 2001). In Arkansas, this species inhabits the lower reaches of moderately sized rivers, mainly below the Fall Line[4], where it is typically found in strong current over a sand or fine gravel substrate (Robison and Buchanan 1992). In Louisiana the crystal darter has only been documented from the Ouachita and Pearl River systems at locations inland from the Mississippi River (Douglas 1974).

Schramm (2004) considers the crystal darter rare in the LMR. He also states that this species is riverine dependent and is most likely to be found on the channel border or backwaters of the LMR. This species has some potential to be found in the LMR, therefore was retained as a T&E species of concern. Since this species is only listed by the State of Mississippi, impingement concerns are primarily focused on the Gerald Andrus and Baxter Wilson Plants. This species has not been documented in any of the impingement studies reviewed in this IMECS; therefore, their potential for impingement and/or entrainment appears very minimal.

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[4] Fall line - the physiographic border between the piedmont and coastal plain regions. The name derives from the river rapids and falls that occur as the water flows from hard rocks of the higher piedmont onto the softer rocks of the coastal plain. (http://www.usca.edu/csrags/fall-line.html)

Appendix C

Comparative Analysis of Impingement Mortality Studies Report

ENSR

Prepared for:
Entergy Operations, Inc.





Comparative Analysis of Impingement Mortality Studies - Waterford 3

ENSR Corporation
December 2007
Document No.: 00970-027-300

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Acronym Glossary

AHP	Ahead of Pass
BPJ	Best Professional Judgment
BTA	Best Technology Available
CFR	Code of Federal Regulations
CWA	Clean Water Act
CWIS	Cooling Water Intake Structure
EPA	Environmental Protection Agency
ESA	Endangered Species Act
GPM	Gallons per Minute
IM	Impingement
IMECS	Impingement and Entrainment Characterization Study
LDEQ	Louisiana Department of Environmental Quality
LMR	Lower Mississippi River
LSU	Louisiana State University
LWFD	Louisiana Wildlife and Fisheries Department
MGD	Million Gallons per Day
MICRA	Mississippi Interstate Cooperative Resource Association
PIC	Proposal for Information Collection
QA/QC	Quality Assurance and Quality Control
RIS	Relative Important Species
RM	River Mile
RTE	Rare, Threatened, and Endangered
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
YOY	Young-of-Year

Executive Summary

This document is designed to characterize and evaluate those species potentially affected by impingement at the Waterford 3 Electric Generating Station located in Killona, Louisiana. Based on proximity and similarities in habitat, historic and recent sampling data collected at the Entergy Waterford 1&2 was used to estimate the impacts of impingement at Waterford 3. Waterford 1&2 is located 0.4 miles upstream from Waterford 3 on the main stem of the Mississippi River. These studies:

1) characterize the fish and shellfish species collected from impingement samples;
2) identify the presence of any rare, threatened or endangered species impinged;
3) note the presence of commercially or recreationally important species;
4) provide size data on impinged species;
5) describe diel and seasonal shifts in species composition; and
6) calculate current impingement rates for those species (individually and combined).

Fish characterization studies performed on the LMR near Waterford 3 from 1977 to 1979 documented the most common species to be gizzard shad, threadfin shad, blue catfish, freshwater drum, striped mullet, skipjack herring, channel catfish, river carpsucker, blue gill, and common carp. Impingement sampling performed at Waterford 1&2 from 1976 to 1977 allowed calculation of historical impingement rates and served as a guideline for sampling procedures followed in this study.

The habitats surrounding the Waterford 3 cooling water intake structure 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. A summary of supporting documents used to describe the biology surrounding the Waterford 3 and Waterford 1&2 facilities can be found in Appendix B.

The most recent impingement sampling was conducted within the sluiceway of the fish return systems at 12-hour intervals over a 24-hour period, monthly for one year, beginning in September 2006. In addition to the biological data, hydrological parameters such as water temperature, dissolved oxygen, and conductivity were also recorded.

Field and laboratory personnel adhered to the Quality Assurance Quality Control (QA/QC) measures during the sampling program. By adhering to the guidelines outlined in this document, Entergy was able to accurately record, analyze, and report a true characterization of impinged organisms.

The current impingement rate at the Waterford 1&2 plant was calculated to be 16.16 organisms per 10,000 m^3, while the historic study obtained a rate of 4.22 organisms per 10,000 m^3. The disparity between the current and historical impingement rates at the site is attributable to inter-annual variations documented in the Mississippi River. Such variations can be correlated with the magnitude of spring flooding and summer drought events, which may alter river flows, water temperature, and suitable reproductive habitat, among other conditions. Based on these calculations and the proximity and habitat similarity of the plants, the current impingement rate at Waterford 3 is also estimated to be 16.16 organisms per 10,000 m^3. However, due to the differences in intake capacity of the two plants, the estimated number of organisms impinged annually at Waterford 3 differs from that of Waterford 1&2. When the rate of 16.16 organisms per 10,000 m^3 and the annual design intake capacity of the Waterford 3 CWIS are incorporated into the impingement formula, the number of organisms estimated to be impinged at Waterford 3 is 3,472,951 annually. This corresponds to about 2.5 times the number of organisms estimated to be impinged annually at Waterford 1&2 (1,379,533).

Entergy owns two other facilities on the LMR that may also be considered "like facilities" in relation to the Waterford 3 plant. Impingement studies were performed at the Baxter Wilson plant located on RM 433.2 in 1973, as well as the Willow Glen facility located on RM 201.6 from 1975-1976. Impingement rates and annual estimates of impingement were lower at these plants than both the Waterford 1&2 and Waterford 3 facilities.

1.0 Introduction

The purpose of this document is to characterize species potentially affected by impingement at the Waterford 3 Electric Generating Station located in Killona, Louisiana. This document was created in support of the Waterford 3 Proposal for Information Collection (PIC) and the Impingement Mortality and Entrainment Characterization Study (IMECS) developed for Waterford 3. The requirements of the PIC and the IMECS are found in 40 CFR Section 125.95(1)(i), (ii), (iii), and (iv), and 125.95(3)(i), (ii), and (iii).

The Clean Water Act established a program to manage cooling water intake structures (CWIS) in Section 316(b). EPA developed regulations in 40 CFR 125 (Subpart J) to implement the program for certain existing facilities. 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 CWISs 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 the one-year impingement sampling study at the Entergy Waterford 1&2 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. Entergy currently owns and operates 10 electric generating facilities on the Lower Mississippi River (LMR), eight of which are located along the mainstem channel of the River. As part of the compliance demonstration strategy, 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, a current impingement study performed at the Waterford 1&2 Electric Generating Station at river mile (RM) 129.9 ahead of pass (AHP)[1] was utilized as a representative impingement study for Waterford 3. The Waterford 3 Electric Generating Station is located just downstream of Waterford 1&2 at RM 129.5 AHP. In addition to proximal location of the plants, the cooling water intakes for both facilities are located over 150 feet offshore, and both plants utilize once-through cooling technology. Entrainment mortality characterization was not required for either facility because design intake flow for both Waterford 3 and Waterford 1&2 is less than 5% of the mean annual flow of the LMR. These factors lend credence to viewing Waterford 3 and Waterford 1&2 as "like facilities", and thus allow Entergy to utilize impingement data collected at the Waterford 1&2 facility in an impingement assessment for Waterford 3.

During the development of the PIC and the IMECS, Entergy consulted with the Louisiana Department of Environmental Quality (LDEQ) and Louisiana Wildlife and Fisheries Department (LWFD) regarding the abundance of relevant historical data that supports Entergy's compliance approach and that is sufficient for the requirements of the Rule. The LDEQ and LWFD 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 and development of impingement mortality rates for all facilities. However, based on the limited extent of current impingement data for facilities on the Mississippi River, the LDEQ and LWFD recommended that additional impingement data would be valuable to validate the existing historical data an determine current impingement (IM) rates.

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[1] Ahead of pass- above "head of passes"; Head of pass- point where the mainstem Mississippi River branches off into 3 different directions at the mouth of the Gulf of Mexico

Because it is the most centrally located of the Entergy-owned plants on the LMR, the Waterford 1&2 plant was chosen as the most appropriate location for an impingement sampling program. From September 2006 to August 2007, impingement sampling was performed at Waterford 1&2. Samples were collected at 12-hour intervals over a 24-hour period once per month for one year. Objectives of this study were to:

- 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 the data necessary for a complete analysis of impingement at the Waterford 3 Plant were collected and 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 Comparative Analysis of Impingement Studies.

2.0 Historical Review

Fish characterization studies were conducted at Waterford 3 from 1977 to 1979 as part of the facility's licensing process for the plant. Trawl samples were performed in the LMR during these studies, and although specific catch data was not available, speciation of catch was documented. Common species captured included *gizzard shad, threadfin shad, blue catfish, freshwater drum, striped mullet, skipjack herring, channel* catfish, river carpsucker, blue gill, and common carp.

Historical impingement studies were conducted at the Waterford 1& 2 Units 1 and 2 CWIS from February 1976 to January 1977 by Espey, Huston, and Associates. This study provided the basis for calculation of historical impingement rates as well as guidelines for sampling procedures followed in this study.

Impingement studies performed at other Entergy plants were also reviewed. Information presented in these studies were utilized in drafting the sampling plan, data recording, and data analysis procedures described for this impingement characterization study.

The habitats surrounding the Waterford 3 CWIS as well as the organisms occupying those habitats are documented extensively. A data review was performed prior to the start of this sampling effort to adequately characterize the biology of aquatic habitats of the LMR. These data were utilized to create the Impingement Mortality and Entrainment Characterization Study (IMECS) this sampling study supplements and to aid in a better understanding of the organisms that might be encountered during this sampling effort.

A summary of the historical studies and supporting documents used in characterizing the biology surrounding the Waterford 3 and Waterford 1&2 facilities can be found in Appendices A and B.

3.0 Description of Study Area

Based on the proximity of the two plants and the similar habitat-settings of their CWIS, the rate of impingement observed at Waterford 1&2 will be used to estimate the number of organisms impinged at Waterford 3. General descriptions of the aquatic habitats surrounding the Waterford 3 and Waterford 1&2 facilities are included below.

Lower Mississippi River (LMR)

The Lower Mississippi River is comprised of a vast alluvial valley which directs the Mississippi River and its tributaries to the Gulf of Mexico. The Mississippi Alluvial Plain is a broad, gently sloping floodplain that lies between Cairo, Illinois and Baton Rouge, Louisiana. The Deltaic Plain is a complex system of channels and natural levees that extend out from the mainstem Mississippi River and are associated with forested swamps and coastal marshes. Two distinct components of the Lower Mississippi River have been described:

1) the river ecosystem above Baton Rouge is quite variable, the main channel is deep with numerous meanders, and floodplain habitats present. Approximately 55% of the aquatic habitat is deep, swift channels and 45% is slack waters. Dikes and revetments are common: and
2) below Baton Rouge the river channel is deeper and narrower with fewer meanders. Approximately 85% of the aquatic habitat is swift, deep channel. Revetments are used extensively in this section of the river to help prevent erosion.

The ecosystem of the river is defined by the area within the river banks (mainstem) and the areas beyond the river banks (floodplain) (Baker et al, 1991). The mainstem includes the main river channel and slackwater areas. The floodplain includes natural levees, forested swamps, swales, ridges, and tributaries. The floodplain along the lower Mississippi River is mostly cutoff from the river due to an extensive levee system that was constructed to reduce flooding to the outlying areas. There is approximately 0.60 million ha of natural floodplain remaining within the levees. Numerous habitats exist within the floodplain and the mainstem portion of the river. Terminologies to describe these habitat variations include main channel, steep clay bank, and slackwater areas. However these descriptions did not take into consideration the biotic communities associated with them. In an effort to account for the different aquatic zones within the river several alterations to these classifications have been established. For the purpose of this section we propose to use the present classification presented by Baker et al. (1991) which accounts for 13 different habitats. Table 1 provides a description for each of the habitats.

The Mississippi River is a highly turbid waterbody with high current velocity. The productivity of the system is limited by light penetration and high suspended solids concentrations, as well as stability and habitability of the available substrate. As a result, the Mississippi River food chain is considered to be detrital-based, because phytoplankton occur in low densities and are not the major energy source. This is typical of larger southeastern and Midwestern Rivers (LL&P 1974).

Waterford 3

Aquatic habitats associated with the offshore intake components of the Waterford 3 CWIS include: seasonally inundated floodplains along the river levee, revetments, natural steep banks, and channel (Figure 1). The seasonally inundated floodplain area is comprised of a narrow band of sediment along the river bank and levee which supports a few areas of forested wetlands. The revetment banks downstream of the CWIS are comprised of crushed concrete rocks and cover a significant portion of the bank above and below the water surface. There is very little vegetation associated with the revetment bank. The natural steep bank habitat is adjacent and parallel to shore (within 100 ft from the main bank) and is crossed by the cofferdam for the intake structure. The opening to the offshore intake structure is estimated to be at least 50 ft out from the natural steep bank and located within the main channel habitat. This habitat is characterized by of high river flows, relatively cool water temperatures, high turbidities, high suspended solids, and mobile bed materials.

Waterford 1&2

Aquatic habitats associated with the offshore intake component of the Waterford 1&2 CWIS include: seasonally inundated floodplains along the river levee, lotic sandbars, natural steep banks, and channel (Figure 2). The seasonally inundated floodplains are heavily forested, except in those areas immediately adjacent to and in front of the onshore intake screenhouse. This area is mechanically cleared due to safety concerns associated with the fuel dock and the plant. The floodplain habitat upstream of the intake is comprised of forested wetland communities, oxbow lakes, and isolated sloughs which are flooded seasonally. The oxbow lakes and isolated sloughs are located approximately 0.5 miles upstream of the CWIS. The lotic sandbar and natural steep bank habitats are located approximately 200 ft from the main bank just inside of the intake crib which lies on the bottom of the river channel. Although the natural steep bank is present year round, the lotic sandbar habitat is only present seasonally due to the high river flow volumes which continuously moves sediment in and out of the area. The channel habitat is the dominant habitat for the offshore intake structure, consisting of high river flows, relatively cool water temperatures, high turbidities, and high suspended solids.

3.1 Source Water Body Information

Cooling water for Waterford 3 is withdrawn from the Mississippi River at a design flow rate of 1555.2 MGD, or 2406 cfs through a cofferdam embayment. The average flow in the Mississippi River in the vicinity of the Waterford 3 plant (RM 129.5) is estimated to be greater than 500,000 cfs[2]. Based on this information, it is determined that Waterford 3 withdraws a maximum of approximately 0.48% of the flow in the Mississippi River. This percentage could be much lower due to the additional, unaccounted-for streamflow contributions entering the Mississippi River downstream of the Vicksburg station and upstream of the Waterford 3 plant. Since Waterford 3 withdraws much less than 5% of the annual flow of the Mississippi River, the facility is not subject to the entrainment performance goal.

The width of the Mississippi River at the Waterford 3 plant is approximately 1,850 feet, the average stage is approximately 9.9 feet, and the average velocity is approximately 3.65 ft/sec. Bathymetric information for the Mississippi River at the Waterford 3 plant (RM 129.5) was available from the USACE from a hydrographic survey conducted by the USACE in 1992 indicating an average maximum depth of approximately 129 feet[3]; cross-sections from that survey are available for download on the USACE New Orleans districts website. The width was measured from a U.S. Geological Survey topographic map of the river, the average stage was estimated to be the average stage at the USACE's gage height measurement station at Bonnet Carre, located approximately 1.4 miles downstream, and the average velocity was determined from stage velocity relationships for USACE stations located at Baton Rouge (RM 229.7) and at New Orleans (102.8) at the stage of 9.9 feet. The hydraulic information describing the Mississippi River in the vicinity of the Waterford 3 plant was used to determine the area of hydraulic influence of the intake. The zone of hydraulic influence is defined here as the area of a hemisphere through which all of the CWIS flow passes, and that is of sufficient size so that the velocity through the surface is equivalent to the ambient velocity in the water source. The size of the Mississippi River and its large flow in the vicinity of the Waterford 3 plant minimize the effects of the CWIS

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[2] Exact flow rates are not available for the Mississippi River in the vicinity of the Waterford 3 plant, so the flow was estimated to be greater than the average flow rate of approximately 500,000 cfs measured at Vicksburg (RM 435.7), which is located well upstream of the Waterford 3 plant and encompasses a smaller watershed area. The flow rate at Vicksburg was calculated using the average stage of 21 feet for the Mississippi River gage at Vicksburg, calculated from data taken from U.S. Army Corps of Engineers website www.rivergages.com, and the results of a USACE flow measurement at the Vicksburg plant taken at a stage of 20.7 feet.

[3] Transect data for the Lower Mississippi River was taken from the U.S Army Corps of Engineers website: http://www.mvn.usace.army.mil/eng2/edsd/misshyd/misshyd.htm

withdrawal, thus the area of the river hydraulically affected by the Waterford 3 intake is a negligible 659 square feet.

Results presented in this report are based on an impingement study conducted at the Waterford 1&2 Power Plant, located on the Lower Mississippi River (LMR) at RM 129.9, just upstream from the Waterford 3 Plant at RM 129.5. The hydrology and flow data presented for the LMR at Waterford 3 is similar to what would be found at Waterford 1&2 due to the proximal location of these two facilities.

3.2 In-Place Technology

The Waterford 3 CWIS is designed to provide 1,080,000 gallons per minute (gpm) of circulating cooling water to the station, using water withdrawn from the Mississippi River (Figure 1). The CWIS consists of an intake embayment and intake structure comprised of eight bays equipped with through-flow traveling water screens, screen wash pumps, and circulating water pumps.

The intake embayment (cofferdam) is formed by steel sheet piling driven into the river bottom and extending approximately 162 feet out from the face of the intake structure. At the shoreline end of the intake canal, the CWIS is comprised of eight intake bays that are defined by concrete wingwalls. Each intake bay contains a trash rack and traveling water screen. The trash rack in each bay consists of a series of bars that are designed to remove large debris. The traveling water screens are composed of 1/4 or 3/8 inch stainless steel mesh. The four circulating water pumps (1 for two intake bays) are each capable of pumping 270,000 gpm of water. The once-through cooling water is discharged 600 ft downstream of the CWIS.

4.0 Materials and Methods

Due to the proximity of the two plants and the similar habitat-settings of their CWIS, the annual impingement rate for Waterford 3 was estimated from the impingement data documented for Waterford 1&2. The Waterford 1&2 rate was then applied to the impingement formula in conjunction with the design intake capacity of Waterford 3 to estimate the number of organisms impinged annually at Waterford 3. Details of the sampling program at Waterford 1&2 are provided in the following sections.

Impingement sampling was conducted within the sluiceway of the fish return systems as close to the mesh traveling screens as was safely and logistically manageable. Screens were washed for 10 to 15 minutes and rotated prior to each 12-hour sampling interval. Screens were then washed and rotated for 30 minutes at the end of the 12-hour interval prior to processing and identification of the impinged organisms. Twelve hour intervals were chosen as they were the most representative of the actual operations of the plant and screens.

Taxonomic identification to the lowest possible taxa level was recorded along with the length of each specimen. An average weight for all specimens of a given species was also recorded (batch weight). One representative specimen from each species observed was preserved in a 10 percent formalin solution and retained in a reference collection for future studies. Data analysis examined trends in species composition and abundance on both a diel and seasonal basis, and annual impingement rates were determined for each species.

Nets constructed of 3/8" mesh netting attached to a steel-piped 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.

Immediately prior to the end of sampling, the rotating screens were checked for any remaining organisms and shut down. Nets were removed from the sluiceway after water had ceased flowing through the sluiceway and organisms captured were identified, measured, and enumerated.

4.1 Collection of Hydrological Data

Upon arrival at the sampling site, hydrological data was recorded from intake waters in front of the rotating screens using a YSI-85 water quality meter. Water parameters such as temperature, dissolved oxygen, and conductivity were recorded on field data sheets and later entered in an Excel spreadsheet. The time of data collection was also recorded, along with 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 in order to allow for 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

Data characterizing the life stages of fish, shellfish, and any species protected under Federal, State, and Tribal Law susceptible to impingement and entrainment at Entergy's LMR plants were reviewed to determine seasonal and diel fluctuations in impingement and to determine relative important species. Further detail on the life history of these species and the general diel and seasonal fluctuations of biota of the LMR can be found in Appendix C. Based upon this review, samples were collected at 12-hour intervals over a 24-hour period, monthly for one year, beginning in September 2006.

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 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. Once the net was set up in the sluiceway, screens were rotated and washed for 30 minutes. If the net became full prior to the completion of the 30 minute wash, a second net was set up behind the first net, and the first net was removed and emptied. This process was repeated if necessary.

Collected organisms were emptied into sorting trays, and organisms were 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.

If more than 30 organisms of each species were collected, a random subset of 30 specimens was chosen for length measurements. If thirty or less specimens were present, all organisms were measured. Fish total length (TL) was recorded, shrimp were measured from the anterior tip of the rostrum to the posterior edge of the telson, and crabs were measured from tip to tip across the lateral length of the dorsal carapace. 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. If an excessive amount of individuals were present (30 or more organisms), a batch weight was obtained and applied to all individuals in the sample. In obtaining a batch weight, a random sub-sample of individuals was split from the group, enumerated, and weighed to the nearest tenth of a gram.

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, and common and scientific name was recorded on an in-jar label and an outer jar label. Collector's initials, date, and location were also recorded on the labels. The specimen and the inner label were then placed into the jar and covered with a 10% formalin solution. Before sealing the jar, the outer rim of the container was wrapped with Teflon plumbing tape to prevent leakage and evaporation of formalin from the jar. The jar was then tightly sealed and the outer label placed on the jar. Reference specimens were stored on a cool, dark shelf. 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 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 commercially important species representing greater than one percent of the total number of organisms impinged were reviewed in the process of generating the majority of the figures presented (Figures 5-15); 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 volume of water pumped through the intake screens. Volume of water pumped is based on the number of circulating waters pumps operating during each sampling period. This rate is expressed as number of organisms per 10,000 cubic meters of water.

$$\mathbf{IMR} = (^{\text{\# organisms captured}} / _{\text{volume of water sampled (cubic meters)}}) * \mathbf{10000}$$

This rate is then annualized to reflect impingement of the facility on a yearly basis.

<u>Waterford 3 Calculations</u>

Because impingement sampling was not performed at Waterford 3, IMR calculations were performed using the impingement rate documented in the most recent Waterford 1&2 impingement study (2006-2007) and the total design intake capacity for Waterford 3. Design intake capacity for Waterford 3 was utilized in place of the "volume of water sampled" in the above IMR calculation to illustrate impingement during peak facility operation (all intake pumps running 24 hours a day annually).

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 were 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 was 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, QA/QC 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.
- Field data recorded on site 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 and Discussion of the Waterford 1&2 Study

5.1 Hydrology

Water temperatures exhibited normal seasonal patterns, with the highest water temperature (32.7°C) recorded in August of 2007 and the lowest water temperature (6.4°C) recorded in January, 2007. An inverse relationship was exhibited between recorded dissolved oxygen (DO) levels and water temperature. DO levels were lowest in the summer (4.48 mg/L, June 2007) when the water was warmest, and highest in the winter (12.08 mg/L, January 2007) when the water was cool. Water temperature and DO typically exhibit an inverse relationship due to physical and chemical properties of water that limit oxygen solubility when heated (see Figures 3 and 4).

5.2 Impingement Rate

The total number of organisms impinged over the course of sampling at the Waterford 1&2 facility was 18,608 individuals comprising 32 species identified from 20 families (see Table 2). It should be noted that no rare, threatened, or endangered (RTE) species were impinged during the sampling period.

Based on findings presented in this study, annual impingement was estimated to be 16.16 organisms per 10,000 m^3. This is a sizeable increase from the 1976-1977 study in which the average annual impingement rate was 4.22 organisms per 10,000 m^3 (see Figure 5). This disparity is likely the result of dynamic fish populations near the CWIS which would have a marked impact upon the observed impingement rate. Such a difference is consistent with inter-annual variations perceived in impingement rates and ambient populations observed elsewhere, where some systems exhibit more than ten-fold increase or decrease of these parameters. Such variations can be correlated with the magnitude of spring flooding and summer drought events, which may alter river flows, water temperature, and suitable reproductive habitat, among other conditions (Appendix C). Improvements in tributary water quality (made possible by changes in legislature governing permitted discharges into streams and rivers and more stringent standards for fertilizers available for use on food crops) could also indirectly contribute to increased impingement rates by allowing fish communities that were once stressed by poor water quality to recover. In fact, recent condition assessments of the Mississippi River from bordering states suggest that improvements in the quality of the Mississippi River system (both water quality and habitat) are evident. The dynamic nature of the LMR could also be considered a contributing factor. A water system that is constantly subjected to perturbations will always exhibit some range of instability, which in turn will affect ambient populations, and thus impingement rates as well.

5.2.1 Seasonal Variation

The annual rate of impingement over the course of the sampling was calculated to be 16.16 organisms per 10,000 m^3. Lowest impingement rates were documented in late winter to early spring (0.45 organisms per 10,000 m^3 during April, 2007). During this time (late February through early April), adult species are involved in spawning activities, and most organisms present in the river are of significant size, as recruits from the previous year have reached or are close to reaching spawning size. Organisms of this size typically exhibit strong swimming ability and are able to avoid the intake structure altogether. Increased river flows also allow for more shoreline and backwater habitat to be utilized by small organisms typically subject to impingement, such as river and grass shrimp, aiding in preventing impingement of these organisms.

