

Higgins Eye (Pearlymussel)
(Lampsilis higginsii)

5-Year Review:
Summary and Evaluation

U.S. Fish and Wildlife Service
Minnesota – Wisconsin Field Office
Bloomington, MN

5-YEAR REVIEW

Species reviewed: Higgins eye (pearlymussel) (*Lampsilis higginsii*)

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5-YEAR REVIEW

Higgins eye (pearlymussel) (*Lampsilis higginsii*)

1.0 GENERAL INFORMATION

1.1 Reviewers

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1.2 Methodology used to complete review

The Endangered Species Act of 1973, as amended (Act), requires the U.S. Fish and Wildlife Service (Service or USFWS) to review the status of species listed as threatened or endangered at least once every five years, colloquially referred to as a 5-year review. Public notice was given in the Federal Register (83 FR 18075) requesting new scientific or commercial data and information that may have a bearing on the status of Higgins eye (pearlymussel) (*Lampsilis higginsii*), a mussel species currently listed as endangered. Pertinent data was obtained from peer reviewed literature, recent reports of mussel surveys and captive rearing work, information presented at meetings or webinars by researchers, and from data submitted by State and other natural resource agencies within the range of the species. This 5-year review was completed by Tamara Smith, Fish and Wildlife Biologist with the Minnesota-Wisconsin Ecological Services Field Office. The focus of this 5-year review is to summarize new information regarding the status of the Higgins eye.

1.3 Background

1.3.1 Federal Register Notice citation announcing initiation of this review

83 FR 18075 (April 25, 2018) – Endangered and Threatened Wildlife and Plants; Initiation of 5-Year Status Reviews of Five Listed Animal Species.

1.3.2 Listing History

Original Listing

FR notice: FR Vol. 41, No. 115, June 14, 1976: 24062-24067

Date listed: June 14, 1976

Entity listed: Higgins eye (pearlymussel) (*Lampsilis higginsii*); Species

Classification: Endangered

1.3.3 Associated rulemakings

1.3.4 Review History

A five year review was completed on May 9, 2006 (70 FR 41423 41424).

1.3.5 Species' Recovery Priority Number at start of 5-year review

5C

1.3.6 Recovery Plan or Outline

Name of plan or outline: Higgins eye pearly mussel (*Lampsilis higginsii*) recovery plan: first revision

Date issued: May 12, 2004 (69 FR42198)

Dates of previous revisions, if applicable: July 29, 1983

2.0 REVIEW ANALYSIS

2.1 Application of the 1996 Distinct Population Segment (DPS) policy

2.1.1 **Is the species under review a vertebrate?** No. The species is an invertebrate; therefore, the DPS policy is not applicable to this listing.

2.2 Recovery Criteria

2.2.1 **Does the species have a final, approved recovery plan containing objective, measurable criteria?** Yes

2.2.2 Adequacy of recovery criteria

2.2.2.1 Do the recovery criteria reflect the best available and most up-to date information on the biology of the species and its habitat? Yes.

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

2.2.3 **List the recovery criteria as they appear in the recovery plan, and discuss how each criterion has or has not been met, citing information.**

Essential Habitat Area (EHA) Criteria:

*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/m².

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

- include a total mussel density of > 10/m² (Mississippi River) or > 2/m² (other rivers); and,
- contain at least 15 other mussel species, each at densities greater than 0.01 individual/m².

We can relate our criteria to the three conservation biology principles of resiliency, redundancy, and representation (Shaffer and Stein 2000, pp. 306–310). Briefly, resiliency supports the ability

of the species to withstand environmental and demographic stochasticity; redundancy supports the ability of the species to withstand catastrophic events (e.g., droughts); and representation supports the ability of the species to adapt over time to long-term changes in the environment. In general, the more redundant, representative, and resilient a species is, the more likely it is to sustain populations over time, even under changing environmental conditions.

The above EHA criteria has been met at Interstate, Hudson, Prescott, Orion, Whiskey Rock, Prairie du Chien, and Cassville EHAs (Appendix, Table 1). This EHA criterion relates to the health (resiliency) of the population within each EHA. Higgins eye populations that make up 0.25% of the community and exhibit stable or increasing population trends within dense and diverse mussel communities are considered healthy. Higgins eye populations with a lower relative abundance are also considered healthy if zebra mussel densities are below a certain threshold.

Under the Endangered Species Act, we can determine that a species is an endangered or threatened species based on any of five factors: (A) The present or threatened destruction, modification, or curtailment of its habitat or range; (B) Overutilization for commercial, recreational, scientific, or educational purposes; (C) Disease or predation; (D) The inadequacy of existing regulatory mechanisms; or (E) Other natural or manmade factors affecting its continued existence. The zebra mussel portion of this criterion also addresses factor E (other natural or manmade factors affecting Higgins eye's continued existence).

EHAs and potential EHAs are discussed individually below.

Interstate EHA has met all of the EHA criteria since 2000 (Appendix, Table 1) (EcoAnalysts, Inc. 2019, p. 21).

Hudson EHA has met all EHA criteria for several years (Appendix, Table 1), except that zebra mussel density was $>0.5/m^2$ during several years (from 2005-2018). The zebra mussel density did not seem to affect species composition, relative abundance, or richness during that time, however (EcoAnalysts, Inc. 2019, p. 23).

