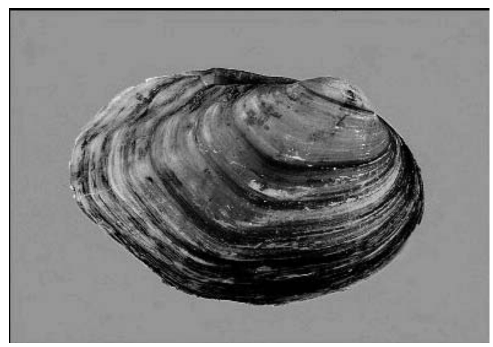
Habitat Conservation Plan (HCP) to support issuance of an Incidental Take Permit (ITP) for the Federally Endangered *Lampsilis higginsii* mussel and the candidate mussel species *Plethobasus cyphyus*

related to operations of the

Quad Cities Station (QCS)

Higgins Eye (*Lampsilis higginsii*)



Sheepnose (*Plethobasus cyphyus*)

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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.

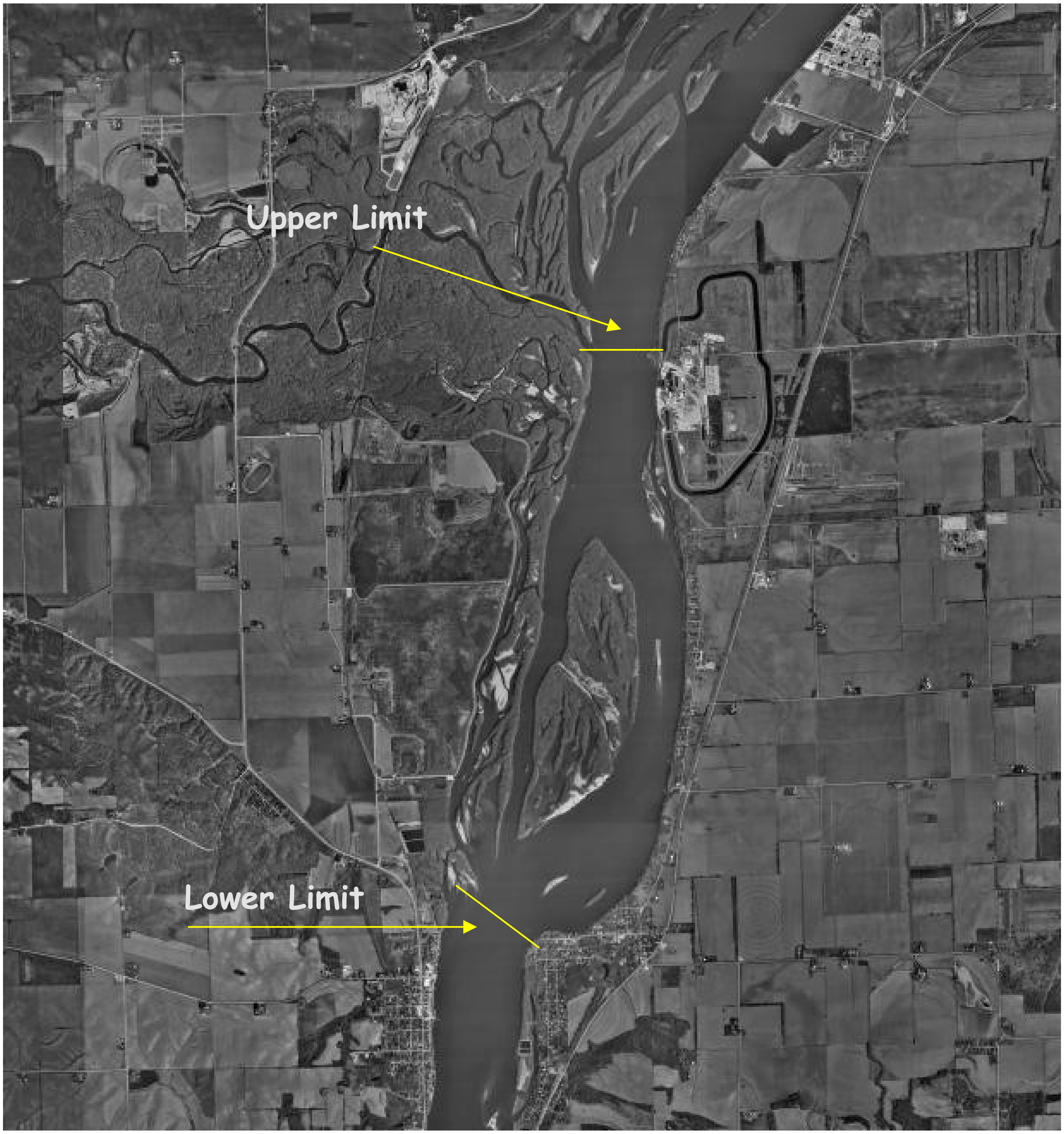
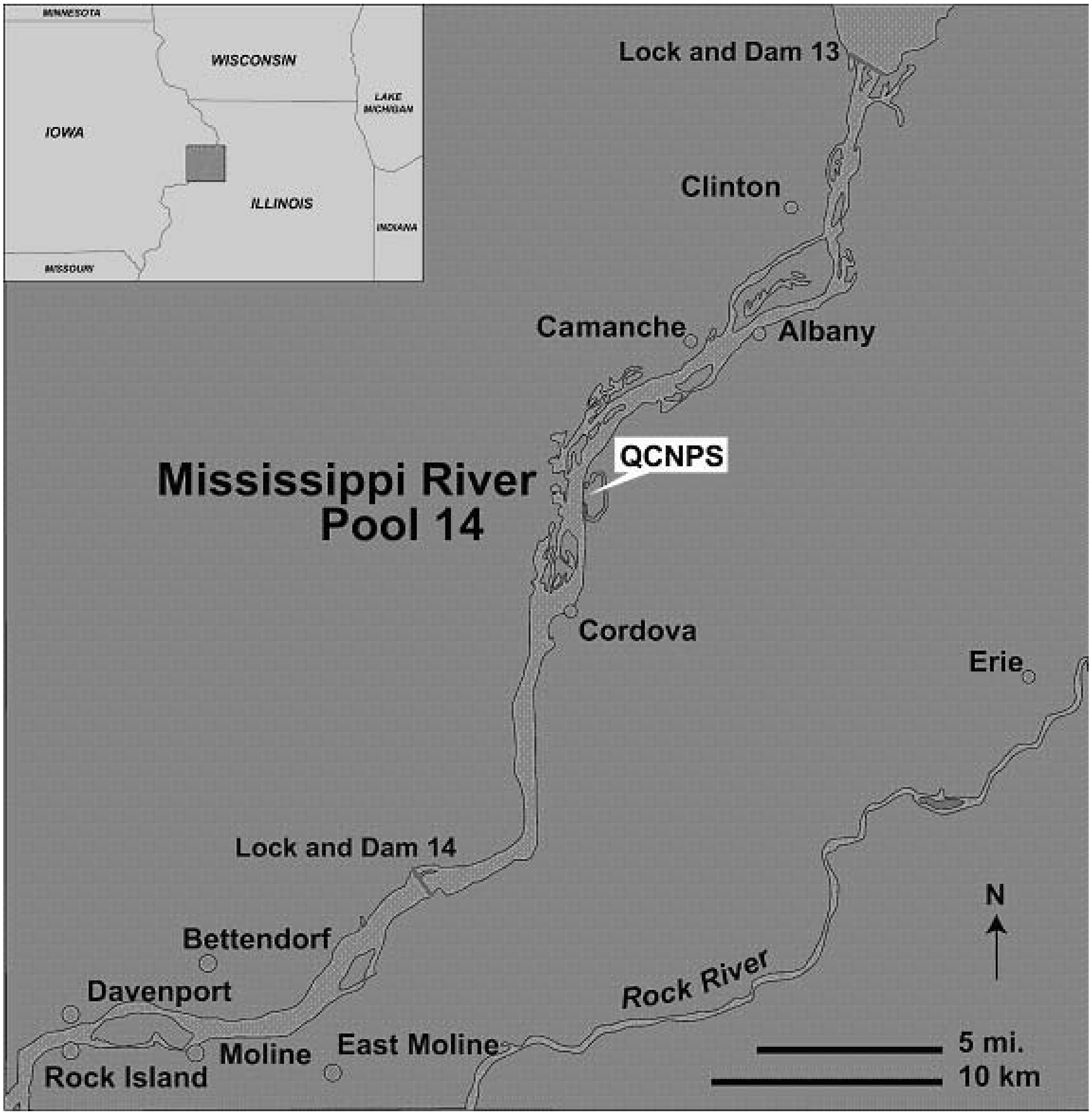


Figure 1-2. Quad Cities Station Location & Description



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).

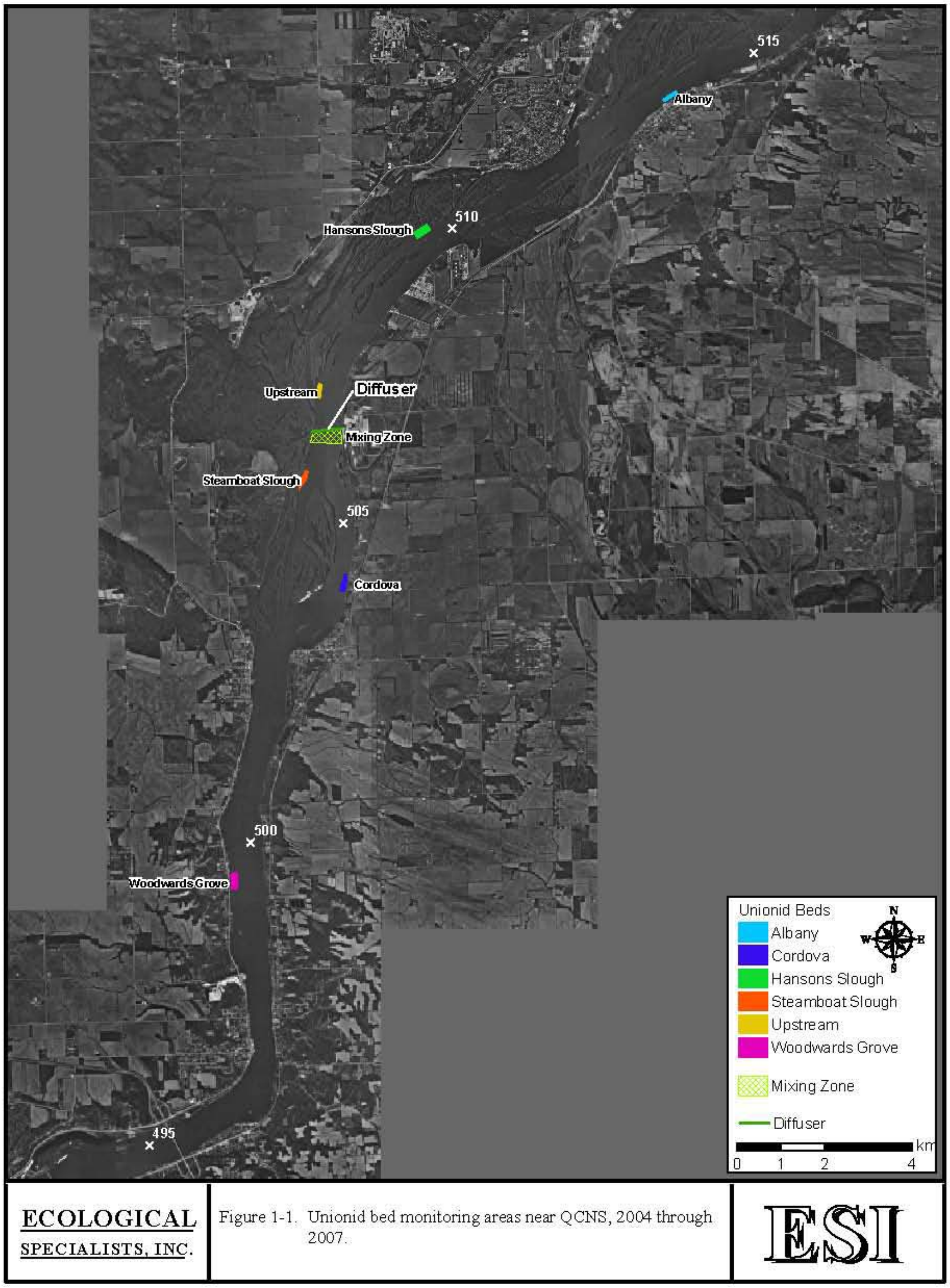


Figure 1-1. Unionid bed monitoring areas near QCNS, 2004 through 2007.

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

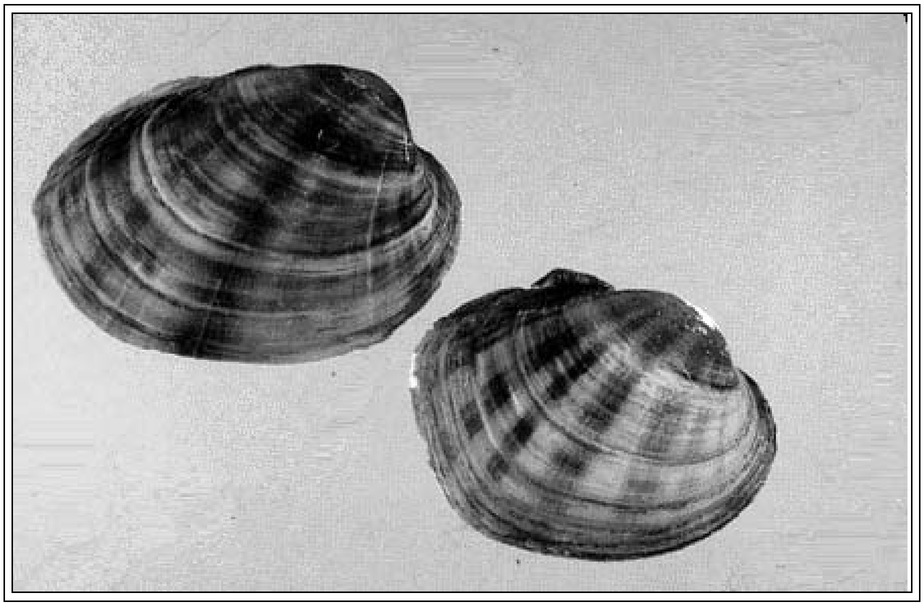
The Woodwards Grove (WG) Mussel Bed, located downstream of the QCS diffuser approximately 8,300 to 10,900 m, was added to the Mussel Monitoring Program in 2007. The bed appears to extend from approximately RM 499.5 to 500.8 along the Iowa bank within a slight outside bend. The bed extends from the bank 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. cyphus*, 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^{0}F). 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.

-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]		Upstream (Ambient)	Cordova	Steamboat Slough	
			Dnstrm	Upstrm			Dnstrm	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 QCNS 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 QCNS anticipates that the HCP will cost a minimum of $20,000 per year based on $15,000 for mitigation and $5,000 per year for HCP monitoring and reporting. The $15,000 for mitigation will be used to cover the costs of mussel propagation at the QCNS's lab. During years when propagation activities are reduced (see Appendix D for mitigation planning timetable), any funds remaining from the $15,000 annual mitigation budget will be added to an initial $15,000 donation by QCNS to the National Fish and Wildlife Foundation. Research partnerships with local and/or state colleges and universities will be formed and at a minimum, one graduate student will be sponsored every five years (starting year five to allow for protocol establishment, etc.) using funding from the National Fish and Wildlife Foundation grant money or directly sponsored by QCNS. By the end of the HCP (25 years hence) all monies set aside at the National Fish and Wildlife Foundation will be fully expended on research/projects related to recovery and/or temperature effects on listed and rare mussel fauna.

In addition, mussel bed temperature monitoring will be conducted annually for the first 2 plus years to establish a baseline relationship between temperatures at the various beds and water temperatures at the continuous monitoring sites. Once the baseline is established, in situ temperature monitoring at the beds will be conducted during excursion periods.

Other expenditures include equipment start-up costs; mussel surveys prior to Edison Pier removal and prior to renewal of the Corps of Engineers 404 permit for dredging near the forebay area; and mussel bed monitoring at the upstream, Steamboat Slough, and Cordova mussel beds to track impacts from the ATS, and take of listed species as outlined in this HCP.

The following table summarizes the components of these expected costs to implement the HCP.

Measure	Minimum Costs	Frequency
Start-up Costs		
Cost of Materials - Fish propagation tanks - Host fish cages - Misc. lab equipment	$5,000	First Year Only
Edison Pier Removal		
Mussel Bed survey prior to Edison Pier removal	$15,000	Within a month prior to removal of Edison Pier
Maintenance Dredging		
Mussel Bed survey prior to maintenance dredging permit renewals	$15,000	Current permit valid until 2016. Mussel survey to be conducted prior to dredging permit renewal
ATS Project		
Place host fish placed on a bed	$10,000	Annually or as determined in the 5-year plan
Propagation for restoration and thermal testing programs	$1,000 (yearly avg)	Periodically after 5 year start up as determined in the 5-year plan
Mussel Bed Temperature Monitoring	$1,000	Annually to establish baseline (approx. 2 years) and during excursion hour periods thereafter
Mussel Bed Monitoring (Upstream, Steamboat Slough and Cordova mussel beds)	$55,000	As needed, based on established monitoring triggers.
National Fish and Wildlife Foundation	$15,000 – at permit issuance Up to $15,000 – following years based on the 5-year plan (see Appendix D)	Annually or as determined in the 5-year plan
Monitoring and Funding Compliance		
HCP Monitoring and Reporting	$5,000	Annually

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

QCNS will establish a fund through the National Fish and Wildlife Foundation (NFWF) that will be used for implementation of the HCP and funding projects that satisfies QCNS minimization and mitigation obligations in concert with those activities that will occur at the QCNS fish hatchery. These may include any of the activities listed in Chapter 5 or additional projects or activities carried out by QCNS, universities, or agencies that further the recovery of these species as deemed appropriate by the FWS and QCNS. The fund will be created by and maintained through contributions by QCNS. Contributions will be in the form of dollars or worked preformed as outlined in 6.1.1. The amount 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. At the initiation of this HCP, QCNS will contribute $15,000 as an initial escrow to the NFWF account. In ensuing years, if no work is preformed in accordance with the program, the full $15,000 will be sent to the NFWF account. All non-annual activities will be funded by QCNS since existing contracts are already in place. Failure to fund these activities would be a violation of the ITP obligations.

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.

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10.0 APPENDICES

<u>Appendix A</u>

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

Higgins Eye Pearlymussel
(*Lampsilis higginsii*)
Recovery Plan: First Revision

May 2004

Original Approved: July 29, 1983

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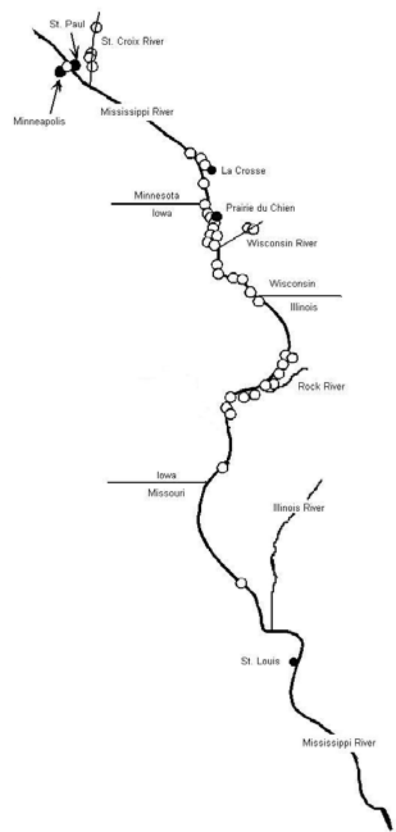

U.S. Department of Interior
U.S. Fish and Wildlife Service
Great Lakes/Big Rivers Region
Ft. Snelling, Minnesota

Higgins Eye Pearlymussel (*Lampsilis higginsii*) Recovery Plan: First Revision

Prepared by the Higgins Eye Pearlymussel Recovery Team

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Date: May 12, 2004

DISCLAIMER

Recovery plans delineate reasonable actions which are believed to be required to recover and/or protect listed species. Plans are published by the U.S. Fish and Wildlife Service (USFWS), sometimes prepared with the assistance of recovery teams, contractors, state agencies, and others. Objectives will be attained and any necessary funds made available subject to budgetary and other constraints affecting the parties involved, as well as the need to address other priorities. Recovery plans do not necessarily represent the views nor the official positions or approval of any individuals or agencies involved in the plan formulation, other than the USFWS. They represent the official position of the USFWS only after they have been signed by the Regional Director or Director as approved. Approved recovery plans are subject to modification as dictated by new findings, changes in species status, and the completion of recovery tasks.

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

Recovery plans can be downloaded from USFWS website: http://endangered.fws.gov.

ACKNOWLEDGMENTS

The Higgins Eye Pearlymussel Recovery Team would like to acknowledge the following individuals for their contributions to the development of this plan: Chuck Kjos and Gerald Bade of the USFWS for overseeing the plan development process; Dr. Teresa Newton of the National Fisheries Research Lab, La Crosse, Wisconsin, and Dave Warburton USFWS Twin Cities Field Office, Minnesota for development of the section dealing with contaminants; and Mark Farr, U.S. Army Corps of Engineers, St. Paul, Minnesota for additional editing and critical review, for updating the information on the status of zebra mussels within the Higgins Eye's range, and for providing a summary of the endangered species consultation between the USFWS and the Corps of Engineers on Operation and Maintenance of the Navigation Channel on the Upper Mississippi River System. Cover photos are used courtesy of the Illinois Natural History Survey.

EXECUTIVE SUMMARY

Current Species Status

This species is currently listed as endangered. Studies before 1993 indicate healthy populations of *Lampsilis higginsii* in the Upper Mississippi River drainage, with no apparent significant declines in its distribution or abundance. In fact, information since completion of the first recovery plan in 1983 has extended its known range by 180 river miles.

There was concern, however, that a major flood in 1993, as well as an infestation of the non-native zebra mussel (*Dreissena polymorpha*), may pose serious threats to the continued existence of this species. In response to these threats and information, the recovery team was constituted to review the status of the species and to revise the initial recovery plan if necessary. The team commissioned a review of all research conducted on the species since 1980, as well as a survey of all sites designated as Essential Habitat Areas in the 1983 recovery plan. During the development of this revised recovery plan, new information suggesting a significant impact of zebra mussels on *Lampsilis higginsii* came forward and the team believes there is now a significant risk that the distribution and abundance of this species will be severely compromised.

The initial Higgins Eye Pearlymussel Recovery Plan listed seven locations as primary habitats (called Essential Habitat Areas in this document) and nine locations as potential secondary habitats. This revised plan identifies ten Essential Habitat Areas -- six in the Mississippi River between river miles 489 (Sylvan Slough) and 656 (Whiskey Rock), one in the Wisconsin River (Orion), and three in the St. Croix River, which empties into the Mississippi River at river mile 811. The term "Essential Habitat Area" is intended to identify those areas that the Service and its partners have found to be of utmost importance to the conservation of the species. Cawley (1996) indicated that since 1980, all seven of the Essential Habitat Areas in the initial Higgins Eye Pearlymussel Recovery Plan had been sampled. In addition, six of the nine secondary habitats had been sampled. *L. higginsii* also occurs elsewhere in the Mississippi River, and this revised plan recommends that surveys be conducted in several specific areas to better describe other potentially important habitats.

Since zebra mussels invaded the Mississippi River in the early 1990's, three of the Essential Habitat Areas, East Channel (Prairie du Chien), Harpers Slough, and Cordova have become severely infested with zebra mussels; only one Essential Habitat Area, Interstate Park (St. Croix River) is entirely free of zebra mussels. There are currently no effective methods to control established populations of zebra mussels of the scale and nature necessary to nullify their threat to *L. higginsii* in the Mississippi River. Since 2000, *L. higginsii* has been reintroduced into four rivers from which it had been extirpated, but it is too soon to determine whether these efforts have resulted in the successful reestablishment of the species there.

Habitat Requirements and Limiting Factors

Lampsilis higginsii is characterized as a large river species occupying stable substrates that vary from sand to boulders, but not firmly packed clay, flocculent silt, organic material, bedrock, concrete or unstable sand. Water velocities should be less than 1 m/second during periods of low discharge. They are usually found in mussel beds that contain at least 15 other species at densities greater than .01 individual/m^2. In the Mississippi River, the density of all mussels in the bed typically exceeds 10/m^2.

The ten identified Essential Habitat Areas are: The Mississippi River at Lansing, Iowa (Whiskey Rock); near Harper's Ferry, Iowa (Harper's Slough); the main and east channel areas at Prairie du Chien, Wisconsin; near Guttenberg, Iowa (McMillan Island); Cordova, Illinois; Moline, Illinois (Sylvan Slough); the St. Croix River at Prescott, Wisconsin, at Hudson, Wisconsin, and near Taylor's Falls, Minnesota (Interstate Park); and the Wisconsin River near Muscoda, Wisconsin (Orion mussel assemblage). Zebra mussels have severely degraded the mussel communities at a few of these areas to the degree that they may no longer support dense and diverse mussel beds. Each of these areas, however, demonstrated its importance to the conservation of *Lampsilis higginsii* before zebra mussel infestation and zebra mussels are the only factor that has, at least temporarily, degraded their ability to support stable or growing populations of *Lampsilis higginsii*. Therefore, we will retain each of these areas as Essential Habitat Areas at this time due to their historical importance to the species and the uncertainty regarding their potential to recover from the effects of zebra mussels. The Service's Twin Cities Field Office will retain an up-to-date list of Essential Habitat Areas. There are no numeric criteria for areas to be added or removed from this list. Any Essential Habitat Areas used as part of the basis for a decision to reclassify or delist the species, however, must meet specific numeric criteria (see Recovery Criteria).

Recovery Strategy

This revised recovery plan continues the approach of the previous 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. This revised recovery plan identifies three additional "Essential Habitat Areas" (Orion, WI, Prescott, WI, and Interstate Park, MN/WI). 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 ten Essential Habitat Areas designated in this revised plan, zebra mussels have had severe impacts on the mussel communities at Harpers

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 removal of zebra mussels in a manner and scale necessary to benefit *L. higginsii* is evidently not currently feasible. Therefore, the 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. Since 2000, workers have removed 471 adult *L. higginsii* from areas near Cassville, WI and Cordova, IL on the Upper Mississippi River and relocated them into Pools 2 and 3 near Minneapolis, MN and Hastings, MN, respectively (Table 1). Cleaning fouled adults *in situ* and artificial propagation and release (Table 1) 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. Therefore, the Corps and other agencies must continue to assess and limit the potential impacts of their actions on *L. higginsii*. 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 will be key to the recovery of *L. higginsii*. In addition to the USFWS, the Implementation Table identifies five other federal agencies and four states as being responsible for various aspects of the recovery of the species. The U.S. Army Corps of Engineers, for example, is called on to implement several of the tasks. The Corps' implementation of the 2000 Biological Opinion on continued operation and maintenance and operation of the 9-foot navigation channel has resulted in the formation of the Mussel Coordination Team (MCT). This MCT has assisted the Corps with the implementation of extensive relocation and reintroduction of *L. higginsii* since 2000 (Table 1). These activities, although necessary to avoid jeopardizing the species, are leading to the development and refinement of techniques for propagating *L. higginsii* and other mussel species.

Recovery Goals and Recovery Criteria

The goal of the recovery plan is the recovery of Higgins eye to levels where its protection under the Act is no longer necessary and it may be removed from the Federal list of Endangered and Threatened Wildlife (50 CFR 17.11). This plan also contains an intermediate goal of reclassifying the species from Endangered to Threatened.

Essential Habitat Areas

Essential Habitat Areas used to support the reclassification or delisting of *L. higginsii* (see below) must meet the following criteria.

1. *L. higginsii* constitute at least 0.25% of the mussel community and the mussel habitat appears to be stable and supports a dense and diverse mussel community; or,

2. *L. higginsii* are found, but constitute <0.25% of the community, the mussel habitat appears to be stable and supports a dense and diverse mussel community, and zebra mussel densities are $< 0.5/m^2$.

For each definition, "dense and diverse" mussel communities are those that:

- include a total mussel density of $> 10/m^2$ (Mississippi River) or $> 2/m^2$ (other rivers); and,
- contain at least 15 other mussel species, each at densities greater than 0.01 individual/m^2.

<u>Intermediate Goal (Reclassification of *Lampsilis higginsii* to Threatened Status)</u>

Criteria for Intermediate Goal (Goal 1: Reclassification)

1. *Lampsilis higginsii* may be considered for reclassification from Endangered to Threatened when at least five identified Essential Habitat Areas contain reproducing, self-sustaining populations of *L. higginsii* that are not threatened by zebra mussels. The five Essential Habitat Areas must meet the above criteria and must include the Prairie du Chien Essential Habitat Area and at least one Essential Habitat Area each in the St. Croix River and in Mississippi River Pool 14.

    a. *L. higginsii* populations will be considered to be "reproducing" if there is evidence that they include a sufficient number of strong juvenile year classes.[1]

    b. Populations will be considered to be "self-sustaining" if they have maintained stable or increasing population densities for at least twenty years.[2] *L. higginsii* populations will be considered stable or increasing if:

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[1] Task 1.2.2 details the questions that the Service must answer to determine the number of strong juvenile year classes sufficient to allow for stable or increasing populations of *L. higginsii.*

[2] For all analyses of trends use a significance level (α) ≤ 0.2 and power ≥ 0.9.

i. total mussel density in each of the identified Essential Habitat Areas is stable or increasing for at least twenty years (significance level (α) ≤ 0.2 and power ≥ 0.9);

ii. and, in each of the identified Essential Habitat Areas *L. higginsii* comprises at least 0.25% of the mussel community in Mississippi River sites or, in other rivers, are consistently present throughout the twenty year period.

The Service will develop standardized sampling protocols (Task 1.2.1) to evaluate the status of populations relative to these criteria.

c. This criterion will be met if zebra mussels are not present in locations where they or their offspring are likely to adversely affect *L. higginsii* populations in any of the five identified Essential Habitat Areas. The Service will make this determination by evaluating zebra mussel densities in the source areas and identified Essential Habitat Areas, the distances between the zebra mussel populations and identified Essential Habitat Areas, water velocities, larval development times, and any other relevant information.

2. Complete the following tasks to determine if water quality criteria for the Final Goal (Delisting) are necessary to ensure the conservation of *L. higginsii* and, if so, to develop measurable water quality criteria for the Final Goal.

   a. Develop a freshwater mussel toxicity database for sediment and water quality parameters to define *L. higginsii* habitat quality goals. (7 sub-tasks)

   b. Characterize specific sediment and water quality parameters in *L. higginsii* Essential Habitat Areas and reestablishment areas. (1 sub-task)

3. Harvest of freshwater mussels is prohibited by law or regulation in Essential Habitat Areas. This applies to all Essential Habitat Areas, not just the five identified for criterion 1.

Criteria for Final Goal (Delisting)

1. Delisting *L. higginsii* requires that populations of *L. higginsii* in at least five Essential Habitat Areas are reproducing, self-sustaining, not threatened by zebra mussels, and are sufficiently secure to assure long-term viability of the species. The five Essential Habitat Areas must meet the above criteria and must include the Prairie du Chien Essential Habitat Area and at least one Essential Habitat Area each in the St. Croix River and in Mississippi River Pool 14. "Reproducing" and “self-sustaining” are defined above under the Intermediate Goal (Reclassification).

Populations at the identified Essential Habitat Areas will be "sufficiently secure to assure long-term viability of the species" if each of the following four conditions is met:

a. The Service can identify no activities that are likely to take place in the foreseeable future that will result in a change in the predominant substrate conditions within each identified Essential Habitat Area to shifting, unstable sands, silt, cobble, boulder, or artificial substrates (*e.g.*, concrete) to the extent that such changes would appreciably reduce the likelihood of conserving the Higgins eye population in the Essential Habitat Area.

b. The Service can identify no activities that are likely to take place in the foreseeable future that will result in water quality characteristics (*e.g.*, harmful concentrations of un-ionized ammonia) in Essential Habitat Areas that have been shown to cause detrimental effects to *L. higginsii* or to sympatric or surrogate species to the extent that such effects would appreciably reduce the likelihood of conserving the Higgins eye population in the Essential Habitat Area.

c. There is no indication that construction of barge loading or off-loading sites, boat harbors, highway bridges, or fleeting areas or dredging of access channels is likely to occur in the foreseeable future within the identified Essential Habitat Areas to the extent that such activities would appreciably reduce the likelihood of conserving the Higgins eye population in the Essential Habitat Area.

d. Measures that provide for review of federally funded, permitted, or planned activities in or near *L. higginsii* habitat pursuant to the Fish and Wildlife Coordination Act and Clean Water Act are in place.

e. This criterion will be met if zebra mussels are not present in locations where they or their offspring are likely to adversely affect *L. higginsii* populations in any of the five identified Essential Habitat Areas. The Service will make this determination by evaluating zebra mussel densities in the source areas and identified Essential Habitat Areas, the distances between the zebra mussel populations and identified Essential Habitat Areas, water velocities, larval development times, and any other relevant information.

2. The use of double hull barges or other actions have alleviated the threat of spills to each of the identified Essential Habitat Areas.

3. *L. higginsii* habitat information and protective responses to conserve each of the identified Essential Habitat Areas have been incorporated into all applicable spill contingency planning efforts.

4. Water quality criteria may be added to the criteria for the Final Goal (Delisting) upon completion of the tasks referred to under the Criteria for the Intermediate Goal (Reclassification) (see 2a-b above and Tasks 1.5.1 and 1.5.2).

Actions Needed: The 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.

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

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

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

A. Identify and rank potential sites of existing *L. higginsii* populations for enhancement.
B. 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.
C. 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.
D. Examine the taxonomic validity of *L. higginsii* especially since *L. abrupt* is found in noncontiguous geographic areas.

Several specific actions are recommended for immediate implementation to ensure the survival of the *L. higginsii*.

A. Limit the impact of the exotic bivalve, the zebra mussel, *Dreissena polymorpha*.

B. Develop uniform protocols for collecting and maintaining information on *L. higginsii* populations.

C. Confirm and modify the locations listed in the initial recovery plan as Essential Habitat Areas.

D. Require the use of double hull barges.

Estimated Cost of Recovery for Fiscal Years 2005-2007 (in $1000s): Costs for fiscal years 2008-2055 will be determined on at least an annual basis by the USFWS and cooperating agencies.

Fiscal Year	Task 1.1	Task 1.2	Task 1.3	Task 1.4	Task 1.5	Task 1.6	Task 1.7	Task 1.8	**Total**
2005	100	160	290	50	745	40	0	10	**1395**
2006	120	160	280	50	745	40	0	0	**1395**
2007	70	110	270	50	470	40	0	0	**1010**
Total	**290**	**430**	**840**	**150**	**1960**	**120**	**0**	**10**	**3800**

The total costs for Years 1 - 3 do not include the cost of two tasks (1.4.1 and 1.4.2) which could not be determined at this time.

Date of Recovery: 2055, if recovery criteria are met and if fully funded.

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I. INTRODUCTION

The Higgins eye pearlymussel (*Lampsilis higginsii*, Lea 1857) was federally listed as an endangered species June 14, 1976 (41 FR 24064). The first Federal recovery plan was approved on July 29, 1983. Revision of the 1983 plan began in 1994, in the wake of the large flood of 1993. There was concern that the flooding may have significantly impacted *L. higginsii.* This revision is part of the Service's ongoing revision of recovery plans, and it supersedes the initial 1983 recovery plan.

Description of *Lampsilis higginsii*

Taxonomy and Systematics

Phylum: Mollusca
Class: Bivalvia
Order: Unionoida
Family: Unionidae
Genus: *Lampsilis*
Species: *higginsii* (Lea 1857)

The type locality for *L. higginsii* is the Mississippi River at Muscatine, Iowa (USFWS 1983). The original species name given was *higginsii*, but many references, including the original listing document, gives the spelling as *higginsi*. Turgeon *et al.* (1998) indicate that the proper name is *Lampsilis higginsii* with the common name for the species being the Higgins Eye. This species belongs to a morphologically variable, geographically widespread genus. Most malacologists agree that *L. higginsii* is a valid species. There was some early confusion between *L. higginsii* and the morphologically similar *L. abrupt* (the pink mucket pearly mussel -- also on the Federal Endangered and Threatened Species list). *Lampsilis abrupt* is distributed further to the south, and *L. higginsii* is found only in the Upper Mississippi River Basin (Oesch 1984). Johnson (1980) discusses the similarities and differences between *L. abrupt* and *L. higginsii* but there is still some controversy surrounding the taxonomic status of these species.

Morphological Description

Baker (1928) provided a general description of the shell morphology. Baker stated that the shell was: "Oval or elliptical, somewhat inflated, solid, with gaping anterior base; beaks placed forward of the center of the dorsal margin, much elevated, swollen, their sculpture consisting of a few feeble ridges slightly looped; anterior end broadly rounded; posterior end truncated in the female, bluntly pointed in the male; ventral and dorsal margins slightly curved, almost parallel; posterior ridge rounded, but well marked; surface shining, marked by irregular growth lines which are better developed at rest periods where they are usually dark colored; epidermis olive or yellowish-green with faint green rays. Hinge massive; pseudocardinals erect, triangular or pyramidal, divergent, serrated, two in the left and one in the right valve, with sometimes indications of additional denticles on either side of the single right pseudocardinal; interdentium narrow, flat;

laterals short, thick, slightly curved, almost smooth; cavity of the beaks deep, containing the dorsal muscle scars; anterior adductor scar deeply excavated, posterior scar distinct; nacre silvery-white, iridescent, often tinged with pink."

This species exhibits marked sexual dimorphism with the posterior end in the females sharply truncated with a post-basal swelling. The posterior end in the males is more roundly pointed. A number of species can be confused with *L. higginsii*. Those cited as most similar are *Obovaria olivaria*, *L. cardium*, *L. siliquoidea, L. abrupt* and *Actinonaias ligamentina* (Baker 1928; Cummings and Mayer 1992). Although nothing has been published specifically on the internal anatomy of *L. higginsii*, Baker (1928) indicates it is most likely similar to that of other lampsilines.

Historical and Present Distributions

In the initial Higgins Eye Pearlymussel Recovery Plan (USFWS 1983), the historic distribution of *L. higginsii* before 1965 was given as the main stem of the Mississippi River from just north of St. Louis, Missouri, to just south of St. Paul, Minnesota; in the Illinois, Sangamon, and Rock Rivers in Illinois; in the Iowa, Cedar, and Wapsipinicon Rivers in Iowa; in the Wisconsin and St. Croix rivers in Wisconsin; and, in the Minnesota River in Minnesota (based on Havlik 1980). A questionable report of this species in the lower Ohio River was also given (Havlik 1980). The initial plan also indicated a great reduction in the range of *L. higginsii* based on studies from 1965 through 1981 (Larsen and Holzer 1978; Mathiak 1979; Perry 1979; Havlik 1980; Fuller 1980; Thiel *et al.* 1980; Thiel 1981; Ecological Analysts 1981a).

Since the 1983 Recovery Plan, a number of studies have provided new information on the distribution and abundance of *L. higginsii*. A study by Cawley (1996) commissioned by the USFWS for the current recovery team provided a review of the information on *L. higginsii* distribution from 1980-1996. Cawley (1996) noted that 510 specimens of *L. higginsii* had been collected since 1980. Cawley (1996) extended the reported range of *L. higginsii* 98 miles to the south and 82 miles to the north based on the collection of dead specimens. Figure 1 (see Section V) summarizes the distributional data before 1965, from 1965-1980 and 1981-1996 based on the 1983 Recovery Plan and Cawley's (1996) study. Thiel (1981) stated that Pool 10 of the Mississippi River supported the largest population of *L. higginsii*. The area in the East Channel of the Mississippi River, by Prairie du Chien, Wisconsin, was considered to be the most productive *L. higginsii* habitat in the Mississippi River system. Cawley's (1996) review supports this assessment. Since Cawley's (1996) review, however, zebra mussels (*Dreissena polymorpha)* have drastically reduced the population of *L. higginsii* at Prairie du Chien.

Based on Cawley's (1996) review, it appears that there has been recruitment of *L. higginsii* (individuals <30 mm in shell length) in locations surveyed since 1980. The age distribution indicated that there were more middle-age mussels (35-85 mm shell length) than young. Miller and Payne (1988) indicated that some mussel species display infrequent, but fairly strong, recruitment and that there can be substantial variability in recruitment among closely located sites.

Given that Cawley's (1996) review included a wide variety of sites examined over a number of years, the actual size distribution of *L. higginsii* populations is unknown at this time.

As mentioned above, one reason for examining the current status of *L. higginsii* was the Great Flood of 1993. Clarke and Loter (1992, 1993, 1994, 1995) have been monitoring the population of *L. higginsii* at Prairie du Chien, Wisconsin, since 1990 as part of a study designed to examine the impacts of barge traffic on mussels. Based on their results, it appears that the flood caused no significant change in the number of *L. higginsii* found, while recruitment of some other mussel species was reduced in 1994. Recruitment varied among years (Miller and Payne 1991, 1992, 1993, 1994, 1995a,b, 1996a, 1997), and thus a cause-effect relationship cannot necessarily be inferred from Clark and Loter's (1995) work. Mussel communities may have been slightly relocated due to the flood.

This recovery team commissioned four studies, funded by the Service, to examine *L. higginsii* populations. The major objective of these studies was to examine what impact, if any, the 1993 floods in the Upper Mississippi River and its tributaries had on *L. higginsii*. These studies were conducted by Davis and Hart (1995), Heath (1995), Hornbach *et al.* (1995) and Miller and Payne (1996b). Differences in methods among these studies may not allow for statistical comparisons among populations.

Heath (1995, 2003) sampled quantitatively and qualitatively for *L. higginsii* and other mussel species at the Orion mussel aggregation in the Wisconsin River in 1988, 1995, and 2002. During each of these three years he counted living and dead mussels present within randomly placed quadrats and supplemented these samples with qualitative collections within the mussel aggregation. *L. higginsii* comprised 0.21% and 0.08% of the live mussels counted in 1988 and 1995, respectively, but no living *L. higginsii* were found during sampling in 2002 (Heath 1995, 2003). Heath (1995) estimated that there were 2,273 *L. higginsii* within the aggregation in 1988. Total mussel densities in the aggregation decreased significantly between 1988 and 2002; sample means were 6.05/m^2 in 1988 and 1.34/m^2 in 2002. Species richness may have also decreased since 1988. Among the initial 600 mussels collected each year, there were 23 species in both 1988 and 1995, but only 21 species in 2002.

Hornbach *et al.* (1995) examined *L. higginsii* populations in the St. Croix River and estimated populations to be 4,000 mussels at Franconia, 4,000 to 10,000 mussels at Prescott, Minnesota, and 238,000 to 260,000 mussels at Hudson, Wisconsin (all listed as Essential Habitat Areas in the initial recovery plan). Doolittle and Heath (1997), Heath (*in litt.* 1998), and Heath *et al.* (1999) collected almost 90 *L. higginsii* from 1987-1999 in the area of the St. Croix river, extending upstream of Franconia, MN to the Interstate Park Area (Taylor's Falls, MN) - about 3 river miles. They estimate *L. higginsii* population densities of approximately 0.01 individuals/m^2. In 2000, mean density estimates of *L. higginsii* at Interstate Park and Hudson were 0.01 and 0.09, respectively (Heath *et al.* 2001); these estimates did not reflect a statistically significant change in abundance at either site. Estimates of population size were 9,224 (95% CI = 4,192 - 14,255) at Hudson and 4,212 (95% CI = 358 - 7,886).

Miller and Payne (1996b) estimated that there were 40,000 m^2 of suitable habitat for *L. higginsii* at McMillan Island in Pool 10 of the Mississippi River near Guttenberg, Iowa, (an area designated as Essential Habitat Areas in the 1983 Recovery Plan) which contained an estimated 5,320 individuals. A more recent report contained revised estimates of both suitable habitat (860,994 m^2) and potential population size (662,965 individuals), although the authors suggest cautious interpretation of these crude estimates due to high levels of variability among the data (Miller and Payne 2001).

Davis and Hart (1995) examined an area downstream of Lock and Dam No. 6 on the Mississippi River near Trempealeau, Wisconsin, to determine whether this area should be classified as essential for *L. higginsii*. They found two live and two dead *L. higginsii* in the area. Although they did not estimate overall population size of *L. higginsii*, they indicated that because this area harbored many other mussel species at high densities, it has potential as an important area for *L. higginsii*. Unfortunately, at the four sites they examined, from 9 to 44% of all unionids were infested with zebra mussels.

Recent Reintroductions

Since 2000, state and federal conservation agencies have cooperated to reintroduce *Lampsilis higginsii* into areas that it occupied historically, but from which it had been extirpated. This work has largely been a result of a consultation between USFWS and the U.S. Army Corps of Engineers (Corps) under section 7(a)(2) of the Endangered Species Act (Act) on the effects to *Lampsilis higginsii* of the Corps' operation and maintenance of a nine-foot navigation channel on the Upper Mississippi River (see below). In 2000 and 2001, biologists relocated 471 adult *Lampsilis higginsii* from the Mississippi River at Cassville, WI and Cordova, IL, where zebra mussels posed an imminent risk, to two sites in Pools 2 and 3 of the Mississippi River where zebra mussel densities are below threatening levels. Davis (2003) examined 59 relocated females at these two sites in 2002 and found that about one-third were gravid. Of the 63 *L. higginsii* recovered in 2002 (59 females, 4 males), only one was found dead, although several had abnormal growth patterns exhibited by "exaggerated growth arrest lines and in-turning along the ventral margin of the shell" (Davis 2003). These mussels appeared to have resumed normal growth patterns in 2003 (M. Davis, Minnesota Department of Natural Resources, pers. comm., 2003).

Workers are also releasing fish artificially infested with *L. higginsii* glochidia and hatchery-propagated juveniles into its historical range and into its current range in an effort to reintroduce the species and refine propagation techniques, respectively (Table 1). To produce glochidia or juveniles for release, gravid females have been collected from the Hudson Essential Habitat Area in the St. Croix River or from relocated *L. higginsii* in Pool 2 (Cordova origin). At Genoa National Fish Hatchery, workers remove glochidia and either place them in water containing suitable fish-hosts or pipette glochidia directly onto the gills. Workers hold the fish at the hatchery for three weeks before releasing them or placing them in cages at the release site (Table 1, Gordon 2002). The hatchery has typically retained about 5% of the infested fish to monitor the success of glochidial transformation, provide juveniles for hatchery propagation trials, and for direct juvenile releases (Table 1, Gordon 2002). Propagation is discussed further below under "Conservation Measures."

Essential Habitat Areas

The initial Higgins Eye Pearlymussel Recovery Plan (USFWS 1983) listed seven locations as primary habitats (called Essential Habitat Areas in this document) and nine locations as potential secondary habitats (Table 2 - see Section IV). Essential Habitat Areas were selected based on:

1) historic and current distribution data (at the writing of the recovery plan);
2) the nature of the data available for each site, *e.g.*, presence of live *L. higginsii*, presence of both sexes, presence of juveniles, numerical abundance of *L. higginsii*, etc.; and,
3) the nature of the associated fauna (*L. higginsii* has often been reported from diverse and dense mussel beds - Nelson and Freitag 1980).

The Essential Habitat Areas described in this Recovery Plan are those areas capable of supporting reproducing populations of *L. higginsii* and are of utmost importance to the conservation of the species. Cawley (1996) indicated that since 1980, all seven of the Essential Habitat Areas in the initial Higgins Eye Pearlymussel Recovery Plan had been sampled. In addition, six of the nine secondary habitats had been sampled.

The Service will maintain a list of Essential Habitat Areas. This list will initially contain the areas described in this plan (Fig. 2), but the Service will revise this list if data indicate that one or more areas are no longer of utmost importance to the conservation of *L. higginsii* or if additional Essential Habitat Areas are identified. The following criteria will be used as a guideline to identify new Essential Habitat Areas and for an ongoing evaluation of identified Essential Habitat Areas. As stated above, any Essential Habitat Area that is one of the five on which either a reclassification or delisting decision is based must meet these criteria:

1. *L. higginsii* constitute at least 0.25% of the mussel community and the mussel habitat appears to be stable and supports a dense and diverse mussel community; or,

2. *L. higginsii* are found, but constitute <0.25% of the community, the mussel habitat appears to be stable and supports a dense and diverse mussel community, and zebra mussel densities are $< 0.5/m^2$.

For each definition, "dense and diverse" mussel communities are those that:

- include a total mussel density of $> 10/m^2$ (Mississippi River) or $> 2/m^2$ (other rivers); and,
- contain at least 15 other mussel species, each at densities greater than 0.01 individual/m^2.

Zebra mussels have severely degraded the native mussel communities at a few of the Essential Habitat Areas to the degree that they may no longer meet the definition above. These sites, however, 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 they 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 will retain an updated list of Essential Habitat Areas for this species and should make this list available on the world wide web.

Critical Habitat

Critical habitat is not currently designated for the Higgins eye. If following the completion of this plan the Service finds that it is prudent and determinable to designate critical habitat for this species, the Service will prepare a critical habitat proposal at such time as our available resources and other listing priorities under the Act allow. This proposal will be based on essential habitat features needed to ensure the conservation and recovery of the species, many of which have been documented in the below Habitat Characteristics section of this Recovery Plan.

Biology, Ecology and Life History

<u>Reproduction</u>

Major aspects of the unionid reproductive cycle have been well described. Males release sperm into the water, often in packets known as volvocoid bodies (Fuller 1974) that are taken in through the incurrent siphon by the female. Fertilization occurs and zygotes are brooded in the water tubes of the gills by the female. In the genus *Lampsilis*, the marsupia that contain the glochidia, are kidney-shaped, occupying the posterior portion of the outer gills. Female unionids can produce up to a million eggs a year (Burky 1983). The zygotes develop into larvae (glochidia) that are released into the water column in various ways. In the genus *Lampsilis,* the edge of the mantle of the female develops into a ribbon-like flap in front of the branchial opening. This flap has been described as "minnow-like" in appearance, often having a dark "eye-spot," and thus it has been suggested to be important in attracting fish hosts (Baker 1928). The glochidia attach to a fish host, where they remain for approximately three weeks (at water temperatures of 20-22ºC) (D. Waller, U.S. Geological Survey, pers. comm.) as 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 prevent being swept away in water currents.

Lampsilis higginsii is a long-term brooder (bradytictic). This means that they spawn in the summer and larvae are retained in the marsupia 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). Glochidia of *L. higginsii* are morphologically similar to those of several other species of lampsilines in the Upper Mississippi River. Waller and Mitchell (1988) have shown that *Lampsilis higginsii* glochidia can be differentiated from *L. cardium, L. siliquoidea,* and *Ligumia recta* by electron microscopy; they could not be differentiated by light microscopy or morphometric measures.

Table 3 (see Section IV) identifies the known hosts for *L. higginsii.* Early studies 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). These identifications were based on examination of natural infestations, but field identifications are not robust (Waller and Holland-Bartels 1988; Waller and Mitchell 1988); Hove and Kapuscinski (2002), however, confirmed sauger as a suitable host. Based on laboratory infestations 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 (*M. 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. Studies by Waller and Holland-Bartels (1988) and Waller and Mitchell (1988) supported those by Sylvester *et al.* (1984) that walleye and largemouth bass were hosts for *L. higginsii,* but Sylvester *et al*. (1984) indicated that the green sunfish and bluegill were not suitable hosts. Hove and Kapuscinski (2002) confirmed largemouth bass as suitable hosts and found that sauger and black crappie also facilitated metamorphosis of *L. higginsii* glochidia. 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

Among the few published studies on unionid feeding mechanisms are recent studies by Tankersley and Dimock (1992, 1993a, 1993b) who used endoscopic techniques to examine feeding in *Pyganodon cataracta*. There have been no 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 (Jørgensen 1975; Winter 1978).

Habitat

Lampsilis higginsii has been characterized as a large river mussel species (USFWS 1983). Davis and Hart (1995) indicated that it was found in the more “riverine” portion of Pool 7 and in the tailwater reaches of other Mississippi River navigation pools. 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.

Additional information regarding habitat characteristics is given below.

Substrate

Strayer (1983, 1993), Vannote and Minshall (1982), and others have suggested substrate stability may be important in determining the presence of freshwater mussel communities. It is the permanence of the populations in substrate that appears to be most important in constituting a mussel "bed". At smaller spatial scales however, such as within mussel beds, substrate difference provided little predictive power (Holland-Bartels 1990; Strayer and Ralley 1993). Heath (1995) found no correlation between overall mussel density and substrate size in the Wisconsin River where *L. higginsii* was found. Hornbach *et al.* (1995) have indicated that substrate size does influence mussel density, although accounting for only a small proportion of the variability in mussel density. Mussels also apparently help to stabilize the substrate of the river in some areas (Watters 1994a).

Lampsilis higginsii has been found in various substrates from sand to boulders, but not in areas of unstable shifting coarse sands. Sylvester *et al.* (1984) found that burrowing times for *L. higginsii* were similar in clay, silt and sand, but longer in pebble-gravel substrate. *Lampsilis higginsii* were not present in rock substrate. Miller and Payne (1996b) considered substratum that was free of plants and consisted of stable, gravelly sand as suitable for *L. higginsii.* Miller and Payne (1996b) noted that immediately downriver of wingdams, mussel diversity was high and new species were found at a more rapid rate on the wingdam than in gravelly sand. *Lampsilis higginsii* was found immediately below the wingdam at McMillan Island and has been collected on wingdams near Prairie du Chien. The distribution of mussels is at least partially mediated by the distribution of their host-fish. Therefore, the distribution of mussels in relation to wing dams and other habitat features may be influenced by the relative distribution of their host fishes in relation to these features. *L. higginsii* is found in substrate that consists of coarse sand and gravel, but not in either finer (silt) or coarser (cobble) substrates (D. Hornbach, Macalester College, St. Paul, MN, pers. comm. 2004). Cawley (1996) indicated that *L. higginsii* were most common in sand/gravel substrate. *L. higginsii* does not only occur in areas where the river bottom is free of rooted plants. Divers have recently found significant numbers of *L. higginsii* in substrates with rooted plants in the "littoral areas of river channels" at Cassville, WI and Cordova, IL (M. Davis, pers. comm., 2003).

