U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW of Higgins eye (*Lampsilis higginsii*)

Current Classification ___Endangered____

Recommendation resulting from the 5-Year Review

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist
__X_ No change is needed

Appropriate Recovery Priority Number _5c____

Review Conducted By ___Susan Oetker_____

FIELD OFFICE APPROVAL:

Lead Field Supervisor, Fish and Wildlife Service

Acting

Approve _____ Date 4/27/06

REGIONAL OFFICE APPROVAL:

Lead Regional Director, Fish and Wildlife Service

Approve _____ Date 5/9/06

Charles M. Wooley
Acting Regional Director

Higgins eye
(Lampsilis higginsii)

5-Year Review:
Summary and Evaluation

U.S. Fish and Wildlife Service
Twin Cities Field Office
Bloomington, MN

5-YEAR REVIEW

Species reviewed: Higgins eye / *Lampsilis higginsii*

TABLE OF CONTENTS

5-YEAR REVIEW
Higgins eye/*Lampsilis higginsii*

I. GENERAL INFORMATION

A. Methodology used to complete the review:

This review was conducted by biologists at the U.S. Fish and Wildlife Service's Twin Cities Ecological Services Field Office. A draft was reviewed by Phil Delphey (Twin Cities ES) Field Office), Jon Duyvejonck (Rock Island ES Field Office), Andy Roberts (Missouri ES Field Office), Gary Wege (Twin Cities ES Field Office), and the Higgins Eye Recovery Team; the final review was prepared by Susan Oetker, Twin Cities ES Field Office endangered species biologist.

B. Reviewers

Lead Region: Region 3, Carlita Payne, 612-713-5339

Lead Field Office: Twin Cities Field Office, Susan Oetker, 612-725-3548, Ext. 219

Cooperating Field Offices: Rock Island Field Office, Jody Millar, 309-793-5800, Ext. 202
Green Bay Field Office, Cathy Carnes, 920-866-1732

C. Background

1. FR Notice: Vol. 70, No. 137; July 19, 2005; 41423-41424

2. Species status: Declining.
No new populations have been established, and zebra mussels (*Dreissena polymorpha*) continue to thrive in the upper Mississippi River, impacting native mussel populations.

3. Recovery achieved: 2 = 26%-50% of species recovery objective achieved (USFWS 2004a)

4. Listing history:

Original Listing

FR notice: FR Vol. 41, No. 115, June 14, 1976: 24062-24067
Date listed: June 14, 1976
Entity listed: species
Classification: endangered

5. Associated actions: none

6. Review History:

July 14, 2004: Revised Recovery Plan for Higgins Eye available (69 FR 42198). The notice of availability summarized the species' status, distribution, and recovery objectives that were reviewed and developed in the revised recovery plan.

May 12, 2004: Higgins eye pearlymussel (*Lampsilis higginsii*) recovery plan: first revision. This plan reviewed the most recent threats to the species and provided a strategy to overcome them.

7. Species' Recovery Priority Number at start of review: 5c

8. Recovery Plan or Outline

Name of plan: Higgins eye pearlymussel (*Lampsilis higginsii*) recovery plan: first revision
Date issued: May 12, 2004
Dates of previous versions: July 29, 1983

II. REVIEW ANALYSIS

A. Application of the 1996 Distinct Population Segment (DPS) policy

1. Is the species under review listed as a DPS?

No

2. Is there relevant new information that would lead you to re-consider the classification of this species with regard to designation of DPSs?

No

B. Recovery Criteria

1. Does the species have a final, approved recovery plan?

Yes

2. Does the recovery plan contain recovery (i.e., downlisting or delisting) criteria?

Yes

3. Adequacy of recovery criteria.

a. Do the recovery criteria reflect the best available (i.e., most up-to-date) information on the biology of the species and its habitat?

Yes

b. Are all of the 5 listing factors that are relevant to the species addressed in the recovery criteria (and there is no new information to consider regarding existing or new threats)?

Yes

4. List the recovery criteria as they appear in the recovery plan, and discuss how each criterion has or has not been met, citing information. For threats-related recovery criteria, please note which of the 5 listing factors* are addressed by that criterion. If any of the 5-listing factors are not relevant to this species, please note that here.

Intermediate Goal (Reclassification of *Lampsilis higginsii* to Threatened Status)

Criteria for Intermediate Goal (Goal 1: Reclassification)

1. Higgins eye may be considered for reclassification from Endangered to Threatened when at least five identified Essential Habitat Areas contain reproducing, self-sustaining populations of Higgins eye 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.

* Section 4(a)(1) of the Endangered Species Act list the five factors as the following: 1)Present or threatened destruction, modification or curtailment of its habitat or range; 2) Overutilization for commercial, recreational, scientific, or educational purposes; 3) Disease or predation; 4) Inadequacy of existing regulatory mechanisms; 5) Other natural or manmade factors affecting its continued existence.

a. Higgins eye populations will be considered to be "reproducing" if there is evidence that they include a sufficient number of strong juvenile year classes.

b. Populations will be considered to be "self-sustaining" if they have maintained stable or increasing population densities for at least twenty years. Higgins eye 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 ($\propto$) ≤ 0.2 and power ≥ 0.9);

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

c. This criterion will be met if zebra mussels are not present in locations where they or their offspring are likely to adversely affect Higgins eye 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.

The above Intermediate Goal for Reclassification has not been met, as only the population in the Cordova Essential Habitat Areas meets the definition of reproducing and self-sustaining. Further, zebra mussels continue to threaten all of the existing populations. The zebra mussel portion of this criterion primarily addresses factor 5 (other natural or manmade factors affecting Higgins eye's continued existence).

