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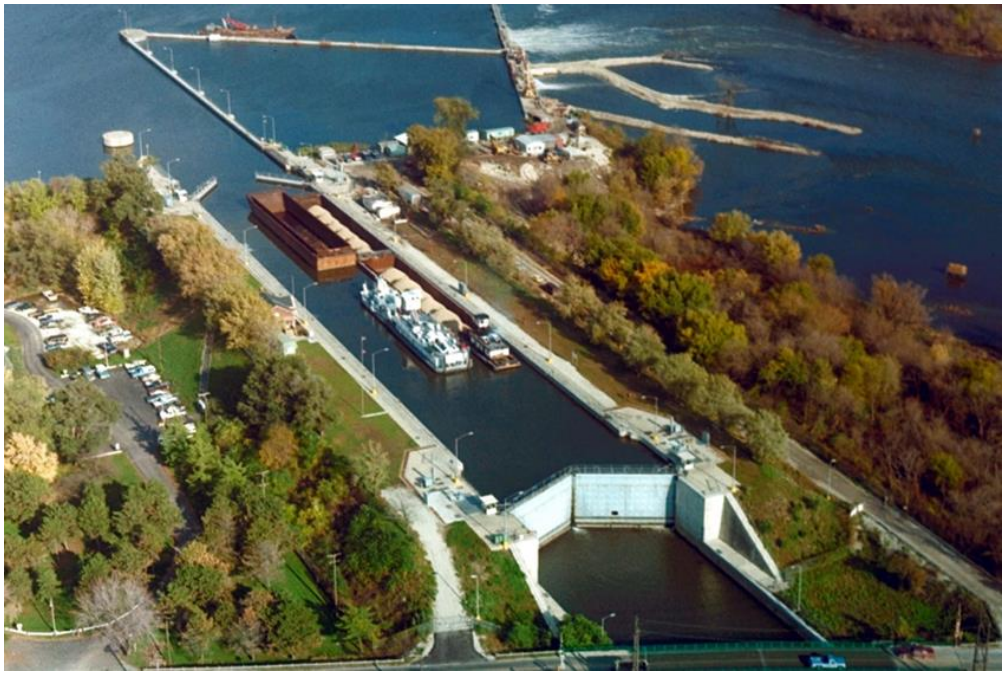
Evaluating the potential responses of native fish and mussels to proposed separation of Lake Michigan from the Illinois River Waterway at Brandon Road Lock and Dam



Altenritter, Matthew E.; Casper, Andrew F.

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Prepared for Illinois Department of Natural Resources, Division of Fisheries

Illinois River Biological Station
704 North Schrader Avenue
Havana, IL 62644

Issued on 9/24/2018

Unrestricted for immediate online release

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Executive Summary

The Brandon Road Lock and Dam (BRLD) location is currently a focal point for developing a barrier to prevent Bighead carp (*Hypophthalmichthys nobilis*) and Silver carp (*H. molitrix*), hereafter referred to as invasive carps, from entering Lake Michigan and the Great Lakes Basin. This location is being considered because it connects the Illinois River to the Chicago Area Waterway System (CAWS) and ultimately Lake Michigan. While the possible effects of the proposed barrier on commercial and recreational navigation are being widely debated, the impacts of the barrier on millions of dollars in aquatic resource restoration projects and decades of management efforts are less thoroughly considered.

In addition to blocking movements of invasive carps, any barrier will also potentially eliminate upriver connectivity that is important to a variety of native fishes and freshwater mussels (hereafter referred to as mussels). Based on surveys of native fishes, we know that fish distribution and species richness in the Illinois River are steadily improving. However, very little is known about how or when fish move between habitats, and to what degree any of these might have been utilizing the lock chamber at BRLD to move upriver. The development of an upstream fish barrier, impassable by either non-native or native fishes, has potential unintended consequences for populations of native fish. We summarized long-term trends in aquatic resources to illustrate both what is known and what is uncertain about a barrier that interrupts upriver connectivity. This includes details about several potential impacts that were developed using the best and most comprehensive information collected by the IDNR-Division of Fisheries (IDNR-DF), Illinois Natural History Survey (INHS), and from the peer-reviewed literature. The summary focuses on long-term trends in species richness and presence or absence over time, found in the neighboring tributary rivers including the Des Plaines River, DuPage River, Kankakee River, Fox River, and upper Illinois River.

The primary impact of the proposed barrier project on native fish and mussels is the blockage of upriver fish movement from the Illinois River and its tributaries, past BRLD into the Des Plaines River and CAWS. Improvements in aquatic habitat quality and connectivity through dam removals upstream of BRLD have, and will continue to open additional aquatic habitat. Long-term fish community surveys in the Des Plaines River suggest numerous species of fish currently pass through the lock at BRLD and that this helped some native fishes such as the pollution intolerant Rosyface shiner (*Notropis rubellus*) re-establish in these formerly degraded reaches after conditions improved (Pescitelli 2017). Despite a record of improvement (similar to fishes) over recent decades, mussel diversity and numbers are currently limited in the Des Plaines River above BRLD. Recruitment of these invertebrates requires both a source of young and fish-hosts to carry them into newly improved habitats. Data suggest that there is a source of young below BRLD: seventeen species of mussels not currently present above BRLD have been documented just 21 kilometers or less below BRLD in the Dresden Pool of the upper Illinois River (an easily covered distance for fish). Thus, any reduction in upriver connectivity will be a threat to the ongoing improvement in both upstream fish and mussel populations.

The extent to which the current fish community above BRLD relies on connectivity through the lock to maintain community stability is uncertain. Though it appears likely continued increases in species richness upriver of BRLD would be truncated after implementation of a barrier, further targeted investigations into trends in recruitment, movement, and abundance may help guide choices of appropriate mitigation efforts. This information could also inform efforts to prioritize the management, translocation, or stocking used to supplement fish-hosts required for rehabilitation of mussels if a barrier is implemented at BRLD.

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Introduction

The rapid inland establishment and spread of aquatic nuisance species (ANS) like the invasive carps has been greatly accelerated by the presence of the nation's waterways and navigation infrastructure over the last century (Ricciardi 2006, Jacobs and Keller 2017). The resulting spread of invaders both threatens the integrity and stability of aquatic ecosystems and has resulted in enormous ecological and economic damages (USACE 2014). The Laurentian Great Lakes and Mississippi River basins have not been spared from this issue. While some seasonal or flood event based exchange between these two basins likely occurred before the 1900's, construction of the Chicago Sanitary and Ship Canal after 1900 began an era of much greater interbasin transfer (Mills et al. 1993). This is when the city of Chicago reversed the flow of the Chicago River with the goal of flushing sewage into the Illinois River instead of Lake Michigan (Olson and Morton 2017). While the discharge of municipal and industrial effluent itself likely acted as a chemical barrier in the short-term, the reversal of flow substantially increased the depth of water in the river and fostered the development of extensive commercial navigation. This development coincided with the construction of a network of tributaries in the Chicago metro area (Chicago Area Waterway System; CAWS), and resulted in five water connections between the Great Lakes Basin and the Mississippi River Basin that all converge upstream of the BRLD site (USACE 2014). Together, these two changes had the intended effect of decreasing water-bourne disease outbreaks and tremendously benefited the regional shipping economy (EDRG 2016). However, they also led to the unintended consequences of steadily accelerating the number and economic costs of ANS moving between basins (Jacobs and Keller 2017).