Stream Flow/Current/Hydrologic Variability

DiMaio and Corkum (1995) indicated certain species of mussels may be more readily found in different hydrologic conditions. *L. higginsii* may be primarily adapted to large river habitats with moderate current, such as the East channel of the Mississippi River near Prairie du Chien, Wisconsin (Andrew Miller, U.S. Army Corps of Engineers - Waterways Experiment Station,pers. comm.).

Water Quality

The effects of water quality, including inorganic and organic contaminants, are not well understood in freshwater mussels. Because of the scarcity of information in this area, most of the available data are not specific to *L. higginsii*; however, these data provide an indication of the relative effects of various water quality measures on unionids. Although this section will not be specific to *L. higginsii*, attempts will be made to reference studies on the genus *Lampsilis* or to species in the same subfamily (Lampsilinae).

In the Upper Mississippi River basin, sedimentation and toxic contaminants have been suggested as the major threats to biotic resources (Wiener *et al*. 1984). As benthic filter-feeding organisms, freshwater mussels are exposed to contaminants dissolved in water, associated with suspended particles, and deposited in bottom sediments. Thus, freshwater mussels can bioaccumulate contaminants to concentrations that exceed those in contaminated water or sediments. This section is organized into two parts: (1) existing water and sediment quality at *L. higginsii* locations where reproduction is occurring and (2) water and sediment quality measures most likely to adversely affect freshwater mussels.

The majority of the available data on mussels and contaminants concerns tissue residue studies (reviewed by Havlik and Marking 1987, Naimo 1995). Although these studies document existing contaminant burdens (*e.g.*, 100 mg of cadmium per gram dry tissue weight), there is little consistency in how the samples are obtained for analysis. For example, factors such as sex, age, season, reproductive status, and feeding status can all substantially alter the results of these studies. More importantly, there is little available information on what effects these residue concentrations have on the individual. For example, information on the highest tissue residue concentration that a mussel can tolerate without an adverse biological effect (lower growth rates, poorer reproduction, etc.) is largely unknown. These types of data are usually inferred from examining residue data from heavily contaminated systems and assuming that these mussels are being adversely affected.

Water and sediment quality at locations where L. higginsii are reproducing

Long-term persistence of *L. higginsii* in the Essential Habitat Areas identified in this plan indicates a history of successful reproduction in these areas. Based on the presence of reproducing populations, except where severely affected by zebra mussels, water and sediment quality are presumed to be presently not adversely affecting the survival of *L. higginsii* in the Essential Habitat Areas. Due to their limited mobility, however, freshwater mussels cannot actively avoid contaminated areas. Therefore, existing conditions at a given location should not necessarily be viewed as optimal or beneficial. Rather, these data should be viewed as ranges of physico-chemical values that allow survival or some level of reproduction of *L. higginsii* at the present time. Even though population size may be stable or even increasing at some sites, poor water or sediment quality could still be limiting population growth (*e.g.*, fecundity, juvenile survival, or growth rates could be negatively affected without causing a net population decline).

An assessment of water and sediment quality near reproducing populations of *L. higginsii* suggests that *L. higginsii* exist at locations with relatively good water and sediment quality (Tables 4 and 5 - see Section IV). It has been suggested that unionids require water with a hardness of at least 20 to 40 mg $CaCO_3$/L (Clarke and Berg 1959, Harman 1969) and an alkalinity of at least 15 mg $CaCO_3$/L (Harman 1970, Pennak 1978); hardness and alkalinity in the St. Croix and the Upper Mississippi rivers exceed these levels.

Few data exist on the concentrations of most contaminants thought to adversely affect freshwater mussels. Nevertheless, the presence of reproducing *L. higginsii* populations and the diversity and abundance of many other unionid species at Essential Habitat Areas, at least before zebra mussel invasions, suggests water quality is not limiting unionid survival and reproduction. Furthermore, because many inorganic and organic contaminants that enter aquatic systems associate with fine sediments (*i.e.*, silts and clays), the greatest likelihood for adverse effects from these contaminants should be in depositional areas with fine sediments.

The existing data for *L. higginsii*, however, suggests that the species is not generally found in areas with a relatively significant amount of sediment deposition (see habitat characteristics section). Thus, *L. higginsii* are generally not located in areas where concentrations of heavy metals and organic contaminants are most likely to reach toxic levels.

Water and sediment quality factors likely to affect unionids

Siltation, Eutrophication, and Ammonia -- High total suspended solids is often cited as a factor affecting the quality of freshwater mussel habitat. Aldridge *et al*. (1987) found intermittent exposure of freshwater mussels *(Quadrula quadrula*, *Pleurobema beadleanum*, and *Fusconaia cerina*) to 600 to 750 mg/L of suspended solids adversely affected feeding rate, oxygen uptake, and excretion. Concentrations of suspended solids of this magnitude, however, are not expected to occur in either the St. Croix or Upper Mississippi Rivers; Dawson *et al*. (1984) found concentrations in these two rivers that ranged from 1 to 54 mg/L and from 1 to 120 mg/L, respectively.

Recently, the effects of un-ionized ammonia (NH_3) on unionids have been evaluated. Augspurger *et al.* (2003) reviewed thirty acute (24-96 hour) median lethal concentrations (LC50s) covering ten species in eight unionid genera and three life history stages. These values indicate that unionids are sensitive to ammonia relative to fish and other vertebrates. They reported that "(G)enus mean acute values ranged from 2.56 to 8.97 mg/L total ammonia as N, normalized to pH 8." LC50s for juvenile unionids are typically "substantially less than the acute national water-quality criteria" (Newton 2003), which is 8.40 mg N/L at pH = 8.0 when salmonids are absent (U.S. Environmental Protection Agency 1999). Augspurger *et al.* (2003) proposed interim criteria for maximum and continuous concentrations of ammonia that may be necessary to protect unionids from acute and chronic exposures, respectively. They acknowledged, however, that it is difficult to calculate criteria for chronic exposures due to the paucity of data on long-term exposure and sub-lethal effects (Augspurger *et al.* 2003).

Ammonia sources "include industrial, municipal, and agricultural wastewaters", precipitation, and natural processes (Newton 2003). Concentrations of 30 Fg NH_3/L are frequently observed in sediment pore water in the Upper Mississippi River during summer (Frazier *et al*. 1996). Concentrations in pore water in the St. Croix River in 2001 ranged from 0.3 to 140.8 Fg NH_3-N/L (Bartsch *et al.* 2003). Because concentrations of NH_3 are related to temperature and pH, elevated concentrations can occur in riverine systems during low flow periods. Concentrations of NH_3 are also related to particle size, however, with finer sediments containing elevated concentrations of NH_3 (Frazier *et al*. 1996). Thus, the greatest threat to unionids from NH_3 is likely to occur in fine sediments during low flow periods.

Although recent data suggest that mussels are generally more sensitive to ammonia than fishes, effects of ammonia on host fishes is also important for the conservation of *L. higginsii*. Mean acute levels of ammonia for two marginal host species (green sunfish and bluegill, Table 3) and three suitable host species (largemouth bass, smallmouth bass, and walleye, Table 3) ranged from 20 to 35 mg NH_3-N/L (at pH = 8, U.S. EPA, unpubl. data summary).

Inorganic and Organic Contaminants -- An assessment of the available data in the Upper Mississippi River basin suggests contamination of riverine sediments with elevated concentrations of pesticides, heavy metals (Cd, Cu, Hg, and Zn), polychlorinated biphenyls (PCBs), and ammonia may pose the greatest harm to benthic invertebrates (Naimo *et al*. 1992a; 1992b; Steingraeber *et al*. 1994; Frazier *et al*. 1996).

Many contaminants, particularly toxic metals, that enter aquatic systems are adsorbed onto suspended particles and subsequently accumulate in surficial sediments (Tessier and Campbell 1987). Toxic concentrations of dissolved metals are uncommon in oxic surface waters. In the Mississippi River, for example, more than 90% of the trace metal load is associated with particles (Trefry *et al*. 1986). Thus, these metals can be accumulated by, and directly affect, filter-feeding benthic organisms such as freshwater mussels. Recently, studies have focused on sediment pore water because it is well known that concentrations of inorganic and organic contaminants in pore water can greatly exceed concentrations in overlying surface water. Yeager *et al.* (1994) demonstrated that although juvenile *Villosa iris* burrowed less than 1 cm into the sediment, they were not exposed to the overlying water. Thus, although freshwater mussels, in general, can be exposed to metals dissolved in water, associated with suspended particles, and deposited in bottom sediments, juvenile mussels are most likely exposed to elevated metal concentrations found in association with sediment or pore water.

The effects of heavy metals on freshwater mussels, particularly cadmium (Cd), copper (Cu), mercury (Hg), and zinc (Zn), have been studied more than other contaminants because they are widespread, persistent, potentially toxic, and because many freshwater ecosystems are contaminated with these metals, as a result of human activities (Naimo 1995). Laboratory-based acute toxicity values for juvenile mussels, range from 44-388 Fg Cu/L (Keller and Zam 1991; Jacobson *et al*. 1993), 211-588 Fg Zn/L (Keller and Zam 1991; McCann 1993), 107-345 Fg Cd/L (Keller and Zam 1991; Lasee 1991). Cherry *et al.* (2002) found mean acute values ranging from 37-4030 Fg Cu/L among eight mussel species using water from Clinch River, Virginia; *Lampsilis fasciola* had the lowest species mean acute value (37, st. dev.=12.6). Concentrations of total Cd, Cu, Hg, and Zn in surface waters of the St. Croix River at St. Croix Falls, Wisconsin, are well below concentrations thought to be harmful to freshwater mussels (Table 5 - see Section IV). Similarly, in the reach of the Upper Mississippi River between Coon Rapids, Minnesota (River Mile 870) and Red Wing, Minnesota (River Mile 800), concentrations of total Cd, Cu, and Zn in surface waters are also below concentrations thought to be detrimental to mussels (ranges, Cd: 0.8-2.0 Fg/L, Cu: 5.2-6.8 Fg/L, and Zn: 20-30 Fg/L; Boyer 1984).

Virtually nothing is known about the sublethal impacts in mussels to long-term exposure to metals at low concentration. Although laboratory toxicity tests provide tolerance limits, few of these tests have used environmentally realistic exposure concentrations. For example, total concentrations of Cd, Cu, Hg, and Zn in many oxic surface waters are in the ng/L range, yet many toxicity studies have exposed mussels to concentrations in the Fg/L or even mg/L range (reviewed in Naimo 1995). Sublethal effects are frequently observed at concentrations only one-half the lethal concentrations, which indicates freshwater mussels become stressed at metal concentrations much lower than those reported in acute toxicity tests. For example, Jacobson *et al*. (1993) determined the 24-h LC_{50} for juvenile *Villosa iris* was 83 Fg Cu/L, but the 24-h EC_{50} (percent gaped and dead or ungaped) was 27 Fg Cu/L. In addition, Lasee (1991) determined that 0-d old juvenile *Lampsilis cardium* were killed at concentrations of 141 Fg Cd/L, but significant reductions in ciliary activity, a surrogate for feeding intensity, were evident at concentrations of 90 Fg Cd/L.

Comparatively less is known about both acute and sublethal effects of organic contaminants on freshwater mussels. Keller (1993) exposed juvenile *Utterbackia imbecillis* to eight organic compounds in laboratory tests and found pentachlorophenol was the most toxic (48-h LC_{50} = 0.6 mg/L) and methanol (48-h LC_{50} = 37.0 mg/L) was the least toxic. Mussels were insensitive to the herbicide Hydrothol-191 (96-h LC_{50} = 4.9 mg/L) and two chlorinated pesticides (chlordane, 96-h LC_{50} = 0.9 mg/L and toxaphene, 96-h LC_{50} = 0.7 mg/L), relative to *Ceriodaphnia dubia*, an organism commonly tested in laboratory studies (Keller 1993). Furthermore, juvenile *Utterbackia imbecillis* and *Villosa villosa* were insensitive to malathion, a commonly used organophosphorus insecticide (Keller and Ruessler 1997).

Although there are fewer data on the effects of organic contaminants to unionid mussels, the available data suggest some compounds in the Upper Mississippi River have the potential to harm *L. higginsii* and to degrade entire benthic invertebrate communities. For example, zebra mussels have been shown to bioaccumulate substantial quantities of PCBs in the Upper Mississippi River (M.R. Bartsch, U.S. Geological Survey - Upper Midwest Environmental Sciences Center, pers. comm.). In addition, a survey of PCBs in emergent mayflies identified two zones of concern regarding PCB contamination of riverine sediments--Pools 2 through 6 and Pool 15 of the Upper Mississippi River (Steingraeber *et al*. 1994).

In the Mississippi River, suspended sediments can transport substantial quantities of organochlorine pesticides such as PCBs, DDT and its metabolites (DDE and DDD), aldrin, and dieldrin. For example, during 1988 to 1993, suspended sediments in the Mississippi River transported between 410 and 37,000 grams per day of total PCBs (Rostad 1997). Because unionids can filter large volumes of water (range, 60 to 490 mL/individual/hour; Stanczykowska *et al.* 1976), the potential exists for unionids to obtain a substantial contaminant mass through inhalation of suspended particles.

Contaminants may also affect mussels via the fish that serve as hosts for the juveniles. Recently, it has been shown that exposure to fish containing elevated body burdens of DDE, toxaphene, or atrazine during transformation reduced the survival of juvenile mussels (N. J. Kernaghan, Florida Caribbean Science Center, pers. comm.). Thus, studies on *L. higginsii* should also examine contaminant body burdens in their fish hosts.

Water Quality Data Gaps

1. The biological effects of contaminant residues on freshwater mussels are largely unknown (*i.e.*, can a mussel accumulate 100 mg/g of contaminant “X” without deleterious effects to reproduction, feeding, and survival?).

2. One serious constraint in evaluating the effects of contaminants on the various life stages of freshwater mussels is the lack of basic information required for laboratory toxicity studies: nutritional requirements, culture methods, and realistic exposure concentrations--all of these likely affect the susceptibility of mussels to contaminant exposure. Furthermore, the lack of data on nutritional requirements and culture methods for species at risk, such as *L. higginsii*, jeopardizes species-specific studies.

3. Comparative data on modes of uptake in freshwater mussels are needed to more fully evaluate contaminant effects, design contaminant monitoring programs, and to develop water-quality criteria that adequately protect freshwater mussels. The relative significance of contaminant uptake from food sources, surface water, pore water, and sediments as routes of exposure is not documented.

4. The existing data on the most sensitive life history stage (*i.e.*, glochidium, juvenile, adult) are conflicting. More information is needed to determine which life history stage and sex

is the most sensitive or to determine if this sensitivity is contaminant-specific. These data will help guide and standardize field and laboratory toxicity tests for unionids.

Community Associations

Lampsilis higginsii is often found in dense and diverse mussel beds. Cawley's (1996) review indicated that on average 20.7 species of mussels were found at sites where *L. higginsii* have been collected (range 2 - 36 species). Havlik (1983) commented on the common occurrence of *L. higginsii* with either *Obovaria olivaria* or *Megalonaias nervosa*. Duncan and Thiel (1983) and Davis and Hart (1995) also reported a close relationship between the presence of *O. olivaria* and *L. higginsii*. Miller and Payne (1996b), however, found no positive relationship between the presence of *M. nervosa* and *L. higginsii*. Heath (1995) noted that four species (*Amblema plicata*, *Quadrula pustulosa*, *Fusconaia flava* and *L. cardium*) are very common at all known *L. higginsii* sites. Others have reported that at most *L. higginsii* sites, *L. higginsii* accounted for approximately 0.5% of the community (Fuller 1980; Thiel 1981; Holland-Bartels 1990; Miller and Payne 1991, 1992, 1993, 1994; Hornbach *et al*. 1995; Miller and Payne 1995a, 1995b, 1996a, 1997). In some areas *L. higginsii* may account for up to approximately 2.75% of the community (A. Miller *unpubl. data*), whereas in some marginal areas it may make up a smaller proportion of the mussel community. Hornbach *et al.* (1995) hypothesized that populations in marginal habitat areas are maintained by fish-mediated transport of glochidia from other populations.

Non-human Predators

The natural predators of adult mussels include a variety of aquatic and semi-aquatic animals: *Ondatra zibethicus* (muskrats) (Apgar 1887; Evermann and Clark 1920; Van Cleave 1940; Errington 1941; Takos 1947; Pennak 1978; Hanson *et al*. 1989; Convey *et al*. 1989; Neves and Odom 1989; Lacki *et al*. 1990), *Lutra canadensis* (river otters) (Morejohn 1969; Toweill 1974; Pennak 1978), *Mephitis mephitis* (striped skunk) (Hazard 1982), *Mustela vison* (mink) (Pennak 1978), turtles (Pennak 1978), *Cryptobranchus* (hell benders) (Pennak 1978), fish (McMahon 1991; Williams *et al*. 1993) and *Procyon lotor* (raccoon) (Evermann and Clark 1920; Hazard 1982). Tyrrell and Hornbach (1998) found differences in the sizes of mussels taken from the middens and adjacent river samples indicating that small mammals are size-specific mussel predators in the St. Croix and Mississippi Rivers. Their conclusions are supported by previous findings in similar studies. Convey *et al*. (1989), Hanson *et al*. (1989) and Jokela and Mutikainen (1995) found that mussels in midden piles were longer on average, than the mussel population in the adjoining body of water. Tyrrell and Hornbach (1998) also found differences in species composition, richness and diversity between mussels collected from middens and adjacent river sites, revealing species-specific selection by small mammal predators. This result was supported by the findings of Neves and Odom (1989) and Watters (1995), who found that muskrats exhibited preferences for some mussel species over others. Davis and Hart (1995) found 2 freshly consumed *L. higginsii*, both females, in muskrat middens in Pool 7 of the Mississippi River.

If populations of *L. higginsii* continue to decline in the mainstem of the Mississippi River, it is possible that predation, especially in smaller river systems such as the St. Croix and Wisconsin rivers may become a more important threat to *L. higginsii*.

<u>Genetics</u>

There have been relatively few studies that address the genetic structure and diversity of unionid populations. Many of the studies that have been conducted have been structured to examine evolutionary relationships among species (*e.g.* Davis and Fuller, 1981; Davis *et al.* 1981; Davis 1984; Lydeard *et al.* 1996). Kat (1983) and Stiven and Alderman (1992) focused their studies on *Lampsilis* species, but neither included *L. higginsii*. As in most genetic studies on unionids, these studies focused on species and subspecies identification - *i.e.*,determining the "status" of various taxonomic groups. Few studies have been designed to examine the degree of genetic variability both among and within populations of unionids. These types of studies are imperative if conservation efforts, including relocation projects, are to be successful in maintaining the genetic diversity of mussel species (Villella *et al.* 1997). One study by Berg *et al.* (1997) indicated that large river species and small stream species may differ in their "within" and "among"-population genetic variability. A large river species was found to have a high level of within-population genetic variability and a low level of among-population variability. Berg *et al.* (1997) claimed that large river populations may be considered a single large metapopulation, and thus preservation of several populations in big rivers will conserve most of a taxon's genetic diversity. While their study is intriguing, it is based on only a single species of mussel (*Quadrula quadrula*).

Data from mitochondrial DNA analysis from four populations of *L. higginsii* in the St. Croix (Hudson) and Mississippi Rivers [Whiskey Rock (IA), Cassville, WI, and Cordova, IL] indicate a high degree of genetic variability within populations with no site-specific haplotypes (genes or sets of genes that are inherited together, Bonnie Bowen, Dept. Animal Ecology, Iowa State University, Ames, Iowa *in litt.* 1999, 2002, and 2003). *L. higginsii* seems to possess a high degree of genetic variability relative to other endangered species (B. Bowen *in litt.* 2002 and 2003). Biologists planning and implementing artificial propagation and reintroduction of *L. higginsii* must be careful to ensure that reintroduced populations reflect the genetic variability found in natural populations.

Reasons for listing

The major reasons for listing *L. higginsii* were the decrease in both abundance and range of the species. As stated in the initial recovery plan (USFWS 1983), the Higgins eye pearlymussel 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 initial listing of the species, 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 (1987a) 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 (1987) also indicated an "unusual" number of fresh-dead *L. higginsii* at this site in 1985. Few papers presented at a workshop examining die-offs (Neves 1987) gave concrete reasons for the cause of the die-off, however Scholla *et al.* (1987) indicated that a gram-negative rod bacterium, which forms yellow colonies was associated with "sick" mussels from the Tennessee River. Research on mussel pathogens (bacterial, viral and protozoan) and their effects on population levels has not been conducted.

<u>Present Threats</u>

Zebra Mussels and other Invasive Species (see Tasks under 1.1 and 2.3 in the step-down outline)

Zebra Mussels -- The introduction of the zebra mussel to North America has negatively affected populations of native mussels (Unionidae) (Mackie 1991; Hunter and Bailey 1992; Strayer 1999). Unionid mussels evolved in the absence of any major fouling organisms and have no mechanisms for dealing with their deleterious effects. Zebra mussels have the potential to impact unionids both directly, by actual attachment, and indirectly, through competition for food or changes in water quality (Descy *et al.* 2003; Makarewicz *et al.* 2000). The relative amount of stress caused by zebra mussel attachment may be species and sex specific. For example, members of the subfamily Ambleminae, which are short-term brooders, are less stressed by zebra mussel colonization than are long-term brooders, such as the Lampsilinae (Haag *et al*. 1993). Sexual differences within a species also exist, with colonized males being less stressed than colonized females (Haag *et al*. 1993). These studies suggest that zebra mussel introduction could drastically alter unionid mussel community structure and overall biodiversity by affecting the fitness of community members unequally.

One way that zebra mussels effect unionids is through direct attachment to their shells. Zebra mussels can colonize all species and may reduce both population size and species richness of unionids (Mackie 1991). Observations by Hebert *et al*. (1989) and laboratory studies by Lewandowski (1976) showed that zebra mussel attachment rates were higher on live unionids than on dead unionids or rocks, although recent studies by Toczylowski and Hunter (1996) indicated that this preference may not be exhibited in the field. In 1989, on Great Lake gravel substrates, one third of the zebra mussels were attached to unionids, while the rest were attached to the gravel (Hebert *et al*. 1989). Unionid shells may provide substrate for zebra mussels in areas that they would otherwise be unable to colonize. Hebert *et al*. (1989) note that zebra mussels are most often found in locations with gravel substrate, but can also be found on sand and silt substrate if hard objects, such as unionids, are available. In the Great Lakes and in Polish lakes, up to 90% of the unionid population had attached zebra mussels (Lewandowski 1976; Hebert *et al*. 1989); although even severe infestations may not cause immediate 100% mortality of unionids in the Great Lakes, reductions in unionid densities to levels <5% of the pre-zebra mussel colonization levels have been documented and the long-term viability of the remnant populations is unclear (Schloesser 1997). Haag *et al*. (1993) examined unionids in Lake Erie and found an average of 216 zebra mussels attached to each unionid. Individual unionids have been found encrusted with over 10,000 zebra mussels (Hebert *et al*. 1991).

The direct attachment of zebra mussels may affect unionids in several ways. Unionid locomotion may be impaired by the attached zebra mussel biomass. Zebra mussel biomass often exceeds that of the underlying host unionid (Lewandowski 1976; Mackie 1991). Tucker (1994) indicated that habitat alteration, with zebra mussels forming a "pavement" over gravel bars, prevented unionids from burrowing. Zebra mussels may interfere with siphon extension or prevent valve closure and opening, resulting in inhibition of feeding, respiration or excretion. Wiktor (1963) reported that zebra mussels can over-grow *Unio spp*. and *Anodonta spp.*, resulting in "suffocation." Prevention of valve closure may increase the susceptibility of unionids to diseases, parasites, and predation. Zebra mussels can also cause shell deformation of unionid shells, especially near the siphons (Lewandowski 1976). These deformations may also contribute to inhibition of physiological functions.

Indirect effects of zebra mussels on unionids include potential competition for food and changes in water quality. Zebra mussels, as filter-feeding organisms, have the potential to strip the water of food and nutrients. The enormous influence of zebra mussels on the phytoplankton dynamics of aquatic systems has been estimated by a number of authors. Stanczykowska *et al*. (1976) calculated that filter feeders, especially zebra mussels, consumed 8% of the primary production per year in a Polish lake. Lewandowski (1983) concluded that a population of zebra mussels in another lake in Poland can filter 213 x 10^6 m^3 of water per year. Reeders *et al*. (1989) indicated that the zebra mussel populations in Lakes Ijsselmeer and Markermeer in the Netherlands had the capacity to filter these lakes once or twice a month, greatly reducing phytoplankton biomass. Descy *et al.* (2003) found that high zebra mussel densities on the River Moselle in western Europe resulted in the loss of "virtually all small zooplankton in the summer." In addition, excretion of ammonium by zebra mussels may lead to increases in ambient concentrations of ammonia (Lavrentyev *et al.* 2000; Makarewicz *et* al. 2000).

Zebra mussels may also be affecting unionid mussel populations by filtering their glochidia. MacIsaac *et al.* (1991) indicated that although mussels preferred algal foods smaller than 50 Fm, they can ingest particles at least up to 400 Fm in length. McMahon (1991) indicated that unionid glochidia range in size from 50-400 Fm, with most less than 200 um. Consequently, it is possible that zebra mussels consume unionid glochidia.

There are no studies that adequately quantify competition for food among freshwater mussels. Based on theoretical considerations, Levinton (1972) claimed it unlikely that there is competition for food among filter-feeding organisms. A number of studies in marine systems (*e.g*. Wildish and Kristmanson 1984, Fréchette *et al*. 1989), however, indicate that food supply to bivalves may be limited and that competition for food may be an important factor in controlling bivalve growth. Certainly, the potential for competition for food resources between zebra mussels and unionids is great. Strayer *et al.* (1996) and Caraco *et al.* (1997) have implicated a reduction of phytoplankton abundance in the Hudson River to the introduction of zebra mussels to this system;

this may also explain subsequent reductions in unionid density, even though the number of zebra mussels attached per unionid is quite low.

Zebra mussels have clearly had major impacts on North American unionids (Strayer 1999). Strayer and Smith (1996) have shown that unionid density fell by 56%, recruitment of young-of-the-year unionids fell by 90%, and condition of unionids fell by 20-50%, 4 years after the introduction of zebra mussels into the Hudson River. Similarly, Ricciardi (1996) found significant declines in unionid density and physiological condition in the St. Lawrence River 3-5 years after the introduction of zebra mussels.

All current populations of *Lampsilis higginsii* are under the potential threat of being colonized by zebra mussels; only one of the current Essential Habitat Areas, Interstate Park in the St. Croix River, is entirely free of zebra mussels. Tucker *et al.* (1993) reported the widespread colonization of unionids by zebra mussels in the upper Mississippi River. Clarke and Loter (1995) found nearly a ten-fold increase in zebra mussel densities from 1993 to 1994 at Prairie du Chien. Cope *et al.* (1996) summarized the status of zebra mussels in the upper Mississippi River and indicated that densities ranged from 1-11,000 zebra mussels/m^2 on the locks and dams in this stretch of the river. Ricciardi *et al.* (1995b) indicated that severe unionid mortality (>90%) is expected when zebra mussel density reach 6000/m^2 with infestation rates of 100 zebra mussels/unionid.

Zebra mussels have had a substantial impact on the mussel community at Prairie du Chien, WI, one of the Essential Habitat Areas (Miller and Payne 2001). Quantitative and qualitative samples for freshwater bivalves have been collected in the east channel of the Mississippi River at Prairie du Chien by the U.S. Army Engineer Waterways Experiment Station since 1984 (A. Miller, pers. comm.). The first zebra mussels in quantitative samples were taken in 1993, averaging 2 individuals/m^2. Zebra mussel density increased to over 10,000 individuals/m^2 in 1996. Although zebra mussel densities decreased and varied from 1996 to 2000, mean density estimates typically exceeded 1,000 individuals/m^2. Coincident with these densities of live zebra mussels, shell material from dead zebra mussels had increased to a depth of approximately 50 cm in some areas. Additionally, divers reported substantial hydrogen sulfide production associated with dead zebra mussels and other organic debris.

Impacts of zebra mussels on reproduction in some areas occupied by *L. higginsii* has been profound. From 1984 to 1994, evidence of recent recruitment for native mussels in the East Channel at Prairie du Chien was highly variable, but obviously unaffected by zebra mussels (A. Miller, *unpubl. data*). The percentage of live unionids less than 30 mm total shell length during this period ranged from 10.7% in 1984 to a maximum of 41.5% in 1993. The percentage of species showing at least some evidence of recent recruitment ranged from a low of 36.8% in 1992 to a high of 75% in 1987. In 1996, when zebra mussel density was at its maximum, juvenile native mussels were present, but the percentage of recent native mussel recruits decreased to 0.0% in 1999 and 2000. Thus, zebra mussel densities in 1996 and 1997 virtually eliminated recruitment of native species by 1999.

Mean density of all unionids in the East Channel varied from a maximum of 149 individuals/m^2 to a minimum of 28.3 individuals/m^2 during the period 1984-1994 (A. Miller, *unpubl. data*). Year-to-year variation could have been caused by slight differences in sample site locations, mortality of older age classes, and variation in recruitment. The rapid decline in native mussel density after 1996, first noted in 1998 (10.1 individuals/m^2) and continuing in 1999 (1.7 individuals/m^2), however, is almost certainly related to the presence of zebra mussels. Before 1999 *L. higginsii* comprised ≥1% of the total native mussel fauna in the East Channel in all study years. Live specimens of *L. higginsii* were not collected at this location during quantitative (*i.e.*, systematic, randomized) sampling in 1999 and 2000, however, and only one live *L. higginsii* was collected during qualitative sampling in those two years. In 1999, quantitative and qualitative samples were also collected in the main channel of the Mississippi River approximately 1 mile from the sampling location in the East Channel. A qualitative sample collected there included five *L. higginsii* out of a total of 198 unionids collected (*i.e.*, *L. higginsii* comprised 2.5% of the sample). Zebra mussel densities were lower in this main channel location than in the East Channel.

Data indicate that densities of live zebra mussels have declined recently at Prairie du Chien, at least temporarily. In 2003, mean zebra mussel density was 30.7 (SD = 42.8, n = 5, U.S. Army Corps of Engineers, unpubl. data), whereas in 2000 it was 9390 individuals/m^2 (SD = 2932.4, n = 10, U.S. Army Corps of Engineers, unpubl. data). Native mussels have persisted, but mean unionid densities are well below the minimum densities observed before zebra mussels invaded. In 2003, mean unionid density was 6.5 individuals/m^2 (SD = 4.9, n = 5, U.S. Army Corps of Engineers, unpubl. data).

The Corps has found similar declines in zebra mussel densities at Cassville, WI (U.S. Army Corps of Engineers, unpubl. data). Upstream populations of zebra mussels persist, however, most notably at Lake Pepin. Therefore, the threat of another devastating influx of zebra mussels at Prairie du Chien and other *L. higginsii* habitats is still imminent despite recent population trends. In the long term, zebra mussels may have only transitory or temporarily depressing impacts on native mussel populations, including those of *L. higginsii.* The current data indicate, however, that it is prudent to consider zebra mussels as a mortal threat to *L. higginsii* until new information indicates otherwise (*e.g.*, data indicating recovery of *L. higginsii* populations affected by zebra mussels).

Humans agents (*e.g.*, barges and recreational boats) are likely the most important and, perhaps, the only way by which zebra mussels spread upstream in rivers (Carlton 1993). Zebra mussels attach to nearly anything submerged and can survive for days out of water, depending on the temperatures and relative humidity to which they are exposed. Recreational and commercial vessels transport zebra mussels when they attach to exterior hulls or other structures or when they inhabit bilges, bait wells, water intake fittings, or any other wetted part of boats. They can be spread by any wetted equipment, such as construction equipment previously used in infested water or by diving equipment, including air tanks and dive suits used in infested waters.

Due to the presence of a veliger larvae in the life-cycle of zebra mussels, downstream transport by flow is common in river populations whereas human-mediated transport is the significant mode of upstream transport. In Europe's Rhine River, studies indicate that upstream lakes and impounded reaches along the river provide the veligers necessary to maintain downstream populations of *Dreissena polymorpha* (Borcherding and De Ruyter Van Steveninck 1992; Janz and Neumann 1992; Kern *et al.* 1994). Kern *et al.* (1994) indicate that zebra mussel population fluctuations in upstream lakes (mainly caused by waterfowl - Cleven and Frenzel 1993) were responsible for downstream fluctuations in population levels, but tests by Johnson and Carlton (1996) seemed to discount the role of waterfowl in the overland transport of zebra mussels. Clarke (1992), Carlton (1993) and Martel (1995), among others, have indicated that upstream dispersal of zebra mussels is due to human transport, primarily on boats. Boats pulled overland on trailers may be the primary mechanism for overland dispersal (Ricciardi *et al.* 1995a; Bossenbroek *et al.* 2001); the majority of within-river upstream transport occurs by attachment to commercial and recreational boats.

Without upstream transport and a stable upstream population of zebra mussels, it is not clear whether downstream populations will remain stable. Whitney *et al.* (1995) reported drastic declines in zebra mussels in the Illinois River after large populations were reported in 1994. It is presumed that transport of zebra mussels from the Great Lakes through the Illinois River, with subsequent upstream transport on commercial barges, resulted in the current distribution of zebra mussels in the Mississippi River from St. Paul, MN and downstream. Whitney *et al.* (1995) indicate "Given the man-made connection with Lake Michigan ... we expect mussels numbers in the Illinois will fluctuate dramatically over the next few years ..."

There are large populations of zebra mussels as far upstream as Lake Pepin on the Mississippi River (Pool 4) and they are now also established in the lower St. Croix River, which is upstream of Lake Pepin. Zebra mussels have been found farther upstream at locks and dams as far as St. Paul, MN, but self-sustaining populations upstream of the mouth of the St. Croix River may not exist at this time, due to a lack of a significant upstream source of veligers. In the St. Croix River zebra mussel populations are recently established and appear to be self-sustaining in the mostly lacustrine portion of the lower river, upstream to Stillwater, MN (N. Rowse, USFWS, pers. comm. 2003); this reach of the St. Croix River includes both the Hudson and Prescott Essential Habitat Areas.

Currently, there is a proposal to develop an invasive species barrier between Lake Michigan and the Illinois River (Moy 1999), although at present the design would not restrict zebra mussels. The only hope of developing effective strategies for managing zebra mussels, or of determining if specific strategies are necessary or feasible, is to monitor the spread of zebra mussels and their potential effects on *L. higginsii*, particularly in Essential Habitat Areas.

Interagency Cooperation Between the Service and U.S. Army Corps of Engineers -- On 15 May 2000, the Service issued a biological opinion to the U.S. Army Corps of Engineers (Corps) in which it determined that the Corps' continued operation and maintenance of the 9-foot navigation channel on the Upper Mississippi River System (UMRS) would jeopardize the continued existence of *Lampsilis higginsii*. The Service based this finding on the effects to *L. higginsii* of the upriver transport of zebra mussels by commercial and recreational vessels. In its biological opinion, the Service provided a reasonable and prudent alternative to the proposed action to avoid jeopardizing *L. higginsii* and mandated further measures to minimize the incidental take that would result from implementation of the proposed action. Implementation of the reasonable and prudent alternative and the reasonable and prudent measures is mandatory for the Corps. As a result, the Corps must (1) conduct a *L. higginsii* relocation feasibility analysis, (2) prepare a Higgins eye Pearlymussel Relocation Plan, (3) implement a monitoring program for *L. higginsii* and other unionids in the Upper Mississippi River System, (4) investigate opportunities to protect live *L. higginsii* individuals within essential habitat areas in the Upper Mississippi River System during the interim period between issuance of the biological opinion and implementation of the relocation phase, and (5) develop and implement an action plan to monitor abundance and distribution of zebra mussels on the Upper Mississippi River System.

In response to the biological opinion, the U.S. Army Corps of Engineers established a Mussel Coordination Team with a Partnership Agreement signed by agency heads of the U.S. Army Corps of Engineers, St. Paul and Rock Island Districts; the USFWS; the U.S. Geological Survey; the National Park Service; the U.S. Coast Guard; and the departments of natural resources from the states of Minnesota, Wisconsin, Iowa and Illinois. The purpose of the Mussel Coordination Team is to work cooperatively to coordinate and plan relevant mussel studies and projects and to share information on the management of native mussel resources and control of invasive non-indigenous mussel species.

The Corps subsequently developed draft interim and long-term goals and objectives to address the conservation of *L. higginsii* (U.S. Army Corps of Engineers 2002). The Interim Goal (next 10 years) is to maintain and/or establish reproductively viable populations of Higgins Eye Pearlymussels based on the following objectives:

Objective 1. Maintain viable populations of *L. higginsii* and other native mussels at the Interstate, Hudson, Prescott and Orion Essential Habitat Areas.

Objective 2. Protect as many *L. higginsii* as practical in the following Essential Habitat Areas and/or other important habitats: Lower St. Croix River (Hudson), Lower St. Croix River (Prescott), UMR - Pool 9 (Whiskey Rock), UMR - Pool 10 (Harpers Slough), UMR - Pool 10 (Prairie du Chien), UMR - Pool 10 (McMillan Island), UMR – Pool 13 (Bellevue), UMR - Pool 14 (Cordova), UMR - Pool 15 (Sylvan Slough).

Objective 3. Establish a minimum of five new and viable populations of *L. higginsii* in the UMR and/or tributaries un-infested or with low level infestations of zebra mussels.

Objective 4. Monitor trends in abundance and distribution of *L. higginsii* and other native mussels.

Objective 5. Monitor trends in abundance and distribution of zebra mussels in the UMRS.

The Long-term Goal of the Corps' conservation plan is to maintain existing (year 2000) population levels of Higgins eye pearlymussels within at least four geographically separate areas meeting the criteria for Essential Habitat.

Objective 1. Prevent zebra mussel infestation above Lake Pepin and into the Lower Wisconsin River and other UMRS tributaries and reverse current zebra mussel population trends in the UMRS, especially from Lake Pepin downstream to the confluence of the Illinois River.

Objective 2. Restore *L. higginsii* populations and habitat in essential and other habitat areas.

Various aspects of these plans were initiated in summer 2001. Higgins eye pearlymussel and zebra mussel populations will be monitored at Essential Habitat Areas and at other key study sites over the next 10-25 years to evaluate the effectiveness of past and current management strategies.

Currently, the areas above Pool 4 include areas of historic *L. higginsii* populations as well as two Essential Habitat Areas (both in the St. Croix River). Invasion of those two areas could result in the relocation of *L. higginsii* to river reaches where zebra mussels are absent or present at low densities. Relocation of *L. higginsii* to uninfested rivers or other waters may become the only means of preserving the species. Thus, there is need for (1) capability to identify suitable *L. higginsii* habitat refuge areas, (2) measures to safely and effectively remove all life stages of zebra mussels from *L. higginsii* to be relocated to avoid contaminating release sites, and (3) safe and effective *L. higginsii* relocation methods and protocols.
The Team, therefore, stresses the importance of:

1. Preventing zebra mussels from spreading to the remaining uninfested *L. higginsii* areas in the St. Croix and Wisconsin rivers.

2. Monitoring, studying, and documenting zebra mussels and their impacts on *L. higginsii*, particularly in infested Essential Habitat Areas.

3. Researching and developing *L. higginsii* habitat identification guidelines for selecting refuge areas outside present *L. higginsii* range.

4. Developing *L. higginsii* relocation techniques.

Black Carp (*Mylopharyngodon piceus*) – Black carp, which were introduced from Asia into aquaculture operations in several southern states, are molluscivores that consume snails and bivalves. Their establishment in the Mississippi River would likely threaten Higgins eye. Black carp inhabit large rivers in their native range, which extends from 22-51° north latitude (K. Duncan, U.S. Fish and Wildlife Service, pers. comm. 2004). Nico *et al.* (2001) found that the likelihood of black carp becoming established in open waters in the U.S. is "High – Very Certain" because many aquaculture facilities in the southern U.S. are highly vulnerable to flooding. Subsequent to their analysis, on March 26, 2003, a commercial fisherman caught one black carp, evidently a sterile triploid specimen, in an oxbow that is "occasionally connected to the Mississippi River during floods" (Chick *et al.* 2003). The Mississippi is among the four major river basins that appear to provide appropriate habitat for the spread of this species (Nico *et al.* 2001). Other Asian carps – bighead (*Hypophthalmichthys nobilis*) and silver (*H. molitrix*) – are already "firmly established and spreading in the Mississippi River system (Nico *et al.* 2001).

Round goby (Neogobius melanostomus) – Round goby is another species introduced into North America from Eurasia that may threaten Higgins eye. Unlike black carp, it was introduced unintentionally from freighter ballast. It has become established in several areas in North America, including the Mississippi River Basin – it now occurs in the upper 18% of the Chicago Sanitary and Shipping Canal, which flows into the Illinois River (P. Thiel, USFWS, pers. comm., 2004). Their size (approx. 7-10 cm) would likely limit their impact to the consumption of Higgins eye < 10 mm in length (Ray and Corkum 1997). Therefore, the consequences of round goby establishment in the range of Higgins eye may be less than that of black carp, but they still pose a potential threat to this and other unionids.

Habitat Alteration (see Tasks under 1.2, 1.3, 1.4, 1.8, and 2.1 in the step-down outline)

Modifications to the Upper Mississippi River (UMR) for navigation began about 1878 when Congress authorized a 4 ½-foot navigation channel. Modifications consisted primarily of clearing and snagging, construction of wing and closing dams, and a canal to bypass the Des Moines rapids at Keokuk, Iowa. In 1907, a 6-foot channel was authorized, with construction of more wing and closing dams, dredging, bank revetment, and two locks at the Rock Island rapids, Illinois. In 1930, a 9-foot channel was authorized, including the construction of locks and dams; it was completed by 1940 (Crittenden 1980). These modifications have resulted in profound changes in the nature of the river, primarily replacing a free-flowing alluvial system with a stepped gradient river. Continual maintenance of the 9-foot channel requires dredging, wing and closing dam reconstruction and maintenance, and bank stabilization. The last major modification on the UMR occurred in 1995 when a second lock at Melvin Price Locks and Dam (Alton, Illinois) became operational, theoretically increasing the capacity of the lock and dam system to pass tow traffic upriver.

Although the immediate result of lock and dam construction was an increase in the volume of backwater lakes and sloughs, over time an equilibrium between flow and cross-section was restored by an increase in sedimentation rates in these new navigation pools. Substrate stability is of paramount importance in maintaining mussel populations (Vannote and Minshall 1982; Strayer 1983, 1993). Therefore, changes in substrate composition are likely to have important impacts on mussel communities. Siltation rates in pools 7, 8 and 9 have been estimated at approximately 0.7-2.9 cm/year (LePage *et al.* 1980). In addition, there has been an increase in sediment deposition in Lake Pepin (Pool 4) since the early 1900s, leading to a shift from a coarse gravel mixed with mud to one dominated by silt (Thiel 1981). Much of this sedimentation has taken place in backwaters, however, rather than in main channel and main channel border habitats where *L. higginsii* is typically found.

These changes have undoubtedly influenced, and continue to influence, mussel habitat. Fuller (1980), Havlik (1983), Hornbach *et al*. (1992) and Thiel (1981) have all shown that there has been a decline in the mussel species richness found in the Upper Mississippi River, compared to species richness found in pre-impoundment studies by Ellis (1931a,b). *L. higginsii* has apparently always been a relatively minor component of the mussel community (USFWS 1983). Therefore, a direct link between changes in the distribution and abundance of this species and habitat alteration is difficult to ascertain.

In 1987, the Corps of Engineers consulted with the Service on the effects of increased tow traffic on *L. higginsii* due to the proposed construction of the second lock at the Melvin Price Locks and Dam. The resulting biological opinion and incidental take statement required the Corps to conduct a baseline and navigation effects study of four mussel beds on the UMR (USFWS 1987). Miller *et al.* (1990) designed and initiated the study in 1988. They indicated that evidence of negative effects of commercial traffic on mussels and *L. higginsii* would be assessed using the following six parameters: 1) decrease in the density of five common-to-abundant species, 2) absence of *L. higginsii*, 3) decrease in live-to-recently-dead ratios for dominant species, 4) loss of more than 25 percent of the mussel species, 5) no evidence of recent recruitment and, 6) significant reduction in growth rates or increase in mortality. These constituted triggering mechanisms, any one of which would necessitate the reinitiation of consultation with the Corps of Engineers to assess the impacts of tow traffic on the species. The baseline phase of this study has been completed (Miller and Payne 1991, 1992, 1993, 1994, 1995a,1995b, 1996a, 1997) and is now in the monitoring phase. In the year 2004, the two agencies will meet and reevaluate the necessity of monitoring beyond that date.

Miller and Payne (1996a) noted that, at no time, could velocity changes from a single or multiple tow passage be considered damaging to benthic organisms or their habitat. Furthermore, they state that tow-induced changes in turbidity and suspended solids at mussel beds in the UMR were minor, of short duration and likely to have only minimal effects (Miller and Payne 1996a). Studies from 1990 to 1994 by Clarke and Loter (1995) on *L. higginsii* populations at Prairie du Chien, indicated that barge traffic did not damage mussels at any site and that no significant changes in the numbers of *L. higginsii* occurred at any sites. They also found that condition indices of a common species (*Amblema plicata*) did not change. Clarke and Loter (1995) did find some changes in the number of mussel species, increases at some sites and decreases at others, which they attributed to the Great Flood of 1993 and not to barge traffic. However, as tow traffic is projected to increase on the UMRS in future years, it is essential that monitoring of these potential effects be continued.

Much of the habitat alterations due to navigation since the late 1800s, including the 4-foot, 6-foot, and 9-foot channel projects, and operation and maintenance of the navigation system, have already occurred. The Corps, in cooperation with USFWS and other agencies, work to ensure that ongoing maintenance activities, such as dredging and disposal, are implemented to avoid *L. higginsii* habitat. Future habitat alterations associated with navigation and increasing tow traffic over the next 50 years, however, may adversely affect the species. These impacts are the subject of two ongoing consultations conducted under section 7(a)(2) of the Endangered Species Act between the Service and the Corps of Engineers on the operation and maintenance of the 9-foot channel project (see above) and system-wide navigation improvements.

The Corps of Engineers indicated that, in their best professional judgement, a 220 percent increase in barge traffic in specific areas of the East channel at Prairie du Chien could result in up to a 20 percent reduction in the number of *L. higginsii* as a result of chronic perturbations over a 40-year period (U.S. Army Corps of Engineers 1993). Based on 10 years of studies in both the main and east channels at Prairie du Chien (Miller and Payne 1991, 1992, 1993, 1994, 1995a, 1995b, 1996a, 1997), there were no significant changes in populations. Intergenerational changes, however, could occur and 10 years is a small portion of the life span of many mussels. Tow traffic impacts should continue to be studied, particularly in main channel borders areas such as those at Prairie du Chien, Wisconsin, where tows move in close proximity to beds containing *L. higginsii*.

The types of activities currently affecting *L. higginsii* habitat on the UMR are primarily related to the development of land-based, water-oriented facilities such as barge loading and off-loading sites, small boat harbors, dredging of access channels, construction of highway bridges and the establishment of fleeting areas. These can have negative impacts to mussels. Dredging access channels directly eliminates habitat and, over time, may cause the slumping of adjacent areas into the channel, further reducing available habitat. The operation of small boats and larger vessels (*e.g.*, casino boats) in the vicinity of mussel beds can have impacts through the redistribution of sediment or accidental spills of fuel and other contaminants. Fleeting barges over mussel beds may directly crush or bury mussels. Pier construction for new highway bridges has taken place in or near mussel beds.

To adequately address these threats, Intermediate Goal 1D (limit construction in areas of essential *L. higginsii* habitat) must be met. In the event that impacts to *L. higginsii* cannot be avoided, they may be mitigated by the relocation of mussels before construction.

Water Quality (see Tasks under 1.5 and 2.3 in the step-down outline)

Water quality issues, including point and non-point contaminant and pollutant sources, and chronic and episodic events, have not been documented as presently having significant adverse impacts to *L. higginsii*. The lack of documented impacts may be a consequence of the lack of investigation as much as a lack of actual impacts. Contaminants and pollutants may have had a role in the presumed decline of the species; they may be presently affecting *L. higginsii* abundance, distribution, and health, and they may be rendering otherwise suitable potential reintroduction areas unfit for the species. Harm to *Lampsilis higginsii* has not been documented as a result of a single contaminant spill or other short-term contaminant episode, but such episodes have been strongly implicated in mussel die-offs elsewhere (Sheehan *et al*. 1989). The presumption must be that *L. higginsii* are as vulnerable to contaminant events as are other mussel species and accidental or unintended contaminant events that occurred elsewhere could also occur where *L. higginsii* is present.

This lack of information and documentation is itself the most significant water-quality related threat to *L. higginsii*. Undocumented harm may be occurring because of the limited availability of data assessing the significance of specific water and sediment quality parameters in relation to life cycle requirements of the species. Data gaps identified in the Water Quality section of this document include the unknown relative susceptibilities of the different life stages to contaminants, as well as the need for comparative data on the different modes of potential contaminant uptake (food sources, surface water, pore water, sediments). Related water quality information at areas designated as, or considered for, *L. higginsii* Essential Habitat Area can then be better evaluated to more effectively manage the recovery of the species. Additional information is also needed to improve laboratory culture and toxicity study requirements for freshwater mussels, thereby facilitating the documentation and use of toxicity data for *L. higginsii*.

Water quality parameters identified to potentially affect *L. higginsii* include un-ionized ammonia, select metals, and possibly some organic compounds. Although these contaminants may exist at varying concentrations throughout the UMR, the species' preferred habitat (coarser substrates in main channel and channel borders) generally would not contain toxic concentrations of these contaminants in finer substrates of depositional areas, thereby offsetting much of the potential threat. Consequently, environmental perturbations resulting from episodic events are probably the most likely water quality factors to affect the recovery of *L. higginsii*. Such events may include spills of oil or hazardous materials, seasonal-runoff or "flushing" of contaminants into river systems, and water development projects unintentionally releasing contaminants from previously deposited sediments. The relative immobility of mussels, combined with the potentially high toxicity associated with such releases, increases the significance of these types of threats to *L. higginsii*.

Both point source discharges and non-point-runoff represent continuing threats to the species. Without the referenced toxicity data, however, it is unknown what water quality criteria or guidelines for specific contaminant or pollutant levels are necessary to protect *L. higginsii* in areas influenced by permitted point-source discharges. Low flow river conditions may result in increased concentrations of contaminants and thus increase impacts to the species from compounds such as un-ionized ammonia associated with fine sediments.

Commercial Harvest (see Tasks under 1.7 in the step-down outline)

The commercial harvest of mussels in the Upper Mississippi River peaked during the pearl button period of the 1920s and later during the cultured pearl era in the late-1980s and early 1990s (Thiel and Fritz 1993). The five Upper Mississippi River States (Iowa, Illinois, Minnesota, Missouri and Wisconsin) have regulated mussel harvest since the latter portion of the pearl button era in the late 1930s (Waters 1980) and are continuing to revise the regulations to strive for uniformity among the states and to reflect present-day biological data and concerns.

No commercial harvest is presently allowed in the Wisconsin and St. Croix Rivers or at the Sylvan Slough refuge on the Mississippi River. There is concern, however, over potential illegal harvest in these areas. Officials indicate that mussel poaching in other areas of the U.S. is an increasing problem (Luoma 1997). Gary Jagodzinski (USFWS, pers. comm.) has indicated that at least 100 cases of illegal take, record keeping and sales violations were made in Wisconsin during 1996 in the Mississippi River or other inland waters. Most violations were for record keeping violations or illegal take such as undersized or prohibited species. Increased enforcement activities at sites in the Wisconsin and St. Croix Rivers and at the Sylvan Slough refuge on the Mississippi River is recommended. In other Essential Habitat Areas, the recovery team recommends that harvest be eliminated.

There are few documented reports of commercial clammers taking *L. higginsii*, but impacts to associated species have been documented. Other than harvest activities such as brailing that may have influenced the entire mussel community, little is known regarding the direct impacts of commercial harvest on *L. higginsii.* Mathiak (1979), based on observations he made at a commercial clamming operation, concluded that hundreds of *L. higginsii* had probably been harvested in 1975 before the species was placed on the list of Threatened and Endangered Species. Although there may be little or no available data to support the contention that commercial clamming is specifically harmful to *L. higginsii* populations, it is reasonable to conclude that clamming could threaten the species in Essential Habitat Areas. Hart (1999), for example, found that commercial harvest depressed threeridge (*Amblema plicata*) populations in Lake Pepin in the early 1990's. He found that if harvest exceeded "5% of the population or if *D. polymorpha* infestations continue at the current rate" threeridge populations were in danger of local extinctions. Threeridge is one of four species that is common at all known *L. higginsii* sites (Heath 1995). Although it is distinct morphologically from *L. higginsii*, it is reasonable to assume that clammers in pursuit of *A. plicata* or other species would inadvertently collect or harm *L. higginsii*.

Conservation Measures

There were four recommendations for immediate action in the initial Higgins Eye Pearlymussel Recovery Plan. In this section we review the progress that has been made on these recommendations and other actions that have been taken to conserve the species.

The following were recommendations for immediate action:

1. Conduct ten-year field studies in Essential Habitat Areas (with initial emphasis on the Prairie du Chien site) to determine the status of each population and its habitat.

2. Develop relocation (translocation) techniques for Higgins Eye Pearlymussels.

3. Develop artificial propagation techniques. This should include a thorough literature review, development of methodology, testing of methodology on closely related, non-endangered species, propagation of Higgins Eye Pearlymussels, and determination of suitable stocking sites.