---

2. Complete the following tasks to determine if water quality criteria for the Final Goal (Delisting) are necessary to ensure the conservation of Higgins eye 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 Higgins eye habitat quality goals.

b. Characterize specific sediment and water quality parameters in Higgins eye Essential Habitat Areas and reestablishment areas.

Intermediate Goal 2 for Reclassification has not been met, although general freshwater mussel toxicity tests are underway at the Columbia Environmental Research Center, including tests on

other species of *Lampsilis*. Characterization of specific sediment and water quality parameters in Essential Habitat Areas has not been accomplished. This criterion addresses factor 1 (the present or threatened destruction, modification, or curtailment of its habitat or range).

---

3. Commercial 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.

Several states have prohibited commercial freshwater mussel harvest in their waters, but this is not the case for all of the states in the range of Higgins eye. Essential Habitat Area-specific prohibitions have not been enacted in states that permit mussel harvest. This criterion addresses factor 2 (overutilization for commercial, recreational, scientific, or educational purposes), as well as factor 4 (inadequacy of existing regulatory mechanisms).

Final Goal (Delisting)

1. Delisting Higgins eye requires that populations of Higgins eye 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 the long-term viability of the species" if each of the following five 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 unionized ammonia) in Essential Habitat Areas that have been shown to cause detrimental effects to Higgins eye 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 Higgins eye 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 Higgins eye 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.

This criterion has not been met. Various aspects of the criterion address factor 1 (present or threatened destruction, modification, or curtailment of its habitat or range) factor 4 (inadequacy of existing regulatory mechanisms), and factor 5 (other natural or manmade factors affecting its continued existence).

---

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

This criterion has not been met. It addresses factor 1 (present or threatened destruction, modification, or curtailment of its habitat or range).

---

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

This criterion has not been met. It addresses factor 1 (present or threatened destruction, modification, or curtailment of its habitat or range).

---

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).

This criterion has not been met. It addresses factor 1 (present or threatened destruction, modification, or curtailment of its habitat or range).

C. Updated Information and Current Species Status

1. Improved Analyses – Has application of improved analytic methods resulted in relevant new information?

No

2. Biology and Habitat:

Distribution

The revised recovery plan for Higgins eye (USFWS 2004a) reviews recent surveys and reports on the species. Dead specimens and distributional studies extended the range of Higgins eye approximately 90 miles to the north and south within the Mississippi River basin from where it was known to be historically. The largest population was known to be in pool 10 of the Mississippi River (Thiel 1981, Cawley 1996), with the most productive population at Prairie du Chien, Wisconsin. Since that time, zebra mussels have changed the habitat and drastically reduced the number of Higgins eye found there. Mean density of all unionids in the east channel at Prairie du Chien prior to heavy zebra mussel infestation ranged from a high of 149 individuals/m^2 to a low of 28 individuals/m^2 (A. Miller, *unpublished data*). After zebra mussel infestation, the density of mussels at Prairie du Chien dropped precipitously to 1.7 individuals/m^2 in 1999. Higgins eye had comprised ≥1% of the total unionid population prior to 1999; however, in 1999 and 2000, no Higgins eye were found during quantitative sampling. Surveys of the east channel at Prairie du Chien in 2005 revealed that the species may be recovering in this area due to the presence of a number of juvenile mussels of several species (including Higgins eye) (Mussel Coordination Team 2005), although recovery is likely to be slow. Currently,

the population of Higgins eye in the Mississippi River pool 14 at Cordova, Illinois appears to be the largest, although zebra mussels at this location continue to threaten this population. Biologists collect and clean Higgins eye of zebra mussels at Cordova annually to ensure this population is able to persist.

Populations in the Wisconsin River at Orion, Wisconsin, the lower St. Croix River, and the Mississippi River pool 10 at Guttenburg, Iowa, were surveyed prior to the revision of the recovery plan. Populations appeared to drop in the Wisconsin River (Heath 2003) and remain steady in the St. Croix (Hornbach 1995), although they could be increasing at Hudson (Wisconsin Department of Natural Resources 2004). No conclusions were drawn regarding the population in Mississippi River pool 10, although since the surveys were completed, zebra mussels have reduced the population.

A single empty shell was found downstream of Gavins Point dam on the Missouri River in 2004. Surveys have been conducted and no additional animals were found, indicating this individual may have been an anomaly (waif) and is not indicative of a population at the site.

Reintroductions

The revised recovery plan also summarizes the Higgins eye reintroductions that have been ongoing. Since 2000, state and federal conservation agencies have cooperated to reintroduce Higgins eye into areas of its historic range from which it has been extirpated (U.S. Army Corps of Engineers 2002). This work has largely been the result of a consultation between the Service and the U.S. Army Corps of Engineers (Corps) under section 7(a)(2) of the Endangered Species Act on the effects to Higgins eye of the Corps' operation and maintenance of the nine-foot navigation channel on the upper Mississippi River (USFWS 2000). In 2000 and 2001, biologists relocated 471 adult Higgins eye from the Mississippi River at Cassville, Wisconsin, and Cordova, Illinois, where zebra mussels posed an imminent risk to the populations. These relocated animals were taken to two sites in pools 2 and 3 of the Mississippi River where zebra mussel densities are below threatening levels.

Additionally, biologists are releasing cage-reared juveniles and fish infested with Higgins eye glochidia into the species' historic range. To collect glochidia for this effort, gravid females have been collected from the St. Croix River at Hudson, Wisconsin, and from the Mississippi River in pools 11 (Cassville, WI) and 14 (Cordova, Illinois). Fish are infested at Genoa National Fish Hatchery and held for several weeks before placing the fish in cages in the river or releasing the fish to reintroduction sites. Several thousand subadult Higgins eye have been released through this highly successful program.