In 2014, the United States Army Corp of Engineers (USACE) led the Great Lakes and Mississippi River Interbasin Study (GLMRIS), which was charged with outlining several potential ANS control options including another electric barrier, without endorsing any particular one. This precluded evaluation of the consequences to aquatic natural resources like fish and mussels (USACE 2014). With the subsequent release of the GLMRIS Brandon Road Draft Integrated Feasibility Study and Environmental Impact Statement report (USACE 2017), the BRLD site has been identified as a recommended location for implementation of single-point control of upstream fish movement. However, the implications of such a barrier on the State of Illinois' investments in managing aquatic resources for the citizens of the State were not considered. Undermining the movement of native fish and mussels from the Illinois River into the restored and improving habitats of the Des Plaines River and CAWS was not adequately documented or assessed.

Currently, passage through the lock chamber is the only pathway for upriver fish movement due to high rate of flow resulting from the 34 feet of hydraulic head above the dam (USACE 2007). While there is no direct tagging- or telemetry-based evidence of upstream passage at BRLD, indirect evidence can be found in recent IDNR-DF fish surveys on the upper Des Plaines River that suggest some species may have originated from areas below BRLD (Pescitelli 2017). The proposed BRLD fish barrier includes an engineered approach channel, complex noise, flushing lock, water jets, and an electric dispersal barrier (USACE 2017). While these are expressly intended to prevent the upriver movement of ANS (including invasive carps), they also reduce or eliminate the possibility of upriver passage for native fish and mussels. If native fish are using the lock chamber at BRLD to move upriver, truncating this movement may eliminate any supplemental connectivity of fish from downstream locations and prevent future re-establishments of native fish or mussels not currently inhabiting the upper Des Plaines River or CAWS.

Substantial progress towards improving aquatic connectivity and habitats in areas above BRLD such as the upper Des Plaines River have been made by many stakeholders including the IDNR, forest preserve districts, and the US Army Corp of Engineers (USACE). Much of this work has focused on dam removals throughout the Des Plaines River watershed and includes the removal of nine main stem dams (Pescitelli 2017) at a cost of approximately $8.8 million dollars (IDNR-OWR 2017; Appendix 1). Two

additional main stem dams on the Des Plaines River are currently being considered for future removal and once complete, will result in 177 kilometers of free-flowing habitat (Pescitelli 2017). The Forest Preserve Districts of Lake and Cook counties in Illinois have also implemented many habitat restoration initiatives within the Des Plaines River Watershed at an approximate cost of $12.2 million dollars (Jim Anderson and John McCabe *personal communication*, Appendix 2). These include an additional dam removal and multiple projects aimed at stabilizing stream banks, rehabilitating stream channels and riparian vegetation, restoring flatwoods and vernal pool habitat, and facilitating the establishment of native vegetation while removing invasive trees, shrubs, and other plants (Appendix 2). The USACE is also considering an additional $6.71 million-dollar investment in the Des Plaines River to reduce flooding and restore degraded ecosystems (USACE 2015). In total, investments in habitat rehabilitation in the upper Des Plaines River watershed exceed $27 million dollars. Thus, it is important to know how native fish and mussels would be affected by the proposed barrier, to understand the best ways to maximize the benefits associated with significant investments in aquatic habitat improvements.

The costs of efforts to ameliorate any consequences of a fish barrier initiated at BRLD also should consider the potential of the Des Plaines River to function as a "self-sustaining" system. Assuming truncation of upriver connectivity is the primary consequence of a fish barrier at BRLD, upriver fish and mussel communities may be required to self-recruit, recruit fish from the neighboring CAWS, or possibly from Lake Michigan. Mitigation may therefore be necessary to supplement species that do not appear to be self-sustaining, or for species that are currently not present, but may have likely moved upriver at BRLD over the lifetime of the project.

The goal of this report is to summarize an understanding of the potential losses and gains among native fishes and mussels inhabiting the Des Plaines River resulting from the proposed ANS barrier at BRLD. The specific objectives include, 1) the development of a conceptual model to highlight potential unintended consequences of a barrier, 2) documentation of the on-going changes in the native fish and mussel communities upstream of the proposed barrier, 3) identification of uncertainties regarding the potential consequences of fish barrier on native fishes and mussels, and 4) development of potential mitigation actions or plans that may help ameliorate negative outcomes for native fishes and mussels.

Methods

Conceptual model

We summarize what is known and uncertain about the project using a conceptual model whose primary objective is to show potential pathways of change resulting from the proposed ANS barrier at BRLD (Figure 1). We suggest the *primary stressors* in the conceptual model are the ANS control mechanisms (e.g., electric dispersal barrier, complex noise, engineered channel, water jets, and flushing lock) that cumulatively produce a loss of upriver connectivity. The loss of upriver connectivity is thus an aggregate form of *primary stress* and we suggest this would result in reduced richness and abundance of native fishes and truncated richness of mussels (Tiemann et al. 2007).

We hypothesize that native fish richness (*a response category*) and abundance (*a separate response category*) above BRLD will both respond negatively to a fish barrier at BRLD because upriver movements of all fishes would be eliminated. Continuation of the ongoing rehabilitation of native fish richness would then be reliant upon passive immigration from Lake Michigan or active translocation or stocking efforts. Moreover, changes in species richness could affect functional group representation (*a third response category*), which also serves as a proxy of ecosystem health (Karr 1999). A final consideration is that any species currently found in low abundance above BRLD could have an increased susceptibility to stochastic extirpation events like disease, contamination, or summer/winter kills.

Freshwater mussel richness (*a fourth response category*) is also hypothesized to respond negatively to a fish barrier at BRLD because mussel larvae (i.e., glochidia) need to be transported into restored habitats by a fish-host (Sietman et al. 2001). Therefore, the elimination of upriver connectivity for any glochidia infested native fishes at BRLD would inadvertently prevent mussels from accessing areas above BRLD, which currently hosts fewer species of mussels than areas below BRLD such as the Kankakee River (Price et al. 2012b), the lower Des Plaines River (EnviroScience 2017), or the upper Illinois River immediately above Dresden Island Lock and Dam (EAE 2014).

Though not the primary focus of the conceptual model, we also have attempted to connect a few select *impacted sectors* in the model in order to assess any trade-offs between aquatic resources and human use practices of a barrier at BRLD. These impacted sectors include river rehabilitation targeting the Des Plaines River above BRLD, navigation and shipping, and the continued possibility of downstream ANS transfer from the Great Lakes to the Mississippi River basin.

Quantitative metrics

To use the conceptual model to evaluate how the proposed barrier might change the recovery trajectory of the upper river, stakeholders also need to understand the recent and historical trends of the resource categories (native fishes and mussels) currently inhabiting areas near BRLD. This includes not only the Des Plaines River above and below the BRLD, but also neighboring tributaries that may act as alternate or secondary sources for re-establishment of native fish and mussels. Therefore, along with the data collected in Des Plaines River, we also informed the model with fish and mussel surveys from the Kankakee River, DuPage River, Fox River, and upper Illinois River. Patterns and trends in native fish and mussel richness and presence or absence over time for those tributaries were compiled from the IDNR-DF and Illinois Natural History Survey. These included IDNR-DF basin surveys carried out every five years on rivers and streams throughout Illinois conducted using gear-standardized fish sampling protocols (Appendix 3). Survey data was collected from main stem sites within the tributaries (e.g., main stem Kankakee River) and partitioned into sections below or above the lowest main stem dam on the various rivers. In addition to reporting overall fish species richness within these river partitions, newly documented species in each basin survey were highlighted to emphasize cumulative community changes over time. The proportion of all surveys during which a species was documented was also assessed as a measure of species continuity over time.

