Habitat Conservation Plan (HCP) to support issuance of an Incidental Take Permit (ITP) for the Federally Endangered *Lampsilis higginsii* mussel and the candidate mussel species *Plethobasus cyphyus*
related to operations of the
Quad Cities Station (QCS)

Higgins Eye (*Lampsilis higginsii*)

Sheepnose (*Plethobasus cyphyus*)

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10.1 **Appendix A. U.S. Fish and Wildlife Service. 2004. Higgins Eye Pearlymussel (Lampsilis higginsii) Recovery Plan: First Revision. Fort Snelling, Minnesota. 126pp. A-1**

10.2 **Appendix B. Draft Report: 2007 Results of Unionid Mussel Monitoring near Quad Cities Nuclear Station, Mississippi River Miles 495 to 515, prepared by Ecological Specialists, Inc. March, 2008. B-1**

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Executive Summary

Exelon Generation (Applicant) has prepared this Habitat Conservation Plan (HCP) to fulfill requirements of Section 10 (a)(1)(B) of the Endangered Species Act to address the potential incidental take of two mussel species: *Lampsilis higginsii* (Higgins eye pearlymussel) and *Plethobasus cyphyus* (sheepnose mussel). Downstream of Exelon Generation's (Exelon) Quad Cities Station (QCS) discharge is a mussel bed, commonly referred to as the Cordova Mussel Bed, which has been designated as one of the essential habitats for the Higgins eye pearlymussel. The U.S. Fish and Wildlife Service originally listed the Higgins eye pearlymussel as an endangered species on June 14, 1976 (Federal Register, 41 FR 24064). One specimen of sheepnose mussel (*Plethobasus cyphyus)*, which is a candidate for federal listing, was recently collected in the Cordova mussel bed. Based on recent discussions with U.S. Fish and Wildlife (USFWS) staff, the sheepnose mussel has been included in this Habitat Conservation Plan (HCP) because it is likely to be federally listed in the near future.

Exelon plans to apply for an incidental take permit (ITP) pursuant to section 10(a)(1)(B) of the Endangered Species Act of 1973 (16 U.S.C. 1531-1544, 87 Stat. 884) as amended, (ESA) from the USFWS for the potential incidental take of the Higgins eye mussels and sheepnose mussels.

The ITP will also serve to authorize Exelon intentional take of Higgins eye and sheepnose mussels associated with implementation of minimization measures (i.e., mussel collection and relocation associated with pre-activity surveys, thermal tolerance studies) and mitigation measures (see Section 5.4). The duration of the requested permit is 24 years.

This HCP describes measures that will be implemented by the QCS to minimize and mitigate potential impacts of three activities (Section 3.2): 1) implementation of an alternate thermal standard, 2) periodic maintenance dredging in front of the intake forebay, and 3) the removal of Edison Pier. This HCP also describes measures to ensure that elements of the HCP are properly implemented. Funding sources for implementation, actions to be taken for changed circumstances and unforeseen events, alternatives to the proposed project, and other measures required by USFWS are also addressed in this document.

1.0 INTRODUCTION AND BACKGROUND

1.1 Overview/Background

On April 19, 2007, Exelon informed the U.S. Environmental Protection Agency (USEPA) of its plans to conduct additional fishery and mussel studies related to the QCS thermal discharge. These additional investigations and studies were planned and implemented to support the QCS Alternative Thermal Standard (ATS) Project to obtain additional fishery and mussel information that, when combined with the extensive data and information previously obtained, should be sufficient to assess whether alternate thermal limits are appropriate for QCS and, if so, what those limits should be. On June 7, 2007, USFWS provided its initial review comments on Exelon's proposed monitoring plan, including comments regarding how alternate thermal limits potentially could adversely affect the federally listed mussel species. Those listed species currently being considered are the Higgins eye and Sheepnose mussel. USFWS proposed that QCS prepare an HCP and file an Incidental Take Permit (ITP) application to ensure the proposed actions are in compliance with the ESA. On August 30, 2007, Exelon met with USFWS to discuss developing such a program. Follow-up discussions with USFWS took place on October 26, 2007. Exelon submitted an initial Draft HCP to the USFWS on January 25, 2008, at which time the formal HCP consultation process began. USFWS provided comments on the Draft HCP on March 4, 2008 and again on April 17, 2008. Exelon submitted revised drafts of the HCP to the USFWS on May 7, 2008, September 15, 2008, December 2, 2008 and February 20, 2009 to continue the formal HCP consultation process. Exelon submitted the HCP to the Illinois DNR and to the Iowa DNR for their review on December 23, 2008.

Many agencies, organizations and individuals have been involved in reviewing and overseeing environmental matters related to thermal discharges from QCS since the plant began operating in 1972, and will continue to be involved in the implementation of this HCP. The QCS Biological Steering Committee and the USFWS will provide oversight of the HCP activities. The Steering Committee is composed of the members of the QCS Long-term Monitoring Program Steering Committee (Section 10.0, Appendices) as well as additional experts, both government and non-government, in the mussel field.

1.2 Permit Duration

Exelon Generation is requesting that the Section 10(a)(1)(B) incidental take permit be issued for a period of twenty-four years. The twenty-four year permit timeframe is consistent with the recently renewed U.S. Nuclear Regulatory Commission operating license No. DPR-29 for Quad Cities Unit 1 and operating license No. DPR-30 for Quad Cities Unit 2, both of which expire on December 14, 2032. The U.S. Nuclear Regulatory Commission, having previously made the findings set forth in License No. DPR-29 and DPR-30 issued on December 14, 1972, found that "after weighing the environmental, economic, technical and other benefits of the facility against environmental and other costs and considering available alternatives, the issuance of this Renewed Facility

Operating License No. DPR-29 and DPR-30 is in accordance with 10 CFR Part 51 of the Commission's regulations and all applicable requirements have been satisfied." Exelon Generation is authorized by the Commission to operate Quad Cities Unit No. 1 and Quad Cities Unit No. 2 at power levels not in excess of 2957 megawatts (thermal) each.

1.3 Regulatory/Legal Framework for Plan

1.3.1 Endangered Species Act

Section 9 of the Endangered Species Act of 1973, as amended (ESA), prohibits the "take" of any fish or wildlife species listed under the ESA. Take, as defined by the ESA, means "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct." In the 1982 amendments to the ESA, Congress established a provision in Section 10 of the ESA that allows for the "incidental take" of endangered and threatened species by non-federal entities. Incidental take is defined by the ESA as take that is "incidental to, and not the purpose of, the carrying out of an otherwise lawful activity."

1.3.2 Section 10 of the ESA

Section 10(a)(2)(A) of the ESA requires an applicant for an incidental take permit to submit a "conservation plan" that specifies, among other things, the impacts that are likely to result from the taking and the measures the permit applicant will undertake to minimize and mitigate such impacts. Conservation plans under the ESA have come to be known as "habitat conservation plans" or "HCPs" for short.

The Section 10 process for obtaining an incidental take permit has three primary phases: (1) the HCP development phase; (2) the formal permit processing phase; and (3) the post-issuance phase.

During the HCP development phase, the project applicant prepares a plan that integrates the proposed project or activity with the protection of listed species. An HCP submitted in support of an incidental take permit application must include the following information:

- impacts likely to result from the proposed taking of the species for which permit coverage is requested;
- measures that will be implemented to monitor, minimize, and mitigate impacts; funding that will be made available to undertake such measures; and procedures to deal with unforeseen circumstances;
- alternative actions considered that would not result in take; and
- additional measures USFWS may require as necessary or appropriate for purposes of the plan.

The HCP development phase concludes and the permit-processing phase begins when a complete application package is submitted to the USFWS. A complete application

package for an HCP consists of an HCP, a permit application, and an application fee from the applicant. Once the USFWS receives a complete application package, the USFWS publishes a Notice of Receipt of a Permit Application in the Federal Register; prepares a Section 7 Biological Opinion; prepares a Set of Findings which evaluates the permit application in the context of the permit issuance criteria (set forth below); and prepares an Environmental Action Statement, which is a document that serves as USFWS's record of compliance with the National Environmental Policy Act (NEPA).

Section 10(a)(2)(B) of the ESA requires the following criteria to be met before USFWS may issue an incidental take permit:

- The taking will be incidental;
- The applicant will, to the maximum extent practicable, minimize and mitigate the impacts of such taking.
- The applicant will ensure that adequate funding for the HCP and procedures to handle unforeseen circumstances will be provided;
- The taking will not appreciably reduce the likelihood of survival and recovery of the species in the wild;
- The applicant will ensure that other measures that the Service may require as being necessary or appropriate will be provided;
- The Service have received such other assurances as may be required that the HCP will be implemented.

If the above listed criteria are met and the HCP and supporting information are statutorily complete, the permit must be issued.

During the post-issuance phase, the permittee and other responsible entities implement the HCP, and USFWS monitors the permittee's compliance with the HCP as well as the long-term progress and success of the HCP.

1.3.3 Section 7 of the ESA

Section 7(a)(2) of the ESA requires all federal agencies to ensure that any action they authorize, fund, or carry out is not likely to jeopardize the continued existence of any listed species or result in the destruction or adverse modification of habitat critical to such species' survival. To ensure that its actions do not result in jeopardy to listed species or in the adverse modification of critical habitat, each federal agency must consult with the Service regarding federal agency actions that have the potential to impact listed species. This consultation may be formal or informal.

Before initiating an action, the federal action agency, or a nonfederal permit applicant, must ask the Service to provide a list of endangered, threatened, and proposed species and designated and proposed critical habitats that may be present in the project area. If no such species or critical habitats are present, then the federal action agency has no further ESA obligation under section 7(a)(2) and consultation is concluded. If such a species or critical habitat is present, then the federal action agency must determine

whether the project may affect listed species or their critical habitat. If so, further consultation is required.

If the action agency determines (and the Service agrees) that the project is not likely to adversely affect any listed species or designated critical habitat, then the consultation (informal to this point) is concluded and the Service's concurrence is put in writing. If the action agency determines that a project may adversely affect a listed species or designated critical habitat, formal consultation is required.

During formal consultation, the Service prepares a biological opinion (BO) which analyzes whether the proposed action would be likely to jeopardize the continued existence of the species or adversely modify designated critical habitat. If the BO reaches a jeopardy or adverse modification conclusion, the opinion must suggest "reasonable and prudent alternatives" that would avoid that result. If the BO concludes that the project as proposed would involve the take of a listed species, but not to an extent that would jeopardize the species' continued existence, the BO must include an incidental take statement. The incidental take statement specifies an amount of take that may occur as a result of the action and may suggest reasonable and prudent measures to minimize the impact of the take. If the action complies with the BO and incidental take statement, it may be implemented without violation of the ESA, even if incidental take occurs.

The issuance of an ITP for this HCP is a federal action that triggers a Section 7 consultation. The Service, as the federal action agency, will consult internally to address this requirement.

1.3.4 National Environmental Policy Act (NEPA)

NEPA requires federal agencies to include in their decision-making process appropriate and careful consideration of all environmental effects of a proposed action and of possible alternatives to that proposed action. Documentation of the environmental impact analysis and efforts to avoid or minimize the adverse effects of proposed actions must be made available for public notice and review.

NEPA requirements for HCPs can be satisfied by one of the three following documents or actions: (1) a categorical exclusion allowed for HCPs considered "low-effect"; (2) an Environmental Assessment; or (3) an Environmental Impact Statement. The agency must disclose whether the proposed action will adversely affect the human environment. NEPA's requirements are more procedural than substantive in that NEPA requires disclosure of environmental effects and mitigation possibilities but includes no mandate to actually require the imposition of mitigation. Because the issuance by the Service of an ITP under Section 10 of the ESA constitutes a federal action, the Service must comply with NEPA. The Service has prepared a draft EA that accompanies this draft HCP.

1.3.5 State Wildlife Laws

Both of the states of Iowa and Illinois have laws protecting sensitive species. The QCS has consulted with both states as part of this planning process. The QCS will continue to coordinate with these state agencies to ensure that it complies with all state wildlife protection laws applicable to the covered activities.

1.4 Planning Area

1.4.1 Upper Boundary Limit

The upper boundary of the QCS HCP (i.e., covered lands) will occur at an imaginary line from 50 yards north of the Edison Pier (RM 506.8L) across to the confluence of the Wapsipinicon River (Figures 1-1 & 1-2). The upper boundary was selected to include the most upper influences of QCS. The upper boundary will also give all parties flexibility in regards to future activities including required maintenance dredging in front of the QCS river intake structure and potential removal of the Edison Pier.

1.4.2 Lower Boundary Limit

The lower boundary of the QCS HCP will occur at the Cordova Slough Light (Figure 1-1), which is near the confluence of Steamboat Slough and the main channel (approximate RM 503.0R). The line would run perpendicular to the main channel. This boundary was chosen because thermal plume modeling for QCS extends down to this part of the river. This boundary also completely captures the lower reaches of the Cordova mussel bed, which is designated as essential habitat for the Higgins eye mussel (USFWS, 2004).

The total acreage included in this HCP is 1,173 acres.

1.5 Species to be Covered by Incidental Take Permit

Two mussel species, *Lampsilis higginsii,* which was federally listed as endangered on June 14, 1976 (41 FR 24064) and *Plethobasus cyphyus* (Sheepnose), a candidate for Federal listing, are covered by this HCP (see Section 2.2 for a complete description). Based on recent discussions with USFWS staff, the sheepnose mussel was included in this HCP because it is expected to be federally listed as threatened or endangered in the near future.

The actions that are planned to minimize and mitigate impacts associated with implementation of this HCP have been carefully laid out. They are intended to be consistent with the *Lampsilis higginsii* Recovery Plan and not conflict in any way with ongoing recovery actions.

Figure 1-1. Quad Cities Station Primary Influence Area as pertaining to the Quad Cities Station Habitat Conservation Plan.

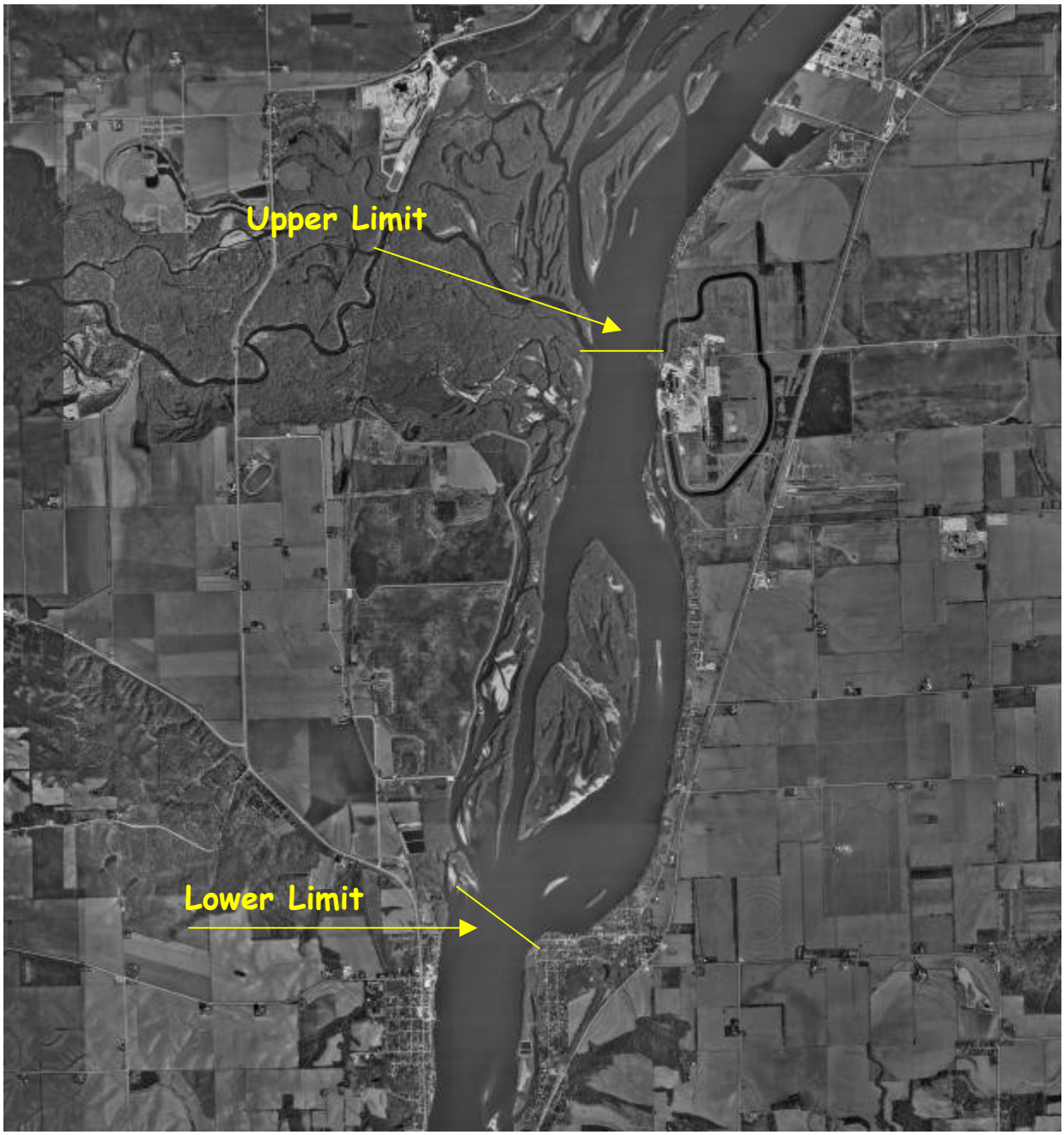


Figure 1-2. Quad Cities Station Location & Description

2.0 ENVIRONMENTAL SETTING/BIOLOGICAL RESOURCES

2.1 Environmental Setting

2.1.1 Site Location and River Hydrology

Quad Cities Station is located on the east (Illinois) shoreline of Pool 14, at River Mile 506.7, approximately half way between Lock and Dam 13 (upstream) at River Mile 522.5 and Lock and Dam 14 (downstream) at River Mile 493.3. Pool 14 is approximately 29 miles long, with a surface area of approximately 10,580 acres. The boundaries of Quad Cities Station extend about three-quarters mile along the banks of the Mississippi River and irregularly one mile inland. Quad Cities Station comprises two units with a combined net generating capacity of 5914 MWt. The facility began operation by Commonwealth Edison in 1972 and is currently owned and operated by Exelon. Quad Cities Station' name is derived from the Quad Cities area comprising the four nearby cities of Davenport, Iowa; Bettendorf, Iowa; Moline/East Moline, Illinois, and Rock Island, Illinois.

The Mississippi River in the vicinity of the QCS has a drainage area of approximately 85,000 square miles. The flow distribution in the river is distinctly seasonal. Annual high river flows usually occur between April and June. Annual low river flows occur between December and February. Average annual river flow is 57,000 cfs. The 7 day, 10-year low river flow is 13,700 cfs.

Since 1984, the Station has operated in an open-cycle (once through cooling) mode, discharging cooling water to the river through a dual pipe diffuser system that extends practically across the river. In the open-cycle mode, cooling water is drawn from the Mississippi River into an intake forebay, passes through the plant systems, and is discharged into the Mississippi River at mile 506.4 via two diffusers. Since the QCS employs a diffuser pipe system as a means of discharging and mixing heated condenser cooling water, there is no outfall in the usual sense of the word. The diffuser pipe system consists of two 16-foot diameter pipes buried in the riverbed. The river in this area is approximately 2,200 feet wide. The main river channel is on the west side and is approximately 400 feet wide and 25 feet deep. The remainder of the river has an average depth of approximately 8 feet. One diffuser pipe extends practically across the river, while the second diffuser pipe terminates about 390 feet before the end of the first pipe. Each diffuser pipe is fitted with 20 discharge risers of 36-inch diameter spaced at 19 feet 8 inches in the deep portion of the river, and 14 discharge risers (nine of which are presently closed) of 24-inch diameter spaced at 78 feet 8 inch intervals in the shallow region of the river. Of the 34 discharge risers located on each diffuser pipe, the first nine 24-inch diameter risers are closed. These closed risers are located in the shallow region of the river. Water to cool the Station's two main condensers is withdrawn from the Mississippi River at a maximum rate of 2253 cfs. The thermal plume at Quad Cities Station is unusual in that heated condenser cooling water is discharged into the Mississippi River by means of a diffuser pipe system that was designed to distribute the condenser cooling water across the river more or less in proportion to the transverse

distribution of the ambient river discharge in such a way that complete mixing is achieved within a short distance.

Open cycle operation with the diffusers was initially permitted by the Illinois Environmental Protection Agency (IEPA) on December 22, 1983. This facility discharges wastewater under the authority of NPDES Permit No. IL0005037, which was issued December 17, 2001.

2.1.2 Long Term Fish Monitoring Program

Quad Cities Station established its Long-Term Fisheries Monitoring Program in Pool 14 of the Mississippi River in 1971. The objective of this program is to determine if station operations are having any measurable impact on the fishery of the Pool. Studies include Long-Term Fisheries Monitoring; a study of the Life History and Population Dynamics of the Freshwater Drum (a major sport and commercial species in Pool 14); Channel and Flathead Catfish, Walleye, and Sauger Studies; Impingement Monitoring; a Fall Stock Assessment Program; and Hydrological Data. The Impingement Monitoring, Freshwater Drum, Channel and Flathead Catfish, and Fall Stock Assessment studies were added to the program in 1973, 1978, 1983, and 1985, respectively. The principal objectives of the Long-Term Fisheries Monitoring Program are to determine species composition and relative species abundance in the various habitat types that occur in Pool 14. The sampling techniques employed include electrofishing, hoop netting, and haul seining.

Annually, the Long-Term Fisheries Monitoring Program and the gamefish rearing program are overviewed at the Quad Cities Station Steering Committee meeting, which occurs in March of each year. The meeting allows those agencies with jurisdiction in the QCS area to gather and review the long-term monitoring programs. Because of the framework already established with these programs, a session will now be added to review those activities associated with the HCP. Additional members will be added to the Quad Cities Station Steering Committee to include those who are knowledgeable with the mussel monitoring and propagation activities.

2.1.3 Mussel Bed Monitoring Program

Quad Cities Station established its Long Term Mussel Monitoring Program in 2004. The purpose of the mussel monitoring program is to determine the baseline unionid community characteristics within mussel beds that occur within the vicinity of QCS and to use historical data to compare mussel bed community characteristics following the implementation of alternate thermal standards for Quad Cities Station. Three mussel beds were part of the original sampling program that started in 2004: Upstream Mussel Bed located at RM 507 on the Iowa bank near the downstream end of Schricker Slough, Steamboat Slough Mussel Bed located just downstream of the mixing zone and the Cordova Mussel Bed located at RM 504. Ecological Specialists Inc. (ESI) monitored each of these unionid beds in 2004, 2005, 2006, 2007 and 2008. In 2007, three additional mussel beds were monitored: Albany Mussel Bed, located approximately 14,000 to 14,400 meters upstream, Hansons Slough Mussel Bed, located approximately 5,000 to

5,400 meters upstream and Woodwards Grove Mussel Bed, located approximately 10,500 to 10,900 meters downstream of the diffuser. Mussel bed sampling includes both quantitative sampling, which determines density, relative abundance, age distribution and observed mortality and qualitative sampling which determines species richness.

The location of the six aforementioned mussel beds is shown on Figure 1-3, "Unionid bed monitoring areas near QCS, 2004 through 2007" (ESI 2008a). The specific characteristics of these mussel beds are described in more detail in the following paragraphs.

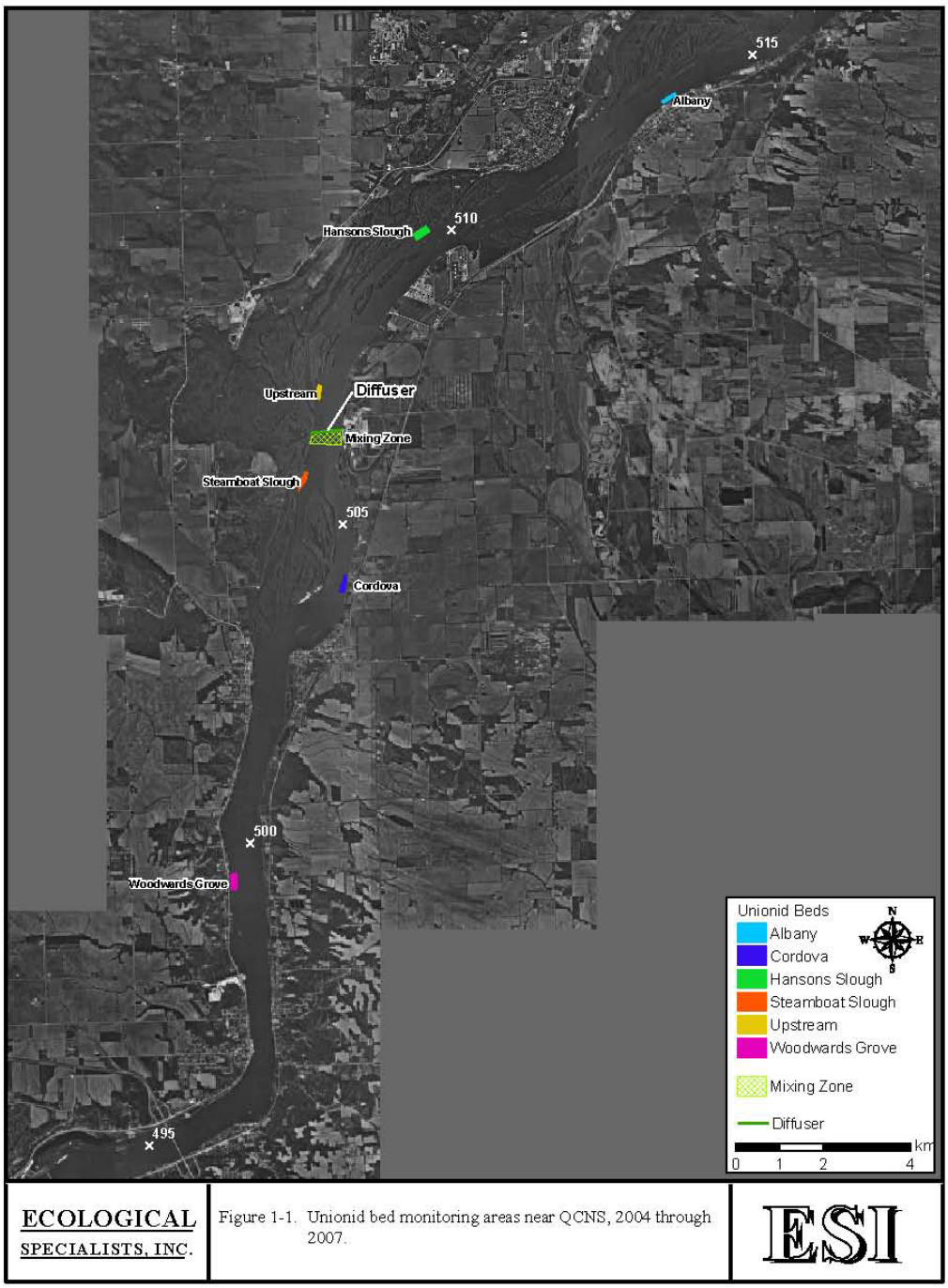
Upstream Mussel Bed Location and Present Characteristics

The Upstream Mussel Bed is located near the mouth of the Wapsipinicon River and upstream of Quad Cities Station diffuser discharge. The Upstream Mussel Bed habitat has remained consistent among monitoring events (July 2004, July and October 2005, August and September 2006, October 2007 and August, 2008). Substrate in the bed is a mixture of sand, silt, and clay, with sand being the major constituent. Water depth within the sampled area ranges from 0.6 to 7.3m. Dissolved oxygen (DO) levels were slightly below saturation during July 2004, October 2005, September 2006, October 2007 and supersaturated in July 2005 and August 2006. River current velocity averaged ≤0.5m/sec in all monitoring events, ranging from a low of 0.0 m/sec in August 2006 and October 2007 to a high of 0.6m/sec in July 2004 and 2005. Average current velocity within the Upstream Mussel Bed was lowest in 2006, averaging 0.04 and 0.1 m/sec in August and September, respectively.

