Risk of Adverse Impacts from the Movement through the CAWS and Establishment of Aquatic Nuisance Species in the Great Lakes and Mississippi River Basins

Volume I: Chapters 1-9 and Appendices A-D

Final Report

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Product of the GLMRIS Team

The Great Lakes and Mississippi River Interbasin Study (GLMRIS) Team consists of a regional, collaborative effort led by the U.S. Army Corps of Engineers (Corps), including various District and Division offices, as well as Corps Centers of Expertise and Research Laboratories. Products of the GLMRIS Team are also made possible in collaboration with various federal, state, local, and non-governmental stakeholders.

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Prepared by

M. Grippo, L. Fox, J. Hayse, and I. Hlohowskyj
Environmental Science Division
Argonne National Laboratory

and

T. Allison
Decision and Information Sciences Division
Argonne National Laboratory

for

The GLMRIS Risk Assessment Team
U.S. Army Corps of Engineers
Chicago District

Prepared by M. Grippo, L. Fox, J. Hayse, and I. Hlohowskyj, Environmental Science Division, and T. Allison, Decision and Information Sciences Division, Argonne National Laboratory. Work by Argonne National Laboratory was supported under Military Interdepartmental Purchase Request W81G6621049856 from the U.S. Department of Defense, Department of the Army, Corps of Engineers Chicago District, through U.S. Department of Energy contract DE-AC02-06CH11357.

About Argonne National Laboratory

CONTENTS

CONTENTS (CONT.)

CONTENTS (CONT.)

CONTENTS (CONT.)

FIGURE

TABLES

TABLES (Cont.)

TABLES (Cont.)

ACRONYMS

ANS	aquatic nuisance species
APHIS	Animal Plant Health Inspection Service
CAWS	Chicago Area Waterway System
EPA	U.S. Environmental Protection Agency
GLB	Great Lakes Basin
GLMRIS	Great Lakes Mississippi River Interbasin Study
ISSG	IUCN/SSC Invasive Species Specialist Group
MRB	Mississippi River Basin
NBII	National Biological Information Infrastructure
NRC	National Research Council
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WRDA	Water Resource Development Act

1 INTRODUCTION

The Water Resources Development Act of 2007 (WRDA) directs the U.S. Army Corps of Engineers (USACE) to conduct a study to determine the range of options and technologies available to prevent aquatic nuisance species (ANS) transfer through aquatic pathways between the Great Lakes Basin (GLB) and the Mississippi River Basin (MRB). For the purposes of GLMRIS, the term prevent means to reduce the risk to the maximum extent possible, because it may not be technologically feasible to achieve an absolute solution. To fulfill this authority, USACE is conducting the Great Lakes and Mississippi River Interbasin Study (GLMRIS).

In support of GLMRIS Program, a risk assessment was conducted for 35 ANS that are currently considered to be established in either the GLB or MRB but not both, and for which a concern of interbasin transfer has been identified. The risk assessment was conducted to identify the potential for ANS establishment within either the GLB or MRB, and the risks of adverse impacts that could be incurred following establishment. Specifically, the GLMRIS risk assessment identifies for each ANS:

- The potential for the ANS to successfully transfer between basins;
- The likelihood of the ANS to become established in a new basin; and
- The potential for establishment of the ANS to result in adverse environmental, economic, and social/political consequences within the new basin.

The risk assessment also characterized and ranked the five pathways within the Chicago Area Waterway System (CAWS) (Figure 1.1) that connect the two basins with regard to the number of ANS that could successfully use each pathway for successful interbasin transfer and the level of potential consequences associated with establishment of those species within a new basin.

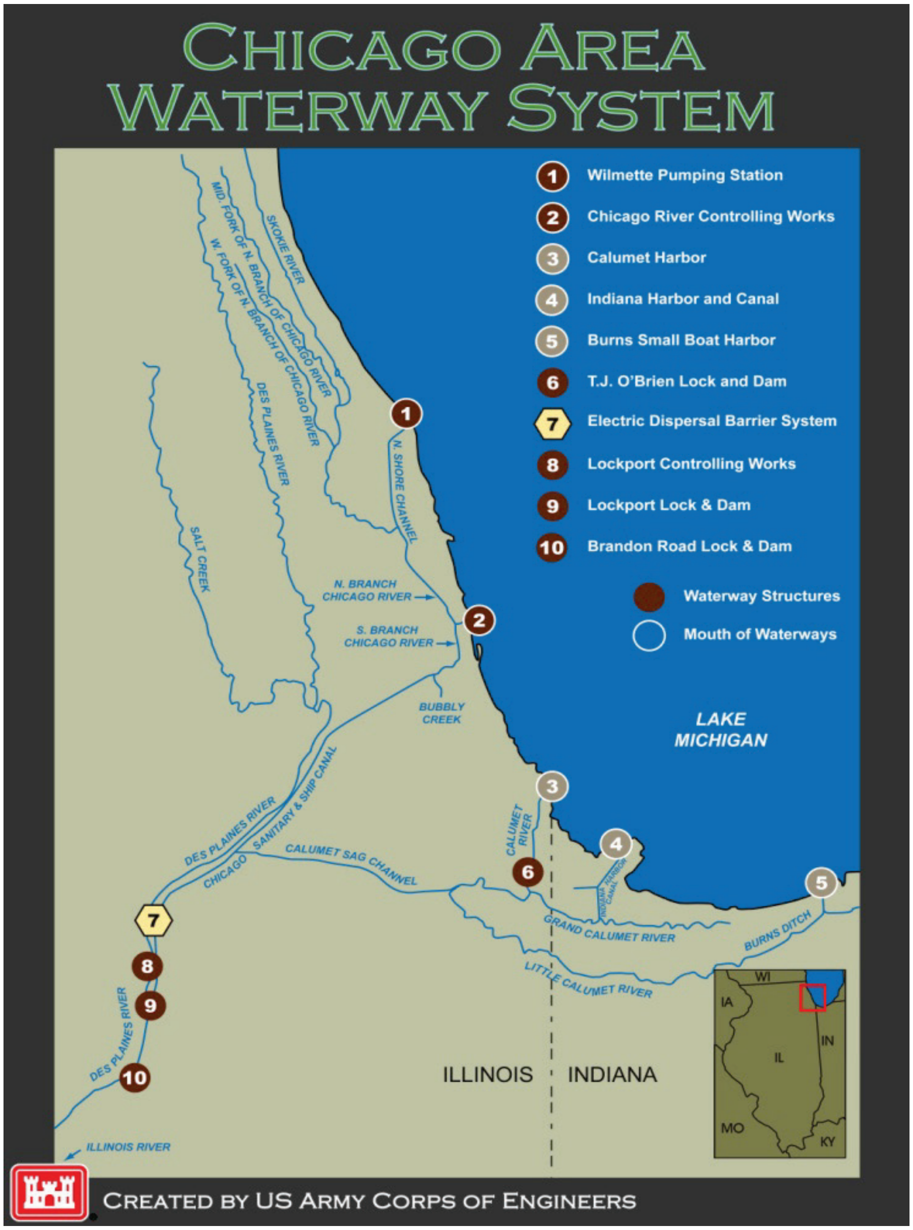

FIGURE 1.1 Chicago Area Waterway System

2 STUDY AREA

The following section provides a brief description of the study area evaluated by this risk assessment. A more detailed description of the study area of the CAWS pathways may be found in Hlohowskyj et al. (2013).

The risk assessment evaluated five aquatic pathways within the CAWS. For the GLMRIS risk assessments, an aquatic pathway within the CAWS is defined as:

- A hydraulically permanent surface water connection between the MRB and GLB that may be used in the interbasin transfer of one or more ANS.

These aquatic pathways are not single point locations along the interface between the MRB and the GLB, but rather are surface water reaches connecting the two basins. The five aquatic pathways identified within the CAWS are shown in Figure 1. Each of the five pathways has a single connection point to the GLB and a single connection point to the MRB. While the five aquatic pathways each have a unique connection point along the Lake Michigan coast (Fig. 1), the five pathways all share a common connection point to the MRB, the Brandon Road Lock and Dam. Water flow within these pathways is primarily from Lake Michigan toward the Brandon Road Lock and Dam.

Moving from Lake Michigan toward Brandon Road Lock and Dam, each aquatic pathway ultimately connects to the Chicago Sanitary and Ship Canal (CSSC), which has a connection with the Des Plaines River at the Lockport Controlling Works and then connects with the river at Lockport Lock and Dam. The Electric Dispersal Barrier System, operated and maintained by USACE to control the spread of invasive fish species between the Great Lakes and Mississippi River basins, has been constructed within the CSSC above the Lockport Controlling Works (Fig. 1).

3 AQUATIC NUISANCE SPECIES EVALUATED

A screening analysis was performed by the GLMRIS Natural Resources Team to identify ANS of concern for potential interbasin transfer through the CAWS pathways (Veraldi et al. 2011). The analysis cataloged known aquatic nuisance species currently present within the GLB and MRB, and served to identify which ANS will undergo GLMRIS risk assessments.

Through this analysis, 39 ANS of concern were identified. Subsequent evaluation of these 39 species identified five species as being present in both basins, and these were removed from further consideration for the risk assessment. Viral hemoragic septicemia (VHSv) was later added to the list because of uncertainty as to whether it was established in both basins. Of the 35 total species (Table 3.1), 10 are of concern for potential transfer to the GLB and 25 are of concern for potential transfer to the MRB.

TABLE 3.1 Aquatic Nuisance Species Occurring in Either the Mississippi River or Great Lakes Basins to Be Evaluated for Risk of Adverse Impacts

Taxonomic Category	Common Name	Scientific Name	Basin Currently Inhabited[a]
Protozoa	Testate amoeba	*Psammonobiotus communis*	GL
	Testate amoeba	*Psammonobiotus dziwnowi*	GL
	Testate amoeba	*Psammonobiotus linearis*	GL
Algae	Cryptic algae	*Cyclotella cryptica*	GL
	Grass kelp	*Enteromorpha flexuosa*	GL
	Red algae	*Bangia atropurpurea*	GL
	Diatom	*Stephanodiscus binderanus*	GL
Bryozoans	Freshwater bryozoan	*Lophopodella carteri*	GL
Molluscs	Greater European peaclam	*Pisidium amnicum*	GL
	European fingernail clam	*Sphaerium corneum*	GL
	European stream valvata	*Valvata piscinalis*	GL
Crustaceans	Scud	*Apocorophium lacustre*	MR
	Fishhook waterflea	*Cercopagis pengoi*	GL
	Waterflea	*Daphnia galeata galeata*	GL
	Bloody red shrimp	*Hemimysis anomala*	GL
	Parasitic copepod	*Neoergasilus japonicas*	GL
	Harpacticoid copepod	*Schizopera borutzkyi*	GL
Fish	Northern snakehead	*Channa argus*	MR
	Skipjack herring	*Alosa chrysochloris*	MR
	Inland silverside	*Menidia beryllina*	MR
	Black carp	*Mylopharyngodon piceus*	MR
	Bighead carp	*Hypophthalmichthyes nobilis*	MR
	Silver carp	*Hypophthalmichthys molitrix*	MR
	Blueback herring	*Alosa aestivalis*	GL
	Threespine stickleback	*Gasterosteus aculeatus*	GL
	Ruffe	*Gymnocephalus cernuus*	GL
	Sea lamprey	*Petromyzon marinus*	GL
	Tubenose goby	*Proterorhinus semilunaris*	GL
Plants	Marsh dewflower	*Murdannia keisak*	MR
	Cuban bullrush	*Oxycaryum cubense*	MR
	Dotted duckweed	*Landoltia punctata*	MR
	Swamp sedge	*Carex acutiformis*	GL
	Reed sweetgrass	*Glyceria maxima*	GL
	Water chestnut	*Trapa natans*	GL
Virus	Viral Hemorrhagic Septicemia Virus	*Novirhabdovirus* sp.	GL

[a] GL = Great Lakes; MR = Mississippi River.

4 RISK ASSESSMENT METHODS

The risk assessment is based on two components: (1) the probability of an ANS entering and becoming successfully established in a new basin; and (2) the consequences of that establishment on ecological, economic, and social aspects of the new basin's environment.

Risk (likelihood) of adverse impacts occurring as a result of the establishment of ANS X in Basin Y	**=**	**Probability of ANS X becoming established in Basin Y (Basin Y becomes *exposed* to ANS X)**	**×**	**The consequences of ANS X becoming established in Basin Y (the *effects* to Basin Y of exposure to ANS X)**

The following sections provide a brief description of the methods used to conduct the risk assessment. A more detailed description of the methods may be found in Hlohowskyj et al. (2013).

4.1 PROBABILITY OF ESTABLISHMENT

For each of the 35 ANS, the probability of establishment ($P_{establishment}$) was based on five probability elements:

P_{path} = Probability that a complete aquatic pathway is available for interbasin transfer;

$P_{arrival}$ = Probability that the ANS will arrive at the pathway from its current distribution within a specified time;

$P_{passage}$ = Probability that the ANS can successfully move through the aquatic pathway from one basin to the other;

$P_{colonize}$ = Probability that the ANS can establish a colony in the newly invaded basin; and

P_{spread} = Probability that the ANS can spread to elsewhere in the new basin.

For the establishment assessment, each of the five probability elements was assigned one of four likelihood ratings, and $P_{establishment}$ takes on the lowest probability rating among the five elements. The probability ratings were:

High = The event (e.g., successful passage through a pathway) will almost certainly occur;

Medium = The event is likely to occur but it is not certain;

Low = The event will likely not occur but is possible; and

None = The event is certain not to occur (it is impossible).

The application of ratings to each probability element was based on the evaluation of information regarding the current distribution, life history, habitat requirements, physiology, and potential for human-mediated transport of each ANS (see Appendix A), as well as information regarding the physical and environmental conditions of each CAWS pathway and of each of the two basins. Where ANS-specific information was unavailable, information on similar (taxonomically related) species was evaluated. Sources of information included the open scientific literature, agency reports, and personal communications with subject matter experts.

The establishment assessment was conducted for four time steps encompassing a 50-year time period:

Time 0 (T_0) = Potential for establishment based on the current distribution of the ANS;

Time 10 (T_{10}) = Potential for establishment 10 years from present time;

Time 25 (T_{25}) = Potential for establishment 25 years from present time; and

Time 50 (T_{50}) = Potential for establishment 50 years from present time.

The use of these time steps is intended to capture changes in the distribution of ANS species that may occur during a time step and thus affect the likelihood of establishment.

4.2 CONSEQUENCES OF ESTABLISHMENT

The consequence assessment qualitatively considered three categories of consequences: environmental, economic, and social/political. The overall consequence from ANS establishment was estimated as:

Overall Consequences = **Environmental Consequences** + **Economic Consequences** + **Social/Political Consequences**

where:

Environmental Consequences = Effects on ecosystem structure and function, including effects on resident species, populations, communities, and habitats.

Economic Consequences = Changes in consumer surplus and property values; effects on employment and income of changes in recreational and commercial fishing and recreational boating and of changes in the cost of maintaining water quality and water withdrawal structures and in boat maintenance costs.

Social/Political Consequences = Perceived effects on leisure, recreational, and subsistence opportunities, and changes in regulatory requirements.

Overall Consequences = Sum of the environmental, economic, and social consequences, with environmental and economic consequences being qualitatively weighted more than social/political consequences.

For the consequence assessment, each ANS was assumed to have become successfully established in the new basin. For each consequence category, the assessment considered (1) how ecosystem structure and function, economic activity, and the regulatory environment might be affected following ANS establishment and (2) the nature and severity of potential environmental, economic, and social/political effects. The characterization of potential consequences also considered whether consequences would be “localized” or “widespread” in spatial extent. A localized consequence was one that would be limited in spatial extent due to the specific habitat requirements of the ANS and the relatively limited availability and distribution of suitable habitat for that species (i.e., the habitat for the ANS occurs in disjunct and widely separated locations). In contrast, a widespread consequence would have a much greater spatial extent in the basin due to the general availability of suitable habitat for the ANS throughout the basin (e.g., in large contiguous patches or in numerous locations throughout the basin). The consequence assessments did not attempt to quantify the magnitude of any consequences.

Each of the three consequence categories was assigned one of the following qualitative ratings:

High (H) = High consequence rating due to the larger number of consequence categories affected, the nature and severity of the consequences, and the broader spatial extent of the consequences.

Medium (M) = Medium consequence rating due to the number of consequence categories affected, the nature and severity of the consequences, and the spatial extent of the consequences.

Low (L) = Low consequence rating due to the lower number of consequence categories affected, the lesser nature and severity of the consequences, and the more localized extent of the consequences.

None (N) = No consequences are anticipated.

4.3 ANS-SPECIFIC RISK

The risk of adverse impacts from an ANS using a CAWS pathway for interbasin transfer and becoming established in a new basin was qualitatively characterized as:

Risk of adverse impacts occurring as a result of the establishment of an ANS = **Probability of an ANS becoming established** × **The level of consequences associated with an ANS becoming established**

A risk rating was assigned for each ANS based on a multiplicative combination of its probability of becoming established in a new basin and the overall consequences level identified from the establishment (Table 4.1) (Hlohowskyj et al. 2013).

TABLE 4.1 GLMRIS Multiplicative Method to Determine the Overall ANS Risk Level[a]

Probability of Establishment	Consequence of Establishment	CAWS Risk Level
H[a]	H	H
M	H	M
H	M	M
M	M	M
L	H	L
H	L	L
M	L	L
L	M	L
L	L	L
H, M, or L	N	N

[a] H = High; M = Medium; L = Low; N = None.

A High risk level was assigned if:

- The probability of establishment and the consequence were both rated High.

A Medium risk level was assigned if either:

- The probability of establishment was High and the consequence was Medium;
- The probability of establishment was Medium and the consequence ratings were Medium or High.

A Low risk level was assigned if:

- The probability of establishment was rated either High or Medium and the consequence was Low;
- The probability of establishment was Low and the consequence was Medium or High; or
- Both the probability of establishment and the consequence were Low.

In the event that no consequences were indicated, then a risk rating of None was assigned for the ANS.

Cox (2008) makes the argument that the multiplicative method used for determining overall risk is the most robust decision-making approach because it better approximates a quantitative risk model (see Section 3.4.1 of Hlohowskyj et al. 2013). Therefore, the GLMRIS study used a multiplicative approach to combine the probability of establishment and the consequences of establishment into an overall risk level. Alternatives to the multiplicative method are the additive approaches described in Section 3.4.1 of Hlohowskyj et al. (2013). These methods are defined as the ANS Task Force Additive Method and the Alternative Additive Method, and the overall risk level determination rules are shown in Table 4.2. The final list of medium and high risk ANS could differ significantly depending on which method is used. Therefore, a sensitivity analysis was performed to compare the composition of the final lists of medium and high risk species generated by the three different methods.

4.4 CAWS PATHWAY-SPECIFIC RISKS

Because of pathway-specific differences in physical and environmental conditions, some pathways may be more amenable to support interbasin transfer for some ANS, while other pathways may be more suitable for transfer by other ANS. The following procedure was used to rank the five CAWS pathways on the basis of potentially supporting interbasin transfer of ANS (see Hlohowskyj et al. [2013] for a detailed description of this procedure).

TABLE 4.2 Additive Methods to Determine the Overall ANS Risk Level[a]

Risk Scenario	Probability of Establishment	Consequence of Establishment	ANS Task Force Additive Method	Alternative Additive Method
1	H	H	H	H
2	M	H	H	H
3	H	M	H	M
4	M	M	M	M
5	L	H	M	M
6	H	L	M	L
7	M	L	M	L
8	L	M	M	L
9	L	L	L	L
10	H, M, or L	N	N	N

[a] H = High; M = Medium; L = Low; N = None.

First, the total number of ANS with a specific risk level rating (high, medium, low, and none) was tabulated for each CAWS pathway. The number of ANS in each risk level was then multiplied by the appropriate risk-level-specific weighting factors:

High Risk = 3
Medium Risk = 2
Low Risk = 1
No Risk = 0

The resulting numerical risk values within each CAWS pathway were then summed to provide an overall CAWS-specific risk value. The CAWS pathways were then ranked from highest to lowest in risk value. The pathway with the highest risk value is considered to have the greatest potential for supporting interbasin transfer of ANS with the greatest potential for adverse impacts.

4.5 UNCERTAINTY

The characterization of ANS-related risks relied on the evaluation and interpretation of existing scientific information together with professional judgment of the GLMRIS risk assessment team. The amount of information available for supporting the risk assessment varied widely among the ANS evaluated. For some ANS, there were relatively few published studies or other available information, while for others there were a relatively large number of published studies, agency reports, and other data. Thus, the risk assessment included identification of the level of uncertainty associated with the designation of the ANS-specific establishment elements and consequences ratings.

Each of the individual establishment (pathway, arrival, passage, colonization, and spread) and consequence (environmental, economic, and social/political) element ratings are accompanied by an uncertainty rating based on the amount and quality of scientifically defensible data that was used to develop each element rating. The less data available, the greater the uncertainty associated with the rating. Four levels of uncertainty were identified:

High = Little or no data were available, or there was a very broad range in the nature and severity of consequences including extreme consequences, and the probability or consequence ratings (as well as all assumptions used to develop the ratings) were based on professional judgment;

Medium = Good data were available but some major data gaps were still evident, or there was a broad range in the nature and severity of the consequences but no extreme consequences were indicated, such that the probability or consequence rating is based on a mixture of ANS-specific data, data from similar species, anecdotal data, and professional judgment;

Low = Good ANS-specific data were available (e.g., peer-reviewed, ANS-specific scientific publications and reports), and no significant data gaps were known, and there was only a limited range of possible consequences; and

None = Adequate data were available to fully support the probability and consequence ratings.

No uncertainty rating was assigned for the probability of establishment rating or the overall consequence of establishment rating because there is no objective way to characterize overall uncertainty for an aggregate rating. Consequently, no uncertainty rating was assigned to the risk of adverse impacts.

5 RISKS OF SPECIES INVADING THE GREAT LAKES BASIN

A total of 10 aquatic nuisance species (ANS) were evaluated for risks to the Great Lakes Basin (GLB) and its resources. These ANS included six species of fish, one crustacean species, and three plant species (Table 5.1). None of these 10 ANS were found to pose a high risk to the GLB, while three of the 10 were found to pose a medium risk; these species are discussed in Section 5.1. The seven remaining ANS currently in the Mississippi River Basin (MRB) (four fish and three plants) were found to pose only a low risk to the GLB; these species are discussed in Appendix A.

TABLE 5.1 Aquatic Nuisance Species of Concern for the Great Lakes Basin

Species	Primary Mode of Interbasin Transfer
Species Posing High Risk	
None	
Species Posing Medium Risk	
Scud (*Apocorophium lacustre*)	Passive drift, hull fouling
Silver carp (*Hypophthalmicthys molitrix*)	Active swimming
Bighead carp (*Hypophthalmichthys nobilis)*	Active swimming
Species Posing Low Risk	
Northern snakehead (*Channa argus*)	Active swimming
Black carp (*Mylopharyngodon piceus*)	Active swimming
Skipjack herring (*Alosa chrysochloris*)	Active swimming
Inland silverside (*Menidia beryllina*)	Active swimming
Cuban bulrush (*Oxycaryum cubense*)	Passive drift
Dotted duckweed (*Landoltia punctata*)	Temporary vessel attachment, passive drift
Marsh dewflower (*Murdannia keisak*)	Passive drift, temporary vessel attachment

5.1 MEDIUM RISK SPECIES

5.1.1 Scud (*Apocorophium lacustre*)

5.1.1.1 Native Range and Current Distribution

The scud (*Apocorophium lacustre*) has been reported from the Mississippi River, Ohio River, and Illinois River (Grigorovich et al. 2008; USGS 2011). This ANS has been found in the Illinois River less than 32.2 km (20 mi) from Brandon Road Lock and Dam; however, the last survey for this species was conducted in 2008, so it may currently be even closer to the dam (USGS 2011;

Grigorovich et al. 2008). The scud is native to the Atlantic coast of North America and may be transported on boat hulls or in ballast water (Grigorovich et al. 2008; Johnson et al. 2007).

5.1.1.2 Life History and Ecology

The scud is a tube-dwelling, benthic filter-feeding amphipod (Grigorovich et al. 1998). During reproduction, females brood embryos on their underside, which hatch out as crawling juveniles—therefore, there is no planktonic stage. This species tolerates a wide range of temperatures and is pollution tolerant (Ysebaert et al. 2000). It is not found in fast-flowing or turbid water (Grigorovich et al. 2008). Habitat for this species includes the benthos of estuaries, rivers and lakes, and intertidal zones in native estuarine habitat. The scud is associated with rocky or sandy shoals and snags (Angradi et al. 2009; Grigorovich et al. 2008). It has been found at shallow 2.5 to 4 m (8.2-13.1 ft) depths, in nearshore non-vegetated areas, including man-made structures such as harbors, and near relict oyster reefs (Grigorovich et al. 2008; USGS 2011).

5.1.1.3 Probability of Establishment

Each of the five CAWS pathways represents a completed pathway which the scud could use to access the GLB, and each would be available at all time steps (Table 5.2). This species was found in the Illinois River just above Dresden Lock and Dam not far from the CAWS pathway entrance at Brandon Road Lock and Dam since 2005 (Appendix E).

The scud will require human-mediated transport to travel upstream through the CAWS and reach the GLB. CAWS Pathways 1, 2, and 3 have vessel traffic that will assist the species with passage to the GLB, and thus there is a high probability of passage for all time steps. For CAWS Pathways 4 and 5, there is no continuous vessel traffic between Brandon Road Lock and Dam and the GLB. Thus, passage through these pathways is unlikely at the current time step; given enough time (10-50 years), this species may be able to naturally move up these pathways and into the GLB. Using these pathways, there is low probability of establishment occurring at the current time step, a medium probability within 10 years, and a high probability within 25-50 years; the uncertainty of passage decreases over time. Regardless of when passage may occur, once the scud reaches the GLB, this species is expected to reach suitable habitat which exists in the basin (Appendix E), become established, and spread to other parts of the basin with low uncertainty.

5.1.1.4 Consequences of Establishment

Environmental Consequences. Should this species become established in the GLB, it could have medium environmental consequences in the basin (see Appendix B and Table 5.3). The scud can have adverse effects on native mussels by smothering them with tubes and by

TABLE 5.2 Probability of Establishment, by CAWS Pathway and Time Step, of the Scud in the GLB

Probability Element	Probability Ratings for Time Steps 0, 10, 25, and 50 years[a,b]																			
	CAWS 1				CAWS 2				CAWS 3				CAWS 4				CAWS 5			
	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}
Pathway	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)
Arrival	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)
Passage	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	L (M)	M (M)	H (L)	H (L)	L (M)	M (M)	H (L)	H (L)
Colonization	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)
Spread	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)
Probability of Establishment	H	H	H	H	H	H	H	H	H	H	H	H	L	M	H	H	L	M	H	H

[a] Probability element ratings: H = high probability, the event will almost certainly occur; M = medium probability, the event is likely to occur but is not certain to do so; L = low probability, the event will likely not occur but is possible.

[b] Uncertainty associated with each Probability Element is indicated in parentheses. Uncertainty ratings: M = medium, good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment; L = low, good data available with no major data gaps; N = none, adequate data available to fully support the probability rating.

TABLE 5.3 Consequences of Establishment of the Scud in the GLB[a,b]

Environmental Consequences	Economic Consequences	Social/Political Consequences	Total Overall Consequences
M (H)	N (L)	N (L)	M

[a] Consequence ratings: M = Medium consequence rating due to the number of consequence categories affected, the nature and severity of the consequences, and the spatial extent of the consequences; N = no consequences are anticipated.

[b] Uncertainty associated with each consequence rating is indicated in parentheses. Uncertainty ratings: H = high, little or no data available and rating based on professional judgment; L = low, good data available with no major data gaps.

competing with them for food (Ysebaert et al. 2000). This species may also adversely affect populations of the non-native zebra mussels in the GLB. In addition, there are federally listed mussels in the GLB that potentially could be affected by an invasion of the scud through competition for space or food. The scud can be locally abundant and cover river bottoms with tubes (Beaumont 1993), which could significantly alter benthic habitat, community structure, and sediment biogeochemistry. However, there are currently no documented ecosystem-level changes that have resulted from the introduction of the scud in the MRB; therefore, the environmental consequences have a high uncertainty (Appendix B).

Economic Consequences. The establishment of the scud in the GLB is not expected to have any economic consequences (see Appendix C). Therefore, this species' economic consequence rating is none, and the uncertainty of the rating is low.

Social/Political Consequences. No consequences based on human use or political regulatory concerns were identified for establishment of the scud in the GLB (Appendix D).

Overall Consequences. The overall consequence level for the scud is considered to be medium (Table 5.3). Potentially widespread environmental consequences are indicated, should the scud become established in the GLB. These consequences would be associated primarily with changes in the benthic habitat, community structure, and Endangered Species Act (ESA) species competition.

5.1.1.5 Risk of Adverse Impacts

If it establishes in the GLB, the scud has an overall consequence rating of low to medium, as this species could impact native mussel communities (Table 5.4). The probability of establishment is high for all pathways at 25 years. The risk of adverse impacts for the scud is medium for all pathways from the 10-year time step to the 50-year time step. The primary uncertainty associated with the risk rating is related to the medium uncertainty of the environmental consequences of the scud establishing in the GLB.

TABLE 5.4 Risk of the Scud to Pose Adverse Impacts to the GLB

	Probability of Establishment[a]					Risk of Adverse Impacts[c]			
Pathway	T_0	T_{10}	T_{25}	T_{50}	Consequences of Establishment[b]	T_0	T_{10}	T_{25}	T_{50}
CAWS 1	H	H	H	H	M	M	M	M	M
CAWS 2	H	H	H	H	M	M	M	M	M
CAWS 3	H	H	H	H	M	M	M	M	M
CAWS 4	L	M	H	H	M	L	M	M	M
CAWS 5	L	M	H	H	M	L	M	M	M

[a] Probability element ratings: H = high probability, the event will almost certainly occur; M = medium probability, the event is likely to occur but is not certain to do so; L = low probability, the event will likely not occur but is possible.

[b] Consequence ratings: M = Medium consequence rating due to the number of consequence categories affected, the nature and severity of the consequences, and the spatial extent of the consequences.

[c] Risk ratings: M = medium risk of adverse impacts; L = low risk of adverse impacts.

5.1.2 Silver Carp (*Hypophthalmichthys molitrix*)

5.1.2.1 Native Range and Current Distribution

Silver carp are native to several major Pacific drainages in eastern Asia from the Amur River of far eastern Russia south through the eastern half of China to the Pearl River (Nico 2012), from approximately 54°N southward to 21°N (Xie & Chen 2001; Froese & Pauly 2004). The species was first introduced to the United States in 1973 by a private fish farmer in Arkansas (Freeze & Henderson 1982). It was first found in natural waters in 1980, likely as a result of escapes from aquacultural facilities (Freeze & Henderson 1982). The species has spread throughout the MRB (Nico 2012). In Illinois, the species has established in the Mississippi, Spoon, Illinois, and Ohio Rivers and their tributaries, and has been reported in the Muddy River; Muscooten Bay; Horseshoe Lake, near the Cache River drainage; and in the Embarras River (Nico 2012). In 2009, a confirmed sighting occurred during Asian carp routine monitoring of a silver carp at the confluence of the CSSC and Des Plaines River (ACRCC 2013a), and silver carp have been captured as far upstream as Dresden Island Pool, four miles downstream of the Brandon Road Lock and Dam (ACCRC 2013c).

5.1.2.2 Life History and Ecology

Silver carp prefer turbid (Radke & Kahl 2002), eutrophic waters (Kolar et al. 2005), but can survive at low growth rates in waters with low plankton concentrations. The species prefers backwaters and impoundments with low-flow/no-flow conditions, large rivers, and contiguous ponds and lakes (Kolar et al. 2005). Spawning may be limited to fast-moving waters with high water levels (Kolar et al. 2005). Silver carp use tributaries much less often than bighead carp, and mostly use them in summer rather than winter (Kolar et al. 2005). Eggs, larvae, and juveniles inhabit wetland floodplains and backwaters (Kolar et al. 2005; Varble et al. 2007; Williamson & Garvey 2005). Optimal growth for the species occurs between 24 and 34°C (75-93.2°F) for adults and at 25-36°C (77-96.8°F) for larvae (Kolar et al. 2005). The species can tolerate long winters under ice cover, as well as temperatures higher than 40°C (104°F) (Opuszynski et al. 1989).

Larval and young of the year silver carp consume zooplankton (Varble et al. 2007), and adults are planktivorous. In the Illinois and Mississippi Rivers, the species mostly consumes rotifers (Sampson et al. 2009). They are pump filter feeders that produce a mucous that allows them to consume various sizes of food items (Kolar et al. 2005). Silver carp spawn between April and June (Varble et al. 2007) and require rivers for spawning (Kolar et al. 2005). Spawning is triggered by rising water levels, flow velocity, and temperatures >17°C (62.6°F) (Stainbrook et al. 2007). Spawning rivers need to be >100 km (62 mi), with fast flow (0.7-1.4 m/s [2.3-4.6 ft/s]) to carry eggs to floodplains and to prevent the eggs from sinking and being covered with silt (Kolar et al. 2005). Fecundity is correlated with increases in body mass and age (Kolar et al. 2005; DeGrandchamp et al. 2007). Populations of silver carp appear to be growing exponentially (Kolar et al. 2005), with abundance peaking quickly following establishment.

5.1.2.3 Probability of Establishment

The silver carp is confirmed to have arrived at the pathway (Appendix E). In 2009, there was a confirmed sighting of a silver carp at the confluence of the CSSC and Des Plaines River during Asian carp routine monitoring efforts (ACRCC 2013a).

The remainder of the silver carp have been captured and observed below Brandon Road Lock and Dam. Since 2007, silver carp were captured in Dresden Island Pool; however, based on the monitoring, it appears that few silver carp have moved from Dresden Island Pool to reaches above the Brandon Road Lock and Dam (USGS point map, ACRCC 2009, ACRCC 2012). The factors driving this apparent stalled range expansion are not understood but may include food and habitat availability, channel morphology and hydrology, and lock specific differences. It is expected that silver carp will remain in low populations in the vicinity of the barrier at T_0 and **T_{10}.**

Monitoring and research have found several potential bypass mechanisms for the Electric Dispersal Barrier System: man overboard scenario when power to the barrier is intentionally turned off, power outages, bypass during flood events, stunned fish floating through the barrier during reverse flow events in the canal (wind, vessel, or current driven), electric field shielding by steel hulled vessels or side wall crevices, small fish passage and fish entrainment within barge induced water currents across the Electric Dispersal Barrier System. Bypass due to these various mechanisms is not expected, because the nearest detectable population of swimming silver carp is in Dresden Island Pool (ACRCC 2013b) and the nearest detected eggs, larvae and fry are farther downstream (ACRCC 2013a). Additionally, research on these bypasses continues and will inform future operations.

The probability of passage through the CAWS is considered low at T0 and T10 with uncertainty equal to medium at T0 and high at T10 (Table 5.5) because: 1) small Asian carp are not expected to be present at the Electric Dispersal Barrier System, 2) the abundance of adults is expected to be absent or low near the Electric Dispersal Barrier System, and 3) if a low population of adults approaches the barrier, then it is expected, based on current research, that the barrier would be effective at controlling passage of these fish. With the continued expected immigration from the lower pools (ACRCC 2013a), the propagule pressure at the Dispersal Barrier System is expected to increase, and thus increase the potential for an individual to move past the barrier system. The probability of passage increases from low to medium at T25 and is a medium at T50. The uncertainty for both timesteps is high.

Although some bioenergetic models suggest that, in general, productivity in the GLB may be too low to support Asian carp (including silver carp) (Cooke & Hill 2010), there are several areas of high productivity within the GLB that are likely to be suitable for supporting this species (Rasmussen et al. 2011). Therefore, if the silver carp is able to pass through the CAWS, it is expected to colonize and spread through the GLB. Overall, the probability of establishment is low until T_{25} and medium at T_{25} and T_{50} for all pathways.

TABLE 5.5 Probability of Establishment, by CAWS Pathway and Time Step, of the Silver Carp in the GLB

	Probability Ratings for Time Steps 0, 10, 25, and 50 years[a,b]																			
	CAWS 1				CAWS 2				CAWS 3				CAWS 4				CAWS 5			
Probability Element	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}
Pathway	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)
Arrival	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)
Passage	L (M)	L (H)	M (H)	M (H)	L (M)	L (H)	M (H)	M (H)	L (M)	L (H)	M (H)	M (H)	L (M)	L (H)	M (H)	M (H)	L (M)	L (H)	M (H)	M (H)
Colonization	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)
Spread	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)
Probability of Establishment	L	L	M	M	L	L	M	M	L	L	M	M	L	L	M	M	L	L	M	M

[a] Probability element ratings: H = high probability, the event will almost certainly occur; M = medium probability, the event is likely to occur but is not certain to do so; L = low probability, the event will likely not occur but is possible.

[b] Uncertainty associated with each Probability Element is indicated in parentheses. Uncertainty ratings: H = high, little or no data available and rating based on professional judgment; M = medium, good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment; L = low, good data available with no major data gaps; N = none, adequate data available to fully support the probability rating.

5.1.2.4 Consequences of Establishment

Environmental Consequences. The environmental consequences of the silver carp becoming established in the GLB are high (Table 5.6; Appendix B). The silver carp is a planktivore that prefers eutrophic rivers, lakes, and backwater habitat (Kolar et al. 2005). Silver carp have been documented to reduce zooplankton abundance and alter their species composition (reviewed in Kipp et al. 2011). In turn, the reduction in zooplankton abundance could reduce the food supply for planktivores and early life stages of higher trophic-level fish species. The silver carp could potentially out compete several planktivorous fish that currently exist in the GLB, such as the gizzard shad, ciscos, alewife, and bigmouth buffalo (Irons et al. 2007; Sampson et al. 2009). There is also the potential for silver carp to outcompete paddlefish and ESA-listed freshwater mussel species. The establishment of silver carp in the GLB could also result in several ecosystem-level effects including effects on phytoplankton biomass, food web dynamics, and nutrient cycling (Kipp et al. 2011). The long-term effects of Asian carp on the MRB have been studied, but are still uncertain. Studies have found variable ecosystem responses to silver carp introductions. Similarly, if silver carp establish in the GLB, the nature and severity of ecosystem impacts are difficult to predict with certainty. Overall, the uncertainty of the consequence rating is medium.

TABLE 5.6 Consequences of Establishment of the Silver Carp in the GLB[a,b]

Environmental Consequences	Economic Consequences	Social/Political Consequences	Total Overall Consequences
H (M)	H (M)	H (M)	H

[a] Consequence ratings: H = High consequence rating due to the larger number of consequence categories affected, the nature and severity of the consequences, and the broader spatial extent of the consequences.

[b] Uncertainty ratings are indicated in parentheses: M = medium, good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment.

Economic Consequences. Widespread establishment of the silver carp in the GLB could produce economic consequences in a number of categories, including loss of consumer surplus and loss of property value, while reductions in recreational boating and fishing and in commercial fishing could adversely impact employment, income, and tax revenues. See Appendix C for more detailed mechanisms and descriptions of potential impacts. For each of these categories, the severity of economic consequences would depend on the extent of species establishment, the resulting impact on existing fisheries resources, and consequent impact on recreational activity, commercial fishing, and the maintenance of boats and equipment. The economic consequence of the silver carp is high with medium uncertainty.

Social/Political Consequences. The social/political consequences of silver carp establishment are high (Table 5.6; Appendix D). The silver carp has the potential to affect the perceived quality of recreational fishing by reducing the abundance of existing fish species through competition (Appendix D). This species is expected to have a widespread distribution in the GLB; therefore, the species could impact fishing in a large area of the GLB. Silver carp could also discourage recreational boating due to their jumping behavior (Appendix D). The establishment of this species is also expected to result in new laws and regulations to address the spread of this species. The severity of the social/political impacts will partly depend on the extent of spread of the silver carp, which is uncertain (Appendix D). Therefore, uncertainty is medium.

Overall Consequences. The silver carp could have high environmental, economic, and social/political consequences, primarily related to its potential to affect biological communities and ecosystem function. Multiple social and political impacts are also possible, including changes in recreational fishing and boat use. Therefore, the overall consequence level of silver carp is high. A medium level of uncertainty is associated with each of the three consequence ratings.

5.1.2.5 Risk of Adverse Impacts

The overall risk associated with the silver carp is low at T_0 and T_{10} and medium at T_{25} and T_{50}, for all pathways and time steps (Table 5.7). The probability of the silver carp establishing in the GLB is low for T_0 and T_{10} because small Asian carp are not expected to be present at the Electric Dispersal Barrier System and the abundance of adults is expected to remain low near the Electric Dispersal Barrier System during these time steps. In addition, if adults do approach the Electric Dispersal Barrier System it is expected to be effective at controlling passage upstream. However, the probability of passage increases to medium at T_{25} and T_{50}, for all pathways, because the population of Asian carp is expected to increase resulting in more individuals challenging the Electric Dispersal Barrier System. The uncertainty of the passage probability from T_0 to T_{50} ranges from medium to high, due to uncertainty about silver carp movement and population trends as well as the effectiveness of the Electric Dispersal Barrier System over time. If the silver carp does enter into and establish in the GLB this event could result in high environmental, economic, and social/political consequences primarily related to its potential to affect biological communities ecosystem function, and, and recreational uses (Table 5.6). The uncertainties associated with these consequence ratings are medium.

TABLE 5.7 Risk of the Silver Carp to Pose Adverse Impacts to the GLB

	Probability of Establishment[a]					Risk of Adverse Impacts[c]			
Pathway	T_0	T_{10}	T_{25}	T_{50}	Consequences of Establishment[b]	T_0	T_{10}	T_{25}	T_{50}
CAWS 1	L	L	M	M	H	L	L	M	M
CAWS 2	L	L	M	M	H	L	L	M	M
CAWS 3	L	L	M	M	H	L	L	M	M
CAWS 4	L	L	M	M	H	L	L	M	M
CAWS 5	L	L	M	M	H	L	L	M	M

[a] Probability element ratings: M = medium probability, the event is likely to occur but is not certain to do so; L = low probability, the event will likely not occur but is possible.

[b] Consequence ratings: H = High consequence rating due to the larger number of consequence categories affected, the nature and severity of the consequences, and the broader spatial extent of the consequences.

[c] Risk ratings: M = medium risk of adverse impacts; L = low risk of adverse impacts.

5.1.3 Bighead Carp (*Hypophthalmichthyes nobilis*)

5.1.3.1 Native Range and Current Distribution

The bighead carp is native to eastern China, eastern Siberia, and extreme North Korea (Kolar et al. 2005). The species has been recorded throughout much of the United States (Nico & Fuller 2012). Bighead carp are reproducing all along the Mississippi, Missouri, and Ohio Rivers (NBII).The species is considered established in Illinois and Missouri (Fuller & Nico 2012), and is very abundant in the Illinois Waterway from Starved Rock Lock & Dam (river mile [RM] 231) to the confluence with the Mississippi River (RM 0). The species is also in great abundance 105 km (65 mi) from the Electric Dispersal Barrier System, a distance of 161 km (100 mi) from Lake Michigan (Stainbrook et al. 2007). Significant numbers of bighead carp were captured in 2013 in Rock Run Rookery Preserve Lake, approximately 4 miles downstream of Brandon Road Lock and Dam (ACCRC 2013c). In 2009 within the Lockport Pool, downstream of the Electric Dispersal Barrier System, a bighead carp was captured during a rotenone application (ACRCC 2009). The second capture occurred during routine monitoring in Lake Calumet. Five bighead carp were collected in western Lake Erie between 1995 and 2003 (http://www.asiancarp.us/faq.htm#Q10), but no other specimens have been found, and they are not considered to have established. Bighead carp were first introduced into the

United States through private fish farms in Arkansas; spread of the species into open waters likely began through escapes during flood events (Nico & Fuller 2012).

5.1.3.2 Life History and Ecology

Bighead carp prefer eutrophic rivers, lakes, and backwater habitat (Kolar et al. 2005). The species rarely occupies water depths >4m (13.1 ft) (DeGrandchamp et al. 2008) and prefer water temperatures of 21-26°C (69.8-78.8°F) for spawning and 25-26.9°C (77-80.4°F) when not spawning (Kolar et al. 2005). Fry occur in waters as low as 10-12°C (50-53.6°F) (Rasmussen et al. 2011). They are typically found in waters with high plankton concentrations, but can survive waters with low concentrations at low growth rates (Kolar et al. 2005). The species is native to large rivers, but requires high-flow (Stone et al. 2000), turbid (Kolar et al. 2005) waters for spawning.

Bighead carp is a generalist primary consumer that filter feeds on phyto- and zooplankton (Kolar et al. 2005). In the Illinois and Missouri Rivers, they mostly consume rotifers (Sampson et al. 2009). Spawning is triggered by changes in water levels, flow velocity, and water temperatures (Stainbrook et al. 2007). Rivers at least 100 km (62.1 mi) long are required for spawning, in order to carry eggs to floodplains and to prevent eggs from sinking and being covered with silt (Kolar et al. 2005). Eggs mature in floodplains or tributary mouths; larvae migrate from nursery areas to river channels (Kolar et al. 2005). Maturity is reached in 2-8 years (Kolar et al. 2005). Fecundity is correlated with increases in body mass and age. In the Illinois River in 2004, mean fecundity was 1.8×10^5 eggs/female (Stainbrook et al. 2007); a single bighead from the Yangtze River reportedly contained 1.1 million eggs (Kolar et al. 2005).

5.1.3.3 Probability of Establishment

The bighead carp is confirmed to have arrived at the Brandon Road Lock and Dam. Since 2007, bighead carp were captured in Dresden Island Pool; however, based on this monitoring, it appears that few bighead carp have moved from Dresden Island Pool to reaches above the Brandon Road Lock and Dam (ACRCC 2009, ACRCC 2012). The factors driving this apparent stalled range expansion are not understood but may include food and habitat availability, channel morphology and hydrology, and lock specific differences. It is expected that bighead carp will remain in low populations in the vicinity of the Electric Dispersal Barrier System at T_0 and T_{10}.

Monitoring and research have found several potential bypass mechanisms for the Electric Barrier System: man overboard scenario when power to the barrier is intentionally turned off, power outages, bypass during flood events, stunned fish floating through the barrier during reverse flow events in the canal (wind, vessel, or current driven), electric field shielding by steel hulled vessels or side wall crevices, small fish passage and fish entrainment within barge induced water currents across the Electric Dispersal Barrier System. Research regarding these bypasses will inform future operations. Bypass due to these various mechanisms is not expected, because the nearest detectable population of swimming bighead carp is in Dresden

Island Pool and the nearest detected eggs, larvae and fry are farther downstream (ACRCC 2013a).

As such, the probability of passage for the bighead carp is low for T_0 and T_{10} because, 1) small Asian carp are not expected to be present at the Electric Dispersal Barrier System, 2) the abundance of adults is expected to be absent or low near the Electric Dispersal Barrier System, and 3) if a low population of adults approaches the barrier, then it is expected, based on current research, that the barrier would be effective at controlling passage of these fish. The uncertainty for P(passage) at T_0 is medium and at T_{10} is high.

With the continued expected immigration from the lower pools (ACRCC 2013a), the propagule pressure at the Dispersal Barrier System is expected to increase, and thus increase the potential for an individual to move past the barrier system. The probability of passage increases from low to medium at T_{25} and is a medium at T_{50}. The uncertainty for both timesteps is high.

Although some bioenergetic models suggest that productivity in the GLB is too low to support bighead carp (Cook & Hill 2010), there are several areas of high productivity within the GLB that are likely to be suitable (Rasmussen et al. 2011). Therefore, if the bighead carp is able to pass through the CAWS, it is expected to colonize and spread through the GLB. Overall, the probability of establishment is low at T_0 and T_{10} and medium at T_{25} and T_{50} for all time steps and for all pathways.

5.1.3.4 Consequences of Establishment

Environmental Consequences. The environmental consequences of the bighead carp becoming established in the GLB are high (Table 5.9; Appendix B). The bighead carp is a planktivore that prefers eutrophic rivers, lakes, and backwater habitat (Kolar et al. 2005). Bighead carp have been documented to reduce zooplankton abundance and alter their species composition (reviewed in Kipp et al. 2011). In turn, the reduction in zooplankton abundance could reduce the food supply for planktivores and early life stages of higher trophic-level fish species. The bighead carp could potentially outcompete several planktivorous fish that currently exist in the GLB, such as the gizzard shad, ciscos, alewife, and bigmouth buffalo (Irons et al. 2007). There is also the potential for bighead carp to outcompete paddlefish and ESA-listed freshwater mussel species. The establishment of bighead carp in the GLB could also result in several ecosystem-level effects including changes in phytoplankton biomass, food web dynamics, and nutrient cycling as well (Kipp et al. 2011). The long-term effects of bighead carp on the MRB have been studied, but are still uncertain. Studies have found variable ecosystem responses in response to bighead carp introductions. Similarly, if bighead carp establish in the GLB, the nature and severity of ecosystem impacts are difficult to predict with certainty. Thus, the uncertainty of the environmental consequence rating is medium.

Economic Consequences. Widespread establishment of the bighead carp could produce economic consequences in a number of categories, including loss of consumer surplus, while

TABLE 5.8 Probability of Establishment, by CAWS Pathway and Time Step, of the Bighead Carp in the GLB

Probability Element	Probability Ratings for Time Steps 0, 10, 25, and 50 years[a,b]																			
	CAWS 1				CAWS 2				CAWS 3				CAWS 4				CAWS 5			
	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}
Pathway	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)
Arrival	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)
Passage	L (M)	L (H)	M (H)	M (H)	L (M)	L (H)	M (H)	M (H)	L (M)	L (H)	M (H)	M (H)	L (M)	L (H)	M (H)	M (H)	L (M)	L (H)	M (H)	M (H)
Colonization	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)
Spread	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)
Probability of Establishment	L	L	M	M	L	L	M	M	L	L	M	M	L	L	M	M	L	L	M	M

[a] Probability element ratings: H = high probability, the event will almost certainly occur; M = medium probability, the event is likely to occur but is not certain to do so; L = low probability, the event will likely not occur but is possible.

[b] Uncertainty associated with each Probability Element is indicated in parentheses. Uncertainty ratings: H = high, little or no data available and rating based on professional judgment; M = medium, good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment; L = low, good data available with no major data gaps; N = none, adequate data available to fully support the probability rating.

TABLE 5.9 Consequences of Establishment of the Bighead Carp in the GLB[a,b]

Environmental Consequences	Economic Consequences	Social/Political Consequences	Total Overall Consequences
H (M)	M (M)	H (M)	H

[a] Consequence ratings: H = High consequence rating due to the larger number of consequence categories affected, the nature and severity of the consequences, and the broader spatial extent of the consequences; M = Medium consequence rating due to the number of consequence categories affected, the nature and severity of the consequences, and the spatial extent of the consequences.

[b] Uncertainty ratings are indicated in parentheses: M = medium, good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment.

reductions in recreational boating and commercial fishing could adversely impact employment, income, and tax revenues. See Appendix C for more detailed mechanisms and descriptions of potential impacts. For each of these consequence categories, the severity of economic consequences would depend on the extent of species establishment, the resulting impact on existing fisheries resources, and the consequent impact on recreational activity and fishing. The economic consequences of the bighead carp are medium with medium uncertainty.

Social/Political Consequences. The social/political consequences of establishment are high. The bighead carp has the potential to affect the perceived quality of recreational fishing by reducing the abundance of existing fish species through competition (Appendix D). This species is expected to have a widespread distribution in the GLB; therefore, the species could impact fishing in a large area of the GLB. The establishment of this species is also expected to result in new laws and regulations to address the spread of this species. The severity of the social/political impacts will partly depend on the extent of spread of the bighead carp, which is uncertain (Appendix D). Therefore, uncertainty is medium.

Overall Consequences. The bighead carp could have high environmental and social/political consequences and medium economic consequences (Table 5.9) primarily related to its potential to affect biological communities and ecosystem function. Multiple social and political impacts are also possible, including changes in recreational fishing. Therefore, the overall consequence level of bighead carp is high. There is a medium level of uncertainty associated with each of the three consequence ratings.

5.1.3.5 Risk of Adverse Impacts

The overall risk associated with the bighead carp is low at T_0 and T_{10} and medium at T_{25} and T_{50}, for all pathways and time steps (Table 5.9). The probability of the bighead carp establishing in the GLB is low for T_0 and T_{10} because small Asian carp are not expected to be present at the Electric Dispersal Barrier System and the abundance of adults is expected to remain low near the Electric Dispersal Barrier System during these time steps. In addition, if adults do approach the Electric Dispersal Barrier System it is expected to effective at controlling passage upstream. However, the probability of passage increases to medium at T_{25} and T_{50}, for all pathways (Table 5.10), because the population of Asian carp is expected to increase resulting in more individuals challenging the Electric Dispersal Barrier System. The uncertainty of the passage probability from T_0 to T_{50} ranges from medium to high, due to uncertainty about silver carp movement and population trends as well as the effectiveness of the Electric Dispersal Barrier System over time. The establishment of bighead carp in the GLB could have high environmental, economic, and social/political consequences, and thus the overall consequence rating is high (Table 5.9). Therefore, the overall risk associated with the bighead carp is is low at T_0 and T_{10} and medium at T_{25} and T_{50}, for all pathways and time steps.

TABLE 5.10 Risk of the Bighead Carp to Pose Adverse Impacts to the GLB

	Probability of Establishment[a]					Risk of Adverse Impacts[c]			
Pathway	T_0	T_{10}	T_{25}	T_{50}	Consequences of Establishment[b]	T_0	T_{10}	T_{25}	T_{50}
CAWS 1	L	L	M	M	H	L	L	M	M
CAWS 2	L	L	M	M	H	L	L	M	M
CAWS 3	L	L	M	M	H	L	L	M	M
CAWS 4	L	L	M	M	H	L	L	M	M
CAWS 5	L	L	M	M	H	L	L	M	M

[a] Probability element ratings: L = low probability, the event will likely not occur but is possible.

[b] Consequence ratings: H = High consequence rating due to the larger number of consequence categories affected, the nature and severity of the consequences, and the broader spatial extent of the consequences.

[c] Risk ratings: M = medium risk of adverse impacts; L = low risk of adverse impacts.

5.2 LOW RISK SPECIES

Seven ANS were found to pose only low risks to the GLB. These species included four fish, the northern snakehead (*Channa argus*), black carp (*Mylopharyngodon piceus*), skipjack herring (Alosa chrysochloris), and inland silverside (*Menidia beryllina*), and three plant species, the Cuban bulrush (*Oxycaryum cubense*), dotted duckweed (*Landoltia punctata*), and marsh dewflower (*Murdannia keisak*) (Appendix A). Each of these species received a low risk rating because of its low expected consequences and/or low probability of establishment within the GLB.

5.3 SENSITIVITY ANALYSIS

As described in Section 4.3, there are multiple methods that can be used to combine the probability of establishment with the consequence rating into a final risk rating (Table 5.11). Using the GLMRIS Multiplicative Method, there would be three medium risk ANS and seven low risk ANS. Using the ANS Task Force method there would be four low risk ANS, three medium risk ANS, and three high risk ANS. For the three species that increased from low under the GLMRIS method to medium risk under the ANS Task Force method, two of the species had a high consequence rating and one had a medium consequence rating. However, these species all had a low probability of establishment. Of the three species that increased from medium to high risk, two were Asian carp with a high consequence rating and one was a crustacean with a medium consequence rating and a high probability of establishment.

Under the Alternative Additive method there would be five low risk ANS, three medium risk ANS, and two high risk ANS. The primary differences from the GLMRIS Multiplicative Method were due to the high consequence ratings of the Asian carps and the northern snakehead. See Appendix A for the risk assessments of the species that increased from low to medium or high using the additive methods (Table 5.11).

For any species that moved up to a medium or high risk level using the additive approaches, their probability of establishment could be managed the same way as other species within their same functional group that were classified as medium or high risk under the Multiplicative Method.

TABLE 5.11 Sensitivity Analysis Results Using Alternative Risk Level Determination Methods

Species	Probability of Establishment	Consequence Rating	GLMRIS Multiplicative Method	ANS Task Force Additive Method	Alternative Additive Method
Black Carp	L	H	L	M	M
Northern Snakehead	L	H	L	M	M
Cuban Bulrush	L	L	L	L	L
Dotted Duckweed	L	L	L	L	L
Marsh Dewflower	L	M	L	M	L
Inland Silverside	L	L	L	L	L
Skipjack Herring	L	L	L	L	L
Scud	H (T_0)	M	M	H	M
Silver Carp	M (T_{25})	H	M	H	H
Bighead Carp	M (T_{25})	H	M	H	H

6 RISKS OF SPECIES INVADING THE MISSISSIPPI RIVER BASIN

A total of 25 aquatic nuisance species (ANS) were evaluated for risks to the Mississippi River Basin (MRB) and its resources. These ANS included five crustacean species, five species of fish, four species of algae, three plant species, three species of mollusk, three protozoan species, and one bryozoan species, and one virus (Table 6.1). Only two of these 24 ANS were found to pose a high risk, and eight of the 25 to pose a medium risk, to the MRB; these species are discussed in Sections 6.1 and 6.2, respectively. The fifteen remaining species were found to pose only a low risk to the MRB; these species are discussed in Appendix A.

TABLE 6.1 Aquatic Nuisance Species of Concern for the Mississippi River Basin

Species	Primary Mode of Interbasin Transfer
Species Posing High Risk	
Bloody red shrimp (*Hemimysis anomala*)	Passive drift
Fishhook waterflea (*Cercopagis pengoi*)	Passive drift, hull fouling
Species Posing Medium Risk	
Grass kelp (*Enteromorpha flexuosa*)	Passive drift, temporary vessel attachment
Red algae (*Bangia atropurpurea*)	Passive drift, temporary vessel attachment
Diatom (*Stephanodiscus binderanus*)	Passive drift, temporary vessel attachment
Reed sweetgrass (*Glyceria maxima*)	Passive drift
Threespine stickleback (*Gasterosteus aculeatus*)	Active swimming
Tubenose goby (*Proterorhinus semilunaris*)	Active swimming
Ruffe (*Gymnocephalus cernuus*)	Active swimming
Viral Hemorrhagic Septicemia Virus (*Novirhabdovirus* sp.)	Passive drift; host transport
Species Posing Low Risk	
Sea lamprey(*Petromyzon marinus*)	Active swimming, temporary vessel attachment
Blueback herring (*Alosa aestivalis*)	Active swimming
Parasitic copepod (*Neoergasilus japonicas*)	Host fish movement, passive drift
Waterflea (*Daphnia g. galeata*)	Passive drift, hull fouling
Harpacticoid copepod (*Schizopera borutzkyi*)	Passive drift
European fingernail clam (*Sphaerium corneum*)	Temporary vessel attachment, passive drift
Greater European peaclam (*Pisidium amnicum*)	Temporary vessel attachment, passive drift
European stream valvata (*Valvata piscinalis*)	Temporary vessel attachment, passive drift
Testate amoeba (*Psammonobiotus communis*)	Passive drift
Testate amoeba (*Psammonobiotus dziwnowi*)	Passive drift
Testate amoeba (*Psammonobiotus linearis*)	Passive drift
Cryptic algae (*Cyclotella cryptica*)	Temporary vessel attachment, passive drift
Water chestnut (*Trapa natans*)	Passive drift, temporary vessel attachment
Swamp sedge (*Carex acutiformis*)	Passive drift, temporary vessel attachment
Freshwater bryozoan (*Lophopodella carteri*)	Passive drift, hull fouling

6.1 HIGH-RISK SPECIES

Two ANS were determined to pose potential high risks, should they become established in the MRB. These species, all crustaceans, are the bloody red shrimp and the fishhook waterflea.

6.1.1 Bloody Red Shrimp (*Hemimysis anomala*)

6.1.1.1 Native Range and Current Distribution

The bloody red shrimp has been reported from several locations in the Great Lakes: southeastern Lake Ontario near Oswego, New York; in a channel connecting Muskegon Lake with Lake Michigan; and in stomach contents of yellow perch collected near Port Dover in Lake Erie. In Lake Michigan in the vicinity of the Chicago Area Waterway System (CAWS), this species has been reported offshore of Jackson Harbor and also just south of Waukegan Harbor (Kipp et al. 2011). The species is native to western Asia/eastern Europe (Black Sea, Caspian Sea, and Azov Sea), and was probably introduced into the Great Lakes via ballast water releases from transoceanic cargo vessels (Kipp et al. 2011).

6.1.1.2 Life History and Ecology

This species normally occurs in lentic waters, but has successfully established in European rivers (Kipp et al. 2011). It prefers slow-moving waters, but may also inhabit rocky, wave-exposed shorelines. It generally inhabits waters in the 6 to 10 m (19-33 ft) depth range, where it exhibits daily vertical migrations. This species occurs most frequently on hard bottom substrates, is less abundant on soft sediments, and is usually scarce in areas of dense vegetation or high siltation (Pothoven et al. 2007).

The bloody red shrimp is an opportunistic omnivore that feeds primarily on zooplankton but also on phytoplankton, insect larvae, and plant and animal detritus. This species breeds from April to September/October and has relatively low fecundity (Kipp et al. 2011). Females may produce 2-4 broods per year, with brood size ranging from 6 to 70 individuals per female.

6.1.1.3 Probability of Establishment

Each of the five CAWS pathways represent a completed pathway that the bloody red shrimp could use to access the MRB, and each will be available at all time steps (Table 6.2). This species spread across several European river and canal systems in less than a decade. The bloody red shrimp has been established in nearshore areas of Lake Michigan near the CAWS pathways since 2007. Although this species has not been documented in the CAWS, it may already have possibly entered undetected into one or more of the CAWS entry points.

TABLE 6.2 Probability of Establishment, by CAWS Pathway and Time Step, of the Bloody Red Shrimp in the MRB

Probability Element	Probability Ratings for Time Steps 0, 10, 25, and 50 Years[a,b]																			
	CAWS 1				CAWS 2				CAWS 3				CAWS 4				CAWS 5			
	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}
Pathway	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)
Arrival	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)
Passage	H (M)	H (L)	H (L)	H (L)	H (M)	H (L)	H (L)	H (L)	H (M)	H (L)	H (L)	H (L)	L (L)	L (L)	M (H)	H (H)	L (L)	L (L)	M (H)	H (H)
Colonization	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)
Spread	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)
Probability of Establishment	H	H	H	H	H	H	H	H	H	H	H	H	L	L	M	H	L	L	M	H

[a] Probability element ratings: H = high probability, the event will almost certainly occur; M = medium probability, the event is likely to occur but is not certain to do so; L = low probability, the event will likely not occur but is possible.

[b] Uncertainty associated with each Probability Element is indicated in parentheses. Uncertainty ratings: H = high, little or no data available and rating based on professional judgment; M = good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment; L = low, good data available with no major data gaps; N = none, adequate data available to fully support the probability rating.

The bloody red shrimp may readily enter CAWS 1-3 and move downstream using a combination of natural transport (downstream drift) and human-mediated transport. Thus, the overall probability of establishment of the bloody red shrimp in the MRB is high for all time steps for CAWS Pathways 1-3. In CAWS Pathways 4 and 5, there is no vessel traffic from Lake Michigan, and normal flow at the Lake Michigan end of each of these pathways is into the lake. Thus, movement into and passage through either of these pathways is unlikely within 0-10 years, but given enough time (25 to 50 years), this species may be able to naturally move into these pathways and on to Brandon Road Lock and Dam and beyond. Suitable habitat exists below Brandon Road Lock and Dam and beyond in the MRB, and the bloody red shrimp may be expected to reach these habitats, become established, and spread to other parts of the basin. There is a low level of uncertainty associated with each establishment probability element.

6.1.1.4 Consequences of Establishment

Environmental Consequences. Establishment of the bloody red shrimp in the MRB may result in high environmental consequences (Table 6.3). On the basis of observations on the effects of other introduced freshwater mysids (Appendix B), the bloody red shrimp has a potential for trophic disruptions in the MRB, such as declines in zooplankton biomass, compositional shifts of macrozooplankton communities, reduced food availability for fish, reduced abundance and growth rates of pelagic fishes, and altered nutrient cycling (Ketelaars et al. 1999; Ricciardi et al. 2011). In general, mysids may also increase the number of trophic levels, which could increase contaminant concentrations (via biomagnification) in fish (Ricciardi et al. 2011). Because of its preference for low-current habitats, the potential effects of the bloody red shrimp will likely be most pronounced in low-velocity areas such as backwaters, impounded areas, and reservoirs (Ricciardi et al. 2011). The uncertainty associated with environmental consequences is high.

Economic Consequences. The bloody red shrimp could cause medium economic consequences with medium uncertainty. Widespread establishment of bloody red shrimp may produce economic consequences in a number of categories (see Appendix C), including loss of consumer surplus, while reductions in recreational boating and fishing and in commercial fishing would adversely impact employment, income, and tax revenues. See Appendix C for more detailed mechanisms and descriptions of potential impacts. For each of these consequence categories, the severity of economic consequences would depend on the extent of species establishment, the resulting impact on existing fisheries resources, and the consequent impact on recreational activity and fishing.

Social/Political Consequences. The social/political consequences of the bloody red shrimp's establishment in the MRB are medium with high uncertainty. The bloody red shrimp has the potential to affect perceived recreational fishing opportunities in those locations where it is able to establish (Appendix D). If establishment of the bloody red shrimp were to result in increased contaminant levels in some fish and waterfowl (Appendix D), this could adversely

TABLE 6.3 Consequences of Establishment of the Bloody Red Shrimp in the MRB[a,b]

Environmental Consequences	Economic Consequences	Social/Political Consequences	Total Overall Consequences
H (H)	M (M)	M (H)	H

[a] Consequence ratings: H = High consequence rating due to the larger number of consequence categories affected, the nature and severity of the consequences, and the broader spatial extent of the consequences; M = Medium consequence rating due to the number of consequence categories affected, the nature and severity of the consequences, and the spatial extent of the consequences.

[b] Uncertainty associated with each of the consequence ratings is indicated in parentheses. M = Medium uncertainty, good data are available but some data gaps exist; rating based on a mixture of data and professional judgment; H = High uncertainty, little or no data available and consequence rating based on professional judgment.

influence fishing activities due to public health concerns. Political consequences could include new laws or regulations to control the bloody red shrimp establishment.

Overall Consequences. Potentially widespread environmental, economic, and social consequences are indicated, should the bloody red shrimp become established in the MRB. These consequences would be associated primarily with changes in the abundance, productivity, and composition of resident fish communities and with potential increases in contaminant levels in fish and waterfowl important in commercial and recreational activities. Thus, the overall consequence level for the bloody red shrimp is considered high, although there is a medium to high uncertainty associated with the three consequence ratings (Table 6.3).

6.1.1.5 Risk of Adverse Impacts

The risks of adverse impacts from the establishment of the bloody red shrimp in the MRB are considered high for all CAWS pathways (Table 6.4). Regardless of the pathway considered, the consequences of bloody red shrimp establishment could be high. However, the time frame in which adverse risks may begin to be incurred differs among the pathways. Because of the possibility of current-driven (i.e., passive downstream drift driven by river flow) and vessel-mediated (i.e., carried in ballast) transport through CAWS Pathways 1-3, establishment of this shrimp and associated risks could begin as soon as the current time (T_0) for these pathways.

TABLE 6.4 Risk of the Bloody Red Shrimp to Pose Adverse Impacts to the MRB

	Probability of Establishment[a]					Risk of Adverse Impacts[c]			
Pathway	T_0	T_{10}	T_{25}	T_{50}	Consequences of Establishment[b]	T_0	T_{10}	T_{25}	T_{50}
CAWS 1	H	H	H	H	H	H	H	H	H
CAWS 2	H	H	H	H	H	H	H	H	H
CAWS 3	H	H	H	H	H	H	H	H	H
CAWS 4	L	L	M	H	H	L	L	M	H
CAWS 5	L	L	M	H	H	L	L	M	H

[a] Probability element ratings: H = high probability, the event will almost certainly occur; M = medium probability, the event is likely to occur but is not certain to do so; L = low probability, the event will likely not occur but is possible.

[b] Consequence ratings: H = High consequence rating due to the larger number of consequence categories affected, the nature and severity of the consequences, and the broader spatial extent of the consequences.

[c] Risk ratings: H = high risk of adverse impacts; M = medium risk of adverse impacts; L = low risk of adverse impacts.

In contrast, entrance into and passage through CAWS Pathways 4 and 5 may not occur until T_{25} (10-25 years) or later, due primarily to the absence of vessel traffic at the Great Lakes Basin (GLB) ends of these pathways as well the limited ability of this species to swim upstream from Lake Michigan to locations within each pathway where current flow direction changes toward Brandon Road Lock and Dam and where vessel traffic begins to occur. Thus, for CAWS Pathways 4 and 5, the risk for adverse effects is considered low at T_0 and T_{10} (0-10 years), but rises to medium at T_{25} and to high by T_{50} (25-50 years) (Table 6.4).

The primary uncertainties associated with the risk rating are related to the high uncertainty of the environmental consequence rating.

6.1.2 Fishhook Waterflea (*Cercopagis pengoi*)

6.1.2.1 Native Range and Current Distribution

The fishhook waterflea is found in Lakes Huron, Erie, Michigan, and Ontario. A single specimen was collected from Lake Superior in 2003, but the species is not believed to be established there (Benson et al. 2011). The fishhook waterflea is native to the Black, Caspian, Azov, and Aral Seas of southeastern Europe and Asia and may be transported in ballast water or on boat hulls.

6.1.2.2 Life History and Ecology

The fishhook waterflea is planktonic and makes daily vertical migrations in the water column (Benson et al. 2011). This species appears to prefer lentic systems, but has also established in rivers. Suitable habitats include estuarine habitats, lakes, marine habitats, water courses, and wetlands (NBII). The preferred temperature range for the fishhook waterflea is 16-26°C (60.8-78.8°F) (NBII), and the majority of individuals are found within the warm uppermost 20 m (65.6 ft) water layer during both day and night (Ojaveer et al. 2001). The fishhook waterflea prefers low-turbidity water systems, 4.37-105.16 nephelometric turbidity units (NTU) and waters with a dissolved oxygen (DO) range of 7.67-14.07 mg/L and pH of 7.32-8.39 (Muirhead et al. 2011).

Female fishhook waterfleas reproduce parthenogenically during the summer and gametogenically later in the year (NBII). Following sexual reproduction, females produce 1-4 resting eggs, while parthenogenic females produce between 1 and 24 embryos (NBII). The species produces resting eggs anytime during the year when environmental conditions become inhospitable (Benson et al. 2012). Resting eggs are resistant to desiccation, freeze-drying, and ingestion by predators, and replenish the population after hatching in the spring (Benson et al. 2012). Resting eggs can hatch regardless of whether the carrier female is alive or dead (Benson et al. 2012). Eggs are brooded until hatching, after which they are planktonic.

6.1.2.3 Probability of Establishment

Each of the five CAWS pathways represent a completed pathway that the fishhook waterflea could use to access the MRB, and each will be available at all time steps (Table 6.5). The fishhook waterflea has been established in Lake Michigan not far from any of the CAWS pathways at least 1999 and is considered to have arrived at the CAWS entry locations.