Prescott EHA has met EHA criteria in multiple years since 2000 (EcoAnalysts, Inc. 2019, pp. 24-25); however, Higgins eye relative abundance declined between 2009 and 2017 and the diverse unionid community criteria was not met in 2017 (Appendix, Table 1).

Wisconsin River Orion EHA met EHA criteria in 2016 (Appendix, Table 1) and has not been further assessed. Overall unionid density may be declining, although there are no clear trends – additional years of monitoring are needed to determine if there are any trends (EcoAnalysts, Inc. 2019, pp. 25-26). Higgins eye density may be increasing due to the release of propagated individuals.

Chippewa River is not currently classified as an EHA in the recovery plan but it does meet EHA criteria because the habitat is stable, there are no zebra mussels, and the mussel community is diverse (Appendix, Table 1). Reintroductions started in 2017 (USFWS 2017) at two locations

(Appendix, Table 2), but it is too early to determine the Higgins eye relative abundance trends in those areas.

Hidden Falls is not currently classified as an EHA in the recovery plan and does not meet EHA criteria, but could meet the criteria in the future (EcoAnalysts Inc. 2019, pp. 27-28). The habitat is stable, zebra mussel density is low, and the mussel community is diverse (Appendix, Table 1). While the unionid density is below 10/m² and may be declining, Higgins eye relative abundance has witnessed a detectable increase over time (EcoAnalysts Inc. 2019, pp. 27-28). Reintroductions have added over 3500 Higgins eyes to this location (Appendix, Table 2).

Winters Landing EHA does not meet the EHA criteria (Appendix, Table 1). Although the total unionid density has remained stable since 2000, unstable sand is increasing, which may be affecting this location. Higgins eye were absent in 2010 and 2015 and the diverse assemblage criteria has not been met (EcoAnalysts, Inc. 2019, p. 30).

Whiskey Rock EHA does not meet the EHA criteria (Appendix, Table 1). Only the Higgins eye relative abundance EHA criteria has been consistently met (EcoAnalysts, Inc. 2019, pp. 31-32). The EHA density and diverse unionid community criteria were met in years with low zebra mussels, but zebra mussel densities and the zebra mussel index exceeded the criteria in all monitoring years (EcoAnalysts, Inc. 2019, pp. 31-32).

Harpers Slough EHA met only a few EHA criteria in any of the monitoring years (Appendix, Table 1). Overall unionid density was met only in 2005 and 2016 and the diverse unionid community criteria was only met in 2016. Zebra mussel density exceeded 0.5 /m² in all monitoring years (EcoAnalysts, Inc. 2019, p. 33).

Prairie du Chien EHA has met most EHA criteria since 2005 (Appendix, Table 1). Higgins eye have comprised more than 0.25% of the community since 2000 (EcoAnalysts, Inc. 2019, pp. 35-36). Habitat was unstable in 2000-2003 due to zebra mussel infestation and dead zebra mussels became a major component of the substrate in 2005. Unionid density fluctuated with zebra mussel densities. Zebra mussel densities did not meet the EHA criteria in any of the monitoring years.

McMillan EHA meets some, but not all EHA criteria. Higgins eye comprised over 0.25% of the unionid community from 2005-2015 and habitat is stable (EcoAnalysts, Inc. 2019, p. 38). Total unionid density was lower than 10/m² in all monitoring years and only 13 species were detected in 2010. Zebra mussel density also did not meet EHA criteria (EcoAnalysts, Inc. 2019, p. 40).

Cassville EHA met most of the EHA criteria since 2003 (Appendix, Table 1) (EcoAnalysts, Inc. 2019, p. 40).

Bellevue EHA meets only a few EHA criteria (Appendix, Table 1). Higgins eye comprise over 0.25% of the unionid community in four of the monitoring years. The substrate is unstable and changed almost entirely to sand in 2004. Unionid density met EHA criteria in 2015, however only in 2000 was there a diverse unionid community with densities over 0.01/m². Zebra mussels were present in all monitoring years (EcoAnalysts, Inc. 2019, p. 41).

Cordova EHA meets only a few EHA criteria (EcoAnalysts, Inc. 2019, pp. 43-44). Total density increased between 2001 and 2005, but has fluctuated since then. Higgins eye has comprised over 0.25% of the unionid community, but the total unionid density was just below 10/m² and zebra mussel densities greater than 0.5/m².

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

Criteria 1 (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.

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 (α) ≤ 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 Reclassification Criterion 1.a – c. works in concert with the EHA criteria by adding in an evaluation of population stability (evaluating the population trend over a 20 year time frame) and evidence of reproduction to the evaluation of the health (resiliency) of a certain number of EHAs. The five EHAs, distributed among specific areas in the Mississippi River (Prairie du

Chien and Pool 14) and in the St. Croix River, gives some insights into the appropriate number and distribution of Higgins eye populations needed to withstand catastrophic events (redundancy). The geographic range could also be a proxy for genetic or environmental diversity needed to adapt to changing environmental conditions (representation), which is somewhat captured with the requirement that EHAs must include one in each Pool 14, Prairie du Chien, and St. Croix EHAs. The zebra mussel portion of this criterion addresses the health of each EHA and addresses factor E (other natural or manmade factors affecting Higgins eye's continued existence).