Zebra mussel (*Dreissena polymorpha*) infestation was moderate (a few zebra mussels on most unionids) in 2004, but declined to an average of <1 and a maximum of 10 zebra mussels per unionid in 2005. Zebra mussels were similarly low in 2006, averaging 0.8 and 1.4 zebra mussels per unionid in August and September, respectively. In 2007, zebra mussel infestation averaged only 0.08/unionid. Infestation increased in 2008 to an average of 6.7 zebra mussels/unionid. Infestation was lower than Albany and Cordova beds, but higher than in the Steamboat Slough and Hansons Slough Bed.

The Upstream Mussel Bed is species rich (25 species total) and moderately dense (average 9.3/m^2). Most species show evidence of recent recruitment into the community, and mortality is low. At least 25 species reside in the Upstream Bed, with at least 20 species (84%) collected during each monitoring event. One new species, fat pocketbook (*Potamilus capax)* was collected in 2007 as a weathered shell. Live *P. capax* have not been collected from Pool 14 in the past 25 years. Lampsilinae tend to be more abundant in the Upstream Bed (53.9%) than Ambleminae (42.7%). Dominant species include: *Obliquaria reflexa* (29.5%), which is the dominant Lampsilinae, and *Amblema plicata* (21.6%), which is the dominant Ambleminae species. Threatened and endangered species that occur in this bed include *Ellipsaria lineolata* and *Ligumia recta* (all

Figure 1-3. Unionid bed monitoring areas near QCS, 2004 through 2007 (from figure 1-1, ESI 2008a).



monitoring events), *Lampsilis higginsii* (2005 to 2008), and *Lampsilis teres* (2005, 2007 and 2008).

Steamboat Slough Mussel Bed Location and Present Characteristics

The Steamboat Slough (SS) Mussel Bed is located approximately 750m downstream of the Quad Cities Station mixing zone. Prior to 2007, the northern portion of the sampling area was downstream and riverward of a small island. This small island was gone in 2007. Substrate in the SS bed was primarily sand in 2004 and 2005, but in 2006 silt increased from <10% to >20%, forming a layer over the sand. A review of the State of Iowa's Impaired Waters Report documents the fact the Wapsipinicon River, which discharges into the Mississippi River just upstream of the Steamboat Slough Bed, is high in total suspended solids due to watershed issues stemming from agricultural runoff. The Wapsipinicon River may be responsible for the deposition and scouring of this silt layer in the Steamboat Slough Mussel Bed. Substrate in 2007 was nearly equal parts sand and silt, with silt forming a layer over the sand. Substrate changed again in 2008, with the upstream portions of the bed having siltier substrate, and waves of sand and silt in the downstream portions of the bed. Water depth ranges from 0.9 to 4.3m and averages 2.2 m. Current velocity has varied from 0.0 to 0.6 m/sec and averages 0.2 m/sec. Dissolved oxygen (DO) ranged from a low of 5.1 mg/L in August 2006 to a high of 12.8 mg/L in July 2005 and was similar to Upstream Mussel Bed DO readings. Very few zebra mussels were found in the SS bed in any monitoring event. An average of only 0.01 and 0.1 zebra mussels/unionid was observed in October 2007 and August 2008, respectively.

The Steamboat Slough Bed supports a less dense ($4.4/m^2$) and less species rich (24 species) unionid community than the Upstream Mussel Bed. Ambleminae comprise a higher percent of the community than Lampsilinae (60.9% vs. 37.2%). *Amblema plicata* (28.0%) is the dominant Ambleminae species, and O. reflexa (22.6%) is the dominant Lampsilinae species. *Quadrula nodulata* (11.8%) is more abundant in the Steamboat Slough Bed than in any of the other mussel beds being studied. *L. higginsii* was not found in the Steamboat Slough Bed in 2004 through 2007 and the silty substrate within this bed is not considered to be conducive to *Lampsilis higginsii* populations. However, two individuals were found in the downstream section of the bed in August 2008 (ESI, 2009). *Megalonaias nervosa, Pleurbema sintoxia,* and *Lampsilis teres,* which are endangered in Iowa, and *E. lineolata*, threatened in Illinois, are occasionally collected in the Steamboat Slough Bed. *Ligumia recta*, threatened in Illinois, has consistently been collected in the Steamboat Slough Bed since October 2005. Recruitment is evident in the Steamboat Slough Bed and mortality is low.

Cordova Mussel Bed Location and Present Characteristics

The Cordova Mussel Bed is one of the Essential Habitat Areas designated in the latest version of the *L. higginsii* Recovery Plan (USFWS, 2004). This bed has historically harbored a dense and diverse unionid community. However, density within this bed has declined in recent years primarily due to heavy zebra mussel infestation (ESI, 2005). The

portion of the Cordova Bed sampled in this study is approximately 3000m downstream of QCS mixing zone, and on the Illinois bank.

The Cordova Bed differs from the Upstream and Steamboat Slough beds in that this bed occurs along a slight outside bend in the river and its substrate is coarser (higher percentages of gravel, cobble, shell). Zebra mussel shells continue to increase within this bed, and in 2007 substrate in the Cordova Bed averaged 44% shell material. In some areas, a 1.0 to 1.5 ft layer of dead zebra mussel shells covered the substrate. In August 2008, some areas of the substrate were carpeted with live zebra mussels. Submergent vegetation was present in 2006, 2007 and 2008 with a thick algal mat covered the water within 10m of the bank throughout the sampled area in 2008. Depth within the sampled portion of the Cordova Bed averages 2.2m and ranges from 0.1 to 6.7m. Unionids were historically more abundant in deeper water; however density has declined in the deeper areas likely due to zebra mussel infestation. Unionids are now also abundant in siltier shallow areas. Silt accumulation was not apparent (except in very shallow areas) in the Cordova Bed as it was in the Steamboat Slough Bed in 2006, 2007 or 2008. Current velocity averaged 0.2m/sec during 2004, 2005 and 2007, but averaged <0.1 m/sec in 2006 and 2008. DO was 6.0mg/L in July 2004 and 8.3mg/L in October 2005, similar to both the Steamboat Slough and Upstream beds. Dissolved oxygen averaged 8.4 mg/l in 2007 and was similar to other beds. However dissolved oxygen was supersaturated in 2008.

Zebra mussels *(Dreissena polymorpha)* were more abundant in the Cordova bed than in either the Upstream and Steamboat Slough bed during past monitoring events. Infestation was highest in 2004, and then declined in 2005 through 2007. Infestation was higher in 2008, but unionids were not encrusted as they were in 2004. Zebra mussel infestation has resulted in high unionid mortality and reduced density within the Cordova bed. Unionid community characteristics differ from the Upstream and Steamboat Slough beds, primarily due to more heterogeneous substrate and less variable current velocity. Species composition is 46.1% Ambleminae and 52.9% Lampsilinae. Similar to the other beds, *A. plicata* is the dominant Ambleminae. *Leptodea fragilis* was the dominant Lampsilinae species in 2004 and 2005; however the percentage of *L. fragilis* seemed to decline in 2006 and the percentage of *O. reflexa* increased in September 2006. *Leptodea fragilis* was the second most abundant species in 2007. A total of 25 mussel species have been found in the Cordova bed.

Albany Mussel Bed Location and Present Characteristics

The Albany Mussel Bed, which is the most upstream mussel bed sampled was added to the Mussel Monitoring Program in 2007. The bed seems to extend upstream from Albany, IL (near RM 513) to Cattail Slough (near RM 516). Although very long, the bed is narrow extending from the bank an average of only about 40 m into the river. The widest portion of the bed (about 70 m wide) was within the town of Albany, IL near RM 513 and was selected for sampling. Land use along the riverbank is residential, and the bank is lined with riprap.

The Albany Mussel Bed is most similar to the Cordova Bed in habitat characteristics. Substrate is primarily zebra mussel shells mixed with cobble, gravel, and sand. Silt is more apparent near the bank. Current velocity within the bed ranged from >0 to 0.3 m/sec, however increases to nearly 1 m/sec immediately riverward of the bed. This dramatic increase in current velocity seems to define the riverward bed boundary. Depth in the sampled area ranges from 0.6 to 4.6 m, and dissolved oxygen was similar to other beds at the time of sampling. This was the last bed sampled in October 2007, and water temperature was coldest at 59°F (15°C). Water temperature in 2008 was extremely variable, ranging from 69.8 to 84.2^{0}F. Few zebra mussels were present at the time of sampling in October; however, all unionids were covered with byssal threads. Zebra mussels covered about 10% of the substrate and live zebra mussels were noted on most unionids during the preliminary sampling in June 2007. However, infestation increased in 2008 with an average of 11.2 zebra mussels/unionid. Submergent vegetation was also noted during sampling.

Community characteristics are also very similar to the Cordova Bed, as Albany Bed is also a moderately dense (5.6/m^2) and species rich mussel bed. Twenty-two species were found, including *L. higginsii* and *L. recta*, *E. lineolata,* and the Iowa endangered *Strophitus undulates.* These species are as abundant in the Albany bed as in the Cordova Bed. *Amblema plicata* (23.8%) is the dominant species, but unlike Cordova, *Quadrula p. pustulosa* (13.9%) is very abundant. *Leptodea fragilis* (7.5%) and *O. reflexa* (11.9%) are also commonly collected in this bed and in the Cordova Bed.

Both Lampsilinae (46.0%) and Ambleminae ((48.4%) are fairly equally represented in the Albany Bed, and density does not differ significantly between the two groups. Recruitment is high in both groups and mortality <10%. The similarity in unionid community characteristics between the upstream Albany Mussel Bed and the downstream Cordova Mussel Bed suggests that QCS operations have had no obvious detrimental affects on the Cordova Mussel Bed unionid community.

Hansons Slough Mussel Bed Location and Present Characteristics

The Hansons Slough Mussel Bed (HS Bed) is upstream of the QCS diffuser approximately 4600 to 6400 m was added to the Mussel Monitoring Program in 2007. The bed appears to extend from approximately RM 509.1 to 510.1. The bed is within the upstream portion of Hansons Slough and within a dike field, similar to the SS Bed. However, the Hansons Slough Bed was shallower (0.3 to 2.7 m), substrate was sandier (primarily fine sand similar to UP Bed), and current velocity was less variable (>0 to 0.3 m/sec, similar to Cordova Bed) than within the SS Bed. During the preliminary survey in June 2007, unionids were heavily infested with zebra mussels, which covered 20 to 50% of their shell. Conversely, in October 2007 an average of only 0.1 zebra mussel/unionid infested unionids. Infestation was also low in 2008 averaging only 0.2 zebra mussels/unionid, similar to the Steamboat Slough Bed.

The unionid community within the Hansons Slough Bed is also similar to the Steamboat Slough Bed in that Ambleminae were the dominant subfamily, *L. fragilis* was very rare,

the percentage of young Lampsilinae was low, and species richness was low. These characteristics were previously thought possibly to be an effect of the higher water temperature within the Steamboat Slough Bed. Ambleminae comprises 66.7% of the unionids collected in the Hanson Slough Bed and Lampsilinae 32.3%. Unlike other beds, *A. plicata*, although abundant (16.2%), was not the dominant species. Rather 33.5% of the unionids collected were *Q. p. pustulosa*. *Obliquaria reflexa* (15.4%) was the most abundant Lampsilinae species. Twenty-five species were found in 2007 and 2008.

Density within the Hansons Slough Bed was significantly higher (10.5 unionids/m^2) than other beds sampled. Similar to the Upstream Bed, a few *E. lineolata*, *L. higginsii*, *L. recta* and *L. teres* were collected. *Pleurobema sintoxia* was also found in this bed, similar to the Steamboat Slough Bed. Mortality (<5%) was low and recruitment evident, similar to other beds.

Woodwards Grove Bed Location and Present Characteristics

The Woodwards Grove (WG) Mussel Bed, located downstream of the QCS diffuser approximately 8,300 to 10,900 m, was added to the Mussel Monitoring Program in 2007. The bed appears to extend from approximately RM 499.5 to 500.8 along the Iowa bank within a slight outside bend. The bed extends from the bank at least 150 m riverward. Unionids were infested with zebra mussels in June 2007; however, an average of only 0.08 zebra mussels/unionid (range 0 to 6) were found in October 2007. Zebra mussel infestation increased in the WG Bed in 2008 and was similar to the Albany and UP Beds. Dead zebra mussel shells comprised approximately 15% and 6% of the substrate within the bed in 2007 and 2008, respectively, suggesting previously heavy zebra infestation although perhaps not as heavy as Cordova or Albany beds. Other than zebra mussels, substrate is primarily silt and clay closer to the bank, turning to finer sand riverward. In 2008, a deeper sandy area was scoured through the center of the bed. Depth varied from 0.3 m near the bank to 5.5 m. Current velocity averaged 0.1 m/sec and ranged from 0 to 0.3 m/sec. Water temperature and dissolved oxygen were similar to other beds during the 2007 and 2008 sampling.

Woodwards Grove Bed's unionid community is moderately dense and species rich compared to other beds. Density averages 6.2 unionids/m^2 and is only significantly different from the Hansons Slough Bed (10.5 unionids/m^2). A total of 23 species were found. Ambleminae (59.1%) dominate this bed, similar to the Hansons Slough and Steamboat Slough Beds, and density of Ambleminae (3.7/m^2) is significantly higher than Lampsilinae (2.0/m^2). However, *Q. quadrula* (29%) is the dominant species in the Woodwards Grove Bed. *Amblema plicata* (18%) is also abundant, as is *O. reflexa* (12%). *Leptodea fragilis* is fairly common in this bed, similar to Cordova and Albany. *Ellipsaria lineolata*, *L. higginsii*, *L. recta* and *P. sintoxia* all occur at a low frequency, similar to the Hansons Slough and UP beds. Young unionids were abundant, as 41.2% of the community was young individuals, and 71.3% of the species collected were represented by young individuals. Young Ambleminae averaged 32.1%. Although Lampsilinae were less abundant than Ambleminae, an average of 55.4% of the Lampsilinae collected were young individuals. Overall mortality was <10% in both 2007 and 2008.

2.2 Species of Concern in the Planning Area

2.2.1 Wildlife Species of Concern

2.2.1.1 Lampsilis higginsii (Higgins eye)

Key Characters

Rounded to slightly elongate, thick, smooth, and inflated shell, yellowish brown, with green rays; posterior end bluntly pointed in males, truncated in females.

Description

Shell rounded to slightly elongate, solid, and inflated. Anterior end rounded, posterior end bluntly pointed (males) or truncated (females). Dorsal margin straight, ventral margin straight to slightly curved. Umbos turned forward and elevated above the hinge line. Beak sculpture, if visible, of three or four double-looped ridges. Shell smooth, yellow, yellowish green, or brown with green rays, obscure on some individuals. Length to 4 inches (10.2 cm).

Current *Lampsilis higginsii* Status

The Higgins eye mussel was federally listed as an endangered species on June 14, 1976 (41 FR 24064). The major reasons for listing the Higgins eye mussel were the decrease in both abundance and range of the species. As documented in the initial *Lampsilis higginsii* recovery plan (USFWS 1983), the Higgins eye mussel was never abundant and Coker (1919) indicated that it was becoming increasingly rare even at the end of the 1800s. The fact that there were few records of live specimens from the early 1900s until the

enactment of the Endangered Species Act in 1973 was a major factor in its listing in 1976.

Since the species was listed, a variety of authors have noted declines in mussel populations within the range of *L. higginsii*. Thiel (1987) reported mid-1980's die-offs of mussels in the Mississippi River that were most noticeable in areas of *L. higginsii* occurrence. Blodgett and Sparks (1987) noted a decline in the unionid community near the Sylvan Slough Essential Habitat Area, and Havlik (1987) noted a die-off near Prairie du Chien, Wisconsin, another Essential Habitat Area. Havlik also indicated an "unusual" number of fresh-dead *L. higginsii* at the Prairie du Chien site in 1985.

Zebra mussels severely degraded the native mussel communities at several of the Essential Habitat Areas in the late 1990s. Essential Habitat Areas demonstrated their importance to the conservation of *L. higginsii* until zebra mussels invaded the Upper Mississippi River in the 1990s and zebra mussels are likely the sole reason that some of these areas no longer meet the Essential Habitat criteria. Moreover, it is unclear how long zebra mussels will continue to suppress native mussel communities at these sites. Therefore, the Service will retain each of these as Essential Habitat Areas until data are sufficient to determine that one or more no longer possesses and is unlikely to recover the physical and biological features that are essential to the conservation of *L. higginsii*. The USFWS's Twin Cities Field Office maintains an updated list of Essential Habitat Areas for this species. Long-term monitoring in the Cordova Bed suggests that although density has declined substantially due to zebra mussels, the bed is surviving at a low density and species richness has remained high. Recent monitoring in the Prairie du Chien Bed also indicates that this bed seems to be surviving at a low density (ESI, 2008b).

Historical and Present Distributions

The historical distribution of *Lampsilis higginsii* is not known with certainty. Although never abundant in the Mississippi River area (Coker, 1919), it is believed to have been widely distributed, inhabiting the Mississippi River from just north of St. Louis, Missouri to Minneapolis-St. Paul, Minnesota (USFWS, 1983). It also occurred in the lower portions of several Mississippi River tributaries, specifically the Minnesota River in Minnesota, the St. Croix River in Wisconsin and Minnesota, the Wisconsin River in Wisconsin, the Rock River and Sangamon River in Illinois, and the Wapsipinicon River, Cedar River and Iowa Rivers in Iowa (Havlik, 1980; Hornbach *et. al*. 1995, Havlik (1980) estimated that its range has been reduced approximately 53% from its historic distribution, and it is now limited to the Mississippi River upstream of Canton, Missouri, the lower St. Croix River, the lower Wisconsin River and the lower Rock River. The greatest numbers of *Lampsilis higginsii* in the upper Mississippi River occur from MRM 716 (Pool 6) to MRM 440 (Pool 17) (Cawley, 1996). The southern most viable reproductive population of this species is believed to be in Sylvan Slough (Hornbach, 1998).

Essential Habitat Areas

The May 2004 Higgins Eye Pearly Mussel Recovery Plan lists 10 locations as primary habitats (called Essential Habitat areas) for *Lampsilis higginsii*. The Essential Habitat Areas are those areas capable of supporting reproducing populations of *L. higginsii* and are considered important to the conservation of the species. The Service in consultation with the recovery team has added four new EHAs. In each of these new areas, recent survey data indicates that key characteristics of the mussel beds exceed the Higgins eye EHA guidelines. Therefore, there are now fourteen EHAs – the ten described in the recovery plan plus the four new EHAs described below. Two of these are included in this project: Hanson's Slough upstream of the project, and Cordova immediately downstream of the project.

1. Mississippi River at Lansing, Iowa (Whiskey Rock)
2. Harper's Ferry, Iowa (Harper's Slough)
3. Main and East Channel areas at Prairie du Chien, Wisconsin
4. Near Guttenberg, Iowa (McMillan Island)
5. Cordova, Illinois (located downstream of QCS)
6. Moline, Illinois (Sylvan Slough)
7. St. Croix River at Prescott, Wisconsin
8. St. Croix River at Hudson, Wisconsin
9. St. Croix River at Taylor's Fall, Minnesota (Interstate Park)
10. Wisconsin River near Muscoda, Wisconsin (Orion mussel assemblage)
11. Cassville Bed at Cassville, WI UMR,
12. Pool 14, RM 509.1 -510.1 (Hanson's Slough)
13. UMR Pool 16, RM 470-471 – Near Buffalo, Iowa
14. UMR, Pool 9, RM 660-661 – Near Lansing, Iowa

Reproduction

The reproductive cycle of *L. higginsii* is similar to most unionid species. Males discharge sperm into the surrounding water. Sperm enters the female through the incurrent siphon. Eggs are fertilized internally and fertilized eggs develop into glochidia within the marsupial gills of the females. The mantle edge near the posterior end of *L. higginsii* is modified into a flap, resembling a small swimming fish, which is used to attract a fish host. The mantle flap's undulating movement is thought to keep the glochidia suspended in the water column and facilitate contact with the host fish (Kraemer, 1970). Gill tissue containing glochidia is generally protruded between the mantle flaps. When fish attacks the tissue, glochidia are released, thus enhancing the probability of glochidial contact with a fish host.

Lampsilis higginsii is a long-term brooder (brachytactic). This means that they spawn in the summer and larvae are retained in the marsupial through the winter until they are released the following spring/summer. Glochidial release has been reported during June and July (Waller and Holland-Bartels 1988) and May and September (Surber 1912). Once expelled from the gills, *L. higginsii* glochidia must attach to the gills of a suitable

host fish, where they remain for approximately three weeks at water temperatures of 20-22°C (68-71.6°F) where they transform into juveniles. They then drop off their fish host, develop a byssal thread, which may assist in dispersal, and upon settling on suitable habitat, use the byssal thread as a means of attachment to the substrate, to prevent being swept away in water currents.

Early studies, based on an examination of natural infections, indicated that the sauger (*Stizostedion canadense*) and freshwater drum (*Aplodinotus grunniens*) were fish hosts for glochidia of *L. higginsii* (Surber 1912; Wilson 1916; Coker *et.al.* 1921). Based on laboratory infections of fish with *L. higginsii* glochidia, Waller and Holland-Bartels (1988) indicated that four species of fish were suitable hosts: largemouth bass *(Micropterus salmoides*), smallmouth bass *(Micropterus dolomieu*), walleye (*Stizostedion vitreum vitreum*) and yellow perch *(Perca flavescens*). There was some transformation of glochidia to juveniles on green sunfish (*Lepomis cyanellus)*, whereas two species, bluegill (*Lepomis macrochirus)* and northern pike (*Esox lucius*), were considered marginal hosts, because each produced only one juvenile. The common carp (*Cyprinus carpio*) and fathead minnow (*Pimephales promelas)* were unsuitable hosts. In general, Waller and Holland-Bartels (1988) indicate that percids and centrarchids are suitable hosts, whereas cyprinids, Ictalurids and Catostomids are unsuitable. Neves and Widlak (1988) also indicated that members of the subfamily Lampsilinae were more likely to be found on centrarchids and percids than on cyprinids and cottids.

Feeding

There are no known studies focusing specifically on *L. higginsii,* but generally unionids are filter feeders, removing small suspended food particles from the water column utilizing the large lamellibranch gills as feeding organs. Feeding rate in bivalves is known to be greatly influenced by temperature, food concentration, food particle size and body size (Jorgensen 1975; Winter 1978).

Habitat/ Stream Flow/Current/Hydrologic Variability

Lampsilis higginsi has been found in various substrates from sand to boulders, but not in areas of unstable shifting coarse sands. *Lampsilis higginsi* is characterized as a large river mussel species occupying stable substrates that vary from sand to boulders, but not firmly packed clay, flocculent silt, organic material, bedrock, concrete or unstable moving sand. *Lampsilis higginsi* is thought to be primarily adapted to large river habitats with moderate current.

Wilcox *et al.* (1993) proposed the following decision criteria for estimating the likelihood of occurrence of *L. higginsii*:

- Substrate: Substrate not firmly packed clay, flocculent silt, organic material, bedrock, concrete or unstable moving sand

- Current Velocity: Current velocities less than 1 m/s during periods of low discharge

- Mussel Relative Abundance: If 2,000 or more mussels are sampled and no *L. higginsii* are found, then it is unlikely to be present

- Density: Density of all mussels should exceed $10/m^2$, and any rare species (including *L. higginsii*) should occur at densities greater than 0.01 individuals/m^2

- Species Richness: Species richness (number of species) should exceed 15 when as few as 250 individuals have been collected.

Lampsilis Higgins Eye Recovery Plan

The goal of the *Lampsilis higginsii* Recovery Plan is the recovery of Higgins eye to levels where its protection under the Endangered Species Act (ESA) is no longer necessary. The first *L. higginsii* recovery plan was approved on July 29, 1983.

Recovery Strategy

The current version of the *L. higginsii* Recovery Plan (2004) continues the approach of the initial recovery plan for *L. higginsii* by focusing recovery on the conservation of the species at identified Essential Habitat Areas. In the 1983 recovery plan, Essential Habitat Areas were specific areas throughout the historical range of *L. higginsii* that supported dense and diverse mussel beds where *L. higginsii* was successfully reproducing. The plan recommends the development of a uniform protocol for collecting information on populations of *L. higginsii*. Use of this protocol will allow for ongoing evaluation of the list of Essential Habitat Areas and progress towards recovery.

The highest priority recovery actions for *L. higginsii* are primarily intended to address the severe impacts and threats posed by zebra mussels. Of the fourteen Essential Habitat Areas designated in the recovery plan, zebra mussels have had severe impacts on the mussel communities at Harper's Slough, Prairie du Chien, and Cordova and are imminent threats at the Prescott, and Hudson, WI areas. The Prairie du Chien Essential Habitat Area may have contained the largest population of *L. higginsii* before its severe infestation by zebra mussels, but Miller and Payne (2001) found nearly 10,000 zebra mussels/m^2 in this area in 2000.

The elimination of zebra mussels from the river system is not currently feasible. Therefore, the recovery plan focuses on developing methods to prevent new infestations, monitoring zebra mussels at Essential Habitat Areas, and developing and implementing contingency plans to alleviate impacts to infested populations. Based on recent activities, the latter may consist largely of removing *L. higginsii* from areas where zebra mussels pose an imminent risk to the persistence of the population and releasing them into suitable habitats within their historical range where zebra mussels are not an imminent threat. Cleaning fouled adults *in situ* and artificial propagation and release are also

currently being implemented in an attempt to alleviate the effects of zebra mussels on the conservation of *L. higginsii*. Although zebra mussels are currently the most important threat to *L. higginsii*, construction activities, environmental contaminants, and poor water quality may also pose significant threats. The plan also outlines tasks needed to improve our understanding of the potential importance that contaminants play in the conservation of *L. higginsii* and calls on the U.S. Coast Guard, Environmental Protection Agency, and other agencies to take actions to minimize the potential impacts of toxic spills. Interagency partnerships are key to the recovery of *L. higginsii*.

Recovery Goals and Criteria

The *L. higginsii* Recovery Plan is organized around two main objectives: 1) Preserving *L. higginsii* and its Essential Habitat Areas and 2) Enhancing the abundance and viability of *L. higginsii* in areas where it currently exists and restoring populations within its historical range. This HCP is intended to be consistent with the objectives of the *L. higginsii* Recovery Plan and is not intended to replace or to supercede any ongoing recovery actions.