Freshwater mussel survey information is more limited than fish data for this region though recent surveys have been carried out on the Des Plaines (Price et al. 2012a; EnviroScience 2017), Kankakee (Price et al. 2012b), DuPage (Price et al. 2012a), Fox (Shasteen et al. 2013), and upper Illinois Rivers (EAE 2014). From these reports, mussel richness was summarized as live or recently dead individuals based on the presence of soft tissue and the condition of the shell. We also examined mussel fish-host relationships to identify mussels that may be unable to naturally re-colonize the Des Plaines River above BRLD if fish hosts are prevented from moving upriver. This was done by comparing a list of native fish species (as summarized here) with a list of the known hosts of extant mussel species (as summarized here). The INHS Freshwater Mussel Host Database (INHS-FMHD) was then queried to ascertain overlap between these two groups (http://wwx.inhs.illinois.edu/collections/mollusk/data/freshwater-mussel-host-database).

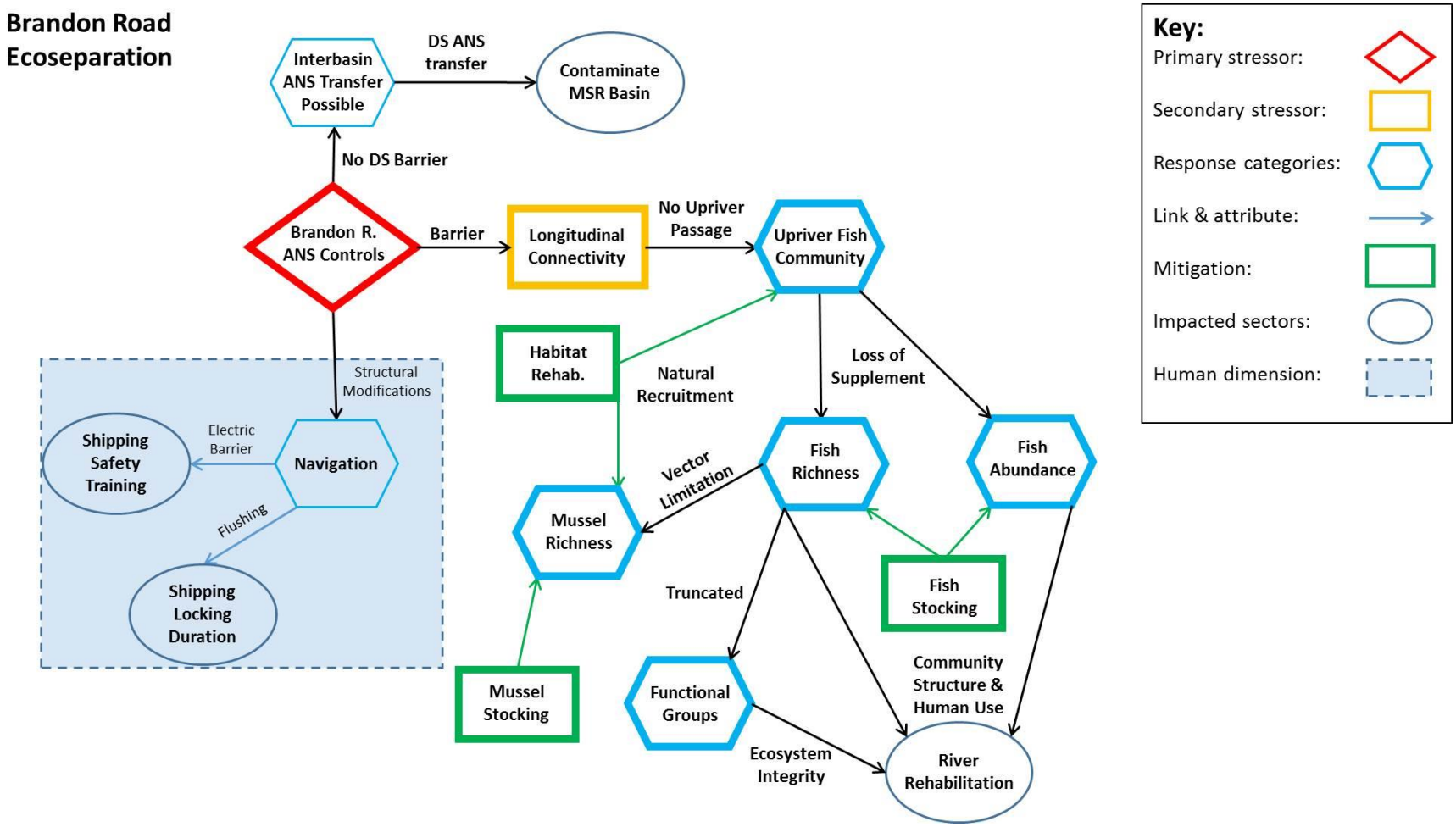

Figure 1. Conceptual model of hypothesized pathways of aquatic changes resulting from ANS controls at Brandon Road Lock and Dam. Limited human dimension aspects are included but were not the primary emphasis of the diagram. Downstream (DS) ANS passage may still be possible at BRLD.

Results

Des Plaines River

During five main stem fish surveys on the Des Plaines River between 1983 and 2013, 73 unique native species were documented (Table 1). Native fish species richness in the Des Plaines River has increased over time at both lower and upper main stem stations (Figure 2). Cumulative species richness as measured during the first basin survey in 1983 was 16 in the lower Des Plaines River and 36 in the upper Des Plaines River. By the 2013 basin survey, cumulative richness reached 43 and 67 in the lower and upper sections respectively. The number of newly observed species across the four basin surveys since the first in 1983 varied from 9 and 18 in the lower river (Table 2) and 6 to 10 in the upper river (Table 3). As of 2013, there were four native species and one non-native species surveyed in the lower Des Plaines River that have yet to be detected above BRLD during basin surveys. These included Bigmouth buffalo, Golden redhorse, Longear sunfish, Brook silverside, and Grass carp.

Eight species of mussels were collected in the Des Plaines River above BRLD between 2009 and 2011 (Table 4). However, limited sampling efficiency due to safety concerns may mean this is an underestimate (D. Shasteen *personal communication*). Mussel surveys in the lower Des Plaines River and upper Illinois River (i.e., above Dresden Island Lock and Dam) within approximately 21 river kilometers of BRLD, revealed twenty-five species of mussels including two state threatened species (Black Sandshell, Purple Wartyback) inhabiting areas near the Dresden Island nuclear station in 2014 (EAE 2014, Table 4). Seventeen of these twenty-five species have not recently been surveyed above BRLD. An additional species, the Flat Floater, was collected (approximately 3 rkm downriver of BRLD) in a survey conducted in 2017 (EnviroScience 2017).