4. Develop uniform regulations concerning clam harvesting methods that would best manage and protect the resource. These regulations should be developed cooperatively by the states, the USFWS, and commercial clammers. Two specific items that should be included in the development of these regulations are:

a. Policies restricting dredging as a method of commercial harvesting clams on the Mississippi River, and

b. A study to determine the potential beneficial and/or detrimental effects of brailing on mussel beds, relative to other harvesting methods (such as diving), with subsequent appropriate regulation.

<u>Ten-Year Field Studies in Essential Habitat Areas</u>

There have been a number of studies of *L. higginsii* since the initial recovery plan was written (Table 6 - Cawley 1996 - see Section IV). Only studies by Miller and Payne (1991, 1992, 1993, 1994, 1995a, 1995b, 1996a, 1997) and Heath (1995, 2002) have chronicled the change in mussel communities over a ten-year period. Their work was conducted at the Prairie du Chien (Miller and Payne) and Orion (Heath) Essential Habitat Areas, respectively.

<u>Development of Relocation (Translocation) Techniques</u>

As stated by Waller *et al*. (1995), "State and Federal agencies are actively conducting ... relocation operations in an effort to preserve the remaining unionid fauna. Information of threshold and tolerance limits of different mussel species to collection and handling conditions is especially critical at this time for planning management and conservation activities for unionid mussels." Although they did not specifically examine *L. higginsii,* they conclude that with proper precautions, handling and exposure associated with relocation efforts should not cause significant levels of mortality in unionid mussels.

A number of relocations of *L. higginsii* have occurred since the initial recovery plan was developed. Before 2000 these relocations were usually associated with construction projects and were not designed to examine the effects of relocation methods on the mussels. However, one relocation project at the I-94 bridge over the St. Croix River included a monitoring program designed specifically to examine the effects of handling, placement methods, and buffer zones on the survivorship of relocated mussels (Dunn 1996a, 1996b).

Oblad (1980) discussed a relocation experiment with *L. higginsii* at Sylvan Slough, one of the Essential Habitat Area Sites designated in the initial Recovery Plan (Table 6 - see Section IV). Three *L. higginsii* were collected from mid-channel and were relocated nearby. A year following the relocation all three *L. higginsii* were recovered.

The US Highway 10 bridge over the St. Croix River near Prescott, Wisconsin, was replaced in 1988 and mussels were transplanted to a region upstream of the project (Heath 1989). Nearly

8000 mussels were transplanted including 42 *L. higginsii*. A large number of the mussels from this relocation died, including greater than 30 *L. higginsii*, possibly because the relocation took place when air and water temperatures were too low and because the mussels may have been harmed by a water surface oil sheen they were exposed to during the relocation effort (Paul Burke, USFWS, pers. comm.). However, when Hornbach *et al.* (1995), sampled the relocation bed in 1994, seven *L. higginsii* relocated in the 1988 project were found. Some of these specimens had experienced measurable growth, and all appeared to be in good condition.

The I-94 bridge over the St. Croix River at Hudson, Wisconsin, has been replaced. This project over the St. Croix River required the relocation of 9,042 mussels in 1994 (Dunn 1996a) and 14,043 mussels in 1995 (Dunn 1996b). A total of 43 *L. higginsii* were moved in 1994 and 36 were moved in 1995. A two-year monitoring program was developed for each year to (1) evaluate overall mussel survival, (2) growth and survival of endangered species, including *L. higginsii*, (3) handling methods, (4) placement methods, and (5) buffer zone size. At each relocation phase, mortality was assessed at one month, one year and two years after relocation. Results of two years of monitoring of the 1994 relocation yielded one dead *L. higginsii* and an average increase in shell length for 35 *L. higginsii* of 4.2 mm (Dunn 1996a). Results of one year of monitoring of the 1995 relocation also yielded only one dead *L. higginsii*; average shell length had increased 1.3 mm (Dunn 1996b). Results of monitoring the general population and experimental subsamples will be used to develop guidelines for future relocation projects.

In 1996, an *in-situ* relocation project was begun in the St. Croix River (D. Waller, pers. comm.). This project involves the refinement of protocols for relocating mussels to *in-situ* refugia from zebra mussels and to assess the suitability of potential refugia for mussels in the St. Croix River. One hundred *L. higginsii* mussels were relocated from the St. Croix River at Hudson, Wisconsin, upstream to a site near Franconia, Minnesota. Mussels will be monitored for a minimum of two years to evaluate growth and survival at the refugium site relative to those at the source site.

In 2000, state and federal agencies markedly increased their attempts to relocate *L. higginsii* to reduce their exposure to zebra mussels. As stated above, the USFWS issued a Biological Opinion to the Corps' on May 15, 2000 that required the Corps to (1) conduct a Higgins eye relocation feasibility analysis and (2) prepare a Higgins eye Pearlymussel Relocation Plan. As a result, the Corps drafted seven interim and long-term objectives to conserve Higgins eye associated with the continued operation and maintenance of a nine-foot navigation channel in the Upper Mississippi River. One of these objectives is to "Establish a minimum of five new and viable populations of Higgins eye in the UMRS and/or tributaries un-infested or with low level infestations of zebra mussels." Work toward this objective has resulted in several relocation attempts (Table 1) and additional attempts are likely to continue for several more years. Of the 63 *L. higginsii* recovered in 2002 at the Hidden Falls (Pool 2) and Hastings (Pool 3) adult relocation sites (59 females, 4 males), only one was found dead, although several had abnormal growth patterns exhibited by "exaggerated growth arrest lines and in-turning along the ventral margin of the shell" (Davis 2003). These mussels appear to have resumed normal growth patterns in 2003 (M. Davis, pers. comm. 2003).

Development of Artificial Propagation Techniques

The recent and severe infestation of the Upper Mississippi River and several tributaries by zebra mussels has significantly raised the importance of the development of artificial propagation techniques for the conservation of *L. higginsii*. Before 2000, workers had explored a variety of techniques for propagating this and other mussel species, including the use of artificial media. Since 2000, however, propagation has mostly focused on the artificial infestation and release of fish into areas where zebra mussels are not an imminent threat.

Waller and Kammer (1985) indicated that a surrogate for *L. higginsii* (*L. cardium*) could artificially infect largemouth bass and walleye. They compared the propagation of *L. higginsii* glochidia in an artificial medium with the use of infested fish in the laboratory (Holland-Bartels and Waller 1988). They were able to successfully transform glochidia with the artificial medium and by infesting fish. Waller and Kammer (1985) indicated that both techniques have potential use for the production of juvenile mussels. Welke *et al*. (2000) used similar techniques to artificially infest largemouth bass and walleye with *L. higginsii* glochidia. Results from the walleye treatment were confounded after an ectoparasitic infection resulted in total fish mortality, but some juvenile mussels successfully excysted from walleye gill tissue incubated in a separate water system and from largemouth bass. Further work on congeners of *L. higginsii* by Holland-Bartels and Zigler (1990) showed that nutritional requirements appeared to be a factor limiting successful laboratory culture of glochidia. They used a combined laboratory/field culture approach to bypass this area of difficulty by infesting fish in the laboratory and then stocking them in the field in floating cages just before metamorphosis. Gordon (2001, 2002) has found greater transformation success with centrarchids (*e.g.*, smallmouth bass) than with percids (walleye) at Genoa National Fish Hatchery. A number of other studies have examined artificial propagation techniques in other species of freshwater mussels (Watters 1994b; Beaty and Neves 1996; Gatenby *et al.* 1997; O'Beirn *et al.* 1998; and references therein).

As with adult translocation, artificial propagation of Higgins eye has increased greatly since the issuance of the Biological Opinion to the Corps in 2000 (see above). Biologists have collected gravid Higgins eye from several locations each year between 2000-2002, taken them to Genoa National Fish Hatchery (Hatchery), and infested fish using the methods described by Welke *et al.* (2000). In May 2002, workers infested 7466 fish (largemouth bass, smallmouth bass, and walleye) with Higgins eye glochidia at the Hatchery. A portion of the fish was retained at the Hatchery to refine techniques for producing juvenile Higgins eye, but most were kept in the Hatchery for about three weeks before being sent to release sites. At these sites, workers simply released the fish to swim freely or confined them in cages secured to the river bottom (Table 1). Cages facilitate monitoring of transformation success and, in some cases, are used to grow juvenile Higgins eye for release elsewhere (M. Davis, pers. comm. 2002). Fish are released from cages after glochidia have excysted.

Biologists have exhibited significant success in culturing Higgins eye since 2000. Juvenile Higgins eye (*i.e.*, less than < 30 mm) have been identified in or beneath several cages containing infested largemouth bass, smallmouth bass, and walleye and as of January 2004, there were several thousand juvenile Higgins eye in cages awaiting release at reintroduction or augmentation sites. Confirmation of success (*i.e.*, transformation of glochidia to independent juveniles) or failure of the caged fish releases is not always possible and a few attempts were likely complete failures due to excessive sedimentation. There are no data yet to evaluate the success of the free-swimming fish releases.

Biologists involved in propagation of Higgins eye continue to refine propagation and release techniques (Gordon 2002). Pre-release mortality of infested fish has been significant (*e.g.*, >20%) in some cases and may be exacerbated by the stress of the mussel infestation process (Gordon 2002). Gordon (2002) counted the number of glochidia and number of juveniles that transformed from a subset of the fish that were inoculated in 2002. Number of glochidia per fish ranged from 146-283 and transformation to the independent juvenile stage in the Hatchery was 38-47%. Assuming that the percent transformation is similar in released fish, a cage of 100 infested fish may produce approximately 4000 juvenile Higgins eye. Attempts to support the transformation and initial growth of juveniles in the hatchery have been hampered by fish mortality, introduction of mussel predators into the culture facilities, and power failures (Gordon 2001, 2002). Nevertheless, approximately 8000 juvenile *L. higginsii* have been released in four separate events since 2000 and, as stated above, several thousand are now in cages in the St. Croix and Mississippi Rivers and available for reintroduction.

<u>Development of Uniform Regulations Concerning Clam Harvesting Methods</u>

Sparks and Blodgett (1983) conducted a study to examine the effects of three types of mussel harvest methods: crowfoot bar (brail), basket dredge and diver. They indicated that crowfoot bar and diving resulted in less dislodgement and damage than the basket dredge. Based on their work they supported Illinois' prohibition of basket dredges and recommended that hand dredges also be banned. They indicated that diving appeared to be the least harmful and most selective method for harvesting mussels and that the crowfoot bar should be retained as a legal device because it appeared to be fairly non-destructive and was safer than diving.

Thiel and Fritz (1993) have reviewed the history of mussel harvest and regulation in the UMR. They indicated that there has been significant improvement in the coordination among the states of the Upper Mississippi River regarding mussel harvest. The main results of the improved coordination are restricted seasons for harvest, size limits for harvest, and the requirement for permit or license in each state. Prime among these are restricted seasons for harvest in each state. Thiel and Fritz (1993) did not comment on the impact of improved harvest regulations on the viability of *L. higginsii* populations. They did indicate that harvest impact has been great on the washboard (*Megalonaias nervosa*), and that catch-per-unit-effort has declined since 1990, partially due to the increase in the minimum size limits for live washboards put in place in 1990. This decrease in catch-per-unit-effort has led to an increase in price. They also indicated that slow-growing washboard populations may no longer be able to keep up with the harvest pressure and concluded that there must be sound scientific management of this resource.

In 1996, the Upper Mississippi River Conservation Committee (UMRCC) Executive Board approved a set of proposed mussel regulations developed by the Fisheries Technical Section's *ad hoc* mussel committee (P. Thiel, pers. comm. 1996). The recommendations were crafted in cooperation with representatives of the Shell Exporters of America, Inc. The goals of the proposed regulation are to: 1) move toward standardizing mussel harvest regulations among the five UMRCC states, 2) close loopholes which make enforcement of existing regulations difficult, and 3) protect populations of species, such as washboard, *Megalonaias nervosa*, from overharvest, with a long-term purpose of sustained harvest of freshwater mussels in the Upper Mississippi River. The proposed regulations address eleven different topics, including season, gear, size limit, license fees, and reporting, and are being routed through each UMRCC member state's natural resource agency for consideration and potential rule-making.

Summary of Current State Mussel Harvest Regulations in the Range of Higgins Eye

Iowa – In Iowa holders of commercial mussel licenses, residents or nonresidents, may take mussels for sale from April 1 to August 31 in the Mississippi River and connected backwaters by hand, diving, or crowfoot bar. Iowa license holders may take six species of mussels: "three-ridge, mapleleaf, pimpleback, pigtoe, hickory nut, and pink heelsplitter." Although several species are commonly referred to as "pigtoe", only the Wabash pigtoe (*Fusconaia flava*) occurs in Iowa. Two species found in Iowa are referred to commonly as "pimpleback", *Quadrula nodulata* and *Q. pustulosa*. Hickory-nut (*Obovaria olivaria*) is similar in appearance to Higgins eye, whereas the other species that may be commercially taken in Iowa are noticeably different in appearance. Holders of sport fishing licenses may take mussels throughout the year in the Mississippi River and connected backwaters and may possess up to 24 whole mussels or 48 shell halves; mussels listed by Iowa as threatened or endangered may not be taken.

Illinois – In Illinois holders of commercial mussel licenses, residents or nonresidents, may take mussels for sale from April 1 to August 31 in the Mississippi River by hand, diving, or crowfoot bar. Illinois license holders may take only "threeridge, mapleleaf, pimpleback, monkeyface, wartyback, pigtoe, pocketbook, hickory nut, and pink heelsplitter." Although several species are commonly referred to as "pigtoe", only the Wabash pigtoe (*Fusconaia flava*) occurs in the Mississippi River in Illinois. Q. *nodulata* and *Q. pustulosa* are both referred to commonly as "wartyback" and "pimpleback." Of the species referred to commonly as "pocketbook" only the plain pocketbook (*Lampsilis cardium*) may be legally collected in Illinois; the fat pocketbook (*Potamilus capax*) is also called "pocketbook", but is listed as endangered by the Illinois Endangered Species Protection Board and under the federal Endangered Species Act. Both fat pocketbook and hickory-nut (*Obovaria olivaria*) are similar in appearance to Higgins eye, whereas the other species that may be commercially taken in Illinois are noticeably different in appearance. Illinois prohibits commercial mussel harvest in several sanctuaries. Only one includes an Essential Habitat Area identified in this plan -- the sanctuary that extends from RM 485.8 to RM 482.6 includes all but the upper 0.2 River Miles of the Sylvan Slough EHA (Fig. 11). The second EHA in Illinois identified in this plan at Cordova, IL is not protected as an Illinois mussel sanctuary. A portion of this EHA lies within Upper Mississippi National Fish and Wildlife Refuge waters (Fig. 10). All of Mark Twain National Fish and Wildlife Refuge waters are protected as Illinois mussel sanctuaries, but Upper Mississippi National Fish and Wildlife Refuge waters are not.

Minnesota – In Minnesota, only residents possessing a valid angling license may apply for a commercial mussel permit. A person may not take, possess, buy, sell, or transport live mussels or more than 24 dead whole shells or 48 dead shell halves without a commercial mussel permit. Commercial permittees may take mussels for sale from May 16 through August 31 only by hand, with or without SCUBA. Harvest sites must be specified in the commercial permit application and in the permit. Only three-ridge mussels (*Amblema plicata*) greater than 3 inches in diameter at the narrowest point may be taken commercially. Additional species may be taken by special permit. Minnesota prohibits commercial mussel harvest within 1000' downstream of dams. A commercial permit can only be issued if it is first determined that harvest will not be detrimental to the species being harvested. If any of the state's twenty endangered or threatened species of mussels "…are found within the harvest site, all harvest operations must immediately stop." Persons possessing an angling license may take (by hand only) and possess up to 24 whole shells or 48 shell halves of dead mussels that are not endangered or threatened.

Wisconsin – In Wisconsin, holders of commercial mussel licenses may take mussels for sale from April 1 to August 31 in the Mississippi River and connected backwaters "by hand when you are diving or wading; or by using crow-foot bars." Only residents of Wisconsin may hold commercial clamming licenses. Three-ridge, mapleleaf, pimpleback, and pigtoe may be commercially harvested. Although several species are commonly referred to as "pigtoe", only the Wabash pigtoe and round pigtoe (*Pleurobema coccineum*) occur in Wisconsin. Two species found in Wisconsin are referred to commonly as "pimpleback", *Quadrula nodulata* and *Q. pustulosa*. None of these species are likely to be confused with Higgins eye. Wisconsin prohibits commercial mussel harvest in the St. Croix River, but allows "pearl hunting" and "personal clamming." on all public Wisconsin waters. For pearl hunting, it is legal to open mussels to hunt for pearls, but you may not open more than 50 pounds of mussels a day or sell or barter any pearls you find unless you hold a commercial clam shelter's license and comply with commercial clamming regulations. Under Wisconsin's clamming law, anyone who takes, possesses or transports 50 or fewer pounds of mussels a day and who does not sell or barter any clams is considered a non-commercial Clammers and does not need to obtain a license or permit. Under current rules, non-commercial clammers may take any clam species (except state-listed threatened or endangered species, including Higgins eye) of any size throughout the year in any waters of the state. Personal clammers may take clams by hand while wading or diving or by using up to three crowfoot bars, each measuring no more than 20 feet long. Only one boat may be used for brailing (collecting clams with a crowfoot bar).

St. Croix River National Scenic Riverway – Minnesota/Wisconsin – In addition to the state rules summarized above, the St. Croix River National Scenic Riverway (Riverway) in Minnesota and Wisconsin prohibits the gathering and use of all live and dead mussels and empty mussel shells. The Riverway includes the three Essential Habitat Areas at Franconia, MN, Hudson, WI, and Prescott, WI.

II. RECOVERY

Recovery Strategy

This revised recovery plan adopts the approach of the previous 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. This revised recovery plan identifies three additional "Essential Habitat Areas" (EHA) (Orion, WI, Prescott, WI, and Interstate Park, MN/WI), but also outlines specific criteria for evaluating additional areas for this designation and for when any EHA would provide the basis for reclassification and delisting decisions. 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 of 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 ten Essential Habitat Areas designated in this revised plan, zebra mussels have had severe impacts on the mussel communities at Harpers Slough, Prairie du Chien, and Cordova and are imminent threats at the Prescott, and Hudson, WI areas. The Prairie du Chien Essential Habitat Area, for example, 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 removal of zebra mussels in a manner and scale necessary to benefit *L. higginsii* is evidently not currently feasible. Therefore, the 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. Within the last two years, workers have removed 471 adult *L. higginsii* from areas near Cassville, WI and Cordova, IL on the Upper Mississippi River and relocated them into Pools 2 and 3 near Minneapolis, MN and Hastings, MN, respectively (Table 1). Cleaning fouled adults *in situ* and artificial propagation and release (Table 1) are also currently being implemented in an attempt to offset 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 and environmental contaminants may also pose significant threats. Therefore, the Corps and other agencies must continue to assess and limit the potential impacts of their actions on the species. 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 will be key to the recovery of *L. higginsii*. In addition to the USFWS, the Implementation Table identifies five other federal agencies and four states as being responsible for various aspects of the recovery of the species. The U.S. Army Corps of Engineers, for example, is called on to implement several of the tasks. The Corps' implementation of the 2000 Biological Opinion on continued operation and maintenance and operation of the 9-foot navigation channel has resulted in the formation of the Mussel Coordination Team (MCT). This MCT has assisted the Corps in the implementation of extensive relocation and reintroduction of *L. higginsii* since 2000 (Table 1). These activities, although necessary to avoid jeopardizing the species, are leading to the development and refinement of techniques for propagating *L. higginsii* and other mussel species.

Recovery Goals and Recovery Criteria

The goal of the recovery plan is the recovery of Higgins eye to levels where its protection under the Act is no longer necessary and it may be removed from the Federal list of Endangered and Threatened Wildlife (50 CFR 17.11). This plan also contains an intermediate goal of reclassifying the species from Endangered to Threatened.

Essential Habitat Areas

Essential Habitat Areas used to support the reclassification or delisting of *L. higginsii* (see below) must meet the following criteria.

1. *L. higginsii* constitute at least 0.25% of the mussel community and the mussel habitat appears to be stable and supports a dense and diverse mussel community; or,

2. *L. higginsii* are found, but constitute <0.25% of the community, the mussel habitat appears to be stable and supports a dense and diverse mussel community, and zebra mussel densities are < $0.5/m^2$.

For each definition, "dense and diverse" mussel communities are those that:

- include a total mussel density of > $10/m^2$ (Mississippi River) or > $2/m^2$ (other rivers); and,
- contain at least 15 other mussel species, each at densities greater than 0.01 individual/m^2.

<u>Intermediate Goal (Reclassification of *Lampsilis higginsii* to Threatened Status)</u>

Criteria for Intermediate Goal (Goal 1: Reclassification)

1. *Lampsilis higginsii* may be considered for reclassification from Endangered to Threatened when at least five identified Essential Habitat Areas contain reproducing, self-sustaining populations of *L. higginsii* that are not threatened by zebra mussels. The five Essential

Habitat Areas must meet the above criteria and must include the Prairie du Chien Essential Habitat Area and at least one Essential Habitat Area each in the St. Croix River and in Mississippi River Pool 14.

a. *L. higginsii* populations will be considered to be "reproducing" if there is evidence that they include a sufficient number of strong juvenile year classes.[3]

b. Populations will be considered to be "self-sustaining" if they have maintained stable or increasing population densities for at least twenty years.[4] *L. higginsii* populations will be considered stable or increasing if:

i. total mussel density in each of the identified Essential Habitat Areas is stable or increasing for at least twenty years (significance level (α) ≤ 0.2 and power ≥ 0.9);

ii. <u>and</u>, in each of the identified Essential Habitat Areas *L. higginsii* comprises at least 0.25% of the mussel community in Mississippi River sites or, in other rivers, are consistently present throughout the twenty year period.

The Service will develop standardized sampling protocols (Task 1.2.1) to evaluate the status of populations relative to these criteria.

c. This criterion will be met if zebra mussels are not present in locations where they or their offspring are likely to adversely affect *L. higginsii* populations in any of the five identified Essential Habitat Areas. The Service will make this determination by evaluating zebra mussel densities in the source areas and identified Essential Habitat Areas, the distances between the zebra mussel populations and identified Essential Habitat Areas, water velocities, larval development times, and any other relevant information.

2. Complete the following tasks to determine if water quality criteria for the Final Goal (Delisting) are necessary to ensure the conservation of *L. higginsii* and, if so, to develop measurable water quality criteria for Goal 2.

a. Develop a freshwater mussel toxicity database for sediment and water quality parameters to define *L. higginsii* habitat quality goals. (7 sub-tasks)

b. Characterize specific sediment and water quality parameters in *L. higginsii* Essential Habitat Areas and reestablishment areas. (1 sub-task)

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[3] Task 1.2.2 details the questions that the Service must answer to determine the number of strong juvenile year classes sufficient to allow for stable or increasing populations of *L. higginsii.*

[4] For all analyses of trends use a significance level (α) ≤ 0.2 and power ≥ 0.9.

3. Harvest of freshwater mussels is prohibited by law or regulation in Essential Habitat Areas. This applies to all Essential Habitat Areas, not just the five identified for criterion 1.

Final Goal (Delisting)

1. Delisting *L. higginsii* requires that populations of *L. higginsii* in at least five Essential Habitat Areas are reproducing, self-sustaining, not threatened by zebra mussels, and are sufficiently secure to assure long-term viability of the species. The five Essential Habitat Areas must meet the above criteria and must include the Prairie du Chien Essential Habitat Area and at least one Essential Habitat Area each in the St. Croix River and in Mississippi River Pool 14. "Reproducing" and “self-sustaining” are defined above under the Intermediate Goal (Reclassification).

   Populations at the identified Essential Habitat Areas will be “sufficiently secure to assure long-term viability of the species” if each of the following four conditions is met:

   a. The Service can identify no activities that are likely to take place in the foreseeable future that will result in a change in the predominant substrate conditions within each identified Essential Habitat Area to shifting, unstable sands, silt, cobble, boulder, or artificial substrates (*e.g.*, concrete) to the extent that such changes would appreciably reduce the likelihood of conserving the Higgins eye population in the Essential Habitat Area.

   b. The Service can identify no activities that are likely to take place in the foreseeable future that will result in water quality characteristics (*e.g.*, harmful concentrations of un-ionized ammonia) in Essential Habitat Areas that have been shown to cause detrimental effects to *L. higginsii* or to sympatric or surrogate species to the extent that such effects would appreciably reduce the likelihood of conserving the Higgins eye population in the Essential Habitat Area.

   c. There is no indication that construction of barge loading or off-loading sites, boat harbors, highway bridges, or fleeting areas or dredging of access channels is likely to occur in the foreseeable future within the identified Essential Habitat Areas to the extent that such activities would appreciably reduce the likelihood of conserving the Higgins eye population in the Essential Habitat Area.

   d. Measures that provide for review of federally funded, permitted, or planned activities in or near *L. higginsii* habitat pursuant to the Fish and Wildlife Coordination Act and Clean Water Act are in place.

   e. This criterion will be met if zebra mussels are not present in locations where they or their offspring are likely to adversely affect *L. higginsii* populations in any of the five identified Essential Habitat Areas. The Service will make this determination by evaluating zebra mussel densities in the source areas and identified Essential Habitat Areas, the distances between the zebra mussel populations and identified Essential Habitat Areas, water velocities, larval development times, and any other relevant information.

2. The use of double hull barges or other actions have alleviated the threat of spills to each of the identified Essential Habitat Areas.

3. *L. higginsii* habitat information and protective responses to conserve each of the identified Essential Habitat Areas have been incorporated into all applicable spill contingency planning efforts.

4. Water quality criteria may be added to the criteria for the Final Goal (Delisting) upon completion of the tasks referred to under the Criteria for the Intermediate Goal (Reclassification) (see 2a-b above and Tasks 1.5.1 and 1.5.2).

Narrative Outline for Recovery Activities

1 Preserve *L. higginsii* and its Essential Habitat Areas.

1.1 Assess and limit impact of the zebra mussel, *Dreissena polymorpha*, on *L. higginsii*.

1.1.1 Develop strategies to prevent zebra mussel infestation.

1.1.2 Monitor zebra mussel populations at Essential Habitat Areas that are currently infested.

1.1.3 Develop and implement a response plan for *L. higginsii* in Essential Habitat Areas.

1.2 Develop uniform protocols for collecting and maintaining information on *L. higginsii* populations.

1.2.1 Develop a uniform protocol for collecting information for populations of *L. higginsii.*

1.2.2 Answer the following three questions to facilitate the implementation of this recovery plan:

1. What would constitute sufficient evidence of a strong juvenile year class of *L. higginsii*?

2. What methods should be used to evaluate the strength of juvenile year classes of *L. higginsii*?

3. How many strong juvenile year classes should be detected to determine that reproduction is sufficient to allow for stable or growing populations of *L. higginsii*?

1.2.3 Develop a central database of information based on the protocol developed in task 1.2.1.

1.2.4 Develop and implement a long-term monitoring plan at Essential Habitat Areas.

1.3 Maintain a list and an ongoing evaluation of Essential Habitat Areas.

1.3.1 Evaluate the ten Essential Habitat Areas recommended in this plan based on the best available information.

Essential Habitat Areas are areas that are of utmost importance to the conservation of *L. higginsii*. Maintain an ongoing evaluation of each of the ten recommended Essential Habitat Areas based on the best available scientific information. Key factors to assess and monitor include native mussel density and diversity, the geographic extent of the Essential Habitat, and threats, such as zebra mussels.

1.3.2 Identify new Essential Habitat Areas.

In addition to the four specific areas discussed below, the Service and its partners will use the guidelines in this plan to assess other areas that may contain the features that indicate that they are of utmost importance for the conservation of Higgins eye.

1.3.2.1 Survey Pool 10 to determine whether additional Essential Habitat Areas may be identified in this pool.

1.3.2.2 Examine a site near river mile 454, Muscatine, Iowa, for inclusion as an Essential Habitat Area.

1.3.2.3 Examine a site near river mile 556.4, Bellevue, Iowa, for inclusion as an Essential Habitat Area.

1.3.2.4 Examine shallow shoreline habitats in Pool 14 to determine if these habitats may currently support significant unknown populations of *L. higginsii.*

1.3.3 Estimate population size in Essential Habitat Areas.

1.3.4 Estimate recruitment in Essential Habitat Areas.

1.3.5 Estimate the existing genetic variability of the populations in Essential Habitat Areas.

Conduct genetic studies on the populations of *L. higginsii* in Essential Habitat Areas to assess the number of populations needed to ensure the maintenance of the species' genetic diversity.

1.3.6 Maintain an up-to-date list of Essential Habitat Areas and the supporting data for each at the Service's Twin Cities Field Office and make this information, or a summary thereof, available through the internet.

1.4 Limit construction in areas of essential *L. higginsii* habitat. Mitigation, including translocation, may be an acceptable alternative in limited instances.

1.4.1 Determine the potential impact of construction projects on Essential Habitat Areas.

1.4.2 Determine alternatives to harmful construction practices.

Ensure that water development projects are designed and reviewed to minimize the potential for resuspension of contaminated sediments in the vicinities of *L. higginsii* Essential Habitat Areas.

1.4.3 Continue monitoring the impacts of commercial navigation activities on Essential Habitat Areas.

1.5 Continue to examine the relationship between water quality, especially contaminants, and *L. higginsii* populations in Essential Habitat Areas.

To most effectively address water quality threats discussed in this document, it is recommended that priority be given to filling data gaps identified under *Water Quality*. As *L. higginsii* toxicity data becomes more available, the relative degree of other water quality-related threats may be better evaluated. In summary, there is need to (1) obtain information on the water and sediment quality requirements of the various life history stages of *L. higginsii*, and (2) take concurrent actions to prevent acute and chronic point and non-point source contamination that is reasonably presumed harmful to the species.

1.5.1 Develop a freshwater mussel toxicity database for sediment and water quality parameters to define *L. higginsii* habitat quality goals.

1.5.1.1 Identify suitable surrogate species for *L. higginsii* for use in laboratory toxicity tests.

1.5.1.2 Determine necessary handling protocols and culturing requirements of each life history stage to be tested.

1.5.1.3 Document existing toxicity data (including test type) available for the species and/or its surrogates.

1.5.1.4 Identify inorganic and organic contaminant compounds and mixtures present in *L. higginsii* Essential Habitat Areas. Use these data to determine realistic ranges of environmental concentrations for use in laboratory exposures.

Report pH, temperature, and hardness associated with data collected in *L. higginsii* Essential Habitat Areas to allow for a robust comparison to existing or proposed water quality criteria.

1.5.1.5 Design and complete acute and chronic laboratory toxicity tests based on Tasks 1.5.1.1 through 1.5.1.4. Include glochidium, juvenile, and adult life stages.

Determine effects of organic and inorganic environmental contaminants identified under 1.5.1.4.

1.5.1.6 Document the exposure pathways and various modes of contaminant uptake for *L. higginsii* (or suitable surrogate species), emphasizing the relative significance of uptake from food sources, surface water, pore water, and sediments.

1.5.1.7 Determine the biological effects and significance of contaminant residues documented in mussel tissues.

1.5.2 Characterize specific sediment and water quality parameters in *L. higginsii* Essential Habitat Areas and reestablishment areas.

1.5.2.1 Collect sediment and pore water from areas identified as currently supporting viable *L. higginsii* populations and proposed reestablishment areas; analyze for a range of organic and inorganic contaminants.

This is especially important in the Sylvan Slough area of Upper Mississippi River Pool 15, where the potential for PCBs in sediments to adversely affect benthic biota has been identified. Report pH, temperature, and hardness for water collected in Essential Habitat Areas and reestablishment areas to allow for a robust comparison to existing or proposed water quality criteria. This assessment may include endocrine disrupters.

1.5.2.2 Develop and implement water quality criteria that would conserve Higgins eye; these criteria should be directly or indirectly protective of sediment and pore water quality, as necessary to conserve Higgins eye.

1.5.3 Promote best management practices in the watersheds of *L. higginsii* Essential Habitat Areas and relocation areas to minimize potential non-point source impacts.

Water quality threats to *L. higginsii* and to future reintroduction efforts may be reduced by ensuring that water development projects minimize re-suspension of contaminated sediments in vicinities of *L. higginsii* Essential Habitat Areas and potential reestablishment areas. Best management practices (erosion control, cropping systems, livestock waste management, etc.) recommended and approved by the U.S. Department of Agriculture and the U.S. Environmental Protection Agency should continue to be encouraged in the watersheds of Essential Habitat Areas to minimize potential run-off impacts to the species.

1.5.3.1 Coordinate with local land use planning and technical assistance offices to increase awareness and need to protect water quality in *L. higginsii* Essential Habitat Areas and relocation areas.

1.6 Develop plans to enhance the safety of shipping toxic or hazardous materials, reduce the introduction of these materials near *L. higginsii* habitat, and develop response plans for any spills that may occur.

1.6.1 Promote the use of double hull barges.

1.6.2 Incorporate *L. higginsii* habitat information into applicable spill contingency planning efforts; identify protective response actions available.

1.6.2.1 Coordinate with state and Federal natural resource trustees responsible for spill planning and response. Identify *L. higginsii* water quality requirements and Essential Habitat Area information, as well as applicable facility, local, state, Federal, and area spill contingency planning efforts.

1.6.2.2 Identify potential response actions that may prevent or minimize impacts to *L. higginsii* (including habitat) in the event of a spill of oil or hazardous materials. Incorporate into applicable response plans as necessary.

1.6.2.3 Identify potential *L. higginsii* habitat restoration and compensation measures that state and Federal natural resource trustees may consider under Natural Resource Damage Assessment responsibilities in the event of a spill of oil or hazardous materials. Incorporate into applicable response plans as necessary.

1.7 Review current regulations of mussel harvest in the upper Mississippi River drainage and develop additional regulations to reduce impacts on *L. higginsii*.

1.7.1 Develop regulations to prevent mussel harvest in Essential Habitat Areas.

1.7.2 Review existing harvest regulations and make recommendations to the USFWS and the States on any regulations needed outside of Essential Habitat Areas.

1.7.3 Enhance enforcement of existing harvest regulations.

1.8 Continue to develop materials to inform the public on the nature of endangered mussels and *L. higginsii*, in particular.

1.8.1 Educate commercial navigation industry, commercial mussel harvesters, and state transportation agencies on the nature of endangered mussels.

2 Enhance the abundance and viability of *L. higginsii* in areas where it currently exists and restore populations within historic range.

2.1 Identify and rank potential sites of existing *L. higginsii* populations for enhancement.

2.1.1 Estimate the population size in non-Essential Habitat Areas.

2.1.2 Estimate recruitment in non-Essential Habitat Areas.

2.1.3 Estimate the genetic variability of the populations in non-Essential Habitat Areas.

2.2 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.

2.2.1 Determine the best method to increase population size.

2.2.2 Utilize the best method to increase population size.

2.2.3 Assess the efficacy of the method used.

2.3 Determine the feasibility of reestablishing *L. higginsii* into historic habitats, particularly streams that are at lower risk for zebra mussel colonization.

2.3.1 Rank historic habitats for the likelihood of zebra mussel colonization.

2.3.2 Examine habitat suitability and fish assemblage for reintroduction.

Sediment and water quality should be characterized in areas designated for reestablishment; comparisons to sediment and water quality parameters in existing *L. higginsii* habitat should provide at least a partial indication of habitat integrity.

2.3.3 Develop a reintroduction/augmentation plan and utilize best method(s) of reintroduction

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

2.4.1 Examine the morphological, conchological and genetic differences between *L. higginsii* and *L. abrupt*.

3 Update, revise, or add to the plan to keep it current and useful.

Follow USFWS procedures to keep the plan current and useful and to determine whether an update, revision, or addendum is most appropriate.

4 Develop a plan to monitor *L. higginsii* after it is removed from the list of Endangered Species.

The Endangered Species Act (4)(g)(1) requires the Service to "...implement a system in cooperation with the States to monitor effectively for not less than five years the status of all species which have recovered to the point at which the measures provided pursuant to this Act are no longer necessary." The Service should begin working on this plan when it determines that the species has met its recovery criteria and its protection under the Act is no longer required and should consider monitoring for at least ten years.

III. IMPLEMENTATION SCHEDULE

The following Implementation Schedule outlines actions and estimated costs for the recovery program. It is a guide for meeting the objective discussed in Part II of this Plan. This schedule indicates task priorities, task numbers, task descriptions, duration of tasks, recovery partners, and estimated costs. These actions, when accomplished, should lead to the recovery of the species and protect its essential habitat. The estimated funding needs for all parties anticipated to be involved in recovery are identified. Part III reflects the estimated costs for the first three years of the recovery program for this species. Costs for year 4 and beyond will be determined approximately every three years by the USFWS and cooperating agencies. When delisting occurs due to recovery of the species, a minimum of five years of monitoring is required by the Act to assess the adequacy of recovery actions and determine if there will be cause to consider relisting. Because of special concerns with the biology of *Lampsilis higginsii*, a minimum of ten years of monitoring is necessary for this species.

Tasks in the first column of the following Implementation Schedule are assigned priorities as follows:

Priority 1: An action that ***must*** be taken to prevent extinction or to prevent the species from declining irreversibly in the ***foreseeable*** future.

Priority 2: An action that must be taken to prevent a significant decline in species population/habitat quality or some other significant negative impact short of extinction.

Priority 3: All other actions necessary to meet the recovery objectives.

Acronyms used in the Implementation Schedule:

	Recovery Partner -- USFWS Program
ES-TE	U.S. Fish and Wildlife Service, Division of Ecological Services, Threatened and Endangered Species Program
ES-EQ	U.S. Fish and Wildlife Service, Division of Ecological Services, Environmental Quality Program
ES-HC	U.S. Fish and Wildlife Service, Division of Ecological Services, Habitat Conservation Program
F	U.S. Fish and Wildlife Service, Division of Fisheries
RW	U.S. Fish and Wildlife Service, Division of Refuges and Wildlife
EA	U.S. Fish and Wildlife Service, Division of External Affairs
LE	U.S. Fish and Wildlife Service, Division of Law Enforcement
Partners	U.S. Fish and Wildlife Service, Partners for Fish and Wildlife Program

	Recovery Partner -- Other Federal Agencies and States
ACOE	U.S. Army Corps of Engineers
USCG	U.S. Coast Guard
USDA	U.S. Department of Agriculture
EPA	U.S. Environmental Protection Agency
BRD	U.S. Geological Survey, Biological Resources Division
WRD	U.S. Geological Survey, Water Resources Division
NPS	National Park Service
States	Minnesota Department of Natural Resources, Division of Ecological Services
	Wisconsin Department of Natural Resources, Bureau of Endangered Resources
	Iowa Department of Natural Resources, Division of State Parks, Recreation and Preserves
	Illinois Department of Natural Resources, Division of Natural Heritage
	Missouri Department of Conservation

Task Nos.	Task Priority	Task Description	Duration (Years)	Recovery Partner		Cost Estimate $ X 1000			Comments
				USFWS Program	Other	Year 1	Year 2	Year 3	
1.1. Assess and limit the impact of the zebra mussel, *Dreissena polymorpha*, on *L. higginsii*.									
1.1.1	1	Develop strategies to prevent zebra mussel infestation.	2	ES-TE	ACOE States BRD	50	50	---	
1.1.2	1	Monitor zebra mussel populations at Essential Habitat Areas that are currently infested.	Ongoing	ES-TE	ACOE States BRD	20	20	20	
1.1.3	1	Develop and implement a response plan for *L. higginsii* in Essential Habitat Areas.	Ongoing	ES-TE	ACOE States BRD	30	50	50	year 2 and 3 cost only if plan is implemented
1.2. Develop uniform protocols for collecting and maintaining information on *L. higginsii* populations.									
1.2.1	2	Develop a uniform protocol for collecting information for populations of *L. higginsii*.	1	ES-TE	ACOE States BRD	50	---	---	

Task Nos.	Task Priority	Task Description	Duration (Years)	Recovery Partner		Cost Estimate $ X 1000			Comments
				USFWS Program	Other	Year 1	Year 2	Year 3	
1.2.2	2	Answer the following three questions to facilitate the implementation of this recovery plan: What would constitute sufficient evidence of a strong juvenile year class of *L. higginsii*? What methods should be used to evaluate the strength of juvenile year classes of *L. higginsii*? How many strong juvenile year classes should be detected to determine that reproduction is sufficient to allow for stable or growing populations of *L. higginsii*?	3	ES-TE	States BRD	10	10	10	
1.2.3	2	Develop a central database of information based on the protocol developed in task 1.2.1.	1	ES-TE	ACOE States BRD	---	50	---	
1.2.4	2	Develop and implement a long-term monitoring plan at Essential Habitat Areas.	Cont.	ES-TE	States ACOE	100	100	100	

Task Nos.	Task Priority	Task Description	Duration (Years)	Recovery Partner		Cost Estimate $ X 1000			Comments
				USFWS Program	Other	Year 1	Year 2	Year 3	
1.3. Maintain a list and an ongoing evaluation of Essential Habitat Areas.									
1.3.1	2	Evaluate the ten Essential Habitat Areas recommended in this plan based on the best available scientific information.	3	ES-TE	States BRD ACOE	100	100	100	
1.3.2	2	Identify new Essential Habitat Areas.	3	ES-TE	States BRD ACOE	100	100	100	
1.3.2.1	2	Survey Pool 10 to determine whether additional Essential Habitat Areas may be identified in this pool.	3	ES-TE	States BRD ACOE	20	20	20	
1.3.2.2	3	Examine a site near river mile 454, Muscatine, IA, for inclusion as an Essential Habitat Area.	1	ES-TE	States BRD	10	---	---	
1.3.2.3	3	Examine a site near river mile 556.4, Bellevue, IA, for inclusion as an Essential Habitat Area.	1	ES-TE	States BRD ACOE	10	---	---	
1.3.2.4	3	Examine shallow shoreline habitats in Pool 14 to determine if these habitats may currently support significant unknown populations of *L. higginsii.*	1	ES-TE	States BRD ACOE	---	10	---	

Task Nos.	Task Priority	Task Description	Duration (Years)	Recovery Partner		Cost Estimate $ X 1000			Comments
				USFWS Program	Other	Year 1	Year 2	Year 3	
1.3.3	2	Estimate population size in Essential Habitat Areas.	Cont.	ES-TE	States BRD	TBD[5]	TBD	TBD	
1.3.4	2	Estimate recruitment in Essential Habitat Areas.	Cont.	ES-TE	States BRD	TBD	TBD	TBD	
1.3.5	3	Estimate the existing genetic variability of the populations in Essential Habitat Areas.	3	ES-TE	States BRD	50	50	50	
1.3.6	2	Maintain an up-to-date list of Essential Habitat Areas and the supporting data for each at the Service's Twin Cities Field Office and make this information, or a summary thereof, available through the internet.	3	ES-TE		-	-	-	
1.4. Limit construction in areas of essential *L. higginsii* habitat. Mitigation, including translocation may be an acceptable alternative in limited instances.									
1.4.1	3	Determine the potential impact of construction projects on Essential Habitat Areas.	Ongoing & cont.	ES-HC	ACOE	TBD	TBD	TBD	
1.4.2	3	Determine alternatives to harmful construction practices.	Ongoing & cont.	ES-HC	ACOE	TBD	TBD	TBD	

[5]To be determined. The Recovery Team was not able to estimate the costs of these tasks.

Task Nos.	Task Priority	Task Description	Duration (Years)	Recovery Partner		Cost Estimate $ X 1000			Comments
				USFWS Program	Other	Year 1	Year 2	Year 3	
1.4.3	3	Continue monitoring the impacts of commercial navigation activities on Essential Habitat Areas.	Ongoing & cont.	ES-HC	ACOE	50	50	50	
1.5. Continue to examine the relationship between water quality, especially contaminants, and *L. higginsii* populations in Essential Habitat Areas.									
1.5.1	3	Develop a freshwater mussel toxicity database for sediment and water quality parameters to help define *L. higginsii* habitat quality goals.	---	ES-EQ F	BRD WRD EPA ACOE	---	---	---	Reference specific tasks for total 1.5.1 cost estimates and duration
1.5.1.1	3	Identify suitable surrogate species for *L. higginsii* for use in laboratory toxicity tests.	3	ES-EQ	EPA BRD	75	75	50	
1.5.1.2	3	Determine necessary handling protocols and culturing requirements of each life history stage to be tested.	3	F ES-TE	BRD EPA	50	50	50	
1.5.1.3	3	Document existing toxicity data (including test type) available for the species and/or its surrogates.	3	ES-EQ	BRD EPA	40	40	0	
1.5.1.4	3	Identify inorganic and organic contaminant compounds and mixtures present in *L. higginsii* Essential Habitat Areas. Use these data to determine realistic ranges of environmental concentrations for use in laboratory exposures.	3	ES-EQ	BRD EPA	75	75	40	

Task Nos.	Task Priority	Task Description	Duration (Years)	Recovery Partner		Cost Estimate $ X 1000			Comments
				USFWS Program	Other	Year 1	Year 2	Year 3	
1.5.1.5	3	Design and complete acute and chronic laboratory toxicity tests based on Tasks Task 1.5.1.1 through Task 1.5.1.4. Include glochidium, juvenile, and adult life stages.	3	ES-EQ	BRD EPA ACOE	75	75	50	
1.5.1.6	3	Document the various modes of contaminant uptake for *L. higginsii* (or suitable surrogate species), emphasizing the relative significance of uptake from food sources, surface water, pore water, and sediments.	3	ES-EQ	BRD WRD EPA	100	100	50	
1.5.1.7	3	Determine the biological effect and significance of contaminant residues documented in mussel tissues.	3	ES-EQ	BRD WRD EPA	150	150	100	
1.5.2	3	Characterize specific sediment and water quality parameters in *L. higginsii* Essential Habitat Areas and reestablishment areas.	---	ES-EQ	BRD WRD EPA ACOE	---	---	---	Reference task 1.5.2.1 for 1.5.2 cost estimates and duration
1.5.2.1	3	Collect sediment and pore water from areas identified as currently supporting viable *L. higginsii* populations and proposed reestablishment areas; analyze for a range of organic and inorganic contaminants.	3	ES-EQ	BRD WRD EPA ACOE	150	150	100	

Task Nos.	Task Priority	Task Description	Duration (Years)	Recovery Partner		Cost Estimate $ X 1000			Comments
				USFWS Program	Other	Year 1	Year 2	Year 3	
1.5.2.2	3	Develop and implement water quality criteria that would conserve Higgins eye; these criteria should be directly or indirectly protective of sediment and pore water quality, as necessary to conserve Higgins eye.	3	ES-EQ	BRD EPA States	10	10	10	
1.5.3	3	Promote best management practices in the watersheds of *L. higginsii* Essential Habitat Areas and relocation areas to minimize potential non-point source impacts.	Cont.	ES-EQ ES-TE RW Partners	States EPA USDA NPS	---	---	---	Reference 1.5.3.1 for 1.5.3 cost estimate
1.5.3.1	3	Coordinate with local land use planning and technical assistance offices to increase awareness and need to protect water quality in *L. higginsii* Essential Habitat Areas and relocation areas	Cont.	ES-EQ ES-TE RW Partners	States EPA USDA NPS	30	30	30	

Task Nos.	Task Priority	Task Description	Duration (Years)	Recovery Partner		Cost Estimate $ X 1000			Comments
				USFWS Program	Other	Year 1	Year 2	Year 3	
1.6. Develop plans to enhance the safety of shipping toxic or hazardous materials, reduce the introduction of these materials near *L. higginsii* habitat, and develop response plans for any spills that may occur.									
1.6.1	2	Promote the use of double hull barges.	Ongoing	ES-TE	USCG	---	---	---	
1.6.2	3	Incorporate *L. higginsii* habitat information into applicable spill contingency planning efforts; identify protective response actions available.	On-going	ES-EQ ES-TE F RW LE	USCG EPA States NPS	---	---	---	Reference tasks 1.6.2.1, 1.6.2.2, and 1.6.2.3 for 1.6.2 cost estimate.
1.6.2.1	3	Coordinate with state and Federal natural resource trustees responsible for spill planning and response. Identify *L. higginsii* water quality requirements and Essential Habitat Area information, as well as applicable facility, local, state, Federal, and area spill contingency planning efforts.	On-going	ES-EQ ES-TE F RW LE	USCG EPA States NPS	10	10	10	
1.6.2.2	3	Identify potential response actions that may prevent or minimize impacts to *L. higginsii* (including habitat) in the event of a spill of oil or hazardous materials. Incorporate into applicable response plans as necessary.	On-going	ES-EQ ES-TE F RW LE	USCG EPA States NPS	10	10	10	

Task Nos.	Task Priority	Task Description	Duration (Years)	Recovery Partner		Cost Estimate $ X 1000			Comments
				USFWS Program	Other	Year 1	Year 2	Year 3	
1.6.2.3	3	Identify potential *L. higginsii* habitat restoration and compensation measures that state and Federal natural resource trustees may consider under Natural Resource Damage Assessment responsibilities in the event of a spill of oil or hazardous materials. Incorporate into applicable response plans as necessary.	On-going	ES-TE ES-EQ F RW LE	States NPS	20	20	20	
1.7. Review current regulations and develop additional regulation of mussel harvest in the upper Mississippi River drainage to reduce impacts on *L. higginsii*.									
1.7.1	2	Develop regulations to prevent mussel harvest in Essential Habitat Areas.	1	ES-TE	States	---	---	---	
1.7.2	3	Review existing harvest regulations and make recommendations to the USFWS and the States on any regulations needed outside of Essential Habitat Areas.	1	ES-TE	States	---	---	---	
1.7.3	2	Enhance enforcement of existing regulations.	Cont.	LE	States	---	---	---	
1.8. Continue to develop materials to educate the public on the nature of endangered mussels and *L. higginsii*, in particular.									
1.8.1	3	Educate commercial navigation industry, commercial mussel harvesters, and state transportation agencies on the nature of endangered mussels.	On-going	ES-TE PA	ACOE States	10	---	---	

Task Nos.	Task Priority	Task Description	Duration (Years)	Recovery Partner		Cost Estimate $ X 1000			Comments
				USFWS Program	Other	Year 1	Year 2	Year 3	
2.1. Identify and rank potential sites of existing *L. higginsii* populations for enhancement.									
2.1.1	3	Estimate the population size in non-Essential Habitat Areas.	3	ES-TE	BRD States	100	100	100	Combined with 2.1.2
2.1.2	3	Estimate recruitment in non-Essential Habitat Areas.	3	ES-TE	BRD States	See 2.1.1	---	---	Combined with 2.1.1
2.1.3	3	Estimate the genetic variability of the populations in non-Essential Habitat Areas.	3	ES-TE	BRD States	70	70	50	In con-junction with 2.1.1
2.2. 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.									
2.2.1	3	Determine the best method to increase population size.	2	ES-TE	BRD States	50	50	---	
2.2.2	3	Utilize the best method to increase population size.	2	ES-TE	BRD States	---	100	100	
2.2.3	3	Assess the efficacy of the method used.	2	ES-TE	BRD States	---	---	---	

Task Nos.	Task Priority	Task Description	Duration (Years)	Recovery Partner		Cost Estimate $ X 1000			Comments
				USFWS Program	Other	Year 1	Year 2	Year 3	
2.3. Determine the feasibility of reestablishing *L. higginsii* into historic habitats, particularly streams that are at lower risk for zebra mussel colonization.									
2.3.1	2	Rank historic habitats for the likelihood of zebra mussel colonization.	Ongoing	ES-TE	BRD States	---	---	---	Combine with 2.3.2
2.3.2	2	Examine habitat suitability and fish assemblage for reintroduction.	Ongoing	ES-TE	BRD States	100	100	100	Combine with 2.3.1
2.3.3	2	Develop a reintroduction/augmentation plan and utilize best method(s) of reintroduction	Ongoing	ES-TE	BRD State	300	300	300	
2.4. Examine the taxonomic validity of *L. higginsii* especially since *L. abrupt* is found in noncontiguous geographic areas.									
2.4.1	3	Examine the morphological, conchological and genetic differences between *L. higginsii* and *L. abrupt*.	1	ES-TE	BRD States	---	---	25	
3	**3**	**Update, revise, or add to the plan to keep it current and useful.**	**Ongoing**	**ES-TE**		**---**	**---**	**---**	**No specific costs anticipated Years 1-3**
4	**3**	**Develop a plan to monitor *L. higginsii* after it is removed from the list of Endangered Species.**	**2**	**ES-TE**		**---**	**---**	**---**	**No costs anticipated Years 1-3**

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IV. TABLES

Table 1. Summary of recent (2000-2003) reintroductions, adult translocations, and other releases of *Lampsilis higginsii.* Releases between sites in the same river include experimental releases and movements of adults and releases of artificially propagated *L. higginsii* into areas with low densities of zebra mussels. Largemouth bass, smallmouth bass, walleye, freshwater drum, spotted bass (*Micropterus punctulatus*), and white bass (*Morone chrysops*) were used as host fish species for artificial propagation. Gordon (2002) estimated 60-68 (smallmouth bass), 57-65 (walleye), and 78-133 (largemouth bass) transformed juveniles per fish. USFWS maintains an up-to-date database of reintroduction events at its Twin Cities Field Office in Bloomington, Minnesota. UMR = Upper Mississippi River.

Action	Source River	Relocation River	No. Mussels	No. Fish
Adult Relocation	UMR	UMR	101	n/a
Adult Relocation	UMR	UMR	99	n/a
Adult Relocation	UMR	UMR	271	n/a
Infested Fish in Cage(s)	St. Croix River	St. Croix River	n/a	100
Infested Fish in Cage(s)	St. Croix River	St. Croix River	n/a	100
Infested Fish in Cage(s)	St. Croix River	St. Croix River	n/a	150
Infested Fish in Cage(s)	St. Croix River	St. Croix River	n/a	150
Infested Fish in Cage(s)	St. Croix River	St. Croix River	n/a	50
Infested Fish in Cage(s)	St. Croix River	St. Croix River	n/a	150
Infested Fish in Cage(s)	St. Croix River	UMR	n/a	150
Infested Fish in Cage(s)	St. Croix River	UMR	n/a	150
Infested Fish in Cage(s)	St. Croix River	UMR	n/a	100
Infested Fish in Cage(s)	St. Croix River	UMR	n/a	50

Table 1. Summary of recent (2000-2003) reintroductions, cont.