Genetics

Genetic analysis within and between Higgins eye populations was completed recently (Bowen 2004). Higgins eye populations exhibit no differentiation among populations but show a wide range of genetic variation within populations, indicating that while there is a high degree of variability between individuals, the populations do not differ from each other. The northernmost population (in the St. Croix River at Hudson, Wisconsin) exhibited less genetic variation than the southern populations, likely due to its relatively recent establishment after the last glaciated period (Bowen 2004). Due to the high degree of genetic variability within populations, Bowen (2004) recommends that glochidia from at least 100 donor females be used to establish each new population.

3. Five Factor Analysis

See the revised recovery plan (USFWS 2004a) for a detailed analysis of the five factors; following is a summary from that document and includes new information since publication.

a. Present or threatened destruction, modification or curtailment of its habitat or range:

The decline of most mussel species in the United States is primarily the result of habitat loss and degradation (Neves 1991). These losses have been documented well since the mid-19th century (Higgins 1858). Chief among the causes of decline are impoundments, channelization, chemical contaminants, mining, and sedimentation (Williams et al. 1993; Neves 1991, 1993; Neves et al. 1997; Watters 2000).

Impoundments

Population losses due to impoundments, particularly the locks and dams on the Mississippi River used for commercial navigation, have probably contributed greatly to the decline and imperilment of Higgins eye. Dams impound large river habitats throughout nearly the entire range of the species. These impoundments have left short and isolated patches of remnant habitat, typically just downstream of the dams. Dams impound most of the upper Mississippi River and many of its tributaries; this system encompasses the stronghold for the Higgins eye.

Modifications to the upper Mississippi River for navigation began in 1878 when Congress authorized a 4.5-foot navigation channel. Channel modifications continued until 1930, when a 9-foot channel was authorized, which included the construction of locks and dams. These alterations resulted in profound changes to the nature of the river, primarily replacing a free-flowing alluvial system with a stepped gradient river. Continual maintenance of the channel required dredging, wing and closing dam reconstruction and maintenance, and bank armoring. Further modifications to the Mississippi River channel are anticipated with the Navigation and Environmental Sustainability Program (NESP), which, if authorized and funded, will consist of construction of larger locks and other navigation improvements downstream of pool 14 (U.S.

Army Corps of Engineers 2004). NESP also includes a variety of ecosystem restoration projects for fish and wildlife benefits. Project effects to Higgins eye for both navigation and ecosystem components of NESP were addressed through section 7 of the Endangered Species Act, which resulted in a biological opinion (USFWS 2004b).

Water Quality

In the upper Mississippi River basin, sedimentation and toxic contaminants have been suggested as the major threats to aquatic fauna (Wiener et al. 1984). These factors are reviewed below:

Sedimentation

Interstitial spaces within stream substrates provide crucial habitat for juvenile mussels. When fine sediments deposit in these spaces, interstitial flow and habitat space for juveniles are reduced or eliminated (Brim Box and Mossa 1999). Fine sediments may also act as a vector for the delivery of contaminants, such as nutrients and pesticides. These may be important factors in the recruitment failures of mussel populations, including those of Higgins eye. Intermittent exposure of freshwater mussels (*Quadrula quadrula, Pleurobema beadleanum,* and *Fusconaia cerina*) to 600 – 750 mg/L of suspended solids adversely affects feeding rate, oxygen uptake, and excretion (Aldridge et al. 1987), although concentrations of this magnitude are not expected to occur with any regularity in the St. Croix or upper Mississippi Rivers.

As Higgins eye tend to inhabit relatively deep water, they may be particularly vulnerable to siltation. The current is slower in this habitat than in riffles and runs, and suspended sediment settles out. However, since they are adapted to these slower currents, they may not be as sensitive to normal, ambient levels of sedimentation as more intolerant species that inhabit riffles and runs.

Siltation has resulted in increased turbidity levels in many midwestern streams. During reproduction, Higgins eye display a mantle lure that resembles a minnow and appears to attract potential hosts. The success of this reproductive strategy depends on water clarity when Higgins eye are displaying, because fish hosts are likely to be attracted visually to the display (Hartfield and Hartfield 1996). Increased turbidity levels also may reduce production of food for Higgins eye by reducing solar energy in the water column (Kanehl and Lyons 1992).

Dredging or other activities that destabilize instream fine sediments are likely to affect Higgins eye adversely. Dredging to maintain barge traffic on the Mississippi River below the mouth of the Chippewa River in Wisconsin, for example, has reduced mussel diversity due to the increase in unstable sand substrates (Thiel 1981). Lake Pepin, a once natural lake formed in the upper Mississippi River upstream from the mouth of the Chippewa River, has become increasingly silted over the past century, reducing habitat for Higgins eye and other mussels (Thiel 1981).

Agricultural activities are responsible for most of the sediment that enters streams (Waters 1995), including both sediment and chemical run off; agriculture affects 72 percent of the impaired river miles in the country (Neves et al. 1997). Grazing may lead to a reduction in infiltration rates and an increase in runoff; moreover, trampling and removal of vegetation reduces resistance of banks

to erosion (Armour et al. 1991, Trimble and Mendel 1995, Brim Box and Mossa 1999). Mississippi River tributaries in the southern portion of Higgins eye's range (e.g., Iowa and Illinois) have been particularly affected by agricultural activities.

Chemical Contaminants

As benthic filter-feeding organisms, freshwater mussels are exposed to contaminants dissolved in water, associated with suspended particles, and deposited to bottom sediments. Thus, freshwater mussels can bioaccumulate contaminants to concentrations that exceed those in contaminated water or sediments.