Kankakee River

The Kankakee River hosts a rich fish community with 93 native species observed among main stem sampling sites surveyed between 1994 and 2010 (Table 1). The number of newly observed species during basin surveys varied from 4 to 15 and 3 to 18 in the lower and upper river respectively (Tables 5, 6). A total of 13 fish species were surveyed below the lowermost dam that have yet to be observed above and include 10 native species (Fantail darter, Goldeye, Mooneye, Redear sunfish, Sauger, Skipjack herring, Spottail shiner, Trout perch, and White bass) and three non-native species (Goldfish, Round goby, and White perch). Three of these species have been documented in the Des Plaines River above BRLD (Table 7). There are currently 29 species present in the Kankakee River that have yet to be documented in the Des Plaines River (Table 8). Importantly, there is also evidence of probable movement of fish from the Kankakee River to the upper Des Plaines River. Recent genetic analyses of Rosyface shiner (*Notropis rubellus*) sampled in the upper Des Plaines River indicates a shared haplotype with individuals originating in the Kankakee River, suggesting this small-bodied fish moved through the lock chamber at BRLD (P. Willink *unpublished data*). Moreover, it was not until the most recent basin survey in 2013 that this species was collected in the upper Des Plaines River (Pescitelli 2017).

The Kankakee River also hosts a rich mussel community with 25 extant species documented in a recent survey (Price et al. 2012b). This includes the state threatened Black Sandshell (*Ligumia recta*), Purple Wartyback (*Cyclonaias tuberculata*), and Spike (*Elliptio dilatata*). Eighteen species of mussels found in Kankakee River main stem areas have not recently been surveyed in the Des Plaines River above BRLD (Table 4). However, 11 of these species have been documented in the Dresden pool near the confluence of the lower Des Plaines and Kankakee Rivers (Table 4).

Table 1. Cumulative fish species richness by river tallied over multiple Basin Surveys conducted by the Illinois Department of Natural Resources Division of Fisheries. Gear types include AC electrofishing (BE), seine haul (SH), backpack electrofishing (PE), and DC electrofishing (BED).

River	Years Sampled	Gears	Native Species Richness
DuPage River	1983, 1997, 2002/2003, 2008, 2013	BE, SH	**55**
Des Plaines River	1983, 1997, 2003, 2008, 2013	BE, SH, BED	**73**
Fox River	1996, 2002, 2007, 2012	BE, SH, BED	**74**
Kankakee River	1994, 2000, 2005, 2010	BE, SH, PE	**93**

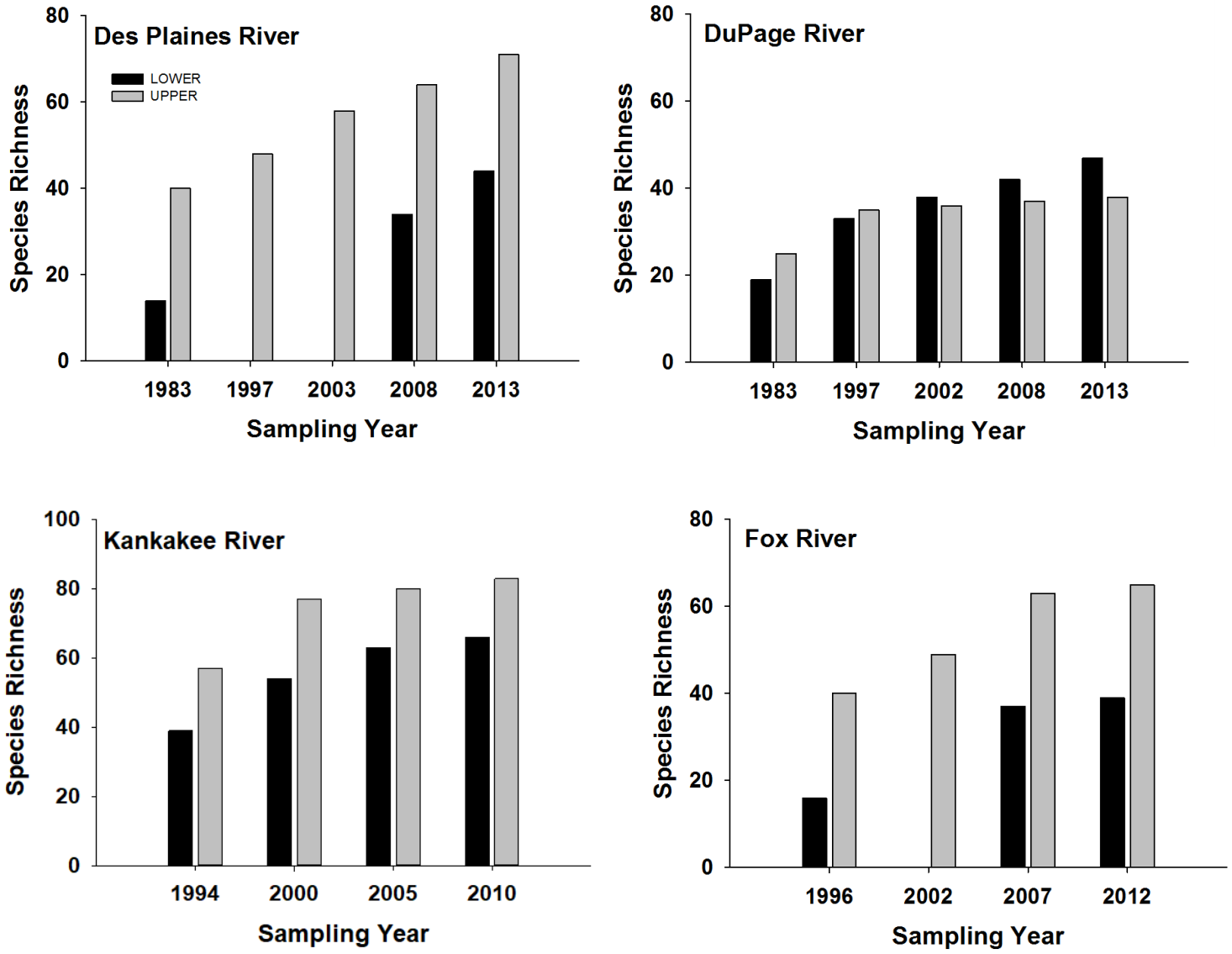

Figure 2. Changes in cumulative fish species richness over time measured during the Illinois Department of Natural Resources-Division of Fisheries Basin Surveys in the Des Plaines, DuPage, Kankakee and Fox Rivers. Lower (black bar) and Upper (grey bar) river segments include main stem stations sampled below and above the lowermost dams on each river respectively.

Table 2. Fish species richness surveyed in the lower Des Plaines River between 1983 and 2013. An "X" indicates presence and grey shading indicates newly surveyed species.

	Basin Surveys				Basin Surveys		
Species	**1983**	**2008**	**2013**	**Species**	**1983**	**2008**	**2013**
Black bullhead	X			Bowfin			X
Black crappie	X		X	Brook silverside			X
Bluegill	X	X	X	Longear sunfish			X
Bullhead minnow	X			Orangespotted sunfish			X
Common carp	X	X	X	Pumpkinseed			X
Creek chub	X			Redear sunfish			X
Emerald shiner	X	X		Silver redhorse			X
Gizzard shad	X	X	X	Spotted sucker			X
Golden shiner	X	X	X	White bass			X
Goldfish	X	X	X				
Green sunfish	X	X	X	Cumulative No. Species	16	34	43
Largemouth bass	X	X	X	No. Species by Year	16	28	30
Quillback	X		X				
Shorthead redhorse	X	X					
Smallmouth bass	X	X	X				
White sucker	X						
Bigmouth buffalo		X	X				
Blackstripe topminnow		X					
Bluntnose minnow		X	X				
Channel catfish		X	X				
Flathead catfish		X	X				
Freshwater drum		X	X				
Golden redhorse		X	X				
Grass carp		X					
Longnose gar		X	X				
Mosquitofish		X					
River carpsucker		X	X				
Rock bass		X					
Round goby		X					
Smallmouth buffalo		X	X				
Spotfin shiner		X	X				
Spottail shiner		X					
Threadfin shad		X					
Yellow bullhead		X	X				

Table 3. Fish species richness surveyed in the upper Des Plaines River between 1983 and 2013. An "X" indicates presence and grey shading indicates newly surveyed species.