The fishhook waterflea may readily enter CAWS Pathways 1-3 and move downstream primarily using natural transport (downstream drift). Entry into and passage through the CAWS may not occur for 25-50 years, because the depth and turbidity of the CAWS may not be suitable for this species. In addition, this species was first recorded in southern Lake Michigan in 1999, but has not been recorded in the Illinois River or the CAWS. Therefore, for pathways 1-3, there is a low

TABLE 6.5 Probability of Establishment, by CAWS Pathway and Time Step, of the Fishhook Waterflea in the MRB

	Probability Ratings for Time Steps 0, 10, 25, and 50 Years[a,b]																			
	CAWS 1				CAWS 2				CAWS 3				CAWS 4				CAWS 5			
Probability Element	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}
Pathway	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)
Arrival	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)
Passage	L (M)	L (M)	M (L)	H (L)	L (M)	L (M)	M (L)	H (L)	L (M)	L (M)	M (L)	H (L)	L (L)	L (L)	L (H)	M (H)	L (L)	L (L)	L (H)	M (H)
Colonization	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)
Spread	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)
Probability of Establishment	L	L	M	H	L	L	M	H	L	L	M	H	L	L	L	M	L	L	L	M

[a] Probability element ratings: H = high probability, the event will almost certainly occur; M = medium probability, the event is likely to occur but is not certain to do so; L = low probability, the event will likely not occur but is possible.

[b] Uncertainty associated with each Probability Element is indicated in parentheses. Uncertainty ratings: H = high, little or no data available and rating based on professional judgment; M = good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment; L = low, good data available with no major data gaps; N = none, adequate data available to fully support the probability rating.

probability of establishment occurring within the next 10 years, a medium probability within 25 years, and a high probability within 50 years. In CAWS Pathways 4 and 5, entry into and passage through may not occur for 50 years. In the eastern segment of these pathways, there is no vessel traffic and the normal flow of each of these pathways is into Lake Michigan. Thus, movement into and passage through either of these pathways is unlikely within 0-25 years, but in 50 years, this species may be able to move naturally through these pathways to Brandon Road Lock and Dam. Regardless of when passage may occur, suitable habitat exists below Brandon Road Lock and Dam and beyond in the MRB, and the fishhook waterflea may be expected to reach these habitats, become established, and spread to other parts of the basin.

6.1.2.4 Consequences of Establishment

Environmental Consequences. Establishment of the fishhook waterflea in the MRB may have high environmental consequences (Table 6.6; Appendix B). A 2002 study of the food web impacts of the fishhook waterflea showed that the depth at which it exists was depleted of small organisms (<0.15 mg) (Benson et al. 2011), suggesting the fishhook waterflea could have a serious effect on the food supply of planktivores. Furthermore, this species may be a low quality replacement food source, because its long spine may make it less palatable to planktivorous fish. For example, yearling alewives compete directly with fishhook waterflea because they are planktivorous and cannot consume fishhook waterflea due to the caudal appendage. Only after they reached their first year were the alewives large enough to handle the caudal appendage (Bushnoe et al. 2003).

Fishhook waterflea predation on small zooplankton has caused decreased juvenile copepod production and changed their vertical distribution (Panov et al. 2007). As a result of the reduction in zooplankton abundance, an increase in phytoplankton abundance occurs (Brown & Balk 2008). Although there is literature to suggest a change in GLB ecosystems following the invasion of the fish hook waterflea, the extent to which this will occur in the MRB is uncertain. Therefore, an uncertainty of medium is associated with the environmental consequences of the fish hook waterflea.

Economic Consequences. Establishment of the fishhook waterflea in the MRB may result in medium economic consequences with medium uncertainty (Table 6.6). Widespread establishment of the fishhook waterflea may produce economic consequences in a number of categories, including loss of consumer surplus and loss of property value, while reductions in recreational and commercial fishing could adversely impact employment, income, and tax revenues. See Appendix C for more detailed mechanisms and descriptions of potential impacts. For each of these consequence categories, the severity of economic consequences would depend on the extent of this species' establishment, the resulting impact on existing fisheries resources, and the consequent impact on recreational activity and fishing.

TABLE 6.6 Consequences of Establishment of the Fishhook Waterflea in the MRB[a,b]

Environmental Consequences	Economic Consequences	Social/Political Consequences	Total Overall Consequences
H (M)	M (M)	M (M)	H

[a] Consequence ratings: H = High consequence rating due to the larger number of consequence categories affected, the nature and severity of the consequences, and the broader spatial extent of the consequences; M = Medium consequence rating due to the number of consequence categories affected, the nature and severity of the consequences, and the spatial extent of the consequences.

[b] Uncertainty associated with each of the consequence ratings is indicated in parentheses: M = medium; good data are available but some data gaps exist; rating based on a mixture of data and professional judgment.

Social/Political Consequences. Medium social/political consequences (with medium uncertainty) may occur if this species becomes established in the MRB (Table 6.6; Appendix D). The fishhook waterflea has the potential to negatively impact the perceived opportunities for recreational fishing. Political consequences could include new laws or regulations to control fishhook waterflea establishment.

Overall Consequences. The overall consequence level for the fishhook waterflea is considered high (Table 6.6). Potentially widespread environmental, economic, and social consequences are indicated, should the fishhook waterflea become established in the MRB. These consequences would be associated primarily with changes in the abundance, productivity, and composition of resident fish communities. The environmental, economic, and social consequences ratings each have a medium level of uncertainty.

6.1.2.5 Risk of Adverse Impacts

Regardless of the pathway considered, the consequences of fishhook waterflea establishment could be high. However, the time frame in which adverse risks may begin to be incurred differs among the pathways (Table 6.7). Because of the possibility of current-driven (i.e., passive downstream drift driven by river flow) transport through CAWS Pathways 1-3, establishment of this waterflea and associated risks could begin as soon as T_{25}. Therefore, overall risk associated with CAWS Pathways 1-3 is low until T_{25}, when it becomes medium and then high at T_{50}. In contrast, entrance into and passage through CAWS Pathways 4 and 5 may not occur until T_{50}, due primarily to the limited ability of this species to swim upstream from Lake Michigan to locations within each pathway where current flow direction changes toward Brandon Road Lock and Dam. Thus, for CAWS Pathways 4 and 5, the risk for adverse effects is considered low at T_0-T_{25}, but rises to medium at T_{50} (Table 6.7).

TABLE 6.7 Risk of the Fishhook Waterflea to Pose Adverse Impacts to the MRB

	Probability of Establishment[a]					Risk of Adverse Impacts[c]			
Pathway	T_0	T_{10}	T_{25}	T_{50}	Consequences of Establishment[b]	T_0	T_{10}	T_{25}	T_{50}
CAWS 1	L	L	M	H	H	L	L	M	H
CAWS 2	L	L	M	H	H	L	L	M	H
CAWS 3	L	L	M	H	H	L	L	M	H
CAWS 4	L	L	L	M	H	L	L	L	M
CAWS 5	L	L	L	M	H	L	L	L	M

[a] Probability element ratings: H = high probability, the event will almost certainly occur; M = medium probability, the event is likely to occur but is not certain to do so; L = low probability, the event will likely not occur but is possible.

[b] Consequence ratings: H = High consequence rating due to the larger number of consequence categories affected, the nature and severity of the consequences, and the broader spatial extent of the consequences.

[c] Risk ratings: H = high risk of adverse impacts; M = medium risk of adverse impacts; L = low risk of adverse impacts

The primary uncertainties associated with the risk rating are related to the time it takes the fishhook waterflea to establish in the MRB and the medium uncertainty associated with the consequence ratings.

6.2 MEDIUM RISK SPECIES

Eight ANS were identified as posing potentially medium risks to the MRB following establishment in the basin. These species include three species of algae (grass kelp, red algae, and a diatom), one plant species (reed sweetgrass), and three species of fish (threespine stickleback, tubenose goby, and ruffe), and one virus (viral hemorragic septicimia).

6.2.1 Grass Kelp (*Enteromorpha flexuosa*)

6.2.1.1 Native Range and Current Distribution

The closest record of grass kelp to the CAWS was from the beaches of Muskegon Lake (2003) located on the eastern shore of Lake Michigan (Lougheed & Stevenson 2004). The native range of grass kelp is unknown, but the species is widespread around the world in inland and/or coastal waters (Lougheed & Stevenson 2004).

6.2.1.2 Life History and Ecology

Grass kelp is primarily a marine species that is tolerant of a wide range of environmental conditions (Lougheed & Stevenson 2004). This species is found at depths ranging from the intertidal zone to approximately 5 m (16.4 ft) below the surface and at temperatures ranging 15.5-30°C (59.9-86°F) (Beach et al. 1995; Hill 2001). Grass kelp typically grows in clusters on plant roots, rocks, wood, or as an epiphyte on other plants (Beach et al. 1995). Although primarily a marine and estuarine species, grass kelp has also been found in freshwater systems like drainage channels, reservoirs, ponds, rivers, and tributaries. However, when found in fresh water, it is associated with specific water quality conditions including high conductivity and high nutrient levels as well as areas directly affected by pollution (Holmes & Whitton 1977; Aguilar-Roasas & Pacheco-Ruiz 1989; Fernandez et al. 1998; John et al. 2002). Within the GLB, this species is generally restricted to polluted waters, waters with limestone attachment sites, or waters receiving salt mine drainage (Kipp 2012). In Muskegon Lake, it was found growing primarily on submerged aquatic macrophytes in windswept, eutrophic, and mesotrophic littoral areas (Lougheed & Stevenson 2004). Aside from movement by currents, grass kelp can be transferred by attaching to boats.

Spores and gametes of this species are photosynthetically competent upon release into the water column, with unicells remaining motile for up to 11 days (Hill 2001). The adult stage is attached unless dislodged, in which case they can be transported as floating mats (John et al. 2002). Grass kelp is highly fecund (Beach et al. 1995), with propagule release via mitotic spores and meiotic gametes occurring on a daily basis in the lower latitudes (Hill 2001). Optimal reproduction occurs at temperatures under 30°C (86°F) in waters with a pH of approximately 8.2 (Hill 2001).

6.2.1.3 Probability of Establishment

Each of the five CAWS pathways is available for the grass kelp to access the MRB (Table 6.8). Because the grass kelp is not documented to have arrived at the CAWS and the closest population is at Muskegon Lake, the probability of this species arriving at the CAWS is low for all pathways until T_{10}, when it increases to medium. The probability of passage through the CAWS is high for CAWS Pathways 1, 2, and 3, because there are favorable conditions in these pathways for the grass kelp to spread to Brandon Road Lock and Dam by natural or human-mediated mechanisms. However, passage probability is low for CAWS Pathways 4 and 5 until

TABLE 6.8 Probability of Establishment, by CAWS Pathway and Time Step, of Grass Kelp in the MRB

Probability Element	Probability Ratings for Time Steps 0, 10, 25, and 50 Years[a,b]																			
	CAWS 1				CAWS 2				CAWS 3				CAWS 4				CAWS 5			
	T0	T10	T25	T50	T0	T10	T25	T50	T0	T10	T25	T50	T0	T10	T25	T50	T0	T10	T25	T50
Pathway	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
	(N)	(N)	(N)	(N)	(N)	(N)	(N)	(N)	(N)	(N)	(N)	(N)	(N)	(N)	(N)	(N)	(N)	(N)	(N)	(N)
Arrival	L	M	M	M	L	M	M	M	L	M	M	M	L	M	M	M	L	M	M	M
	(M)	(M)	(M)	(M)	(M)	(M)	(M)	(M)	(M)	(M)	(M)	(M)	(M)	(M)	(M)	(M)	(M)	(M)	(M)	(M)
Passage	H	H	H	H	H	H	H	H	H	H	H	H	L	L	M	M	L	L	M	M
	(M)	(M)	(M)	(M)	(M)	(M)	(M	(M)	(M)	(M)	M)	(M)	(H)	(H)	(H)	(H)	(H)	(H)	(H)	(H)
Colonization	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
	(M)	(M)	(M)	(M)	(M)	(M)	(M)	(M)	(M)	(M)	(M)	(M)	(M)	(M)	(M)	(M)	(M)	(M)	(M)	(M)
Spread	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
	(H)	(H)	(H)	(H)	(H)	(H)	(H)	(H)	(H)	(H)	(H)	(H)	(H)	(H)	(H)	(H)	(H)	(H)	(H)	(H)
Probability of Establishment	L	M	M	M	L	M	M	M	L	M	M	M	L	L	M	M	L	L	M	M

[a] Probability element ratings: H = high probability, the event will almost certainly occur; M = medium probability, the event is likely to occur but is not certain to do so; L = low probability, the event will likely not occur but is possible.

[b] Uncertainty associated with each Probability Element is indicated in parentheses. Uncertainty ratings: H = high, little or no data available and rating based on professional judgment; M = medium, good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment; N = none, adequate data available to fully support the probability rating.

T_{25}, due to a lack of vessel traffic in the eastern segments of these pathways and the direction of river flow toward Lake Michigan. At T_{25}, the passage probability for CAWS Pathways 4 and 5 increases to medium because by this time step the grass kelp may be able to overcome these impediments to passage by natural transport mechanisms.

Once in the MRB, grass kelp has a medium probability of colonization and spread, depending on whether suitable water quality is present. The overall probability of establishment for CAWS Pathways 1, 2, and 3 is low for T_{10} and medium for the remaining time steps (Table 6.8). For CAWS Pathways 4 and 5, the probability of establishment is low for T_0 and T_{10} and medium for T_{25} and T_{50}. There is high uncertainty associated with the probability of spread due primarily to uncertainty about whether water quality is suitable to allow this species to spread through the CAWS and through the MRB.

6.2.1.4 Consequences of Establishment

Environmental Consequences. In coastal areas, the grass kelp is potentially a major fouling algae that is capable of replacing native algal species and smothering aquatic plants (Sturtevant 2011) and grass kelp were found to form extensive beds in nutrient-rich habitats in the GLB (Lougheed& Stevenson 2004). Grass kelp may adversely affect native macrophytes (Sturtevant 2011), benthic invertebrate communities (Lougheed & Stevenson 2004), and overall habitat quality (Sand-Jensen et al. 2008; reviewed in Kipp et al. 2011). Grass kelp can also alter sediment redox conditions, potentially resulting in changes to nutrient cycling. However, grass kelp primarily inhabits marine and brackish waters, and therefore requires waters with suitable conductivity. Because of these specific water quality requirements, the distribution of grass kelp may be limited to urbanized areas of the MRB or areas with high runoff (Lougheed & Stevenson 2004). Therefore, grass kelp is not expected to establish widely in the MRB and is expected to have only localized ecological impacts in the MRB. Given the specific water quality conditions required by this species, it is uncertain how extensively it will spread and potentially alter existing freshwater ecosystems. Therefore, there is a medium degree of uncertainty regarding the environmental consequences of the species.

Economic Consequences. The establishment of grass kelp may produce medium economic consequences in a number of categories, including loss of consumer surplus and loss of property value, while reductions in recreational boating and fishing and in commercial fishing could adversely impact employment, income, and tax revenues. See Appendix C for more detailed mechanisms and descriptions of potential impacts. For each of these consequence categories, the severity of economic consequences would depend on the extent of species establishment, the resulting impact on existing fisheries resources, and the consequent impact on recreational activity and fishing. The economic consequence of grass kelp establishing in the MRB is medium with high uncertainty.

Social/Political Consequences. Grass kelp can form mats and reduce habitat quality, which could adversely affect the perceived opportunities for recreational fishing, as well as boating, swimming, and beach activities. However, grass kelp have very specific water quality requirements and are expected to form relatively localized populations, the extent of which is uncertain. Thus, the social/political consequences of establishment are medium and the uncertainty of this rating is high (Appendix C).

Overall Consequences. The overall consequence rating of grass kelp becoming established in the MRB is medium (Table 6.9). The establishment of grass kelp in the MRB may have medium economic and social/political consequences, but it is expected to have low environmental consequences, as this species is not expected to be widespread in the MRB due to its specialized water chemistry requirements. The potential consequences of this species establishing depend on its potential productivity in the MRB and how widely it is able to spread, neither of which is well characterized. Therefore, the uncertainties of the three individual consequence ratings range from medium to high.

TABLE 6.9 Consequences of Establishment of Grass Kelp in the MRB[a,b]

Environmental Consequences	Economic Consequences	Social/Political Consequences	Total Overall Consequences
L (M)	M (H)	M (H)	M

[a] Consequence ratings: M = Medium consequence rating due to the number of consequence categories affected, the nature and severity of the consequences, and the spatial extent of the consequences; L = Low consequence rating due to the lower number of consequence categories affected, the lesser nature and severity of the consequences, and the more localized extent of the consequences.

[b] Uncertainty ratings are indicated in the parentheses: H = high, little or no data available and rating based on professional judgment; M = medium, good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment.

6.2.1.5 Risk of Adverse Impacts

By T_{10}, grass kelp has a medium probability of establishing via CAWS Pathways 1-3, but the probability of establishment increases to medium at T_{25} for CAWS Pathways 4 and 5. The species was determined to have a medium consequence rating. Therefore, the overall risk associated with the establishment of grass kelp in the MRB is medium for all pathways and at time step 25-50 years (Table 6.10). The primary uncertainties associated with the risk rating are related to the high uncertainty about how widespread this species will become in the MRB and the resulting high uncertainty of the economic consequence rating.

TABLE 6.10 Risk of Grass Kelp to Pose Adverse Impacts to the MRB

Pathway	Probability of Establishment[a] T_0	T_{10}	T_{25}	T_{50}	Consequences of Establishment[b]	Risk of Adverse Impacts[c] T_0	T_{10}	T_{25}	T_{50}
CAWS 1	L	M	M	M	M	L	M	M	M
CAWS 2	L	M	M	M	M	L	M	M	M
CAWS 3	L	M	M	M	M	L	M	M	M
CAWS 4	L	L	M	M	M	L	L	M	M
CAWS 5	L	L	M	M	M	L	L	M	M

[a] Probability element ratings: M = medium probability, the event is likely to occur but is not certain to do so; L = low probability, the event will likely not occur but is possible.

[b] Consequence ratings: M = Medium consequence rating due to the number of consequence categories affected, the nature and severity of the consequences, and the spatial extent of the consequences.

[c] Risk ratings: M = medium risk of adverse impacts; L = low risk of adverse impacts.

6.2.2 Red Algae (*Bangia atropurpurea*)

6.2.2.1 Native Range and Current Distribution

Red algae have been reported from several locations in the Great Lakes: Lake Erie, southern Lake Michigan, and the Canadian side of Lake Huron (Kipp 2011; Lin & Blum 1977). In the vicinity of the CAWS, this species has been observed historically in southern Lake Michigan offshore of Wilmette, Illinois (Lin & Blum 1977), but recent surveys do not indicate the presence of red algae. This species is native to both eastern and western coastlines of the Atlantic Ocean and may be transported in ballast water and on ship hulls (Kipp 2011; Lin & Blum 1977).

6.2.2.2 Life History and Ecology

Red algae are filamentous algae that disperse by passive currents. This species is typically found in the littoral splash zone on exposed permanent rock or other hard substrates (Kipp 2011). It prefers fast-moving and turbulent water; however, this species has been found to colonize slow-moving water in sheltered areas, harbors, and freshwater canals (Belcher 1956; Lin & Blum 1977; Sheath & Cole 1980; Reed 1980). Red algae are typically found in waters that are heavily affected by human uses, which provide the necessary levels of halogens and trace metals from point and nonpoint sources (Lin & Blum 1977). Red algae are tolerant of a wide range of temperatures (2-26°C [35.6-78°F]) (Kipp 2011; Garwood 1982) and are globally distributed across wide latitudes.

This species produces both asexual and sexual plants in marine environments, but only asexual plants occur in the Great Lakes (Kipp 2011). It is a seasonal annual, which produces several generations per year and has a 4 to 6 week generation time (Sheath & Cole 1980; Sheath et al. 1985). Red algae may be able to resist changes in salinity and desiccation by undergoing a period of dormancy (Sheath & Cole 1980).

6.2.2.3 Probability of Establishment

There are records of this species in southern Lake Michigan, although it appears to be uncommon in the GLB. If it does arrive at the CAWS it could establish on natural and manmade hard substrates near the pathway entry points. The red algae could move through the CAWS by natural dispersal (spread along shoreline or floating spores or fragments) or vessel-mediated transport. Therefore, the probability of passage through the CAWS is high for CAWS Pathways 1, 2, and 3 for all time steps (Table 6.11). However, the passage probability is low for CAWS Pathways 4 and 5 until T_{25}, due to a lack of vessel traffic and to the direction of water flow into Lake Michigan in the eastern segments of these pathways (Appendix E). At T_{25}, the passage probability for CAWS Pathways 4 and 5 increases to medium.

Once in the MRB, red algae have a medium probability of colonization and spread, depending on whether suitable water quality is present. The overall probability of establishment for CAWS Pathways 1, 2, and 3 is medium for all time steps. For CAWS Pathways 4 and 5, the probability of establishment is low for T_0 and T_{10} and medium for T_{25} and T_{50}.

The red algae has been sporadically documented in southern Lake Michigan for several decades, but has not been reported in the CAWS. The ability of hydraulic and chemical conditions in the CAWS and the MRB to support red algae is highly uncertain. Therefore, the uncertainties associated with the arrival, passage, and spread establishment element ratings are high.

TABLE 6.11 Probability of Establishment, by CAWS Pathway and Time Step, of Red Algae in the MRB

Probability Element	Probability Ratings for Time Steps 0, 10, 25, and 50 Years[a,b]																			
	CAWS 1				CAWS 2				CAWS 3				CAWS 4				CAWS 5			
	T_{0}	T_{10}	T_{25}	T_{50}	T_{0}	T_{10}	T_{25}	T_{50}	T_{0}	T_{10}	T_{25}	T_{50}	T_{0}	T_{10}	T_{25}	T_{50}	T_{0}	T_{10}	T_{25}	T_{50}
Pathway	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)
Arrival	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)
Passage	H (H)	H (H)	H (H)	H (H)	H (H)	H (H)	H (H)	H (H)	H (H)	H (H)	H (H)	H (H)	L (H)	L (H)	M (H)	M (H)	L (H)	L (H)	M (H)	M (H)
Colonization	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)
Spread	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)
Probability of Establishment	M	M	M	M	M	M	M	M	M	M	M	M	L	L	M	M	L	L	M	M

[a] Probability element ratings: H = high probability, the event will almost certainly occur; M = medium probability, the event is likely to occur but is not certain to do so; L = low probability, the event will likely not occur but is possible.

[b] Uncertainty associated with each Probability Element is indicated in parentheses. Uncertainty ratings: H = high, little or no data available and rating based on professional judgment; M = medium, good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment; N = none, adequate data available to fully support the probability rating.

6.2.2.4 Consequences of Establishment

Environmental Consequences. Only low environmental consequences are anticipated with establishment of red algae in the MRB (Table 6.12; Appendix B). Red algae have the ability to displace algal species, although it has yet to do so in the GLB (reviewed in Kipp 2011) and reduce macroinvertebrate biodiversity in the GLB (Chilton et al. 1986). Similar impacts may occur in the MRB, if this species is able to establish. Red algae may alter the basal food resources and productivity in the MRB. For example, Sonzongni et al. (1983) state that epiphytic algae do not grow well on red algae, which may reduce food resources for grazers. The spread of red algae in the Great Lakes appears to be facilitated by high chloride and potentially high sodium levels (Sonzogni et al. 1983). Because of these specific water quality requirements, the distribution of red algae may be limited to urbanized areas of the MRB or areas with high runoff. Consequently, red algae are not expected to have significant or widespread effects on ecosystem structure and function. Overall, the consequences of red algae establishing in the MRB would be low. However, it is unknown whether red algae can occupy more than urbanized areas of the MRB. The effects of red algae on existing macrophyte and macroalgal communities in the MRB are also uncertain. Therefore, there is medium uncertainty associated with the environmental consequences of red algae spread.

Economic Consequences. The establishment of red algae may produce economic consequences in a number of categories including loss of consumer surplus and loss of property value, while reductions in recreational boating and fishing and in commercial fishing could adversely impact employment, income, and tax revenues. See Appendix C for more detailed mechanisms and descriptions of potential impacts. For each of these consequence categories, the severity of economic consequences would depend on the spatial extent of species establishment, the resulting impact on existing fisheries resources, and the consequent impact on recreational activity and fishing. The economic consequence of red algae establishing in the MRB is medium with high uncertainty.

Social/Political Consequences. Establishment of the red algae could reduce the perceived opportunities for recreational fishing, as well as boating, swimming, and beach activities (Appendix D). However, red algae have very specific water quality requirements and are expected to only form relatively localized populations, the extent of which is uncertain. The social/political consequences of establishment are medium and the uncertainty of this rating is high.

Overall Consequences. The overall consequence rating for establishment of red algae in the MRB is medium (Table 6.12). The establishment of red algae in the MRB may have medium economic and social/political consequences, but it is expected to have low environmental consequences, as this species is not expected to be widespread in the MRB due to its specialized water chemistry requirements. The potential consequences of this species establishing depend on its potential productivity in the MRB and how widely it is able to spread,

TABLE 6.12 Consequences of Establishment of Red Algae in the MRB[a,b]

Environmental Consequences	Economic Consequences	Social/Political Consequences	Total Overall Consequences
L (M)	M (H)	M (H)	

[a] Consequence ratings: M = Medium consequence rating due to the number of consequence categories affected, the nature and severity of the consequences, and the spatial extent of the consequences; L = Low consequence rating due to the lower number of consequence categories affected, the lesser nature and severity of the consequences, and the more localized extent of the consequences.

[b] Uncertainty ratings are indicated in the parentheses: H = high, little or no data available and rating based on professional judgment; M = medium, good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment.

neither of which is well characterized. Therefore, the uncertainty of the environmental, economic, and social consequences ratings have associated uncertainty levels ranging from medium to high.

6.2.2.5 Risk of Adverse Impacts

Using CAWS Pathways 1, 2, or 3, the red algae begin to pose a medium risk to the MRB as early as T_0 (Table 6.13). Because of the direction of current flow into Lake Michigan from CAWS Pathways 4 and 5, the red algae is not expected to begin to pose a medium risk to the MRB until T_{25} if either of these pathways are used for interbasin transfer. The probability of establishment increases from low to medium at T_{25} for CAWS Pathways 4 and 5. Although red algae may establish in the MRB, they are not expected to spread widely and may or may not result in any significant ecological, economic, or social/political consequences. Therefore, the overall risk associated with the establishment of red algae is medium for all pathways and at time steps 25 and 50 years (Table 6.13). The primary uncertainties associated with the risk rating are related to the high uncertainty about when this species will enter the MRB and how widespread this species will become in the MRB and the resulting high uncertainty of the economic and social/political consequence ratings.

TABLE 6.13 Risk of Red Algae to Pose Adverse Impacts to the MRB

Pathway	Probability of Establishment[a]				Consequences of Establishment[b]	Risk of Adverse Impacts[c]			
	T_0	T_{10}	T_{25}	T_{50}		T_0	T_{10}	T_{25}	T_{50}
CAWS 1	M	M	M	M	M	M	M	M	M
CAWS 2	M	M	M	M	M	M	M	M	M
CAWS 3	M	M	M	M	M	M	M	M	M
CAWS 4	L	L	M	M	M	L	L	M	M
CAWS 5	L	L	M	M	M	L	L	M	M

[a] Probability element ratings: M = medium probability, the event is likely to occur but is not certain to do so; L = low probability, the event will likely not occur but is possible.

[b] Consequence ratings: M = Medium consequence rating due to the number of consequence categories affected, the nature and severity of the consequences, and the spatial extent of the consequences.

[c] Risk ratings: M = medium risk of adverse impacts; L = low risk of adverse impacts.

6.2.3 Diatom (*Stephanodiscus binderanus*)

6.2.3.1 Native Range and Current Distribution

The diatom *Stephanodiscus binderanus* has been reported from several locations in the Great Lakes, being first recorded in Lake Michigan in 1938 and Lake Ontario in the late 1940s to early 1950s (Kipp 2011). This species may have been in Lake Erie since before the 1930s and also now occurs in Lake Huron as well as the Cuyahoga River (Kipp 2011). This species historically occurs in Lake Michigan offshore of Chicago, suggesting suitable habitat exists in the vicinity of the CAWS. This diatom is native to the Baltic Sea, and was probably introduced into the Great Lakes by ballast water discharge (Kipp 2011).

6.2.3.2 Life History and Ecology

S. binderanus is typically found in lakes, but is established in the Cuyahoga River (Kipp 2011) and in European lowland rivers and their tributaries (Hindák et al. 2006). It sometimes occurs in lakes near river outlets, and reservoirs may provide suitable habitat (Kipp 2011). This species is sensitive to nutrient levels and prefers eutrophic waters with high phosphate and a nitrogen:phosphate ratio of 7 (Kipp 2011). It is most abundant in nearshore areas, but is also common in pelagic habitat in Lake Michigan (Stoermer & Yang 1969). Being planktonic, this species moves passively in flowing water. It reproduces through cell division and can form dense blooms under high nutrient conditions. Resting cells are found in sediment (Kipp 2011).

6.2.3.3 Probability of Establishment

There are records of this species in southern Lake Michigan, although populations have declined in recent decades as nutrients levels in Lake Michigan have been reduced by more stringent water quality requirement. *S. binderanus* is common in nutrient-rich inshore waters. If currents carried this species to the CAWS pathway entry points, it could move through the CAWS to Brandon Road Lock and Dam by natural dispersal or vessel-mediated transport. Therefore, the probability of passage through the CAWS is high for CAWS Pathways 1, 2, and 3 for all time steps (Table 6.14). However, the passage probability is low for CAWS Pathways 4 and 5 until T_{50}, due to a lack of vessel traffic and water flow into Lake Michigan in the eastern most segments of these pathways. At T_{50}, the passage probability for CAWS Pathways 4 and 5 increases to medium. Once in the MRB, this diatom has a medium probability of colonization and spread, depending on whether suitable water quality is present. The overall probability of establishment for CAWS Pathways 1, 2, and 3 is medium for all time steps. For CAWS Pathways 4 and 5, the probability of establishment is low for T_0 and T_{10} and medium for T_{25} and T_{50}. Within the MRB, ports, reservoirs/navigation tools, harbors, and urban areas with anthropogenic inputs may provide suitable habitat. This species is not described in the literature as a riverine species, although it is present in eutrophic rivers. Although it has been in Lake Michigan for decades, there are no records of this diatom in the CAWS or downstream of Brandon Road Lock and Dam. It is uncertain why this species has not yet been detected in the CAWS. Because of current direction, it is also uncertain how readily this species may enter the CAWS through Pathways 4 and 5. Therefore, the uncertainty associated with the probability of passage rating is high for this species.

TABLE 6.14 Probability of Establishment, by CAWS Pathway and Time Step, of the Diatom in the MRB

Probability Element	Probability Ratings for Time Steps 0, 10, 25, and 50 Years[a,b]																			
	CAWS 1				CAWS 2				CAWS 3				CAWS 4				CAWS 5			
	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}
Pathway	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)
Arrival	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)
Passage	H (H)	H (H)	H (H)	H (H)	H (H)	H (H)	H (H)	H (H)	H (H)	H (H)	H (H)	H (H)	L (H)	L (H)	L (H)	M (H)	L (H)	L (H)	L (H)	M (H)
Colonization	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)
Spread	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)
Probability of Establishment	M	M	M	M	M	M	M	M	M	M	M	M	L	L	L	M	L	L	L	M

[a] Probability element ratings: H = high probability, the event will almost certainly occur; M = medium probability, the event is likely to occur but is not certain to do so; L = low probability, the event will likely not occur but is possible.

[b] Uncertainty associated with each Probability Element is indicated in parentheses. Uncertainty ratings: H = high, little or no data available and rating based on professional judgment; M =medium, good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment; L = low, good data available with no major data gaps; N = none, adequate data available to fully support the probability rating.

6.2.3.4 Consequences of Establishment

Environmental Consequences. The environmental consequence rating of this species becoming established in the MRB is low (Table 6.15; Appendix B). The introduction of this species in Lake Ontario has caused local extinctions of native diatoms (Spaulding et al. 2010). In addition to changes in phytoplankton communities, blooms of this species can have ecosystem-level effects. For example, there is evidence that blooms contributed to hypoxia in Lake Erie (Lashway & Carrick 2010). Blooms may reduce light penetration into the water and lower dissolved oxygen. If these were to occur, habitat quality may be reduced in the area affected by the bloom. However, this species may be problematic only in areas of the MRB with habitat conditions conducive to bloom formation (i.e., high light and nutrients). Therefore, the blooms of this species and their associated impacts are not expected to be common or widespread within the MRB. It is uncertain as to the extent that this diatom could occur in the MRB. If a large, dense population occurs, impacts on the environment could be greater. However, if there are only small, isolated populations, the impacts will be minor. Therefore, the uncertainty associated with this diatom and its environmental consequences is medium (Appendix B).

Economic Consequences. The establishment of this species may produce economic consequences by possibly increasing the cost of maintaining water quality. See Appendix C for more detailed mechanisms and descriptions of potential impacts. The severity of economic consequences would depend on the spatial extent of its establishment in the MRB. The economic consequence of this diatom establishing in the MRB is medium, with high uncertainty (Appendix C).

Social/Political Consequences. Because it can form blooms, this diatom could reduce the perceived quality of swimming and beach activities (Appendix D). The blooms can also reduce habitat quality, which could affect perceived opportunities for recreational fishing. Therefore, the social/political consequences of this species establishing in the MRB are potentially medium, although the uncertainty of this rating is high (Appendix D), due to uncertainty about how widespread and productive this species will be in the MRB.

Overall Consequences. Establishment of this diatom in the MRB could result in medium social/political consequences in areas where it forms dense blooms. Therefore, the establishment of this species could have medium overall consequences (Table 6.15). However, the uncertainty of these consequence ratings range from medium to high, due to uncertainty about how widespread and productive this species will be in the MRB.

TABLE 6.15 Consequences of Establishment of the Diatom in the MRB[a,b]

Environmental Consequences	Economic Consequences	Social/Political Consequences	Total Overall Consequences
L (M)	M (H)	M (H)	M

[a] Consequence ratings: M = Medium consequence rating due to the number of consequence categories affected, the nature and severity of the consequences, and the spatial extent of the consequences; L = Low consequence rating due to the lower number of consequence categories affected, the lesser nature and severity of the consequences, and the more localized extent of the consequences.

[b] Uncertainty ratings are indicated in the parentheses: H = high, little or no data available and rating based on professional judgment; M = medium, good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment.

6.2.3.5 Risk of Adverse Impacts

For CAWS Pathways 1, 2, and 3, the probability of establishment is medium for all time steps, while for CAWS Pathways 4 and 5 the probability of establishment is low until T_{50} (Table 6.16). The establishment of this diatom in the MRB may result in ecological, economic, or social/political consequences, giving it an overall consequence rating of medium. Thus, for CAWS Pathways 1, 2, and 3, the overall risk is medium for all time steps. For CAWS Pathways 4 and 5, the overall risk is low until T_{50}, when it increases to medium. The primary uncertainties associated with the risk rating are related to the high uncertainty about when this species will pass through the CAWS and how common or widespread bloom formation by this species will be in the MRB and the resulting high uncertainty of the economic and social/political consequence ratings.

TABLE 6.16 Risk of the Diatom to Pose Adverse Impacts to the MRB

Pathway	Probability of Establishment[a]				Consequences of Establishment[b]	Risk of Adverse Impacts[c]			
	T_0	T_{10}	T_{25}	T_{50}		T_0	T_{10}	T_{25}	T_{50}
CAWS 1	M	M	M	M	M	M	M	M	M
CAWS 2	M	M	M	M	M	M	M	M	M
CAWS 3	M	M	M	M	M	M	M	M	M
CAWS 4	L	L	L	M	M	L	L	L	M
CAWS 5	L	L	L	M	M	L	L	L	M

[a] Probability element ratings: M = medium probability, the event is likely to occur but is not certain to do so; L = low probability, the event will likely not occur but is possible.

[b] Consequence ratings: M = Medium consequence rating due to the number of consequence categories affected, the nature and severity of the consequences, and the spatial extent of the consequences.

[c] Risk ratings: M = medium risk of adverse impacts; L = low risk of adverse impacts.

6.2.4 Reed Sweetgrass (*Glyceria maxima*)

6.2.4.1 Native Range and Current Distribution

Reed sweetgrass was first recorded in North America in the 1940s from the far west end of Lake Ontario (Howard 2012). In the 1970s, the species was found in Racine and Milwaukee Counties in Wisconsin (Howard 2012). There are cultivated populations in Door and Wood Counties, Wisconsin, with an unvouched-for specimen noted in Calumet County (Howard 2012). The closest established population relative to the CAWS is in Oak Creek (a tributary of Lake Michigan) in Milwaukee County, Wisconsin (Howard 2012). An isolated population was discovered growing out of a recently replaced manhole cover at Illinois Beach State Park, just north of Waukegan, Illinois; this population was treated with herbicide and will have continued monitoring to ensure it has been eradicated (Howard 2012). Reed sweetgrass is native to temperate Eurasia (Howard 2012). Introduction of this species is thought to have been intentional in some areas, being brought in as a forage species (Howard 2012); it may also have been introduced as an ornamental species, or transported with packing material or by waterfowl (Howard 2012).

6.2.4.2 Life History and Ecology

Reed sweetgrass is a large perennial aquatic grass found in temperate areas (Howard 2012). The species prefers nutrient rich soils and can be found on the banks of slow-moving rivers, streams, and lakes (NBII Undated; Washington State Noxious Weed Control Board Undated). It grows well in shallow water (<1.5 m [4.9 ft]) and can form floating mats in deeper water (Loo et al. 2009). The species is found in soils with relatively high phosphorus, nitrogen, and iron concentrations (Wei & Chow-Fraser 2006). Reed sweetgrass prefers full sun and can tolerate only light shade (NBII Undated; Loo et al. 2009).

Reproduction in reed sweetgrass appears to be entirely vegetative when in dense stands, with rhizome growth starting in early spring (NBII Undated; Sundblad & Robertson 1989). This species can produce large numbers of seeds throughout the summer and autumn (DPIWE 2012). The seeds can remain dormant for several years (NBII Undated); however, the plant becomes weakly dormant during the winter, with leaves remaining physiologically active during mild winters (Tylová et al. 2008). Reed sweetgrass grows rapidly in early spring, giving it a competitive advantage over other wetland plants (Noxious Weeds Undated).

6.2.4.3 Probability of Establishment

The probability of the reed sweetgrass becoming established in the MRB is considered low for T_0-T_{25} and medium for T_{50} for all of the CAWS pathways (Table 6.17; Appendix E). Each of the CAWS pathways provides a complete hydrologic connection that reed sweetgrass could use to access the MRB during all time steps. Reed sweetgrass was first observed in Lake Ontario in the 1940s and was established in the southern portions of the Lake Michigan drainage by the 1970s; however, it is not considered widespread in Lake Michigan and is not documented to have spread to the CAWS during this time period. Therefore, the probability of arrival to the CAWS entry points within the next 25 years is considered low for all pathways, although the probability that arrival could occur within the next 50 years is considered to be medium for all pathways (Table 6.17).

The probability of passage through the various CAWS pathways is considered low within the current time step (T_0), but rises to a moderate probability by T_{10} for CAWS Pathways 1, 2, and 3 and by T_{25} for CAWS Pathways 4 and 5; the difference in time frames for increasing probability of passage results because the flow in the easternmost segments of these pathways is toward Lake Michigan rather than toward the MRB, thereby reducing the potential for passively drifting seeds to enter the MRB.

TABLE 6.17 Probability of Establishment, by CAWS Pathway and Time Step, of Reed Sweetgrass in the MRB

	Probability Ratings for Time Steps 0, 10, 25, and 50 Years[a,b]																			
	CAWS 1				CAWS 2				CAWS 3				CAWS 4				CAWS 5			
Probability Element	T_{0}	T_{10}	T_{25}	T_{50}	T_{0}	T_{10}	T_{25}	T_{50}	T_{0}	T_{10}	T_{25}	T_{50}	T_{0}	T_{10}	T_{25}	T_{50}	T_{0}	T_{10}	T_{25}	T_{50}
Pathway	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)
Arrival	L (L)	L (L)	L (L)	M (M)	L (L)	L (L)	L (L)	M (M)	L (L)	L (L)	L (L)	M (M)	L (L)	L (L)	L (L)	M (M)	L (L)	L (L)	L (L)	M (M)
Passage	L (M)	M (M)	M (M)	M (M)	L (M)	M (M)	M (M)	M (M)	L (M)	M (M)	M (M)	M (M)	L (M)	L (M)	M (H)	M (H)	L (M)	L (M)	M (H)	M (H)
Colonization	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)
Spread	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)
Probability of Establishment	L	L	L	M	L	L	L	M	L	L	L	M	L	L	L	M	L	L	L	M

[a] Probability element ratings: H = high probability, the event will almost certainly occur; M = medium probability, the event is likely to occur but is not certain to do so; L = low probability, the event will likely not occur but is possible.

[b] Uncertainty associated with each Probability Element is indicated in parentheses. Uncertainty ratings: H = high, little or no data available and rating based on professional judgment; M = medium, good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment; L = low, good data available with no major data gaps; N = none, adequate data available to fully support the probability rating.

The potential for colonization and spread within the MRB is considered high, if the species is successful in reaching the MRB. The range of habitats the species inhabits indicates that it can tolerate a range of environmental conditions, although it prefers nutrient-rich soils. Transport of the species within the basin via drifting seeds and pieces of plants is possible, and suitable climate and habitat conditions are likely to be present in much of the MRB. Consequently, it is anticipated that the species could become widespread within the MRB if invasion is successful.

6.2.4.4 Consequences of Establishment

Environmental Consequences. Because of the range of ecosystem effects that could occur with establishment of this species, and because the species could become distributed widely in the MRB, the environmental consequences of the reed sweetgrass are characterized as medium (Table 6.18). Although establishment of reed sweetgrass in the MRB would have the potential to alter nutrient cycling, primary productivity, and food web dynamics and displace other plant species through shading or competition for nutrients, it is anticipated that the effects would be localized, based upon experience in the areas in the GLB where the species has become established (see Appendix B). Reed sweetgrass is also capable of producing dense vegetative mats that can reduce flow in stream habitats. The uncertainty associated with the rating for the environmental consequences of establishment of the reed sweetgrass is considered to be high.

Economic Consequences. Widespread establishment of reed sweetgrass may produce economic consequences in a number of categories, including loss of consumer surplus and loss of property value, while reductions in fishing could adversely impact employment, income, and tax revenues. See Appendix C for more detailed mechanisms and descriptions of potential impacts. For each of these consequence categories, the severity of economic consequences would depend on the extent of species establishment, the resulting impact on existing fisheries resources, and the consequent impact on recreational activity and fishing. The economic consequence of reed sweetgrass establishing in the MRB is medium with medium uncertainty (Appendix C).

Social/Political Consequences. If reed sweetgrass were to become established in the MRB, it has the potential to generate social/political consequences, including potential effects on the perceived opportunities to fish and hunt in some areas (Appendix D). Thus, the rating for social/political consequences is determined to be medium. The uncertainty associated with the rating for social/political consequences is considered to be medium (Appendix D).

Overall Consequences. Successful establishment of reed sweetgrass within the MRB could have a medium environmental, economic, and social/political consequences. Thus, the overall level of consequences for the establishment of this species in the MRB is determined to be medium.

TABLE 6.18 Consequences of Establishment of Reed Sweetgrass in the MRB[a,b]

Environmental Consequences	Economic Consequences	Social/Political Consequences	Total Overall Consequences
M (H)	M (M)	M (M)	M

[a] Consequence ratings: M = Medium consequence rating due to the number of consequence categories affected, the nature and severity of the consequences, and the spatial extent of the consequences.

[b] Uncertainty ratings are indicated in the parentheses: H = high, little or no data available and rating based on professional judgment; M = good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment.

6.2.4.5 Risk of Adverse Impacts

The overall risk of adverse impacts to the MRB from establishment of reed sweetgrass is determined to be low for all CAWS pathways during the next 25 years (T_0 through T_{25}) and medium by 50 years (T_{50}) (Table 6.19). The probability of this species becoming established in the MRB over the next 25 years is considered to be low because it is unlikely that reed sweetgrass plants, seeds, or vegetative propagules would arrive at and pass through the CAWS pathways during that time. The probability of the reed sweetgrass plants, seeds, or vegetative propagules arriving at and passing through the CAWS pathways increases over time, resulting in an increase in the risk of establishment in the MRB to medium by T_{50}. It is anticipated that environmental, economic, and social/political consequences of establishment of the species in the MRB could potentially be moderate. The primary uncertainties associated with the overall risk rating are related to the medium to high uncertainties associated with the environmental, economic, and social/political consequences ratings.

TABLE 6.19 Risk of Reed Sweetgrass to Pose Adverse Impacts to the MRB

	Probability of Establishment[a]					Risk of Adverse Impacts[c]			
Pathway	T_0	T_{10}	T_{25}	T_{50}	Consequences of Establishment[b]	T_0	T_{10}	T_{25}	T_{50}
CAWS 1	L	L	L	M	M	L	L	L	M
CAWS 2	L	L	L	M	M	L	L	L	M
CAWS 3	L	L	L	M	M	L	L	L	M
CAWS 4	L	L	L	M	M	L	L	L	M
CAWS 5	L	L	L	M	M	L	L	L	M

[a] Probability element ratings: M = medium probability, the event is likely to occur but is not certain to do so; L = low probability, the event will likely not occur but is possible.

[b] Consequence ratings: M = Medium consequence rating due to the number of consequence categories affected, the nature and severity of the consequences, and the spatial extent of the consequences.

[c] Risk ratings: M = medium risk of adverse impacts; L = low risk of adverse impacts.

6.2.5 Threespine Stickleback (*Gasterosteus aculeatus*)

6.2.5.1 Native Range and Current Distribution

The threespine stickleback is native to marine and freshwaters of the Arctic and Atlantic drainages from Baffin Island and the western side of Hudson Bay to the Cape Fear Estuary of North Carolina (Fuller 2012), as well as Pacific drainages from Alaska to Baja California (Fuller 2012); the species is also native to Europe, Iceland, Greenland, and the Pacific coast of Asia. Eastern freshwater populations can be found far inland, including in Lake Ontario (Page & Burr 1991), although the species is native only below Niagara Falls in the Great Lakes (Smith 1985). The spread of the species north of Niagara Falls is thought to have occurred through bait release by anglers (Fuller 2012) or through travel through the artificial Nipissing Canal (Smith 1985). The species is currently present in Lakes Michigan, Superior, and Huron, with populations also established in the states of Massachusetts, Oregon, California, and Alaska (Fuller 2012). The species is established in southern Lake Michigan, and specimens have been found in the North Shore Channel in 1988 (Johnston 1991) and near the Lockport Lock and Dam (INHS Undated).

6.2.5.2 Life History and Ecology

The native range of the threespine stickleback covers Arctic to temperate climates, in the range of 3-19°C (Allen & Wooton 1982). Populations of the species can be wholly marine, anadromous, or strictly freshwater (Willacker et al. 2010). Threespine sticklebacks inhabit a wide range of flowing and still-water habitats (Rushbrook et al. 2010) but do prefer low velocities (Copp & Kovac 2003). They are found in sluggish waters of lakes, ponds, large lowland rivers, estuaries, and marine coastlines at depths ranging from 0 to 100 m (0 to 328 ft) (Copp & Kovac 2003). They prefer sand and mud substrates, and freshwater populations are typically associated with submerged vegetation (NatureServe 2010).

Threespine sticklebacks are a generalist species that feed on invertebrates, fish eggs and fry (including northern pike) (Nilsson 2006), crustaceans, insect larvae (NatureServe 2010), plankton, and plant matter (Wootton 1976). The species spawn between April and June (Alexandre & Almeida 2009), with females producing 15 to more than 1,000 eggs, depending on their size (Baker et al. 2008). Eggs are deposited in nests in shallow freshwater with low flow (not exceeding 13 cm/s [5.1 in./s]) (Rushbrook et al. 2010), in temperatures of 14-16°C (57.2-60.8°F) (Alexandre & Almeida 2009). Minimum population doubling time is less than 15 months (FishBase Undated).

6.2.5.3 Probability of Establishment

The threespine stickleback is currently found within the CAWS, and there is a high probability that it will pass through the CAWS (Table 6.20; Appendix B). Once it is below the Brandon Road Lock and Dam, it has a high probability of colonizing and spreading in the MRB. Establishment probability is high for all CAWS pathways and time steps. There is suitable habitat in the MRB, and the threespine stickleback has been documented to establish in river basins.

TABLE 6.20 Probability of Establishment, by CAWS Pathway and Time Step, of the Threespine Stickleback in the MRB[a,b]

Probability Element	CAWS 1 T0	CAWS 1 T10	CAWS 1 T25	CAWS 1 T50	CAWS 2 T0	CAWS 2 T10	CAWS 2 T25	CAWS 2 T50	CAWS 3 T0	CAWS 3 T10	CAWS 3 T25	CAWS 3 T50	CAWS 4 T0	CAWS 4 T10	CAWS 4 T25	CAWS 4 T50	CAWS 5 T0	CAWS 5 T10	CAWS 5 T25	CAWS 5 T50
	Probability Ratings for Time Steps 0, 10, 25, and 50 Years[a,b]																			
Pathway	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)
Arrival	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)
Passage	H (M)	H (L)	H (L)	H (L)	H (M)	H (L)	H (L)	H (L)	H (M)	H (L)	H (L)	H (L)	H (M)	H (L)	H (L)	H (L)	H (M)	H (L)	H (L)	H (L)
Colonization	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)
Spread	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)
Probability of Establishment	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H

[a] Probability element ratings: H = high probability, the event will almost certainly occur.

[b] Uncertainty associated with each Probability Element is indicated in parentheses. Uncertainty ratings: M = medium, good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment; L = low, good data available with no major data gaps; N = none, adequate data available to fully support the probability rating.

6.2.5.4 Consequences of Establishment

Environmental Consequences. The threespine stickleback has an environmental consequence rating of medium with an associated uncertainty rating of medium (Table 6.21). If it becomes established in the MRB, this species could compete with and reduce the abundance of MRB fishes because this species preys on fish eggs and fry (Fuller 2012). However, the threespine stickleback is a generalist with a life history similar to those of existing MRB species, including sticklebacks native to the MRB. Therefore, even if it replaced existing species, it may not alter food web dynamics or secondary productivity. In addition, this species is not reported to be dominant or a nuisance species where it is established (see Appendix B).

Economic Consequences. The establishment of the threespine stickleback in the MRB is not expected to have economic consequences (Appendix C). Therefore, this species' economic consequence rating is none, and the uncertainty of the rating is low.

Social/Political Consequences. The threespine stickleback could affect the perceived quality of recreational fishing opportunities (Appendix D). However, this species is not expected to have consequences that could lead to the generation of new laws or regulations designed to limit its spread. Overall, no social/political consequences are anticipated from the establishment of this species (Table 6.21; Appendix D). The uncertainty of this consequence rating is low.

TABLE 6.21 Consequences of Establishment of the Threespine Stickleback in the MRB[a,b]

Environmental Consequences	Economic Consequences	Social/Political Consequences	Total Overall Consequences
M (M)	N (L)	N (L)	M

[a] Consequence ratings: M = Medium consequence rating due to the number of consequence categories affected, the nature and severity of the consequences, and the spatial extent of the consequences; N = no consequences are anticipated.

[b] Uncertainty ratings are indicated in the parentheses: M = Medium, good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment; L = Low, good ANS-specific data available with no known major data gaps.

Overall Consequences. The threespine stickleback could have medium environmental consequences and no economic or social/political consequences, primarily related to its potential to alter fish communities and its potentially widespread distribution in the MRB. However, this species is not reported to be dominant or a nuisance species where it is established, and it is uncertain what effect, if any, this species will have on sport and food fish populations in the MRB. Therefore, the threespine stickleback has an overall consequence rating of medium.

6.2.5.5 Risk of Adverse Impact

The overall consequences of the establishment of the threespine stickleback in the MRB could be medium (Table 6.22). The probability of this species becoming established in the MRB is considered high for all time steps and pathways, and it is considered likely that the species would ultimately become widespread in the MRB once established. The overall risk of adverse impacts on the MRB from the threespine stickleback was determined to be medium for all CAWS pathways and for all time steps. There is a medium uncertainty associated with the environmental consequence rating.

TABLE 6.22 Risk of the Threespine Stickleback to Pose Adverse Impacts to the MRB

	Probability of Establishment[a]					Risk of Adverse Impacts[c]			
Pathway	T_0	T_{10}	T_{25}	T_{50}	Consequences of Establishment[b]	T_0	T_{10}	T_{25}	T_{50}
CAWS 1	H	H	H	H	M	M	M	M	M
CAWS 2	H	H	H	H	M	M	M	M	M
CAWS 3	H	H	H	H	M	M	M	M	M
CAWS 4	H	H	H	H	M	M	M	M	M
CAWS 5	H	H	H	H	M	M	M	M	M

[a] Probability element ratings: H = high probability, the event will almost certainly occur.

[b] Consequence ratings: M = Medium consequence rating due to the number of consequence categories affected, the nature and severity of the consequences, and the spatial extent of the consequences.

[c] Risk ratings: M = medium risk of adverse impacts.

6.2.6 Tubenose Goby (*Proterorhinus semilunaris*)

6.2.6.1 Native Range and Current Distribution

The tubenose goby was first recorded in the Great Lakes Basin in 1990 in the St. Clair River (Fuller et al. 2012). It has since been recorded throughout Lake St. Clair and its tributaries (Jude et al. 1992), in the Detroit River system, in the Duluth-Superior harbor of Lake Superior, and in the western basin of Lake Erie (Kocovsky et al. 2011). The tubenose goby is native to slightly brackish to freshwaters of Eurasia, primarily in rivers and estuaries of the Black Sea Basin, as well as rivers of the northern Aegean (Neilson & Stepien 2009; Fuller et al. 2012). The introduction of the species to the Great Lakes likely occurred via ballast water from transoceanic cargo ships (Fuller et al. 2012).

6.2.6.2 Life History and Ecology

The tubenose goby is a benthic omnivore of shallow (<5m [<16.4 ft]), slow-moving, nearshore waters of low-salinity estuaries, lakes, rivers, and wetlands (Fuller et al. 2012; Dopazo et al. 2008). It is often abundant in riprap habitat (Jude & DeBoe 1996) or in sheltered areas with abundant macrophytes (Kocovsky et al. 2011). Tubenose gobies prefer water temperatures of 10-15.6°C (50-60°F) (Rasmussen 2002), and were positively associated with temperatures up to 24°C (75.2°F) (Dopazo et al. 2008).

This species is omnivorous (Fuller et al. 2012); in the Great Lakes, the species feeds mainly on amphipods, crustaceans, and insects (French & Jude 2001) and occasionally consumes larval fishes (Adámek et al. 2010). Tubenose goby reach maturity at 1-2 years; spawning occurs from April to August, with female spawning more than once per season (Freyhof & Kottelat 2008). This species spawns on the underside of fixed objects such as rocks (Kocovsky et al. 2011), and also lay their eggs among vegetation (Fuller et al. 2011). Tubenose goby likely has a protracted spawning period (Leslie et al. 2002).

6.2.6.3 Probability of Establishment

Each of the CAWS pathways provides a pathway for the tubenose goby to enter the MRB. For all pathways, there is a low probability of arrival at T_{10}, but the probability of arrival increases to medium at T_{10} (Table 6.23; Appendix E). If the tubenose goby were to reach the CAWS, there is a high probability of it passing through to the MRB by T_0 and a medium probability of colonization and spread (primarily depending on whether this species can tolerate the temperatures in the MRB). For all pathways, the overall probability of establishment is low at T_0, but it increases to medium for the remainder of the time periods. The uncertainty of the colonization and spread establishment rating elements are high, because the tubenose goby is a cool-water fish and there is uncertainty about the suitability of climate in the MRB.

TABLE 6.23 Probability of Establishment, by CAWS Pathway and Time Step, of the Tubenose Goby in the MRB

	Probability Ratings for Time Steps 0, 10, 25, and 50 Years[a,b]																			
	CAWS 1				CAWS 2				CAWS 3				CAWS 4				CAWS 5			
Probability Element	T0	T10	T25	T50	T0	T10	T25	T50	T0	T10	T25	T50	T0	T10	T25	T50	T0	T10	T25	T50
Pathway	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)
Arrival	L (L)	M (M)	M (M)	M (M)	L (L)	M (M)	M (M)	M (M)	L (L)	M (M)	M (M)	M (M)	L (L)	M (M)	M (M)	M (M)	L (L)	M (M)	M (M)	M (M)
Passage	H (M)	H (M)	H (L)	H (L)	H (M)	H (M)	H (L)	H (L)	H (M)	H (M)	H (L)	H (L)	H (M)	H (M)	H (L)	H (L)	H (M)	H (M)	H (L)	H (L)
Colonization	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)
Spread	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)
Probability of Establishment	L	M	M	M	L	M	M	M	L	M	M	M	L	M	M	M	L	M	M	M

[a] Probability element ratings: H = high probability, the event will almost certainly occur; M = medium probability, the event is likely to occur but is not certain to do so; L = low probability, the event will likely not occur but is possible.

[b] Uncertainty associated with each Probability Element is indicated in parentheses. Uncertainty ratings: H = high, little or no data available and rating based on professional judgment; M = medium, good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment; L = low, good data available with no major data gaps; N = none, adequate data available to fully support the probability rating.

6.2.6.4 Consequences Summary

Environmental Consequences. Overall, the environmental consequences of the tubenose goby establishing in the MRB are expected to be medium (Table 6.24; Appendix B). Tubenose goby are found in most habitats within rivers and lakes. The tubenose goby consumes benthic invertebrates and zooplankton (Fuller et al. 2012), and its diet overlaps with other benthic fishes in the MRB (Kocovsky et al. 2011; Adámek et al. 2010). Tubenose gobies potentially pose a threat to Endangered Species Act (ESA)-listed species directly by predation or indirectly by reducing the abundance of mussel hosts. In Europe, it is documented to have spread rapidly and reached relatively high abundance after introduction into the Danube basin (Adámek et al. 2010). However, unlike the round goby, tubenose gobies have not yet exhibited any known ecosystem effects in the GLB since their establishment (Dopazo et al. 2008). In addition, the tubenose goby is a true cool-water species, and its temperature preferences may limit movement south into the Illinois River (Rasmussen 2002), which could in turn limit its expansion into other parts of the MRB. Consequently, the spatial extent of the environmental impacts is expected to be localized. The uncertainty of this rating is also medium. There are few reports of adverse ecological effects attributable to this species, and it is uncertain to what extent the warmer temperatures of the MRB may limit the distribution, abundance, and therefore the potential impacts of this species in the MRB.

Economic Consequences. The establishment of the tubenose goby in the MRB is predicted to have low economic consequences, and the uncertainty of the rating is medium (Appendix C).

Social/Political Consequences. The establishment of the tubenose goby in the MRB is not expected to result in impacts on public uses, although it could result in some political consequences (Appendix D). In addition, any impacts from the tubenose goby are expected to be local, due to the preference of this species for cooler water. The social/political consequence rating is therefore low, as is the uncertainty of this rating.

Overall Consequences. The environmental consequences of the establishment of the tubenose goby in the MRB are expected to be medium; social/political are expected to be low; and no economic consequences are expected following establishment of this species in the MRB. Consequences of establishment of this species are primarily related to its potential to adversely affect fish communities and endangered species in the MRB. However, the tubenose goby is a cool-water fish and may not spread widely enough or reach densities high enough to adversely affect ecological communities. Therefore, the overall consequence rating is medium and there is a medium uncertainty associated with the environmental and economic consequence ratings.

TABLE 6.24 Consequences of Establishment of the Tubenose Goby in the MRB[a,b]

Environmental Consequences	Economic Consequences	Social/Political Consequences	Total Overall Consequences
M (M)	L (M)	L (L)	M

[a] Consequence ratings: M = Medium consequence rating due to the number of consequence categories affected, the nature and severity of the consequences, and the spatial extent of the consequences; L = Low consequence rating due to the lower number of consequence categories affected, the lesser nature and severity of the consequences, and the more localized extent of the consequences.

[b] Uncertainty ratings are indicated in the parentheses: M = Medium, good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment; L = Low, good ANS-specific data available and no major data gaps known.

6.2.6.5 Risk of Adverse Impacts

The tubenose goby has a low probability of establishment, and therefore a low risk until T_{10}, when the probability of establishment increases to medium and then high. Once in the MRB, the tubenose goby has an overall consequence rating of medium, primarily related to its potential effects on resident fish communities and ESA-listed species. However, the tubenose goby is a cool-water species, and that temperature preference may limit its expansion into the MRB. Consequently, the spatial extent of possible impacts is expected to be localized. The overall risk of adverse impacts is low for all pathways at T_0 and is medium for the remaining time steps (Table 6.25). The uncertainty of the establishment probability elements and the consequence rating are generally medium to high, based on the uncertainty about how rapidly and widely the tubenose goby will pass through the CAWS and spread in the MRB (Appendix E).

TABLE 6.25 Risk of the Tubenose Goby to Pose Adverse Impacts to the MRB

Pathway	Probability of Establishment[a]				Consequences of Establishment[b]	Risk of Adverse Impacts[c]			
	T_0	T_{10}	T_{25}	T_{50}		T_0	T_{10}	T_{25}	T_{50}
CAWS 1	L	M	M	M	M	L	M	M	M
CAWS 2	L	M	M	M	M	L	M	M	M
CAWS 3	L	M	M	M	M	L	M	M	M
CAWS 4	L	M	M	M	M	L	M	M	M
CAWS 5	L	M	M	M	M	L	M	M	M

[a] Probability element ratings: M = medium probability, the event is likely to occur but is not certain to do so; L = low probability, the event will likely not occur but is possible.

[b] Consequence ratings: M = Medium consequence rating due to the number of consequence categories affected, the nature and severity of the consequences, and the spatial extent of the consequences.

[c] Risk ratings: M = medium risk of adverse impacts; L = low risk of adverse impacts.

6.2.7 Ruffe (*Gymnocephalus cernuus*)

6.2.7.1 Native Range and Current Distribution

The ruffe was first reported from the St. Louis River between Minnesota and Wisconsin in 1986 (Peterson et al. 2011). The species has since been reported in Lakes Michigan, Superior, and Huron, as well as in the Amnicon, Flag, Iron, Middle, Raspberry, and Bad Rivers in Wisconsin and in Torch Lake, Little Bay de Noc, Big Bay de Noc, Misery River, Ontonagon River, Thunder Bay and Sturgeon River Sloughs, and multiple tributary rivers (Bowen & Goehle 2011). In Lake Michigan, the species has not been detected outside of Green Bay (Bowen & Goehle 2011). The ruffe is native to northern Europe and Asia (Fuller & Jacobs 2012), and was likely introduced to the Great Lakes Basin via ship ballast water from transoceanic ships and spread within the Great Lakes by shipping transport (Fuller & Jacobs 2012).

6.2.7.2 Life History and Ecology

Ruffe are tolerant of a wide range of environmental conditions, tolerating fresh and brackish waters at depths from 0.25 to 85 m (0.82-279 ft) (NBII & ISSG 2006), but prefer well-oxygenated (Kovac 1998), still or slow-moving waters (FishBase 2010), with temperatures ranging from 10 to 20°C (50-68°F) (Rasmussen 2002). For spawning, temperatures of 4.9-20°C (40.8-68°F) are preferred (NBII & ISSG 2006), and temperatures between 30 and 34°C (86-93.2°C) are considered lethal for the species (Crosier et al. 2005). Spawning requires submerged vegetation, debris (logs, branches, gravel), and hard bottoms of clay or sand (NBII & ISSG 2006); adults prefer soft bottoms with no vegetation (FishBase 2010) and deep water with deposits of sand and gravel (Rasmussen 2002). In general, ruffe abundance increases with increased eutrophication (Kottelat & Freyhof 2007).

Ruffe are opportunistic feeders that almost exclusively feed on benthic organisms (Fuller et al. 2012). As ruffe mature, their diet becomes more benthic in nature (Ogle 1998). Common prey of ruffe larvae are copepods, *Daphnia* spp., and *Bosmian longirostrus*; as ruffe mature, chironomids and other insect larvae comprise a larger portion of their diet. Other common prey include rotifer nauplii, fish larvae, fish eggs, and small fish (NBII & ISSG 2006). Spawning for this species occurs late April through mid-June/July (Fuller & Jacobs 2012; White 2002). Females can produce 130,000-200,000 eggs per season (White 2002), producing up to 200,000 in the first batch and up to 6000 per subsequent batch (NBII & ISSG 2006). Ruffe take 2-3 years to mature, but may mature in 1 year in warmer waters (White 2002).

6.2.7.3 Probability of Establishment

While each of the CAWS pathways may be used by the ruffe to enter the MRB, and despite this species having the ability to spread to southern Lake Michigan by swimming and ballast water discharge, the ruffe has not yet spread to southern Lake Michigan even though it has been in the Great Lakes since the 1980s. Therefore, there is a low probability of arrival until T_{50} (Table 6.26). If the ruffe were to reach the CAWS, there would be a high probability of it passing through the CAWS by T_0 and a medium probability of colonization and spread (primarily depending on whether this species can tolerate the warmer water temperatures in the middle and lower MRB). Because of the low probability of arrival at all pathways, the overall probability of establishment is low for all pathways until T_{50} when it increases to medium (Table 6.26). The uncertainty of the establishment elements range up to high, due to uncertainty about the speed of arrival, the suitability of climate in the MRB, and why the ruffe has not spread more widely in the GLB.

TABLE 6.26 Probability of Establishment, by CAWS Pathway and Time Step, of the Ruffe in the MRB

Probability Element	Probability Ratings for Time Steps 0, 10, 25, and 50 Years[a,b]																			
	CAWS 1				CAWS 2				CAWS 3				CAWS 4				CAWS 5			
	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}
Pathway	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
	(N)	(N)	(N)	(N)	(N)	(N)	(N)	(N)	(N)	(N)	(N)	(N)	(N)	(N)	(N)	(N)	(N)	(N)	(N)	(N)
Arrival	L	L	L	M	L	L	L	M	L	L	L	M	L	L	L	M	L	L	L	M
	(L)	(M)	(M)	(H)	(L)	(M)	(M)	(H)	(L)	(M)	(M)	(H)	(L)	(M)	(M)	(H)	(L)	(M)	(M)	(H)
Passage	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H
	(M)	(M)	(L)	(L)	(M)	(M)	(L)	(L)	(M)	(M)	(L)	(L)	(M)	(M)	(L)	(L)	(M)	(M)	(L)	(L)
Colonization	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
	(H)	(H)	(H)	(H)	(H)	(H)	(H)	(H)	(H)	(H)	(H)	(H)	(H)	(H)	(H)	(H)	(H)	(H)	(H)	(H)
Spread	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
	(H)	(H)	(H)	(H)	(H)	(H)	(H)	(H)	(H)	(H)	(H)	(H)	(H)	(H)	(H)	(H)	(H)	(H)	(H)	(H)
Probability of Establishment	L	L	L	M	L	L	L	M	L	L	L	M	L	L	L	M	L	L	L	M

[a] Probability element ratings: H = high probability, the event will almost certainly occur; M = medium probability, the event is likely to occur but is not certain to do so; L = low probability, the event will likely not occur but is possible.

[b] Uncertainty associated with each Probability Element is indicated in parentheses. Uncertainty ratings: H = high, little or no data available and rating based on professional judgment; M = medium, good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment; L = low, good data available with no major data gaps; N = none, adequate data available to fully support the probability rating.

6.2.7.4 Consequences Summary

Environmental Consequences. The ruffe has an environmental consequence rating of medium (Table 6.27). The ruffe have several traits that make them highly successful invaders: (1) they are prolific breeders, (2) they mature quickly, and (3) they are aggressive feeders with indiscriminate habitat requirements (Hajjar 2002; see Appendix B). Ruffe eat small fish as well as the eggs of other species (NBII & ISSG 2006), and this species has affected fish populations found in the MRB. Ruffe could have a detrimental effect on MRB fishes by feeding on the young of resident species or by competing with them for food (Fullerton et al. 1998; Fuller & Jacobs 2012). However, it is unclear whether the decline in certain fish species attributed to ruffe was due to natural population dynamics or because of predation and competition with the ruffe (Bronte et al. 1998). Although ruffe may alter fish community structure and biodiversity, they occupy a similar niche to existing fish species and are not likely to alter the food web, nutrient cycling, or productivity at the ecosystem level. In addition, the ruffe is a cold-water fish (Rasmussen 2002), and it may not reach high abundance or wide distribution in the MRB. The climatological suitability of the MRB is also uncertain. Therefore, there remains a medium degree of uncertainty regarding the environmental consequences of a ruffe invasion in the MRB (Appendix B).

TABLE 6.27 Consequences of Establishment of the Ruffe in the MRB[a,b]

Environmental Consequences	Economic Consequences	Social/Political Consequences	Total Overall Consequences
M (M)	M (M)	M (M)	M

[a] Consequence ratings: M = Medium consequence rating due to the number of consequence categories affected, the nature and severity of the consequences, and the spatial extent of the consequences.

[b] Uncertainty ratings are indicated in the parentheses: M = medium, good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment.

Economic Consequences. The establishment of the ruffe could produce economic consequences in a number of categories and may include a loss of consumer surplus, reductions in recreational and commercial fishing that could adversely impact employment, income, and tax revenues, and reductions in supporting service industries. See Appendix C for more detailed mechanisms and descriptions of potential impacts. The severity of economic consequences would depend on the extent of species establishment, the resulting impact on existing fisheries resources, and the consequent impact on recreational and commercial fishing and associated support services. The economic consequences of ruffe establishing in the MRB is medium with high uncertainty (Appendix C).

Social/Political Consequences. The ruffe has generated significant management activities in the GLB. This species has the potential to reduce the abundance of important recreational fish species, and, therefore, has the potential to reduce the perceived quality of recreational fishing opportunities (Appendix D). However, due to the cool-water preference of this species, these effects are likely to be localized rather than widespread, should this species become established in the MRB. Overall, the social/political impacts of the ruffe are medium (Appendix D). The uncertainty of this rating is medium because it is uncertain whether this species could reach high abundance or become widespread in the MRB.

Overall Consequences. The environmental, economic, and social/political consequences of the establishment of the ruffe in the MRB could be medium. These consequences are primarily related to the potential for this species to adversely affect fish communities and endangered species in the MRB. However, the ruffe is a cool-water fish and may not spread widely enough or reach densities high enough to adversely affect ecological communities. Therefore, the overall consequence rating is medium and the uncertainty of the consequence ratings are also medium.

6.2.7.5 Risk of Adverse Impacts

The ruffe has not spread to the CAWS in the several decades it has been established in Lake Michigan. Consequently, the ruffe has a low probability of establishment in the MRB, and therefore poses only a low risk to the MRB until T_{50}, when the probability of establishment increases to medium. Once in the MRB, the ruffe has an overall consequence rating of medium, primarily related to its effects on fish communities. However, the ruffe is a cool-water species, and that temperature preference may limit its expansion into the MRB. Consequently, the spatial extent of the impacts is expected to be localized. The overall risk of adverse impacts is low for all pathways until T_{50} when it increases to medium (Table 6.28). The greatest uncertainties associated with the risk rating elements are related to how rapidly the ruffe may reach and pass through the CAWS, and whether it will become widespread in the MRB.

TABLE 6.28 Risk of the Ruffe to Pose Adverse Impacts to the MRB

	Probability of Establishment[a]					Risk of Adverse Impacts[c]			
Pathway	T_0	T_{10}	T_{25}	T_{50}	Consequences of Establishment[b]	T_0	T_{10}	T_{25}	T_{50}
CAWS 1	L	L	L	M	M	L	L	L	M
CAWS 2	L	L	L	M	M	L	L	L	M
CAWS 3	L	L	L	M	M	L	L	L	M
CAWS 4	L	L	L	M	M	L	L	L	M
CAWS 5	L	L	L	M	M	L	L	L	M

[a] Probability element ratings: M = medium probability, the event is likely to occur but is not certain to do so; L = low probability, the event will likely not occur but is possible.

[b] Consequence ratings: M = Medium consequence rating due to the number of consequence categories affected, the nature and severity of the consequences, and the spatial extent of the consequences.