The effects of contaminants are especially profound on juvenile mussels (Robison et al. 1996), which readily ingest contaminants adsorbed to sediment particles while feeding, and on glochidia, which appear to be very sensitive to toxicants (Goudreau et al. 1993, Jacobson et al. 1997). Mussels are very intolerant of heavy metals (Keller and Zam 1991, Havlik and Marking 1987), and even at low levels, certain heavy metals may inhibit glochidial attachment to fish hosts (Huebner and Pynnönen 1992). Cadmium appears to be the heavy metal most toxic to mussels (Havlik and Marking 1987), although chromium, copper, mercury, and zinc also adversely affect biological processes (Naimo 1995, Keller and Zam 1991, Jacobson et al. 1997, Keller and Lydy 1997).

Among pollutants, ammonia has been shown to be lethal to adult and juvenile mussels at concentrations of 2.5 ppm (Augsperger et al. 2003), which is substantially less than the national water quality criterion. Ammonia is oftentimes associated with animal feedlots, industrial waste, nitrogenous fertilizers, and the effluents of out-dated municipal wastewater treatment plants that do not control ammonia (Goudreau et al. 1993, Augspurger et al. 2003). In streams, ammonia is most prevalent at the substrate/water interface (Frazier et al. 1996). Due to its high level of toxicity and the occurrence of the highest concentrations in the microhabitats where mussels live, ammonia may be limiting mussel populations at some locations (Augspurger et al. 2003, Bartsch et al. 2003). Ammonia sources include industrial, municipal, and agricultural sources, precipitation, and natural processes (Newton 2003).

Although recent data suggest that mussels are generally more sensitive to ammonia than fishes, effects of ammonia on host fishes is also a potential threat to the persistence of Higgins eye populations. Mean acute levels of ammonia for two marginal host species (green sunfish and bluegill) and three suitable host species (largemouth bass, smallmouth bass, and walleye) ranged from 20 to 35 ppm, which is higher than the toxic level for juvenile mussels.

Contaminants associated with households and urban areas, particularly those from industrial and municipal effluents, may include heavy metals, chlorine, phosphorus, and numerous organic compounds. Wastewater is discharged through National Pollution Discharge Elimination System (NPDES) permitted (and some non-permitted) sites throughout the country. Elimination sites are common throughout the range of Higgins eye.

Agricultural sources of chemical contaminants are considerable and include two broad categories: nutrient enrichment (e.g., runoff from livestock farms and feedlots, fertilizers from

row crops) and pesticides (e.g., from row crops) (Frick et al. 1998). Nitrate concentrations are particularly high in surface waters downstream of agricultural areas (Mueller et al. 1995). Fertilizers and pesticides also are used commonly in developed areas. These contaminants have the potential to impact all extant populations of Higgins eye.

Little is known about the effects of organic contaminants on freshwater mussels, but the available data suggest some compounds in the upper Mississippi River have the potential to harm Higgins eye and to degrade entire benthic invertebrate communities. For example, zebra mussels have been shown to bioaccumulate substantial quantities of polychlorinated biphenyls (PCBs) in the upper Mississippi River (M. R. Bartsch, U.S. Geological Survey, pers. com.). In addition, a survey of PCBs in emergent mayflies identified two zones of concern regarding PCB contamination in riverine sediments: Pools 2 through 6 and Pool 15 of the upper Mississippi River (Steingraeber et al. 1994).

Toxic chemical spills have killed mussels and fish throughout the range of Higgins eye, particularly in the Mississippi River where officials have documented several spills, the most recent on March 19, 2005, when a train derailment along the Mississippi River near Cottage Grove, Minnesota, spilled an estimated 2,000 pounds of granular potassium chloride (potash) (Keis 2005). Chemical spills likely will continue to occur and have the potential to eliminate Higgins eye populations completely from river reaches and, possibly, entire rivers.

b. Overutilization for commercial, recreational, scientific, or educational purposes:

Higgins eye is not a commercially valuable species, although it is likely that Higgins eye have been collected accidentally as bycatch. No commercial harvest is permitted in the Wisconsin and St. Croix Rivers or at the Sylvan Slough Essential Habitat Area on the Mississippi River, although illegal harvest may occur.

The species also may be increasingly sought by collectors as it becomes rarer. Although scientific collecting is not thought to represent a significant threat, unregulated collecting could adversely affect localized populations.

c. Disease or predation:

Scientists know very little about the occurrence of disease in mussels, although several mussel die offs have been documented in the past 20 years (Neves 1986) in which disease may have played a role. Parasites on mussels include water mites, trematodes, leeches, bacteria, and some protozoa, but biologists generally do not suspect parasites to be limiting mussel populations (Oesch 1984).

Natural predators of freshwater mussels include muskrats, river otters, striped skunk, turtles, fish (particularly drum and carp), and raccoon. Small mammal predators select for larger individuals, while fish and turtles select for small individuals. The level of predation at Higgins eye sites does not exceed natural levels by most species of predators, and robust populations would be able to withstand this amount of predation. However, it has recently been discovered that

common carp may be foraging on young Higgins eye (3 to 4 years old) that were placed out as part of reintroduction efforts (D. Kelner, U.S. Army Corps of Engineers, pers. comm.). It is not yet known to what degree carp are predating on Higgins eye, but since carp are not native to the Mississippi River basin and therefore are not predators to which Higgins eye populations have been adapted, Higgins eye populations are particularly vulnerable to this potential threat.

d. Inadequacy of existing regulatory mechanisms:

Most states with extant Higgins eye populations prohibit the taking of mussels for scientific purposes without a state collecting permit, although some states may find it difficult to enforce this requirement. Furthermore, state regulations generally do not protect mussels from other threats that may be likely to harm habitats and populations incidentally (*i.e.*, upstream dock or fleeting area construction).