The above Intermediate Goal for Reclassification has not been met (Appendix, Table 3). Only the populations at Hudson EHA meets the definition of both reproducing and self-sustaining for at least twenty years. Further, zebra mussels continue to be present (and therefore continue to affect the species) at almost all of the existing EHAs and pEHAs. Zebra mussels have not infested the Interstate EHA. Each EHA is summarized in terms of the classification criteria below and in Appendix, Table 3.

Interstate EHA has met the reclassification criteria from 2004 through 2018 (Appendix, Table 3). If the metrics continue to remain stable or improve over the next few monitoring cycles (through 2024 to achieve 20 years), Interstate could meet the reclassification criteria (EcoAnalysts, Inc. 2019, p. 21).

Hudson EHA meets all reclassification criteria (Appendix, Table 3). Hudson has been monitored for 30 years, overall density has remained stable or increasing, and the Higgins eye population is stable and reproducing (EcoAnalysts, Inc. 2019, p. 23).

Prescott EHA does not meet the reclassification criteria (Appendix, Table 3). Total unionid density has decreased since 2009 (EcoAnalysts, Inc. 2019, pp. 24-25).

Chippewa River is not currently an EHA and does not meet reclassification criteria (Appendix, Table 3), but could meet the criteria in the future. Reintroduction efforts began in 2017 and it will be a number of years before we will be able to determine the success of those efforts. The area is not infested by zebra mussels.

Wisconsin River Orion EHA does not meet the declassification criteria (Appendix, Table 3). Overall unionid density may be declining, although there are no clear trends (EcoAnalysts, Inc. 2019, pp. 26-27). Higgins eye density may be increasing due to the release of propagated individuals and there is some evidence of Higgins eye recruitment.

Hidden Falls is not currently an EHA and does not meet reclassification criteria (Appendix, Table 3), but could meet the criteria in the future. Total unionid density may be declining. Reintroductions have added over 3,500 Higgins eye to the location (Appendix, Table 2). Some released individuals have survived and there is evidence of some reproduction, but Higgins eye has no measurable increase in relative abundance over time (EcoAnalysts, Inc. 2019, pp. 27-28).

Winters Landing EHA does not meet the reclassification criteria (Appendix, Table 3). Although the total unionid density has remained stable since 2000, unstable sand is increasing,

which may be affecting this location. Higgins eye were absent in 2010 and 2015 and no recruitment has been observed (EcoAnalysts, Inc. 2019, p. 30).

Whiskey Rock EHA does not meet the declassification criteria (Appendix, Table 3). Only the Higgins eye relative abundance criteria (1.b.ii) has been met consistently and there was evidence of reproduction in 2004 and 2014 (EcoAnalysts, Inc. 2019, pp. 31-32). There is no clear trend in total unionid density over time.

Harpers Slough EHA has not met declassification criteria (Appendix, Table 3). There is no evidence of Higgins eye reproduction, no clear trend in overall unionid density over time, and Higgins eye relative abundance is low (EcoAnalysts, Inc. 2019, pp. 33, 164 and 167).

Prairie du Chien EHA has met most reclassification criteria since 2005 (Appendix, Table 3). Higgins eye have comprised more than 0.25 % of the community since 2000 and juvenile Higgins eye have been observed since 2005. Additionally, total unionid community density has been stable to increasing since since 2011 (EcoAnalysts, Inc. 2019, pp. 35-36). Habitat was unstable in 2000-2003 due to zebra mussel infestation (dead zebra mussels became a major component of the substrate in 2005) and unionid density fluctuated with zebra mussel densities (EcoAnalysts 2019, pp. 35-36). EcoAnalysts recommended that this location be monitored annually, through at least 2031, to evaluate the stable unionid community criteria (1.b.i) (EcoAnalysts, Inc. 2019, p. 36).

McMillan EHA meets some reclassification criteria (Appendix, Table 3). Higgins eye comprised over 0.25% of the unionid community from 2005 through 2015 (EcoAnalysts, Inc. 2019, p. 38). Total unionid density was low but may be increasing and there is evidence of Higgins eye reproduction (EcoAnalysts, Inc. 2019, pp. 37-38, 182).

Cassville EHA does not meet the declassification criteria (Appendix, Table 3), because no juvenile Higgins eye have been observed at this location (EcoAnalysts, Inc. 2019, pp. 40). The total unionid community density has been stable since 2012 (EcoAnalysts, Inc. 2019, pp. 40).

Bellevue EHA does not meet the declassification criteria (Appendix, Table 3), because no juvenile Higgins eye have been observed at this location (EcoAnalysts, Inc. 2019, pp. 41-42). There is no clear trend in the total unionid community density (EcoAnalysts, Inc. 2019, pp. 41-42).

Cordova EHA does not meet the declassification criteria (Appendix, Table 3). Total density increased between 2001 and 2005, but has since fluctuated (EcoAnalysts, Inc. 2019, pp. 43-44). Juvenile Higgins eye were observed in 2014 and 2018. Criteria 1 must be met in at least one location in Pool 14.