[c] Risk ratings: M = medium risk of adverse impacts; L = low risk of adverse impacts.

6.2.8 Viral Hemorrhagic Septicemia Virus (*Novirhabdovirus* sp.)

6.2.8.1 Native Range and Current Distribution

Viral hemorrhagic septicemia was first reported in Europe in the late 1930s (Warren 2002). Four strains of the virus have since been identified in Europe, Japan, and the Atlantic and Pacific coasts of North America (Skall et al. 2005). The Great Lakes strain, first discovered in 2003, is considered a variant of the Atlantic coast North American strain of the virus (Elsayed et al. 2006). The spread of the virus into the Great Lakes is thought to be a result of transport through ship ballast water or the movement of infected migratory fish through the St. Lawrence River (Elsayed et al. 2006). Viral hemorrhagic septicemia has been detected in all five Great Lakes, as well as in the St. Lawrence River and several inland waters of New York, Ohio, Michigan, and Wisconsin (Kipp et al. 2013). This species has also been detected in Clear Fork Reservoir, which is within the Ohio River Watershed.

6.2.8.2 Life History and Ecology

Viral hemorrhagic septicemia (VHSv) strains are found across the globe in both marine and fresh water. The Great Lakes strain has been confirmed in 24 fish species (Whelan 2009). The virus is transmitted through contact with infected individuals or infected material, entering the body through the gills, open wounds, or ingestion (Whelan 2009). Incubation time for the virus is dependent on water temperature, but typically ranges from 7 to 15 days (CFSPH 2003). While fish are susceptible to the virus at any age, they are most at risk during times of stress, in crowded conditions, during early life stages, and at cold temperatures (Smail 1999). The virus replicates at temperatures of 2–15°C (35.6–59°C), with highest fish mortality at 3–12°C (Wolf 1988; McAllister 1990; Meyers & Winton 1995). At cool temperatures the virus can persist for extended periods of time without a host, remaining active for 2 months at 4°C and 1 week at 30°C (Hawley & Garver 2008). Survivors of the virus continually shed the virus in urine and reproductive fluids throughout their lifetime (Whelan 2009). Invertebrates carrying the virus can act as reservoirs (Faisal & Winters 2011). The virus is inactivated when subjected to desiccation, or to pH levels below 2.4 or greater than 12.2 (CFSPH 2003; McAllister 1990).

6.2.8.3 Probability of Establishment

VHSv has spread throughout the Great Lakes in less than a decade. It has been documented in Lake Michigan as far south as Waukegan. There are no barriers to the movement of VHSv into the CAWS, through Brandon Road Lock and Dam, and into the MRB. VHSv could be rapidly transported into the CAWS and move downstream to the Brandon Road Lock and Dam by boat hulls, ballast water, gravity flow, or fish hosts. This species is documented to spread through rivers and has been detected in Clear Fork Reservoir, which is within the Ohio River Watershed, suggesting it could also establish in reservoirs in the MRB. There are also suitable fish hosts in the MRB. Consequently, VHSv has high probability of arriving, spreading, and colonizing the MRB at T_0 (Table 6.29). However, laboratory studies suggest this species may not spread south into the lower MRB because VHSv becomes inactive at temperatures above 20°C (Goodwin and Merry 2011; reviewed in Kipp et al. 2013). Consequently, the probability of establishing throughout the MRB is medium.

6.2.8.4 Consequences Summary

Environmental Consequences. The Great Lakes genotype of VHSv has resulted in large fish kills in the Great Lakes region. In addition to mortality, VHSv can result in fitness-reducing effects including hyperactivity, erratic swimming behavior, and tissue and organ damage. VHSv can infect fish at all lifestages. It has been documented to infect several species within the Great Lakes that are also present in the MRB, including centrarchids, freshwater drum, walleye yellow perch, and gizzard shad (Kipp et al. 2013). VHSv may produce population- or ecosystem-level consequences such as changes in food web structure, depending on the mortality rate and the trophic level of the fish species affected by the virus. However, in the GLB, these events were episodic and no population-level impacts have been documented (reviewed in Kipp et al. 2013).

TABLE 6.29 Probability of Establishment, by CAWS Pathway and Time Step, of the Viral Hemorrhagic Septicemia Virus in the MRB

	Probability Ratings for Time Steps 0, 10, 25, and 50 Years[a,b]																			
	CAWS 1				CAWS 2				CAWS 3				CAWS 4				CAWS 5			
Probability Element	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}
Pathway	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)
Arrival	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)
Passage	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)
Colonization	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)
Spread	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)
Probability of Establishment	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M

[a] Probability element ratings: H = high probability, the event will almost certainly occur; M = medium probability, the event is likely to occur but is not certain to do so; L = low probability, the event will likely not occur but is possible.

[b] Uncertainty associated with each Probability Element is indicated in parentheses. Uncertainty ratings: M = good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment; L = low, good data available with no major data gaps; N = none, adequate data available to fully support the probability rating.

VHSv readily spreads through aquatic pathways and suitable host fish are present throughout the MRB. However, VHSv is most virulent in cold waters; the virus becomes inactive after 24 hours in water temperatures greater than 20°C (reviewed in Kipp et al. 2013), and mortality is uncommon at temperatures greater than 15°C (McAllister 1990: Goodwin and Merry 2011). Therefore, VHSv may not spread to the lower MRB, and/or it may have greatly reduced virulence in the middle and lower MRB. Overall, the environmental consequence of VHSv establishing in the MRB are expected to be low. The natural rate of mutations in the virus, the geographic extent of its spread within the MRB, and the development of increased resistance of fish to the virus are uncertain. The impacts on ESA-listed fish in the MRB are also uncertain. Overall, there is a medium uncertainty associated with the ecological consequence rating for VHSv.

Economic Consequences. VHSv could affect several fish species of commercial, recreational, and aquaculture value (APHIS 2006). Economic loss to aquaculture facilities could result from loss of fish stocks, additional routine testing costs for the virus, and disinfection costs if the virus was detected at the facility. European strains of VHSv have caused significant mortality in trout farms in Europe, and farmed fish could be affected in the United States as well. However, Considering its temperature sensitivities, VHSv may not spread to the lower MRB, and/or may have greatly reduced virulence in the middle and lower MRB. Consequently, impacts on the large number of aquaculture facilities in the middle and lower MRB may be minor. Overall, given the potential impacts on aquaculture, VHSv is expected to result in medium economic consequences if it were to establish in the MRB. See Appendix C for more detailed mechanisms and descriptions of potential impacts.

Social/Political Consequences. If VHSv were to establish in the MRB, several social/political consequences may result. The appearance of diseased fish may discourage recreational fishing, and fish kills could impact beach use. However, McAllister (1990) states that mortality in fish is uncommon at temperatures greater than 15°C. Considering these temperature sensitivities, VHSv may not spread to the lower MRB, and/or it may have greatly reduced virulence in the middle and lower MRB. Consequently, impacts on fishing and beach use may be geographically limited.

Multiple state regulations restricting or regulating interstate or international shipments of fish have been enacted to control VHSv in the Great Lakes Basin and limit its spread to other states (APHIS 2008). Currently, Illinois, Indiana, Michigan, Minnesota, New York, Pennsylvania, Ohio, and Wisconsin are regulated under the U.S. Department of Agriculture's (USDA's) Animal and Plant Health Inspection Service (APHIS) interim rules. Restrictions on the sale and transport of bait fish have also been enacted in the GLB and the northeast (Kipp et al. 2013). Similar regulations may be put in place in other states if VHSv were to establish in the middle and lower MRB. Additional regulations may also require more widespread testing to verify aquaculture facilities are free from the disease. Overall, the potential social/political impacts resulting from the establishment of VHSv in the MRB may be high and the uncertainty associated with the social/political consequence rating is low.

Overall Consequences. The economic and social/political consequences of the establishment of the VHSv in the MRB could be medium and high, respectively (Table 6.30). Environmental consequences are expected to be low. The consequence rating is primarily related to the potential for VHSv to adversely affect recreational fishing, beach use, and aquaculture facilities. However, VHSv is adapted to relatively cold water and may not spread widely enough to affect economically valuable aquaculture in the lower MRB. Therefore, the uncertainty of the environmental an economic consequence ratings are medium and high, respectively.

TABLE 6.30 Consequences of Establishment of the Viral Hemorrhagic Septicemia Virus in the MRB[a,b]

Environmental Consequences	Economic Consequences	Social/Political Consequences	Total Overall Consequences
L (M)	M (H)	H (L)	M

[a] Consequence ratings: H = High consequence rating due to the larger number of consequence categories affected, the nature and severity of the consequences, and the broader spatial extent of the consequences; M = Medium consequence rating due to the number of consequence categories affected, the nature and severity of the consequences, and the spatial extent of the consequences; L = Low consequence rating due to the lower number of consequence categories affected, the lesser nature and severity of the consequences, and the more localized extent of the consequences.

[b] Uncertainty ratings are indicated in the parentheses: H = high, little or no data available and rating based on professional judgment; M = medium, good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment; L = low uncertainty, good supporting data are available.

6.2.8.5 Risk of Adverse Impacts

VHSv is expected to spread widely through the upper MRB via water or host transport. Consequently, VHSv has a high probability of establishment in the MRB at T_0. Once in the MRB, VHSv has an overall consequence rating of medium, primarily related to its economic and social/political impacts resulting from its effects on recreational fishing, beach use, and aquaculture facilities. However, VHSv is adapted to cold waters, and that temperature preference may limit its spread in the MRB. Consequently, the spatial extent of the impacts may be localized to the upper MRB. The overall risk of adverse impacts is medium for all pathways (Table 6.31). The primary uncertainties associated with the overall risk rating are related to how widespread this species will become in the MRB and the resulting high uncertainty of the economic consequence rating.

TABLE 6.31 Risk of the Viral Hemorrhagic Septicemia Virus to Pose Adverse Impacts to the MRB

	Probability of Establishment[a]					Risk of Adverse Impacts[c]			
Pathway	T_0	T_{10}	T_{25}	T_{50}	Consequences of Establishment[b]	T_0	T_{10}	T_{25}	T_{50}
CAWS 1	M	M	M	M	M	M	M	M	M
CAWS 2	M	M	M	M	M	M	M	M	M
CAWS 3	M	M	M	M	M	M	M	M	M
CAWS 4	M	M	M	M	M	M	M	M	M
CAWS 5	M	M	M	M	M	M	M	M	M

[a] Probability element ratings: M = medium probability, the event is likely to occur but is not certain to do so.

[b] Consequence ratings: M = Medium consequence rating due to the number of consequence categories affected, the nature and severity of the consequences, and the spatial extent of the consequences.

[c] Risk ratings: M = medium risk of adverse impacts.

6.3 LOW-RISK SPECIES

Fifteen ANS currently present in the GLB were all given a low overall risk (for all CAWS pathways and time steps) for the MRB (Table 6.1), primarily because of their low expected consequence and/or low probability of establishment. These species include the parasitic copepod (*Neoergasilus japonicas*), the harpacticoid copepod (*Schizopera borutzkyi*), the water flea (*D. galeata galeata*), the European fingernail clam (*Sphaerium corneum*), the greater European peaclam (*Pisidium amnicum*), the European stream valvata (*Valvata piscinalis*), the cryptic algae (*Cyclotella cryptica*), a freshwater bryozoan (*Lophopodella carteri*), three species of testate amoeba (*Psammonobiotus communis*, *P. dziwnowi*, and *P. linearis*), the sea lamprey (*Petromyzon marinus*), the blueback herring (*Alosa aestivalis*), the water chestnut (*Trapa natans*), and the swamp sedge (*Carex acutiformis*).

6.4 SENSITIVITY ANALYSIS

Using the GLRMIS method, there would be 15 low risk ANS, eight medium risk ANS, and two high risk ANS. The species risk ratings using the Alternative Additive Method are equivalent to the GLMRIS method. Using the ANS Task Force method (ANSTF 1996) there would be four low risk ANS, 18 medium risk ANS, and three high risk ANS. For the 11 species that increased from low under the GLMRIS method to medium risk under the ANS Task Force method, the increase was due to the probability of establishment being high or medium for 8 species, and all 8 had a consequence rating of low. The remaining three species had a consequence rating of medium and a low probability of establishment. One species, the threespine stickleback, increased from medium to high risk using the ANS Task Force method. The threespine stickleback has a high probability of establishment and a medium environmental consequence. See Appendix A for the risk assessments of the species that increased from low to medium using the additive methods (Table 6.32).

For any species that moved up a medium risk level using the additive approaches, their probability of establishment could be managed the same way as other species within their same functional group that were classified as medium or high risk under the multiplicative method.

TABLE 6.32 Sensitivity Analysis Results Using Alternative Risk Level Determination Methods

Species	Probability of Establishment	Consequence Rating	GLMRIS Method	ANS Task Force Additive Method	Alternative Additive Method
		Great Lakes Basin			
P. Communis	L	L	L	L	L
P. dziwnowi	L	L	L	L	L
P. linearis	L	L	L	L	L
Bryozoan	H (T_{25})	L	L	M	L
Cryptic Algae	M (T_0)	L	L	M	L
Swamp Sedge	L	L	L	L	L
Water Chestnut	L	M	L	M	L
European Peaclam	M (T_{50})	L	L	M	L
European Fingernail Clam	H (T_0)	L	L	M	L
European Stream Valvata	H (T_{50})	L	L	M	L
D. g. galeata	M (T_{25})	L	L	M	L
Parasitic Copepod	H (T_{50})	L	L	M	L
Harpacticoid Copepod	H (T_{50})	L	L	M	L
Sea Lamprey	L	M	L	M	L
Blueback Herring	L	M	L	M	L
Bloody Red Shrimp	H	H	H	H	H
Fishhook Waterflea	H	H	H	H	H
Grass Kelp	M	M	M	M	M
Red Algae	M	M	M	M	M
Diatom	M	M	M	M	M
Reed Sweetgrass	M	M	M	M	M
Threespine Stickleback	H (T_0)	M	M	H	M
Tubenose Goby	M	M	M	M	M
Ruffe	M	M	M	M	M
VHSv	M	M	M	M	M

7 CAWS PATHWAY RISKS

Each of the five Chicago Area Waterway System (CAWS) pathways provides a complete year-round waterway connection between the two basins that could allow the interbasin transfer for all 35 of the aquatic nuisance species (ANS) of concern. However, successful interbasin transfer and establishment, and thus potential risks of adverse impacts, are not indicated to be equally supported neither by the five CAWS pathways nor for each of the four time steps evaluated in the risk assessment.

7.1 PATHWAY USE BY HIGH RISK ANS

Only two of the 35 ANS are indicated as posing potential high risks to either the Mississippi River Basin (MRB) or the Great Lakes Basin (GLB) at any time step (Table 7.1). Each of these species (the bloody red shrimp [*Hemimysis anomala*] and the fishhook waterflea [*Cercopagis pengoi*]) may pose a high risk to the MRB (see Chapter 6). No species were identified as posing a high risk to the GLB (see Chapter 5).

The bloody red shrimp could pose a high risk to the MRB at all time steps when considering interbasin transfer through CAWS Pathways 1-3 (Table 7.1). When considering CAWS Pathways 4 and 5 as the means for interbasin transfer, this species would not begin to pose a high risk to the MRB until at least T_{50} for the bloody red shrimp. For Pathways 4 and 5, the direction of current flow at the entry points of each pathway is toward Lake Michigan, which is expected to reduce the potential for successful movement of this species from Lake Michigan into the CAWS and subsequent entry into the MRB (Chapter 6).

For interbasin transfer via CAWS Pathways 1-3, the fishhook waterflea is not expected to begin posing a high risk to the MRB until T_{50} (within 25–50 years) (Table 7.1). For CAWS Pathways 1-3, the timing of potential high risks is associated with the limited mobility of this species and the fact that it has not been documented in the CAWS even though it has been established at the pathway since the 1990s. For Pathways 4 and 5, the direction of current flow at the GLB connections for these pathways (Indiana Harbor and Canal and Burns Small Boat Harbor, respectively) is toward Lake Michigan, and this flow is expected to reduce the potential for successful movement of fishhook waterflea from Lake Michigan into the CAWS (Chapter 6). Therefore, overall risk for Pathways 4 and 5 is low until T_{50}, when it increases to medium.

7.2 PATHWAY USE BY MEDIUM RISK SPECIES

Following interbasin transfer and establishment, 11 ANS were identified as posing as much as a medium risk at one or more time steps: three species moving into the GLB (Chapter 5) and eight species moving into the MRB (Chapter 6). For the GLB, the bighead (*Hypophthalmichthyes nobilis*) and silver carp (*H. molitrix*) pose a medium risk beginning at T_{25} for all pathways. The scud (*Apocorophium lacustre*) poses a medium risk to the GLB beginning at T_0 for CAWS Pathways 1, 2, and 3, and beginning at T_{10} for CAWS Pathways 4 and 5. The threespine

TABLE 7.1 Pathway-Specific Risks for High Risk Species[a]

			Risk Level				
Species	Basin at Risk	Time Step	CAWS 1	CAWS 2	CAWS 3	CAWS 4	CAWS 5
Bloody red shrimp (*Hemimysis anomala*)	MRB	T_0	H	H	H	L	L
		T_{10}	H	H	H	L	L
		T_{25}	H	H	H	M	M
		T_{50}	H	H	H	H	H
Fishhook waterflea (*Cercopagis pengoi*)	MRB	T_0	L	L	L	L	L
		T_{10}	L	L	L	L	L
		T_{25}	M	M	M	L	L
		T_{50}	H	H	H	M	M

[a] T_0 = current time; T_{10} = within 0-10 years; T_{25} = within 10-25 years; T_{50} = within 25-50 years; risk ratings: H = high risk of adverse impacts; M = medium risk of adverse impacts; L = low risk of adverse impacts.

stickleback (*Gasterosteus aculeatus*) poses a medium risk to the GLB beginning at T_0 for all pathways.

The ruffe and reed sweetgrass could pose a medium risk to the MRB only at T_{50}, regardless of which pathway is used for interbasin transfer. For both of these species, the medium risk identified for T_{50} is associated with the expected time needed for these species to reach, enter, and successfully pass through any of the five pathways (Chapter 6).

VHSv could pose a medium risk to the MRB as early as T_0. Red algae and diatom could each pose a medium risk to the MRB as early as T_0 (current time) if CAWS Pathways 1-3 served as the route for interbasin transfer (Table 7.2). However, for either Pathway 4 or 5, the red algae would not begin to pose a medium risk until T_{25}, and the diatom not until T_{50}. This delay in the potential onset of medium risks for CAWS Pathways 4 or 5 is associated with the limited ability of each of these species to be passively transported against the current and into these pathways from Lake Michigan (Chapter 6).

Regardless of which CAWS pathway may be used for interbasin transfer, the tubenose goby could pose a medium risk at all time steps except T_0. At this time step, this ANS would pose a low risk, primarily due to its current location in the GLB and the low probability of it arriving in the short term at any of the CAWS pathway entrances from the basin.

TABLE 7.2 Pathway-Specific Risks for Medium Risk Species

Species	Basin at Risk	Time Step	Risk Level: CAWS 1	CAWS 2	CAWS 3	CAWS 4	CAWS 5
Bighead carp (*Hypophthalmichthyes nobilis*)	GLB	T_0	L	L	L	L	L
		T_{10}	L	L	L	L	L
		T_{25}	M	M	M	M	M
		T_{50}	M	M	M	M	M
Silver carp (*Hypophthalmichthys molitrix*)	GLB	T_0	L	L	L	L	L
		T_{10}	L	L	L	L	L
		T_{25}	M	M	M	M	M
		T_{50}	M	M	M	M	M
Scud (*Apocorophium lacustre*)	GLB	T_0	M	M	M	L	L
		T_{10}	M	M	M	M	M
		T_{25}	M	M	M	M	M
		T_{50}	M	M	M	M	M
Threespine Stickleback (*Gasterosteus aculeatus*)	MRB	T_0	M	M	M	M	M
		T_{10}	M	M	M	M	M
		T_{25}	M	M	M	M	M
		T_{50}	M	M	M	M	M
Tubenose Goby (*Proterorhinus semilunaris*)	MRB	T_0	L	L	L	L	L
		T_{10}	M	M	M	M	M
		T_{25}	M	M	M	M	M
		T_{50}	M	M	M	M	M
Diatom (*Stephanodiscus binderanus*)	MRB	T_0	M	M	M	L	L
		T_{10}	M	M	M	L	L
		T_{25}	M	M	M	L	L
		T_{50}	M	M	M	M	M
Red algae (*Bangia atropurpurea*)	MRB	T_0	M	M	M	L	L
		T_{10}	M	M	M	L	L
		T_{25}	M	M	M	M	M
		T_{50}	M	M	M	M	M
Grass kelp (*Enteromorpha flexuosa*)	MRB	T_0	L	L	L	L	L
		T_{10}	M	M	M	L	L
		T_{25}	M	M	M	M	M
		T_{50}	M	M	M	M	M
Reed sweetgrass (*Glyceria maxima*)	MRB	T_0	L	L	L	L	L
		T_{10}	L	L	L	L	L
		T_{25}	L	L	L	L	L
		T_{50}	M	M	M	M	M

TABLE 7.2 (Cont.)

Species	Basin at Risk	Time Step	CAWS 1	CAWS 2	CAWS 3	CAWS 4	CAWS 5
			Risk Level				
Ruffe	MRB	T_0	L	L	L	L	L
(*Gymnocephalus cernuus*)		T_{10}	L	L	L	L	L
		T_{25}	L	L	L	L	L
		T_{50}	M	M	M	M	M
Viral Hemoragic Scepticimia	MRB	T_0	M	M	M	M	M
(*Novirhabdovirus* sp.)		T_{10}	M	M	M	M	M
		T_{25}	M	M	M	M	M
		T_{50}	M	M	M	M	M

[a] T_0 = current time; T_{10} = within 0-10 years; T_{25} = within 10-25 years; T_{50} = within 25-50 years; M = medium; L = low.

The grass kelp is not expected to begin posing a medium risk to the MRB until T_{10} (within 0-10 years), and then only with interbasin transfer via CAWS Pathways 1, 2, or 3 (Table 7.2). If CAWS Pathways 4 or 5 are considered as the routes for interbasin transfer, this species would not begin to pose a medium risk to the MRB until T_{25}. The longer time associated with transfer via CAWS Pathways 4 and 5 is due to the limited ability of this species to be passively transported from Lake Michigan into either of these two pathways because the direction of water flow is from the CAWS Pathways 4 and 5 toward Lake Michigan.

7.3 PATHWAY USE BY LOW RISK SPECIES

Twenty-two of the 35 ANS species were determined to pose a low risk at all time steps (see Chapters 5 and 6 for species-specific discussions of risk levels), regardless of which CAWS pathway might serve as the route for interbasin transfer. These low-risk species are listed in Table 7.3.

TABLE 7.3 Aquatic Nuisance Species Posing Low Risks for All Pathways and Time Steps

Species	Basin Currently Inhabited
Testate amoeba (*Psammonobiotus communis*)	GLB
Testate amoeba (*Psammonobiotus dziwnowi*)	GLB
Testate amoeba (*Psammonobiotus linearis*)	GLB
Cryptic algae (*Cyclotella cryptica*)	GLB
Freshwater bryozoan (*Lophopodella carteri*)	GLB
Greater European peaclam (*Pisidium amnicum*)	GLB
European fingernail clam (*Sphaerium corneum*)	GLB
European stream valvata (*Valvata piscinalis*)	GLB
Waterflea (*Daphnia galeata galeata*)	GLB
Parasitic copepod (*Neoergasilus japonicas*)	GLB
Harpacticoid copepod (*Schizopera borutzkyi*)	GLB
Blueback herring (*Alosa aestivalis*)	GLB
Sea lamprey (*Petromyzon marinus*)	GLB
Swamp sedge (*Carex acutiformis*)	GLB
Water chestnut (*Trapa natans*)	GLB
Marsh dewflower (*Murdannia keisak*)	MRB
Cuban bulrush (*Oxycaryum cubense*)	MRB
Dotted duckweed (*Landoltia punctate*)	MRB
Northern snakehead (*Channa argus*)	MRB
Black carp (*Mylopharyngodon piceus*)	MRB
Skipjack herring (*Alosa chrysochloris*)	MRB
Inland silverside (*Menidia beryllina*)	MRB

7.4 CAWS PATHWAY RISK RANKING

Following the assessment of risks of successful interbasin transfer by, and subsequent establishment of, the 35 ANS of concern, the five CAWS pathways were evaluated to determine which, if any, may play the biggest role in supporting interbasin transfer of ANS that pose the greatest risk to either the MRB or GLB. In this evaluation, the pathways were ranked within each time step on the basis of the risk levels of all of the ANS that may use each pathway for interbasin transfer (see Section 4.4 for a description of this ranking process). The greater the number of higher risk species that could use a pathway at any time step, the higher the rank of that pathway. CAWS Pathways 2 and 3 ranked first for all time steps; all other CAWS pathway rankings varied by time step, and all pathways were identically ranked at T_{50} (Table 7.4).

TABLE 7.4 CAWS Pathway Risk Ranking

		Number of ANS with a Specific Risk Level by Time Step[a]									
		Risk Ranking-High		Risk Ranking-Medium		Risk Ranking-Low		Risk Ranking-None			
Time Step	CAWS Pathway	No. ANS	Weighted Risk Value[b]	No. ANS	Weighted Risk Value	No. ANS	Weighted Risk Value	No. ANS	Weighted Risk Value	Total Weighted ANS Risk Value	Overall Pathway Risk Rank
T_0	1	1	3	5	10	29	29	0	0	42	1
	2	1	3	5	10	29	29	0	0	42	1
	3	1	3	5	10	29	29	0	0	42	1
	4	0	0	2	4	33	33	0	0	37	3
	5	0	0	2	4	33	33	0	0	37	3
T_{10}	1	1	3	7	14	27	27	0	0	44	1
	2	1	3	7	14	27	27	0	0	44	1
	3	1	3	7	14	27	27	0	0	44	1
	4	0	0	4	8	31	31	0	0	39	2
	5	0	0	4	8	31	31	0	0	39	2
T_{25}	1	1	3	10	20	24	24	0	0	47	1
	2	1	3	10	20	24	24	0	0	47	1
	3	1	3	10	20	24	24	0	0	47	1
	4	0	0	9	18	26	26	0	0	44	2
	5	0	0	9	18	26	26	0	0	44	2
T_{50}	1	2	6	11	22	22	22	0	0	50	1
	2	2	6	11	22	22	22	0	0	50	1
	3	2	6	11	22	22	22	0	0	50	1
	4	1	3	12	24	22	22	0	0	47	1
	5	1	3	12	24	22	22	0	0	47	1

[a] T_0 = current time; T_{10} = within 0-10 years; T_{25} = within 10-25 years; T_{50} = within 25-50 years.

[b] Weighting factor values: High = 3; Medium = 2; Low = 1; None = 0.

7.4.1 Time Step T_0

At T_0, CAWS Pathways 1, 2, and 3 ranked highest for supporting the most interbasin transfer of high and medium risk ANS (Table 7.4). This ranking is largely the result of these two pathways having heavy vessel traffic between Lake Michigan and Brandon Road Lock and Dam and the fewest natural (e.g., current flow into Lake Michigan) barriers that limit the ability of some ANS species to readily enter a pathway.

Pathways 4 and 5 ranked last at T_0, with each supporting interbasin transfer of only two medium-risk species and no high-risk species (Table 7.4). The primary factors affecting this low rank are the direction of water flow toward Lake Michigan at the GLB end of each of these pathways and the absence of vessel traffic in these same areas. Current flow into the lake would greatly limit ANS in the GLB that rely on passive transport via drift from fully entering either pathway, while the absence of vessel traffic would limit pathway entry for species that may rely on vessel-assisted transport (i.e., attachment to boat hulls).

7.4.2 Time Step T_{10}

At T_{10}, CAWS Pathways 1-3 were similarly ranked highest, with each supporting the interbasin transfer of the same number and species of high- and medium-risk ANS (1 and 7 species, respectively; Table 7.4). CAWS Pathways 4 and 5 were ranked lowest, with neither supporting interbasin transfer of any high-risk ANS. As discussed for T_0, the direction of current flow and the absence of vessel traffic at the Lake Michigan end of each of these pathways are expected to greatly limit the likelihood that ANS that rely on passive drift in the current or attachment to and subsequent transport by vessels could successfully enter either of these pathways within 10 years.

7.4.3 Time Step T_{25}

At T_{25}, CAWS Pathways 1, 2, and 3 would each support interbasin transfer of the same number and species of ANS, and thus these pathways receive the highest pathway ranking. At this time step, each pathway could support the interbasin transfer of one high-risk species and 10 medium-risk species (Table 7.4). Pathways 4 and 5 were ranked lower, with each supporting interbasin transfer of one fewer high- and medium-risk ANS than CAWS Pathways 1, 2, or 3.

7.4.4 Time Step T_{50}

At T_{50}, CAWS Pathways 1, 2, and 3 would each support interbasin transfer of the same number and species of ANS, and thus these pathways receive the highest pathway ranking. At this time step, each pathway could support the interbasin transfer of two high-risk species and 11 medium-risk species (Table 7.4). Pathways 4 and 5 were ranked lower, with each supporting interbasin transfer of one fewer high-risk ANS, but a higher number of medium-risk ANS than CAWS Pathways 1, 2, or 3. It is not until this time step that there is the potential for any high-risk species to successfully use CAWS Pathways 4 or 5 for interbasin transfer.

8 CONCLUSIONS

The risk assessment evaluated 35 aquatic nuisance species (ANS) that were determined to be of concern for possibly posing adverse risks to either the Great Lakes Basin (GLB) or the Mississippi River Basin (MRB). Among these 35 species, 10 are currently established in the MRB and 25 are currently established in the GLB. The risk assessment examined each of the 35 species with regard to the probability of the ANS successfully accessing and passing through each of five Chicago Area Waterway System (CAWS) pathways and becoming established in a "new" basin under four time steps. Each species was further evaluated with regard to the types of environmental, economic, and social/political consequences that each species could have, should it become established in a new basin. The probability of establishment and the consequences of establishment were then considered together to characterize the level of risk that the ANS could pose to resources in the new basin. The risk assessment also examined each of the five CAWS pathways with regard to the relative potential of each pathway to support interbasin transfer of the ANS.

Through this process, 13 of the 35 ANS examined were determined to pose either a high or medium risk of adverse impacts to either the GLB (three species) or MRB (ten species) (Table 8.1). These medium- and high-risk species include five species of fish, three crustacean species, one species of plant, one virus, and three species of algae.

8.1 ANS POSING MEDIUM OR HIGH RISKS TO THE GLB

Three ANS that are currently established in the MRB were identified as posing a medium risk to the GLB, should they undergo successful interbasin transfer and establishment (Table 8.1). Two of these species are fish, which could undergo successful interbasin transfer by actively swimming through any of the five CAWS pathways. The remaining ANS is a crustacean, which would need to rely on its limited movement capability and/or on attachment to vessel hulls in order to pass through the CAWS and enter the GLB.

The silver and bighead carp were determined to pose a medium risk as early as T_{25} to the GLB (Table 8.1). The medium-risk ratings are based largely on a low probability of establishment identified for each species, which in turn is based upon the assumed efficacy of the EDBS in controlling upstream passage of these species, should they enter the CAWS at Brandon Road Lock and Dam. The highest uncertainties associated with the risk ratings for each of these two ANS are related to the effectiveness of the Electric Dispersal Barrier System in controlling passage of each ANS through the CAWS (Section 5.1.2.3). There is also a medium uncertainty associated with each of the three consequence ratings.

TABLE 8.1 Aquatic Nuisance Species Posing Medium or High Risks

Species Posing Medium or High Risks to the GLB		
Species	Primary Mode of Interbasin Transfer	Time Period When Indicated Risk Level Likely to Be Attained
Medium Risk		
Scud (*Apocorophium lacustre*)	Passive drift, hull fouling	T_0
Silver carp (*Hypophthalmichthys molitrix*)	Active swimming	T_{25}
Bighead carp (*Hypophthalmichthys nobilis*)	Active swimming	T_{25}
Species Posing High or Medium Risks to the MRB		
Species	Primary Mode of Interbasin Transfer	
Medium Risk		
Grass kelp (*Enteromorpha flexuosa*)	Passive drift, vessel attachment	T_{10}
Red algae (*Bangia atropurpurea*)	Passive drift, vessel attachment	T_0
Diatom (*Stephanodiscus binderanus*)	Passive drift	T_0
Reed sweetgrass (*Glyceria maxima*)	Passive drift	T_{50}
Threespine stickleback (*Gasterosteus aculeatus*)	Active swimming	T_0
Tubenose goby (*Proterorhinus semilunaris*)	Active swimming	T_{10}
Ruffe (*Gymnocephalus cernuus*)	Active swimming	T_{50}
Viral Hemorrhagic Septicemia Virus (*Novirhabdovirus* sp.)	Passive drift, fish host, vessel traffic	
High Risk		
Bloody red shrimp (*Hemimysis anomala*)	Passive drift	T_0
Fishhook waterflea (*Cercopagis pengoi*)	Passive drift	T_{25}

The scud is a small crustacean with very limited ability for long-distance upstream movement. In order to successfully pass through the CAWS pathways, this species would need to move along the pathway bottom and/or be carried through the CAWS attached to ship hulls. Only CAWS Pathways 1, 2, and 3 have vessel traffic that fully moves through each pathway; thus, medium risks may be begin as early as T_0 for the scud using these pathways to become established in the GLB. In contrast, there is no end-to-end vessel traffic for CAWS Pathways 4 and 5. For these pathways, passage at T_0 is unlikely and the risk level is thus considered low. Given sufficient time (10-50 years) this ANS could slowly increase its distribution through the CAWS and enter the GLB; thus, risks posed by the scud using any of these three pathways increases to medium by T_{10}. The primary uncertainty related to the risk rating is the high uncertainty level associated with the environmental consequence risk element..

8.2 ANS POSING MEDIUM OR HIGH RISKS TO THE MRB

The risk assessment identified ten ANS that are currently established in the GLB and may pose a medium or high risk to the MRB, should they undergo successful interbasin transfer and establishment (Table 8.1). These ANS include three species of algae, one plant species, two crustacean species, one virus, and three species of fish. Only the two crustacean species are indicated to pose a high risk to the MRB, whereas the remaining eight ANS are indicated to pose no more than a medium risk to the basin.

The two crustaceans (the bloody red shrimp and the fishhook waterflea) may pose high risks to the MRB, and the time period in which they may begin to pose high risks is directly associated with the time when successful interbasin transfer is considered likely to occur. The bloody red shrimp is present in southern Lake Michigan and could swim or drift into the CAWS and to Brandon Road Lock and Dam at T_0. The fishhook waterflea could move into the CAWS through pathways 1, 2, and 3 via passive drift. However, this species was first recorded in southern Lake Michigan in 1999 and has not been recorded in the CAWS. Therefore its probability of passage for this time step is low until T_{25}. Water flow at the GLB connections of CAWS Pathways 4 and 5 is into Lake Michigan rather than from the lake into the CAWS, and neither of these pathways supports vessel traffic at their Lake Michigan entrances. Each of these species has a limited ability for long-distance upstream movement, and as a result, interbasin transfer will depend on their passive drift with the current. Thus, the probability of either of these crustaceans successfully entering either of these pathways from Lake Michigan is considered to be low until T25 for the bloody red shrimp and T_{50} for the two waterfleas. .

Grass kelp, red algae, reed sweetgrass, and a diatom are all indicated to pose a medium risk to the MRB following interbasin transfer and establishment. The timing at which a medium risk may begin varies among the four species, and is related to the time at which each is anticipated to reach the CAWS and/or undergo successful interbasin transfer. Because of its current location well away from the CAWS, grass kelp is not expected to reach any of the CAWS pathways until T_{10}, at which time interbasin transfer may occur allowing this species to begin posing a medium risk to the MRB. Because of its current location in the GLB, reed sweetgrass is not expected to arrive at the CAWS until T_{50}, at which time it may begin to pose a medium risk. Using CAWS Pathway 1, 2, or 3 for interbasin transfer, the red algae and the diatom may each begin to pose a medium risk to the MRB as early as T_0. Because of current flow direction and the absence of vessel traffic at the entrances of CAWS Pathways 4 and 5 at Lake Michigan, use of either of these pathways by grass kelp and red algae is not expected to begin to pose a medium risk to the MRB until T_{25}, and not until T_{50} for the diatom. The risk ratings for these species have medium to high uncertainty levels associated with (1) the ability of these species to enter and pass through some of the CAWS pathways, (2) whether hydraulic and chemical water quality conditions would support establishment in the MRB, (3) how widespread the ANS could become established, and (4) the severity of possible environmental, economic, and social/political consequences that could result with establishment of these ANS.

The threespine stickleback, tubenose goby, and ruffe were determined to pose medium risks to the MRB, should they become established; however, when each may begin to pose a risk varies among the three species. Using any of the five CAWS pathways, the threespine stickleback may pose a medium risk as early as T_0. The primary uncertainties associated with the risk rating for this ANS are related to the severity and extent of environmental consequences that may be incurred, should this species successfully establish in the MRB.

In contrast, the ruffe is not predicted to begin posing a medium risk until T_{50} regardless of which pathway is used for interbasin transfer. These risk ratings are based primarily on the amount of time that may be needed for the ruffe to reach any of the CAWS from its current location. Several of the establishment and consequence element ratings have a high to medium uncertainty related to when the ruffe may actually reach the CAWS and whether environmental conditions would support establishment and spread of this species within the CAWS.

Regardless of which CAWS pathway may be used, the tubenose goby is not predicted to pose a medium risk to the MRB until T_{10}. The low risk level identified at T_0 is associated primarily with the amount of time this species may need to reach any of the CAWS pathways from its current location in the GLB. Several of the establishment and consequence element ratings have a medium uncertainty related to how suitable environmental and climatic conditions in the MRB may be to supporting this species in the basin, as well as uncertainty regarding the nature and extent of environmental consequences that may be incurred, should this species become established in the MRB.

VHSv may pose up to a medium risk beginning at T_0. VHSv may be transported from the GLB into the MRB by water flow, fish hosts, and vessel traffic. The primary uncertainties associated with the risk rating for VHSv is related to the high and medium uncertainties of the economic and environmental consequence ratings, respectively.

8.3 CAWS PATHWAY USE

Each of the CAWS pathways provides a complete year-round waterway connection between the two basins. However, interbasin transfer of ANS is not equally supported among the pathways, nor among time steps within any individual pathway. These differences are due primarily to differences among the pathways in flow direction and levels of recreational and commercial vessel activity.

Pathway Use – Time Step T_0. At this time step, only CAWS Pathways 1, 2, and 3 are predicted to support interbasin transfer of a high-risk ANS (the bloody red shrimp into the MRB). Because the direction of current flow for CAWS Pathways 4 and 5 is into Lake Michigan, this species is not expected to be able to enter either pathway from Lake Michigan at this time step. Each of the five CAWS pathways could support interbasin transfer of a similar number (2-5) of medium-risk species.

Pathway Use – Time Step T_{10}. Similar to T_0, at T_{10} only CAWS Pathways 1, 2, and 3 are predicted to support interbasin transfer of a high-risk ANS (the bloody red shrimp). The five pathways would support interbasin transfer of 4 to 7 medium-risk ANS. This increase in medium-risk ANS interbasin transfer is primarily due to the assumption that the longer time period would allow more species to reach entry locations of the pathways and/or provide sufficient time for some species to completely move through a pathway.

Pathway Use – Time Step T_{25}. At T_{25}, each of the five pathways is predicted to support interbasin transfer by high-risk ANS. With the longer time period (25 years), one additional high-risk species is predicted to access and pass through CAWS Pathways 1, 2, or 3, while CAWS Pathways 4 and 5 are predicted to have been accessed and used for interbasin transfer by a single high-risk species. All five pathways would support interbasin transfer of a similar number (9-10) of medium-risk species.

Pathway Use – Time Step T_{50}. There are minor differences among the five CAWS pathways in the number of high- and medium-risk ANS species undergoing interbasin transfer by T_{50}. A 50-year time period is assumed to provide sufficient time for all of the ANS to access, enter, and pass through any of the CAWS pathways. All five pathways are predicted to support a similar number of high- and medium- risk species undergoing interbasin transfer.

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APPENDIX A

LOW-RISK ANS SUMMARIES

CONTENTS

APPENDIX A

LOW-RISK ANS SUMMARIES

A.1 LOW-RISK ANS POTENTIALLY INVADING THE GREAT LAKES BASIN

A.1.1 Plants

A.1.1.1 Cuban Bulrush - *Oxycaryum cubense*

I. Species Overview

A. Native Range and Current Distribution

Cuban bulrush has been in the southeastern United States for more than a century and is sporadically found in Florida, Louisiana, southern Georgia, southern Alabama, Mississippi, and coastal Texas. Recently, populations of Cuban bulrush were discovered in Aliceville Lake, Pickens County, Alabama, and in Aberdeen Lake and the Tennessee-Tombigbee Waterway in east-central Mississippi. The native range of the species is throughout the tropics and subtropics of Africa, the Americas, and the West Indies (Bryson et al. 2008; McLaurin & Wersal 2011). Introduction of the species likely occurred via ship ballast from the West Indies or South America (Bryson et al. 1996).

B. Life History and Ecology

Cuban bulrush is a perennial, rhizomatous, emergent sedge of littoral regions (NBII 2008). This species forms free-floating mats that may detach from the land and float freely 0-50 m (0-164 ft) from the shoreline (NBII 2008). The species is typical of freshwater ditches, marshes, ponds, lakes, rivers and swamps (McLaurin & Wersal 2011). Based on its typically tropical and subtropical distribution, the species may be unable to tolerate freezing temperatures.

This species reproduces by rhizomes/stolons and by the production of achenes (seeds) (NBII 2008). Asexual reproduction by fragmentation also occurs (Bryson et al. 2008). The floating mats of Cuban bulrush send out runners over other emergent plants and can crowd or exclude them (NBII 2008).

II. Probability of Establishment

Probability of Establishment																				
	Probability Range for Time Steps 0, 10, 25, and 50 years[a,b]																			
	CAWS 1				CAWS 2				CAWS 3				CAWS 4				CAWS 5			
Probability Element	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}
Pathway	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)
Arrival	L (L)	L (L)	L (L)	L (M)	L (L)	L (L)	L (L)	L (M)	L (L)	L (L)	L (L)	L (M)	L (L)	L (L)	L (L)	L (M)	L (L)	L (L)	L (L)	L (M)
Passage	L (L)	L (L)	L (L)	M (M)	L (L)	L (L)	L (L)	M (M)	L (L)	L (L)	L (L)	M (M)	L (L)	L (L)	L (L)	M (M)	L (L)	L (L)	L (L)	M (M)
Colonization	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)
Spread	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)
Probability of Establishment	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L

[a] H = high probability, the event will almost certainly occur; M = medium probability, the event is likely to occur but is not certain to do so; L = low probability, the event will likely not occur but is possible.

[b] Uncertainty associated with each Probability Element is indicated in parentheses. Uncertainty ratings: H = high, little or no data available and rating based on professional judgment; M = good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment; L = low, good data available with no major data gaps; N = none, adequate data available to fully support the probability rating.

The probability of establishment for the Cuban bulrush is low across all time steps. It is unlikely to arrive at southern Lake Michigan within 50 years from its current location in the southern United States. The Cuban bulrush has been in the southern United States for more than 100 years (Bryson et al. 2008) and has not yet spread to the upper Midwest. If it does reach the Great Lakes Basin (GLB), this species is not expected to spread, because the Cuban bulrush is primarily a tropical and subtropical species (McLaurin & Wersal 2011). For these reasons, the overall probability of establishment is low for all time steps and pathways.

III. Consequences of Establishment

Consequences of Establishment[a,b]			
Environmental Consequences	Economic Consequences	Social/Political Consequences	Total Overall Consequences
L(M)	L (M)	M(M)	L

[a] L = Low consequence rating due to the lower number of consequence categories affected, the lesser nature and severity of the consequences, and the more localized extent of the consequences; M = Medium consequence rating due to the number of consequence categories affected, the nature and severity of the consequences, and the spatial extent of the consequences.

[b] Uncertainty associated with each of the consequence ratings is indicated in parentheses. M = Medium uncertainty, good data are available but some data gaps exist; rating based on a mixture of data and professional judgment.

A. Environmental Consequences

The Cuban bulrush is found in the littoral zone of lakes, ponds, and streams, forming large monotypic floating mats that can shade out other species of aquatic macrophytes or outcompete them for space (Bryson et al. 2008; McLaurin & Wersal 2011), potentially resulting in alteration of plant community structure in wetland habitats in the GLB. It is slowly spreading northward in the southeastern United States (Bryson et al. 2008). There are also multiple ESA-listed wetland plant and invertebrate species that could potentially be adversely affected by the spread of Cuban bulrush. The Cuban bulrush also has the potential to generate adverse ecosystem-level effects. Hypoxic conditions can develop beneath the floating mats of Cuban bulrush (McLaurin & Wersal 2011), reducing habitat quality for aquatic organisms and affecting sediment biogeochemical processes. However, the Cuban bulrush is found only sporadically in the Southeast, and it is typically a tropical and subtropical species (Bryson et al. 2008); therefore, impacts on ecosystem in the GLB may be localized to areas of suitable temperature. Overall, the consequences of this species establishing in the GLB are low. It is uncertain whether the productivity of this species in the GLB will be high enough to generate significant ecological consequences. Therefore, there remains a medium degree of uncertainty regarding environmental consequences of the Cuban bulrush.

B. Economic Consequences

Establishment of the Cuban bullrush in the GLB is expected to result in low economic consequences, with medium associated uncertainty. The Cuban bulrush is typically a tropical and subtropical species and impacts on ecosystems in the GLB would be spatially and temporally limited to the relatively small area of suitable temperature. Therefore, the establishment of this species is not expected to significantly affect environmental conditions or biological communities (see Appendix B). Consequently, the Cuban bulrush is not expected to decrease property values, increase economic costs, or reduce recreational, commercial, and industrial water uses.

C. Social/Political Consequences

The Cuban bulrush has the potential to affect recreational fishing by reducing habitat quality. The formation of large floating mats could also affect swimming and recreational boating. However, the Cuban bulrush is primarily a tropical and subtropical species. Therefore, it is expected to have a limited area of impact. Overall, social/political consequences could be medium. Although suitable habitat is present throughout much of the MRB, the realized spread, and with it the extent of social/political consequences, is uncertain. Therefore, uncertainty is medium.

D. Overall Consequences

The Cuban bulrush has the potential to alter habitat and species diversity and also affect swimming and recreational boating. However, the Cuban bulrush is primarily a tropical and subtropical species and is not expected to spread widely in the GLB. Therefore, the overall consequence of establishment is low. However, the extent to which this species will spread in the GLB is uncertain. Therefore, there remains a medium degree of uncertainty regarding environmental consequences of the Cuban bulrush.

IV. Risk of Adverse Impacts

Risk of Adverse Impacts

Pathway	Probability of Establishment[a] T_0	T_{10}	T_{25}	T_{50}	Consequences of Establishment[b]	Risk of Adverse Impacts[c] T_0	T_{10}	T_{25}	T_{50}
CAWS 1	L	L	L	L	L	L	L	L	L
CAWS 2	L	L	L	L	L	L	L	L	L
CAWS 3	L	L	L	L	L	L	L	L	L
CAWS 4	L	L	L	L	L	L	L	L	L
CAWS 5	L	L	L	L	L	L	L	L	L

[a] Probability rating elements: L = low probability, the event will likely not occur.

[b] Consequence ratings: L = Low consequence rating due to the lower number of consequence categories affected, the lesser nature and severity of the consequences, and the more localized extent of the consequences; associated uncertainty indicated in parentheses.

[c] Risk ratings: L = low risk of adverse impacts.

CAWS Risk Summary

The probability of establishment is low for all time steps and pathways, because the Cuban bulrush is not expected to reach the CAWS over the 50-yr time horizon. In addition, if it were to establish in the GLB, the consequences of establishment are low, because this is primarily a tropical and subtropical species and is therefore unlikely to reach the CAWS over the 50-yr timeframe or spread widely in the GLB. Therefore, the overall risk associated with the establishment of Cuban bulrush is low for all pathways and time steps.

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A.1.1.2 Dotted Duckweed - *Landoltia punctata*

I. Species Overview

A. Native Range and Current Distribution

Dotted duckweed was first documented in Missouri in 1934; it has since become naturalized in the southeastern United States (Jacono 2002). In Illinois, the species is established in Senachwine Lake in Bureau County (Jacono 2002), a distance of less than 161 km (100 mi) from the Brandon Road Lock and Dam. It has also been reported in the Northeast (Pennsylvania, Massachusetts, Maryland, and Delaware) and the West Coast (California, Oregon, and Arizona) (USDA undated). The species is extending northward, particularly through drainages of the lower Mississippi River in Arkansas, Tennessee, and Kentucky (Jacono 2002). Dotted duckweed is native to Australia and Southeast Asia (Jacono 2002). Introduction of the species to the United States is thought to have occurred through the transport of fish or plants at multiple sites (Landolt 1986). The species can be spread through floodwaters or via vessel traffic.

B. Life History and Ecology

Dotted duckweed thrives in nutrient-rich waters and prefers slow-moving or stagnant ponds (Jacono 2002). The plants are frequently found in stagnant small ponds or ditches rich in organic matter or near sewer outlets (Hillman 1961). Seeds of the plant are unable to tolerate temperatures of 0°C (32°F) for extended periods of time (Landolt 1986). Fronds are sensitive to frost and cannot withstand temperatures lower than 20°C (−4°F) (Jacono 2002). Members of *Lemnaceae* grow well in a pH range of 4.5-7.5 (Hillman 1961).

Dotted duckweed is a free-floating aquatic plant that is found at or just below the surface (Hillman 1961). Dotted duckweed exhibits a high rate of vegetative propagation, reproducing via vegetative budding of daughter fronds; sexual reproduction by seed can occasionally occur (Jacono 2002). Seeds of this species can survive seasonal dryout (Jacono 2002); however, this species is unable to form turions, and this limits its ability to survive cold temperatures (Jacono 2002).

II. Probability of Establishment

Probability of Establishment

Probability Range for Time Steps 0, 10, 25, and 50 years [a,b]

	CAWS 1				CAWS 2				CAWS 3				CAWS 4				CAWS 5			
Probability Element	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}
Pathway	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)
Arrival	L (L)	L (L)	L (M)	M (H)	L (L)	L (L)	L (M)	M (H)	L (L)	L (L)	L (M)	M (H)	L (L)	L (L)	L (M)	M (H)	L (L)	L (L)	L (M)	M (H)
Passage	L (L)	L (L)	L (M)	M (H)	L (L)	L (L)	L (M)	M (H)	L (L)	L (L)	L (M)	M (H)	L (L)	L (L)	L (M)	M (H)	L (L)	L (L)	L (M)	M (H)
Colonization	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)
Spread	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)
Probability of Establishment	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L

[a] H = high probability, the event will almost certainly occur; M = medium probability, the event is likely to occur but is not certain to do so; L = low probability, the event will likely not occur but is possible.

[b] Uncertainty associated with each Probability Element is indicated in parentheses. Uncertainty ratings: H = high, little or no data available and rating based on professional judgment; M = good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment; L = low, good data available with no major data gaps; N = none, adequate data available to fully support the probability rating.

A pathway to the Great Lakes Basin (GLB) exists for the dotted duckweed. However, the dotted duckweed is a free-floating plant that must move upstream by natural dispersal or vessel transport to reach the CAWS pathway entrance. The dotted duckweed has been established less than 161 km (100 mi) from the Brandon Road Lock and Dam for 25 yr and has not spread north; therefore, the plant has a low probability of arriving at the CAWS until T_{50}, when the probability increases to medium.

There is suitable physical habitat for the dotted duckweed in the GLB, and human-mediated dispersal may assist the species in spreading to the GLB. However, the dotted duckweed is sensitive to cold temperatures (Jacono 2002), and if it does spread to the GLB, the cold winters may be too cold for it to survive. Therefore, the probability of colonization and spread in the GLB is low. Overall, the probability of establishment in the GLB is low for all time steps and pathways. There is suitable habitat in the GLB in the form of emergent wetland and littoral habitat. However, it is uncertain whether the climate of the GLB is too cold for this species. Therefore, there is a medium to high level of uncertainty associated with the species' ability to spread throughout the GLB.

III. Consequences of Establishment

Consequences of Establishment[a,b]			
Environmental Consequences	Economic Consequences	Social/Political Consequences	Total Overall Consequences
L (M)	L (L)	M (M)	L

[a] L = Low consequence rating due to the lower number of consequence categories affected, the lesser nature and severity of the consequences, and the more localized extent of the consequences; M = Medium consequence rating due to the number of consequence categories affected, the nature and severity of the consequences, and the spatial extent of the consequences.

[b] Uncertainty associated with each of the consequence ratings is indicated in parentheses. M = medium uncertainty, good data are available but some data gaps exist; rating based on a mixture of data and professional judgment; L = low uncertainty, good supporting data are available.

A. Environmental Consequences

Dotted duckweed is regarded as a pioneer species in that it is distributed easily, colonizes quickly, and has a high rate of vegetative propagation (Landolt 1986). Dotted duckweed prefers stagnant waters (Lembi 2009); therefore, the species will be found only in backwaters of the GLB. It is considered a pioneer species that would thrive in a disturbed habitat (Landolt 1986). If dotted duckweed does establish in an area, it can affect other plant species in the region by crowding out native species (Jacono 2002). Thick growth of duckweed can prevent sunlight from reaching deeper parts of the lake, preventing underwater plants and algae from photosynthesizing and producing oxygen. In turn, the lack of oxygen can stress or kill fish (Lembi 2009). However, the dotted duckweed is sensitive to cold temperatures and may not be able to establish widely or attain high abundance, and this could significantly reduce impacts. Therefore, the consequences of establishment are low. The localized effects of dotted duckweed will likely not affect a large portion of the GLB. Therefore, a medium uncertainty is associated with environmental consequences

B. Economic Consequences

Establishment of the dotted duckweed in the GLB is expected to result in low economic consequences, with medium associated uncertainty. The dotted duckweed is not cold tolerant and impacts on ecosystems in the GLB would be spatially and temporally limited to the relatively small area of suitable temperature (See Appendix B). Therefore, the establishment of this species is not expected to significantly affect environmental conditions or biological communities. Consequently, the Cuban bulrush is not expected to decrease property values, increase economic costs, or reduce recreational, commercial, and industrial water uses.

C. Social/Political Consequences

The dotted duckweed is a floating plant that can reach high densities, and, therefore, it has the potential to affect perceived opportunities for swimming, recreational fishing, and recreational boating. However, given the cold intolerance of this species, it is not expected to be widespread in the GLB. Therefore, social and political consequences are medium, and the uncertainty of this rating is medium and depends on how abundant and widespread this species becomes in the GLB.

IV. Risk of Adverse Impacts

Risk of Adverse Impacts									
	Probability of Establishment[a]					Risk of Adverse Impacts[c]			
Pathway	T_0	T_{10}	T_{25}	T_{50}	Consequences of Establishment[b]	T_0	T_{10}	T_{25}	T_{50}
CAWS 1	L	L	L	L	L	L	L	L	L
CAWS 2	L	L	L	L	L	L	L	L	L
CAWS 3	L	L	L	L	L	L	L	L	L
CAWS 4	L	L	L	L	L	L	L	L	L
CAWS 5	L	L	L	L	L	L	L	L	L

[a] Probability rating elements: L = low probability, the event will likely not occur.

[b] Consequence ratings: L = Low consequence rating due to the lower number of consequence categories affected, the lesser nature and severity of the consequences, and the more localized extent of the consequences

[c] Risk ratings: L = low risk of adverse impacts.

D. Overall Consequences

The dotted duckweed has the potential to alter habitat and species diversity and consequently sport fisheries. The establishment of the dotted duckweed could also affect swimming and recreational boating. However, the dotted duckweed is not tolerant of cold climates and is not expected to spread widely in the GLB. Therefore, the overall consequence of establishment is low.

CAWS Risk Summary

The probability of establishment is low for all time steps and pathways. If the plant were to establish in the GLB, the consequences of establishment are low, because this species is cold sensitive and therefore unlikely to spread widely in the GLB. Therefore, the overall risk associated with the establishment of dotted duckweed is low for all pathways and time steps.

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A.1.1.3 Marsh Dewflower - *Murdannia keisak*

I. Species Overview

A. Native Range and Current Distribution

Marsh dewflower occurs from Virginia south to Florida and west to Arkansas and Louisiana; it has also been reported in the Columbia River estuary in Washington and Oregon (NatureServe 2010). The species is spreading in Virginia, Tennessee, Alabama, and Mississippi (NatureServe 2010); however, the species is currently located over 805 km (500 mi) from the Brandon Rd Lock and Dam. Marsh dewflower is native to eastern Asia (China, Japan, Korea, and Tibet) (Howard 2011). This species was introduced in agriculture by accident (Dunn & Sharitz 1990b). Additionally, there is potential for the seeds to be dispersed by wildlife and for root fragments to be spread during flood events (Swearingen et al. 2010). Vessel traffic may also assist in the spread of the species, although it is not cited as a means of transport.

B. Life History and Ecology

Marsh dewflower typically occurs in littoral, herbaceous marsh with saturated conditions (Bason 2004; Dunn & Sharitz 1991). It can also be found along large lakes as well as saturated littoral, emergent and shrub scrub wetlands (Bason 2004; Dunn & Sharitz 1990b). This species prefers slow-moving water in marshy areas. It has been found rooted in water up to 1.5 m (4.9 ft) deep (Jacono 2011). Marsh dewflower has no tolerance for saline waters (Wetzel et al. 2005). This species is capable of growing in almost full sunlight; however, plant biomass increases most rapidly in shaded areas (Dunn & Sharitz 1990a). Increases in water temperature >10°C (50°F) did not significant effects on the growth or mortality of the species (Dunn & Sharitz 1990a).

This species has been described as both an annual and a perennial (Dunn & Sharitz 1991; USDA Undated). Marsh dewflower can produce 9,000-70,000 seeds per m^2 (Dunn & Sharitz 1990a); it can also reproduce vegetatively (Dunn & Sharitz 1990b). Growth begins from overwintered seed in late April (Dunn & Sharitz 1990a) and the species can exist at high density where it establishes. The seeds are an important food for ducks and other waterfowl (Dunn & Sharitz 1990b).

II. Probability of Establishment

Probability Element	Probability of Establishment — Probability Range for Time Steps 0, 10, 25, and 50 years [a,b]																			
	CAWS 1				CAWS 2				CAWS 3				CAWS 4				CAWS 5			
	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}
Pathway	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)
Arrival	L (L)	L (L)	L (L)	L (M)	L (L)	L (L)	L (L)	L (M)	L (L)	L (L)	L (L)	L (M)	L (L)	L (L)	L (L)	L (M)	L (L)	L (L)	L (L)	L (M)
Passage	L (L)	L (L)	L (L)	M (M)	L (L)	L (L)	L (L)	M (M)	L (L)	L (L)	L (L)	M (M)	L (L)	L (L)	L (L)	M (M)	L (L)	L (L)	L (L)	M (M)
Colonization	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)
Spread	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)
Probability of Establishment	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L

[a] H = high probability, the event will almost certainly occur; M = medium probability, the event is likely to occur but is not certain to do so; L = low probability, the event will likely not occur but is possible.

[b] Uncertainty associated with each Probability Element is indicated in parentheses. Uncertainty ratings: H = high, little or no data available and rating based on professional judgment; M = good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment; L = low, good data available with no major data gaps; N = none, adequate data available to fully support the probability rating.

A pathway exists for the marsh dewflower to spread to the GLB. The marsh dewflower was reported in Louisiana in the 1920s and has not spread very far up the Mississippi River in the approximately 90 years since that time (Dunn & Sharitz 1990b), so the species has a low probability of arriving at the CAWS at all time steps and pathways. In addition, flood-mediated transport would likely act to move plant fragments downstream and away from the CAWS.

If the marsh dewflower were to spread to the GLB, it has a low probability of passage and colonization after exiting the CAWS due to the lack of an upstream transport mechanism in the CAWS and the lack of suitable habitat along the shoreline of Lake Michigan. The overall probability of establishment is low for all time steps and pathways.

III. Consequences of Establishment

Consequences of Establishment[a,b]			
Environmental Consequences	Economic Consequences	Social/Political Consequences	Total Overall Consequences
M(M)	L(M)	M(M)	M

[a] L = Low consequence rating due to the lower number of consequence categories affected, the lesser nature and severity of the consequences, and the more localized extent of the consequences; M = Medium consequence rating due to the number of consequence categories affected, the nature and severity of the consequences, and the spatial extent of the consequences.

[b] Uncertainty associated with each of the consequence ratings is indicated in parentheses. M = medium uncertainty, there is some good supporting data available, but there are still some major data gaps.

A. Environmental Consequences

The marsh dewflower may establish in backwaters and emergent wetlands of the GLB. The marsh dewflower forms dense mats, and could change native plant species abundance and distribution through competition and shading (Newberry 1991; Swearingen et al. 2010). The marsh dewflower could also compete with ESA-listed plant species in the GLB as it does in the MRB (Newberry 1991; Swearingen et al. 2010). If it does establish in the GLB, the marsh dewflower is expected to have localized impacts. Therefore, the environmental consequence rating is medium. However, the environmental impacts of the marsh dewflower depend on how widely this species is able to spread through the GLB. As this is uncertain, there is a medium uncertainty associated with environmental consequences.

B. Economic Consequences

Establishment of the marsh dewflower is expected to have low economic consequences, with medium associated uncertainty. Although the marsh dewflower may replace existing vegetation communities (see Appendix B), no evidence was found suggesting this species would reduce habitat quality for fish and wildlife as is common with other invasive plant species. Therefore, this species is not expected to decrease property values, increase economic costs, or reduce recreational, commercial, and industrial water uses.

C. Social/Political Consequences

The marsh dewflower is a mat-forming plant species and therefore has the potential to affect perceived opportunities for swimming, recreational fishing activity, and recreational boating. As with many invasive plants, the establishment of the marsh dewflower could result in new laws and regulations designed to minimize the spread of this species. Overall, the social/political consequence is medium. The consequences are highly dependent on how widespread this species becomes. Therefore, uncertainty is medium.

D. Overall Consequences

The marsh dewflower may establish in backwater and emergent wetland habitats in the GL basin, where it could forms dense mats, and affect native plant species abundance and distribution (including ESA-listed plant species) and affect habitat quality for fish and invertebrates. In addition, as a mat-forming plant species, the marsh dewflower has the potential to affect recreational fishing activity, as well as swimming and recreational boating.

IV. Risk of Adverse Impacts

Risk of Adverse Impacts

	Probability of Establishment[a]					Risk of Adverse Impacts[c]			
Pathway	T_0	T_{10}	T_{25}	T_{50}	Consequences of Establishment[b]	T_0	T_{10}	T_{25}	T_{50}
CAWS 1	L	L	L	L	M	L	L	L	L
CAWS 2	L	L	L	L	M	L	L	L	L
CAWS 3	L	L	L	L	M	L	L	L	L
CAWS 4	L	L	L	L	M	L	L	L	L
CAWS 5	L	L	L	L	M	L	L	L	L

[a] Probability rating elements: L = low probability, the event will likely not occur.

[b] Consequence ratings: M = Medium consequence rating due to the number of consequence categories affected, the nature and severity of the consequences, and the spatial extent of the consequences.

[c] Risk ratings: L = low risk of adverse impacts.

The overall consequences of establishment are rated as medium. The consequences are highly dependent on how widespread this species becomes.

CAWS Risk Summary

If it establishes in the GLB, the marsh dewflower has an overall consequence rating of medium, as this species could impact plant communities, aquatic habitat, and recreational activities. However, the marsh dewflower has a low probability of spreading to the GLB during the 50-year period of analysis. Therefore, the probability of establishment is low for all pathways and time steps. The risk of adverse impacts for the marsh dewflower is low for all time steps and pathways, and the uncertainty of this rating is high, due to uncertainty concerning the probability of this species colonizing in the GLB via the CAWS.

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A.1.2 Fish

A.1.2.1 Inland Silverside - *Menidia beryllina*

I. Species Overview

A. Native Range and Current Distribution

The inland silverside has been recorded in Illinois from Lake Baldwin, Lake of Egypt, Rend Lake, Cache River, Wabash River, and the Mississippi, Ohio, and Kankakee Rivers (Laird & Page 1996). The species has also been introduced in large reservoirs in Arkansas and several locations in California (Fuller & Nico 2012). It is present in the lower Missouri River drainage in Missouri, as well as the Pecos River drainage in New Mexico and Lake Optima in Oklahoma (Fuller & Nico 2012). Inland silverside is native to the coastal areas of eastern North America from Massachusetts to the Rio Grande drainage, and north from the Mississippi River to southern Illinois and eastern Oklahoma (Page & Burr 1991). In many areas, the species was intentionally stocked as a forage fish for larger sport fish species; however, introduction of the species to the upper Mississippi and Ohio Rivers may have been the result of natural dispersal (Fuller & Nico 2012).

B. Life History and Ecology

Inland silverside is a marine species that ascends rivers (FishBase 2010). It is most abundant in the littoral zone (Lienesch & Gophen 2001) of estuaries, lagoons, brackish seas, rivers, streams (FishBase 2010), lakes, coastal and freshwater habitats (NatureServe 2010), and reservoirs (Chizinski et al. 2007). It prefers moderate to highly alkaline and euryhaline waters (NatureServe 2010), with temperatures ranging from 9.8-30°C (49.6-86°F) (Weltzien et al. 1999). Huge aggregations of inland silverside have occurred over inundated vegetation and near docks (Wurtsbaugh & Li 1985).

This species is a size-selective, particulate feeding zooplanktivore (Lienesch & Gophen 2001), consuming mainly copepods, mysids, isopods, amphipods, and insects (NatureServe 2010). In the northern limits of their range, inland silversides have a unimodal reproductive season, and a unimodal or bimodal reproductive season in the south (Middaugh & Hemmer 1992). In Florida and Texas, spawning occurs anywhere from February-July (NatureServe 2010; Hubbs 1982; http://www.bio.txstate.edu/~tbonner/txfishes/menidia%20beryllina.htm). Females are capable of producing 30,000 eggs/month (Chizinski et al. 2007) and can lay daily clutches varying between 384 and 1,699 eggs (Hubbs 1982). Spawning occurs in freshwater (FishBase 2010) over live or detrital vegetation (NatureServe 2010), and ceases when water temperatures are between 27 and 32.4°C (80.6-90.3°C) (Middaugh & Hemmer 1992). Most inland silverside spawn and die their second summer of life (NatureServe 2010).

II. Probability of Establishment

Probability of Establishment																				
	Probability Range for Time Steps 0, 10, 25, and 50 years[a,b]																			
	CAWS 1				CAWS 2				CAWS 3				CAWS 4				CAWS 5			
Probability Element	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}
Pathway	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)
Arrival	M (M)	H (M)	H (M)	H (H)	M (M)	H (M)	H (M)	H (H)	M (M)	H (M)	H (M)	H (H)	M (M)	H (M)	H (M)	H (H)	M (M)	H (M)	H (M)	H (H)
Passage	L (L)	M (H)	H (M)	H (M)	L (L)	M (H)	H (M)	H (M)	L (L)	M (H)	H (M)	H (M)	L (L)	M (H)	H (M)	H (M)	L (L)	M (H)	H (M)	H (M)
Colonization	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)
Spread	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)
Probability of Establishment	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L

[a] H = high probability, the event will almost certainly occur; M = medium probability, the event is likely to occur but is not certain to do so; L = low probability, the event will likely not occur but is possible.

[b] Uncertainty associated with each Probability Element is indicated in parentheses. Uncertainty ratings: H = high, little or no data available and rating based on professional judgment; M = good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment; L = low, good data available with no major data gaps; N = none, adequate data available to fully support the probability rating.

A pathway to the GLB exists for this species and the species is currently near the pathway. There are ongoing studies on the efficacy of the Electric Dispersal Barrier System with regard to small fish. As part of the Corps' efficacy testing of the Demonstration Barrier, it was discovered that small fish are capable of swimming though an electrical field of similar strength to the Demonstration Barrier (Holliman 2011). Inland silverside typically do not grow to more than 10.2 cm (4 in.) (Weinstein 1986) and they swim near the surface where the current is weakest. This suggests the possibility that small inland silverside may be able to safely pass through the Electric Dispersal Barrier System. Although suitable habitat is available in the GLB, the low winter temperatures may prevent the species from colonizing and spreading throughout the GLB (Stoeckel& Heidinger 1998). Therefore, persistent populations are unlikely to develop, especially in more northern latitudes, which would reduce the probability of spread. Although there is potential for this species to establish in the Great Lakes, the existing literature suggests that a harsh winter could wipe out the species in the region or leave a small population. Therefore, the probability of establishment is low for all time steps and pathways and the uncertainty associated with this species colonizing the Great Lakes is high.

III. Consequences of Establishment

Consequences of Establishment[a,b]			
Environmental Consequences	Economic Consequences	Social/Political Consequences	Total Overall Consequences
L(L)	N(L)	L(L)	L

[a] L = Low consequence rating due to the lower number of consequence categories affected, the lesser nature and severity of the consequences, and the more localized extent of the consequences; N = no consequences are anticipated.

[b] Uncertainty associated with each of the consequence ratings is indicated in parentheses. L = low uncertainty, good supporting data is available.

A. Environmental Consequences

Inland silverside are found in littoral and pelagic waters of lakes, streams, and estuaries. It feeds primarily on zooplankton, but also consumes benthic invertebrates (FishBase 2010; Chizinski et al. 2007). If inland silverside establish in the GLB, they could compete with other fish species that consume zooplankton as adults and/or during early life stages. After introduction to a new habitat, the inland silverside can become a dominant planktivore and has been documented to have altered fish species composition by outcompeting other species (Fuller & Nico 2011) that are common in the GLB. There are several species within the GLB that occupy an ecological niche similar to the inland silverside, including the brook silverside. Therefore, the establishment of this species is not expected to alter ecosystem level processes in the GLB. In addition, this species is not adapted to cold temperatures found in the GLB (Stoeckel & Heidinger 1998), and may not be able to form abundant, widespread, and persistent populations. Overall, the consequences of establishment would be low and the uncertainty associated with the consequence ratings is low, as there is no evidence suggesting the inland silverside would significantly alter ecosystem processes in the GLB.

B. Economic Consequences

The establishment of the inland silverside in the GLB is not expected to have economic consequences, and any impacts that do occur would be widespread. Therefore, this species' economic consequence rating is none, and the uncertainty of the rating is low.

C. Social/Political Consequences

The establishment of the inland silverside in the GLB is not expected to result in social/political consequences. However, in the unlikely event it does become a nuisance species in the GLB, it could result in the proposal of new regulations to limit its spread. The social/political consequences of this species establishing in the GLB are low, as is the uncertainty associated with this rating.

D. Overall Consequences

The establishment of the inland silverside in the GLB is expected to result in no economic consequences, and low social/political and environmental consequences. The inland silverside is not tolerant of cold climate and is not expected to spread widely in the GLB. Therefore, the overall consequence of establishment is low and there is a low degree of uncertainty regarding the individual consequence ratings.

CAWS Risk Summary

Although there is a high probability of passage through the CAWS by T_{25} for all CAWS pathways, the overall probability of establishment is low for all time steps and pathways, because the inland silverside is not expected to spread through the GLB due to its cold sensitivity. If the inland silverside were to establish in the GLB, the consequences of establishment are low, as this species has a low probability of generating environmental, economic or social/political consequences. Therefore, the overall risk associated with the inland silverside is low for all pathways and time steps.