Action	Source River	Relocation River	No. Mussels	No. Fish
Infested Fish in Cage(s)	St. Croix River	Wisconsin River	n/a	445
Infested Fish in Cage(s)	St. Croix River	Wisconsin River	n/a	150
Infested Fish in Cage(s)	UMR	UMR	n/a	245
Infested Fish in Cage(s)	UMR	UMR	n/a	520
Infested Fish in Cage(s)	UMR	UMR	n/a	804
Release Free-Ranging Fish	UMR	Wapsipinicon River	n/a	1890
Release Free-Ranging Fish	St. Croix River	Cedar River	n/a	793
Release Free-Ranging Fish	St. Croix River	Cedar River	n/a	405
Release Free-Ranging Fish	St. Croix River	Wisconsin River	n/a	450
Release Free-Ranging Fish	UMR	Cedar River	n/a	615
Release Free-Ranging Fish	UMR	Iowa River	n/a	1000
Release Free-Ranging Fish	UMR	Iowa River	n/a	11
Release Free-Ranging Fish	UMR	Iowa River	n/a	87
Release Free-Ranging Fish	UMR	Iowa River	n/a	577
Release Free-Ranging Fish	UMR	Iowa River	n/a	60
Release Free-Ranging	UMR	Iowa River	n/a	615

Table 1. Summary of recent (2000-2003) reintroductions, cont.

Action	Source River	Relocation River	No. Mussels	No. Fish
Fish				
Release Free-Ranging Fish	UMR	Iowa River	n/a	65
Release Free-Ranging Fish	UMR	Wapsipinicon River	n/a	620
Release Free-Ranging Fish	Wisconsin River	Wisconsin River	n/a	300
Release Juveniles	St. Croix River	Black River	1914	n/a
Release Juveniles	St. Croix River	Black River	1200	n/a
Release Juveniles	St. Croix River	St. Croix River	3	n/a
Release Juveniles	St. Croix River	Wisconsin River	3750	n/a
Release Juveniles	St. Croix River	Wisconsin River	1100	n/a

Table 2. List of primary and secondary habitats described in the 1983 *L. higginsii* recovery plan.

Habitat Type	Site	UMRS Pool	River Mile
Primary	Sylvan Slough, IL	15	485.5-486
	Cordova, IL	14	503-505.5
	McMillan Island, IA	10	616.4-619.1
	Prairie du Chien, WI/MN	10	634-636
	Harper's Slough, IA/WI	10	639-641.1
	Whiskey Rock, IA	9	655.8-658.4
	Hudson, WI (Lakeland, MN)	St. Croix River	16.2-17.6
Secondary	Jonas Johnson Island, IL	17	439
	Barkis Island, IL	17	444
	Andalusia Slough, IL	16	473
	Lower Sylvan Slough, IL	16	482
	Rapids City, IL	14	496
	Adams Island (vicinity), IA	14	507
	Dubuque, IA	12	580
	Cassville, WI	11	607
	Guttenberg, IA	11	613

Table 3. Fishes that have been examined as potential hosts for *L. higginsii.*

Fish species	Common name	Family	Suitability as a host	Reference
Stizostedion canadense	sauger	Percidae	Suitable	Surber (1912); Wilson (1916); Coker *et al.* (1921); Hove and Kapuscinski (2002)
Aplodinotus grunniens	freshwater drum	Sciaenidae	Suitable	Wilson (1916); Coker *et al.* (1921)
Micropterus salmoides	largemouth bass	Centrarchidae	Suitable	Sylvester *et al.* (1984); Waller & Holland-Bartels (1988); Hove and Kapuscinski (2002)
Micropterus dolomieu	smallmouth bass	Centrarchidae	Suitable	Waller & Holland-Bartels (1988)
Stizostedion vitreum vitreum	walleye	Percidae	Suitable	Sylvester *et al.* (1984); Waller & Holland-Bartels (1988)
Perca flavescens	yellow perch	Percidae	Suitable	Waller & Holland-Bartels (1988)
Pomoxis nigromaculatus	black crappie	Centrarchidae	Suitable	Hove and Kapuscinski (2002)
Lepomis macrochirus	bluegill	Centrarchidae	Marginal	Waller & Holland-Bartels (1988)
Esox lucius	northern pike	Esocidae	Marginal	Waller & Holland-Bartels (1988)
Lepomis cyanellus	green sunfish	Centrarchidae	Marginal	Waller & Holland-Bartels (1988); Sylvester *et al.* (1984)
Lepomis macrochirus	bluegill	Centrarchidae	Unsuitable	Sylvester *et al.* (1984)
Lepomis humilis	orange-spotted sunfish	Centrarchidae	Unsuitable	Hove and Kapuscinski (2002)
Lepomis gibbosus	pumpkinseed	Centrarchidae	Unsuitable	Hove and Kapuscinski (2002)
Ambloplites rupestris	rock bass	Centrarchidae	Unsuitable	Hove and Kapuscinski (2002)
Percina maculata	blackside darter	Centrarchidae	Unsuitable	Hove and Kapuscinski (2002)
Cyprinus carpio	common carp	Cyprinidae	Unsuitable	Sylvester *et al.* (1984)
Pimephales promelas	fathead minnow	Cyprinidae	Unsuitable	Waller & Holland-Bartels (1988)
Luxilus cornutus	common shiner	Cyprinidae	Unsuitable	Hove and Kapuscinski (2002)
Semolitus atromaculatus	creek chub	Cyprinidae	Unsuitable	Hove and Kapuscinski (2002)
Nocomis biguttatus	hornyhead chub	Cyprinidae	Unsuitable	Hove and Kapuscinski (2002)
Cyprinella spiloptera	spotfin shiner	Cyprinidae	Unsuitable	Hove and Kapuscinski (2002)
Ictalurus punctatus	northern hognose sucker	Ictaluridae	Unsuitable	Sylvester *et al.* (1984); Hove and Kapuscinski (2002)
Ameiurus melas	black bullhead	Ictaluridae	Unsuitable	Sylvester *et al.* (1984)
Pylodictis olivaris	flathead catfish	Ictaluridae	Unsuitable	Hove and Kapuscinski (2002)

Table 3. Fishes that have been examined as potential hosts for *L. higginsii*, cont.

Fish species	Common name	Family	Suitability as a host	Reference
Nocturus gyrinus	tadpole madtom	Ictaluridae	Unsuitable	Hove an`d Kapuscinski (2002)
Ameiurus natalis	yellow bullhead	Ictaluridae	Unsuitable	Hove and Kapuscinski (2002)
Carpiodes carpio	river carpsucker	Catostomidae	Unsuitable	Sylvester *et al.* (1984)
Catostomus commersoni	white sucker	Catostomidae	Unsuitable	Sylvester *et al.* (1984)
Hypentelium nigricans	northern hognose sucker	Catostomidae	Unsuitable	Hove and Kapuscinski (2002)
Oncorhynchus mykiss	rainbow trout	Salmonidae	Unsuitable	Sylvester *et al.* (1984)
Acipenser fulvescens	lake sturgeon	Acipenseridae	Unsuitable	Hove and Kapuscinski (2002)
Lepisosteus osseus	longnose gar	Lepisosteidae	Unsuitable	Hove and Kapuscinski (2002)
Percopsis omiscomaycus	trout-perch	Percoppsidae	Unsuitable	Hove and Kapuscinski (2002)
Lota lota	burbot	Lotidae	Unsuitable	Hove and Kapuscinski (2002)

Table 4.Water quality data from the St. Croix River at St. Croix Falls, Wisconsin, during 1975-1983. During the sampling period mean pH was 7.3 (6.4-8.3, n = 76); mean concentrations of calcium and magnesium were 21 (SD=5.0, n=81) and 6.7 (SD=1.5, n=81) mg/L, respectively. All data are summarized from Graczyk (1986).

Measure	Mean	Range	Number of observations
Total cadmium, ug/L	1.0	<1-3	30
Total chromium, ug/L	9	<20-20	30
Total copper, ug/L	4	<2-24	30
Total mercury, ug/L	0.20	<0.01-0.6	30
Total zinc, ug/L	30	<10-380	29
Alkalinity, mg/L	76	28-110	60
Calcium, mg/L	21	8.5-40	81
Conductivity, umhos	180	65-295	91
Total Nitrogen, mg/L	0.83	0.25-1.8	67
Ammonia Nitrogen, mg/L	0.61	0.13-1.6	89
Dissolved oxygen, mg/L	9.7	6.6-14	68
pH	7.3	6.4-8.3	76
Total phosphorus, mg/L	0.05	0.01-.016	82
Suspended sediment, mg/L	7.5	1-54	72

Table 5. Heavy metals and hydrocarbons in surficial sediments in 1986 from five locations in Pool 10 near Prairie du Chien, Wisconsin. Concentrations are mg/kg dry weight or ppm. Data are unpublished data from the U.S. Army Corps of Engineers (locations 1, 5, 6, 7, and 8).

Measure	Mean	Range	N
Heavy metals			
Cd	0.4	<0.3-0.5	10
Cr	11.6	8.3-17.0	10
Cu	8.8	5.0-15.0	10
Zn	41.2	28.9-63.5	10
*Aliphatic hydrocarbons**			
n-pentadecane	0.03	0.02-0.05	10
n-hexadecane	0.02	0.01-0.05	7
n-heptadeccane	0.06	0.02-0.12	10
pristane	0.02	0.01-0.03	4
n-octadecane	0.03	0.02-0.06	10
n-nonadecane	0.07	0.03-0.18	10
n-eicosane	0.03	0.01-0.10	9
Polyaromatic hydrocarbons			
napthalene	0.01	0.01	2
anthracene	0.01	0.01-0.03	5
fluroanthrene	0.04	0.01-0.20	7
pyrene	0.05	0.01-0.27	7
1,2-	0.01	0.01	5
chrysene	0.09	0.01-0.34	5
benzo(b)fluoranth	0.02	0.01-0.03	7
benzo(a)pyrene	0.01	0.01-0.02	7
1,2,5,6-	0.05	0.01-0.16	4
benzo(g,h,i)peryle	0.02	0.01-0.04	5

*In addition to the aliphatic hydrocarbons listed in the table, sediments were also analyzed for n-dodecane, n-tridecane, n-tetradecane, octylcyclohexane, and nonylcyclohexane. Concentrations of these compounds were below the lower level of detection of 0.01 ppm.. Sediments were also analyzed for 20 organochlorine compounds including HCB, BHC, oxychlordane, heptachlor epoxide, t-nonachlor, total PCBs, arochlor 1242, 1248, 1254, and 1260, o, p'-DDE, p, p'-DDE, dieldrin, o, p'-DDD, endrin, cis-nonachlor, o, p'-DDT, p, p'-DDD, p, p'-DDT, and mirex. Concentrations of these organochlorine pesticides were below the lower level of detection of 0.01 ppm (0.05 ppm for total PCBs).

Table 6. Studies conducted at the Essential Habitat sites that were recommended in the 1983 *L. higginsii* recovery plan.

Site	UMRS Pool	River Mile	References
Sylvan Slough, IL	15	485.5-486	Ecological Analysts (1981b); Blodgett & Sparks (1987b); Cawley (1989); Miller and Payne (2001)
Cordova, IL	14	503-505.5	Stanley Consultants (1988); Miller *et al.* (1990); Miller and Payne (1991,1993,1994,1996a,b, 1997, 2001); Helms (2000)
McMillan Is., IA	10	616.4-619.1	Miller *et al.* (1990); Miller & Payne (1996b, 2001)
Prairie du Chien, WI/MN	10	634-636	Thiel (1981); Havlik (1983);Duncan & Thiel (1983); Andrew Miller and Barry Payne (U.S. Army Corps of Engineers, <u>in</u> <u>litt.</u> 1984); Miller and Payne (1991, 1992, 1993, 1994, 1995a, 1995b, 1996a, 1996b, 1997, 2001); Holland-Bartels & Waller (1988); Clarke & Loter (1992, 1993, 1994, 1995)
Harper's Slough, IA/WI	10	639-641.1	Duncan & Thiel (1983); Miller & Payne (1996b, 2001); David Heath (Wisconsin Department of Natural Resources, <u>in</u> <u>litt.</u> 1996)
Whiskey Rock, IA	9	655.8-658.4	Miller & Payne (1996b, 2001)
Hudson, WI/MN	St. Croix River	16.2-17.6	Fuller (1980); Heidi Dunn (Ecological Specialists, <u>in</u> <u>litt.</u> 1994); Hornbach *et al.* (1995); Heath *et al.* (2001)

V. FIGURES

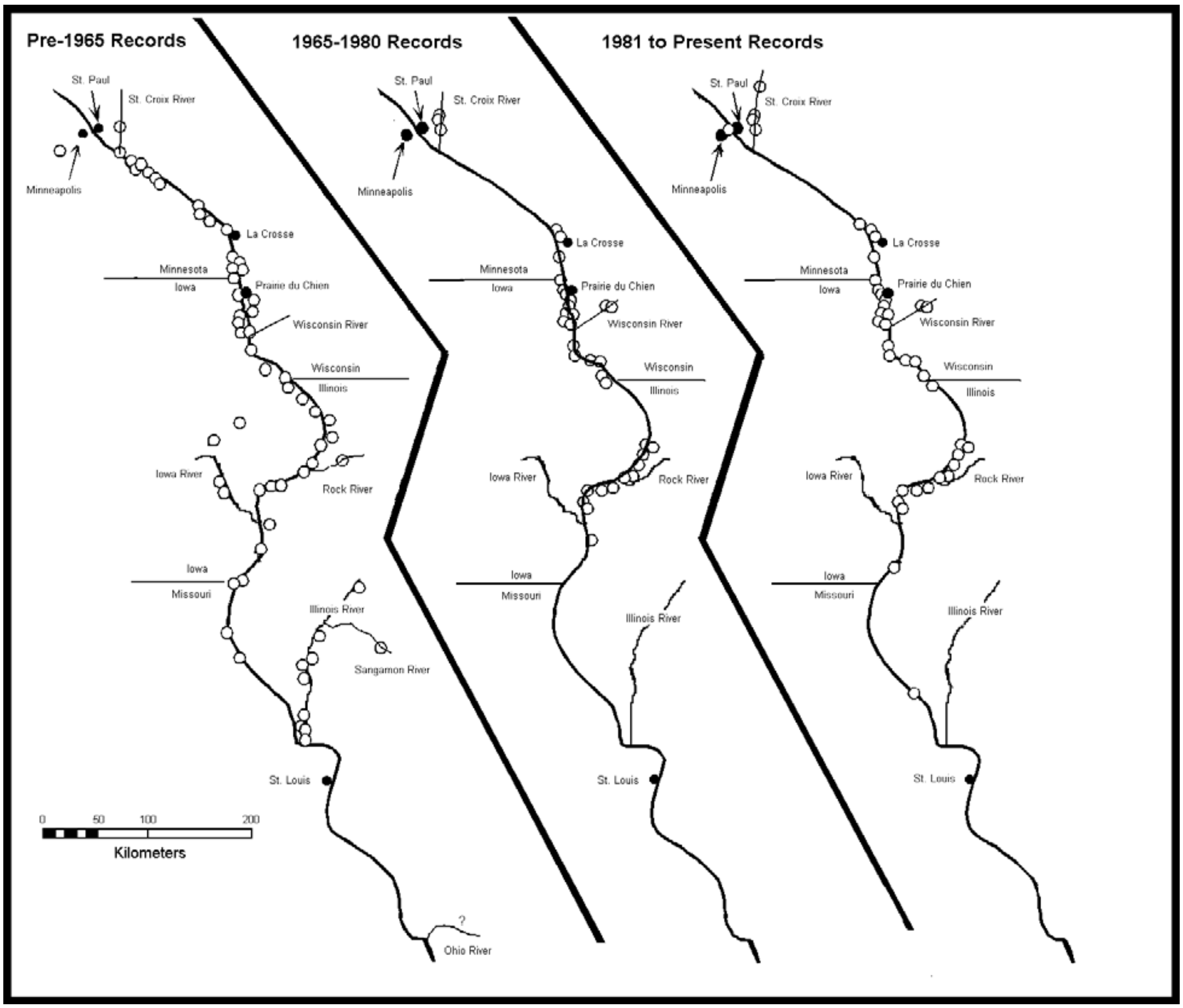

Figure 1. Distribution of *Lampsilis higginsii* in the Upper Mississippi River and major tributaries (from Havlik 1980 and Cawley 1996). *L. higginsii* has recently been introduced into some areas not indicated on this map (see Table 1). Open circles indicate locations of *L. higginsii* records; solid circles show locations of cities for geographic reference.

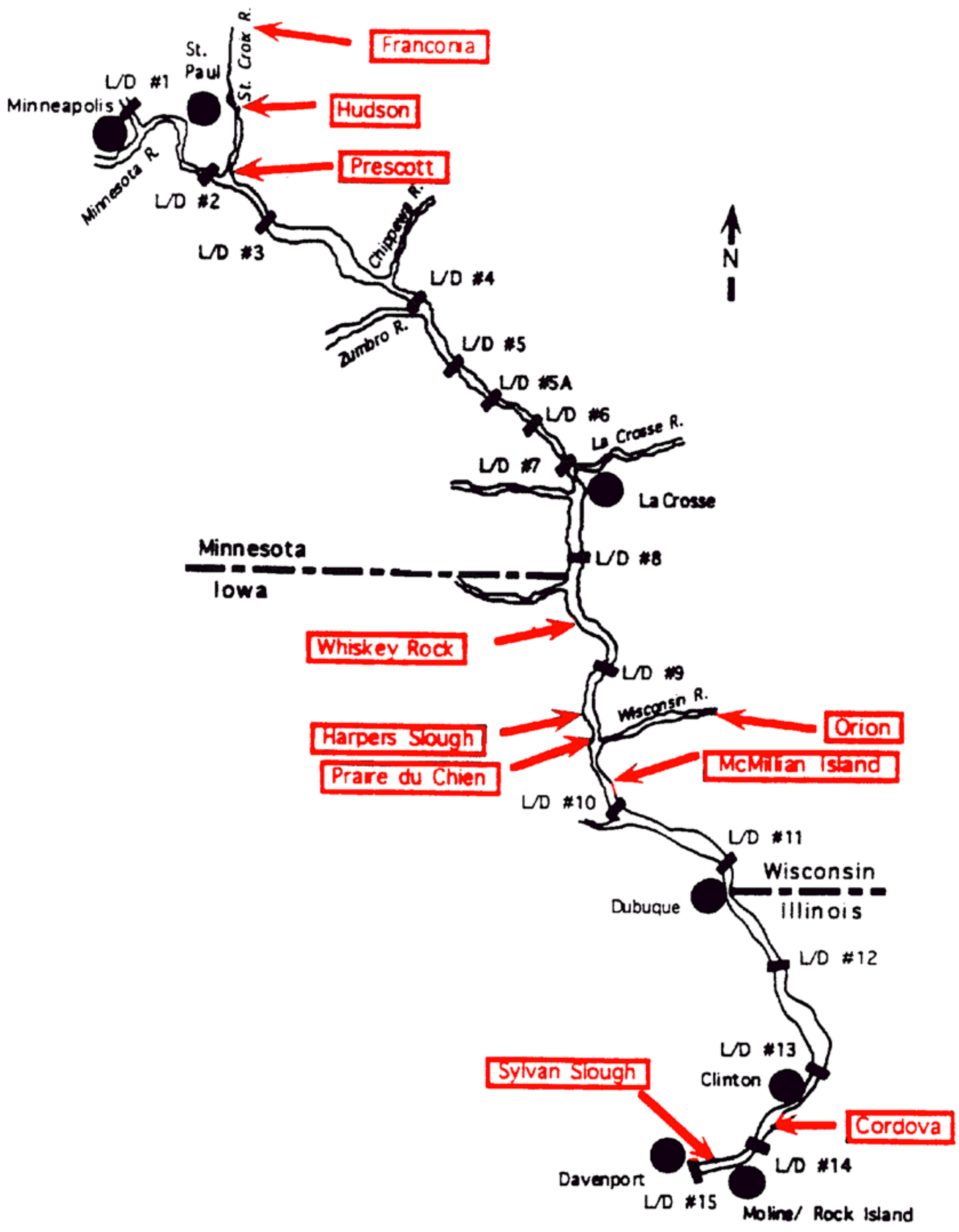

Figure 2. Recommended Essential Habitat Areas for Higgins' Eye Pearlymussel.

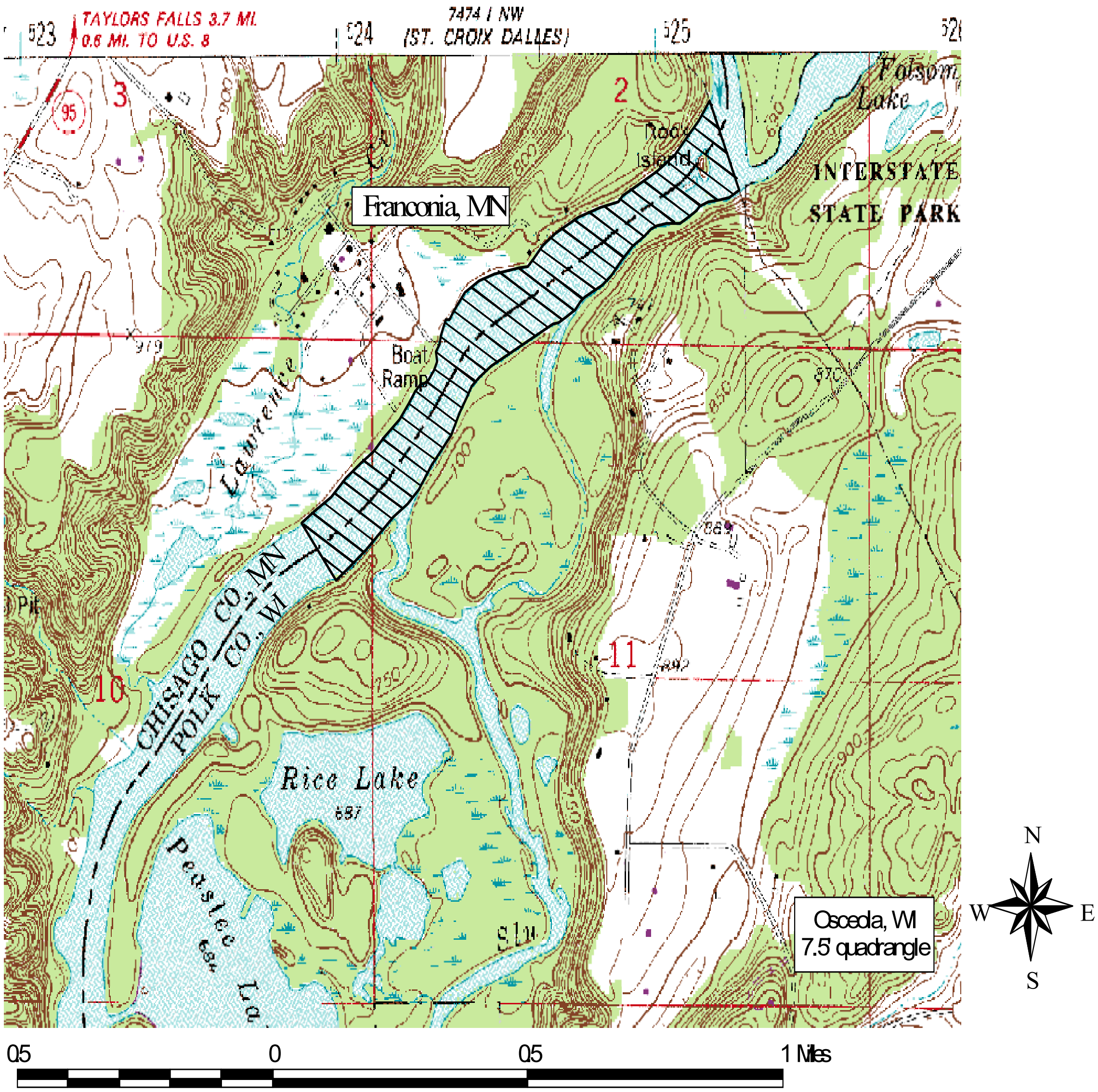

Figure 3. Essential Habitat Area at Franconia, Minnesota, St. Croix River, Chisago County, Minnesota, and Polk County, Wisconsin.

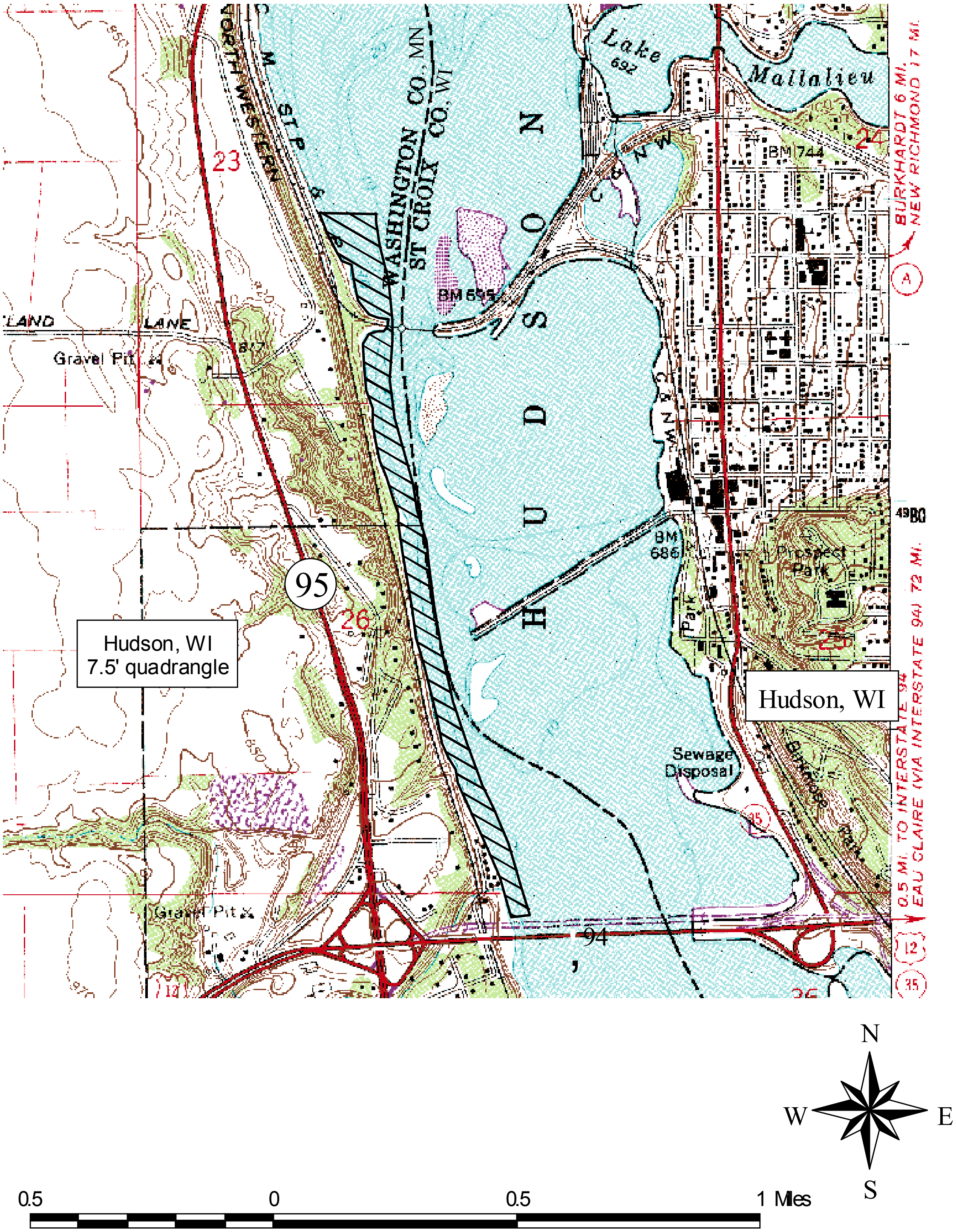

Figure 4. Essential Habitat Area at Hudson, Wisconsin, St. Croix River Washington County, Minnesota.

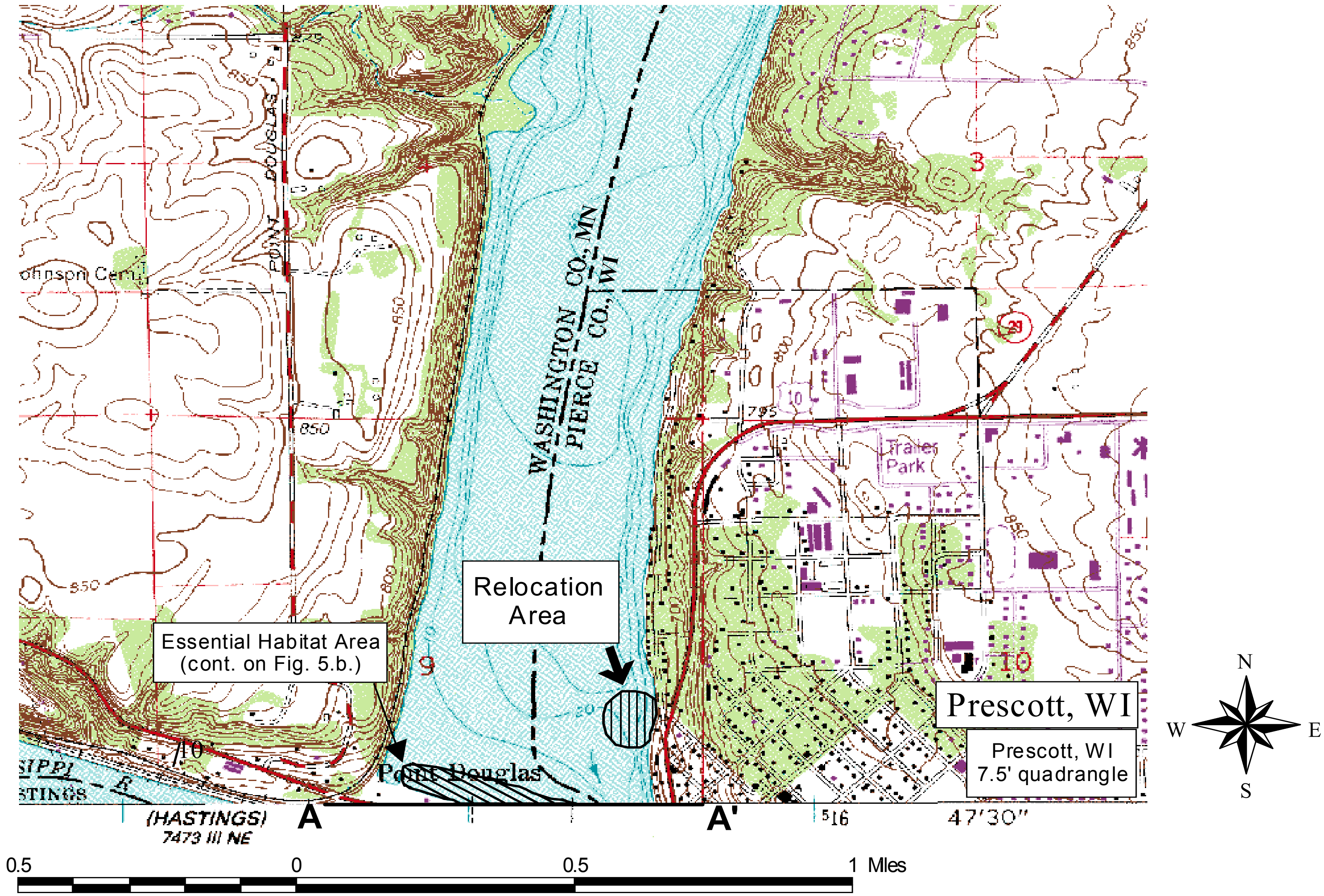

Figure 5.a. Essential Habitat Area at Prescott, Wisconsin, St. Croix River, Washington County, Minnesota, and Pierce County, Wisconsin. Match line A-A' to Figure 5.b.

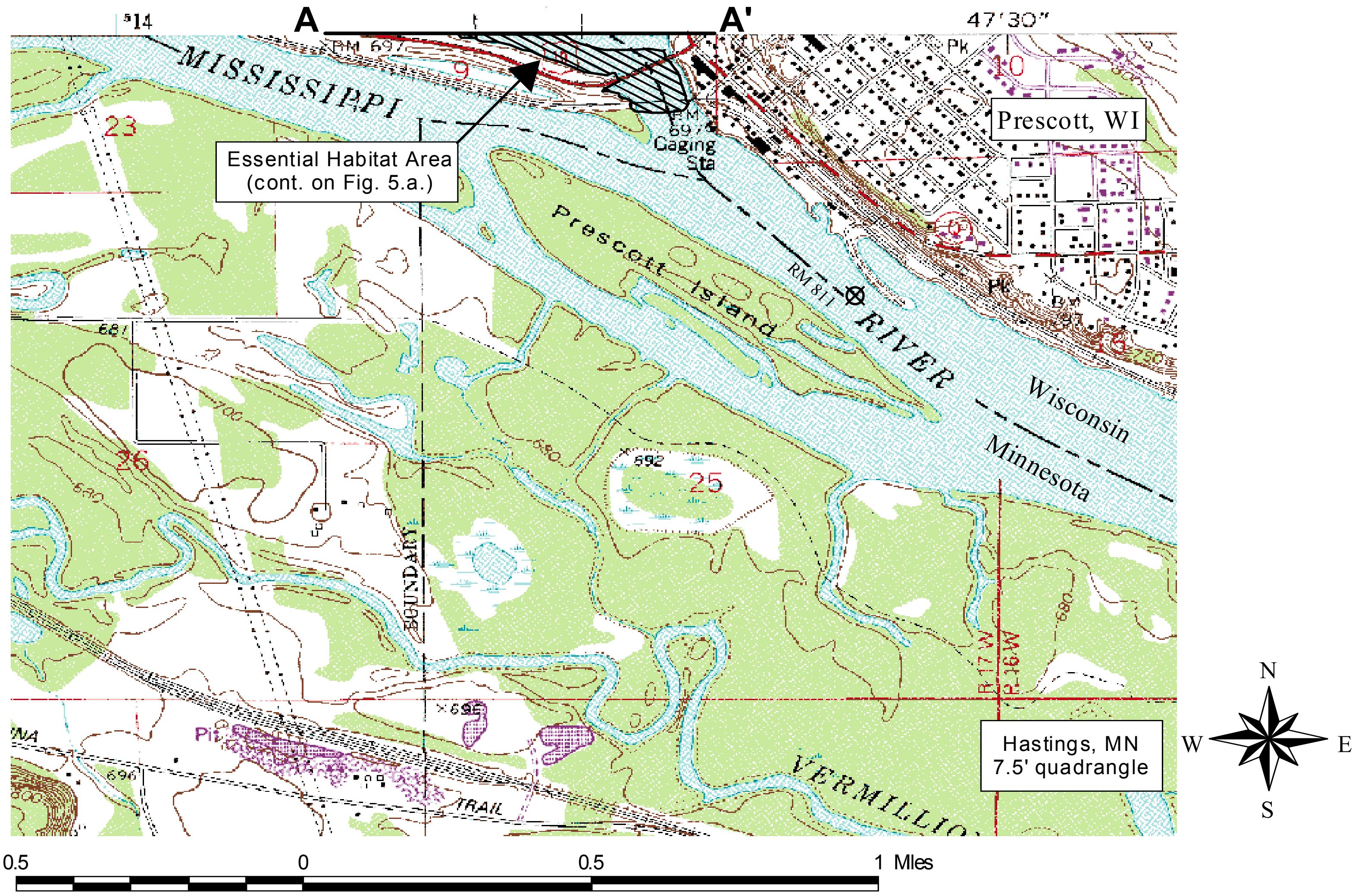

Figure 5.b. Essential Habitat Area at Prescott, Wisconsin, St. Croix River, Washington County, Minnesota, and Pierce County, Wisconsin. Match line A-A′ to Figure 5.a.

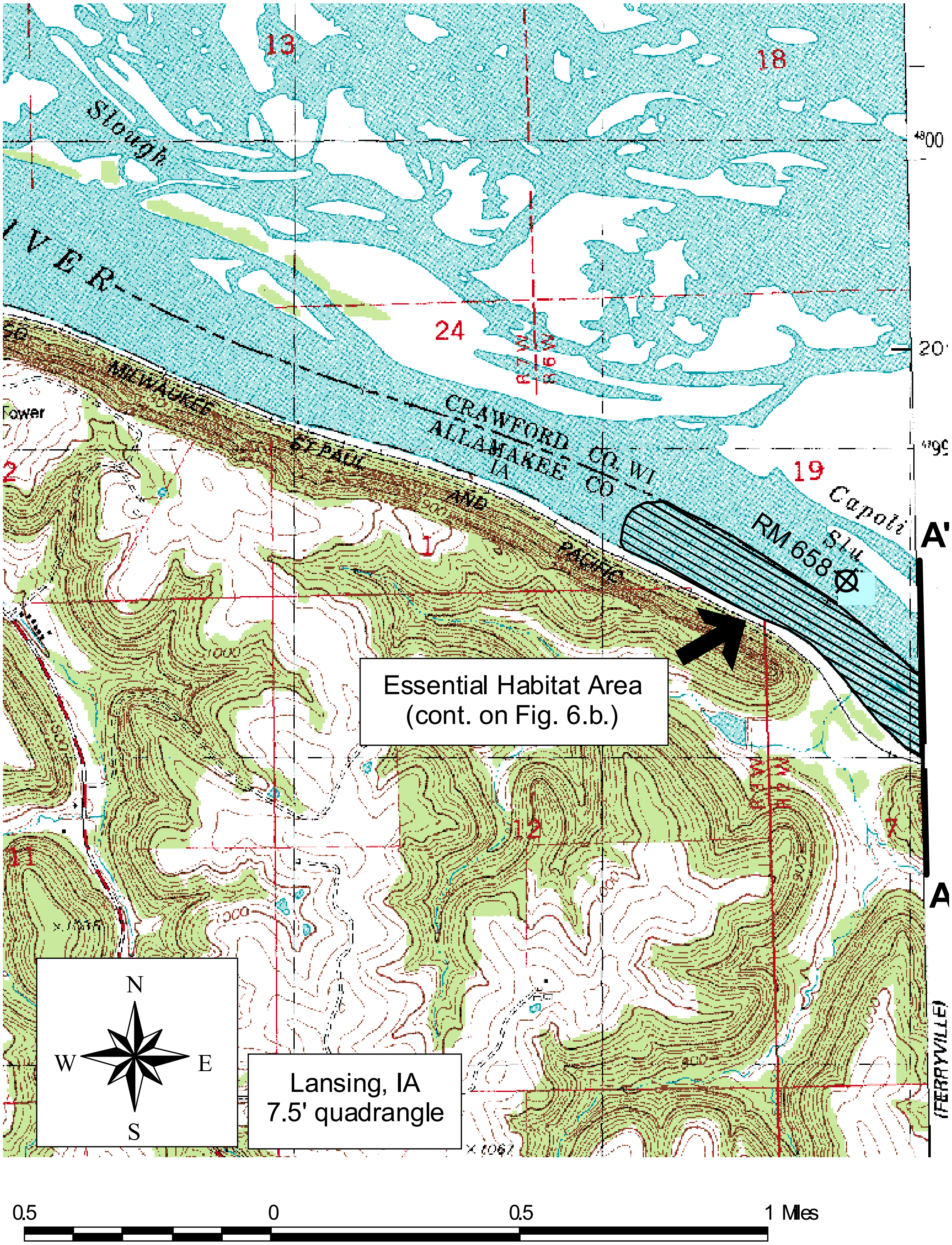

Figure 6.a. Essential Habitat Area at Whiskey Rock, Iowa, Pool 9, Mississippi River, Allamakee County, Iowa, and Crawford County, Wisconsin. Match line A-A' to Figure 6.b.

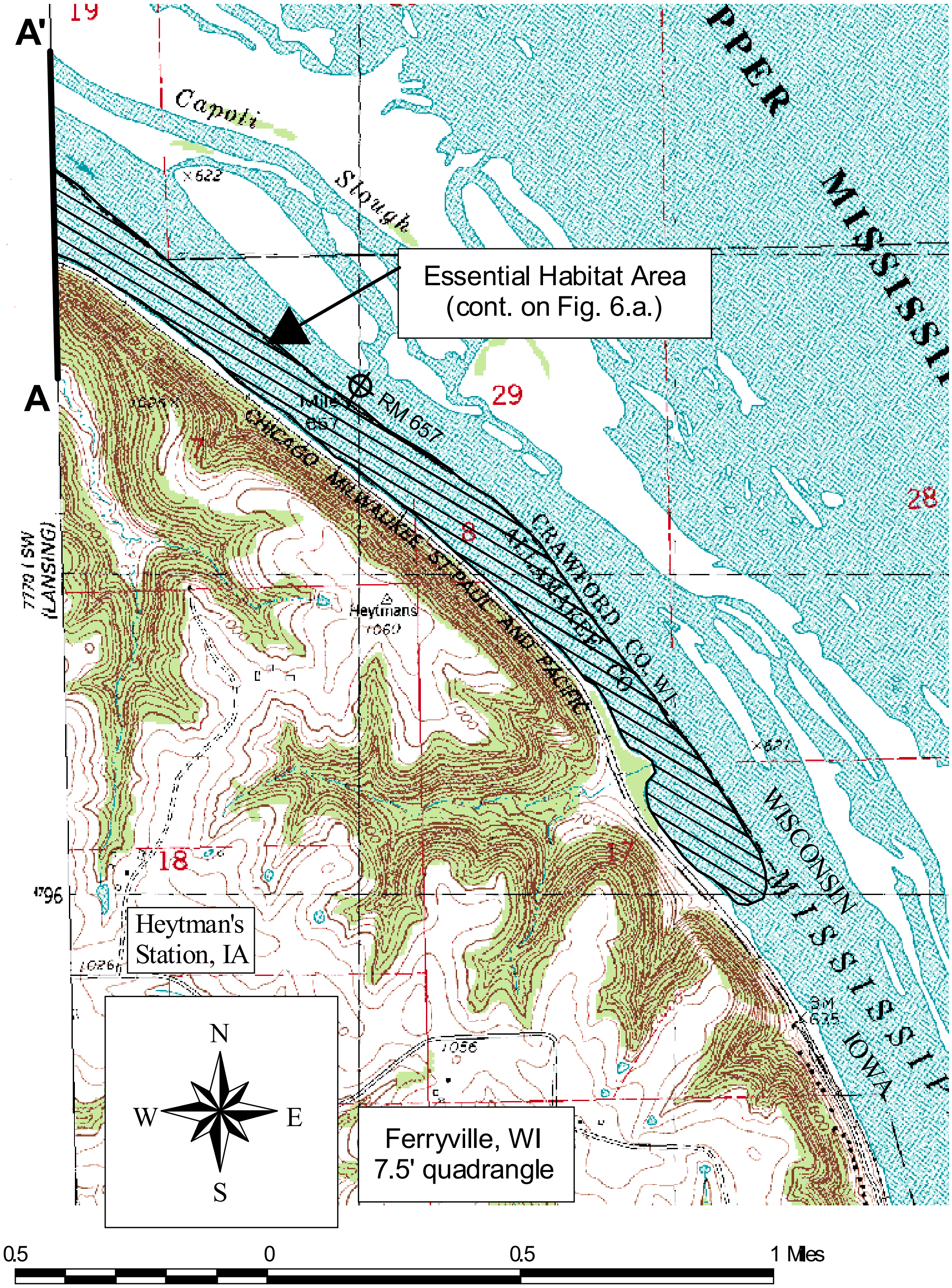

Figure 6.b. Essential Habitat Area at Whiskey Rock, Iowa, Pool 9, Mississippi River, Allamakee County, Iowa, and Crawford County, Wisconsin. Match line A-A' to Figure 6.a.

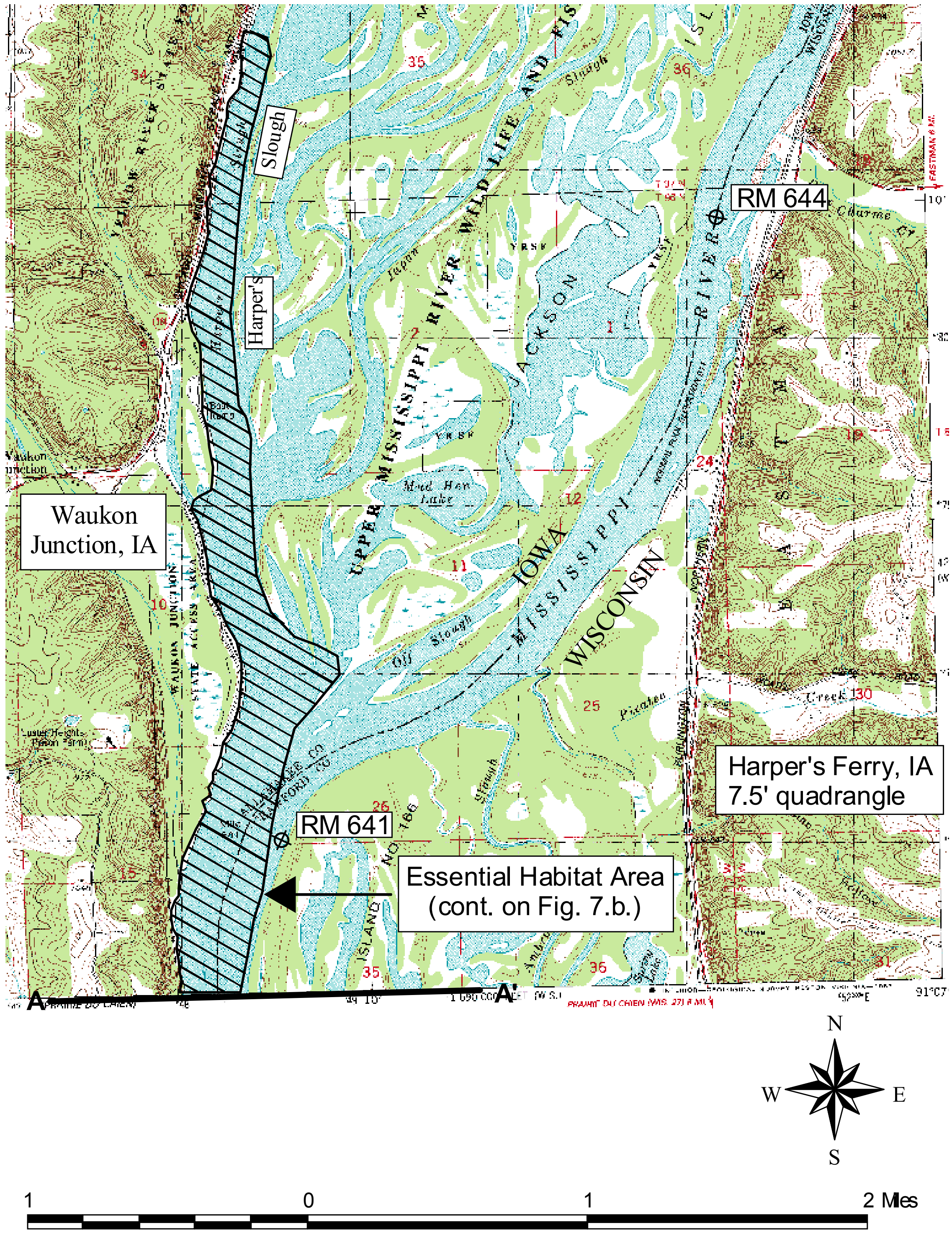

Figure 7.a. Essential Habitat Area at Harper's Slough, Pool 10, Mississippi River, Allamakee County, Iowa, and Crawford County, Wisconsin. Match line A-A' to Figure 7.b.

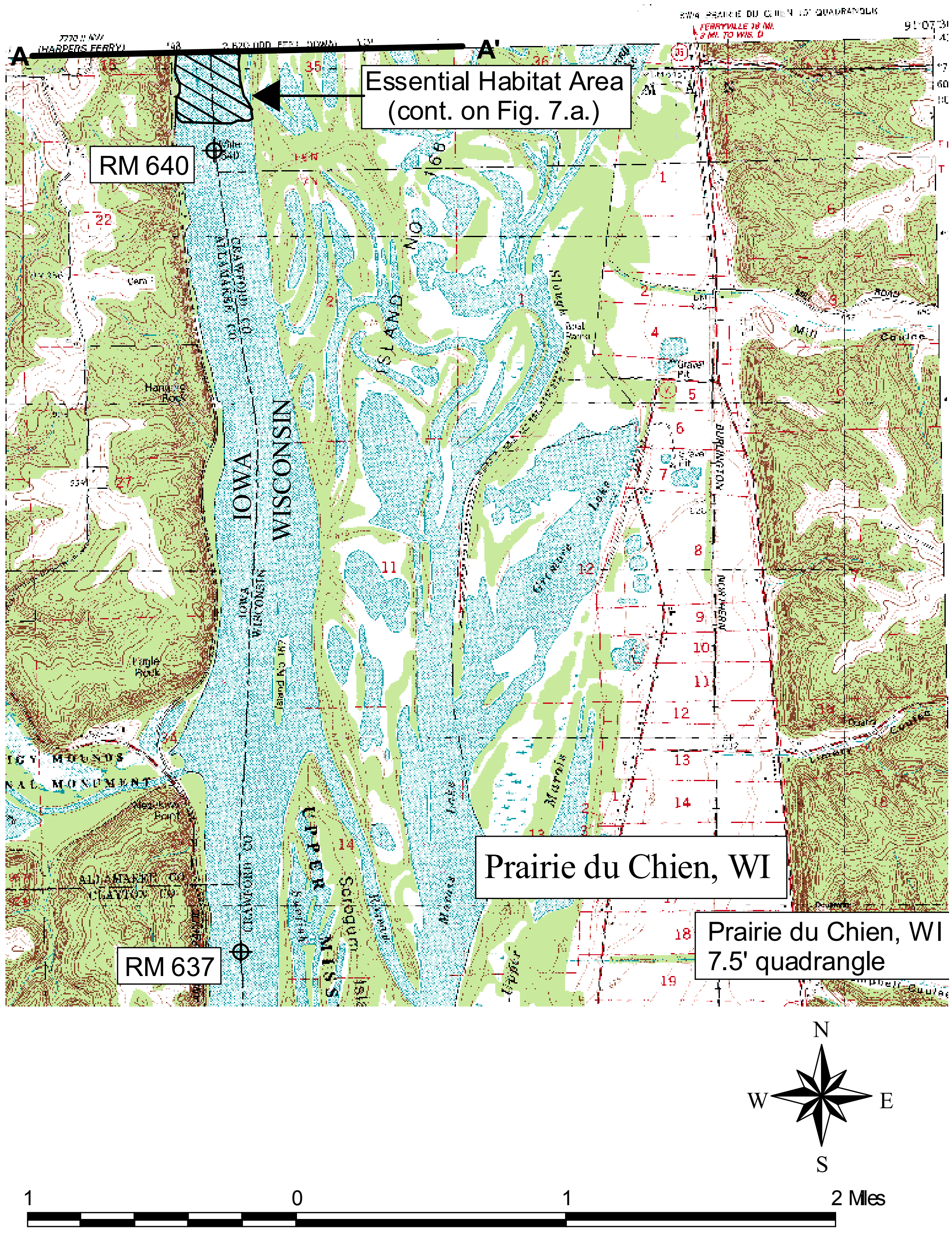

Figure 7.b. Essential Habitat Area at Harper’s Slough, Pool 10, Mississippi River, Allamakee County, Iowa, and Crawford County, Wisconsin. Match line A-A’ to Figure 7.a.

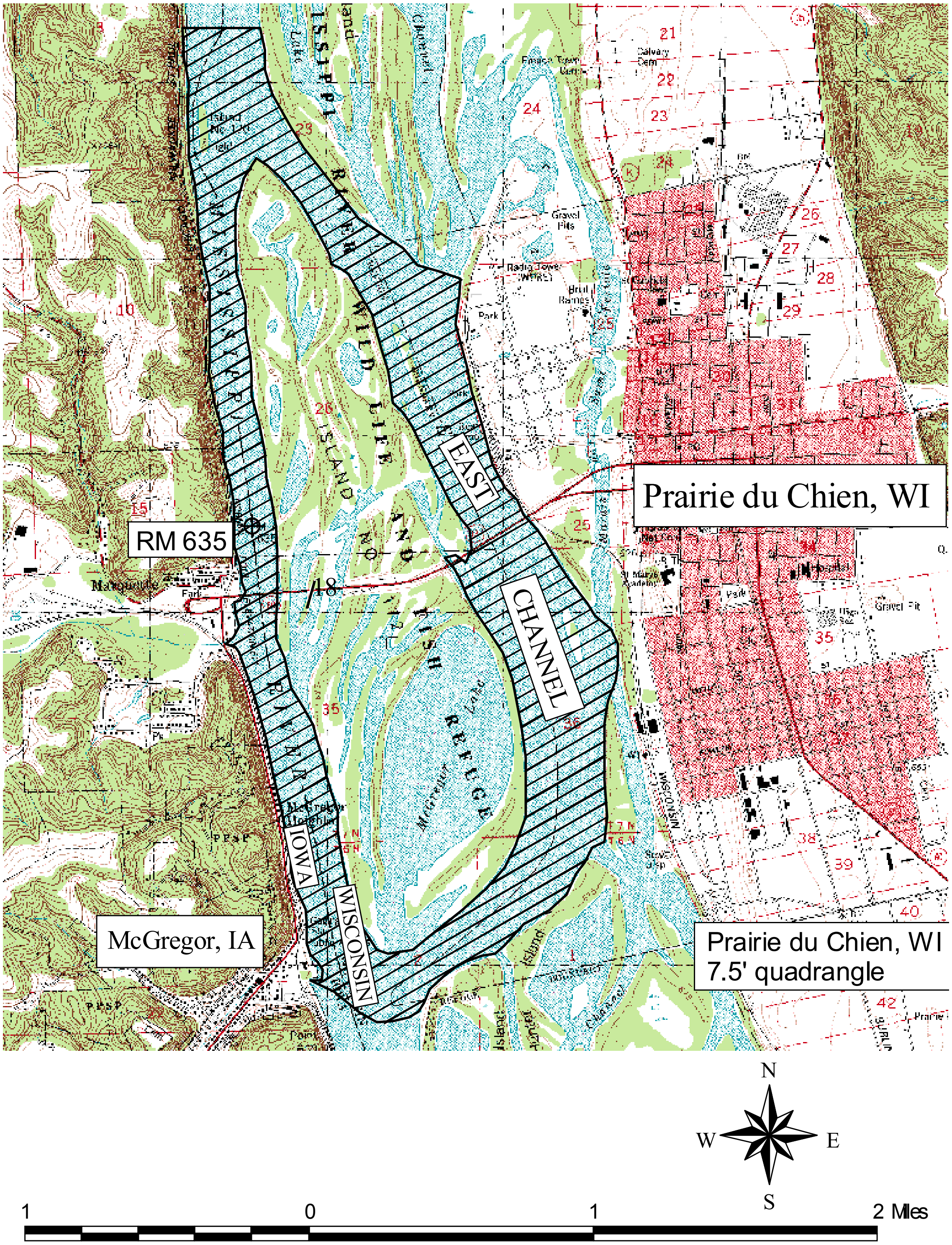

Figure 8. Essential Habitat Area at Prairie du Chien, Wisconsin, Pool 10, Mississippi River Clayton County, Iowa, and Crawford County, Wisconsin.