At the start of sampling in September, impingement rates were high (27.53 organisms per 10,000 m^3). As water temperatures cooled and seasons began to shift, impingement rates slowly declined through late fall into winter and early spring (November 2006 – April 2007). A sharp increase in impingement was exhibited from April to May, with the highest documented impingement rate recorded in August (42.25 organisms per 10,000 m^3). Fall and springtime impingement rates were also the highest documented in the historic Waterford 1&2 study. This suggests that organisms in the LMR are most active and susceptible to impingement from spring to fall months, as would be expected as a result of spawning activity and low water conditions. On the LMR, low water conditions typically drive fish from more favorable habitats in shoreline and backwater areas into deeper, more channelized areas, causing a greater concentration of fishes near the intake pipes which may result in increased impingement rates (see Appendix C, Biological Profile of the Mississippi River for more detail on the ecological dynamics of the LMR) (see Figure 5).

The five months with the highest impingement rates, September, October, May, June, and August accounted for 81% of total organisms impinged during the 12 month study period. It should be noted that these months also exhibited the lowest water conditions during the study, providing further evidence of the correlation between river stage and perceived impingement rates (Figure 17). An impingement rate of less than 6 organisms per 10,000 m^3 was observed throughout the rest of the sampling period (December 2006 – April 2007). Historical studies performed in 1976-1977 show similar peaks in impingement rates and river stage data when compared with those documented in the most recent study.

5.2.2 Diel Variation

The average daytime impingement rate (16.02 organisms per 10,000 m^3) was nearly identical to the nighttime impingement rate (16.30), and the species comprising >1% of all organisms impinged were consistent. River shrimp, threadfin shad, grass shrimp, blue catfish, channel catfish, freshwater drum, and bay anchovy comprised >1% during both the daytime and nighttime samples. Grass shrimp comprised a greater percentage of the daytime samples, while threadfin shad and freshwater drum comprised a greater percentage of the nighttime samples. Variation in nighttime and daytime observations can be explained by differences in feeding behavior between organisms. Fish are more active when feeding, and thus exhibit a higher impingement rate (see Figures 6 & 7 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 river shrimp, threadfin shad, channel catfish, freshwater drum, blue catfish, bay anchovy and grass shrimp (see Figures 8 & 9). The historic impingement studies performed in 1976-1977 indicated a similar balance of species with a few noticeable differences. In the historic study, gizzard shad and skipjack herring each accounted for greater than 1% of the total impingement sample. Additionally, grass shrimp did not account for more than 1% of the sample (see Figures 10 & 11). When monthly impingement rates are totaled using only these species, respective current and historical impingement rates of 15.96 and 4.42 are obtained (see Table 4). A more specific discussion of impingement by species is included below.

River Shrimp (*Macrobrachium ohione*)

River shrimp comprised nearly 56% of all organisms impinged during the 2006-2007 study. The annual impingement rate was calculated to be 9.06 per 10,000 m^3. In historic studies, the river shrimp was also the most frequently impinged species, comprising approximately half of the number of organisms impinged. Both studies exhibit similar seasonal variation, although the 2006-2007 study exhibits a much larger spread between its maximum and minimum impingement rates over the course of the year (see Figure 12).

River shrimp are reported to receive reproductive cues from spring flood spates and use flooded terrestrial habitat for reproduction. This coincides with the observed decrease in river shrimp impingement throughout early spring as the shrimp had largely vacated the main river to reproduce. Body lengths recorded during the June sampling event (peak impingement month, see Table 4) documented that the majority of river shrimp captured ranged from 36 to 50 mm in length, indicating juvenile (post-spawning) shrimp.

Threadfin Shad (D*orosoma petenense*)

The average annual impingement rate for threadfin shad was calculated to be 3.26 organisms per 10,000 m^3, with threadfin comprising over 13% of all organisms impinged. Average monthly impingement rates during the current study closely mirrored historic monthly impingement rates, as seasonal impingement rates exhibited the same trends throughout the study. However, data collected in this survey exhibits a much larger spread between its maximum and minimum total impingement rates over the course of the samples, (see Table 4 and Figure 13 for more detail).

Blue Catfish (*Ictalurus furcatus*)

Blue catfish accounted for 11% of all organisms impinged, which is lower than historic studies in which blue catfish accounted for 21% of organisms impinged over the course of sampling. The average annual impingement rate for the species was calculated to be 2.37 per 10,000 m^3. Little seasonal variation in numbers impinged was documented for this species, as is evident in the historic impingement study (see Table 4 and Figure 14 for more detail).

Freshwater Drum (*Aplodinotus grunniens*)

The average annual rate of impingement for freshwater drum was calculated to be 0.46 per 10,000 m^3 (see Table 4). Freshwater drum accounted for 3.2% of all organisms impinged during the sampling period, similar to historic impingement studies which documented this species to comprise 4.6% of all organisms impinged. Both studies indicate low impingement rates for freshwater drum. The 2006 data peak in late fall (October and November) is not accounted for in the historic data (see Figure 15).

Channel Catfish (*Ictalurus punctatus*)

The average annual rate of impingement for channel catfish was calculated to be 0.44 per 10,000 m^3, with peak impingement occurring in October (1.72 per 10,000 $m^{3)}$ (see Table 4 for more detail). Channel catfish accounted for 4.4% of all organisms impinged during the 2006-2007 study, while only 2.1% during the 1976-1977 study. The two sampling studies exhibit similar trends in seasonal variation; however, an increase in the total number of channel catfish impinged in the 2006-2007 study was documented.

Bay Anchovy (*Anchoa mitchilli*)

The average rate of impingement for the bay anchovy was calculated to be 0.16 per 10,000 m^3. This species accounted for 1.2% of all organisms impinged (See Table 4 for more detail). Peak impingement for this species was recorded in the fall (September). Historically, the bay anchovy accounted for 6.1% of all impinged organisms, with an average impingement rate of 0.31 per 10,000 m^3. Impingement also peaked in the fall during historic studies (See Figure 16). The impingement rates for the bay anchovy are relatively low and consistent between the two studies.

Grass Shrimp (*Palaemonetes kadiakensis*)

The grass shrimp accounted for 8% of all organisms impinged during sampling events. The average rate of impingement for the species was 1.31 per 10,000 m^3 with a maximum impingement rate of 7.52 per 10,000 m^3 during June (Table 4). In the historic impingement study, grass shrimp did not comprise greater than 1% of impingement.

5.2.3.2 Species Abundance

Impingement rates are correlated to overall species abundance in the river. Species abundances are influenced by a variety of factors which can cause significant increases or decreases in populations. These factors include, but are not limited to the following: river flow, spawning habitats, seasonal variations, turbidity, water quality, and salinity. In many cases these factors are correlated with one another and can result in highly variable impingement rates. These variable impingement rates can fluctuate monthly, seasonally, and yearly depending on how significant the changes in the influencing factors.

6.0 Comparisons with "Like Facilities"

Impingement analysis at the Waterford 3 Electric Generating Station was determined from sampling data at Waterford 1&2, another Entergy-owned plant, in accordance with the "like facilities" clause of the recently remanded section 40 CFR 125.95 of the EPA's Clean Water Act. Evaluation of historical studies of impingement, an extensive document review, and a current impingement study were used in conjunction to obtain a comprehensive analysis of impingement potential at Waterford 3.

The current impingement rate at the Waterford 1&2 plant was calculated to be 16.16 organisms per 10,000 m^3, while the historic study obtained a rate of 4.22 organisms per 10,000 m^3. The disparity between the current and historical impingement rates at the site is attributable to inter-annual variations documented in the Mississippi River. Based on these calculations and the proximity and habitat similarity of the plants, the current impingement rate at Waterford 3 is also estimated to be 16.16 organisms per 10,000 m^3. However, due to the differences in intake capacity of the two plants, the estimated number of organisms impinged annually at Waterford 3 differs from that of Waterford 1&2. When the rate of 16.16 organisms per 10,000 m^3 and the annual design intake capacity of the Waterford 3 CWIS are incorporated into the impingement formula, the number of organisms estimated to be impinged at Waterford 3 is 3,472,951 annually. This corresponds to about 2.5 times the number of organisms estimated to be impinged annually at Waterford 1&2 (1,379,533)(Table 5)

Entergy owns two other facilities on the LMR that may also be considered "like facilities" in relation to the Waterford 3 plant. Impingement studies were performed at the Baxter Wilson plant located on RM 433.2 in 1973, as well as the Willow Glen facility located on RM 201.6 from 1975-1976. Impingement rates and annual estimates of impingement were lower at these plants than both the Waterford 1&2 and Waterford 3 facilities (Table 5 and Figure 18).

7.0 References

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Appendix A

Historic Impingement Studies

Louisiana Power & Light, April, 1979. Demonstration Under Section 316(b) of the Clean Water Act. Waterford Steam Electric Plant Unit No. 3.

This document includes fisheries data collected in the Mississippi River between Baton Rouge and New Orleans. Common species included gizzard shad, threadfin shad, blue catfish, freshwater drum, striped mullet, skipjack herring, channel catfish, river carpsucker, blue gill, and common carp. The most common species reported were consistent with literature for the Lower Mississippi River.

Summary of the Waterford 1&2 Impingement Study

Espey, Huston and Associates, Inc. (1977a) conducted a study between February 1976 and January 1977 at Entergy's Waterford Unit 1 and 2 CWIS. The purpose of the investigation was to evaluate the impact of the existing intake structures on the biota of the Mississippi River. The facility is located at Mississippi River mile marker 129.9 on the west descending bank of the Mississippi River in Killona, Louisiana.

Impingement sampling was conducted bi-weekly for 24 hour durations for one year for a total of 26 samples. Samples were collected in the sluiceway with three baskets; two constructed of ¼" expanded metal, framed with angle iron and the third basket of ½" hardware cloth framed with angle iron. Weights of captured organisms were measured on an Ohaus Dial-O-Gram balance, sensitive to ± 0.1 gram. Lengths were measured to the nearest millimeter. Standard length was measured for finfish. Shrimp were measured from the tip of the rostrum to the tip of the telson, while the carapace width of the blue crab was measured. A 24-hour time unit was designated with the screens being run, washed, and cleared at the outset of the period. Baskets were then set in a series in the sluiceway. The two ¼" expanded metal baskets were placed closest to the screens with the ½" hardware cloth basket last as the backup. Collections were made when one or more of the screens operated during the 24-hour sampling period. For the final 30 minutes, all screens were run, washed and simultaneously stopped at the end of the 24th hour. All organisms collected during each diel period were identified to species, except when precluded by physical condition. Physical injuries were noted. All fish and crustaceans were individually weighed and measured except for large collection events. These samples were sub-sampled such that all measurements were taken on 25 randomly selected individuals. The number of circulators operating per each unit was recorded, as well as other physical parameters, including temperature, dissolved oxygen, conductivity and pH.

Results of this study show that an equal number of both fish and invertebrates were impinged, however, the overall species richness was greater for fish (46 species) as compared to invertebrates (3 species). Total sample weight for each 24-hour sample ranged from 3,593 grams to 33,560 grams. Impinged organisms were primarily juveniles (>25mm); however, larger organisms (375 mm) were also impinged including the American eel and common carp. River shrimp dominated numerically and constituted 49.7% of the total catch, followed by blue catfish (20.3%), threadfin shad (10.5%), bay anchovy (6.0%), freshwater drum (4.5%), gizzard shad (2.9%), skipjack herring (2.4%), channel catfish (2.1%), striped mullet (0.3%), and blue crab (0.2%). These ten species represented 98.7% of the total biomass. Annual impingement was estimated to be 336,454 individuals, equating to a rate of 4.33 individuals per 10,000 m^3 of water pumped through the plant for both units combined.

Of the top ten species comprising 98.7% of the total "catch" in the impingement study, only the blue catfish, threadfin shad, gizzard shad, freshwater drum, skipjack herring, channel catfish, and river shrimp are considered common throughout the Lower Mississippi River range. The presence of bay anchovy, blue crab, and striped mullet is attributed the Plant's proximity to the Gulf of Mexico. These species are considered estuarine species but are commonly associated with brackish to freshwater areas of rivers and tributaries. The Waterford 1 & 2 Plant is considered to be located in a non-estuarine segment of the river, as the documented salt wedge for the LMR is typically found at a considerable distance downstream (River Mile 90). In all as many as 46 species of estuarine fishes have been documented as far north as St. Francisville, Louisiana. This occurrence is usually associated with extreme low-flow periods when saltwater intrudes into the river.

Appendix B

Summary of Supporting Biological Studies

Haines, D.E. Biological control of gizzard shad impingement at a nuclear power plant. *Environmental Science & Policy* 3 (2000) S275-S281.

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.

Coutant, C.C. What is 'normative' at cooling water intakes? Defining normalcy before judging adverse. *Environmental Science & Policy* 3 (2000) S37-S42.

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.

Lewis, R. B. and G. Seegert. Entrainment and impingement studies at two power plants on the Wabash River in Indiana. *Environmental Science & Policy* 3 (2000) S303-S312.

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.

McLaren, J.B. Fish survival on fine mesh traveling screens. *Environmental Science & Policy* 3 (2000) S369-S376.

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.

Michaud, D.T. Wisconsin Electric's experience with fish impingement and entrainment studies. *Environmental Science & Policy* 3 (2000) S333-S340.

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.

Spicer, G., T. O'Shea and G. Piehler. Entrainment, impingement and BTA evaluation for an intake located on a cooling water reservoir in the southwest. *Environmental Science & Policy* 3 (2000) S323-S331.

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.

Appendix C

Biological Profile of the Lower Mississippi River

Life Histories of Relative Important Species (RIS)

The following section provides an overview of the relative important species subject to impingement mortality at the Waterford 3 Plant. These species include any threatened or endangered species as well as any commercially or recreationally important species.

River shrimp (*Macrobrachium ohione*)

Ohio river shrimp (*Macrobrachium ohione*) may grow up to 4 inches long, live in fresh and brackish water along the eastern United States seaboard to the Gulf of Mexico, and are the only species of Macrobrachium found in the Mississippi River. Once common in the Mississippi River below St. Louis, they supported commercial fisheries that once existed near Chester and Cairo, Illinois. Ohio shrimp were thought to be extirpated (locally extinct) in the Mississippi River bordering Missouri and Illinois by 1962. In 1991; however, they were rediscovered. The decline in the population of Ohio shrimp is thought to be related to the channelization of the river (Hrabik 1999). The species is still quite abundant in the LMR.

River shrimp were harvested by commercial fishermen in the UMR, mainly for bait, prior to the 1940's. Population declines attributed to over-harvesting, river channelization and habitat loss have led to the species decline. River shrimp are no longer considered to be of economic importance in the UMR. River shrimp do not have a commercial or recreational value in the LMR; however, they do serve as a forage species for larger predators.

Gizzard Shad (*Dorosoma cepedianum*)

Gizzard shad (*Dorosoma cepedianum*) occur primarily in freshwater and are most abundant in large rivers and reservoirs, avoiding high gradient streams. The species is most often found in large schools. Spawning generally takes place in late spring, usually in shallow protected water. 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. Gizzard shad generally grow to 14 inches and provide forage for most game species (Chilton 1997). Ross (2001) noted that young gizzard shad tend to occur along shorelines in very shallow water, gradually moving offshore into deep water as they grow. Individuals older than age class 3 rarely occur in shallow water (Bodola 1966).

Schramm (2004) stated that this species is abundantly taken in the LMR. He also states that the gizzard shad is a backwater dependent species that may be found in all three main habitat zones; the main channel, channel border and backwaters.

Gizzard shad are not considered suitable as a food fish and are only taken on hook and line by accident. They are very sensitive to handling and therefore not utilized as a live bait species. They are commonly used as a source of cut bait for trotlines, jug or set-line fishing. Their importance as a forage species seems to outweigh the nuisance quality of being so prolific. They form a short, efficient link in the food chain of the white bass, crappies, and largemouth bass.

Threadfin Shad (*Dorosoma petenense*)

Like gizzard shad, threadfin shad (*Dorosoma petenense*) 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). The threadfin shad is a pelagic schooling species that primarily occupies the areas between the surface and the thermocline with the greatest densities near the surface (Netsch et al. 1971). Schramm (2004) stated that this species is abundantly taken in all LMR surveys. He also states that the threadfin shad is a backwater dependent species that is most likely to be found in the channel border and backwaters.

Threadfin's value lies in its desirable use as a forage fish for developing trophy largemouth bass and crappie fisheries due to its small adult size. Since they are sensitive to low temperatures (< 5°C), winter die-off provides a tool for population control.

Freshwater Drum (*Aplodinotus grunniens*)

Freshwater drum (*Aplodinotus grunniens*) occurs in a wide variety of habitats, and is one of the most widely-ranging fish in North America. They inhabit deep pools of medium to large rivers and large impoundments, spending most of their time at or near the bottom. Young drum feed on small crustaceans and aquatic insect larvae, and adults feed on snails, small clams, crayfish, small fishes, and insect larvae (Swedberg 1968; Robison and Buchanan 1992). They are often found rooting around in the substrate or moving rocks to dislodge their prey (Chilton 1997). The freshwater drum is a pelagic spawner, usually spawning in the spring. The eggs are semi-buoyant and pelagic. In Wisconsin, schools of spawning fish have been observed milling at the surface with backs out of the water (Becker 1983; Chilton 1997). Schramm (2004) stated that this species is taken abundantly in all river surveys in the LMR. He also states that the freshwater drum is a riverine dependent species that is most likely to be found in the channel border and backwaters.

Freshwater drum are an important sport and commercial fish of the Mississippi River and other streams of Mississippi. They are strong fighters when hooked and a fair food fish. The greatest commercial catches have traditionally occurred in the Upper Mississippi River above the confluence of the Missouri River. They are not important as a commercial species in the LMR.

Blue catfish (*Ictalurus furcatus*)

The blue catfish (*Ictalurus furcatus*) is primarily a large-river fish, occurring in main channels, tributaries and impoundments of major river systems. They are native to major rivers of the Ohio, Missouri, and Mississippi river basins. They tend to move upstream in summer in search of cooler temperatures, and downstream in winter for warmer temperatures. Blue catfish do not mature until reaching 24-inches. They spawn in late spring or early summer when water temperatures reach 75° F. Males select nest sites which are normally dark secluded areas such as cavities in drift piles, logs, undercut banks, rocks, cans, etc. The blue catfish diet is quite varied but smaller fish tend to eat invertebrates, while larger fish eat fish and large invertebrates (Chilton 1997).

The blue catfish is beneficial both as a commercial and recreational fishery due to its firm, well-flavored flesh. They are frequently caught in deep, swift areas of main channels. In the late spring and early summer, blue catfish are one of the most sought after species during the hand-grabbing season.

Common Carp (*Cyprinus carpio*)

Common carp (*Cyprinus carpio*) were first introduced into North America in 1877 and are now one of the most widely distributed fish in North America. They are primarily a warm-water species, and do very well in warm, muddy, highly productive (eutrophic) waters. Adults are primarily benthic and omnivorous, feeding on both plant and animal material. Common carp may grow as big as 75 pounds and are generally considered a nuisance by North American anglers (Chilton 1997).

Ross (2001) states that carp occur in a variety of habitats but are more common in deep pools of streams or in reservoirs, especially in or near vegetated areas with mud or sand substrata. They are fairly tolerant of poor water quality and can survive low oxygen levels and high turbidity. Schramm (2004) stated that this species is commonly taken in most surveys in the LMR. He also states that the common carp is a backwater dependent species that is most likely to be found in the channel border and backwaters. Schramm notes the importance of invasive species in the Mississippi River and stated the most common invasive species presently established in the river include the common carp, grass carp, silver carp, bighead carp, and zebra mussel. Since the carp is a nuisance, any reduction in their numbers (i.e., impingement mortality) would be a benefit to the aquatic ecosystem as this would allow the proliferation of indigenous, non-invasive species.

Common carp form an important part of a wild commercial and recreational fishery in the LMR. Since they have the ability to occupy areas with marginal habitat they provide fishing opportunities where none would otherwise exist.

Channel Catfish (*Ictalurus punctatus*)

Channel catfish (*Ictalurus punctatus*) are extremely adaptable and occur in a variety of habitats but are especially characteristic of major rivers and large streams having low or moderate gradients. They prefer to live in cool to warm clear water habitats but will tolerate turbid waters. They are highly active at night from dusk to midnight when they do most of their feeding. Channel catfish spawn during the months of May thru July when water temperatures are above 75 degrees. They prefer overhanging rock ledges, cut banks, and submerged trees and roots systems for their nesting. Females mature at 14 inches and males somewhat smaller. At one year old, channel catfish are about four inches long. By their fourth year they have usually reached 12 inches. The channel catfish is an opportunistic omnivore, feeding on just about any living or dead material. Being primarily a nocturnal animal, channel catfish must rely on its tactile sensory organs, including the well-developed barbels, to find food. Their diet consists of aquatic insects, worms, clams, crayfish, snails, and fish, all of which could be dead or alive. Their stomachs might be packed with vegetable materials dropped into the water or minnows depending on what's available. However, large channel catfish feed almost exclusively on fish.

Channel catfish provide major recreational and commercial fisheries in lakes and streams across the LMR region. Recreational fishing methods include rod-and-reel, trotlines, limblines, jugs, and hand grabbing. Channel catfish appear to be abundant and underutilized by recreational fishers. Natural populations of channel catfish are secure throughout the LMR as more than 90% of the commercial harvest is attributed to farm raised stocks.

Skipjack Herring (*Alosa chrysochloris*)

The skipjack herring (*Alosa chrysochloris*) is a migratory species commonly found in the LMR basin. They are commonly found near dams in the rivers where they congregate prior to the spring and summer spawn (April – June). Little documented information is available concerning spawning habitat. They prefer clear waters associated with sand or gravel beds in larger rivers. Skipjacks eat plankton, minnows and larvae of mayflies and caddisflies. They feed in large schools, leaping out of the water while pursuing prey. Adult lengths average 12-16 inches (30.5-40.7cm).

Skipjack herring are considered a bait fish and have no food value as table fare. Although populations have declined in the Upper Mississippi River due to construction of navigation locks and dams, populations in most states in the LMR appear to be stable.

Bay anchovy (*Anchoa mitchilli*)

The anchovies are the most abundant of the schooling, pelagic fishes in the LMR. The bay anchovy (*Anchoa mitchilli*) is an extremely common fish, restricted to the bays and close inshore areas. The species ranges from Maine to Florida and also occurs throughout the Gulf of Mexico. Adults usually attain a size of four inches (Hoese and Moore 1977). Bay anchovies are planktonic feeders. This species is able to exploit a wide variety of habitats, has the potential to overpopulate a waterbody, and can be used to indicate poor water quality (Monaco et al. 1989).

Due to its small size, the bay anchovy is not harvested commercially in the U.S. It is recognized as an important bait fish and forage species for other game fishes.

Atlantic croaker (*Micropogonias undulatus*)

The croakers (Family Sciaenidae) are among the most common groups of northern Gulf inshore fishes. In numbers of species, they exceed all other families, and in numbers of individuals, or biomass, they are among the top three (others being mullet and anchovies) species of fish found in the bay systems throughout the Gulf (Hoese and Moore, 1977) The most abundant species of croakers occurring along the Gulf Coast is the

Atlantic Croaker (*Micropogonias undulatus*). They spawn in the shallow Gulf near passes, with the larvae entering the bays, where they spend their first summer in brackish water. Although most croaker are adapted to living on muddy bottoms, a few are found in more sandy habitats, and a few are adapted to rocky habitats.

The Atlantic croaker is one of the most common bottom-dwelling estuarine species, with the young occurring in the deeper parts of the bays in the summer but departing in the fall. Only a few fish live past their first year but very large croaker are found at the mouth of the Mississippi River.

Grass Shrimp (*Palaemonetes kadiakensis*)

The Grass shrimp is common in the central and southeastern United States ranging from northeastern Mexico, north to the Great Lakes and east to Florida. Grass shrimp generally live about 1 year and reach a total length of about 36mm. They are most abundant in main channel areas associated with border wing dike structures and low velocity backwaters. Sexually mature females produce 8-160 eggs. Grass shrimp are most likely affected by annual fluctuations in environmental conditions (seasonal drying and extended high water). While information is sparse on the life history of *Palaemonetes kadiakensis,* competitive exclusion when in association with *Macrobrachium ohione,* when they are present, may offer a reasonable explanation for reduced numbers of grass shrimp. Several Centrarchid species occupy similar habitats and may offer an explanation to the low abundance of grass shrimp due to predation. This hypothesis is apparently supported by reporting of the converse situation: high grass shrimp abundance in pools with low fish abundance. Grass shrimp are omnivorous and typically considered scavengers feeding on dead plant and/or animal material.

Grass shrimp have a limited commercial value due to their small size, and therefore, are not harvested. They are also found to have little recreational value.