IV. Risk of Adverse Impacts

Risk of Adverse Impacts

Pathway	Probability of Establishment[a] T_0	T_{10}	T_{25}	T_{50}	Consequences of Establishment[b]	Risk of Adverse Impacts[c] T_0	T_{10}	T_{25}	T_{50}
CAWS 1	L	L	L	L	L	L	L	L	L
CAWS 2	L	L	L	L	L	L	L	L	L
CAWS 3	L	L	L	L	L	L	L	L	L
CAWS 4	L	L	L	L	L	L	L	L	L
CAWS 5	L	L	L	L	L	L	L	L	L

[a] Probability rating elements: L = low probability, the event will likely not occur.

[b] Consequence ratings: L = Low consequence rating due to the lower number of consequence categories affected, the lesser nature and severity of the consequences, and the more localized extent of the consequences.

[c] Risk ratings: L = low risk of adverse impacts.

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A.1.2.2 Skipjack Herring - *Alosa chrysochloris*

I. Species Overview

A. Native Range and Current Distribution

Skipjack herring have been collected at the junction of the Kankakee and Des Plaines Rivers (http://www.inhs.uiuc.edu/cbd/ilspecies/fishmaps/al_chrysoc.gif), and as far upstream in the CAWS as Lockport pool (Shanks 2012). Individual skipjack herring have been collected in Lake Michigan in Kenosha, Green Bay, and in Bailey's Harbor, Wisconsin (Fago 1993), but the species did not establish. This species is native to the Red River drainage/Hudson Bay Basin and to the Mississippi River Basin from central Minnesota to the Gulf of Mexico and from southwest Pennsylvania to South Dakota (Fuller 2011). The introduction of skipjack herring to Lake Michigan likely occurred via the Chicago Sanitary and Ship Canal (Fago 1993).

B. Life History and Ecology

Skipjack herring are an euryhaline species found in marine, fresh water, and brackish waters (FishBase 2010). The species typically avoids turbid water (Cross & Huggins 1975). It migrates upstream through rivers and streams (FishBase 2010). Adult skipjack herring prefer deep (Cross & Huggins 1975), fast-flowing (FishBase 2010), medium-to-large rivers and large reservoirs (NatureServe 2010). Spawning is thought to occur in deep waters of main channels over coarse sand or gravel (NatureServe 2010). Skipjack herring can tolerate a wide range of temperatures (FishBase 2010).

This species feeds in large schools with adults feeding on small fishes (commonly eating shad; http://www.bio.txstate.edu/~tbonner/txfishes/alosa%20chrysochloris.htm), juveniles feeding on insects (FishBase 2010), and zooplankton (NatureServe 2010). Skipjack herring spawn from April to mid-June (WDNR 2009) and are presumably broadcast spawners. Eggs are thought to be laid in deep water channels on coarse sand or gravel (NatureServe 2010). The minimum population doubling time of skipjack herring is 1.4-4.4 years (Cross & Huggins 1975).

II. Probability of Establishment

Probability of Establishment																				
	Probability Range for Time Steps 0, 10, 25, and 50 yr[a,b]																			
	CAWS 1				CAWS 2				CAWS 3				CAWS 4				CAWS 5			
Probability Element	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}
Pathway	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)
Arrival	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)
Passage	L (M)	L (H)	L (H)	L (H)	L (M)	L (H)	L (H)	L (H)	L (M)	L (H)	L (H)	L (H)	L (M)	L (H)	L (H)	L (H)	L (M)	L (H)	L (H)	L (H)
Colonization	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)
Spread	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)
Probability of Establishment	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L

[a] H = high probability, the event will almost certainly occur; M = medium probability, the event is likely to occur but is not certain to do so; L = low probability, the event will likely not occur but is possible.

[b] Uncertainty associated with each Probability Element is indicated in parentheses. Uncertainty ratings: H = high, little or no data available and rating based on professional judgment; M = good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment; L = low, good data available with no major data gaps; N = none, adequate data available to fully support the probability rating.

The skipjack herring is confirmed to have arrived at the pathway and is collected in the CAWS. However, the probability of passage through the CAWS is considered low across all time steps because of the Electric Dispersal Barrier System. However, the uncertainty of the passage probability ranges from medium to high. If the skipjack herring is able to pass through the CAWS, there is a medium probability that it will colonize and spread through the GLB. This species has been collected in Lake Michigan in the past, but it did not establish. Overall, the Electric Dispersal Barrier System renders the probability of establishment low across all time steps and for all pathways, although the uncertainty of the passage probability rating is high due to uncertainty concerning the effectiveness of the electric dispersal barrier.

III. Consequences of Establishment

Consequences of Establishment[a,b]			
Environmental Consequences	Economic Consequences	Social/Political Consequences	Total Overall Consequences
L(L)	N(L)	N(L)	L

[a] L = Low consequence rating due to the lower number of consequence categories affected, the lesser nature and severity of the consequences, and the more localized extent of the consequences; N = No consequences are anticipated.

[b] Uncertainty associated with each of the consequence ratings is indicated in parentheses. L = low uncertainty, good supporting data is available.

A. Environmental Consequences

The skipjack herring is native to the MRB where it has coexisted with other herring species (Fuller 2011). Based on its dietary preferences, the skipjack herring could potentially compete with and prey on several species within the GLB. The species could have widespread distribution in the MRB. However, herring-like fish are common in the GLB, and there is no data suggesting the skipjack herring has or will affect the overall ecology of the GLB, nor is there evidence that they will significantly alter ecological community structure in the GLB through predation or competition. There are several existing fish species in the GLB (i.e., ciscoes) whose ecological niches are similar to the skipjack herring. Therefore, this species is not expected to alter existing food webs or productivity. Overall, the skipjack herring has an environmental consequence rating of low. The skipjack herring is not reported in the literature to be a nuisance species. Consequently, uncertainty is low for the ecological consequences rating.

B. Economic Consequences

The establishment of the skipjack herring in the GLB is not expected to have economic consequences, and any impacts that do occur could be widespread (See Appendix B). Therefore, this species' consequence rating is none, and the uncertainty of the rating is low.

C. Social/Political Consequences

Although the skipjack herring could be widespread in the GLB, it is not expected to have any social or political impacts. The skipjack herring is not documented to have social and political consequences where it is established. Therefore, no consequences are expected to result from the establishment of this species and the uncertainty low.

D. Overall Consequences

The establishment of the skipjack herring in the GLB is expected to result in up to low environmental consequences and have no social/political or economic consequences. Therefore, the overall consequence of establishment is low, as is the degree of uncertainty associated with the individual consequence ratings.

IV. Risk of Adverse Impacts

Risk of Adverse Impacts

Pathway	Probability of Establishment[a]				Consequences of Establishment[b]	Risk of Adverse Impacts[c]			
	T_0	T_{10}	T_{25}	T_{50}		T_0	T_{10}	T_{25}	T_{50}
CAWS 1	L	L	L	L	L	L	L	L	L
CAWS 2	L	L	L	L	L	L	L	L	L
CAWS 3	L	L	L	L	L	L	L	L	L
CAWS 4	L	L	L	L	L	L	L	L	L
CAWS 5	L	L	L	L	L	L	L	L	L

[a] Probability rating elements: L = low probability, the event will likely not occur.

[b] Consequence ratings: L = Low consequence rating due to the lower number of consequence categories affected, the lesser nature and severity of the consequences, and the more localized extent of the consequences.

[c] Risk ratings: L = low risk of adverse impacts.

CAWS Risk Summary

There is a low probability of passage through the CAWS due to the Electric Dispersal Barrier System. Therefore, the overall probability of establishment is low for all time steps and pathways. If the skipjack herring were to establish in the GLB, the consequences of establishment would be low, as this species has a low probability of generating environmental, economic or social/political consequences. Therefore, the overall risk rating associated with the skipjack herring is low for all pathways and time steps.

V. References

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A.1.2.3 Black Carp - *Mylopharyngodon piceus*

I. Species Overview

A. Native Range and Current Distribution

Black carp are most abundant in the lower MRB, having been reported in Arkansas (White River), Mississippi (Mississippi River near the mouth of the Homochitto River), Louisiana (Atchafalaya and Red Rivers), and Missouri (Mississippi River near Lock & Dam 24 in Clarksville) (Nico & Nielson 2012). Within Illinois, the species was first collected from Horseshoe Lake in 2004, and has since been reported in the Mississippi River near Lock and Dam 24 and in Pool 25 near Hamburg, IL (Nico & Nielson 2012). Assuming the species is present at the confluence of the Mississippi and Illinois Rivers, the distance of the species from Brandon Road Lock and Dam is about 458 km (285 mi). The species is native to most major Pacific drainages of eastern Asia from latitude 22°N to about 51°N (Williams et al. 2007). Black carp were first introduced to the United States in imported grass carp stocks, with subsequent introductions occurring by the importation of the species as a food fish and a control agent for yellow grub in aquaculture ponds (Nico et al. 2005).

B. Life History and Ecology

Black carp is a bottom-dwelling freshwater fish that inhabits lakes, large rivers, and backwaters at depths of 0-10 m (0-32.8 ft) (Nico et al. 2005). The species requires flowing water to establish, and prefers fast-moving rivers (Williams et al. 2007). They are thought to occupy lakes and tributaries in the summer and main river channels in winter (Nico et al. 2005). Optimum water temperatures for the species range between 20 and 29°C (68-84.2°F); temperatures <0.5°C (32.9°F) and >40°C (104°F) are lethal (Nico et al. 2005). Spawning occurs in turbulent rivers, with eggs drifting downstream and newly hatched larvae drifting to nursery habitat (floodplain lakes, vegetated shores of rivers having little or no current) (Nico et al. 2005).

Juvenile black carp feed on zooplankton and fingerlings when small (Williams et al. 2007); adults primarily feed on molluscs, including snails (Nico et al. 2005), but also eat insects and occasionally vegetation. Black carp reach maturity at 6-11 years, with some females maturing at 3 years of age (Williams et al. 2007). Spawning occurs annually when water temperatures reach 17-27°C (62.6-80.6°F), water levels are rising, and mollusks are available (Williams et al. 2007; Crosier et al. 2003; Nico et al. 2005). Spawning may occur more than once per season, with individuals producing 1-3 million eggs each year (Williams et al. 2007). Black carp have a population doubling time of 4.5-14 years (http://www.usbr.gov/gp/dkao/biota_transfer/app3a.pdf).

II. Probability of Establishment

Overall the probability of establishment is low across all time steps and for all pathways. The black carp has not yet arrived at Brandon Road Lock and Dam, but has high probability of arrival by T_{25}. However, due to the low anticipated abundance of this species and the efficacy of the

Electric Barrier Dispersal System, this species has a low probability of passing through the CAWS for all time steps and pathways (see table below). The uncertainty of the passage ranges from medium to high due to uncertainty about when the species will arrive at the CAWS and the effectiveness over time of the Electric Dispersal Barrier System in blocking passage of this species through the CAWS. Small Asian carp are capable of swimming though an electrical field of similar strength to the Demonstration Barrier (Holliman 2011). USACE continues to study the optimal operating parameters to deter very small fish. However, small black carp are not expected to exist at the barrier because reproduction is not known to occur nearby. If black carp do arrive at the barrier, adults could potentially pass the electric barrier by accidental power failure, wind-driven reverse flow events in the canal, electric field shielding by steel-hulled vessels or sidewall crevices, and fish entrainment within barge-induced water currents across the Electric Dispersal Barrier System. However, these are expected to be low probability events. In addition, propagule pressure of this species immediately downstream of the Dispersal Barrier is expected to remain low during all time steps because existing populations in Illinois are small and a portion are triploid and not capable of reproduction. Consequently, it is assumed that black carp propagule pressure would remain low, and the Electric Barrier is expected to remain effective at preventing the passage of this species. Therefore, the probability of passage is expected to remain low at all time steps. The current and future reproductive status of this species is unknown, and therefore future propagule pressure at the Electric Barrier is also unknown.

Black carp collected in Illinois can be diploid (capable of reproduction) or triploid (not capable of reproduction) (Conover 2012). If diploid individuals of this species pass through the CAWS and enter the GLB, the black carp has the potential to spread and colonize in the GLB (Appendix E).

Probability of Establishment																				
	Probability Ratings for Time Steps 0, 10, 25, and 50 years[a,b]																			
	CAWS 1				CAWS 2				CAWS 3				CAWS 4				CAWS 5			
Probability Element	T_{0}	T_{10}	T_{25}	T_{50}	T_{0}	T_{10}	T_{25}	T_{50}	T_{0}	T_{10}	T_{25}	T_{50}	T_{0}	T_{10}	T_{25}	T_{50}	T_{0}	T_{10}	T_{25}	T_{50}
Pathway	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)
Arrival	L (L)	M (M)	H (M)	H (L)	L (L)	M (M)	H (M)	H (L)	L (L)	M (M)	H (M)	H (L)	L (L)	M (M)	H (M)	H (L)	L (L)	M (M)	H (M)	H (L)
Passage	L (M)	L (H)	L (H)	L (H)	L (M)	L (H)	L (H)	L (H)	L (M)	L (H)	L (H)	L (H)	L (M)	L (H)	L (H)	L (H)	L (M)	L (H)	L (H)	L (H)
Colonize	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)
Spread	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)
Probability of Establishment	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L

[a] Probability element ratings: H = high probability, the event will almost certainly occur; M = medium probability, the event is likely to occur but is not certain to do so; L = low probability, the event will likely not occur but is possible.

[b] Uncertainty associated with each Probability Element is indicated in parentheses. Uncertainty ratings: H = high, little or no data available and rating based on professional judgment; M = good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment; L = low, good data available with no major data gaps; N = none, adequate data available to fully support the probability rating.

III. Consequences of Establishment

A. Environmental Consequences

Overall, the potential environmental consequences of black carp establishment are high (see table below; Appendix B), and the uncertainty associated with ecosystem consequences of the black carp is low. As a bottom-dwelling species, black carp may reduce the number of snails and mollusks and can outcompete native molluscivores (Nico et al. 2005). Black carp will likely outcompete competitors since there is no fish of the same size and diet. It is not certain that the black carp will be able to consume zebra mussels in the MRB because there is limited evidence that black carp can consume zebra mussels in their natural clustered formations (Nico et al. 2005). However, if black carp are able to consume large amounts of zebra mussels, they may impact phytoplankton abundance. The black carp have high fecundity and could become abundant in the GLB.

B. Economic Consequences

Widespread establishment of black carp could produce economic consequences in a number of categories, including loss of consumer surplus, while reductions in recreational boating and commercial fishing could adversely impact employment, income, and tax revenues. See Appendix C for more detailed mechanisms and descriptions of potential impacts. For each of these consequence categories, the severity of economic consequences would depend on the extent of species establishment, the resulting impact on existing fisheries resources, and the consequent impact on recreational activity and fishing. The economic consequences of the black carp are medium with medium uncertainty.

Consequences of Establishment[a,b]			
Environmental Consequences	Economic Consequences	Social/Political Consequences	Total Overall Consequences
H (L)	M (M)	H (M)	H

[a] Consequence ratings: H = High consequence rating due to the larger number of consequence categories affected, the nature and severity of the consequences, and the broader spatial extent of the consequences; M = Medium consequence rating due to the number of consequence categories affected, the nature and severity of the consequences, and the spatial extent of the consequences.

[b] Uncertainty associated with each of the consequence ratings is indicated in parentheses. L = Low uncertainty, good ANS-specific data are available and no major data gaps are known; M = Medium uncertainty, good data are available but some data gaps exist; rating based on a mixture of data and professional judgment.

C. Social/Political Consequences

Establishment of the black carp in the GLB could reduce the perceived opportunities for recreational fishing (Appendix D). In addition, establishment of this species could have political consequences, as management of this species could result in laws and regulations to address the spread of the species (Appendix D). Therefore, the social/political impact of black carp is medium. However, the uncertainty associated with the consequences of this species is medium, due to the uncertainty associated with the environmental consequences of this species in the GLB.

D. Overall Consequences

The black carp could have high environmental and social/political consequences and medium economic consequences. The impacts are related to potential changes in fish and invertebrate communities, with related impacts to recreational fisheries. Therefore, the overall consequence level of black carp is high, and the uncertainty of these ratings range from low to medium.

IV. Risk of Adverse Impacts

CAWS Risk Summary

The overall risk of black carp is low for all pathways and time steps (see table below). Although the establishment of black carp in the GLB could have potentially high consequences, the Electric Dispersal Barrier System is expected to control the risk of this species entering the GLB. The uncertainty associated with the probability of passage for this species is high because of uncertainty about the reproductive competence of this species and the efficacy of the Electric Dispersal Barrier system over time.

Risk of Adverse Impacts									
	Probability of Establishment[a]				Consequences of Establishment[b]	Risk of Adverse Impacts[c]			
Pathway	T_0	T_{10}	T_{25}	T_{50}		T_0	T_{10}	T_{25}	T_{50}
CAWS 1	L	L	L	L	H	L	L	L	L
CAWS 2	L	L	L	L	H	L	L	L	L
CAWS 3	L	L	L	L	H	L	L	L	L
CAWS 4	L	L	L	L	H	L	L	L	L
CAWS 5	L	L	L	L	H	L	L	L	L

[a] Probability element ratings: L = low probability, the event will likely not occur but is possible.

[b] Consequence ratings: H = High consequence rating due to the larger number of consequence categories affected, the nature and severity of the consequences, and the broader spatial extent of the consequences.

[c] Risk ratings: L = low risk of adverse impacts.

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A.1.2.4 Northern Snakehead - *Channa argus*

I. Species Overview

A. Native Range and Current Distribution

The northern snakehead was first collected in Lake Michigan in 2004 at Burnham Harbor in downtown Chicago, Illinois (Fuller & Benson 2012). The closest established population of the species to the Chicago Area Waterway System (CAWS) is in Piney Creek, Arkansas, in a tributary of the Mississippi River (Sattelberg et al. 2008). Established populations of the species can also be found in Maryland (Potomac River and Anacostia River), Pennsylvania (FDR Park; Schuylkill River; Delaware River; Philadelphia, Pennsylvania), Delaware, Virginia (Potomac River Basin), and New York (Meadow Lake, Queens, New York) (Fuller & Benson 2012). The species is native to China, Russia, and Korea (Courtenay & Williams 2004), and was likely introduced intentionally to the Mississippi River Basin to support the Asian food market (Fuller & Benson 2012).

B. Life History and Ecology

The northern snakehead is found in lakes, water courses, wetlands, slow muddy streams, canals, reservoirs, and rivers (NBII Undated), but prefers stagnant shallow ponds, swamps, and slow streams with mud or vegetated substrates (Fuller & Benson 2012). The species is found in muddy substrates and shallow water (<2 m [6.6 ft]) (Courtenay & Williams 2004). In China, it is found in temperature ranges of 9.7-18.7°C (49.5-65.7°F); the species becomes physiologically stressed at 35°C (Landis et al. 2011). The species can survive under ice and in temperatures ranging from 0-30°C (32 -86°F) (NBII Undated). The northern snakehead is an obligate air-breather and can survive out of water for up to 4 days; it is also capable of surviving in water with very low oxygen content (NBII Undated). The species is associated with submersed weeds and floating or emergent plants.

Young northern snakeheads consume zooplankton (Courtenay & Williams 2004), while fish comprise 64-70% of their adult diet (NBII Undated). Other prey includes frogs, tadpoles, crustaceans, aquatic insects, reptiles, small birds, and mammals (Fuller and Benson 2012). The species does not feed in the winter, but hibernates by burrowing in the mud (NBII Undated). The northern snakehead reaches maturity in 2-3 years, and produces eggs 1-5 times per year, releasing 22,000-51,000 eggs per spawn (NBII Undated). Spawning occurs in June and July (FishBase 2010) and fecundity is about 50,000 oocytes (Courtenay & Williams 2004). Spawning occurs in the early morning in shallow waters (NBII Undated), with spawning fish preferring macrophytes and cover in shallow water (~88 cm; 34.6 in.) (Lapointe et al. 2010). The minimum population doubling time is less than 15 months (Courtenay & Williams 2004).

II. Probability of Establishment

Because of its current location well away from the CAWS, the northern snakehead has a low probability of arriving at the pathway until T_{50}, when the probability of arrival increases to medium (see table below). Following arrival at the CAWS, this species has a low probability of passage due to the Electric Dispersal Barrier System, which is most effective against benthic fishes like snakeheads. If the northern snakehead does move into the GLB, the probability of colonization and spread are medium, as suitable habitat is present but widely distributed within the basin (see Appendix E). Overall, the northern snakehead has a low probability of establishment across all pathways and time steps due to the Electric Dispersal Barrier System. The uncertainties of several establishment elements are high due to uncertainty associated with the time of arrival, the effectiveness of control measures where this species is currently located, and the effectiveness of the Electric Dispersal Barrier System in preventing this species from reaching Lake Michigan. Unfortunately as part of the Corps' efficacy testing of the Demonstration Barrier, it was discovered that small fish are capable of swimming though an electrical field of similar strength to the Demonstration Barrier (Holliman 2011). If they were to begin reproducing in the vicinity of the barrier, very small northern snakehead may be able to pass through the barrier. USACE continues to study the optimal operating parameters to deter very small fish.

Adult northern snakehead could also potentially pass the Electric Barrier by accidental power failure, wind-driven reverse flow events in the canal, electric field shielding by steel-hulled vessels or sidewall crevices, and fish entrainment within barge-induced water currents across the Electric Dispersal Barrier System. However, propagule pressure of this species immediately downstream of the Dispersal Barrier is expected to remain low at T_{50}, because populations in Illinois are expected to be small or non-existent at T_{50}, resulting in low propagule pressure. Therefore, the Electric Barrier is expected to remain effective at controlling the passage of this species, and the probability of passage is expected to remain low.

Measures may be taken in the future to increase the efficacy of the Electric Dispersal Barrier, thereby reducing uncertainty. However, the uncertainty associated with the propagule pressure of this species at the Electric Barrier and the potential for this species to pass upstream of the barrier by one of the barrier failure mechanisms identified above also increase with time. Therefore, the uncertainty associated with its passage during this time step is high.

Probability of Establishment

Probability Element	CAWS 1 T_0	CAWS 1 T_{10}	CAWS 1 T_{25}	CAWS 1 T_{50}	CAWS 2 T_0	CAWS 2 T_{10}	CAWS 2 T_{25}	CAWS 2 T_{50}	CAWS 3 T_0	CAWS 3 T_{10}	CAWS 3 T_{25}	CAWS 3 T_{50}	CAWS 4 T_0	CAWS 4 T_{10}	CAWS 4 T_{25}	CAWS 4 T_{50}	CAWS 5 T_0	CAWS 5 T_{10}	CAWS 5 T_{25}	CAWS 5 T_{50}
	Probability Ratings for Time Steps 0, 10, 25, and 50 years[a,b]																			
Pathway	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)
Arrival	L (L)	L (L)	L (M)	M (H)	L (L)	L (L)	L (M)	M (H)	L (L)	L (L)	L (M)	M (H)	L (L)	L (L)	L (M)	M (H)	L (L)	L (L)	L (M)	M (H)
Passage	L (M)	L (H)	L (H)	L (H)	L (M)	L (H)	L (H)	L (H)	L (M)	L (H)	L (H)	L (H)	L (M)	L (H)	L (H)	L (H)	L (M)	L (H)	L (H)	L (H)
Colonization	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)
Spread	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)
Probability of Establishment	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L

[a] Probability element ratings: H = high probability, the event will almost certainly occur; M = medium probability, the event is likely to occur but is not certain to do so; L = low probability, the event will likely not occur but is possible.

[b] Uncertainty associated with each Probability Element is indicated in parentheses. Uncertainty ratings: H = high, little or no data available and rating based on professional judgment; M = medium, good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment; L = low, good data available with no major data gaps; N = none, adequate data available to fully support the probability rating.

III. Consequences of Establishment

A. Environmental Consequences

The environmental consequence rating for the northern snakehead is high. The ecology and physiology of the northern snakehead give it a competitive advantage over native species for food and habitat (Fuller and Benson 2012). The diet of the northern snakehead consists mainly of fish; therefore, negative impacts on existing fish populations in its introduced range could be high (NBII Undated). Snakeheads may introduce parasites and disease to native fish populations (NBII Undated). The environmental consequences of the northern snakehead could be widespread, as suitable habitat exists in the tributaries of the GLB.

B. Economic Consequences

Widespread establishment of the northern snakehead in the GLB could produce economic consequences in a number of categories, including loss of consumer surplus, while reductions in recreational fishing and in commercial fishing could adversely impact employment, income, and tax revenues (Appendix C). See Appendix C for more detailed mechanisms and descriptions of potential impacts. For each of these categories, the severity of economic consequences would depend on the extent of species establishment, the resulting impact on existing fisheries resources, and consequent impact on recreational activity, commercial fishing, and the maintenance of boats and equipment. The economic consequence of the northern snakehead is medium with high uncertainty.

C. Social/Political Consequences

The northern snakehead has the potential to reduce the perceived quality of recreational fishing opportunities (Appendix D). The potential for this species to prey on native fish communities could result in new regulation and laws to control this species. In addition, the social/political consequences of the northern snakehead could be widespread, given its potentially widespread distribution in the GLB. Overall, the social/political consequences of the northern snakehead's spread could be high. The uncertainties of these consequences are medium due to the uncertain effects this species could have on recreational fishing.

D. Overall Consequences

The northern snakehead could have high environmental and social/political consequences with medium economic consequences. Therefore, the overall consequence level of northern snakehead is high (see table below). The impacts are related to the potential for this species to alter fish communities, which could in turn adversely affect recreational fisheries. However, the environmental and economic consequence ratings have an uncertainty rating of high, as the actual effects of the northern snakehead on fish populations in the GLB are speculative. The northern snakehead is currently far from the CAWS and has a low probability of arrival and passage into the GLB until T_{25}, when the probability increases to medium. Therefore, these consequences are not expected to occur in the near term.

Consequences of Establishment[a,b]			
Environmental Consequences	Economic Consequences	Social/Political Consequences	Total Overall Consequences
H (H)	M (H)	H (M)	H

[a] Consequence ratings: H = High consequence rating due to the larger number of consequence categories affected, the nature and severity of the consequences, and the broader spatial extent of the consequences; M = Medium consequence rating due to the number of consequence categories affected, the nature and severity of the consequences, and the spatial extent of the consequences.

[b] Uncertainty associated each of the consequence elements is indicated in parentheses. Uncertainty ratings: H = high, little or no data available and rating based on professional judgment; M = medium, good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment.

IV. Risk of Adverse Impacts

CAWS Risk Summary

The establishment of northern snakehead in the GLB could have potentially high consequences, although the northern snakehead has a low probability of arrival until at least T_{50} (see table below). Also, the Electric Dispersal Barrier System is expected to control the risk of the passage of the northern snakehead through the CAWS. Therefore, the overall risk associated with the northern snakehead is low for all pathways and time steps. The primary uncertainties associated with the risk rating are related to the ability to contain the snakehead in its current location in the Mississippi River Basin (MRB), and the outcome of interspecific interactions if it does establish in the GLB.

Risk of Adverse Impacts									
	Probability of Establishment[a]					Risk of Adverse Impacts[c]			
Pathway	T_0	T_{10}	T_{25}	T_{50}	Consequences of Establishment[b]	T_0	T_{10}	T_{25}	T_{50}
CAWS 1	L	L	L	L	H	L	L	L	L
CAWS 2	L	L	L	L	H	L	L	L	L
CAWS 3	L	L	L	L	H	L	L	L	L
CAWS 4	L	L	L	L	H	L	L	L	L
CAWS 5	L	L	L	L	H	L	L	L	L

[a] Probability element ratings: L = low probability, the event will likely not occur but is possible.

[b] Consequence ratings: H = High consequence rating due to the larger number of consequence categories affected, the nature and severity of the consequences, and the broader spatial extent of the consequences.

[c] Risk ratings: L = low risk of adverse impacts.

V. References

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A.2 LOW-RISK ANS POTENTIALLY INVADING THE MISSISSIPPI RIVER BASIN

A.2.1 Protozoa

A.2.1.1 Testate Amoeba - *Psammonobiotus communis*

I. Species Overview

A. Native Range and Current Distribution

Psammonobiotus communis has been reported along beaches in all of the Great Lakes except Lake Michigan (Nicholls & MacIsaac 2011). It was first recorded in Lake Huron in 2001 and in Lakes Superior, Erie, and Ontario in 2002 (Kipp 2012). Its current location (2012) is uncertain; however, surveys for *P. communis* have not yet been conducted in Lake Michigan (Kipp 2012). This species has been found in every ocean basin of the world, but is most likely native to the Ponto-Caspian region (Black Sea, Caspian Sea, and Aral Sea basins) (Kipp 2012). *P. communis* was probably introduced into the Great Lakes via ballast water release (Nicholls & MacIsaac 2004).

B. Life History and Ecology

This species is found in littoral and supralittoral sand sediments where oxygen levels and interstitial water movement are adequate (Golemansky 2008). *P. communis* inhabits waters with DO ranging from 1.3-10.2 mg/L (Todorov & Golemansky 2007); anoxic sand sediments and underground water lack interstitial testate amoebae (Golemansky 2008). This species requires a grain size large enough for interstitial water movement. It tolerates salinities of 0-37‰ (Kipp 2012) and has been recorded in water temperatures ranging from 9.3 to 29.5°C (48.74-85°F) (Todorov & Golemansky 2007). The species is found at sand depths ranging from 10-105 cm (3.9-41 in.) at distances of 0-35 m (0-115 ft) from the shoreline (Kipp 2012; Nicholls & MacIsaac 2004; Golemansky 2008).

P. communis feeds on bacteria, algae, and particular organic matter (Golemansky 2008; Kipp 2012). This species feeds by licking the surface of sand grains for bacteria, fungi, and algae, or through phagocytosis (Golemansky 2008). This species undergoes asexual reproduction.

II. Probability of Establishment

Probability Element	Probability of Establishment																			
	Probability Range for Time Steps 0, 10, 25, and 50 yr[a,b]																			
	CAWS 1				CAWS 2				CAWS 3				CAWS 4				CAWS 5			
	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}
Pathway	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)
Arrival	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)
Passage	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)
Colonization	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)
Spread	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)
Probability of Establishment	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L

[a] H = high probability, the event will almost certainly occur; M = medium probability, the event is likely to occur but is not certain to do so; L = low probability, the event will likely not occur but is possible.

[b] Uncertainty associated with each Probability Elements is indicated in parentheses. Uncertainty ratings: H = high, little or no data available and rating based on professional judgment; M = good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment; L = low, good data available with no major data gaps; N = none, adequate data available to fully support the probability rating.

A pathway exists for *P. communis* to enter the MRB and there is a high probability that this species has arrived at the CAWS. However, suitable sediment, hydrology, and dissolved oxygen conditions are not expected to be present in the CAWS. Therefore, the probability of passage is low for all time steps. If *P. communis* were to spread through the CAWS, it could potentially colonize and spread to sandy high flow habitat in the MRB. However, *P. communis* is documented in the literature in large inland seas and coastal habitat and the highly specific habitat requirements of this species suggests a high uncertainty associated with this colonization and spread. Overall, probability of establishment is low for all time steps and pathways.

III. Consequences of Establishment

Consequences of Establishment[a,b]			
Environmental Consequences	Economic Consequences	Social/Political Consequences	Total Overall Consequences
L(M)	N(L)	N(L)	L

[a] L = Low consequence rating due to the lower number of consequence categories affected, the lesser nature and severity of the consequences, and the more localized extent of the consequences; N = no consequences are anticipated.

[b] Uncertainty associated with each of the consequence ratings is indicated in parentheses. L = low uncertainty, good supporting data is available. M = medium uncertainty, good data are available but some data gaps exist; rating based on a mixture of data and professional judgment.

A. Environmental Consequences

P. communis is a benthic amoeba that moves between sand grains. Its ecological effects are unknown, but the species could potentially alter the biogeochemistry and bacterial communities of areas it invades. However, there is no evidence it has done so in the GLB, where it is currently established. Because it is not predicted to be widespread in the GLB, any effects it does have are expected to be localized and minimal. Therefore the consequences of this species establishing in the MRB is low. There is a lack of research available on *P. communis*, so little is known of its environmental effects. However, no adverse impacts on ecosystem structure and function have been reported in the literature to result from the introduction of this species. Therefore, there is a medium degree of uncertainty regarding its environmental consequences.

B. Economic Consequences

The establishment of *P. communis* in the MRB is not expected to have economic consequences (see Appendix C). Therefore, this species’ consequence rating is none, and the uncertainty of the rating is low.

C. Social/Political Consequences

The establishment of *P. communis* in the MRB is not expected to have social or political consequences and any impacts that do occur will be localized. Therefore, this species' social/political consequence rating is none and the uncertainty of the rating is low.

D. Overall Consequences

The establishment of *P. communis* in the GLB is expected to result in no more than low environmental, economic, and social/political consequences. In addition, *P. communis*is is not expected to spread widely in the GLB, because of its unique habitat requirements. Therefore, the overall consequence of establishment is low.

IV. Risk of Adverse Impact

Risk of Adverse Impacts

Pathway	Probability of Establishment[a] T_0	T_{10}	T_{25}	T_{50}	Consequences of Establishment[b]	Risk of Adverse Impacts[c] T_0	T_{10}	T_{25}	T_{50}
CAWS 1	L	L	L	L	L	L	L	L	L
CAWS 2	L	L	L	L	L	L	L	L	L
CAWS 3	L	L	L	L	L	L	L	L	L
CAWS 4	L	L	L	L	L	L	L	L	L
CAWS 5	L	L	L	L	L	L	L	L	L

[a] Probability rating elements: L = low probability, the event will likely not occur.

[b] Consequence ratings: L = Low consequence rating due to the lower number of consequence categories affected, the lesser nature and severity of the consequences, and the more localized extent of the consequences.

[c] Risk ratings: L = low risk of adverse impacts.

CAWS Risk Summary

There is a low probability of *P. communis* passing through the CAWS, due to the unsuitability of sediments. Therefore, the probability of establishment is low for all time steps and pathways. If *P. communis* were to establish in the GLB, the consequences of establishment are low, as this species has a low probability of generating environmental, economic or social/political consequences. Therefore, the overall risk associated with *P. communis*is is low for all pathways and time steps.

V. References

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A.2.1.2 Testate Amoeba - *Psammonobiotus dziwnowi*

I. Species Overview

A. Native Range and Current Distribution

Psammonobiotus dziwnowi has been reported in scattered locations along beaches in all of the Great Lakes, except Lake Michigan (Nicholls & MacIsaac 2004). No surveys for this species have been conducted in Lake Michigan (Kipp 2011). This species was first reported from Lakes Superior, Huron, Erie, and Ontario in 2002 (Kipp 2011; Nicholls 2005). This species probably originated from the Ponto-Caspian region (Black, Caspian, and Aral Sea basins) (Kipp 2011). This species was most likely introduced to the Great Lakes via ship ballast (Nicholls & MacIsaac 2004).

B. Life History and Ecology

P. dziwnowi typically occurs in littoral and supralittoral sandy beach sediments (Golemansky 2008; Kipp 2011), where interstitial water movement and oxygen levels are suitable (Kipp 2011). Anoxic sand sediments and underground water lack interstitial testate amoebae (Golemansky 2008). This species also requires a grain size large enough for interstitial water movement. This species has been reported along the Baltic Sea coast in salinities from 2% in marine-brackish water (Nicholls & MacIsaac 2004). *P. dziwnowi* occupies toxic, low-silt, and sandy sediments; it is typically associated with littoral sandy beach sediments, but can be found near river mouths. This species has spread to scattered locations within the Great Lakes but is not found at high densities (Nicholls & MacIsaac 2004).

Psammonobionts are bacterivorous and algivorous, taking in food by phagocyctosis or by licking the surface of sand grains for bacteria, fungi, and algae (Golemansky 2008). This species reproduces asexually; its rate of population growth is unknown.

II. Probability of Establishment

Probability of Establishment																				
	Probability Range for Time Steps 0, 10, 25, and 50 years[a,b]																			
	CAWS 1				CAWS 2				CAWS 3				CAWS 4				CAWS 5			
Probability Element	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}
Pathway	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)
Arrival	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)
Passage	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)
Colonization	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)
Spread	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)
Probability of Establishment	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L

[a] H = high probability, the event will almost certainly occur; M = medium probability, the event is likely to occur but is not certain to do so; L = low probability, the event will likely not occur but is possible.

[b] Uncertainty associated each Probability Element is indicated in parentheses. Uncertainty ratings: H = high, little or no data available and rating based on professional judgment; M = good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment; L = low, good data available with no major data gaps; N = none, adequate data available to fully support the probability rating.

A pathway exists for *P. dziwnowi* to enter the Mississippi River Basin (MRB), and there is a high probability that this species has arrived at the CAWS. However, suitable sediment, hydrology, and dissolved oxygen conditions are not expected to be present in the CAWS. Therefore, the probability of passage is low for all time steps. If *P. dziwnowi* were to spread through the CAWS, it could potentially colonize and spread to sandy, high-flow habitat. However, *P. dziwnowi* is documented in the literature in large inland seas and coastal habitat, and the highly specific habitat requirements of this species suggest a high uncertainty associated with its colonization and spread. Overall, probability of establishment is low for all time steps and pathways.

III. Consequences of Establishment

Consequences of Establishment[a,b]			
Environmental Consequences	Economic Consequences	Social/Political Consequences	Total Overall Consequences
L(M)	N(L)	N(L)	L

[a] L = Low consequence rating due to the lower number of consequence categories affected, the lesser nature and severity of the consequences, and the more localized extent of the consequences; N = no consequences are anticipated.

[b] Uncertainty associated with each of the consequence ratings is indicated in parentheses. L = low uncertainty, good supporting data is available. M = medium uncertainty, good data are available but some data gaps exist; rating based on a mixture of data and professional judgment.

A. Environmental Consequences

This species has been found in every ocean basin of the world (Kipp 2011). Its ecological effects are unknown, but the species could potentially alter the sediment biogeochemistry and bacterial communities of areas it invades. However, there is no evidence it has done so in the GLB, where it is currently established. Because it is not predicted to be widespread in the GLB, any effects it does have are expected to be localized and minimal. Therefore, the consequences of the establishment of this species in the MRB are low. There is a lack of research available on *P. dziwnowi*, so little is known of its environmental effects. However, no adverse impacts on ecosystem structure and function resulting from the introduction of this species have been reported in the literature. Therefore, there is a medium degree of uncertainty regarding its environmental consequences.

B. Economic Consequences

The establishment of *P. dziwnowi* in the MRB is not expected to have economic consequences (see Appendix C). Therefore, this species' consequence rating is none, and the uncertainty of the rating is low.

C. Social/Political Consequences

The establishment of *P. dziwnowi* in the MRB is not expected to have social or political consequences, and any impacts that do occur will be localized. Therefore, this species' consequence rating is none, and the uncertainty of the rating is low.

D. Overall Consequences

The establishment of *P. dziwnowi* in the GLB is expected to result in no more than low environmental, economic, and social/political consequences. In addition, *P. dziwnowi* is not expected to spread widely in the GLB because of its unique habitat requirements. Therefore, the overall consequence of establishment is low, and there is a low degree of uncertainty regarding the consequence rating.

IV. Risk of Adverse Impacts

Risk of Adverse Impacts

	Probability of Establishment[a]					Risk of Adverse Impacts[c]			
Pathway	T_0	T_{10}	T_{25}	T_{50}	Consequences of Establishment[b]	T_0	T_{10}	T_{25}	T_{50}
CAWS 1	L	L	L	L	L		L	L	L
CAWS 2	L	L	L	L	L		L	L	L
CAWS 3	L	L	L	L	L		L	L	L
CAWS 4	L	L	L	L	L		L	L	L
CAWS 5	L	L	L	L	L		L	L	L

[a] Probability rating elements: L = low probability, the event will likely not occur.

[b] Consequence ratings: L = Low consequence rating due to the lower number of consequence categories affected, the lesser nature and severity of the consequences, and the more localized extent of the consequences.

[c] Risk ratings: L = low risk of adverse impacts.

There is a low probability of *P. dziwnowi* passing through the CAWS due to the unsuitability of sediments. Therefore, the probability of establishment is low for all time steps and pathways. If *P. dziwnowi* were to establish in the GLB, the consequences of establishment are low, because this species has a low probability of generating environmental, economic, or social/political consequences. Therefore, the overall risk associated with *P. dziwnowi* is low for all pathways and time steps.

V. References

Golemansky, V. 2008. Origin, phylogenetic relations, and adaptations of the marine interstitial testate amoebae (*Rhizopoda: Lobosea, Filosea,* and *Granuloreticulsea*). *Monographs*, vol. 12, pp. 87-100.

Kipp, R.M. 2012. *Psammonobiotus dziwnowi.* USGS Nonindigenous Aquatic Species Database, Gainesville, FL. Revision Date July 5, 2007. http://nas.er.usgs.gov/queries/GreatLakes/SpeciesInfo.asp?NoCache=5%2F2012+4%3A38%3A09+PM&SpeciesID=2653&State=&HUCNumber=DErie

Nicholls, K.H. & H.J. MacIsaac. 2004. Euryhaline, sand-dwelling, testate rhizopods in the Great Lakes. *Journal of Great Lakes Research*, vol. 30(1), pp. 123-132.

A.2.1.3 Testate Amoeba - *Psammonobiotus linearis*

I. Species Overview

A. Native Range and Current Distribution

Psammonobiotus linearis has been recorded along beaches in Lake Erie and Lake Ontario (Nicholls & MacIsaac 2004; Kipp 2011). No surveys have been conducted for this species in Lake Michigan (Kipp 2011), and the current location of the species is unknown. *P. linearis* was first described from the Black Sea and has been recorded from the Baltic Sea and Bay of Biscay; its native range is therefore thought to be the Ponto-Caspian region of Eurasia (Black Sea, Caspian Sea, and Aral Sea basins) (Kipp 2011). This species was most likely introduced to the Great Lakes via ship ballast (Nicholls & MacIsaac 2004).

B. Life History and Ecology

P. linearis is found in littoral and supralittoral sand sediments (Golemansky 2008), where interstitial water movement and oxygen levels are suitable (Kipp 2011). It has been recorded in salinities up to 31 ppt (Kipp 2011) at sand depths of 60 cm (23.6 in.) in beach sands (Golemansky 1970). This species requires a grain size large enough to allow interstitial water movement. Suitable sediments types for this species are well oxygenated, low-silt, sandy sediments. *P. linearis* are associated with littoral sandy beach sediments, but they can also be found near river mouths.

Psammonobionts are bacterivorous and algivorous (Golemansky 2008); they take in food by phagocytosis or by licking the surface of sand grains for bacteria, fungi, and algae with their pseudopodia (Golemansky 2008). *P. linearis* reproduces asexually; its population growth rates are unknown.

II. Probability of Establishment

Probability of Establishment																				
	Probability Range for Time Steps 0, 10, 25, and 50 years[a,b]																			
	CAWS 1				CAWS 2				CAWS 3				CAWS 4				CAWS 5			
Probability Element	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}
Pathway	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)
Arrival	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)	H (M)
Passage	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)
Colonization	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)
Spread	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)
Probability of Establishment	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L

[a] H = high probability, the event will almost certainly occur; M = medium probability, the event is likely to occur but is not certain to do so; L = low probability, the event will likely not occur but is possible.

[b] Uncertainty associated each Probability Element is indicated in parentheses. Uncertainty ratings: H = high, little or no data available and rating based on professional judgment; M = good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment; L = low, good data available with no major data gaps; N = none, adequate data available to fully support the probability rating.

A pathway exists for *P. linearis* to enter the Mississippi River Basin (MRB), but this species has been found in only two of the Great Lakes and is typically rare (Kipp 2011). This species is spread by ballast water and therefore could be present in Lake Michigan, although it is not currently documented. The heavy ballast water discharge at the Calumet Harbor increases the probability of *P. linearis* introduction. Overall, however, the probability of the species arriving at the pathway during this time step is considered to be low until T_{25} when it increases to medium. Once it reaches the CAWS pathway, there is a low probability of passage at all time steps and pathways, because suitable sediment, hydrology, and dissolved oxygen conditions are not expected to be present in the CAWS. If *P. linearis* were to spread through the CAWS, it could potentially colonize and spread to sandy, high-flow habitat. However, *P. linearis* is documented in the literature in large inland seas and coastal habitat, and the highly specific habitat requirements of this species suggest a high uncertainty associated with its colonization and spread. Overall, probability of establishment is low for all time steps and pathways.

III. Consequences of Establishment

Consequences of Establishment[a,b]			
Environmental Consequences	Economic Consequences	Social/Political Consequences	Total Overall Consequences
L(M)	N(L)	N(L)	L

[a] L = Low consequence rating due to the lower number of consequence categories affected, the lesser nature and severity of the consequences, and the more localized extent of the consequences; N = no consequences are anticipated.

[b] Uncertainty associated with each of the consequence ratings is indicated in parentheses. L = low uncertainty, good supporting data is available. M = medium uncertainty, good data are available but some data gaps exist; rating based on a mixture of data and professional judgment.

A. Environmental Consequences

P. linearis is a benthic amoeba that moves between sand grains. It is known to feed on bacteria, fungi, and algae found on sand grains (Golemansky 2008). Its ecological effects are unknown, but the species could potentially alter the biogeochemistry and bacterial communities of areas it invades. However, there is no evidence it has done so in the GLB, where it is currently established. Because it is not predicted to be widespread in the GLB, any effects it does have are expected to be localized and minimal. Therefore, the consequences of establishment of this species in the MRB are low. There is a lack of research available on *P. linearis*, so little is known of its environmental effects. However, no adverse impacts on ecosystem structure and function resulting from the introduction of this species have been reported in the literature. Therefore, there is a medium degree of uncertainty regarding its environmental consequences.

B. Economic Consequences

The establishment of *P. linearis* in the MRB is not expected to have economic consequences (see Appendix C). Therefore, this species' consequence rating is none, and the uncertainty of the rating is low.

C. Social/Political Consequences

The establishment of *P. linearis* in the MRB is not expected to have social or political consequences, and any impacts that do occur will be localized. Therefore, this species consequence rating is none, and the uncertainty of the rating is low.

D. Overall Consequences

The establishment of *P. linearis* in the GLB is expected to result in no more than low environmental, economic, and social/political consequences. In addition, *P. linearis* is not expected to spread widely in the GLB, because of its unique habitat requirements. Therefore, the overall consequence of establishment is low.

IV. Risk of Adverse Impacts

Risk of Adverse Impacts

	Probability of Establishment[a]					Risk of Adverse Impacts[c]			
Pathway	T_0	T_{10}	T_{25}	T_{50}	Consequences of Establishment[b]	T_0	T_{10}	T_{25}	T_{50}
CAWS 1	L	L	L	L	L		L	L	L
CAWS 2	L	L	L	L	L		L	L	L
CAWS 3	L	L	L	L	L		L	L	L
CAWS 4	L	L	L	L	L		L	L	L
CAWS 5	L	L	L	L	L		L	L	L

[a] Probability rating elements: L = low probability, the event will likely not occur.

[b] Consequence ratings: L = Low consequence rating due to the lower number of consequence categories affected, the lesser nature and severity of the consequences, and the more localized extent of the consequences.

[c] Risk ratings: L = low risk of adverse impacts.

There is a low probability of *P. linearis* passing through the CAWS due to the unsuitability of sediments. Therefore, the probability of establishment is low for all time steps and pathways. If *P. linearis* were to establish in the GLB, the consequences of establishment are low, because this species has a low probability of generating environmental, economic, or social/political consequences. Therefore, the overall risk associated with *P. linearis* is low for all pathways and time steps.

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A.2.2 Bryozoans

A.2.2.1 Freshwater Bryozoan - *Lophopodella carteri*

I. Species Overview

A. Native Range and Current Distribution

Lophopodella carteri has been reported in Lake Erie, southern Lake Michigan, and lakes in Illinois (Wood & Marsh 1996; Lauer et al. 1999). The closest record of *L. carteri* to the WPS is a 1995 record at the Michigan City Harbor in Indiana, over 112 shoreline km (70 mi) away from the WPS (Lauer et al. 1999). However, no comprehensive surveys of southern Lake Michigan were found, so *L. carteri* may be present, but unrecorded at the WPS. *L. carteri* is native to Southeast Asia and Northeast Africa, and is thought to have been introduced into the Great Lakes via imported aquatic Asian plants in the 1930s, although human-mediated transport through non-aquatic pathways may have been the primary spread mechanism (Masters 1940).

B. Life History and Ecology

L. carteri is an attached, generally colonial invertebrate. This species is found on sandy shoals (Smith 1985) and attached to macrophytes, as well as solid substrata like docks and rocks (Lauer et al. 1999). It has also been collected from substrate of gravel and rubble with scattered patches of vegetation (Ricciardi and Lewis 1991). *L. carteri* can live in bivalve shells, attached to algae, concrete walls, vertical surfaces, submerged logs, and aquatic vegetation (Lauer et al. 1999). This species is a suspension feeder and consumes bacteria, desmids, diatoms, flagellates, rotifers, and other minute animals (Watermolen 2004).

L. carteri is capable of sexual and asexual reproduction (Watermolen 2004). If reproducing sexually, the larvae have a brief planktonic stage (which may be dispersed by water currents) and then attach to a substrate or surface (Wood 1993). They reproduce asexually by releasing statoblasts, which sink immediately to the sediments, where they will eventually germinate into adults under favorable conditions (Rogick 1935; Wood 1993). Statoblasts will re-establish colonies after long periods of unfavorable conditions years (Wood and Marsh 1996).

II. Probability of Establishment

	Probability of Establishment																			
	Probability Range for Time Steps 0, 10, 25, and 50 yr[a,b]																			
	CAWS 1				CAWS 2				CAWS 3				CAWS 4				CAWS 5			
Probability Element	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}
Pathway	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)
Arrival	H (M)	H (M)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)
Passage	L (M)	M (M)	H (L)	H (L)	L (M)	M (M)	H (L)	H (L)	L (M)	M (M)	H (L)	H (L)	L (L)	L (L)	L (H)	M (H)	L (L)	L (L)	L (H)	M (H)
Colonization	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)
Spread	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)
Probability of Establishment	L	M	H	H	L	M	H	H	L	M	H	H	L	L	L	M	L	L	L	M

[a] H = high probability, the event will almost certainly occur; M = medium probability, the event is likely to occur but is not certain to do so; L = low probability, the event will likely not occur but is possible.

[b] Uncertainty associated each Probability Element is indicated in parentheses. Uncertainty ratings: H = high, little or no data available and rating based on professional judgment; M = good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment; L = low, good data available with no major data gaps; N = none, adequate data available to fully support the probability rating.

L. carteri has been in southern Lake Michigan since at least 1999, but has not been documented in the CAWS. Therefore, *L. carteri* has a low probability of entering and passing through the CAWS at T_0. However, with time the probability increases to high by T_{25}. Passage probability is low for CAWS pathways 4 and 5 until T_{50}, due to lack of vessel traffic and the fact that water flows toward Lake Michigan in the Grand Calumet River and south branch of the Little Calumet River. At T_{50}, passage probability for CAWS 4 and 5 increases to medium. *L. carteri* can live in bivalve shells, attached to algae, concrete walls, vertical surfaces, submerged logs, rocks, and aquatic vegetation (Lauer et al. 1999). Such habitat is abundant in the MRB, so once in the MRB, *L. carteri* has a high probability of colonization and spread. The overall probability of establishment for CAWS 1, 2, and 3 ranges from low at T_{10} to high at T_{25}. For CAWS 4 and 5, the probability of establishment is low until $T_{50,}$ when it increases to medium.

III. Consequences of Establishment

Consequences of Establishment[a,b]			
Environmental Consequences	Economic Consequences	Social/Political Consequences	Total Overall Consequences
L(M)	N(L)	N(L)	L

[a] L = Low consequence rating due to the lower number of consequence categories affected, the lesser nature and severity of the consequences, and the more localized extent of the consequences; N = no consequences are anticipated.

[b] Uncertainty associated with each of the consequence ratings is indicated in parentheses. L = low uncertainty, good supporting data is available. M = medium uncertainty, good data are available but some data gaps exist; rating based on a mixture of data and professional judgment.

A. Environmental Consequences

L. carteri competes with zebra mussels over space and may limit settling and recruitment of the zebra mussel (Ricciardi & Reiswig 1994; Lauer et al. 1999). Therefore, this species may affect *Dreissena* spp. populations in the MRB. The coelomic fluid of *L. carteri* colonies damages the gill epithelium of certain fish and salamander species (Lauer et al. 1999). Although *L. carteri* can be locally abundant (Wood & Marsh 1996), no widespread changes in ecosystem structure or function are reported to be associated with this species in the literature. Bryozoans are common in the MRB, and therefore, this species is not expected to significantly alter community structure or ecosystem function. Overall, the consequences of the establishment of this species in the MRB are low. There are no documented ecological impacts from the introduction of *L. carteri* into the GLB. However, the species does not appear to have been studied extensively. Overall, there is a medium degree of uncertainty regarding the environmental consequences of the freshwater Bryozoan.

B. Economic Consequences

The establishment of *L. carteri* in the MRB is not expected to have economic consequences (see Appendix C). Therefore, this species' consequence rating is none, and the uncertainty of the rating is low.

C. Social/Political Consequences

Although *L. carteri* could be widespread in the MRB, it is not expected to result in any social or political consequences based on its life history and ecology. Therefore, the establishment of *L. carteri* is expected to have no social/political consequence, and the uncertainty of this rating is low.

D. Overall Consequences

Although *L. carteri* may establish in the MRB, it is not expected to result in any significant ecological, economic, or social/political consequences. Therefore, the establishment of *L. carteri* is expected to have low consequences.

IV. Risk of Adverse Impacts

Risk of Adverse Impacts									
	Probability of Establishment[a]					Risk of Adverse Impacts[c]			
Pathway	T_0	T_{10}	T_{25}	T_{50}	Consequences of Establishment[b]	T_0	T_{10}	T_{25}	T_{50}
CAWS 1	L	M	H	H	L	L	L	L	L
CAWS 2	L	M	H	H	L	L	L	L	L
CAWS 3	L	M	H	H	L	L	L	L	L
CAWS 4	L	L	L	M	L	L	L	L	L
CAWS 5	L	L	L	M	L	L	L	L	L

[a] Probability rating elements: H = high probability, the event will almost certainly occur. M = medium probability, the event is likely to occur, but it is not certain; L = low probability, the event will likely not occur.

[b] Consequence ratings: L = Low consequence rating due to the lower number of consequence categories affected, the lesser nature and severity of the consequences, and the more localized extent of the consequences.

[c] Risk ratings: L = low risk of adverse impacts.

CAWS Risk Summary

For CAWS pathways 1, 2, and 3, the probability of establishment ranges from low for T_0 and increases to high at T_{25}, while the probability of establishment is low until T_{50} for CAWS 4 and 5. Although *L. carteri* may establish in the MRB, it is not expected to result in any significant ecological, economic, or social/political consequences. Therefore, the overall risk is low for all pathways and time steps.

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A.2.3 Algae

A.2.3.1 Cryptic Algae - *Cyclotella cryptica*

I. Species Overview

A. Native Range and Current Distribution

Cyclotella cryptica was first recorded in Lake Michigan in 1964 and the Sandusky River (a major tributary of Lake Erie) in 1976. It now also occurs in Lake Ontario, Lake Erie and Lake Huron (Kipp 2011). In the vicinity of the CAWS, this species has been reported in Lake Michigan offshore of Evanston, IL. The native range of *C. cryptica* is unknown, but the species was probably introduced into the Great Lakes by ballast water discharge.

B. Life History and Ecology

C. cryptica is a planktonic diatom that moves passively by flowing water. This species is typically reported in marine and brackish systems, but it has been reported in rivers with suitable conductivity and water quality (Kipp 2011). *C. cryptica* is sensitive to nutrients and conductivity levels and is found in waters with abnormally high chloride concentrations such as harbors and ports (Kipp 2011). This species is capable of surviving heterotrophically on glucose, so cells found on the lake bottom may survive an extended period in low light. *C. cryptica* reproduce through asexual mitotic divisions and is reported to have a generation time ranging from 1.6 to 4 divisions a day depending on environmental conditions (White 1974; Liu & Hellebust 1976; Sriharan et al. 1991).

II. Probability of Establishment

Probability of Establishment

Probability Range for Time Steps 0, 10, 25, and 50 yrs[a,b]

	CAWS 1				CAWS 2				CAWS 3				CAWS 4				CAWS 5			
Probability Element	T0	T10	T25	T50	T0	T10	T25	T50	T0	T10	T25	T50	T0	T10	T25	T50	T0	T10	T25	T50
Pathway	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)
Arrival	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)
Passage	H (H)	H (H)	H (H)	H (H)	H (H)	H (H)	H (H)	H (H)	H (H)	H (H)	H (H)	H (H)	L (L)	L (L)	L (M)	M (M)	L (L)	L (L)	L (M)	M (M)
Colonization	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)
Spread	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)	M (H)
Probability of Establishment	M	M	M	M	M	M	M	M	M	M	M	M	L	L	L	M	L	L	L	M

[a] H = high probability, the event will almost certainly occur; M = medium probability, the event is likely to occur but is not certain to do so; L = low probability, the event will likely not occur but is possible.

[b] Uncertainty associated with each Probability Element is indicated in parentheses. Uncertainty ratings: H = high, little or no data available and rating based on professional judgment; M = good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment; L = low, good data available with no major data gaps; N = none, adequate data available to fully support the probability rating.

C. cryptica has been documented near the CAWS, and has a high probability of entering and passage through the CAWS for pathways 1, 2, and 3 at all time steps. However, passage probability is low for CAWS pathways 4 and 5 until T_{50}, due to lack of vessel traffic and the water flow toward Lake Michigan in the Grand Calumet River and south branch of the Little Calumet River. At T_{50}, passage probability for CAWS 4 and 5 increases to medium. *C. cryptica* is typically a marine and brackish species, but is widely distributed and has been found in the Sandusky River, so there is potential for establishment in the MRB (Kipp 2011). However, the species has been present in Lake Michigan since 1964 and has not yet established in the MRB. Thus, once in the MRB, *C. cryptica* has a medium probability of colonization and spread, depending on whether suitable water quality is present. The overall probability of establishment for CAWS 1, 2, and 3 is medium for all time steps. For CAWS 4 and 5, the probability of establishment is low until T_{50} when it increases to medium.

III. Consequences of Establishment

Consequences of Establishment[a,b]			
Environmental Consequences	Economic Consequences	Social/Political Consequences	Total Overall Consequences
L(L)	N(L)	N(L)	L

[a] L = Low consequence rating due to the lower number of consequence categories affected, the lesser nature and severity of the consequences, and the more localized extent of the consequences; N = no consequences are anticipated.

[b] Uncertainty associated with each of the consequence ratings is indicated in parentheses. L = low uncertainty, good supporting data is available.

A. Environmental Consequences

In the Great Lakes, *C. cryptica* is typical of harbors where high chloride concentrations are present (Kipp 2011). Therefore, industrialized regions of the MRB may be suitable. Because it is not predicted to be widespread in the MRB, any effects of *C. cryptica* are expected to be localized and minimal. *C. cryptica* produce an exudate that may competitively inhibit other phytoplankton (Messina & Baker 1981; Kipp 2011). However, the species has been present in Lake Michigan since 1964 and no adverse impacts to ecosystem structure and function have been reported to result from the introduction of this species. Therefore, the consequences of the establishment of this species in the MRB are low and the uncertainty associated with the environmental consequences of *C. cryptica* is low.

B. Economic Consequences

The establishment of *C. cryptica* in the MRB is not expected to have economic consequences (see Appendix C). Therefore, this species' consequence rating is none, and the uncertainty of the rating is low.

C. Social/Political Consequences

The cryptic algae is not expected to result in any social or political consequences. This species is not expected to be widespread in the MRB. Therefore, the establishment of the cryptic algae is expected to have no social/political consequence, and the uncertainty of this rating is low.

D. Overall Consequences

Although the cryptic algae may establish in the MRB, it is not expected to result in any significant ecological, economic, or social/political consequences. This species is also not expected to be widespread in the MRB, due to its specialized water chemistry requirements. Therefore, the establishment of the cryptic algae is expected to have low consequence and there is a low degree of uncertainty associated with each of the consequence ratings..

IV. Risk of Adverse Impacts

Risk of Adverse Impacts

	Probability of Establishment[a]					Risk of Adverse Impacts[c]			
Pathway	T0	T10	T25	T50	Consequences of Establishment[b]	T0	T10	T25	T50
CAWS 1	M	M	M	M	L	L	L	L	L
CAWS 2	M	M	M	M	L	L	L	L	L
CAWS 3	M	M	M	M	L	L	L	L	L
CAWS 4	L	L	L	M	L	L	L	L	L
CAWS 5	L	L	L	M	L	L	L	L	L

[a] Probability rating elements: M = medium probability, the event is likely to occur, but it is not certain; L = low probability, the event will likely not occur.

[b] Consequence ratings: L = Low consequence rating due to the lower number of consequence categories affected, the lesser nature and severity of the consequences, and the more localized extent of the consequences.

[c] Risk ratings: L = low risk of adverse impacts.

CAWS Risk Summary

For CAWS pathways 1, 2, and 3, the probability of establishment is medium for all time steps, while the probability of establishment is low until T_{50} for CAWS 4 and 5. Although the cryptic algae may establish in the MRB, it is not expected to result in any significant ecological, economic, or social/political consequences. Therefore, the overall risk is low for all pathways and time steps.

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A.2.4 Macrophytes

A.2.4.1 Swamp Sedge - *Carex acutiformis*

I. Species Overview

A. Native Range and Current Distribution

There is an established population of swamp sedge at St. Joseph Lake in South Bend, Indiana (location not hydrologically connected to Lake Michigan) (Cao 2012). The swamp sedge has also been reported from Traverse City Bay (location hydrologically connected to Lake Michigan) in 1998. This record is located approximately 644 km (400 mi) from WPS. There is no data available on the current abundance of the species in the Great Lakes. Swamp sedge is native to Eurasia and Africa and is thought to have spread to North America through hay from Europe. Spread can occur via seeds, rhizomes, and root masses attaching to vessels (Cao 2012).

B. Life History and Ecology

The swamp sedge is a tall perennial sedge that inhabits open swamps, wet open thickets, marsh edges, sedge meadows, and lakeshores (Cao 2012). This species is tolerant of salt (Cao 2011), as well as extremes of soil conditions as long as there is moisture (Evergreen Brick Works). It can occur 0-300 m (0-984 ft) inland from shorelines (Cao 2012). Swamp sedge prefers sun over partial shade (Cao 2012), and is reported to have a very low seed germination rate at shaded sites (Cao 2012). This species forms large, glaucous clones where it is established. Swamp sedge reproduces asexually by rhizomes and clones, as well as sexually by producing floating seeds (Bernard 1990). Under appropriate conditions, this species has high productivity. Fruiting occurs from June through August (Cao 2012).

II. Probability of Establishment

	Probability of Establishment																			
	Probability Range for Time Steps 0, 10, 25, and 50 yrs[a,b]																			
	CAWS 1				CAWS 2				CAWS 3				CAWS 4				CAWS 5			
Probability Element	T0	T10	T25	T50	T0	T10	T25	T50	T0	T10	T25	T50	T0	T10	T25	T50	T0	T10	T25	T50
Pathway	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)
Arrival	L (L)	L (L)	L (L)	L (M)	L (L)	L (L)	L (L)	L (M)	L (L)	L (L)	L (L)	L (M)	L (L)	L (L)	L (L)	L (M)	L (L)	L (L)	L (L)	L (M)
Passage	L (L)	M (M)	M (M)	M (M)	L (L)	M (M)	M (M)	M (M)	L (L)	M (M)	M (M)	M (M)	L (M)	L (M)	M (H)	M (H)	L (M)	L (M)	M (H)	M (H)
Colonization	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)
Spread	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)
Probability of Establishment	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L

[a] H = high probability, the event will almost certainly occur; M = medium probability, the event is likely to occur but is not certain to do so; L = low probability, the event will likely not occur but is possible.

[b] Uncertainty associated with each Probability Element is indicated in parentheses. Uncertainty ratings: H = high, little or no data available and rating based on professional judgment; M = good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment; L = low, good data available with no major data gaps; N = none, adequate data available to fully support the probability rating.

The probability of the swamp sedge becoming established in the MRB is low for all time steps and for all of the CAWS pathways. Each of the CAWS pathways represents a complete hydrologic connection that the swamp sedge could use to access the MRB during all time steps and the potential for colonization and spread within the MRB is considered high if the species was successful in reaching the MRB. However, the probability of arrival to the CAWS entry points is considered low for all pathways and all time steps, resulting in a low overall probability of establishment. The swamp sedge was introduced to the Lake Michigan drainage in 1951. Although it has formed large clonal stands where established, the species does not appear to be aggressively spreading into adjacent habitats. The range of habitats the species inhabits would seem to indicate that it can tolerate a range of environmental conditions as long as moisture and adequate light are present. However, no spread beyond the initial areas of introduction within the GLB have been observed even though the species is reported to be capable of high productivity and can reproduce through a variety of means, including seeds, rhizomes, and clones. Transport of the species within the basin via drifting debris and seeds is possible and suitable climate and habitat conditions are likely to be present in much of the MRB. Consequently, it is anticipated that the species could become widespread within the MRB if invasion is successful.

III. Consequences of Establishment

Consequences of Establishment[a,b]			
Environmental Consequences	Economic Consequences	Social/Political Consequences	Total Overall Consequences
L(H)	L(L)	N(L)	L

[a] L = Low consequence rating due to the lower number of consequence categories affected, the lesser nature and severity of the consequences, and the more localized extent of the consequences; N = no consequences are anticipated.

[b] Uncertainty associated with each of the consequence ratings is indicated in parentheses. L = low uncertainty, good supporting data is available. H = high uncertainty, little or no data available and consequence rating based on professional judgment.

A. Environmental Consequences

Although the swamp sedge has a potential to affect nutrient cycling and displace other species by shading or competing for nutrients, it is anticipated that the effects would be localized and would not significantly alter the ecosystem based upon experience in the areas where the species has become established in the GLB. Therefore the environmental consequences of the swamp sedge becoming established in the MRB are characterized as low. The uncertainty associated with the rating for the environmental consequences of establishment of the swamp sedge is considered to be high.

B. Economic Consequences

Although swamp sedge could be widespread in the MRB, it is not expected to result in any economic consequences based on its life history and ecology (see Appendix C). Therefore, the establishment of swamp sedge is expected to have low economic consequence, and the uncertainty of this rating is low.

C. Social/Political Consequences

Significant social/political consequences are considered unlikely if the swamp sedge was to become established in the MRB, even though distribution of the species could be relatively widespread. The uncertainty associated with the rating for social/political consequences is considered to be low.

D. Overall Consequences

It was determined that establishment of the swamp sedge within the MRB could result in low environmental consequences and would be unlikely to have any significant economic or social/political consequences. Thus, the overall consequences of the establishment of this species in the MRB were determined to be low.

IV. Risk of Adverse Impacts

Risk of Adverse Impacts

	Probability of Establishment[a]					Risk of Adverse Impacts[c]			
Pathway	T_0	T_{10}	T_{25}	T_{50}	Consequences of Establishment[b]	T_0	T_{10}	T_{25}	T_{50}
CAWS 1	L	L	L	L	L	L	L	L	L
CAWS 2	L	L	L	L	L	L	L	L	L
CAWS 3	L	L	L	L	L	L	L	L	L
CAWS 4	L	L	L	L	L	L	L	L	L
CAWS 5	L	L	L	L	L	L	L	L	L

[a] Probability rating elements: L = low probability, the event will likely not occur.

[b] Consequence ratings: L = Low consequence rating due to the lower number of consequence categories affected, the lesser nature and severity of the consequences, and the more localized extent of the consequences.

[c] Risk ratings: L = low risk of adverse impacts.

CAWS Risk Summary

The overall risk of adverse impacts to the MRB basin from the swamp sedge was determined to be low for all CAWS pathways and for all time steps. The probability of this species becoming established in the MRB basin was considered to be low for all time steps even though there is a potential, based upon information about tolerances for environmental conditions, for the species to eventually become widespread in the MRB once established. It is anticipated that environmental and economic consequences would be low and there are unlikely to be any significant social/political consequences for this species.

V. References

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A.2.4.2 Water Chestnut - *Trapa natans*

I. Species Overview

A. Native Range and Current Distribution

The water chestnut currently ranges from Vermont to Virginia (Cao 2011), with a population in southwestern Quebec. The species was first introduced to North America in the 1870s (Cao 2011). Its range is expanding in the Northeast; however, an eradication program in the Chesapeake Bay region has largely eliminated the population in that area (NatureServe 2010). There is a major infestation of the species in Lake Champlain between New York and Vermont. The closest established population of the species to WPS is in Erie County, NY in the Tonawanda Creek in eastern Lake Erie (NatureServe 2010). Water chestnut is native to Europe, Asia and Africa (Cao 2011). The species can disperse by fragmentation, floating rosettes, or the floating of water chestnut fruit to other water bodies (Haber 1999).

B. Life History and Ecology

Water chestnut is an annual plant that grows best in shallow, nutrient-rich lakes and rivers (NBII). The species grows in waters 0.3-3.6 m (0.98-11.8 ft) deep but is most abundant in sheltered water bodies about 2 m (6.6 ft) deep with soft, muddy bottoms (Muenscher 1937; Countryman 1978; Bogucki et al. 1980). It is typically found in waters with a pH of 6.7-8.2 and an alkalinity of 12-128 mg/L of calcium carbonate (NBII). Water chestnut is most abundant in full sun (Hummel & Findlay 2006). The species can create impenetrable mats that severely limit the passage of light into the water (Cao 2011; NatureServe 2010).

Water chestnut reproduces sexually, with pollination occurring in the air or self-pollination occurring before the flower opens (Hummel & Kiviat 2004). The mature fruit sink to the water bottom, its horns anchoring the seed keeping it at suitable water depths (Pemberton 2002). The seeds overwinter at the bottom and germinate in the spring (Pemberton 2002). One seed can give rise to 10 to 15 rosettes, with each rosette capable of producing 15-20 seeds (NBII).

II. Probability of Establishment

	Probability of Establishment																			
	Probability Range for Time Steps 0, 10, 25, and 50 yrs[a,b]																			
	CAWS 1				CAWS 2				CAWS 3				CAWS 4				CAWS 5			
Probability Element	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}
Pathway	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)
Arrival	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)
Passage	L (M)	M (M)	M (M)	M (M)	L (M)	M (M)	M (M)	M (M)	L (M)	M (M)	M (M)	M (M)	L (M)	L (M)	M (H)	M (H)	L (M)	L (M)	M (H)	M (H)
Colonization	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)
Spread	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)
Probability of Establishment	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L

[a] H = high probability, the event will almost certainly occur; M = medium probability, the event is likely to occur but is not certain to do so; L = low probability, the event will likely not occur but is possible.

[b] Uncertainty associated with each Probability Element is indicated in parentheses. Uncertainty ratings: H = high, little or no data available and rating based on professional judgment; M = good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment; L = low, good data available with no major data gaps; N = none, adequate data available to fully support the probability rating.

The probability of establishment for the water chestnut is low across all time steps. Although this species has a high probability of colonization and spread if it were to reach the Mississippi River Basin (MRB), it is unlikely to arrive at southern Lake Michigan as the water chestnut has been in eastern Lake Erie for more than 50 years has not yet spread to other parts of that lake or Lake Michigan. In addition, passage probability is expected to be slowest in CAWS 4 and 5, because in these two pathways water flows into Lake Michigan and there is no vessel traffic that would transport this species, which would limit the potential for movement into the CAWS. This species has a low probability of arrival, and there is a low uncertainty associated with this rating. Therefore, the overall probability of establishment is low for all time steps and pathways.