Preserving the current populations of *L. higginsii* and its Essential Habitat Areas requires the following actions:

- Limit the impact of the exotic bivalve, the zebra mussel, *Dreissena polymorpha*.
- Develop uniform protocols for collecting and maintaining information on *L. higginsii* populations.
- Confirm and modify the list of Essential Habitat Areas.
- Limit construction in areas of essential *L. higginsii* habitat. Mitigation, including translocation, may be an acceptable alternative in limited instances.
- Continue to examine the relationship between water quality, especially contaminants, and *L. higginsii* populations in Essential Habitat Areas.
- Develop plans to reduce the shipment of toxic materials near *L. higginsii* habitat and develop response plans for any spills that may occur.
- Review current regulations and develop additional regulation of mussel harvest in the upper Mississippi River drainage to reduce impacts on *L. higginsii*.
- Develop materials to educate the public on the nature of endangered mussels and *L. higginsii*, in particular.

Enhancing and restoring populations of *L. higginsii* within its historic range requires the following actions:

- Identify and rank potential sites of existing *L. higginsii* populations for enhancement.
- Increase the number of *L. higginsii* at enhancement sites to current levels found in Essential Habitat Areas or to numbers appropriate for the local habitat.
- Determine the feasibility of reestablishing *L. higginsii* into historic habitats, particularly streams that are at lower risk for zebra mussel colonization, and carry out reintroduction using the best available methods.

- Examine the taxonomic validity of *L. higginsii* especially since *L. abrupt* is found in noncontiguous geographic areas.

Specific actions recommended for immediate implementation to ensure the survival of the *L. higginsii* include:

- Limiting the impact of the exotic bivalve, the zebra mussel, *Dreissena polymorpha*.
- Developing uniform protocols for collecting and maintaining information on *L. higginsii* populations.
- Confirming and modifying the locations listed in the initial recovery plan as Essential Habitat Areas.
- Requiring the use of double hull barges.

Restoration Projects

Mussel Propagation at the Genoa National Fish Hatchery (GNFH)

Mussel conservationists in 2000 developed a protocol for collecting gravid females and glochidia, inoculating host fish, and producing juvenile mussels at the GNFH and in cages (Steingraeber 2002). In 2001, the Corps conducted a literature search of previous mussel culture activities on the Upper Mississippi River to assist in refining mussel propagation activities (Pritchard 2001). Methods, procedures, and results at the GNFH are described in Steingraeber (2002) and Welke et al. (2000).

Like many freshwater mussels, the Higgins eye requires a host fish to complete its life cycle. Eggs are fertilized and stored in the female's gills. Here they transform into a parasitic form called glochidia. When gravid, adult females display a unique lure on their mantle tissue that resembles a small fish. The lure attracts predatory fish like largemouth bass, smallmouth bass, and walleye. When a fish strikes the lure, it ruptures the gill chambers of the mussel. Glochidia are expelled into the mouth of the fish and attach to the gills. If the fish is a suitable host, glochidia encyst, transform into juvenile mussels, detach from the gills, and fall to the sediment. Juveniles surviving to adulthood complete the life cycle. In nature, the female mussel brings (lures) a host fish to her glochidia. In the hatchery, glochidia are brought to the fish. Gravid female Higgins eye are collected in the field by divers and transported to the hatchery. Females used for propagation are measured and marked. Glochidia are flushed from the gills of the female with a syringe and water into a glass container. Glochidia are tested for viability with a microscope and table salt; viable glochidia quickly "snap shut" their shells when contacting salt placed in their water. A quantity of viable glochidia (2 to 10 milliliters) is added to a bucket containing host fish, water, and an air stone. Contents are mixed for a period of time (2 to 5 minutes) and a sample fish is examined under a microscope to estimate the number of attached glochidia. If the gills appear adequately inoculated with glochidia (50 to 100), fish are placed in a holding tank. If not, the sample fish is returned to the bucket, the contents stirred, and the process continued until inoculation occurs. These fish are used in cage propagation activities, released into the wild, or kept as transforming juveniles in the

hatchery. It takes approximately 2 to 4 weeks for transformation from glochidia to juvenile mussel.

Propagation of Higgins eye mussels in Cages

Cage propagation techniques and monitoring techniques are described in Davis 2001 and 2002. In a typical placement, glochidia inoculated fish and cages are transported by boat to the relocation site. Depending on their size, approximately 30 to 50 fish are placed in each cage. Divers are used to transport and secure the cage to the river bottom. Cage locations are marked with Global Positioning System (GPS) coordinates, lines/buoys, and shoreline references. After approximately 3 to 4 weeks, glochidia transform and fall off the gills of the host fish into the substrate of the river in open cages. Closed cages are also used. In the closed cages, juveniles drop into a tray within the cage. Divers return at this time and release host fish to the river; the divers usually return in approximately 4 months to inventory contents of closed cages.

Stocking Juveniles

Stocking juvenile Higgins eye is a relocation method that is being used in several Upper Mississippi River tributaries. In July and August 2000, juveniles were taken from the Genoa NFH and placed by a diver into wooden-framed, screen covered trays that were anchored to the bottom of the lower Wisconsin River, Wisconsin. On July 20, 2001, the contents of six hatchery trays (substrate and juvenile Higgins eye) were placed by a diver in the lower Black River, Wisconsin (Heath 2002). The contents of all trays were placed on the substrate within 2 meters of each other in an area previously identified as a mussel bed.

Since the inception of the program, juveniles have been placed in Pools 2, 3, 4, 16 and the Wisconsin River. As of the conclusion of the 2007 season, a total of 28,385 juveniles have been released into the Mississippi and Wisconsin Rivers.

Stocking Glochidia-inoculated Fish

Another relocation technique is stocking host fish that have been inoculated with glochidia. To illustrate this technique, on October 10 and 11, 2001, 1,800 host fish of six species were inoculated with Higgins eye glochidia (Gritters 2001). Glochidia came from female mussels collected in the UMR, Pool 14, at Cordova, Illinois. Host fish included largemouth bass, smallmouth bass, spotted bass (*Micropterus punctulatus*), walleye, white bass (*Morone chrysops*) and freshwater drum (*Aplodinotus grunniens*). Hatchery fish (1,050) came from the GNFH and the Rathburn State Fish Hatchery. The remaining wild fish (750) were collected by electrofishing in the Iowa River in the vicinity of the release site. Host fish were inoculated in the field and released into the Iowa River. Attachment rates for glochidia ranged from 27 to 65 per fish; an estimated 101,227 glochidia were attached to released fish. Assuming a transformation rate of 65 percent, approximately 65,765 juveniles may have settled to the bottom of the Iowa River. In another release, 450 glochidia-inoculated smallmouth bass were released into the lower

Wisconsin River (Heath 2001). These fish were inoculated at the Genoa NFH with glochidia from females collected from the lower St. Croix River; estimated total attachment was 25,020 glochidia and potential for 16,263 juvenile Higgins eye. Host fish released were inoculated and held at the GNFH, or captured from the receiving water and inoculated in the field. Although this technique is simple to conduct, monitoring is difficult because biologists do not know where fish travel over the 3- to 4-week period when transformation occurs.

As of the end of 2007, approximately 2.8 million glochidia have been released into the Wapsipinicon, Cedar and Iowa Rivers in Iowa and the lower Wisconsin River in Wisconsin via free release of inoculated fish and open bottomed cages.

Cleaning and Stockpiling Adults

One way to increase survival of native mussels in waters infested with zebra mussels is to periodically clean them of zebra mussels and return them to their habitat (Hallac and Marsden 2001). In general, mussels are collected at a site infested with zebra mussels, cleaned of zebra mussels by scrubbing with a stiff brush, measured, sexed, individually marked and photographed. They are returned to the river and hand-placed on the bottom by divers at a known location marked by GPS coordinates, rope/buoys, or shoreline references. A year later, they are monitored and recleaned, if necessary. Another benefit of the stockpile sites is that females can easily be collected for fish inoculation.

2.2.1.2 *Plethobasus cyphyus* (Sheepnose)

Key Characters

Oblong shell with a smooth surface except for a single row of bumps or knobs running from the umbo to the ventral margin.

Description

Shell thick, oval or oblong, somewhat elongate, and slightly inflated. Anterior end rounded, posterior end bluntly pointed. Dorsal margin straight, ventral margin curved anteriorly, straight posteriorly. Umbos slightly elevated above the hinge line. Beak sculpture of two heavy ridges, visible only in young shells. Shell smooth, except for a row of knobs or tubercles on the center of the valve, running from the umbo to the ventral margin (sometimes obscure). A shallow sulcus or furrow present between the row of tubercles and the posterior ridge. Periostracum yellow or light brown in juveniles, becoming chestnut to dark brown in adults. Length to 5 inches (12.7 cm). Pseudocardinal teeth rather small relative to overall shell size; two in the left valve, one in the right (occasionally with a smaller tubercular tooth on either side). Lateral teeth long, straight or slightly curved; two in the left valve, one in the right. Beak cavity shallow. Nacre white, occasionally tinged with pink or salmon.

Current *Plethobasus cyphyus* (Sheepnose) Status

The sheepnose mussel is State-listed in every state that keeps such a list (in addition to Pennsylvania and West Virginia, which do not keep official imperiled species lists). The level of protection it receives from State-listing varies from state to state. One specimen of *Plethobasus cyphyus*, a candidate for Federal endangered status, was recently collected in the Cordova mussel bed. Based on recent discussions with USFWS Staff, the sheepnose mussel is included in this HCP because it is probable that it will be listed as either federally threatened or federally endangered over the next several months.

Historical and Present Distributions

Historically, the sheepnose occurred throughout much of the Mississippi River system with the exception of the upper Missouri River system and most lowland tributaries in the lower Mississippi River system. This species is known from the Mississippi, Ohio, Cumberland, Tennessee, and Ohio main stems, and scores of tributary streams range wide.

During historical times, the sheepnose was fairly widespread in many Mississippi River system streams although rarely very common. Archaeological evidence on relative abundance indicates that it has been an uncommon or even rare species in many streams for centuries (Morrison 1942; Patch 1976; Parmalee et al. 1980, 1982; Parmalee and Bogan 1986; Parmalee and Hughes 1994), and relatively common in only a few (Bogan 1990).

The sheepnose was historically known from 26 streams in the upper Mississippi River system, or one-third of the total streams known over its entire range. Currently, only eight streams are thought to have extant sheepnose populations remaining. The percentage of stream population losses in the Mississippi River system (18 of 26, 69%) is slightly higher than that recorded range wide (51 of 77, 66%).

Judging from the archeological record, the sheepnose was not uncommon at some sites on the Mississippi (Bogan 1990). Historical sites are known from numerous localities, including the entire length of the Wisconsin portion of the Mississippi River (D.J. Heath, Wisconsin Department of Natural Resources [WDNR], pers. comm., 2001). Paul Bartsch conducted sampling at 140 upper Mississippi River sites in 1907. Bartsch's findings were presented by M. Havlik, Malacological Consultants, at the second annual meeting of the Freshwater Mollusk Conservation Society in Pittsburgh, Pennsylvania, in March 2001. According to INHS museum records, Bartsch found the sheepnose at least at 12 sites (K.S. Cummings, INHS, pers. comm., 2001) from what are now Mississippi River Pools (MRP) 13-23. Kelner (2003) listed *P. cyphyus* as historically occurring (not collected live since 1980) in Upper Mississippi River pools (MRP) 2, 3, 4, 5a, 6, 8, 12, 13, 14, 18 and 25, and rare (not typically collected due to small populations) in pools 5, 7, 10, 15, 16, 17, 20, 22, 24.

Recent records of sheepnose in the Upper Mississippi River are rare. Whitney et al. (1996) reported the sheepnose from Sylvan Slough, in Pool 15. They recorded single live specimens in 1985 and 1987, and 10 specimens from 1994-95. Densities in the latter sampling period were $0.03/ft^2$. ESI found one live sheepnose mussel specimen out of 2,510 unionids in a recent survey (2007) upstream of the Cassville Bed during work performed in Pool 11 for the U.S. Army Corps of Engineers (ESI 2008b). One sheepnose was found in the Cordova Bed in 2006 (Dan Sallee, Illinois DNR, pers. comm.). During the 2008 QCS monitoring, ESI found sub-fossil shells of *Plethobasus cyphyus* (sheepnose) in the Albany and Woodward Grove Mussel Beds, indicating that this species historically occurred within these beds.

In the upper Mississippi River, the sheepnose is an example of a rare species becoming rarer. Zebra mussels seriously threaten the sheepnose and other mussel populations in the upper Mississippi River. Even if some level of sheepnose recruitment was documented, the status of this species in the Mississippi is highly jeopardized, with imminent extirpation a distinct possibility. Other threats include channel maintenance dredging and sedimentation from tributary systems.

Essential Habitat Areas

There are no established essential habitat areas for the *P. cyphyus* like there are for *L. higginsii.* At this time there is no specified Federal or State Recovery Plan for *P. cyphyus.*

Reproduction

The reproductive cycle of *P. cyphyus* is similar to most unionid species. Most mussels, including the sheepnose, generally have separate sexes. Age at sexual maturity for the sheepnose is unknown, but most Ambleminae species mature between five and ten years old. Males expel clouds of sperm into the water column, which are drawn in by females through their incurrent siphons. Fertilization takes place internally, and the resulting zygotes develop into specialized larvae termed glochidia within the gills. The sheepnose utilizes only the outer pair of gills as a marsupium for its glochidia. It is thought to be a

short-term brooder, with most reproduction taking place in early summer (Parmalee and Bogan 1998), and glochidial release presumably occurring later in the summer. Tony Brady (USFWS, personal communication) recently (2008) found gravid female *P. cyphus* containing immature glochidia in June, and fully mature glochidia in early July in the Chippewa River in Wisconsin.

Hermaphroditism occurs in many mussel species (van der Schalie 1966), but is not known for the sheepnose. This reproductive mechanism, which is thought to be rare in dense populations, may be implemented when populations exhibit low densities and high dispersion levels. Females changing to hermaphrodites may be an adaptive response (Bauer 1987), assuring that a recruitment class may not be lost in small populations. If hermaphroditism does occur in the sheepnose, it may explain the occurrence of small, but persistent populations over long periods of time common in many parts of its range. Glochidia are released in the form of conglutinates, which are analogous to cold capsules (i.e., gelatinous containers with numerous glochidia within), and mimic fish food organisms. The conglutinates of the sheepnose are narrow and lanceolate in outline, solid and red in color, and discharged in unbroken form (Oesch 1984). Conglutinates for many species typically contain not only glochidia, but embryos and undeveloped ova as well. This may explain the color differences described by Oesch (1984) and Ortmann (1911). However, conglutinates in the Chippewa River changed color upon maturity (Tony Brady, personal communication). Sheepnose glochidia are semicircular in outline, with the ventral margin obliquely rounded, hinge line long, and medium in size. The length (0.009 inches) is slightly greater than the height (0.008 inches) (Oesch 1984). Several score to a few hundred glochidia probably occur in each conglutinate. Fecundity is positively related to body size and inversely related to glochidia size (Bauer 1994). Total fecundity (including glochidia and ova) per female sheepnose is probably in the tens of thousands. Glochidia must come into contact with a specific host fish(es) in order for their survival to be ensured. Without the proper host fish, the glochidia will perish. Little is known regarding host fishes of the sheepnose (Roberts and Bruenderman 2000). The sauger (*Stizostedion canadense*) is the only known natural host (Surber 1913), Wilson 1914). However, glochidia did not transform on sauger in recent fish host studies (Tony Brady, personal communication). Rather, stoneroller, creek chub, and fathead minnow seemed to produce the best results in the laboratory (Tony Brady, personal communication). In many species of mussels, a few weeks are spent parasitizing the fishes' gill tissues. Newly metamorphosed juveniles drop off to begin a free-living existence on the stream bottom. Unless they drop off in suitable habitat, they will die. Thus, the complex life history of the sheepnose and other mussels has many weak links that may prevent successful reproduction and/or recruitment of juveniles into existing populations (Neves 1993).

Feeding

There are no known studies focusing specifically on *P. cyphyus,* but generally unionids are filter feeders, siphoning phytoplankton, diatoms, and other microorganisms from the water column (Fuller 1974). For their first several months juvenile mussels employ foot (pedal) feeding, and are thus suspension feeders that feed on algae and detritus (Yeager et

al. 1994). Mussels tend to grow relatively rapidly for the first few years, and then slow appreciably at sexual maturity, when energy is being diverted from growth to reproductive activities (Baird 2000).

Habitat/Streamflow/Current/Hydrologic Variability

The following habitat requirements of the sheepnose are generally summarized from Oesch (1984) and Parmalee and Bogan (1998). The sheepnose is primarily a larger-stream species. It occurs primarily in shallow shoal habitats with moderate to swift currents over coarse sand and gravel (Oesch 1984). Habitats with sheepnose may also have mud, cobble, and boulders. Specimens in larger rivers may occur in deep runs (Parmalee and Bogan 1998). Strayer (1999a) demonstrated in field trials that mussels in streams occur chiefly in flow refuges, or relatively stable areas that displayed little movement of particles during flood events. Flow refuges conceivably allow relatively immobile mussels to remain in the same general location throughout their entire lives. He thought that features commonly used in the past to explain the spatial patchiness of mussels (e.g., water depth, current speed, sediment grain size) were poor predictors of where mussels actually occur in streams.

Plethobasus cyphyus Recovery Plan

Even though there is no specified Federal of State Recovery Plan for *P. cyphyus*, there are, however, a number of recommended conservation activities that have been identified that would benefit the species include Funding Programs, Research and Surveys, Public Outreach and Habitat Improvements and Conservation. Details on each of these recommended conservation activities are described in more detail below.

Funding Programs

The Clean Water Act (CWA) Section 319, Natural Resource Conservation Service programs (e.g., Environmental Quality Incentives Program, Wildlife Habitat Improvement Program, Conservation Reserve Enhancement Program [CREP]), Landowners Incentives Program, National Fish and Wildlife Foundation (NFWF) habitat programs, and numerous other Federal programs are potential sources of money for sheepnose habitat restoration and conservation.

Research and Surveys

Research subjects involving mussels have included sediment contamination, juvenile toxicity, status surveys, population dynamics, and zebra mussel control. These efforts may pay dividends in improving conditions for the sheepnose and a host of other imperiled aquatic organisms in the upper Mississippi River. Information gathered from these surveys will help determine its population status, and generates other data useful for conservation management and recovery efforts. Research is also ongoing to identify host species and life history aspect for *Plethobasus cyphyus*. This research will hopefully

result in successful future propagation, population augmentation, and reintroduction for this species.

Management

During Interagency Consultation, or in the development of a Habitat Conservation Plan, minimization and mitigation of adverse effects to listed mussel species should consider conservation measures, in addition to relocation, which further species recovery goals. Species of concern and candidate species, such as the sheepnose, receive no regulatory protection under the Act, however, the Service strongly encourages federal agencies and other planners to consider them when planning and implementing their projects.

Best Management Practices on Riparian Lands

Maintaining vegetated riparian buffers is a well-known method of reducing stream sedimentation and runoff of chemicals and nutrients. Buffers reduce impacts to fish and other aquatic faunas and are particularly crucial for mussels. Other Best Management Practices should be implemented on riparian lands throughout the range of the sheepnose. As previously mentioned, the State of Iowa's Impaired Waters Report documents the fact the Wapsipinicon River, which discharges into the Mississippi River just upstream of the Steamboat Slough Bed, is high in total suspended solids due to watershed issues stemming from agricultural runoff. Future actions to be considered for farmlands bordering the Wapsipinicon River include changes to farming practices to eliminate fall plowing, installation of buffer strips between farmlands and drainage ditches and creeks and changes to fertilizer practices that take place in the fall. Based on a review of the environmental status of the Wapsipinicon River, its potential long-term impacts on the Steamboat Slough mussel bed require further investigation. The Wapsipinicon River begins in Mitchell County near the Minnesota border. It joins the Mississippi River 10 mi SW of Clinton, Iowa. It drains a rural farming region of rolling hills and bluffs north of Waterloo and Cedar Rapids. The Wapsipinicon River has lower levels of dissolved oxygen compared to statewide rivers, partly due to low flow conditions. Total phosphorus levels were lower compared to statewide river. More fecal and E.coli bacteria is found in the river in the months of October, compared to May, in comparison to statewide rivers. There is far more bacteria found south of Tripoli according to maps. With regard to the Concentrated Animal Feedings Operations (CAFO) Rule, Iowa DNR is in the process of moving forward with rule making for state. Presently, the Wapsipinicon River is Iowa's leading non-point source of water pollution is sediment. In Iowa, most sediment comes from agricultural practices such as cropland tillage and livestock in pastures, woodlands and feedlots. High levels of sediment also erode and are deposited in water bodies from construction sites, streambanks and lake shorelines. Additional nutrients in the river come from fertilizers originating in agricultural land, residential areas, manure, and human sewage. Indicator bacteria found in category 5a of the river can be due to manure and human sewage as well.

Monitor Populations and Habitat Conditions

A monitoring program should be developed and implemented to evaluate efforts and monitor population levels and habitat conditions and assess the long-term viability of extant, newly discovered, augmented, and reintroduced sheepnose populations.

Research, Surveys, and Monitoring Needed To Bring About Recovery

Determine all host fishes: The sauger has been determined to be a host fish for the sheepnose, but other fishes must serve as host for this species. Research into other hosts is critical. Knowing all its host fishes range wide will facilitate sheepnose recovery.

Develop Propagation Technologies

Propagation technology for the sheepnose should be developed. By propagating significant numbers of juveniles in laboratory or hatchery settings, population augmentation and reintroduction into historical habitats will become much more feasible.

Research Life History and Habitat Needs

Very little information is available with regard to the life history of the sheepnose. Much life history information in addition to determining its host species will be needed in order to successfully implement the recovery tasks. In addition, the habitats (e.g., relevant physical, biological, chemical components) for each sheepnose life-history stage needs to be elucidated. The sensitivity of each life history stage to contaminants and general threats to the species also need investigating.

Monitor Zebra Mussel Populations

Monitoring existing populations of the zebra mussel and its spread into new systems should be implemented in the most at-risk systems. These include, among others, the Mississippi, Chippewa, Meramec, Ohio, and Tennessee Rivers, which currently harbor populations of *Plethobasus cyphyus* (sheepnose).

Determine Population Attributes Necessary for Long-Term Viability

Criteria that determine long-term population viability are crucial if we are to understand what constitutes a healthy sheepnose population. Detailed information is needed on the demographic structure, effective population size, and other genetic attributes of extant populations.

Develop Parameters for Species Augmentation

A set of biological, ecological, and habitat parameters will need to be developed to determine if an extant sheepnose population will be suitable for species augmentation. This is particularly important in habitats that may be considered marginal (e.g., where the

sheepnose appears to be barely hanging on). Prioritized populations and potential augmentation sites for this task will be selected based on present population size, demographic composition, population trend data, potential site threats, habitat suitability, and any other limiting factor that might decrease the likelihood of long-term benefits from population augmentation efforts. Augmentation activities should not be conducted at totally unprotected sites or at sites with significant uncontrollable threats.

Develop Parameters for Reintroduction

A set of biological, ecological, and habitat characterization parameters will need to be developed to determine if a site will be suitable for sheepnose reintroduction. These will include habitat suitability, substrate stability, presence of host fishes, potential site threats, and any other limiting factor that might decrease the likelihood of long-term benefits from population reintroduction efforts. Reintroduction activities should not be conducted at totally unprotected sites or at sites with significant uncontrollable threats.

Survey for Additional Populations

The loss of much of its historical habitat, coupled with past and ongoing threats, clearly indicates the heightened level of imperilment of the sheepnose. However, survey work to search for potentially new sheepnose populations, and populations thought to be extirpated would be beneficial.

Determine Potential Taxonomic Distinctions of Populations

A range wide phylogenetic study on the sheepnose should be conducted to determine if there are any populations that may be taxonomically distinct. There is a possibility that disjunctive populations, such as the upper Tennessee River system *Unio compertus*, a synonym of *Plethobasus cyphyus*, described from the Clinch and Holston Rivers or the Ozark populations in Missouri, may represent undescribed taxa. Numerous endemic mussels, fishes, and other aquatic organisms are known particularly from the Tennessee River system, which has been geologically stable for eons longer than glaciated streams in much of the remainder of the sheepnose's range.

Develop and Implement Cryogenic Techniques

Developing and implementing cryogenic techniques to preserve the sheepnose's genetic material until such time as conditions are suitable for reintroduction may be beneficial to recovery. If a population were lost to a catastrophic event, such as a toxic chemical spill, cryogenic preservation could allow for the eventual reestablishment of the population using genetic material preserved from that population.

2.2.1.3 State Listed Species

The following State listed mussels have been observed in the vicinity of the QCS discharge. However, these species are not proposed for inclusion in this HCP and associated ITP.

- *Pleurobema sintoxia*, which is endangered in Iowa, has been found in the Steamboat Slough, Hansons Slough and Woodwards Grove mussel beds.
- The Illinois and Iowa threatened *Ellipsaria lineolata* has been collected in the Upstream, Steamboat Slough, Cordova, Albany, Hansons Slough and Woodwards Grove mussel beds.
- The Illinois threatened *Ligumia recta* have been observed in the Upstream, Steamboat Slough, Cordova, Albany, Hansons Slough and Woodwards Grove mussel beds.
- *Lampsilis teres*, which is endangered in Iowa, was found in the Hansons Slough, Upstream and Steamboat Slough mussel beds.

2.2.2 Plant Species of Concern

There are no terrestrial or aquatic plant species of concern included or discussed in this HCP.

3.0 PROJECT DESCRIPTION/ACTIVITIES COVERED BY PERMIT

3.1 Project Description

Exelon Generation (Exelon) is considering requesting that alternate thermal standards pursuant to Section 316(a) of the Clean Water Act be issued for Exelon's Quad Cities Station (QCS). If the Illinois Pollution Control Board (IPCB) were to rule in favor of Exelon Generation's request, the alternate standards would be incorporated into the QCS N.P.D.E.S. permit that regulates discharges from the plant into the Mississippi River.

This HCP has been written to address three specific activities that include: (1) the proposed implementation of an Alternate Thermal Standard (ATS) at the QCS, which is described in detail in Section 3.2.1, (2) Maintenance Dredging, which is described in detail in Section 3.2.2 and (3) Edison Pier Removal, which is described in detail in Section 3.2.3.

3.2 Activities Covered by Incidental Take Permit

3.2.1 Alternate Thermal Standard (ATS)

Part 1 of the HCP Project Plan involves seeking relief from the thermal regulations specified in the QCS NPDES Permit. The alternate thermal standards that Exelon Generation is considering for Quad Cities Station includes: (1) changing the method for tracking and regaining excursion hours (during which the plant currently is authorized to exceed thermal limits by up to 3ºF) from a rolling 12-month basis to a calendar year basis (January through December); (2) increasing the number of excursion hours available per year from 1% (87.6 hours), which is currently allowed by the plant's N.P.D.E.S. Permit, to 3% (262.8 hours), of which only 1.5% (131.4 hours) of those hours may be between 89°F and 91°F; and (3) increasing the excursion hour downstream temperature limit to no more than 5°F delta-T (i.e., 91°F downstream instead of current N.P.D.E.S Permit limit of 89°F in July and August and 90°F downstream rather than current N.P.D.E.S Permit limit of 88°F in September). These new standards would be adopted following proceedings before the Illinois Pollution Control Board's pursuant to the Board's authority to issue alternate thermal standards under Section 316 of the Clean Water Act. Following the Board's decision to issue alternate standards for QCS, the Environmental Protection Agency's (IEPA) would incorporate the standards in the QCS N.P.D.E.S Permit.