Paddlefish (*Polyodon spathula*)

Paddlefish, which were once prevalent in all of the tributaries of the Mississippi River, have been in decline due to habitat destruction and river modification, and were proposed for listing under the Endangered Species Act (ESA) in the 1990s. Although they were not listed under the ESA, trade in paddlefish became regulated under the CITES Convention on International Trade in Endangered Species of Wild Fauna and Flora in 1992. Fish and Wildlife studies and state reviews caused several states to list and protect paddlefish, while adjacent states continued to maintain sport and commercial fisheries. This interstate problem was addressed in the 1991 founding of the Mississippi Interstate Cooperative Resource Association (MICRA) and its development of regional plans and research projects. MICRA continues to address the issues of inter-jurisdictional problems posed by the migratory paddlefish (Rasmussen and Graham 1998). Evidence suggests that the paddlefish population on the LMR is steadily improving. Bobby Reed, with LDWF, stated that the department has been receiving phone calls from LMR fishermen complaining of an increase in the net fouling by fingerling paddlefish (LDWF 2007). Paddlefish spawn in the spring and usually require fast flowing water (floods which lasts several days), and clean sand or gravel bottoms for successful spawning. During spawning, paddlefish gather in schools. Young fish grow quickly, as much as six inches in a few months. According to LDWF, these fingerling paddlefish are noted for a tendency to migrate towards slightly brackish waters. With a tolerance of up to 8ppt, their preference is water that has a salinity of about 2ppt (LDWF 2007). Fish generally become mature at 5-10 years and may live to be 20-30 years old. Paddlefish are plankton feeders inhabiting open waters where they can filter large quantities of water (Chilton 1997).

In Louisiana and Mississippi, the paddlefish is given an S3 ranking (National Heritage Ranking System) which means it is rare and local throughout the state, or found locally (even abundantly at some of its locations) in a restricted region of the state, which, in conjunction with other factors make it vulnerable to extirpation (21 to 100 known extant populations). In Louisiana, paddlefish are prohibited from harvest year-round.

Shovelnose Sturgeon (*Scaphirhynchus platorynchus*)

The shovelnose sturgeon is listed in both Mississippi and Arkansas as a species of special concern (SC) due to relatively low population density. Its existence may become endangered due to habitat destruction or alteration caused primarily by dam construction blocking access to traditional spawning areas. The shovelnose sturgeon is documented in Mississippi and is still common in the larger rivers of Arkansas. It occurs primarily in the Mississippi River and its larger tributaries including the Missouri and Ohio Rivers. Individuals grow slowly reaching sexual maturity at about 6 years of age. At that time sturgeon are about 0.9 kg with males measuring 508 mm and females about 635 mm. The shovelnose occupies shallow areas and deep channels of larger rivers inhabiting sand bars or areas of strong current over sand and gravel substrates. It is tolerant of high turbidity. In the Mississippi River it occurs in the tailwaters below wing dams and other structures which accelerate the water flow. Adults generally migrate upstream from April to early July to spawn over a rocky substrate in channels of large rivers at water temperatures of 19.5-21.1 °C. Reported runs of this sturgeon in the Mississippi River have occurred during low spring conditions. Individuals spawn every 2-3 years. Hermaphroditism occasionally occurs with gonads of up to 3% consisting of both ovaries and testes. The shovelnose is a small, slow-growing sturgeon and seldom exceeds 2.25 kg and a maximum length of 914 mm. Newly hatched larvae are 8-9 mm. By 10-11 mm eyes are well-pigmented, the mouth is forming and barbels are evident and measurable. The meso-larval stage occurs at 25-30 mm and the meta-larval stage at 56-60 mm which last through at least 130 mm. The shovelnose sturgeon feeds along the bottom using its ventral, protrusile mouth to suck in prey. Shovelnose sturgeon are opportunistic and feed on drifting aquatic insects including immature stages of aquatic insects, especially trichopterans, dipterans, and ephemeropterans. They switch to chironomids when drift biomass declines. Midges (chironomids) are especially important during the late spring and summer.

Fisheries on the LMR

Commercial Fisheries

Commercial harvest of fishes in the LMR is difficult to assess because of inconsistencies in methods of gathering and reporting data; however, limited information indicates commercial harvest is increasing (Schramm 2004). According to Schramm, neither the commercial nor recreational fisheries appear to be over harvested; however, fisheries for sturgeon and paddlefish should be carefully monitored. He also notes that future fisheries production may be threatened by loss of aquatic habitat, altered spatial and temporal aspects of floodplain inundation and nuisance invasions. In addition, navigation traffic affects fish survival and recruitment via direct impacts and habitat alteration, and is expected to increase in the future (Schramm 2004).

In the LMR, NMFS statistics for 1954-1977 show fish harvest of 6-12 million kg (6600 – 13,200 tons) and increasing over time (Risotto and Turner 1985). Self-reported commercial harvests have been collected by the Tennessee Wildlife Resources Agency since 1990 and by the Kentucky Department of Fish and Wildlife resources since 1999. Annual catch for the Mississippi River bordering Tennessee during 1999-2000 varied from 36 to125 tons. Landings of blue catfish and flathead catfish have increased substantially, while harvests of common carp, buffalo fishes, channel catfish and freshwater drum have been highly variable. In Kentucky waters, catch ranged from 18-56 tons between 1999 and 2001, and buffalo and catfishes dominated the catch as well. Schramm (2004) notes that other states on the LMR either do not measure commercial catch, or do so sporadically. In Louisiana, commercial catch is measured but is not designated as being from specific waters.

Recreational Fisheries

The recreational fishery has not been rigorously defined in the LMR. Schramm (2004) states that fresh-water fishing catch rates are relatively high: but efforts are extremely low. Because of the large size, swift and dangerous currents, the presence of large commercial vessels and lack of public access, recreational fishing on these reaches has been largely discouraged. Providing access is difficult due to the large fluctuations in river levels and separation of many of the remaining floodplain lakes from the river during low water stages. Although recreational fishing has been somewhat limited historically on the main channel of the LMR, management agencies have initiated measures to improve access and increase public education regarding fishing opportunities (Schramm 2004).

According to the literature, the recreational species targeted most often in the freshwater portions of the LMR include the bass, catfish, crappie, gar, and carp species. In the lower portions of the LMR, increased salinity allows estuarine species to be targeted as well. The most commonly impinged species at Waterford 1&2 have very little significant recreational value.

Lower Mississippi River Ecosystem Dynamics

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 (See Figure 16), all of which are conducive to spawning and other reproductive activities. The primary period of reproduction and peak abundance for most aquatic organisms in the LMR is in spring and summer months (typically March through June). Peak egg recruitment occurs in early spring (channel-oriented species); larval recruitment occurs from late spring into early summer (all species). Therefore, spring and summer months are typically when the highest levels of impingement and entrainment are documented.

Upon reaching a size greater than ⅜-inch (approximately 10mm), aquatic organisms become subject to impingement due to industry standards developed that requires intake screens to utilize mesh size of ⅜-inches or smaller. Time necessary to attain this size varies by species and individual, but appears to occur quickly in the Mississippi River. According to LSU professors, Drs. Kelso and Rutherford, most fish species must grow very quickly to enable their survival and most species reach 100 mm in a matter of months. A fish of this size would be subject to impingement. This rapid growth is required primarily due to the harsh conditions in the river and the vast temperature differences between seasons.

It is interesting to note that the spawning period in the LMR correlates to the seasonal flooding/high water period. At Waterford 3, seasonal average flows have been calculated to be 580,000, 650,000, 280,000 and 240,000 cfs for winter, spring, summer, and fall, respectively. Elevated flows increase the flood zone of the river and are most likely responsible for pushing the eggs and larval fish past the CWIS during this time.

Species comprising greater than 1% of impingement mortality, such as river shrimp, grass shrimp, threadfin shad, and bay anchovy are present in higher numbers in the LMR during late spring, summer and early fall, due in part to low river flow forcing shoreline oriented species into the main channel. Other impinged species comprising greater than 1% of the sample, such as channel and blue catfish and freshwater drum, are typical inhabitants of the channel areas of the LMR. Summer and early fall months peak periods for juvenile recruitment for these species. Smaller body size and reduced swimming speeds can allow juveniles to become susceptible to impingement.

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.

Appendix D

Species Identification Guides

Field Species Identification Guides

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

- Douglas, N.H. *Freshwater Fishes of Louisiana.* 1974. Claitor's Publishing Division. Baton Rouge, LA.
- Heard, R.W. 1982. *Guide to Common Tidal Marsh Invertebrates of the Northeastern Gulf of Mexico.* Mississippi-Alabama Sea Grant Publication.
- Hoese, H.D., and Moore, R.H. *Fishes of the Gulf of Mexico.* 1998. Texas A&M University Press. College Station, TX.
- Murdy, E.O. 1995. *Saltwater Fishes of Texas: A Dichotomous Key.* Texas Sea Grant Publication.
- Williams, A.B. 1965. *Marine Decapod Crustaceans of the Carolinas.* U.S. Department of the Interior, Fish and Wildlife Service.

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 will utilized have been established by the American Fisheries Society.

Appendix E

Figures and Tables

LEGEND

Location of Intake

Habitat Interpretation from Baker et al. 1991.
Orthophoto taken 2004 at 1 meter resolution.

Figure 1:
Aquatic Habitat Map
for Waterford 3 Plant

ENSR

J:\Water\BD\316(b)\Entergy\PIC Project\Hydrology\Locations\LA_Waterford3.mxd

LEGEND

Location of Intake

Habitat Interpretation from Baker et al. 1991.
Orthophoto taken 2004 at 1 meter resolution.

Figure 2:
Aquatic Habitat Map
for Waterford 1&2 Plant

ENSR

J:\Water\BD\316(b)\Entergy\PIC Project\Hydrology\Locations\LA Waterford1&2.mxd

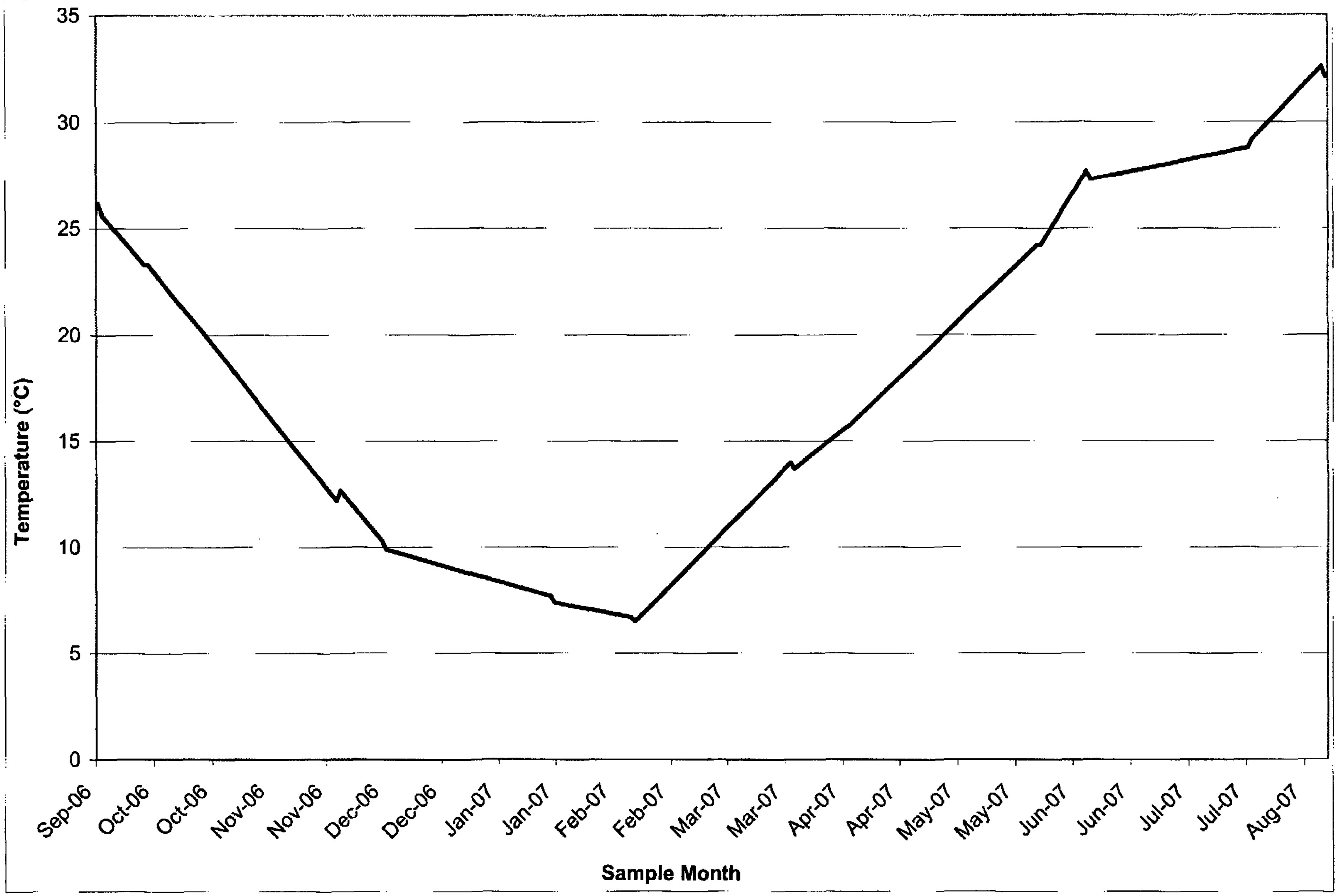


Figure 3: Water Temperature at Time of Sampling 2006-2007

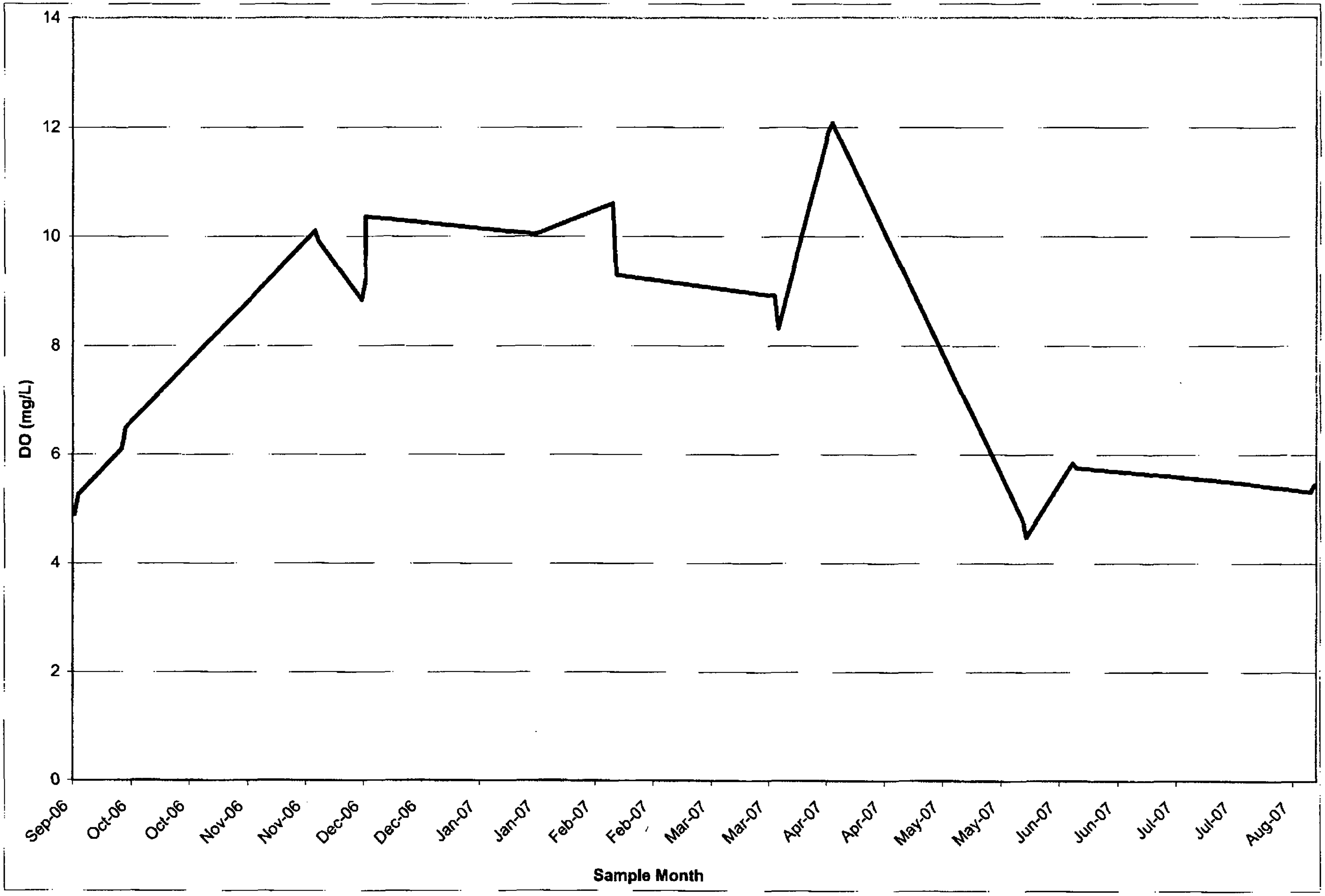


Figure 4: Dissolved Oxygen Concentration at Time of Sampling 2006-2007

Entergy, 2006-2007
316(b) Impingement Sampling

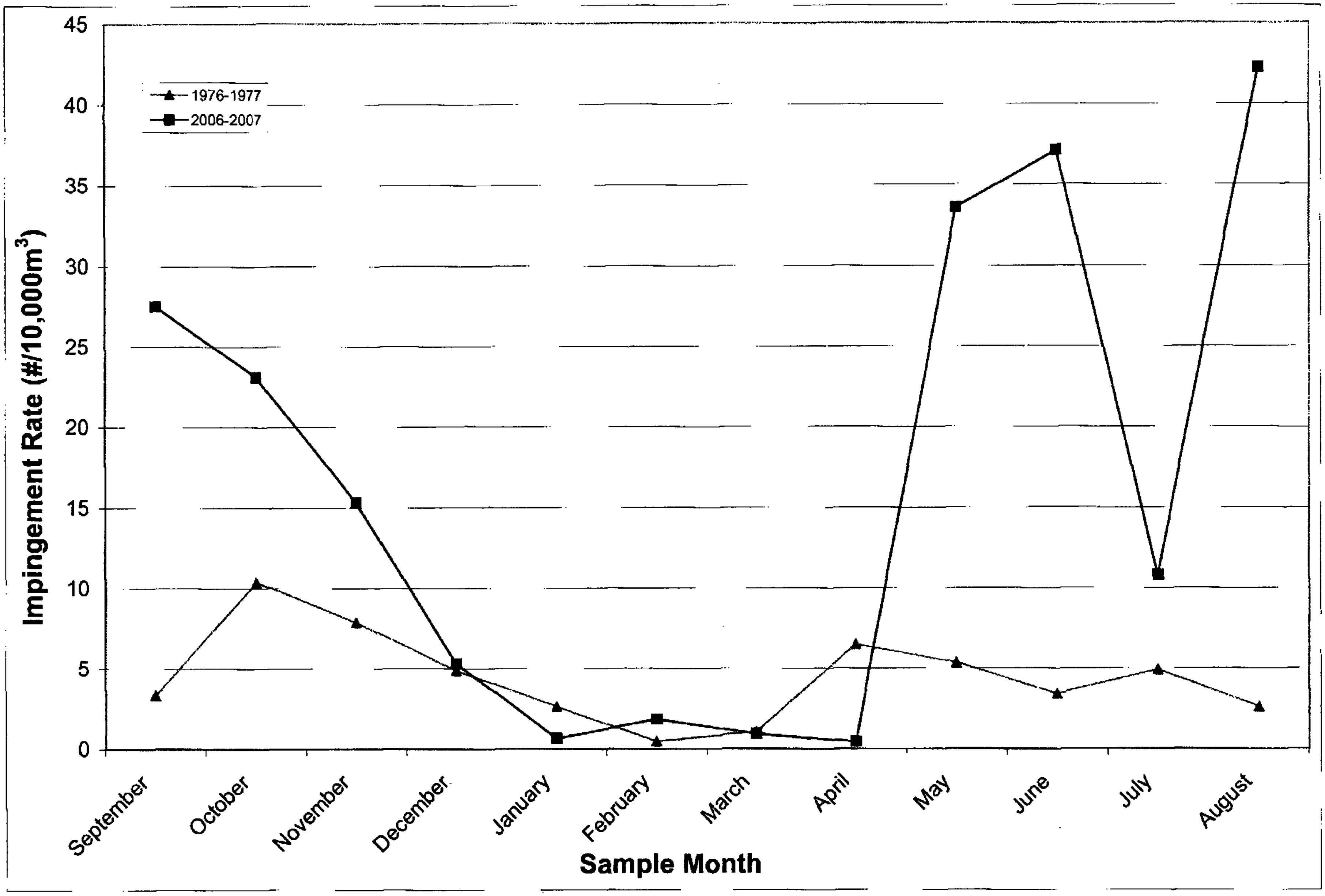


Figure 5: Average Monthly Impingement Rate: Current vs. Historic

Entergy, 2006-2007
Espey, Huston, and Associates, Inc. 1976-1977
316(b) Impingement Sampling