III. Consequences of Establishment

Consequences of Establishment[a,b]			
Environmental Consequences	Economic Consequences	Social/Political Consequences	Total Overall Consequences
M(L)	M(M)	H(M)	M

[a] H = High consequence rating due to the larger number of consequence categories affected, the nature and severity of the consequences, and the broader spatial extent of the consequences; M = Medium consequence rating due to the number of consequence categories affected, the nature and severity of the consequences, and the spatial extent of the consequences.

[b] Uncertainty rating is indicated in parentheses. L = low uncertainty, good supporting data is available. M = medium uncertainty, good data are available but some data gaps exist; rating based on a mixture of data and professional judgment.

A. Environmental Consequences

Water chestnut is easily spread to new sites and can grow in most freshwater habitat (NatureServe 2010) allowing it to outcompete native submersed and floating plants for sunlight (Cao 2011). This species is also capable of affecting habitat quality by intercepting 95% of incident sunlight (NatureServe 2010), causing low dissolved oxygen levels (Caraco & Cole 2002; Kornijow et al. 2010), and potentially reducing habitat quality for fish and invertebrates (NatureServe 2010). The water chestnut affects feeding and wintering grounds for many ducks by outcompeting native submersed vegetation that is preferred by waterfowl (NatureServe 2010). This species has the potential to spread into warm temperate and subtropical regions of the United States (Pemberton 2002), and may establish in submergent and emergent marshes of the MRB. Therefore, widespread changes in the wetland ecosystem structure and function are possible if this species establishes. Overall, the consequences of establishment are medium for the water chestnut. Several studies have documented changes in plant community abundance and distribution following the introduction of the water chestnut. The species does best in shallow, nutrient-rich lakes and rivers, which are common throughout the MRB. Consequently, uncertainty regarding the environmental consequences of the water chestnut is low.

B. Economic Consequences

The water chestnut could significantly reduce habitat quality for fish and wildlife as well as human users (see Appendix C). Large populations of water chestnut can impede boating by fouling motors and limiting access within the water body. Swimming and beach activity could be affected because of the mat-forming nature of this species and because the seed pods have sharp spines/barbs. Widespread establishment of the water chestnut could produce economic consequences in a number of categories, including loss of consumer surplus and loss of property value, while reductions in recreational boating and fishing which could adversely impact employment, income and tax revenues. For each of these consequence categories, the severity of economic consequences would depend on the extent of species establishment, the resulting impact on existing fisheries resources, and the consequent impact on recreational activity and fishing. The economic consequence is medium with medium uncertainty.

C. Social/Political Consequences

The water chestnut has the potential to affect recreational fishing by reducing habitat quality. The establishment of water chestnut can also impact perceived opportunities for swimming, beach activities, and recreational boating. Large populations of water chestnut can impede boating by fouling motors and limiting access within the water body. Swimming and beach activity could be affected because of mat forming nature of this species and because the seed pods have sharp spines/barbs. The distribution of this species in the MRB could be widespread, as there is abundant suitable wetland habitat. Given its potential consequences and invasiveness, laws and regulations could be implemented to address the spread of this species. Overall, social/political consequences could be high. However, although suitable habitat is present through much of the MRB, the realized spread, and with it the extent of social/political consequences is uncertain. Therefore, uncertainty is medium.

D. Overall Consequences

Water chestnut could outcompete native submersed and floating plants and is capable of affecting habitat quality for fish and wildlife. The water chestnut has the potential to affect recreational fishing by reducing habitat quality. The establishment of water chestnut can also impact swimming, beach activities, and recreational boating. The water chestnut may establish widely in the submergent and emergent marshes of the MRB. Therefore, significant and widespread changes in the wetland ecosystem structure and function are possible if this species establishes. Overall, the consequences of establishment are medium for the water chestnut. However, these consequences are unlikely to occur over the next 50 years, because the water chestnut has a low probability of arriving at the CAWS during that time period.

IV. Risk of Adverse Impacts

Risk of Adverse Impacts									
	Probability of Establishment[a]					Risk of Adverse Impacts[c]			
Pathway	T_0	T_{10}	T_{25}	T_{50}	Consequences of Establishment[b]	T_0	T_{10}	T_{25}	T_{50}
CAWS 1	L	L	L	L	M	L	L	L	L
CAWS 2	L	L	L	L	M	L	L	L	L
CAWS 3	L	L	L	L	M	L	L	L	L
CAWS 4	L	L	L	L	M(	L	L	L	L
CAWS 5	L	L	L	L	M	L	L	L	L

[a] Probability rating elements: L = low probability, the event will likely not occur.

[b] Consequence ratings: M = Medium consequence rating due to the number of consequence categories affected, the nature and severity of the consequences, and the spatial extent of the consequences.

[c] Risk ratings: L = low risk of adverse impacts.

CAWS Risk Summary

If the water chestnut were to pass through the CAWS into the MRB, it has a high probability of colonizing and spreading. If the water chestnut does establish in the MRB, environmental, economic, and social/political consequences could result, giving this species an overall consequence rating of medium. However, the water chestnut is not expected to arrive at the CAWS during the 50 year period of analysis, and, consequently, there is a low probability of establishment for all time steps and pathways. The risk of adverse impacts from the water chestnut is low for all time steps and CAWS pathways, because of the low probability of establishment.

V. References

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A.2.5 Molluscs

A.2.5.1 Greater European Peaclam - *Pisidium amnicum*

I. Species Overview

A. Native Range and Current Distribution

Pisidium amnicum was first recorded in the Great Lakes drainage in 1897 near the mouth of the Genesee River at Lake Ontario (Kipp & Benson 2011; Grigorovich et al. 2003). It now also occurs in Lakes Ontario, Huron, Erie, Michigan, and Superior, as well as Lake Champlain and in the Hudson and St. Lawrence Rivers (Kipp & Benson 2011). The specific location of the species in relation to the CAWS is unknown; however, it may occur in inland waters of the GLB. The native range of *P. amnicum* is widely distributed in Eurasia and North Africa – spanning between Naples, Siberia, and Algiers (Kipp & Benson 2011). This species was likely introduced to the Great Lakes in solid ballast, a method used in the early 1900s by ships entering the Great Lakes (Kipp & Benson 2011).

B. Life History and Ecology

P. amnicum is a small, sediment-dwelling invertebrate. It is found in freshwater lakes and slow-moving rivers with soft bottoms (Kipp & Benson 2011). In its native range, the species is typically rheophilic, but it can also occur in lakes (Kipp & Benson 2011). It prefers water temperature ranges from 1-21°C (33.8-69.8°F) [but can survive for 200 days in 0°C (32°F)], and prefers sand but has been found on mud and gravel (Kipp & Benson 2011). The species occurs down to 30 m (98.4 ft) in Europe, but only down to 10 m (32.8 ft) in the Great Lakes (Kipp & Benson 2011; Mackie et al. 1980). *P. amnicum* can survive anoxic conditions under ice cover, but it may be limited in some upper river reaches where temperatures do not exceed 15-17°C (59-62.6°F) (Kipp & Benson 2011). This species is generally sensitive to organic pollution (Mouthon 1996).

P. amnicum is a filter feeder, consuming primarily algae and bacteria; diatoms are particularly favored by the species (Kipp & Benson 2011). This species has low fecundity, producing a few dozen offspring per year at most (Keller et al. 2007). *P. amnicum* is hermaphroditic, ovoviviparous, and can undergo cross-fertilization (Kipp & Benson 2011). Eggs are laid between July and October and are brooded for 9-10 months (Kipp & Benson 2011). In the St. Lawrence River, this species is iteroparous, reproducing once at age 2 and again at age 3 (Kipp & Benson 2011); however, most fertilized eggs of adults reproducing for the second time die because of the limited life span of the adults (Araujo & Ramos 1999). Individuals of this species typically live between 1-3 years (Kipp & Benson 2011).

II. Probability of Establishment

Probability of Establishment																				
	Probability Range for Time Steps 0, 10, 25, and 50 years[a,b]																			
	CAWS 1				CAWS 2				CAWS 3				CAWS 4				CAWS 5			
Probability Element	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}
Pathway	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)
Arrival	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)
Passage	L (H)	L (H)	L (H)	M (H)	L (H)	L (H)	L (H)	M (H)	L (H)	L (H)	L (H)	M (H)	L (L)	L (L)	L (M)	M (M)	L (L)	L (L)	L (M)	M (M)
Colonization	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)
Spread	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)
Probability of Establishment	L	L	L	M	L	L	L	M	L	L	L	M	L	L	L	M	L	L	L	M

[a] H = high probability, the event will almost certainly occur; M = medium probability, the event is likely to occur but is not certain to do so; L = low probability, the event will likely not occur but is possible.

[b] Uncertainty associated with each Probability Element is indicated in parentheses. Uncertainty ratings: H = high, little or no data available and rating based on professional judgment; M = good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment; L = low, good data available with no major data gaps; N = none, adequate data available to fully support the probability rating.

The probability of the greater European peaclam becoming established in the MRB is low for time steps T_0 through T_{25} and medium for T_{50} for all of the CAWS pathways. Each of the CAWS pathways provide a complete hydrologic connection that the greater European peaclam could use to access the MRB during all time steps. However, the arrival and passage through the CAWS pathways prior to T_{50} is considered to have a low probability; the species has been established in Lake Michigan for at least two decades and has not spread into the CAWS suggesting a slow dispersal rate. The greater European peaclam was first observed in the Lake Ontario drainage in 1897 and has since spread to most of the Great Lakes, indicating that it can tolerate a wide range of environmental conditions. Even though the spread of this species within the GLB has progressed relatively slowly and the species has a low fecundity, suitable climate and habitat conditions are likely to be present in much of the MRB; consequently, it is anticipated that the species is likely to eventually become widespread within the MRB if invasion is successful.

III. Consequences of Establishment

Consequences of Establishment[a,b]			
Environmental Consequences	Economic Consequences	Social/Political Consequences	Total Overall Consequences
L(M)	N(L)	N(L)	L

[a] L = Low consequence rating due to the lower number of consequence categories affected, the lesser nature and severity of the consequences, and the more localized extent of the consequences; N = no consequences are anticipated.

[b] Uncertainty associated with each of the consequence ratings is indicated in parentheses. L = low uncertainty, good supporting data is available. M = medium uncertainty, good data are available but some data gaps exist; rating based on a mixture of data and professional judgment;

A. Environmental Consequences

The greater European peaclam has a potential to affect ecosystems due to competition with other benthic organisms. The species can reach high densities (Holopainen & Jonasson 1989) and has the potential to crowd out some native benthic macroinvertebrates. However, even though the greater European peaclam has become relatively widespread within the GLB and has developed relatively high densities in some areas, the long-term presence of this species does not appear to have been implicated in significant ecosystem changes. Thus, even if it is assumed that the species becomes widely established within the MRB, it is anticipated that the environmental consequences would be low. The uncertainty associated with the rating for the environmental consequences of establishment for this species is considered to be medium.

B. Economic Consequences

The establishment of the greater European peaclam in the MRB is not expected to have economic consequences (see Appendix C). Therefore, this species' consequence rating is none, and the uncertainty of the rating is low.

C. Social/Political Consequences

No social/political consequences are considered likely if the greater European peaclam becomes established in the MRB, even though distribution of the species could be widespread. The uncertainty associated with the rating for social/political consequences is considered to be low.

D. Overall Consequences

It was determined that widespread establishment of the greater European peaclam would result in low environmental and economic consequences and would not have any significant social/political consequences. Thus, even though the probability of this species becoming established in the MRB basin is considered moderate at the T_{50} time step, the overall consequences of the establishment of this species in the MRB is determined to be low.

IV. Risk of Adverse Impacts

Risk of Adverse Impacts

	Probability of Establishment[a]					Risk of Adverse Impacts[c]			
Pathway	T_0	T_{10}	T_{25}	T_{50}	Consequences of Establishment[b]	T_0	T_{10}	T_{25}	T_{50}
CAWS 1	L	L	L	M	L	L	L	L	L
CAWS 2	L	L	L	M	L	L	L	L	L
CAWS 3	L	L	L	M	L	L	L	L	L
CAWS 4	L	L	L	M	L	L	L	L	L
CAWS 5	L	L	L	M	L	L	L	L	L

[a] Probability rating elements: H=high probability, the event will almost certainly occur.

[b] Consequence ratings: L = Low consequence rating due to the lower number of consequence categories affected, the lesser nature and severity of the consequences, and the more localized extent of the consequences.

[c] Risk ratings: L = low risk of adverse impacts.

CAWS Risk Summary

The probability of this species becoming established in the MRB basin is considered low for T_0 through T_{25} and medium for T_{50} for all CAWS pathways; it is considered likely that the species would ultimately become widespread in the MRB once established. Environmental and economic consequences would be low and there are unlikely to be any significant social/political consequences for this species. Therefore, the overall risk of adverse impacts on the MRB from the greater European peaclam is determined to be low for all CAWS pathways and for all time steps.

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A.2.5.2 European Fingernail Clam - *Sphaerium corneum*

I. Species Overview

A. Native Range and Current Distribution

The European fingernail clam was first recorded in the Great Lakes in Lake Ontario in 1924; it is now found in all of the Great Lakes (Kipp et al. 2012). The species is most common in Lake Erie and Lake Ontario, but is uncommon in Lake Huron (Kipp et al. 2012). The species has been listed as established in Lake Michigan since 1980 (Mackie et al. 1980), but its current distribution in the lake is unknown. The European fingernail clam has also been found in Lake Champlain and the Hudson River (Kipp et al. 2012). The species is native to Eurasia (Kipp et al. 2012), and was probably introduced to the Great Lakes via solid ballast, a method used in the early 1900s by ships entering the Great Lakes (Kipp et al. 2012).

B. Life History and Ecology

The European fingernail clam is found in freshwater lakes and slow-moving rivers (Boycott 1936), but prefers eutrophic, shallow waters 0-1.5 m (0-4.9 ft) deep and temperatures ranging from 2 to 25°C (35.6-77°F) (Kipp et al. 2012; Holopainen & Penttinen 1993). The species has been found at depths of 10 m (32.8 ft) in Lake Michigan (Kipp et al. 2012). It is found on fine sand, mud, silt, organic matter, and occasionally on gravel (Kipp et al. 2012). The species is more common in hard waters, with HCO_3^-, K^+, Cl^-, Mg^{2+}, temperature, and Ca^{2+} being significant in determining presence (Dussart 1979). The species prefers areas with vegetation and is often found among submerged vegetation instead of soft sediment (Watson & Ormerod 2005).

The European fingernail clam is mainly a filter feeder that consumes diatoms and other phytoplankton; however, it can also feed on organic materials on substrates (Kipp et al. 2012). The species reproduces in the spring. Adults typically carry 6-7 embryos (Boycott 1936), although numbers as high as 30 embryos have been reported (Kipp et al. 2012; Boycott 1936). Individuals can live up to 3 years and reach maturity at 4 mm (0.2 in.), which can be as young as 3 months of age (Kipp et al. 2012). Densities as high as 62 clams/m^2 have been reported from Lake Superior, while densities as high as 500-8,000 clams/m^2 have been observed in the St. Lawrence River (Kipp et al. 2012).

II. Probability of Establishment

Probability Element	Probability of Establishment																			
	Probability Range for Time Steps 0, 10, 25, and 50 yr[a,b]																			
	CAWS 1				CAWS 2				CAWS 3				CAWS 4				CAWS 5			
	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}
Pathway	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)
Arrival	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)
Passage	H (H)	H (H)	H (M)	H (M)	H (H)	H (H)	H (M)	H (M)	H (H)	H (H)	H (M)	H (M)	H (H)	H (H)	H (M)	H (M)	H (H)	H (H)	H (M)	H (M)
Colonization	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)
Spread	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)
Probability of Establishment	H	H	H	H	H	H	H	H	H (H)	H (H)	H (M)	H (M)	H	H	H	H	H	H	H	H

[a] H = high probability, the event will almost certainly occur; M = medium probability, the event is likely to occur but is not certain to do so; L = low probability, the event will likely not occur but is possible.

[b] Uncertainty associated with each Probability Element is indicated in parentheses. Uncertainty ratings: H = high, little or no data available and rating based on professional judgment; M = good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment; L = low, good data available with no major data gaps; N = none, adequate data available to fully support the probability rating.

The probability of the European fingernail clam becoming established in the MRB is high for all time steps and for all of the CAWS pathways. Each of the CAWS pathways represents a complete route that the European fingernail clam could use to access the MRB during all time steps. The European fingernail clam was introduced to Lake Ontario in 1924 and has since spread to all of the Great Lakes, indicating that it can tolerate a wide range of environmental conditions. Presence of this species at the downstream extent of the CAWS pathways has been confirmed. Even though the spread of this species within the GLB has progressed relatively slowly, the species has a low fecundity, and transport of the species within the basin via vessel hulls and drifting debris is not considered to be very likely. Suitable climate and habitat conditions are likely to be present in much of the MRB; consequently, it is anticipated that the species is likely to eventually become widespread within the MRB if invasion is successful.

III. Consequences of Establishment

Consequences of Establishment[a,b]			
Environmental Consequences	Economic Consequences	Social/Political Consequences	Total Overall Consequences
L(M)	N(L)	N(L)	L

[a] L = Low consequence rating due to the lower number of consequence categories affected, the lesser nature and severity of the consequences, and the more localized extent of the consequences; N = no consequences are anticipated.

[b] Uncertainty associated with each of the consequence ratings is indicated in parentheses. L = low uncertainty, good supporting data is available. M = medium uncertainty, good data are available but some data gaps exist; rating based on a mixture of data and professional judgment.

A. Environmental Consequences

The European fingernail clam has a potential to affect ecosystems due to competition with native species of fingernail clams and perhaps other benthic species. However, even though the European fingernail clam has a relatively wide distribution within the GLB and has developed relatively high densities in some areas, the long-term presence of this species does not appear to have been implicated in significant ecosystem changes. Thus, even if it is assumed that the species becomes widely established within the MRB, it is anticipated that the environmental consequences would be low. However, there are few studies of this species and its environmental impacts. Therefore, the uncertainty associated with the rating for the environmental consequences of establishment is considered to be medium.

B. Economic Consequences

The establishment of the greater European fingernail clam in the MRB is not expected to have economic consequences (see Appendix C). Therefore, this species' consequence rating is none, and the uncertainty of the rating is low.

C. Social/Political Consequences

No significant social/political consequences are considered likely if the European fingernail clam were to become established in the MRB, even though distribution of the species could be widespread. The uncertainty associated with the rating for social/political consequences is considered to be low.

D. Overall Consequences

It was determined that widespread establishment of the European fingernail clam would result in low environmental consequences and would not have any significant economic or social/political consequences. Thus, even though the probability of this species becoming established in the MRB was considered high for all time steps, the overall consequences of the establishment of this species in the MRB was determined to be low.

IV. Risk of Adverse Impacts

Risk of Adverse Impacts

	Probability of Establishment[a]					Risk of Adverse Impacts[c]			
Pathway	T_0	T_{10}	T_{25}	T_{50}	Consequences of Establishment[b]	T_0	T_{10}	T_{25}	T_{50}
CAWS 1	H	H	H	H	L	L	L	L	L
CAWS 2	H	H	H	H	L	L	L	L	L
CAWS 3	H	H	H	H	L	L	L	L	L
CAWS 4	H	H	H	H	L	L	L	L	L
CAWS 5	H	H	H	H	L	L	L	L	L

[a] Probability rating elements: H=high probability, the event will almost certainly occur.

[b] Consequence ratings: L = Low consequence rating due to the lower number of consequence categories affected, the lesser nature and severity of the consequences, and the more localized extent of the consequences.

[c] Risk ratings: L = low risk of adverse impacts.

CAWS Risk Summary

Even though the probability of this species becoming established in the MRB was considered high for all time steps and it is considered likely that the species would eventually become widespread in the MRB once established, it was determined that environmental consequences would be low and any significant economic or social/political consequences for this species are unlikely. Therefore, the overall risk of adverse impacts to the MRB from the European fingernail clam was determined to be low for all CAWS pathways and for all time steps.

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A.2.5.3 European Stream Valvata - *Valvata piscinalis*

I. Species Overview

A. Native Range and Current Distribution

Valvata piscinalis was introduced to Lake Ontario in 1897 (Kipp & Benson 2011). Within 40 years, it had dispersed to Lake Erie, the St. Lawrence River, Hudson River, Lake Champlain, and Cayuga Lake (Kipp & Benson 2011). In the 1990s and 2000s, *V. piscinalis* was reported in Superior Bay of Lake Superior (Minnesota), Lake Michigan (Wisconsin), and Oneida Lake (New York) (Kipp & Benson 2011). In 2002, the species was discovered in soft-bottomed sediment in the southern basin of Lake Michigan. The species is currently established in all of the Great Lakes except Lake Huron (Grigorovich et al. 2005). Shipping traffic is thought to have facilitated the spread of the species across the Great Lakes (Grigorovich et al. 2005). *V. piscinalis* is native to Europe, the Caucasus, western Siberia, and central Asia (Kipp & Benson 2011). In Europe, the species ranges from the arctic to southern arid zones (Grigorovich et al. 2005).

B. Life History and Ecology

V. piscinalis is a small snail that is found in a wide range of substrate types (mud, silt, sand) in freshwater lakes and streams (Kipp & Benson 2011). This species has wide environmental tolerances, including temperature ranges, and has been found to be tolerant of organic pollution (Grigorovich et al. 2005; Mouthon & Daufresne 2006; Sereflisan et al. 2009). In the Great Lakes, the species has been found in depths of 0.5-23 m (1.64-75.5 ft) (Kipp & Benson 2011), with maximum densities observed in shallower waters with depths of 3.7-4.4 m (12.1-14.4 ft) (Grigorovich et al. 2005). *V. piscinalis* does not require warmer temperatures to survive (Grigorovich et al. 2005) and can overwinter in mud (Kipp & Benson 2011).

V. piscinalis is an efficient feeder that grazes on epiphytic algae and detritus and can filter-feed on suspended organic matter and algae (Grigorovich et al. 2005). Adults can also rasp off aquatic vegetation (Kipp & Benson 2011); newborns scrape diatoms from aquatic plants (Ducrot et al. 2006). Adults mate in the sediment and lay eggs on aquatic plants or on stones (Ducrot et al. 2006; Mouthon & Daufresne 2008). *V. piscinalis* can spawn 2-3 times a year, with breeding occurring from April-September in Europe (Kipp & Benson 2011). The species has high fecundity and a single individual can lay 10 capsules, each containing 5-60 eggs (Mouthon & Daufresne 2008). Individuals typically reach maturity at one year of age (Kipp & Benson 2011), but can become reproductive after only 56 days at water temperatures of 21°C (69.8°F) or 8 months at 19°C (66.2°F)] (Ducrot et al. 2006).

II. Probability of Establishment

Probability Element	Probability of Establishment																			
	Probability Range for Time Steps 0, 10, 25, and 50 years[a,b]																			
	CAWS 1				CAWS 2				CAWS 3				CAWS 4				CAWS 5			
	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}
Pathway	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)
Arrival	L (L)	L (M)	L (M)	M (M)	L (M)	M (M)	M (M)	H (L)	L (M)	M (M)	M (M)	H (L)	L (M)	M (M)	M (M)	H (L)	L (M)	M (M)	M (M)	H (L)
Passage	L (L)	L (M)	M (M)	H (M)	L (H)	M (H)	M (M)	H (L)	L (H)	M (H)	M (M)	H (L)	L (L)	L (M)	M (M)	H (M)	L (L)	L (M)	M (M)	H (M)
Colonization	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)
Spread	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)
Probability of Establishment	L	L	L	M	L	M	M	H	L	M	M	H	L	L	M	H	L	L	M	H

[a] H = high probability, the event will almost certainly occur; M = medium probability, the event is likely to occur but is not certain to do so; L = low probability, the event will likely not occur but is possible.

[b] Uncertainty associated with each Probability Element is indicated in parentheses. Uncertainty ratings: H = high, little or no data available and rating based on professional judgment; M = good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment; L = low, good data available with no major data gaps; N = none, adequate data available to fully support the probability rating.

The probability of the European stream valvata becoming established in the MRB via all CAWS pathways is low for T_0. The probability of establishment increases to medium by T_{50} for the CAWS 1 pathway and increases to high by T_{50} for the CAWS 2, 3, 4, and 5 pathways. Differences are related to the presence of commercial boat traffic and distance from existing known occurrences of the European stream valvata in Lake Michigan, which increases the potential for arrival of this species. Each of the CAWS pathways provides a complete hydrologic connection that the European stream valvata could use to access the MRB during all time steps. The species has been present in southern Lake Michigan since at least 2002 and has not yet been reported from the CAWS pathways. The European stream valvata is now present in most of the Great Lakes, indicating that it can tolerate a wide range of environmental conditions. Even though the spread of this species within the GLB has apparently progressed relatively slowly, the species has a moderate fecundity and suitable climate and habitat conditions are likely to be present in much of the MRB; consequently, it is anticipated that the species is likely to eventually become widespread within the MRB if invasion is successful.

III. Consequences of Establishment

Consequences of Establishment[a,b]			
Environmental Consequences	Economic Consequences	Social/Political Consequences	Total Overall Consequences
L(M)	N(L)	N(L)	L

[a] L = Low consequence rating due to the lower number of consequence categories affected, the lesser nature and severity of the consequences, and the more localized extent of the consequences; N = no consequences are anticipated.

[b] Uncertainty associated with each of the consequence ratings is indicated in parentheses. L = low uncertainty, good supporting data is available. M = medium uncertainty, good data are available but some data gaps exist; rating based on a mixture of data and professional judgment.

A. Environmental Consequences

The European stream valvata has a potential to affect ecosystems due to competition with other benthic organisms and, potentially with ESA-listed gastropods within the MRB. However, even though the European stream valvata has become relatively widespread within the GLB and has developed relatively high densities in some areas, the long-term presence of this species does not appear to have been implicated in significant ecosystem changes in the GLB. Thus, even if it is assumed that the species becomes widely established within the MRB, it is anticipated that the environmental consequences would be low. The uncertainty associated with the rating for the environmental consequences of establishment for this species is considered to be medium.

B. Economic Consequences

The establishment of the European stream valvata in the MRB is not expected to have economic consequences (see Appendix C). Therefore, this species' consequence rating is none, and the uncertainty of the rating is low.

C. Social/Political Consequences

No social/political consequences are considered likely if the European stream valvata becomes established in the MRB, even though distribution of the species could be widespread. The uncertainty associated with the rating for social/political consequences is considered to be low.

D. Overall Consequences

It was determined that widespread establishment of the European stream valvata could result in low environmental consequences and would not have any significant economic or social/political consequences. Thus, even though the probability of this species becoming established in the MRB was considered moderate to high at the T_{50} time step, depending upon which CAWS pathway is being considered, the overall consequences of the establishment of this species in the MRB is determined to be low.

IV. Risk of Adverse Impacts

Risk of Adverse Impacts

	Probability of Establishment[a]					Risk of Adverse Impacts[c]			
Pathway	T_0	T_{10}	T_{25}	T_{50}	Consequences of Establishment[b]	T_0	T_{10}	T_{25}	T_{50}
CAWS 1	L	L	L	M	L	L	L	L	L
CAWS 2	L	M	M	H	L	L	L	L	L
CAWS 3	L	M	M	H	L	L	L	L	L
CAWS 4	L	L	M	H	L	L	L	L	L
CAWS 5	L	L	M	H	L	L	L	L	L

[a] Probability rating elements: H=high probability, the event will almost certainly occur.

[b] Consequence ratings: L = Low consequence rating due to the lower number of consequence categories affected, the lesser nature and severity of the consequences, and the more localized extent of the consequences.

[c] Risk ratings: L = low risk of adverse impacts.

CAWS Risk Summary

The probability of this species becoming established in the MRB is considered low via all CAWS pathways for T_0. The probability of establishment increases to medium by T_{50} for the CAWS 1 pathway and increases to high by T_{50} for the CAWS 2, 3, 4, and 5 pathways. It is considered likely that the species would ultimately become widespread in the MRB if it becomes established. However, it is determined that environmental consequences would be low and there are unlikely to be any significant economic or social/political consequences for this species. Therefore, the overall risk of adverse impacts on the MRB from the European stream valvata is determined to be low for all CAWS pathways and for all time steps.

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A.2.6 Crustaceans

A.2.6.1 Waterflea - *Daphnia galeata galeata*

I. Species Overview

A. Native Range and Current Distribution

Daphnia galeata galeata was likely introduced to Lake Erie in the 1970s or 1980s, it has not yet reached Lake Michigan (Kipp 2011). Hybrid *D. g. mendotae* x *D. g. galeata* was first noticed in the early 1990s in Lake Erie & outlying areas of the Lake Ontario watershed, in Onondaga Lake, Oneida Lake, and Grenadier Pond, Toronto (Taylor & Hebert 1993; Kipp 2011). The species has a near-cosmopolitan distribution and is native to the Palearctic region. *D. g. galeata* was very likely introduced to the GLB by ballast water (Taylor & Hebert 1993).

B. Life History and Ecology

D. g. galeata is a small waterflea that moves actively (vertical migration) and passively (by currents). Eggs can be attached to the adult or found in the sediment (Kipp 2011), in which case they could be transported passively by strong currents that disturb the sediment. Cladocerans are capable of reproducing asexually through parthenogenesis. The life cycle of this species is dominated by asexual reproduction, with sexual reproduction occurring during certain times of the year (Weider 1993). They can also produce resting eggs that are able to survive periods of desiccation in the sediment (Taylor & Hebert 1993). Average clutch size was 2.66 ± 0.86 and egg development time in days was 7.98 ± 3.46 (Maier 1996).

D. g. galeata is characteristic of large, eutrophic lakes, but can also be found in ponds and even slow running rivers (Dumont & Negrea 1996; Kipp 2011); they are occasionally found in hyporheic water (Dumont & Negrea 1996). In Lake Erie, it was found in nearshore areas (Kipp 2011). Most daphnids prefer large lakes (Kipp 2011) and crowding by other zooplankton can reduce growth (Burns 2000). Optimal growth of this species occurs at 20°C (68°F) (Weider 1993). Within the water column, *Daphnia spp*. are generalist filter feeders on small particles and more selective feeders on larger particles (Kipp 2011). Particle size selection varies with body size (Kipp 2011; Repka 1997).

II. Probability of Establishment

Probability Element	CAWS 1 T_0	CAWS 1 T_{10}	CAWS 1 T_{25}	CAWS 1 T_{50}	CAWS 2 T_0	CAWS 2 T_{10}	CAWS 2 T_{25}	CAWS 2 T_{50}	CAWS 3 T_0	CAWS 3 T_{10}	CAWS 3 T_{25}	CAWS 3 T_{50}	CAWS 4 T_0	CAWS 4 T_{10}	CAWS 4 T_{25}	CAWS 4 T_{50}	CAWS 5 T_0	CAWS 5 T_{10}	CAWS 5 T_{25}	CAWS 5 T_{50}
Probability of Establishment — Probability Range for Time Steps 0, 10, 25, and 50 years[a,b]																				
Pathway	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)
Arrival	L (L)	L (L)	M (H)	M (H)	L (L)	L (L)	M (H)	M (H)	L (L)	L (L)	M (H)	M (H)	L (L)	L (L)	M (H)	M (H)	L (L)	L (L)	M (H)	M (H)
Passage	H (M)	H (L)	H (L)	H (L)	H (M)	H (L)	H (L)	H (L)	H (M)	H (L)	H (L)	H (L)	L (L)	L (L)	L (H)	M (H)	L (L)	L (L)	L (H)	M (H)
Colonization	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)
Spread	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)
Probability of Establishment	L	L	M	M	L	L	M	M	L	L	M	M	L	L	L	M	L	L	L	M

[a] H = high probability, the event will almost certainly occur; M = medium probability, the event is likely to occur but is not certain to do so; L = low probability, the event will likely not occur but is possible.

[b] Uncertainty associated with each Probability Element is indicated in parentheses. Uncertainty ratings: H = high, little or no data available and rating based on professional judgment; M = good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment; L = low, good data available with no major data gaps; N = none, adequate data available to fully support the probability rating.

Each of the five CAWS pathways represent a completed pathway which *D. g. galeata* could use to access the Mississippi River Basin (MRB), and each will be available at all time steps. *D. g. galeata* has been established in Lake Erie, far from any of the CAWS pathways since 1980. Regardless of pathway there is a low probability of arrival within the next 10 years, a medium probability at 25 years, and a high probability within 50 years, uncertainty increases with time.

The waterflea may readily enter CAWS 1-3 and move downstream primarily using natural transport (downstream drift) passage may occur at any time step. In CAWS 4 and 5, normal flow at the Lake Michigan end of each of these pathways is into the lake. Thus, movement into and passage through either of these pathways is unlikely within 0-25 years, but given 50 years this species may be able to naturally move into these pathways and on to Brandon Road Lock and Dam and beyond. The uncertainty associated with passage through CAWS 4 and 5 increases to high over time. Suitable habitat exists below Brandon Road Lock and Dam and beyond in the MRB, and *D. g. galeata* may be expected to reach these habitats, become established, and spread to other parts of the basin with low uncertainty.

III. Consequences of Establishment

Consequences of Establishment[a,b]			
Environmental Consequences	Economic Consequences	Social/Political Consequences	Total Overall Consequences
L(L)	N(L)	N(L)	L

[a] L = Low consequence rating due to the lower number of consequence categories affected, the lesser nature and severity of the consequences, and the more localized extent of the consequences; N = no consequences are anticipated.

[b] Uncertainty associated with each of the consequence ratings is indicated in parentheses. L = low uncertainty, good supporting data is available.

A. Environmental Consequences

D. g. galeata have hybridized in Lake Erie with *D. g. mendoatae*, the resultant clones are very common (Taylor & Hebert 1993). *Daphnia* hybrids tend to have greater variation in relative niche breadths (Weider 1993). It has been suggested that the clones may be more fit than either parent clone (Taylor & Hebert 1993), potentially allowing them to outcompete native zooplankton. However, it is unknown whether *D. g. galeata* can hybridize with daphnids in the MRB. If this species does establish in the MRB, it would fill an ecological niche similar to existing zooplankton and is not expected to result in ecosystem changes. This species does not appear to have adversely affected the ecosystem structure and function after its establishment in the GLB. Therefore, the ecological consequences of establishment and the associated uncertainty are low.

B. Economic Consequences

The establishment of *D. g. galeata* in the MRB is not expected to have economic consequences (see Appendix C). Therefore, this species' consequence rating is none, and the uncertainty of the rating is low.

C. Social/Political Consequences

There are no consequences based on human use or political regulatory concerns for *D. g. galeata*.

D. Overall Consequences

It was determined that widespread establishment of *D. g. galeata* could result in low environmental consequences and would not have any significant economic or social/political consequences. Thus, even though the probability of this species becoming established in the MRB was considered medium at time step 50, the overall consequences of the establishment of this species in the MRB was determined to be low.

IV. Risk of Adverse Impacts

Risk of Adverse Impacts									
	Probability of Establishment[a]					Risk of Adverse Impacts[c]			
Pathway	T_0	T_{10}	T_{25}	T_{50}	Consequences of Establishment[b]	T_0	T_{10}	T_{25}	T_{50}
CAWS 1	L	L	M	M	L	L	L	L	L
CAWS 2	L	L	M	M	L	L	L	L	L
CAWS 3	L	L	M	M	L	L	L	L	L
CAWS 4	L	L	L	M	L	L	L	L	L
CAWS 5	L	L	L	M	L	L	L	L	L

[a] Probability rating elements: M = medium probability, the event is likely to occur, but it is not certain; L = low probability, the event will likely not occur.

[b] Consequence ratings: L = Low consequence rating due to the lower number of consequence categories affected, the lesser nature and severity of the consequences, and the more localized extent of the consequences.

[c] Risk ratings: L = low risk of adverse impacts.

CAWS Risk Summary

Regardless of the pathway considered, the consequences of *D. g. galeata* establishment could be low. Therefore, the risks of adverse impacts from the establishment of *D. g. galeata* in the MRB are considered low for all CAWS pathways.

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A.2.6.2 Parasitic Copepod - *Neoergasilus japonicas*

I. Species Overview

A. Native Range and Current Distribution

Neoergasilus japonicas has been documented in Saginaw Bay in Lake Huron for three decades and has not spread to other areas of Lake Huron. In 2011, several specimens were found on green sunfish and bluegill in an Ottawa National Wildlife Refuge wetland of Crane Creek, adjacent to Lake Erie and east of Toledo, Ohio (Kipp et al. 2012). No recent surveys of fish in Lake Michigan were found, so the species' distance from the pathway is not well documented. Suitable habitat is present in southern Lake Michigan near the WPS pathway entrance. *N. japonicas* is native to eastern Asia and the means of introduction to North America are unknown. However, it could have occurred through ballast water (Hudson & Bowen 2002).

B. Life History and Ecology

N. japonicas is a freshwater species of eutrophic and polluted aquatic environments (Kipp et al. 2012). Larvae, males, and immature females do not live as parasites and are free living in the water column (Hayden & Rogers 1998). They feed on algae and zooplankton (Hudson & Bowen 2002; Baud et al. 2004). Only ovigerous females require a freshwater fish host. They usually attach to adult fish hosts (Hudson & Bowen 2002; Jordan et al. 2009), most frequently to the dorsal fin (Hudson & Bowen 2002) where they feed on fish tissue. Host fishes include largemouth bass, smallmouth bass, bluegill, redear sunfish, pumpkinseed, yellow perch, green sunfish, rock bass, channel catfish, common carp, goldfish, and fathead minnows (Hayden & Rogers 1998; Hudson & Bowen 2002; Kipp et al. 2012).

This species has a rapid reproductive cycle with females capable of producing 1,500-2,000 eggs over their lifetime (Kipp et al. 2012). After hatching, the larvae pass through 6 nauplius stages and around 5 copepodid stages before reaching the adult stage (Kipp et al. 2012). Development to sexual maturity occurs in less than 21 days (Hudson & Bowen 2002). Sexual maturity is attained more quickly at temperatures of 30°C (86°F) than at 20°C (68°F) (Kipp et al. 2012). Population levels slow during the cold winter months, but increase in the spring (Kipp et al. 2012).

II. Probability of Establishment

Probability of Establishment																				
	Probability Range for Time Steps 0, 10, 25, and 50 years[a,b]																			
	CAWS 1				CAWS 2				CAWS 3				CAWS 4				CAWS 5			
Probability Element	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}
Pathway	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)
Arrival	L (H)	L (H)	M (M)	H (L)	L (H)	L (H)	M (M)	H (L)	L (H)	L (H)	M (M)	H (L)	L (H)	L (H)	M (M)	H (L)	L (H)	L (H)	M (M)	H (L)
Passage	H (M)	H (L)	H (L)	H (L)	H (M)	H (L)	H (L)	H (L)	H (M)	H (L)	H (L)	H (L)	H (M)	H (L)	H (L)	H (L)	H (M)	H (L)	H (L)	H (L)
Colonization	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)
Spread	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)
Probability of Establishment	L	L	M	H	L	L	M	H	L	L	M	H	L	L	M	H	L	L	M	H

[a] H = high probability, the event will almost certainly occur; M = medium probability, the event is likely to occur but is not certain to do so; L = low probability, the event will likely not occur but is possible.

[b] Uncertainty associated with each Probability Element is indicated in parentheses. Uncertainty ratings: H = high, little or no data available and rating based on professional judgment; M = good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment; L = low, good data available with no major data gaps; N = none, adequate data available to fully support the probability rating.

Each of the five CAWS pathways represent a completed pathway which *N. japonicas* could use to access the Mississippi River Basin (MRB), and each will be available at all time steps. *N. japonicas* has been established in Saginaw Bay, Lake Huron since 1994. Regardless of pathway there is a low probability of arrival within the next 10 years with high uncertainty, a medium probability at 25 years, and a high probability within 50 years, uncertainty decreases over time.

N. japonicas may readily enter CAWS 1-5 and move downstream using primarily natural transport (downstream drift or as parasite on mobile fish). Thus, the overall probability of passage of *N. japonicas* into the MRB is high for all time steps for all CAWS pathways.

III. Consequences of Establishment

Consequences of Establishment[a,b]			
Environmental Consequences	Economic Consequences	Social/Political Consequences	Total Overall Consequences
L(L)	N(L)	L(L)	L

[a] L = Low consequence rating due to the lower number of consequence categories affected, the lesser nature and severity of the consequences, and the more localized extent of the consequences; N = no consequences are anticipated.

[b] Uncertainty associated with each of the consequence ratings is indicated in parentheses. L = low uncertainty, good supporting data is available.

A. Environmental Consequences

Adult female parasitic copepods are parasitic on fish (Abdelhalim et al. 1993). Within Lake Huron, individuals have been found more frequently on adult than on young-of-the-year fish hosts (Kipp 2011). In the Great Lakes, females have been found on a number of fish species also present in the MRB, including Centrarchids, channel catfish, common carp, perch, and fathead minnows (Hayden & Rogers 1998; Hudson & Bowen 2002; Kipp et al. 2012). In Saginaw Bay, Michigan, the infection rate of the 11 species of fish sampled ranged from 7-86% (Hudson & Bowen 2002); yellow perch and golden shiner were found to have the highest intensity of parasitism, with 15.1 and 14.6 copepods/individual (Hudson & Bowen 2002). Once established, parasitic copepods are capable of surviving on many different host fish species, and transferring from one host fish to another (Kipp 2012). No serious adverse effects were found on infected fish in Britain, however low growth rates of roach may be due to parasitic copepod infection (Mugridge et al. 1982). However, high parasitism rates and densities are typically only found in ponds rather than rivers and large lakes (Hudson & Bowen 2002) suggesting the impacts to fish will be limited. Overall, the consequences *N. japonicas* establishing in the MRB are expected to be low with low uncertainty.

B. Economic Consequences

The establishment of *N. japonicas* in the MRB is not expected to have economic consequences (see Appendix C). Therefore, this species' consequence rating is none, and the uncertainty of the rating is low.

C. Social/Political Consequences

N. japonicas could have a low social consequence on fishing if the number of parasites per fish were perceived as a problem. Yellow perch and golden shiner were found to have the highest intensity of parasitism, with 15.1 and 14.6 copepods/individual (Hudson & Bowen 2002). This is not thought to be a large impact on fishing and is therefore a low consequence with a low uncertainty.

D. Overall Consequences

It was determined that widespread establishment of *N. japonicas* could result in low environmental and social/political consequences and no economic consequences. Thus, even though the probability of this species becoming established in the MRB was considered high at time step 50, the overall consequences of the establishment of this species in the MRB was determined to be low.

IV. Risk of Adverse Impacts

Risk of Adverse Impacts

	Probability of Establishment[a]					Risk of Adverse Impacts[c]			
Pathway	T_0	T_{10}	T_{25}	T_{50}	Consequences of Establishment[b]	T_0	T10	T_{25}	T_{50}
CAWS 1	L	L	M	H	L	L	L	L	L
CAWS 2	L	L	M	H	L	L	L	L	L
CAWS 3	L	L	M	H	L	L	L	L	L
CAWS 4	L	L	M	H	L	L	L	L	L
CAWS 5	L	L	M	H	L	L	L	L	L

[a] Probability rating elements: H = high probability, the event will almost certainly occur. M = medium probability, the event is likely to occur, but it is not certain; L = low probability, the event will likely not occur.

[b] Consequence ratings: L = Low consequence rating due to the lower number of consequence categories affected, the lesser nature and severity of the consequences, and the more localized extent of the consequences.

[c] Risk ratings: L = low risk of adverse impacts.

CAWS Risk Summary

Even though the probability of this species becoming established in the MRB was considered high at time step 50, it is considered likely that the species would become widespread in the MRB once established, it was determined that the consequences of establishment would be low. Therefore, the overall risk of adverse impacts from the establishment of the parasitic copepod in the MRB is considered low for all CAWS pathways and for all time steps.

V. References

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A.2.6.3 Harpacticoid Copepod - *Schizopera borutzkyi*

I. Species Overview

A. Native Range and Current Distribution

Schizopera borutzkyi has been documented in Lake Michigan and Lake Erie. In southern Lake Michigan it was found in nearshore waters in Michigan City, Indiana (Garza & Whitman 2004), Indiana Dunes National Lakeshore, and has been reported in Chicago between Diversey Harbor and Belmont Harbor within 16 km (10 mi) of the WPS (Horvath et al. 2001). However, no surveys are available after 2000 and its current distance from the WPS is uncertain. *S. borutzkyi* is native to the delta of the Danube River and Black Sea basin and was introduced to the Great Lakes by ballast water release (Horvath et al. 2001; Kipp et al. 2012).

B. Life History and Ecology

S. borutzkyi is a small copepod that lives in the sediment. Females carry two egg sacs (Lesko et al. 2003) and there is no planktonic life stage (Kipp et al. 2012). The physical and chemical habitat preferences of *S. borutzkyi* are not well documented, but in southern Lake Michigan, it has been found between 2 and 15 m (6.6-49.2 ft) and it can be the dominant species at depths of 15 m (49.2 ft) (Horvath et al. 2001). In Lake Michigan, this species prefers shallow muds and sands (Horvath et al. 2001). *S. borutzkyi* appears to be a benthic generalist feeding on microbes and algae. This species has the ability to diapause, which may contribute to its survival in ship ballast tanks (Kipp et al. 2012).

II. Probability of Establishment

Probability of Establishment																				
	Probability Range for Time Steps 0, 10, 25, and 50 years[a,b]																			
	CAWS 1				CAWS 2				CAWS 3				CAWS 4				CAWS 5			
Probability Element	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}
Pathway	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)
Arrival	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)
Passage	L (H)	L (H)	M (H)	H (H)	L (H)	L (H)	M (H)	H (H)	L (H)	L (H)	M (H)	H (H)	L (H)	L (H)	M (H)	H (H)	L (H)	L (H)	M (H)	H (H)
Colonization	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)
Spread	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)
Probability of Establishment	L	L	M	H	L	L	M	H	L	L	M	H	L	L	M	H	L	L	M	H

[a] H = high probability, the event will almost certainly occur; M = medium probability, the event is likely to occur but is not certain to do so; L = low probability, the event will likely not occur but is possible.

[b] Uncertainty associated with each Probability Element is indicated in parentheses. Uncertainty ratings: H = high, little or no data available and rating based on professional judgment; M = good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment; L = low, good data available with no major data gaps; N = none, adequate data available to fully support the probability rating.

Each of the five CAWS pathways represent a completed pathway which *S. borutzkyi* could use to access the MRB, and each will be available at all time steps. *S. borutzkyi* has been established in Lake Michigan not far from any of the CAWS pathways, and may already have arrived at one or more of the CAWS entry locations.

This species may readily enter CAWS 1-5 and move downstream primarily using natural transport (downstream drift). Because this is a benthic species the flow of the pathway should not impact the species dispersal. Using these pathways, there is a low probability of establishment occurring within the next 10 years, a medium probability within 25 years, and a high probability within 50 years. Given 25-50 years this species may be able to naturally move into these pathways and on to Brandon Road Lock and Dam and beyond. There is high uncertainty across all time steps for passage of the species. Suitable habitat exists below Brandon Road Lock and Dam and beyond in the MRB, and *Schizopera borutzkyi* may be expected to reach these habitats, become established, and spread to other parts of the basin with low uncertainty.

III. Consequences of Establishment

Consequences of Establishment[a,b]			
Environmental Consequences	Economic Consequences	Social/Political Consequences	Total Overall Consequences
L(M)	N(L)	N(L)	L

[a] L = Low consequence rating due to the lower number of consequence categories affected, the lesser nature and severity of the consequences, and the more localized extent of the consequences; N = no consequences are anticipated.

[b] Uncertainty associated with each of the consequence ratings is indicated in parentheses. L = low uncertainty, good supporting data is available. M = medium uncertainty, good data are available but some data gaps exist; rating based on a mixture of data and professional judgment.

A. Environmental Consequences

S. borutzkyi is a small copepod that lives in the sediment. Since its arrival in Lake Michigan, *S. borutzkyi* has become the dominant harpacticoid in deep sites (at 15 m), where it has been recorded at densities of 3,700/m^2 (Horvath et al. 2001). These results suggest this species has the capacity to alter the local species composition of benthic invertebrates in nearshore communities and replace native copepods. However, there is no evidence *S. borutzkyi* has altered food webs or ecosystem-level processes where it has established in the Great Lakes. There is little available information on the role of harpacticoids within the Great Lakes or the habitat preferences of *S. borutzkyi* in rivers. Overall, the environmental consequences of establishment are low with medium uncertainty.

B. Economic Consequences

The establishment of *S. borutzkyi* in the MRB is not expected to have economic consequences (see Appendix C). Therefore, this species' consequence rating is none, and the uncertainty of the rating is low.

C. Social/Political Consequences

There are no consequences based on human use or political regulatory concerns for *S. borutzkyi*.

D. Overall Consequences

Potentially widespread, low consequences are indicated should *S. borutzkyi* become established in the MRB. The overall consequence level for *S. borutzkyi* is considered to be low.

IV. Risk of Adverse Impacts

Risk of Adverse Impacts									
	Probability of Establishment[a]					Risk of Adverse Impacts[c]			
Pathway	T_0	T_{10}	T_{25}	T_{50}	Consequences of Establishment[b]	T_0	T_{10}	T_{25}	T_{50}
CAWS 1	L	L	M	H	L	L	L	L	L
CAWS 2	L	L	M	H	L	L	L	L	L
CAWS 3	L	L	M	H	L	L	L	L	L
CAWS 4	L	L	M	H	L	L	L	L	L
CAWS 5	L	L	M	H	L	L	L	L	L

[a] Probability rating elements: H = high probability, the event will almost certainly occur. M = medium probability, the event is likely to occur, but it is not certain; L = low probability, the event will likely not occur.

[b] Consequence ratings: L = Low consequence rating due to the lower number of consequence categories affected, the lesser nature and severity of the consequences, and the more localized extent of the consequences.

[c] Risk ratings: L = low risk of adverse impacts.

CAWS Risk Summary

Even though the probability of this species becoming established in the MRB was considered high at time step 50, it is considered likely that the species would ultimately become widespread in the MRB once established; it was further determined that environmental consequences would be low and there would be no economic or social/political consequences for this species. Therefore, the risks of adverse impacts on the MRB from the establishment of *S. borutzkyi* were determined to be low for all CAWS pathways and for all time steps.

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A.2.7 Fish

A.2.7.1 Sea Lamprey - *Petromyzon marinus*

I. Species Overview

A. Native Range and Current Distribution

The first record of sea lamprey in the Great Lakes is from Lake Ontario in 1835. It has since been recorded in Lakes Erie, Michigan, Huron and Superior (Fuller et al. 2012). It is present in tributaries of the Great Lakes in Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, and Wisconsin (Fuller et al. 2012). Sea lamprey are native to the Atlantic Coast of North America from Labrador to the Gulf of Mexico, as well as the Atlantic Coast of Europe and the Mediterranean Sea. It is unclear whether sea lampreys are native to Lake Ontario; however, their introduction to the other Great Lakes likely occurred through natural dispersal after the building of the Welland Canal or by attaching to boats or fish (Fuller et al. 2012).

B. Life History and Ecology

Adult sea lamprey are found in coastlands, lakes, and watercourses (NBII Undated), as well as marine, freshwater and brackish waters (FishBase 2010). In freshwater, adult sea lampreys are found in cool-water lakes (NBII Undated; FishBase 2010). They are not present in high turbidity waters (Morman et al. 1980). Temperatures of 11-25°C are needed for successful spawning (Morman et al. 1980); temperatures of 32.4°C (88.5°F) are lethal to ammocoetes (Beamish 1980). A low flow of 0.4-1.5 m/s (1.31-4.92 ft/s) is suitable for spawning (Morman et al. 1980).

Adult sea lampreys are parasitic on all species of large Great Lakes fish, including lake trout, salmon, and whitefish; larvae feed on bottom debris and algae carried to them by stream currents (GLFC 2000). Sea lampreys spawn from spring to early summer (GLFC 2000). Adults travel to gravel areas of tributary streams (GLFC 2000) in freshwater running rivers and spawn in clean, hard bottom spawning beds, after which the adults die (NBII Undated). Ammocoetes, after hatching, drift downstream and burrow into silt beds in various parts of the river, but particularly along protected banks (Potter 1980). Females lay between 35,000-260,000 eggs (NBII Undated; FishBase 2010), resulting in a minimum population doubling time of 4.5-14 years (FishBase 2010).

II. Probability of Establishment

Probability of Establishment																				
	Probability Range for Time Steps 0, 10, 25, and 50 years[a,b]																			
	CAWS 1				CAWS 2				CAWS 3				CAWS 4				CAWS 5			
Probability Element	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}
Pathway	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)
Arrival	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)	H (L)
Passage	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)	L (M)
Colonization	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)
Spread	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)	L (L)
Probability of Establishment	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L

[a] H = high probability, the event will almost certainly occur; M = medium probability, the event is likely to occur but is not certain to do so; L = low probability, the event will likely not occur but is possible.

[b] Uncertainty associated with each Probability Element is indicated in parentheses. Uncertainty ratings: H = high, little or no data available and rating based on professional judgment; M = good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment; L = low, good data available with no major data gaps; N = none, adequate data available to fully support the probability rating.

Sea lampreys are documented to have arrived at the CAWS, and a pathway to the MRB is present. Adult sea lamprey will only move into the rivers to spawn, but they could potentially occupy reservoirs/navigation pools in the MRB. However, sea lampreys have been present in the Great Lakes for over a century, and they have not been recorded in Illinois rivers (Starrett et al. 1960), suggesting the probability of passage and spread is low. Therefore, the overall probability of establishment for the sea lamprey is low across all time steps and all pathways. The primary uncertainties associated with the probability of establishment rating are related to uncertainty about how extensively the sea lamprey can colonize and spread in the MRB and why it has not done so historically.

III. Consequences Summaries

Consequences of Establishment[a,b]			
Environmental Consequences	Economic Consequences	Social/Political Consequences	Total Overall Consequences
L(M)	M(H)	H(H)	M

[a] L = Low consequence rating due to the lower number of consequence categories affected, the lesser nature and severity of the consequences, and the more localized extent of the consequences; M = Medium consequence rating due to the number of consequence categories affected, the nature and severity of the consequences, and the spatial extent of the consequences; H = High consequence rating due to the larger number of consequence categories affected, the nature and severity of the consequences, and the broader spatial extent of the consequences.

[b] Uncertainty associated with each of the consequence ratings is indicated in parentheses. H = high, little or no data available and ratings based on professional judgment; M = medium, good data available but some major data gaps exist, rating is based on a mixture of available data and professional judgment.

A. Environmental Consequences

Sea lampreys inhabit lentic or oceanic habitats and move into rivers only to spawn (Fuller et al. 2012). Therefore, if sea lamprey were to establish in the MRB, it would be in lakes and large reservoirs. Within the Great Lakes, their introduction has resulted in the substantial decline of several fish species (GLFC 2000), some of which are found in the MRB. Consequently, if they establish, sea lamprey have the potential to affect food web dynamics and biodiversity in the MRB. The species could affect the abundance and productivity of larger fish species, and may have a widespread distribution in the MRB. However, multiple management strategies have been developed to control sea lamprey populations. These control programs, if applied in the MRB, could significantly reduce the potential for impacts on invaded lakes. Because they are not expected to be reach high abundance in the MRB, the sea lamprey has an environmental consequence rating of medium. If sea lamprey were to establish in the MRB, it is uncertain whether large populations would develop. Based on the documented successful control of sea lamprey in the GLB (GLFC 2000), impacts from sea lamprey are likely to be low if they were to establish in the MBR. Consequently, uncertainty is medium.

B. Economic Consequences

Sea lamprey are parasitic fish that have historically generated significant adverse economic impacts in the Great Lakes. Widespread establishment of sea lamprey could produce economic consequences in a number of categories, including loss of consumer surplus, while reductions in recreational boating and fishing, and in commercial fishing could adversely impact employment, income and tax revenues (see Appendix C). For each of these consequence categories, the severity of economic consequences would depend on the extent of species establishment, the resulting impact on existing fisheries resources, and the consequent impact on recreational activity and fishing. The economic consequences are medium with high uncertainty.

C. Social/Political Consequences

Sea lamprey could generate significant political interest if they were to establish in the MRB. Sea lamprey could also reduce the abundance of fish species of recreational importance. Sea lamprey would primarily occupy large lakes and pools, and would therefore reduce the perceived quality of recreational fisheries in those areas. However, there is significant uncertainty about whether the sea lamprey could attain widespread and high abundance in the MRB. Therefore, the social/political consequences of the sea lamprey establishment are high, and the uncertainty associated with this rating is high as well.

D. Overall Consequences

If sea lamprey were to establish in the MRB, the adults would primarily occupy large lakes, reservoirs, and navigation pools, and could adversely affect fisheries in those areas. Sea lamprey could reduce the abundance of fish species of recreational importance and could result in significant political consequences. However, sea lamprey are not expected to reach high abundance due to the lack of suitable habitat in the MRB. In addition, there are well-developed management methods for controlling sea lamprey populations (GLFC 2000) if they were to establish in the MRB. Therefore, sea lamprey has an overall consequence rating of medium.

IV. Risk of Adverse Impacts

Risk of Adverse Impacts									
	Probability of Establishment[a]					Risk of Adverse Impacts[c]			
Pathway	T_0	T_{10}	T_{25}	T_{50}	Consequences of Establishment[b]	T_0	T_{10}	T_{25}	T_{50}
CAWS 1	L	L	L	L	M	L	L	L	L
CAWS 2	L	L	L	L	M	L	L	L	L
CAWS 3	L	L	L	L	M	L	L	L	L
CAWS 4	L	L	L	L	M	L	L	L	L
CAWS 5	L	L	L	L	M	L	L	L	L

[a] Probability rating elements: L = low probability, the event will likely not occur.

[b] Consequence ratings: M = Medium consequence rating due to the number of consequence categories affected, the nature and severity of the consequences, and the spatial extent of the consequences.

[c] Risk ratings: L = low risk of adverse impacts.

CAWS Risk Summary

Sea lamprey have the potential to affect the abundance and productivity of larger fish species, resulting in environmental, economic, and social/political consequences. However, this species is not likely to achieve high abundance in the MRB and multiple management strategies have been developed to control sea lamprey populations. These control programs, if applied in the MRB, could significantly reduce the potential for impacts on invaded lakes. Therefore the overall consequence rating is medium. The sea lamprey has a low probability of passage through the CAWS for all CAWS pathways and time steps. Therefore, the overall risk of adverse impacts is low for all pathways and time steps.

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A.2.7.2 Blueback Herring - *Alosa aestivalis*

I. Species Overview

A. Native Range and Current Distribution

Two juvenile blueback herring were documented near Oswego, NY, in Lake Ontario in 1994 over 2,090 km from southern Lake Michigan (Owens et al. 1998). The blueback herring has not spread west to the other Great Lakes since that time (Fuller et al. 2012). This species has been collected in the Tennessee River and reservoirs in Tennessee (Rasmussen 1998; Tennessee Wildlife Resources Agency 2012); Oneida Lake, the Oswego River in Minetto, Lake Champlain, and the upper Mohawk River upstream of Cohoes Falls, New York (Greeley 1935; Limburg et al. 2001; Fuller et al. 2012). The native range of the blueback herring is the Atlantic Coast from Cape Breton, Nova Scotia, to the St. Johns River, Florida (Page & Burr 1991).

B. Life History and Ecology

Blueback herring are filter feeders that strain zooplankton from the water. The have also been documented to consume benthic invertebrates (Simonin et al. 2007). In freshwater, adult blueback herring prefer deep open waters of lakes for most of the year, but migrate upstream to spawn once a year in spring or early summer (Raney & Massmann 1953). They prefer to spawn in fast currents over hard substrate in temperatures ranging from 14 to27°C (57.2-80.6°F) (Loesch & Lund 1977; Pardue 1983). Eggs are demersal in still water and adhesive or pelagic in running water (Loesch & Lund 1977). After water hardening, the eggs become pelagic and lose their adhesive properties (Pardue 1983). Larvae and juveniles remain in the surface water near the spawning site. Adults are primarily pelagic, preferring temperatures ranging from 2 to 17°C (35.6-62.6°F) (Pardue 1983).

II. Probability of Establishment

Probability of Establishment

Probability Range for Time Steps 0, 10, 25, and 50 yrs[a,b]

Probability Element	CAWS 1				CAWS 2				CAWS 3				CAWS 4				CAWS 5			
	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}	T_0	T_{10}	T_{25}	T_{50}
Pathway	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)	H (N)
Arrival	L (L)	L (L)	L (L)	M (M)	L (L)	L (L)	L (L)	M (M)	L (L)	L (L)	L (L)	M (M)	L (L)	L (L)	L (L)	M (M)	L (L)	L (L)	L (L)	M (M)
Passage	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)
Colonization	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)	L (H)
Spread	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)	M (M)
Probability of Establishment	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L

[a] H = high probability, the event will almost certainly occur; M = medium probability, the event is likely to occur but is not certain to do so; L = low probability, the event will likely not occur but is possible.

[b] Uncertainty associated with each Probability Element is indicated in parentheses. Uncertainty ratings: H = high, little or no data available and rating based on professional judgment; M = good data available but some major data gaps exist, and rating is based on a mixture of available data and professional judgment; L = low, good data available with no major data gaps; N = none, adequate data available to fully support the probability rating.

A. Overall Probability of Establishment

Blueback herring was reported in Lake Ontario in 1995 and has not spread to the other Great Lakes since that time. Therefore, for all pathways, the species has a low probability of arriving at the CAWS until T_{50} when the probability increases to medium. Based on other fish species with similar migratory patterns, if the blueback herring were to spread to the CAWS, it has a low probability of passage through the CAWS and of colonization in the MRB after exiting the CAWS. The overall probability of establishment is low for all time steps and pathways.

III. Consequences Summaries

Consequences of Establishment[a,b]			
Environmental Consequences	Economic Consequences	Social/Political Consequences	Total Overall Consequences
M(M)	M(M)	M(M)	M

[a] M = Medium consequence rating due to the number of consequence categories affected, the nature and severity of the consequences, and the spatial extent of the consequences.

[b] Uncertainty associated with each of the consequence ratings is indicated in parentheses. M = medium, good data available but some major data gaps exist, rating is based on a mixture of available data and professional judgment.

A. Environmental Consequences

If the blueback herring were to establish in the MRB, it is likely to be most abundant in lakes, reservoirs, and navigation pools that provide suitable habitat. Once established, blueback herring could alter ecosystem structure by competing with native planktivores for resources and altering zooplankton community composition and biodiversity (Fuller et al. 2012). There is the potential to reduce fish populations by consumption of fish eggs or competition with larval and juvenile fishes that also prey on zooplankton (Wheeler & Loftis 2004). Blueback herring can also cause Thiamine deficiency complex in fish (Tennessee Wildlife Resources Agency 2012). By altering zooplankton and fish communities, blueback herring have the potential for ecosystem-level effects on food webs. Although there is some evidence of ecological alterations following the introduction of blueback herring, the realized environmental effects if this species where to establish in the MRB are uncertain, as is the extent to which this species will spread in the MRB. Overall, the blueback herring has an environmental consequence rating of medium, and the uncertainty associated with this rating is medium.

B. Economic Consequences

Fishery losses of quality and population size could accompany blueback herring establishment as described under environmental consequences. Examples of species that could potentially be affected by the blueback herring include bass (*Micropterus* spp.), crappie (*Pomoxis* spp.), sunfish (*Lepomis* spp.), and perch (Rasmussen 1998; Wheeler & Loftis 2004, and references therein). These impacts would have the potential to significantly impact employment, income, and tax revenues in locations that are highly dependent on these activities, and in supporting industries, particularly rural locations with few other sources of local employment. Reduction in recreational and commercial fish populations could affect recreational charter boating, fuel suppliers' income generated through the sale of commercial fish species, and other supporting industries which would, in turn, impact employment, income, and tax revenues in local communities. Establishment could also reduce employment, income, and tax revenue in supporting industries that provide fishing equipment and supplies. Therefore, the economic consequences of the blueback herring are rated as medium. Although there is some evidence of reductions in fish populations following the introduction of blueback herring, the realized effects of this species on recreational and commercial fishing activity in the MRB is uncertain. Consequently, the uncertainty associated with the economic consequence rating is medium.

C. Social/Political Consequences

The social and political consequences associated with the establishment of the blueback herring are primarily related to its potential to reduce populations of fish species of recreational value. Examples of such species that could potentially be affected by the blueback herring include bass (*Micropterus* spp.), crappie (*Pomoxis* spp.), sunfish (*Lepomis* spp.), and perch (Rasmussen 1998; Wheeler & Loftis 2004, and references therein). Blueback herring would primarily occupy large lakes, reservoirs, and pools, and could therefore affect the perceived quality of recreational fishing opportunities in those areas. Blueback herring could also generate significant political interest if they were to establish in the MRB. Therefore, the social/political consequences of the blueback herring are medium. If blueback herring were to establish in the MRB, it is uncertain whether large populations would develop. Although there is some evidence of reductions in fish populations following the introduction of blueback herring (Rasmussen 1998; Wheeler & Loftis 2004), the realized effects of this species on recreational fish species in the MRB are uncertain. Consequently, the uncertainty associated with the social/political consequence rating is medium.

D. Overall Consequences

If blueback herring were to establish in the MRB, the adults would primarily occupy large lakes, reservoirs, and navigation pools, and could be seasonally abundant in riverine habitat. Blueback herring could compete with and consume native species and therefore have the potential to alter zooplankton and fish community structure and affect food webs. In doing so, blueback herring could reduce the abundance of fish species of recreational and commercial importance, resulting in significant political consequences and economic impacts to communities that participate in and derive income from these activities. Therefore, blueback herring have an overall consequence rating of medium.

IV. Risk of Adverse Impacts

Risk of Adverse Impacts									
	Probability of Establishment[a]					Risk of Adverse Impacts[c]			
Pathway	T_0	T_{10}	T_{25}	T_{50}	Consequences of Establishment[b]	T_0	T_{10}	T_{25}	T_{50}
CAWS 1	L	L	L	L	M	L	L	L	L
CAWS 2	L	L	L	L	M	L	L	L	L
CAWS 3	L	L	L	L	M	L	L	L	L
CAWS 4	L	L	L	L	M	L	L	L	L
CAWS 5	L	L	L	L	M	L	L	L	L

[a] Probability rating elements: L = low probability, the event will likely not occur.

[b] Consequence ratings: M = Medium consequence rating due to the number of consequence categories affected, the nature and severity of the consequences, and the spatial extent of the consequences.

[c] Risk ratings: L = low risk of adverse impacts.

CAWS Risk Summary

Blueback herring have the potential to affect the abundance and productivity of larger fish species, resulting in environmental, economic, and social/political consequences. Therefore, the overall consequence rating is medium. However, the blueback herring has a low probability of establishment for all CAWS pathways and time steps. Therefore, the overall risk of adverse impacts is low for all pathways and time steps.

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APPENDIX B

ENVIRONMENTAL CONSEQUENCES

CONTENTS

CONTENTS (CONT.)

APPENDIX B

ENVIRONMENTAL CONSEQUENCES

B.1 OVERVIEW OF ENVIRONMENTAL CONSEQUENCES ASSESSMENT

To assess the environmental consequences of aquatic nuisance species (ANS) establishment, each ANS will be evaluated with respect to its potential to affect one or more ecosystem structure and function categories. To determine the level of potential environmental consequences for each ANS, the assessment considered (1) the number of ecosystem categories that may be affected following establishment, (2) the nature and severity of the potential ecosystem effects as suggested by the scientific literature, and (3) the spatial extent of where those effects might be realized following establishment of the ANS in the new basin. The evaluation did not quantify the magnitude of any consequences.

Each ANS was evaluated on each ecosystem category, and a qualitative determination was made as to whether the ANS could or could not affect the category. Environmental categories considered included:

Nutrient cycling;

Productivity;

Food web dynamics;

Competition and/or predation;

Habitat quality and quantity;

Biodiversity; and

Interaction with species listed under the Endangered Species Act.

The more categories identified as being potentially affected, the greater the likelihood for environmental consequences to be realized from ANS establishment. Each category identified as possibly affected was then further examined with regard to the nature and severity of any possible effects.

The environmental consequences assessment also considered the potential spatial extent where ecosystem structure and function could be affected, although no attempt was made to quantify the magnitude of any potential effects. The spatial extent was evaluated by quantifying potentially suitable habitat available in the potentially invaded basin. For some ANS, environmental consequences may be relatively localized, being centered on the habitats in which the ANS has become established. Alternately, for species that may become widely established in a new basin, any associated environmental consequences could similarly become widespread as well. The amount of suitable habitat present in the potentially invaded basin was determined by habitat mapping, as described in "GLMRIS Aquatic Habitat Types and Methodology." Levels of environmental consequences were assigned based on existing information pertaining to distributions, ecological requirements, species characteristics, potential ecological effects, and reported consequences of establishment.

The environmental consequence assessment assigned one of the following qualitative ratings for each ANS evaluated:

High (H) = High consequence rating due to the larger number of consequence categories affected, the nature and severity of the consequences, and the broader spatial extent of the consequences.

Medium (M) = Medium consequence rating due to the number of consequence categories affected, the nature and severity of the consequences, and the spatial extent of the consequences.

Low (L) = Low consequence rating due to the lower number of consequence categories affected, the lesser nature and severity of the consequences, and the more localized extent of the consequences.

None (N) = No consequences are anticipated.

A rating assignment was based on the amount of consequence information available for that ANS (or closely related species), the interpretations of that information by the Great Lakes Mississippi River Interbasin Study (GLMRIS) Risk Assessment Team, and the thresholds selected to distinguish among the consequence levels. For each ANS, the environmental consequence is accompanied by an uncertainty rating which reflects the confidence placed on the assessment. The uncertainty rating is based on the amount and quality of scientifically defensible data used in the assessment to support the consequence determination. The less data available, the greater the uncertainty associated with the consequence rating. The uncertainty ratings used for the environmental consequence assessments are:

High = There is little to no concrete evidence available, or there is a very broad range in the nature and the severity of the consequences including extreme consequences.

Medium = There are some good supporting data but also still some major data gaps, or there is a broad range in the nature and severity of the consequences, but no extreme consequences have been identified.

Low = Good supporting data are available, data gaps are not significant, or there is a limited range of possible consequences.

None = Adequate data are available to fully support the consequence determination.

Ecosystem Structure and Function Impacts Matrix (• = indicates a potential to affect the category)	Nutrient Cycling[a]	Productivity[b]	Food Web Dynamics[c]	Competition and/or Predation[d]	Habitat Quality and Quantity[e]	Biodiversity[f]	ESA-listed Species[g]	Spatial Extent of ANS Establishment
Protozoa								
Testate amoeba (*Psammonobiotus communis*)								Localized
Testate amoeba (*P. dziwnowi*)								Localized
Testate amoeba (*P. linearis*)								Localized
Algae								
Cryptic algae (*Cyclotella cryptica*)								Localized
Grass kelp *(Enteromorpha flexuosa*)	•	•	•		•			Localized
Red algae (*Bangia atropurpurea*)		•	•	•	•	•		Localized
Diatom (*Stephanodiscus binderanus*)	•	•			•			Widespread
Bryozoan								
Freshwater bryozoan (*Lophopodella carteri*)								Widespread
Molluscs								
Greater European peaclam (*Pisidium amnicum*)				•				Widespread
European fingernail clam (*Sphaerium corneum*)				•				Widespread
European stream valvata (*Valvata piscinalis*)				•			•	Widespread
Crustaceans								
Scud (*Apocorophium lacustre)*	•		•	•	•	•		Widespread
Fishhook waterflea (*Cercopagis pengoi*)			•	•		•		Widespread
Waterflea (*Daphnia g. galeata*)				•		•		Widespread

(Cont.)