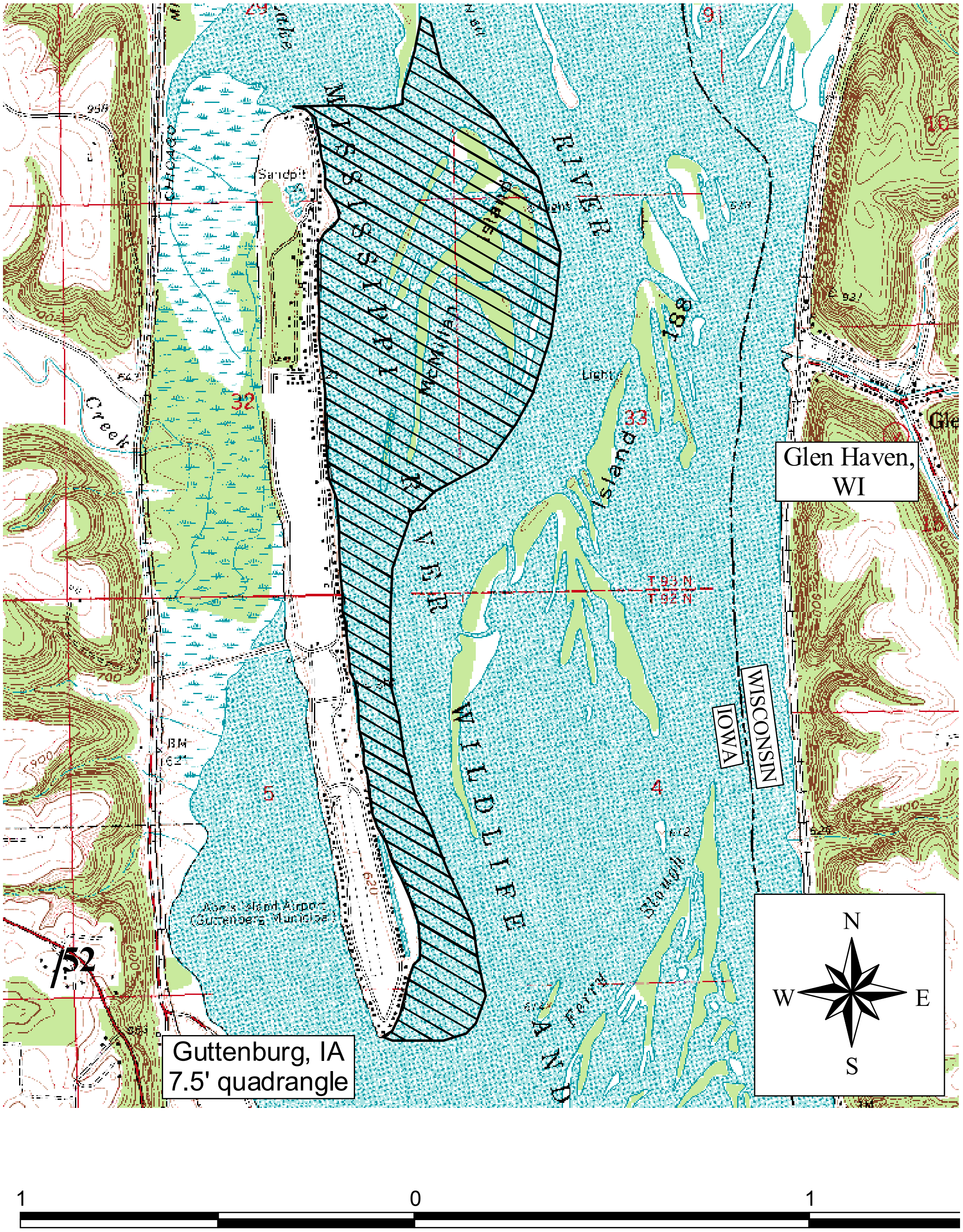

Figure 9. Essential Habitat Area at McMIllan Island, Pool 10, Mississippi River, Clayton County, Iowa.

Figure 10. Essential Habitat Area at Cordova, Illinois, Pool 14, Mississippi River, Rock Island County, Illinois.

Figure 11. Essential Habitat Area at Sylvan Slough, Pool 15, Mississippi River, Rock Island County, Illinois.

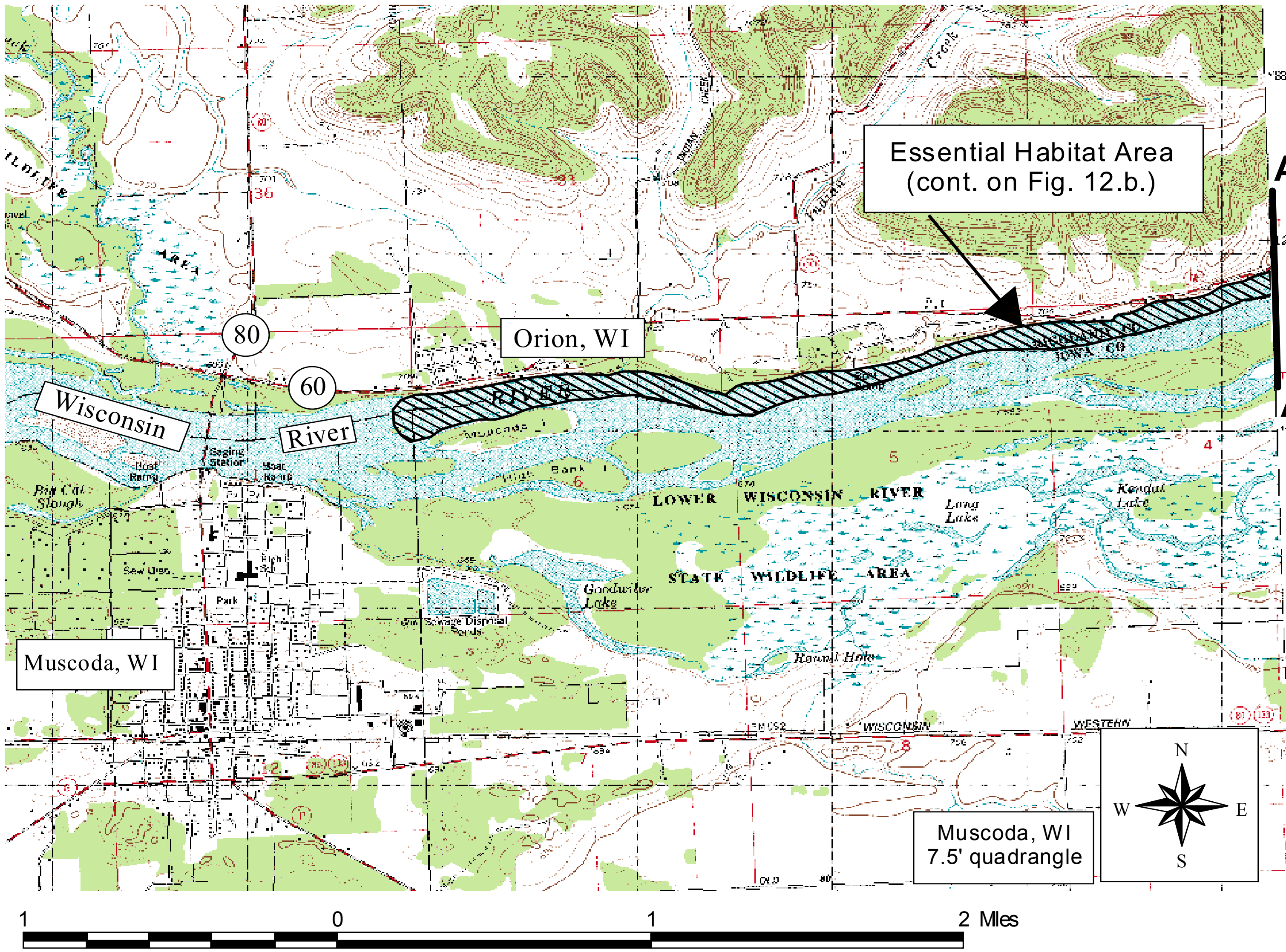

Figure 12.a. Essential Habitat Area at Orion, Wisconsin River, Richland and Iowa Counties, Wisconsin. Match line A-A' to Figure 12.b.

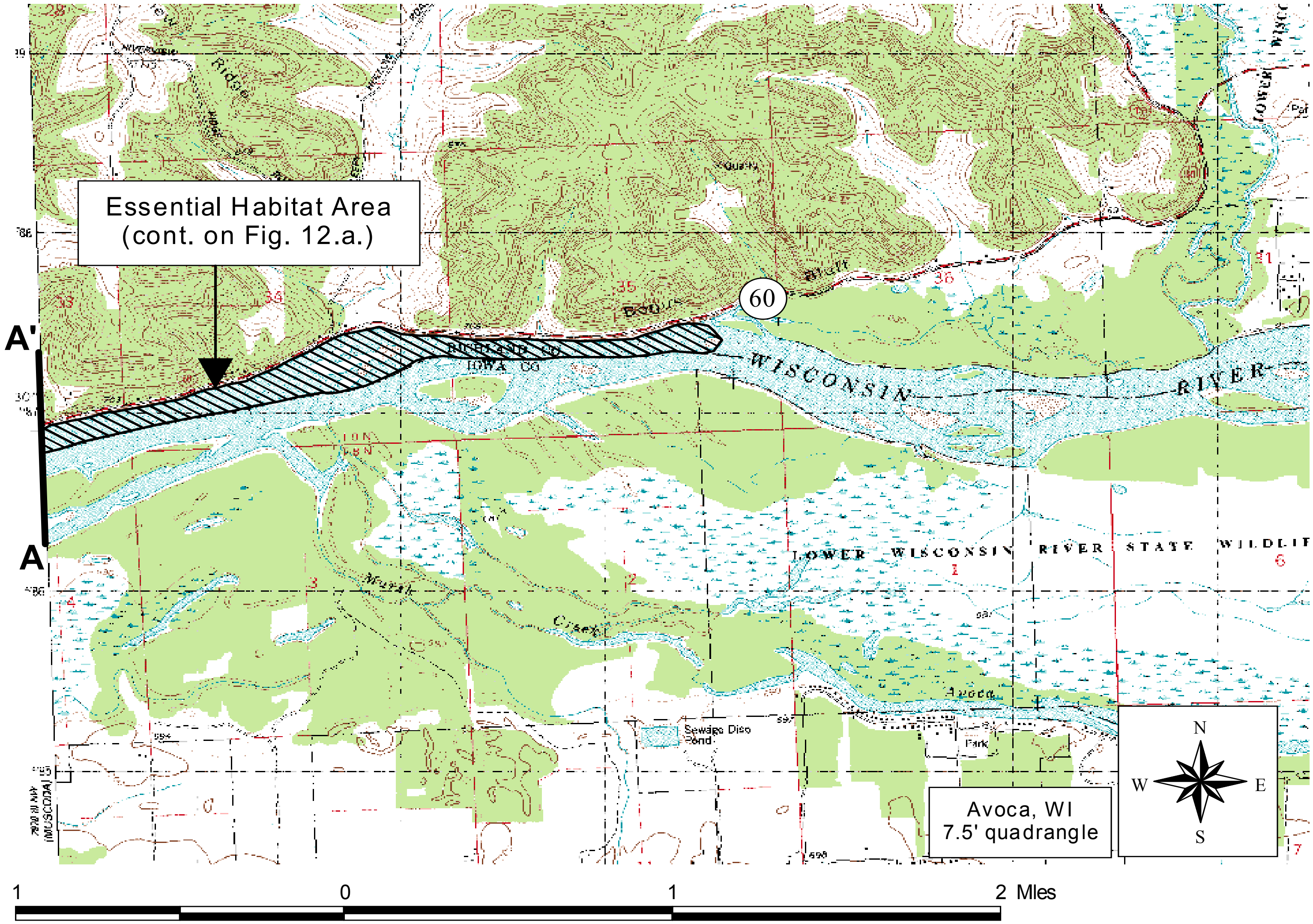

Figure 12.b. Essential Habitat Area at Orion, Wisconsin River, Richland and Iowa Counties, Wisconsin. Match line A-A' Figure 12.a.

VI. APPENDICES

Appendix A. Peer Review and Peer Contributors

The U.S. Fish and Wildlife Service extends special thanks to various experts, in addition to the experts on the recovery team, who reviewed drafts and/or provided their information or expert recommendations for the draft Higgins Eye Pearlymussel Revised Recovery Plan. This peer input was invaluable in bringing current biological information on the species and ecosystem management concepts to the current draft of the plan.

The following expert peers provided review and/or scientific information to the Service. Dr. Neves provided peer review for the 1998 and 2003 drafts.

Dr. G. Thomas Watters
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Virginia Polytechnic Institute and State University
Blacksburg, Virginia

Dr. Anne Keller
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Appendix B. Higgins Eye Pearlymussel 1998 Technical/Agency Draft Revised Recovery Plan Review

The Service published a notice of availability of a technical/agency draft revised plan on June 22, 1998 (63 FR 33944) and transmitted the document for public review and comment shortly thereafter. The Service and individual members of the Higgins Eye Recovery Team received substantial formal and informal comments addressing a variety of format, content, and organizational points of the technical/agency draft. The team carefully considered all comments received. As a result of the technical/agency draft plan comment period, the recovery team was able to substantially improve the revised plan by incorporating the latest available biological information on the species and the measurement of its recovery, and by improving the flexibility and practicality of the plan's tasks and recovery criteria.

The following individuals/agencies provided comments on the 1998 technical/agency draft revised plan:

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Comments and individual responses are maintained in the administrative record at the U.S. Fish and Wildlife Service, 4101 E. 80th Street, Bloomington, Minnesota 55425-1665.

Appendix C. Summary of Threats and Recommended Recovery Actions.

Listing Factor	Threat	Recovery Criteria	Tasks and Task Numbers
A	Habitat Alteration	Final Goal - 1a, 1c, 3, 4	Develop uniform protocols for collecting and maintaining information on *L. higginsii* populations. Confirm and modify the list of Essential Habitat Areas in the initial recovery plan. Limit construction in areas of essential *L. higginsii* habitat. Mitigation, including translocation, may be an acceptable alternative in limited instances. Develop plans to enhance the safety of shipping toxic or hazardous materials, reduce the introduction of these materials near *L. higginsii* habitat, and develop response plans for any spills that may occur. (see Tasks 1.3, 1.3.1, 1.3.2, 1.3.2.1, 1.3.2.2, 1.3.2.3, 1.3.3, 1.3.4, 1.3.5, 1.3.6, 1.4.1, 1.4.2, 1.4.3, 1.6.1, 1.6.2, 1.6.2.1, 1.6.2.2, 1.6.2.3)
A	Water Quality	Intermediate Goal - 2 Final Goal - 1b, 6	Continue to examine the relationship between water quality, especially contaminants, and *L. higginsii* populations in Essential Habitat Areas. (See Tasks 1.2.4, 1.5.1, 1.5.1.1, 1.5.1.2, 1.5.1.3, 1.5.1.4, 1.5.1.5, 1.5.1.4, 1.5.1.5, 1.5.1.6, 1.5.1.7, 1.5.2, 1.5.2.1, 1.5.2.2, 1.5.3, 1.5.3.1)
B and D	Commercial Harvest	Intermediate Goal - 3 Final Goal - 5	Review current regulations and develop additional regulation of mussel harvest in the upper Mississippi River drainage to reduce impacts on *L. higginsii*. Continue to develop materials to educate the public on the nature of endangered mussels and *L. higginsii*, in particular. (see Tasks 1.7.1, 1.7.2, 1.7.3 1.8.1)
E	Zebra mussels	Intermediate Goal - 1 Final Goal - 2	Assess and limit the impact of the zebra mussel, *Dreissena polymorpha*, on *L. higginsii*. Determine the feasibility of reestablishing *L. higginsii* into historic habitats, particularly streams that are at lower risk for zebra mussel colonization. (see Tasks 1.1, 1.1.1, 1.1.2, 1.1.3, 2.3, and 2.3.1)

Listing Factors:
A. The Present or Threatened Destruction, Modification, or Curtailment Of Its Habitat or Range
B. Overutilization for Commercial, Recreational, Scientific, Educational Purposes
C. Disease or Predation (not a factor)
D. The Inadequacy of Existing Regulatory Mechanisms
E. Other Natural or Manmade Factors Affecting Its Continued Existence

Appendix D. Public Comments on the 2003 Higgins Eye Pearlymussel Draft Recovery Plan: First Revision.

The Service published a notice of availability of a second draft revised plan on August 15, 2003 (68 FR 48933) and transmitted the document for public review and comment shortly thereafter. The Service received substantial formal and informal comments addressing a variety of points of the second draft. The Service carefully considered all comments received. As a result of the comment period on the second draft plan, the Service was able to further improve the revised plan.

Following is the list of individuals and agencies that submitted comments on the second draft of the Higgins' Eye Pearlymussel Draft Recovery Plan: First Revision. All comments have been reviewed and incorporated, as appropriate, into this recovery plan. Comments are on file in the Service's Twin Cities Ecological Services Field Office, Bloomington, Minnesota. Review and responses to comments received from the peer reviewer are included below.

LIST OF REVIEWERS

Peer Reviewer

Dr. Richard Neves
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Virginia Polytechnic Institute & State University
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Comment: EPA and other state and federal agencies are called upon to take specific actions under the Plan, specifically in the conservation section. We agree that this is appropriate, but are unsure if the Recovery Plan is "binding" or how it would affect budgets, etc. Also, we were wondering how recovery tasks in this plan and the GLI BO (Great Lakes Initiative Biological Opinion) could be coordinated between funding agencies and work plans. It seems like this plan could benefit from close coordination with other activities, but this was not mentioned.

Response: The identification of specific agencies or states as Responsible Parties for actions in the recovery plan and the assignment of cost estimates for the related tasks does not constitute a mandate for action by those parties. All federal agencies, however, are required by section 7(a)(1) of the Endangered Species Act to utilize their authorities in furtherance of the purposes of the Act. Federal agencies and other parties willing to participate may benefit by being able to show in their own budgets that their funding request is for a recovery action identified in an approved recovery plan. When implementing the plan, the Service will work to determine how recovery tasks in this plan might benefit through coordination with the Great Lakes Initiative (GLI) and other activities.

Comment: In regards to Task 1.5, the development of a toxicity database could be coordinated with EPA databases like Ecotox or the GLI Clearinghouse. Other efforts such as development of toxicological testing methods and determining which life stage is most sensitive should also be coordinated with EPA to ensure that the methods will be suitable for use by EPA.

Response: The Service will work to see how development of a toxicity database mentioned in Task 1.5 could be coordinated with EPA databases, such as Ecotox, or the GLI clearinghouse. The Service will also plan to coordinate with EPA when implementing this task and its associated sub-tasks. EPA is identified as a Responsible Party for each of the sub-tasks.

Comment: I feel the major obstacle to determining if water quality is affecting Higgins' eye is the lack of toxicity information for mussels in general. The plan does point this out, but it does not clearly point out that the best way to protect mussels from ammonia/metal (at least within the current framework of the Clean Water Act and EPA regulations) is to develop and implement protective water quality criteria. The real limitation, currently, is the fact that sediment and pore water quality do not have associated criteria. In the future, the effectiveness of the criteria may be bolstered through collection of additional information which could lead to the development of a "translator" from water column to sediment concentrations which would prevent toxic buildup of contaminants in the sediments.

Response: We added a new sub-task (1.5.2.2) that states: "Develop and implement water quality criteria that would conserve Higgins' eye; these criteria should be directly or indirectly protective of sediment and pore water quality, as necessary to conserve Higgins' eye. We assumed that this task would rely on the review and analysis of data collected and analyzed under the prior task (1.5.2.1) and would cost approximately $10,000 over three years to accomplish.

Comment: EPA provided information to FWS associated with the GLI BO that shows that juveniles and glochidia are similarly sensitive overall. Thus, the statement on page 12 may not be completely accurate.

Response: We reviewed the available literature on ammonia and other contaminants that may affect *L. higginsii*, updated the information on these topics in the plan, and reviewed this text to ensure that the information accurately reflected the current literature.

Comment: The ambient water quality and sediment quality information could be more effectively utilized in the analysis, but this would require reporting the pH, temperature, and hardness associated with the data. This would allow a more robust comparison between in situ water quality and water quality criteria. For example, if pH, temperature, and hardness were reported, the ambient levels could be compared to applicable criteria values. This would strengthen any conclusions about the possible impacts of water quality on Higgins' eye survival. Also, the plan compares instream ammonia to the 1985 criteria. However, the plan was updated in 1998 and 1999, so these values should be added or the applicable state standards should be compared. Also, the ammonia mussel toxicity levels cited in the plan may be inconsistent with the numbers reported in our database, so this is a point to follow up.

Response: We added the following statement to the narrative description of tasks 1.5.1.4 and 1.5.2.1 to address the first part of this comment: "Report pH, temperature, and hardness associated with data collected in *L. higginsii* Essential Habitat Areas to allow for a robust comparison to existing or proposed water quality criteria." We also provided an updated (1999) EPA acute ammonia criterion and updated information on the effects of ammonia on mussels, most of which was taken from a recent published review of this topic.

Comment: It also may be worthwhile to compare instream ammonia concentrations with host fish toxicity data. An initial analysis indicated that host sensitivity is within a factor of 5 from the current 1999 criteria.

Response: EPA provided data on acute toxicity values of ammonia to species that have been identified and marginal or suitable hosts for *L. higginsii* and we summarized these data in the plan.

Comments (two similar comments):

(1) Essential Habitat Areas. This section references nine locations as potential secondary habitats but does not mention the location of those sites either in text or in Table 6 in Section IV. Those locations need to be included. What is the value placed on secondary habitats, and how do those habitats play into meeting the outlined tasks and subsequent measurement criteria for Goal 1?

(2) Nine potential "secondary habitats" are actually listed in Table 2, page 76, not Table 6, in Section IV. Those locations need to be described, and the basis for their inclusion cited in the text, including which six were sampled, when and how (p. 5). Furthermore, "secondary habitats" merit definition, including the qualifying criteria for future consideration of these, or other areas upon further study. And, is the site actually nearer RM 444 or 446, Bogus or Barkis Island?

Response: All references to "secondary habitats" in the draft revised plan summarize the use of this term in the original (1983) plan. The term "secondary habitats" has no specific function in the current recovery plan, which relies on the term *Essential Habitat Area* only. The plan outlines criteria that allow for the evaluation and addition of new Essential Habitat Areas. Federal agencies should attempt to conserve any areas that possess features that may justify their addition to the list of Essential Habitat Areas for *L. higginsii*. Areas that the original recovery plan identified as "secondary habitat areas" for *L. higginsii* are likely to be among those that the Service and other agencies will continue to assess against the current plan's criteria for Essential Habitat Areas.

Comments (two similar comments):

(1) Essential Habitat Areas. The Recovery plan is very clear about designation requirements for essential habitat areas. The Corps of Engineers relocation plan for *L. higginsii* will likely include at least two sites that are not essential habitat areas. If relocations were successful in these areas, based on the existing recovery plan, these populations would not count towards the recovery Goal #1. The discrepancies between these two plans needs to be addressed.

(2) The draft Recovery Plan offers very detailed criteria for essential habitats. If the Corps of Engineers Mussel Coordination Team relocation plans for *L. higginsii* include sites that are not essential habitat areas, would these populations count towards recovery Goal #1? Any discrepancies between these plans merit reconciliation.

Response: The Service may designate additional areas as an Essential Habitat Areas for *L. higginsii* using the guidelines contained in the plan. Therefore, successful relocation of *L. higginsii* into an area that meets the Essential Habitat Area guidelines could contribute to reaching the plan's recovery goals.

Comments (two similar comments):

(1) Non-human predators. This section needs to include discussion on the potential impacts on the *L. higginsii*, and other freshwater unionids, from the introduction of black carp (*Mylopharyngodon piceus*). The species has already been collected in a Mississippi River backwater lake in Illinois.

(2) Under Recovery Goal 1- 5 and Pg. 34- Goal 2-1. We request that the sentence in each of these paragraphs be changed from "… not threatened by zebra mussels" to "…not threatened by invasive aquatic species such as the zebra mussel." The round goby and black carp have both been identified as mollusk eaters. We also believe that a section should be added to the plan that identifies known potential threats to Higgins' eye such as the black carp and round goby, species now known to inhabit the Mississippi drainage. We believe tasks should be identified in the plan to assess and address impacts from these potential threats.

Response: We agree that each of these may threaten Higgins eye and have added relevant information about each species to the Threats section of this plan. We have also modified some aspects of the plan (e.g., recovery criteria) to reflect the threat posed by invasive species in addition to zebra mussels.

Comment: Zebra Mussel Survivability. The Comprehensive Conservation Plan (CCP) for the Mark Twain National Wildlife Refuge cites a study by Tucker *et al.* 1997, which concludes that a 24 hour exposure during the summer caused high mortality in zebra mussels while having minimal impact on native mussels. This study would seem to contradict the statement in the subject paragraph concerning survival of zebra mussels for days out of water.

Response: It is clear from this study (Tucker *et al.* 1997) that zebra mussels exposed to air and substrate temperatures of 25.6-35.6° and relative humidity of 40-52% for 24 hours are very likely to die unless they are relatively protected (e.g., on the underside of native mussels). Zebra mussels are presumably transported between water bodies attached to aquatic vegetation picked up by boats or boat trailers. Zebra mussels attached to aquatic vegetation on boats or trailers would likely be exposed to more moderate temperatures and higher relative humidity than in this study, thus prolonging the number of hours or days they may survive outside of water. This comment addressed the following sentence in the draft, which is part of the discussion of overland transport of zebra mussels between water bodies: "Zebra mussels attach to nearly anything submerged and can survive for days out of water." We changed the sentence as follows (emphasis added): "Zebra mussels attach to nearly anything submerged and can survive for days out of water, depending on the temperatures and relative humidity to which they are exposed."

Comment: Development of Uniform Regulations Concerning Clam Harvesting Methods. This entire section is outdated, referencing that new rules will not be in place till 1998, which was five years ago. The existing status of state mussel regulations needs to be addressed.

Response: We worked with the states to update this information.

Comment: Recovery Goals and Interim Recovery Criteria. Goal 1 (1.c.) Zebra mussel numbers vary greatly by year. We are now seeing larger numbers of small zebra mussels, after seeing a large die off of adult zebra mussels. The criteria for this measure is that zebra mussel densities have not increased over 5 years. This criteria needs refinement. A similar number of small juvenile zebra numbers and large adult zebra mussels (i.e. the same density) would have substantially different impacts on native mussels.

Response: We refined this criterion in a way that should address this concern.

Comment: (three similar comments)

(1) Recovery Goals and Interim Recovery Criteria. It appears that the stated conditions for recovery may well be unobtainable. With the major infestation of Lake Pepin, it is reasonable to expect significant periodic re-infestations of the Essential Habitat Areas, perhaps several times, within the twenty year requirement for *L. higginsii* population establishment. Therefore, in the absence of highly significant sustainable reduction or complete eradication of all populations of zebra mussels upstream of the essential habitat areas, recovery cannot, by definition, take place. I suggest that the recovery team take a closer look at the recovery goals and objectives and not define recovery based solely on the Essential Habitat Areas concept.

(2) The criteria for Reclassification and Delisting are not realistic because the Prairie du Chien Essential Habitat Area must be one of the 5 Essential Habitat Areas. Prairie du Chien is severely

infested with zebra mussels, and *L. higginsii* is experiencing severe impacts at this location. So, short of a miraculous disappearance of zebra mussel from this location, how can the *L. higginsii* population at this site ever achieve a "reproducing, self-sustaining population not threatened by zebra mussels"?

(3) The volatile and unknown nature of zebra mussels should be discussed.

Response: Recovery of *L. higginsii* will depend on populations of the species in five Essential Habitat Areas, including the Prairie du Chien Essential Habitat Area and at least one Essential Habitat Area each in the St. Croix River and in Mississippi River Pool 14. This does make recovery dependent on at least one specific (Prairie du Chien) and two general (St. Croix River and Pool 14) areas, whereas the other two Essential Habitat Areas may occur anywhere within the range of the species. Given the historical significance of the Prairie du Chien Essential Habitat Area to *L. higginsii*, the recency of its demise, and some uncertainty regarding the future distribution and abundance of zebra mussels in the range of the species, we will maintain the focus on this particular area in the recovery plan. Moreover, the Service and the recovery team think that it is important that recovery depend on the conservation of *L. higginsii* populations that occur in relatively disparate portions of the species' range. Therefore, we will retain the dependence on recovery of at least one population in the St. Croix River and Pool 14 of the Upper Mississippi River. We have found Essential Habitat Areas to be a useful concept for assessing the recovery status of a species that is largely sedentary as an adult and whose populations are relatively discrete. Recovery cannot be obtained for any species under the Endangered Species Act until the factors that threaten or endanger it are resolved. Zebra mussels are clearly a major threat to *L. higginsii*. Therefore, the species will not be recovered until the they are no longer a pressing threat to the species in a significant portion of its range.

Comment: I think the habitat section in the original plan should be changed to reflect what we have noted in recent years. Specifically we have been consistently finding *L. higginsii* in the littoral areas of river channels. That is, in areas 2-4 feet deep that are colonized by rooted submersed aquatic plants. At both Cordova, IL and at Cassville, WI we have collected more animals from this habitat than in the gravel/sand channel areas of deeper flowing water. As currently written, the recovery plan describes the required habitat as this deeper channel condition and specifically excludes the vegetated shoreline areas.

Response: We modified the plan to recognize this recent discovery of the potential importance of these types of habitats to *L. higginsii*. We removed wording that specifically described habitats with rooted plants as being unsuitable for *L. higginsii* and summarized this recent information.

Comment: According to Turgeon *et al.* (1998) the name should be Higgins (no apostrophe) -- or, alternately, the use of Higgins' should be discussed and explained.

Response: The commenter is correct – Turgeon *et al.* (1998) uses Higgins eye without the apostrophe. We have modified the plan accordingly.

Comments: (three similar comments)

(1) The East Channel (at Prairie du Chien) should not be closed to commercial clamming and yet continue to allow up to 1000 barges/year in that Essential Habitat Area. I am not aware of any evidence that commercial clamming by divers is harmful to this endangered mussel. The shortage of funds and personnel gets worse yearly, so it remains very difficult to know what is going on with Upper Mississippi River mussels if hardly anyone is looking at the river, zebra mussel impacts etc. Clammers could help biologists. Commercial clamming should be regulated some other way, such as limiting the number of licenses in each state, so that a Clammers can be assured of a living wage. However, if the low demand for mussel shells for export continues, then this issue becomes a moot point.

(2) Is the decision to preclude mussel harvest based on scientific data or a political decision? We have not seen evidence of endangered species decline resulting from harvest of commercial species in the Tennessee River. Is there evidence of cause-effect at a population level?

(3) Under Commercial Harvest- last paragraph. It states that little is known regarding the direct impacts of commercial harvest on *L. higginsii*. However, in the Recovery Section under Goals 1 and 2 (pages 34 and 36 respectively), downlisting and delisting requires that commercial harvest MUST be prohibited by law or regulation. Again, a threat should be identified before it is dealt with. Recovery Task 1.7 (pg. 41) says nothing about determining whether harvest is causing an impact. It simply goes directly to closure within all identified Essential Habitat Areas. The states that currently allow commercial harvest that will be affected by this recovery plan will likely need data to demonstrate a negative impact of harvest on *L. higginsii* before closure can occur. Therefore, this sub-task should be added under this section and in the Task Table (as a new 1.7.1) on pg. 41. Existing Task 1.7.1 should change to 1.7.2 and be modified to read, "If warranted, develop regulations to prevent mussel harvest in all Essential Habitat Areas." We also believe that the requirements for closure under the Recovery Goals (pg. 34 & 36) should be modified to require closure if harvest is demonstrated to cause an impact on *L. higginsii*.

Response: Although there may be little or no available data to support the contention that commercial clamming is specifically harmful to *L. higginsii* populations, it is reasonable to conclude that clamming would threaten the species if it is allowed in Essential Habitat Areas. Hart (1999), for example, found that commercial harvest depressed threeridge (*Amblema plicata*) populations in Lake Pepin in the early 1990s. He found that if harvest exceeded “5% of the population or if *D. polymorpha* infestations continue at the current rate” threeridge populations were in danger of local extinctions. Threeridge is one of four species that Heath (1995) found to be very common at all known *L. higginsii* sites. Although it is morphologically distinct from *L. higginsii*, it is reasonable to assume that clammers in pursuit of *A. plicata* would inadvertently collect or harm *L. higginsii*. In addition, some commercially harvested mussels (e.g., pocketbook, hickory nut) are similar in appearance to *L. higginsii*.

The Service will monitor the status of populations and threats to their continued existence at and outside of Essential Habitat Areas. Barging or other activities cannot take *L. higginsii* without proper authorization from the Service and the Service may not authorize such take if it would appreciably reduce the likelihood of survival and recovery of the species.

Comment: There are no D. Helms references listed in the casino discussion on page 24 (of the draft); he has done many studies at this site.

Response: The draft plan contained only one reference to floating casinos -- i.e., as an example of large vessels that may crush *L. higginsii*. Floating casinos could pose a risk to *L. higginsii* in certain areas, but we do not think that the recovery plan needs further information regarding the specific effects of casinos.

Comment: Leave the '?' indicated for the Ohio River; it is just that – a questionable location for the specimen.

Response: We inserted the '?' for the Ohio River record to indicate that this represents a questionable location for *L. higginsii*.

Comment: If a self-sustaining population in Pool 14 is a minimum requirement for recovery, then some plan should be developed about the use of the Cordova bed. Collection for relocation and other purposes is relatively easy at this bed and it may get over-exploited.

Response: In July 2001, biologists found that *L. higginsii* at the Cordova site were subject to high fouling densities of zebra mussels and decided that as many as possible should be cleaned and moved to a location where they would not be refouled. As a result, they cleaned and moved 271 *L. higginsii* to two locations in the Mississippi River in and near St. Paul/Minneapolis, MN. In 2002, biologists returned to Cordova to determine if further relocation would be warranted. At that time, biologists found more than 371 *L. higginsii* and removed attached zebra mussels, but did not remove any *L. higginsii* from the Cordova area. In 2003, several females were temporarily removed from the Cordova bed, used to infest fish at Genoa National Fish Hatchery for reintroduction of glochidia-infested fish, and returned to the Cordova bed. The Service will continue to review proposed relocation and propagation activities on a case-by-case basis to ensure that these activities do not harm the population in Pool 14.

Comment: Why are the Essential Habitat Areas not designated as critical habitat?

Response: In the June 14, 1976 final rule to list *L. higginsii* as endangered, the Service stated, "(N)o critical habitat is presently being determined for United States species. That action, if and when it occurs, will be a separate rulemaking." The Wisconsin Department of Natural Resources petitioned the Service on October 6, 1980 to designate critical habitat for *L. higginsii*. Although the Service found that the petition contained substantial information to indicate that designation of critical habitat may be warranted, it has not formally addressed critical habitat for *L. higginsii*. Under current regulations, when the Service lists species under the Act it must determine whether designation of critical habitat is prudent and, if so, whether it is feasible to determine what is critical habitat for the species. Although *L. higginsii* is already listed as an endangered species, the Service could propose a separate rule in the Federal Register to designate critical habitat for *L.*

higginsii. The number of critical habitat designations that the Service may propose and finalize in any year, however, is limited by available funding. In recent years, court-ordered critical habitat designations or court-approved settlement agreements have used all available critical habitat designation funds, thereby precluding the ability of the Service to designate critical habitat according to its own conservation priorities. If a proposal for critical habitat is prepared in the future, it would be based on the habitat features essential to the conservation of the species, similar to those used to identify essential habitat areas in the recovery plan.

Comment: The statement regarding the transplanting of adults assumes it is a beneficial action rather than an experimental strategy. It also is not consistent with recovery of parent sites as "essential habitat".

Response: In general, the plan simply states the facts with regard to translocation of adult *L. higginsii*. The inclusion of this practice under Conservation Measures may imply that the Service views this is a beneficial action. The Service has approved the translocation of adults from two locations in the Mississippi River to avoid catastrophic mortality as a result of fouling by zebra mussels – at Cassville, WI (September 2000) and Cordova, IL (July 2001). This practice could be viewed as both beneficial and experimental. The benefits of these two actions likely include reduced harm or mortality of relocated *L. higginsii* caused by fouling by zebra mussels and the reintroduction of the species into two locations within its historical range (one site each in Pools 2 and 3 of the Mississippi River). The former assumes that the survival of the cleaned *L. higginsii* would have been lower if left in the source locations (Cassville and Cordova) and the latter depends on the successful establishment of *L. higginsii* populations at the reintroduction sites. Biologists evaluated the evidence at each site before relocating the mussels and decided that their survival was likely to be higher if relocated to areas with few or no zebra mussels. Evidence of survival and reproduction at the relocation site, which is presented in the plan, suggests that the relocated mussels have not experienced unusual mortality or adverse sub-lethal effects as a result of being relocated. Continued monitoring for several years will be necessary to determine whether this relocation will result in established populations of *L. higginsii* at the relocation sites. There are also risks of adult relocation. It is possible that survival of the relocated *L. higginsii* would have been equaled or exceeded if they had been left in place after they were cleaned of attached zebra mussels. This may have occurred if zebra mussel densities had declined to non-threatening densities shortly after relocation or if teams of biologists returned frequently enough to effectively remove attached zebra mussels. When we consider relocating adults, we will assess the current and expected conditions at the threatened sites, resources for repeated cleanings, etc., and the likely benefits of relocation to determine the appropriate course of action. This was done in each case thus far and the Service will ensure that no relocations occur that would not help to conserve the species. This will be considered at all sites whether or not they are designated as Essential Habitat Areas by the Service.

Comment: (two similar comments)

(1) The following should be changed from a recovery criterion to a recovery task: "The use of double hull barges is required at and upstream of each of the identified Essential Habitat Areas that may otherwise be threatened by spills from commercial barges."

(2) Executive Summary, item D, bottom, page ix and Narrative outline, item 1.6.1, Page 41. There is a significant difference between the phrases "Require the use of...." vs "Promote the use of...." A phase-in period is needed for any double-hulled barge requirement, and then may need to be phased in by the relative toxicity of the bulk commodity in transit.

Response: We modified this recovery criterion to the following: "The use of double hull barges or other actions have alleviated the threat of spills to each of the identified Essential Habitat Areas." If means other than double hull barges alleviate the threat of spills to the identified Essential Habitat Areas, then this criterion will be met. Therefore, the criterion focuses on the alleviation of the threat of spills and allows for some flexibility in addressing the threat.

Comment: As with commercial harvest, restrictions on the collection of *L. higginsii* at Essential Habitat Areas for propagation or relocation of the species should be in place as a criterion for reclassification and delisting.

Response: This type of collection is done to conserve the species. Moreover, females collected for propagation are returned to the area from which they were removed, usually within a few weeks of collection. The Service does not think that this type of activity is a threat to the continued existence of ths species. Therefore, it would be inappropriate to address it with a recovery criterion.

Comment: Do not offer translocation of *L. higginsii* as acceptable mitigation for adverse effects caused by construction in Essential Habitat Areas.

Response: The plan states that "(M)itigation, including translocation, may be an acceptable alternative in limited instances." The Service will review such proposals on a case-by-case basis and shall not allow any action to proceed that would appreciably reduce the likelihood of the survival and recovery of *L. higginsii*.

Comment: The revised Plan needs to acknowledge *L. higginsii* population changes since the initial 1983 Recovery Plan. Weren't some of the goals of that plan accomplished? If so, revised recovery goals should recognize whatever progress has been made relative to the revised evaluation period.

Response: The recovery goals and criteria in the revised recovery plan are based on the current species' status and the current environmental baseline within its historic range. Therefore, it incorporates changes that have occurred since the original recovery plan.

Comment: The recovery strategy proposes the removal of *L. higginsii* from areas where zebra mussels pose an imminent risk, but I don't see comparable narrative for the three Essential Habitat

Areas where zebra mussels have had severe impacts. Of the ten Essential Habitat Areas, three are experiencing severe impacts and two are under imminent threat. I don't understand why removal is proposed for the latter but not the former.

Response: The plan states that the alleviation of impacts to "infested populations" ... "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." "Infested populations" refers to populations that zebra mussels have already severely affected (e.g., populations in the three Essential Habitat Areas where zebra mussels have had severe impacts). Under recovery task 1.1.3, the Service plans to "Develop and implement an emergency response plan in the event of a demonstrable impact of zebra mussels on *L. higginsii* in Essential Habitat Areas." The Service has the discretion, in cooperation with any affected states, to also remove *L. higginsii* from locations where severe effects are imminent and cannot be prevented. This was the case in the three adult relocations that the Service and the states carried out in 2000 and 2001. No adult relocations have occurred since 2001.

Comment: The lack of quantifiable criteria makes Goal 1a subjective. For example (5a), "a sufficient number of strong juvenile year classes" is complete avoidance of the need to make a decision based on best available science at this time. The reality is that this criterion will never be fully measurable (p. 34), so delaying the decisions on what constitutes 'strong year class' or 'number of year classes' for adequate reproduction is not a substitute for current uncertainty to provide an answer. Other recovery plans have made such decisions based on best available data and expert opinion and the recovery team for *L. higginsii* should do the same. Those decisions can be revised in subsequent years, should new data become available to better quantify this criterion.

Response: The Service and the Recovery Team decided that the best available information at this time would not sufficiently reduce the uncertainty associated with selecting measurable criteria for each goal. Therefore, we decided to complete this plan revision and develop measurable criteria as part of its implementation.

Comment: In 1b (p. 33), how was the 20 years decided? Does the Recovery Team really believe that they can measure e.g. a 10% increase or decrease in the population at any site, short of a huge and unrealistic sampling effort to reduce confidence intervals?

Response: *L. higginsii* typically comprises a small portion of mussel communities in which it occurs. Therefore, as this commenter pointed out, the detection of population trends with acceptable power and precision would require a sampling efforts that may not be feasible. Therefore, we have modified the recovery criteria to ensure that the sampling required to assess the status of *L. higginsii* populations would be feasible.

Comment: In 5c (p. 33-34), I disagree that a five year status quo population of zebra mussels constitutes a 'no threat' to the resident *L. higginsii*. Zebra mussels at constant moderate densities likely pose a chronic threat to resident unionids because of physiological stress, food competition, space limitations, etc., such that the persistence of *L. higginsii* at that site is at some low level of jeopardy and negatively affected. What evidence exists that a constant, moderate density of zebra mussels poses no threat to *L. higginsii* at a site? I have yet to see such data for any unionid species.

Response: We agree that this criterion in isolation would not be sufficient to determine that zebra mussels pose no threat to a population of *L. higginsii* and have removed the words “not threatened by zebra mussels” from the criterion. When the Service determines whether *L. higginsii* may be reclassified or delisted, it will evaluate the status of the species against all criteria (three for reclassification and six for delisting). For example, the species’ populations must be stable or increasing for at least twenty years for the Service to consider them for reclassification or delisting. We do not think that *L. higginsii* populations and associated mussel communities under chronic stress are likely to have stable or growing populations over a twenty year period. Moreover, the zebra mussel criterion includes a fallback measure to ensure that populations that are not currently stressed by zebra mussels are not likely to become infested in the foreseeable future. The change in wording should avoid the perception that one portion of the criteria would be used to evaluate the potential zebra mussel threat for any population.

Comment: There are too many subjective narrations under this goal, such that delisting will never be achieved. Phrases such as, "reasonably likely to occur in the foreseeable future" and "appreciably reduce the likelihood of", are unquantifiable now and likely twenty years from now. The best scientific data now will not be much different from the best scientific data twenty years from now, because the cost of data collection will only escalate to infeasible levels, even more so than today. The Recovery Team seems to be unwilling to make biological decisions based on best available data on *L. higginsii* and data on other endangered mussel species. Unless those decisions are made, no matter what the level of uncertainty, the section on Recovery is one of procrastination, with a false expectation that answers will be forthcoming in the future. None have appeared in the last ten years, nor will they in the next ten years.

Response: The phrases, “reasonably likely to occur in the foreseeable future" and "appreciably reduce the likelihood of”, were used in the delisting criteria reference to potential human actions that would cause significant adverse impacts to L. *higginsii* habitat in Essential Habitat Areas. There will always be some uncertainty when assessing the likelihood of future human impacts to these habitats. Nevertheless, we have modified these criteria to reduce subjectivity and ambiguity in their interpretation.

Comment: I have no problem with the concept of Essential Habitat Areas. The following statement (p. 5) supports my concern expressed earlier: "Moreover, it is unclear how long zebra mussels will continue to suppress native mussel communities at these sites." This seems to contradict the requirement of stable population density of zebra mussels for 5 years to achieve a 'no threat' status.

Response: It is unclear whether zebra mussels will return to the high densities that devastated populations of native unionids in some *L. higginsii* beds (e.g., at Prairie du Chien). Moreover, we are unconvinced that these beds do not retain the ability to recover from zebra mussels. Given the historical importance of the beds at Harpers Slough and Prairie du Chien and uncertainty about the future nature of zebra mussel impacts there, we will keep them as Essential Habitat Areas for now and have retained the importance of Prairie du Chien in this plan's recovery criteria.

Comment: Several of these sections are outdated, with no recent citations in the last five years. For example, Tom Augspurger has an excellent paper on un-ionized ammonia that summarizes recent data on unionids. There are several recent papers on Cu, Cl, and other contaminants that are not cited. It doesn't appear that the contaminants section was updated in the last 7 years.

Response: We have reviewed the recent literature on the effects of ammonia and other contaminants to freshwater unionids and have updated the recovery plan with the relevant information.

Comment: The statement is made (p. 4) that two sites in Pools 2 and 3 have zebra mussel densities below threatening levels. What is that threshold level and how was it determined?

Response: Malacologists inspected the current unionid communities and zebra mussel densities in the two reintroduction sites and also evaluated the available information on zebra mussels upstream of these sites. Zebra mussels were sparse in each reintroduction area, unionid communities were relatively diverse, and there were no upstream concentrations of zebra mussels likely to produce significant numbers of veligers that would drift and settle into the reintroduction sites. No threshold level was evaluated, per se. Monitoring of these sites and of upstream areas thorough 2003 indicates that zebra mussels are still not a threat at these sites.

Comment: I am pleased to see the efforts being made to propagate this species. This section (p. 30) acknowledges that there are no data to evaluate the success of infested fish releases. This then brings up the question of how to objectively determine whether the populations at any of the 10 Essential Habitat Areas are stable or increasing in abundance. Release of infested fish or propagated juveniles may be adding to the population at a site, while zebra mussels, water quality, sediment contaminants, etc. are subtracting from the population. How does the Recovery Team expect to decide whether the criteria under Reclassification or Delisting are achieved when releases of undetermined numbers and unknown success will affect the overall status of the species throughout its range? For example, the use of infested fish in cages in the St. Croix River should be adding juveniles of unknown number to the population in that river. So if that population increases to the yet undefined "self-sustaining" level, will that population be declared to be recovered? Will augmentation of that population stop, such that 'self-sustaining' status can be determined? There doesn't seem to be a clear rationale that incorporates the release of fish, juveniles, and relocations (Table 1, p. 74) with the subjective criteria under Recovery. Is there any strategy to augment some sites and not others to monitor measurable effects of these attempted augmentations on population size? Is the goal to simply release as many as possible, even if there is no way to determine how many and survival rate? I do not see a cohesive plan to mesh the induced propagation efforts and their evaluation with the vague criteria proposed for the two stages of recovery.

Response: The plan states that, "(T)here are no data to evaluate the success of the free-swimming fish releases."

At this time, reintroduction and relocation of *L. higginsii* is being done primarily by the Corps of Engineers as part of its action to operate and maintain the nine-foot navigation channel in the Upper Mississippi River. The Corps' is carrying out these *L. higginsii* conservation actions as part of their operations to avoid jeopardizing the continued existence of the species and has developed a plan to guide these activities (U.S. Army Corps of Engineers 2002). The Corps plans to establish new *L. higginsii* populations at ten sites within the species' historical range. Its plan does have measurable criteria to determine whether viable populations have become established; after determining that a new population has met these criteria, the Corps will monitor for an additional twenty years to ensure that the population continues to meet its viability criteria. The Corps has released artificially propagated *L. higginsii* at a few sites at which the species already exists to refine its propagation techniques. Such augmentation of existing populations is not the primary focus of these activities. Any propagation that the Service carries out in addition to the Corps' conservation program will likely also focus on establishing new populations within its historical range where the species has been extirpated or greatly reduced in numbers. Like the Corps', the Service would allow for a lag in time between the release of fish infested with *L. higginsii* and a final evaluation of the new population's viability.

Comment: On p. 74, it would be more useful to see the number of glochidia rather than the number of fish caged or free-ranging, as that is a better indicator of attempted population augmentation.

Response: Gordon (2002) estimated the number of juveniles that transformed per fish for three species used -- smallmouth bass, largemouth bass, and walleye. We included those estimates to give the reader a rough idea of the number of juvenile mussels that may be produced for each fish released.

Comment: I would recommend three items: 1. Determination of potential contamination of essential habitat from groundwater. 2. Identification of endocrine disrupters at essential habitat. 3. Identification of hydrologic parameters at essential habitat.

Response: Completion of task 1.5.1.6 should address potential adverse effects of contaminated groundwater to *L. higginsii*. Under 1.5.2.1, the plan calls for the collection of "sediment and pore water from areas identified as currently supporting viable *L. higginsii* populations" and to analyze that water "for a range of organic and inorganic contaminants." If warranted, endocrine disrupters would be included in this analysis. Hydrologic parameters may be assessed at Essential Habitat Areas in conjunction with the identification of contaminants at Essential Habitat Areas.

Comment: It was good to see the inclusion of significance levels and power for sampling of zebra mussels and *L. higginsii* that are found on pages vi and 35. There is only one issue unresolved with this -- to construct a sampling regime, the magnitude of the trend must be specified. For the *L. higginsii* sampling the Service can figure this out when it defines "self-sustaining populations." The plan also states, however, that for Essential Habitat Areas the Service will consider them not to be threatened by zebra mussels if densities have not increased for five consecutive years. So, it will be important to state what is meant by "have not increased." I would suggest that if zebra mussels have not increased by more than 5% per year for 5 consecutive years, then the Service should conclude that their populations "have not increased."

Response: When finalizing the plan, we considered this comment and also considered changing the 'zebra mussel criterion' to reflect a density, as opposed to a trend, that would indicate that zebra mussels were not a threat to *L. higginsii* at any of the identified Essential Habitat Areas. The best available information seems to indicate that native mussels, such as *L. higginsii*, may survive in the presence of zebra mussels at some (low) densities. The information from published and unpublished sources, however, falls well short of quantifying such 'safe' densities. Therefore, if we specified an absolute density that would be safe for *L. higginsii* we would run too great of a risk of the density being impractically and unrealistically low or unacceptably high. In addition, we did not think that it would be prudent to suggest that any increasing trend (e.g., 4%, see above) in zebra mussel densities would indicate that they were not a threat. Therefore, we decided to use a criterion that would allow for a site-specific assessment of the potential threat of zebra mussels to any of the identified Essential Habitat Areas (see Recovery Criteria) without specific numeric criteria.

Comment: A note should be added that the apparent increased density of Higgins' eye associated with wing dams might be the result of both substrate suitability for mussels and their host fishes. The host fishes may spend more time in these locations, potentially depositing higher densities of glochidia in these habitats.

Response: We inserted a sentence to point out that the distribution of mussels is likely influenced to some degree by the distribution of their host fish.

Comments (three similar comments):

(1) We believe that many of the tasks under 1.5 should be considered as separate projects and should not be included in the recovery plan unless there have been specific toxins associated with Higgins' eye mortality. A toxicity database would benefit all mussel species and should be expanded beyond the Upper Mississippi basin. Costs under 1.5 comprise more than 51% of the total three-year budget and could be better used to evaluate mussel populations, evaluate habitat – including other potential habitats for reintroduction -- and to mitigate current and pending threats (round goby for example) to Higgins' eye.

(2) Page 24. Under Water Quality- Sentence one of paragraph 1 is contradicted by sentence one of paragraph 2. If there is no documentation that water quality issues are adversely impacting *L. higginsii*, then how can the plan make the statement, "The lack of information or documentation is itself the most significant water-quality related threat." An impact must be demonstrated before its significance can be evaluated. It would read more clearly to state that, "While no water-quality related issues have been documented to impact *L. higginsii*, our lack of knowledge does not preclude water quality as a threat. Therefore, we need to determine whether any impacts can be demonstrated. Then continue with the second sentence in paragraph two of this section.