Special Condition 6B of the plant's current N.P.D.E.S. Permit limits the temperature at the edge of the mixing zone to 86°F in July and August and 85°F in September, except when the Station is using excursion hours, during which time the temperatures at the edge of the mixing zone may be 3°F warmer than these limits (i.e., 89°F in July and August and 88°F in September). As a general rule, Quad Cities Station has been able to operate well within these limits due to the fact that the ambient temperatures of the Mississippi River (measured upstream of the plant's intake) generally remain below the non-

excursion hour temperature limits. Even when the ambient river temperatures begin to approach the non-excursion hour limits, the significant river flows, which are generally characteristic of the Mississippi River, are sufficient to allow the Station to avoid using a significant percentage of its excursion hour allowance. It is only during periods when the ambient river temperatures are very close to or exceed the non-excursion hour limits or during periods of extreme low flows that the Station is forced to use a significant number of its excursion hour allowance. When the ambient river temperatures exceed the non-excursion hour limits, the Station has no other option other than to use excursion hours, and once its allotment of excursion hours is depleted, the Station must cease operating to maintain compliance with its N.P.D.E.S. Permit.

3.2.2 Maintenance Dredging

Part 2 of the HCP Project Plan involves dredging activities in front of the plant's intake. QCS requires a consistent supply of water for safe operations of the two nuclear reactors. Over the past few years (2005, 2007, and 2008), dredging in front of the intake forebay has been a maintenance necessity to achieve the consistent water supply. High water events tend to deposit course materials in front of the intake. In October 2005, QCS enlisted Ecological Specialist, Inc. (ESI) to perform a mussel survey in the intake area (ESI, 2006). Results of the survey indicated that impacts associated with maintenance dredging should be limited to a few unionids of common species. Species included threehorn, threeridge, hickorynut, and plain pocketbook. All other species were represented by two individuals or less. One butterfly mussel was also found in the survey. Dredging permit (CEMVR-OD-P-2006-1856) allows dredging within a 500' x 700' area in front of the station's forebay. QCS does not expect to increase the size of the dredging area. QCS anticipates dredging will be necessary in the near future and consequently this activity is being included in this HCP. Maintenance dredging is assumed to occur bi-annually over the life of this permit. If the dredging area needs to be expanded from the current levels in the future, Exelon will consult with USFWS prior to such activities.

3.2.3 Edison Pier Removal

Part 3 of the HCP Project Plan involves a structure known as the Edison Pier (RM 506.8L), which has been in existence since the initial building process of QCS in the late 1960's. Although there are no immediate plans to remove this structure, preliminary demolition planning has occurred and this project could begin in the next few years. The process of removing this structure would extend a minimal distance out into the river channel, and could potentially cause an interaction between the removal equipment and any mussels in the area. It is important to note that coverage by this HCP does not exempt an activity from other local, state and federal regulations, including permits issued by the U.S. Army Corps of Engineers.

4.0 POTENTIAL BIOLOGICAL IMPACTS/TAKE ASSESSMENT

4.1 Direct Impacts

4.1.1 ATS

In order to determine direct impacts on freshwater unionid mussel communities, Exelon requested that Ecological Specialists, Inc. (ESI) assess impacts of an increase in excursion hours from 1% (87.6 hours) to 3% (262.8 hours), of which 1.5% (131.4 hours) of those hours may be between 89°F and 91°F (5ºF above the limit), on the freshwater unionid mussel communities within the study area (RM 503.0 to 506.9). The study area selected for the assessment corresponds with the area used for the thermal modeling studies (Holly *et al*., 2004) and the fisheries bio-assessment studies (LMS, 2004a) that were done to support the mussel impact assessment.

Unionid Distribution and Community Characteristics

To determine unionid distribution, literature on unionid studies in the study area was reviewed, and U.S. Fish and Wildlife Service (USFWS; Ginger Molitor, Rock Island Field Office), U.S. Army Corps of Engineers (USACE; Kenneth Cook, Rock Island District), Iowa Department of Natural Resources (IADNR; Scott Gritters), and Illinois Department of Natural Resources (ILDNR; Robert Schanzle, Springfield, IL office; Dean Corgiat, Pittsfield, IL office) were contacted for unpublished data. These data were compiled and mapped with ArcGIS (Geographic Information System mapping software) to determine if existing data were sufficient for this assessment, or if additional data were needed.

Both USFWS and IADNR indicated that unionid beds occur on the Iowa bank both upstream and downstream of the QCS mixing zone. However, no data were available regarding these beds. Additionally, it is known that zebra mussel infestation has severely affected unionids in this reach of the Mississippi River since zebra mussels first appeared in the Mississippi River in 1994. Because data were lacking for the Iowa bank unionid beds, and because zebra mussel infestation may have affected community characteristics in the Cordova Bed, ESI determined that a field study should be conducted to better define present unionid distribution and community characteristics within the study area.

The study area was first sampled on July 13 through 16, 2004, using reconnaissance, quantitative and qualitative sampling techniques. Summary results of the 2004 field studies that began in 2004 and are continuing to date are presented later on in this HCP in a section titled “Recent Mussel Monitoring Program Results”.

Methodology for Assessment of Excursion Hours in Mussel Beds

Literature was reviewed and researchers were contacted to obtain information on the effects of temperature on unionid mussels and zebra mussels. Researchers contacted included Dr. Jerry Farris (Arkansas State University), Dr. Chris Barnhart (Southwest Missouri State University), Dr. Jess Jones (Virginia Polytechnic University), and Dr. G. Thomas Watters (Ohio State University), who have all propagated threatened and endangered unionids. Dr. Farris also conducts toxicity tests on unionid mussels.

The assessment of possible impacts of increased excursion hours was based on worst-case conditions of maximum power output, a series of relatively low flow levels (13,700 cfs (7Q10) to 30,000 cfs), and high ambient water temperatures (28.9°C (84.0°F)). Temperatures were obtained from a thermal model developed by IIHR (Holly *et al*., 2004). The IIHR model was calibrated using data collected in September 2003 (LMS, 2004b). Model calibration results indicate that actual temperatures and modeled temperatures differed by approximately 1.1°C (2°F) on the surface and 0.6°C (1°F) in vertical profile around the dike, just upstream of the head of Steamboat Slough. Therefore, modeled water temperatures in the Steamboat Slough Bed are most likely higher temperatures than actually would occur. LMS provided model results for surface temperature to ESI. LMS (2004a) calculated excursion time expected under the series of low flows.

Temperature Effects on Unionids

Since unionids are poikilothermic animals, temperature affects all aspects of their life history (Table 4-1), "Temperature effects on unionids", ESI 2005). Temperature is believed to be the most important exogenous factor controlling reproduction (Matteson, 1948; Tedla and Fernando, 1969; Zale and Neves, 1982; McMurray *et al.*, 1999). Temperature triggers spawning. Release of glochidia from the female may also be temperature dependent. Watters and O'Dee (2000) found a decline in temperature triggered the release of glochidia from the female in *L. fragilis* (11°C (51.8°F)) and *P. grandis* (12 to 5°C) (53.6°F to 41°F), while an increase in temperature to near 23°C (73.4°F) triggered release in *A. plicata*. *Lampsilis higginsii* release glochidia between 20 and 22°C (68 and 71.6°F), mainly in the spring (USFWS, 2004). The survival of glochidia between release from the female and attachment to a host is also temperature dependent and species specific (Jansen *et al.*, 2001). Jansen *et al*. (2001) found *Anodonta cygnea* survived 10 to 17 days at 5°C (41°F) and 2.5 to 5 days at 10 to 16°C (50 to 60.8°F), but only 50% survived after 5 days at 18°C (64.4°F). Similarly, *Lampsilis radiata* experienced only 1% survival at 20°C (68°F) (Tedla and Fernando, 1969) and no *L. higginsii* glochidia survived at temperatures exceeding 25°C (77°F) (Sylvester *et al*., 1984). Glochidial development on a host and host immune response also seem to be temperature dependent (Jansen *et al*., 2001). Host fish infestation seems to be optimal at 12 to 15°C (53.6 to 59°F) for *A. plicata* and *M. nervosa* (Hubbs, 2000).

Fish hosts may also avoid areas above a threshold or could remain in the area, but slough off glochidia due to stress. The five fish species used by LMS (2004a) in its thermal

Table 4-1. Temperature effects on unionids.

Life stage/Effect	Effect or Trigger temperature	Reference
Glochidia		
Glochidial release from female		
Leptodea fragilis	Decline to 11° C	Watters and O'Dee (2000)
Pyganodon grandis	Decline from 12 to 5° C	Watters and O'Dee (2000)
Amblema plicata	Increase to 20 to 23° C	Watters and O'Dee (2000)
Glochidial survival after release		
M. margaritifera, A. anatina,	10 to 17 days at 5° C	Jansen *et al*. (2001)
A. cygnea, U. crassus, U. pictorum	2.5 to 5 days at 10 to 16° C	
A. cygnea	LC50 5 days 18° C	Jansen *et al*. (2001)
Lampsilis radiata	1% survival after 36hrs at 20° C	Tedla and Fernando (1969)
Lampsilis higginsii	0% survival after 72hrs at 25° C	Sylvester *et al.* (1984)
Glochidial release from fish		
Fish host availability and condition		see Tables 4-2 and 4-3
Lampsilis higginsii	20 to 22° C	USFWS (2004)
Newly metamorphosed juveniles		
Reduced fitness		
Increase heart rate		
U. imbecillis	Rate more than double that of adult	
	Increase 3.3x from 10° to 30°	
P. cataracta	Rate more than double that of adult	
Mortality		
Upper lethal limits		
L. fasciola, C. stegaria, D. dromas,	26 to 27° C	Mr. J. Jones (pers. comm.)
L. dolabelloides, F. cor		
Utterbackia imbecillis	30° C, <35% mortality	Dimock and Wright (1993)
	LC50 (96hrs) = 31.5°	
Pyganodon cataracta	LC50 (96hrs) = 33° C	
Young unionids (≤5 years old)		
Upper lethal limits	Not available	
Metabolic rate	Higher in Lampsilinae than Ambleminae	Baker and Hornbach (1997)
Adults		
Decreased fitness		
Metabolic rate		
	Higher in Lampsilinae than Ambleminae	Baker and Hornbach (1997)
Actinonaias ligamentina	2.5 fold increase in O_2 uptake at 25° C	Baker and Hornbach (2001)
Amblema plicata	2.9 fold increase in O_2 uptake at 25° C	Baker and Hornbach (2001)
Lampsilis siliquoidea	Rate incr. from 1.88 to 4.98 w/10° incr.	McMahon and Bogan (2001)
Pyganodon grandis	Rate incr. from 1.27 to 10.35 w/10° incr.	McMahon and Bogan (2001)
Heart rate		
Pyganodon cataracta	4.4 fold increase at 30° C	Polhill and Dimock (1996)
Utterbackia imbecillis	4 fold increase at 30° C	Polhill and Dimock (1996)
Feeding rate		
Maximum	May be an upper thermal limit	Stuart *et al.* (2000)
Optimal		
Elliptio complanata	13.5 to 18.3° C	Stuart *et al*. (2000)
Lampsilis siliquoidea	21 to 24° C	Vanderploeg *et al.* (1995)
Mortality		
Upper lethal limit		
Elliptio complanata	>33.4° C	Starkey *et al.* (2000)
Anodontoides ferussacianus	29° C	Fuller (1974)
Pyganodon grandis	>29° C	Fuller (1974)
Lampsilis siliquoidea	>29° C	Fuller (1974)

bioassessment serve as hosts for many of the unionid species in this study (Table 4-2, "Temperature effects on fish hosts of common unionid species in the study area", ESI 2005). Four of these species (freshwater drum, walleye, largemouth bass, and spotfin shiner) would be stressed at 30°C (86^0F). Drum, the host for many species, particularly Lampsilinae, and walleye, one of the hosts for *L. higginsii*, would avoid areas with water temperature over 30°C (86°F). Most Lampsilinae release glochidia during cooler water temperature, triggered by either the increase in temperature in the spring or decrease in temperature during the fall. Hosts for Ambleminae are more temperature tolerant, particularly channel catfish (Table 4-3, "Summer brooders in the study area and possible temperature effects on host availability", ESI 2005). However, largemouth bass and minnows may become stressed at 30.5°C (86.9°F) and avoid areas with water temperature >32°C (>89.6°F).

Release and development of metamorphosed juveniles is also temperature dependent. Watters and O'Dee (2000) suggest that an upper temperature threshold exists above which glochidia will fail to metamorphose, and a lower temperature threshold exists below which glochidia will not release. The duration of attachment decreases with increased temperature, until an upper thermal limit is reached at which the glochidia release but fail to metamorphose (Dudgeon and Morton, 1984 in Watters and O'Dee, 2000). The minimum temperature seems to apply to species whose glochidia over winter on their fish host (some Lampsilinae), while the upper thermal limit seems to apply to summer releasers (most Ambleminae).

Basic functions in unionids, such as metabolic rate and associated functions (heart rate, oxygen uptake rate and feeding rate), although species specific, are also controlled by temperature. Lampsilinae have a higher metabolic rate than Ambleminae (Baker and Hornbach, 1997). McMahon and Bogan (2001) found that metabolic rate increases two to ten-fold in some unionids (*L. siliquoidea* 1.88 to 4.98; *P.grandis* 1.27 to 10.35) with a 10°C (50°F) temperature increase, and neither of these species has the ability to acclimate their metabolic rate with an increase in temperature. Dimock and Wright (1993) found *Pyganodon cataracta* metabolic rate (measured as oxygen uptake) also varied directly with water temperature, but *U. imbecillis* maintained a constant oxygen uptake rate with increase in water temperature. Baker and Hornbach (2001) found that oxygen uptake for *Actinonaias ligamentina* and *A. plicata* was 2.5 and 2.9 times higher, respectively, at 25°C (77°F) than at 5 to 9°C (41 to 48.2°F). Heart rate and food clearance rate also seem to be directly related to water temperature (Pusch *et al.*, 2001).

The effect of increased water temperature on metabolic rate seems to be greater for juvenile unionids than for adults (Polhill and Dimock, 1996). Heart rate was measured as <5 beats per minute at 10°C (50°F) and 22 beats per minute at 30°C (86°F) for adult *P. cataracta*, whereas juveniles of this species had heart rates of 15 and 70 beats per minute at 10 and 30°C (50 and 86°F), respectively (Polhill and Dimock, 1996). Similar results were observed for *U. imbecillis*: adult heart rate was <5 at 10°C (50°F) and 20 beats per minute at 30°C (86°F), whereas juvenile *U. imbecillis* increased their heart rate from 20 to 50 beats per minute at the two temperatures.

I-2. Temperature effects on fish hosts of common unionid species in the study area.

	FW Drum	Walleye	LM Bass	C. Catfish	Spotfin sh.
Host for unionid species[1]					
Ambleminae					
Amblema plicata	-	-	x	-	-
Megalonaias nervosa	x	-	x	x	-
Quadrula nodulata	-	-	x	x	-
Quadrula p. pustulosa	-	-	-	x	-
Truncilla donaciformis	x	-	-	-	-
Anodontinae					
Arcidens confragosus	x	-	-	x	-
Lasmigona complanata	-	-	x	-	-
Pyganodon grandis	x	-	x	-	-
Utterbackia imbecillis	-	-	-	-	x
Lampsilinae					
Actinonaias ligamentina	-	-	x	-	-
Ellipsaria lineolata	x	-	-	-	-
Lampsilis cardium	-	x	x	-	-
Lampsilis higginsii	x	x	x	-	-
Leptodea fragilis	x	-	-	-	-
Ligumia recta	-	x	x	-	-
Potamilus alatus	x	-	-	-	-
Potamilus ohiensis	x	-	-	-	-
Truncilla truncata	x	-	-	-	-
Upper temperature tolerance[2]					
Preferred temperature	-	27 to 28°	27.5 to 30°	31°	28 to 30°
Temperature tolerance limits	-	29 to 30°	30.5 to 31.8°	33.6 to 34.5°	30.8 to 32.7°
25% avoidance temperature	-	-	31.5 to 32.6°	32.7 to 33.8°	31.7 to 33.5°
50% avoidance temperature	-	30.0 to 31.7°	32.6 to 33.8°	34 to 35°	32.8 to 34.6°
Upper avoidance temperature	30°	-	-	-	-
25% chronic mortality	-	32.2 to 32.7°	34.5 to 35.7°	36.3 to 37	-
50% chronic mortality	-	32.6 to 33.2°	34.7 to 36.2°	36.7 to 37.7°	-
50% acute mortality	-	32 to 33°	38°	39 to 40°	-
Habitat availability[3]					
Upstream Bed habitat	Yes	No	Yes	Yes	Yes
Steamboat Slough Bed habitat	Yes	Limited	Limited	Yes	No
Cordova Bed habitat	Yes	Yes	Yes	Yes	Yes
Temperature effects on host					
Steamboat Slough Bed (32.6 C)					
Stress	Yes	Yes	Yes	Yes	Yes
Avoidance	Yes	Yes	Yes	No	Yes
Cordova Bed (30.7° C)					
Stress	Yes	Yes	Yes	No	Yes
Avoidance	Yes	Yes	Yes	No	No

[1]OSU host fish database; http://www.biosci.ohio-state.edu/~molluscs/OSUM2/

[2]Fish temperature data at 26.7 and 29.4° C acclimation (LMS, 2004a)

[3]Based on LMS (2004a)

Table 4-3. Summer brooders in the study area and possible temperature effects on host availability.

				Temperatures during excursions[3]			
				Cordova Bed		Steamboat Slough Bed	
Species	Period of gravidity[1]	Hosts	Host tolerance[2]	30.5°	30.8°	32.1°	32.6°
A. plicata	Late May to Mid-Aug	Sunfish, bass, crappie, yellow perch white bass, shortnose gar	LM Bass	Stress	Stress	Stress, 25% avoidance	Stress, 50% avoidance
F. flava	May to August	Minnows, sunfish	LM Bass, Spotfin sh.	Stress	Stress	Stress, 25% avoidance	Stress, 50% avoidance
Q. metanevra	May to July	Sunfish, sauger	LM Bass	Stress	Stress	Stress, 25% avoidance	Stress, 50% avoidance
Q. nodulata	June to July	Sunfish, catfish	LM Bass	Stress	Stress	Stress, 25% avoidance	Stress, 50% avoidance
			C. catfish	None	None	Stress	Stress
Q. pustulosa	June to August	Catfish	C. catfish	None	None	Stress	Stress
Q. quadrula	May to August	Catfish	C. catfish	None	None	Stress	Stress

[1]Howard (1913), Baker (1928), Oesch (1984), Holland-Bartels and Kammer (1989), Howells (2000)

[2]Species in LMS (2004a) used for temperature tolerance data

[3]Minimum based on 22,500cfs model results, maximum based on 17,500cfs model results

Feeding, growth, and burrowing behavior in unionids are temperature dependent and appear affected by both a thermal minimum and maximum. Stuart *et al*. (2000) found *Elliptio complanata*'s maximum feeding rate to increase between 13.5 to 18.3°C (56.3° to 64.9°F), while Vanderploeg *et al*. (1995) found *L. siliquoidea*'s maximum feeding rate was at temperatures of 21 to 24°C (69.8 to 75.2°F). Walker *et al.* (2001) reported that Australian unionids become inactive, stop growing, and burrow into the substrate at 12° C (53.6°F), and that growth increases with temperature between 13 and 22°C (55.4 and 71.6°F). Waller *et al*. (1999) also found that unionids burrowing behavior (righting and moving) increased 8 to 10% for each degree of temperature increase from 7 to 21°C (44.6 and 69.8°F), but suspect there is a thermal maximum.

The literature suggests there are thermal minimums and maximums for unionid survival, behavior, and most stages of reproduction. Thermal minimums are reported for some species, but information is limited on thermal maximums. At some high temperature adult unionids become inactive, stop feeding, and burrow into the substrate; glochidia may not survive long enough to attach to a fish host, released glochidia fail to metamorphose, and juvenile metabolism may increase to the point that they cannot survive. Few lethal or sublethal upper temperature limits are reported in the literature. Fuller (1974) list the upper lethal temperature of *A. ferussacianus* as 29°C (84.2°F), but also mentioned this temperature was not lethal to *P. grandis* or *L. siliquoidea*. Starkey *et al*. (2000) reported a 96% survival of *Elliptio complanata* when water temperature was increased temporarily to 33.4°C (92.1°F). However, neither Fuller (1974) nor Starkey *et al*. (2000) reported the duration during which the unionids that were subjects in their studies were exposed to high temperatures. Bartsch *et al*. (2000) held adult unionids in air temperatures up to 35°C (95°F) for 15 to 60 minutes, with no apparent harmful effects. Additionally, adult unionids of most species can tightly close their valves, switch from metabolism to catabolism under stressful conditions, and remain in this state for extended time periods (Fuller, 1974). Thicker shelled species (Ambleminae) can remain closed for longer time periods, as they can more tightly close their valves (reducing exposure) and apparently have a slower metabolic rate. Once conditions are no longer stressful, unionids open their valves, start siphoning, and return to metabolism.

Juvenile unionids would be less likely to survive higher water temperatures, as they have less lipid reserves and a much higher metabolic rate. Dr. Jones (VPI, pers. comm.) reported that newly metamorphosed juveniles of *Lampsilis fasciola*, *Cyprogenia stegaria*, *Dromus dromas*, *Fusconaia cor*, and *Lexingtonia dolabelloides* experienced high rates of mortality during laboratory conditions of 26 to 27°C (78.8 to 80.6°F). Lethal limits for newly metamorphosed juvenile *U. imbecillis* and *P. cataracta* were reported in Dimock and Wright (1993). *Utterbackia imbecillis* experienced <35% mortality at 30°C (86°F), 50% mortality after 96 hours at 31.5°C (88.7°F), and 50% mortality after 48 hours at 34°C (93.2°F). *Pyganodon cataracta* experienced 50% mortality after 96 hours at 33°C (91.4°F), 46% mortality after 48 hours, and 100% mortality at 34°C (93.2°F) in 96 hours. However, both *U. imbecillis* and *P. cataracta* are Anodontinae, which are scarce in the QCS study area.

Historical Use of Excursion Hours

Excursion hours for QCS start to accumulate when the downstream river temperature exceeds the N.P.D.E.S permit limit of 89°F in July and August and 88°F in September. When these specified N.P.D.E.S permit temperature limits are exceeded, QCS starts counting excursion hours up to it presently N.P.D.E.S permit allowable 1% value (87.6 hours) of the hours in a rolling year timeframe. The 87.6 hour clock starts when the first excursion hour is used and it resets back to a full compliment of 87.6 hours one year later (i.e., rolling year clock). The history of QCS operations shows that QCS generally has been able to operate well within the Station's N.P.D.E.S. Permit limits due to the fact that the ambient temperatures of the river (measured upstream of the plant's discharge) generally remain below the non-excursion hour limits of 86°F in July and August and 85°F in September. When the ambient river temperatures begin to approach the non-excursion hour limits of 86°F in July and August and 85°F in September, the significant river flows generally are sufficient to prevent the Station from needing to utilize a significant percentage of its excursion hour allowance. As a general rule, it is only during periods when the ambient river temperatures are very close to or exceed the non-excursion hour limits or during periods of extreme low Mississippi River flows when QCS is forced to use its excursion hour allowance.

Instead of having the existing N.P.D.E.S maximum downstream temperature limits of 89°F in July, 89°F in August and 88°F in September, which is a 3°F delta-T (difference from upstream ambient river temperature and downstream river temperature) the proposed maximum downstream temperature limits that are proposed for Quad Cities Station would not exceed a 5°F delta-T, which equates to 91°F downstream in July, 91°F in August and 90°F in September.

It is important to review historical excursion hour events over the life of QCS in order to gain an understanding of both the expected frequency and duration of likely future events. Future events are more likely to be driven by climate changes as a result of global warming. The climate changes that are likely to impact Quad Cities Station in the future are higher ambient river temperatures working in combination with lower Mississippi River flows.

Looking back over time, excursion hours are accumulated anywhere from a few days to a week to two weeks when Mississippi River flows are low and ambient Mississippi River temperatures are high. The determining factors for the duration of excursion hour episodes are a change in weather patterns resulting in cooler air temperature conditions or rain, which usually impacts both Mississippi River ambient temperature and flow simultaneously. Years during which excursion hours were used include 1987, 1988, 1989, 1995, 1999, 2001, 2005, 2006 and 2007.

In 1987, 45 excursion hours were accumulated on 5 different days. The inlet temperature reached 86°F or above on 3 of the 5 days. Of the 45 hours accumulated, 31 hours were accumulated on days when the inlet temperature reached 86°F or above. The units were derated to less than 50% on two of the three days when river temperature was 86°F or

above. River flows averaged 68,000 cfs on the days excursion hours were accumulated and on the days that the units were at or near full power, the temperature rise at 500' downstream averaged 1.1°F.

In 1988, 108 excursion hours were accumulated on 10 different days. The inlet temperature reached 86°F or above on 5 of the 10 days. Of the 108 hours accumulated, 89 hours were accumulated on days when the inlet temperature reached 86°F or above. The units' derate ranged from 90 - 20% (1584 MWE total output to 1300 MWE with the majority of the time spent at 400-500 MWE total station output) on the days the temperature was 86°F or above. River flows averaged 16,000 cfs on the days hours were accumulated. The maximum temperature rise recorded in 1988 on a day that hours were accumulated was 4.3°F with a river flow of 12,500 cfs and total station output of 1336 MWE. The Station had one unit down for outage work during part of this period.

In 1989, 23 excursion hours were accumulated on 5 different days. The inlet temperature reached 86°F or above on 3 of the 5 days. Of the 23 hours accumulated, 15 hours were accumulated on days when the inlet temperature reached 86°F or above. The units were derated to 30% on the three days when river temp was $86°^{0}$F or above. River flows averaged 27,000 cfs on the days hours were accumulated. The station maximum output during the times when hours were accumulated was 1392 MWE. The maximum temperature rise recorded in 1989 on a day hours were accumulated was 2.0°F, with a river flow of 25,300 cfs and total station output of 1200 MWE.

In 1995, 7.5 excursion hours were accumulated on 2 days. The inlet temperature reached 86°F or above on both days. One unit was at full power and the other unit was shutdown when the hours were accumulated. River flows averaged 45,000 cfs on the days hours were accumulated. The maximum temperature rise recorded in 1995 on a day hours were accumulated was 0.4°F, with a river flow of 45,000 cfs and total station output of 780 MWE.

In 1999, 17 excursion hours were accumulated on 2 days. The inlet temperature reached 86°F or above on both days. Both units were at full power when the hours were accumulated. River flows averaged 94,000 cfs on the days hours were accumulated. The maximum temperature rise recorded in 1999 on a day hours were accumulated was 0.5°F, with a river flow of 94,000 cfs and total station output of 1590 MWE.

In 2001, 57 excursion hours were accumulated on 6 different days. The inlet temperature reached 86°F or above on 5 of the 6 days. Of the 57 hours accumulated, 50 hours were accumulated on days when the inlet temperature reached 86°F or above. The station was at 50% capacity on three of the 5 days when river temp was 86°F or above. River flows averaged 49,000 cfs on the days hours were accumulated. The station maximum output during the times which hours were accumulated was 1590 MWE. The maximum temperature rise recorded in 2001 on a day hours were accumulated was 1.3°F, with a river flow of 41,000 cfs and total station output of 1583 MWE.