	Nutrient Cycling[a]	Productivity[b]	Food Web Dynamics[c]	Competition and/or Predation[d]	Habitat Quality and Quantity[e]	Biodiversity[f]	ESA-listed Species[g]	Spatial Extent of ANS Establishment
Molluscs (Cont.)								
Bloody red shrimp (*Hemimysis anomala*)	•		•	•		•		Widespread
Parasitic copepod (*Neoergasilus japonicas*)								Widespread
Harpacticoid copepod (*Schizopera borutzkyi*)				•				Widespread
Fish								
Skipjack herring (*Alosa chrysochloris*)								Widespread
Northern snakehead (*Channa argus*)			•	•		•		Widespread
Inland silverside (*Menidia beryllina*)				•		•		Localized
Black carp (*Mylopharyngodon piceus)*			•	•		•	•	Widespread
Bighead carp (*Hypophthalmichthyes nobilis*)	•	•	•	•	•	•	•	Widespread
Silver carp (*Hypophthalmichthys molitrix*)	•	•	•	•	•	•	•	Widespread
Threespine stickleback (*Gasterosteus aculeatus*)				•		•		Widespread
Blueback herring (*Alosa aestivalis*)		•	•	•		•		Widespread
Ruffe (*Gymnocephalus cernuus*)			•	•		•	•	Localized
Sea lamprey (*Petromyzon marinus*)			•	•				Widespread
Tubenose goby (*Proterorhinus semilunaris*)				•		•	•	Localized
Plants								
Marsh dewflower (*Murdannia keisak*)				•	•	•		Localized
Cuban bullrush (*Oxycaryum cubense*)	•			•	•	•		Localized
Dotted duckweed (*Landoltia punctate*)	•			•	•	•		Localized

(Cont.)

	Nutrient Cycling[a]	Productivity[b]	Food Web Dynamics[c]	Competition and/or Predation[d]	Habitat Quality and Quantity[e]	Biodiversity[f]	ESA-listed Species[g]	Spatial Extent of ANS Establishment
Plants (Cont.)								
Swamp sedge (*Carex acutiformis*)	•			•				Widespread
Reed sweetgrass (*Glyceria maxima*)	•	•	•	•	•	•		Widespread
Water Chestnut (*Trapa natans*)	•			•	•	•		Widespread
Viruses								
Viral Hemorrhagic Septicemia Virus (*Novirhabdovirus* sp.)			•			•		Widespread

[a] ANS establishment may disrupt nutrient cycling.

[b] ANS establishment may disrupt primary or secondary productivity through a decrease or loss of primary producers and/or consumers.

[c] ANS establishment may alter food webs, affecting food resources, prey abundance, and energy flow between trophic levels.

[d] ANS establishment may result in decreased abundance and/or reduced distribution of one or more resident species through competition or predation.

[e] ANS establishment may reduce quality and/or availability of important habitats.

[f] ANS establishment may alter species composition of communities, including loss or reduction in abundance of resident species.

[g] ANS establishment may adversely impact one or more species listed as threatened or endangered, or habitat designated as critical, under the Endangered Species Act.

For more details on the methods used to conduct the environmental consequence evaluations, see Hlohowskyj et al. (2013). A summary of the consensus ratings for environmental consequences is provided in the following table.

Reference

Hlohowskyj, I., M. Grippo, J. Hayse, L. Fox & C. Yo. 2013. GLMRIS Assessment Approach for Characterizing the Risks of Adverse Impacts from the Movement and Establishment of Aquatic Nuisance Species between the Great Lakes and Mississippi River Basins. Draft. Prepared for the GLMRIS Risk Assessment Team, U.S. Army Corps of Engineers, Chicago District.

B.2 SPECIES-SPECIFIC ENVIRONMENTAL CONSEQUENCES ASSESSMENT

B.2.1 Protozoa

B.2.1.1 Testate Amoeba - *Psammonobiotus communis*

Environmental Consequences Rating: LOW
Psammonobiotus communis is a benthic amoeba that actively moves between sand grains. It is known to feed on bacteria, fungi, and algae (Golemansky 2008). This species has been found in every ocean basin of the world (Kipp 2011). Its ecological effects are unknown, but the species could potentially alter the biogeochemistry and bacterial communities of areas it invades. However, no studies were found suggesting this species generated ecological effects following its establishment in the Great Lakes Basin (GLB). Because it is not predicted to be widespread in the Mississippi River Basin (MRB), any effects it does have are expected to be localized and minimal. Therefore, the consequences of this species establishing in the MRB are low.

Uncertainty Rating: MEDIUM
There is a lack of research available on *Psammonobiotus communis*, so little is known of its environmental effects. However, no adverse impacts on ecosystem structure and function have been reported in the literature to result from the introduction of this species. Overall, there is a medium degree of uncertainty regarding its environmental consequences.

References

Golemansky, V. 2008. Origin, phylogenetic relations, and adaptations of the marine interstitial testate amoebae (*Rhizopoda: Lobosea, Filosea,* and *Granuloreticulsea*). *Monographs*, vol. 12, pp. 87-100.

Kipp, R.M. 2012. *Psammonobiotuscommunis*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. http://nas.er.usgs.gov/queries/GreatLakes/SpeciesInfo.asp?NoCache=5%2F2012+4%3A38%3A09+PM&SpeciesID=2653&State=&HUCNumber=DErie

B.2.1.2 Testate Amoeba - *Psammonobiotus dziwnowi*

Environmental Consequences Rating: **LOW**
Psammonobiotus dziwnowi is a benthic amoeba that moves between sand grains. It is known to feed on bacteria, fungi, and algae (Golemansky 2008). Its ecological effects are unknown, but the species could potentially alter the biogeochemistry and bacterial communities of areas it invades. However, no studies were found suggesting this species generated ecological effects following its establishment in the Great Lakes. Because it is not predicted to be widespread in the Mississippi River Basin (MRB), any effects it does have are expected to be localized and minimal. Therefore, the consequences of this species establishing in the MRB are low.

Uncertainty Rating: **MEDIUM**
There is a lack of research available on *Psammonobiotus dziwnowi*, so little is known of its environmental effects. However, no adverse impacts on ecosystem structure and function have been reported in the literature to result from the introduction of this species. Overall, there is a medium degree of uncertainty regarding its environmental consequences.

References

Golemansky, V. 2008. Origin, phylogenetic relations, and adaptations of the marine interstitial testate amoebae (*Rhizopoda: Lobosea, Filosea,* and *Granuloreticulsea*). *Monographs*, vol. 12, pp. 87-100.

Kipp, R.M. 2012. *Psammonobiotus dziwnowi.* USGS Nonindigenous Aquatic Species Database, Gainesville, FL. http://nas.er.usgs.gov/queries/GreatLakes/SpeciesInfo.asp?NoCache=5%2F2012+4%3A38%3A09+PM&SpeciesID=2653&State=&HUCNumber=DErie

B.2.1.3 Testate Amoeba - *Psammonobiotus linearis*

Environmental Consequences Rating: **LOW**
Psammonobiotus linearis is a benthic amoeba that moves between sand grains (Kipp 2011). It is known to feed on bacteria, fungi, and algae found on sand grains (Golemansky 2008). Its ecological effects are unknown, but the species could potentially alter the biogeochemistry and bacterial communities of areas it invades. However, no studies were found suggesting this species generated ecological effects following its establishment in the Great Lakes. Because it is not predicted to be widespread in the Mississippi River Basin (MRB), any effects it does have are expected to be localized and minimal. Therefore, the consequences of this species establishing in the MRB are low.

Uncertainty Rating: **MEDIUM**
There is a lack of research available on *Psammonobiotus linearis*, so little is known of its environmental effects. However, no adverse impacts on ecosystem structure and function have been reported in the literature to result from the introduction of this species. Overall, there is a medium degree of uncertainty regarding its environmental consequences.

References

Golemansky, V. 2008. Origin, phylogenetic relations, and adaptations of the marine interstitial testate amoebae (*Rhizopoda: Lobosea, Filosea,* and *Granuloreticulsea*). *Monographs*, vol. 12, pp. 87-100.

Kipp, R.M. 2011. *Psammonobiotus linearis*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. http://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=2655

B.2.2 Algae

B.2.2.1 Cryptic Algae - *Cyclotella cryptica*

Environmental Consequences Rating: **LOW**
Cryptic algae is a planktonic alga that produces an exudate that may competitively inhibit the growth response of *Skeletonema costatum* in environments enriched by vitamin B_{12} (Messina & Baker 1981; Kipp 2011). This species is typically a marine and brackish species but is widely distributed and has been found in the Sandusky River, so there is potential for establishment in the MRB (Kipp 2011). C. cryptica produce an exudate that may competitively inhibit other phytoplankton (Messina & Baker 1981; Kipp 2011). However, the species has been present in Lake Michigan since 1964 and no adverse impacts to ecosystem structure and function have been reported to result from the introduction of this species. There is 4,848,544 acres of littoral and open water habitat and 81,400 miles of large and medium sized rivers in the MRB, some of which is potentially suitable for this species. In the Great Lakes, cryptic algae is typical of harbors in which high chloride concentrations are present (Kipp 2011); therefore, industrialized regions of the MRB may be suitable for the species. Because of these specialized water quality preferences, this species is not predicted to be widespread in the MRB, any effects of cryptic algae are expected to be localized and minimal. Therefore, the consequences of the establishment of this species in the MRB are low.

Uncertainty Rating: LOW
This species has been present in Lake Michigan since 1964, and no adverse impacts to ecosystem structure and function have been reported. Overall, the uncertainty associated with the environmental consequences of cryptic algae is low.

References

Kipp, R.M. 2011. *Cyclotella cryptica*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. http://nas.er.usgs.gov/queries/factsheet.aspx?SpeciesID=1671

Messina, D.S. & A.L. Baker. 1981. Interspecific growth regulation in species succession through Vitamin B_{12} competitive inhibition. *Journal of Plankton Research*, vol. 4(1), pp. 41-46.

B.2.2.2 Grass Kelp - Enteromorpha flexuosa

Environmental Consequences Rating: **LOW**

In coastal areas, this species is potentially a major fouling alga that is capable of replacing native algal species and smothering aquatic plants (Sturtevant 2011). Grass kelp was found to form extensive beds in nutrient-rich habitats in the GLB (Lougheed & Stevenson 2004). Macrophytes in the MRB may be shaded by dense grass kelp mats (Sturtevant 2011). Where it establishes and forms nuisance blooms, grass kelp has the potential to alter biodiversity and habitat quality (Sand-Jensen et al. 2008 reviewed in Sturtevant 2011). The density of epiphytic diatoms appears to be lower on grass kelp compared to that in other macroalgae, suggesting grass kelp invasion may also affect primary productivity and basal food resources (Lougheed & Stevenson 2004). Grass kelp can also alter sediment redox conditions, potentially resulting in changes to nutrient cycling. However, grass kelp primarily inhabits marine and brackish waters and therefore requires specific water column conditions. Therefore, grass kelp is expected to have only localized ecological impacts in the MRB. Overall, the consequences of grass kelp establishment in the MRB are expected to be low.

Uncertainty Rating: **MEDIUM**

Grass kelp is documented to have potentially significant ecological consequences in fresh water habitats (Sand-Jensen et al. 2008). However, given the specific water quality conditions required by this species, it is uncertain how extensively it will spread and potentially alter existing fresh water ecosystems. Therefore, there is a medium degree of uncertainty regarding the environmental consequences of the species.

Ecosystem Structure and Function Impacts Matrix
(• indicates a potential to affect the category)

ANS	Ecosystem Function: Nutrient Cycling[a]	Ecosystem Function: Productivity[b]	Ecosystem Function: Food Web Dynamics[c]	Ecosystem Structure: Competition and/or Predation[d]	Ecosystem Structure: Habitat Quality and Quantity[e]	Ecosystem Structure: Biodiversity[f]	ESA-Listed Species[g]	Potentially Available Suitable Habitat[h]	Spatial Extent of ANS Establishment
Grass Kelp (*Enteromorpha flexuosa*)	•	•	•	•	•	•			Localized

[a] ANS establishment may disrupt nutrient cycling.

[b] ANS establishment may disrupt primary or secondary productivity through a decrease or loss of primary producers and/or consumers.

[c] ANS establishment may alter food webs, affecting food resources, prey abundance, and energy flow between trophic levels.

[d] ANS establishment may result in decreased abundance and/or reduced distribution of one or more resident species through competition or predation.

[e] ANS establishment may reduce quality and/or availability of important habitats.

[f] ANS establishment may alter species composition of communities, including loss or reduction in abundance of resident species.

[g] ANS establishment may adversely impact one or more species listed as threatened or endangered, or habitat designated as critical, under the Endangered Species Act.

[h] Amount of potentially available habitat for ANS establishment; linear miles for lentic habitats; acres for lotic habitats.

References

Lougheed, V.L. & R.J. Stevenson. 2004. Exotic marine macroalgae (*Enteromorphaflexuosa*) reaches bloom proportions in a coaster lake of Lake Michigan. *Journal of Great Lakes Research*, vol. 30(4), pp. 538-544.

Sand-Jensen, K., N.L. Pedersen, I. Thorsgaard, B. Moeslund, J. Borum& K.P. Brodersen. 2008. 100 years of vegetation decline and recovery in Lake Fure, Denmark. *Journal of Ecology*, vol. 96, pp. 260-271.

Sturtevant, R. 2011. *Enteromorphaflexuosa subsp. Flexuosa and flexuosa subsp. Paradoxa*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. http://nas.er.usgs.gov/queries/greatlakes/SpeciesInfo.asp?NoCache=6%2F6%2F2012+9%3A02%3A12+AM&SpeciesID=2726&State=&HUCNumber=>

B.2.2.3 Red Algae - *Bangia atropurpurea*

Environmental Consequence Rating: LOW

Red algae has the ability to displace algal species such as *Ulothrix zonata* and *Cladophora glomerata* (Sonzogni et al. 1983). In the Great Lakes, the species has yet to displace native algal species; instead, it occupies previously unutilized space higher in the splash zone (reviewed in Kipp 2012). The replacement of native algal species by red algae can potentially reduce macroinvertebrate biodiversity in the GLB (Chilton et al. 1986), and similar impacts may occur in the MRB where this species is able to establish. Red algae may alter the basal food resources and productivity in the MRB. For example Sonzogni et al. (1983) state that epiphytic algae do not grow well on red algae, which may reduce food resources for grazers. The spread of red algae in the Great Lakes appears to be facilitated by high chloride and potentially high sodium levels (Sonzogni et al. 1983). Because of these specific water quality requirements, the distribution of red algae may be limited to urbanized areas of the MRB or areas with high runoff. Consequently, red algae is not expected to have significant or widespread effects on ecosystem structure and function. Overall, the consequences of red algae establishing in the MRB would be low.

Uncertainty Rating: MEDIUM

It is unknown whether red algae can occupy more than urbanized areas of the MRB. The effects of red algae on existing macrophyte and macroalgal communities in the MRB are uncertain. Therefore, there is medium uncertainty associated with the environmental consequences of red algae spread.

Ecosystem Structure and Function Impacts Matrix
(• indicates a potential to affect the category)

ANS	Ecosystem Function			Ecosystem Structure					
	Nutrient Cycling[a]	Productivity[b]	Food Web Dynamics[c]	Competition and/or Predation[d]	Habitat Quality and Quantity[e]	Biodiversity[f]	ESA-Listed Species[g]	Potentially Available Suitable Habitat[h]	Spatial Extent of ANS Establishment
Red Algae (*Bangia atropurpurea*)		•	•	•	•	•			Localized

[a] ANS establishment may disrupt nutrient cycling.

[b] ANS establishment may disrupt primary or secondary productivity through a decrease or loss of primary producers and/or consumers.

[c] ANS establishment may alter food webs, affecting food resources, prey abundance, and energy flow between trophic levels.

[d] ANS establishment may result in decreased abundance and/or reduced distribution of one or more resident species through competition or predation.

[e] ANS establishment may reduce quality and/or availability of important habitats.

[f] ANS establishment may alter species composition of communities, including loss or reduction in abundance of resident species.

[g] ANS establishment may adversely impact one or more species listed as threatened or endangered, or habitat designated as critical, under the Endangered Species Act.

[h] Amount of potentially available habitat for ANS establishment; linear miles for lentic habitats; acres for lotic habitats.

References

Chilton, E.W., R.L. Lowe & K.M. Schurr. 1986. Invertebrate communities associated with *Bangia Atropurpurea* and *Cladophora Glomerata* in Western Lake Erie. *Journal of Great Lakes Research*, vol. 12(3), pp. 149-153.

Kipp, R.M. 2012. *Bangiaatropurpurea*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. http://nas.er.usgs.gov/queries/greatlakes/SpeciesInfo.asp?NoCache=6%2F7%2F2012+11%3A22%3A25+AM&SpeciesID=1700&State=&HUCNumber=

Sonzogni, W.B., A. Robertson & A.M. Beeton. 1983. Great Lakes management: Ecological factors. *Environmental Management*, vol. 7(6), pp. 531-542.

B.2.2.4 Diatom - Stephanodiscus binderanus

Environmental Consequences Rating: **LOW**
S. binderanus is a diatom that has declined in abundance as nutrient inputs into the Great Lakes declined (Kipp 2011). Introductions of this species in Lake Ontario caused local extinctions of native diatoms (Spaulding et al. 2010). The species produces dense near-shore blooms (Kipp 2011). In addition to changes in phytoplankton communities, this diatom's blooms can have ecosystem-level effects. For example, there is evidence that blooms contributed to hypoxia in Lake Erie (Lashaway & Carrick 2010). The blooms may reduce light penetration into the water and lower dissolved oxygen. If this were to occur, habitat quality may be reduced in the area affected by the bloom. There is 4,848,544 acres of littoral and open water habitat and 81,400 miles of large and medium sized rivers in the MRB, some of which is potentially suitable for this species. However, the species may be problematic only in areas of the MRB with habitat conditions conducive to bloom formation (i.e., high light and nutrients). Therefore, the blooms of this species and their associated impacts are not expected to be common or widespread. The environmental consequence rating for this species is low.

Uncertainty Rating: MEDIUM
It is uncertain as to the extent that this diatom will exist in the MRB. If a large, dense population occurs, the species could have big impacts on the environment. However, if there are only small, isolated populations, the impacts will be minor. Therefore, the uncertainty associated with the environmental consequences of this diatom is medium.

Ecosystem Structure and Function Impacts Matrix
(• indicates a potential to affect the category)

ANS	Ecosystem Function			Ecosystem Structure					
	Nutrient Cycling[a]	Productivity[b]	Food Web Dynamics[c]	Competition and/or Predation[d]	Habitat Quality and Quantity[e]	Biodiversity[f]	ESA-Listed Species[g]	Potentially Available Suitable Habitat[h]	Spatial Extent of ANS Establishment
Diatom (*Stephanodiscus binderanus*)	•	•			•				Widespread

[a] ANS establishment may disrupt nutrient cycling.

[b] ANS establishment may disrupt primary or secondary productivity through a decrease or loss of primary producers and/or consumers.

[c] ANS establishment may alter food webs, affecting food resources, prey abundance, and energy flow between trophic levels.

[d] ANS establishment may result in decreased abundance and/or reduced distribution of one or more resident species through competition or predation.

[e] ANS establishment may reduce quality and/or availability of important habitats.

[f] ANS establishment may alter species composition of communities, including loss or reduction in abundance of resident species.

[g] ANS establishment may adversely impact one or more species listed as threatened or endangered, or habitat designated as critical, under the Endangered Species Act.

[h] Amount of potentially available habitat for ANS establishment; linear miles for lentic habitats; acres for lotic habitats.

References

Kipp, R.M. 2011. *Bangia atropurpurea*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. http://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=1700

Lashaway, A.R. & H.J. Carrick. 2010. Effects of light, temperature and habitat quality on meroplanktonic diatom rejuvenation in Lake Erie: implications for seasonal hypoxia. *Journal of Plankton Research*, vol. 32, pp. 479-490.

Spaulding, S.A., B. Kilroy & M.B. Edlund. 2010. "Chapter 32: Diatoms as non-native species." pp. 560-569. In: J.P. Smol & E.F. Stoermer (Eds.). The Diatoms: Applications for the Environmental and Earth Sciences. Cambridge University Press. New York, NY.

B.2.3 Bryozoan

B.2.3.1 Freshwater Bryozoan - *Lophopodella carteri*

Environmental Consequences Rating: LOW
L. carteri is a sessile, suspension-feeding bryozoan that forms colonies on hard surfaces, soft sediments, mollusk shells, and aquatic plants. This bryozoan competes with zebra mussels over space and may limit settling and recruitment of the zebra mussel (Ricciardi & Reiswig 1994; Lauer et al. 1999). Therefore, this species may affect *Dreissena* spp. populations in the MRB. The coelomic fluid of this species damages the gill epithelium of certain fish and salamander species (Lauer et al. 1999). Although this bryozoan can be locally abundant (Wood & Marsh 1996), no studies were found suggesting this species generated ecological effects following its establishment in the Great Lakes. There is 18,781,437 acres of littoral and wetland habitat and 15,195,531 miles of stream and riverine habitat in the MRB, some of which is potentially suitable for this species. Therefore, this species could potentially be widespread. However, bryozoans are common in the MRB, and therefore this species is not expected to significantly alter community structure or ecosystem function. Overall, the consequences of the establishment of this species in the MRB are low.

Uncertainty Rating: **MEDIUM**
There are no documented ecological impacts from the introduction of this bryozoan species into the GLB, although the species does not appear to have been studied extensively. Overall, there is a medium degree of uncertainty regarding the environmental consequences of the freshwater bryozoan.

References

Lauer, T.E., D.K. Barnes, A. Ricciardi & A. Spacie. 1999. Evidence of recruitment inhibition of zebra mussels (Dreissenapolymorpha) by a freshwater bryozoan (*Lophopodellacarteri*). *Journal of the North American Benthological Society*, vol. 18(3), pp. 406-413.

Ricciardi, A. & H.M. Reiswig. 1994. Taxonomy, distribution, and ecology of the freshwater bryozoans (Ectoprocta of eastern Canada. *Canadian Journal of Zoology*, vol. 72, pp. 339-359.

Wood, T.S. & T.G. Marsh. 1996. “The Sinking Floatblasts of Lophopodellacarteri (Bryozoa: Phylactolaemata).” pp. 383-389. In: Gordon, D.P., A.M. Smith, and J.A. Grant-Mackie (eds.) Bryozoans in Space and Time: National Institute of Water & Atmospheric Research. Wellington, New Zealand.

B.2.4 Molluscs

B.2.4.1 Greater European Peaclam - *Pisidium amnicum*

Environmental Consequences Rating: **LOW**
The greater European peaclam can reach high densities (Holopainen & Jonasson 1989) in Europe and has the potential to crowd out native benthic macroinvertebrates. However, this species is often found at low densities in the GLB (Trebitz 2010; Kipp et al. 2012). There is 16,408,679 acres of littoral and wetland habitat and 1,519,531 miles of stream and riverine habitat in the MRB, that may potentially be suitable for this species. Therefore, this species could potentially be widespread in the MRB. However, the existing literature on this species did not suggest its establishment had resulted in significant environmental impacts in the GLB. Therefore, the environmental consequences of the establishment of the greater European peaclam in the MRB are expected to be low.

Uncertainty Rating: MEDIUM
It is uncertain how abundant the greater European peaclam will be in the MRB. A low density may not have much of an impact on the ecosystem of the MRB, while at higher densities this species may displace native benthic macroinvertebrates. There are few studies of this species, but it has been established in the MRB for over 100 years, and is not linked to any known environmental consequences. Overall, the uncertainty is medium.

Ecosystem Structure and Function Impacts Matrix
(• indicates a potential to affect the category)

	Ecosystem Function			Ecosystem Structure					
ANS	Nutrient Cycling[a]	Productivity[b]	Food Web Dynamics[c]	Competition and/or Predation[d]	Habitat Quality and Quantity[e]	Biodiversity[f]	ESA-Listed Species[g]	Potentially Available Suitable Habitat[h]	Spatial Extent of ANS Establishment
European Peaclam (*Pisidium amnicum*)				•					Widespread

[a] ANS establishment may disrupt nutrient cycling.

[b] ANS establishment may disrupt primary or secondary productivity through a decrease or loss of primary producers and/or consumers.

[c] ANS establishment may alter food webs, affecting food resources, prey abundance, and energy flow between trophic levels.

[d] ANS establishment may result in decreased abundance and/or reduced distribution of one or more resident species through competition or predation.

[e] ANS establishment may reduce quality and/or availability of important habitats.

[f] ANS establishment may alter species composition of communities, including loss or reduction in abundance of resident species.

[g] ANS establishment may adversely impact one or more species listed as threatened or endangered, or habitat designated as critical, under the Endangered Species Act.

[h] Amount of potentially available habitat for ANS establishment; linear miles for lentic habitats; acres for lotic habitats.

References

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B.2.4.2 European Fingernail Clam - *Sphaerium corneum*

Environmental Consequences Rating: **LOW**
The European fingernail clam could displace native species and is a host to parasitic flatworms. The European fingernail clam hosts such digenean species as *Crepidostomum transmarinum, Bunodera lucipercae*, and *Phyllodistomum simile* in North America (Mackie 1976, 2000). There is 16,408,679 acres of littoral and wetland habitat and 577,029 miles of stream and riverine habitat in the MRB, that may potentially be suitable for this species. Therefore, this species could potentially be widespread in the MRB. However, no studies were found suggesting this species generated ecological effects following its introduction to non-native habitats, including the Great Lakes. Overall, the consequences of the establishment of this species in the MRB are low.

Uncertainty Rating: MEDIUM
It is uncertain how abundant the European fingernail clam will be in the MRB. A low density may not have little impact, while at higher densities this species may displace native benthic macroinvertebrates. There are few studies of this species, but it is relatively uncommon in the MRB, and is not linked to any known environmental consequences. Overall, the uncertainty is medium.

Ecosystem Structure and Function Impacts Matrix
(• indicates a potential to affect the category)

	Ecosystem Function			Ecosystem Structure					
ANS	Nutrient Cycling[a]	Productivity[b]	Food Web Dynamics[c]	Competition and/or Predation[d]	Habitat Quality and Quantity[e]	Biodiversity[f]	ESA-Listed Species[g]	Potentially Available Suitable Habitat[h]	Spatial Extent of ANS Establishment
European Fingernail Clam (*Sphaerium corneum*)				•					Widespread

[a] ANS establishment may disrupt nutrient cycling.

[b] ANS establishment may disrupt primary or secondary productivity through a decrease or loss of primary producers and/or consumers.

[c] ANS establishment may alter food webs, affecting food resources, prey abundance, and energy flow between trophic levels.

[d] ANS establishment may result in decreased abundance and/or reduced distribution of one or more resident species through competition or predation.

[e] ANS establishment may reduce quality and/or availability of important habitats.

[f] ANS establishment may alter species composition of communities, including loss or reduction in abundance of resident species.

[g] ANS establishment may adversely impact one or more species listed as threatened or endangered, or habitat designated as critical, under the Endangered Species Act.

[h] Amount of potentially available habitat for ANS establishment; linear miles for lentic habitats; acres for lotic habitats.

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B.2.4.3 European Stream Valvata - *Valvata piscinalis*

Environmental Consequences Rating: **LOW**
The European stream valvata has the potential to compete with native gastropods for food and space (Grigorovich et al. 2005). Unlike native gastropods, it is capable of filter feeding on suspended food items in eutrophic conditions, and this could conceivably allow it to become competitively dominant in such conditions (Kipp et al. 2011). There are 23,458,649 acres of littoral and wetland habitat and 1,519,531 miles of stream and riverine habitat in the MRB, that may potentially be suitable for this species. The European stream valvata can have locally high densities (Grigorovich et al. 2005). Therefore, this species could potentially be widespread in the MRB. However, no studies were found on suggesting this species generated ecological effects following its introduction to non-native habitats, including the Great Lakes. As with any introduced species, the European stream valvata will compete with similar species but is not likely to have large environmental consequences. Therefore, the probability of environmental consequences is low.

Uncertainty Rating: MEDIUM
The European stream valvata may outcompete native snails. The existing literature does not suggest a significant environmental consequence will result from the introduction of the European stream valvata. However, this species is not well studied in the GLB. Therefore, the uncertainty is medium.

Ecosystem Structure and Function Impacts Matrix
(• indicates a potential to affect the category)

	Ecosystem Function			Ecosystem Structure					
ANS	Nutrient Cycling[a]	Productivity[b]	Food Web Dynamics[c]	Competition and/or Predation[d]	Habitat Quality and Quantity[e]	Biodiversity[f]	ESA-Listed Species[g]	Potentially Available Suitable Habitat[h]	Spatial Extent of ANS Establishment
European Stream valvata (*Valvata piscinalis*)				•			•		Widespread

[a] ANS establishment may disrupt nutrient cycling.

[b] ANS establishment may disrupt primary or secondary productivity through a decrease or loss of primary producers and/or consumers.

[c] ANS establishment may alter food webs, affecting food resources, prey abundance, and energy flow between trophic levels.

[d] ANS establishment may result in decreased abundance and/or reduced distribution of one or more resident species through competition or predation.

[e] ANS establishment may reduce quality and/or availability of important habitats.

[f] ANS establishment may alter species composition of communities, including loss or reduction in abundance of resident species.

[g] ANS establishment may adversely impact one or more species listed as threatened or endangered, or habitat designated as critical, under the Endangered Species Act.

[h] Amount of potentially available habitat for ANS establishment; linear miles for lentic habitats; acres for lotic habitats.

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B.2.5 Crustaceans

B.2.5.1 Scud - Apocorophium lacustre

Environmental Consequences Rating: **MEDIUM**
The scud is a tube-dwelling, benthic, filter-feeder. Within the Great Lakes Basin, approximately 4,995,604 acres of littoral, open water, and floodplain wetland habitat and 55,468 mi of stream have been identified as suitable or potentially suitable for the scud. Within the five Great Lakes, there is approximately 60,028,226 acres of nearshore and benthic habitat that may be suitable for this species. In coastal systems, the scud can have adverse effects on native mussels by smothering them with tubes and by competing with them for food (Ysebaert et al. 2000). Therefore, this species may adversely affect populations of the non-native zebra mussels in the GLB. Edward Dewalt of the Illinois Natural History Survey said the potential competitive interactions with native mussels, other invertebrates, and fish "might have severe repercussions for native species in the Illinois River" (Beaumont 1993). In addition, there are federally listed mussels in the GLB that could potentially be affected by an invasion of the scud through competition for space or food. Alternatively, the scud could be an important food source for benthic fish like the sturgeon (Seibert et al. 2011). The scud can be locally abundant and cover river bottoms with tubes (Beaumont 1993), which could significantly alter benthic habitat, community structure, and sediment biogeochemistry. However, there are currently no documented ecosystem-level changes that have resulted from the introduction of the scud in the MRB. Overall, the consequences are medium.

Uncertainty Rating: **HIGH**
There is little biological information available on the scud; however, the species is known to cause the displacement of native benthos and to potentially compete with mussels for resources (Ysebaert et al. 2000; Evans et al. 2004). However, no ecological effects of these species have been reported in the MRB where this species is established. Therefore, there is a high degree of uncertainty associated with its environmental effects.

Ecosystem Structure and Function Impacts Matrix
(• indicates a potential to affect the category)

	Ecosystem Function			Ecosystem Structure					
ANS	Nutrient Cycling[a]	Productivity[b]	Food Web Dynamics[c]	Competition and/or Predation[d]	Habitat Quality and Quantity[e]	Biodiversity[f]	ESA-Listed Species[g]	Potentially Available Suitable Habitat[h]	Spatial Extent of ANS Establishment
Scud (*Apocorophium lacustre*)	•			•	•	•	•		Widespread

[a] ANS establishment may disrupt nutrient cycling.

[b] ANS establishment may disrupt primary or secondary productivity through a decrease or loss of primary producers and/or consumers.

[c] ANS establishment may alter food webs, affecting food resources, prey abundance, and energy flow between trophic levels.

[d] ANS establishment may result in decreased abundance and/or reduced distribution of one or more resident species through competition or predation.

[e] ANS establishment may reduce quality and/or availability of important habitats.

[f] ANS establishment may alter species composition of communities, including loss or reduction in abundance of resident species.

[g] ANS establishment may adversely impact one or more species listed as threatened or endangered, or habitat designated as critical, under the Endangered Species Act.

[h] Amount of potentially available habitat for ANS establishment; linear miles for lentic habitats; acres for lotic habitats.

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B.2.5.2 Fishhook Waterflea - *Cercopagis pengoi*

Environmental Consequences Rating: **HIGH**
A 2002 study of the food web impacts of the fishhook water flea showed that the depth at which it exists was depleted of small organisms (less than 0.15 mg) (Benson et al. 2011). It is unclear as to whether this is due to predator evasion or predation by the fishhook water flea. The fishhook water flea could have a serious effect on the food supply of planktivores. Its long spine makes it less palatable to planktivorous fish. For example, yearling alewives compete directly with fishhook water flea, because they are planktivorous, and cannot consume fishhook water flea because of the caudal appendage. Once alewives reach their first year, they are large enough to handle the caudal appendage (Bushnoe et al. 2003).

Fishhook water flea predation on small zooplankton has caused decreased juvenile copepod production and changed their vertical distribution (Panov et al. 2007). Predation has caused large late-summer decreases in several smaller zooplankton groups in Lake Ontario, including bosminids, *D. thomasi* copepodites, and nauplii (Warner et al. 2006). Significant reduction in the densities of rotifers and cyclopoids following the introduction of the fishhook water flea was observed (Witt et al. 2005). As a result of the reduction in zooplankton abundance, an increase in phytoplankton abundance occurs (Brown & Balk 2008). In addition, there are 4,848,544 acres of littoral and open water habitat and 81,400 miles of riverine habitat in the MRB, that may potentially be suitable for this species. Therefore, the fishhook water flea could potentially be widespread in the MRB. Therefore, there is a high probability of environmental consequences.

Uncertainty Rating: MEDIUM
The uncertainty associated with the fishhook water flea's environmental consequences is medium. There is literature to support a change to the environment with an invasion of the fishhook water flea; however, the extent to which this will occur in the MRB is uncertain.

Ecosystem Structure and Function Impacts Matrix
(• indicates a potential to affect the category)

	Ecosystem Function			Ecosystem Structure					
ANS	Nutrient Cycling[a]	Productivity[b]	Food Web Dynamics[c]	Competition and/or Predation[d]	Habitat Quality and Quantity[e]	Biodiversity[f]	ESA-Listed Species[g]	Potentially Available Suitable Habitat[h]	Spatial Extent of ANS Establishment
Fishhook water flea (Cercopagis pengoi)			•	•		•			Widespread

[a] ANS establishment may disrupt nutrient cycling.

[b] ANS establishment may disrupt primary or secondary productivity through a decrease or loss of primary producers and/or consumers.

[c] ANS establishment may alter food webs, affecting food resources, prey abundance, and energy flow between trophic levels.

[d] ANS establishment may result in decreased abundance and/or reduced distribution of one or more resident species through competition or predation.

[e] ANS establishment may reduce quality and/or availability of important habitats.

[f] ANS establishment may alter species composition of communities, including loss or reduction in abundance of resident species.

[g] ANS establishment may adversely impact one or more species listed as threatened or endangered, or habitat designated as critical, under the Endangered Species Act.

[h] Amount of potentially available habitat for ANS establishment; linear miles for lentic habitats; acres for lotic habitats.

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B.2.5.3 Waterflea - Daphnia galeata galeata

Environmental Consequences Rating: **LOW**

Daphnia galeata galeata is a water flea that can crowd other zooplankton. Although Daphnia depth-habitat choice is influenced by food availability (Leibold & Tessier 1997; Ringelberg 1999). Most daphnids are lake species, but the invasive *Daphnia lumholtzi* has established in the MRB. There are 4,848,545 acres of littoral, open water, and wetland habitat and 577,029 miles of stream and riverine habitat in the MRB, that may potentially be suitable for this species. Therefore, this species could potentially be widespread in the MRB.

This water flea has hybridized in Lake Erie with *D. g. mendoatae*; the resultant clones are very common (Taylor & Hebert 1993). Daphnia hybrids tend to have greater variation in relative niche breadths (Weider 1993). It has been suggested that the clones may be more fit than either parent clone (Taylor & Hebert 1993), potentially allowing them to outcompete native zooplankton. However, it is unknown whether *D. g. galeata* can hybridize with daphnids in the MRB. If this species does establish in the MRB, it would fill an ecological niche similar to existing zooplankton and is not expected to result in ecosystem changes. The existing literature does not suggest this species adversely affected the ecosystem structure and function after its establishment in the GLB. Therefore, the ecological consequences of establishment are predicted to be low.

Uncertainty Rating: LOW

D. g. galeata has not been documented to generated ecosystem consequences. Therefore, the uncertainty of the consequence rating is low.

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B.2.5.4 Bloody Red Shrimp - *Hemimysis anomala*

Environmental Consequences Rating: **HIGH**
The bloody red shrimp has the potential to disrupt trophodynamics in lakes, consistent with the effects of other introduced fresh water mysids. Investigations of introduced mysids have demonstrated the potential for severe declines and compositional shifts of macrozooplankton communities, reduced abundances and growth rates of pelagic fishes, and altered nutrient and contaminant cycling (Ricciardi et al. 2011).

The feeding activities of a dense mysid population could reduce energy flow between benthic and pelagic food webs (Ricciardi et al. 2011). There are 4,848,545 acres of littoral and open water habitat and 1,519,531 miles of stream and riverine habitat in the MRB, that may potentially be suitable for this species. Therefore, this species could potentially be widespread in the MRB. Within river systems, the impacts of the bloody red shrimp will likely be most pronounced in backwater lakes, impounded areas, and reservoirs (Ricciardi et al. 2011). Bloody red shrimp may reduce zooplankton biomass and diversity in the MRB, as seen in some European reservoirs with cladocerans, rotifers, and ostracods being most affected (Ketelaars et al. 1999). Because of their role as top-down regulators of the planktonic communities, the mysids may destroy food resources of young fish and totally change the community structure (Richards et al. 1975). Preferential predation on daphniidae may increase abundance of other zooplankton through competitive release (Ricciardi et al.2011). Its omnivory may reduce local phytoplankton if small-sized juvenile mysids are abundant (Ketelaars et al. 1999). However, phytoplankton biomass typically increases (sometimes doubling) following mysid invasions due to predation on other herbaceous invertebrates (Borcherding et al. 2006). The presence of abundant dreissenid mussel populations could alter the bloody red shrimp's impact on phytoplankton populations.

Bloody red shrimp are energy-rich prey items for near-shore fishes and may provide new food sources for percids, centrarchids and small-sized burbot (*Lota lota*) (Ricciardi et al. 2011). In some lakes mysid introductions have preceded the increased growth of salmonids, whereas in other lakes they are associated with rapid declines in abundance and productivity of pelagic fishes (Lasenby et al. 1986; Langeland et al. 1991; Spencer et al. 1991). If predation on the bloody red shrimp by fish is low and mysid abundance is high, it is thought that the bloody red shrimp will negatively affect the growth and abundance of young of the year and planktivorous fish in near-shore areas (Ricciardi et al. 2011).

Through direct transmission and indirect effects on the food web, introduced mysids may cause increased parasitism by nematodes, cestodes, and acanthocephalans in fishes (Lasenby et al. 1986; Northcote 1991). In addition to serving as intermediate hosts for a variety of fish parasites, they affect host-parasite relationships by altering the composition of zooplankton. Following mysid introductions in Swedish lakes, the incidence of parasitism by cestodes increased in arctic char, driven by an increased abundance of copepods replacing cladocerans in fish diets (Lasenby et al. 1986). As an abundant carnivorous zooplankter, the bloody red shrimp may also increase the number of trophic levels, thereby increasing biomagnfication of contaminants such as mercury (Ricciardi et al. 2011). Overall, the consequences of the establishment of this species in the GLB are high.

Uncertainty Rating: HIGH

The uncertainty associated with environmental consequences of the bloody red shrimp is high. There is literature that states that changes in lake dynamics will occur; however the predictions vary and a realistic prediction is not known.

Ecosystem Structure and Function Impacts Matrix
(• indicates a potential to affect the category)

	Ecosystem Function			Ecosystem Structure					
ANS	Nutrient Cycling[a]	Productivity[b]	Food Web Dynamics[c]	Competition and/or Predation[d]	Habitat Quality and Quantity[e]	Biodiversity[f]	ESA-Listed Species[g]	Potentially Available Suitable Habitat[h]	Spatial Extent of ANS Establishment
Bloody Red Shrimp (*Hemimysis anomala*)	•		•	•		•			Widespread

[a] ANS establishment may disrupt nutrient cycling.

[b] ANS establishment may disrupt primary or secondary productivity through a decrease or loss of primary producers and/or consumers.

[c] ANS establishment may alter food webs, affecting food resources, prey abundance, and energy flow between trophic levels.

[d] ANS establishment may result in decreased abundance and/or reduced distribution of one or more resident species through competition or predation.

[e] ANS establishment may reduce quality and/or availability of important habitats.

[f] ANS establishment may alter species composition of communities, including loss or reduction in abundance of resident species.

[g] ANS establishment may adversely impact one or more species listed as threatened or endangered, or habitat designated as critical, under the Endangered Species Act.

[h] Amount of potentially available habitat for ANS establishment; linear miles for lentic habitats; acres for lotic habitats.

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B.2.5.5 Parasitic Copepod - *Neoergasilus japonicas*

Environmental Consequences Rating: **LOW**
Adult female parasitic copepods are parasitic on fish (Abdelhalim et al. 1993). Within Lake Huron, individuals have been found more frequently on adult than on young-of-the-year fish hosts (Kipp 2011). In the Great Lakes, females have been found on a number of fish species also present in the MRB, including Centrarchids, channel catfish, common carp, perch, and fathead minnows (Hayden & Rogers 1998; Hudson & Bowen 2002; Kipp et al. 2012). In Saginaw Bay, Michigan, the infection rate of the 11 species of fish sampled ranged from 7 to 86% (Hudson & Bowen 2002); yellow perch and golden shiner were found to have the highest intensity of parasitism, with 15.1 and 14.6 copepods/individual, respectively (Hudson & Bowen 2002). Once established, parasitic copepods are capable of surviving on many different host fish species, and transferring from one host fish to another (Kipp 2011). No serious adverse effects were found on infected fish in Britain; however low growth rates of roach may be due to parasitic copepod infection (Mugridge et al. 1982). However, high parasitism rates and densities are typically found in ponds rather than rivers and large lakes (Hudson & Bowen 2002). Overall, the consequences of parasitic copepods establishing in the MRB are expected to be low.

Uncertainty Rating: **LOW**
High infection rates of fish have been reported in Hungary and Japan; however, the ecological effects of these infections have not been described (Hudson & Bowen 2002). Thus far, infection rates of parasitic copepods are reported to be low in the United States, and their impact on socioeconomically important fish species is predicted to be modest (O'Connor et al. 2008). Therefore, there is a low uncertainty rating associated with the environmental consequences of the parasitic copepod.

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B.2.5.6 Harpacticoid Copepod - *Schizopera borutzkyi*

Environmental Consequences Rating: **LOW**

Schizopera borutzkyi is a small copepod that lives in the sediment. The species can occupy rivers and lakes, so it may be able to spread through these habitats in the MRB. There are 16,408,680 acres of littoral, open water, and wetland habitat and 1,519,531 miles of stream and riverine habitat in the MRB, that may potentially be suitable for this species. Therefore, this species could potentially be widespread in the MRB. Since its arrival in Lake Michigan, the copepod has become the dominant harpacticoid in deep sites (at 15 m [49 ft]), where it has been recorded at densities of 3,700/m^2 (Horvath et al. 2001). These results suggest this species has the capacity to alter the local species composition of benthic invertebrates in near-shore communities and replace native copepods. However, the existing literature does not suggest that this copepod has altered food webs or ecosystem level processes where it has established in the Great Lakes. Overall the consequences of establishment are low.

Uncertainty Rating: **MEDIUM**

Although this species has become a dominant copepod in Lake Michigan, it is uncertain whether the introduction of this species resulted in loss of species diversity (Horvath et al. 2001). This copepod is also larger than other Great Lakes harpacticoids (Horvath et al. 2001) and may not be as easily eaten by higher trophic levels, although this has not been established experimentally. Thus, although this copepod has affected the composition of the harpacticoid community, it is unclear how these changes will affect the food web in these near-shore habitats. In addition, no studies were found on whether this species generated ecological effects following its introduction to non-native habitats. Overall, there is a medium degree of uncertainty regarding the environmental consequences.

Ecosystem Structure and Function Impacts Matrix
(• indicates a potential to affect the category)

	Ecosystem Function			Ecosystem Structure					
ANS	Nutrient Cycling[a]	Productivity[b]	Food Web Dynamics[c]	Competition and/or Predation[d]	Habitat Quality and Quantity[e]	Biodiversity[f]	ESA-Listed Species[g]	Potentially Available Suitable Habitat[h]	Spatial Extent of ANS Establishment
Harpacticoid Copepod (*Schizopera borutzkyi*)				•					Widespread

[a] ANS establishment may disrupt nutrient cycling.

[b] ANS establishment may disrupt primary or secondary productivity through a decrease or loss of primary producers and/or consumers.

[c] ANS establishment may alter food webs, affecting food resources, prey abundance, and energy flow between trophic levels.

[d] ANS establishment may result in decreased abundance and/or reduced distribution of one or more resident species through competition or predation.

[e] ANS establishment may reduce quality and/or availability of important habitats.

[f] ANS establishment may alter species composition of communities, including loss or reduction in abundance of resident species.

[g] ANS establishment may adversely impact one or more species listed as threatened or endangered, or habitat designated as critical, under the Endangered Species Act.

[h] Amount of potentially available habitat for ANS establishment; linear miles for lentic habitats; acres for lotic habitats.

References

Horvath, T.G., R.L. Whitman & L.L. Last. 2001. Establishment of two invasive crustaceans (Copepoda: Harpacticoida) in the nearshore sands of Lake Michigan. *Canadian Journal of Fisheries and Aquatic Sciences*, vol. 58, pp. 1261-1264.

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B.2.6 Fish

B.2.6.1 Skipjack Herring - *Alosa chrysochloris*

Environmental Consequences Rating: LOW

Within the Great Lakes Basin, approximately 1,025,807 acres of littoral and open water habitat and 92,267 mi of stream and riverine habitat have been identified as suitable or potentially suitable for the skipjack herring. Within the five Great Lakes, there is approximately 60,028,226 acres of littoral and deepwater habitat that may be suitable for this species. The skipjack herring is native to the MRB, where it has coexisted with other herring species (Fuller 2011). Although it has historically had access to the GLB, the skipjack herring has been found in the Great Lakes only infrequently (Fuller 2011). Adult skipjack herring feed on small fishes, while juveniles feed on insects and zooplankton (FishBase 2010; NatureServe 2010; Fuller 2011). On the basis of its dietary preferences, the skipjack herring would potentially compete with and prey on several species within the GLB. The species could have widespread distribution in the MRB. However, there are several existing fish species in the GLB (i.e., ciscoes) whose ecological niches are similar to those of the skipjack herring. Therefore, this species is not expected to alter existing food webs or productivity. They could potentially compete with the mooneye (*Hiodon tergisus*), which has protected status in some states. Overall, the skipjack herring has an environmental consequence rating of low.

Uncertainty Rating: LOW

In the literature skipjack herring are not reported to be a nuisance species. It is unlikely that this species would alter ecosystem dynamics in the GLB, because it is not documented to be a superior competitor. Consequently, uncertainty is low for the ecological consequences rating.

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NatureServe. 2010. NatureServe Explorer: An online encyclopedia of life [Web application]. Version 7.1. NatureServe, Arlington, Virginia. http://www.natureserve.org/explorer

B.2.6.2 Northern Snakehead - *Channa argus*

Environmental Consequences Rating: **HIGH**
The northern snakehead prefers slow-moving water and is likely to be found in backwaters (Fuller & Benson 2011). Within the Great Lakes Basin, approximately 4,995,604 acres of littoral, open water, and floodplain wetland habitat and 92,267 mi of stream and riverine habitat have been identified as suitable or potentially suitable for the northern snakehead. Within the five Great Lakes, there is approximately 1,254,666 acres of nearshore habitat that may be suitable for this species. The ecology and physiology of the northern snakehead gives it a competitive advantage over native species for food and habitat (Fuller & Benson 2011). The diet of the northern snakehead consists mainly of fish; therefore, negative impacts on native fish populations in its introduced range could be high (NBII & ISSG 2008). The species has the potential to modify the biodiversity of an area (USFWS 2002). Although impacts on other fish species may be high, negative impacts on the physical habitat would be low (Courtenay & Williams 2004). Snakeheads may introduce parasites and disease to native fish populations (NBII & ISSG 2008). Overall, the environmental consequences of the establishment of the northern snakehead on the GLB is high.

Uncertainty Rating: HIGH
Although the existing literature suggests this species could alter fish communities, no studies were found on whether this species has actually generated ecological effects following its introduction to non-native habitats like the Chesapeake Bay system. The effect that the species can have on fish populations in the GLB is also uncertain. Therefore, the uncertainty rating associated with the environmental consequences of the northern snakehead is high.

Ecosystem Structure and Function Impacts Matrix
(• indicates a potential to affect the category)

	Ecosystem Function			Ecosystem Structure					
ANS	Nutrient Cycling[a]	Productivity[b]	Food Web Dynamics[c]	Competition and/or Predation[d]	Habitat Quality and Quantity[e]	Biodiversity[f]	ESA-Listed Species[g]	Potentially Available Suitable Habitat[h]	Spatial Extent of ANS Establishment
Northern Snakehead (*Channa argus*)			•			•			Widespread

[a] ANS establishment may disrupt nutrient cycling.

[b] ANS establishment may disrupt primary or secondary productivity through a decrease or loss of primary producers and/or consumers.

[c] ANS establishment may alter food webs, affecting food resources, prey abundance, and energy flow between trophic levels.

[d] ANS establishment may result in decreased abundance and/or reduced distribution of one or more resident species through competition or predation.

[e] ANS establishment may reduce quality and/or availability of important habitats.

[f] ANS establishment may alter species composition of communities, including loss or reduction in abundance of resident species.

[g] ANS establishment may adversely impact one or more species listed as threatened or endangered, or habitat designated as critical, under the Endangered Species Act.

[h] Amount of potentially available habitat for ANS establishment; linear miles for lentic habitats; acres for lotic habitats.

References

Courtenay, W.R. & J.D. Williams. 2004. Snakeheads (*Pisces*, *Channidae*) – A Biological Synopsis and Risk Assessment. U.S. Geological Survey, Circular 1251.

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NBII & ISSG (National Biological Information Infrastructure & IUCN/SSC Invasive Species Specialist Group). 2008. Global Invasive Species Database. http://www.issg.org/database/species/ecology.asp?si=380&fr=1&sts=sss&lang=EN

USFWS (U.S. Fish and Wildlife Service). 2002. Invasive Species Program Snakeheads – The Newest Aquatic Invader.

B.2.6.3 Inland Silverside - *Menidia beryllina*

Environmental Consequences Rating: **LOW**
The inland silverside is found in littoral and pelagic waters of lakes, streams, and estuaries. Within the Great Lakes Basin, approximately 4,995,604 acres of littoral, open water, and floodplain wetland habitat and 92,267 mi of stream and riverine habitat have been identified as suitable or potentially suitable for the inland silverside. Within the five Great Lakes, there is approximately 1,254,666 acres of nearshore habitat that may be suitable for this species. It feeds primarily on zooplankton but also consumes benthic invertebrates (FishBase 2010; Chizinski et al. 2007). If the inland silverside establishes in the GLB, it could compete with other fish species that consume zooplankton as adults and/or during early life stages. After introduction to a new habitat, the inland silverside can become a dominant planktivore and has been documented to have altered fish species composition by out-competing other species (Fuller & Nico 2012). For example, studies of introduced inland silverside have documented reduced growth of bluegill sunfish, crappie, and brook silverside *Labidesthes sicculus* (Fuller & Nico 2012), all three of which are common in the GLB. In Clear Lake, California, they may have contributed to the local extinction of the Clear Lake splittail (Suchanek et al. 2002). However, within the GLB, there are no ESA-listed species the inland silverside is predicted to affect. There are several species within the GLB that occupy an ecological niche similar to that of the inland silverside, including the brook silverside. Therefore, the establishment of this species is not expected to alter ecosystem-level processes in the GLB. In addition, this species is not adapted to cold temperatures found in the GLB (Stoeckel & Heidinger 1998) and may not be able to form abundant, widespread, and persistent populations. Overall, the environmental consequences of establishment would be low.

Uncertainty Rating: LOW
The Inland silverside is typically documented to be abundant where established. Several studies have documented changes in fish community structure following the introduction of the inland silverside. Several species that are present in the GLB are documented to have been adversely affected by the inland silverside. However, this is a temperature-sensitive species and existing studies suggest it will not reach a high abundance in the GLB. There is no evidence suggesting the inland silverside would significantly alter ecosystem processes in the GLB. Consequently, uncertainty is low.

Ecosystem Structure and Function Impacts Matrix
(• indicates a potential to affect the category)

ANS	Ecosystem Function: Nutrient Cycling[a]	Ecosystem Function: Productivity[b]	Ecosystem Function: Food Web Dynamics[c]	Ecosystem Structure: Competition and/or Predation[d]	Ecosystem Structure: Habitat Quality and Quantity[e]	Ecosystem Structure: Biodiversity[f]	Ecosystem Structure: ESA-Listed Species[g]	Potentially Available Suitable Habitat[h]	Spatial Extent of ANS Establishment
Inland silverside (*Menidia beryllina*)				•		•			Localized

[a] ANS establishment may disrupt nutrient cycling.

[b] ANS establishment may disrupt primary or secondary productivity through a decrease or loss of primary producers and/or consumers.

[c] ANS establishment may alter food webs, affecting food resources, prey abundance, and energy flow between trophic levels.

[d] ANS establishment may result in decreased abundance and/or reduced distribution of one or more resident species through competition or predation.

[e] ANS establishment may reduce quality and/or availability of important habitats.

[f] ANS establishment may alter species composition of communities, including loss or reduction in abundance of resident species.

[g] ANS establishment may adversely impact one or more species listed as threatened or endangered, or habitat designated as critical, under the Endangered Species Act.

[h] Amount of potentially available habitat for ANS establishment; linear miles for lentic habitats; acres for lotic habitats.

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FishBase. 2010. Inland silverside. http://fishbase.org/Summary/SpeciesSummary.php?ID=3241&AT=inland+silverside

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Stoeckel, J.N. & Heidinger, R.B. 1998. Overwintering of the inland silverside in Southern Illinois. *North American Journal of Fisheries Management*, vol. 8(1), pp. 137-131.

B.2.6.4 Black Carp - *Mylopharyngodon piceus*

Environmental Consequences Rating: **HIGH**
Within the Great Lakes Basin, approximately 4,995,604 acres of littoral, open water, and floodplain wetland habitat and 92,267 mi of stream and riverine habitat have been identified as suitable or potentially suitable for the black carp. Within the five Great Lakes, there is approximately 60,028,226 acres of nearshore and deepwater habitat that may be suitable for this species. There are no known native fish with the same combination of size, morphology, and diet to the black carp in the GLB. Black carp could threaten new fish species not currently subject to predation and change ecosystem function by altering the food web in a new environment (Williams et al. 2007). As a bottom-dwelling species, black carp may disrupt the benthic community by direct predation (Nico & Neilson 2012). Fish farmers report that black carp is very effective in reducing the number of snails in some ponds (Nico & Neilson 2012). This indicates that black carp could cause significant declines in native mollusk populations and can out-compete native molluscivores (Nico et al. 2005). There is a large population of invasive zebra mussels (*Dreissena polymorpha)* in the GLB. It is not certain whether the black carp will be able to consume zebra mussels, because it does not have jaw teeth and its mouth is relatively small (Nico et al. 2005). If black carp is able to consume large amounts of zebra mussels, it may affect phytoplankton abundance. High filtering rates by mussels consume an abundance of phytoplankton, suggesting that intense mussel predation may lead to increased algal standing stocks. Black carp also hosts parasites as well as bacterial and viral diseases that may infect native species (Nico & Neilson 2012). Overall, the environmental consequences of the black carp are high.

Uncertainty Rating: **LOW**
Black carp has the potential to out-compete molluscivores, If black carp are able to consume zebra mussels, it could possibly affect phytoplankton abundance in the GLB. However, it is uncertain whether black carp will be able to consume zebra mussels The uncertainty associated with ecosystem consequences of the black carp is low.

Ecosystem Structure and Function Impacts Matrix
(• indicates a potential to affect the category)

ANS	Ecosystem Function: Nutrient Cycling[a]	Ecosystem Function: Productivity[b]	Ecosystem Function: Food Web Dynamics[c]	Ecosystem Structure: Competition and/or Predation[d]	Ecosystem Structure: Habitat Quality and Quantity[e]	Ecosystem Structure: Biodiversity[f]	Ecosystem Structure: ESA-Listed Species[g]	Potentially Available Suitable Habitat[h]	Spatial Extent of ANS Establishment
Black Carp (*Mylopharyngodon piceus*)			•			•	•		Widespread

[a] ANS establishment may disrupt nutrient cycling.

[b] ANS establishment may disrupt primary or secondary productivity through a decrease or loss of primary producers and/or consumers.

[c] ANS establishment may alter food webs, affecting food resources, prey abundance, and energy flow between trophic levels.

[d] ANS establishment may result in decreased abundance and/or reduced distribution of one or more resident species through competition or predation.

[e] ANS establishment may reduce quality and/or availability of important habitats.

[f] ANS establishment may alter species composition of communities, including loss or reduction in abundance of resident species.

[g] ANS establishment may adversely impact one or more species listed as threatened or endangered, or habitat designated as critical, under the Endangered Species Act.

[h] Amount of potentially available habitat for ANS establishment; linear miles for lentic habitats; acres for lotic habitats.

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Nico, L.G. & M.E. Neilson. 2012. *Mylopharyngodon piceus*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. http://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=573

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B.2.6.5 Bighead Carp - Hypophthalmichthyes nobilis

Environmental Consequences Rating: **HIGH**
The bighead carp is a generalist primary consumer that filter-feeds on plankton and prefers eutrophic rivers, lakes, and backwater habitat (Kolar et al. 2005). Although some bioenergetics models suggest that productivity in the GLB is too low to support Asian carp (Cooke & Hill 2010), there are several areas of high productivity within the GLB that are likely to be suitable (Rasmussen et al. 2011). Within the Great Lakes Basin, approximately 4,995,604 acres of littoral, open water, and floodplain wetland habitat and 92,267 mi of stream and riverine habitat have been identified as suitable or potentially suitable for the bighead carp. Within the five Great Lakes, there is approximately 60,028,226 acres of littoral and deepwater habitat that may be suitable for this species although the actual area utilized may be much smaller. The bighead carp could also potentially out-compete many of the filter-feeding species that currently exist in the GLB (Kipp et al. 2011). Native fish species that filter-feed for some or all of their life cycle, such as all larval fish stages, bigmouth buffalo, gizzard shad, and native (and potentially ESA-listed) mussels, could be affected, thereby reducing native biodiversity and altering community structure. For example, in the Illinois River, it has been reported that bigmouth buffalo has been reduced in numbers in areas that have been invaded by the bighead carp (Kolar et al. 2005). In addition, the body condition of both bigmouth buffalo and gizzard shad may have been reduced by competition with Asian carp (Irons et al. 2007).

The bighead carp has the potential to affect ecosystem-level processes. For example, impacts on gizzard shad could have food web implications, because the gizzard shad is an important forage fish for many predatory fish species (Sampson et al. 2009). The bighead carp would not be a suitable replacement for the existing forage fish because its rapid growth may significantly reduce predation by native fishes, and it has no known predators after growing to maturity.

The bighead carp is considered to be a voracious feeder that could change the food web dynamics of newly invaded systems (Cudmore & Mandrak 2004). The bighead carp is typically found to reduce zooplankton abundance. By reducing zooplankton abundance, Asian carp have been found to increase phytoplankton abundance, although not consistently (reviewed in Kipp et al. 2011). By altering plankton communities and excreting nutrients, Asian carp have the potential to alter nutrient cycling within regions of the GLB where they are able to establish (Kolar et al. 2005). Cudmore et al. (2012) ranked the consequences of Asian carp establishment within the GLB as high. Overall, the consequences of the establishment of the bighead carp are high.

Uncertainty Rating: **MEDIUM**
According to Nico and Fuller (2012), the full impact of the bighead carp on ecosystem function and structure in the United States is still uncertain. The spatial extent of the bighead carp establishment in the GLB is uncertain and depends on the availability of food and spawning habitat (Cudmore et al. 2011). However, where the bighead carp is able to establish, it has the potential to generate significant changes to ecosystem structure and function. The long-term effects of Asian carp on the MRB have been studied but are still uncertain. Similarly, if the silver carp establishes in the GLB, the nature and severity of ecosystem impacts are difficult to

predict with certainty. Therefore, the level of uncertainty regarding the predicted consequences of this species is medium.

Ecosystem Structure and Function Impacts Matrix
(• indicates a potential to affect the category)

ANS	Ecosystem Function: Nutrient Cycling[a]	Ecosystem Function: Productivity[b]	Ecosystem Function: Food Web Dynamics[c]	Ecosystem Structure: Competition and/or Predation[d]	Ecosystem Structure: Habitat Quality and Quantity[e]	Ecosystem Structure: Biodiversity[f]	Ecosystem Structure: ESA-Listed Species[g]	Potentially Available Suitable Habitat[h]	Spatial Extent of ANS Establishment
Bighead carp (*Hypophthalmichthys nobilis*)	•	•	•	•	•	•	•		Widespread

[a] ANS establishment may disrupt nutrient cycling.

[b] ANS establishment may disrupt primary or secondary productivity through a decrease or loss of primary producers and/or consumers.

[c] ANS establishment may alter food webs, affecting food resources, prey abundance, and energy flow between trophic levels.

[d] ANS establishment may result in decreased abundance and/or reduced distribution of one or more resident species through competition or predation.

[e] ANS establishment may reduce quality and/or availability of important habitats.

[f] ANS establishment may alter species composition of communities, including loss or reduction in abundance of resident species.

[g] ANS establishment may adversely impact one or more species listed as threatened or endangered, or habitat designated as critical, under the Endangered Species Act.

[h] Amount of potentially available habitat for ANS establishment; linear miles for lentic habitats; acres for lotic habitats.

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B.2.6.6 Silver Carp - Hypophthalmichthys molitrix

Environmental Consequences Rating: **HIGH**
The silver carp is a planktivore that prefers eutrophic rivers, lakes, and backwater habitat (Kolar et al. 2005). Although some bioenergetics models suggest that productivity in the GLB is too low to support Asian carp (Cooke & Hill 2010), there are several areas of high productivity within the GLB that are likely to be suitable (Rasmussen et al. 2011). Within the Great Lakes Basin, approximately 4,995,604 acres of littoral, open water, and floodplain wetland habitat and 92,267 mi of stream and riverine habitat have been identified as suitable or potentially suitable for the silver carp. Within the five Great Lakes, there is approximately 60,028,226 acres of littoral and deepwater habitat that may be suitable for this species although the actual area utilized may be much smaller. Asian carp have been documented to reduce zooplankton abundance and alter their species composition (reviewed in Kipp et al. 2011). Silver carp have high fecundity, and large numbers of silver carp could further deplete zooplankton populations in the GLB, which have already been significantly reduced by *Dreissena* spp. In turn, the reduction in zooplankton abundance could reduce the food supply for planktivores and early life stages of higher-trophic-level fish species. Asian carp are suspected to have altered fish community structure (abundance and species composition) in several lakes in Asia (reviewed in Kipp et al. 2011 and Cudmore et al. 2012). Asian carp now dominate the fish assemblage in many locations within the MRB, having dramatically reduced the abundance of existing fish species (Kipp et al. 2011; Cudmore et al. 2012). The silver carp could potentially out-compete several planktivorous fish that currently exist in the GLB, such as the gizzard shad, ciscos, alewife, and bigmouth buffalo (Irons et al. 2007). Several authors have noted the potential for silver carp to out-compete the paddlefish (*Polyodon spathula*; a planktivore) (Kolar et al. 2005), although other studies suggested little dietary overlap (Sampson et al. 2009). Silver carp also have the potential to reduce food resources available to ESA-listed freshwater mussel species.

The establishment of silver carp in the GLB could also result in several ecosystem-level effects. Therefore, Cudmore et al. (2012) ranked the consequences of Asian carp establishment within the GLB as high. There is experimental evidence that Asian carp may affect phytoplankton biomass by reducing zooplankton abundance. This could result in reduced abundance and altered community composition of fish and invertebrates as well as changes in food web dynamics. There is speculation that Asian carp could alter nutrient cycling by affecting phytoplankton and zooplankton ratios as described above, by their excretion, and by reducing organic matter export to the sediment (Kipp et al. 2011). Overall, the consequences of the silver carp establishing are high.

Explanation for Uncertainty Rating: MEDIUM
Given the low primary productivity of some of the Great Lakes, it is uncertain whether the GLB could support large numbers of silver carp. However, where it is able to exist, it has the potential to substantially alter ecosystem structure and function. The long-term effects of Asian carp on the MRB have been studied but are still uncertain. Similarly, if silver carp establish in the GLB, the nature and severity of ecosystem impacts are difficult to predict with certainty. Overall, the uncertainty of the consequence rating is medium.

Ecosystem Structure and Function Impacts Matrix
(• indicates a potential to affect the category)

ANS	Ecosystem Function: Nutrient Cycling[a]	Ecosystem Function: Productivity[b]	Ecosystem Function: Food Web Dynamics[c]	Ecosystem Structure: Competition and/or Predation[d]	Ecosystem Structure: Habitat Quality and Quantity[e]	Ecosystem Structure: Biodiversity[f]	Ecosystem Structure: ESA-Listed Species[g]	Potentially Available Suitable Habitat[h]	Spatial Extent of ANS Establishment
Silver carp (*Hypophthalmichthyes molitrix*)	•	•	•	•	•	•	•		Widespread

[a] ANS establishment may disrupt nutrient cycling.

[b] ANS establishment may disrupt primary or secondary productivity through a decrease or loss of primary producers and/or consumers.

[c] ANS establishment may alter food webs, affecting food resources, prey abundance, and energy flow between trophic levels.

[d] ANS establishment may result in decreased abundance and/or reduced distribution of one or more resident species through competition or predation.

[e] ANS establishment may reduce quality and/or availability of important habitats.

[f] ANS establishment may alter species composition of communities, including loss or reduction in abundance of resident species.

[g] ANS establishment may adversely impact one or more species listed as threatened or endangered, or habitat designated as critical, under the Endangered Species Act.

[h] Amount of potentially available habitat for ANS establishment; linear miles for lentic habitats; acres for lotic habitats.

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B.2.6.7 Threespine Stickleback - *Gasterosteus aculeatus*

Environmental Consequences Rating: **MEDIUM**
Fresh water populations of threespine stickleback feed primarily on bottom-dwelling invertebrates or organisms living on aquatic plants, while limnetic forms in some lakes feed mainly on plankton (NatureServe 2010; Fuller 2011). There have been reports of rapid expansion and aggressive feeding behavior (Zhuikov 1997). Threespine stickleback could compete with and reduce the abundance of MRB fishes, because this species eats fish eggs and fry. For example, there is evidence that the threespine stickleback has reduced the recruitment success of northern pike in the Baltic (Nilsson 2006). However, the threespine stickleback is a generalist with a life history similar to that of existing MRB species, including sticklebacks native to the MRB. Therefore, even if it replaced existing species, it may not alter food web dynamics or secondary productivity. Threespine stickleback is a habitat generalist; it has a global distribution; and it is capable of adaptive radiation. There are 23458,649 acres of littoral, open water, and wetland habitat and 1,519,531 miles of stream and riverine habitat in the MRB, that may potentially be suitable for this species. Therefore, this species could potentially be widespread in the MRB. Consequently, it has a high potential for spread in the MRB. It has spread through Europe in the past 140 years (Lucek et al. 2010). However, this species is not reported to be dominant or a nuisance species where it is established. Overall, the threespine stickleback has an environmental consequence rating of medium.

Uncertainty Rating: MEDIUM
The threespine stickleback is documented to be a significant egg predator and to affect the abundance of species found in the MRB such as the northern pike (Nilsson 2006). It is also documented to adapt well to new habitats, and this could increase its spread and abundance. However, this species is not reported to be dominant or a nuisance species where it is established and is in population decline in some portions of its native range (Clavero et al. 2009; Fuller 2011). Consequently, the uncertainty rating associated with the environmental consequences is medium.

Ecosystem Structure and Function Impacts Matrix
(• indicates a potential to affect the category)

ANS	Ecosystem Function: Nutrient Cycling[a]	Ecosystem Function: Productivity[b]	Ecosystem Function: Food Web Dynamics[c]	Ecosystem Structure: Competition and/or Predation[d]	Ecosystem Structure: Habitat Quality and Quantity[e]	Ecosystem Structure: Biodiversity[f]	Ecosystem Structure: ESA-Listed Species[g]	Potentially Available Suitable Habitat[h]	Spatial Extent of ANS Establishment
Threespine stickleback (*Gasterosteus aculeatus*)				•		•			Widespread

[a] ANS establishment may disrupt nutrient cycling.

[b] ANS establishment may disrupt primary or secondary productivity through a decrease or loss of primary producers and/or consumers.

[c] ANS establishment may alter food webs, affecting food resources, prey abundance, and energy flow between trophic levels.

[d] ANS establishment may result in decreased abundance and/or reduced distribution of one or more resident species through competition or predation.

[e] ANS establishment may reduce quality and/or availability of important habitats.

[f] ANS establishment may alter species composition of communities, including loss or reduction in abundance of resident species.

[g] ANS establishment may adversely impact one or more species listed as threatened or endangered, or habitat designated as critical, under the Endangered Species Act.

[h] Amount of potentially available habitat for ANS establishment; linear miles for lentic habitats; acres for lotic habitats.

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B.2.6.8 Blueback Herring - *Alosa aestivalis*

Environmental Consequences Rating: **MEDIUM**
In freshwater systems, blueback herring generally occupy lacustrine habitat, but make seasonal, upriver spawning runs (Fuller et al. 2012). Therefore, if this species were to establish in the MRB, it is likely to be most abundant in lakes, reservoirs, and navigation pools that provide suitable habitat. There are 4,848,545 acres of littoral, open water, and wetland habitat and 1,519,531 miles of stream and riverine habitat in the MRB, that may potentially be suitable for this species. Therefore, this species could potentially be widespread in the MRB. Once established, blueback herring could alter ecosystem structure by competing with native planktivores for resources and altering zooplankton community composition and biodiversity. For example, the introduction of blueback herring into Theo Reservoir in Briscoe County, Texas, resulted in the elimination of large-bodied zooplankton, an increase in small-bodied zooplankton, and a shift in the zooplankton community from cladoceran to copepod dominance (Fuller et al. 2012). There is very little evidence of larval fish predation by blueback herring in reservoirs, but consumption of fish eggs can be considerable and may reduce gamefish recruitment, if it were to occur (Wheeler & Loftis 2004). Rasmussen (1998) also states that blueback herring have been implicated in the reduction of bass recruitment in certain reaches of the Tennessee River. By altering zooplankton and fish communities, blueback herring have the potential for ecosystem level effects on food webs and productivity. Overall, the blueback herring has an environmental consequence rating of medium.

Uncertainty Rating: **MEDIUM**
If blueback herring were to establish in the MRB, it is uncertain whether large populations would develop. Although there is evidence of ecological alterations following the introduction of blueback herring, the realized environmental effects if this species where to establish in the MRB are uncertain, as is the extent to which it will spread in the MRB. Consequently, uncertainty is medium.

Ecosystem Structure and Function Impacts Matrix
(• indicates a potential to affect the category)

	Ecosystem Function			Ecosystem Structure					
ANS	Nutrient Cycling[a]	Productivity[b]	Food Web Dynamics[c]	Competition and/or Predation[d]	Habitat Quality and Quantity[e]	Biodiversity[f]	ESA-Listed Species[g]	Potentially Available Suitable Habitat[h]	Spatial Extent of ANS Establishment
Blueback herring (*Alosa aestivalis*)		•	•	•		•			Widespread

[a] ANS establishment may disrupt nutrient cycling.