Buffalo Slough EHA does not meet the declassification criteria (Appendix, Table 3). There is no clear trend in total unionid density and the relative abundance of Higgins eye was only met in 2004 (EcoAnalysts, Inc. 2019, pp. 45-46).

Criteria 2 (Goal 1: Reclassification)

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 U.S. Geological Survey’s Columbia Environmental Research Center in Columbia, Missouri, including tests on other species of *Lampsilis*. Characterization of specific sediment and water quality parameters in EHAs has not been accomplished. Characterization of substrate composition and stability has been completed and tracked over time (Appendix, Table 3). Toxicity database has been developed for other species (G. Cope, University of North Carolina, pers. comm. 2019), which may be able to be adapted for Higgins eye. The intent of this criterion is to help ensure that the water quality is conducive to the maintenance of healthy Higgins eye populations, which addresses factor A (the present or threatened destruction, modification, or curtailment of its habitat or range). Once developed, we can use the water quality criteria to evaluate de-listing criterion 4.

Criteria 3 (Goal 1: Reclassification)

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 (Table 1), 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 B (overutilization for commercial, recreational, scientific, or educational purposes), as well as factor D (inadequacy of existing regulatory mechanisms).

Table 1. Status of Higgins eye by state and commercial harvest restrictions.

State	State Status	Is Commercial Harvest Prohibited?	EHA Commerical Harvest Restrictions	Citations
Illinois	Endangered	No, need commercial license	Some location restrictions. Harvest is not allowed within Sylvan Slough	IL Admin Code 2019 ILDNR 2019 IL ESPB 2015

Iowa	Endangered	No, need commercial license, no TE permitted	No EHA restrictions. Harvest is allowed in the Mississippi River	IA DNR 2014 IAC 2019
Minnesota	Endangered	Yes	NA	MNDNR2019
Missouri	Endangered	Yes in 2009	NA	McMurray 2017 MDC 2019
Wisconsin	Endangered	Yes	NA	WIDNR 2020

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 builds upon the EHA and reclassification criteria by ensuring that measures are in place to maintain healthy populations over the long term. This criterion has not been met, but will be evaluated thoroughly once goal 1 has been met or nearly met. Various aspects of the criterion address factor A (present or threatened destruction, modification, or curtailment of its habitat or range), factor D (inadequacy of existing regulatory mechanisms), and factor E (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 A (present or threatened destruction, modification, or curtailment of its habitat or range). This criterion ensures that measures are in place to maintain healthy populations over the long term.

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. A spill response contingency plan has been developed for the upper Mississippi River (UMBRA 2014), which incorporates protocols for sensitive wildlife areas, but does not specifically delineate Higgins eye or Higgins eye EHAs. This criterion ensures that measures are in place to maintain healthy populations over the long term. It addresses factor A (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. This criterion builds upon reclassification criterion (Intermediate Goal 2) and will help ensure that the water quality is conducive to maintenance of healthy Higgins eye populations. It addresses factor A (present or threatened destruction, modification, or curtailment of its habitat or range).

2.3 Updated Information and Current Species Status

2.3.1 Biology and Habitat

2.3.1.1 New information on the species' biology and life history:

No new information.

2.3.1.2 Abundance, population trends (e.g., increasing, decreasing, stable), demographic features (e.g., age structure, sex ratio, family size, birth rate, age at mortality, mortality rate, etc.), or demographic trends:

Population trends are provided in the Appendix, Table 1 and are further detailed in EcoAnalysts, Inc. (2019, entire).

In 2008, EHAs were re-evaluated (USFWS 2008). Categories were changed to EHAs and potential EHAs.

2.3.1.3 Genetics, genetic variation, or trends in genetic variation (e.g., loss of genetic variation, genetic drift, inbreeding, etc.):

Genetic techniques continue to advance, which may aid in conservation efforts of Higgins eye. For example, Boyer et al. (2011) developed a genetic-barcoding approach to identify newly transformed juvenile mussels, including Higgins eye, collected from naturally infested fishes in the St Croix River.

2.3.1.4 Taxonomic classification or changes in nomenclature:

There has been no change in taxonomic classification or changes in nomenclature for the species since the final listing rule was published in 1976.

The Service's Whitney Genetics Lab is conducting a genetic analysis to compare Higgins eye with the pink mucket (*L. abrupta*), fatmucket (*L. siliquoidea*), and the mucket (*Actinonaias ligamentina*). Higgins eye and pink mucket were originally defined from morphological characteristics and a genetic assessment has not yet been completed. There is possible shared mitochondrial lineages between Higgins eye and fatmucket (Bowen 2004, entire).