(3) We believe that many of the tasks under 1.5. should be considered as separate projects and should not be included in the recovery plan unless there have been specific toxins associated with Higgins' eye mortality. A toxicity database would benefit all mussel species and should be expanded beyond the Upper Mississippi basin. Costs under 1.5 comprise more than 51 % of the

total three-year budget and could be better used to evaluate mussel populations, evaluate habitat -- including other potential habitats for reintroduction and to mitigate current and pending threats (round goby for example) to Higgins' eye.

Response: The Service decided that the potential for contaminants to be a threat to *L. higginsii* is significant despite the lack of evidence that specific toxins have killed or harmed this species. Contaminants that may threaten *L. higginsii* are likely to also threaten other aquatic organisms, especially other mussels. Therefore, implementation of these tasks should occur in cooperation with other agencies and should not rely solely on the Service's endangered species recovery funds. Augspurger *et al.* (2003), for example, state that "A need exists to work toward standardizing the toxicity tests for early life stages of freshwater mussels." This is an example of a recovery need for *L. higginsii* that it shares with many mussel species.

Comment: What baseline population densities will be used to demonstrate stability and increasing densities at Essential Habitat Areas? Population levels in some essential habitats have been significantly reduced in recent years and stability at those low levels for 20 years should signal that something is still wrong there. Some level of population recovery, especially in essential habitat like the East Channel at Prairie du Chien, should be required before reclassifying the species to threatened or delisting it, unless most of the EHAs have experienced some "reasonable level" of population recovery. Recovery levels should be defined in this plan (perhaps defined by using recent-historical Higgins' eye densities for each EHA.) The level of recovery that is needed to consider downlisting or delisting should be identified.

Response: The baseline population density could be obtained at any point in time, depending on the sufficiency of the available data. In the scenario presented above, zebra mussels or some other factor has sharply reduced the density of a population of *L. higginsii* within an Essential Habitat Area – a scenario that resembles the current situations for the species in some areas on the Mississippi River (e.g., Prairie du Chien and Harpers Slough) – and monitoring has shown that the *L. higginsii* population has been stable for twenty years. For this population to contribute to the reclassification or delisting of the species, however, it must also have evidence of reproduction based on the presence of a "sufficient number of strong juvenile year classes" and meet the mussel density and diversity criteria for Essential Habitat Areas, persistence criterion, etc. Moreover, other threats (zebra mussels, adverse changes in habitat, water quality, etc.) must also be resolved to allow for such a population to contribute toward a reclassification or delisting decision. Therefore, we think that the criteria are sufficient to identify populations in Essential Habitat Areas that are viable and that should contribute to a reclassification or delisting decision.

Comment: Section on Historical and Present Distributions- para 2. It should be pointed out that the data presented are not based on comparable quantitative sampling since no standardized methods have been established for evaluating and monitoring freshwater mussel populations involving Higgins' eye.

Response: We inserted a sentence that indicates that the available data may not allow for robust quantitative comparisons among *L. higginsii* populations.

Comment: Habitat- Water and Sediment Quality Factors. At the end of paragraph 2, a sentence should be added that the decomposition of dead zebra mussels might also result in elevated ammonia levels. It should also be added somewhere in the larger Habitat section that the identified affects, such as water quality or flows, on habitats also may influence their suitability for Higgins' eye host fishes. Those affects should also be stated where known. Under Present Threats Section add a brief paragraph on the chemical and physical alterations that are caused by zebra mussels and their decomposition and remnant shells on host fishes. If nothing is known about this, the acquisition of this information should be identified in the Task Section of the plan as at least a Priority 2.

Response: We reviewed the literature relative to zebra mussels and ammonia and added some information about this issue (e.g., excretion of ammonia by zebra mussels). We also briefly reviewed the literature on the effects of zebra mussels to native fish populations in North America. This is an important area of study that we will continue to monitor relative to *L. higginsii*. We will not add the specific task recommended above, however, but will address effects of zebra mussels via host fishes under Task 1.1, "Assess and limit impact of the zebra mussel, *Dreissena polymorpha*, on *L. higginsii*." Part of this task includes Goal 3 of the "Zebra Mussel Emergency Response Plan": "Minimize loss of *L. higginsii* in areas already infested by zebra mussels, including restoration of habitat suitability (i.e., reducing or removing zebra mussels), where feasible."

Comment: Paragraph 3 under Recovery should include language about the Corps' potential to improve conditions to benefit unionids and potentially reduce zebra mussel threats. We recommend developing an additional Task section (2.5) to address this as a recovery option as follows:

> 2.5 Examine alternatives to operation and maintenance of the 9-foot channel project to affect zebra mussel and unionid populations.
>
> > 2.5.1 Examine flow alteration on veliger distribution.
> >
> > 2.5.2 Explore creation of new habitats by altering existing wing dams and/or construction of new wing dams.

Response: Under section 7(a)(2) of the Endangered Species Act, federal agencies, such as the Corps, must consult with the Service on any action that they fund, authorize, or carry out that may affect endangered or threatened species. These issues are the subject of consultations between the Service and the Corps and we have chosen to not address them in detail in the recovery plan. The recovery plan and its goals, objectives, and criteria, however, will inform and help to guide these consultations.

Comment: Development of uniform protocols under 1.2.1 should be moved up to a priority 1 task. Standardized protocols are essential for determining mussel densities and long term trends in the populations. Much of the historical freshwater mussel work was conducted using simple random searches by various methods that provide little more than presence of species captured at site locations. Development of standardized protocols will facilitate answering questions in tasks 1.2.2

and conducting tasks1.2.4, 1.3.3 and 1.3.4. Standardized protocols for mussels and habitat will allow for valid statistical comparisons across time scales and among sites.

Response: We agree that the development of uniform protocols is important to be able to evaluate the status of *L. higginsii*, but we do not agree that it rises to the level of a Priority 1 task. In the (August 2003) draft recovery plan 1.2.2 was a Priority 1 task, but it is a Priority 2 task in the final plan.

Comment: Task 1.2. Consider adding a sub-task (1.2.5) -- develop criteria to define a stable attendant mussel community within essential habitat areas.

Add a sub-task (1.2.6) -- develop indices for growth and mortality to help define population status accurately.

Response: Essential habitat areas used as a basis for reclassification and delisting decisions must include a total mussel density of >10/m2 (Upper Mississippi River) or > 2/m2 (other rivers) and contain at least 15 other mussel species, each at densities greater than 0.01 individual/m2. Although these criteria may not be sensitive to trends in mussel abundance and diversity in EHAs, populations of *L. higginsii* must be stable or increasing in an EHA to contribute to reclassification or delisting of the species. Because L. higginsii is relatively rare, it is difficult to quantify population trends. Therefore, evaluations of the trends of *L. higginsii* populations will rely in part on trends of sympatric species' populations.

Comment: Under Tasks 2.2- We believe these tasks should be increased to priority 2. The plan does not mention any task to enhance natural contact between Higgins' eye mussels and natural fish hosts. One of the limiting factors may simply be lack of mussel/host contacts for glochidia transfer within their natural habitat. Comments by Miller and Payne (1996b) on the value of wing dams for Higgins' eye and other mussels may be more indicative of fish holding habitat than true mussel habitat preferences. Areas that concentrate and hold fish for extended periods of time will likely have more mussels due to glochidia released from fish.

There is no mention of developing strategies for host fish stability, protection or enhancement, such as the regulation of fishing tournaments or the creation of fish refuges. We believe this should be included as additional tasks- priority 3.

Response: Seven fish species from three families are suitable fish hosts for *L. higginsii* (Table 3). The diversity of these species and their relative abundance in the Mississippi River system does not support the contention that *L. higginsii* are threatened by limited availability to fish hosts.

Comment: Consider adding a task to develop an alternative preservation plan for Higgins' eye mussels either through hatchery salvage or introduction into non-historical locations as a safeguard measure if this plan's primary efforts to save and recover the species fail.

Response: Such an alternative plan does not seem warranted at this time. The Service will continue to monitor the status of species and of any new threats to its continued existence. If such drastic measures seem warranted, the Service will act on the best available alternatives to prevent the extinction of the species.

Comment: Introduction (p. 3): The last sentence under "Taxonomy and Systematics" mentions that there is still some controversy surrounding the taxonomic status of *L. higginsii*. It is unclear how significant this controversy is when an earlier statement said that "most malacologists agree that *L. higginsii* is a valid species." A recovery action does suggest a need for further study. It would be helpful to provide additional explanation about the controversy as to what additional questions need to be asked, or whether a second review, similar to Johnson (1980) should be done.

Response: The Priority 3 task, "Examine the morphological, conchological and genetic differences between *L. higginsii* and *L. abrupt*", is sufficient to address any current uncertainty about the taxonomic status of *L. higginsii*.

Comment: There is no mention after the introduction about the threat of another flood. It would be helpful to address this threat again, even if there are few recovery actions that can be taken to prevent weather-created flooding. Since the impacts of the 1993 flood was a major factor in the revision of the plan as stated on page 1 of the document, it should be clarified as to what the recovery plan's approach to flood impacts are, i.e. is there a need for additional actions, or are no actions necessary because *L. higginsii* have survived OK as demonstrated by 1993 flood, etc.

Response: Floods are not generally regarding as a threat to *L. higginsii*, although they are likely to modify the species' habitat roughly in proportion to the magnitude of each event. The Service commissioned several studies after the 1993 floods due to the great magnitude of this event. These studies corresponded to the initial invasion and population growth of zebra mussels in the Upper Mississippi River. The severe impacts of this invasive species and other factors, not floods, are the recognized threats to *L. higginsii*.

Comment: Criteria #3 under Goal 2 (p. 36), use of double hull barges: There is little argument / documentation for the requirement of double hull barges earlier in the recovery plan. On p. 24, the plan states that "Harm to *L. higginsii* has not be documented as a result of a single contaminant spill or short-term contaminant episode, but such episodes have been strongly implicated in mussel die-offs elsewhere." Additional explanation of why double hull barges is a must should be added to the document or else this recovery criteria should be reworded. Perhaps, "the threat of spills from commercial barges has been minimized through regulation or other actions, i.e. use of double hull barges, upstream of each of the identified Essential Habitat Areas."

Response: We changed this criterion to: "The use of double hull barges or other actions have alleviated the threat of spills to each of the identified Essential Habitat Areas."

Comment: Narrative Outline (p.37-42): The Executive Summary and Introduction section of the plan state that the Twin Cities Field Office will retain an up-to-date list of Essential Habitat Areas and post it on the Internet, however there is no recovery action that cites this action.

Response: We added the following task (1.3.6): "Maintain an up-to-date list of Essential Habitat Areas and the supporting data for each at the Service's Twin Cities Field Office and make this information, or a summary thereof, available through the internet."

Comment: The recovery plan states that the list of seven Essential Habitat Areas identified in the original recovery plan will remain and an additional three EHAs will be added to a current list of ten EHAs (p. 5). It is unclear as to why action 1.3 is needed, "Confirm and modify the list of seven Essential Habitat Areas in the initial recovery plan". It seems that this action item should be retitled "Maintain a list of Essential Habitat Areas." Action 1.3.1 should be replaced with "Post the list of Essential Habitat Areas on the Internet so that is it easily available to partners and the public."

Response: We modified Task 1.3 to state: "Maintain a list and an ongoing evaluation of Essential Habitat Areas." Under this task, the ten Essential Habitat Areas recommended in this plan will be evaluated and additional areas will be added; the guidelines contained in the plan will be used to evaluate potential new Essential Habitat Areas.

Comment: (p. 37): It is unclear why the zebra mussel emergency response plan will "determine whether, and how, *L. higginsii* essential habitat areas should be redefined." This revised recovery plan is stating that it accepts the original 7 plus adds 3. What redefining is needed?

Response: The list of Essential Habitat Areas will not necessarily be static, but will include only those areas that the Service, in consultation with the Recovery Team, has determined are of utmost importance to the conservation of the species. Zebra mussels are one of the key factors to assess and monitor, including native mussel density and diversity, the geographic extent of the Essential Habitat, and other threats, to ensure that each site that we have designated as an Essential Habitat Area still maintains this importance to *L. higginsii*.

Comment: 1.3.2.1 (p. 38). It is unclear if this is one task or two? Could there be more than one EHA within Pool 10 or are the other areas to be identified as EHAs outside of pool 10?

Response: This task was changed to the following: "Survey Pool 10 to determine whether additional Essential Habitat Areas may be identified in this pool."

Comment: 1.7.2 (p. 42): 1.7.1 already recommends that mussel harvest no longer be permitted in EHAs so should this recovery action be to review existing harvest regulations for areas outside of EHAs?

Response: We changed this task to the following: "Review existing harvest regulations and make recommendations to the USFWS and the States on any regulations needed outside of Essential Habitat Areas."

Comment: 2.1 (p. 42): This action calls for ranking existing populations for enhancement but the step-down actions only look at non-EHAs. I recommend adding a recovery action to "prioritize existing EHAs based on data collected under 1.3."

Response: Task 2.1 is meant to apply to areas that do not meet the guidelines for Essential Habitat Areas. Therefore we changed it to read as follows: "Identify and rank potential sites of existing *L. higginsii* populations for enhancement." The sub-tasks are unchanged from the draft.

Comment: The Tumbling Creek cavesnail recovery plan (actions 6-8 and their subtasks) and the Lake Erie watersnake recovery plan (action 5 and its subtasks) include additional recovery actions such as revising the recovery plan when needed, convening a recovery implementation team, and developing a post-delisting monitoring plan. I recommend adding similar recovery actions to this revised recovery plan.

Response: We added the following tasks to the plan:

3 Update, revise, or add to the plan to keep it current and useful.

4 Develop a plan to monitor *L. higginsii* **after it is removed from the list of Endangered Species.**

We did not add a task to convene a recovery implementation team. An active recovery team is in place that will assist the Service with the implementation of the recovery plan.

Appendix B

Draft Final Report: 2007 Results of Unionid Mussel Monitoring near Quad Cities Nuclear Station, Mississippi River Miles 495 to 515, prepared by Ecological Specialists, Inc. December, 2008.

Draft Final
2007 Results of Unionid Mussel Monitoring near Quad Cities Nuclear Station, Mississippi River Miles 495 to 515

Prepared for:

Exelon Generation Company

Warrenville, IL

Prepared by:

Ecological Specialists, Inc.

O'Fallon, Missouri

ESI Project #07-001

December 2008

Authors' signature:________________________________

Heidi L. Dunn, President Ecological Specialists, Inc.

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Exelon Generation Company (Exelon) provided funds for this study. Mr. John Petro (Exelon) managed the project and Mr. Mark Stuhlman provided substrate data and intake and discharge records from Quad Cities Nuclear Station (QCNS). Mr. Petro and Mr. Stuhlman provided valuable comments on the report. Ecological Specialists, Inc. (ESI) was contracted by Exelon to monitor three unionid beds near their power plant. Ms. Heidi Dunn (ESI) was the principle investigator and primary author of this report.

Ms. Heidi Dunn, Mr. Nathan Badgett (aquatic biologist/diver), Mr. Dan Scoggin (technician), Mr. Kendall Cranney (dive supervisor), Mr. Dusty Witherwax (diver), and Mr. Nathan Wurmb (diver) of ESI conducted the field studies. Mr. Belt (GIS analysis and map preparation) and Mr. Nathan Badgett (data management) assisted with report preparation.

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1.0 Introduction

Exelon Generation (Exelon) is considering requesting alternate thermal standards pursuant to Section 316(a) of the Clean Water Act from the Illinois Pollution Control Board for its Quad Cities Nuclear Station (QCNS). Freshwater unionid mussel (unionids) beds harboring the federally endangered *Lampsilis higginsii* and Illinois threatened species *Ellipsaria lineolata* and *Ligumia recta* occur upstream and downstream of the QCNS. Additionally, the Cordova Essential Habitat Area (EHA) for *Lampsilis higginsii* occurs downstream of the QCNS plant. In 2004, Exelon established a monitoring program for freshwater unionids near the QCNS thermal discharge diffuser. The purpose of the monitoring program is to provide data and information regarding the unionid community, to evaluate the effects QCNS discharge has had on the community, and to establish the baseline unionid community characteristics for comparison with community characteristics observed following the issuance of alternate thermal standards.

Three unionid beds occur in the vicinity of QCNS: the Steamboat Slough (SS) Bed, located approximately 675 to 1125 meters (m) downstream of the QCNS mixing zone; the Upstream (UP) Bed, located approximately 730 to 1130 m upstream of the QCNS diffuser; and the Cordova Bed, located about 3000 m downstream of QCNS (Figure 1-1). Ecological Specialists, Inc. (ESI) monitored each of these unionid beds in 2004, 2005, 2006, and 2007. In 2007, 400m sections of three additional beds were added to the monitoring program to further describe stochastic variability of unionid community characteristics among and within unionid beds. The three additions were: the Albany Bed, located approximately 14,000 to 14,400 m upstream of the diffuser, Hansons Slough (HS) Bed, located approximately 5000 to 5400 m upstream of the diffuser, and Woodwards Grove (WG) Bed located approximately 10,500 to 10,900 m downstream of the diffuser (see Figure 1-1).

QCNS currently operates under NPDES permit conditions that allow 87.6 excursion hours per year, during which the plant may cause river temperatures to exceed maximum temperature standards by up to 3° F. QCNS operated within permit conditions between 2000 and 2005. Excursion hours were only used in 2001 (57.35 hours) and 2005 (42.50 hours; Table 1-1). In July and August 2006, QCNS was granted provisional variances from these permit conditions, that allowed additional excursion hours (beyond the annual allotment of 87.6 hours) at temperatures up to 5°F. The provisional variances were granted to address periods of low Mississippi River flows and high ambient river temperatures experienced in the summer of 2006. QCNS used 222.75 excursion hours in 2006, and water temperature during excursion hour events exceeded maximum temperature standards by 5°F. In 2007, QCNS operated within permit conditions, and 74.0 excursion hours were used in early August (see Table 1-1).

Exelon requested that ESI include, as part of its existing mussel bed monitoring program, studies designed to assess whether QCNS discharges in 2006 authorized by the provisional variances impacted the mussel beds in the vicinity of the QCNS discharge. ESI initiated a two-year sampling and monitoring program, to be conducted in 2007 and 2008, to evaluate whether the 2006 thermal events had either short or long term impacts. This report presents the results of the 2007 monitoring activities.

2.0 Sampling and Analytical Methods

Study sites within the QCNS study area are listed in Table 2-1. A total of 16 sites were evaluated for a preliminary investigation, of which six sites received more intensive evaluation (in October 2007). Eleven (11) sites were sampled in June 2007, two were sampled in October of 2007, and three sites were sampled in July of 2004.

2.1 Selection of Additional Sites

Known unionid beds in the Mississippi River between river miles (RM) 495.4 and 515.0 were plotted using ArcViewGIS. Sources included Peterson (1984) and Arlington (2003 data from pers. comm. through G. Kruse, ILDNR). Professional judgment by ESI lead malacologist Heidi L. Dunn was also used to identify additional potential sites. Five upstream sites were selected for preliminary sampling (see Table 2-1 and Figure 2-1): UP-4 (Albany Bed; straight reach, Illinois bank, RM 513.0 to 515.5), UP-7 (backwater, Illinois bank, RM 510.5 to 511.0), UP-8 (Hansons Slough [HS] Bed; mouth of side channel, within dike field similar to Steamboat Slough, Iowa bank, RM 509.1 to 510.1), UP-10 (slight inside bend, Illinois bank, RM 507.5 to 509.0), and UP-11 (slight outside bend, Iowa bank, 507.5 to 509.5).

Additional downstream sites selected for preliminary sampling included two sites within Steamboat Slough (SS-1 and SS-2), DN-1 (downstream of Steamboat Slough, Iowa bank, approximately RM 501.5 to 502.8), DN-2 (slight inside bed, dike field, Illinois bank, approximately RM 501.2 to 501.5), DN-3 (Woodwards Grove [WG] Bed, slight outside bend, Iowa bank, approximately RM 499.5 to 500.8), DN-4 (straight reach, Illinois bank, approximately RM 499.1 to 500), DN-5 (riverward of shallow sand, silt flat, Iowa bank, approximately RM 498.5 to 499), DN-6 (straight reach, Illinois bank, approximate RM 497.7 to 498), and DN 8 (downstream of outside bend, Illinois bank, 495.5 to 496.5) (see Table 2-1). Two of the UP sites (Albany and Hansons Slough in addition to the UP Bed) and one of the DN sites (Woodwards Grove Bed, in addition to SS Bed and Cordova Bed) were selected for characterizing the unionid communities (see Table 2-1).

2.2 2007 Monitoring

The Albany, Hanson Slough, Upstream, Steamboat Slough, Cordova, and Woodwards Grove beds were sampled between October 4 to 14, 2007, 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.

At each of the six sites, 90 0.25m^2 quadrat samples were collected. Sampling locations in each bed were randomly selected using GIS and points were plotted on a Hummingbird Depthfinder with GPS matrix 76. Samples were obtained from each location by a diver who excavated all substrate material from the quadrat to a depth of 15cm into a 6mm mesh bag. A surface crew retrieved the bag and rinsed material through 12mm and 6mm sieves. Substrate and debris were searched and unionids removed. All live unionids were identified to species, measured (length in millimeters [mm]), aged (external annuli count), and returned to the river. Freshly dead shells (FD; dead within the past year, nacre shiny, hinge flexible, valves attached, with or without tissue) were identified, counted, and classified as young unionids

(Ambleminae ≤5 years old; Lampsilinae and Anodontinae ≤3 years old) or adults. Weathered shells (WD; dead many months to years, nacre chalky, hinge brittle, valves typically separated, periostracum intact) and subfossil shells (SF; dead many years to decades, periostracum eroded, valves separate, very chalky) were noted as present. Substrate characteristics (Wentworth scale) and water depth (pneumometer) were recorded for each sample location.

The qualitative sampling approach was designed to collect as many individuals as possible, thereby increasing the probability of finding rare species (Kovalak *et al*., 1986). For each qualitative sample, a diver searched for and collected unionids for 5-minute intervals at 25 locations spread throughout each bed. All live and fresh shells of unionids were identified, designated as adults or young unionids, and counted. Live unionids were returned to the river. The position of each qualitative sample location was recorded with a Trimble Pathfinder XP or Hummingbird depthfinder GPS. Additionally, surface and bottom water temperature, dissolved oxygen (DO) levels, and current velocity (meters/second) were recorded at each location.

In addition to obtaining water temperature data upstream and downstream of QCNS and over the unionid beds, temperature recorders were installed in the substrate at the north and south ends of Upstream, Steamboat Slough, and Cordova beds. The recorders measured with greater precision temperatures to which unionids were actually exposed. The substrate temperature recorders were installed on May 22 and removed on October 24, 2007.

Data regarding the mussel bed community characteristics were analyzed using Analysis of Variance methodology (ANOVA). The following parameters were analyzed: differences in total, young and adult density; differences in Ambleminae and Lampsilinae density; and differences in density of freshly dead shells based on sampling dates and bed location. The data were log (x+1) transformed for ANOVAs and significance level was $p<0.05$ for all tests. Regression analysis was used to determine the slope (rate of increase) of species with respect to cumulative individuals, using the equation: cumulative species = slope * log (cumulative individuals). The intercept constant was set to zero, as no species are present if no individuals are collected.

3.0 Results and Discussion

3.1 River Flow Rates and Water and Substrate Temperatures

River conditions in 2007 included very low flows (discharge) in July and early August similar to 2006 (Table 3-1; Figure 3-1). A total of 74.0 excursion hours were used during this time (see Table 1-1). However, a flood event (discharge exceeded 100,000 cubic feet per second [cfs] at Lock & Dam 14) occurred in late August that increased ambient river water temperatures.

In 2007, substrate temperature seemed to mimic water temperature rather than buffer water temperature as seen in 2006. Measured water temperature (measured as an average across the channel 1000 feet [ft] upstream of the diffuser), when compared to the continuous monitors placed in the UP Bed substrate, was either between the north and south substrate temperature range, or was very similar to the Upstream north temperature monitor (Figure 3-2). However, substrate temperature in the UP Bed was similar or less than maximum daily water temperature recorded at L&D's 13 and 14 (Figure 3-3). Measured water temperature downstream of the diffuser (measured across the channel 500 ft downstream) was similar to or slightly less than SS Bed substrate temperature (Figure 3-4). SS Bed substrate temperature tended to be higher than water temperature measured at L&D's 13 and 14 (Figure 3-5). Cordova Bed substrate temperature was similar to L&D water temperatures and was within the range of water temperatures measured upstream and downstream of the diffuser (Figure 3-6).

Substrate temperatures in 2007 were less than the extreme temperatures experienced in 2006. In July and August of 2007, the UP Bed north maximum substrate temperatures were 84.5°F and 85.2°F, respectively (see Table 3-1; Figure 3-6). In 2006, maximum substrate temperature in the UP Bed south was 3°F higher at 87.5 and 88.4 in July and August, respectively. In the SS Bed north, maximum 2007 substrate temperature was 87.7°F and 88.9°F, compared to 91.2°F and 92.0°F in July and August of 2006, respectively (see Table 3-1; Figure 3-7). Average substrate temperatures, however, were higher in early August 2007 than in August 2006 in both the UP and SS beds.

The difference in substrate temperature between the UP Bed south substrate and the SS Bed north substrate ranged from a minimum of 0.1°F warmer in June 2007 to a maximum of 5.2°F warmer in August 2007 (see Table 3-1; Figure 3-8) The substrate temperature difference between UP Bed south and SS Bed north averaged 2.1, 1.8, 3.2, 3.6, 2.6, and 1.6°F higher in May through October 2007 (see Table 3-1). However, substrate temperature in the SS Bed was actually cooler than the UP Bed for a short time in both August and June (see Table 3-1; Figure 3-8).

Cordova Bed substrate temperature was cooler in May through most of June and in most of September and October than the UP Bed south substrate temperature, but averaged 2.1 and 1.8°F warmer in July and August 2007 (see Table 3-1; Figure 3-9).

3.2 Upstream Bed

The Upstream Bed habitat has remained consistent among monitoring events (July 2004, July and October 2005, August and September 2006, October 2007; Table 3-2). The Upstream Bed is located near the mouth of the Wapsipinicon River and upstream of QCNS diffuser discharge (see Figure 1-1). Substrate in the bed is a mixture of sand, silt, and clay, with sand being the major constituent (see Table 3-2). However, substrate constituents varied considerably among sample points (CV [coefficient of variation] exceeding 100 except for sand).

Water depth within the sampled area averaged 3.8 m, and ranged from 0.6 to 7.3 m (see Table 3-2). DO levels were slightly (>75% but <100%) below saturation during July 2004, October 2005, September 2006, October 2007, and supersaturated (>100%) in July 2005 and August 2006. The high DO during July/August 2005 and 2006 is likely a result of higher levels of aquatic flora associated with the low flow and high temperature conditions that occurred in both years. River current velocity averaged ≤0.5 m/sec in all monitoring events, ranging from a low of 0.0 m/sec in August 2006 and October 2007 to a high of 0.6 m/sec in July 2004 and 2005 (see Table 3-2). Average current velocity within the Upstream Bed was lowest in 2006, averaging 0.04 and 0.1 m/sec in August and September, respectively.

Both water and substrate temperature declined rapidly during the October 2007 sampling. Water temperature (measured approximately 0.5m above the substrate) averaged 60.8°F on October 13, 2007 (see Table 3-2). Water temperature at L&D 14 between October 4 and 13, 2007 ranged from 68°F to 60°F. Substrate temperature was slightly above (≤0.5°F) water temperature during sampling and ranged from 68.4°F to 61.3°F (see Table 3-2).

Substrate temperature did not exceed 86°F in 2007. In 2006, substrate temperature exceeded 86.0°F for 86 hours, and 87.8°F for 2 hours in late July/early August (Table 3-3). The maximum substrate temperature recorded in the Upstream Bed in 2007 was 85.2°F, compared to 88.4°F in 2006 (see Table 3-1).

Zebra mussel 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 (see Table 3-2). In 2007, zebra mussel infestation averaged only 0.08/unionid. Most unionids were not infested, and the most zebra mussels on any unionid was five (see Table 3-2).

Upstream Bed unionid community characteristics have remained fairly consistent across monitoring events. The bed continues to be species rich and moderately dense. No residual effects of the extended period of high water temperature in 2006 were noted in the 2007 community characteristics. An increase in Lampsilinae mortality was noted in 2006; however, mortality in 2007 was similar to pre-2006 levels. Most species show evidence of recent recruitment into the community, and mortality generally was low.

At least 25 species reside in the Upstream Bed, with at least 20 species (77%) collected during each monitoring event (see Table 3-4). The slope of the cumulative individuals vs. cumulative species regression was high and consistent across monitoring events, averaging near seven. One new species, *Potamilus capax*, was collected in 2007 as a weathered shell. Live *P. capax* have not been reported from Pool 14 in the past 25 years (Kelner, 2003). Dominant species in 2007, as in other monitoring years, were *Obliquaria reflexa* (34.9%) and *Amblema plicata* (17.4%). The state and federally listed species *Lampsilis higginsii* (adult), *Ellipsaria lineolata* (young and adult), and *Ligumia recta* (adult) were all collected in 2007. Twenty to 23 species have been collected per monitoring event and the slope of the species area curve has ranged from 6.5 to 7.9.

Total density and density of adult unionids has remained consistent among monitoring events. Total density has ranged from 6.9 (±3.1) to 11.0 (±4.3) unionids/m^2, and density of adult unionids ranged from 4.5 (±2.4) to 7.5 (±1.9) unionids/m^2, but estimates have not differed significantly among monitoring events (see Table 3-4). Mortality has been <10%, with the exception of September 2006 (15.1%), and was only 4.4% in 2007. Young unionids have comprised an average of 31.9% of the Upstream Bed unionid community throughout monitoring events. Density of young unionids has varied among years, but with no significant trend over time. In 2007, 78.2% of the species collected in the Upstream Bed were represented by young unionids (see Table 3-4 and Table 3-5).

Density within the subfamilies also appears to be consistent over time despite the higher mortality noted for Lampsilinae in 2006. Ambleminae density has ranged from 2.2 (±1.3) to 5.0 (±1.8) unionids/m^2, but estimates did not differ significantly in any year. Lampsilinae density has been slightly higher than Ambleminae, ranging from 4.5 (±1.2) to 6.1 (±1.5), but has not differed significantly among years. Overall, average Lampsilinae density (5.1 ±0.8) was higher than Ambleminae density (4.0 ±0.7), however density did not differ between subfamilies in 2006 and 2007 (see Table 3-4). Mortality of both subfamilies was <5% in 2007, compared to 5.9% and 21.7% mortality of Ambleminae and Lampsilinae in September 2006, respectively.

3.3 Steamboat Slough Bed

The Steamboat Slough bed is located approximately 750 m downstream of the QCNS mixing zone (see Figure 1-1). In previous years, the northern portion of the sampling area was downstream and riverward of a small island. This island was absent 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 (Table 3-6). Substrate in 2007 was nearly equal parts sand and silt, with silt forming a layer over the sand.

Water depth ranged from 0.9 to 4.3 m and average 2.4m (see Table 3-6). Current velocity has varied from 0 to 0.6 m/sec and in 2007 ranged from 0.1 to 0.4 m/sec. Dissolved oxygen 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 observed Upstream Bed DO measurements. Very few zebra mussels were found in the SS Bed in any monitoring event; an average of only 0.01 zebra mussels/unionid was observed in October 2007. As in previous years, zebra mussels increased with distance from the QCNS discharge. The paucity of zebra mussels in the SS Bed may be due to fluctuating conditions with respect to substrate, current velocity, DO, and temperature.

Both water and substrate temperature declined rapidly during the October 2007 sampling. Water temperature (measured approximately 0.5m above the substrate) averaged 60.8°F on October 13, 2007 (see Table 3-6). Water temperature at L&D 14 between October 4 and 13, 2007 ranged from 68°F to 60°F. Substrate temperature ranged from 70.1°F to 61.4°F during sampling (see Table 3-6).

Substrate temperature in the SS Bed exceeded 86°F in 2007 for 337 hours and exceeded 87.8°F for 106 hours (see Table 3-3). The maximum temperature recorded in the SS Bed substrate in 2007 was 88.9°F, compared to 92.0°F in 2006 (see Table 3-1). Although maximum substrate temperature and duration of higher substrate temperature was lower in 2007 than in 2006, the difference in temperature between the UP Bed and SS Bed substrate was similar in June and July of both years (2.1° vs. 1.8° in June and 3.1° vs. 3.2° in July 2006 and 2007, respectively). The difference in substrate temperature, however, was greater in August 2007 (average 3.6°F; maximum 5.5°F) than in 2006 (average 2.9°, maximum 4.4°F; see Table 3-1).

The extended period of higher water temperature in 2006 did not seem to affect the unionid community characteristics in the SS Bed. As with the Upstream Bed, changes in the SS Bed noted in 2006 community characteristics were not apparent in 2007. The SS Bed continues to support a less dense and less species rich unionid community than the Upstream Bed. *Amblema plicata* (22.6% in 2007) and *O. reflexa* (28.0% in 2007) continue to be the dominant species (Table 3-7). *Quadrula nodulata* is more abundant in this than any of the other beds sampled in this study (Table 3-8). *Ligumia recta* were collected in 2007; however no *E. lineolat*a were collected. As in previous years, *L. higginsii* was absent. However, *Megalonaias nervosa* and *Lampsilis teres* were collected in the SS Bed for the first time in 2007; thus, the total number of species found to date in the SS Bed is 23 (see Table 3-7). Fifteen to 18 species have been collected per monitoring event and the slope of the species area curve has ranged from 5.1 to 6.1.

Density estimates have been consistent, averaging 4.6 unionids/m^2 overall and 4.1 unionid/m^2 in 2007 (see Table 3-7). Density was only significantly different (greater) from other monitoring events in August 2006. Ambleminae continue to comprise a higher percent of the community than Lampsilinae (59.8% vs. 38.9%), and overall, Ambleminae density was significantly greater than Lampsilinae density. However, density did not differ significantly between the two subfamilies in 2006 and 2007.

Recruitment has fluctuated among years, with <10% young unionids in 2004 and 2005, and ≥20% in 2006 and 2007. In 2007, 32.3% of the unionids in the SS Bed were young (see Table 3-7), and most of the dominant species were represented by young unionids (Table 3-9). Compared to other beds sampled in 2007, the SS bed had the highest percentage of young Ambleminae and the lowest percentage of young Lampsilinae (see Table 3-8). Mortality of both Lampsilinae and Ambleminae was low (<5%) in 2007.

3.4 Cordova Bed

The Cordova Bed is one of the Essential Habitat Areas designated in 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. The portion of the Cordova Bed sampled in this study is approximately 3000 m downstream of QCNS mixing zone, on the Illinois bank of the river (see Figure 1-1).

Zebra mussels (*Dreissena polymorpha*) were more abundant in the Cordova Bed than in either the Upstream and Steamboat Slough bed during past monitoring events; however, very few unionids were infested with zebra mussels in 2007 (Table 3-10). Zebra mussel density in the Cordova bed was <10/m^2 in 1994 (Miller and Payne, 1995). In 1999, most unionids in the Cordova Bed had <50 zebra mussels attached (Table 3-11). By 2000, zebra mussels encrusted all unionids and covered the substrate in most of the Cordova Bed. In 2001, few zebra mussels were found within 20 m of the bank, but density further from the bank averaged 3000 to 4000/m^2. However in 2002, zebra mussels declined appreciably and only one-third of the unionid had a few zebra mussels attached. Zebra mussel density in 2003 had declined to <1000/m^2. Zebra mussel density increased in the Cordova Bed in 2004; however, density declined in 2005 and remained low in 2006 and 2007 (see Table 3-10). In 2005, an average of 0.3 and 1.3 zebra mussels per unionids was observed in July and October, respectively, and an average of 0.1 and 0.3 zebra mussel per unionid was observed in August and September 2006 (see Table 3-10). In 2007, zebra mussel infestation was very low (0 to 1 per unionid) and similar to infestation noted in October 2007 in other sampled beds (Table 3-12). However, heavy zebra mussel infestation (unionids 20 to 100% covered) was noted within other mussel beds in Pool 14 during the late June preliminary sampling. Additionally, the percentage of zebra mussel shell increased from 18% of the substrate in 2006 to 44% of the substrate in 2007 (see Table 3-10). This suggests that zebra mussel infestation within the Cordova Bed was higher earlier in 2007 than noted in October 2007.

Zebra mussel infestation has resulted in high unionid mortality and reduced density within the Cordova Bed. Before heavy zebra mussel infestation (1994), density in the Cordova Bed ranged from 51 to 83 unionids/m^2 and recruitment (measured as percentage of unionids ≤30 mm) ranged from 10 to 49% (Miller and Payne, 1996). In 1999, zebra mussel density was extremely high, unionid mortality was near 50%, and recruitment was near zero at RM 504.3 (ESI, 1999). Zebra mussel density declined between 2001 and 2003, unionid density and recruitment increased, and mortality declined. Density in 2002 and 2003 ranged from 3.6 to 8.1 unionids/m^2 and, in 2003, recruitment was near 44% (Farr *et al.*, 2002; ERDC, 2003 preliminary data). Unionid density has remained stable since 2004, averaging 4.4 unionids/m^2 and percentage young unionids (≤5 years old) averaging 33% (Table 3-13).

The Cordova Bed differs from the Upstream and Steamboat Slough beds in that it occurs along a slight outside bend in the river and its substrate is coarser (higher percentages of gravel, cobble, shell; see Table 3-12). 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 to 1.5 ft layer of dead zebra mussel shells covered the substrate. Submergent vegetation was present in both 2006 and 2007. Depth within the sampled portion of the Cordova Bed averaged 1.9 m and ranged from 0.1 to 6.7 m.

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 in the Cordova Bed as it was in the Steamboat Slough Bed in 2006 or in 2007. Current velocity averaged 0.2 m/sec during 2004, 2005, and 2007, but averaged <0.1 m/sec in 2006 (see Table 3-10). Dissolved oxygen was 6.0 mg/L in July 2004 and 8.3 mg/L in October 2005, similar to both the Steamboat Slough and Upstream beds. In 2006, DO average was similar to previous years, but ranged from 4.3 mg/L to 18.1mg/L in October, most likely due to the increase in submerged vegetation. Dissolved oxygen averaged 8.4mg/L in 2007 and was similar to other beds (see Table 3-12).

Water temperature in the Cordova Bed averaged 77.5°F in July 2004 and 2005, 87.3°F in August 2006, 65.5°F in October 2005, 64.2°F in September 2006, and 60.9°F in October 2007 (see Table 3-10). These temperatures were lower than both Upstream Bed and Steamboat Slough Bed temperatures in 2004 and 2005, but in 2006, Cordova Bed temperatures were higher than temperatures recorded in the Upstream Bed. Cordova Bed water temperature did exceed 87.8°F in some samples in August 2006.

Substrate temperature loggers were placed in the Cordova Bed in 2007. Substrate and water temperature were similar at the time of sampling (October 12, 2007; see Table 3-10). Average Cordova Bed substrate temperature was cooler than the Upstream Bed substrate in May, June, September, and October 2007, and 1.5 to 2.1°F warmer in July and August (see Table 3-1); however, both cooler and warmer substrate temperatures were recorded in all months.

Unionid community characteristics in the Cordova Bed differ from the Upstream and Steamboat Slough beds, primarily due to more heterogeneous substrate and less variable current velocity. Species composition is 43.9% Ambleminae and 52.9% Lampsilinae, and density between subfamilies did not differ significantly for any of the sample dates (Table 3-13). Similar to the other beds, *A. plicata* was the dominant Ambleminae (see Table 3-13). *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 (see Table 3-12). *Leptodea fragilis* was the second most abundant species in 2007, however it only comprised 12.4% of the community compared to almost 30% in 2005. *Obliquaria reflexa* has a thicker shell than *L. fragilis* and may be less affected by stressors. *Obliquaria reflexa* is the dominant species in both the Upstream and Steamboat Slough beds (see Table 3-13). *Megalonaias nervosa* was collected consistently in the Cordova Bed, but only in 2007 in the SS Bed, whereas, *Q. nodulata*, which is abundant in the Steamboat Slough Bed, is rare in the Cordova Bed. *Lampsilis siliquoidea* was collected in the Cordova Bed in 2006, but not in other beds. Although not found in this study, *Plethobasus cyphyus* was reported from the Cordova Bed in 2006 (D. Sallee, pers. comm., IDNR). *Lampsilis higginsii* and *L. recta* seem more abundant in the Cordova Bed, whereas *E. lineolata* seems less abundant, but all three species were collected in the Cordova Bed in 2006 and 2007. Most species found in the Cordova Bed (25 total) have also been collected in the Upstream Bed, with the exception of

Lampsilis siliquoidea and *Strophitus undulatus*. *Quadrula metanevra* and *L. teres* were absent in the Cordova Bed during this study, although these species were collected in the Cordova Bed in previous studies (ESI, 2005).

The extended period of high water temperature in 2006 did not seem to have any residual effect on unionid community characteristics in the Cordova Bed. Similar to the UP and SS Beds, changes in community characteristics observed in 2006 returned to previous levels in 2007. The decline in density, decline in the species area curve slope, and increase in mortality observed in 2006 were not observed in 2007 (see Table 3-13). Density in the Cordova Bed has ranged from 3.0 unionids/m^2 in July 2005 and September 2006 to 5.8 unionids/m^2 in October 2005, and averaged 4.7 unionids/m^2 in October 2007. Density of Ambleminae has not differed significantly among monitoring events, and Lampsilinae density has fluctuated with no clear trend. Mortality seemed particularly high in 2006, with 31.6% of the unionids found as FD shells in September. Adult Lampsilinae mortality was 43.2% and young Ambleminae mortality was 35.7% (see Table 3-13). However in 2007, mortality averaged only 3.7% overall, and 5.9% for Ambleminae and 1.8% for Lampsilinae. Additionally, 35% of the collected unionids were young individuals, and 69.6% of the species collected were represented by young individuals (see Table 3-13). No young *L. higginsii* were found in 2007, but young *L. recta* were collected (Table 3-14).

3.5 Additional monitoring beds 2007

Three additional beds were selected for monitoring in 2007; Albany, Hansons Slough (HS) and Woodwards Grove (WG) beds (see Figure 1-1). Similarities and differences were noted among these and the UP, SS, and Cordova Beds.

3.5.1 Albany Bed

Albany bed was the upstream-most bed sampled. The bed seems to extend upstream from Albany, IL (near RM 513) to Cattail Slough (near RM 516; see Figure 2-1). 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 rip-rap.

The bed was most similar to the Cordova Bed in habitat characteristics. Substrate was primarily zebra mussel shells mixed with cobble, gravel, and sand (see Table 3-12). Silt was more apparent near the bank. Current velocity within the bed ranged from 0 to 0.3 m/sec, however increased to nearly 1 m/sec immediately riverward of the bed. This dramatic increase in current velocity seems to define the riverward bed boundary. Depth ranged from 0.6 to 2.4 m, and DO (8.2 mg/L) was similar to other beds at the time of sampling. This was the last bed sampled in October, and water temperature was coldest at 59°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. Submergent vegetation was also noted during sampling.

Community characteristics were also very similar to the Cordova Bed, as Albany Bed was also a moderately dense and species rich mussel bed (see Table 3-8). Density averaged 6.6 (±1.8) unionids/m^2 and was only significantly different than Hansons Slough Bed (11.1 ±3.1 unionids/m^2; see Table 3-8). Twenty-one species were found, including *L. higginsii* and *L. recta*, however no *E. lineolata* were found (see Table 3-8). Both *L. higginsii* and *L. recta* were as abundant in the Albany bed as in the Cordova Bed. However young individuals of these species were found in the Cordova Bed, but no young individuals of either species was found in the Albany Bed (Table 3-15). The slope of the species area curve was 7.28, similar to Cordova Bed. *Amblema plicata* (20.3%) was the dominant species, but unlike Cordova, *Quadrula p. pustulosa* (17.6%) was very abundant. *Leptodea fragilis* (9.5%) and *O. reflexa* (12.8%) were also commonly collected in this and the Cordova Bed.

Both Lampsilinae (48.0%) and Ambleminae (47.3%) were fairly equally represented in the Albany Bed, and density did not differ significantly between the two groups (3.1 and 3.2 unionids/m^2, respectively; see Table 3-8). Recruitment was high in both groups; with 34.3% of the Ambleminae and 45.1% of the Lampsilinae being young individuals. Although no *L. higginsii* or *L. recta* ≤3 external annuli were found, one *L. higginsii* had four external annuli and *L. recta* had five, six, and seven external annuli (Table 3-15). Mortality was <10%.

The similarity in unionid community characteristics between the Albany and Cordova beds suggests that water temperature effects associated with the QCNS discharge do not have a major affect on the Cordova Bed unionid community.

3.5.2 Hansons Slough Bed

The Hansons Slough Bed (HS Bed) is upstream of the QCNS diffuser approximately 4600 to 6400 m (see Table 2-1). The bed appears to extend from approximately RM 509.1 to 510.1 (see Figure 2-1). 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 (0.6 to 2.7 m), substrate was sandier (primarily fine sand similar to UP Bed), and current velocity was less variable (0.1 to 0.3 m/sec, similar to Cordova Bed) than within the SS Bed (see Table 3-12). 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.

The unionid community within the Hansons Slough Bed was similar to the SS 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 (see Table 3-8). Ambleminae comprised 68.0% of the unionids collected in the Hanson Slough Bed in October 2007, and Ambleminae density (7.6 unionids/m^2) was significantly higher than Lampsilinae density (3.5 unionids/m^2). Unlike other beds, *A. plicata*, although abundant (16.0%), was not the dominant species. Rather 32.4% of the unionids collected were *Q. p. pustulosa*. *Obliquaria reflexa* (14.8%) was the most abundant Lampsilinae species. Slope of the species area curve was 6.17, and 23 species were found in 2007.

Density within the Hansons Slough Bed was significantly higher (11.1 unionids/m^2) than other beds sampled in 2007 except the Upstream bed (8.7 unionids/m^2). Also similar to the Upstream Bed, a few *E. lineolata*, *L. higginsii*, and *L. recta* were collected, although none of the individuals of these species had ≤3 external annuli (Table 3-16). Mortality (<5%) was low, 29.2% of the individuals were young animals, and 69.6% of the species were represented by young individuals, similar to other beds (see Table 3-8).

3.5.3 Woodwards Grove Bed

The Woodwards Grove Bed is downstream of the QCNS diffuser approximately 8300 to 10,900 m (see Table 2-1). The bed appears to extend from approximately RM 499.5 to 500.8 along the Iowa bank within a slight outside bend (see Figure 2-1). 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 (see Table 3-12). Dead zebra mussel shells comprised approximately 15% of the substrate within the bed, suggesting previously heavy zebra infestation although perhaps not as heavy as Cordova or Albany beds. Other than zebra mussels, substrate was primarily silt and clay closer to the bank, turning to finer sand riverward. Depth varied from 0.3 m near the bank to 4.3 m riverward. Current velocity averaged 0.1 m/sec and ranged from 0 to 0.3 m/sec (see Table 3-12). Water temperature and DO were similar to other beds during the October 2007 sampling.

Woodwards Grove Bed's unionid community was moderately dense and species rich compared to other beds. Density was 5.9 unionids/m^2 and only significantly different from the Hansons Slough Bed (11.1 unionids/m^2; see Table 3-8). A total of 26 species were found, and the slope of the species area curve was 6.97. Ambleminae (60.2%) dominated this bed, similar to the Hansons Slough and Steamboat Slough Beds, and density of Ambleminae (3.6/m^2) was significantly higher than Lampsilinae (2.0/m^2). However, *Q. quadrula* (29%) was the dominant species in the Woodwards Grove Bed. *Amblema plicata* (18%) was also abundant, as was *O. reflexa* (18%). *Leptodea fragilis* was fairly common in this bed, similar to Cordova and Albany. *Ellipsaria lineolata*, *L. higginsii*, and *L. recta* were all collected at a low frequency, similar to the Hansons Slough and Upstream beds. No young individuals of these listed species were found (Table 3-17). Young unionids were abundant, as 40.6% of the community was young individuals, and 60.9% of the species collected were represented by young individuals (see Table 3-8). Approximately 33.8% of the Ambleminae were young individuals. Although Lampsilinae were less abundant than Ambleminae, 55.6% of the Lampsilinae collected were young individuals. Overall mortality was <10%; however, 20% of the Lampsilinae were collected as FD shells.

4.0 Conclusions

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 river 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 Upstream, Steamboat Slough, 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 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 shared some habitat and community characteristics with both the Steamboat Slough and Upstream beds. The bed is within a slough and dike field similar to the Steamboat Slough Bed, but substrate consists of more fine sand, similar to the Upstream 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 Steamboat Slough 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 Upstream Bed. The Woodwards Grove Bed, downstream of QCNS, differed in substrate (mostly silt and clay) and shared some community characteristics with the other beds.

In summary, community characteristics within unionid beds sampled in this study do not seem to be significantly affected by the QCNS thermal effluent. Unionid beds downstream of the QCNS exhibited similarities and differences in habitat and unionid community characteristics with unionid beds upstream of the QCNS. Increased mortality noted in some beds in 2006 was not observed in 2007 and did not appear to affect unionid density either upstream or downstream of the QCNS.

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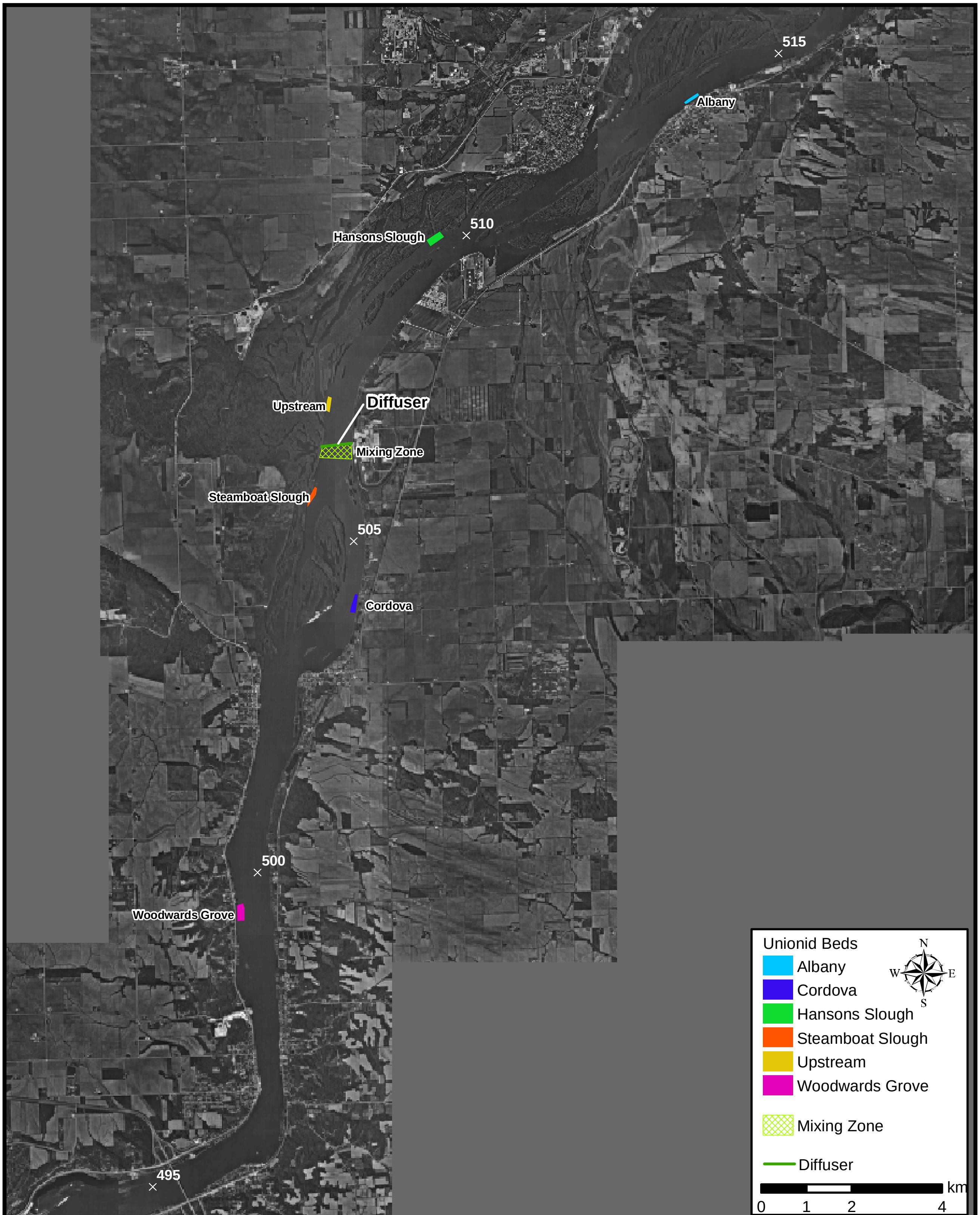

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Figure 1-1. Unionid bed monitoring areas near QCNS, 2004 through 2007.