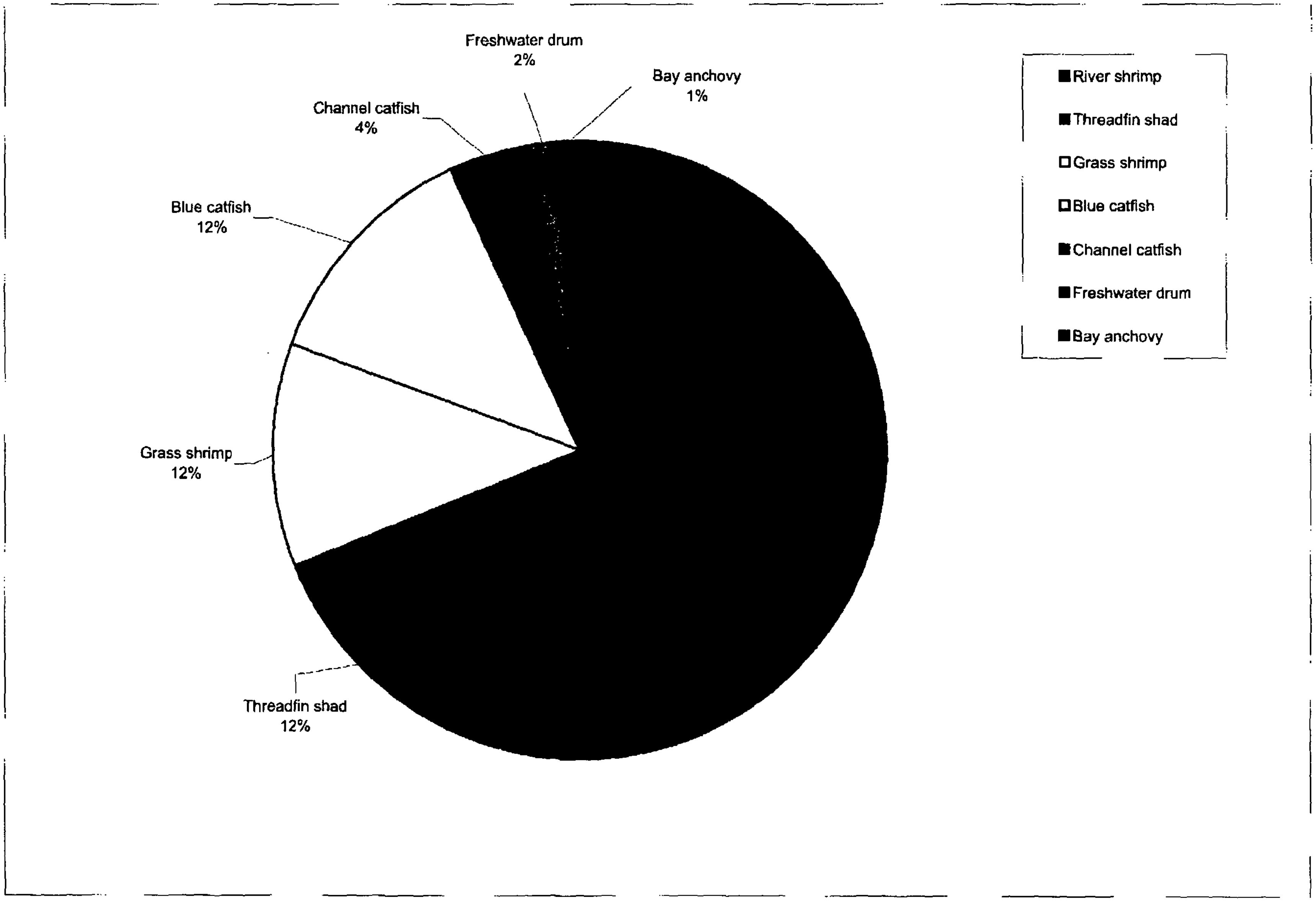


Figure 6: Composition of Impinged Species Comprising >1% of Daytime Samples

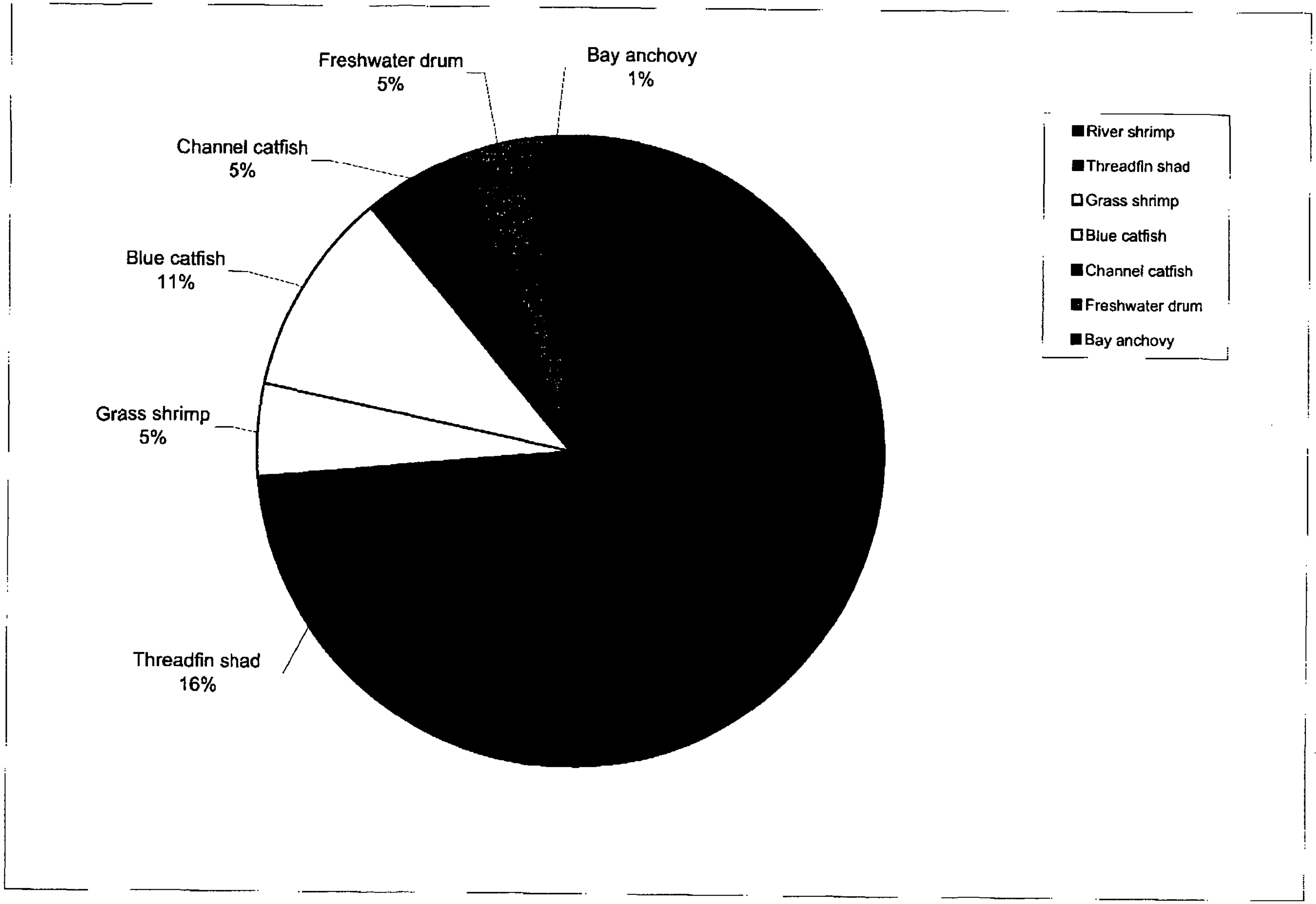


Figure 7: Composition of Impinged Species Comprising >1% of Nighttime Samples

Entergy. 2006-2007
316(b) Impingement Sampling

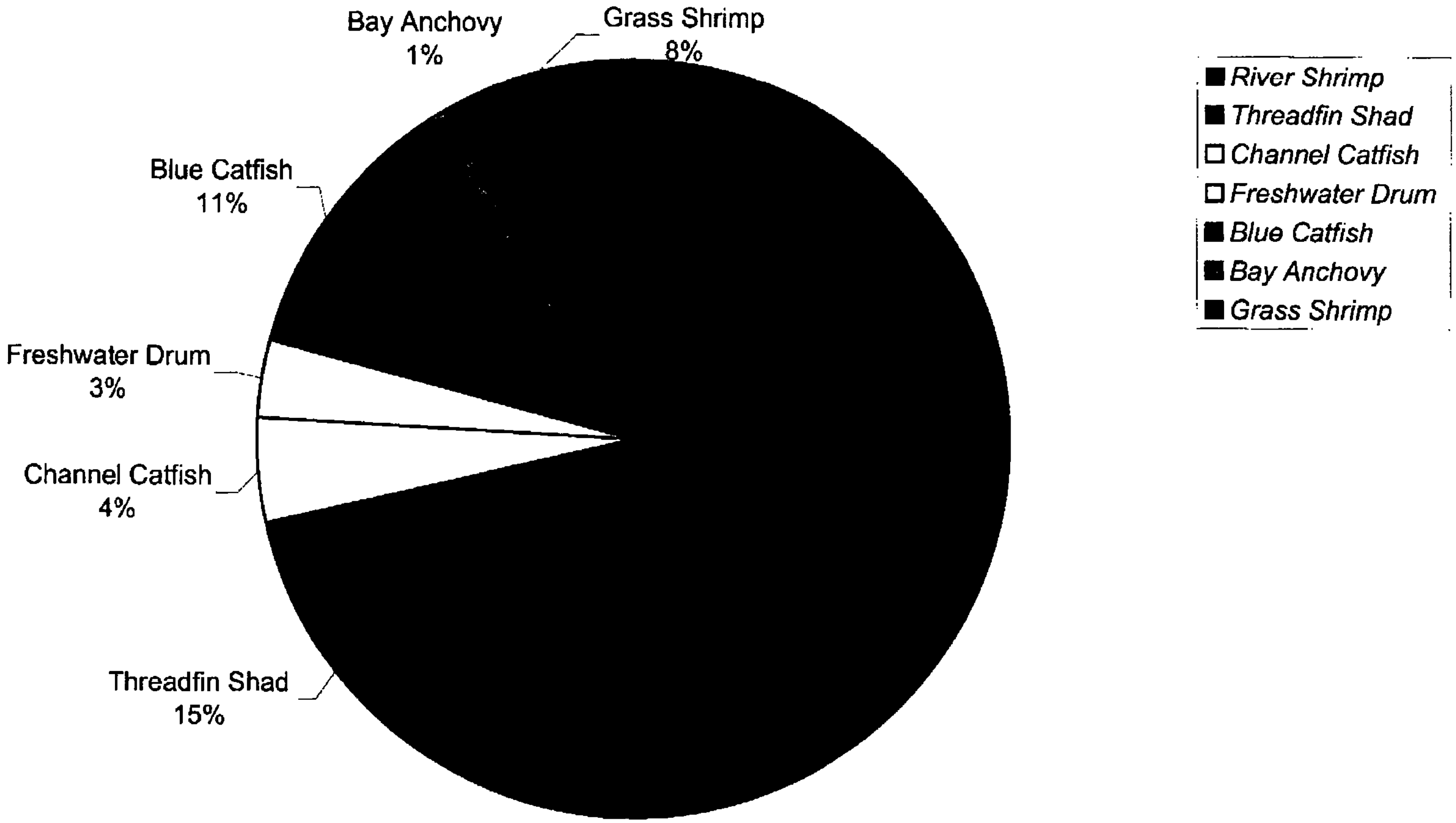


Figure 8: Composition of Impinged Species Comprising > 1% of Total: 2006-2007

Entergy, 2006-2007
316(b) Impingement Sampling

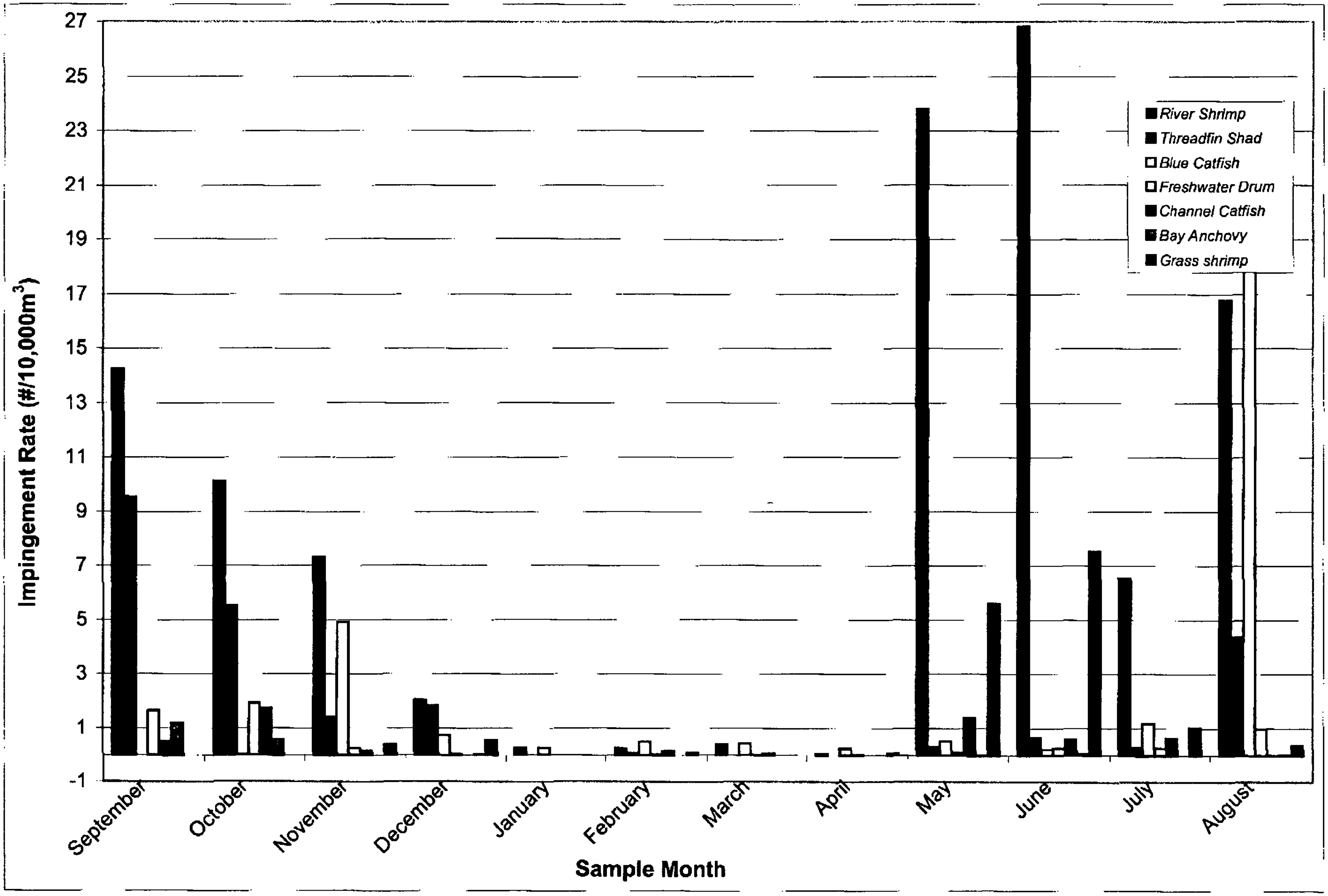


Figure 9: Impingement Rates for Dominant Species 2006-2007

Entergy, 2006-2007
316(b) Impingement Sampling

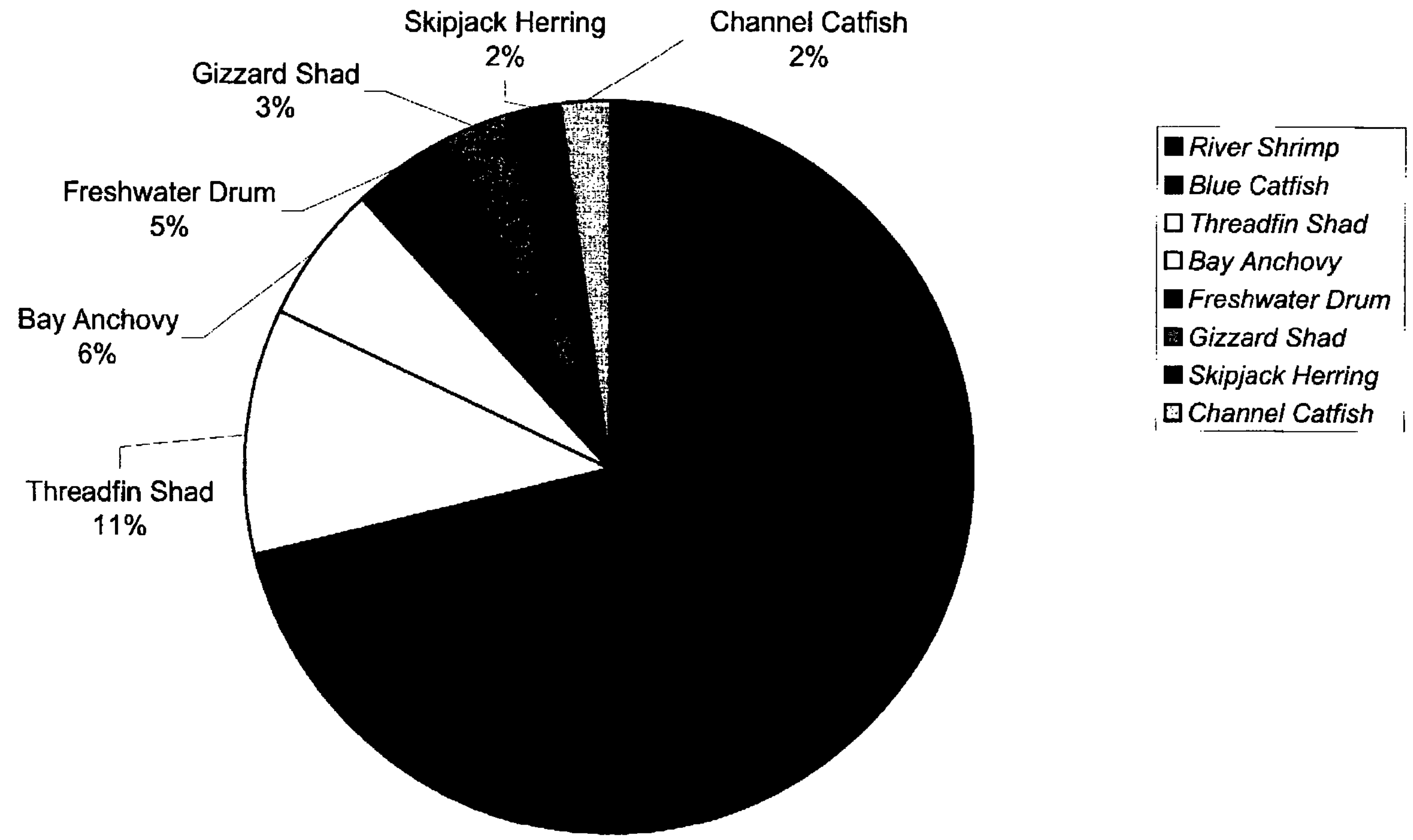


Figure 10: Composition of Impinged Species Comprising >1% of Total: 1976-1977

Espey, Huston, and Associates, Inc.
1976-1977 Impingement Sampling

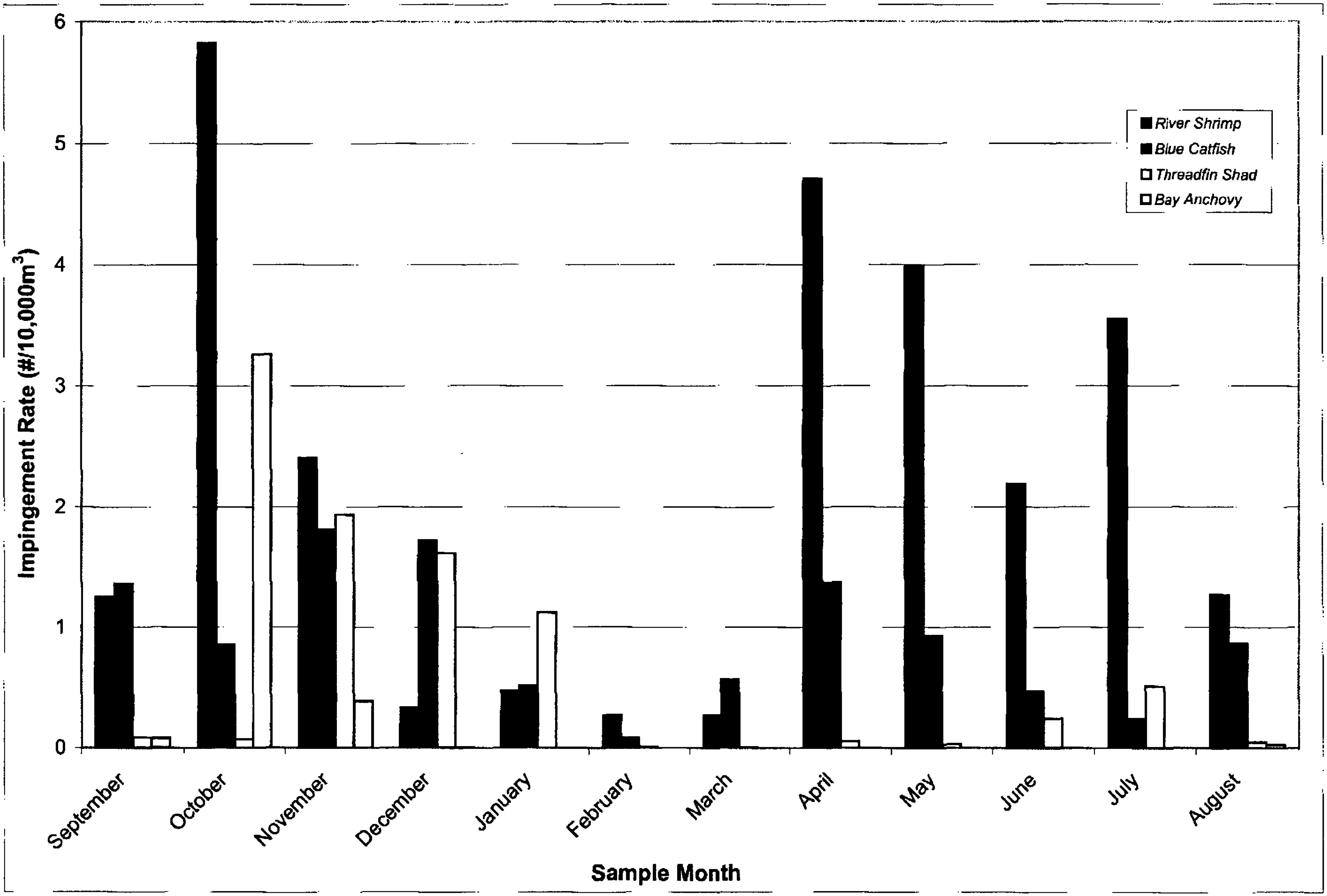


Figure 11: Impingement Rates for Dominant Species 1976-1977

Espey, Huston, and Associates, Inc.
1976-1977 316(b) Impingement Sampling

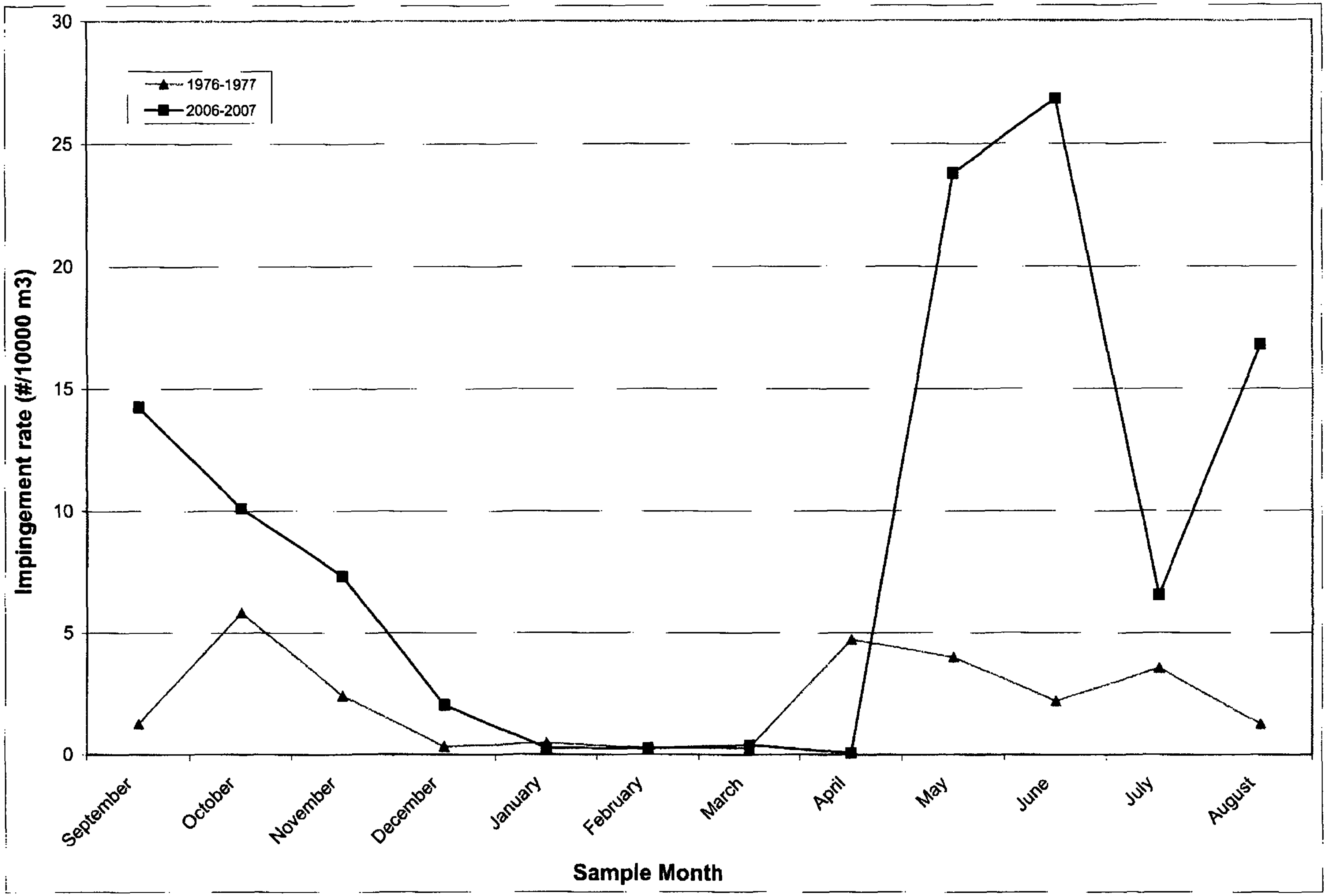


Figure 12: River Shrimp Average Monthly Impingement Rate: Current vs. Historic

Entergy, 2006-2007
Espey, Huston, and Associates, Inc. 1976-1977
316(b) Impingement Sampling

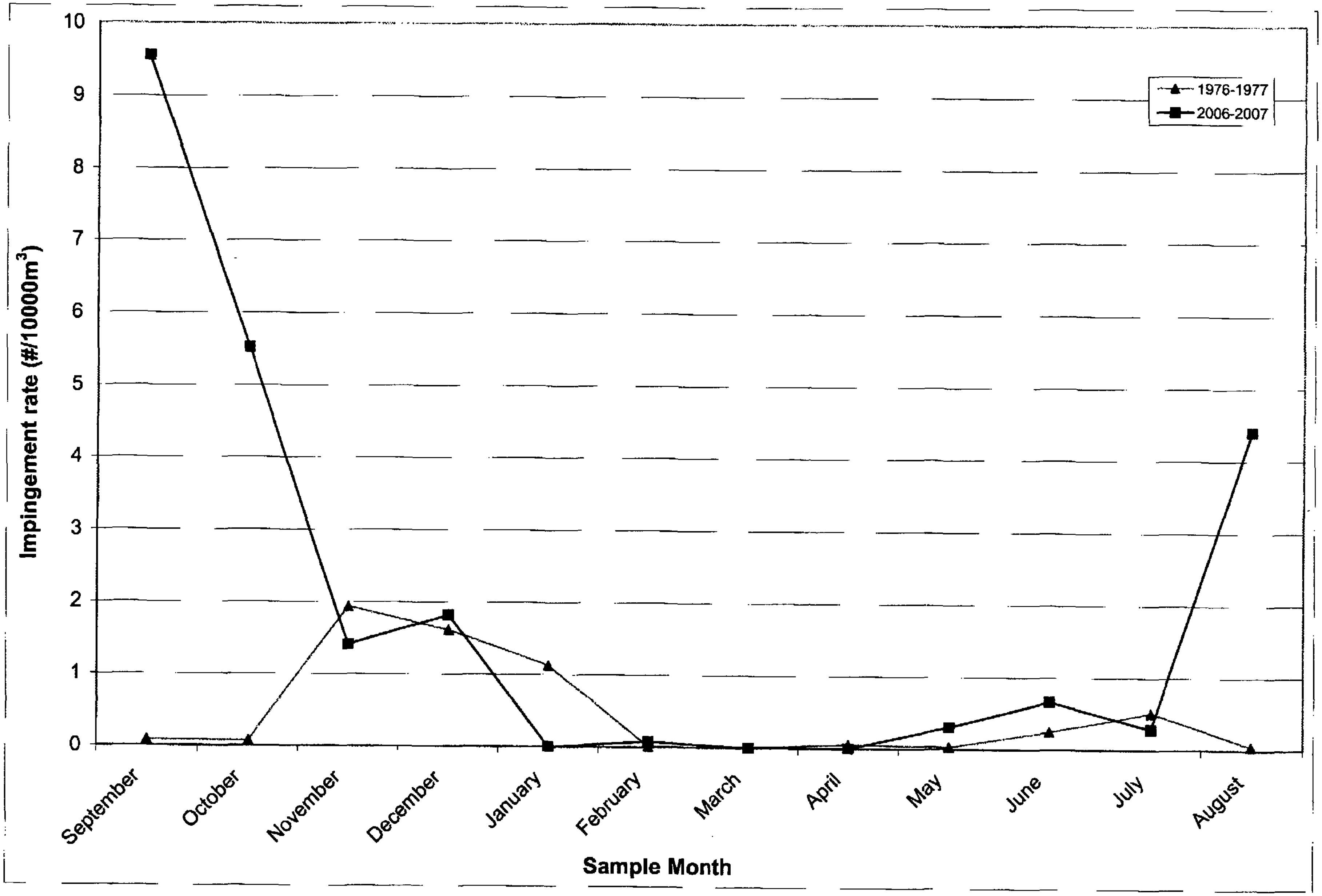


Figure 13: Threadfin Shad Average Monthly Impingement Rate: Current vs. Historic

Entergy, 2006-2007
Espey, Huston, and Associates, Inc. 1976-1977
316(b) Impingement Sampling