2.3.1.5 Spatial distribution, trends in spatial distribution (e.g., increasingly fragmented, increased numbers of corridors, etc.), or historic range (e.g., corrections to the historical range, change in distribution of the species' within its historic range, etc.):

There is some uncertainty regarding the historical distribution of Higgins eye but it is believed to have been distributed widely, inhabiting the Upper Mississippi River main stem from just north of St. Louis, Missouri, to Minneapolis-St. Paul, Minnesota (Coker 1919). It also was found in several Upper Mississippi River tributaries including the Ohio, Illinois, Sangamon, Iowa, Cedar, Wapsipinicon, Rock, Wisconsin, Black, Minnesota, St. Croix

Rivers (USFWS 2004), and the Chippewa River in Wisconsin (USFWS 2018, p. 6). The range of Higgins eye has been reduced from its historical distribution and now includes the Upper Mississippi River upstream of Lock and Dam 22 near Hannibal, Missouri, the lower St. Croix River between Wisconsin and Minnesota, the lower Wisconsin River, Wisconsin, and the lower Rock River in Illinois (USFWS 2004). The species has been recently reintroduced to two locations on the Chippewa River in Wisconsin (Smith 2018, p. 1), although it is too soon to determine whether these efforts have resulted in the successful reestablishment of the species in those areas.

2.3.1.6 Habitat or ecosystem conditions (e.g., amount, distribution, and suitability of the habitat or ecosystem):

Since listing, almost all of the extant sites have had encroachment of zebra mussels. Only the Chippewa River and Interstate populations have not experienced zebra mussel encroachment.

2.3.1.7 Other:

Higgins eye is present in Effigy Mounds National Monument, Mississippi National River Recreation Area, Missouri National Recreational River, and Saint Croix National Scenic Riverway.

2.3.2 Threats and Conservation Measures

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. For example, approximately 295 Higgins eye were estimated to be lost as a direct result of the Guttenberg train wreck oil spill in Pool 11 of the Mississippi River (USFWS 2010, p. 5). Chemical spills likely will continue to occur and have the potential to eliminate Higgins eye populations completely from river reaches and, possibly, entire rivers. No one spill is likely to eliminate the entire range; however, one spill could affect multiple EHAs in succession. For example, a spill in Harpers Slough, which is upstream and in close proximity to several other EHAs (Prairie du Chien, McMillan, and Cassville) has potential to affect all of those areas. The extent of any spill is dependent on several variables (e.g., type and amount of chemical, timing of the spill response).

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 stressor to the Higgins eye is the zebra mussel, although the Asian clam, non-native carp, and round goby all continue to impact Higgins eye and other freshwater mussels. These alien species can outcompete Higgins eye for resources (e.g., food, space) and prevent them from normal behavior (e.g., movement, burrowing, siphoning). Since the last review, non-native carp (e.g.,

black carp) have expanded their distribution within the range of Higgins eye. Black carp are known molluscivores, but the extent to which they prey on Higgins eye is not known.

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 EHA on the Mississippi River (Table 1), although illegal harvest may occur. In Missouri, the commercial harvest of freshwater mussels closed in 2009 (McMurray 2017, p. 2). 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. Most states with extant Higgins eye populations prohibit the taking of mussels for scientific purposes without a state collecting permit (Table 4), although some states may find it difficult to enforce this requirement.

Conservation Measures:

Conservation work has been an active area for Higgins eye since the last review in 2006. Major activities that have taken place include: monitoring, captive propagation and release, outreach, and funding acquisition.

Monitoring: Monitoring of Higgins eye locations, including zebra mussel monitoring has occurred for several years at multiple locations (Appendix, Table 1). See EcoAnalysts, Inc. (2019), Smith (2019, 2020), and works cited within for more detailed survey and monitoring information.

Captive Propagation and Release: Approximately 55,000 Higgins eye adults and subadults have been released into four rivers (Mississippi, Rock, Wisconsin, and Chippewa) and fish infested with millions of glochidia have been released into additional locations (Wisconsin, Iowa, Cedar, and Wapsipinicon) (Appendix, Table 2). It is too soon to determine whether these efforts have resulted in the successful reestablishment of the species in those areas.

Releases in most locations occurred from 2000-2014, however recent releases continue in a few locations, including the Mississippi River at Hidden Falls (A. Scheunemann pers comm 2019) and the Chippewa River. In 2017, approximately 3,000 sub-adult Higgins eye were reintroduced to the Chippewa River near Meridean, WI (Smith 2018, p. 1) and 2,799 were released in 2018 at a nearby location (Smith and Bradley 2019, p. 9). Plans are in place to release Higgins eye at several additional locations on the Chippewa River to form a somewhat continuous population (USFWS 2018, entire).

Outreach: Outreach has focused on informing the public about the decline of the freshwater mussels generally and increasing awareness and support for conservation activities, including captive propagation and releases.

Funding: Partners have secured various sources of funds for Higgins eye conservation work, including but not limited to funds from the St. Louis, Rock Island, and St. Paul Districts of the Army Corps of Engineers, Legislative-Citizen Commission on Minnesota Resources (LCCMR), and State Wildlife Grants.