	Basin Surveys						Basin Surveys				
Species	**1983**	**1997**	**2003**	**2008**	**2013**	**Species**	**1983**	**1997**	**2003**	**2008**	**2013**
Bigmouth shiner	X	X	X	X	X	Channel catfish		X	X	X	X
Black bullhead	X	X	X	X	X	Freshwater drum		X	X	X	X
Black crappie	X	X	X	X	X	Hornyhead chub		X	X	X	X
Blackside darter	X	X	X	X	X	Orangespotted sunfish		X	X	X	X
Blackstripe topminnow	X	X	X	X	X	Silver redhorse		X			
Bluegill	X	X	X	X	X	Spotted sucker		X	X	X	X
Bluntnose minnow	X	X	X	X	X	Walleye		X	X	X	X
Bowfin	X	X	X	X	X	Yellow bass		X		X	X
Bullhead minnow	X	X				Blackchin shiner			X		
Common carp	X	X	X	X	X	Central stoneroller			X	X	
Central mudminnow	X	X		X		Mimic shiner			X	X	
Common shiner	X	X	X			Mosquitofish			X		X
Creek chub	X	X	X	X	X	Redfin shiner			X		
Emerald shiner	X	X	X	X	X	Round goby			X	X	X
Fathead minnow	X	X	X	X	X	Sauger			X	X	X
Gizzard shad	X	X	X	X	X	Smallmouth buffalo			X	X	X
Golden shiner	X	X	X	X	X	Spottail shiner			X	X	X
Goldfish	X	X	X	X	X	Warmouth			X	X	X
Green sunfish	X	X	X	X	X	Flathead catfish				X	
Johnny darter	X	X	X	X	X	Logperch				X	X
Largemouth bass	X	X	X	X	X	River carpsucker				X	X
Northern pike	X	X	X	X	X	Striped shiner				X	
Pumpkinseed	X	X	X	X	X	Suckermouth minnow				X	X
Quillback	X	X	X	X	X	Threadfin shad				X	
Red shiner	X					Banded killifish					X
Rock bass	X	X	X	X	X	Grass pickeral					X
Sand shiner	X	X	X	X	X	Iowa darter					X
Shorthead redhorse	X					Longnose gar					X
Smallmouth bass	X	X	X	X	X	Muskellunge					X
Spotfin shiner	X	X	X	X	X	Redear sunfish					X
Stonecat	X		X	X	X	Rosyface shiner					X
Tadpole madtom	X	X	X	X	X						
White crappie	X		X	X		Cumulative No. Species	36	44	54	60	67
White sucker	X	X	X	X	X	No. Species by Year	36	39	48	52	53
Yellow bullhead	X	X	X	X	X						
Yellow perch	X		X	X	X						

Table 4. Extant mussels sampled in the Des Plaines and DuPage Rivers (2009 - 2011), Kankakee (2010), Fox (2010 – 2012), and upper Illinois River main stem areas (near Dresden Island Nuclear in 2014, between Seneca, IL and Morris, IL, in 2017). Species occurrence may be based on the presence of shells only (e.g., recently dead). Mussel sampling sites located between Seneca, IL and Morris, IL are approximately 21 rkm below Dresden Island Lock and Dam and 42 rkm below BRLD. State threatened species are denoted with an asterisk (*).

Common Name	Scientific Name	Des Plaines River (Live + Dead)	DuPage River (Live + Dead)	Kankakee River (Live + Dead)	Above Dresden Island Lock and Dam & Dredsen Nuclear (Live)	Below Dresden Island Lock and Dam (Live)	Illinois River (between Seneca & Morris IL; Live + Dead)	Fox River (Live + Dead)
Black Sandshell*	*Ligumia recta*			X	X	X		
Creeper	*Strophitus undulatus*		X	X	X	X	X	
Deertoe	*Truncilla truncata*			X	X	X	X	
Elktoe	*Alasmidonta marginata*			X	X	X	X	X
Ellipse	*Venustaconcha ellipsiformis*			X				
Fatmucket	*Lampsilis siliquoidea*	X	X	X	X	X		
Fawnsfoot	*Truncilla donaciformis*			X				
Flutedshell	*Lasmigona costata*			X	X	X	X	
Fragile Papershell	*Leptodea fragilis*			X	X	X	X	X
Giant Floater	*Pyganodon grandis*	X	X	X	X		X	X
Hickorynut	*Obovaria olivaria*						X	
Lilliput	*Toxolasma parvum*	X	X	X	X			
Mapleleaf	*Quadrula quadrula*			X	X	X	X	X
Monkeyface	*Quadrula metanevra*			X				
Mucket	*Actinonaias ligamentina*			X	X	X	X	
Paper Pondshell	*Utterbackia imbecillis*	X			X			X
Pimpleback	*Quadrula pustulosa*			X	X	X	X	X
Pink Heelsplitter	*Potamilus alatus*			X	X	X	X	
Pink Papershell	*Potamilus ohiensis*				X			
Pistolgrip	*Tritogonia verrucosa*				X	X		
Plain Pocketbook	*Lampsilis cardium*	X	X	X	X	X	X	X
Purple Wartyback*	*Cyclonaias tuberculata*			X	X	X		
Rock Pocketbook	*Arcidens confragosus*				X		X	
Round Pigtoe	*Pleurobema sintoxia*			X				
Sheepnose	*Plethobasus cyphyus*			X				
Spike*	*Elliptio dilatata*			X				
Threehorn Wartyback	*Obliquaria reflexa*				X	X	X	
Threeridge	*Amblema plicata*	X		X	X	X	X	X
Wabash Pigtoe	*Fusconaia flava*	X		X	X	X	X	
Washboard	*Megalonaias nervosa*			X	X	X	X	
White Heelsplitter	*Lasmigona complanata*	X		X	X	X	X	X
Yellow Sandshell	*Lampsilis teres*				X	X		
TOTAL		**8**	**5**	**25**	**25**	**20**	**18**	**9**

Table 5. Fish species richness surveyed in the lower Kankakee River between 1994 and 2010. An "X" indicates presence and grey shading indicates newly surveyed species.