Sedimentation continues to be an issue throughout the range of Higgins eye. The authority of the Clean Water Act to regulate sedimentation has not been sufficient to ameliorate this threat to the species.

e. Other natural or manmade factors affecting its continued existence:

Non-native species

Various alien or nonnative species of aquatic organisms are established firmly in the range of Higgins eye. The alien species that poses the most significant threat to the Higgins eye is the zebra mussel. Its invasion of freshwater habitats in the United States poses a threat to mussel faunas in many regions (Ricciardi et al. 1998). Strayer (1999) reviewed in detail the mechanisms in which zebra mussels impact native mussels. The primary means of impact is direct fouling of the shells; zebra mussels attach in large numbers to the shells of live native mussels and other hard relatively stable substrates and may destroy entire mussel beds. The impacts of fouling include impeding locomotion (both laterally and vertically), interfering with normal valve movements, deforming valve margins, locally depleting food resources and oxygen, and increasing waste products. Heavy infestations of zebra mussels on native mussels may stress the animals by reducing their energy stores. They may also reduce food concentrations to levels too low to allow for survival and reproduction. Zebra mussels also may impede reproduction of unionids by filtering sperm and larvae from the water column. Large deposits of zebra mussel pseudofeces also may degrade habitat for native mussels by, for example, reducing dissolved oxygen concentrations (USFWS 1997).

Overlapping much of the current range of Higgins eye, zebra mussels are established thoroughly throughout the upper Mississippi and lower St. Croix Rivers. Kelner and Davis (2002) stated that zebra mussels in the Mississippi River from Mississippi River Pool 4 downstream are "extremely abundant and are decimating the native mussel communities." Huge numbers of dead and live zebra mussels cover the bottom of the river in some localities up to 1-2 inches deep (Havlik 2001), where they have reduced significantly the quality of the habitat with their pseudofeces (S.J. Fraley, NCWRC, pers. comm., 2000). From 1993 to 1994, nearly a ten-fold

increase in zebra mussel densities occurred in Mississippi River pool 10 at Prairie du Chien (Clarke and Loter 1995), which had been the largest and most productive population of Higgins eye until zebra mussel infestation. Zebra mussels have reduced Higgins eye populations throughout the Mississippi River's heavily infested waters. Zebra mussels are most likely to affect Higgins eye populations adversely in big rivers, large tributaries, and below infested reservoirs and are likely to continue to spread to additional streams in the foreseeable future.

Zebra mussel densities have declined recently at several essential habitat areas for Higgins eye. In the Mississippi River at Prairie du Chien, densities of zebra mussels have gone from 9,390 individuals/m^2 in 2000 to 30.7 individuals/m^2 in 2003 (U.S. Army Corps of Engineers, unpubl. data). Other populations exhibited similar population crashes during the same time period. Although it appears the zebra mussel populations are at low, stable levels, the populations are likely to increase again in the future; these areas are not protected from future zebra mussel impacts. In 2005, densities increased to 251 individuals/m^2 (U.S. Army Corps of Engineers, unpubl. data), indicating a possible increasing trend, although future monitoring will occur to confirm this.

The Asian clam (*Corbicula fluminea*) has spread throughout the Mississippi River system since its introduction into the basin in the mid-1900s. This species has been implicated as a competitor with native mussels for resources such as food, nutrients, and space, particularly as juveniles (Neves and Widlak 1987). Dense populations of Asian clams may ingest large numbers of unionid sperm, glochidia, and newly metamorphosed juveniles (Strayer 1999, Yeager et al. 2001). Additionally, they may disturb sediments, thereby reducing habitat for juvenile native mussels. Periodic die offs may produce enough ammonia and consume enough oxygen to kill native mussels (Strayer 1999). Specific impacts to native unionids, however, remain largely unresolved (Leff et al. 1990, Strayer 1999).

A molluscivore, the black carp (*Mylopharyngodon piceus*) is a potential threat to native unionids (Strayer 1999); it has been introduced into North America since the 1970s. The species has been proposed for widespread use by aquaculturists to control snails, the intermediate host of a trematode (flatworm) parasite that affects catfish in ponds in the southeast and lower midwest. Black carp are known to eat clams (*Corbicula spp.*) and unionid mussels in China, in addition to snails. They are the largest of the Asian carp species, reaching more than four feet in length and achieving a weight in excess of 150 pounds (Nico and Williams 1996). In 1994, 30 black carp escaped from an aquaculture facility in Missouri during a flood, although none of the escapees have been found elsewhere. However, given past history and the frequency of flooding and other natural disasters in the southern states in which black carp are held, other escapes into the wild by non-sterile black carp are likely to occur. Escaped black carp are likely to escape and thrive in the wild with or without reproduction. If the escapees were able to reproduce, they would quickly spread throughout the waters of the United States as there are no known limiting factors to prevent their establishment.

The common carp (*Cyprinus carpio*), widespread throughout the Mississippi River basin, may eat juvenile mussels opportunistically. Field observations in the upper Mississippi River have indicated that predation by common carp may be a larger factor in juvenile recruitment than previously thought. The effects of this potential threat are currently under study.

The round goby (*Neogobius melanostomus*), a molluscivore, was introduced into North America from Eurasia and has become established in several areas, including the Mississippi River basin. Their small size (approximately 7-10 cm) likely limits the impact the species could have on Higgins eye to predation of individuals less than 10 mm (Ray and Corkum 1997). The consequences of the establishment of the round goby within the range of Higgins eye may be less than that of black carp, but they still pose a threat to Higgins eye and other freshwater mussels.

Population Fragmentation and Isolation

Most of the remaining Higgins eye populations are isolated and thus are susceptible to extirpation from catastrophic events, such as toxic chemical spills. Even if habitats retain or recover their ability to support Higgins eye after such events, natural recolonization of isolated habitats is unlikely. Population isolation also reduces or eliminates gene flow among local populations. This isolation in combination with small effective population size can lead to inbreeding depression within populations (Avise and Hambrick 1996).