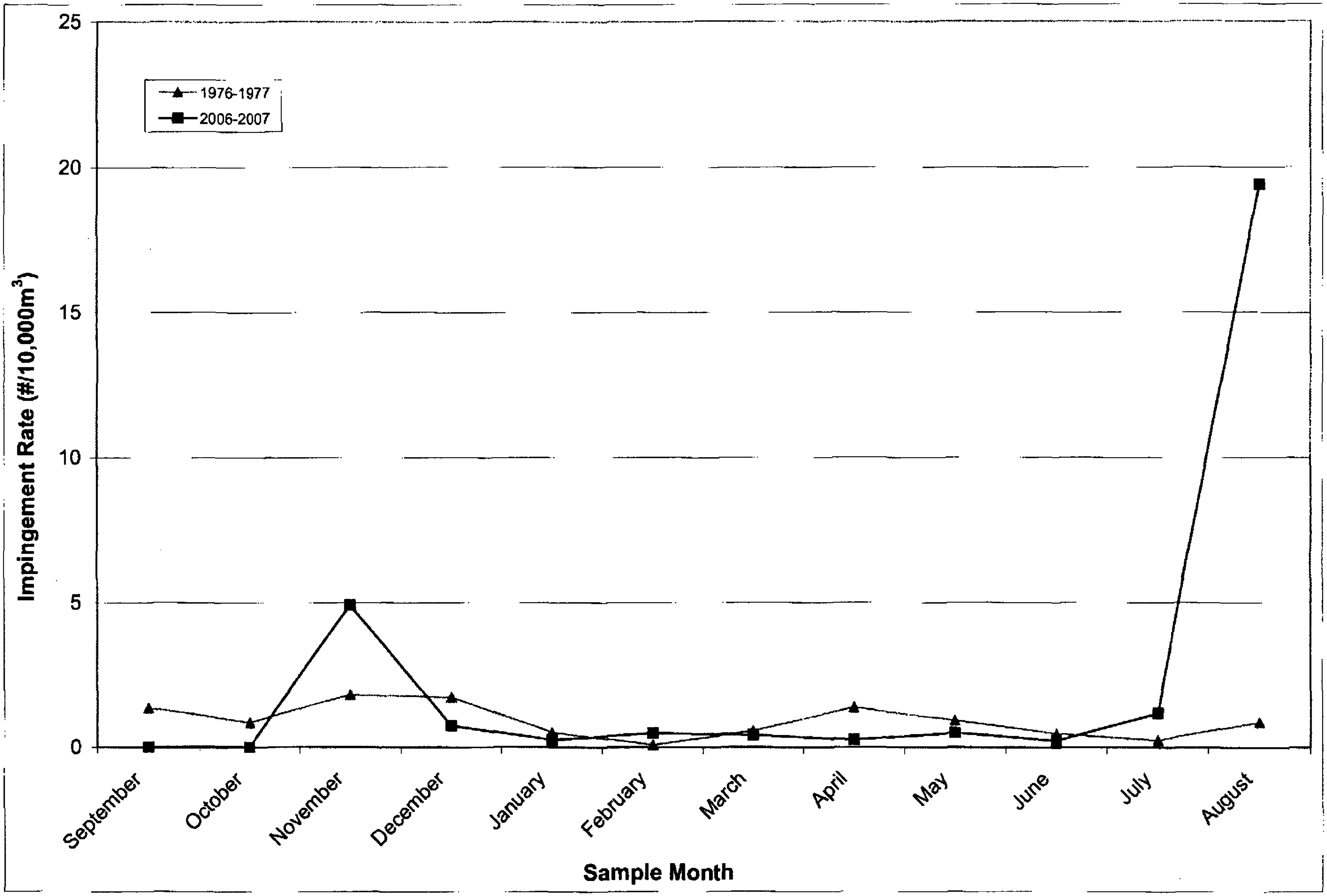


Figure 14: Blue Catfish Average Monthly Impingement Rate: Current vs. Historic

Entergy, 2006-2007
Espey, Huston, and Associates Inc. 1976-1977
316(b) Impingement Sampling

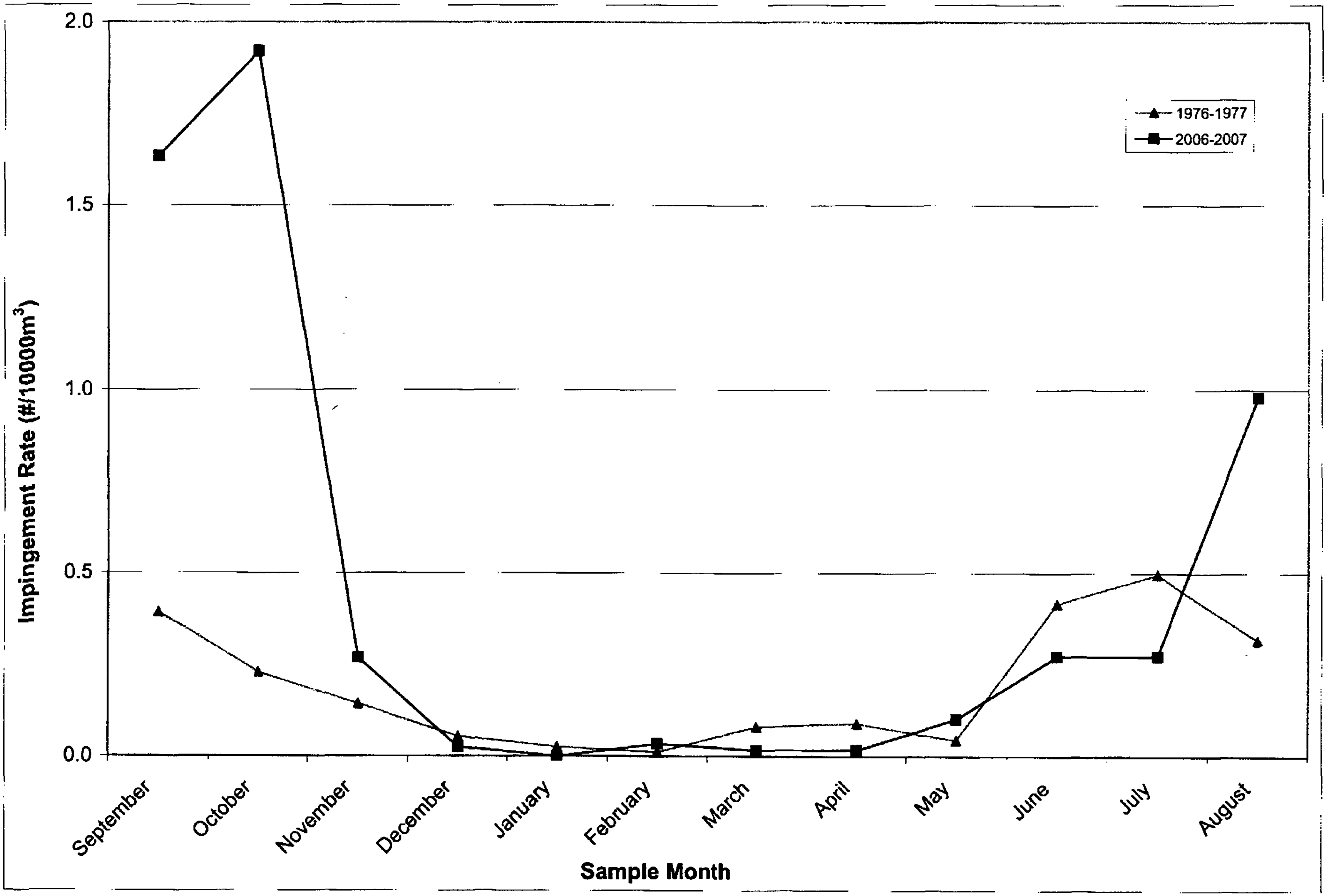


Figure 15: Freshwater Drum Average Monthly Impingement Rate: Current vs. Historic

Entergy, 2006-2007
Espey, Huston, and Associates, Inc. 1976-1977
316(b) Impingement Sampling

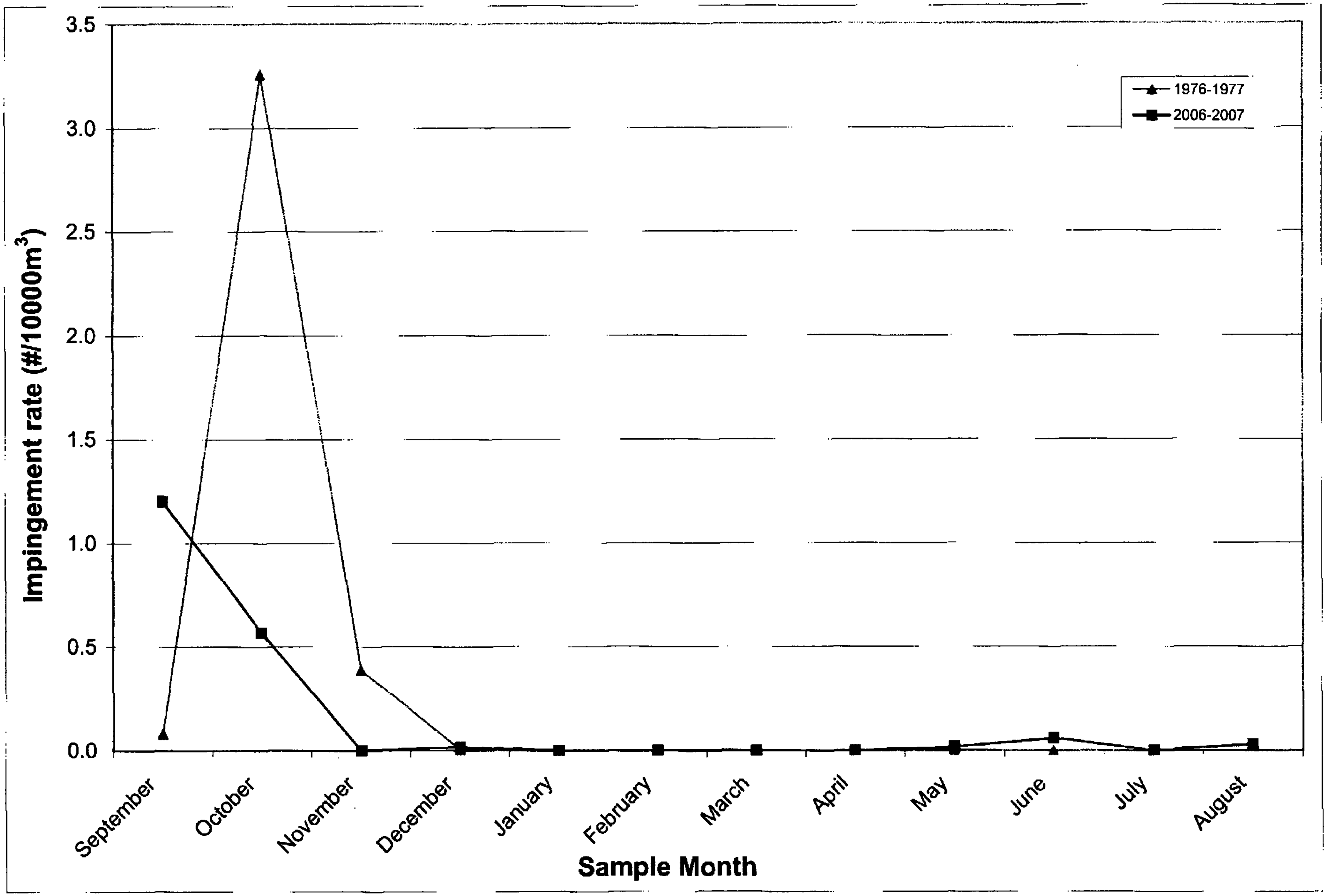


Figure 16: Bay Anchovy Average Monthly Impingement Rate: Current vs. Historic

Entergy, 2006-2007
Espey, Huston, and Associates, Inc. 1976-1977
316(b) Impingement Sampling

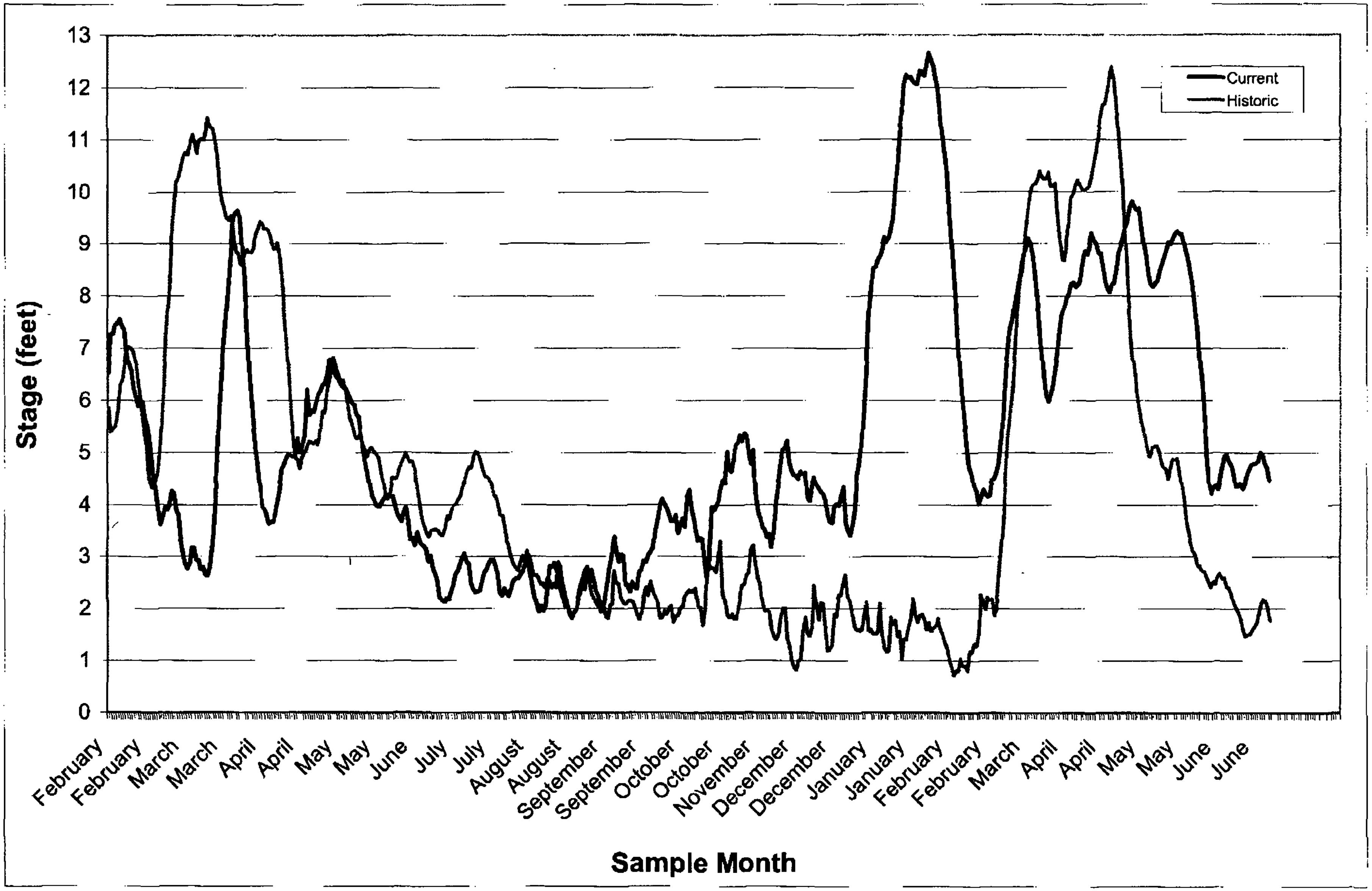
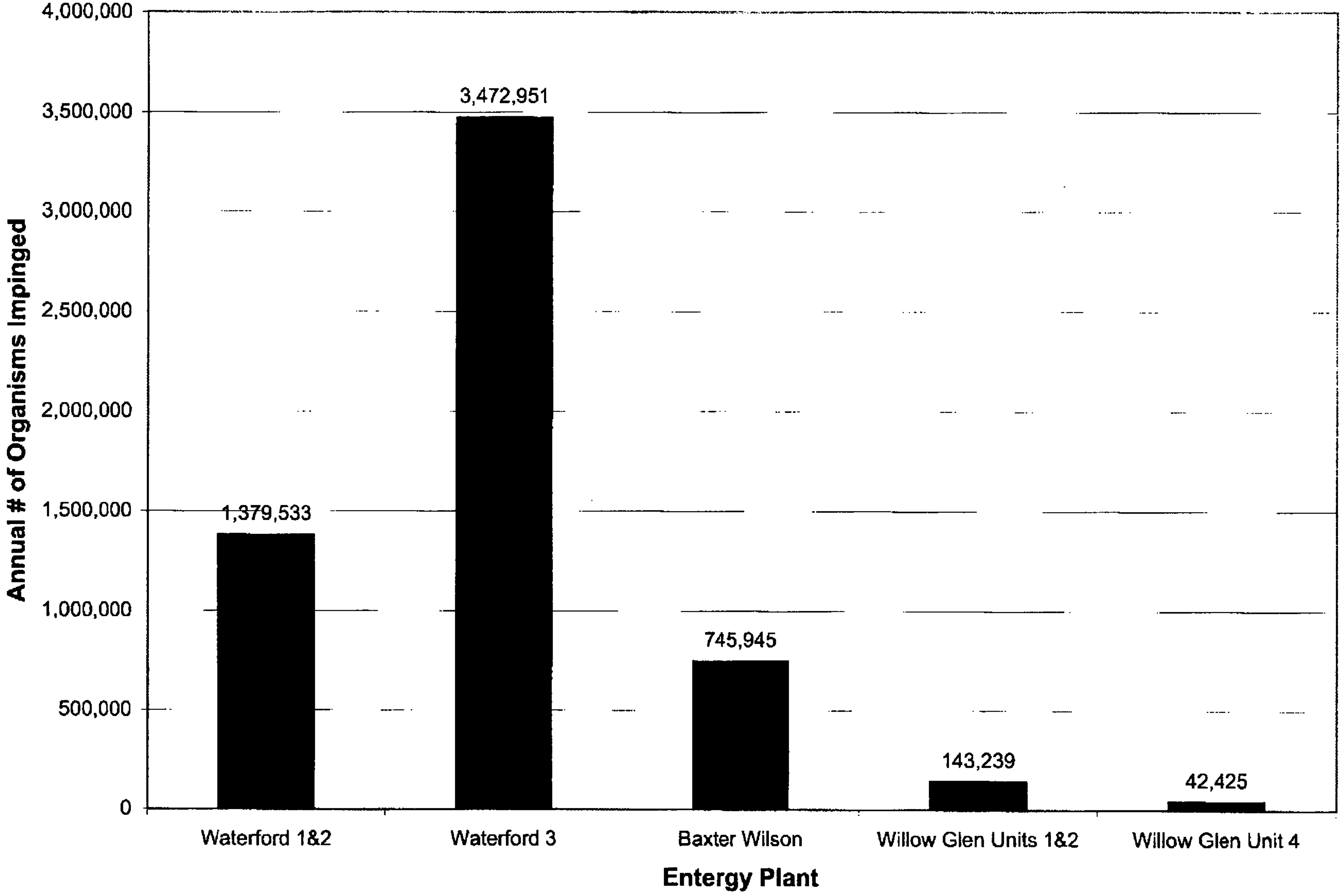


Figure 17: Mississippi River Stage Data for New Orleans, LA (Carrollton): Current vs. Historic

U.S. Army Corps of Engineers



Entergy, 2006-2007
Espey, Huston, and Associates, Inc., 1975-1977
Mississippi Power and Light, 1973-1974
316(b) Impingement Sampling

Figure 18: Maximum Annual Impingement at Selected Entergy Plants on the Mississippi River

River Habitat[1]	Features	Description	Location
Channel	Main channel & Secondary Channel	Channel habitat is characterized by those portions of the river with continuous flowing water. Habitats change little from season or river stage. Microhabitats associated with shifting sediments are common and change on a daily basis. Sediment loads vary by location on the river.	Channel habitats are present throughout the entire reach of the river. Channel steepness and depth are dependent upon sediment types in the substrate.
Natural Steep Bank	Steep slopes or cut banks	Occur on the concave sides of river bends. Steep banks typically adjoin channel habitats. Highly subject to erosion.	More common in portions of the river north of Baton Rouge where sediments are comprised of sand and gravel, mud and point bar deposits.
Revetment	Protective materials usually consisting of man-made materials such as concrete, tires, rip rap etc.	Usually associated with the concave side of bends. Commonly used throughout the lower Mississippi River along the steep banks.	Due to increased erosion revetments are commonly used in the lower Mississippi River.
Lotic Sandbar	Shallow sloping habitats	Habitats located along point bars, borders of islands, middle bars, and dike systems. Moderate to swift currents, coarse sand or sand-gravel substrate. Conditions are similar to the channel habitats.	Materials from these habitats typically create dunes on the river bottom. Usually occurs a few meters from shore.

Table 1: Description of Aquatic Habitats in the Lower Mississippi River

Baker et al., 1991

River Habitat[1]	**Features**	**Description**	**Location**
Pool	Slack or slow water areas	Slow or no current areas associated with downstream sides of dikes, islands, middle bars, and point bars. They are typically deep and have fine sediments and do not support substantial amounts of brush or debris.	Pools are more common during low flow conditions and can be found along the entire reach of the river. However, most pools are associated with dike systems which are common in portions of the river north of Baton Rouge.
Lentic Sandbar	Shallow sloping habitats	Usually associated with low currents, fine sediments and shallower depths. These habitats are ephemeral and are more common during constant river stage.	Usually occurs near the shoreline.
Contiguous slough	Slackwater, flood plain habitats. Connected to the main channel during most river stages	Usually remnants from abandoned river channels; however, they are usually quite narrow and closer to the mainstem river.	Typically found in those portions of the river where substantial river meanders occur. Also present throughout the river during low flow conditions.
Isolated Slough	Slackwater, flood plain habitats.	Usually remnants from abandoned river channels; however; they are usually quite narrow and closer to the mainstem river.	Typically found in those portions of the river where substantial river meanders occur.

Table 1: Description of Aquatic Habitats in the Lower Mississippi River

Baker et al., 1991

River Habitat[1]	Features	Description	Location
Oxbow Lake	Former river channels	Remnant portions of the river which were cut off from the main river channel. They are fairly deep and fairly large (200 to > 1600ha). Shorelines associated with oxbows are usually wooded and heavily vegetated.	Located along meandering sections of the river. The greatest numbers of Oxbow lakes are found north of Baton Rouge.
Levee Borrow Pit	Manmade floodplain habitats	These habitats are formed by the removal of fill materials for levee construction. They vary in size, time period in which they are flooded, and habitats associated with them.	Located in those reaches of the river that have high sediment deposits in the floodplain and are typically above river flood stage.
Floodplain Ponds .	Permanent, small, shallow ponds	These ponds are located in the alluvial river swamps. They are similar to isolated sloughs and oxbow lakes; however, much smaller. They form in depressional areas and tributaries to the river and are associated with Tupelo-Cypress wetlands.	Typically found in those portions of the river where substantial river meanders occur.