[b] ANS establishment may disrupt primary or secondary productivity through a decrease or loss of primary producers and/or consumers.

[c] ANS establishment may alter food webs, affecting food resources, prey abundance, and energy flow between trophic levels.

[d] ANS establishment may result in decreased abundance and/or reduced distribution of one or more resident species through competition or predation.

[e] ANS establishment may reduce quality and/or availability of important habitats.

[f] ANS establishment may alter species composition of communities, including loss or reduction in abundance of resident species.

[g] ANS establishment may adversely impact one or more species listed as threatened or endangered, or habitat designated as critical, under the Endangered Species Act.

[h] Amount of potentially available habitat for ANS establishment; linear miles for lentic habitats; acres for lotic habitats.

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B.2.6.9 Ruffe - *Gymnocephalus cernuus*

Environmental Consequences Rating: **MEDIUM**

The ruffe is a generalist species that typically feeds on benthic organisms (Schleuter & Eckmann 2006). The ruffe has several traits that make it a highly successful invader: (1) it is a prolific breeder; (2) it matures quickly; and (3) it is an aggressive feeder with indiscriminate habitat requirements (Hajjar 2002). Ruffe eats small fish as well as the eggs of other species (Global Invasive Species Database), and this species has affected fish populations in areas where it has been introduced. For example, in Europe, ruffe invasions were followed by a decline of whitefish and perch populations (Fuller et al. 2012; McLean 1997). Since the introduction of the ruffe to Chequemegon Bay, Lake Superior, populations of yellow perch, emerald shiners, and trout-perch have all declined (Bronte et al. 1998). Many of these fish species are also found in the MRB. Therefore, ruffe could have a detrimental effect on MRB fishes by feeding on the young of resident species or by competing with them for food (Fullerton et al. 1998; Fuller et al. 2012). Although ruffe may alter fish community structure and biodiversity, it occupies a similar niche to existing fish species and is not likely to alter the food web, nutrient cycling, or productivity at the ecosystem level. There are 23,458,649 acres of littoral, open water, and wetland habitat and 1,519,531 miles of stream and riverine habitat in the MRB, that may potentially be suitable for this species. However, the ruffe is a cold-water fish (Rasmussen 2002), and it may not reach high abundance or wide distribution in the MRB. Overall, the ruffe has an environmental consequence rating of medium.

Uncertainty Rating: MEDIUM

It is unclear whether the decline in certain fish species attributed to ruffe was due to natural population dynamics or to predation and competition with the ruffe (Bronte et al. 1998). In addition, ruffe is a cold-water fish, and it is uncertain whether this species will reach high abundance and widespread distribution in the MRB. Therefore, there remains a medium degree of uncertainty regarding the environmental consequences of a ruffe invasion in the MRB.

Ecosystem Structure and Function Impacts Matrix
(• indicates a potential to affect the category)

ANS	Ecosystem Function			Ecosystem Structure					
	Nutrient Cycling[a]	Productivity[b]	Food Web Dynamics[c]	Competition and/or Predation[d]	Habitat Quality and Quantity[e]	Biodiversity[f]	ESA-Listed Species[g]	Potentially Available Suitable Habitat[h]	Spatial Extent of ANS Establishment
Ruffe (*Gymnocephalus cernuus*)			•	•		•	•		Localized

[a] ANS establishment may disrupt nutrient cycling.

[b] ANS establishment may disrupt primary or secondary productivity through a decrease or loss of primary producers and/or consumers.

[c] ANS establishment may alter food webs, affecting food resources, prey abundance, and energy flow between trophic levels.

[d] ANS establishment may result in decreased abundance and/or reduced distribution of one or more resident species through competition or predation.

[e] ANS establishment may reduce quality and/or availability of important habitats.

[f] ANS establishment may alter species composition of communities, including loss or reduction in abundance of resident species.

[g] ANS establishment may adversely impact one or more species listed as threatened or endangered, or habitat designated as critical, under the Endangered Species Act.

[h] Amount of potentially available habitat for ANS establishment; linear miles for lentic habitats; acres for lotic habitats.

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B.2.6.10 Sea Lamprey - *Petromyzon marinus*

Environmental Consequences Rating: LOW

The sea lamprey is a parasitic fish that attaches to fish and feeds on their blood, usually resulting in the death of the host fish (Great Lakes Fishery Commission 2000). Sea lamprey inhabits lentic or oceanic habitats and moves into rivers only to spawn (Fuller et al. 2012). Therefore, if sea lamprey were to establish in the MRB, it would be in lakes and large reservoirs. Within the Great Lakes, its introduction has resulted in the substantial decline of several species, some of which are found in the MRB. Consequently, if is establishes, sea lamprey have the potential to affect food web dynamics and biodiversity in reservoirs in the MRB. The species could affect the abundance and productivity of larger fish species and may have a widespread distribution in the MRB. However, there are multiple management strategies that have been developed to control sea lamprey populations. These control programs, if applied in the MRB, could significantly reduce the potential for impacts on invaded lakes. The sea lamprey has an environmental consequence rating of low.

Uncertainty Rating: MEDIUM

If sea lamprey were to establish in the MRB, it is uncertain whether large populations of sea lamprey would develop. The sea lampreys is documented to have resulted in significant changes in fish communities in the GLB. However, based on the documented successful control of sea lamprey in the GLB, impacts from sea lamprey in the MBR are likely to be low if it were to establish. Consequently, uncertainty is low.

Ecosystem Structure and Function Impacts Matrix
(• indicates a potential to affect the category)

	Ecosystem Function			Ecosystem Structure					
ANS	Nutrient Cycling[a]	Productivity[b]	Food Web Dynamics[c]	Competition and/or Predation[d]	Habitat Quality and Quantity[e]	Biodiversity[f]	ESA-Listed Species[g]	Potentially Available Suitable Habitat[h]	Spatial Extent of ANS Establishment
Sea lamprey (*Petromyzon marinus*)			•	•					Widespread

[a] ANS establishment may disrupt nutrient cycling.

[b] ANS establishment may disrupt primary or secondary productivity through a decrease or loss of primary producers and/or consumers.

[c] ANS establishment may alter food webs, affecting food resources, prey abundance, and energy flow between trophic levels.

[d] ANS establishment may result in decreased abundance and/or reduced distribution of one or more resident species through competition or predation.

[e] ANS establishment may reduce quality and/or availability of important habitats.

[f] ANS establishment may alter species composition of communities, including loss or reduction in abundance of resident species.

[g] ANS establishment may adversely impact one or more species listed as threatened or endangered, or habitat designated as critical, under the Endangered Species Act.

[h] Amount of potentially available habitat for ANS establishment; linear miles for lentic habitats; acres for lotic habitats.

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B.2.6.11 Tubenose Goby - *Proterorhinus semilunaris*

Environmental Consequences Rating: **MEDIUM**

The tubenose goby is found in most habitats within rivers and lakes. In Europe, it is documented to have spread rapidly and reached relatively high abundance after introduction into the Danube basin (Adámek et al. 2010). The tubenose goby consumes benthic invertebrates and zooplankton (Fuller et al. 2012), and its diet overlaps with those of other benthic fishes, such as darters (*Etheostoma* spp. and *Percina* sp.), madtoms (*Noturus* spp.), and sculpins (*Cottus* spp.), and the invasive round goby (*Neogobius melanostomus*) (Kocovsky et al. 2011; Adámek et al. 2010). Surveys indicate tubenose goby is found in habitat associated with round goby, yellow perch, and rock bass (Dopazo et al. 2008). Unlike the round goby, tubenose goby has not yet exhibited any known ecosystem effects in the GLB since its establishment (Dopazo et al. 2008). Tubenose goby has ecological niches similar to those of darters, many of which are protected. In addition, the goby consumes mussels and may therefore affect listed mussels directly by predation or indirectly by reducing the abundance of mussel hosts such as darters. Consequently, tubenose goby potentially poses a threat to ESA-listed species. There are 18,781,437 acres of littoral and wetland habitat and 1,519,531 miles of stream and riverine habitat in the MRB, that may potentially be suitable for this species. However, Rasmussen (2002) states that the tubenose goby is a true cool-water species and that temperature preference may discourage movement south into the Illinois River, which could in turn limit its expansion into other parts of the Mississippi River Basin. Consequently, the spatial extent of its ecological impacts is expected to be localized. Overall, the ecological consequences of the tubenose goby establishing in the MRB are expected to be medium.

Uncertainty Rating: **MEDIUM**

There are few reports of adverse ecological effects attributable to the tubenose goby. Although there is a large amount of habitat within the MRB that is potentially suitable for the tubenose goby, this species generally has a low abundance in the Great Lakes, so it is uncertain whether it will reach a population size sufficient to generate significant environmental consequences in the MRB. It is uncertain to what extent the warmer temperatures in the MRB will reduce the distribution and abundance of this species in the MRB. Overall, uncertainty is medium.

Ecosystem Structure and Function Impacts Matrix
(• indicates a potential to affect the category)

ANS	Ecosystem Function: Nutrient Cycling[a]	Ecosystem Function: Productivity[b]	Ecosystem Function: Food Web Dynamics[c]	Ecosystem Structure: Competition and/or Predation[d]	Ecosystem Structure: Habitat Quality and Quantity[e]	Ecosystem Structure: Biodiversity[f]	Ecosystem Structure: ESA-Listed Species[g]	Potentially Available Suitable Habitat[h]	Spatial Extent of ANS Establishment
Tubenose goby *(Proterorhinus semilunaris)*				•		•	•		Localized

[a] ANS establishment may disrupt nutrient cycling.

[b] ANS establishment may disrupt primary or secondary productivity through a decrease or loss of primary producers and/or consumers.

[c] ANS establishment may alter food webs, affecting food resources, prey abundance, and energy flow between trophic levels.

[d] ANS establishment may result in decreased abundance and/or reduced distribution of one or more resident species through competition or predation.

[e] ANS establishment may reduce quality and/or availability of important habitats.

[f] ANS establishment may alter species composition of communities, including loss or reduction in abundance of resident species.

[g] ANS establishment may adversely impact one or more species listed as threatened or endangered, or habitat designated as critical, under the Endangered Species Act.

[h] Amount of potentially available habitat for ANS establishment; linear miles for lentic habitats; acres for lotic habitats.

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B.2.7 Plants

B.2.7.1 Marsh Dewflower - *Murdannia keisak*

Environmental Consequences Rating: **MEDIUM**
Within the Great Lakes Basin, approximately 3,999,752 acres of littoral and marsh habitat and 92,267 mi of stream habitat have been identified as suitable or potentially suitable for the marsh dewflower. This species may also establish in suitable shoreline habitat around the five Great Lakes. Its vigorous growth enables it to out-compete native plants by forming dense mats (Swearingen et al. 2010). The species could change native species abundance and distribution through competition by shading out native species and competing with them for nutrients and space (Newberry 1991). It also promotes successional change by reducing water flow rates and stabilizing soils, allowing the colonization of other species (NatureServe 2010). The marsh dewflower could compete with ESA-listed plant species in the GLB as it does in the MRB (Newberry 1991; Swearingen et al. 2010). If it does establish in the GLB, the marsh dewflower is expected to have localized impacts. Therefore, the environmental consequence rating is medium.

Uncertainty Rating: MEDIUM
The marsh dewflower prefers slow-moving water in marshy areas and so may only establish in emergent marsh and littoral habitats in the GLB floodplain. However, the environmental impacts of the marsh dewflower depend on how widely this species is able to spread through the GLB. Because this is uncertain, there is a medium uncertainty associated with environmental consequences.

Ecosystem Structure and Function Impacts Matrix
(• indicates a potential to affect the category)

	Ecosystem Function			Ecosystem Structure					
ANS	Nutrient Cycling[a]	Productivity[b]	Food Web Dynamics[c]	Competition and/or Predation[d]	Habitat Quality and Quantity[e]	Biodiversity[f]	ESA-Listed Species[g]	Potentially Available Suitable Habitat[h]	Spatial Extent of ANS Establishment
Marsh Dewflower (*Murdannia keisak*)				•	•	•			Localized

[a] ANS establishment may disrupt nutrient cycling.

[b] ANS establishment may disrupt primary or secondary productivity through a decrease or loss of primary producers and/or consumers.

[c] ANS establishment may alter food webs, affecting food resources, prey abundance, and energy flow between trophic levels.

[d] ANS establishment may result in decreased abundance and/or reduced distribution of one or more resident species through competition or predation.

[e] ANS establishment may reduce quality and/or availability of important habitats.

[f] ANS establishment may alter species composition of communities, including loss or reduction in abundance of resident species.

[g] ANS establishment may adversely impact one or more species listed as threatened or endangered, or habitat designated as critical, under the Endangered Species Act.

[h] Amount of potentially available habitat for ANS establishment; linear miles for lentic habitats; acres for lotic habitats.

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B.2.7.2 Cuban Bulrush - *Oxycaryum cubense*

Environmental Consequences Rating: **LOW**

The Cuban bulrush is found in the littoral zone of lakes, ponds, and streams, forming large monotypic floating mats (NBII & ISSG 2008; McLaurin & Wersal 2011). Within the Great Lakes Basin, approximately 3,999,752 acres of littoral and marsh habitat and 55,468 mi of stream habitat have been identified as suitable or potentially suitable for the Cuban bulrush. This species may also establish in suitable shoreline habitat around the five Great Lakes. It is slowly spreading northward in the southeastern United States (Bryson et al. 2008). Weakley (2007) describes Cuban bulrush as "aggressively weedy," and the large mats can shade out other species of aquatic macrophytes or out-compete them for space (Schardt 2006; Bryson et al. 2008; McLaurin & Wersal 2011), potentially resulting in alternation of plant community structure in wetland habitats in the GLB. There are also multiple ESA-listed wetland plant and invertebrate species that could potentially be adversely affected by the spread of Cuban bulrush.

In addition to altering the composition of native plant communities, the Cuban bulrush has the potential to generate adverse ecosystem-level effects. Hypoxic conditions can develop beneath the floating mats of Cuban bulrush (McLaurin & Wersal 2011), reducing habitat quality for aquatic organisms and affecting sediment biogeochemical processes. This species is found only sporadically in the Southeast, and it is typically a tropical and subtropical species (Bryson et al. 2008); therefore impacts on ecosystems in the GLB may be localized to areas of suitable temperature. Overall, the consequences of this species establishing in the GLB are low.

Uncertainty Rating: **MEDIUM**

The interactions between the Cuban bulrush and native Great Lakes plant species are unknown. In addition, the Cuban bulrush is typically found in tropical or subtropical climates. Therefore, it is uncertain whether the productivity of this species in the GLB will be high enough to generate significant ecological consequences. Therefore, there is a medium degree of uncertainty regarding environmental consequences of the species.

Ecosystem Structure and Function Impacts Matrix
(• indicates a potential to affect the category)

ANS	Ecosystem Function			Ecosystem Structure					
	Nutrient Cycling[a]	Productivity[b]	Food Web Dynamics[c]	Competition and/or Predation[d]	Habitat Quality and Quantity[e]	Biodiversity[f]	ESA-Listed Species[g]	Potentially Available Suitable Habitat[h]	Spatial Extent of ANS Establishment
Cuban Bulrush *(Oxycaryum cubense)*	•			•	•	•			Localized

[a] ANS establishment may disrupt nutrient cycling.

[b] ANS establishment may disrupt primary or secondary productivity through a decrease or loss of primary producers and/or consumers.

[c] ANS establishment may alter food webs, affecting food resources, prey abundance, and energy flow between trophic levels.

[d] ANS establishment may result in decreased abundance and/or reduced distribution of one or more resident species through competition or predation.

[e] ANS establishment may reduce quality and/or availability of important habitats.

[f] ANS establishment may alter species composition of communities, including loss or reduction in abundance of resident species.

[g] ANS establishment may adversely impact one or more species listed as threatened or endangered, or habitat designated as critical, under the Endangered Species Act.

[h] Amount of potentially available habitat for ANS establishment; linear miles for lentic habitats; acres for lotic habitats.

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B.2.7.3 Dotted Duckweed - *Landoltia punctata*

Environmental Consequences Rating: **LOW**
Dotted duckweed is regarded as a pioneer species in that it is distributed easily, colonizes quickly, and has a high rate of vegetative propagation (Landolt 1986). Dotted duckweed prefers stagnant waters (Lembi 2009); therefore, the species will be found only in backwaters of the GLB. Within the Great Lakes Basin, approximately 3,999,752 acres of littoral and marsh wetland habitat and 88,551 mi of stream habitat have been identified as suitable or potentially suitable for the dotted duckweed. These species may also establish in suitable shoreline habitat around the five Great Lakes. It is considered a pioneer species that would thrive in a disturbed habitat (Landolt 1986). If dotted duckweed does establish in an area, it can affect other plant species in the region by crowding out native species (Jacono 2002). Thick growth of duckweed can prevent sunlight from reaching deeper parts of the lake, preventing underwater plants and algae from photosynthesizing and producing oxygen. In turn, the lack of oxygen can stress or kill fish (Lembi 2009). However, the dotted duckweed is not cold tolerant (Jacono 2002), and therefore it is not expected to reach high abundance in the GLB. Therefore, the environmental consequences are low.

Uncertainty Rating: MEDIUM
The localized effects of dotted duckweed will likely not affect a large portion of the GLB. However, the extent of the spread of this species is a source of uncertainty. Therefore, a medium uncertainty is associated with environmental consequences.

Ecosystem Structure and Function Impacts Matrix
(• indicates a potential to affect the category)

	Ecosystem Function			Ecosystem Structure					
ANS	Nutrient Cycling[a]	Productivity[b]	Food Web Dynamics[c]	Competition and/or Predation[d]	Habitat Quality and Quantity[e]	Biodiversity[f]	ESA-Listed Species[g]	Potentially Available Suitable Habitat[h]	Spatial Extent of ANS Establishment
Dotted Duckweed (*Landoltia punctata*)	•			•	•	•			Localized

[a] ANS establishment may disrupt nutrient cycling.

[b] ANS establishment may disrupt primary or secondary productivity through a decrease or loss of primary producers and/or consumers.

[c] ANS establishment may alter food webs, affecting food resources, prey abundance, and energy flow between trophic levels.

[d] ANS establishment may result in decreased abundance and/or reduced distribution of one or more resident species through competition or predation.

[e] ANS establishment may reduce quality and/or availability of important habitats.

[f] ANS establishment may alter species composition of communities, including loss or reduction in abundance of resident species.

[g] ANS establishment may adversely impact one or more species listed as threatened or endangered, or habitat designated as critical, under the Endangered Species Act.

[h] Amount of potentially available habitat for ANS establishment; linear miles for lentic habitats; acres for lotic habitats.

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B.2.7.4 Swamp Sedge - *Carex acutiformis*

Environmental Consequences Rating: **LOW**

Swamp sedge may thrive in wetlands in the MRB and form large, glaucous clones where it is established (Cao 2011). There are 4,958,179 acres of littoral and wetland habitat and 1,438,131 miles of stream habitat in the MRB, that may potentially be suitable for this species. Therefore, this species could potentially be widespread in the MRB. Swamp sedge could compete with native species for light, leading to suppression of competing species (Aerts & De Caluwe 1994). The plant is capable of changing the nutrient cycling of the environment, because it has a high litter production (Aerts & De Caluwe 1997). These impacts on the MRB would be localized. Therefore, the environmental consequences of swamp sedge establishment is low.

Uncertainty Rating: HIGH

Interactions between swamp sedge and the native MRB plant species are uncertain. Therefore, the uncertainty associated with environmental consequences is high.

Ecosystem Structure and Function Impacts Matrix
(• indicates a potential to affect the category)

	Ecosystem Function			Ecosystem Structure					
ANS	Nutrient Cycling[a]	Productivity[b]	Food Web Dynamics[c]	Competition and/or Predation[d]	Habitat Quality and Quantity[e]	Biodiversity[f]	ESA-Listed Species[g]	Potentially Available Suitable Habitat[h]	Spatial Extent of ANS Establishment
Swamp Sedge (*Carex acutiformis*)	•			•					Widespread

[a] ANS establishment may disrupt nutrient cycling.

[b] ANS establishment may disrupt primary or secondary productivity through a decrease or loss of primary producers and/or consumers.

[c] ANS establishment may alter food webs, affecting food resources, prey abundance, and energy flow between trophic levels.

[d] ANS establishment may result in decreased abundance and/or reduced distribution of one or more resident species through competition or predation.

[e] ANS establishment may reduce quality and/or availability of important habitats.

[f] ANS establishment may alter species composition of communities, including loss or reduction in abundance of resident species.

[g] ANS establishment may adversely impact one or more species listed as threatened or endangered, or habitat designated as critical, under the Endangered Species Act.

[h] Amount of potentially available habitat for ANS establishment; linear miles for lentic habitats; acres for lotic habitats.

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B.2.7.5 Reed Sweetgrass - *Glyceria maxima*

Environmental Consequences Rating: **MEDIUM**

Reed sweetgrass is a highly productive species that forms dense root-mats and spreads by rhizomes. Reed sweetgrass can reduce plant species diversity by out-competing native plants (Howard 2012) and can reduce the diversity and distribution of macroinvertebrates (Clarke et al. 2004). Reed sweetgrass often displaces seed-producing plants which provide food for wildlife (Howard 2012). Reed sweetgrass generally do not provide suitable food or nesting habitat for wildlife (IPANE 2004). The reed sweetgrass can affect habitat quality, because the dense mats formed by this species are capable of reducing stream flow and decreasing dissolved oxygen (NBII & ISSG 2008; Loo et al. 2009). Growth of reed sweetgrass can also significantly alter nutrient dynamics in streams, particularly for phosphorus and nitrogen (Clarke et al. 2004). There are 4,958,179 acres of littoral and wetland habitat and 1,519,531 miles of stream and riverine habitat in the MRB, that may potentially be suitable for this species. Therefore, this species could spread to the abundant wetland habitat in the MRB. Overall, the potential consequences of establishment are medium.

Uncertainty Rating: **HIGH**

Reed sweetgrass is documented to alter habitat in multiple locations where it has been introduced (Loo et al. 2009; Howard 2012). It is uncertain whether this species will achieve high density and cover in the MRB. The competitive interactions of this species with existing plant species in the MRB are uncertain. Overall, uncertainty is high.

Ecosystem Structure and Function Impacts Matrix
(• indicates a potential to affect the category)

	Ecosystem Function			Ecosystem Structure					
ANS	Nutrient Cycling[a]	Productivity[b]	Food Web Dynamics[c]	Competition and/or Predation[d]	Habitat Quality and Quantity[e]	Biodiversity[f]	ESA-Listed Species[g]	Potentially Available Suitable Habitat[h]	Spatial Extent of ANS Establishment
Reed Sweetgrass (*Glyceria maxima*)	•	•	•	•	•	•			Widespread

[a] ANS establishment may disrupt nutrient cycling.

[b] ANS establishment may disrupt primary or secondary productivity through a decrease or loss of primary producers and/or consumers.

[c] ANS establishment may alter food webs, affecting food resources, prey abundance, and energy flow between trophic levels.

[d] ANS establishment may result in decreased abundance and/or reduced distribution of one or more resident species through competition or predation.

[e] ANS establishment may reduce quality and/or availability of important habitats.

[f] ANS establishment may alter species composition of communities, including loss or reduction in abundance of resident species.

[g] ANS establishment may adversely impact one or more species listed as threatened or endangered, or habitat designated as critical, under the Endangered Species Act.

[h] Amount of potentially available habitat for ANS establishment; linear miles for lentic habitats; acres for lotic habitats.

References

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B.2.7.6 Water Chestnut - *Trapa natans*

Environmental Consequences Rating: **MEDIUM**

Water chestnut is easily spread to new sites and can grow in most fresh water habitat (NatureServe 2010). The water chestnut is capable of out-competing native submersed and floating plants for sunlight (Cao 2011) and has been documented to eliminate plant species within ponds (Groth et al. 1996). This species is also capable of affecting habitat quality. For example, when at high densities, water chestnut is capable of intercepting 95% of incident sunlight (NatureServe 2010), causing low dissolved oxygen levels (Caraco & Cole 2002; Kornijow et al. 2010) and potentially reducing habitat quality for fish and invertebrates (NatureServe 2010). In the Hudson River, the water chestnut supported higher invertebrate densities than native vegetation, but this greater biodiversity may be unavailable for consumption by fish due to low oxygen concentrations (Kornijow et al. 2010). The water chestnut affects feeding and wintering grounds for many ducks by out-competing native submersed vegetation that is preferred by waterfowl (NatureServe 2010). The water chestnut has spread widely in the northeastern United States and some mid-Atlantic states (Cao 2011). This species has the potential to spread into warm temperate and subtropical regions of the United States (Pemberton 2002) and may establish in submergent and emergent marshes of the MRB. There are 4,958,179 acres of littoral and wetland habitat and 1,518,126 miles of stream and riverine habitat in the MRB, that may potentially be suitable for this species. Therefore, significant and widespread changes in the wetland ecosystem structure and function are possible if this species establishes. Overall, the consequences of establishment are medium for the water chestnut.

Uncertainty Rating: **LOW**

Water chestnut is a potentially rapid invader (NatureServe 2010). Several studies have documented changes in plant community abundance and distribution following the introduction of the water chestnut. The species does best in shallow, nutrient-rich lakes and rivers, which are common throughout the MRB. Consequently, uncertainty regarding the environmental consequences of the water chestnut is low.

Ecosystem Structure and Function Impacts Matrix
(• indicates a potential to affect the category)

	Ecosystem Function			Ecosystem Structure					
ANS	Nutrient Cycling[a]	Productivity[b]	Food Web Dynamics[c]	Competition and/or Predation[d]	Habitat Quality and Quantity[e]	Biodiversity[f]	ESA-Listed Species[g]	Potentially Available Suitable Habitat[h]	Spatial Extent of ANS Establishment
Water Chestnut (*Trapa natans*)	•			•	•	•			Widespread

[a] ANS establishment may disrupt nutrient cycling.

[b] ANS establishment may disrupt primary or secondary productivity through a decrease or loss of primary producers and/or consumers.

[c] ANS establishment may alter food webs, affecting food resources, prey abundance, and energy flow between trophic levels.

[d] ANS establishment may result in decreased abundance and/or reduced distribution of one or more resident species through competition or predation.

[e] ANS establishment may reduce quality and/or availability of important habitats.

[f] ANS establishment may alter species composition of communities, including loss or reduction in abundance of resident species.

[g] ANS establishment may adversely impact one or more species listed as threatened or endangered, or habitat designated as critical, under the Endangered Species Act.

[h] Amount of potentially available habitat for ANS establishment; linear miles for lentic habitats; acres for lotic habitats.

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B.2.8 Virus

B.2.8.1 Viral Hemorrhagic Septicemia Virus - *Novirhabdovirus* sp.

Environmental Consequences Rating: Low

The Great Lakes genotype of viral hemorrhagic septicemia virus (VHSv) has resulted in large fish kills in the Great Lakes region, although these events were episodic and no population-level impacts have been documented (Kipp et al. 2013). Mortality rates vary among species. In addition to mortality, VHSv can result in fitness-reducing effects including hyperactivity, erratic swimming behavior, and tissue and organ damage. VHSv can infect fish at all life stages. It has been documented to infect several species within the Great Lakes that are also present in the MRB, including centrarchids, freshwater drum, walleye yellow perch, and gizzard shad (Kipp et al. 2013). There may be a greater risk of ecosystem-level changes if fish kills occurred in closed systems like lakes and reservoirs. VHSv has been detected in Clear Fork Reservoir, which is within the Ohio River Watershed, suggesting it could also establish in reservoirs in the MRB. VHSv may have population- or ecosystem-level consequences such as changes in food web structure, depending on the mortality rate and the trophic level of the fish species affected by the virus. VHSv readily spreads through aquatic pathways, and suitable host fish are present throughout the MRB. However, VHSv survives best in cold waters. Optimum replication temperature is 14-15°C, and VHSv can last a few weeks in freshwater at moderate temperatures (10-15°C; 59°F) without a host (Hawley & Garver 2008; Whelan 2009). Replication is low at 6°C and the virus becomes inactive after 24 hours in water temperatures greater than 20°C (reviewed in Kipp et al. 2013). In addition, mortality is uncommon at temperatures greater than 15°C (McAllister 1990; Goodwin and Merry 2011). Considering these temperature sensitivities, VHSv may not spread to the lower MRB, and/or may have greatly reduced virulence in the middle and lower MRB. Overall, the environmental consequences of VHSv establishing in the MRB are expected to be low because VHSv is not expected to generate population- or ecosystem-level impacts.

Uncertainty Rating: Medium

The existing data indicates that VHSv will not cause significant mortalities at temperatures above 15°C, suggesting that the environmental effects of this species within the MRB will be geographically limited. In cold waters, where VHSv is most virulent, VHSv has been documented to kill large numbers of fish. However, no population-level impacts have been documented in the Great Lakes Basin. The natural rate of mutations in the virus, the geographic extent of its spread within the MRB, and the development of increased resistance of fish to the virus are uncertain. The impacts on ESA-listed fish in the MRB are also uncertain. Overall, there is a medium uncertainty associated with the ecological consequence rating for VHSv.

Ecosystem Structure and Function Impacts Matrix
(• indicates a potential to affect the category)

	Ecosystem Function			Ecosystem Structure					
ANS	Nutrient Cycling[a]	Productivity[b]	Food Web Dynamics[c]	Competition and/or Predation[d]	Habitat Quality and Quantity[e]	Biodiversity[f]	ESA-Listed Species[g]	Potentially Available Suitable Habitat[h]	Spatial Extent of ANS Establishment
Viral Hemorrhagic Septicemia Virus			•			•			Upper MRB

[a] ANS establishment may disrupt nutrient cycling.

[b] ANS establishment may disrupt primary or secondary productivity through a decrease or loss of primary producers and/or consumers.

[c] ANS establishment may alter food webs, affecting food resources, prey abundance, and energy flow between trophic levels.

[d] ANS establishment may result in decreased abundance and/or reduced distribution of one or more resident species through competition or predation.

[e] ANS establishment may reduce quality and/or availability of important habitats.

[f] ANS establishment may alter species composition of communities, including loss or reduction in abundance of resident species.

[g] ANS establishment may adversely impact one or more species listed as threatened or endangered, or habitat designated as critical, under the ESA.

[h] Amount of potentially available habitat for ANS establishment; linear miles for lentic habitats; acres for lotic habitats.

References

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APPENDIX C

POTENTIAL ECONOMIC CONSEQUENCES OF THE ESTABLISHMENT OF AQUATIC NUISANCE SPECIES IN THE GREAT LAKES AND MISSISSIPPI RIVER BASINS

CONTENTS

CONTENTS (CONT.)

APPENDIX C

POTENTIAL ECONOMIC CONSEQUENCES OF THE ESTABLISHMENT OF AQUATIC NUISANCE SPECIES IN THE GREAT LAKES AND MISSISSIPPI RIVER BASINS

C.1 INTRODUCTION

In general, the economic consequences the establishment of 36 aquatic nuisance species (ANS) identified by the U.S. Army Corps of Engineers (USACE) can be measured as both changes in economic welfare and economic impacts. Changes in economic welfare correspond to changes in consumer surplus, which is the amount of value a consumer of a good or service receives over and above that which would be paid for the good or service. Because valuation may not be reflected in terms of market transactions, consumer surplus is often referred to as *non-market use value,* which incorporates direct use value and non-use value or passive use value. The passive economic use value includes the existence value, the willingness to pay a given amount to maintain a resource in a certain condition, without directly using it, and bequest value, the willingness to pay to ensure a resource is available for future generations in a certain condition. Economic impacts are the marketplace effects of expenditures associated with recreational visitation, commercial fishing activities, for the maintenance of water quality and water withdrawal structures, and the secondary effects of the associated expenditures on income, employment, and tax revenues.

This report has seven parts: Section C.2 describes aspects of the measurement of direct use values, including revealed preference and contingent valuation methods, and hedonic methods for estimating changes in property values. This is followed by a discussion of passive use and estimation methods in Section C.3. Section C.4 describes and discusses the various methods used to estimate economic impacts of changes in recreational expenditures that might result from ANS establishment, followed by a brief discussion of the importance of environmental amenities to economic development in Section C.5. Section C.6 considers potential ANS impacts to commercial fish harvests. Section C.7 provides a qualitative assessment of the economic consequences of the establishment of 36 aquatic nuisance species, including their potential impact on consumer surplus, property values, recreational and commercial fishing, and recreational boating, and the cost of maintaining water quality, infrastructure, and boating equipment.

C.2 CHANGES IN DIRECT USE VALUE

The economic cost of the deterioration of the quality of recreational resources is best measured as the change in income that would keep consumer utility, or satisfaction, at the original level before the fall in the quality of recreational resources, or alternatively, the amount of income required to move an individual to a new utility level in lieu of achieving that level through an improvement in the quality of recreational resources. This measure is known as consumer (or equivalent) surplus.

The problem with estimating the demand for the quality of recreational resources is that these resources are not a market good, and characteristics of the demand for these resources cannot be based on direct observation of transactions for recreational resources of a certain quality in the marketplace. A simple way to quantify the value of recreational would be to measure changes in revenue generated by user fees and other charges for public use with changes in recreational quality. However, visitation statistics are often incomplete, and in many cases federal and state agencies do not charge visitors a fee for entrance to recreational resources on public lands; where fees are charged, they may be nominal compared to the value of the visit to recreational users. Instead, there are two general approaches for obtaining data on the demand for environmental quality, including recreational resources:

- Revealed Preference—examines the relationship between private goods and the quality of recreational resources, in particular, recreation and housing, in order to draw inferences about the demand for the quality of recreational resources; and

- Contingent Valuation—individuals are asked to reveal their willingness to pay for improvements in the quality of recreational resources.

C.2.1 Revealed Preference

One method of estimating the net willingness to pay, or consumer surplus, associated with resources on public lands used for recreation is the travel cost method. This method uses variation in the cost of traveling different distances, and the number of trips taken over each distance, as a way to represent the demand for recreational resources in any given location (Loomis and Walsh 1997).The travel cost method attempts to relate the cost of accessing an outdoor recreation site to the decision to visit specific recreational sites. A demand curve can be generated to represent the number of visits to a given site with the associated travel costs and other exogenous variables; higher travel costs typically lead to lower levels of visitation, other things being equal.

Site choice models can be specified to include the quality of fisheries resources as part of an individual's utility function; they can also be used to determine how variations in recreational quality influence the probability of a user selecting a particular location (Bockstael et al. 1987; Ribaudo & Hellerstein 1992). Site choice models (also known as discrete choice models) assume that an individual will choose the site that yields the greatest utility, given the recreational quality and the cost of accessing the site.

Hedonic travel cost models may be used to relate recreational quality to the incremental costs of accessing sites with better recreational quality. These models assume that an individual derives utility directly from recreational site characteristics, and would represent the actual sites as "bundles" of site characteristics. If a sufficient number of these bundles exist, demand curves can be identified for each of these characteristics. In other words, for each characteristic, the individual can consume a quantity up to the point where the marginal cost of increasing consumption of the characteristics is greater than its marginal value (Ribaudo and Hellerstein 1992).

Multiple-site travel cost models classify sites into groups, with each group having similar site characteristics. For example, one group could consist of clear-water lakes, another group of cloudy-water lakes, and another of clear-water lakes that have periodic algal blooms. Each group of sites could then be treated as a separate good. Rather than estimate the demand for trips to a particular site, the models would estimate the demand for trips to sites of a specific class.

In addition to influencing recreational visitation, the quality of recreational resources can also influence residential decisions, with houses adjacent to waterways at prime fishing locations likely to be more attractive than similar houses located next to waterways with fewer fishing opportunities. Therefore, property values can be used to measure the “amenity value” of a location. If environmental quality in a location decreases, from the establishment of invasive species, for example, the value of housing in a location could also fall. Since there are many factors that affect property values, a hedonic property model is often used, which relates the value of a house to its characteristics, such as number of bedrooms, size of kitchen, and ambient environmental quality. Hedonic property models are similar to hedonic travel cost models, with observed prices as the dependent variable in a hedonic regression equation and observed characteristics, including environmental quality, as the independent variables.

C.2.2 Contingent Valuation

Using site data in a revealed preference framework to estimate the cost of changes in the quality of recreational resources has certain limitations. Identifying a set of water bodies representative of all water resources affected by ANS establishment can be difficult. Contingent valuation methods avoid this problem, since they are not dependent on a particular site or sites and individuals. Individuals are asked directly their willingness to pay for a general improvement in the quality of recreational resources as a result of ANS establishment. Contingent valuation methods attempt to induce people to reveal directly their willingness-to-pay (WTP) for the provision of a non-market good, such as the quality of fisheries resources, or their willingness-to-accept (WTA) payment to sacrifice the non-market good.

C.3 CHANGES IN PASSIVE USE

In addition to use values, a certain portion of the value of resources may lie in the passive use of a resource, or the extent of the availability of the resource to current and future generations. Attempts to establish passive use values—or the willingness to pay for, or accept compensation for the loss of, different levels of non-marketed recreational resources on public lands—have used contingent valuation methods, which rely on telephone interviews or questionnaire surveys. Typically, a description of a particular resource is presented to respondents, who are then asked to place a dollar value on their use of the resource, or on the preservation of the resource (Loomis 2000).

C.4 ECONOMIC IMPACTS OF ANS ESTABLISHMENT

Economic impacts are measured by changes in visitor expenditures associated with recreational fishing and boating, commercial fishing and with maintaining water quality, aquaculture facilities, and water withdrawal structures. Economic impacts also include the secondary effects of these changes in expenditures on, income, employment, and tax revenues.

Visitor expenditures in a river corridor may include spending on food and beverages, fishing equipment, gasoline for vehicles and boats, camping fees or motel expenses, and on fishing license fees. Commercial fishing expenditures may include fishing equipment purchases or rentals, building maintenance or rentals, gasoline for vehicles and boats, fish processing costs, and mooring and license fees. ANS establishment may also lead to changes in operating expenditures associated with maintaining water quality and water withdrawal structures, such as for water monitoring, water treatment and equipment maintenance and replacement, and biomass removal, and may also lead to increased recreational and commercial boat maintenance costs.

A recent USACE study (USACE 2012a,b) quantified the value of commercial fishery harvests in the Great Lakes Basin, the Upper Mississippi Basin, and the Ohio River Basin based on recent harvest level and dockside value data available from state agencies. The study incorporated annual harvest levels and the associated dockside values for the years 1989 through 2009 in order to generate analyses of harvesting trends over time.

Indirect effects occur when the suppliers to these local businesses increase or decrease their purchases of production materials and services from other businesses, and those businesses in turn change their level of purchases. Each exchange increases the total indirect effects. For food and beverages, indirect effects occur when local food manufacturers purchase additional produce from local farmers, and the farmers then purchase additional supplies in order to grow products necessary to meet this demand. Additional, induced effects result from wages paid to households by both directly and indirectly affected business.

Basic input-output data are used to produce multipliers for each sector in the economy under consideration (county, multi-county region, state, or multi-state region). These multipliers typically give the total (direct plus indirect plus induced) benefits to the region in terms of employment, income, and taxes.

C.5 AMENITIES AND ECONOMIC DEVELOPMENT

Changes in environmental quality (in the quality of recreational resources, for example) may affect environmental amenities in a location, and consequently may affect the ability of these communities to attract new entrepreneurial activity that is highly sensitive to actual or perceived changes in environmental quality, stable rural community, and cultural values. Over recent decades, many areas of the United States have been able to diversify their economies away from agriculture, mining and manufacturing industries and toward, the professional and services sectors, and retirement, recreation, and tourism (Bennett and McBeth 1998). It is apparent that growth in these parts of the economy has become highly sensitive to changes in environmental amenities, meaning that environmental quality and access to environmental amenities may have become important factors in the economic development of the rural U.S. Although not all sectors of the economy are highly responsive to changes in environmental quality (various other influences include quality and availability of regional human resources, energy availability and reliability of energy supply, and the prevailing relative cost of doing business) there is a large amount of literature that indicates that perceived deterioration of the natural environment and the natural amenities offered in particular locations, particularly those available on public lands, may have an important impact on the ability of communities in adjacent regions to foster sustainable economic growth (Rudzitis & Johansen 1989; Johnson & Rasker 1995; Rasker 1994; Rudzitis 1999; Rasker et al. 2004; Chipeniuk 2004; Holmes & Hecox 2005; Reeder & Brown 2005).

C.6 POTENTIAL EFFECTS OF ANS ESTABLISHMENT ON COMMERCIAL FISHERIES

A recent USACE study (USACE 2012a,b) quantified the value of commercial fishery harvests in the Great Lakes Basin, the Upper Mississippi Basin, and the Ohio River Basin based on recent harvest level and dockside value data available from state agencies. The study incorporated annual harvest levels and the associated dockside values for the years 1989 through 2009 in order to generate analyses of harvesting trends over time. ANS have the potential to impact commercial fisheries by reducing the abundance of commercially desirable fish species, making commercial fishing activity less efficient, or by increasing equipment maintenance costs.

C.7 QUALITATIVE ASSESSMENT OF THE POTENTIAL ECONOMIC CONSEQUENCES OF ANS ESTABLISHMENT

To assess the economic consequences of ANS establishment, each ANS was evaluated against the following economic categories:

- Consumer surplus,
- Property values,
- Recreational and commercial fishing,
- Recreational boating,
- Commercial and recreational support industries,
- Maintaining water quality,
- Water withdrawal structure maintenance,
- Aquaculture facilities, and
- Boating maintenance.

Summary of Assigned Levels of Economic Consequences for Aquatic Nuisance Species[a]

	Spatial Extent	Decrease in Property Values	Reduction in Recreational Hunting and Fishing	Reduction in Recreational Boating	Reduction in Commercial Fishing	Reduction in Supporting Industries	Increased Cost of Maintaining Water Quality	Increased Cost of Water Withdrawal Structures	Increased Boat Maintenance Costs	Loss of Consumer Surplus
Protozoa										
Testate amoeba (*Psammonobiotus communis*)	Localized									
Testate amoeba (*P. dziwnowi*)	Localized									
Testate amoeba (*P. linearis*)	Localized									
Algae										
Cryptic algae (*Cyclotella cryptica*)	Localized									
Grass kelp (*Enteromorpha flexuosa*)	Localized	•	•	•		•			•	•
Red algae (*Bangia atropurpurea*)	Localized	•		•		•			•	•
Diatom (*Stephanodiscus binderanus*)	Widespread						•			
Bryozoan										
Freshwater bryozoan (*Lophopodella carteri*)	Widespread									
Molluscs										
Greater European peaclam (*Pisidium amnicum*)	Widespread									
European fingernail clam (*Sphaerium corneum*)	Widespread									
European stream valvata (*Valvata piscinalis*)	Widespread									

(Cont.)

	Spatial Extent	Decrease in Property Values	Reduction in Recreational Hunting and Fishing	Reduction in Recreational Boating	Reduction in Commercial Fishing	Reduction in Supporting Industries	Increased Cost of Maintaining Water Quality	Increased Cost of Water Withdrawal Structures	Increased Boat Maintenance Costs	Loss of Consumer Surplus
Crustaceans										
Scud (*Apocorophium lacustre*)	Widespread									
Fishhook waterflea (*Cercopagis pengoi*)	Widespread	•	•		•	•				•
Waterflea (*Daphnia g. galeata*)	Widespread									
Bloody red shrimp (*Hemimysis anomala*)	Widespread		•		•	•				•
Parasitic copepod (*Neoergasilus japonicas*)	Widespread									
Harpacticoid copepod (*Schizopera borutzkyi*)	Widespread									
Fish										
Skipjack herring (*Alosa chrysochloris*)	Widespread									
Blueback Herring (*Alosa aestivalis*)	Widespread		•		•	•				•
Northern snakehead (*Channa argus*)	Widespread		•		•	•				•
Inland silverside (*Menidia beryllina*)	Localized									
Black carp (*Mylopharyngodon piceus*)	Widespread		•		•	•				•
Bighead carp (*Hypophthalmichthyes nobilis*)	Widespread		•		•	•				•

(Cont.)

	Spatial Extent	Decrease in Property Values	Reduction in Recreational Hunting and Fishing	Reduction in Recreational Boating	Reduction in Commercial Fishing	Reduction in Supporting Industries	Increased Cost of Maintaining Water Quality	Increased Cost of Water Withdrawal Structures	Increased Boat Maintenance Costs	Loss of Consumer Surplus
Fish (Cont.)										
Silver carp (*Hypophthalmichthys molitrix*)	Widespread	•	•	•	•	•			•	•
Threespine stickleback (*Gasterosteus aculeatus*)	Widespread									
Ruffe (*Gymnocephalus cernuus*)	Localized		•		•	•				•
Sea lamprey (*Petromyzon marinus*)	Widespread		•		•	•				•
Tubenose goby (*Proterorhinus semilunaris*)	Localized									
Plants										
Marsh dewflower (*Murdannia keisak*)	Localized									
Cuban bulrush (*Oxycaryum cubense*)	Localized									
Dotted duckweed (*Landoltia punctata*)	Localized									
Swamp sedge (*Carex acutiformis*)	Widespread									
Reed sweetgrass (*Glyceria maxima*)	Widespread	•	•			•			•	•
Water chestnut (*Trapa natans*)	Widespread	•	•	•		•			•	•
Viruses	Widespread									
Viral hemorrhagic septicemia Virus (*Novirhabdovirus* sp.)			•		•	•				•

[a] Bullet = Possibly affected area; H = High; M = Medium; L = Low; N = None.

For the assessment, the more economic categories identified as being potentially affected, the greater the likelihood for economic consequences to be realized for ANS establishment. As described in Sections C.2 and C.3, consumer surplus is the amount of value a consumer of a good or service receives over and above what he or she has to pay for the good or service. Changes in consumer surplus may occur as a result of both changes in direct use and the passive use valuation of recreational resources by existing and potential users. Revealed preference methods, including travel cost models and site choice models, would be used to measure direct use valuation at specific recreation locations, and contingent valuation methods would be used to measure willingness to pay for improvements in recreational quality for individuals that have visited, or intend to visit, a particular water resource. Contingent valuation methods would also be used to measure resource value for individuals who wish to place a value on the improvement or preservation of the quality of recreational resources for future generations.

ANS establishment may also affect property values associated with changes in both aesthetic quality and the economic viability of locations whose economies depend on recreational boating and commercial and recreational fishing. As outlined in Section C.5, changes in aesthetic quality may also affect the overall economic development prospects of rural areas.

As outlined in Section C.4, economic impacts of ANS establishment may result from reductions in recreational and boating activity, in commercial fishing, and in supporting industries, such as boat and tackle sales; rental and repair facilities; hotels, motels and campsites; restaurants and gas stations; and other miscellaneous equipment facilities. Declining expenditures in each of these categories would lead to losses of employment and income in sectors directly involved in providing goods and services to recreational boating and recreational and commercial fishing, as well as in the economy as a whole; reductions in spending in those sectors directly affected means reductions in indirect employment and income in sectors supplying those sectors that are directly affected. In addition to reductions in direct and indirect employment and income, reduced economic activity would also affect local and state tax revenues, including sales taxes, personal income taxes, and corporate income taxes. The economic impacts of reductions in these activities would be estimated using input-output, econometric, or CGE models.

Changes in property valuation would also affect property tax revenues. Reductions in local and state tax revenues would affect public service provision, educational provision, and infrastructure provision, further impacting overall economic development prospects. As outlined in Section C.2, impacts on property values would be estimated using hedonic regression models.

C.7.1 Consequence and Uncertainty Ratings

C.7.1.1 Consequence Ratings

For the economic consequence assessment, it is assumed that each ANS species has successfully become established. The economic consequences assessment assigned one of the following qualitative ratings for each ANS evaluated:

- High—High consequence rating due to the larger number of consequence categories affected, the nature and severity of the consequences, and the broader spatial extent of the consequences .

- Medium—Medium consequence rating due to the number of consequence categories affected, the nature and severity of the consequences, and the spatial extent of the consequences.

- Low—Low consequence rating due to the lower number of consequence categories affected, the lesser nature and severity of the consequences, and the more localized extent of the consequences.

- None—No consequences are anticipated.

The assigned rating is based on the amount of consequence information available for each ANS (or closely related species), the interpretation of that information, and the thresholds selected to distinguish between the consequence levels. The application of these ratings requires the risk assessment team to judge or otherwise differentiate between different levels of consequence; consequence distinctions will differ not only by ANS but also according to the location and spatial extent of the ANS establishment.

For each ANS, the severity of economic consequences depends on the extent of species establishment, the resulting impact on existing fisheries resources, and the consequent impact on recreational activity, commercial fishing, and the cost of maintaining water quality, water withdrawal structures, aquaculture facilities, and boats and equipment. The assessment of economic consequences did not quantify the magnitude of any consequences. As noted in the following discussion of the consequences associated with individual species, the economic impact in each category depends on the nature of the location where impacts may occur (rural or urban), the size of the economy in each location, and the relative importance of impacts compared to overall economic activity in each location.

C.7.1.2 Uncertainty Ratings

The economic consequence rating for each ANS has an associated uncertainty rating, reflecting the confidence that is placed on the assessment. The uncertainty rating is based on the amount and quality of scientifically defensible data that was used to identify the consequence components and to support the consequence determination. The uncertainty ratings are as follows:

- High—There is little to no concrete evidence available, or there is very broad range in the nature and severity of the consequences that includes extreme consequences.

- Medium—There is some good supporting data but also some major data gaps, or there is a broad range in the nature and severity of the consequences but no extreme consequences have been identified;

- Low—Good supporting data are available, data gaps are not significant, or there is a limited range of possible consequences.

- None—Adequate data are available to fully support the consequence determination.

These uncertainty levels provide an understanding of how confident the risk assessors are in the rating provided for each consequence. High uncertainty expresses little to no confidence in the rating. Medium uncertainty indicates some confidence in the rating, while a low uncertainty rating indicates a high degree of certainty in the consequence determination. When uncertainty is rated none, the assessors are certain. A high consequence rating with high uncertainty indicates that the consequence determination is largely unsupported by direct or indirect data, that it is based predominantly on professional judgment, and that the indicated consequences are as likely to be incurred as not. Alternately, a high consequence rating combined with a low uncertainty rating indicates that the consequences identified as possible are very likely to be incurred if an ANS were to become established.

C.7.2 Potential Economic Consequences of Species Establishing in the Mississippi River Basin (MRB)

C.7.2.1 Testate Amoeba (*Psammonbiotus communis*)

The establishment of *Psammonbiotus communis* in the Mississippi River Basin (MRB) is expected to have low economic consequences with low uncertainty. The establishment of this species is not expected to significantly affect environmental conditions or biological communities (see Appendix B). Because *Psammonbiotus communis* is not predicted to be widespread in the Mississippi River Basin (MRB; see Appendix B), any effects it does have are expected to be localized and minimal. Therefore, this species is not expected to decrease property values, increase economic costs, or reduce recreational, commercial, and industrial water uses.

C.7.2.2 Testate Amoeba (*P. dziwnowi*)

The establishment of *P. dziwnowi* in the MRB is expected to have low economic consequences with low uncertainty. The establishment of this species is not expected to significantly affect environmental conditions or biological communities (see Appendix B). Because *P. dziwnowi* is not predicted to be widespread in the MRB (see Appendix B), any effects it does have are expected to be localized and minimal. Therefore, this species is not expected to decrease property values, increase economic costs, or reduce recreational, commercial, and industrial water uses.

C.7.2.3 Testate Amoeba (*P. linearis*)

The establishment of *P. linearis* in the MRB is expected to have low economic consequences with low uncertainty. The establishment of this species is not expected to significantly affect environmental conditions or biological communities (see Appendix B). Because *P. linearis* is not predicted to be widespread in the MRB (see Appendix B), any effects it does have are expected to be localized and minimal. Therefore, this species is not expected to decrease property values, increase economic costs, or reduce recreational, commercial, and industrial water uses.

C.7.2.4 Cryptic Algae

The establishment of cryptic algae in the MRB is expected to have low economic consequences with low uncertainty. The establishment of this species is not expected to significantly affect environmental conditions or biological communities (see Appendix B). Because cryptic algae are not predicted to be widespread in the MRB (see Appendix B), any effects of cryptic algae are expected to be localized and minimal. Therefore, this species is not expected to decrease property values, increase economic costs, or reduce recreational, commercial, and industrial water uses.

C.7.2.5 Grass Kelp

Grass kelp is potentially a major fouling algae and has been documented to form extensive beds in nutrient-rich habitats in the Great Lakes Basin (GLB) (Appendix B). As explained below, grass kelp could form nuisance algal mats in the MRB, producing economic consequences in a number of categories, including loss of consumer surplus and loss of property value, along with reductions in recreational boating and fishing. Such impacts could adversely impact employment, income, and tax revenues. However, due to its unique water quality requirements, nuisance blooms of grass kelp in the MRB are expected to be uncommon and highly localized, which will significantly limit the potential extent of economic impacts. Overall, the establishment of the grass kelp could have up to medium economic consequences. However, the spatial extent and locations of water chemistry conditions suitable for the growth of this species are uncertain. Therefore, the economic consequence rating has a high associated uncertainty.

Economic Consequences of Grass Kelp Establishment (● indicates a potential to affect the category)								
	Loss of Personal Wealth	Losses of Employment, Income, and Tax Revenues				Additional Potential Costs Due to ANS		
Loss of Consumer Surplus	Decrease in Property Values	Reduction in Recreational Hunting and Fishing	Reduction in Recreational Boating	Reduction in Commercial Fishing	Reduction in Supporting Service Industries	Increased Cost of Maintaining Water Quality	Increased Costs of Water Withdrawal Structures	Increased Ship Maintenance Costs
●	●	●	●		●	None	None	●

Losses in consumer surplus associated with grass kelp establishment could occur as a result of deterioration in the quality and availability of the fisheries resources on which recreational activity is currently based, and could include losses in both use and non-use (passive use) valuation. Although a potential deterioration in the quality of recreational experience concentrated primarily among individuals residing in the vicinity of water and fisheries resources and the recreational activities they support, these resources might also be valued by individuals living some distance from affected water and fisheries resources.

Losses in property values might occur if grass kelp becomes established in the MRB, primarily through potential changes in the attractiveness of locations for property owners, recreational fishermen and boaters. Nuisance algal blooms might reduce the demand for riverside or lakeside property if a decline in visitation and recreational expenditure occur with establishment. Declining property values could also lead to declining property taxes and could affect the quality of local public service and infrastructure provision, which could reduce local economic development prospects, thus reducing employment income and overall tax revenues.

Nuisance algal blooms of grass kelp could cause reductions in recreational fishing as a result of floating mats of algae in waterways, increased equipment snagging risk, and impacts on boats, notably propellers. These impacts have the potential to affect employment, income, and tax revenues in locations that are highly dependent on these activities, and in supporting industries, particularly in rural locations that have few alternative sources of local employment. Because of this dependence, relatively small reductions in the amount of recreational fishing in rural communities could produce fairly substantial impacts on local economies and fiscal viability. Greater changes in recreational activity, and in supporting industries, in larger urban areas could have smaller relative economic and fiscal impacts, because employment, income, and tax revenues are produced by a larger number of economic sectors.

The effects described, if they were to occur, are expected to be highly localized due to the unique water chemistry requirements of the grass kelp (see Appendix B). Therefore, although this species could potentially affect the economic variables as described, the overall magnitude will be limited and therefore the consequence rating is medium rather than high.

C.7.2.6 Red Algae

Red algae (*Bangia atropurpurea*) is a filamentous algae that could grow on hard substrate in rivers, streams, and lakes in the MRB. As explained below, localized establishment of red algae could produce economic consequences such as loss of consumer surplus and loss of property value, while reductions in recreational boating could adversely impact employment, income, and tax revenues. However, due to its unique water quality requirements, the distribution of red algae in the MRB is expected to be uncommon and highly localized, which will significantly limit the potential extent of economic impacts. Overall, the establishment of the red algae could have up to medium economic consequences. However, the spatial extent and locations of water chemistry conditions suitable for the growth of this species are uncertain. Therefore, the economic consequence rating has a high associated uncertainty.

Economic Consequences of Red Algae Establishment
(● indicates a potential to affect the category)

	Loss of Personal Wealth	Losses of Employment, Income, and Tax Revenues				Additional Potential Costs Due to ANS		
Loss of Consumer Surplus	Decrease in Property Values	Reduction in Recreational Hunting and Fishing	Reduction in Recreational Boating	Reduction in Commercial Fishing	Reduction in Supporting Service Industries	Increased Cost of Maintaining Water Quality	Increased Costs of Water Withdrawal Structures	Increased Ship Maintenance Costs
●	●		●		●	None	None	●

Losses in consumer surplus associated with red algae establishment could occur as a result of deterioration in the quality and availability of the fisheries resources on which recreational activity is currently based, and could include losses in both use and non-use (passive use) valuation. Although a potential deterioration in the quality of recreational experience would be concentrated primarily among individuals residing in the vicinity of water and fisheries resources and the recreational activities they support, these resources might also be valued by individuals living some distance from affected water and fisheries resources.

Losses in property values might occur if red algae become established in the MRB primarily through potential changes in the visual attractiveness of locations for property owners, recreational fishermen and boaters. Declining visual quality might reduce the demand for riverside or lakeside property if a decline in visitation and recreational expenditure occur with establishment. Declining property values would also lead to declining property taxes and could affect the quality of local public service and infrastructure provision, which could reduce local economic development prospects, thus reducing employment income and overall tax revenues.

The effects described, if they were to occur, are expected to be highly localized due to the unique water chemistry requirements of the red algae. Therefore, although this species could potentially impact the economic variables as described, the overall magnitude will be limited and therefore the consequence rating is medium rather than high.

C.7.2.7 Diatom

Within the Great Lakes, the diatom (*Stephanodiscus binderanus*) is documented to clog filters at municipal water treatment plants, and seasonal blooms of this species have caused water taste and odor problems (reviewed in Kipp et al. 2013). Kipp et al. (2013) states that this species also adversely affects water quality, visual appearance, and recreational uses. The widespread establishment of diatom (*Stephanodiscus binderanus*) could produce economic consequences in a single category, increased expenditure on water quality improvements, including increased capital spending and maintenance expenditures. However, the species would be problematic only seasonally and in areas of the MRB (primarily lakes and reservoirs) with habitat conditions conducive to bloom formation (i.e., high light and nutrients). Therefore, the blooms of this species and their associated impacts are not expected to be common or widespread. Overall, the establishment of the diatom could have medium economic consequences, although this rating has a high associated uncertainty.

Economic Consequences of Diatom Establishment
(● indicates a potential to affect the category)

	Loss of Personal Wealth	Losses of Employment, Income, and Tax Revenues				Additional Potential Costs Due to ANS		
Loss of Consumer Surplus	Decrease in Property Values	Reduction in Recreational Hunting and Fishing	Reduction in Recreational Boating	Reduction in Commercial Fishing	Reduction in Supporting Service Industries	Increased Cost of Maintaining Water Quality	Increased Costs of Water Withdrawal Structures	Increased Ship Maintenance Costs
None	None	None	None	None	None	●	None	None

C.7.2.8 Freshwater Bryozoan

The establishment of the freshwater bryozoan in the MRB is expected to have low economic consequences with low uncertainty. The establishment of this species is not expected to significantly affect environmental conditions or biological communities (see Appendix B). Therefore, this species is not expected to decrease property values, increase economic costs, or reduce recreational, commercial, and industrial water uses.

C.7.2.9 Greater European Peaclam

The establishment of the greater European peaclam in the MRB is expected to have low economic consequences with low uncertainty. The establishment of this species is not expected to adversely affect environmental conditions or biological communities (see Appendix B). Therefore, this species is not expected to decrease property values, increase economic costs, or reduce recreational, commercial, and industrial water uses.

C.7.2.10 European Fingernail Clam

The establishment of the European fingernail clam in the MRB is expected to have low economic consequences with low uncertainty. The establishment of this species is not expected to significantly affect environmental conditions or biological communities (see Appendix B). Therefore, this species is not expected to decrease property values, increase economic costs, or reduce recreational, commercial, and industrial water uses.

C.7.2.11 European Stream Valvata

The establishment of the European stream valvata in the MRB is expected to have low economic consequences with low uncertainty. The establishment of this species is not expected to significantly affect environmental conditions or biological communities (see Appendix B). Therefore, this species is not expected to decrease property values, increase economic costs, or reduce recreational, commercial, and industrial water uses.

C.7.2.12 Fishhook Waterflea

As explained below, fishhook waterflea has the potential to impact fish communities (see Appendix B), potentially impacting recreationally and commercially important species and resulting in economic consequences in a number of categories, including loss of consumer surplus and loss of property value as well as reductions in recreational and commercial fishing. This could adversely impact employment, income, and tax revenues. There is substantial lake and to a lesser degree riverine habitat in the MRB that would be suitable for this species. Therefore, the fishhook waterflea could potentially be widespread in the lakes and reservoirs of the MRB (Appendix B). Overall, the establishment of this species could result in medium economic consequences, with an associated medium uncertainty

Economic Consequences of Fishhook Waterflea Establishment (● indicates a potential to affect the category)								
	Loss of Personal Wealth	Losses of Employment, Income, and Tax Revenues				Additional Potential Costs Due to ANS		
Loss of Consumer Surplus	Decrease in Property Values	Reduction in Recreational Hunting and Fishing	Reduction in Recreational Boating	Reduction in Commercial Fishing	Reduction in Supporting Service Industries	Increased Cost of Maintaining Water Quality	Increased Costs of Water Withdrawal Structures	Increased Ship Maintenance Costs
●	●	●	None	●	●	None	None	None

Losses in consumer surplus associated with the fishhook waterflea establishment could occur as a result of deterioration in the quality and availability of the fisheries resources on which recreational activity is currently based, and could include losses in both use and non-use (passive use) valuation. Although a potential deterioration in the quality of recreational experience would be concentrated primarily among individuals residing in the vicinity of water and fisheries resources and the recreational activities they support, these resources might also be valued by individuals living some distance from affected water and fisheries resources.

Establishment of the fishhook waterflea could cause reductions in commercial and recreational fishing activity through reductions in the availability of desirable fish species (see Appendix B) and the fouling of fishing gear that is commonly associated with this species (Bensen et al. 2013). Reductions in commercial fishing could reduce income generated through the sale of commercial fish species, which could, in turn, affect employment, income, and tax revenues in local communities following a reduction in spending by commercial fishing participants. Establishment could also reduce employment, income, and tax revenue in supporting industries that provide fishing equipment and supplies. These impacts could have the potential to affect employment, income, and tax revenues in locations that are highly dependent on these activities, and in supporting industries, particularly in rural locations that have few alternative sources of local employment. Because of this dependence, relatively small reductions in the amount of recreational fishing in rural communities could produce fairly substantial impacts on local economies and fiscal viability. Greater changes in recreational activity, and in supporting industries, in larger urban areas would have smaller relative economic and fiscal impacts, because employment, income, and tax revenues are produced by a larger number of economic sectors.

Losses in property values in the MRB might occur primarily through potential changes in the attractiveness of locations for recreational fishermen and boaters. Declining fisheries quality and the nuisance fouling of fishing gear might reduce the demand for riverside or lakeside property if declines in visitation and recreational expenditure occur with establishment.

Declining property values could also lead to declining property taxes and could affect the quality of local public service and infrastructure provision, which could reduce local economic development prospects, thus reducing employment income and overall tax revenues.

C.7.2.13 Waterflea

The establishment of the waterflea (*Daphnia g. galeata*) in the MRB is expected to have low economic consequences with low uncertainty. The establishment of this species is not expected to significantly affect environmental conditions or biological communities (see Appendix B). Therefore, this species is not expected to decrease property values, increase economic costs, or reduce recreational, commercial, and industrial water uses.

C.7.2.14 Bloody Red Shrimp

As explained below, bloody red shrimp has the potential to impact fish communities (see Appendix B), resulting in economic consequences in a number of categories, including loss of consumer surplus and reductions in recreational and commercial fishing that could adversely impact employment, income, and tax revenues. This species can establish lake and riverine habitat and could therefore be widespread in the MRB. Although there is the potential for economic impacts, the economic impacts of this species where it is currently established in the Great Lakes have not been documented. Therefore, the establishment of the bloody red shrimp could result in medium economic consequences, with a high associated uncertainty.

Economic Consequences of Bloody Red Shrimp Establishment
(● indicates a potential to affect the category)

	Loss of Personal Wealth	Losses of Employment, Income, and Tax Revenues				Additional Potential Costs Due to ANS		
Loss of Consumer Surplus	Decrease in Property Values	Reduction in Recreational Hunting and Fishing	Reduction in Recreational Boating	Reduction in Commercial Fishing	Reduction in Supporting Service Industries	Increased Cost of Maintaining Water Quality	Increased Costs of Water Withdrawal Structures	Increased Ship Maintenance Costs
●	None	●	None	●	●	None	None	None

Losses in consumer surplus associated with bloody red shrimp establishment could occur as a result of deterioration in the quality and availability of the fisheries resources on which recreational activity is currently based, and would include losses in both use and non-use (passive use) valuation. Although a potential deterioration in the quality of recreational experience would be concentrated primarily among individuals residing in the vicinity of water and fisheries resources and the recreational activities they support, these resources might also be valued by individuals living some distance from affected water and fisheries resources.

Investigations of introduced mysids like the bloody red shrimp have demonstrated that they have the potential to reduce the abundance and growth rates of pelagic fishes and alter contaminant cycling (see Appendix B). Consequently, the establishment of bloody red shrimp could cause reductions in recreational fishing through reductions in the availability of desirable fish species and an increase their tissue contaminant levels. These impacts have the potential to significantly impact employment, income, and tax revenues in locations that are highly dependent on these activities, and in supporting industries, particularly in rural locations that have few alternative sources of local employment. Because of this dependence, relatively small reductions in the amount of recreational fishing in rural communities could produce fairly substantial impacts on local economies and fiscal viability. Greater changes in recreational activity, and in supporting industries, in larger urban areas would have smaller relative economic and fiscal impacts, because employment, income, and tax revenues are produced by a larger number of economic sectors.

Reductions in commercial fishing activity could result from the establishment of bloody red shrimp if this species were to reduce the abundance of desirable commercial fish species. This could, in turn, reduce income generated through the sale of commercial fish species and affect employment, income, and tax revenues in local communities following a reduction in spending by commercial fishing participants. Establishment could also reduce employment, income, and tax revenue in supporting industries that provide fishing equipment and supplies. The economic and fiscal impacts of reductions in commercial fishing, and in supporting industries, would primarily affect rural communities; the relative importance of impacts on these communities would vary depending on the importance of alternate sources of economic activity. As was the case with recreational fishing, relatively small reductions in commercial fishing in rural communities could produce fairly substantial impacts on local economies and fiscal viability, while greater changes in commercial fishing in larger urban areas would have smaller relative economic and fiscal impacts.

C.7.2.15 Parasitic Copepod

The establishment of the parasitic copepod (*Neoergasilus japonicas*) in the MRB is expected to have low economic consequences with low uncertainty. The establishment of this species is not expected to significantly affect environmental conditions or biological communities (see Appendix B). Therefore, this species is not expected to decrease property values, increase economic costs, or reduce recreational, commercial, and industrial water uses.

C.7.2.16 Harpacticoid Copepod

The establishment of the harpacticoid copepod (*Schizopera borutzkyi*) in the MRB is expected to have low economic consequences with low uncertainty. The establishment of this species is not expected to significantly affect environmental conditions or biological communities (see Appendix B). Therefore, this species is not expected to decrease property values, increase economic costs, or reduce recreational, commercial, and industrial water uses.

C.7.2.17 Ruffe

As explained below, the ruffe has the potential to impact fish communities in the MRB by directly competing with or preying upon desirable fish species (see Appendix B), resulting in economic consequences in a number of categories, including including loss of consumer surplus, and reductions in recreational and commercial fishing that could adversely impact employment, income, and tax revenues. This species can establish in lake and riverine habitat, but the ruffe is a coldwater fish (Rasmussen 2002), and it may not reach high abundance or wide distribution in the MRB, which could limit its potential to generate economic consequences. In addition, although the ruffe has been found to impact fish species where it is currently established in the Great Lakes, the resulting economic consequences for fisheries are uncertain. Overall, the establishment of the ruffe could potentially result in medium economic consequences, with medium associated uncertainty.

Economic Consequences of Ruffe Establishment
(● indicates a potential to affect the category)

	Loss of Personal Wealth	Losses of Employment, Income, and Tax Revenues				Additional Potential Costs Due to ANS		
Loss of Consumer Surplus	Decrease in Property Values	Reduction in Recreational Hunting and Fishing	Reduction in Recreational Boating	Reduction in Commercial Fishing	Reduction in Supporting Service Industries	Increased Cost of Maintaining Water Quality	Increased Costs of Water Withdrawal Structures	Increased Ship Maintenance Costs
●	None	●	None	●	●	None	None	None

Losses in consumer surplus associated with ruffe establishment could occur as a result of deterioration in the quality and availability of the fisheries resources on which recreational activity is currently based, and could include losses in both use and non-use (passive use) valuation. Although a potential deterioration in the quality of recreational experience would be concentrated primarily among individuals residing in the vicinity of water and fisheries resources and the recreational activities they support, these resources might also be valued by individuals living some distance from affected water and fisheries resources.

The ruffe is documented to be a strong ecological competitor that could have a detrimental effect on MRB fishes by feeding on the young of resident species or by competing with them for food or habitat (see Appendix B). Consequently, the establishment of ruffe could cause reductions in recreational fishing through reductions in the availability of desirable fish species. Furthermore, the ruffe would not replace the lost value of the species it outcompetes because the ruffe is considered a nuisance species with little commercial or recreational value. Similarly, reductions in commercial fishing activity following ruffe establishment could reduce income generated through the sale of commercial fish species, which could, in turn, impact employment, income, and tax revenues in local communities following a reduction in spending by commercial fishing participants. Establishment could also reduce employment, income, and tax revenue in supporting industries that provide fishing equipment and supplies. Fisheries impacts would have the potential to significantly affect employment, income, and tax revenues in locations that are highly dependent on these activities, and in supporting industries, particularly in rural locations that have few alternative sources of local employment. Because of this dependence, relatively small reductions in fishing activity in rural communities could produce fairly substantial impacts on local economies and fiscal viability. Greater changes in recreational activity, and in supporting industries, in larger urban areas would have smaller relative economic and fiscal impacts, because employment, income, and tax revenues are produced by a larger number of economic sectors.

The effects described, if they were to occur, may not be widespread in the MRB because the ruffe is a coldwater fish, and it may not reach high abundance or wide distribution in the MRB (see Appendix B). Therefore, although this species could potentially impact the economic variables as described, the overall magnitude will be limited and therefore the consequence rating is medium rather than high.

C.7.2.18 Sea Lamprey

Sea lamprey are parasitic fish that have historically generated significant adverse economic impacts in the Great Lakes (see Appendix B). As explained below, the establishment of sea lamprey in the MRB could produce economic consequences in a number of categories, including loss of consumer surplus and reductions in recreational and commercial fishing that could adversely impact employment, income, and tax revenues. However, the sea lamprey is not expected to reach high abundance in the MRB due to the lack of suitable habitat (see Appendix B). Overall, the establishment of the sea lamprey in the MRB could result in medium economic consequences, with high associated uncertainty.