2.4 Synthesis

Reclassification Criteria - In order for Higgins eye to meet reclassified criteria, at least five sites within the Upper Mississippi River basin must have stable, reproducing populations (USFWS 2004). One of these five sites must be in the St. Croix River, one must be Prairie Du Chien, and one site must be in Mississippi River Pool 14. To be considered stable, the location must meet the EHA criteria, density must be stable or increasing over 20 years, there must be evidence of Higgins eye recruitment, and the sites need to be unaffected by zebra mussels. In the St. Croix River, Hudson EHA has met the reclassification criteria despite zebra mussel presence and Interstate EHA met the reclassification criteria from 2004-2018, but six more years of monitoring is needed to reach 20 years. Prairie du Chien has been stable since 2011, has evidence of Higgins eye recruitment, and could meet the reclassification criteria if zebra mussels remain low. Cordova EHA does not currently meet reclassification criteria, but if the density continues to increase, Cordova may meet the criteria in the future. Cordova is the only EHA in Pool 14 that is currently being monitored, although Hanson's Sough did not meet the EHA criteria when it was last monitored in 2016 (ESI 2017). Other sites on the Mississippi River that may meet reclassification criteria in the future include Hidden Falls, Whiskey Rock, and Cassville.

EHA Criteria - Interstate EHA, Hudson EHA, and Orion EHA (Table 1) meet EHA criteria and are currently not affected by zebra mussels (EcoAnalysts, Inc. 2019, p. 50). Higgins eye density at Hidden Falls is stable but below 10/m² and zebra mussels are not affecting the site. If density improves, Hidden Falls could meet EHA criteria. Whiskey Rock, Prairie Du Chien, and Cassville meet EHA criteria, except they are affected by zebra mussels.

Work is being done by a coalition of partners to conserve Higgins eye, including population monitoring, population restoration, zebra mussel monitoring, and outreach. However, even with this conservation work, the threats for Higgins eye have not been ameliorated. These threats include habitat degradation through invasive species, contaminant spills, and altered hydrology (e.g., resulting in shifting unstable substrate).

Resiliency describes the ability of populations to withstand stochastic events (arising from random factors). We can assess resiliency based on metrics of population health, for example, population trends, such as those specified in the EHA and reclassification criteria. Higgins eye populations that make up 0.25% of the community and exhibit stable or increasing population trends within dense and diverse mussel communities are considered healthy. Higgins eye populations with a lower relative abundance are also considered healthy if zebra mussel densities are below a certain threshold. Few EHAs and potential EHAs met these criteria.

Redundancy describes the ability of a species to survive catastrophic events and is often assessed in terms of the number of populations of a species and distribution of those populations across

the landscape. Theoretically, for a species like Higgins eye, the greater the size and number of populations, and the more widely they are distributed, the lower the likelihood a single catastrophic event will cause a species to become extinct. Higgins eye historically inhabited an approximately 500-mile stretch of the Mississippi River from Prescott, Wisconsin, to Louisiana, Missouri, as well as nine tributaries. Before listing, the range in the Mississippi River declined by 50 percent and it was found in only two tributaries (St. Croix and Wisconsin rivers) (Miller and Payne 2007, p. 233). Since reintroduction efforts began in 2000, the distribution of Higgins eye has expanded back to some of the areas that it once historically occurred. This range expansion is largely due to reintroductions into tributaries (Wapsipinicon, Chippewa, Cedar, Iowa, Rock) and the upper Mississippi River, but it is still too early to tell if these reintroduced populations will result in healthy and resilient populations.

Representation is the ability of a species to adapt to changing environmental conditions (adaptive capacity). Representation refers to the breadth of genetic diversity within a species; however, environmental diversity can sometimes be used as a surrogate for genetic diversity. In theory, the greater the diversity, the more potential a species has to respond to changing environmental conditions. Our understanding of representation for Higgins eye is limited due to the lack of genetic information available and the minimal geographic variation among populations.

The risk of extinction remains high because many of the remaining EHA populations are exhibiting declining (or undeterminable) population trends, there is little or no evidence of reproduction in most EHAs, and significant threats remain in these areas (e.g., exotic species, contaminant spills). Furthermore, the EHA criteria and the reclassification criteria have not been met in most EHAs and threats persist throughout the range. Considering all of the above factors we have concluded that there is no information to indicate that the species status should change from endangered at this time.

3.0 RESULTS

3.1 Recommended Classification

Downlist to Threatened
 Uplist to Endangered
 Delist
 No change is needed

4.0 RECOMMENDATIONS FOR FUTURE ACTIONS

Continue to preserve current populations of Higgins eye and their EHAs by doing the following actions:

- Continue to quantify and limit the impact of zebra mussels.
- Develop uniform protocols for collecting and maintaining information on Higgins eye populations and restoration projects (e.g., reintroductions).

- Limit construction in areas of essential Higgins eye habitat. Mitigation, including translocation, may be an acceptable alternative in limited instances.
- Continue to examine the relationship between water quality, especially contaminants, and Higgins eye populations in EHAs. Develop water quality parameter goals for Higgins eye. Create an online, searchable, and curated mussel toxicity database.
- Develop plans to reduce the shipment of toxic materials near Higgins eye habitat.
- Incorporate EHAs and other important Higgins eye locations into spill response plans.
- Review current regulations and develop additional regulation of mussel harvest in the upper Mississippi River drainage to reduce impacts on Higgins eye.
- Develop materials to educate the public on the nature of endangered mussels and Higgins eye, in particular.
- Require the use of double hull barges near EHAs or other important Higgins eye locations.