	Basin Surveys					Basin Surveys			
Species	**1994**	**2000**	**2005**	**2010**	**Species**	**1994**	**2000**	**2005**	**2010**
Bluegill	X	X	X	X	Black crappie		X	X	
Bluntnose minnow	X	X	X	X	Black redhorse		X	X	X
Brook silverside	X	X	X	X	Blackside darter		X	X	X
Bullhead minnow	X	X	X	X	Blackstripe topminnow		X	X	X
Common carp	X	X	X	X	Bowfin		X		
Channel catfish	X	X	X	X	Central stoneroller		X	X	X
Emerald shiner	X	X	X	X	Fantail darter		X		
Flathead catfish	X		X	X	Goldeye		X		
Freshwater drum	X	X	X	X	Grass pickerel		X	X	
Gizzard shad	X	X	X	X	Mooneye		X		
Golden redhorse	X	X	X	X	Redfin shiner		X		
Green sunfish	X	X	X	X	Sand shiner		X	X	X
Hornyhead chub	X	X	X		Slenderhead darter		X	X	X
Johnny darter	X	X	X	X	Suckermouth minnow		X	X	X
Largemouth bass	X	X	X	X	Walleye		X	X	X
Logperch	X	X	X	X	Banded darter			X	X
Longear sunfish	X	X	X	X	Black buffalo			X	X
Longnose gar	X	X	X	X	Black bullhead			X	
Mimic shiner	X	X	X	X	Golden shiner			X	
Northern hog sucker	X	X	X	X	Goldfish			X	
Orangespotted sunfish	X	X	X	X	Northern pike			X	
Quillback	X	X	X	X	Rainbow darter			X	
River carpsucker	X		X	X	Sauger			X	X
River redhorse	X	X	X	X	Spotted sucker			X	
Rock bass	X	X	X	X	White perch			X	
Rosyface shiner	X		X	X	Fathead minnow				X
Shorthead redhorse	X	X	X	X	Redear sunfish				X
Silver redhorse	X	X	X	X	Round goby				X
Skipjack herring	X	X			Threadfin shad				X
Smallmouth bass	X	X	X	X					
Smallmouth buffalo	X	X	X	X	Cumulative No. Species	39	54	64	68
Spotfin shiner	X	X	X	X	No. Species by Year	1	1	1	1
Spottail shiner	X		X						
Stonecat	X	X	X						
Striped shiner	X	X	X						
Trout perch	X								
White bass	X	X							
White crappie	X			X					
White sucker	X								

Table 6. Fish species richness surveyed in the upper Kankakee River between 1994 and 2010. An "X" indicates presence and grey shading indicates newly surveyed species.

	Basin Surveys					Basin Surveys					Basin Surveys			
Species	**1994**	**2000**	**2005**	**2010**	**Species**	**1994**	**2000**	**2005**	**2010**	**Species**	**1994**	**2000**	**2005**	**2010**
American eel	X				River redhorse	X	X	X	X	Mosquitofish				X
Banded darter	X	X	X	X	Rock bass	X	X	X	X					
Bigmouth buffalo	X	X	X	X	Rosyface shiner	X	X	X	X	Cumulative No. Species	58	75	78	81
Black buffalo	X	X	X	X	Sand shiner	X	X	X	X	No. Species by Year	58	69	61	64
Black crappie	X	X	X	X	Shorthead redhorse	X	X	X	X					
Black redhorse	X	X	X	X	Silver redhorse	X	X	X	X					
Blackside darter	X	X	X	X	Silverjaw minnow	X		X						
Blackstripe topminnow	X	X	X	X	Slenderhead darter	X	X	X	X					
Bluegill	X	X	X	X	Smallmouth bass	X	X	X	X					
Bluntnose minnow	X	X	X	X	Smallmouth buffalo	X	X	X	X					
Bowfin	X	X	X	X	Spotfin shiner	X	X	X	X					
Brook silverside	X	X	X	X	Steelcolor shiner	X								
Bullhead minnow	X	X	X	X	Striped shiner	X	X	X	X					
Common carp	X	X	X	X	Suckermouth minnow	X	X		X					
Channel catfish	X	X	X	X	Walleye	X	X	X	X					
Common shiner	X				Warmouth	X	X	X	X					
Creek chub	X		X		White sucker	X	X	X	X					
Fathead minnow	X	X		X	Yellow bullhead	X	X	X						
Freshwater drum	X	X	X	X	Blacknose dace		X							
Gizzard shad	X	X	X	X	Bluntnose darter		X							
Golden redhorse	X	X	X	X	Brown bullhead		X							
Golden shiner	X	X	X	X	Central mudminnow		X		X					
Grass pickerel	X	X	X	X	Central stoneroller		X	X	X					
Green sunfish	X	X	X	X	Emerald shiner		X	X						
Highfin carpsucker	X			X	Ironcolor shiner		X		X					
Hornyhead chub	X	X	X	X	Lake chubsucker		X							
Johnny darter	X	X	X	X	Pumpkinseed		X	X	X					
Largemouth bass	X	X	X	X	Rainbow darter		X	X						
Logperch	X	X	X	X	Shortnose gar		X							
Longear sunfish	X	X	X	X	Spotted sucker		X	X	X					
Longnose gar	X	X	X	X	Starhead topminnow		X	X	X					
Mimic shiner	X	X	X	X	Stonecat		X	X	X					
Northern hog sucker	X	X	X	X	Tadpole madtom		X		X					
Northern pike	X	X	X	X	Weed shiner		X							
Orangespotted sunfish	X	X	X	X	White crappie		X		X					
Pirate perch	X	X	X	X	Black bullhead			X						
Quillback	X	X	X	X	Flathead catfish			X	X					
Red shiner	X	X	X		Threadfin shad			X						
Redfin shiner	X	X	X	X	American brook lamprey				X					
River carpsucker	X	X		X	Creek chubsucker				X					

Table 7. List of fish species found below, but not above, the lowermost main stem dam on the DuPage, Kankakee, and Fox Rivers and whether they have been observed above the BRLD on the Des Plaines River. An "X" indicates presence.

River	Species exclusive to LOWER river sections	Found above BRLD
DuPage River	Banded darter	
	Black redhorse	
	Blackside darter	X
	Central stoneroller	X
	Logperch	X
	Longnose gar	X
	Mimic shiner	X
	Red shiner	X
	River carpsucker	X
	River redhorse	
	Smallmouth buffalo	X
	Spottail shiner	X
	Striped shiner	X
	Suckermouth minnow	X
	Walleye	X
	Yellow bullhead	X
	TOTAL	**13/16 (81%)**
Kankakee River	Fantail darter	
	Goldeye	
	Goldfish	
	Mooneye	
	Redear sunfish	X
	Round goby	
	Sauger	X
	Skipjack herring	
	Spottail shiner	X
	Trout perch	
	White bass	
	White perch	
	TOTAL	**3/12 (25%)**
Fox River	Black buffalo	
	Mooneye	
	Sauger	X
	Shortnose gar	
	Silver carp	
	Skipjack herring	
	Smallmouth buffalo	X
	TOTAL	**2/7 (29%)**

Table 8. Species present in the DuPage, Kankakee, and Fox Rivers that have NOT been observed in the Des Plaines River above BRLD. Note asterisk on Silver carp as species not desired to occur above BRLD.

Species	DuPage River	Kankakee River	Fox River
Banded darter	X	X	X
Black redhorse	X	X	X
Northern hog sucker	X	X	X
River redhorse	X	X	X
Black buffalo		X	X
Blacknose dace		X	X
Bullhead minnow		X	X
Highfin carpsucker		X	X
Mooneye		X	X
Shortnose gar		X	X
Skipjack herring		X	X
Slenderhead darter		X	X
Starhead topminnow		X	X
American brook lamprey		X	
American eel		X	
Bluntnose darter		X	
Brown bullhead		X	
Creek chubsucker		X	
Fantail darter		X	
Goldeye		X	
Ironcolor shiner		X	
Lake chubsucker		X	
Pirate perch		X	
Rainbow darter		X	
Silverjaw minnow		X	
Steelcolor shiner		X	
Trout perch		X	
Weed shiner		X	
White perch		X	
Pugnose minnow			X
Silver carp*			X
Total species	4	29	14 (15 total)

DuPage River

The main stem of the DuPage River hosts the lowest fish species richness of the four rivers examined here with a total of 55 native fish species observed during basin surveys between 1983 and 2013 (Table 1). While fish species richness in both the lower and upper main stem DuPage River increased across basin surveys, increases in richness in the upper river appear truncated over time relative to the lower river (Figure 2). The number of newly observed species in the lower DuPage River varied between 4 and 13 among basin surveys (Table 9), while in the upper section it varied between 1 and 10 species (Table 10). There were also 16 native species of fish surveyed in the lower DuPage River that have not been captured above its lowest most main stem dam during any previous basin survey (Table 7). These included the Banded darter, Black redhorse, Blackside darter, Central stoneroller, Logperch, Longnose gar, Mimic shiner, Red shiner, River carpsucker, River redhorse, Smallmouth buffalo, Spottail shiner, Striped shiner, Suckermouth minnow, Walleye, and Yellow bullhead. The DuPage River also hosts 4 fish species not currently observed in the Des Plaines River (Table 8).