Higgins eye are relatively long-lived. Therefore, it may take decades for non-reproducing populations to become extinct following their isolation by, for example, the construction of a dam. Small isolated populations that may now be comprised predominantly of adult specimens could be dying out slowly in the absence of recruitment, even without other the threats described above. In reality, however, isolated populations usually face other threats that result in continually decreasing population size (Fahrig and Merriam 1985).

Synthesis -

The Higgins eye population in the Mississippi River at Prairie du Chien, Wisconsin, has crashed as a result of skyrocketing zebra mussel populations at that site. What was once the stronghold for the species now holds only a few pockets of Higgins eye, while the main portions of the habitat at this site now consist of layers of zebra mussel shells. As a result, the population in the Mississippi River at Cordova, Illinois, is likely the stronghold for the species.

Recent reintroductions of Higgins eye outside of areas heavily infested by zebra mussels have been conducted by the Corps of Engineers to counteract the effects of operation and maintenance of the nine-foot channel project in the Mississippi River in Minnesota, Wisconsin, Illinois, Iowa, and Missouri. These efforts have been ongoing since 2000, and if successful they will likely ensure the species is established in areas protected from the threat of zebra mussels.

The primary threats to Higgins eye are habitat changes (chiefly in the form of impoundments), water quality problems, and non-native species, both as predators (carp) and competitors (zebra mussels and Asian clams). In particular, zebra mussels pose the most immediate threat to the species by colonizing and rapidly increasing populations in the majority of reaches inhabited by Higgins eye. No control measures are yet known, although the Corps' reintroductions will enable the species to persist while zebra mussel eradication efforts are researched. In 2006, the Corps will initiate a federal feasibility study on zebra mussel management on the upper Mississippi River (Dennis Anderson, U.S. Army Corps of Engineers, pers. comm.). The

feasibility study was recommended in a federal reconnaissance study that evaluated potential management measures for zebra mussels (U.S. Army Corps of Engineers 2003).

Sedimentation and contaminants also pose a large threat to Higgins eye. Dredging, other channel maintenance activities, and upper watershed practices greatly increase sediment load, which interferes with feeding and breeding activities and also degrades substrate conditions. Contaminants are often bound to fine sediment particles, exacerbating the effects of sedimentation to the species.

Since the Revised Recovery Plan was issued in 2004, the species' status has not changed. The threats to Higgins eye remain prominent, and in the case of zebra mussels, threats are worsening. Without the protections of the Endangered Species Act and all of the recovery and reintroduction activities it has fostered and continues to promote or mandate, Higgins eye would be extremely close to extinction. The remaining stronghold for the species in the Mississippi River at Cordova, Illinois, must be surveyed annually and Higgins eye collected and scrubbed of zebra mussels in order to persist. No populations are thriving independent of protection or conservation actions by state or federal agencies. Higgins eye continues to meet the definition of endangered and will do so until the threat of zebra mussels is alleviated either through zebra mussel eradication or successful population establishment outside of zebra mussel-infested waters within Higgins eye's historic range. Population viability, water quality, harvest restrictions, and other threats of lesser magnitude will also need to be addressed for the species to be downlisted or delisted.

At this time, it is unclear whether the recovery of the Higgins eye population in the Essential Habitat Area (EHA) at Prairie du Chien should be included as a requirement for downlisting or delisting. While this population used to be the most productive throughout the species' range, it may not be recoverable as it seems to have the characteristics of good habitat for zebra mussels, as well. It is possible that this area is more susceptible than other Mississippi River EHAs to zebra mussel invasion; if that is the case, ensuring this site's freedom from future zebra mussel population increases may not be attainable. However, because this population was once the most productive, its recovery could herald the recovery of the species. The Recovery Team held a conference call about this issue on January 31, 2006, and decided that no decision should be made for five years while the Higgins eye and zebra mussel populations at Prairie du Chien are monitored and more information is gathered.

III. RESULTS

A. Recommended Classification

No change is needed

B. Recovery Priority Number

The recovery priority number should remain the same (5c).

IV. RECOMMENDATIONS FOR FUTURE ACTIONS

Because the Revised Recovery Plan was issued so recently, there are no new information needs at the time of this review.

Recommended future actions:

- Estimated costs for revised recovery plan implementation should be provided through fiscal year 2012.

- When the plan is updated, change the wording of the first criterion of the Final Goal (Delisting) as follows: "Populations at the identified Essential Habitat Areas will be 'sufficiently secure to assure long-term viability of the species' if each of the following five conditions is met."

- Work with industry representatives to develop a cooperative approach to limit zebra mussel spread upstream of pool 4 on the Mississippi River.

V. REFERENCES

Aldridge, D.W., Payne, B.S., and A.C. Miller. 1987. The effects of intermittent exposure to suspended solids and turbulence on three species of freshwater mussels. Environmental Pollution 45:17-28.

Armour, C.L., D.A. Duff, and W. Elmore. 1991. The effects of livestock grazing on riparian and stream ecosystems. Fisheries 16(1):7-11.

Augspurger, T., A.E. Keller, M.C. Black, W.G. Cope, and F.J. Dwyer. 2003. Water quality guidance for protection of freshwater mussels (Unionidae) from ammonia exposure. Environmental Toxicology and Chemistry 22:2569-2575.

Avise, J.C. and J.L. Hambrick, eds. 1996. Conservation genetics: case histories from nature. Chapman and Hall, New York.

Bartsch, M.R., T.J. Newton, J.W. Allen, J.A. O'Donnell, and W.B. Richardson. 2003. Effects of pore-water ammonia on in situ survival and growth of juvenile mussels (*Lampsilis cardium*) in the St. Croix Riverway, Wisconsin, USA. Environmental Toxicology and Chemistry 22:2561-2568.

Bowen, B. S. 2004. Genetic variability and geographic structure of *Lampsilis higginsii* mussels in the upper Mississippi River and tributaries. Report submitted to the U.S. Army Corps of Engineers, St. Paul District. 24pp.