In 2005, 42 excursion hours were accumulated on 5 different days. The inlet temperature did not exceed 86°F on any of the 5 days. Both units were at full power when the hours were accumulated. River flows averaged 36,000 cfs on the days which hours were accumulated. The maximum temperature rise recorded in 2005 on a day hours were accumulated was 2.1°F, with a river flow of 28,000 cfs and total station output of 1684 MWE.

In 2006, 222 excursion hours were accumulated on 13 different days. The inlet temperature reached 86°F or above on 4 of the 13 days. Of the 222 hours accumulated, 96 hours were accumulated on days when the inlet temperature reached 86°F or above. The units derate ranged from 0 - 50% (1824 MWE total output to 900 MWE with the majority of the time spent at 1400 MWE total station output) on the days the temperature was 86°F or above. River flows averaged 23,500 cfs on the days which hours were accumulated. The maximum temperature rise recorded in 2006 on a day hours were accumulated was 4.1°F, with a river flow of 12,700 cfs and total station output of 1430 MWE.

In 2007, 74 excursion hours were accumulated on 6 different days of the year. The inlet temperature did not exceed 86°F on any of the 6 days. Both units were at full power when the hours were accumulated. River flows averaged 21,000 cfs on the days which hours were accumulated. The maximum temperature rise recorded in 2007 on a day hours were accumulated was 3.2°F, with a river flow of 18,700 cfs and total station output of 1824 MWE.

Effect of Change In Excursion Hours

The effect of increased water temperature on unionids appears to be related to both the magnitude and duration of exposure. Based on model results (Holly *et al.*, 2004) under worst-case conditions, unionids in the Steamboat Slough Bed and Cordova Bed experience temperatures of 32.5°C (90.5°F) and 30.8° C (87.4°F), respectfully. Under the existing N.P.D.E.S. permit, unionids could be exposed to these worst-case temperatures for a maximum of 87.6 hours (up to 3.6 consecutive days) in any 12-month period. Under the requested adjusted thermal standard, exposure time could be increased to as much as 262.8 hours (11 consecutive days) per calendar year.

The Steamboat Slough Bed, which is characterized by low density, low species richness, low recruitment, lower abundance and higher minimum age of Lampsilinae, and low mortality, exists 675 m downstream of the mixing zone. The Cordova Bed, which is characterized by higher density, higher species richness, higher recruitment, higher percentage and wider age distribution of Lampsilinae, and higher mortality, occurs on the Illinois bank, over 3000 m downstream of the mixing zone. Both of these beds have been exposed to thermal discharges from QCS for about 25 years, including six periods when the plant's thermal discharge contributed to river temperatures that exceeded July and August monthly maximum standard (30°C) (86°F) by as much as 1.3°C (2.3°F). Estimated maximum water temperature and the duration of elevated temperature within the Steamboat Slough and Cordova Beds during the six excursion periods are

summarized in Table 4-4 (from Table 3-12, "Estimated maximum number of consecutive days unionids exposed to >30°C during previous excursions", March, 2005). In 1988, unionids were exposed to >30°C (>86°F) for over 25 and 40 consecutive days in the Cordova and Steamboat Slough Beds, respectively. Within the past 10 years, unionids in the Steamboat Slough Bed were exposed to temperatures up to 33.1°C (91.6°F), and <30° C (<86°F) for up to 10.5 consecutive days.

Water temperature at low flow cannot be ignored as a possible factor that could influence community characteristics, particularly in the Steamboat Slough Bed. The release of Lampsilinae and Anodontinae glochidia occurs with a decline or increase in temperature in the fall or spring. Existing temperatures or increased duration of low flow temperature should not affect glochidial release, as the increase and decrease in temperature during spring and fall will still occur (Table 4-5 from Table 5-2, "Effects of extended duration of high temperature on unionid life stages", ESI 2005). *Amblema plicata* releases glochidia at 23°C (73.4°F), and glochidia would be released well before excursion conditions occur. Additionally, *A. plicata* is the most abundant species in the Steamboat Slough Bed, suggesting a tolerance to water temperature in this bed.

Survival of glochidia after release from the female and before attaching to a host should not affect species that release in the fall or spring (most Lampsilinae and Anodontinae). However, high summer water temperature may affect survival of species that release in the early summer. Species in this study that could be affected include *A. plicata*, *F. flava*, *Q. metanevra*, *Q. nodulata*, *Q. p. pustulosa*, and *Q. quadrula*. Of these, *A. plicata* was abundant in all study area beds, and *Q. nodulata* was most abundant in the Steamboat Slough Bed. *Quadrula p. pustulosa* and *Q. quadrula* seemed slightly more abundant in the Upstream Bed, but the difference in density was not significant. Additionally, Ambleminae were more abundant in the Steamboat Slough Bed than the other two beds. Temperatures that result in mortality of glochidia presented in the literature (25°C or less) (77°F or less) suggest that even ambient summer temperature (29°C) (84.2°F) during summer would likely cause mortality to Ambleminae glochidia (see Table 4-1, "Temperature effects on unionids", ESI 2005). Thus, high summer temperatures do not seem to currently be affecting Ambleminae recruitment and an increase in duration of high summer temperature should have no additional effects on glochidial survival.

Increased excursion hours could reduce the availability of fish hosts during glochidial release or the ability of fish to carry glochidia for a sufficient period of time; (see Table 4-2, "Temperature effects on fish hosts of common unionid species in the study area", March, 2005 and Table 4-3, "Summer brooders in the study area and possible temperature effects on host availability", ESI 2005). High summer water temperature should not stress fish hosts for spring and fall releasing species. However, hosts for summer releasing species could be affected. Summer release of glochidia from the female should generally occur before high water temperature occurs. However, fish generally carry glochidia for several days to weeks (depending on water temperature) and could be carrying Ambleminae glochidia when summer water temperature is increased by thermal effluent. LMS (2004a and 2004b) indicates that largemouth bass and spotfin shiner would be stressed at water temperatures predicted to occur in the Cordova Bed during low

Table 4-4. Estimated[1] maximum number of consecutive days unionids exposed to >30° during previous excursions.

	Upstream[2] (Ambient)	Cordova	Steamboat Slough[3] Dnstrm	Steamboat Slough[3] Upstrm	Upstream (Ambient)	Cordova	Steamboat Slough Dnstrm	Steamboat Slough Upstrm
	July 28 to August 4, 1987				July 9 to August 20, 1988			
>30°	1.3	4.5	7.0	7.0	2.5	25.2	40.0	43.0
>31°	-	0.3	4.5	5.5	-	4.0	14.0	27.0
>32°	-	-	0.3	1.3	-	0.5	3.7	6.0
>33°	-	-	-	-	-	-	0.3	2.0
>34°	-	-	-	-	-	-	-	-
Max. temp. (°C)	30.8	31.7	32.5	33.0	30.8	32.7	33.6	33.8
°C > Ambient	-	0.9	1.7	2.2	-	1.9	2.8	3.0
	July 7 to July 14, 1989				July 16 to 17, 1995			
>30°	0.3	6.8	7.0	7.0	0.3	0.6	2.0	2.0
>31°	-	0.7	6.8	7.0	-	0.2	0.6	1.1
>32°	-	-	0.5	2.0	-	-	0.2	0.5
>33°	-	-	-	0.3	-	-	-	-
>34°	-	-	-	-	-	-	-	-
Max. temp. (°C)	30.2	31.6	32.6	33.0	30.7	31.5	32.5	33.0
°C > Ambient	-	1.4	2.4	2.8	-	0.8	1.8	2.3
	July 29 to August 2, 1999				July 23 to August 11, 2001			
>30°	1.8	3.3	3.9	4.0	0.5	3.0	7.0	10.5
>31°	-	1.0	2.3	3.1	-	0.3	2.8	4.5
>32°	-	-	-	0.3	-	-	0.5	0.8
>33°	-	-	-	-	-	-	-	0.3
>34°	-	-	-	-	-	-	-	-
Max. temp. (°C)	30.7	31.5	32.0	32.5	30.9	31.7	32.7	33.1
°C > Ambient	-	0.8	1.3	1.8	-	0.8	1.8	2.2

[1]Temperature data from IIHS model at 20,000 cfs

[2]Ambient temperature used for Upstream Bed

[3]Estimated at a point near the upstream and downstream ends of the Steamboat Slough Bed

Table 4-5. Effects of extended duration of high temperature on unionid life stages.

Life stage	Temperature effects
Glochidia	
Release from female	Process occurs at temps lower than those anticipated in July and August
Survival after release from female	Free glochidia would die at excursion temperatures regardless of duration
Release from fish	Process occurs before excursion Ambleminae hosts may become stressed and pre-maturely excyst glochidia Juveniles may fail to metamorphose Extended duration may increase chance of this happening
Newly metamorphosed juveniles	Juveniles highly susceptible to high temperatures due to high metabolism and low energy reserves *L. higginsii* juveniles should be beyond this stage Ambleminae juveniles may suffer additional mortality with extended excursion
Young unionids (≤5 years old)	Higher metabolism and less energy reserves due to smaller size Extended duration of high temps may increase mortality of young unionids, particularly Lampsilinae
Adults	
Decreased fitness	Higher metabolic rate along with reduced feeding rate may affect fitness of unionids, particularly Lampsilinae with higher metabolic rate and less ability to tightly close shells. Reduced fitness may lead to decline in ability to survive zebra mussel infestation, to over winter or successfully reproduce in the fall or following spring
Mortality	Increased effects of extended duration are possible, but unknown due to lack of lethal temperature limit data

summer flow and would avoid the Steamboat Slough Bed. Stressed fish may slough off glochidia (mortality), while fish avoiding high temperature would not release glochidia within the bed. Juveniles may fail to metamorphose if released prematurely or if released when water temperature is too high. Since *A. plicata* and *Q. nodulata* are more abundant in the Steamboat Slough Bed than in other beds, and abundance of other Ambleminae species did not differ among beds, the duration of high summer temperatures under the existing permit do not seem to be affecting this process.

Newly metamorphosed juveniles are highly susceptible to high water temperatures, due to their high metabolic rate and low energy reserves (Polhill and Dimock, 1996). Juveniles of Ambleminae are typically buried in the substrate, which offers a buffer against temperature fluctuation. Many Lampsilinae juveniles form long byssal threads, allowing attachment to substrate, woody debris, or other unionids. In contrast to Ambleminae, Lampsilinae may be more exposed to elevated water temperature. After shell formation, unionids have the ability to tightly close their valves and shift from metabolism to catabolism. The time period they can survive in this mode depends on ability to tightly close their valves (greater in Ambleminae than other subfamilies), metabolic rate (higher in Lampsilinae than Ambleminae), and lipid reserves (higher in animals not previously stressed and larger animals). Metabolism increases while feeding rate decreases with increased temperature (see Table 4-1, "Temperature effects on unionids", ESI 2005).

Young unionids and smaller species have less energy reserves than adults, and would experience higher stress and/or mortality during extended periods of high temperature. Lampsilinae species may be particularly susceptible due to their higher metabolism and inability to close their valves as tightly as Ambleminae. Further, as energy reserves are depleted in adults, unionids are less able to withstand winter conditions and may not be able to spawn the following spring. The effects of zebra mussel infestation may be intensified by reduced fitness. Excursion temperature during summer could affect the relative abundance and age distribution of Lampsilinae.

Recent Mussel Monitoring Program Results

2004 (1 Sampling Event)

The study area was sampled on July 13 through 16, 2004 using reconnaissance, quantitative and qualitative sampling techniques in three mussel beds (Upstream Mussel bed sampled at MRM 507 on the Iowa bank near the downstream end of Stricker Slough, Steamboat Slough Bed sampled from 675 meters to 1120 meters downstream of the mixing zone and the Cordova Mussel Bed sampled at MRM 504). Quantitative samples are necessary to estimate density, relative abundance, age structure and mortality, which are used for spatial and temporal comparisons of unionid communities for management and impact analysis. Qualitative sampling is a visual and tactile search for unionids and by design is often times biased towards large and sculptured animals.

Prior to the 2004 study, no data regarding unionids were available for the river along the Iowa bank either upstream or downstream of the mixing zone of the QCS discharge. Reconnaissance dives suggested patches of unionids occur from the mixing zone upstream to at least the small island riverward of Adams Island, approximately 1545 m upstream of the mixing zone. The area selected for sampling in the Upstream Bed was 730 m to 1130 m upstream of the mixing zone and 45 to 115 m from the bank. The Upstream Bed was moderately species rich. A total of 902 unionids of 21 species were found during quantitative and qualitative sampling. The most abundant species found in the Upstream Bed were *Obliquaria reflexa* (38.1%), *Amblema plicata* (17.5%) and *Q. p. pustulosa* (8.2%). Despite the density and species richness of unionids in the Upstream Bed, no *L. higginsii* were collected. The Upstream Bed substrate was primarily sand and silt with very little gravel, and current velocity was higher both during the study and modeled at low flow. Zebra mussels were moderately abundant in the Upstream Bed during sampling and entirely encrusted a few individuals. The Illinois and Iowa threatened *E. lineolata* and Illinois threatened *L. recta* were both found in the Upstream Bed.

Prior to the 2004 mussel study, unionid data were also unavailable for the Iowa bank downstream of the mixing zone. Unionids were found downstream of the mixing zone to the upper end of Steamboat Slough Bed. Only a few unionids and few zebra mussels occurred immediately downstream of the mixing zone. Zebra mussels increased somewhat approximately 500 m downstream of the mixing zone, but unionid infestation remained mild. An area from 750 m to 1150 m downstream of the mixing zone was selected for sampling. Dives revealed that this bed was very patchy. There was a lack of substrate heterogeneity in the Steamboat Slough Bed. Substrate was primarily sand in the Steamboat Slough Bed. Silt was present in most samples, along with a minor amount of clay. More unionids, more species, and more young unionids were found in areas with gravel and/or cobble mixed in with the sand. Most of the species in the Steamboat Slough Bed were collected during the 2004 mussel study. Species richness seemed lower in the Steamboat Slough Bed, as only 15 species were found. Most notably the Steamboat Slough Bed was characterized by higher Ambleminae abundance and a paucity of Lampsilinae species. In the Steamboat Slough Bed over 40% of the unionids in quantitative samples were *A. plicata*, compared to <30% in the Upstream Bed and Cordova Bed. *Ellipsaria lineolata* (threatened in Illinois and Iowa) was the only threatened and endangered species found in the Steamboat Slough Bed. No *L. higginsii* were found in the Steamboat Slough Bed in 2004. They are less likely to occur in this bed than in the Upstream Bed due to the lack of gravel and cobble in the substrate, lack of host habitat, lower unionid density, and lower unionid species richness.

The Cordova Bed is between 0 to 100 m from the bank at the downstream end and 0 to 40 m from the bank at the upstream end, and is 3000 m to 3400 m downstream of the mixing zone.). Substrate was a heterogeneous mixture throughout, consisting of at least two or three constituents at all sampled points. Boulder, cobble, gravel, and shells (both zebra mussel and unionid) comprised a higher percentage of the substrate than in the Upstream and Steamboat Slough Mussel Beds. Almost all unionids were encrusted with layers of zebra mussels. Many juvenile unionids and snails were completely encased. A

total of 320 unionids representing 20 species were collected in the Cordova Bed. Most of the species collected during quantitative sampling (53.8%) were represented by individuals ≤5 years old (including *L. higginsii*), and five species, *A. plicata, L. fragilis, L. recta, O. reflexa,* and *Truncilla donaciformis*, were represented by individuals ≤3 years old. *Leptodea fragilis* (33.8%) was the dominant species in the Cordova Bed; it was not found in the Steamboat Slough Bed and only comprised 6% of the animals in the Upstream Bed. *Amblema plicata* (28%) was more abundant in the Cordova Bed than in the Upstream Bed, but less so than in the Steamboat Slough Bed. Threatened and endangered species were also more abundant in the Cordova Bed; eight *L. higginsii* (all adults) and 21 (one three year old and the rest adults) *L. recta* were collected. Cordova Mussel Bed river temperatures are presented in a table after the 2008 sample results.

2005 (2 Sampling Events)

In July 2005, QCS sought 100 additional excursion hours to support the plant's continued operation during a period of anticipated low flow and high ambient water temperature. Due to better than expected weather and river flow conditions, QCS did not use the additional excursion hours. Special Condition "C" of IEPA's Order granting the requested additional excursion hours required monitoring of three mussel beds (Cordova Bed, Upstream Bed, and Steamboat Slough Bed). These three mussel beds were sampled July 26, 27, and 28 and October 2 through 12, 2005 following methods used in 2004. Density, age distribution, and observed mortality were estimated from quantitative samples. Species richness was estimated from qualitative samples. Most unionids within the Steamboat Slough Bed did not seem to be affected by high July 2005 water temperatures. Community characteristics within this bed were consistent over the three monitoring events. Although unionid shells were warm to the touch, only one unionid was observed gaping and only one was collected dead with tissue (very recent mortality). Additionally, mortality did not differ from July 2004 to October 2005. Water temperatures recorded during this study in both the UP and SS beds were comparable to those calculated and measured by Quad Cities Station. Water temperature was lower than predicted by modeled values, however discharge was higher during July 2005 than the discharge used during modeling. However, Cordova Bed water temperature was predicted to be higher than the UP Bed under high ambient water temperature conditions, but measured water temperature during this study was lower than both other beds. A conclusion reached in 2005 was that the Cordova mussel bed might not be as affected by higher temperature as previously thought (ESI, 2005).

2006 Mussel Bed Monitoring (2 Sampling Events)

Cordova, Upstream (UP), and Steamboat Slough (SS) beds were sampled August 3, 4, and 5 using the same methods as in July 2005. These beds were also sampled September 20 to 25, 2006 following methods used in October 2005 to support the petition for the increase in excursion hours. Density, age distribution, and observed mortality were estimated from quantitative samples. Species richness was estimated from qualitative samples.

The high ambient water temperature and low discharge over almost a month in July/August 2006 resulted in the use of 222.25 excursion hours (2.5%) in 2006. Unionid community characteristics changed somewhat in 2006 over previous years in all three beds, which might be due to high 2006 temperature. In both the Upstream and Steamboat Slough beds, the density of Ambleminae and Lampsilinae were similar in 2006, whereas the Upstream Bed previously supported more Lampsilinae and the Steamboat Slough Bed previously supported more Ambleminae.

Some changes were noted in the subfamily Ambleminae, but changes were not as dramatic as in the Lampsilinae. In the Upstream Bed, neither overall, adult, nor freshly dead shell Ambleminae density changed with time, but young Ambleminae seem to be increasing. This increase was observed in October 2005 and continued through 2006. Percent mortality of both young and adult Ambleminae was very low (<10%). In the Steamboat Slough Bed, total, young, and adult Ambleminae density increased, then declined in September 2006 even though mortality remained consistent. In the Cordova Bed, Ambleminae density, adult density, young density, and freshly dead shell density has not changed over time. However, percent mortality increased from ≤10% in 2004 and 2005 to 12% and 18% in 2006. Most of this mortality was within the young Ambleminae, particularly in September, when young Ambleminae mortality was 36% and adult mortality was 8%.

Lampsilinae changes also occurred in 2006. In the Upstream Bed, total, young, and adult Lampsilinae density did not differ among sample dates. However the percentage of young Lampsilinae increased to 50% in August, then declined to 26% in September. Lampsilinae mortality did not differ between July 2004 and August 2006, but increased in September 2006. Percent mortality of adults was similar between August and September 2006, but young Lampsilinae mortality increase from 4.3% in August to 39.6% in September, perhaps latent mortality from the warm water conditions in July and August. The density of Lampsilinae increased in the Steamboat Slough Bed in August 2006, but declined in September 2006. Although the density of adult and young Lampsilinae did not differ significantly among sample dates, both were higher in August 2006 compared to the previous years, most of the decline in density in the Steamboat Slough density was due to decline in adult density rather than young Lampsilinae density as would be expected under warm water conditions. Young comprised 36% of the Lampsilinae in September 2006 compared to 18% in August. In the Cordova Bed, total Lampsilinae density and young unionid density declined, but the decline occurred in August and density remained consistent in September 2006. A similar decline in total and young Lampsilinae was also observed in July of 2005, perhaps latent mortality from the heavy 2004 zebra mussel infestation.

Some changes were observed, particularly in the subfamily Lampsilinae. These changes could be due to high temperatures in 2006, but effects on Lampsilinae seemed to be greater in the Upstream Bed, with respect to the increase then decline of young Lampsilinae and high mortality in young Lampsilinae. If the temperature downstream of the discharge was affecting Lampsilinae, the effect on density and mortality should be greater in the Steamboat Slough Bed. However in the Steamboat Slough Bed, the percent

young Lampsilinae increased in October 2006 and mortality was only slightly higher than in previous years. Mortality of adult and young Ambleminae was similar. Young Lampsilinae also declined in the Cordova Bed, but the decline in 2006 was not as great as was seen in July 2005 after heavy zebra mussel infestation.

Threatened and endangered species did not seem affected by the warm temperature in July/August 2006. *Lampsilis higginsii* were alive in both the Cordova and Upstream beds. *Ellipsaria lineolata* and *L. recta* were also in the Cordova and Upstream beds. However, one freshly dead *E. lineolata* shell was in the Upstream Bed, and two were found in the Cordova Bed. Two fresh shells of *L. recta* were in the Cordova Bed. No fresh shells of T&E species were in the Steamboat Slough Bed, but live *L. recta* were collected. Additionally, one live *Pleurobema sintoxia*, endangered in Iowa, was collected from the Steamboat Slough Bed. No live or shells of *E. lineolata* have been collected from the Steamboat Slough Bed since July 2005.

2007 Mussel Bed Monitoring (2 Sampling Events)

Ecological Specialists, Inc. (ESI) sampled five unionid beds upstream and six downstream of the QCS between June 21 and 26, 2007. The objectives of sampling were to define the indigenous unionid community between RM 493 and 418 of the Upper Mississippi River and select two beds upstream and one bed downstream for more intensive community characterization.

The high ambient water temperature and low river flows over almost a month in July/August 2006 resulted in the use of 222.75 excursion hours in 2006. Although July and August water temperatures in 2007 were high, they never reached 2006 levels and only 74 excursion hours were used in 2007. Unusually high discharges occurred in mid-August 2007 that reduced water temperatures. Substrate temperature was similar to water temperature, and the buffering effect noted in 2006 was not observed in 2007.

Changes to unionid community characteristics were observed in all three beds in 2006 compared to prior years; however, these changes seemed to be temporary or simply due to stochastic factors. Community characteristics in October 2007 in the UP, SS, and Cordova Beds were similar to previous monitoring events. Recruitment (% young individuals) was high and mortality was low in 2007.

Three beds were added to the monitoring program in October 2007: Albany Bed, Hansons Slough Bed, and Woodwards Grove Bed. The Albany Bed shared many of the same habitat and unionid community characteristics with the Cordova Bed. Both of these beds appear to have been heavily affected by zebra mussel infestation, species composition was similar, and species richness higher than other beds. *Ligumia recta* and *L. higginsii* were fairly common in both beds. The Hansons Slough Bed shares some habitat and community characteristics with both the SS and UP beds. The bed is within a slough and dike field similar to the SS Bed, but substrate is more fine sand similar to the UP bed. Zebra mussel infestation was also apparent within this bed, but shells were not a major substrate constituent. Ambleminae dominated the community, and the percentage

young Ambleminae was high and Lampsilinae low similar to the SS Bed, but *Q. p. pustulosa* rather than *A. plicata* was the dominant species. Density was high in the Hansons Slough Bed and *L. higginsii* were present, similar to the UP bed. The Woodwards Grove Bed, downstream of QCS, differed in substrate (mostly silt and clay) and shared some community characteristics with the other beds.

2008 Mussel Bed Monitoring (1 Sampling Event)

The Albany, Hanson Slough, Upstream, Steamboat Slough, Cordova, and Woodwards Grove beds were sampled between October 4 to 14, 2007 and August 17 to 25, 2008, using the same methods ESI used in October 2005 and September 2006 (ESI, 2007). Density, age distribution, and observed mortality were estimated using quantitative sampling methods. Species richness was estimated from qualitative samples. The extent of infestation by zebra mussels (*Dreissena polymorpha*) in the beds was also observed and recorded during monitoring events.

The high ambient water temperature and low river flows over almost a month in July/August 2006 resulted in the use of 222.75 excursion hours in 2006. Although July and August water temperatures in 2007 were high, they never reached 2006 levels and only 74.00 excursion hours were used in 2007. Unusually high discharges occurred in mid-August 2007 that reduced water temperatures. Substrate temperature was similar to water temperature in 2007, and the buffering effect noted in 2006 was not observed in 2007. High flows (>200,000 cfs) occurred within Pool 14 in early 2008. Water temperature and substrate temperature within the monitored mussel beds remained fairly low throughout the summer. The high spring flow did affect substrate characteristics at least in the SS Bed, where sand peaks and silt valleys were observed in the downstream portions of the sampled area, and perhaps in the WG Bed, where a sandy, deep channel bisected the bed in 2008. Flow was fairly low during the August sampling (27,000 to 33,500 cfs), but did not fall to the levels observed in August of 2006 and 2007 (<20,000cfs). No excursion hours were used in 2008, and some current velocity was present at sample points in all beds except the Cordova Bed. The area within 10 to 20m of the Cordova Bed was covered with a heavy algae mat, which was not observed in other monitoring years.

Changes to unionid community characteristics were observed in all three beds in 2006 compared to prior years. However, these changes seemed to be temporary or simply due to stochastic factors. Community characteristics in October 2007 and August 2008 in the UP, SS, and Cordova beds were similar to previous monitoring events. In 2007 and 2008, recruitment (% young individuals) was high and mortality was low. Total density of live unionids fluctuated among monitoring events, but no increasing or decreasing trends were apparent. Increased mortality was observed in the UP and Cordova beds in 2006, but declined to pre-2006 levels in 2007 and 2008. Density of both live Ambleminae and Lampsilinae has similarly fluctuated over time. Most of the increase in 2006 mortality, particularly in the UP Bed, was due to mortality of Lampsilinae, which was most apparent upstream of the QCS.

The monitoring program added three beds in October 2007: Albany Bed, HS Bed, and WG Bed. The Albany Bed shared many of the same habitat and unionid community characteristics with the Cordova Bed in both 2007 and 2008. Both of these beds appear to have been heavily affected by zebra mussel infestation, species composition was similar, and species richness higher than in other beds. *Ligumia recta* and *L. higginsii* were fairly common in both beds. The HS Bed shares some habitat and community characteristics with both the SS and UP beds. The bed is within a slough and dike field similar to the SS Bed, but substrate consisted more of fine sand similar to the UP Bed. Zebra mussel infestation was also apparent within this bed in 2007, but shells were not a major substrate constituent. However, zebra mussel infestation in the HS and SS beds was much lower than within other beds in 2008. Similar to the SS Bed, Ambleminae dominated the community, and the percentage of young Ambleminae was high and Lampsilinae low in the HS Bed, but *Q. p. pustulosa* rather than *A. plicata* was the dominant species. Similar to the UP Bed, density was high in the HS Bed and *L. higginsii* were present. The WG Bed, downstream of QCS, differed in substrate (mostly silt and clay) but shared some community characteristics with the other beds. Adding these beds to the 2007 and 2008 study expanded the knowledge base for comparisons of mussel bed and community characteristics upstream and downstream of the QCS diffuser, and strengthen the conclusions that can be drawn from such comparisons in evaluating the impacts, if any, on the mussel beds and communities associated with the plant's discharges.