Economic Consequences of Sea Lamprey Establishment
(● indicates a potential to affect the category)

	Loss of Personal Wealth	Losses of Employment, Income, and Tax Revenues				Additional Potential Costs Due to ANS		
Loss of Consumer Surplus	Decrease in Property Values	Reduction in Recreational Hunting and Fishing	Reduction in Recreational Boating	Reduction in Commercial Fishing	Reduction in Supporting Service Industries	Increased Cost of Maintaining Water Quality	Increased Costs of Water Withdrawal Structures	Increased Ship Maintenance Costs
●	None	●	None	●	●	None	None	None

Losses in consumer surplus associated with sea lamprey establishment could occur as a result of deterioration in the quality and availability of the fisheries resources on which recreational activity is currently based, and could include losses in both use and non-use (passive use) valuation. Although a potential deterioration in the quality of recreational experience would be concentrated primarily among individuals residing in the vicinity of water and fisheries resources and the recreational activities they support, these resources might also be valued by individuals living some distance from affected water and fisheries resources.

The sea lamprey is well documented to have caused a significant reduction in commercially and recreationally desirable fish species In the Great Lakes (see Appendix B). Establishment of sea lamprey in the MRB could potentially impact recreational and commercial fishing through reductions in the availability of desirable fish species in the MRB. Such impacts could reduce income generated through the sale of commercial fish species, which could, in turn, impact employment, income, and tax revenues in local communities following a reduction in spending by commercial fishing participants. Establishment could also reduce employment, income, and tax revenue in supporting industries that provide fishing equipment and supplies, especially in locations that are highly dependent on these activities, such as rural locations that have few alternative sources of local employment. Because of this dependence, relatively small reductions in recreational and commercial fishing in rural communities could produce fairly substantial impacts on local economies and fiscal viability. Greater changes in recreational activity, and in supporting industries, in larger urban areas would have smaller relative economic and fiscal impacts, because employment, income, and tax revenues are produced by a larger number of economic sectors.

The effects just described, if they were to occur, are not predicted to be widespread in the MRB because the existing data suggests the sea lamprey will not establish widely in the MRB (see Appendix B). In addition there are multiple management strategies that have been developed to control sea lamprey populations. These control programs, if applied in the MRB, could significantly reduce the potential for impacts on invaded lakes. Therefore, the consequence rating is medium rather than high.

C.7.2.19 Tubenose Goby

The tubenose goby has the potential to impact fish communities by directly competing with or preying upon desirable fish species (see Appendix B). However, this species is a coldwater fish and it may not reach high abundance or wide distribution in the MRB (see Appendix B). In addition, fishery impacts caused by the tubenose goby have not been documented where they are currently established in the Great Lakes (see Appendix B). These factors suggest a limited potential for the tubenose goby to generate economic consequences in the MRB. Therefore, the establishment of the tubenose goby is rated as having low economic consequences, with medium associated uncertainty.

C.7.2.20 Blueback Herring

As explained below, the establishment of blueback herring could produce economic consequences in a number of categories, including loss of consumer surplus, and reductions in recreational and commercial fishing that could adversely impact employment, income, and tax revenues. This species can establish lake and riverine habitat and could therefore be widespread in the MRB. Therefore, the establishment of the blueback herring may result in medium economic consequences, with medium associated uncertainty.

Economic Consequences of Blueback Herring Establishment
(● indicates a potential to affect the category)

	Loss of Personal Wealth	Losses of Employment, Income, and Tax Revenues				Additional Potential Costs Due to ANS		
Loss of Consumer Surplus	Decrease in Property Values	Reduction in Recreational Hunting and Fishing	Reduction in Recreational Boating	Reduction in Commercial Fishing	Reduction in Supporting Service Industries	Increased Cost of Maintaining Water Quality	Increased Costs of Water Withdrawal Structures	Increased Ship Maintenance Costs
●	None	●	None	●	●	None	None	None

Losses in consumer surplus associated with blueback herring establishment could occur as a result of deterioration in the quality and availability of the fisheries resources on which recreational activity is currently based, and could include losses in both use and non-use (passive use) valuation. Although a potential deterioration in the quality of recreational experience would be concentrated primarily among individuals residing in the vicinity of water and fisheries resources and the recreational activities they support, these resources might also be valued by individuals living some distance from affected water and fisheries resources.

There is stream and riverine habitat in the MRB that may potentially be suitable for this species. Therefore, this species could potentially be widespread in the MRB. Once established, consumption of fish food and fish eggs by the blueback herring can be considerable and may reduce gamefish recruitment (see Appendix B). Consequently, the establishment of blueback herring in the MRB could cause reductions in recreational fishing through reductions in the abundance of desirable fish species. Blueback herring establishment could also affect commercial fishing by reducing the abundance of desirable species, which could reduce income generated through the sale of commercial fish species. This could, in turn, affect employment, income, and tax revenues in local communities following a reduction in spending by commercial fishing participants. Establishment could also reduce employment, income, and tax revenue in supporting industries that provide fishing equipment and supplies. Such impacts would likely be restricted to reservoirs which is where this species spends most of its adult life. Fishery impacts could have the potential to significantly affect employment, income, and tax revenues in locations that are highly dependent on these activities, and in supporting industries, particularly in rural locations that have few alternative sources of local employment. Because of this dependence, relatively small reductions in recreational fishing in rural communities could produce fairly substantial impacts on local economies and fiscal viability. Greater changes in recreational activity, and in supporting industries, in larger urban areas would have smaller relative economic and fiscal impacts, because employment, income, and tax revenues are produced by a larger number of economic sectors.

C.7.2.21 Threespine Stickleback

The establishment of the threespine stickleback in the MRB is expected to have no economic consequences with low uncertainty. The establishment of this species is not expected to significantly affect environmental conditions or biological communities (see Appendix B). Therefore, this species is not expected to decrease property values, increase economic costs, or reduce recreational, commercial, or industrial water uses.

C.7.2.22 Viral Hemorrhagic Septicemia Virus

Viral hemorrhagic septicemia virus (VHSv) could affect several fish species with commercial, recreational, and aquaculture value (APHIS 2006). Economic loss to aquaculture facilities could result from loss of fish stocks, additional virus testing costs, and disinfection costs if the virus was detected at the facility. European strains of VHSv have caused significant mortality in trout farms in Europe, and farmed fish could be similarly affected in the United States. However, no infections of VHSv had been reported in aquaculture facilities in the United States as of June 2011 (Kipp et al. 2013). Temporary economic impacts on recreational fisheries could result if large fish kills occurred in a reservoir, thereby reducing the abundance of fish populations or discouraging fishing due to the appearance of infected fish. Similarly, if there is a reduction in commercially important species, there is the potential for economic impacts on commercial fisherman. If commercial and/or recreational fishing were reduced, there could also be a loss of income for supporting businesses. Fish kills have been relatively infrequent in the GLB, and a review by Kipp et al. (2013) states that VHSv has had little effect on commercial and recreational fisheries in the Great Lakes thus far.

VHSv survives best at moderate temperatures (10–15°C; 59°F) and the virus becomes inactive after 24 hours in water temperatures greater than 20°C (Kipp et al. 2013). In addition, McAllister (1990) states that mortality is uncommon at temperatures greater than 15°C. Considering these temperature sensitivities, VHSv may not spread to the lower MRB, and/or may have greatly reduced virulence in the middle and lower MRB. Consequently, economic impacts on the large number of aquaculture facilities in the middle and lower MRB may be minor.

Given the potential for fish infections to reduce fishing activity, and the potential impacts on aquaculture, VHSv could potentially result in medium economic consequences if it were to establish in the MRB. If VHSv were to establish in the MRB, the realized effects of VHSv fish kills on recreational fish and water use as well as the ability of this species to spread to aquaculture facilities in the lower MRB are uncertain. Therefore, the uncertainty of the VHSv rating is high.

Economic Consequences of VHSv Establishment
(● indicates a potential to affect the category)

	Loss of Personal Wealth	Losses of Employment, Income, and Tax Revenues				Additional Potential Costs Due to ANS		
Loss of Consumer Surplus	Decrease in Property Values	Reduction in Recreational Hunting and Fishing	Reduction in Recreational Boating	Reduction in Commercial Fishing	Reduction in Supporting Service Industries	Increased Cost of Maintaining Water Quality	Increased Costs of Water Withdrawal Structures	Increased Ship Maintenance Costs
●		●		●	●	●	None	None

C.7.2.23 Swamp Sedge

The establishment of the swamp sedge in the MRB is expected to have low economic consequences with low uncertainty. Although the swamp sedge may replace existing vegetation communities (see Appendix B), no evidence was found suggesting this species would reduce habitat quality for fish and wildlife as is common in other invasive plant species. Therefore, this species is not expected to decrease property values, increase economic costs, or reduce recreational, commercial, and industrial water uses.

C.7.2.24 Reed Sweetgrass

As explained below, the reed sweetgrass could significantly reduce habitat suitability for fish and wildlife and recreational users in the MRB. Consequently, the establishment of reed sweetgrass could produce economic consequences in a number of categories, including loss of property value and consumer surplus as well as reductions in recreational boating, waterfowl hunting, and fishing, which could adversely impact employment, income, and tax revenues. There is substantial wetland habitat in the MRB that would be suitable for this species. therefore, the reed sweetgrass could potentially be widespread in the MRB (see Appendix B). Overall, the establishment of the reed sweetgrass may result in medium economic consequences, with medium uncertainty.

Economic Consequences of Reed Sweetgrass Establishment (● indicates a potential to affect the category)								
	Loss of Personal Wealth	Losses of Employment, Income, and Tax Revenues				Additional Potential Costs Due to ANS		
Loss of Consumer Surplus	Decrease in Property Values	Reduction in Recreational Hunting and Fishing	Reduction in Recreational Boating	Reduction in Commercial Fishing	Reduction in Supporting Service Industries	Increased Cost of Maintaining Water Quality	Increased Costs of Water Withdrawal Structures	Increased Ship Maintenance Costs
●	●	●	None	None	●	None	None	●

Losses in consumer surplus associated with reed sweetgrass establishment could occur as a result of deterioration in the quality and availability of the fisheries resources on which recreational activity is currently based, and could include losses in both use and non-use (passive use) valuation. Although a potential deterioration in the quality of recreational experience would be concentrated primarily among individuals residing in the vicinity of water and fisheries resources and the recreational activities they support, these resources might also be valued by individuals living some distance from affected water and fisheries resources.

Reed sweetgrass is a highly productive species that often displaces seed-producing plants that provide food for wildlife, while not providing suitable replacement food or nesting habitat (see Appendix B). The reed sweetgrass can also degrade fish habitat quality and become a nuisance to fisherman by its widespread growth in the littoral zone of lakes and by producing dense floating mats (see Appendix B). Consequently, the establishment of reed sweetgrass could cause economic impacts in a number of ways including reductions in fish and game populations; decreased attractiveness of locations for recreational fishermen, boaters and waterfowl hunters; floating mats of algae in waterways; increased equipment snagging risk; and impacts on boat propellers. These impacts could have the potential to significantly impact employment, income, and tax revenues in locations that are highly dependent on these activities, and in supporting industries, particularly in rural locations that have few alternative sources of local employment. Because of this dependence, relatively small reductions in recreational fishing in rural communities could produce fairly substantial impacts on local economies and fiscal viability. Greater changes in recreational activity, and in supporting industries, in larger urban areas would have smaller relative economic and fiscal impacts, because employment, income, and tax revenues are produced by a larger number of economic sectors.

Losses in property values might occur through potential changes in the attractiveness of locations for recreational fishermen and boaters. Declining fisheries quality and accessibility, increased equipment snagging risk, and decreased swimming accessibility might reduce the demand for riverside or lakeside property if a decline in visitation and recreational expenditure occur with establishment. Declining property values would also lead to declining property taxes and could affect the quality of local public service and infrastructure provision. This could reduce local economic development prospects, thus reducing employment income and overall tax revenues.

C.7.2.25 Water Chestnut

As explained below, the water chestnut could significantly reduce habitat quality for fish and wildlife as well as human users. Consequently, the establishment of water chestnut could produce economic consequences in a number of categories, including loss of property values and consumer surplus and reductions in recreational boating, recreational fishing, and commercial fishing, which could adversely impact employment, income, and tax revenues. There is substantial wetland habitat in the MRB that would be suitable for this species. Therefore, the water chestnut could potentially be widespread in the MRB (seer Appendix B). Overall, the establishment of water chestnut may result in medium economic consequences, with medium associated uncertainty.

Economic Consequences of Water Chestnut Establishment
(● indicates a potential to affect the category)

	Loss of Personal Wealth	Losses of Employment, Income, and Tax Revenues				Additional Potential Costs Due to ANS		
Loss of Consumer Surplus	Decrease in Property Values	Reduction in Recreational Hunting and Fishing	Reduction in Recreational Boating	Reduction in Commercial Fishing	Reduction in Supporting Service Industries	Increased Cost of Maintaining Water Quality	Increased Costs of Water Withdrawal Structures	Increased Ship Maintenance Costs
●	●	●	●	None	●	None	None	●

Losses in consumer surplus associated with water chestnut establishment could occur as a result of deterioration in the quality and availability of the fisheries resources on which recreational activity is currently based, and would include losses in both use and non-use (passive use) valuation. Although a potential deterioration in the quality of recreational experience would be concentrated primarily among individuals residing in the vicinity of water and fisheries resources and the recreational activities they support, these resources might also be valued by individuals living some distance from affected water and fisheries resources.

The water chestnut is capable of reducing habitat suitability for fish and waterfowl (see Appendix B). The water chestnut affects feeding and wintering grounds for many ducks by outcompeting native submersed vegetation that are preferred by waterfowl (see Appendix B).

In addition, the water chestnut has been documented to cause low dissolved oxygen levels, potentially reducing habitat quality for fish (see Appendix B). The effects of the water chestnut may be widespread, as this species has the potential to spread into warm temperate and subtropical regions of the MRB. Consequently, the establishment of water chestnut could cause economic impacts in a number of ways including reductions in fish and game populations and, in turn, decreased attractiveness of locations for recreational fishermen, boaters and waterfowl hunters. Large populations of water chestnut can impede boating by fouling motors and limiting access within the water body. Swimming and beach activity could be affected because of the mat-forming nature of this species and because the seed pods have sharp spines/barbs that could injure beach users. These impacts have the potential to significantly impact employment, income, and tax revenues in locations that are highly dependent on these activities, and in supporting industries, particularly in rural locations that have few alternative sources of local employment. Because of this dependence, relatively small reductions in recreational fishing in rural communities could produce fairly substantial impacts on local economies and fiscal viability. Greater changes in recreational activity, and in supporting industries, in larger urban areas would have smaller relative economic and fiscal impacts, because employment, income, and tax revenues are produced by a larger number of economic sectors.

Losses in property values might occur if the water chestnut becomes established in the GLB, primarily through potential changes in the attractiveness of locations for recreational fishermen, swimmers, and boaters. Swimming and beach activity could be affected because of the mat-forming nature of this species and because the seed pods have sharp spines/barbs that could injure beach users. These impacts might reduce the demand for riverside or lakeside property if a decline in visitation and recreational expenditure occur with establishment. Declining property values would also lead to declining property taxes and could affect the quality of local public service and infrastructure provision. This could reduce local economic development prospects, thus reducing employment income and overall tax revenues.

C.7.3 Potential Economic Consequences of Species Establishing in the Great Lakes Basin (GLB)

C.7.3.1 Scud

The establishment of the scud (*Apocorophium lacustre*) in the GLB is expected to have low economic consequences with low uncertainty. The establishment of this species is not expected to significantly affect environmental conditions in a way that could decrease property values, increase economic costs, or reduce recreational, commercial, and industrial water uses (see Appendix B).

C.7.3.2 Skipjack Herring

The establishment of the skipjack herring in the GLB is expected to have low economic consequences with low uncertainty. The establishment of this species is not expected to significantly affect environmental conditions or biological communities (see Appendix B). Therefore, this species is not expected to decrease property values, increase economic costs, or reduce recreational, commercial, and industrial water uses.

C.7.3.3 Northern Snakehead

As explained below, the northern snakehead has the potential to impact fish communities in the GLB by directly competing or preying upon desirable fish species. Such impacts could result in economic consequences in a number of categories, including loss of consumer surplus and reductions in recreational and commercial fishing, which could adversely impact employment, income and tax revenues. The northern snakehead could establish widely in the MRB (see Appendix B). Overall, the establishment of the northern snakehead could result in medium economic consequences, with a high associated uncertainty.

Economic Consequences of Northern Snakehead Establishment
(● indicates a potential to affect the category)

	Loss of Personal Wealth	Losses of Employment, Income, and Tax Revenues				Additional Potential Costs Due to ANS		
Loss of Consumer Surplus	Decrease in Property Values	Reduction in Recreational Hunting and Fishing	Reduction in Recreational Boating	Reduction in Commercial Fishing	Reduction in Supporting Service Industries	Increased Cost of Maintaining Water Quality	Increased Costs of Water Withdrawal Structures	Increased Ship Maintenance Costs
●	None	●	None	●	●	None	None	None

Losses in consumer surplus associated with northern snakehead establishment could occur as a result of deterioration in the quality and availability of the fisheries resources on which recreational activity is currently based, and could include losses in both use and non-use (passive use) valuation. Although a potential deterioration in the quality of recreational experience would be concentrated primarily among individuals residing in the vicinity of water and fisheries resources and the recreational activities they support, these resources might also be valued by individuals living some distance from affected water and fisheries resources.

The northern snakehead is documented to be a strong ecological competitor that could have a detrimental effect on GLB fishes by feeding on resident species or by outcompeting them for food or habitat (see Appendix B). Consequently, the establishment of the northern snakehead could cause reductions in recreational fishing through reductions in the availability of desirable fish species. Similarly, reductions in commercial fishing activity following snakehead establishment could reduce income generated through the sale of commercial fish species and spending by commercial fishing participants. Establishment could also reduce employment, income, and tax revenue in supporting industries that provide fishing equipment and supplies. Commercial and recreational fisheries impacts would have the potential to significantly affect employment, income, and tax revenues in locations that are highly dependent on these activities, and in supporting industries, particularly in rural locations that have few alternative sources of local employment. Because of this dependence, relatively small reductions in fishing activity in rural communities could produce fairly substantial impacts on local economies and fiscal viability. Greater changes in fishing activity, and in supporting industries, in larger urban areas would have smaller relative economic and fiscal impacts, because employment, income, and tax revenues are produced by a larger number of economic sectors.

Northern snakehead establishment could affect recreational charter boating in the Great Lakes, because some participants in certain areas, notably lakeside locations, prefer to charter boats for recreational fishing; this could be affected by species establishment through impacts on availability of native species. Reductions in charter boating employment would affect boat chartering, fuel suppliers, and other supporting industries; this would, in turn, affect employment, income, and tax revenues in local communities following a reduction in spending by boating participants.

C.7.3.4 Inland Silverside

The establishment of the inland silverside in the MRB is expected to have low economic consequences with low uncertainty. The establishment of this species is not expected to significantly affect environmental conditions or biological communities (see Appendix B). Therefore, this species is not expected to decrease property values, increase economic costs, or reduce recreational, commercial, and industrial water uses.

C.7.3.5 Black Carp

The black carp has the potential to impact fish communities in the GLB by directly competing with molluscivorous fish species, many of which are recreationally and commercially significant. These impacts that could produce economic consequences in a number of categories, including loss of consumer surplus and reductions in recreational and commercial fishing that could adversely impact employment, income, and tax revenues. If the black carp were to establish in the GLB it would be expected to be widespread (see Appendix B). However, most of the U.S. population is incapable of reproduction (see Appendix B), and the economic impacts of this species where it is currently established in the MRB have not been documented. Overall, the establishment of the black carp could result in medium economic consequences, with medium associated uncertainty.

Economic Consequences of Black Carp Establishment (● indicates a potential to affect the category)								
	Loss of Personal Wealth	Losses of Employment, Income, and Tax Revenues				Additional Potential Costs Due to ANS		
Loss of Consumer Surplus	Decrease in Property Values	Reduction in Recreational Hunting and Fishing	Reduction in Recreational Boating	Reduction in Commercial Fishing	Reduction in Supporting Service Industries	Increased Cost of Maintaining Water Quality	Increased Costs of Water Withdrawal Structures	Increased Ship Maintenance Costs
●	None	●	None	●	●	None	None	None

Losses in consumer surplus associated with black carp establishment could occur with deterioration in the quality and availability of fisheries resources on which recreational activity is currently based, and could include losses in both use and non-use (passive use) valuation. Although a potential deterioration in the quality of recreational experience would be concentrated primarily among individuals residing in the vicinity of water and fisheries resources and the recreational activities they support, these resources might also be valued by individuals living some distance from affected water and fisheries resources.

The black carp could outcompete recreationally and commercially significant molluscivorous fish like centrachids and perch, potentially resulting in reductions in recreational fishing through reductions in the availability of desirable fish species. These impacts could have the potential to significantly affect employment, income, and tax revenues in locations that are highly dependent on these activities, and in supporting industries, particularly in rural locations that have few alternative sources of local employment. Similarly, reductions in commercial fishing activity following black carp establishment, could reduce income generated through the sale of commercial fish species, which could, in turn, impact employment, income, and tax revenues in local communities following a reduction in spending by commercial fishing participants. Establishment could also reduce employment, income, and tax revenue in supporting industries that provide fishing equipment and supplies. The economic and fiscal impacts of reductions in recreational and commercial fishing, and in supporting industries, would primarily affect rural communities; the relative importance of impacts on these communities would vary depending on the importance of alternate sources of economic activity. Relatively small reductions in fishing activity in rural communities could produce fairly substantial impacts on local economies and fiscal viability, while greater changes in commercial fishing in larger urban areas would have smaller relative economic and fiscal impacts.

Black carp establishment could affect recreational charter boating, which is economically significant in the GLB. The charter boat industry could be affected by reductions in the abundance of recreationally important fish species through the mechanisms described above.

Reductions in charter boating employment would affect boat chartering, fuel suppliers, and other supporting industries; this would, in turn, impact employment, income, and tax revenues in local communities following a reduction in spending by boating participants.

C.7.3.6 Bighead Carp

As described below, by outcompeting the resident fish species, the bighead carp could produce economic consequences in the GLB in a number of categories, including loss of consumer surplus and reductions in recreational and commercial fishing that could adversely impact employment, income, and tax revenues. Although the extent of suitable habitat in the GLB is uncertain, this species is expected to be widespread if it were to establish. Overall, the bighead carp could result in medium economic consequences, with medium associated uncertainty.

Losses in consumer surplus associated with bighead carp establishment could occur as a result of deterioration in the quality and availability of the fisheries resources on which recreational activity is currently based, and could include losses in both use and non-use (passive use) valuation. Although a potential deterioration in the quality of recreational experience would be concentrated primarily among individuals residing in the vicinity of water and fisheries resources and the recreational activities they support, these resources might also be valued by individuals living some distance from affected water and fisheries resources.

Economic Consequences of Bighead Carp Establishment
(● indicates a potential to affect the category)

	Loss of Personal Wealth	Losses of Employment, Income, and Tax Revenues				Additional Potential Costs Due to ANS		
Loss of Consumer Surplus	Decrease in Property Values	Reduction in Recreational Hunting and Fishing	Reduction in Recreational Boating	Reduction in Commercial Fishing	Reduction in Supporting Service Industries	Increased Cost of Maintaining Water Quality	Increased Costs of Water Withdrawal Structures	Increased Ship Maintenance Costs
●	None	●	None	●	●	None	None	None

The bighead carp could potentially outcompete GLB fish species that filter feed for some or all of their life cycle (see Appendix B). Many of these species are recreationally or commercially significant. For example, in the Illinois River, it has been reported that bigmouth buffalo (a commercial fish species) has been reduced in numbers in areas that have been invaded by Asian carp (Kolar et al. 2005). In addition, the body condition of both bigmouth buffalo and gizzard shad (an important food for sportfish) may have been reduced by competition with Asian carp (Irons et al. 2007). Furthermore, the bighead carp would not replace the lost value of the species it outcompetes because it has little commercial or recreational value. The bighead carp is also expected to be widespread in the GLB, although the full extent is uncertain (see Appendix B). Consequently, the establishment of bighead carp could cause reductions in recreational fishing through reductions in the availability of desirable fish species. Similarly, reductions in commercial fishing activity following bighead carp establishment could reduce income generated through the sale of commercial fish species and spending by commercial fishing participants. Establishment could also reduce employment, income, and tax revenue in supporting industries that provide fishing equipment and supplies. These impacts would have the potential to significantly affect employment, income, and tax revenues in locations that are highly dependent on these activities, and in supporting industries, particularly in rural locations that have few alternative sources of local employment. Because of this dependence, relatively small reductions in commercial and recreational fishing in rural communities could produce fairly substantial impacts on local economies and fiscal viability. Greater changes in fishing activity, and in supporting industries, in larger urban areas would have smaller relative economic and fiscal impacts, because employment, income, and tax revenues are produced by a larger number of economic sectors.

Bighead carp establishment could affect recreational charter boating, which is economically significant in the MRB. The charter boat industry could be affected by reductions in the abundance of recreationally important fish species through the mechanisms described above. Reductions in charter boating employment would affect boat chartering, fuel suppliers, and other supporting industries; this would, in turn, impact employment, income, and tax revenues in local communities following a reduction in spending by boating participants.

C.7.3.7 Silver Carp

As described below, by outcompeting the resident fish species, the silver carp could produce economic consequences in a number of categories, including loss of consumer surplus and loss of property value; reductions in recreational boating, recreational fishing, and commercial fishing that could adversely impact employment, income, and tax revenues. Unlike the bighead and black carp, the silver carp jumps from the water, which could discourage recreational boating as well. The silver carp could be widespread in the GLB. Overall, the silver carp could result in high economic consequences, with medium associated uncertainty.

Economic Consequences of Silver Carp Establishment (● indicates a potential to affect the category)								
	Loss of Personal Wealth	Losses of Employment, Income, and Tax Revenues				Additional Potential Costs Due to ANS		
Loss of Consumer Surplus	Decrease in Property Values	Reduction in Recreational Hunting and Fishing	Reduction in Recreational Boating	Reduction in Commercial Fishing	Reduction in Supporting Service Industries	Increased Cost of Maintaining Water Quality	Increased Costs of Water Withdrawal Structures	Increased Ship Maintenance Costs
●	●	●	●	●	●	None	None	●

Losses in consumer surplus associated with silver carp establishment could occur as a result of deterioration in the quality and availability of the fisheries resources on which recreational activity is currently based, and could include losses in both use and non-use (passive use) valuation. Although a potential deterioration in the quality of recreational experience would be concentrated primarily among individuals residing in the vicinity of water and fisheries resources and the recreational activities they support, these resources might also be valued by individuals living some distance from affected water and fisheries resources.

The silver carp could potentially outcompete GLB fish species that filter feed for some or all of their life cycle (see Appendix B). Many of these species are recreationally or commercially significant. For example, in the Illinois River, it has been reported that bigmouth buffalo (a commercial fish species) has been reduced in numbers in areas that have been invaded by Asian carp (Kolar et al. 2005). In addition, the body condition of both bigmouth buffalo and gizzard shad (an important food for sportfish) may have been reduced by competition with Asian carp (Irons et al. 2007). Furthermore, the silver carp would not replace the lost value of the species it outcompetes because Asian carp have little commercial or recreational value. The silver carp is also expected to be widespread in the GLB, although the full extent is uncertain (see Appendix B). Consequently, the establishment of silver carp could cause reductions in recreational fishing through reductions in the availability of desirable fish species. Similarly, reductions in commercial fishing activity following silver carp establishment could reduce income generated through the sale of commercial fish species and spending by commercial fishing participants. Establishment could also reduce employment, income, and tax revenue in supporting industries that provide fishing equipment and supplies. These impacts would have the potential to significantly affect employment, income, and tax revenues in locations that are highly dependent on these activities, and in supporting industries, particularly in rural locations that have few alternative sources of local employment. Because of this dependence, relatively small reductions in commercial and recreational fishing in rural communities could produce fairly substantial impacts on local economies and fiscal viability. Changes in fishing activity, and in supporting industries, in larger urban areas would have smaller relative economic and fiscal impacts, because employment, income, and tax revenues are produced by a larger number of economic sectors.

Silver carp establishment could affect recreational charter boating, which is economically significant in the GLB. Silver carp could affect the charter boat industry by reducing the abundance of desirable fish species. Nuisance jumping could also affect boater safety. Reductions in charter boating employment would affect boat chartering, fuel suppliers, and other supporting industries; this would, in turn, affect employment, income, and tax revenues in local communities following a reduction in spending by boating participants.

Losses in property values might occur if silver carp becomes established in the GLB, primarily through potential changes in the attractiveness of locations for recreational fishermen and boaters. Declining fisheries quality and the nuisance jumping by the silver carp (a behavior not found in other Asian carp species) might reduce the demand for riverside or lakeside property if a decline in visitation and recreational expenditure occur with establishment. Declining property values would also lead to declining property taxes and could affect the quality of local public service and infrastructure provision, which could reduce local economic development prospects, thus reducing employment income and overall tax revenues.

C.7.3.8 Marsh Dewflower

Establishment of the marsh dewflower is expected to have low economic consequences, with medium associated uncertainty. Although the marsh dewflower may replace existing vegetation communities (see Appendix B) no evidence was found suggesting this species would reduce habitat quality for fish and wildlife as is common with other invasive plant species. Therefore, this species is not expected to decrease property values, increase economic costs, or reduce recreational, commercial, and industrial water uses.

C.7.3.9 Cuban Bullrush

Establishment of the Cuban bullrush in the GLB is expected to result in low economic consequences, with medium associated uncertainty. The Cuban bulrush is typically a tropical and subtropical species and impacts on ecosystems in the GLB would be spatially and temporally limited to the relatively small area of suitable temperature. Therefore, the establishment of this species is not expected to significantly affect environmental conditions or biological communities (see Appendix B). Consequently, the Cuban bulrush is not expected to decrease property values, increase economic costs, or reduce recreational, commercial, and industrial water uses.

C.7.3.10 Dotted Duckweed

Establishment of the dotted duckweed in the GLB is expected to result in low economic consequences, with medium associated uncertainty. The dotted duckweed is not cold tolerant and impacts on ecosystems in the GLB would be spatially and temporally limited to the relatively small area of suitable temperature (see Appendix B). Therefore, the establishment of this species is not expected to significantly affect environmental conditions or biological communities. Consequently, the dotted duckweed is not expected to decrease property values, increase economic costs, or reduce recreational, commercial, and industrial water uses.

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APPENDIX D

SOCIAL/POLITICAL CONSEQUENCES

CONTENTS

APPENDIX D

SOCIAL/POLITICAL CONSEQUENCES

D.1 APPROACH

For the purpose of the Great Lakes Mississippi River Interbasin Study (GLMRIS) risk assessments, social consequences were considered to be perceived effects on leisure or recreational opportunities. Political consequences were considered to be those associated with the potential implementation of new regulations to address aquatic nuisance species (ANS) establishment. Social consequences could result if an ANS becomes established in a new area and subsequently affects the perceived quality of leisure or recreational opportunities and political consequences could result if ANS effects result in regulatory changes. Potential positive effects from ANS were not considered in the consequence rating.

For the evaluation, each ANS was examined for its potential for perceived effects on leisure or recreational opportunities provided by the environment in the following categories:

- Swimming,
- Fishing,
- Beach activities,
- Hunting, and
- Recreational boating.

The more leisure or recreational opportunities that are perceived to be affected, the greater the likelihood of social/political consequences from establishment of that ANS. In addition, the consequence assessment also evaluated establishment of each ANS for its potential to result in regulatory changes associated with the control or prevention of ANS establishment. Each social/political category identified as possibly affected by ANS establishment was further examined with regard to the qualitative nature and severity of any possible effects to that category. The assessment of social/political consequences also considered the spatial extent of where people may perceive leisure and recreational opportunities as being affected by ANS establishment, as well as any temporal aspects of the consequences. The social/political consequences assessment did not quantify the magnitude of any social or political consequences.

The social/political consequence assessment assigned one of the following qualitative ratings for each ANS evaluated:

High (H) = High consequence rating due to the larger number of consequence categories affected, the nature and severity of the consequences, and the broader spatial extent of the consequences.

Medium (M) = Medium consequence rating due to the number of consequence categories affected, the nature and severity of the consequences, and the spatial extent of the consequences.

Low (L) = Low consequence rating due to the lower number of consequence categories affected, the lesser nature and severity of the consequences, and the more localized extent of the consequences.

None (N) = No consequences are anticipated.

Assignment of a specific consequence rating was based on the amount of consequence information available for that ANS (or closely related species), the interpretations of that information by the GLMRIS Risk Assessment Team, and the thresholds selected to distinguish among the consequence levels. For each ANS, the social/political consequence rating is accompanied by an uncertainty rating which reflects the confidence placed on the assessment. The uncertainty rating is based on the amount and quality of scientifically defensible data used to support the consequence determination. The less data available, the greater the uncertainty associated with the consequence rating. The uncertainty ratings used for the social/political consequence assessments are:

High = There is little to no concrete evidence available, or there is a very broad range in the nature and the severity of the consequences, including extreme consequences.

Medium = There are some good supporting data but also still some major data gaps, or there is a broad range in the nature and severity of the consequences, but no extreme consequences have been identified.

Low = Good supporting data are available, data gaps are not significant, or there is a limited range of possible consequences.

None = Adequate data are available to fully support the consequence determination.

Summary of Assigned Levels of Social/Political Consequences for Aquatic Nuisance Species[a] (• = indicates a potential to affect the category)

	Swimming[a]	Fishing[b]	Beach Activities[c]	Hunting[d]	Recreational Boating[e]	Political[f]	Spatial Extent
Protozoa							
Testate amoeba (*Psammonobiotus communis*)							Localized
Testate amoeba (*P. dziwnowi*)							Localized
Testate amoeba (*P. linearis*)							Localized
Algae							
Cryptic algae (*Cyclotella cryptica*)							Localized
Grass kelp (*Enteromorpha flexuosa*)	•	•	•		•	•	Localized
Red algae (*Bangia atropurpurea*)	•	•	•		•		Localized
Diatom (*Stephanodiscus binderanus*)	•	•	•				Widespread
Bryozoan							
Freshwater bryozoan (*Lophopodella carteri*)							Widespread
Molluscs							
Greater European peaclam (*Pisidium amnicum*)							Widespread
European fingernail clam (*Sphaerium corneum*)							Widespread
European stream valvata (*Valvata piscinalis*)							Widespread

(Cont.)

	Swimming[a]	Fishing[b]	Beach Activities[c]	Hunting[d]	Recreational Boating[e]	Political[f]	Spatial Extent
Crustaceans							
Scud (*Apocorophium lacustre*)							Widespread
Fishhook water flea (*Cercopagis pengoi*)		•				•	Widespread
Waterflea (*Daphnia g. galeata*)							Widespread
Bloody red shrimp (*Hemimysis anomala*)		•				•	Widespread
Parasitic copepod (*Neoergasilus japonicas*)							Widespread
Harpacticoid copepod (*Schizopera borutzkyi*)							Widespread
Fish							
Skipjack herring (*Alosa chrysochloris*)							Widespread
Northern snakehead (*Channa argus*)		•				•	Widespread
Inland silverside (*Menidia beryllina*)						•	Localized
Black carp (*Mylopharyngodon piceus*)		•				•	Widespread
Bighead carp (*Hypophthalmichthyes nobilis*)		•				•	Widespread
Silver carp (*Hypophthalmichthys molitrix*)		•			•	•	Widespread
Threespine stickleback (*Gasterosteus aculeatus*)							Widespread

(Cont.)

	Swimming[a]	Fishing[b]	Beach Activities[c]	Hunting[d]	Recreational Boating[e]	Political[f]	Spatial Extent
Fish (Cont.)							
Blueback herring (*Alosa aestivalis*)		•				•	Widespread
Ruffe (*Gymnocephalus cernuus*)		•				•	Localized
Sea lamprey (*Petromyzon marinus*)		•				•	Widespread
Tubenose goby (*Proterorhinus semilunaris*)						•	Localized
Plants							
Marsh dewflower (*Murdannia keisak*)	•	•			•	•	Localized
Cuban bulrush (*Oxycaryum cubense*)	•	•			•		Localized
Dotted duckweed (*Landoltia punctata*)	•	•			•	•	Localized
Swamp sedge (*Carex acutiformis*)							Widespread
Reed sweetgrass (*Glyceria maxima*)		•				•	Widespread
Water chestnut (*Trapa natans*)	•	•	•	•	•	•	Widespread
Viruses							
Viral Hemorrhagic Septicemia Virus (*Novirhabdovirus* sp.)	•	•	•			•	Widespread

[a] Swimming = Perceived effects on swimming due to unpleasant odor, water color, excessive vegetation growth, etc.

[b] Fishing = Perceived effects on fishing due to unpleasant odor, water color, excessive vegetation growth, etc.

[c] Beach Activities = Perceived effects on recreational beach use due to unpleasant odor, water color, excessive vegetation growth, etc.

[d] Hunting = Perceived effects on the desire to hunt or the availability of suitable hunting areas.

[e] Recreational Boating = Perceived effects on the desire to fish, canoe, sail, waterski, and recreate via other boat-based activities.

[f] Political = ANS concerns may result in implementation of new regulations to address ANS establishment and spread.

Additional details regarding the evaluation of social/political consequences can be found in Hlohowskyj et al. (2013). Qualitative levels of social/political consequences and associated uncertainty were assigned to the ANS during a workshop at which experts from the U.S. Army Corps of Engineers (USACE) and Argonne National Laboratory reviewed the existing information pertaining to potential effects on the environment, reported consequences of establishment, and the literature associated with development of regulations. The consensus on the consequences rating for each ANS and the level of uncertainty in the assigned ratings was based upon evaluation of the available information and discussions among workshop participants. A summary of the consensus ratings for social/political consequences is provided in the following table.

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D.2 SPECIES-SPECIFIC SOCIAL AND POLITICAL CONSEQUENCES ASSESSMENT

D.2.1 Species Posing a Risk for the Great Lakes Basin

D.2.1.1 Northern Snakehead - *Channa argus*

Explanation for Social/Political Consequences Rating: **HIGH**
Northern snakehead are generalist predators (Fuller & Benson 2011) and could prey upon and/or compete with fish species of recreational importance (Courtenay & Williams 2004). Therefore, the northern snakehead has the potential to affect the perceived quality of recreational fishing opportunities. The potential for the northern snakehead to prey on native fish communities could result in new regulation and laws to control this species. For example, many states have passed rules banning importation, possession, and sale of live snakeheads and developed rapid response containment and eradication protocols targeting this species (Courtenay & Williams 2004). The social/political consequences of the northern snakehead could be widespread, given its potentially widespread distribution in the Great Lakes Basin (GLB). However, no studies were found suggesting that the introduction of the northern snakehead has reduced recreational fishing activity in areas where they have established. Overall, the social/political consequences of the northern snakehead's spread could be high, and the uncertainty of the consequence rating is medium.

Social Impacts Matrix (• = indicates a potential to affect the category)

ANS	Swimming[a]	Fishing[b]	Beach Activities[c]	Hunting[d]	Recreational Boating[e]	Political[f]	Spatial Extent of ANS Establishment
Northern snakehead (*Channa argus*)		•				•	Widespread

[a] ANS establishment may reduce desire to swim due to unpleasant odor, water color, excessive vegetation growth, etc.

[b] ANS establishment may reduce desire to fish because of unpleasant odor, water color, excessive vegetation growth, etc.

[c] ANS establishment may reduce desire for recreational beach use because of unpleasant odor, water color, excessive vegetation growth, etc.

[d] ANS establishment may reduce desire to hunt or reduces availability of suitable hunting areas.

[e] ANS establishment may reduce desire for fishing, canoeing, sailing, water skiing and other boat-based recreation.

[f] Political consequences are associated with the potential implementation of new regulations to address ANS establishment.

Reference

Fuller, P.F. & A.J. Benson. 2011. *Channa argus*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. http://nas.er.usgs.gov/queries/factsheet.aspx?speciesid=2265

Courtenay, W.R., Jr. & J.D. Williams. 2004. Snakeheads (Pisces, Channidae)—A Biological Synopsis and Risk Assessment. U.S. Department of the Interior, U.S. Geological Survey, Circular 1251.

D.2.1.2 Scud - *Apocorophium lacustre*

Explanation for Social/Political Consequences Rating: **NONE**

No consequences on human use or political regulatory concerns were identified as resulting from the establishment of the scud in the GLB. The uncertainty of this rating is low.

Social Impacts Matrix (• = indicates a potential to affect the category)

ANS	Swimming[a]	Fishing[b]	Beach Activities[c]	Hunting[d]	Recreational Boating[e]	Political[f]	Spatial Extent of ANS Establishment
Scud (*Apocryphal lacustre*)							Widespread

[a] ANS establishment may reduce desire to swim due to unpleasant odor, water color, excessive vegetation growth, etc.

[b] ANS establishment may reduce desire to fish because of unpleasant odor, water color, excessive vegetation growth, etc.

[c] ANS establishment may reduce desire for recreational beach use because of unpleasant odor, water color, excessive vegetation growth, etc.

[d] ANS establishment may reduce desire to hunt or reduces availability of suitable hunting areas.

[e] ANS establishment may reduce desire for fishing, canoeing, sailing, water skiing and other boat-based recreation.

[f] Political consequences are associated with the potential implementation of new regulations to address ANS establishment.

D.2.1.3 Silver Carp - *Hypophthalmichthys molitrix*

Explanation for Social/Political Consequences Rating: **HIGH**

Asian carp are suspected to have altered fish community structure (abundance and species composition) in several lakes in Asia and the Mississippi River (reviewed in Kipp et al. 2011 and Cudmore et al. 2012). Thus, silver carp have the potential to affect the perceived quality of recreational fishing opportunities. This species is expected to have a widespread distribution in the GLB; therefore, it could have widespread impacts on fishing. Silver carp could also discourage recreational boating due to its jumping behavior. The establishment of this species is also expected to result in new laws and regulations to eradicate or prevent the spread of this species. For example, the Asian Carp Regional Coordinating Committee was established to prevent introduction and implement actions to protect the Great Lakes ecosystem from an Asian carp invasion (http://asiancarp.us/). The social/political consequences of silver carp establishment are high. The severity of the social/political impacts will partly depend on the extent of spread of the silver carp, which is uncertain (Rasmussen et al. 2011). Overall, uncertainty associated with the social/political consequences is medium.

Social Impacts Matrix (• = indicates a potential to affect the category)

ANS	Swimming[a]	Fishing[b]	Beach Activities[c]	Hunting[d]	Recreational Boating[e]	Political[f]	Spatial Extent of ANS Establishment
Silver carp *(Hypophthalmichthyes molitrix)*		•			•	•	Widespread

[a] ANS establishment may reduce desire to swim due to unpleasant odor, water color, excessive vegetation growth, etc.

[b] ANS establishment may reduce desire to fish because of unpleasant odor, water color, excessive vegetation growth, etc.

[c] ANS establishment may reduce desire for recreational beach use because of unpleasant odor, water color, excessive vegetation growth, etc.

[d] ANS establishment may reduce desire to hunt or reduces availability of suitable hunting areas.

[e] ANS establishment may reduce desire for fishing, canoeing, sailing, water skiing and other boat-based recreation.

[f] Political consequences are associated with the potential implementation of new regulations to address ANS establishment.

References

Cudmore, B., N.E. Mandrak, J. Dettmers, D.C. Chapman & C.S. Kolar. 2012. Binational Ecological Risk Assessment of Bigheaded Carps (*Hypophthalmichthys* spp.) for the Great Lakes Basin. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/114.

Kipp, R., B. Cudmore & N.E. Mandrak. 2011. Updated (2006-early 2011) Biological Synopsis of Bighead Carp (*Hypophthalmichthys nobilis*) and Silver Carp (*H. molitrix*). Canadian Manuscript Report of Fisheries and Aquatic Science, vol.2962, vi + 50 pp.

Rasmussen, J.L., H.A. Regier, R.E. Sparks & W.W. Taylor. 2011. Dividing the waters: the case for hydrologic separation of the North American Great Lakes and Mississippi River basins. *Journal of Great Lakes Research*, in press.

D.2.1.4 Bighead Carp - *Hypophthalmichthys nobilis*

Explanation for Social/Political Consequences Rating: **HIGH**

The bighead carp has the potential to affect the perceived quality of recreational fishing opportunities. Asian carp are suspected to have altered fish community structure (abundance and species composition) in several lakes in Asia and the Mississippi River (reviewed in Kipp et al. 2011 and Cudmore et al. 2012). This species is expected to have a widespread distribution in the GLB (Rasmussen et al. 2011); therefore, the species could impact fishing in a large area of the GLB. The establishment of the bighead carp is also expected to result in new laws and regulations to eradicate or prevent the spread of this species. For example, the Asian Carp Regional Coordinating Committee was established to prevent introduction and implement actions to protect the Great Lakes ecosystem from an Asian carp invasion (http://asiancarp.us/). The social/political consequences of establishment are high. The severity of the social/political impacts will partly depend on the extent of spread of the bighead carp and the extent to which it reduces the abundance of native fish species, both of which are uncertain (Cooke & Hill 2010). Therefore, uncertainty is medium.

Social Impacts Matrix (• = indicates a potential to affect the category)

ANS	Swimming[a]	Fishing[b]	Beach Activities[c]	Hunting[d]	Recreational Boating[e]	Political[f]	Spatial Extent of ANS Establishment
Bighead carp *(Hypophthalmichthys nobilis)*		•				•	Widespread

[a] ANS establishment may reduce desire to swim due to unpleasant odor, water color, excessive vegetation growth, etc.

[b] ANS establishment may reduce desire to fish because of unpleasant odor, water color, excessive vegetation growth, etc.

[c] ANS establishment may reduce desire for recreational beach use because of unpleasant odor, water color, excessive vegetation growth, etc.

[d] ANS establishment may reduce desire to hunt or reduces availability of suitable hunting areas.

[e] ANS establishment may reduce desire for fishing, canoeing, sailing, water skiing and other boat-based recreation.

[f] Political consequences are associated with the potential implementation of new regulations to address ANS establishment.

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D.2.1.5 Black Carp - *Mylopharyngodon piceus*

Explanation for Social/Political Consequences Rating: **MEDIUM**

Fish farmers report that black carp is very effective in reducing the number of snails in some ponds (Nico et al. 2005). This indicates that black carp could cause significant declines in native mollusk populations and can out-compete native molluscivorous fishes (Nico et al. 2005). Species of recreational importance that could be in direct completion with the black carp include buffalo (*Ictiobus* spp.), freshwater drum (*Aplodinotus grunniens*), sunfish (*Lepomis* spp.), and various species of catfish (Williams et al. 2007). The black carp is a generalist and could potentially be widespread in the GLB. Therefore, the black carp has the potential to affect the perceived quality of recreational fishing opportunities. In addition, establishment of this species could have political consequences, as management of this species could result in laws and regulations to prevent their spread. For example, 16 states ban or restrict the import or transport of black carp (Nico et al. 2005) and the Asian Carp Regional Coordinating Committee was established to protect the Great Lakes ecosystem from an Asian carp invasion (http://asiancarp.us/). Therefore, the social/political consequences of black carp could be medium. However, no studies documenting impacts to fish populations in the MRB resulting from the introduction of black carp were found. Therefore, the uncertainty associated with the consequences of this species is also medium.

Social Impacts Matrix (• = indicates a potential to affect the category)

ANS	Swimming[a]	Fishing[b]	Beach Activities[c]	Hunting[d]	Recreational Boating[e]	Political[f]	Spatial Extent of ANS Establishment
Black carp (*Mylopharyngodon piceus*)		•				•	Widespread

[a] ANS establishment may reduce desire to swim due to unpleasant odor, water color, excessive vegetation growth, etc.

[b] ANS establishment may reduce desire to fish because of unpleasant odor, water color, excessive vegetation growth, etc.

[c] ANS establishment may reduce desire for recreational beach use because of unpleasant odor, water color, excessive vegetation growth, etc.

[d] ANS establishment may reduce desire to hunt or reduces availability of suitable hunting areas.

[e] ANS establishment may reduce desire for fishing, canoeing, sailing, water skiing and other boat-based recreation.

[f] Political consequences are associated with the potential implementation of new regulations to address ANS establishment.

References

Nico, L.G., J.D. Williams, & H.L. Jelks. 2005. Black Carp: Biological Synopsis and Risk Assessment of an Introduced Fish. American Fisheries Society Special Publication 32, Bethesda, MD.

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D.2.1.6 Low-Risk ANS Potentially Invading the Great Lakes Basin

Cuban bulrush (*Oxycaryum cubense*), dotted duckweed (*Landoltia punctate*), marsh dewflower (*Murdannia keisak*), inland silverside (*Menidia beryllina*), and skipjack herring (*Alosa chrysochloris*) were all given a low overall risk rating. Species risk summaries for these species, including social and political consequences, are found in Appendix A.

D.2.2 Species Posing a Risk for the Mississippi River Basin

D.2.2.1 Bloody red shrimp - *Hemimysis anomala*

Explanation for Social/Political Consequences Rating: **MEDIUM**

The bloody red shrimp has the potential to negatively impact the growth and abundance of young of the year and planktivorous fish in nearshore areas (Ricciardi et al. 2011). Therefore, this species has the potential to affect the perceived opportunities for recreational fishing. A mysid introduction can also increase the biomagnification of contaminants in piscivores and waterfowl, through a lengthening of the food chain (Rasmussen et al. 1990; Cabana et al. 1994). Thus fishing in the MRB may decrease or be prohibited due to public health concerns. The bloody red shrimp has the potential to spread throughout the MRB, potentially resulting in widespread impacts. Although there are several potential impacts related to the establishment of the bloody red shrimp (Walsh et al. 2010), no impacts on fish populations have been documented in the Great Lakes at this time. Therefore, the uncertainty associated with the social consequences is high.

Social Impacts Matrix (• = indicates a potential to affect the category)

ANS	Swimming[a]	Fishing[b]	Beach Activities[c]	Hunting[d]	Recreational Boating[e]	Political[f]	Spatial Extent of ANS Establishment
Bloody red shrimp (*Hemimysis anomala*)		•				•	Widespread

[a] ANS establishment may reduce desire to swim due to unpleasant odor, water color, excessive vegetation growth, etc.

[b] ANS establishment may reduce desire to fish because of unpleasant odor, water color, excessive vegetation growth, etc.

[c] ANS establishment may reduce desire for recreational beach use because of unpleasant odor, water color, excessive vegetation growth, etc.

[d] ANS establishment may reduce desire to hunt or reduces availability of suitable hunting areas.

[e] ANS establishment may reduce desire for fishing, canoeing, sailing, water skiing and other boat-based recreation.

[f] Political consequences are associated with the potential implementation of new regulations to address ANS establishment.

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D.2.2.2 Fishhook waterflea - *Cercopagis pengoi*

Explanation for Social/Political Consequences Rating: **MEDIUM**

The fishhook waterflea could outcompete planktivores like alewife (Bushnoe et al. 2003; Benson et al. 2011), that are consumed by recreationally important fish species. In addition, new laws and regulations are likely to be implemented to prevent the spread of the fishhook waterflea, such as requirements to wash or inspect boats before entering a water body (Rothlisberger et al. 2010). The fish hook waterflea also foul fishing lines (Jacobs & MacIsaac 2007), which could affect the perceived quality of recreational fishing opportunities. The fishhook waterflea and its associated impacts could be widespread in the MRB. Overall, the social consequence of the establishment of the fishhook waterflea is considered medium. The realized effects of the fishhook waterflea on the food web are uncertain due to the complexity of ecological systems; therefore, the uncertainty associated with the economic consequence is also medium.

Social Impacts Matrix (• = indicates a potential to affect the category)

ANS	Swimming[a]	Fishing[b]	Beach Activities[c]	Hunting[d]	Recreational Boating[e]	Political[f]	Spatial Extent of ANS Establishment
Fishhook waterflea (*Cercopagis pengoi*)		•				•	Widespread

[a] ANS establishment may reduce desire to swim due to unpleasant odor, water color, excessive vegetation growth, etc.

[b] ANS establishment may reduce desire to fish because of unpleasant odor, water color, excessive vegetation growth, etc.

[c] ANS establishment may reduce desire for recreational beach use because of unpleasant odor, water color, excessive vegetation growth, etc.

[d] ANS establishment may reduce desire to hunt or reduces availability of suitable hunting areas.

[e] ANS establishment may reduce desire for fishing, canoeing, sailing, water skiing and other boat-based recreation.

[f] Political consequences are associated with the potential implementation of new regulations to address ANS establishment.

References

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D.2.2.3 Grass Kelp - *Enteromorpha flexuosa*

Explanation for Social/Political Consequences Rating: MEDIUM

In coastal areas, this species is potentially a major fouling algae that is capable of smothering aquatic plants (Sturtevant 2011). Grass kelp was found to form extensive beds in nutrient-rich habitats in the GLB (Lougheed & Stevenson 2004) and could also do so in the MRB where habitat conditions are suitable. Grass kelp are capable of forming mats that reduce habitat quality, which could reduce access to fishing areas. Therefore, this species has the potential to affect the perceived quality of recreational fishing. The visual impact of fouling algae could also discourage boating, swimming, and beach activities. Grass kelp could also have political consequences, as new laws and regulations could be implemented to prevent its spread. However, grass kelp are typically a marine/estuarine species and have very specific water quality requirements (i.e., high conductivity and nutrients; Holmes, & Whitton 1977; Lougheed & Stevenson 2004) that may not be common in the MRB. It is therefore not expected to be widespread in the MRB and is expected to have relatively localized rather than widespread impacts. The extent and density of grass kelp that conditions in the MRB will support are uncertain. Therefore, the social/political consequences of establishment are medium, and the uncertainty of this rating is high.

Social Impacts Matrix (• = indicates a potential to affect the category)

ANS	Swimming[a]	Fishing[b]	Beach Activities[c]	Hunting[d]	Recreational Boating[e]	Political[f]	Spatial Extent of ANS Establishment
Grass kelp *(Enteromorpha flexuosa)*	•	•	•		•	•	Localized

[a] ANS establishment may reduce desire to swim due to unpleasant odor, water color, excessive vegetation growth, etc.

[b] ANS establishment may reduce desire to fish because of unpleasant odor, water color, excessive vegetation growth, etc.

[c] ANS establishment may reduce desire for recreational beach use because of unpleasant odor, water color, excessive vegetation growth, etc.

[d] ANS establishment may reduce desire to hunt or reduces availability of suitable hunting areas.

[e] ANS establishment may reduce desire for fishing, canoeing, sailing, water skiing and other boat-based recreation.

[f] Political consequences are associated with the potential implementation of new regulations to address ANS establishment.

References

Lougheed, V.L. & R.J. Stevenson. 2004. Exotic marine macroalgae (*Enteromorpha flexuosa*) reaches bloom proportions in a coaster lake of Lake Michigan. *Journal of Great Lakes Research*, vol. 30(4), pp. 538-544.

Holmes, N.T.H. & B. A. Whitton. The macrophytic vegetation of the river tees in 1975: observed and predicted changes. *Freshwater Biology*, vol. 7, pp.43-60.

Sturtevant, R. 2011. *Enteromorphaflexuosa subsp. Flexuosa and flexuosa subsp. Paradoxa*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. http://nas.er.usgs.gov/queries/greatlakes/SpeciesInfo.asp?NoCache=6%2F6%2F2012+9%3A02%3A12+AM&SpeciesID=2726&State=&HUCNumber=>

D.2.2.4 Red Algae - *Bangia atropurpurea*

Explanation for Social/Political Consequences Rating: **MEDIUM**

Red algae have the potential to foul shoreline habitat (Sonzongni et al. 1983). Therefore, the establishment of the red algae could affect the perceived quality of recreational fishing, as well as boating, swimming, and beach activities. However, red algae are typically a marine/estuarine species and have very specific water quality requirements (i.e., high halogen, trace metals, and nutrients; Lin & Blum 1977) that may not be common in the MRB. It is therefore not expected to be widespread in the MRB and is expected to have relatively localized rather than widespread impacts. The extent and density of red algae that conditions in the MRB will support are uncertain. Overall, the social/political consequences of establishment are medium, and the uncertainty of this rating is high.

Social Impacts Matrix (• = indicates a potential to affect the category)

ANS	Swimming[a]	Fishing[b]	Beach Activities[c]	Hunting[d]	Recreational Boating[e]	Political[f]	Spatial Extent of ANS Establishment
Red algae (*Bangia atropurpurea*)	•	•	•		•		Localized

[a] ANS establishment may reduce desire to swim due to unpleasant odor, water color, excessive vegetation growth, etc.

[b] ANS establishment may reduce desire to fish because of unpleasant odor, water color, excessive vegetation growth, etc.

[c] ANS establishment may reduce desire for recreational beach use because of unpleasant odor, water color, excessive vegetation growth, etc.

[d] ANS establishment may reduce desire to hunt or reduces availability of suitable hunting areas.

[e] ANS establishment may reduce desire for fishing, canoeing, sailing, water skiing and other boat-based recreation.

[f] Political consequences are associated with the potential implementation of new regulations to address ANS establishment.

References

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Lin, C.K. & J.L. Blum. 1977. Recent invasion of red alga (*Bangia atropurpurea*) in Lake Michigan. *Journal of the Fisheries Research Board of Canada*, vol. 34(12), pp. 2413-2416.

D.2.2.5 Diatom - *Stephanodiscus binderanus*

Explanation for Social/Political Consequences Rating: MEDIUM

As documented in the Great Lakes, this diatom species can form dense nearshore blooms (Kipp 2011) that alter water color and odor. Such blooms could affect perceived water quality and discourage swimming, fishing, and beach activities. Nuisance blooms only form under certain habitat conditions (including high nutrients) within reservoirs or pools within large rivers. Therefore, the social/political consequences of this species establishing in the MRB are potentially medium, although the uncertainty of this rating is high, as this is primarily a lake species and there is uncertainty about how widespread and productive this species will be in the MRB.

Social Impacts Matrix (• = indicates a potential to affect the category)

ANS	Swimming[a]	Fishing[b]	Beach Activities[c]	Hunting[d]	Recreational Boating[e]	Political[f]	Spatial Extent of ANS Establishment
Diatom (*Stephanodiscus binderanus*)	•	•	•				Localized

[a] ANS establishment may reduce desire to swim due to unpleasant odor, water color, excessive vegetation growth, etc.

[b] ANS establishment may reduce desire to fish because of unpleasant odor, water color, excessive vegetation growth, etc.

[c] ANS establishment may reduce desire for recreational beach use because of unpleasant odor, water color, excessive vegetation growth, etc.

[d] ANS establishment may reduce desire to hunt or reduces availability of suitable hunting areas.

[e] ANS establishment may reduce desire for fishing, canoeing, sailing, water skiing and other boat-based recreation.

[f] Political consequences are associated with the potential implementation of new regulations to address ANS establishment.

Reference

Kipp, R.M. 2011. *Stephanodiscus binderanus*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. http://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=1687

D.2.2.6 Reed Sweetgrass - *Glyceria maxima*

Explanation for Social/Political Consequences Rating: **MEDIUM**

Reed sweetgrass is a highly productive species that can reduce habitat quality by forming dense mats along the shoreline (NBII & ISSG; Loo et al. 2009), thereby affecting the perceived opportunities for recreational fishing. Reed sweetgrass could also have political consequences, as new laws and regulations are likely to be implemented to prevent its spread. Reed sweetgrass is documented to alter habitat in multiple locations where it has been introduced (Loo et al. 2009; Howard 2012), and it has the potential to become widespread in wetland habitats. However, the interaction of the reed sweetgrass with existing plant communities and its ability to achieve high density and cover in the MRB are uncertain. Therefore, the social/political consequences of this species establishing in the MRB are potentially medium, and the uncertainty of this rating is medium.

Social Impacts Matrix (• = indicates a potential to affect the category)

ANS	Swimming[a]	Fishing[b]	Beach Activities[c]	Hunting[d]	Recreational Boating[e]	Political[f]	Spatial Extent of ANS Establishment
Reed sweetgrass (*Glyceria maxima*)		•				•	Widespread

[a] ANS establishment may reduce desire to swim due to unpleasant odor, water color, excessive vegetation growth, etc.

[b] ANS establishment may reduce desire to fish because of unpleasant odor, water color, excessive vegetation growth, etc.

[c] ANS establishment may reduce desire for recreational beach use because of unpleasant odor, water color, excessive vegetation growth, etc.

[d] ANS establishment may reduce desire to hunt or reduces availability of suitable hunting areas.

[e] ANS establishment may reduce desire for fishing, canoeing, sailing, water skiing and other boat-based recreation.

[f] Political consequences are associated with the potential implementation of new regulations to address ANS establishment.

References

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Loo, S.E., R.M. Nally, D.J. O'Dowd & P.S. Lake. 2009. Secondary invasions: implications of riparian restoration for in-stream invasion by an aquatic grass. *Restoration Ecology*, vol. 17(3), pp. 378-385.

NBII & ISSG (National Biological Information Infrastructure & IUCN/SSC Invasive Species Specialist Group [ISSG]). Global Invasive Species Database. http://www.issg.org/database/species/ecology.asp?si=891&fr=1&sts=sss&lang=EN

D.2.2.7 Threespine stickleback - *Gasterosteus aculeatus*

Explanation for Social/Political Consequences Rating: NONE

The threespine stickleback is not expected to result in impacts to human uses or generate new laws or regulations designed to limit its spread. Therefore, no social/political consequences are expected to result from the establishment of this species. The uncertainty of this consequence rating is low.

Social Impacts Matrix (• = indicates a potential to affect the category)

ANS	Swimming[a]	Fishing[b]	Beach Activities[c]	Hunting[d]	Recreational Boating[e]	Political[f]	Spatial Extent of ANS Establishment
Threespine stickleback (*Gasterosteus aculeatus*)							Widespread

[a] ANS establishment may reduce desire to swim due to unpleasant odor, water color, excessive vegetation growth, etc.

[b] ANS establishment may reduce desire to fish because of unpleasant odor, water color, excessive vegetation growth, etc.

[c] ANS establishment may reduce desire for recreational beach use because of unpleasant odor, water color, excessive vegetation growth, etc.

[d] ANS establishment may reduce desire to hunt or reduces availability of suitable hunting areas.

[e] ANS establishment may reduce desire for fishing, canoeing, sailing, water skiing and other boat-based recreation.

[f] Political consequences are associated with the potential implementation of new regulations to address ANS establishment.

D.2.2.8 Tubenose goby - *Proterorhinus semilunaris*

Explanation for Social/Political Consequences Rating: LOW

Unlike the round goby, tubenose gobies have not yet exhibited any known ecosystem effects in the GLB since their establishment (Dopazo et al. 2008). The establishment of the tubenose goby in the MRB is not expected to result in impacts on public uses, although it could result in some political consequences if laws are passed to limit the spread of this species. Any impacts from the tubenose goby are not expected to be widespread in the MRB, due to the preference of this species for cooler water (Rasmussen 2002). The social/political consequence rating is therefore low, as is the uncertainty of this rating.

Social Impacts Matrix (• = indicates a potential to affect the category)

ANS	Swimming[a]	Fishing[b]	Beach Activities[c]	Hunting[d]	Recreational Boating[e]	Political[f]	Spatial Extent of ANS Establishment
Tubenose goby *(Proterorhinus semilunaris)*						•	Localized

[a] ANS establishment may reduce desire to swim due to unpleasant odor, water color, excessive vegetation growth, etc.

[b] ANS establishment may reduce desire to fish because of unpleasant odor, water color, excessive vegetation growth, etc.

[c] ANS establishment may reduce desire for recreational beach use because of unpleasant odor, water color, excessive vegetation growth, etc.

[d] ANS establishment may reduce desire to hunt or reduces availability of suitable hunting areas.

[e] ANS establishment may reduce desire for fishing, canoeing, sailing, water skiing and other boat-based recreation.

[f] Political consequences are associated with the potential implementation of new regulations to address ANS establishment.

References

Dopazo, S.N., L.D. Corkum & N.E. Mandrak. 2008. Fish assemblages and environmental variables associated with Gobiids in nearshore areas of the lower Great Lakes. *Journal of Great Lakes Research*, vol. 34(3), pp. 450-460.

Rasmussen, J.L. 2002. The Cal-Sag and Chicago Sanitary and Ship Canal: A perspective on the Spread and Control of Selected Aquatic Nuisance Species. U.S. Fish and Wildlife Service, Rock Island, IL.

D.2.2.9 Ruffe - *Gymnocephalus cernuus*

Explanation for Social/Political Consequences Rating: MEDIUM

Ruffe is a highly successful invader (Hajjar 2002), and ruffe invasions have been associated with a decline of whitefish and perch populations (Fuller et al. 2012; McLean 1997; Bronte et al. 1998). Therefore, ruffe could have a detrimental effect on MRB recreational fishes by feeding on the young of resident species and by competing with them for food (Fullerton et al. 1998; Fuller et al. 2012). Among the recreational fish species found in the MRB that could be in direct completion with the ruffe are catfish, drum, bass, perch, and walleye. Therefore, this species has the potential to affect the perceived quality of recreational fishing opportunities. Because of its potential impacts to native fishes, the ruffe has generated significant management activities in the GLB. For example, the Great Lakes Fishery Commission created a Ruffe Task Force to control the ruffe (http://anstaskforce.gov/spoc/ruffe.php). Due to the cool-water preference of this species, these effects are not expected to be widespread in the MRB, should this species become established. Overall, the social/political impacts of the ruffe are medium. The uncertainty of this rating is medium because of uncertainty as to whether this species could reach high abundance or become widespread in the MRB.

Social Impacts Matrix (• = indicates a potential to affect the category)

ANS	Swimming[a]	Fishing[b]	Beach Activities[c]	Hunting[d]	Recreational Boating[e]	Political[f]	Spatial Extent of ANS Establishment
Ruffe *(Gymnocephalus cernuus)*		•				•	Localized

[a] ANS establishment may reduce desire to swim due to unpleasant odor, water color, excessive vegetation growth, etc.

[b] ANS establishment may reduce desire to fish because of unpleasant odor, water color, excessive vegetation growth, etc.

[c] ANS establishment may reduce desire for recreational beach use because of unpleasant odor, water color, excessive vegetation growth, etc.

[d] ANS establishment may reduce desire to hunt or reduces availability of suitable hunting areas.

[e] ANS establishment may reduce desire for fishing, canoeing, sailing, water skiing and other boat-based recreation.

[f] Political consequences are associated with the potential implementation of new regulations to address ANS establishment.

References

Bronte, B.R., L.M. Evrard, W.P. Brown, K.R. Mayo & A.J. Edwards. 1998. Fish community changes in the St. Louis River Estuary, Lake Superior, 1989-1996: Is it ruffe or population dynamics? *Journal of Great Lakes Research*, vol. 24(2), pp. 309-318.

Fuller, P., G. Jacobs, J. Larson & A. Fusaro. 2012. Gymnocephalus cernua. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. http://nas.er.usgs.gov/queries/GreatLakes/SpeciesInfo.asp?NoCache=6%2F25%2F2012+7%3A53%3A06+AM&SpeciesID=7&State=&HUCNumber=DGreatLakes

Hajjar, R. 2002. Ruffe (*Gymnocephalus cernuus*). Columbia University, New York, NY. http://www.columbia.edu/itc/cerc/danoff-burg/invasion-_bio/inv_spp_summ/Gymnocephalus%20cernuus.html

McLean, M. 1997. Ruffe: A New Threat to Our Fisheries. Minnesota Sea Grant Program, Great Lakes Sea Grant Network, Duluth, MN. http://seagrant.umn.edu/ais/ruffe_threat

D.2.2.10 Viral Hemorrhagic Septicemia Virus - *Novirhabdovirus* sp.

Explanation for Social/Political Consequences Rating: **HIGH**

If VHSv were to establish in the MRB, several social/political consequences may result. The appearance of diseased fish may discourage recreational fishing and fish kills could impact beach use. However, fish kills in the GLB have been relatively uncommon (reviewed in Kipp et al. 2013) and mortality in fish is uncommon at temperatures greater than 15°C (McAllister 1990; Goodwin and Merry 2011). Considering these temperature sensitivities, VHSv may not spread to the lower MRB, and/or may have greatly reduced virulence in the middle and lower MRB. Consequently, impacts on fishing and beach use may be geographically limited.

Multiple state regulations restricting or regulating interstate or international shipments of fish have been enacted to control this species in the Great Lakes Basin and its spread to other states (APHIS 2008). Additional regulations may also require more widespread testing to verify aquaculture facilities are free from the disease. Currently, Illinois, Indiana, Michigan, Minnesota, New York, Pennsylvania, Ohio, and Wisconsin are regulated under the U.S. Department of Agriculture's (USDA's) Animal and Plant Health Inspection Service (APHIS) interim rules. Restrictions on the sale and transport of bait fish have also been enacted in the GLB and the northeast (reviewed in Kipp et al. 2013). Similar regulations may be put in place in other states if VHSv were to establish in the middle and lower MRB. Overall, the potential social/political impacts resulting from the establishment of VHSv in the MRB may be high.

Regulations designed to restrict the spread of VHSv have already been enacted in numerous states (APHIS 2008). Therefore, the uncertainty associated with the social/political consequence rating is low.

Social Impacts Matrix (• = indicates a potential to affect the category)

ANS	Swimming[a]	Fishing[b]	Beach Activities[c]	Hunting[d]	Recreational Boating[e]	Political[f]	Spatial Extent of ANS Establishment
VHSv *(Novirhabdovirus* sp.)	•	•	•			•	Widespread

[a] ANS establishment may reduce desire to swim due to unpleasant odor, water color, excessive vegetation growth, etc.

[b] ANS establishment may reduce desire to fish because of unpleasant odor, water color, excessive vegetation growth, etc.

[c] ANS establishment may reduce desire for recreational beach use because of unpleasant odor, water color, excessive vegetation growth, etc.

[d] ANS establishment may reduce desire to hunt or reduces availability of suitable hunting areas.

[e] ANS establishment may reduce desire for fishing, canoeing, sailing, water skiing and other boat-based recreation.

[f] Political consequences are associated with the potential implementation of new regulations to address ANS establishment.

References

Animal and Plant Health Inspection Service (APHIS). 2008. Questions and Answers: Viral Hemorrhagic Septicemia Interim Rule. http://www.aphis.usda.gov/publications/animal_health/content/printable_version/faq_vhs_interim_rule.pdf

Goodwin, A.E., & G.E. Merry. 2011. Mortality and carrier status of bluegills exposed to viral hemorrhagic septicemia virus genotype IVb at different temperatures. *Journal of Aquatic Animal Health* vol. 23(2):85-91.

Kipp, R.M., A. Ricciardi, A.K. Bogdanoff, & A. Fusaro. 2013. *Novirhabdovirus sp. genotype IV sublineage b*. USGS Nonindigenous Aquatic Species Database, Gainesville, FL. http://nas.er.usgs.gov/queries/GreatLakes/SpeciesInfo.asp?NoCache=9%2F29%2F2008+2%3A05%3A31+PM&SpeciesID=2656&State=&HUCNumber=DGreatLakes. Revised September 27, 2012.

McAllister, P.E. 1990. Fish Disease Leaflet 83. Viral Hemorrhagic Septicemia of Fishes. U.S. Fish and Wildlife Service, National Fisheries Research Center-Leetown, National Fish Health Research Laboratory, Kearneysville, West Virginia.

D.2.3 Low-Risk ANS Potentially Invading the Mississippi River Basin

Testate amoeba (*Psmmonobiotus* spp.), freshwater bryozoan (*Lophopodella carteri*), cryptic algae (*Cyclotella cryptica*), swamp sedge (*Carex acutiformis*), water chestnut (*Trapa natans*), greater European peaclam (*Pisidium amnicum*), European fingernail clam (*Sphaerium corneum*), European stream valvata (*Valvata piscinalis*), waterflea (*Daphnia galeata galeata*), parasitic copepod (*Neoergasilus japonicas*), harpacticoid copepod (*Schizopera borutzkyi*), sea lamprey (*Petromyzon marinus*), and blueback herring (*Alosa aestivalis*) were all given a low overall risk rating. Species risk summaries for these species, including social and political consequences, are found in Appendix A.