Brim Box, J., and J. Mossa. 1999. Sediment, land use, and freshwater mussels: prospects and problems. Journal of the North American Benthological Society 18:99-117.

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

Clarke, A.H., Jr. and J.C. Loter. 1995. The 1994 mussel monitoring program in the east branch of the Mississippi River at Prairie du Chien, Wisconsin. A report for DeWitt, Porter, and Co. for Didion, Inc.

Fahrig, L. and G. Merriam. 1985. Habitat patch connectivity and population survival. Ecology 66:1762-1768.

Frazier, B.E., T.J. Naimo, and M.B. Sandheinrich. 1996. Temporal and vertical distribution of total ammonia nitrogen and un-ionized ammonia nitrogen in sediment pore water from the upper Mississippi River. Environmental Toxicology and Chemistry 15:92-99.

Frick, E.A., D.J. Hippe, G.R. Buell, C.A. Couch, E.H. Hopkins, D.J. Wangsness, and J.W. Garrett. 1998. Water quality in the Apalachicola-Chattahoochee-Flint River basin, Georgia, Alabama, and Florida, 1992-95. U.S. Geological Survey Circular 1164. 38 pp.

Goudreau, S., R.J. Neves, and R.J. Sheehan. 1993. Effects of wastewater treatment plant effluents on freshwater mollusks in the upper Clinch River, Virginia, U.S.A. Hydrobiologia 252:211-230.

Hartfield, P.W., and E. Hartfield. 1996. Observations on the conglutinates of *Ptychobranchus greeni* (Conrad 1834) (Mollusca: Bivalvia: Unionoidea). American Midland Naturalist 135:370-375.

Havlik, M.E. 2001. Are unionids capable of reproduction in upper Mississippi River areas with large *Dreissena polymorpha* populations? Unpublished report, Ellipsaria 3(1):16.

Havlik, M.E., and L.L. Marking. 1987. Effects of contaminants on naiad mollusks (Unionidae): a review. U.S. Fish and Wildlife Service Resource Publication 164. 20 pp.

Heath, D.J. 2003. Results of 2002 monitoring of freshwater mussel communities of the Wisconsin River near Orion, Richland County, Wisconsin. Wisconsin Department of Natural Resources, La Crosse, Wisconsin. 16pp.

Higgins, F. 1858. A catalogue of the shell-bearing species, inhabiting the vicinity of Columbus, Ohio, with some remarks thereon. 12th Annual Report, Ohio State Board of Agriculture for 1857:548-555.

Hornbach, D.J., P. Baker, and T. Deneka. 1995. Abundance and distribution of the endangered mussel, *Lampsilis higginsii* in the lower St. Croix River, Minnesota and Wisconsin. Final Report to the U.S. Fish and Wildlife Service, Bloomington, Minnesota. 40pp.

Huebner, J.D., and K.S. Pynnönen. 1992. Viability of glochidia of *Anodonta* exposed to low pH and selected metals. Canadian Journal of Zoology 70:2348-2355.

Jacobson, P.J., R.J. Neves, D.S. Cherry, and J.L. Farris. 1997. Sensitivity of glochidial stages of freshwater mussels (Bivalvia: Unionidae) to copper. Environmental Toxicology and Chemistry 16:2384-2392.

Kanehl, P. and J. Lyons. 1992. Impacts of in-stream sand and gravel mining on stream habitat and fish communities, including a survey on the Big Rib River, Marathon County, Wisconsin. Wisconsin Department of Natural Resources Research Report 155. 32 pp.

Keis, B. 2005. Follow-up sediment and water sampling report for potassium chloride release, river mile 818.7, Cottage Grove, Minnesota. Pinnacle Engineering, Inc., Maple Grove, Minnesota. 56 pp.

Keller, A.E. and M. Lydy. 1997. Biomonitoring and the hazards of contaminants to freshwater mollusks. Unpublished report *in*: Freshwater mollusks as indicators of water quality: a workshop. U.S. Geological Survey Biological Resources Division and National Water Quality Assessment Program. 55 pp.

Keller, A.E. and S.G. Zam. 1991. The acute toxicity of selected metals to the freshwater mussel *Anodonta imbecilis* [sic]. Environmental Toxicology and Chemistry 10:539-546.

Leff, L.G., J.L. Burch, and J.V. McArthur. 1990. Spatial distribution, seston removal, and potential competitive interactions of the bivalves *Corbicula fluminea* and *Elliptio complanata* in a coastal plain stream. Freshwater Biology 24:409-416.

Miller, A.C. and B.S. Payne. 2001. Effects of zebra mussels (*Dreissena polymorpha*) at essential habitats for *Lampsilis higginsii* in the upper Mississippi River system, 2000. Report for St. Paul District, U.S. Army Corps of Engineers. 31pp.

Mueller, D.K., P.A. Hamilton, D.R. Helsel, K.J. Hitt, and B.C. Ruddy. 1995. Nutrients in ground water and surface water of the United States--an analysis of data through 1992. U.S. Geological Survey, Water-Resources Investigations Report 95-4031. 74 pp.

Mussel Coordination Team. 2005. Mussel Coordination Team 2005 Mussel Surveys, Harpers and Prairie du Chien, *Lampsilis higginsii* Essential Habitat Areas, Pool 10, Upper Mississippi River. U.S. Army Engineer District, St. Paul.

Naimo, T.J. 1995. A review of the effects of heavy metals on freshwater mussels. Ecotoxicology 4:341-362.