The 2007 and 2008 studies show that community characteristics within unionid beds sampled in this study do not seem to be significantly affected by the QCS thermal effluent, including the increased river temperatures experienced during the Summer of 2006, at least in the short-term. Unionid beds downstream of the QCS exhibited similarities and differences in habitat and unionid community characteristics with unionid beds upstream of the QCS. Increased mortality noted in some beds in 2006 was not observed in 2007 or 2008 and did not appear to affect unionid density either upstream or downstream of the QCS.

Comparison of Cordova Bed habitat conditions between July 2004 and August 2008

	Jul-04	Jul-05	Oct-05	Aug-06	Sept-06	Oct-07	Aug-08
Average Temperature (F)	77.5	77.5	65.5	87.3	64.2	60.9	78.3
range	73.4 to 79.3	73.4 to 80.2	54.0 to 67.1	85.6 to 89.1	63.9 to 65.3	60.9 to 61.7	77.0 to 79.9
% saturation	73.1	-	88.2	87.5	82.4	85.1	114.8
average	6.0	-	8.3	8.5	7.8	8.4	9.3
Velocity (m/sec.)	0.2	0.2	0.2	<0.1	<0.1	0.2	<0.1
range	<0.1 to 0.4	<0.1 to 0.3	<0.1 to 0.5	0 to 0.2	<0.1 to 0.1	(0 to 0.4)	(0 to 0.1)

[a] from ESI 2009

4.1.2 Maintenance Dredging

Dredging permit (CEMVR-OD-P-2006-1856) allows dredging within a 500' x 700' area in front of the station's forebay. QCS does not expect to increase the size of the dredging area. QCS anticipates dredging will be necessary in the near future and consequently this activity is being included in this HCP. No direct impacts are anticipated to either of the listed species addressed in this HCP. This activity is listed for the sole reason of potential interactions that could occur. In the event that dredging does occur, the result could be the mortality of the few unionids that reside in the area. Survey results showed that no listed species were found within the dredging area. Maintenance dredging areas are typically highly disturbed and are not quality areas for these species. The current habitat is highly disturbed sand and/or sand & silt, which are not typically preferred habitats. As experienced in 2008, several feet of sand can be deposited within this area in a single high water event. However, due to the close proximity of mussel beds containing listed species, it is possible such an individual could occur at this site that would be impacted by dredging. Dredging will cause the deepening of the habitat, but should remain sand based. The recent frequency of dredging has occurred every other year. Mitigation measures will be deployed as described in Section 5.4.

4.1.3 Removal of Edison Pier

Anticipated impacts to either of the listed species are expected to be minimal to none. This activity is listed for the sole reason of potential interactions that could occur. In the event that it did occur, the result would be the mortality of a few unionids that may reside in the area. The habitat around the pier is shallow mud flat with some flowing water on the point of the pier. Shallow macrophyte beds have become established in the shoreline corners of the upstream and downstream sides. The dredging survey went upstream to the pier, but did not encompass the entire pier. It is anticipated that removing the pier will also reduce the frequency of dredging in front of the intake bay.

4.2. Indirect Impacts

4.2.1 ATS

Effects on Host Fish

QCS operations under an alternative thermal standard will not result in any impacts on host availability for Higgins eye mussel. Fish studies using several different gears were conducted directly over the mussel beds. These studies yielded results consistent with those observed during the long-term monitoring program at adjacent sites. The proposed change in the temperature standard occurs at a temperature level where spawning activity for Higgins eye mussel is minimal or absent, yet the host fish (freshwater drum, walleye, largemouth bass, channel catfish, and spotfin shiner) are still available if the mussel releases glochidia. It is not expected that the change in thermal standard will have an effect on host fish availability.

Water Quality

QCS has taken dissolved oxygen measurements as part of the long-term fisheries biological monitoring program and in all cases oxygen concentrations have been near or above expected saturation levels. The same holds true for oxygen concentrations taken as part of the mussel monitoring program. The water quality monitoring that is ongoing for both the Long Term Fisheries and Mussel Monitoring Programs has not indicated any water quality issues that require special attention. Long-term temperature monitoring will be included as part of this program.

4.2.2 Maintenance Dredging

Effects on Host Fish

Maintenance dredging at QCS will not result in any impacts on host availability for either species. The dredging will expand available deep-water habitat, which may have a positive effect for fish.

Water Quality

Maintenance dredging at QCS will not result in any water quality issues that may impact either mussel or their host fish. Standard dredging practices minimize the effects to the both local and downstream habitats.

4.2.3 Removal of Edison Pier

Effects on Host Fish

Removal of Edison Pier at QCS will not result in any impacts on host availability for either species. The current macrophyte beds around the pier do hold some fish, but adequate habitats are readily available above and below the pier.

Water Quality

Removal of Edison Pier at QCS will not result in any water quality issues that may impact either mussel or their host fish. Standard techniques and guidelines to limit siltation will be used in accordance with the USACE permit.

4.3 Anticipated Take

4.3.1 ATS

The effect of high water temperature on unionids appears to be related to both the magnitude and duration of exposure, and acclimation. Based on model results (Holly *et al.*, 2004) under worst-case conditions, unionids in the Steamboat Slough Bed and Cordova Bed experience temperatures of 32.5°C (90.5°F) and 30.8°C (87.4°F),

respectfully. During past excursions, unionids in the Steamboat Slough Bed and Cordova Bed were exposed to temperatures 1.3 to 3.0°C (2.3 to 4.8°F) and 0.8 to 1.9°C (1.4 to 3.4°F) greater than ambient, respectively. Under the existing N.P.D.E.S. permit, unionids could be exposed to these worst-case temperatures for a maximum of 87.6 hours (up to 3.6 consecutive days) in any 12-month period. Under the requested adjusted thermal standard, exposure time could be increased to as much as 262.8 hours (11 consecutive days) per calendar year.

Water temperature at low flow cannot be ignored as a possible factor influencing community characteristics, particularly in the Steamboat Slough Bed. The release of Lampsilinae and Anodontinae glochidia occurs with a decline or increase in temperature in the fall or spring. Existing temperatures or increased duration of low flow temperature should not affect glochidial release, as the increase and decrease in temperature during spring and fall will still occur (Table 5-2, "Effects of extended duration of high temperature on unionid life stages", ESI 2005). *Amblema plicata* releases glochidia at 23°C (73.4°F), and glochidia would be released well before excursion conditions occur under normal conditions. Additionally, *A. plicata* is the most abundant species in the Steamboat Slough Bed, suggesting a tolerance to water temperature in this bed.

Increased excursion hours could reduce the availability of fish hosts during glochidial release or the ability of fish to carry glochidia for a sufficient period of time (see Table 4-2, "Temperature effects on fish hosts of common unionid species in the study area", March, 2005 and Table 4-3, "Summer brooders in the study area and possible temperature effects on host availability", ESI 2005). High summer water temperature should not stress fish hosts for spring and fall releasing species. However, hosts for summer releasing species could be affected. Summer release of glochidia from the female should occur before high water temperature occurs. However, fish generally carry glochidia for several days to weeks (depending on water temperature) and could be carrying Ambleminae glochidia when summer water temperature is increased by thermal effluent. LMS (2004a and 2004b) indicates that largemouth bass and spotfin shiner would be stressed at water temperatures predicted to occur in the Cordova Bed during low summer flow and would avoid the Steamboat Slough Bed. Stressed fish may slough off glochidia (mortality), while fish avoiding high temperature would not release glochidia within the bed. Juveniles may fail to metamorphose if released prematurely or if released when water temperature is too high. Since *A. plicata* and *Q. nodulata* are more abundant in the Steamboat Slough Bed than in other beds, and abundance of other Ambleminae species did not differ among beds, the duration of high summer temperatures under the existing permit do not seem to be affecting this process.

Newly metamorphosed juveniles are highly susceptible to high water temperatures, due to their high metabolic rate and low energy reserves (Polhill and Dimock, 1996). Juveniles of Ambleminae are typically buried in the substrate, which offers a buffer against temperature fluctuation. Many Lampsilinae juveniles form long byssal threads, allowing attachment to substrate, woody debris, or other unionids. In contrast to Ambleminae, Lampsilinae may be more exposed to elevated water temperature. After shell formation, unionids have the ability to tightly close their valves and shift from

metabolism to catabolism. The time period they can survive in this mode depends on ability to tightly close their valves (greater in Ambleminae than other subfamilies), metabolic rate (higher in Lampsilinae than Ambleminae), and lipid reserves (higher in animals not previously stressed and larger animals). Metabolism increases while feeding rate decreases with increased temperature (see Table 4-1, "Temperature effects on unionids", ESI 2005). Young unionids and smaller species have less energy reserves than adults, and would experience higher stress and/or mortality during extended periods of high temperature. Lampsilinae species may be particularly susceptible due to their higher metabolism and inability to close their valves as tightly as Ambleminae. Further, as energy reserves are depleted in adults, unionids are less able to withstand winter conditions and may not be able to spawn the following spring. The effects of zebra mussel infestation may be intensified by reduced fitness. Excursion temperature during summer could affect the relative abundance and age distribution of Lampsilinae.

Unionid communities are influenced by the interaction of numerous physical, chemical, and biological factors. Unionid metrics in the Upstream, Steamboat Slough and Cordova mussel beds correlated with distance from the bank (abundance and recruitment), depth (abundance), current velocity at the time of sampling (recruitment), and low flow temperature (species richness). Species relative abundance within samples correlated with distance from the bank, temperature at the time of sampling, and percentage of sand in the substrate.

Other factors contributing to the characteristics of unionid communities in the study area include zebra mussel infestation (Schloesser and Kovalak, 1991; Hunter and Bailey, 1992; Haag *et al*., 1993; Nalepa *et al*., 1996; Ricciardi *et al*., 1996; Schloesser *et al*., 1996; Strayer and Smith, 1996), host fish availability (Watters, 1997; Haag and Warren, 1998), substrate characteristics (Cvancara, 1970; Strayer and Ralley, 1991), and shear stress (Layzer and Madison, 1995; Feminella and Gangloff, 2001; Hardison and Layzer, 2001.

Conclusions

QCS, operating under the proposed alternative thermal standard, is not expected to take adult Higgins eye or Sheepnose mussels. Downstream mussel beds are expected to experience periods of thermal stress during the summer that are similar (though potentially to a higher degree) to that which has occurred since the change in operations at QCS in 1984. The anticipated take for the ATS is one-year class during extreme events (estimated occurrence of once every five years) by potential reduced recruitment. These levels of take are not expected to rise above natural fluctuations of the population as can be readily detected by customary monitoring methods such as used by QCS. The reduced recruitment would be due to vulnerabilities of juveniles and host fish to warm water stresses, as described above. Take will be monitored by an ongoing mussel monitoring program (Appendix B) that began in 2004 and continues today. This program compares all the local beds to each other above and below QCS.

The biological evidence collected from the 2004 through 2007 mussel monitoring program supports that the balanced indigenous mussel community in the study area is not likely to be impacted by the additional excursion hours being requested. In particular, the biological monitoring study results from the last four years of mussel bed monitoring, which has included the highest amount of excursion hours ever used (222.25 excursion hours in 2006), has produced no documented instances of acute mussel mortality due to the additional thermal inputs into the downstream mussel beds, based on mussel monitoring evidence that upstream beds incurred higher mortality in 2006 than the downstream beds. Unionid beds downstream of the QCS exhibited similarities and differences in habitat and unionid community characteristics with unionid beds upstream of the QCS. Increased mortality noted in some beds (both upstream and downstream) in 2006, was not observed in 2007 and did not appear to affect unionid density either upstream or downstream of the QCS.

QCS is going to continue the mussel monitoring program to verify the results of the previous surveys and to monitor take. If it is found that take is occurring at levels in excess of the values described above due to the ATS, then appropriate mitigation measures will be employed, in concert with those being conducted for the other activities described in this HCP, using the adaptive management principles described in Section 5.5, and consultation for this HCP with the Service will be reinitiated.

4.3.2 Maintenance Dredging

Take is not anticipated in conjunction with maintenance dredging activities because the mussel survey conducted prior to receiving the current dredging permit indicated no viable mussel bed existed in the project area. However, if an individual mussel were to migrate into the area immediately prior to dredging, take would occur and it could be lethal. Therefore, this activity is included in the HCP. It is assumed that a lethal take of no more than 2 individuals per dredging event (i.e., a worst case scenario) averaged over a five year period could occur. This number was selected as the potential may exist for mussels to migrate through the area, or be sloughed off host fish prior to or at the time of the maintenance dredging. Future habitats in this area should remain consistently non-preferred due to the high degree of disturbance and frequency of dredging events. Monitoring from the ATS program will suffice for oversight of this project.

4.3.3 Removal of Edison Pier

No take is anticipated as a result of this one-time activity. However, due to the proximity of the Cordova Bed and other local beds, and because previous mussel surveys only encompassed the lower end of Edison pier (no listed species were found), it is assumeda take may occur of up to 2 individuals (worst case scenario). Avoidance and minimization measures will be used prior to and during this activity. The number of covered species that could be taken was derived from a potential for listed mussels to migrate through the area near the time of pier removal or be sloughed off host fish. The major habitat surrounding the pier is shallow mud and dense macrophytes, which are not conducive for either of the covered species. Monitoring from the ATS program will suffice for

oversight of this project. Standard techniques and guidelines to limit siltation will be used in accordance with the USACE permit.

4.4 Cumulative Impacts

Cumulative effects in biological opinions are effects of future State, Tribal, local, or private actions, not involving Federal action, reasonably certain to occur in the action area and [50 CFR 402.14 (g)(3) and (4)] would be considered in the Biological Opinion by U.S. Fish and Wildlife Service. Future Federal actions that are unrelated to the proposed action are not considered in this section because they will undergo separate consultation pursuant to Section 7 of the Act.

It is well documented that threats to mussels over time are the same as those impacting all freshwater riverine species: siltation, chemical pollution, impoundments, in-stream disturbances (gravel mining, dock construction, dredging, river channelization, etc.), and most notably competition from exotic species such as zebra mussels. To date, a total of eight mussel surveys (July 2004, July 2005, October 2005, August 2006, September 2006, June 2007, October 2007, August 2008) have been conducted in the Mississippi River near Quad Cities Station. Since July 2004, when the Quad Cities Station Mussel Monitoring Program began, which has included time periods of both drought and elevated water temperatures, mussel community parameters have not changed. The actual impacts that may or may not be occurring over time at a particular mussel bed, which is described in this Habitat Conservation Plan can only be determined through implementation of a long-term mussel monitoring program similar to what has been in place for the past 25 years with regard to the fisheries monitoring program for Quad Cities Station. .

Residential, industrial, and recreational uses will likely continue on the Upper Mississippi River and may change habitat conditions for Higgins' eye. Other than these normal and expected uses, there are no known projects that are reasonably certain to occur in the action area that will produce cumulative effects.

5.0 CONSERVATION PROGRAM/MEASURES TO MINIMIZE AND MITIGATE IMPACTS

5.1 Biological Goals

The primary biological goal of this HCP is to support state and federal agency efforts to recover and conserve the Higgins eye pearlymussel and sheepnose mussel.

Appendix A, Lampsilis higginsi Recovery Plan, contains recovery goals and recovery criteria for the Higgins eye pearlymussel and a narrative outline for proposed recovery activities. Information on the sheepnose mussel was obtained from the Status Assessment Report for the sheepnose mussel (U.S. Fish and Wildlife Service Regions 3, 4, and 5) can be found at http://www.fws.gov/midwest/Endangered/clams/sheepnose-sa.pdf.

Guiding Principles

1. Avoid, minimize, and fully mitigate adverse effects of covered activities on covered species. Where practicable, the QCS will utilize avoidance and minimization measures before employing mitigation measures.

2. Monitor HCP compliance and project-specific impacts, as well as report on progress towards meeting the biological goal.

3. Utilize adaptive management, where appropriate, so information gathered during monitoring can be incorporated into avoidance, minimization, or mitigation measures.

4. Ensure that the conservation measures are consistent with species conservation and recovery objectives.

5.2 Biological Objectives

1. Maintain diversity and species composition to retain Essential Habitat Area characteristics and guidelines for the Cordova bed.

2. Enhance recruitment of Higgins eye pearlymussels at the Cordova bed and select sites.
    a. Work to ensure habitat characteristics at Cordova bed (and potentially other sites) are conducive to Higgins eye pearlymussel viability.
    b. Augument/reintroduce Higgins eye pearlymussels as needed and with regard to native genetic characteristics in consultation with the USFWS.

3. Enhance recruitment of Sheepnose mussels at select sites
    a. Work to ensure habitat characteristics at the Cordova bed (and potentially other sites) are conducive to sheepnose mussel viability.
    b. Augument/reintroduce sheepnose mussels as needed and with regard to native genetic characteristics in consultation with the Service.

5.3 Measures to Minimize Impacts

Since some impacts cannot be fully avoided, QCS will utilize the following minimization measures when implementing the activities covered in this HCP.

5.3.1 ATS

5.3.1.1 Continue Diffuser Operations

QCS utilizes a diffuser pipe system consisting of two 16-foot diameter pipes that are buried in the Mississippi River bed. One pipe extends practically across the river, while the second pipe terminates about 300 feet before the end of the first pipe. Each diffuser pipe is fitted with 20 discharge risers of 36-inches in diameter spaced at 19 feet 8 inches in the deep portion of the river, and 14 discharge risers (nine of which are presently closed) of 24-inches in diameter spaced at 78 feet 8 inch intervals in the shallow region of the river. This diffuser has been operated in its current capacity since 1984. Quad Cities Station has no plans to change the design or configuration of the installed diffusers. The location of the open discharge risers avoids direct impacts to the Cordova mussel bed and instead directs the mixing zone down the main channel and Steamboat Slough. Neither Higgins eye or sheepnose mussel are established in the Steamboat Slough bed, though two Higgins eye mussels were recently (August, 2008) found in the downstream portion of the monitoring area.

5.3.1.2 Monitoring populations and habitat conditions

A monitoring program will be developed and implemented to evaluate ATS effects on covered species population levels and habitat conditions, including temperature-induced effects and long-term viability of augmented and reintroduced Higgins Eye, Sheepnose and other rare mussel populations. Monitoring will include a temperature monitoring program (estimated at $1,000 annually) at the established Upstream, Steamboat Slough and Cordova mussel beds such that substrate, mid-depth and near-surface water temperatures will be measured as field conditions allow, but in particular during excursion hour periods. In addition, a mussel population monitoring program will be implemented as described in Section 5.5. The monitoring sites are identified via GPS and coordinated between the site biologist and the bed monitoring team (ESI), essentially giving a fixed-point sample.

QCS will attend the annual Mussel Coordination Team Meeting each year to share monitoring information with partners. The QCS will include a temperature focus in its monitoring, and will facilitate temperature effects studies that may make use of lab-reared animals, lab facilities at QCS and/or in-situ experiments. QCS will network with area agencies and universities to promote such studies.

5.3.2 Maintenance Dredging

Surveys

A survey will be conducted prior to permit renewal or area expansion of maintenance dredging to determine the presence/absence of mussels. The current permit (CEMVR-OD-P-2006-1856) is valid until 2016. Additional dredging details can be found in section 3.2.2. The surveys must involve the most intensive and effective survey methods currently available, since sheepnose mussels occur in low numbers and may be missed even by surveys conducted using otherwise acceptable survey techniques. If a survey concludes that either Higgins eye and/or sheepnose mussels are present in the project area, they will be captured and relocated out of the project area into suitable habitat.

Relocation of Mussels

Relocation of a mussel community is often used to minimize the impact of specific development-related projects (e.g., dredging, mooring cells, etc.) on important mussel resources. This technique, however, may provide limited benefit for overall species conservation and recovery. Further, failed relocation attempts have resulted in increased mortality of both relocated and resident populations in some circumstances. However, ESI has developed relocation techniques that have resulted in minimal mortality (no more than observed in the native community; Dunn et.al.,2000). QCS will relocate all known covered species out of the maintenance dredging impact zone to a suitable area following the best available protocols.

Prior to relocating mussels, biological, ecological, and habitat characterization parameters will be followed to determine if a relocation site will be suitable for reintroduction. These will include habitat suitability, substrate stability, presence of host fishes, potential site threats, and any other limiting factors that might decrease the likelihood of long-term benefits from population reintroduction efforts. Relocation activities will not be conducted at unprotected sites or at sites with significant uncontrollable threats.

Following relocation, those mussels will be monitored to evaluate species survival, adequacy of handling techniques (acute and delayed mortality), and recolonization of the area. An inventory of all relocated mussels will be provided to the USFWS.

Exotic Species

All equipment used in maintenance dredging activities will be cleaned following established guidelines to remove zebra mussels (and other potential exotic or invasive species). It is important to follow these guidelines even if work is not occurring in the immediate vicinity of listed species since once introduced into a watershed, an invasive species may eventually affect the listed species.

5.3.3 Edison Pier Removal

Surveys

A survey will be conducted within a month prior to removal of the Edison Pier to determine the presence/absence of mussels. The survey must involve the most intensive and effective survey methods currently available, since sheepnose mussels occur in low numbers and may be missed even by surveys conducted using otherwise acceptable survey techniques. If a survey concludes that either Higgins eye and/or sheepnose mussels are present in the project area, they will be captured and relocated out of the project effect area into suitable habitat at the time of the survey.

Relocation of Mussels

Relocation of a mussel community is often used to minimize the impact of specific development-related projects (e.g., dredging, mooring cells, etc.) on important mussel resources. This technique, however, may provide limited benefit for overall species conservation and recovery. Further, failed relocation attempts have resulted in increased mortality of both relocated and resident populations in some circumstances. However, ESI has developed relocation techniques that have resulted in minimal mortality (no more than observed in the native community; Dunn *et. al*. 2000) QCS will relocate all known covered species out of an impact zone of a project to a suitable area immediately upstream of the impact zone (if available) following the best available protocols.

Prior to relocating mussels, biological, ecological, and habitat characterization parameters will be followed to determine if a relocation site will be suitable for reintroduction. These will include habitat suitability, substrate stability, presence of host fishes, potential site threats, and any other limiting factor that might decrease the likelihood of long-term benefits from population reintroduction efforts. Relocation activities will not be conducted at unprotected sites or at sites with significant uncontrollable threats and will be coordinated with the USFWS.

Following relocation, those mussels will be monitored to evaluate species survival, adequacy of handling techniques (acute and delayed mortality), and recolonization of the area. An inventory of all relocated mussels will be provided to the FWS.

Exotic Species

All equipment used will be cleaned following established guidelines to remove zebra mussels (and other potential exotic or invasive species). It is important to follow these guidelines even if work is not occurring in the immediate vicinity of listed species since once introduced into a watershed, an invasive species may eventually affect the listed species.

Contaminants

Staging areas for equipment, fuel, materials, and personnel will be kept at least 300 feet from the waterway to reduce the potential for sediment and hazardous spills entering the waterway. Ensure fill material is free from contaminants.

5.4 Measures to Mitigate Unavoidable Impacts

5.4.1 Fish Propagation at the QCS for infestation with Higgins Eye Pearly Mussel and Sheepnose Mussel Glochidia

Through a research grant to the Fishery Research Laboratory, Southern Illinois University, the spray canal at QCS was converted into a game fish rearing facility in 1984 and this project remains vitally active today. The intent of the project is to determine how the cooling canal can best be operated for the production of large numbers of game fish fingerlings and to evaluate whether stocking of these fingerlings into the Mississippi River can improve and enhance the existing sport fishery. One of the species selected for the project is walleye. This species was selected under the guidance of the Illinois and Iowa Departments of Natural Resources. Thus far, the project has been very successful both in terms of suitability as an aquaculture facility and as a management tool for increasing game fish abundance in several of the Mississippi River's navigation pools. Since 1985, over 3.2 million walleye advanced fingerlings have been stocked directly into Pool 14 (Heidinger and Bergerhouse, 2007). A substantial percentage of these fish have been released at the downstream end of the essential habitat designated in the Higgins Eye Recovery Plan, located at Cordova, Illinois. These fish may have indirectly aided in the reproduction of the Higgin's Eye mussel by making large numbers of potential hosts available to the gravid females.

As a result of the QCS fish stocking program, there is an abundance of fingerling walleye available as host for artificial glochidia infection for mussel species such as Higgins eye. As part of this HCP, Exelon will expand the QCS fish stocking program (see section 5.4.2.2) to promote Higgins Eye Mussel propagation and recovery in coordination with the USFWS and with regard to local genetic characteristics. These activities for Higgins eyes will be conducted in concert with the activities and guidelines set forth in the Higgins Eye Pearlymussel Recovery Plan: First Revision (USFWS, 2004). Coordination between USFWS, IADNR, ILDNR, USACE and Exelon will be instrumental to the success of this program. Particular attention will be given to the Genoa Federal Fish Hatchery Programs, which will serve as the model for the QCS Higgins Eye propagation and recovery program. Exelon fish biologist will be the Exelon contact for these activities and will coordinate with the aforementioned agencies.

Specific techniques will be determined with the guidance of the agencies, but will likely include the following measures.

a. The QCS will produce 4,000 walleye host fish per year or other specified quantities (Agency requested) specifically for Agency use in the inoculation process of Higgins

eye pearly mussel glochidia, which will be used for species augmentation and/or reintroduction efforts at sites TBD. Should the USFWS determine that such inoculation is not needed for a given year, the monetary equivalent will be donated to a fund located with the National Fish and Wildlife Foundation. For the purposes of this HCP, the value of the inoculated fish is $1.00 per fish in 2009.

b. Within 3 years, the QCS will produce 2,500 host fish per year (sp. TBD) to be available specifically for the Agencies' use in inoculation with Sheepnose mussel glochidia, or other approved rare mussel species such as those listed in Section 2.2.1.3, which will then be used for species augmentation and/or reintroduction efforts at sites TBD. Should the USFWS determine that such inoculation is not needed for a given year; the monetary equivalent will be donated to a fund located with the National Fish and Wildlife Foundation. For the purposes of this HCP, the value of the inoculated fish is $1.00 per fish in 2009.

c. When appropriate, the inoculation process, holding infected fish, and caged mussel programs will be conducted at the Quad Cities Station Fish Hatchery.

d. Consult with the Genoa National Fish Hatchery to develop mussel propagation techniques

5.4.2 QCS will work with the Service and other partners to develop parameters for determining appropriate species augmentation/reintroduction sites and rates with regard to protection of native resident genetics.

Biological, ecological, and habitat parameters need to be developed to determine if an extant population will be suitable for species augmentation. This is particularly important in habitats that may be considered marginal (e.g., where the mussels appear to be barely hanging on). Prioritized populations and potential augmentation sites for this task will be selected based on present population size, demographic composition, population trend data, potential site threats, habitat suitability, and any other limiting factor that might decrease the likelihood of long-term benefits from population augmentation efforts. Augmentation activities should not be conducted at totally unprotected sites or at sites with significant uncontrollable threats. Augmentation at the Cordova bed will approximate the species abundance and distribution determined by the baseline monitoring program and will protect the genetic integrity of the resident species such that swamping or other type of genetic malady is avoided.