Continue to enhance and restore populations of Higgins eye within its historical range including:

- Identify and rank potential sites of existing Higgins eye populations for enhancement.
- Increase the number of Higgins eye at enhancement sites to current levels found in EHAs or to numbers appropriate for the local habitat.
- Continue to determine the feasibility of reestablishing Higgins eye into historical habitats, particularly streams that are at lower risk for zebra mussel colonization, and carry out reintroduction using the best available methods.
- Examine the representation of Higgins eye using genetic techniques. Develop a genetics management plan, including a plan for long term genetic material storage.
- Consider conducting a species status assessment (SSA) for the Higgins eye to determine appropriate measures of resiliency, representation, and redundancy to assess current and future conditions. Consider revisions to recovery plan per results of the SSA, if appropriate.

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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
- No change needed

Appropriate Listing/Reclassification Priority Number, if applicable:

Review Conducted By: Tamara Smith, Fish and Wildlife Biologist

FIELD OFFICE APPROVAL:

Lead Field Supervisor, Fish and Wildlife Service

Approve _____ Date _____

The lead Field Office must ensure that other offices within the range of the species have been provided adequate opportunity to review and comment prior to the review's completion. The lead field office should document this coordination in the agency record.

Appendix

Table 1. Essential Habitat Areas (EHAs) and EHA criteria. Data is given for the most recent survey year at each location. Italicized text indicates that it does not meet EHA criteria. Substrate abbreviations are: sand (Sd), gravel (Gr), cobble (Co), clay (Cl), silt (Silt), and boulder (Bo).

EHA	Drainage	Pool	River Mile(s)	State	Monitoring Duration (yrs)	Cumulative time met EHA criteria	Higgins eye (%)	Dense Community Unionid Density (#/m²)	Diverse Community Number of other Species with Density >0.01/m²	Is the Habitat Stable? (Substrate Composition)	Zebra Mussel Infestation (%)	Zebra Mussel Density (#/m²)
Interstate	St. Croix		47.5-48.5	MN	30	18	0.70	14.7	24	Yes (Sd/Gr/Cb)	NA	0.00
Hudson	St. Croix		16.2-17.6	MN/WI	30	30	1.60	23.7	27	Yes (Sd/Gr)		0.17
Prescott	St. Croix		0 -0.2	MN/WI	13	0	0.60	6.0	14	Yes (Sd/Gr)		0.13
Orion	Wisconsin		near MRM631	WI	28	1	0.60	2.1	15	Yes (Cb/Gr/Sd)		0.01
Chippewa¹	Chippewa		undefined	WI	1	?	<i>0.5</i>	10.25	26	Yes (Cb/Gr/Sd)	NA	0.00
Hidden Falls²	Mississippi	2	846	MN	8	0	<i>0.00</i>	7.5	19	Yes (Sd/Gr)		0.02
Winters Landing	Mississippi	7	709	WI/IA	15	0	<i>0.00</i>	11.5	<i>13</i>	<i>No - Increasing Sd</i>		<i>48.90</i>
Whiskey Rock	Mississippi	9	655.8--658.4	WI/IA	14	1	1.14	15.9	24	Yes (Sd/Silt/Sh)	33.2	N/A
Harpers Slough	Mississippi	10	639.0 - 641.4	WI/IA	16	0	<i>0.10</i>	11.5	17	Yes (Sd/Gr)		<i>20.20</i>
Prairie du Chien	Mississippi	10	633.4 - 637	WI/IA	25	4	1.95	14.9	16	Yes (Sd/Gr)		<i>4.00*</i>
McMillan	Mississippi	10	616.4 - 619.1	WI/IA	15	0	0.80	<i>7.0</i>	20	Yes (Sd/Gr/Sh)		<i>0.70</i>

Cassville	Mississippi	11	606-608	WI/IA	16	14	0.60	15.5	23	Yes (Gr/Sd/St/Sh)		7.20
Bellevue*	Mississippi	13		IL/IA	15	0	0.30	12.0	13	No (Sd)	81.7	NA
Cordova	Mississippi	14	503.0 - 505.5	IL/IA	27	0	2.90	9.6	20	Yes (Sd/Gr/Cl/St)		0.60
Sylvan Slough	Mississippi	15	485.5 - 486.0	IL/IA								
Buffalo Slough	Mississippi	16	470.5	IL/IA	14	0	0.22	7.4	20	Yes (Cl/Sd/St/Gr /Cb/Bo)		3.30

¹Not currently an EHA but may be considered one in the future. ²Potential EHA (USFWS 2008).

Table 2. Numbers of Higgins eye released by location as adults, sub-adults, or via free release of infested host fish (juv-free) or in cages (juv-cage) as reported by MNDNR (A. Scheunemann pers. comm. 2019), Smith and Bradley (2019), Smith (2018), and EcoAnalysts, Inc. (2019). Italicized numbers indicate a slight discrepancy in numbers between MNDNR data and the data presented in EcoAnalysts, Inc. (2019, Table 1-1). Table 2 is continued on the next page.