Table 1: Description of Aquatic Habitats in the Lower Mississippi River

Baker et al., 1991

River Habitat[1]	Features	Description	Location
Seasonally Inundated Floodplain	High river stages over low-lying lands	Areas used to include lands well outside the main river. However, construction of the levee system has separated those floodplain areas and isolated those within the river channel areas. Some of the outlying areas still receive flood waters associated with tributary flooding. The river floodplain within the levees is inundated during peak flood periods. Habitats in these areas are associated with swift currents to slack areas near the periphery.	Located in those areas near old river meanders and around sandbar deposits. Found throughout the entire reach of the river except where revetments occur.
Tributary	Downstream portion of tributary where it meets the mainstem river.	Habitats are associated with the backwater flooding of the tributaries. Usually low flowing areas with sand-silt to mud bottoms. Have areas of significant brush and debris accumulation.	There are no significant tributaries to the Mississippi River below Baton Rouge.

[1] Habitats presented in this table are derived from Baker et al. (1991).

Table 1: Description of Aquatic Habitats in the Lower Mississippi River

Baker et al., 1991

Family	Common Name	Scientific Name	Total Number Impinged
Palaemonidae	River shrimp	*Macrobrachium ohione*	10326
	Grass shrimp	*Palaemonetes kadiakensis*	1489
	Unidentified shrimp	*Unidentified sp.*	122
Cambaridae	Crayfish	*Procambarus sp.*	2
Portunidae	Blue crab	*Callinectes sapidus*	2
Corbiculidae	Asian clam	*Corbicula sp.*	15
Unionidae	Lampsilis clam	*Lampsilis sp.*	3
Acipenseridae	Shovelnose sturgeon	*Scaphirhynchus platorynchus*	3
Polyodontidae	Paddlefish	*Polyodon spathula*	76
Engraulidae	Bay anchovy	*Anchoa mitchilli*	217
Clupeidae	Skipjack herring	*Alosa chrysochloris*	40
	Threadfin shad	*Dorosoma petenense*	2493
	Gizzard shad	*Dorosoma cepedianum*	117
	Unidentified shad	*Dorosoma sp.*	1
Cyprinidae	Silverband shiner	*Notropis shumardi*	82
	Emerald shiner	*Notropus atherinoides*	4
	Bighead carp	*Hypophthalmichthys nobilis*	1
	Common carp	*Cyprinus carpio*	9
	Goldfish	*Carassius auratus*	8
Ictaluridae	Blue catfish	*Ictalurus furcatus*	2062
	Channel catfish	*Ictalurus punctatus*	820
	Flathead catfish	*Pylodictis olivaris*	13
	Unidentified catfish	*Ictalurus sp.*	1
Moronidae	Striped bass	*Morone saxatilis*	2
	White bass	*Morone chrysops*	1
Mugilidae	Striped mullet	*Mugil cephalus*	2
Centrarchidae	Black crappie	*Pomoxis nigromaculatus*	1
	Unidentified crappie	*Pomoxis sp.*	1
	Blue gill	*Lepomis macrochirus*	1
	Orangespotted sunfish	*Lepomis humilis*	1
	Unidentified centrarchid	*Lepomis sp.*	5
Sciaenidae	Freshwater drum	*Aplodinotus grunniens*	588
Achiridae	Hogchoker	*Trinectes maculatus*	91
Lepisosteidae	Longnose gar	*Lepisosteus osseus*	1
Catostomidae	Bigmouth buffalo	*Ictiobus cyprinellus*	6
Ophichthidae	Worm eel	*Ophichthidae sp.*	1
Dasyatidae	Atlantic stingray	*Dasyatis sabina*	1
		Total	18608

Table 2: Phylogenetic Distribution of Species Impinged 2006-2007

Common Name	Number of Organisms Collected																							
	January		February		March		April		May		June		July		August		September		October		November		December	
	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
River shrimp	13	17	66	48	14	9	2	2	652	745	2054	1089	623	334	523	623	593	1018	283	944	215	221	76	162
Grass shrimp			9				3	2	167	163	732	149	88	64		25					11	12	37	27
Unidentified shrimp		1								22			39	58							1	1		
Crayfish																	1						1	
Blue crab																		1		1				
Asian clam	1	8													3							1	2	
Lampsilis clam					1																	1	1	
Shovelnose sturgeon	1								1										1					
Paddlefish									12	2	31	27		1		1				1			1	
Bay anchovy									1			7			2		67	69	34	35				2
Skipjack herring											5	19	1							1	4	8	1	1
Threadfin shad			3	6					12	6	47	31	24	18	139	161	67	1013	669		76	8	53	160
Gizzard shad	2	1	1	1					11	26		16	13	5		1					26	8	1	5
Unidentified shad														1										
Silverband shiner																			1	81				
Emerald shiner									3	1														
Bighead carp					1																			
Common carp									8							1								
Goldfish									7				1											
Blue catfish	10	19	36	22	13	12	7	8	13	17	21	5	90	84	755	568				2	123	170	48	39
Channel catfish			13	7	1	3			42	39	25	45	53	38	1		19	39	208	277	5	5		
Flathead catfish		1	1				1		4	1	1		1	1					1		1			
Unidentified catfish													1											
Striped bass		1																		1				
White bass				1																				
Striped mullet															1			1						
Black crappie										1														
Unidentified crappie											1													
Blue gill														1										
Orangespotted sunfish															1									
Unidentified centrarchid			1						1						1			1		1				
Freshwater drum			3	1		1	1		3	3	17	15	10	30	26	41	16	169	71	162	8	8	2	1
Hogchoker									2	1	7	4			5	3		38	8	23				
Longnose gar										1														
Bigmouth buffalo									3		1	2												
Worm eel											1													
Atlantic stingray											1													
Total	27	48	133	86	30	25	14	12	942	1028	2944	1409	944	635	1457	1424	763	2349	1276	1529	470	443	223	397

Table 3: Diel Enumeration of Species Impinged 2006-2007

		1976-1977	2006-2007	1976-1977	2006-2007	1976-1977	2006-2007	1976-1977	2006-2007	1976-1977	2006-2007	1976-1977	2006-2007	1976-1977	2006-2007
Scientific Name	**Common Name**	**September**		**October**		**November**		**December**		**January**		**February**		**March**	
Macrobrachium ohione	River Shrimp	1.25	14.25	5.83	10.12	2.40	7.32	0.33	2.04	0.47	0.26	0.27	0.26	0.27	0.39
Ictalurus furcatus	Blue Catfish	1.36	0.00	0.86	0.02	1.81	4.92	1.72	0.74	0.52	0.25	0.09	0.49	0.57	0.43
Dorosoma petenense	Threadfin Shad	0.09	9.56	0.07	5.52	1.94	1.41	1.61	1.82	1.12	0.00	0.01	0.08	0.00	0.00
Anchoa mitchilli	Bay Anchovy	0.08	1.20	3.26	0.57	0.39	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Apolodinotus grunniens	Freshwater Drum	0.39	1.64	0.23	1.92	0.14	0.27	0.05	0.03	0.03	0.00	0.01	0.03	0.08	0.02
Dorosoma cepedianum	Gizzard Shad	0.00	0.00	0.01	0.00	0.80	0.57	0.33	0.05	0.13	0.00	0.04	0.02	0.07	0.00
Alosa chrysochloris	Skipjack Herring	0.00	0.00	0.00	0.01	0.14	0.20	0.79	0.02	0.28	0.00	0.01	0.00	0.02	0.00
Ictalurus punctatus	Channel Catfish	0.12	0.51	0.03	1.72	0.03	0.17	0.02	0.00	0.06	0.00	0.04	0.17	0.07	0.07
Paleomonetes kadiakensis	Grass Shrimp	--	0.00	--	0.00	--	0.39	--	0.55	--	0.00	--	0.08	--	0.00
	Total Monthly IM Rate	**3.29**	**27.16**	**10.29**	**19.88**	**7.65**	**15.25**	**4.85**	**5.27**	**2.61**	**0.51**	**0.47**	**1.13**	**1.08**	**0.91**

		1976-1977	2006-2007	1976-1977	2006-2007	1976-1977	2006-2007	1976-1977	2006-2007	1976-1977	2006-2007	1976-1977	2006-2007	1976-1977	2006-2007
Scientific Name	**Common Name**	**April**		**May**		**June**		**July**		**August**		**Total IM Rate (#/10000m3)**		**Relative Abundance (%)**	
Macrobrachium ohione	River Shrimp	4.71	0.07	3.99	23.80	2.19	26.82	3.55	6.56	1.27	16.80	2.21	9.06	49.65%	58.37%
Ictalurus furcatus	Blue Catfish	1.37	0.26	0.93	0.51	0.47	0.22	0.24	1.19	0.87	4.40	0.90	2.37	20.27%	4.70%
Dorosoma petenense	Threadfin Shad	0.06	0.00	0.03	0.31	0.24	0.67	0.51	0.29	0.05	19.40	0.48	2.00	10.47%	13.95%
Anchoa mitchilli	Bay Anchovy	0.00	0.00	0.00	0.02	0.00	0.06	0.00	0.00	0.03	0.03	0.31	0.16	6.01%	1.37%
Apolodinotus grunniens	Freshwater Drum	0.09	0.02	0.04	0.10	0.42	0.27	0.50	0.27	0.32	0.98	0.19	0.46	4.51%	3.31%
Dorosoma cepedianum	Gizzard Shad	0.01	0.00	0.02	0.63	0.05	0.14	0.05	0.12	0.00	0.01	0.13	0.13	2.87%	0.74%
Alosa chrysochlons	Skipjack Herring	0.01	0.00	0.00	0.00	0.00	0.20	0.00	0.01	0.00	0.00	0.11	0.04	2.36%	0.25%
Ictalurus punctatus	Channel Catfish	0.24	0.00	0.33	1.38	0.03	0.60	0.07	0.62	0.06	0.01	0.09	0.44	2.06%	5.21%
Paleomonetes kadiakensis	Grass Shrimp	–	0.09	–	5.62	–	7.52	–	1.04	–	0.37	–	1.31	–	9.30%
	Total Monthly IM Rate	**6.49**	**0.44**	**5.34**	**32.37**	**3.40**	**36.50**	**4.92**	**10.10**	**2.60**	**42.00**	**4.42**	**15.96**		

Table 4: Monthly Impingement Rates of Species Comprising >1%: Current vs. Historic

Entergy 2006-2007
Espey Huston and Associates, Inc. 1976-1977
316(b) Impingement Sampling

Table 5a: Impingement Comparison of the Waterford 1&2 and Waterford 3 Facilities

	Design Intake Capacity (gpm)	Annualized Intake Capacity (gpy)	Annualized Intake Capacity (cubic mpy)	Impingement Rate*	Annual Number of Organisms Impinged (ANOI)**
Waterford 1&2	429,000	225,482,400,000	853,543,783	16.16241872	1,379,533
Waterford 3*	1,080,000	567,648,000,000	2,148,781,551	16.16241872	3,472,951

Ratio of ANOI at Waterford 3 to Waterford 1&2 **2.52**

*The Impingement Rate for the Waterford 3 Plant was estimated from the Waterford 1&2 rate

**The Annual Number of Organisms Impinged is an estimate based on extrapolation of rate and intake capacity

Table 5b: Impingement Comparison of Selected Entergy Plants

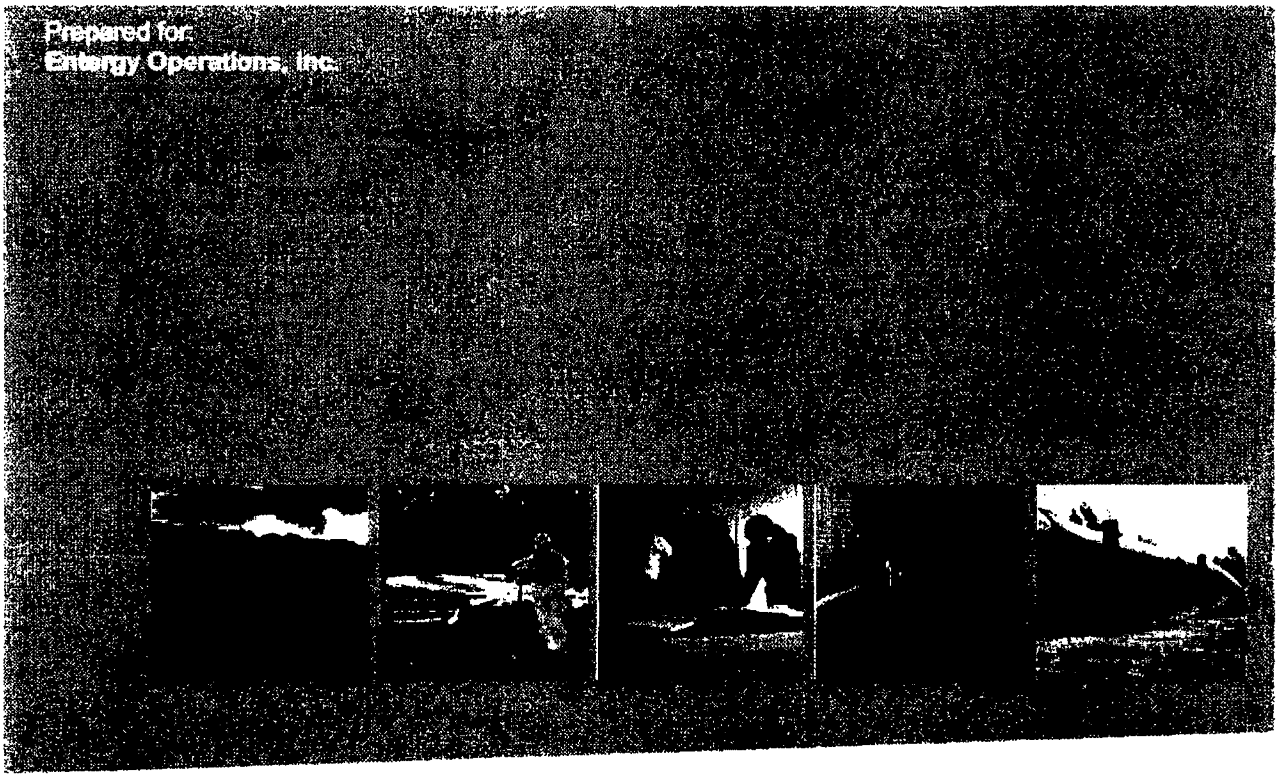
	Design Intake Capacity (gpm)	Annualized Intake Capacity (gpy)	Annualized Intake Capacity (cubic mpy)	Impingement Rate*	Annual Number of Organisms Impinged (ANOI)**	Ratio of Waterford 3 ANOI vs. Other Plants
Waterford 1&2	429,000	225,482,400,000	853,543,783	16.16241872	1,379,533	2.52
Waterford 3*	1,080,000	567,648,000,000	2,148,781,551	16.16241872	3,472,951	N/A
Baxter Wilson	412,000	216,547,200,000	819,720,369	9.099994572	745,945	4.66
Willow Glen Units 1&2	171,000	89,877,600,000	340,223,746	4.210149202	143,239	24.25
Willow Glen Unit 4	228,000	119,836,800,000	453,631,661	0.93524051	42,425	81.86

*The Impingement Rate for the Waterford 3 Plant was estimated from the Waterford 1&2 rate

**The Annual Number of Organisms Impinged is an estimate based on extrapolation of rate and intake capacity

Table 5: Impingement Comparisons of Selected Entergy Plants on the Mississippi River

Entergy. 2006-2007
Espey, Huston.and Associates, Inc 1975-1977
Mississippi Power and Light. 1973-1974
316(b(Impingement Sampling



Prepared for:
Entergy Operations, Inc.

Source Waterbody Flow Information Waterford 3 Plant – Killona, Louisiana

ENSR Corporation
December 2007
Document No.: 00970-027-0200

ENSR

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List of Figures

1.0 Introduction

The Entergy Operations, Inc. (Entergy) Waterford 3 Plant (Waterford 3) is located on the right descending bank of the Mississippi River in Killona, Louisiana approximately 25 miles upstream of New Orleans. The plant consists of a nuclear reactor with a net plant output of 1,165 MW. Because the plant uses cooling water from the Mississippi River in excess of 50 million gallons per day (MGD), the plant is regulated by the Phase II Rule (the Rule) developed under the Clean Water Act's Section 316(b).

The Rule requires Phase II plants to submit a Comprehensive Demonstration Study (CDS). One part of this CDS is a submittal of source water body flow information. This document contains the source waterbody flow information required by the rule. The required information is described in the following excerpt from the Rule:

> 40 CFR 125.95 (b)(2) S*ource waterbody flow information.* "You must submit to the Director the following source waterbody flow information: (i) If your cooling water intake structure is located in a freshwater river or stream, you must provide the annual mean flow of the waterbody and any supporting documentation and engineering calculations to support your analysis of whether your design intake flow is greater than five percent of the mean annual flow of the river or stream for purposes of determining applicable performance standards under paragraph (b) of this section. Representative historical data (from a period of time up to 10 years, if available) must be used; and (ii) If your cooling water intake structure is located in a lake (other than one of the Great Lakes) or a reservoir and you propose to increase its design intake flow, you must provide a description of the thermal stratification in the waterbody, and any supporting documentation and engineering calculations to show that the total design intake flow after the increase will not disrupt the natural thermal stratification and turnover pattern in a way that adversely impacts fisheries, including the results of any consultations with Federal, State, or Tribal fish and Wildlife management agencies."

At Waterford 3, only 40 CFR 125.95 (b)(2)(i) (i.e. river flow) is applicable. A consideration relative to the applicability of the Rule is the percentage of river flow taken by the Waterford 3 cooling water intake structure (CWIS). The Rule's performance goal for entrainment is only applicable if the CWIS flow exceeds 5% of the river's mean annual discharge. The mean annual flow of the Mississippi River at the Waterford 3 plant is 509,000 cfs. In contrast, the design intake flow of the Waterford 3 plant is 2,406 cfs, approximately 0.48% of the River's mean annual flow. Therefore, Waterford 3 is not subject to the entrainment performance goal.

2.0 Facility Location

The Entergy Operations, Inc. (Entergy) Waterford 3 Plant is located on the right descending bank of the Mississippi River approximately 25 miles upstream of New Orleans, near River Mile 129.5 AHP (Ahead of Pass). The cooling water intake for the Waterford 3 plant consists of a sheet piling intake canal that extends approximately 160 feet from the shoreline and a screen well that houses eight traveling water screens located at the shoreline (Figure 2-1). The cooling water design intake flow is 1,555.2 MGD.

The width of the Mississippi River at the Waterford 3 plant is approximately 1,850 feet (measured from a U.S. Geological Survey topographic map of the river). Transect data from a hydrographic survey conducted by the USACE in 1992 indicate that average maximum depth is approximately 129 feet[1].

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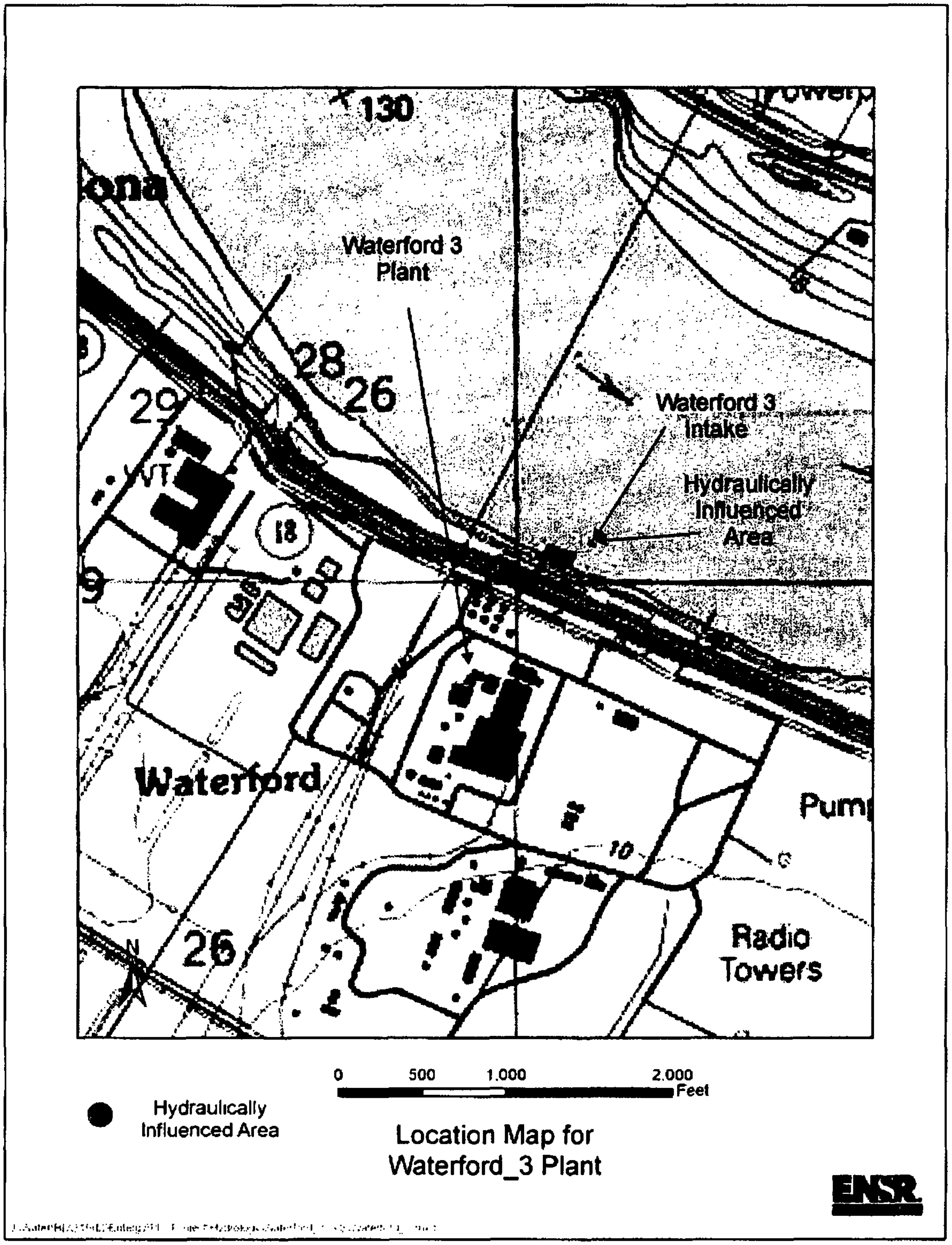
[1] Transect data for the Lower Mississippi River was taken from the U.S Army Corps of Engineers website: http://www.mvn.usace.army.mil/eng2/edsd/misshyd/misshyd.htm

Figure 2-1 Plant location



3.0 Review of Waterbody Flow and Design Intake Flow

The extremely large drainage basin of the lower Mississippi and the resulting high flow rate minimizes the impacts of the cooling water withdrawal by the Waterford 3 plant. The mean annual flow of the Mississippi River at the Waterford 3 plant is 509,000 cfs. In contrast, the design intake flow of the Waterford 3 plant is 2,406 cfs, approximately 0.48% of the River's mean annual flow.

3.1 Annual Mean Source Waterbody Flow

Records of river discharge are not readily available for the Mississippi River in the vicinity of the Waterford 3 plant. Therefore, Josh Gilbert at the US Geological Survey's (USGS) Louisiana Office was contacted to identify which river gage was most appropriate for estimating flow in the portion of the river just north of New Orleans. He indicated that data from the US Army Corps of Engineers gage at Tarbert Landing[2] would provide a good approximation of the flow in the vicinity of Waterford 3 since there are no major diversions or tributaries below this gage. The Tarbert Landing gage is located closely downstream of the Old River Control Structure, approximately 180 river miles upstream of Waterford 3. The rate of discharge at the Tarbert Landing is likely to underestimate the flow at Waterford 3.

Daily flow measurements for a ten year period (1996-2005) at Tarbert Landing were obtained from the U.S Army Corps of Engineers website[3]. The estimated annual mean flow calculated from these data was approximately 509,000 cfs. Average monthly flows over this same period range from a low of 241,000 cfs for September to a high of 763,000 cfs for March (Figure 3-1). These data reflect the discharge of the Mississippi below the Old River Control Structure. The discharge statistics are supported by several other gages located upstream of Tarbert Landing.

3.2 Design Intake Flow

The design intake flow for the Waterford 3 plant is 2,406 cfs. The Waterford 3 plant has four circulating water pumps and three service water pumps. The circulating pumps each have a capacity of 250,000 gpm and the service water pumps have a capacity of 3,000 gpm, resulting in a total plant design intake flow of 1,009,000 gpm or 2,406 cfs.

3.3 Percent of River Flow Used for Cooling Water

The Waterford 3 design intake flow of 2,406 cfs is 0.48% of the Mississippi River mean annual flow of 509,000 cfs, using the flow data at Tarbert landing as a representative approximation of the flow at the Waterford 3 plant.