ESI

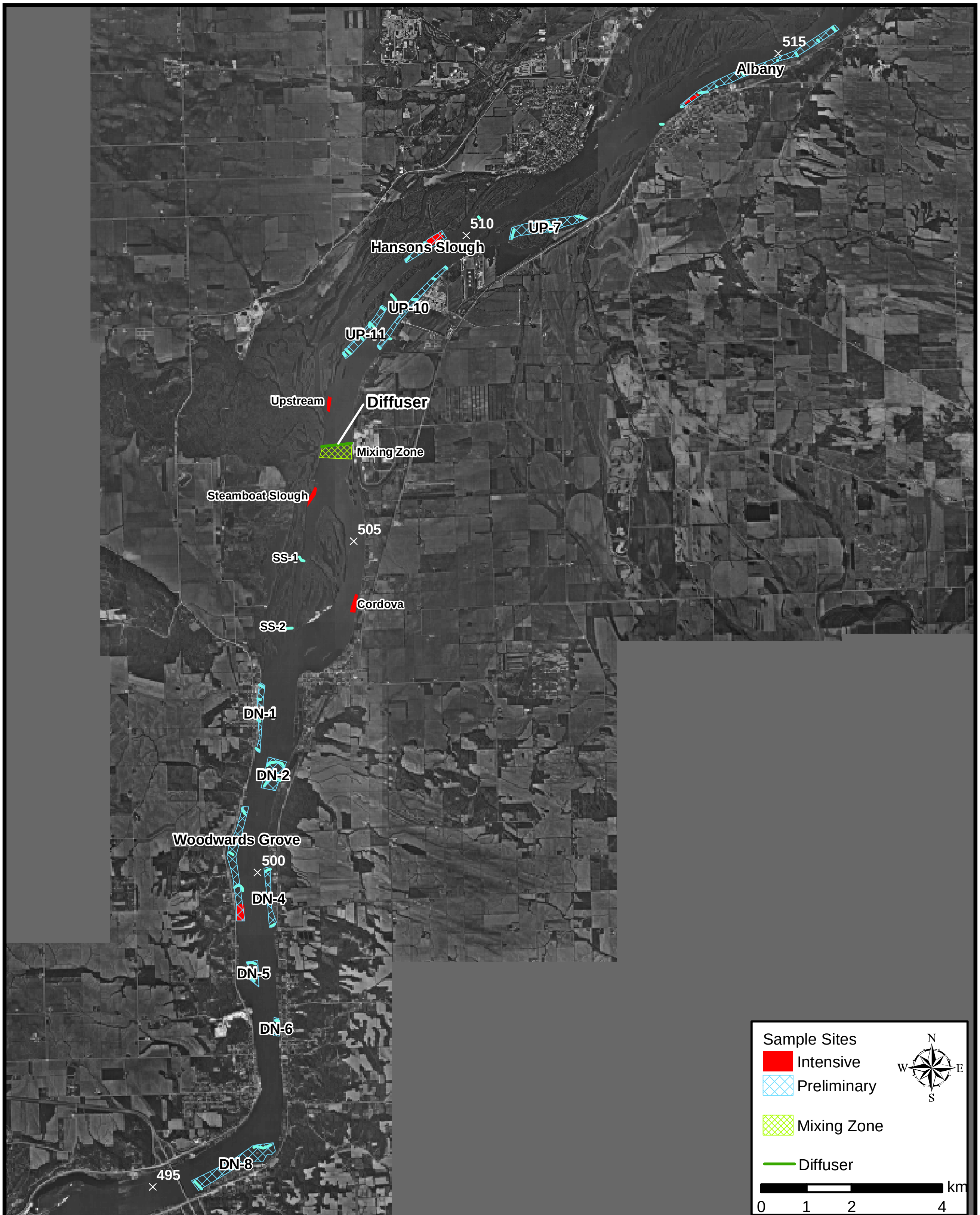

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Figure 2-1. Preliminary and intensive sample sites, Pool 14, 2007.

ESI

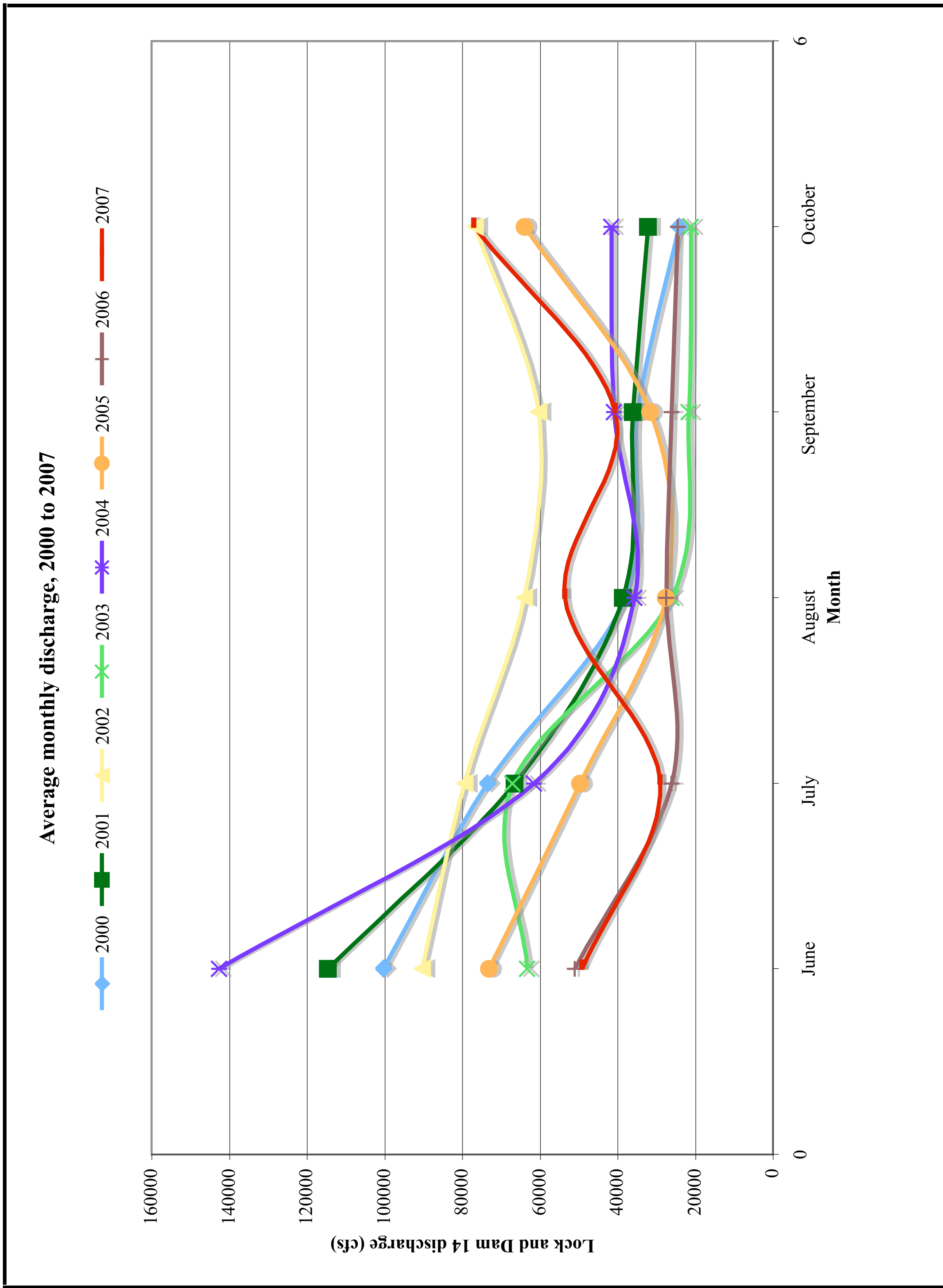

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Figure 3-1. Mississippi River, Lock and Dam 14, average monthly discharge, June to October, 2000 to 2007.

ESI

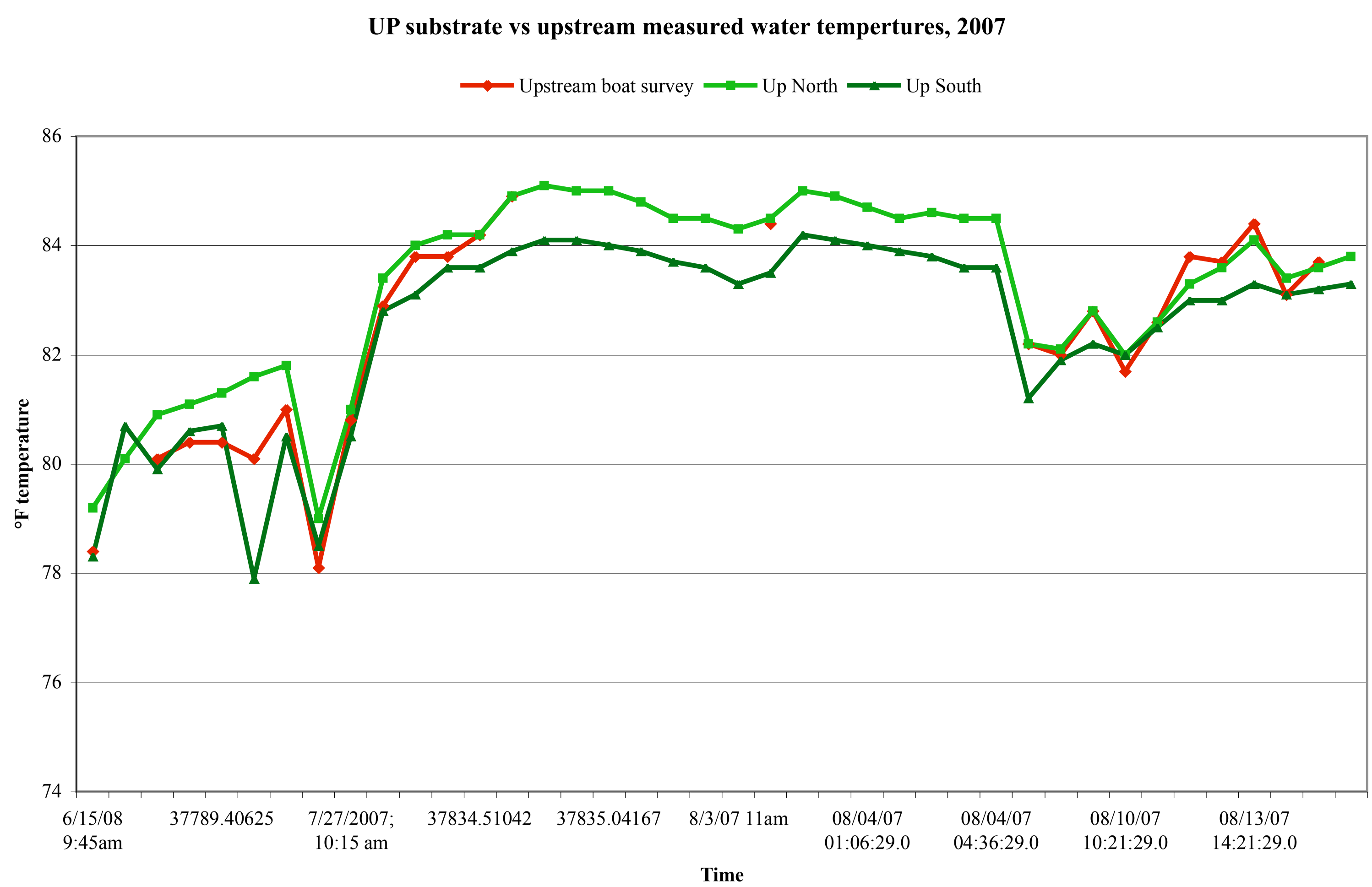

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Figure 3-2. UP Bed substrate temperature compared to upstream measured water temperature, 2007.

ESI

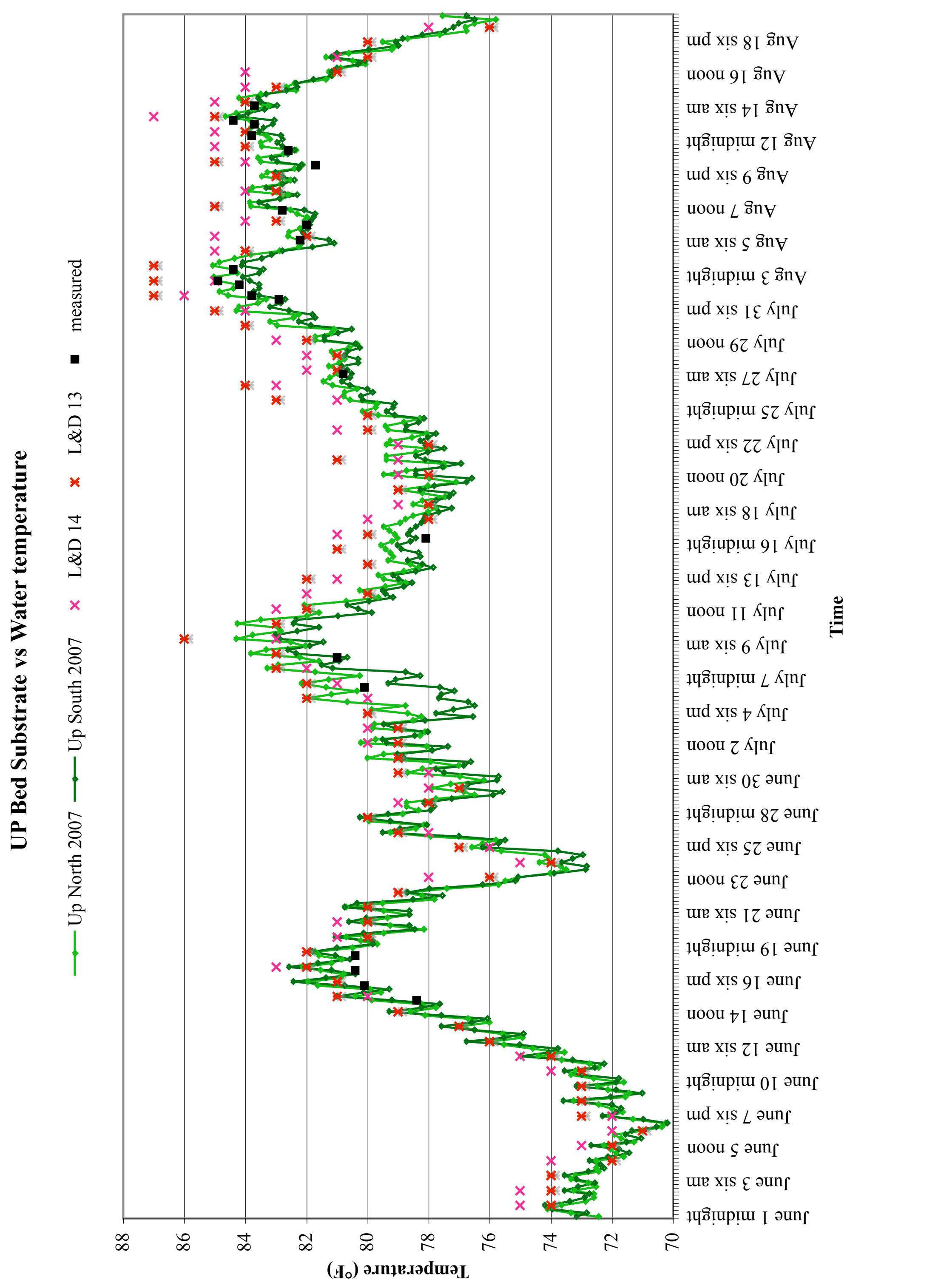

Figure 3-3. UP Bed substrate compared with Pool 14 water temperature June through August, 2007.

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ESI

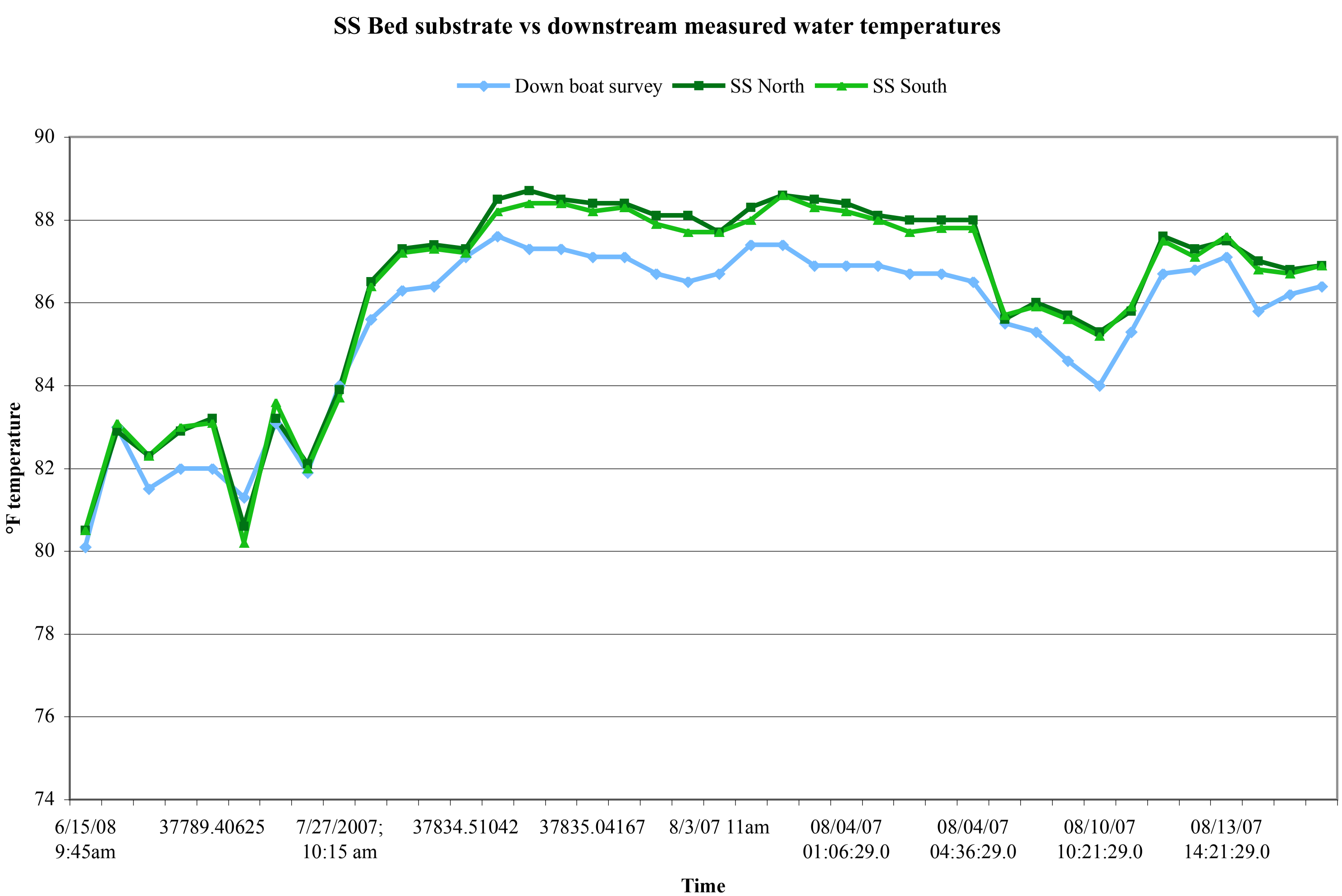

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Figure 3-4. SS Bed substrate temperature compared to downstream measured water temperature, 2007.

ESI

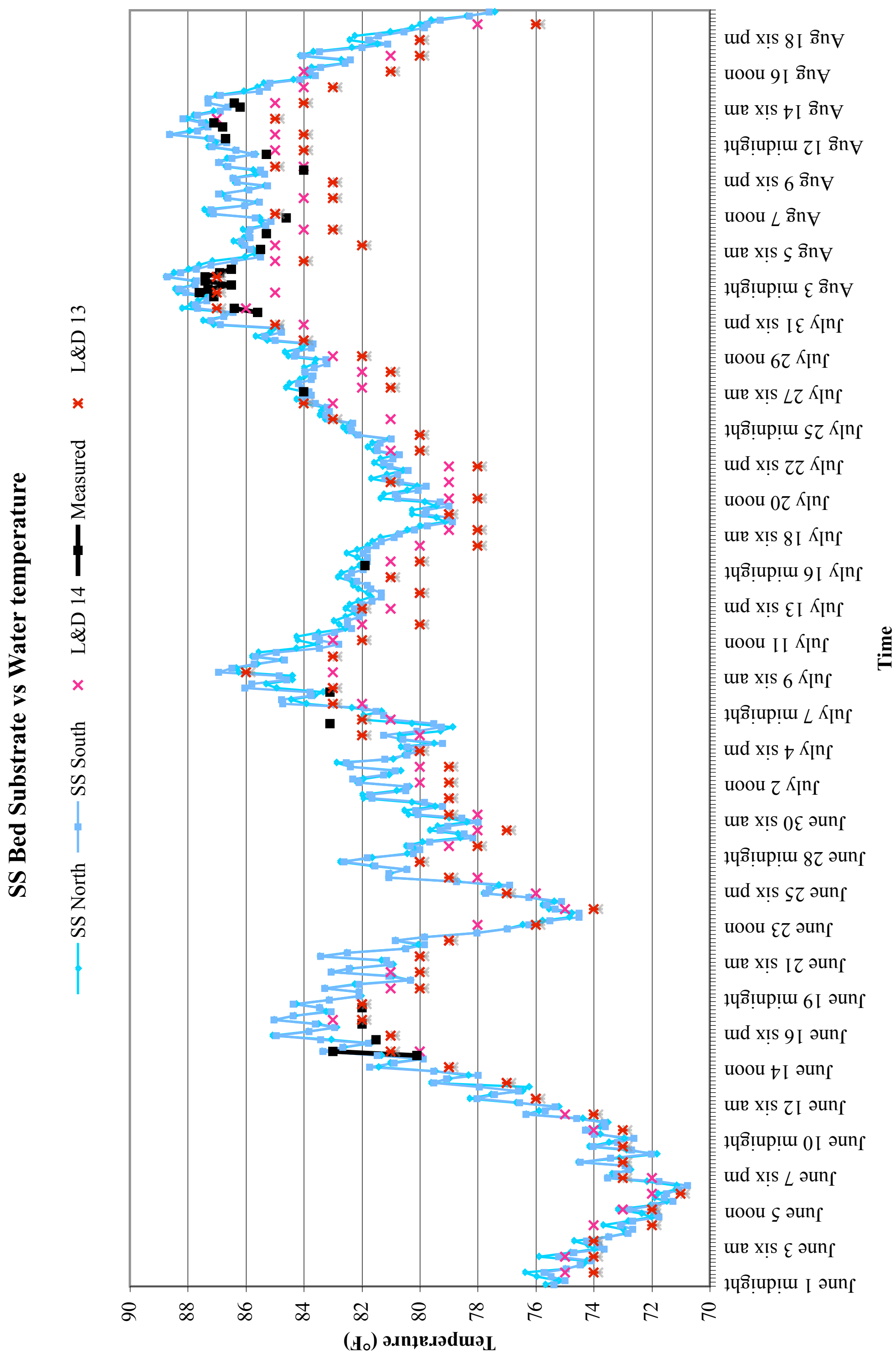

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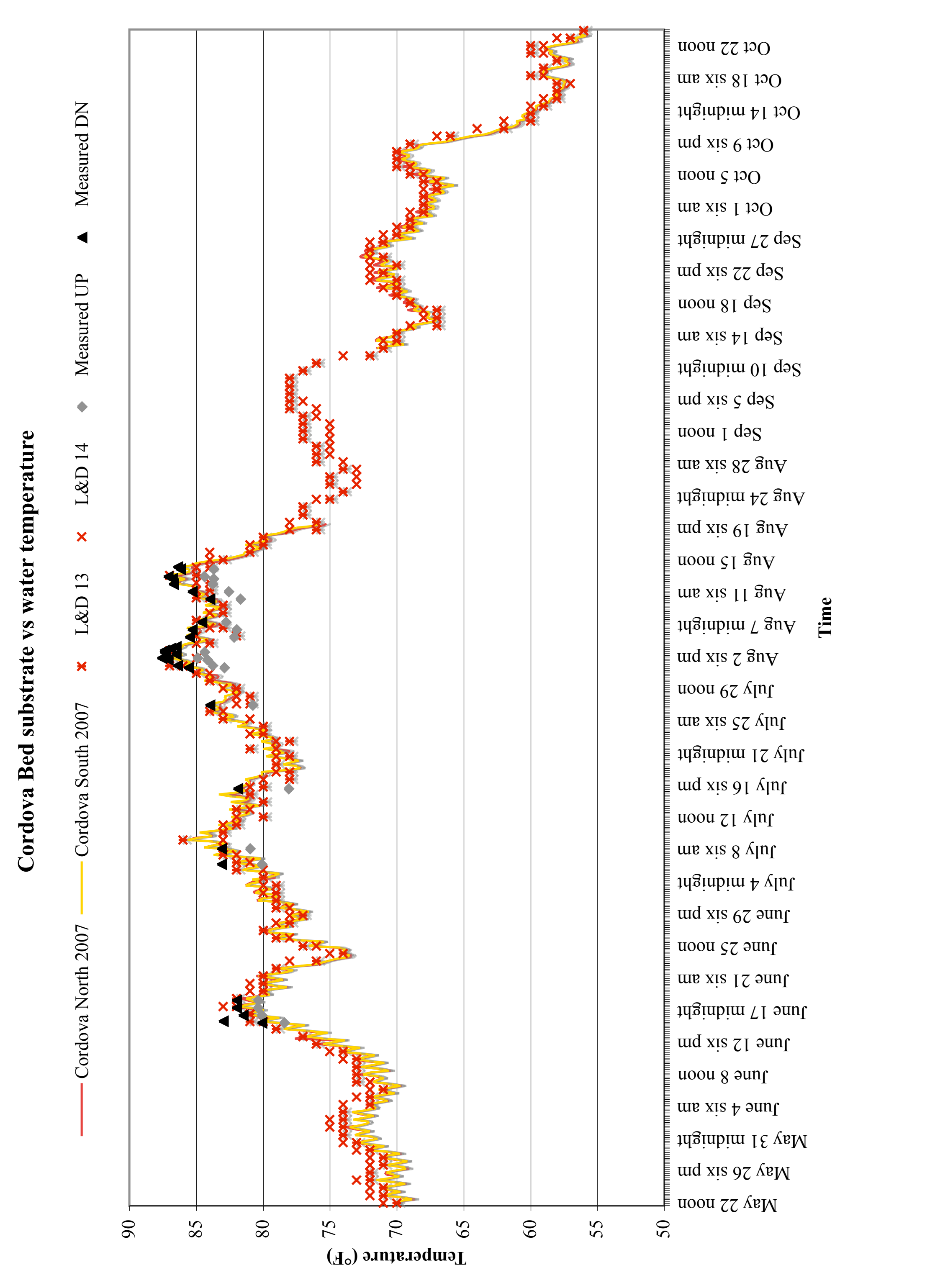
Figure 3-5. SS Bed substrate compared with Pool 14 water temperature June through August, 2007.

ESI



ECOLOGICAL SPECIALISTS, INC.

Figure 3-6. Cordova Bed substrate compared with Pool 14 water temperature June through August, 2007.

ESI

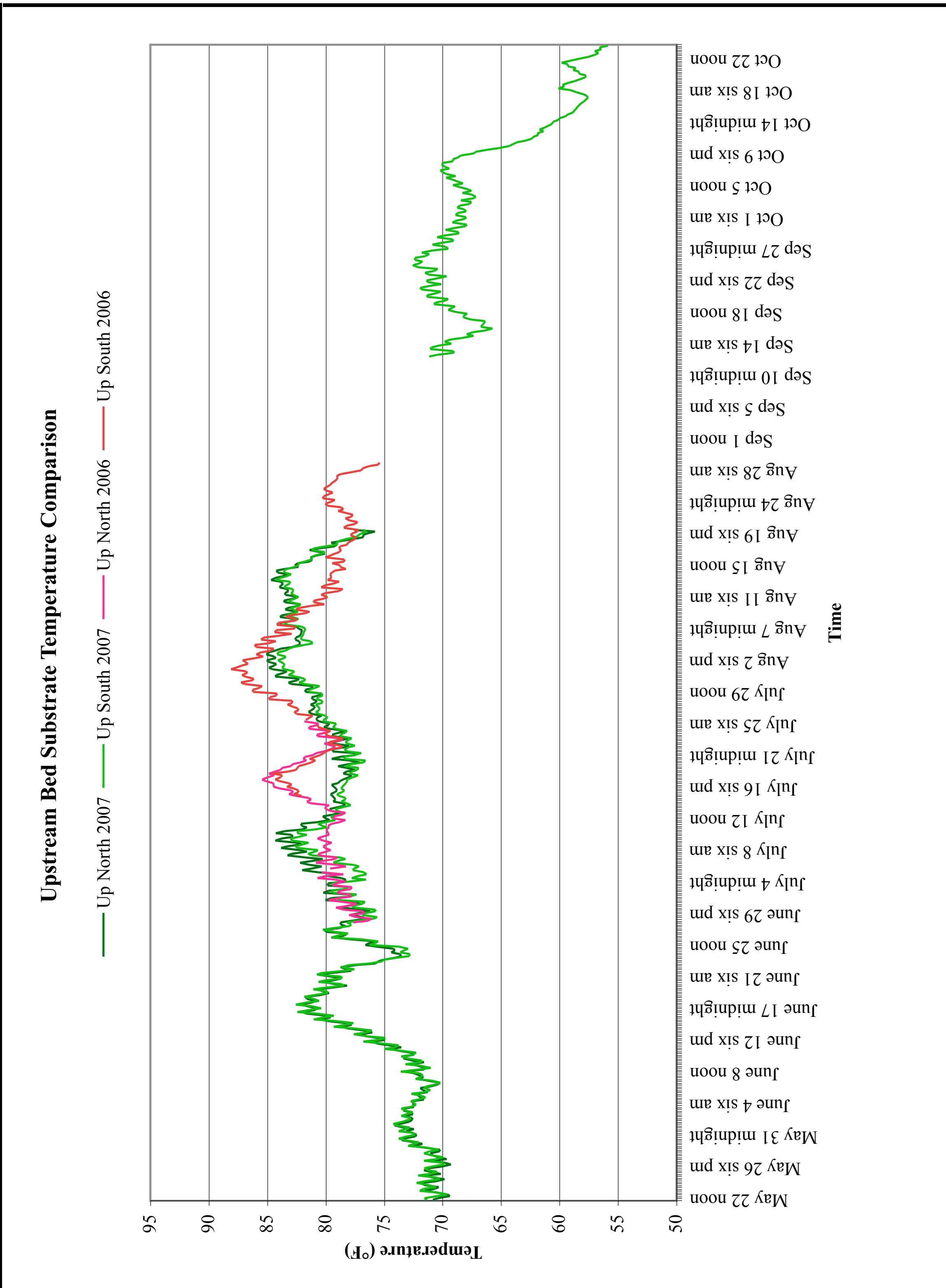


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Figure 3-7. Comparison of UP Bed substrate temperature, 2006 vs. 2007.

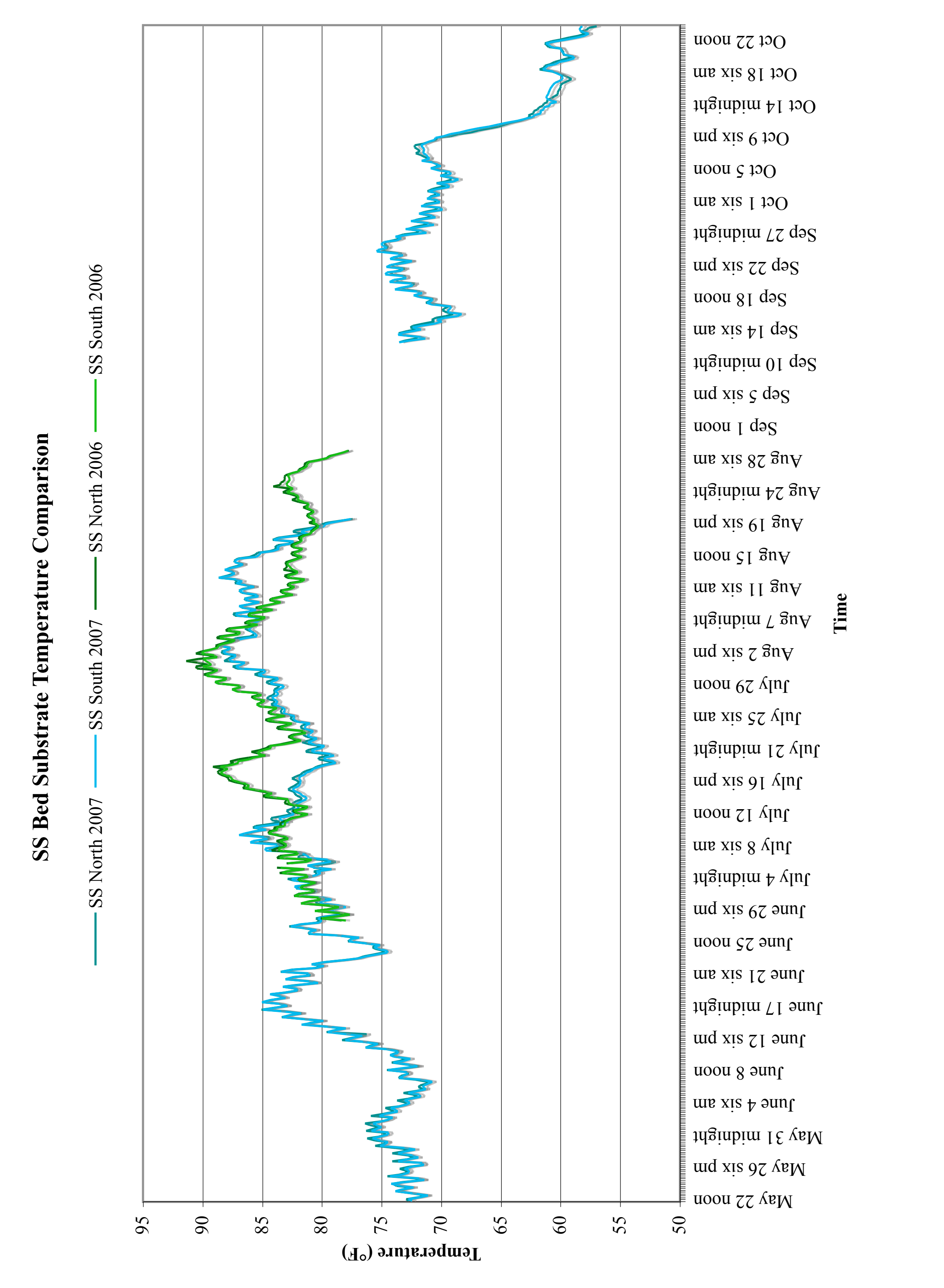

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Figure 3-8. Comparison of S Bed substrate temperature, 2006 vs. 2007.

ESI

Table 1-1. Summary of QCNS excursion hours used between 2000 and 2007.

	River discharge (cfs)		Intake temperature (°F)		Measured Dn Temp (°F)[1]	Excursion hours	
	Min	Max	Min	Max	Max	Cumulative	%
2000							
June	55,400	131,000	66.4	74.6	-	0	-
July	39,500	102,000	73.4	82.1	-	0	-
August	26,500	55,100	73.8	82.8	-	0	-
September	22,000	50,000	59.0	81.4	-	0	-
2001							
June	94,900	129,000	60.0	80.4	-	0	
July	43,300	131,000	75.2	86.4	87.0	25.25	0.3
August	25,600	56,800	73.5	87.8	87.0	57.35	0.7
September	25,800	45,200	59.7	76.9	-	57.35	0.7
2002							
June	67,000	154,000	64.5	82.1	81.0	0	-
July	62,700	104,000	77.3	84.8	83.0	0	-
August	54,300	80,800	74.7	84.2	84.0	0	-
September	38,900	74,400	63.6	79.6	80.5	0	-
2003							
June	39,600	94,300	64.7	80.3	-	0	-
July	41,500	89,900	74.9	83.2	-	0	-
August	16,200	34,100	77.0	86.2	86.0	0	-
September	16,100	43,500	59.9	81.6	82.0	0	-
2004							
June	103,000	169,000	64.9	76.6	-	0	-
July	32,100	100,000	72.5	81.2	-	0	-
August	31,700	49,300	68.2	79.6	-	0	-
September	23,100	58,300	65.2	78.8	-	0	-
2005							
June	64,500	81,718	67.4	83.0	82.0	0	
July	27,980	74,820	75.2	86.4	88.0	42.50	0.5
August	18,030	34,998	77.0	85.4	85.0	42.50	0.5
September	19,064	45,317	63.6	79.8	79.0	42.50	0.5
2006							
June	42,023	72,849	68.0	79.1	80.0	0	0.0
July	12,700	37,600	76.9	91.1	91.0	117.25	1.3
August	12,600	39,800	73.8	91.6	91.0	222.75	2.5
September	21,200	37,600	60.0	76.6		222.75	2.5
2007							
May	43,900	84,000	60.1	73.5	82.0	0	-
June	34,100	63,700	69.8	80.2	83.0	0	-
July	21,200	47,400	76.6	84.5	84.0	0	-
August	18,600	123,000	72.8	87.3	87.6	74.00	0.8
September	27,500	77,300	65	78.2	-	74.00	0.8

Exelon discharge records 2000 to 2007

[1]Maximum termperature measured as an average across the channel at various depths 500 feet downstream of the diffuser

Table 2-1. Sample sites within the QCNS study area, 2007.

	Preliminary					Intensive[3]				
Site	RM	Bank	Distance from diffuser (km)	Transects	Samples	RM	Sample area (m)	Distance from diffuser (km)	No. qual. samples	No. quan samples
UP-4 [1]	513-515.5	Illinois	10.3 - 15.3	4	12	513.5	400 x 70	14.0 -14.8	25	90
UP-7 [1]	510.5-511	Illinois	6.2 - 7.8	3	13	-	-	-	-	-
UP-8 [1]	509.1-510.1	Iowa	4.6 - 6.4	4	11	509.5	400 x 150	5.0 - 5.4	25	90
UP-10 [1]	507.5-509	Illinois	1.9 -4.6	5	13	-	-	-	-	-
UP-11 [1]	507.5-509.5	Iowa	2.1 - 3.8	3	10	-	-	-	-	-
UP Bed [2]	506.9-507.4	Iowa	0.6 - 1.5	-	12	507	400 x 80	0.7 - 1.1	25	90
SS Bed [2]	505.5-506	Iowa	0.2 - 1.3	-	13	505.6	400 x 50	0.9 - 1.3	25	90
Cordova Bed [2]	503-505.5	Illinois	1.4 - 4.8	-	4	504	400 x 100	3.3 - 3.7	25	90
Steamboat slough [3]	503.2-504.5	Iowa	2.6 - 4.1	2	4	-	-	-	-	-
DN-1 [3]	501.5-502.8	Iowa	5.5 - 6.9	4	13	-	-	-	-	-
DN-2 [1]	501.2-501.5	Illinois	7.7 - 8.2	2	11	-	-	-	-	-
DN-3 [1]	499.5-500.8	Iowa	8.3 - 10.9	3	14	499.5	400 x 150	10.5 - 10.9	25	90
DN-4 [1]	499.1-500	Illinois	9.4 - 10.7	3	5	-	-	-	-	-
DN-5 [1]	498.5-499	Iowa	11.6 - 12.0	2	12	-	-	-	-	-
DN-6 [1]	497.7-498	Illinois	12.8 - 13.2	2	5	-	-	-	-	-
DN-8 [1]	495.5-496.5	Illinois	15.6 - 17.4	3	16	-	-	-	-	-

[1] sampled June 2007
[2] sampled July 2004
[3] sampled October 2007

Table 3-1. Flow (cfs) and substrate temperature (°F) comparison between years and beds, 2006 and 2007.

	2007 May 22-31	2006 June 28-30	2007 June 1-30	2006 July 1-31	2007 July 1-31	2006 Aug 1-29	2007 [1] Aug 1-20	2007 [1] Sept 12-31	2007 Oct 1-24
Flow [2]									
Mean	60,396	51,063	49,173	26,116	29,139	27,486	53,607	40,711	76,972
Min	43,906	42,023	34,184	19,780	21,214	12,650	18,601	27,558	39,826
Max	84,014	72,849	63,757	37,641	47,420	39,828	123,040	77,372	96,063
Up Bed N									
Mean	71.1	77.4	76.0	80.6	80.2		82.4		
Min	69.1	76.1	70.2	77.3	76.8		75.0		
Max	73.5	79.2	82.2	85.4	84.5		85.2		
Up Bed S									
Mean	71.4		75.9	84.3	79.3	80.7	82.1	69.7	63.2
Min	69.6		70.2	81.0	76.1	75.2	75.2	65.7	55.8
Max	73.8		82.6	87.5	83.2	88.4	84.3	72.6	70.2
SS Bed N									
Mean	73.5	79.6	77.7	84.4	82.5	83.7	85.7	72.4	64.9
Min	71.1	77.3	70.6	79.9	78.7	77.7	75.2	69.0	57.0
Max	76.5	81.9	85.1	91.2	87.7	92.0	88.9	75.0	72.4
SS Bed S									
Mean	73.3	79.5	77.6	84.2	82.2	83.4	85.5	72.2	64.8
Min	71.0	77.2	70.3	79.8	78.6	77.8	75.2	68.2	57.2
Max	75.9	82.0	85.2	90.1	87.6	90.4	88.8	75.6	71.7
Cordova Bed N									
Mean	70.7		75.2		81.2		83.6	69.9	62.6
Min	68.6		69.6		77.0		74.8	66.8	55.7
Max	73.2		82.0		85.6		87.4	72.8	70.2
Cordova Bed S									
Mean	70.7		75.6		81.4		83.9	69.7	62.5
Min	68.7		69.7		77.1		74.8	66.8	55.9
Max	73.1		81.8		85.8		87.6	72.4	69.8
			Differences between Upstream S and downstream bed substrate temperatures						
SS N - UP									
Mean	2.1	2.1	1.8	3.1	3.2	2.9	3.6	2.6	1.6
Min	1.1	0.8	0.1	1.7	1.5	1.7	-0.2	1.8	0.5
Max	2.9	3.0	3.3	4.8	4.6	4.4	5.2	3.5	2.5
SS S - UP									
Mean	1.8	2.1	1.7	2.9	3.0	2.7	3.5	2.5	1.6
Min	1.1	0.6	-0.1	1.5	1.0	1.3	-0.1	1.4	-0.2
Max	2.5	3.0	3.1	4.3	4.4	3.8	5.1	3.5	2.7
Cordova N - UP									
Mean	-0.8		-0.2		1.9		1.5	0.2	-0.7
Min	-1.6		-1.1		-0.3		-2.0	-0.9	-1.5
Max	-0.1		2.0		4.1		3.6	1.8	0.3
Cordova S - UP									
Mean	-0.8		-0.3		2.1		1.8	-0.1	-0.7
Min	-1.5		-1.3		-0.2		-1.4	-1.2	-1.6
Max	-0.2		2.0		4.7		4.0	1.7	0.4

[1] Temperature recorders removed between August 20 and September 12, 2007 due to high river flow

[2] Discharge L&D 14, USACE gage at LeClaire

Table 3-2. Comparison of Upstream Bed habitat conditions between July 2004, July and October 2005, August and September 2006, and October 2007.

	Jul-04	Jul-05	Oct-05	Aug-06	Sep-06	Oct-07	Average
Sample date	July 15- 16, 2004	July 28, 2005	Oct. 6, 2005	Aug. 5, 2006	Sept. 22-25, 2006	Oct. 4-13, 2007	
Discharge (cfs)[1]	67,226 to 65,969	41,262	52,887	35,139	21,257 to 25,820	45,500 to 77,800	
Water temperature (°F)[1]						60 to 68	
Substrate temp (°F)				84.7		61.3 to 68.4	
Dist from bank (m)	45 to 115	45 to 115	45 to 115	45 to 115	45 to 115	45 to 115	
Dist from mix zone (m)	730 to 1130	730 to 1130	730 to 1130	730 to 1130	730 to 1130	730 to 1130	
Substrate Ave % (CV)[2]							
% Boulder	-	-	-	-	-	-	
% Cobble	-	-	-	-	-	<1 (949)	<1
% Gravel	1 (300)	<1 (632)	2 (192)	1 (268)	<1 (410)	3 (310)	1
% Sand	57 (66)	88 (18)	56 (67)	71 (50)	64 (55)	66 (59)	62
% Silt	36 (99)	11 (126)	15 (159)	9 (143)	12 (88)	5 (184)	13
% Clay	5 (224)	1 (304)	26 (121)	18 (142)	21 (140)	25 (138)	22
% Detritus	<1 (755)	-	<1 (954)	0	1 (881)	<1 (563)	<1
% Shell	<1 (343)	-	1 (215)	1 (496)	<1 (396)	1 (314)	1
Depth (m)							
Ave.	3.4	2.7	4.9	3.3	3.4	3.1	3.8
Range	(0.9 to 6.4)	(0.6 to 5.8)	(0.9 to 7.3)	(0.9 to 5.8)	(0.6 to 6.4)	(0.6 to 5.2)	
CV	16	51	102	36	30	43	
Bottom temp (°F)							
Ave.	77.9	80.4	67.8	85.3	62.1	60.8	70.3
Range	(77.5 to 79.0)	(79.7 to 80.6)	(67.5 to 68.2)	(84.6 to 85.6)	(61.0 to 62.2)	(59.9 to 60.8)	
CV	2	1	1	1	1	0.3	
Bottom DO (mg/L)							
% saturation	82.0	151.8	92.4	148.5	82.9	76.0	
Ave.	6.2	12.1	8.4	11.3	8.1	7.5	8.9
Range	(6.0 to 7.2)	(11.1 to 12.5)	(8.1 to 8.9)	(9.7 to 11.8)	(7.1 to 9.4)	(7.2 to 8.4)	
CV	22	2	3	1	6	4	
Bottom current velocity (m/sec)							
Ave.	0.5	0.3	0.4	0.04	0.1	0.2	0.2
Range	(0.2 to 0.6)	(0.03 to 0.60)	(0.19 to 0.54)	(0 to 0.2)	(0.1 to 0.2)	(0 to 0.4)	
CV	30	53	27	165	25	35	
Rel. zebra mussel inf.[4]	Moderate	0.1 (0 to 2)	0.7 (0 to 7)	0.8 (0 to 15)	1.4 (0 to 30)	0.1 (0 to 5)	0.7

[1]Lock and Dam 14 (LeClaire, IA; MRM 493.3)
[2]CV = coefficient of variation (Standard deviation*100/mean)
[3]Moderate = a few zebra mussels attached to most unionids; 2005, 2006, 2007 average and range of zebra mussels per unionid

Table 3-3. Hours substrate exceeded extreme temperatures during July and August, 2006 and 2007.

°F (°C)	>84.2 (29)	>86 (30)	>87.8 (31)	>89.6 (32)	>91.4 (33)
2006					
Upstream	304	86	2	0	0
SS Bed	746	382	185	129	2
2007					
Upstream	386	0	0	0	0
SS Bed (N)	684	337	106	0	0
Cordova Bed (N)	408	96	0	0	0

Table 3-4. Comparison of Upstream Bed unionid community characteristics between July 2004, July and October 2005, August and September 2006, and October 2007.

	Jul-04	Jul-05	Oct-05	Aug-06	Sep-06	Oct-07	Average
Species rel. abundance (%)[1]							
Ambleminae							
Amblema plicata	17.5	20.3	18.7	22.9	25.0	17.4	20.4
Fusconaia ebena	WD	-	WD	WD	-	-	WD
Fusconaia flava	6.2	1.4	5.2	4.8	4.8	6.7	5.2
Megalonaias nervosa	-	1.4	-	X	X	X	0.1
Pleurobema sintoxia	-	-	-	WD	-	-	WD
Quadrula metanevra	1.0	-	WD	-	-	-	0.1
Quadrula nodulata	1.0	X	1.2	2.4	0.8	1.5	1.2
Quadrula p. pustulosa	8.2	4.3	9.1	6.0	5.2	12.3	8.1
Quadrula quadrula	6.2	4.3	6.7	7.2	9.3	6.7	7.2
Tritogonia verrucosa	WD	-	WD	-	-	-	WD
Total Ambleminae	40.1	31.9	40.9	43.4	45.2	44.6	42.3
Anodontinae							
Arcidens confragosus	X	X	0.4	1.2	X	0.5	0.3
Lasmigona c. complanata	X	1.4	2.4	2.4	2.8	1.5	2.0
Pyganodon grandis	X	<0.5	1.2	X	X	0.5	0.4
Strophitus undulatus	WD	-	-	-	-	-	WD
Utterbackia imbecillis	1.0	<0.5	0.4	X	2.4	0.5	1.0
Total Anodontinae	1.0	1.4	4.4	3.6	5.2	3.1	3.7
Lampsilinae							
Actinonaias ligamentina	X	-	-	-	-	-	X
Ellipsaria lineolata	**1.0**	**1.4**	**X**	**X**	**X**	**X**	**0.2**
Lampsilis cardium	5.2	11.6	7.9	6.0	9.3	5.6	7.6
Lampsilis higginsii	**-**	**X**	**0.4**	**X**	**0.8**	**X**	**0.1**
Lampsilis siliquoidea	-	-	-	-	-	-	-
Lampsilis teres	WD	1.4	WD		WD	X	0.3
Leptodea fragilis	6.2	11.6	7.1	6.0	4.8	4.6	6.1
Ligumia recta	**1.0**	**X**	**0.8**	**1.2**	**1.2**	**0.5**	0.8
Obliquaria reflexa	38.1	30.4	27.8	27.7	25.4	34.9	29.9
Obovaria olivaria	5.2	2.9	2.4	2.4	1.2	1.0	2.1
Potamilus alatus	X	X	X	2.4	X	X	0.2
Potamilus capax	**-**	**-**	**-**	**-**	**-**	**WD**	**WD**
Potamilus ohiensis	1.0	2.9	0.8	2.4	0.8	0.5	1.1
Toxolasma parvus	-	-	1.2	WD	-	1.0	0.5
Truncilla donaciformis	X	4.3	5.6	4.8	4.8	3.6	4.2
Truncilla truncata	1.0		0.8	WD	1.2	0.5	0.7
Total Lampsilinae	58.7	66.7	54.8	53.0	49.6	52.3	54.0

WD = weathered shell
Bold indicates Illinois and Federally threatened and endangered species

Table 3-4. Comparison of Upstream bed unionid community characteristics between July 2004, July and October 2005, August and September 2006, and October 2007 (cont.).

	Jul-04	Jul-05	Oct-05	Aug-06	Sep-06	Oct-07	Average
Total no.[2]	902	399	822	609	508	958	699.7
Ave. no./m[2,1]	8.1±3.1A	6.9±3.1A	11.2±2.6A	8.3±4.2A	11.0±4.3A	8.7±2.1A	9.5±1.4
Ave. CPUE [3]	53.7	15.7	22.8	26.3	12.4	30.5	25.2
No. species/qual sample	10.7	6.0	6.3	7.4	6.0	7.1	
Total no. species[2]	21	21	21	20	21	23	21.3
Cumulative live/FD species	21	24	25	25	25	25	
Theoretical species richness[3]							
100	13	16	14	15	14	14	
250	15	19	17	18	17	17	
500	17	21	19	20	19	19	
1000	19	24	21	22	21	21	
5000	23	29	26	27	26	26	
Regression slope	6.5	7.9	7.0	7.3	7.1	6.9	
Ave. no. young/m[2 1]	1.3 ±0.9B	1.5 ±0.9AB	3.7 ±1.1A	3.8±2.2AB	3.8±1.2A	2.8±0.9AB	3.0±0.5
Ave. no. adults/m[2 1]	6.8 ±2.5A	5.4 ±2.8A	7.5±1.9A	4.5±2.4A	7.2±3.6A	5.9±1.7A	6.5±1.1
% young[1]	16.5	21.7	33.3	45.8	34.3	32.3	31.9
% of species w/young[1]	73.3	46.7	80.0	46.7	81.3	78.2	
Ave. no. FD/m[2,1]	0.6 ±0.5A	0.1±0.2A	0.4±0.3A	0.6±0.5A	2.0±0.8B	0.4±0.3A	0.8±0.2
%Mortality[1]	6.7	1.4	3.1	6.7	15.1	4.4	7.4
% adult mortality				10.0	8.9	4.3	
% juvenile mortality				2.6	24.8	4.5	
Ambleminae							
Total no. [1]	39	22	103	36	112	87	66.5
Total no. [3]	396	145	236	230	128	317	242.0
Ave. no./m[2,1]	3.3±1.6A*	2.2±1.3A*	4.6±1.4A*	3.6±2.1A*	5.0±1.8A*	3.9±1.2A*	4.0±0.7*
Ave. no.≤5yrs/m[2,1]	0.5±0.4AB	0.1±0.2A	1.7±0.7BC	1.6±1.1ABC	2.1±0.8C	1.5±0.6B	1.4±0.3
Ave. no.>5yrs/m[2,1]	2.8±1.3A	2.1±1.2A	2.9±0.9A	2.0±1.6A	2.9±1.5A	2.4±0.9A	2.6±0.5
% young	15.4	4.5	36.9	44.4	42.0	37.9	35.3
Total no. species[2]	6	6	5	6	6	6	5.8
Total no. juv species	6	4	5	5	5	6	
Total no. adult species	5	6	5	6	6	5	
Ave. no. FD/m[2,1]	0.1±0.2A	0A	0.1±0.1A	0.1±0.2A	0.3±0.3A	0.2±0.2A	0.2±0.1
%Mortality[1]	2.5	0	1.9	2.7	5.9	4.4	3.6
% adult mortality				4.8	3.0	3.6	
% juvenile mortality				0	9.6	5.7	
Lampsilinae							
Total no. [1]	57	46	138	44	123	102	85.0
Total no. [3]	378	169	321	273	154	416	285.2
Ave. no./m[2,1]	4.8±2.0A#	4.6±2.1A#	6.1±1.5A#	4.4±2.1A*	5.5±2.5A*	4.5±1.2A*	5.1±0.8#
Ave. no.≤3yrs/m[2,1]	0.8±0.7A	1.4±0.9A	2.0±0.8A	2.2±1.5A	1.4±0.8A	1.3±0.5A	1.5±0.3
Ave. no.>3yrs/m[2,1]	3.9±1.6A	3.2±1.7A	4.1±1.3A	2.2±1.1A	4.0±2.2A	3.2±1.0A	3.6±0.7
% young	17.5	30.4	32.6	50.0	26.0	28.4	29.8
Total no. species[2]	11	10	12	10	11	14	11.3
Total no. juv species	9	5	9	10	8	10	
Total no. adult species	11	9	11	7	10	12	
Ave. no. FD/m[2,1]	0.4±0.5A	0A	0.2±0.2A	0.4±0.4A	1.5±0.6B	0.1±0.2A	0.5±0.2
%Mortality[1]	8.1	0	3.5	8.3	21.7	2.9	9.1
% adult mortality				12.0	12.5	2.7	
% juvenile mortality				4.3	39.6	3.3	

[1]Quantitative data only; [2]Quantitative and Qualitative combined; [3]Qualitative data only
Different letters within a row indicates a significant difference (ANOVA, p<0.05)
Different symbols within a column indicates a significant difference (t-test; p<0.10)

Table 3-5. Age (external annuli count) frequency of unionid species collected in the UP Bed, October 2007.