Drainage	Mississippi River									
Location	Hidden Falls	Upper Pool 2		Lower Pool 2		Pool 3		Pool 4 - Goose Lake	Pool 4 - 4th Cut	Pool 16 - Fairpt.
Year Placed	Sub-adults	Adults	Sub - adults	Adults	Sub - adults	Adults	Sub - adults	Sub - adults	Sub - adults	Sub - adults
2000		100				101				
2001		271								
2002										
2003							<i>196</i>	<i>349</i>		
2004			5		<i>845</i>			<i>577</i>	<i>605</i>	
2005					800		1400	500	500	
2006			1679		-301		744			
2007			5260				2260			4779
2008			521				1092	270	30	2061
2009										
2010			1900				1631	1473	1473	
2011	2									164
2012	826		759				160			47
2013	525		520							
2014	1341									1300
2015	833									
2016	0									
2017	0									
2018	0									
2019	17									
TOTAL	3,544	371	10,644	-	1,344	101	7,483	3,169	2,608	8,351

Table 2 (continued). Numbers of Higgins eye released by location as adults, sub-adults, or via free release of infested host fish (juv-free) or in cages (juv-cage) as reported by MNDNR (A. Scheunemann pers. comm. 2019), Smith and Bradley (2019), Smith (2018), and EcoAnalysts, Inc. (2019). Italicized numbers indicate a slight discrepancy in numbers between MNDNR data and the data presented in EcoAnalysts, Inc. (2019, Table 1-1).

Drainage	Rock River	Wisconsin River				Iowa River	Cedar River	Wapsipinicon River		Chippewa River	
Location	Rock River	Orion		Praire du Sac		Iowa River	Cedar River	Central City	Anamosa	Hwy H	Meridean
Year Placed	Sub - adults	Sub - adults	Juv-cage	Sub - adult	Juv-free	Juv-free	Juv-free	Juv-free	Juv-free	Sub - adults	Sub - adults
2000			1100								
2001			34042		13485		69200				
2002					16500	131551	35615	71000	69700		
2003			59952		51748	13359	38657	21084	21117		
2004			29471		26101	99721	87888	45198	45198		
2005		1437	226262		41205	83602	106752	229141	53320		
2006	500				221445	120141	?	549312	227772		
2007	4828	1922						135003	135003		
2008	1162		100000	1723	200000				100000		
2009					55127						
2010					61020	676972					
2011						120910					
2012						50000			50000		
2013											
2014											
2015											
2016						494250					
2017						1031050		1,238,450			3000
2018						255000		552,048		2799	2
2019											
TOTAL	6,490	3,359	450,827	1,723	686,641	3,076,556	338,112	2,841,236	702,110	2,799	3,002

Table 3. Essential Habitat Areas (EHAs) and reclassification criteria 1.a (reproducing) and 1.b (self-sustaining). Italicized text indicates that it does not meet the reclassification criteria.

EHA	Drainage	Reproducing? (Criteria 1.a)	Total Unionid Density trend (# years) (Criteria 1.b.i)	% Higgins eye (Criteria 1.b.ii)	>0.25% for 20 years (Criteria 1.b.ii)	Affected by zebra mussels?	Meets Reclassification Criteria?
Interstate	St. Croix	Yes, 1988 and 2014	stable or increasing since 2004	0.70	NA	No	<i>No</i>
Hudson	St. Croix	Yes, 2000, 2009, 2014, and 2018	stable or increasing since 1988	1.60	NA	?	Yes
Prescott	St. Croix	Yes	<i>decreasing since 2009</i>	0.60		<i>Yes</i>	<i>No</i>
Chippewa¹	Chippewa	No	<i>Trend unknown</i>	0.50	No	No	<i>No</i>
Orion	Wisconsin	Yes, but low	<i>may be declining, no consistent trend</i>	0.60		No	<i>No</i>
Hidden Falls²	Mississippi	Yes 2012	Stable since 2012	0.00		No	<i>No</i>
Winters Landing	Mississippi	<i>No</i>	Stable since 2000	0.00	<i>No</i>	No	<i>No</i>
Whiskey Rock	Mississippi	Yes, 2004 and 2014	<i>no clear trend</i>	1.14	N/A	<i>Yes</i>	<i>No</i>
Harpers Slough	Mississippi	<i>No</i>	<i>no clear trend</i>	0.10	Yes	<i>Yes</i>	<i>No</i>
Prairie du Chien	Mississippi	Yes, since 2005	stable to increasing since 2011	1.95	NA	<i>Yes</i>	<i>No</i>
McMillan	Mississippi	Yes, 2015	low, increasing since 2015	0.80	NA	No	<i>No</i>
Cassville	Mississippi	<i>No</i>	Stable since 2012	0.60	NA	?	<i>No</i>
Bellevue²	Mississippi	Yes	<i>no clear trend</i>	0.30	NA	?	<i>No</i>
Cordova	Mississippi	Yes, 2014 and 2018	increased 2001-2005, fluctuating since 2010	2.90	NA	<i>Yes</i>	<i>No</i>
Sylvan Slough	Mississippi						<i>No</i>
Buffalo Slough	Mississippi	Yes	Stable since 2014	0.22	Yes	?	<i>No</i>

¹Not currently an EHA but may be considered one in the future. ²Potential EHA (USFWS 2008).