5.4.3 Free Release of Fish inoculated with Higgins Eye Pearlymussel and Sheepnose Mussel Glocidia in select locations

First, because of the availability of potential hosts from the walleye hatchery program and concerns regarding the adverse impacts of zebra mussels in the Cordova Bed and Pool 14 generally, glochidia infestation at the QCS hatchery (a zebra mussel veliger free water source) and translocation of infested host fish to other locations are probable measures

that will be selected. The high survivability of walleye from the QCS hatchery has been documented from the fisheries' monitoring program for more than twenty years (HDR/LMS, 2008). Because of the proximity of the QCS fish hatchery to the Cordova Bed, gravid female Higgins eye mussels movement would be minimal, potentially reducing the stress on the mussels. This will be a deviation from the current program because walleye will be held on-site until fall and/or the following spring, whereas they are normally released into the river in early summer as two-inch fingerlings. Free release of these inoculated fish (6"-8") in the fall would be the preferred technique. Some fish could be held over until spring (9"-11") if spring free release was the preferred technique. Based on what is known of the actual life cycle of *Lampsilis higginsii*, a spring release (May/June timeframe) is recommended because this is when *Lampsilis higginsii* generally release glochidia.

QCS will develop onsite propagation technology for the Higgins eye pearlymussel. Sheepnose may be added as technology, need and habitats permit. Propagation for sheepnose mussels will be emphasized along with Higgins eye mussels providing sheepnose can be successfully artificially propagated at the QCS. If sheepnose broodstock is not available, or they cannot be successfully propagated then propagation of other rare mussels should be developed, in coordination with the USFWS. All propagation will be consistent with the best practices to protect the integrity of the species (e.g. Bowen 2004; Hoftyzer et al. 2007). By propagating significant numbers of juveniles, population augmentation and reintroduction into historical habitats in support of recovery goals will become much more feasible. We estimate the cost of transportation and free release to be $1,000 per event. The actual commitment to free release of inoculated fish will be based on documented amount and anticipated take levels.

5.4.4 Cage Culture techniques of Higgins Eye Pearlymussel and Sheepnose Mussel in select locations

Cage culture techniques could be used, but would be coordinated through the USFWS. This technique has been used in concert with the other programs. Walleye normally are not as hardy as other hosts species, which may be better candidates for the cage culture. Cage culture success is typically variable due to site conditions. The preferred method is free release. If cage culture is preferred in the future, we estimate the cost per year at $2,500. The actual commitment to cage culture will be based on documented amount and anticipated take levels.

5.5 Monitoring, Reporting and Adaptive Management

Monitoring

The ESA, under Section 10 regulations, requires that an HCP specify measures that will be taken to monitor the impacts of take resulting from project actions (50 CFR

17.22(b)(1)(iii)(B) and 50 CFR 222.22(b)(5)(iii)). Monitoring for the HCP will focus primarily on the following three monitoring objectives:

1. Determine whether the conservation measures are implemented as written.

2. Determine whether desired outcomes have resulted from implementation of the conservation measures.

3. Evaluate cause-and-effect relationships between desired outcomes resulting from implementation of the conservation measures and the animal populations that these measures are intended to benefit.

These three objectives are referred to as implementation monitoring, effectiveness monitoring, and validation monitoring, respectively.

Implementation Monitoring—Used to determine if the conservation measures specified in the HCP are being accomplished. Implementation monitoring is used to determine whether specified actions or criteria are being met.

Effectiveness Monitoring—Used to determine if the design and execution of the conservation measures are achieving the HCP goals and objectives. Every management decision is intended to achieve a given set of future conditions. Effectiveness monitoring can be used to compare existing conditions to both past and desired future conditions to describe the overall progress or success of the management activities.

Validation Monitoring—Used to determine whether data and assumptions for predicting outcomes and effects are correct. Validation monitoring seeks to verify the assumed linkages between cause and effect. Validation monitoring is long term, and will be accomplished through formal research and effectiveness monitoring projects.

Implementation Monitoring

Monitoring of covered activities and implementation of minimization measures will be accomplished by QCS personnel, as well as contract specialists, as needed. As described above, for one of the covered activities the QCS will perform pre-activity surveys. These surveys will be done either by internal experts or contract specialists who meet qualifications established by the USFWS and the QCS.

In addition to the monitoring and reporting of the implementation of the HCP, the QCS will maintain and report a running total of species impacts and compensation over the life of the permit. This documentation will be used to verify that the QCS is meeting its commitment to achieve a level of compensation that meets or exceeds the requirements of the HCP and will help ensure that the biological goals and objectives are being achieved.

Effectiveness and Validation Monitoring

1. Projects funded and carried out using the funding set aside by this HCP must be monitored and evaluated with annual reporting provided by the contractors (when applicable) to USFWS and QCS to assure biological goals of this HCP are met.

2. Propagation and Augmentation/Reintroduction of Higgins Eye Pearlymussels and Sheepnose Mussels

The effectiveness of the proposed mussel propagation and augmentation projects at the Cordova bed will be validated through the mussel bed monitoring program. In addition, genetic microsatellite markers may be used to identify stocked mussels from residents should such marker information be obtained. A few fish should be analyzed to estimate total number of glochidia infested on the walleye. This would give an estimated glochidia release. Successful glochidia development in the lab would not be applicable to field conditions, thus taking potential recruitment to the lab for analysis is not advised.

The walleye program independently is known to be very successful through the stock assessment program. It is assumed that these fingerlings will continue to have the same success and attached glochidia should have the best chances of survival that could be afforded them in the wild. By inoculating fish artificially, we maximize the effectiveness of a single contribution to the population. If the inoculating program was initiated for a mussel species, which is not as abundant as Higgins eye, then some conclusions could be made if a particular species (such as sheepnose) were to become more abundant.

a. QCS will provide funding necessary to facilitate the development of necessary monitoring protocols.

3. Mussel Bed Monitoring

Quad Cities Station established its Long Term Mussel Monitoring Program in 2004. The purpose of the mussel monitoring program is to determine the baseline unionid community characteristics within mussel beds that occur within the vicinity of QCS and to use historical data to compare mussel bed community characteristics following the implementation of alternate thermal standards for Quad Cities Station. Three mussel beds were part of the original sampling program that started in 2004: Upstream Mussel Bed located at RM 507 on the Iowa bank near the downstream end of Schricker Slough, Steamboat Slough Mussel Bed located just downstream of the mixing zone and the Cordova Mussel Bed located at RM 504. Ecological Specialists Inc. (ESI) monitored each of these unionid beds in 2004, 2005, 2006, 2007 and 2008. In 2007 and 2008, three additional mussel beds were monitored: Albany Mussel Bed, located approximately 14,000 to 14,400 meters upstream, Hansons Slough Mussel Bed, located approximately 5,000 to 5,400 meters upstream and Woodwards Grove Mussel Bed, located approximately 10,500 to 10,900 meters downstream of the diffuser. Mussel bed sampling includes both quantitative sampling, which determines density, relative abundance, age

distribution and observed mortality and qualitative sampling which determines species richness.

Sampling areas and methods will be similar to those used since the 2004 mussel monitoring effort (ESI, 2004). The study sites will specifically include the Steamboat Slough Mussel Bed, Cordova Mussel Bed, and Upstream Mussel Bed as well as three additional mussel beds (one downstream and two upstream for more intensive community characterization).

Unionid species composition and species richness will be estimated from qualitative sampling. Unionid density, age structure, and mortality will be estimated from quantitative sampling. The initial baseline conditions will be established from five consecutive years of monitoring data (2004, 2005, 2006, 2007, 2008). Metrics will be compared spatially and temporally.

Qualitative sampling will consist of 25, 5-minute samples in each bed. A diver will collect all unionids encountered (visually and tactually) during a 5-minute sampling interval. Depth, substrate, and GPS position will be recorded at each point. Unionids will be identified to species, counted, and categorized as adult or juvenile (≤5 years old for Ambleminae and <3 years for Lampsilinae and Anodontinae). Species richness will be calculated as total number of species, number of species per sample, and rarefaction richness [regression of log (cumulative individuals) vs. log (cumulative species)]. To detect differences in species richness, the slope of the regression lines and the number of species per sample will be compared among years and among sites. Principle Component Analysis (PCA) will be used to assess changes in species relative abundance among years and sites.

Quantitative sampling will consist of collecting 90 randomly located whole substrate $0.25m^2$ quadrat samples at each mussel bed. This sample size will be sufficient to detect a 25% change in mean density within a 95% confidence interval based on data collected in 2004. For each sample, a diver will excavate all substrate within a $0.25m^2$ quadrat into a 20L bucket, which will be brought to the surface and sieved through 12mm and 6mm sieves. Substrate composition will be visually assessed according to the Wentworth Scale (Wentworth, 1922). Quadrat position and depth will also be recorded for each quadrat. Live and freshly dead unionids (shiny nacre, periostracum intact, dead less than one year) will be identified to species, aged (external annuli count), and measured (length in mm). Sexually dimorphic species will be checked for gravidity. ANOVA will be used to detect changes in density due to time and site. Total density of live unionids, density of live unionids ≤5 years old, and density of live unionids >5 years old will be tested. Mortality will be calculated as the number of freshly dead shells compared to the total of freshly dead and live shells. Density of freshly dead shell (if in sufficient number) will also be tested for effects of time and site using ANOVA. Recruitment will be calculated as the percentage of individuals ≤5 years old and ≤3 years old. Percentage of unionids per age category (≤5, 6 to 10, 11 to 15, 16 to 20, 20+) will be compared using paired t-tests, ANOVA, or contingency tables as appropriate.

Monitoring Triggers

Triggers are a tool to help managers determine if information indicates a need for change. The mussel bed monitoring program will be triggered when any of the following conditions occur.

a. QCS uses hours in excess of 1% (87.6 hours which is the limit of formerly permitted hours), mussel bed monitoring in the Upstream, Steamboat Slough and Cordova mussel beds will be conducted in that year.

b. QCS Biological Steering Committee deems it necessary to monitor the mussel beds due to a plant incident and concern for the Essential Habitat. Any follow-up monitoring must be approved by the Quad Cities Steering Committee following a review of data and monitoring results;

c. 4 years has lapsed since the last monitoring effort.

It is important to remember that the potential for a break in monitoring will in no way null the obligation of mitigation activities described in Section 5.4. In addition, the temperature monitoring will be ongoing.

The QCS Biological Steering Committee will review the results of monitoring. This committee will recommend changes to the following year's program, if necessary in coordination with the USFWS.

All zebra mussels will be removed and destroyed from specimens sampled from the above beds.

4. Monitoring of temperature studies.

Temperature measurements year round (or as field conditions allow) will also be included at each of the beds to examine variations, particularly during excursion periods, and be relatable to mussel bed quantitative and qualitative data. These temperatures will be taken at sub-surface, mid-depth and substrate levels. Outreach to universities would focus on soliciting studies related to temperature and mussels, in situ or in conjunction with the lab facilities at QCS. These studies would have applicability not only to discharges at QCS, but may also relate to potential ambient temperature increases derived from climate change.

5. Long Term Fish Monitoring (on-going)

Quad Cities Station established its Long-Term Fisheries Monitoring Program in Pool 14 of the Mississippi River in 1971. The objective of this program is to determine if Station operations are having any measurable impact on the fishery of the Pool. Studies include Long-Term Fisheries Monitoring; a study of the Life History and Population Dynamics of the Freshwater Drum (a major sport and commercial species in Pool 14); Channel and

Flathead Catfish, Walleye, and Sauger Studies; Impingement Monitoring; a Fall Stock Assessment Program; and Hydrological Data. The Impingement Monitoring, Freshwater Drum, Channel and Flathead Catfish, and Fall Stock Assessment studies were added to the program in 1973, 1978, 1983, and 1985, respectively. The principal objectives of the Long-Term Fisheries Monitoring Program are to determine species composition and relative species abundance in the various habitat types that occur in Pool 14. The sampling techniques employed include electrofishing, hoop netting, and haul seining.

Annually, the Long-Term Fisheries Monitoring Program and the gamefish rearing program are overviewed at the Quad Cities Station Steering Committee meeting, which occurs in March of each year. The meeting allows those agencies with jurisdiction in the QCS area to gather and review the long-term monitoring programs. Because of the framework already established with these programs, a session will now be added to review those activities associated with the HCP. Additional members will be added to the Quad Cities Station Steering Committee, if necessary, to include those who are knowledgeable with the mussel monitoring and propagation activities.

Reporting

The QCS will file an annual report by March 31 of each year that provides the results of implementation, effectiveness and compliance monitoring. The report will include information on the following areas:

- Number and type of covered activities completed for the calendar year

- Minimization and Mitigation implemented (frequency and type).

- Presumptive take

- Calculations of the amount that QCS must either contribute to the mitigation fund or provide in mitigation.

- Temperature monitoring report

- Summary of the status of HCP biological goals and objectives

- Documentation of compliance with the previous year's compensation requirements (funding and project implementation, if appropriate), including a discussion of mitigation (details about the nature of the project, who is implementing it, the amount of QCS funds provided, status of the project, what take it is compensating for, and the timeframe for the project).

- Process for Convening Periodic Meetings

- The QCS, the Service, and other stakeholders, as appropriate, will convene as needed during the first three years of implementation, and at least annually until the fifth year

of implementation. In addition to these set periodic meetings, the QCS and the Service may convene stakeholder meetings as needed throughout the life of the Permit. Such meetings may be in person or handled by conference call. The purpose of these meetings will be to address any issues with implementation of the HCP; whether implementation could be streamlined; whether the avoidance, minimization, and mitigation measures have been effective; whether adaptive management thresholds have been triggered; and other HCP-related concerns.

Adaptive Management

Adaptive management is a process by which management practices are incrementally improved through the implementation of plans that provide opportunities to learn from experience. It is an approach that integrates research, monitoring, and management designed to test and improve the effectiveness of management prescriptions. Adaptive management is based on clear "experimental" hypotheses developed from real policy options informed by previous experience and understanding. A timely change in minimization and mitigation approaches in accordance with new knowledge provides the cornerstone for a successful HCP. As new information from monitoring, research, field trials, or day-to-day management becomes available, the information will be evaluated in the context of this HCP's goals, objectives, and guiding principles. The information must be evaluated in terms of its scientific, biological, or technical implications to the affected resources, and upon the operational feasibility and implications of implementing the change.

The QCS HCP will be implemented using an adaptive management approach; thereby allowing the QCS to evaluate and modify conservation measures to ensure the continued achievement of the HCP's biological goals and objectives. Recommendations on implementing changes to the HCPs operating conservation program will be made by various people and/or institutional bodies, depending on the implications of the change. The QCS proposes the following process:

1. Agencies and/or stakeholders should contact the Exelon Fish Biologist with any proposed change. It is assumed that the Exelon fish biologist, in coordination with the USFWS, will evaluate all potential changes.

2. Exelon Fish Biologist will consult with the USFWS to determine the viability, relevance and potential ramifications of the proposed change. If the USFWS deems the change is in compliance with the rules and obligations of the HCP, the Exelon Fish Biologist will then distribute the proposed changes to the Steering Committee members prior to the annual spring meetings to allow time for feedback preparation, if possible.

3. If no objections to the change are found, a letter outlining the changes will be drafted and sent to all agencies with jurisdiction in the applicable areas. These additional steps are included to strengthen the multi-agency transparent approach of this program and minimize confusion.

4. In the event that the change needs to be made in a timely manner that will not allow the issue to be brought up at the spring meeting, the Exelon Fish Biologist will verbally contact those Agencies that have jurisdiction or interest in the program.

6.0 FUNDING

6.1 Funding for Minimization and Mitigation Measures

Exelon Corporation will fund all minimization and mitigation measures, including monitoring, associated with this HCP. This work is in addition to programs already conducted at the site.

Fish monitoring programs associated with the QCS are already funded because of the Long-term Monitoring program. This monitoring is mandated as part of the NPDES permit and the open-cycle agreement.

6.1.1 Costs to Implement HCP

The QCS anticipates that the HCP will cost, on average, approximately $15,000 annually (with Year 1 costing $20,000 due to equipment purchases) to implement, recognizing that the costs of implementation will vary depending on the nature and extent of the covered activities undertaken in any given year. The following table summarizes the components of the expected costs to implement the HCP:

Measure	Cost	Frequency
Cost of Materials - Fish propagation tanks - Host fish cages - Misc. lab equipment	$5,000	First Year Only
HCP Monitoring and Reporting	$5,000	Annually
Impact Minimization Measure: Mussel Bed Temperature Monitoring	$1,000	During excursion hour periods
Impact Minimization Measure: Mussel Bed survey prior to Edison Pier removal	$15,000	Within a month prior to removal of Edison Pier
Impact Minimization Measure: Mussel Bed survey prior to maintenance dredging	$15,000	Current permit valid until 2016. Mussel survey to be conducted prior to dredging permit renewal
Mitigation Measures: Host fish placed on the Bed	$10,000	Annually
Mussel Bed Monitoring (Upstream, Steamboat Slough and Cordova mussel beds)	$55,000	As needed, based on established monitoring triggers.

6.1.2 Adequacy of Funds

Exelon is solvent and is able to meet its current financial obligations. Exelon has, and will expend, adequate resources to fulfill all implementation and mitigation commitments as described in the HCP and the Implementing Agreement (IA). By March 31 of each year the ITP is in effect, Exelon shall submit to the USFWS, concurrently with its submission of the annual report, an annual budget with regard to its obligations under the

HCP. The annual budget will demonstrate that sufficient funds to carry out Exelon's commitments under the ITP for that fiscal year have been authorized for expenditure. Exelon will provide the first annual budget covering the period immediately following issuance of the ITP up to the end of the first calendar year of operation within 60 days of the effective date of the ITP.

Exelon will promptly notify the USFWS of any material change in funding resources. A material change in funding resources is any change in the financial condition of Exelon that will adversely affect Exelon's ability to implement the HCP and IA. If Exelon does not implement the terms of the HCP and IA, it is in violation of the ITP and the ITP may be revoked.

6.1.3 Funding Assurances

QCS will establish a fund through the National Fish and Wildlife Foundation that will be used for implementation of the HCP and funding projects that satisfies QCS minimization and mitigation obligations. These may include any of the activities listed in Chapter 5 or additional projects or activities carried out by QCS, universities, or agencies that further the recovery of these species as deemed appropriate by the FWS and QCS. The fund will be created by and maintained through contributions by QCS at an amount equal to or greater than the sum total of the annual cost of HCP implementation for the preceding year. It is presumed that the minimum contribution paid to the mitigation fund is $15,000 per year. This is based on the anticipated take (in the form of harassment) for the ATS of one year class during extreme events (estimated occurrence of once every five years) and reduced recruitment that is not expected to rise above natural fluctuations of the population. It will also include the anticipated incidental take of 2 *L. higginsii* on 8 to 10 occasions during the maintenance dredging for a total of 16 to 20 individuals, and the loss of 2 *L. higginsii* during the removal of the Edison pier.

7.0 ALTERNATIVES

Several alternatives were considered to avoid the possibility of take. Those options include:

1. Closing the plant
2. Closed cycle cooling
3. Limited power operation during summer months
4. Moving the Cordova Mussel Bed
5. Operating in a partially open cycle mode
6. Eliminate dredging practices
7. Leave Edison Pier as is

First, closing the plant has obvious ramifications that are self-explanatory. The action would be irresponsible in a time of high-energy demands.

Second, closed cycle operations would require installation of cooling towers. A study was completed in 2006, which showed that building towers would be impractical due to retrofitting requirements, space limitations, and overall costs. Historically, about half the days when excursion hours occur have upstream temperatures exceeding 86°F, the limit where excursion hours begin to accumulate. Also, one of the original reasons that open cycle cooling and the spray canal were used instead of cooling towers was public outcry of having cooling towers on the banks of the Mississippi River.

Third, power generated by QCS (particularly during summer months) will continue to be needed to meet existing and projected demand in the future. Thus, limiting power operation during summer months would be an irresponsible action because the time periods of excursion usually coincide with the highest demand for electrical energy and subsequent grid stress.

Fourth, moving the Cordova Bed is not practical for several reasons. First, the length of the bed extends from RM 503.0 to RM 505.5 and extends essentially to the edge of the main channel. Second, the area within these borders is considered Higgins Eye Essential Habitat as described in the Higgins Eye Recovery Program (USFWS, 2004). Finally, suitable habitat for a mass translocation has not been sited and is probably not available. The historical significance of this bed makes translocation not practical. Ultimately, this would not be a prudent action since protecting excellent mussel habitat should a goal as well.

Next, operating in a partially open cycle mode also is not a viable option. As originally designed, the Station utilized Mississippi River water for condenser cooling in a once-through (open-cycle) mode. Shortly after the Station began operating, a cooling canal was constructed around the Station's perimeter for recycling of condenser cooling water. The canal was equipped with 328 spray modules to facilitate more rapid cooling. The canal measures approximately 3 miles in length, 180 feet in width, with an average depth

of almost 6 feet at capacity. It was constructed at a cost of 35 million dollars (1975 dollars).

Shortly after the Station began using the cooling canal, it became obvious the cooling capacity of the canal was not sufficient to allow for normal plant operation, especially in the summer. Concurrent with the operational history of QCS, extensive biological monitoring studies of the River's ecosystem have been conducted each year to assess impacts, if any, of Station operation on the varied aquatic communities inhabiting Pool 14. Earlier studies (1971-1978) assessed potential impacts to all trophic levels of aquatic life, while more recent studies (1978 to present) have focused on the River's varied and valuable fishery and mussel population. Results of these extensive studies have not demonstrated any measurable adverse effects of Station operations on the River's biota under either closed-cycle or open-cycle operation.

In consideration of the findings, ComEd (Exelon) and MidAmerican Energy petitioned to allow QCS to return to once-through cooling and discontinue further use of the spray canal for cooling purposes. Following a thorough review of the biological data, QCS was allowed the return to once-through operation. A revised NPDES permit was issued in late 1983 permitting once-through cooling. The fish propagation projects were a result of the dormant cooling canal being available as a "mitigative" action.

Next, to eliminate dredging is currently not an alternative available to QCS. A reliable supply of water is needed for safe nuclear operations. Not dredging will eventually cause a sand bar in front of the intake, blocking all water flow into the station, causing unsafe operating conditions and a complete shutdown.

Finally, Edison Pier has remained in place since it's creation in the late 1960's. It is speculated that this pier may be one of the reasons that sediment increasingly builds up in front of the intake. After a high water event, the sediment accumulation seems to happen at a faster pace. This removal project may lessen the need for maintenance dredging in the future.

8.0 PLAN IMPLEMENTATION, CHANGED AND UNFORESEEN CIRCUMSTANCES

8.1 Plan Implementation

USFWS will work with the Exelon fish biologist to obtain necessary permits in order to implement the mitigation techniques described in section 5.4. The States of Illinois, Iowa and other Agencies with jurisdiction will assist in any permitting that is deemed necessary for these mitigative techniques. Exelon's Fish Biologist will take the lead to contact those Agencies with the assistance of USFWS. The Agencies will also assist in the placement of the fish in the translocation process. Monitoring programs will occur within the framework of the programs in which QCS already conducts and those mentioned in section 5.5.

Exelon will be responsible for the day-to-day planning and implementing specific measures of the HCP. USFWS will be responsible for being the primary oversight and technical guidance in regards to implementing the program. All aspects of the process will also be presented to the Steering Committee for additional oversight on the project.

Tentative Implementation Schedule:

- Spring-Summer 2009: Learn glochidia harvest and propagation techniques from Federal Biologists. Acquire any needed federal collectors permits from USFWS and State agencies. During the late summer, Exelon Staff will begin to hold fingerlings for fall stocking. Implement temperature monitoring at the three mussel beds. Outreach to universities regarding support for temperature/mussels studies at QCS.

- Fall 2009: Make available a batch of advanced fingerling walleye for infection and free-release in Illinois waters, if acceptable. Release locations will be coordinated with State and Federal Biologists.

- Winter/Spring, 2010: QCS will contribute the first year's worth of mitigation (see Section 6.1.1.) in the first quarter of 2010. A written summary of the future activities will be presented to the Steering Committee and to the Mussel Coordination Team at the annual meetings in March.

- Spring-Summer 2010: Finalize mitigation techniques and programs. Conduct the mitigative programs that were approved. Have additional fish available for free release, if selected.

- Future years to mimic the Fall 2009-Summer 2010 Program schedule.

8.2 Changed Circumstances and Unforeseen Circumstances

8.2.1 Changed Circumstances

There may be circumstances beyond the participating entities control that adversely impact the success and execution of the QCS HCP. Possible circumstances could include:

- Low flows
- Barge fleeting
- Shoreline urbanization effects
- Channel maintenance or channel flow pattern changes
- Removal of Edison Pier and subsequent river substrate changes
- Any additional activities that would negatively impact the species recovery

8.2.2 Unforeseen Circumstances

Major Earth Quake
Chemical Spill by Others
Change to Closed Cycle Cooling
Dam Failure
Plant Closure

Pursuant to its no surprises policy, the USFWS will not require the Exelon Corporation to mitigate these unforeseen circumstances by establishing and sustaining baseline responsibilities beyond the scope of this plan. Exelon may, however, work with the agencies to mitigate additional circumstances at their own discretion. Amendments to the Incidental Take Permit will not extend its total duration, which is set at 24 years. Assuming the Incidental Take Permit is issued in 2009, it will expire in December 31, 2032. Therefore, any amended versions of this Incidental Take Permit will also expire in December 31, 2032. If the operating permit of Quad Cities Station were extended past 2032, future changes to the Habitat Conservation Plan and the Incidental Take Permit (ITP) would need to be considered. The ITP will be deemed expired if the Station were to discontinue open-cycle operation, which is the principle reason for the HCP. Dredging frequency would also greatly diminish if this operational change were to occur, making the dredging assumptions stated earlier invalid. Therefore, the HCP will most likely be discontinued as well.

In the event that affected mussels are delisted, the HCP mitigation will be terminated.

8.3 Other Measures as Required by Director

At this time, there are no other identified measures as required by the Director of the USFWS.

9.0 LITERATURE CITED

Anderson, D. 2002. Report of 2001 collecting, cleaning, and stockpiling of adult *Lampsilis higginsii* from the Mississippi River in pool 11 near Cassville, Wisconsin. U.S. Army Corps of Engineers, St. Paul District, St. Paul, Minnesota. 16 pp.

Anderson, D., D. Sallee, M. Davis and P. Delphey. 2002. Report of 2001 relocation of adult *Lampsilis higginsii* from the Mississippi River in Pool 14 near Cordova, Illinois, to pool 2, Minnesota. U.S. Army Corps of Engineers, St. Paul District, St. Paul, Minnesota. 8 pp.

Blodgett, K.D., and R.E. Sparks. 1987. Documentation of a mussel die-off in pools 14 and 15 of the upper Mississippi River. In*:* Neves, R.J., editor. Proceedings of the workshop on die-offs of freshwater mussels in the United States. Upper Mississippi River Conservation Committee, Rock Island, Illinois. p. 76-90.

Bogan, A.E. 1990. Stability of recent unionid (Mollusca: Bivalvia) communities over the past 6000 years. Pp. 112-136 *in*: W. Miller, III, ed. Paleocommunity temporal dynamics: the long-term development of multispecies assemblies. The Paleontological Society Special Publication No. 5.

Bowen, B. 2003. Progress report on genetic study of *Lampsilis higginsii*. Iowa State University, Ames, Iowa. 1 p.

Bowzer, T.W. and B.L. Lippincott. 1995. A synoptic review of long-term fisheries monitoring in Pool 14 of the Upper Mississippi River near Quad Cities Station. Prepared for Commonwealth Edison Company. Chicago, IL. 65 p.

Bowzer, T.W. and B.L. Lippincott. 2000. A summary review of long-term fisheries monitoring in Pool 14 of the Upper Mississippi River near Quad Cities Station (1971-1999). Prepared for Commonwealth Edison Company. Chicago, IL. 67 p.