Neves, R.J. 1986. Recent die-offs of freshwater mussels in the United States: an overview. Pp. 7-18 *in*: R.J. Neves, ed. Proceedings of the workshop on die-offs of freshwater mussels in the United States, June 1986, Davenport, Iowa. Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Neves, R.J. 1991. Mollusks. Pp. 251-319 *in*: K. Terwilliger, coordinator. Virginia's endangered species. Proceedings of a symposium, April 1989, Blacksburg, Virginia. McDonald & Woodward Publishing Co., Blacksburg.

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

Neves, R.J., A.E. Bogan, J.D. Williams, S.A. Ahlstedt, and P.W. Hartfield. 1997. Status of aquatic mollusks in the southeastern United States: a downward spiral of diversity. Pp. 43-85 *in*: G.W. Benz and D.E. Collins, eds. Aquatic fauna in peril: the southeastern perspective, March-April 1994, Chattanooga, Tennessee. Special Publication 1, Southeast Aquatic Research Institute, Chattanooga.

Neves, R J., and J.C. Widlak. 1987. Habitat ecology of juvenile freshwater mussels (Bivalvia: Unionidae) in a headwater stream in Virginia. American Malacological Union Bulletin 5(1):1-7.

Newton, T.J. 2003. The effects of ammonia on freshwater unionid mussels: Letter to the editor. Environmental Toxicology and Chemistry 22:2543-2544.

Nico, L.G. and J.D. Williams. 1996. Risk assessment on black carp (Pisces: Cyprinidae). Unpublished report, U.S. Geological Survey, Gainesville, Florida. 61 pp.

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

Ray, W.J. and L.D. Corkum. 1997. Predation of zebra mussels by round gobies, *Neogobius melanostomus*. Environmental Biology of Fishes 50:267-273.

Ricciardi, A., R.J. Neves, and J.R. Rasmussen. 1998. Impending extinctions of North American freshwater mussels (Unionoida) following the zebra mussel (*Dreissena polymorpha*) invasion. Journal of Animal Ecology 67:613-619.

Robison, W.A., S.R. Alexander, T. Hibner, and M. Wilson. 1996. Clinch River Project: sediment contaminants in the lower Clinch River. Unpublished report, U.S. Fish and Wildlife Service, Cookeville, Tennessee. 52 pp.

Steingraeber, M.T., T.R. Schwartz, J.G. Wiener, and J.A. Lebo. 1994. Polychlorinated biphenyl congeners in emergent mayflies from the upper Mississippi River. Environmental Science and Technology 28:707-714.

Strayer, D.L. 1999. Effects of alien species on freshwater mollusks in North America. Journal of the North American Benthological Society 18:74-98.

Thiel, P.A. 1981. A survey of unionid mussels in the upper Mississippi River (Pools 3-11). Wisconsin Department of Natural Resources Technical Bulletin No. 124. 24 pp.

Thiel, P.A., M. Talbot, and J. Holzer. 1980. Survey of mussels in the upper Mississippi River pools 3 through 8. Pp148-157 *in*: Rasmussen, J.L., editor. Proceedings of the UMRCC symposium on upper Mississippi River bivalve mollusks. Upper Mississippi River Conservation Committee, Rock Island, Illinois.

Trimble, S.W., and A.C. Mendel. 1995. The cow as a geomorphic agent: a critical review. Geomorphology 13:233-253.

U.S. Army Corps of Engineers. 2002. Definite project report and environmental assessment for relocation plan for the endangered Higgins eye pearlymussel (*Lampsilis higginsii*), Upper Mississippi River and tributaries, Minnesota, Wisconsin, Iowa, and Illinois. July 2002. U.S. Army Corps of Engineers, St. Paul District, Minnesota. 56pp.

U.S. Fish and Wildlife Service. 1997. Winged Mapleleaf Mussel (*Quadrula fragosa*) Recovery Plan. Ft. Snelling, Minnesota. 100 pp.

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

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

U.S. Fish and Wildlife Service. 2004b. Final biological opinion for the Upper Mississippi River-Illinois Waterway System Navigation Feasibility Study. August 2004. Rock Island Field Office, Illinois. 141pp.

Waters, T.F. 1995. Sediment in streams: sources, biological effects, and control. American Fisheries Society Monograph 7. 251 pp.

Watters, G.T. 2000. Freshwater mollusks and water quality: effects of hydrologic and instream habitat alterations. Pp. 261-274 *in*: P.D. Johnson and R.S. Butler, eds. Freshwater Mollusk Symposium Proceedings--Part II: Proceedings of the First Symposium of the Freshwater Mollusk Conservation Society, March 1999, Chattanooga, Tennessee. Ohio Biological Survey, Columbus.

Wiener, J.G., R.V. Anderson, and D.R. McConville. 1984. Introduction: contaminants in the upper Mississippi River. Pp. 1-4 *in*: J.G. Wiener, R.V. Anderson, and D.R. McConville, eds. Contaminants in the upper Mississippi River. Butterworth Publishers, Boston, Massachusetts.

Williams, J.D., M.L. Warren, Jr., K.S. Cummings, J.L. Harris, and R.J. Neves. 1993. Conservation status of freshwater mussels of the United States and Canada. Fisheries 18(9):6-22.

Wisconsin Department of Natural Resources, National Park Service, and U. S. Fish and Wildlife Service. 2004. Results of 2004 Monitoring of Freshwater Mussel Communities of the Saint Croix National Scenic Riverway, Minnesota and Wisconsin. 21 pp.

Yeager, M.M., R.J. Neves, and D.S. Cherry. 2001. Competitive interactions between early life stages of *Villosa iris* (Bivalvia: Unionidae) and adult Asian clams (*Corbicula fluminea*). Pp. 253-259 *in*: P.D. Johnson and R.S. Butler, eds. Freshwater Mollusk Symposium Proceedings--Part II: Proceedings of the First Symposium of the Freshwater Mollusk Conservation Society, March 1999, Chattanooga, Tennessee. Ohio Biological Survey, Columbus.