Surveys of freshwater mussels in the DuPage River reveal a relatively limited community with only five live or recently dead species surveyed between 2009 and 2011 (Table 4; Price et al. 2012). As in the other rivers discussed earlier, limited sampling and the patchy distribution of mussels may lead to underestimates of the actual extant mussel population in the DuPage River. Of the five mussel species considered extant in the DuPage River, a single species (Creeper, *Strophitus undulatus*) has not recently been documented in the Des Plaines River.

Fox River

Basin surveys in the Fox River show there are 74 native fish species inhabiting the main stem (Tables 11, 12). Native fish species richness in the lower and upper Fox River increased over time with the number of newly observed species at each basin survey varying from 3 - 24 and 2 - 16 respectively (Tables 11, 12). There were also seven fish species documented in the lower Fox River below the dam at Dayton, IL (~rkm 9) that were not documented in the upper segment during any other basin survey (Table 7). These species included six native species (Black buffalo, Mooneye, Sauger, Shortnose gar, Skipjack herring, and Smallmouth buffalo) and one non-native species (Silver carp). Fourteen species of fish (excluding the silver carp) surveyed in the Fox River have yet to be surveyed in the Des Plaines River above BRLD (Table 8).

Mussel surveys in the main stem Fox River suggest there are nine extant species (Table 4; Shasteen et al. 2013). Four of the nine mussel species surveyed in the Fox River have yet to be surveyed in the Des Plaines River above BRLD and include the Elktoe, Fragile Papershell, Mapleleaf, and Pimpleback (Table 4).

Species presence absence

Most species of fishes were encountered more than once during all basin surveys that spanned 30 years in the Des Plaines and DuPage Rivers, and 16 years in the Kankakee and Fox Rivers. The proportion of fish species present (i.e. surveyed) more than once ranged between 49% and 90% on the four rivers (Table 13). A subset of the species sampled once were only collected during the most recent surveys and represented new additions to the overall community. These new species additions varied between sites located below and above the lowest dams on each river. Newly surveyed species accounted for between 6% and 21% of species sampled below the lowest most dams and between 3% and 11% of species sampled above the lowest dam (Table 13). In both the lower and upper sites, the highest

proportions of new species additions occurred in the Des Plaines River with 9 (21%) new species surveyed in the lower sites in 2013 and 7 (11%) new species surveyed in the upper sites in the same year.

Indirect evidence of fish passage

The IDNR-DF basin survey data provide evidence that barriers like the one proposed for BRLD can limit the movement of individual fish into the Des Plaines River, thereby limiting the ongoing increase in species richness. In three of the tributaries, multiple species of fish were found below the lowermost dam that were not observed above the dam (DuPage River n = 16, Kankakee River n = 12, and Fox River n = 7, Table 7). Many of the species apparently blocked from moving upriver in tributaries by dams have been observed above BRLD, providing further circumstantial evidence of fish passage through the existing locks. In particular, 81%, 25%, and 29% of fish species found exclusively below the lowermost main stem dams on the DuPage, Kankakee, and Fox Rivers respectively, have been surveyed above BRLD. Moreover, two species including the smallmouth buffalo (*Ictiobus bubalus*), and spottail shiner (*Notropis hudsonias*) appear to be excluded from the upper reaches of two of the three rivers of interest, but have been observed above BRLD.

Identification of potential mussel hosts

A query of the INHS Freshwater Mussel Host Database revealed native fish surveyed for this study were potential hosts for between 0 and 16 of the 32 mussel species considered extant in the rivers of interest (Table 14). Though the majority (53%) of fishes surveyed in the Des Plaines River were potential hosts for between 0 and 4 mussel species, the remaining 47% were potential hosts for between 5 and 16 species of mussels (Figure 3). Fish species only recently observed above BRLD (i.e. since 2008), or denoted as migratory species (Anderson et al. 2017) were also potential hosts for between 0 and 10 mussel species. Noteworthy species that were only observed above BRLD since 2013 include the Longnose gar, Banded Killifish, and Logperch, which are potential hosts for 6, 10, and 6 mussel species respectively. Moreover, the intermittently sampled Flathead catfish and Striped shiner which were observed above BRLD in 2008, but not in 2013, may host as many as 9 and 8 species of mussels respectively. The flathead catfish may also support natural infestations of glochidia from the state threatened Purple Wartyback mussel (Appendix 5).

Table 9. Fish species richness surveyed in the lower DuPage River between 1983 and 2013. An "X" indicates presence and grey shading indicates newly surveyed species.

	Basin Surveys							Basin Surveys					
Species	**1983**	**1997**	**2002**	**2003**	**2008**	**2013**	**Species**	**1983**	**1997**	**2002**	**2003**	**2008**	**2013**
Bigmouth shiner	X		NA				Logperch				X	X	X
Black crappie	X	X		X		X	Northern hog sucker				X	X	X
Bluegill	X	X		X	X	X	River redhorse				X		
Bluntnose minnow	X	X			X	X	Silver redhorse				X	X	
Common carp	X	X		X	X	X	Banded darter					X	
Creek chub	X	X					Black redhorse					X	
Fathead minnow	X						Mimic shiner					X	X
Gizzard shad	X	X		X	X	X	Smallmouth buffalo					X	
Golden shiner	X					X	Longnose gar						X
Goldfish	X						Pumpkinseed						X
Green sunfish	X	X			X	X	River carpsucker						X
Hornyhead chub	X				X		Walleye						X
Largemouth bass	X	X		X	X	X	Yellow bullhead						X
Quillback	X					X							
Red shiner	X						Cumulative No. Species	21	34	NA	38	42	47
Sand shiner	X	X				X	No. Species by Year	21	25	NA	14	29	27
Shorthead redhorse	X	X		X	X	X							
Spotfin shiner	X	X			X	X							
Spottail shiner	X												
Striped shiner	X				X								
White sucker	X	X		X	X	X							
Blackside darter		X			X								
Blackstripe topminnow		X			X	X							
Central stoneroller		X			X								
Channel catfish		X			X	X							
Emerald shiner		X			X								
Freshwater drum		X											
Golden redhorse		X		X	X	X							
Johnny darter		X											
Longear sunfish		X			X								
Orangespotted sunfish		X			X	X							
Rock bass		X		X	X	X							
Smallmouth bass		X		X	X	X							
Suckermouth minnow		X			X								

Table 10. Fish species richness surveyed in the upper DuPage River between 1983 and 2013. An "X" indicates presence and grey shading indicates newly surveyed species.