			Age (external annuli count)[2]																		
Subfamily	Species	Young[1]	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	24	Total
Ambleminae	*Amblema plicata*	Y			3	4	2	4	5	2	2	1		1	1	2	1	2	1	3		34
	Fusconaia flava	Y		1	3	1		1		1	1	1		1	1	2						13
	Megalonaias nervosa	Y																				
	Quadrula nodulata	Y			1		1		1													3
	Quadrula p. pustulosa	Y		2	3		2	3	1	2	1	1	1	1	3	1		2		1		24
	Quadrula quadrula	Y			1			1		1	1	2	3	1			1	1				12
Ambleminae Total				3	11	5	5	9	7	6	5	5	4	4	5	5	2	5	1	4		86
Anodontinae	*Arcidens confragosus*													1								1
	Lasmigona c. complanata																		1	1	1	3
	Pyganodon grandis	Y												1								1
	Utterbackia imbecillis	Y		1																		1
Anodontinae Total				1										2					1	1	1	6
Lampsilinae	***Ellipsaria lineolata***	**Y**																				
	Lampsilis cardium	Y		1				1	2			2	1	1		2	1					11
	Lampsilis higginsii																					
	Lampsilis teres	Y																				
	Leptodea fragilis	Y		1	5	1		1			1											9
	Ligumia recta											**1**										**1**
	Obliquaria reflexa	Y		2	4	7	12	15	6	4	6	5	3	3	1							68
	Obovaria olivaria	Y											1		1							2
	Potamilus alatus	Y																				
	Potamilus ohiensis	Y		1																		1
	Toxolasma parvus	Y	1		1																	2
	Truncilla donaciformis	Y		1	2	2	1		1													7
	Truncilla truncata							1														1
Lampsilinae Total			1	6	12	10	13	18	9	4	7	8	5	4	2	2	1					102
Total			1	10	23	15	18	27	16	10	12	13	9	10	7	7	3	5	2	5	1	194

Bold indicates Illinois and Federally threatened and endangered species
[1]All methods
[2]Quantitative samples only

Table 3-6. Comparison of Steamboat Slough Bed habitat conditions between July 2004, July and October 2005, August and September 2006, and October 2007.

	Jul-04	Jul-05	Oct-05	Aug-06	Sep-06	Oct-07	Average
Sample date	July 16, 2004	July 26 -28, 2005	Oct 5- 6, 2005	Aug 4-5, 2006	Sept 20-24, 2006	Oct 5-13, 2007	
Discharge (cfs)[1]	65,969	39,203 to 41,262	54,383 to 52,887	27,695 to 35,189	21,257 to 30,178	56,600 to 77,700	
Water temperature (°F)[1]						60 to 70	
Substrate temp N end				88.0 to 87.4		62.0 to 70.1	
Substrate temp S end				88.0 to 87.1		61.4 to 70.1	
Dist from bank (m)	35 to 115	35 to 115	35 to 115	35 to 115	35 to 115	35 to 115	
Dist from mix zone (m)	675 to 1125	675 to 1125	675 to 1125	675 to 1125	675 to 1125	675 to 1125	
<u>Substrate Ave % (CV)[2]</u>							
% Boulder	-	-	2 (22)	-	-	-	<1
% Cobble	<1 (762)	-	-	-	-	-	<1
% Gravel	<1 (645)	-	-	-	-	-	<1
% Sand	90 (21)	91 (21)	95 (16)	69 (35)	71 (29)	49 (76)	75
% Silt	6 (200)	9 (211)	3 (166)	23 (83)	26 (67)	49 (76)	22
% Clay	3 (281)	<1 (632)	-	6 (105)	2 (174)	1 (501)	1
% Detritus	<1 (313)	1 (371)	-	2 (207)	1 (352)	1 (498)	1
% Shell	-	-	<1 (954)	-	-		<1
<u>Depth (m)</u>							
Ave.	2.4	1.8	2.7	2.0	2.1	1.9	2.4
Range	(1.7 to 3.7)	(0.9 to 2.7)	(0.9 to 4.3)	(1.2 to 3.4)	(1.2 to 3.3)	(0.9 to 3.4)	
CV	24	20	74	32	18	25	
<u>Bottom temp (°F)</u>							
Ave.	79.7	85.1	71.1	88.0	66.4	60.8	73.0
Range	(77.0 to 80.6)	(81.5 to 86.0)	(69.4 to 73.2)	(87.4 to 88.7)	(64.6 to 67.1)	60.8	
CV	1.2	3.0	4.4	0.6	1.3	0	
<u>Bottom DO (mg/L)</u>							
% saturation	83.3	119.3	92.2	146.5	91.8	84.1	
Ave.	6.7	9.1	8.1	10.9	8.5	8.3	8.7
Range	(6.4 to 7.4)	(7.5 to 12.8)	(7.8 to 8.9)	(5.1 to 12.0)	(7.9 to 9.5)	(7.6 to 9.0)	
CV	10.9	20.7	3.1	14.0	4.0	5.3	
<u>Bottom current velocity (m/sec)</u>							
Ave.	0.4	0.2	0.3	0.03	0.1	0.2	0.2
Range	(0.2 to 0.6)	(0.11 to 0.30)	(0.14 to 0.45)	(0 to 0.19)	(0.09 to 0.2)	(0.1 to 0.4)	
CV	15.7	20.7	30.5	185	22.6	225.9	
Rel. zebra mussel inf.[3]	Minor	0.1 (0 to 1)	0.1 (0 to 10)	-	0.02 (0 to 1)	0.01 (0 to 1)	0.04

[1]Lock and Dam 14 (LeClaire, IA; MRM 493.3)
[2]CV = coefficient of variation (Standard deviation*100/mean)
[3]Minor = a few zebra mussels attached to a few unionids; 2005, 2006, 2007 average and range of zebra mussels per unionid

Table 3-7. Comparison of Steamboat Slough Bed unionid community characteristics between July 2004, July and October 2005, August and September 2006, and October 2007.

	Jul-04	Jul-05	Oct-05	Aug-06	Sep-06	Oct-07	Average
Species rel. abundance (%)[1]							
Ambleminae							
Amblema plicata	41.5	26.8	30.9	32.2	22.3	22.6	28.3
Fusconaia ebena	-	-	-	-	-	-	-
Fusconaia flava	X	9.8	2.1	1.1	3.2	2.2	2.6
Megalonaias nervosa	-	-	-	-	-	X	X
Pleurobema sintoxia	-	-	-	X	-	X	X
Quadrula metanevra	-	-	-	-	-	-	-
Quadrula nodulata	9.8	2.4	6.4	11.1	13.8	16.1	10.8
Quadrula p. pustulosa	4.9	7.3	5.3	4.4	3.2	10.8	6.0
Quadrula quadrula	4.9	14.6	17.0	12.2	11.7	9.7	12.1
Tritogonia verrucosa	-	-	-	-	-	-	-
Total Ambleminae	61.1	61.0	61.7	61.1	54.3	61.3	59.8
Anodontinae							
Arcidens confragosus	X	2.4	X	-	-	-	0.2
Lasmigona c. complanata	2.4	X	X	X	1.1	1.1	0.7
Pyganodon grandis	X	2.4	X	1.1	FD	X	0.4
Strophitus undulatus	-	-	-	-	-	-	-
Utterbackia imbecillis	-	X	X	-	FD	-	X
Total Anodontinae	2.4	4.9	0.0	1.1	1.1	1.1	1.3
Lampsilinae							
Actinonaias ligamentina	-	-	-	-	X	-	X
Ellipsaria lineolata	**2.4**	**X**	**-**	-	-	-	**0.2**
Lampsilis cardium	4.9	X	5.3	4.4	7.4	2.2	4.4
Lampsilis higginsii	-	-	-	-	-	-	-
Lampsilis ovata	-	-	-	-	-	-	-
Lampsilis siliquoidea	-	-	-	-	-	-	-
Lampsilis teres	-	-	-	-	-	X	X
Leptodea fragilis	X	2.4	4.3	2.2	3.2	-	2.2
Ligumia recta	**-**	**-**	**1.1**	**X**	**1.1**	**X**	**0.4**
Obliquaria reflexa	26.8	22.0	22.3	23.3	19.1	28.0	23.4
Obovaria olivaria	2.4	-	X	X	2.1	X	0.7
Potamilus alatus	-	-	X	1.1	-	1.1	0.4
Potamilus capax	-	-	-	-	-	-	-
Potamilus ohiensis	X	7.3	3.2	4.4	7.4	3.2	4.4
Toxolasma parvus	-	-	WD	-	-	-	WD
Truncilla donaciformis	-	2.4	2.1	2.2	4.3	2.2	2.4
Truncilla truncata	-	X	X	-	-	1.1	0.2
Total Lampsilinae	36.5	34.1	38.3	37.8	44.7	37.6	38.9

WD = weathered shell
Bold indicates Illinois and Federally threatened and endangered species

Table 3-7. Comparison of Steamboat Slough Bed unionid community characteristics between July 2004, July and October 2005, August and September 2006, and October 2007 (cont).

	Jul-04	Jul-05	Oct-05	Aug-06	Sep-06	Oct-07	Average
Total no.[2]	547	426	657	398	537	546	518.5
Ave. no./m[2,1]	3.4±2.0A	4.1±1.2A	4.2±0.9A	9.0±2.6B	4.2±1.0A	4.1±1.0A	4.6±0.6
Ave. CPUE [3]	36.1	19.3	22.5	15.4	17.7	18.1	20.6
Ave. no. species/qual sample[3]	7.8	5.6	7.2	6.0	6.3	6.8	
Total no. species[2]	15	16	18	16	16	18	16.5
Cumulative live/FD species	15	18	19	20	21	23	
Theoretical species richness[3]							
100	12	11	13	12	10	12	
250	14	14	16	14	12	15	
500	16	15	18	16	14	17	
1000	17	17	20	18	15	18	
5000	22	21	24	22	19	23	
Regression slope	5.8	5.6	6.5	6.0	5.1	6.1	
Ave. no. young/m[2,1]	0.2 ±0.2A	0.4 ±0.4AB	0.4 ±0.2A	1.8±0.8C	1.5±0.5C	1.3±0.5BC	1.0±0.2
Ave. no. adults/m[2,1]	3.3 ±1.9A	3.7 ±1.2AB	3.8 ±0.9A	7.2±2.3B	2.7±0.8A	2.8±0.8A	3.6±0.5
% young[1]	4.9	9.8	8.5	20.0	35.1	32.3	21.0
% of species w/ young[1]	33.3	41.7	63.6	66.7	84.6	55.6	
Ave. no. FD/m[2,1]	0.2 ±0.2A	0.1 ±0.2A	0.1 ±0.2A	0.1±02A	0.5±0.3A	0.09±0.12A	0.18±0.09
%Mortality[1]	4.7	2.4	3.1	1.1	8.7	2.1	
% adult mortality				1.4	9.0	1.6	
% young mortality				0	8.3	3.2	
Ambleminae							
Total no. [1]	25	25	58	55	51	57	45.2
Total no. [3]	335	259	347	207	275	287	285.0
Ave. no./m[2,1]	2.1±1.4A*	2.5±1.0AB*	2.6±0.7A*	5.5±2.2B*	2.3±0.7A*	2.5±0.7A*	2.7±0.4*
Ave. no.≤5yrs/m[2,1]	0.2±0.2A	0.2±0.3A	0.2±0.2A	1.2±0.7B	0.8±0.4AB	1.1±0.5B	0.6±0.2
Ave. no.>5yrs/m[2,1]	1.9±1.3A	2.3±1.0AB	2.4±0.7AB	4.3±1.9B	1.5±0.6A	1.4±0.5A	2.1±0.4
% young	8.0	8.0	6.9	21.8	33.3	43.9	22.9
Total no. species[2]	5	5	5	6	5	7	5.5
Total no. juv species	5	4	4	4	5	5	
Total no. adult species	5	5	5	6	5	7	
Ave. no. FD/m[2,1]	0.1±0.2A	0A	0.04±0.09A	0.1±02A	0.04±0.09A	0.04±0.09A	0.05±0.04
%Mortality[1]	3.8	0	1.7	1.8	1.9	1.7	
% adult mortality				2.3	2.9	0	
% young mortality				0	0	3.8	
Lampsilinae							
Total no. [1]	15	14	36	34	42	35	29.3
Total no. [3]	163	123	197	99	265	152	166.5
Ave. no./m[2,1]	1.3±0.9A*	1.4±0.8A*	1.6±0.6A#	3.4±1.3B*	1.9±0.7AB*	1.6±0.6A*	1.8±0.3#
Ave. no.≤3yrs/m[2,1]	0A	0.2±0.3AB	0.2±0.2AB	0.6±0.5B	0.7±0.4B	0.2±0.2AB	0.3±0.1
Ave. no.>3yrs/m[2,1]	1.3±0.9A	1.2±0.7A	1.4±0.6A	2.8±1.3A	1.2±0.5A	1.3±0.5A	1.4±0.3
% young	0	14.3	11.1	17.6	35.7	14.3	18.2
Total no. species[2]	9	7	10	8	8	9	
Total no. juv species	7	3	5	6	6	4	
Total no. adult species	7	7	10	6	8	8	
Ave. no. FD/m[2,1]	0.1±0.2A	0.1 ±0.2A	0.1±0.1A	0A	0.3±0.2A	0.04±0.09A	0.11±0.07
%Mortality[1]	6.3	6.7	7.1	0	12.5	2.8	
% adult mortality				0	12.9	3.2	
% young mortality				0	11.8	0	

[1]Quantitative data only; [2]Quantitative and Qualitative combined; [3]Qualitative data only; Species richness includes prelimimary samples in 2004
Different letters within a row indicates a significant difference (ANOVA, p<0.05)
Different symbols within a column indicates a significant difference (t-test; p<0.10)

Table 3-8. Comparison of unionid beds sampled in October 2007.

	Albany	HS	UP	SS	Cordova	WG
Species rel. abundance (%)[1]						
Ambleminae						
Amblema plicata	20.3	16.0	17.4	22.6	33.3	18.0
Fusconaia ebena	-	-	-	-	-	-
Fusconaia flava	4.7	5.6	6.7	2.2	1.0	1.5
Megalonaias nervosa	1.4	0.4	X	X	1.9	3.0
Pleurobema sintoxia	-	0.8	-	X	-	X
Quadrula metanevra	-	-	P	-	-	-
Quadrula nodulata	0.7	6.0	1.5	16.1	X	6.8
Quadrula p. pustulosa	17.6	32.4	12.3	10.8	7.6	1.5
Quadrula quadrula	2.7	6.8	6.7	9.7	1.9	29.3
Tritogonia verrucosa	-	-	-	-	-	-
Total Ambleminae	47.3	68.0	44.6	61.3	45.7	60.2
Anodontinae						
Arcidens confragosus	0.7	X	0.5	P	X	1.5
Lasmigona c. complanata	X	0.4	1.5	1.1	X	2.3
Pyganodon grandis	2.0	X	0.5	X	X	2.3
Strophitus undulatus	X	X	-	-	1.0	-
Utterbackia imbecillis	2.0	-	0.5	P	1.0	X
Total Anodontinae	4.7	0.4	3.1	1.1	1.9	6.0
Lampsilinae						
Actinonaias ligamentina	-	-	P	P	1.0	-
Ellipsaria lineolata	-	**0.8**	**X**	**P**	**X**	**0.8**
Lampsilis cardium	8.8	7.2	5.6	2.2	7.6	2.3
Lampsilis higginsii	**1.4**	**0.4**	**X**	-	**1.9**	**X**
Lampsilis siliquoidea	-	-	-	-	P	-
Lampsilis teres	-	X	X	X	-	X
Leptodea fragilis	9.5	0.8	4.6	P	12.4	8.3
Ligumia recta	**2.7**	**0.8**	**0.5**	**X**	**2.9**	**0.8**
Obliquaria reflexa	12.8	14.8	34.9	28.0	8.6	18.0
Obovaria olivaria	1.4	1.2	1.0	X	X	X
Potamilus alatus	0.7	0.8	X	1.1	3.8	X
Potamilus capax	-	-	WD	-	-	-
Potamilus ohiensis	0.7	1.6	0.5	3.2	X	4.5
Toxolasma parvus	2.7	-	1.0	-	5.7	-
Truncilla donaciformis	7.4	2.4	3.6	2.2	8.6	6.8
Truncilla truncata	-	0.8	0.5	1.1	P	X
Total Lampsilinae	48.0	31.6	52.3	37.6	52.4	33.8

WD = weathered shell
Bold indicates Illinois and Federally threatened and endangered species

Table 3-8. Comparison of unionid beds sampled in October 2007 (cont.).

	Albany	HS	UP	SS	Cordova	WG
Total no.[2]	659	1311	958	546	651	1339
Ave. no./m[2,1]	6.6±1.8AC	11.1±3.1B	8.7±2.1BC	4.1±1.0A	4.7±1.2A	5.9±1.3AC
Ave. CPUE [3]	15.1	27.6	30.5	18.1	21.8	34.2
Ave. no. species/qual sample[3]	7.4	7.4	7.1	6.8	7.6	7.4
Total no. species[2]	21	23	24	18	23	23
Cumulative live/FD species	21	23	26	23	25	23
Theoretical species richness[3]						
100	15	12	14	12	15	14
250	17	15	17	15	18	17
500	20	17	19	17	20	19
1000	22	19	21	18	23	21
5000	27	23	26	23	28	26
Regression slope	7.28	6.17	6.92	6.12	7.52	6.97
Ave. no. young/m[2,1]	2.8±0.8A	3.2±0.9B	2.8±0.9AB	1.3±0.5A	1.6±0.7A	2.4±0.7A
Ave. no. adults/m[2,1]	3.8±1.3BC	7.9±2.9B	5.9±1.7BC	2.8±0.8A	3.0±0.9AC	3.5±1.0ABC
% young[1]	41.9	29.2	32.3	32.3	35.2	40.6
% of species w/ ≤5 yrs[1]	81.0	69.6	75.0	55.6	69.6	60.9
Ave. no. FD/m[2,1]	0.6±0.27A	0.13±0.15A	0.4±0.3A	0.09±0.12A	0.18±0.22A	0.27±0.21A
%Mortality[1]	5.1	1.2	4.4	2.1	3.7	4.3
% adult mortality	8.5	1.7	4.3	1.6	2.9	7.1
% juvenile mortality	0	0	4.5	3.2	5.1	0
Ambleminae						
Total no. [1]	70	170	87	57	48	80
Total no. [3]	286	638	317	287	304	606
Ave. no./m[2,1]	3.1±1.1A*	7.6±2.2B*	3.9±1.2A*	2.5±0.7A*	2.1±0.8A*	3.6±1.0A*
Ave. no.≤5yrs/m[2,1]	1.1±0.5A	2.3±0.8B	1.5±0.6AB	1.1±0.5A	0.5±0.3A	1.2±0.5AB
Ave. no.>5yrs/m[2,1]	2.0±0.9A	5.2±2.0B	2.4±0.9A	1.4±0.5A	1.6±0.7A	2.4±0.8A
% young	34.3	30.6	37.9	43.9	25.0	33.8
Total no. species[2]	6	7	6	7	6	7
Total no. juv species	6	6	6	5	6	6
Total no. adult species	6	6	5	7	5	7
Ave. no. FD/m[2,1]	0.13±0.20A	0.09±0.12A	0.2±0.2A	0.04±0.09A	0.13±0.15A	0.04±0.09A
%Mortality[1]	4.1	1.1	4.4	1.7	5.9	1.2
% adult mortality	6.1	1.2	3.6	0	5.3	1.9
% juvenile mortality	0.0	0	5.7	3.8	7.7	0
Lampsilinae						
Total no. [1]	71	79	102	35	55	45
Total no. [3]	165	106	416	152	164	169
Ave. no./m[2,1]	3.2±1.1ABC*	3.5±1.1BC#	4.5±1.2B*	1.6±0.6A*	2.4±0.8AC*	2.0±0.7AC#
Ave. no.≤3yrs/m[2,1]	1.4±0.5A	0.9±0.4AB	1.3±0.5A	0.2±0.2B	1.1±0.5A	1.1±0.5A
Ave. no.>3yrs/m[2,1]	1.7±0.8AC	2.6±1.1BC	3.2±1.0B	1.3±0.5AC	1.4±0.5A	0.9±0.5A
% young	45.1	26.6	28.4	14.3	43.6	55.6
Total no. species[2]	10	12	14	9	13	12
Total no. juv species	7	8	10	4	7	5
Total no. adult species	10	11	12	8	12	10
Ave. no. FD/m[2,1]	0.22±0.19A	0.04±0.09A	0.1±0.2A	0.04±0.09A	0.04±0.09A	0.22±0.19A
%Mortality[1]	6.6	1.3	2.9	2.8	1.8	10.0
% adult mortality	11.4	1.7	2.7	3.2	0.0	20.0
% juvenile mortality	0	0	3.3	0.0	4.0	0.0

[1]Quantitative data only for %, X=collected in qualitative sample only, P=collected during previous monitoring;
2Quantitative, Qualitative, Prelimimary samples (new beds) combined; 3Qualitative data only
Different letters within a row indicates a significant difference (ANOVA, p<0.05)

Table 3-9. Age (external annuli count) frequency of unionid species collected in the SS Bed, October 2007.

			Age (external annuli count)[2]																		
Subfamily	Species	Young[1]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Total
Ambleminae	*Amblema plicata*	Y	1		3	4			1	2	1	1		2	1	2		1	1	1		21
	Fusconaia flava	Y									1								1			2
	Megalonaias nervosa																					
	Pleurobema sintoxia																					
	Quadrula nodulata	Y	1	3	3	1	3	2	1							1						15
	Quadrula p. pustulosa	Y		1	1			1		1			1	1		2	2					10
	Quadrula quadrula	Y		1	2	1						1		1	2						1	9
Ambleminae Total			2	5	9	6	3	3	2	3	2	2	1	4	3	5	2	1	2	1	1	57
Anodontinae	*Lasmigona c. complanata*																			1		1
	Pyganodon grandis	Y																				
Anodontinae Total																				1		1
Lampsilinae	*Lampsilis cardium*	Y											1		1							2
	Lampsilis teres																					
	Ligumia recta																					
	Obliquaria reflexa	Y			2	1	1	2	1	1	3	1	4	4	4	2						26
	Obovaria olivaria																					
	Potamilus alatus																1					1
	Potamilus ohiensis	Y			1	1		1														3
	Truncilla donaciformis	Y		2																		2
	Truncilla truncata									1												1
Lampsilinae Total				2	3	2	1	3	1	2	3	1	5	4	5	2	1					35
Total			2	7	12	8	4	6	3	5	5	3	6	8	8	7	3	1	2	2	1	93

Bold indicates Illinois and Federally threatened and endangered species
[1]All methods
[2]Quantitative samples only

Table 3-10. Comparison of Cordova Bed habitat conditions between July 2004, July and October 2005, August and September 2006, and October 2007.

	Jul-04	Jul-05	Oct-05	Aug-06	Sep-06	Oct-07	Average
Sample date	Jul 13-14, 2004	July 27, 2006	Oct 3-4, 2005	Aug 3-4, 2006	Sept 20-24, 2006	Oct 6-12, 2007	
Discharge (cfs)[1]	72,916 to 69,220	38,153	47,125 to 52,245	18,544 to 27,695	21,257 to 30,178	67,300 to 77,700	
Water temperature (°F)[1]						60 to 70	
Substrate temp N end						60.8 to 69.3	
Substrate temp S end						61.0 to 69.0	
Dist from bank (m)	10 to 90	10 to 90	10 to 90	10 to 90	10 to 90	10 to 90	
Dist from mix zone (m)	3030 to 3365	3030 to 3365	3030 to 3365	3030 to 3365	3030 to 3365	3030 to 3365	
Substrate Ave % (CV)[2]							
% Boulder	<1	3 (2.6)	2 (700)	0	0	3 (525)	1
% Cobble	2 (377)	-	1 (663)	<1 (624)	<1 (500)	<1 (949)	1
% Gravel	13 (152)	6 (118)	10 (142)	13 (120)	8 (113)	15 (182)	13
% Sand	33 (105)	77 (29)	66 (39)	40 (64)	43 (66)	17 (155)	43
% Silt	27 (106)	6 (128)	9 (212)	9 (116)	21 (86)	19 (150)	17
% Clay	13 (185)	0	0	19 (131)	7 (208)	1 (585)	4
% Detritus	<1 (332)	0	<1 (412)	0	0	<1 (949)	<1
% Shell	12 (181)	8 (171)	13 (143)	18 (135)	18 (147)	44 (98)	21
% Vegetation				<1 (624)	1 (479)	1 (534)	1
Depth (m)							
Ave.	2.0	2.1	3.0	1.7	2.2	1.6	1.9
Range	(0.6 to 3.4)	(1.2 to 3.7)	(0.6 to 6.7)	(0.6 to 3.0)	(0.1 to 6.4)	(0.9 to 2.7)	
CV	28.3	85.7	146.7	45	57	32	
Bottom temp (°F)							
Ave.	77.5	77.5	65.5	87.3	64.2	60.9	69.9
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)	
CV	0.6	5.9	5.3	2.8	1.0	0.9	
Bottom DO (mg/L)							
% saturation	73.1		88.2	87.5	82.4	85.1	
Ave.	6.0		8.3	8.5	7.8	8.4	8.2
Range	(5.7 to 6.6)		(7.2 to 14.0)	(7.7 to 9.6)	(4.3 to 18.1)	(8.0 to 8.6)	
CV	12.6		3.7	7.3	55.6	1.7	
Bottom current velocity (m/sec)							
Ave.	0.2	0.2	0.2	0.04	0.06	0.2	0.1
Range	(0.1 to 0.4)	(0.06 to 0.30)	(0.05 to 0.45)	(0 to 0.2)	(0.01 to 0.13)	(0 to 0.4)	
CV	48	42	54	127	52	71	
Rel. zebra mussel inf.[3]	Very heavy	0.3 (0 to 5)	1.3 (0 to 50)	0.1 (0 to 20)	0.3 (0 to 12)	0.01 (0 to 1)	0.6

[1]Lock and Dam 14 (LeClaire, IA; MRM 493.3)
[2]CV=coefficient of variation (Standard deviation*100/mean)
[3]Very heavy=most unionids coated or encased with zebra mussels; 2005, 2006, and 2007 average and range of zebra mussels per unionid

Table 3-11. Zebra mussel occurrence in the Cordova Bed, 1991 to 2003.

Year	Density (no./m^2)	% of unionids infested	Ave. no/unionid	Source
1991	0			Miller and Payne (1993)
1992	0			Miller and Payne (1994)
1993				
1994	8.2			Miller and Payne (1995)
1999		74	<50	ESI (1999)
2000 (near bank)	Substrate covered	100	<30 near bank	Helms (2000), ESI (2001)
2000 (riverward)			encrusted	
2001		Few	<5	ESI (2002)
2001	3000 to 4000			Farr *et al.* (2002)
2002		33	<10	ESI (2004)
2003	813			ERDC (2003)

Table 3-12. Habitat conditions in Albany, HS, UP, SS, Cordova, and WG beds, October 2007.

	Albany	HS	UP	SS	Cordova	WG
Sample date	Oct. 10,11, 14	Oct. 9, 10, 14	Oct. 4, 5, 13	Oct 5, 6, 13	Oct 6, 7, 12	Oct. 8,12
Discharge (cfs)[1]	74,700 to 77,700	75,200 to 77700	45,500 to 77,800	56,600 to 77,700	67,300 to 77,700	70,600 to 77,700
Water temperature (°F)[1]	59 to 66	59 to 69	60 to 68	60 to 70	60 to 70	60 to 70
Substrate temp N end (°F)				62.0 to 70.1	60.8 to 69.3	
Substrate temp S end (°F)			61.3 to 68.4	61.4 to 70.1	61.0 to 69.0	
Dist from bank (m)	10 to 70	10 to 150	45 to 115	35 to 115	10 to 90	10 to 150
Dist from mix zone (m)	14,000 to 14,400	5000 to 5400	730 to 1130	675 to 1125	3030 to 3365	10,500 to 10,900
Bank	Illinois	Iowa	Iowa	Iowa	Illinois	Iowa
Substrate Ave % (CV)[2]						
% Bedrock	2 (667)	0	0	0	0	0
% Boulder	-	<1 (949)	0	0	3 (525)	<1 (943)
% Cobble	7 (240)	<1 (780)	<1 (949)	0	<1 (949)	0
% Gravel	24 (133)	<1 (949)	3 (310)	0	15 (182)	1 (559)
% Sand	18 (177)	82 (42)	66 (59)	49 (76)	17 (155)	18 (135)
% Silt	4 (284)	11 (205)	5 (184)	49 (76)	19 (150)	33 (76)
% Clay	1 (327)	6 (274)	25 (138)	1 (501)	1 (585)	33 (96)
% Detritus	0	<1 (575)	<1 (563)	1 (498)	<1 (949)	<1 (663)
% Shell	44 (86)	0	1 (314)	0	44 (98)	15 (207)
% Vegetation	<1 (917)	0	0	0	1 (534)	0
Depth (m)						
Ave.	1.4	1.5	3.1	1.9	1.6	2.8
Range	(0.6 to 2.4)	(0.6 to 2.7)	(0.6 to 5.2)	(0.9 to 3.4)	(0.9 to 2.7)	(0.3 to 4.3)
CV	36	41	43	25	32	50
Bottom temp (°F)						
Ave.	59.0	59.5	60.8	60.8	60.9	61.6
Range	(58.1 to 59.0)	(57.2 to 60.8)	(59.9 to 60.8)	60.8	(60.9 to 61.7)	(59.0 to 62.6)
CV	0.7	2.7	0.3	0	0.9	2.8
Bottom DO (mg/L)						
% saturation	81.3	81.8	76.0	84.1	85.1	84.0
Ave.	8.2	8.2	7.5	8.3	8.4	8.2
Range	(7.8 to 8.4)	(8.0 to 8.3)	(7.2 to 8.4)	(7.6 to 9.0)	(8.0 to 8.6)	(7.6 to 8.6)
CV	1.8	1.0	4.0	5.3	1.7	3.3
Bottom current velocity (m/sec)						
Ave.	0.1	0.2	0.2	0.2	0.2	0.1
Range	(0 to 0.3)	(0.1 to 0.3)	(0 to 0.4)	(0.1 to 0.4)	(0 to 0.4)	(0 to 0.3)
CV	67	22	35	226	71	51
Rel. zebra mussel inf.[3]	0.01 (0 to 1)	0.1 (0 to 4)	0.08 (0 to 5)	0.01 (0 to 1)	0.01 (0 to 1)	0.08 (0 to 6)

[1]Lock and Dam 14 (LeClaire, IA; MRM 493.3)
[2]CV=coefficient of variation (Standard deviation*100/mean)
[3]Average no. zebra mussels/unionid (range)

Table 3-13. Comparison of Cordova Bed unionid community characteristics between July 2004, July and October 2005, August and September 2006, and October 2007.

	Jul-04	Jul-05	Oct-05	Aug-06	Sep-06	Oct-07	Average
Species rel. abundance (%)[1]							
Ambleminae							
Amblema plicata	27.9	50.0	24.6	27.0	35.8	33.3	30.9
Fusconaia ebena	WD	-	-	-	-	-	WD
Fusconaia flava	X	3.3	3.1	2.7	4.5	1.0	2.3
Megalonaias nervosa	2.9	X	4.6	2.7	4.5	1.9	3.2
Quadrula metanevra	WD	-	-	-	-	-	WD
Quadrula nodulata	-	-	-	2.7	FD	X	0.2
Quadrula p. pustulosa	5.9	6.7	4.6	2.7	4.5	7.6	5.5
Quadrula quadrula	2.9	X	2.3	2.7	X	1.9	1.8
Tritogonia verrucosa	SF	-	WD	-	-	-	WD
Total Ambleminae	39.6	60.0	39.2	40.5	49.3	45.7	43.9
Anodontinae							
Arcidens confragosus	X	3.3	X	X	X	X	0.2
Lasmigona c. complanata	1.5	X	1.5	WD	1.5	X	0.9
Pyganodon grandis	X	X	0.8	8.1	X	X	0.9
Strophitus undulatus	-	-	-	-	-	1.0	0.2
Utterbackia imbecillis	X	FD	1.5	2.7	FD	1.0	0.9
Total Anodontinae	1.5	3.3	3.8	10.8	1.5	1.9	3.2
Lampsilinae							
Actinonaias ligamentina	X	-	-	-	1.5	1.0	0.5
Ellipsaria lineolata	**WD**	**-**	**X**	2.7	-	X	0.2
Lampsilis cardium	7.4	6.7	5.4	16.2	6.0	7.6	7.3
Lampsilis higginsii	**1.5**	**X**	**0.8**	2.7	4.5	1.9	1.8
Lampsilis siliquoidea	-	-	-	-	X	-	X
Lampsilis teres	-	-	-	WD	-	-	WD
Leptodea fragilis	33.8	16.7	29.2	8.1	10.4	12.4	20.4
Ligumia recta	**1.5**	**X**	**6.2**	5.4	7.5	2.9	4.3
Obliquaria reflexa	8.8	3.3	6.9	5.4	14.9	8.6	0.2
Obovaria olivaria	X	X	0.8	X	WD	X	0.2
Potamilus alatus	X	X	0.8	5.4	1.5	3.8	1.8
Potamilus capax	-	-	-	-	-	-	-
Potamilus ohiensis	1.5	3.3	X	-	FD	X	0.5
Toxolasma parvus	1.5	6.7	3.8	-	1.5	5.7	3.4
Truncilla donaciformis	2.9	-	2.3	X	1.5	8.6	3.4
Truncilla truncata	WD	-	0.8	2.7	-	-	0.5
Total Lampsilinae	58.9	36.7	56.9	48.6	49.3	52.4	52.9

WD = weathered shell
Bold indicates Illinois and Federally threatened and endangered species

Table 3-13. Comparison of Cordova Bed unionid community characteristics between July 2004, July and October 2005, August and September 2006, and October 2007 (cont.).

	Jul-04	Jul-05	Oct-05	Aug-06	Sep-06	Oct-07	Average
Total no.[2]	320	164	375	430	745	651	447.5
Ave. no./m[2,1]	5.7±1.9A	3.0±1.3AB	5.8±1.5A	3.7±1.4AB	3.0±1.1B	4.7±1.2AB	4.4±0.6
Ave. CPUE [3]	15.8	6.7	10.2	19.7	27.1	21.8	17.3
Ave. no. species/qual sample[3]	6.6	3.3	5.1	7.4	7.4	7.6	
Total no. species[2]	20	18	21	19	20	23	20.2
Cumulative live/FD species	20	20	22	23	24	25	
Theoretical species richness[3]							
100	15	15	15	14	12	15	
250	18	18	17	16	14	18	
500	21	20	20	18	16	20	
1000	23	22	22	20	18	23	
5000	28	27	27	25	22	28	
Regression slope	7.7	7.4	7.3	6.8	6.0	7.5	
Ave. no.young/m[2,1]	2.2±1.0A	0.6 ±0.5AB	2.1 ±0.9A	1.1±0.6AB	0.8±0.4B	1.6±0.7AB	1.4±0.3
Ave. no.adults/m[2,1]	3.5 ±1.4A	2.4±1.2A	3.7 ±0.9A	2.6±1.3A	2.2±0.9A	3.0±0.9A	2.9±0.4
% young	33.8	20.0	36.2	29.7	25.4	35.2	33.0
% of species w/young[1]	53.8	55.6	61.1	62.5	71.4	69.6	
Ave. no. FD/m[2,1]	1.8 ±1.6AB	0.8 ±0.9AB	0.2 ±0.2A	0.6±0.5AB	1.4±0.6B	0.2±0.2A	0.8±0.3
%Mortality[1]	24.4	21.1	3.0	14.0	31.6	3.7	
% adult mortality				13.3	30.6	2.9	
% juvenile mortality				15.4	32.0	5.1	
<u>Ambleminae</u>							
Total no. [1]	27	18	51	15	33	48	32.0
Total no. [3]	120	79	151	221	497	304	228.7
Ave. no./m[2,1]	2.3±1.1A*	1.8±1.1A*	2.3±0.8A*	1.5±0.8A*	1.5±0.7A*	2.1±0.8A*	1.9±0.4*
Ave. no.≤5yrs/m[2,1]	0.8±0.6A	0.5±0.4A	0.5±0.4A	0.5±0.4A	0.4±0.3A	0.5±0.3A	0.5±0.2
Ave. no.>5yrs/m[2,1]	1.5±0.8A	1.3±1.0A	1.8±0.7A	1.0±0.6A	1.1±0.6A	1.6±0.7A	1.4±0.3
% young	33.3	27.8	21.6	33.3	27.3	25.0	26.6
Total no. species[2]	6	5	5	6	5	6	5.5
Total no. juv species	4	2	4	6	5	6	
Total no. adult species	6	5	5	5	5	5	
Ave. no. FD/m[2,1]	0.3±0.3A	0.3±0.5A	0.2±0.2A	0.2±0.3A	0.3±0.3A	0.1±0.2A	0.2±0.1
%Mortality[1]	10.0	14.3	7.8	11.8	17.5	5.9	
% adult mortality				9.1	7.7	5.3	
% juvenile mortality				16.7	35.7	7.7	
<u>Lampsilinae</u>							
Total no. [1]	40	11	74	18	33	55	38.5
Total no. [3]	116	50	72	147	147	164	116.0
Ave. no./m[2,1]	3.3±1.2A*	1.1±0.6B*	3.3±1.0A*	1.8±0.9AB*	1.5±0.6B*	2.4±0.8AB*	2.3±0.4#
Ave. no.≤3yrs/m[2,1]	1.4±0.7A	0.1±0.2B	1.6±0.7A	0.5±0.4AB	0.4±0.2B	1.1±0.5AB	0.9±0.2
Ave. no.>3yrs/m[2,1]	1.9±0.8A	1.0±0.6A	1.7±0.6A	1.3±0.8A	1.1±0.5A	1.4±0.5A	1.4±0.3
% young	42.5	9.1	47.3	27.8	24.2	43.6	39.0
Total no. species[2]	11	9	12	10	10	13	10.8
Total no. juv species	8	4	4	7	6	7	
Total no. adult species	9	9	12	10	9	12	
Ave. no. FD/m[2,1]	1.5±1.2B	0.4±0.5AB	0A	0.2±0.3AB	0.9±0.5B	0.04±0.09A	0.5±0.2
%Mortality[1]	37.5	26.7	0	10.0	38.9	1.8	
% adult mortality				7.1	43.2	0.0	
% juvenile mortality				16.7	20.0	4.0	

[1]Quantitative data only; [2]Quantitative and Qualitative combined; [3]Qualitative data only
Different letters within a row indicates a significant difference (ANOVA, $p<0.05$)
Different symbols within a column indicate a significant difference (t-test, $p\leq0.05$)

Table 3-14. Age (external annuli count) frequency of unionid species collected in the Cordova Bed, October 2007.

			Age (external annuli count)[2]																			
Subfamily	Species	Young[1]	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	20+	Total
Ambleminae	*Amblema plicata*	Y			3	5	1	1	4	1	6	1	1	2	2	4	3				1		35
	Fusconaia flava	Y										1											1
	Megalonaias nervosa																			1		1	2
	Quadrula nodulata	Y																					
	Quadrula p. pustulosa	Y					1	1	1		2			1	1				1				8
	Quadrula quadrula	Y										1		1									2
Ambleminae Total					3	5	2	2	5	1	8	3	1	4	3	4	3		1	1	1	1	48
Anodontinae	*Arcidens confragosus*	Y																					
	Lasmigona c. complanata																						
	Pyganodon grandis	Y																					
	Strophitus undulatus																1						1
	Utterbackia imbecillis	Y			1																		1
Anodontinae Total					1												1						2
Lampsilinae	*Actinonaias ligamentina*													1									1
	Ellipsaria lineolata																						
	Lampsilis cardium	Y					1	1		2	1		1		2								8
	Lampsilis higginsii											**1**				**1**							**2**
	Leptodea fragilis	Y	7	2	2	1				1													13
	Ligumia recta	**Y**						**1**		**1**		**1**											**3**
	Obliquaria reflexa				1	2	3	3															9
	Obovaria olivaria																						
	Potamilus alatus	Y								1	2			1									4
	Potamilus ohiensis																						
	Toxolasma parvus	Y			2	1	3																6
	Truncilla donaciformis	Y			2	4	2	1															9
Lampsilinae Total			7	2	7	8	9	6		5	3	2	1	2	2	1							55
Total			7	2	11	13	11	8	5	6	11	5	2	6	5	5	4	0	1	1	1	1	105

Bold indicates Illinois and Federally threatened and endangered species
[1]All methods
[2]Quantitative samples only

Table 3-15. Age (external annuli count) frequency of unionid species collected in the Albany Bed, October 2007.

			Age (external annuli count)[2]																	
Subfamily	Species	Young[1]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total
Ambleminae	*Amblema plicata*	Y		4	4	2	3	4	1		2	1	5	3	1					30
	Fusconaia flava	Y				2		1			2		1	1						7
	Megalonaias nervosa	Y							1										1	2
	Quadrula nodulata	Y						1												1
	Quadrula p. pustulosa	Y		1	3	1	4	2	2	4	1	2	1	3	2					26
	Quadrula quadrula	Y											1		1	2				4
Ambleminae Total				5	7	5	7	8	4	4	5	3	8	7	4	2			1	70
Anodontinae	*Arcidens confragosus*	Y									1									1
	Lasmigona c. complananta	Y																		
	Pyganodon grandis	Y		2	1															3
	Strophitus undulatus																			0
	Utterbackia imbecillis	Y			3															3
Anodontinae Total				2	4						1									7
Lampsilinae	*Lampsilis cardium*	Y	1		1			3	3	3	1	1								13
	Lampsilis higginsii					**1**					**1**									**2**
	Leptodea fragilis	Y	3	1	1	1	6	2												14
	Ligumia recta						**1**	**2**	**1**											**4**
	Obliquaria reflexa	Y		1	6	3	2	2		2	2	1								19
	Obovaria olivaria	Y	1	1																2
	Potamilus alatus	Y		1																1
	Potamilus ohiensis	Y			1															1
	Toxolasma parvus	Y		3	1															4
	Truncilla donaciformis	Y		4	6	1														11
Lampsilinae Total			5	11	16	6	9	9	4	5	4	2								71
Total			5	18	27	11	16	17	8	9	10	5	8	7	4	2			1	148

Bold indicates Illinois and Federally threatened and endangered species
[1]All methods
[2]Quantitative samples only

Table 3-16. Age (external annuli count) frequency of unionid species collected in the Hansons Slough Bed, October 2007.

Subfamily	Species	Young[1]	Age (external annuli count)[2] 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Ambleminae	*Amblema plicata*	Y		2	9	1	2	5	2	1	1	3	7	2	1	2	1	1	40
	Fusconaia flava	Y	4	1	3	1	1	1	1		1			1					14
	Megalonaias nervosa	Y		1															1
	Pleurobema sintoxia													1	1				2
	Quadrula nodulata	Y			2			3	6	3		1							15
	Quadrula p. pustulosa	Y		6	9	3	3	5	3	2	3	11	18	14	4				81
	Quadrula quadrula	Y	1	2			1	1	3			1	5	1	1		1		17
Ambleminae Total			5	12	23	5	7	15	15	6	5	16	30	19	7	2	2	1	170
Anodontinae	*Arcidens confragosus*																		
	Lasmigona c. complanata	Y										1							1
	Pyganodon grandis	Y																	
	Strophitus undulatus																		
Anodontinae Total												1							1
Lampsilinae	***Ellipsaria lineolata***									**1**		**1**							**2**
	Lampsilis cardium	Y	1		1		4	3	1	3	1	2	1	1					18
	Lampsilis higginsii															**1**			**1**
	Lampsilis teres																		
	Leptodea fragilis	Y			1			1											2
	Ligumia recta												**1**	**1**					**2**
	Obliquaria reflexa	Y		4	1	2	2	3	7	5	5	5	3						37
	Obovaria olivaria	Y		1					1			1							3
	Potamilus alatus	Y	1			1													2
	Potamilus ohiensis	Y	1	3															4
	Truncilla donaciformis	Y	1	1	4														6
	Truncilla truncata	Y		1			1												2
Lampsilinae Total			4	10	7	3	7	7	9	9	6	9	5	2		1			79
Total			9	22	30	8	14	22	24	15	11	26	35	21	7	3	2	1	250

Bold indicates Illinois and Federally threatened and endangered species
[1]All methods
[2]Quantitative samples only

Table 3-17. Age (external annuli count) frequency of unionid species collected in the Woodward Grove Bed, October 2007.

			Age (external annuli count)[2]																				
Subfamily	Species	Young[1]	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Total
Ambleminae	*Amblema plicata*	Y				1	2		3	2	4	1	2	2		3	1	2	1				24
	Fusconaia flava	Y				1									1								2
	Megalonaias nervosa	Y			1									1			1					1	4
	Pleurobema sintoxia																						
	Quadrula nodulata	Y			1			2	2	3		1											9
	Quadrula p. pustulosa	Y							2														2
	Quadrula quadrula	Y			11	4	1	3	7	2			2		6		2			1			39
Ambleminae Total					13	6	3	5	14	7	4	2	4	3	7	3	4	2	1	1		1	80
Anodontinae	*Arcidens confragosus*	Y				1		1															2
	Lasmigona c. complanata							1						1						1			3
	Pyganodon grandis	Y			1									1	1								3
	Utterbackia imbecillis	Y																					
Anodontinae Total					1	1		2						2	1					1			8
Lampsilinae	***Ellipsaria lineolata***							**1**															**1**
	Lampsilis cardium							1			1				1								3
	Lampsilis higginsii																						
	Lampsilis teres																						
	Leptodea fragilis	Y	2	2	4	2	1																11
	Ligumia recta								**1**														**1**
	Obliquaria reflexa	Y			3	2	3	1		1			3		1								14
	Obovaria olivaria																						
	Potamilus alatus	Y																					
	Potamilus ohiensis	Y		2	3	1																	6
	Truncilla donaciformis	Y			1	3	4	1															9
	Truncilla truncata																						
Lampsilinae Total			2	4	11	8	8	4	1	1	1		3		2								45
Total			2	4	25	15	11	11	15	8	5	2	7	5	10	3	4	2	1	2	0	1	133

Bold indicates Illinois and Federally threatened and endangered species
[1]All methods
[2]Quantitative samples only

Appendix C

Current Agencies, Organizations, Universities and Individuals of the Long-Term Monitoring Program at QCS prior to the initiation of this program:

U.S. Environmental Protection Agency (USEPA)
Illinois Environmental Protection Agency (IL EPA)

US Army Corp of Engineers (USACE)
US Fish and Wildlife Service (USFWS)

Illinois Department of Natural Resources (IL DNR)
Iowa Department of Natural Resources (IA DNR)

Office of IL Attorney General

Southern Illinois University
Illinois Natural History Survey (INHS)

Izaak Walton League of America
Izaak Walton League of America, Midwest Office
Izaak Walton League of America, Clinton County

United Auto Workers (UAW)

Karaganis & White, Ltd.

Katz, Friedman, Eagle, Eisenstein & Johnson

Mensinger Aquatic Resources, Inc. (MAR, Inc.)

Exelon Corporation
MidAmerican Energy

Dr. Roy Heidinger, Southern Illinois University, *retired*
Mr. Larry LaJeone, Exelon Corp., *retired*
Mr. James Mayhew, IADNR, *retired*

Appendix D

First Five Year Goals Based on Current Activities and Future 5 Year Block Goals thereafter.

Year	Activity	Timeframe	Cost
At Permit Issuance	National Fish and Wildlife Foundation		$15,000
1	Startup Equipment	As needed	Up to $5000
	Place host fish placed on a bed	Annually or as determined	$10,000
	Propagation for restoration and thermal testing programs	Periodically	$1,000 (yearly avg)
	Mussel Bed Temperature Monitoring	Annually to establish baseline (approx. 2 years) and during excursion hour periods thereafter	$1,000
	Mussel Bed Monitoring (Upstream, Steamboat Slough and Cordova mussel beds)	As needed, based on established monitoring triggers.	$55,000
	National Fish and Wildlife Foundation	Annually or as determined in the 5-year plan	Up to $15,000
	HCP Monitoring and Reporting	Annually	$5000
	YEAR 1 TOTAL COSTS		≥$25,000
2	Place host fish placed on a bed	Annually or as determined	$10,000
	Propagation for restoration and thermal testing programs	Periodically	$1,000 (yearly avg)
	Mussel Bed Temperature Monitoring	Annually to establish baseline (approx. 2 years) and during excursion hour periods thereafter	$1,000
	Mussel Bed Monitoring (Upstream, Steamboat Slough and Cordova mussel beds)	As needed, based on established monitoring triggers.	$55,000
	National Fish and Wildlife Foundation	Annually or as determined in the 5-year plan	Up to $15,000
	HCP Monitoring and Reporting	Annually	$5000
	YEAR 2 TOTAL COSTS		≥$20,000
3	Place host fish placed on a bed	Annually or as determined	$10,000

	Propagation for restoration and thermal testing programs	Periodically	$1,000 (yearly avg)
	Mussel Bed Temperature Monitoring	During excursion hour periods thereafter	$1,000
	Mussel Bed Monitoring (Upstream, Steamboat Slough and Cordova mussel beds)	As needed, based on established monitoring triggers.	$55,000
	National Fish and Wildlife Foundation	Annually or as determined in the 5-year plan	Up to $15,000
	HCP Monitoring and Reporting	Annually	$5000
	YEAR 3 TOTAL COSTS		≥$20,000
4	Place host fish placed on a bed	Annually or as determined	$10,000
	Propagation for restoration and thermal testing programs	Periodically	$1,000 (yearly avg)
	Mussel Bed Temperature Monitoring	During excursion hour periods thereafter	$1,000
	Mussel Bed Monitoring (Upstream, Steamboat Slough and Cordova mussel beds)	As needed, based on established monitoring triggers.	$55,000
	National Fish and Wildlife Foundation	Annually or as determined in the 5-year plan	Up to $15,000
	HCP Monitoring and Reporting	Annually	$5000
	YEAR 4 TOTAL COSTS		≥$20,000
5	Place host fish placed on a bed	Annually or as determined	$10,000
	Propagation for restoration and thermal testing programs	Periodically	$1,000 (yearly avg)

	Mussel Bed Temperature Monitoring	During excursion hour periods thereafter	$1,000
	Mussel Bed Monitoring (Upstream, Steamboat Slough and Cordova mussel beds)	As needed, based on established monitoring triggers.	$55,000
	National Fish and Wildlife Foundation	Annually or as determined in the 5-year plan	Up to $15,000
	HCP Monitoring and Reporting	Annually	$5000
	YEAR 5 TOTAL COSTS		≥$75,000
	FIRST 5 YEAR TOTAL COSTS		≥$175,000

6-10	-Mitigation Measures: Host fish placed on the Bed	As Required	$50,000
	-Impact Minimization Measure: Mussel Bed Temperature Monitoring		$5000
	- Begin Higgins Eye Propagation for future thermal testing and restorations		≥$5000
	- Thermal Testing Program (Graduate Student) initiation related to listed or rare species through NFWF or site		≥$5000
	- National Fish and Wildlife Foundation		≤$75,000
	-Mussel Bed Monitoring (Upstream, Steamboat Slough and Cordova mussel beds)		≥$55,000
	-HCP Monitoring and Reporting		$25,000
	TOTAL		≥$155,000
11-15	-Mitigation Measures: Host fish placed on the Bed	As Required	$50,000
	-Impact Minimization Measure: Mussel Bed Temperature Monitoring		$5000
	- Begin Higgins Eye Propagation for future thermal testing and restorations		≥$5000
	- Thermal Testing Program (Graduate Student) initiation related to listed or rare species through NFWF or site		≥$5000
	- National Fish and Wildlife Foundation		≤$75,000
	-Mussel Bed Monitoring (Upstream, Steamboat Slough and Cordova mussel beds)		≥$55,000
	-HCP Monitoring and Reporting		$25,000
	TOTAL		≥$155,000

16-20	-Mitigation Measures: Host fish placed on the Bed	As Required	$50,000
	-Impact Minimization Measure: Mussel Bed Temperature Monitoring		$5000
	- Begin Higgins Eye Propagation for future thermal testing and restorations		≥$5000
	- Thermal Testing Program (Graduate Student) initiation related to listed or rare species through NFWF or site		≥$5000
	- National Fish and Wildlife Foundation		≤$75,000
	-Mussel Bed Monitoring (Upstream, Steamboat Slough and Cordova mussel beds)		≥$55,000
	-HCP Monitoring and Reporting		$25,000
	TOTAL		≥$155,000
21-25	-Mitigation Measures: Host fish placed on the Bed	As Required	$50,000
	-Impact Minimization Measure: Mussel Bed Temperature Monitoring		$5000
	- Begin Higgins Eye Propagation for future thermal testing and restorations		≥$5000
	- Thermal Testing Program (Graduate Student) initiation related to listed or rare species through NFWF or site		≥$5000
	- National Fish and Wildlife Foundation		≤$75,000
	-Mussel Bed Monitoring (Upstream, Steamboat Slough and Cordova mussel beds)		≥$55,000
	-HCP Monitoring and Reporting		$25,000
	TOTAL		≥$155,000
	All Monies in NFWF Fund to be spent prior to the permit expiring.		
	PERMIT TOTAL COSTS		$795,000