Cawley, E.T. 1996. A compendium of reports of mussel studies containing *Lampsilis higginsii* from the period 1980-1996. Report for the Higgins Eye Recovery Team - Fish and Wildlife Service. Environmental Research Center - Loras College, Dubuque, Iowa. 84 p.

Coker, R.E. 1919. Fresh water mussels and mussel industries of the United States. Bulletin of the Bureau of Fisheries 36:13-89.

Coker, R.E., A.F. Shira, H.W. Clark, and A.D. Howard. 1921. Natural history and propagation of fresh-water mussels. Bulletin of the U.S. Bureau of Fishes 37:77-181.

Commonwealth Edison Company (ComEd). 1980. Quad-Cities aquatic program, 1979 annual report. Volumes I and II.

Cummings, K.S. and C.A. Mayer. 1992. Field guide to freshwater mussels of the Midwest. Illinois Natural History Survey Manual 5. 194 pp.

Cvancara, A. M. 1970. Mussels (Unionidae) of the Red River Valley in North Dakota and Minnesota, U.S.A. *Malacologia* 10:57-92.

Davis, M. 2001. Emergency conservation, relocation and reintroduction of Higgins' eye pearlymussel (*Lampsilis higginsii*) and other mussel species from zebra mussel affected areas in the Upper Mississippi River. Minnesota Department of Natural Resources, Lake City, Minnesota. 17 pp.

Davis, M. 2002. An account of activities associated with efforts to propagate and repatriate *Lampsilis higginsii* in the Mississippi River, Minnesota. Minnesota Department of Natural Resources, Lake City, Minnesota. 22 pp.

Dimock, R. V. Jr. and A. H. Wright. 1993. Sensitivity of juvenile freshwater mussels to hypoxic, thermal and acid stress. *J. Elisha Mitchell Scientific Society* 109:183-192.

Dudgeon, D. and B. Morton. 1984. Site selection and attachment duration of *Anodonta woodiana* (Bivalvia: Unionacea) glochidia on fish hosts. *Journal of Zoology* 204:355-362.

Dunn, H.L., B.S. Sietman, D.E. Kelner. 2000. Evaluation of recent Unionid (Bivalvia) relocations and suggestions for future relocations and reintroductions. Pages 169 to 184 in *Freshwater Mullusk Symposium Proceedings*. Ohio Biological Survey, Columbus, OH 274 pp.

Ecological Specialists, Inc. 2005. Final Draft Report: Unionid Mussel Biothermal Assessment for the Quad Cities Nuclear Station, Mississippi River Miles 503.0 to 506.9. Prepared for Exelon Generation Company, Warrenville, IL. 146 p.

Ecological Specialists, Inc. 2006. Draft Report: Unionid Survey of Exelon's QCS Intake. Prepared for Exelon Generation Company, Warrenville, IL. 12 p.

Ecological Specialists, Inc. 2007. Draft Report: Unionid Mussel Monitoring near Quad Cities Nuclear Station, Mississippi River Miles 504 to 507.5, 2006. Prepared for Exelon Generation Company, Warrenville, IL. 34 p.

Ecological Specialists, Inc. 2008a. Draft Final Report: 2007 Results of Unionid Mussel Monitoring near Quad Cities Nuclear Station, Mississippi River Miles 495 to 515. Prepared for Exelon Generation Company, Warrenville, IL. 48 p.

Ecological Specialists, Inc. 2008b. Final Report: 2007 Monitoring of native and non-indigenous mussel species in the Upper Mississippi River Cassville and Prairie du Chien Higgins' Eye pearlymussel Essential Habitat areas. Prepared for URS

Corporation. Gaithersburg, MD under contract to U.S. Army Corps of Engineers, St. Paul District W912ES-05-D-0002, DO No. 7. 39 pp. and appendices.

Ecological Specialists, Inc. 2009. Final Draft Report: Indigenous Unionid Community Study, Upper Mississippi River, Pool 14, River Miles 495.5 to 516.0. Prepared for Exelon Generation Company, Warrenville, IL. 73 p.

Farr, M.D. and A.C. Miller. 2002. Draft summary of unionid and zebra mussel sampling in the Upper Mississippi River, July 2002. U.S. Army Corps of Engineers, Aquatic Ecology Branch, Engineering Research and Development Center, Vicksburg, Mississippi. 40 pp. 13

Farr, M.D. and A.C. Miller. 2003. Draft summary of unionid and zebra mussel sampling in the Upper Mississippi River in 2002. U.S. Army Corps of Engineers, Aquatic Ecology Branch, Engineering Research and Development Center, Vicksburg, Mississippi, unpublished report. 26 pp.

Federal Register, Volume 41, No. 115, Monday, June 14, 1976

Feminella, J. W. and M. M. Gangloff. 2001. Analysis of relationships between unionid mussels andstream hydrology in tributaries of the Coosa and Talapoosa Rivers, Alabama. Alabama Department of Conservation and Natural Resources, Project E-1.

Fuller, S.L.H. 1974. Clams and mussels (Mollusca: Bivalvia). In: C.W. Hart, and S.L.H. Fuller (eds.). Pollution Ecology of Freshwater Invertebrates. Academic Press, New York. P. 215-273.

Gordon, R. 2001. *Lampsilis higginsii* recovery project. U.S. Fish and Wildlife Service, Genoa National Fish Hatchery, Genoa, Wisconsin. 10 pp.

Gordon, R. 2002. *Lampsilis higginsii* recovery project. U.S. Fish and Wildlife Service, Genoa National Fish Hatchery, Genoa, Wisconsin. 7 pp.

Gritters, S. 2001. Iowa River Inoculations. Iowa Department of Natural Resources, Guttenberg, Iowa. 2 pp.

Haag, W. R., D. J. Berg, D. W. Garton, and J. L. Farris. 1993. Reduced survival and fitness in native bivalves in response to fouling by the introduced zebra mussel (*Dreissena polymorpha*) in western Lake Erie. *Can. J. Fish. Aquat. Sc.* 50:13-19.

Haag, W. R. and M. L. Warren, Jr. 1998. Role of ecological factors and reproductive strategies in structuring freshwater mussel communities. *Can. J. Fish. Aquat. Sci.* 55:297-306.

Hallac, D.E. and J.E. Marsden. 2001. Comparison of conservation strategies for unionids threatened by zebra mussels (*Dreissena polymorpha*): periodic cleaning vs. quarantine and translocation. Journal of the North American Benthological Society, 20(2):200-210.

Hardison, B. S. and J. B. Layzer. 2001. Relations between complex hydraulics and the localized distribution of mussels in three regulated rivers. Regulated Rivers: Research and Management 17:77-84.

Havlik, M.E. 1980. The historic and present distributions of the endangered naiad mollusk, *Lampsilis higginsii*. Bulletin of the American Malacological Union 1980:19-22.

Havlik, M.E. 1987. Probable causes and considerations of the naiad mollusk die-off in the upper Mississippi River. In: Neves, R.J., editor. Proceedings of the workshop on die-offs of freshwater mussels in the United States. Upper Mississippi River Conservation Committee, Rock Island, Illinois. p. 91-103.

Hazleton Environmental Sciences, Inc. 1979. Environmental monitoring in the Mississippi River near Quad-Cities Station, January 1971 through November 1978. Chapter 8. Ichthyoplankton monitoring. Prepared for Commonwealth Edison Company. Chicago, IL.

HDR/LMS. 2005. Quad Cities Nuclear Generation Station Biothermal Assessment Report. Prepared for Exelon Corporation, Warrenville, IL.

HDR/LMS. 2007. Quad Cities Aquatic Program, 2006 Annual Report. Prepared for Exelon Corporation, Warrenville, IL.

HDR/LMS. 2008. Quad Cities Aquatic Program, 2007 Annual Report. Prepared for Exelon Corporation, Warrenville, IL.

Heath, D.J. 2001. Report on placement of *L. higginsii*, inoculated fish in cages, and free ranging fish, lower Wisconsin River, 2001. Wisconsin Department of Natural Resources, La Crosse, Wisconsin. 4 pp.

Heath, D.J. 2002. Report on placement of juvenile *L. higginsii* into the lower Black River, Wisconsin, during 2001. Wisconsin Department of Natural Resources, La Crosse, Wisconsin. 2 pp.

Heidinger, R.C. and D. L. Bergerhouse. 2007. Investigation of the Potential for Producing Sport Fishes of Various Sizes at the Quad Cities Spray Canal. Progress report (January 1-December 31, 2006). Fisheries Research laboratory, Southern Illinois University-Carbondale, Carbondale, IL. USA.

Holland-Bartels, L.E. and D.L. Waller. 1988. Aspects of the life history of the endangered Higgins Eye Pearly Mussel, *Lampsilis higginsi* (Lea, 1957). U.S. Fish and Wildlife Service, National Fisheries Research Center, LaCrosse, Wisconsin. 188 p.

Holly, F. M., Jr., S. Li, and L. J. Weber. 2004. River temperature predictions downstream of Quad Cities Nuclear Generating Station. Submitted to Exelon Generation, Warrenville, IL. 46pp.

Hornbach, D.J., P. Baker, and T. Deneka. 1995. Abundance and distribution of the endangered mussel, *Lampsilis higginsii* in the lower St. Croix River, Minnesota and Wisconsin. Final Report to the U.S. Fish and Wildlife Service, Contract # 14-48-000394-1009. 40 p.

Hubbs, D. 2000. Augmentation of natural reproduction by freshwater mussels to sustain shell harvest. Pages 49 to 51 in R. A. Tankersly, P. I. Warmolts, B. J. Armitage, P. D. Johnson, and R. S. Butler (eds.). Freshwater Mollusk Symposium Proceedings. Ohio Biological Survey, Columbus, OH. 274pp.

Hunter, R. D. and J. F. Bailey. 1992. *Dreissena polymorpha* (zebra mussel): colonization of soft substrata and some effects on unionid bivalves. Nautilus 106:60-67.

Illinois Endangered Species Protection Board. 2004. Checklist of endangered and threatened animals and plants of Illinois. Illinois Department of Natural Resources, Springfield, IL. 26 p.

Iowa Department of Natural Resources (IADNR). Division of Fish and Game. 2002. Article 571-77.2 (481B). Endangered or threatened plants and animals species. Chapter 77. pp. 1-14.

Jansen, W., G. Bauer, and E. Zahner-Meike. 2001. Glochidia mortality in freshwater mussels. Pages 185-211 *in* G. Bauer and K. Wachtler (eds.). Ecology and evolution of freshwater mussels (Unionoida). Springer-Verlag, New York. 394pp.

Jørgensen, C.B. 1975. Comparative physiology of suspension feeding. Annual Review of Physiology. 37:57-79.

Kelner. D. 2003. Upper Mississippi River mussel species list. U.S. Army Corps of Engineers, St. Paul District, St. Paul, MN.

Kelner, D. and M. Davis. 2000. Will Mississippi River Pools 1-3 be the last big river mussel refuge in the Midwestern United States? Minnesota Department of Natural Resources, Ecological Services Division, St. Paul, Minnesota. 5 pp.

Kelner, D. and M. Davis. 2002. Final Report: Mussel (Bivalvia: Unionidae) survey of the Mississippi National River and Recreation Area Corridor, 2000-01. Minnesota Department of Natural Resources, Ecological Services Division, St. Paul, Minnesota. 44 pp.

Kelner, D. and D. Heath. 2003. Relocated *Lampsilis higginsii* juvenile and adult monitoring protocol, and sub-adult placement into new relocation sites and long-term monitoring. U.S. Army Corps of Engineers, St. Paul, Minnesota. 8 pp.

Kraemer, L.R. 1970. The mantle flap in three species of *Lampsilis* (Pelecypoda: Unionidae), Malacologia*,* 10: 225-282.

Lawler, Matusky & Skelly Engineers LLP (LMS). 1985. Quad Cities Aquatic Program, 1984 Annual Report. Prepared for Commonwealth Edison Company, Chicago, IL.

Lawler, Matusky & Skelly Engineers LLP (LMS). 1992. Quad Cities Aquatic Program, 1991 Annual Report. Prepared for Exelon Corporation, Warrenville, IL.

Lawler, Matusky & Skelly Engineers LLP (LMS). 2004a. Quad Cities Nuclear Generating Station PhaseII Biothermal Assessment, draft report. Prepared for Exelon Generation, Warrenville, IL.

Lawler, Matusky & Skelly Engineers LLP (LMS). 2004b. Quad Cities Nuclear Generating Station PhaseIAI Biothermal Assessment, draft technical report. Prepared for Exelon Generation, Warrenville, IL.

Layzer, J. B. and L. M. Madison. 1995. Microhabitat use by freshwater mussels and recommendations for determining their instream flow needs. *Regulated Rivers: Research and Management* 10:329-345.

Lewis, W.M. and L. Bodensteiner. 1985. State of health of freshwater drum (*Aplodinotus grunniens* Rafinesque) through the winter in Pool 14 of the Mississippi River. Interim Report to Commonwealth Edison Company, Chicago, IL; by the Cooperative Fisheries Laboratory, Southern Illinois University, Carbondale, Il.

Lewis, W.M. and L. Bodensteiner. 1986. State of health and impingement of freshwater drum (*Aplodinotus grunniens* Rafinesque) at Quad Cities Station. Final Report to Commonwealth Edison Company, Chicago, IL; by the Cooperative Fisheries Laboratory, Southern Illinois University, Carbondale, Il.

Magoulick, D. and L.C. Lewis. 2002. Predation on exotic zebra mussels by native fishes: effects on predator and prey. Pages 1908 - 1918 in Freshwater Biology (2002): 47.

Matteson, M. R. 1948. Life history of *Elliptio complanatus* (Dillwyn, 1817). American Midland Naturalist 40:690-723.

McMahon, R. F. and A. E. Bogan. 2001. Mollusca: Bivalvia. Pages 331-429 in J. H. Thorp and A. P. Covich (eds.). Ecology and Classification of North American Freshwater Invertebrates, 2nd ed. Academic Press, New York. 1056pp.

McMurray, S. E., G. A. Schuster, and B.A. Ramey. 1999. Recruitment in a freshwater unionid (Mollusca: Bivalvia) community downstream of Cave Run Lake in the Licking River, Kentucky. American Malacological Bulletin 15:57-63

Miller, A.C. and B.S. Payne. 2001. Effects of zebra mussels (*Dreissena polymorpha*) at Essential Habitats for *Lampsilis higginsi* in the upper Mississippi River System, 2000. Report for St. Paul District, U.S. Army Corps of Engineers. 31 p.

Mississippi Interstate Cooperative Resource Association. 2002. Gulf/Lake Erie dead zones grow. P.O. Box 774, Bettendorf, Iowa. Page 9 in River Crossings, Volume 11, September/October, Number 5.

Morrison, J.P.E. 1942. Preliminary report on mollusks found in the shell mounds of the Pickwick Landing basin in the Tennessee River Valley. Pp. 337-392 *in*: W.S. Webb and D.L. DeJarnette, eds. An archeological survey of Pickwick Basin in the adjacent portions of the states of Alabama, Mississippi, and Tennessee. Bureau of American Ethnology Bulletin No. 129.

Nalepa, T. F., D. J. Hartson, G. W. Gostenik, D. L. Fanslow, and G. A. Lang. 1996. Changes in the freshwater mussel community of Lake St. Clair: from Unionidae to *Dreissena polymorpha* in eight years. Journal of Great Lakes Research 22:354-369.

Neves, R.J. 1993. A state-of-the unionid address. Pp. 1-10 *in*: K.S. Cummings, A.C. Buchanan, and L.M. Koch, eds. Conservation and management of freshwater mussels. Proceedings of a UMRCC symposium, October 1992, St. Louis, Missouri. Upper Mississippi River Conservation Committee, Rock Island, Illinois.

Neves, R.J. and J.C. Widlak. 1988. Occurrence of glochidia in stream drift and on fishes of the upper North Fork Holston River, Virginia. American Midland Naturalist 119:111-120.

Oesch, R.D. 1984. Missouri naiades: a guide to the mussels of Missouri. Missouri Department of Conservation, Jefferson City. 270 pp.

Ortmann, A.E. 1911. A monograph of the naiades of Pennsylvania. Parts I and II: systematic account of the genera and species. Memoirs of the Carnegie museum 4(6):279-347.

Parmalee, P.W., W.E. Klippel, and A.E. Bogan. 1980. Notes on the prehistoric and present status of the naiad fauna on the middle Cumberland River, Smith County, Tennessee. The Nautilus 94(3):93-105.

Parmalee, P.W., W.E. Klippel, and A.E. Bogan. 1982. Aboriginal and modern freshwater mussel assemblages (Pelecypoda: Unionidae) from the Chickamauga Reservoir, Tennessee. Brimleyana 8:75-90.

Parmalee, P.W., and A.E. Bogan. 1986. Molluscan remains from aboriginal middens at the Clinch River Breeder Reactor Plant site, Roane County, Tennessee. American Malacological Bulletin 4(1):25-37.

Parmalee, P.W., and A.E. Bogan. 1998. The freshwater mussels of Tennessee. The University of Tennessee Press, Knoxville. 328 pp.

Parmalee, P.W., and M.H. Hughes. 1994. Freshwater mussels (Bivalvia: Unionidae) of the Hiwassee 55 River in east Tennessee. American Malacological Bulletin 11(1):21-27.

Patch, D.C. 1976. An analysis of the archaeological shell of fresh water [sic] mollusks from the Carlston Annis Shellmound, west central Kentucky. Unpublished bachelors thesis, Washington University. 98 pp.

Pitlo, J., A. VanVooren and J. Rasmussen. 1995. Distribution and Relative Abundance of Upper Mississippi River Fishes. UMRCC Fish Tech. Sec. Rep., 20 pp.

Polhill, J. B. and R. V. Dimock, Jr. 1996. Effects of temperature and pO2 on the heart rate of juvenile and adult freshwater mussels (Bivalvia: Unionidae). Comp. Biochem Physiol. 114:135-141.

Pritchard, J. 2001. An historical analysis of mussel propagation and culture: research performed at the Fairport Biological Station. December 2001. Clear Creek Historical Research, Ames, Iowa. 76 pp.

Pusch, M., J. Siefert, and N. Walz. 2001. Filtration and respiration rates of two unionid species and their impact on the water quality of a lowland river. Pages 317-326 *in* G. Bauer and K. Wachtler (eds*.).* Ecology and evolution of freshwater mussels (Unionoida). Springer-Verlag, New York. 394pp.

Ricciardi, A., F. G. Whoriskey, and J. B Rasmussen. 1996. Impact of the *Dreissena* invasion on native unionid bivalves in the upper St. Lawrence River. Can. J. Fish. Aq. Sci. 53:1434-1444.

Roberts, A., and S.A. Bruenderman. 2000. A reassessment of the status of freshwater mussels in the Meramec River basin, Missouri. Unpublished report, Missouri Department of Conservation, Columbia. 141 pp.

Schloesser, D. W. and W. P. Kovalak. 1991. Infestation of unionids by *Dreissena polymorpha* in a power plant canal in Lake Erie. Journal of Shellfish Research 10:355-359.

Schloesser, D. W., T. F. Nalepa, and G. L Mackie. 1996. Zebra mussel infestation of unionid bivalves (Unionidae) in North America. American Zoologist 36:300-310.

Starkey, R. G., A. G. Eversole, and D. E. Brune. 2000. Growth and survival of juvenile and adult freshwater mussels in the Partitioned Aquaculture System. Pages 109-114 *in* R. A. Tankersly, P. I. Warmolts, B. J. Armitage, P. D. Johnson, and R. S. Butler (eds.). Freshwater Mollusk Symposium Proceedings. Ohio Biological Survey, Columbus, OH. 274pp.

Steingraeber, M. 2002. Propagation and restoration of Higgins' eye pearlymussels in the Upper Mississippi River Basin; partnership efforts and achievements in 2000 - 2001. June 2002. U.S. Fish and Wildlife Service, Onalaska, Wisconsin. 14 pp.

Stoeckel, H. 2002. Evaluation of zebra mussel veliger abundances in the Upper Mississippi River, 2001. Illinois Natural History Survey, Illinois River Biological Station, Illinois. 2 pp.

Strayer, D.L. 1999a. Use of flow refuges by unionid mussels in rivers. Journal of the North American Benthological Society 18(4):468-476.

Strayer, D. L. and L. C. Smith. 1996. Relationships between zebra mussels (*Dreissena polymorpha*) and unionid clams during the early stages of the zebra mussel invasion of the Hudson River. Freshwater Biology 36:771-779.

Strayer, D. L. and J. Ralley. 1991. The freshwater mussels (Bivalvia: Unionoida) of the upper Delaware River drainage. American Malacological Bulletin 9:21-25.

Stuart, K. R., A. G. Eversole, and D. E. Brune. 2000. Effect of flow rate and temperature on algal uptake by freshwater mussels. Pages 219-224 *in* R. A. Tankersly, P. I. Warmolts, B. J. Armitage, P. D. Johnson, and R. S. Butler (eds.). Freshwater Mollusk Symposium Proceedings. Ohio Biological Survey, Columbus, OH. 274pp.

Surber, T. 1912. Identification of the glochidia of freshwater mussels, U.S. Bureau of Fisheries, Doc. 771:1-10.

Surber, T. 1913. Notes on the natural hosts of fresh-water mussels. Bulletin of U. S. Bureau of Fisheries 32:101-115.

Sylvester, J. R., L. E. Holland, and T. K. Kammer. 1984. Observations on burrowing rates and comments on host specificity in the endangered mussel *Lampsilis higginsi.* Journal of Freshwater Ecology 2:555-559

Tedla, S. and C. H. Fernando. 1969. Observations on the glochidia of *Lampsilis radiata* (Gmelin) infesting yellow perch, *Perca flavescens* (Mitchill) in the Bay of Quinte, Lake Ontario. Canadian Journal of Zoology 47: 705-712.

Thiel, P.A. 1987. Recent events in the mussel mortality problem on the upper Mississippi River. In: Neves, R.J., editor. Proceedings of the workshop on die-offs of freshwater mussels in the United States. Upper Mississippi River Conservation Committee, Rock Island, Illinois. p.66-75.

U.S. Army Corps of Engineers. 2002. Definite project report and environmental assessment for relocation plan for the endangered Higgins' eye pearlymussel (*Lampsilis higginsii*), Upper Mississippi River and tributaries, Minnesota, Wisconsin, Iowa, and Illinois. July 2002.

U.S. Army Corps of Engineers, St. Paul District, St. Paul, Minnesota. 56 pp.

U.S. Fish and Wildlife Service. 1983. Higgins Eye mussel recovery plan. Ft. Snelling, Minnesota. 98 p.

U.S. Fish and Wildlife Service. 2000. Final biological opinion for the operation and maintenance of the 9-foot navigation channel on the Upper Mississippi River System. April 2000. U.S. Fish and Wildlife Service, Region 3, Fort Snelling, Minnesota. 240 pp.

U.S. Fish and Wildlife Service. 2004. Higgins Eye Pearlymussel (*Lampsilis higginsii*) Recovery Plan: First Revision. Ft. Snelling, Minnesota. 126 pp.

Vanderploeg, H. A., J. R. Liebig, and T. F. Nalepa. 1995. From picoplankton to microplankton: temperature-driven filtration by the unionid bivalve *Lampsilis radiata siliquoidea* in Lake St. Clair. Can. J. Fish. Aquat. Sci. 52:63-74.

Van der Schalie, H. 1966. Hermaphroditism among North American freshwater mussels. Malacologia 5:77-78.

Waller, D.L., and L.E. Holland-Bartels. 1988. Fish hosts for glochidia of the endangered freshwater mussel *Lampsilis higginsii* Lea (Bivalvia: Unionidae). Malacological Review 21:119-122.

Waller, D. L., S. Gutreuter, and J. J. Rach. 1999. Behavioral responses to disturbance in freshwater mussels with implications for conservation and management. J. N. Am. Benthol. Soc. 18:381-390.

Walker, K. F., M. Byrne, C. W. Hickey, and D. S. Roper. 2001. Freshwater Mussels (Hyriidae) of Australasia. Pages 5-32 *in* G. Bauer and K. *Wachtler (eds.). Ecology and evolution of freshwatermussels (Unionoida).* Springer-Verlag, New York. 394pp.

Watters, G. T. 1997. Individual-based models of mussel-fish interactions: a cautionary study. Pages 45-62 *in* Cummings, K. S., A. C. Buchanan, C. A. Mayer, and T. J. Naimo (eds.). Conservation and management of freshwater mussels II, initiatives

for the future. Proceedings of a Upper Mississippi River Conservation Committee symposium, October 1995, St. Louis, Missouri. Upper Mississippi River Conservation Committee, Rock Island, Illinois. 293pp.

Watters, G. T. and S. H. O'Dee. 2000. Glochidial release as a function of water temperature: Beyond bradyticty and tachyticty. Pages 135-140 *in* R. A. Tankersly, P. I. Warmolts, B. J. Armitage, P. D. Johnson, and R. S. Butler (eds.). Freshwater Mollusk Symposium Proceedings. Ohio Biological Survey, Columbus, OH. 274pp.

Welke, K., T. Turner, R. Gordon, V. Hyde, and P. Thiel. 2000. Propagation of the federally endangered Higgins' eye pearlymussel (*Lampsilis higginsii*) at the Genoa National Fish Hatchery as a survival strategy. Interim report, October 25, 2000, Wisconsin Department of Natural Resources, Madison, Wisconsin. 5 pp.

Whitney, S.D., K.D. Blodgett, and R.E. Sparks. 1996. A comprehensive evaluation of three mussel beds in Reach 15 of the upper Mississippi River. Illinois Natural History Survey, Aquatic Ecology Technical report 96/7. 132 pp.

Wilcox, D.B., D.D.Anderson, and A.C. Miller. 1993. Survey procedures and decision criteria for estimating the likelihood that *Lampsilis higginsi* is present in areas in the Upper Mississippi River system. In: Cummings, K.S., A.C. Buchanan, and L.M. Koch, editors. Conservation and management of freshwater mussels. Proceedings of a UMRCC sysmposium, 12-14 October 1992, St. Louis, Missouri. Upper Mississippi River Conservation Committee, Rock Island, Illinois. P. 163-167.

Wilson, C.B. 1914. Copepod parasites of fresh-water fishes and their economic relations to mussel glochidia. Bulletin of the Bureau of Fisheries 34:331-379.

Wilson, C.B. 1916. Copepod parasites of fresh-water fishes and their economic relations to mussel glochidia. Bulletin of the U.S. Bureau of Fisheries 34:331-374.

Winter, T.E. 1978. A review on the knowledge of suspension-feeding in Lamellibranchiate bivalves, with special reference to artificial aquaculture systems. Aquaculture13: 1-33.

Wisconsin Department of Natural Resources. 1985. Freshwater Mussels of the Upper Mississippi River. Wisconsin Department of Natural Resources, Madison, Wisconsin. 63 pp.

Yager, T. 1993. Zebra mussel monitoring. U.S. Army Corps of Engineers, St. Paul District, St. Paul, Minnesota. 32 pp.

Yeager, M.M., D.S. Cherry, and R.J. Neves. 1994. Feeding and burrowing behaviors of juvenile rainbow mussels, *Villosa iris* (Bivalvia: Unionidae). Journal of the North American Benthological Society 13(2):217-222.

Zale, A. V. and R. J. Neves. 1982. Fish hosts of four species of lampsiline mussels (Mollusca: Unionidae) in Big Moccasin Creek, Virginia. Canadian Journal of Zoology 60: 2535-2542.

10.0 APPENDICES