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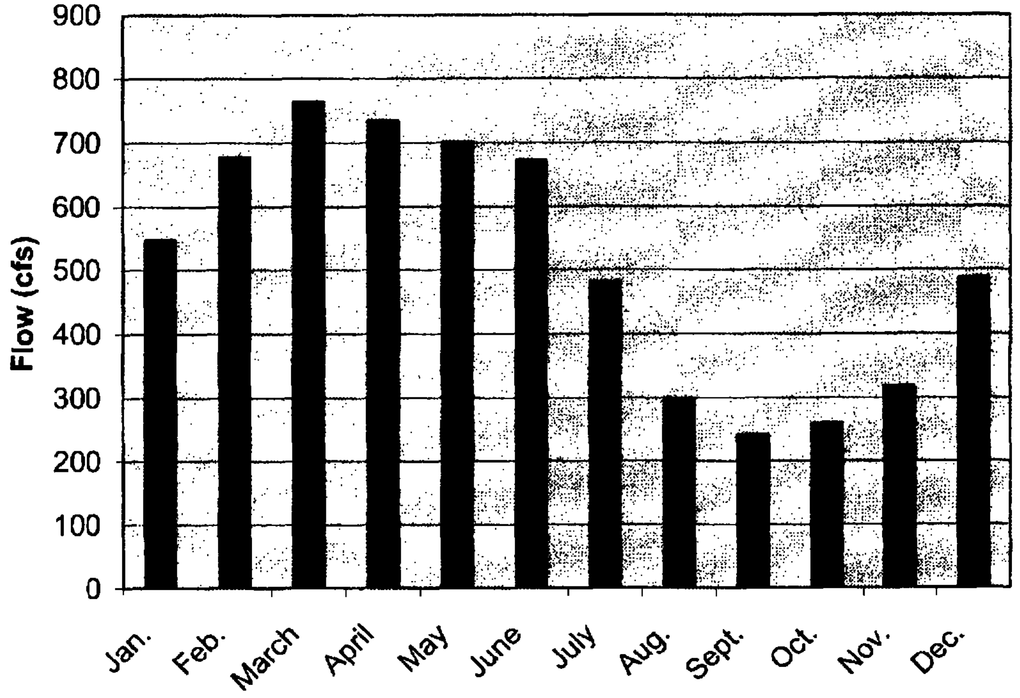
[2] US Army Corps of Engineers Gage # 01100. Located at river mile 306.3, below the Old River Control Structure.

[3] Daily flow data at Tarbert Landing are available at: http://www.mvn.usace.army.mil/cgi-bin/wcmanual.pl?01100

Figure 3-1 Mean monthly flows (cfs) at Tarbert Landing 1996-2005[4]



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[4] Data from downloaded from http://www.mvn.usace.army.mil/cgi-bin/wcmanual.pl?01100

4.0 Summary and Implications

Waterford 3, as the calculations above demonstrate, withdraws less than 0.48% of the Mississippi River flow. The Rule requires facilities that withdraw more than 5% of the flow from freshwater rivers to meet entrainment performance standards (40 CFR 125.94(b)(2)(B)). Since the Waterford 3 withdraws less than 5% of the annual flow of Mississippi River, the plant is not subject to the entrainment performance goal of the Rule. In addition, the low proportion of water withdrawn strongly suggests that entrainment impacts will be insignificant. Therefore, the Waterford 3 plant is subject only to the impingement mortality performance standard in the Rule.

Prepared for:
Entergy Operations, Inc.

Submittals Under Section 122.21(r) 2, 3 and 5 - Waterford 3 Plant, Killona, Louisiana LPDES Permit No. LA0007374

Prepared By:
ENSR Corporation
December, 2007
Document No.: 00970-027-0100

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Executive Summary

The Entergy Operations Inc. (Entergy) Waterford 3 Plant uses cooling water from the Mississippi River in excess of the regulatory threshold of 50 million gallons per day (MGD) and is regulated by the Phase II Rule developed under the Clean Water Act's Section 316(b) (the Rule). Since the design cooling water intake flow is less than 5% of the mean annual flow of the Mississippi River and the source water body is a freshwater river, the Waterford 3 Plant is subject to the Rule's performance goals for impingement mortality but not entrainment.

Plants regulated by the Rule are required by section 40 CFR 122.21(r) to submit information on their cooling water system as part of their NPDES application. Specifically, Phase II plants are required to submit:

- Source water body physical data (40 CFR 122.21(r)(2));
- Cooling water intake structure (CWIS) data (40 CFR 122.21(r)(3)); and
- Cooling water system data ((40 CFR 122.21(r)(5)).

This document contains information to fulfill these requirements. (Note: requirements under 40 CFR 122.21(r)(1) and (4) are not applicable to Phase II facilities).

1.0 Introduction

The Entergy Operations, Inc. (Entergy) Waterford 3 Plant is located on the right descending bank of the Mississippi River approximately 25 miles upstream of New Orleans, near River Mile 129.5 AHP (Ahead of Pass). The cooling water intake for the Waterford 3 plant consists of a sheet piling intake canal that extends approximately 160 feet from the shoreline and a screen well that houses eight traveling water screens located at the shoreline (Figure 2-1). The cooling water design intake flow is 1,555.2 MGD.

1.1 Review of the Rule's Requirements

As part of the application process for a National Pollution Discharge Elimination System (NPDES) permit, 40 CFR 122.21(r) requires Phase II existing facilities to submit information on the facility and the source water body. Phase II facilities must submit the following (as excerpted from the Rule):

> 40 CFR 122.21(r) (2) Source water physical data. These requirements include:
>
> > "(i) A narrative description and scaled drawings showing the physical configuration of all source water bodies used by your facility, including areal dimensions, depths, salinity and temperature regimes, and other documentation that supports your determination of the water body type where each cooling water intake structure is located;
> >
> > (ii) Identification and characterization of the source waterbody's hydrological and geomorphological features, as well as the methods you used to conduct any physical studies to determine your intake's area of influence within the waterbody and the results of such studies; and
> >
> > (iii) Locational maps."
>
> 40 CFR 122.2(r)(3) Cooling water intake structure data. These include:
>
> > (i) A narrative description of the configuration of each of your cooling water intake structures and where it is located in the water body and in the water column;
> >
> > (ii) Latitude and longitude in degrees, minutes, and seconds for each of your cooling water intake structures;
> >
> > (iii) A narrative description of the operation of each of your cooling water intake structures, including design intake flows, daily hours of operation, number of days of the year in operation and seasonal changes, if applicable;
> >
> > (iv) A flow distribution and water balance diagram that includes all sources of water to the facility, recirculating flows, and discharges; and
> >
> > (v) Engineering drawings of the cooling water intake structure.
>
> 40 CFR 122.2(r)(5) Cooling water system data. Phase II existing facilities as defined in part 125, subpart J of this chapter must provide the following information for each cooling water intake structure they use:
>
> > (i) A narrative description of the operation of the cooling water system, its relationship to cooling water intake structures, the proportion of the design intake flow that is used in the system, the number of days of the year the cooling water system is in operation and seasonal changes in the operation of the system, if applicable; and

(ii) Design and engineering calculations prepared by a qualified professional and supporting data to support the description required by paragraph (r)(5)(i) of this section."

1.2 Document Organization

This document provides the information required by of 40 CFR 122.21(r) for Phase II existing facilities. The following is a summary of the sections of this document and the applicable sections of the requirements they are addressing:

- **Section 2.** Contains information on source water physical characteristics as required by 40 CFR 122.21(r)(2);
- **Section 3.** Contains information on the configuration, location, and operation of the cooling water intake structure as required by 40 CFR 122.21(r)(3); and
- **Section 4.** Contains a description of the cooling water system's characteristics and operation as required by 40 CFR 122.21(r)(5).

2.0 Source Water Physical Data – 40 CFR 122.21(r)(2)

This section provides information on the source water body for the Entergy Waterford 3 Plant. Phase II existing facilities are required to submit the following information on the physical characteristics of the source water body (40 CFR 122.21(r)(2)) (as excerpted from the Rule):

> "(i) A narrative description and scaled drawings showing the physical configuration of all source water bodies used by your facility, including areal dimensions, depths, salinity and temperature regimes, and other documentation that supports your determination of the water body type where each cooling water intake structure is located;
>
> (ii) Identification and characterization of the source waterbody's hydrological and geomorphological features, as well as the methods you used to conduct any physical studies to determine your intake's area of influence within the waterbody and the results of such studies; and
>
> (iii) Locational maps."

2.1 Physical Configuration

The Entergy Operations, Inc. (Entergy) Waterford 3 Plant is located on the right descending bank of the Mississippi River approximately 25 miles upstream of New Orleans, near River Mile 129.5 AHP (Ahead of Pass). The cooling water intake for the Waterford 3 plant consists of a sheet piling intake canal that extends approximately 160 feet from the shoreline and a screen well that houses eight traveling water screens located at the shoreline. The cooling water design intake flow is 1,555.2 million gallons per day (MGD).

The width of the Mississippi River at the Waterford 3 plant is approximately 1,850 feet (measured from a U.S. Geological Survey topographic map of the river). Transect data from a hydrographic survey conducted by the USACE in 1992 indicate that average maximum depth is approximately 129 feet in this section of the river (USGS 1991-1992.)

2.2 Geomorphological Characteristics

There are two major Louisiana eco-regions in the vicinity of the Waterford 3 plant. The Inland Swamps eco-region transitions from freshwater dominant cypress and tupelo marsh forest to briny-water grass and rush marshes. Freshwater habitat dominates in the north and gradually transitions to salt water habitat in the south. The Southern Holocene Meander Belts eco-region, historically contained natural levees and abandoned channels of the Mississippi. This eco-region has largely been cleared of its natural oak forest for soybean, sugarcane, cotton, and corn crops. An extensive levee system controls the natural river fluctuations to allow for this agriculture. (Daigle, 2006)

The northeastern portion of the Waterford 3 site is a natural levee consisting of firm to stiff silty clays. The remainder of the site is wetlands. Soils in the wetlands are composed primarily of soft highly organic clays interspersed with silt and peat lenses (U.S Nuclear Regulatory Commission 1981). The area surrounding the intake structure is subject to extreme river stage fluctuations.

2.3 Overview of Waterbody Hydrodynamics

River discharge records are not readily available for the Mississippi River in the vicinity of the Waterford 3 plant. Therefore, the US Army Corps of Engineers (USACE) gage at Tarbert Landing was used as an approximation of the flow in the vicinity of Waterford 3 since there are no major diversions or tributaries below this gage. The Tarbert Landing gage is located closely downstream of the Old River Control Structure, approximately 180 river miles upstream of Waterford 3. The rate of discharge at the Tarbert Landing is likely to underestimate the flow at Waterford 3.

Daily flow measurements for a 10 year period (1996-2005) at Tarbert Landing were obtained from the USACE website. The estimated annual mean flow calculated from these data was approximately 509,000 cubic feet per second (cfs). Average monthly flows over this same period range from a low of 241,000 cfs for September to a high of 763,000 cfs for March. These data reflect the discharge of the Mississippi below the Old River Control Structure. The discharge statistics are supported by several other gages located upstream of Tarbert Landing (US Army Corp of Engineers 1996-2005).

2.4 Salinity and Temperature Data

Mean monthly water temperatures, measured at the Entergy Nine Mile Plant located approximately 25 miles downstream of Waterford 3 (river mile 104), range from 45° F in January to 85° F in August for the period from 1951-1978 (Louisiana Power and Light, no date). A temperature cross section taken at the Nine Mile Plant indicates that there are not significant vertical or horizontal temperature gradients in this portion of the river. This is likely due to the relatively high current velocities in the river. The Mississippi River is freshwater and not influenced by tidal fluctuations at this location.

2.4.1 Potential for Stratification

Stratification is not expected due to the high current velocity in this portion of the Mississippi River. This is confirmed by measurements of summer water temperatures that indicate there are not significant vertical or horizontal temperature gradients (Geo-Marine Inc. 1975).

2.5 Estimation of Zone of Hydraulic Influence

The high ambient water velocities in and the depth of the Mississippi River in the vicinity of the Waterford 3 Plant minimize the zone of influence of the cooling water withdrawal. The zone of hydraulic influence is defined here as an area of sufficient size so that the velocity through the area is equivalent to the ambient velocity in the source water if all cooling water passes through it.

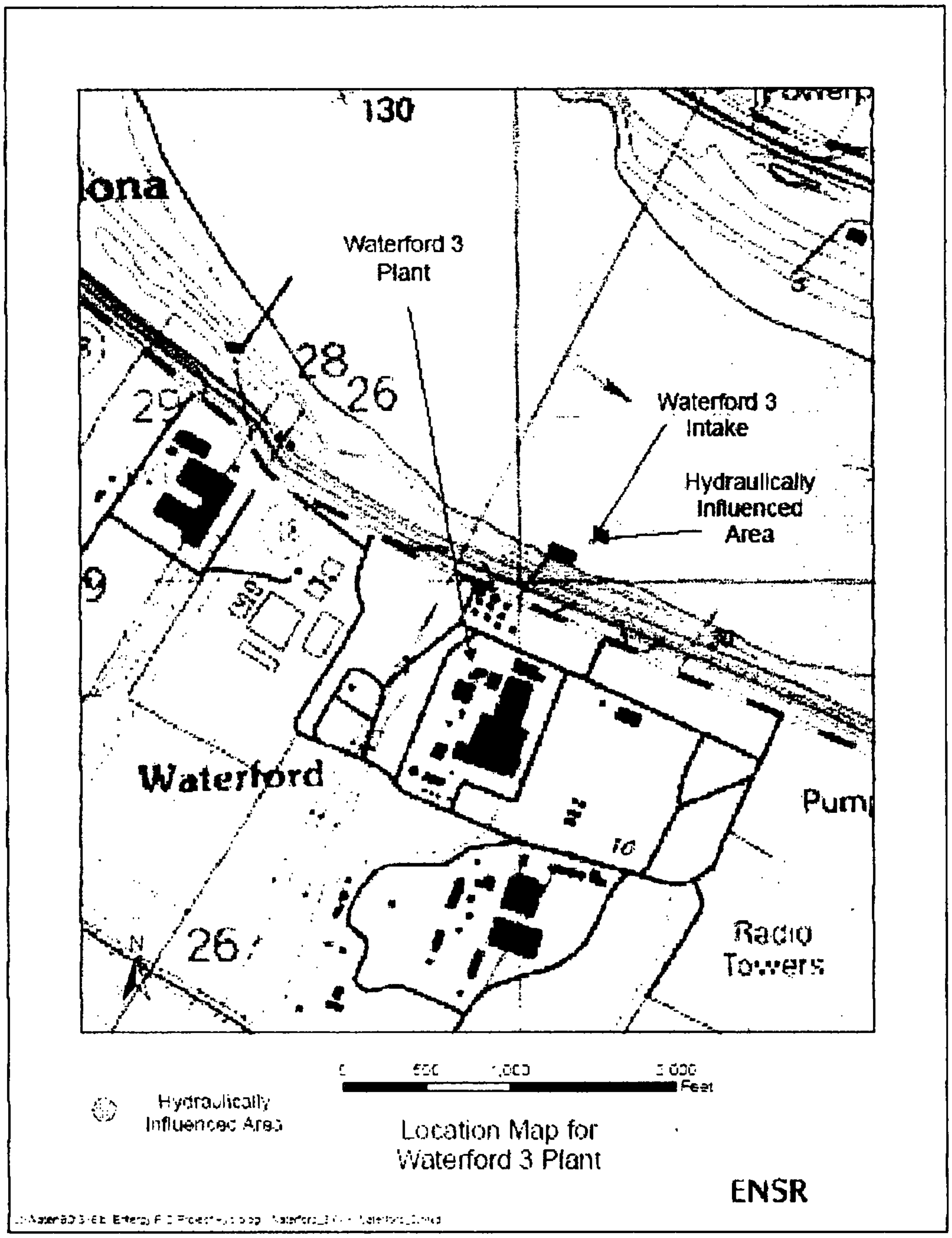
The ambient velocity was calculated by dividing the flow of the Mississippi River in the vicinity of Waterford 3 by the cross-sectional area. Using the width of 1,850 feet and the average maximum depth of 129 feet, the cross-sectional area of approximately 239,000 square feet was calculated. This corresponds to an average river velocity of 2.1 f/s.

Therefore, using the design intake flow at the facility of 2,406 cfs, the zone of influence is a cylinder of depth 50 feet (depth at the intake) and diameter 7.1 feet.

2.6 Discussion of Implications

Based on the information presented in this section, the Waterford 3 plant is calculated to withdraw less than 0.48% of the flow in the Mississippi River. Therefore, this plant withdraws much less than 5% of the annual Mississippi River flow and is not subject to the entrainment performance goal.

Figure 2-1. Location of Plant



3.0 Cooling Water Intake Structure Data – 40 CFR 122.21(r)(3)

This section provides information on the Waterford 3 Plant's cooling water intake structure (CWIS). Phase II facilities are required to submit the following information on the CWIS (40 CFR 122.21(r)(3):

> "(i) A narrative description of the configuration of each of your cooling water intake structures and where it is located in the water body and in the water column;
>
> (ii) Latitude and longitude in degrees, minutes, and seconds for each of your cooling water intake structures;
>
> (iii) A narrative description of the operation of each of your cooling water intake structures, including design intake flows, daily hours of operation, number of days of the year in operation and seasonal changes, if applicable;
>
> (iv) A flow distribution and water balance diagram that includes all sources of water to the facility, recirculating flows, and discharges; and
>
> (v) Engineering drawings of the cooling water intake structure."

3.1 Location of the CWIS

Once through cooling water enters the Waterford 3 plant through an intake canal comprised of sheet piling that extends approximately 160 feet from the shoreline. Water from the canal is carried to the intake structure which consists of eight traveling screens located on the shoreline (Figure 3-1). The coordinates of the intake structure are: 29° 59' 51" N, 90° 28' 11" W.

3.2 CWIS Overview

The Waterford 3 CWIS is designed to withdraw 1,080,000 gallons per minute (gpm) of cooling water from the Mississippi River. The CWIS was designed for operation during water elevations ranging from 23.6 feet mean sea level (msl) to 0.8 feet msl. The CWIS consists of an intake canal, intake structure, eight trash racks, eight through-flow traveling water screens and three screen wash pumps.

The intake canal is formed by steel sheet piling driven into the river bottom and extending approximately 162 feet out from the face of the intake structure (perpendicular to the shoreline - Figure 3-2). The canal has a skimmer wall across its entrance which inhibits floating debris from entering the canal. The elevation at the top of the sheet piles is +15.0 feet msl. The elevation at the bottom of the skimmer wall is at elevation -1 foot msl. The dimensions of the opening to the river are 36.9 feet in length by 34 feet in depth. The induced water velocity through the intake opening at the river boundary during maximum pump operation pump is approximately 1.9 ft/sec.

At the shoreline end of the intake canal, the CWIS is comprised of eight intake bays that are defined by concrete wingwalls. Each intake bay is approximately 11 feet wide, and has a curtain wall (extending vertically from +15 feet to -4.0 feet, and across the width of each bay), trash rack and traveling water screen. The maximum design flow rate for each intake bay is 135,000 gpm. At the maximum design flow rate, the screen approach velocity is approximately 1.0 ft/sec in each bay.

The trash rack in each CWIS bay is designed to remove large debris. Each trash rack consists of a series of 1/2 inch by 3 1/2 inch bars spaced 3 inches on center and oriented at an angle of approximately 10 degrees from vertical. Plant personnel clean the trash racks with a mechanical trash rack cleaner. A travelling screen and screen wash system remove additional debris and fish from the CWIS.

The traveling water screens are located 29 ft 9 in. upstream of the circulating water pumps and 19 ft 3 in. downstream from the trash racks and are composed of stainless steel wire mesh, most with 1/4-inch-square openings. Some screen panels (approximately 10%) have 3/8-inch mesh. The traveling screens are conventional through-flow screens, oriented perpendicular to the walls of the intake bays. Each traveling water screen is cleaned by a high pressure spray (80 psi) from two parallel headers located on the inside of the ascending side of the screen. Each header contains nine spray nozzles (for a total of 18 nozzles per screen), directed toward the river. The spray cleaning system can be operated manually or automatically based on a water level differential (18 inches) across the traveling water screens. The screens can operate at either high or low speeds (20 ft/sec and 5 ft/sec). Depending on the debris load, the screens might be rotated and cleaned anywhere from hourly to once each day.

The four circulating water pumps (1 for two intake bays) are vertical mixed flow pumps. Each pump is rated for 3,500 hp at 273 rpm and is capable of pumping 557 cfs (250,000 gpm) of water. Three service water pumps are located 12.5 ft upstream of the circulating pumps. Each service water pump is rated for 250 hp at 1,775 rpm and capable of providing 7 cfs (3,000 gpm) of service water. Cooling water is discharged 600 ft downstream of the CWIS.

3.2.1 Traveling Screens

Traveling screens continuously remove debris from the incoming river water before the water is drawn in by the circulating water pumps. If debris were to enter the system, damage to the circulating water pumps or plugging of the condenser tubes could occur. A diagram of the traveling screens is shown in Figure 3-3.

There are eight link-belt traveling screens for Waterford 3 in the screen well structure. The screens are approximately 11-feet wide and 51-feet tall. They are located 29 ft 9 in. upstream of the circulating water pumps and 19 ft 3 in. downstream from the trash racks and are composed of stainless steel wire mesh, most with1/4-inch-square openings. Some screen panels (approximately 10%) have 3/8-inch mesh. The traveling screens are conventional through-flow screens, oriented perpendicular to the walls of the intake bays. The screens can operate at either high or low speeds (20 ft/sec and 5 ft/sec). Depending on the debris load, the screens might be rotated and cleaned anywhere from hourly to once each day. Normally, the screens are rotated a least once per 8-hour shift. The screens are typically rotated manually, because in automatic mode there can be excessive debris carryover (Matys 2004).

The traveling screen and wash system is designed to maintain the differential water level across the traveling water screens below 18 inches. This design ensures that the water level in the circulating water pump bays will never drop to the pump design minimum elevation of -0.7 msl (Entergy 2003).

The differential water level across each traveling water screen is sensed by a differential pressure transmitter in conjunction with a pair of bubbler pipes. The transmitters are located in the instrument cabinet mounted onto the operating deck of the intake structure. The two bubbler pipes, one on each side of the screen, determine the differential water level across the screen. The pipes extend into the water and are filled with regulated instrument air through flow-controlled purge meters. The constant flow allows air to escape (bubble) from the open bottom end of the pipe. The pressure in the pipe is proportional to the water level and the signal is transmitted to the plant computer and can be read locally. Three differential pressure indicating switches are connected in parallel with the differential pressure transmitter of each screen. These switches are located in each traveling water screen panel and are used for traveling water screen and screen wash pump control. A pressure switch is also provided for each of the traveling water screens to detect a loss of instrument air to the bubbler pipes. The switch will sound an alarm in the Control room on panel CP-1 in the event air pressure in the upstream bubbler pipes falls below 2.0 psig. (Entergy 2003)

Each of the eight traveling water screens contains 58 panels (baskets) 2 feet high and 10 feet long, interconnected to form a continuous belt extending vertically downward into the bay of the intake structure. Each basket consists of a frame that houses stainless steel wire mesh, with 1/4-inch-square openings. Each screen is designed for up to 135,000 gpm of water at a river depth of 4.0 feet above sea level. Each traveling water screen is powered by a two-speed induction motor in combination with a geared speed reducer. A shear pin prevents damage to the motor or other screen components in the event the screen gets jammed. Each motor has an output of 15 horsepower at 1800 rpm for a high-speed screen rotation of 20 feet per minute and an output of 3.75 horsepower at 450 rpm for a slow speed screen rotation of 5 feet per minute. The portion of the traveling water screens extending above the intake structure deck is enclosed by a splash-proof fiberglass enclosure. (Entergy 2003)

It should be noted that the Waterford 3 Plant has an infrequent but recurring issue with debris carry-over from the traveling screens. The debris in the circulating water leads to macro fouling of the inlet water box side of the condenser, which causes associated integrity concerns with the station condensers. This issue was identified during the last two Institute of Nuclear Power Operations (INPO) inspections as an Area for Improvement. As such, any technological or operational change that possibly would increase the post-screen debris load could potentially create plant operational issues.

3.2.2 Screen Wash System

Each traveling water screen is cleaned by a high pressure spray (80 psi) from two parallel headers located on the inside of the ascending side of the screen. Each header contains nine spray nozzles (for a total of 18 nozzles per screen), directed toward the river. The spray cleaning system can be operated manually or automatically based on a water level differential (18 inches) across the traveling water screens. The spray nozzles are flat-spray, non-clogging types, positioned so that the fan-shaped sprays are evenly distributed over the entire basket length. The spray patterns are checked periodically and the nozzles are cleared if necessary to prevent the carryover of small debris to the circulating water pumps. The Screen Wash Pumps discharge into respective screen wash headers. From these headers the river water flows through two distribution lines on each of the traveling screens to the screen spray nozzle headers and spray nozzles. The nozzles spray water through the screens to flush any debris from the screens. A concrete trough collects debris from the screens. Each traveling screen has a sluice line supplied by the screen wash pumps to sluice debris from the trough into the river. The spray nozzle header pressure is measured to provide a start to the Traveling Screen Motors. The spray headers are maintained at 72 psi, assuring removal of debris from the screens to prevent carryover of debris to the Circulating Water Pumps (Entergy 2003). Wash water discharges through a single concrete trough that returns the fish and debris to the river. (Matys 2004)

The three 50% capacity screen wash pumps are located in the intake structure pump bays between the traveling water screens and the circulating water pumps. The screen wash pumps are suspended from the operating deck of the intake structure and extend downward 31 feet into the bays to ensure adequate submergence under all operating conditions. Each of the four-stage vertical centrifugal (turbine) pumps is rated for 3000 gpm flow at 118 psig and is driven by a direct-coupled 250 hp, 1775 rpm motor. Parallel operation of two screen wash pumps provides a supply of river water adequate to remove debris from all traveling water screens and flushing water to wash the debris from the trough back into the river. Screen Wash Pump A is a swing pump which can be aligned to either spray wash header. Screen Wash Pumps B and C are connected to the number 2 and number 1 screen wash headers, respectively (Entergy 2003).

The Clearwell Tank is filled by off-site parish-supplied water and provides a continuous supply of potable water for cooling the pump motor bearings. The water is supplied to the bearings at a rate of 3.5 gpm at 25 psig by the circulating water pump bearing lubricating water pumps. Bearing cooling water flow to each screen wash pump motor is monitored by flow indicating switches. The switch indicating scales continuously display the actual flow. A low flow of 1.75 gpm (decreasing) will prevent the associated pump from starting and alarm on Control Room panel CP-1. These pumps supply motor-bearing cooling only. The pumps are self lubricated. Once used, the cooling water is discharged into the intake bay. Pump motor short circuit or overload will automatically trip the breaker. Tripping is delayed to prevent a trip during the normal high starting currents. An undervoltage condition on the bus will also trip the breaker. The breaker also includes a motor circuit ground fault current detection system. Discharge pressure for each of the three screen wash pumps is displayed locally on pressure gauges. The indicators display pressure from 0-200 psig. (Entergy 2003)

3.3 CWIS Operation

The Waterford 3 CWIS is a once through system, designed to withdraw 1,080,000 gpm of cooling water from the Mississippi River. The CWIS was designed for operation during water elevations ranging from 23.6 feet msl to 0.8 feet msl. The CWIS consists of an intake canal, intake structure, eight trash racks, eight through-flow traveling water screens and three screen wash pumps. Water passes through the intake canal and into the intake structure. The water velocity through the intake opening at the river boundary during maximum pump operation pump is approximately 1.9 ft/sec (Louisiana Power & Light. 1979).

After passing through the traveling screens, water is carried from the intake structure pumps through the condenser and into the discharge structure. The intake canal is formed by steel sheet piling driven into the river bottom and extending approximately 162 feet out from the face of the intake structure. The canal has a skimmer wall across its entrance which inhibits floating debris from entering the canal. The elevation at the top of the sheet piles is +15.0 feet msl. The elevation at the bottom of the skimmer wall is -1 foot msl. The dimensions of the opening to the river are 36.9 feet in length by 34 feet in depth. At the end of the intake canal (at the shoreline), there are eight intake bays that are defined by concrete wingwalls. Each intake bay is approximately 11 feet wide, and has a curtain wall (extending vertically from +15 feet to -4.0 feet, and across the width of each bay), trash rack and traveling water screen. The maximum design flow rate for each intake bay is 135,000 gpm. At the maximum design flow rate, the screen approach velocity is approximately 1.0 ft/sec in each bay (Louisiana Power & Light. 1979).

There are four circulating water pumps that are vertical mixed flow pumps. During a typical year, intake water temperature will exceed 70 ° F for approximately 34% of the year. Under this condition, all four circulating water pumps are utilized. The pumps operate at 1 million gpm during the summer. Most of this water passes through the main condenser where its temperature is raised by 16.4 ° F. The remaining fraction of water, approximately 30,000 gpm enters the Turbine Closes Cooling Water System heat exchangers and the Steam Generator Blowdown System heat exchangers, where its temperature is raised by 7.6 ° F. These streams are recombined as the water is discharged 600 ft downstream of the intake at a temperature of 16.1° F above ambient temperatures (Louisiana Power & Light. 1979).

Three pumps will be utilized approximately 25% of the year, when intake water temperatures range between 55 ° F and 70 ° F. The flow rate under this condition is approximately 84% of the design flow and the discharged water has a temperature 19.2 ° F above ambient water temperatures. For 30% of the year intake water temperatures are below 55 ° F and two pumps are utilized, resulting in 62% of the design flow. The discharged water has a temperature 26 ° F above ambient conditions. During the remaining 11% of the year, the system is shutdown (Louisiana Power & Light. 1979).

3.4 Facility Water Balance

The facility water use diagram is provided in Figure 3-4. Water is used for a variety of systems including cooling, potable and sanitary waste systems, chemical waste systems and process water systems. However, the vast majority of the water withdrawn from the Mississippi River is used as cooling water.

3.5 Discussion and Implications

There are a number of attributes of the CWIS that reduce the impingement mortality (IM) at the Waterford 3 plant. These attributes are briefly discussed in this section.

The physical location of the CWIS in deep, fast-moving water reduces impingement because fish densities are much lower away from the shoreline habitat. The shoreline habitat represents the baseline conditions under the Rule. The impingement mortality reduction relative to the baseline resulting from the location of the intake is estimated to be 93% based on literature values of the fish biomass present in different Mississippi River habitats.

The fish handling system is expected to further reduce impingement mortality. Species composition was not evaluated at Waterford 3 but is likely to be similar to Waterford 1&2. The fish handling system is expected to reduce IM by 14%. This estimate is likely to be low given the relatively robust nature of river shrimp which constituted nearly 50% of impinged organisms in the historical study at Waterford 1&2. Reduction in IM from the combined effects of the fish handling system and the offshore location of the intake is estimated to be 94% (note reduction is not an additive effect).

Figure 3-1. Site Layout (Matys 2004)

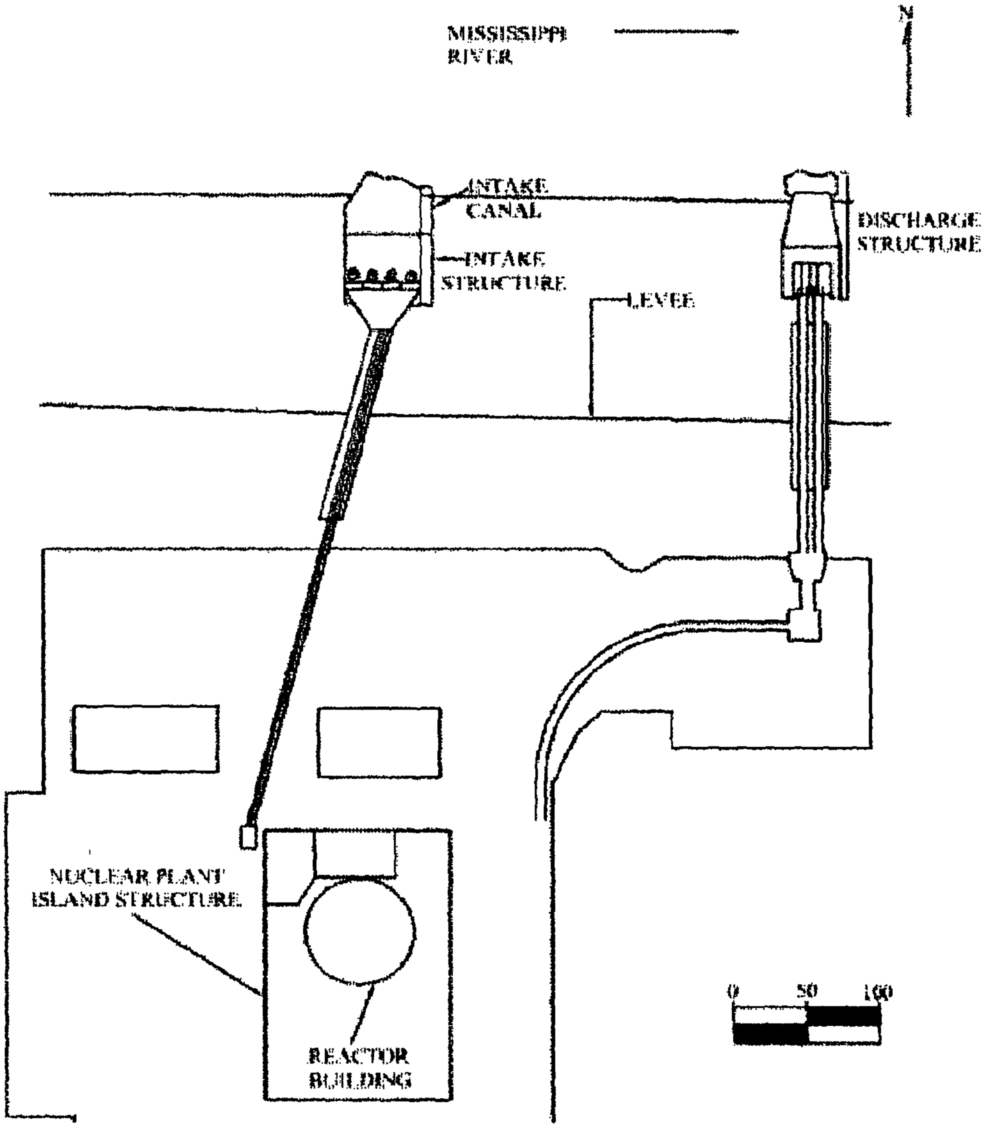


Figure 3-2. Unit 3 (Entergy 2003)

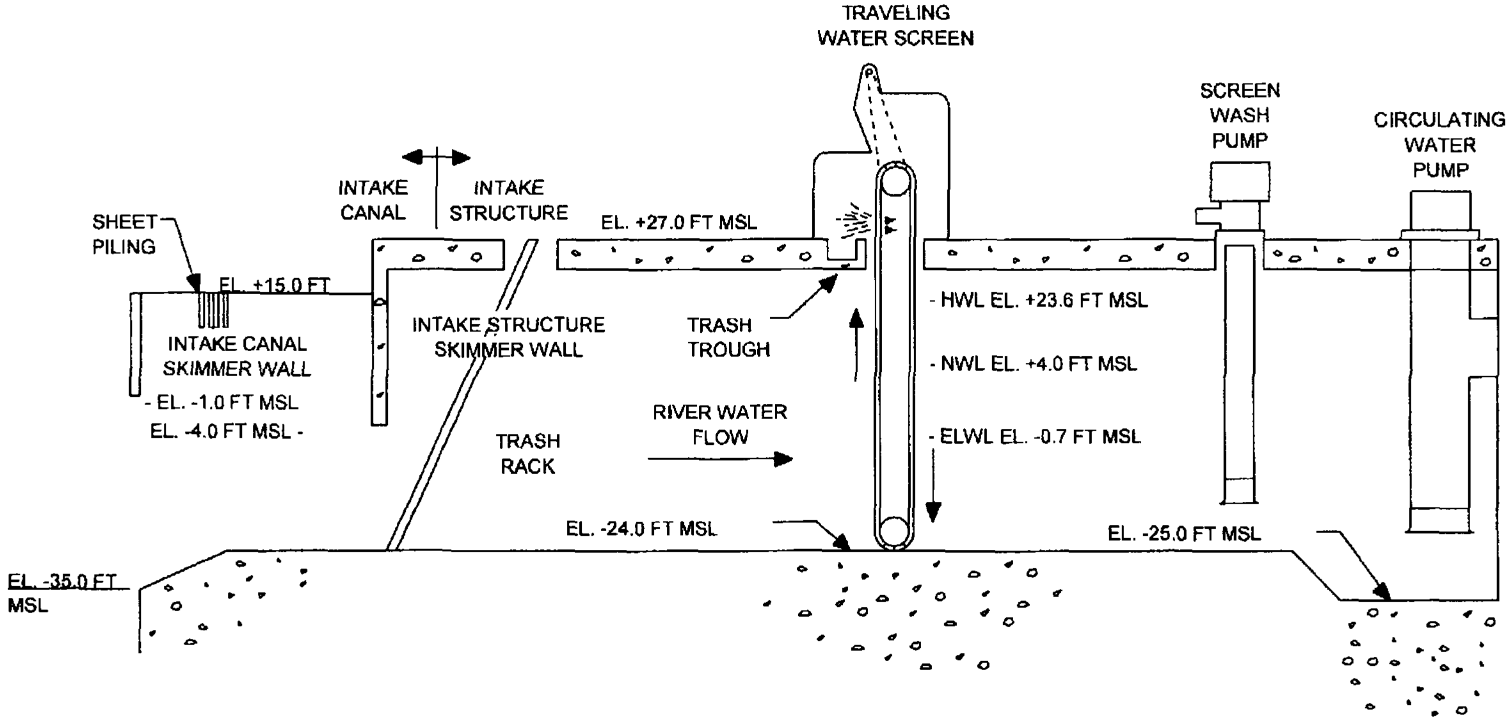


Figure 3-3. Traveling Screen (Entergy 2003)

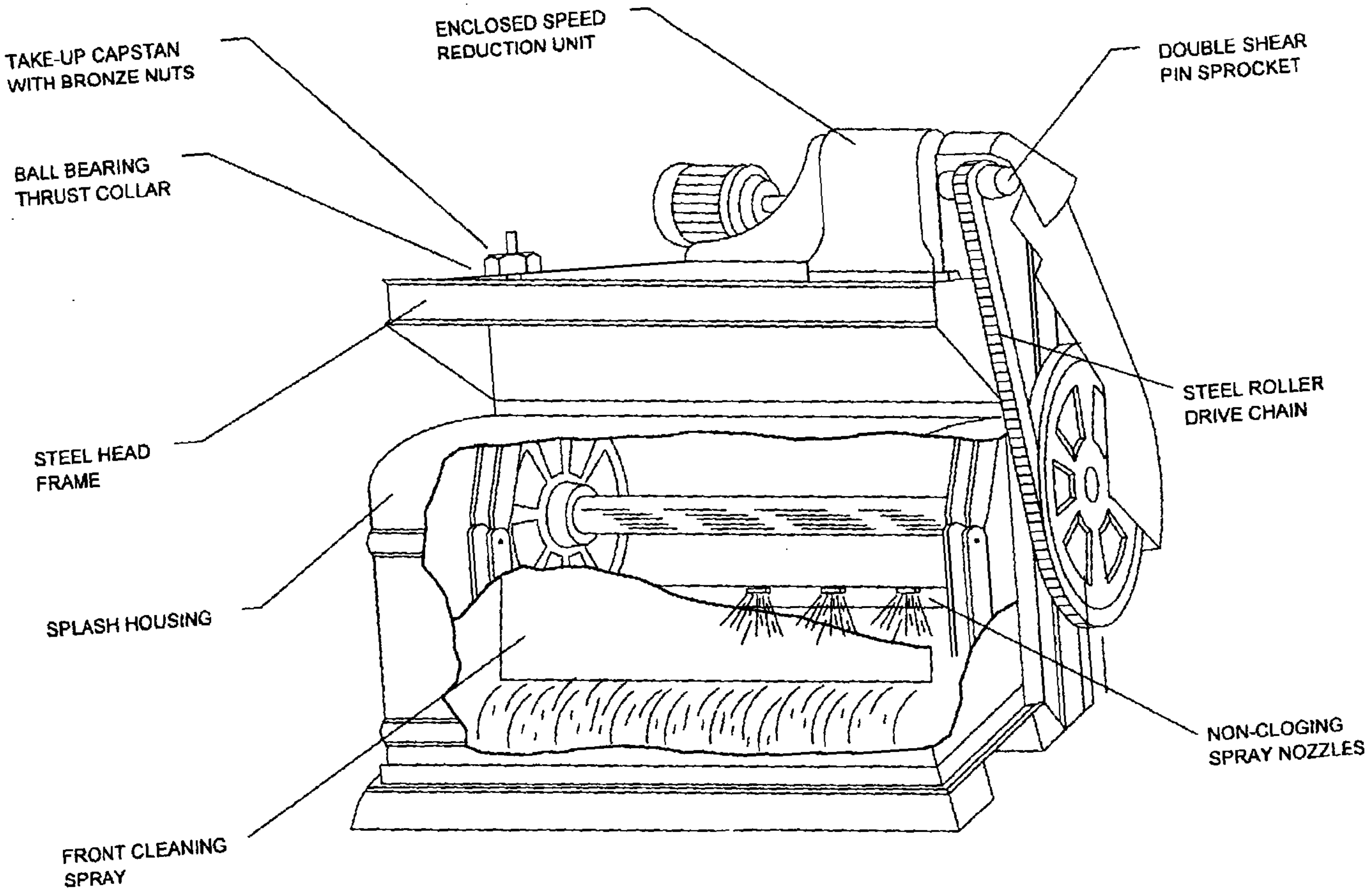
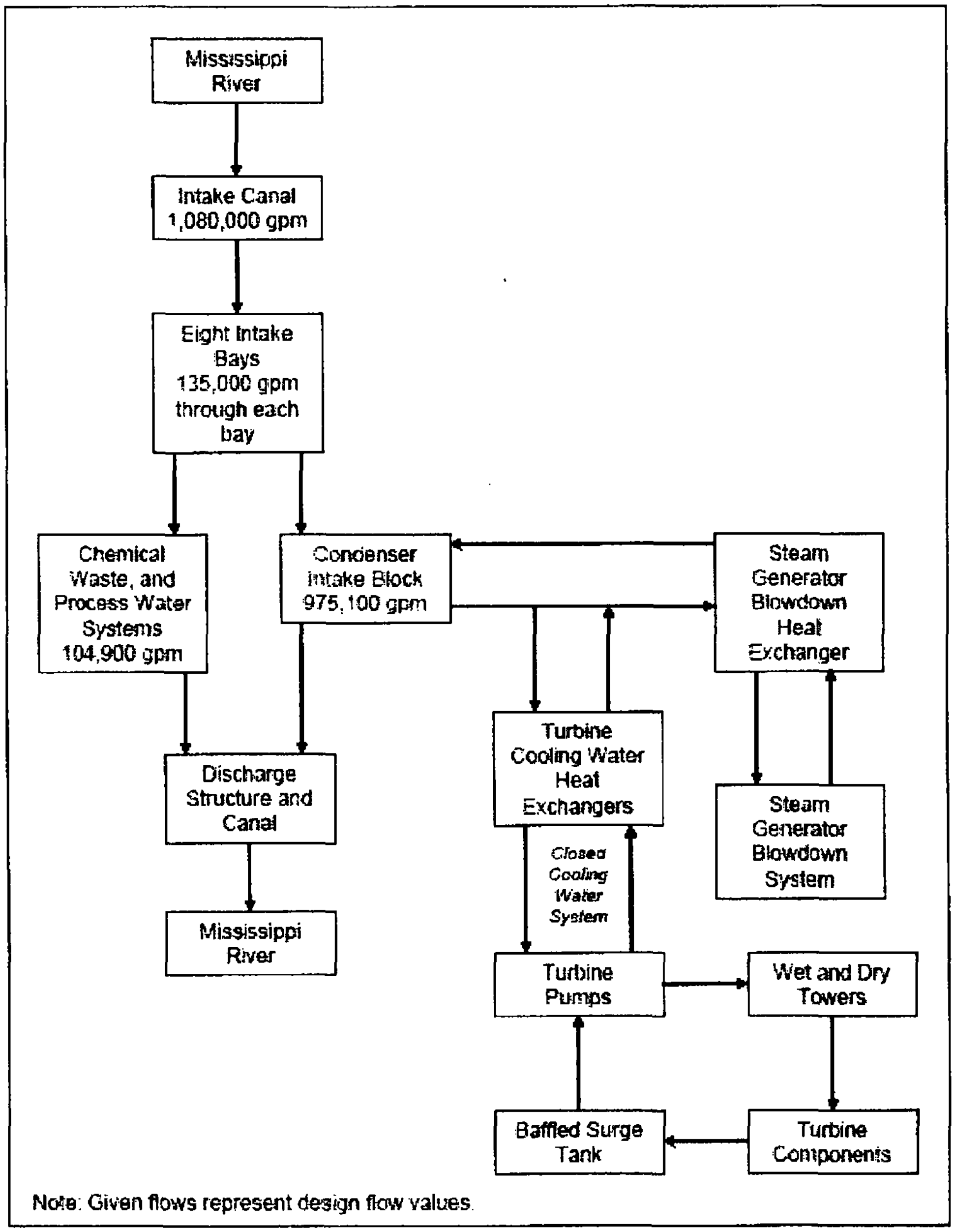


Figure 3-4. Facility Water Balance



Note: Given flows represent design flow values.

4.0 Cooling Water System Data – 40 CFR 122.21(r)(5)

This section contains information on of the Waterford 3 Plant cooling water system. This information was prepared by a qualified professional and represents the current configuration and operation of the Waterford 3 plant. Phase II facilities are required to submit the following information on the cooling water system (40 CFR 122.21(r)(5) (as excerpted from the Rule):

> "(5) Cooling water system data. Phase II existing facilities as defined in part 125, subpart J of this chapter must provide the following information for each cooling water intake structure they use:
>
> (i) A narrative description of the operation of the cooling water system, its relationship to cooling water intake structures, the proportion of the design intake flow that is used in the system, the number of days of the year the cooling water system is in operation and seasonal changes in the operation of the system, if applicable; and
>
> (ii) Design and engineering calculations prepared by a qualified professional and supporting data to support the description required by paragraph (r)(5)(i) of this section."

4.1 Description of Cooling Water System

This section describes the operation and configuration of the components of the cooling water system upstream of the CWIS. These include the circulating pumps and the condensers.

4.1.1 System Overview

There are two components to the cooling water system at Waterford 3:

- the circulating cooling water system; and
- the component cooling water system.

Water in the circulating water system is used to condense the turbine exhaust steam. The component cooling water system is a closed loop system used to cool the reactor coolant and reactor auxiliary system components. Since the circulating water cooling system uses the vast majority of the water withdrawn we focus on the description of this descriptions is focused on that system.

The circulating water system is capable of withdrawing approximately 1,000,000 gpm. From the intake system, the water is transported to the through the condenser and then back to the river. When it passes through the condenser the water temperature is increased approximately 16.4° F when the plant is at full load. The cooling water system has a design load of approximately 8.0×10^9 BTU per hour (Louisiana Power & Light 1979).

4.1.2 Circulating Cooling Water System

Each cooling water (CW) pump takes suction from a bay in the intake structure. The CW Pump discharges through a discharge valve. CW flow then enters Distribution Block 1. Two, 11 foot diameter pipes carry the CW flow to Distribution Block 2. The east pipe connects to a vacuum breaker and the blowdown heat exchanger. The west pipe connects to the river water supply pump and a vacuum breaker.

Distribution Block 2 disburses water to the condenser waterbox inlets and the turbine cooling water (TCW) heat exchangers. Water is distributed to each condenser water box through two lines and 975,100 gpm is proportionally distributed to the three water boxes. Air can be bled from the inlet water boxes through vents to ensure no air is trapped in the inlet water boxes. The condenser tubes are made of stainless steel. The condenser shell, tubesheet, and water box are made of carbon steel. Cathodic protection is provided to reduce corrosion in the condenser (Entergy 2003).

Priming jets driven by Station Air take suction on the water box outlets to remove air from the water boxes. Air comes out of solution as the water is heated in the condenser. Air is removed from the CW side of the condenser to ensure that the top condenser tubes do not become air bound. The priming jets are used only when needed during CW system startup. Water exiting the condensers is collected in Distribution Block 3. Temperature elements send condenser discharge temperature to the plant computer. Two 11 foot diameter pipes carry the water to Distribution Block 4 where it is divided into four outlet pipes which discharge through the discharge structure. The CW Air Evacuation Pumps take suction on the piping at the top of the levee. Leakage from each of the four CW pump discharge valves is collected in a valve pit. The four pits drain to a common sump from which two pumps discharge the leakage and rain water accumulated in the pits to the river (Entergy 2003).

The reinforced concrete discharge structure is located approximately 600 feet down river from the intake structure. The structure is divided into four individual bays which discharge the flow from the four circulating water pipes into the discharge canal through adjustable stop-log weirs. The weirs are located at the front and sides of the structure. The top of the discharge structure mat is at elevation -5.00 feet msl, and the weir is adjustable from elevation +6.00 to +11.00 feet msl. Each bay is 40 feet long and 10.5 feet wide with steel turning vanes to direct water flow. The turning vanes provide a uniform flow distribution over the weirs, thereby minimizing hydraulic losses. Ten stop-log weirs are utilized in controlling the siphon head on the discharge piping as it runs over the top of the levee. A steel platform is provided at elevation +15.00 feet msl for stop-log access. Stop-log elevations have been developed based on a siphon head of 27.5 feet and an unsubmerged weir crest. These stop-log elevations are +9.00, +8.00 and +7.00 feet msl for two, three and four pump operations, respectively (Entergy 2003).

4.1.3 The Component Cooling Water System

The Component Cooling Water System is a closed loop cooling system. Water is pumped through the components, where it becomes heated. It then passes through the baffled surge tank and the chemical addition tank. Finally, it travels through two dry cooling towers in parallel, and to a heat exchanger where it interacts with water from the wet cooling tower. Because this system is closed loop, it requires very little water from the river, and is not significant in regards to the plants IM (Louisiana Power & Light 1979).

4.2 Review of Historic and Likely Future Operation

The operation of the CWIS is dependent on the water temperature. When the intake temperature exceeds 70°F, all four circulating water pumps are operated. This is occurs approximately 34% of the year. Three pumps are operated when water temperatures are between 55°F and 70°F, a condition that is occurs 30% of the time. When temperatures are below 55°F, two circulating pumps are utilized. This occurs approximately 30% of the time. The remaining 11% of the year the unit does not operate (Louisiana Power & Light 1979).

5.0 References

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