	Basin Surveys							Basin Surveys					
Species	**1983**	**1997**	**2002**	**2003**	**2008**	**2013**	**Species**	**1983**	**1997**	**2002**	**2003**	**2008**	**2013**
Bigmouth shiner	X			NA			Blackstripe topminnow		X				
Black bullhead	X	X					Channel catfish		X	X		X	
Black crappie	X	X	X				Emerald shiner		X				
Bluegill	X	X	X		X		Freshwater drum		X				
Bluntnose minnow	X	X					Johnny darter		X				
Common carp	X	X	X		X		Longear sunfish		X	X		X	
Central mudminnow	X						Northern pike		X				
Common shiner	X						Orangespotted sunfish		X				
Creek chub	X						Rock bass		X	X		X	
Fathead minnow	X						Silver redhorse		X			X	
Gizzard shad	X	X					Hornyhead chub			X		X	
Golden redhorse	X	X	X		X		Stonecat					X	
Golden shiner	X						Flathead catfish						X
Goldfish	X												
Green sunfish	X	X	X				Cumulative No. Species	26	36	37	NA	38	39
Largemouth bass	X	X	X		X		No. Species by Year	26	25	14	NA	14	1
Northern hog sucker	X	X	X		X								
Pumpkinseed	X												
Quillback	X	X											
Redfin shiner	X												
Sand shiner	X												
Shorthead redhorse	X	X	X		X								
Smallmouth bass	X	X	X		X								
Spotfin shiner	X	X											
White sucker	X	X	X		X								
Yellow perch	X												

Table 11. Fish species richness surveyed in the lower Fox River between 1996 and 2012. An "X" indicates presence and grey shading indicates newly surveyed species.

	Basin Surveys					Basin Surveys			
Species	**1996**	**2002**	**2007**	**2012**	**Species**	**1996**	**2002**	**2007**	**2012**
Black crappie	X	NA			Black buffalo				X
Bluegill	X		X	X	Silver carp				X
Common carp	X		X	X	Spottail shiner				X
Channel catfish	X		X	X					
Flathead catfish	X		X	X	Cumulative No. Species	17	NA	41	44
Freshwater drum	X		X	X	No. Species Surveyed	17	NA	38	31
Gizzard shad	X		X	X					
Golden redhorse	X		X	X					
Green sunfish	X		X						
Highfin carpsucker	X		X	X					
Largemouth bass	X			X					
Longnose gar	X		X	X					
River carpsucker	X		X	X					
Shorthead redhorse	X		X	X					
Skipjack herring	X								
Smallmouth bass	X		X	X					
Smallmouth buffalo	X		X	X					
Black redhorse			X	X					
Blackstripe topminnow			X						
Bluntnose minnow			X	X					
Brook silverside			X						
Bullhead minnow			X						
Central stoneroller			X	X					
Common shiner			X						
Emerald shiner			X						
Fathead minnow			X						
Grass carp			X	X					
Johnny darter			X						
Logperch			X						
Mooneye			X	X					
Northern hog sucker			X	X					
Quillback			X	X					
Rock bass			X						
Sand shiner			X	X					
Sauger			X	X					
Shortnose gar			X	X					
Silver redhorse			X	X					
Spotfin shiner			X	X					
Suckermouth minnow			X						
Walleye			X	X					
White bass			X	X					

Table 12. Fish species richness surveyed in the upper Fox River between 1996 and 2012. An "X" indicates presence and grey shading indicates newly surveyed species.

	Basin Surveys					Basin Surveys			
Species	**1996**	**2002**	**2007**	**2012**	**Species**	**1996**	**2002**	**2007**	**2012**
Black crappie	X	X	X	X	Bigmouth shiner		X	X	X
Black redhorse	X	X	X		Black bullhead		X	X	X
Bluegill	X	X	X	X	Blackstripe topminnow		X	X	X
Bluntnose minnow	X	X	X	X	Hornyhead chub		X	X	
Brook silverside	X	X	X	X	Logperch		X	X	X
Bullhead minnow	X	X	X	X	Northern hog sucker		X	X	X
Common carp	X	X	X	X	River carpsucker		X		
Channel catfish	X	X	X	X	Stonecat		X		
Emerald shiner	X	X	X	X	Suckermouth minnow		X	X	
Flathead catfish	X	X	X	X	Common shiner			X	X
Freshwater drum	X	X	X	X	Fathead minnow			X	X
Gizzard shad	X	X	X	X	Banded darter			X	X
Golden redhorse	X	X	X	X	Slenderhead darter			X	X
Golden shiner	X	X	X	X	Muskellunge			X	X
Green sunfish	X	X	X	X	Central stoneroller			X	X
Highfin carpsucker	X	X	X	X	Starhead topminnow			X	
Johnny darter	X	X	X	X	Northern pike			X	X
Largemouth bass	X	X	X	X	Longnose gar			X	X
Orangespotted sunfish	X	X	X	X	Creek chub			X	X
Pugnose minnow	X	X	X	X	Grass carp			X	
Pumpkinseed	X	X	X	X	Striped shiner			X	X
Quillback	X	X	X	X	Blacknose dace			X	X
River redhorse	X	X			Bowfin			X	X
Rock bass	X	X	X	X	Grass pickerel			X	X
Rosyface shiner	X		X	X	Goldfish			X	X
Sand shiner	X	X	X	X	Blackside darter				X
Shorthead redhorse	X	X	X	X	Mimic shiner				X
Silver redhorse	X	X	X	X					
Smallmouth bass	X	X	X	X	Cumulative No. Species	40	49	65	67
Spotfin shiner	X	X	X	X	No. Species Surveyed	40	45	61	58
Spottail shiner	X	X	X	X					
Tadpole madtom	X								
Walleye	X	X	X	X					
Warmouth	X		X	X					
White bass	X	X	X	X					
White crappie	X		X	X					
White sucker	X	X	X	X					
Yellow bass	X	X	X	X					
Yellow bullhead	X	X	X	X					
Yellow perch	X	X	X	X					

Table 13. Trends in fish species presence and absence across basin surveys based on the proportion of species sampled during more than one basin survey below (Lower Sites) and above (Upper Sites) the lowermost dams and the proportion of all species sampled that were newly surveyed in the most recent basin survey.

	% Fish Species Surveyed > Once		% New Species Most Recent Survey	
River	**Lower Sites**	**Upper Sites**	**Lower Sites**	**Upper Sites**
Des Plaines	54	78	21	11
DuPage	60	49	11	3
Kankakee	68	83	6	4
Fox	66	90	7	3

Table 14. List of fish hosts and the number of potential mussel species hosted. Migratory or backwater designation based on Anderson et al. (2017).

Fish Species	Migratory or Backwater	Potential # of Mussel Species Hosted	Fish Species	Migratory or Backwater	Potential # of Mussel Species Hosted	Fish Species	Migratory or Backwater	Potential # of Mussel Species Hosted
Bluegill	B	16	Northern pike	M/B	3	Grass pickerel		0
White crappie	B	16	Northern hog sucker	M	3	Ironcolor shiner		0
Green sunfish		16	Quillback	M	3	Lake chubsucker		0
Largemouth bass	M/B	14	Shorthead redhorse	M	3	Muskellunge		0
Black crappie	B	14	Skipjack herring	M	3	Silver carp		0
Sauger	M	13	Central mudminnow	B	3	Starhead topminnow		0
Yellow perch	B	13	Fantail darter		3	Threadfin shad		0
Creek chub		12	Goldfish		3			
Rock bass		12	Tadpole madtom		3			
Freshwater drum	M/B	11	Smallmouth buffalo	M/B	2			
Channel catfish	M	10	Golden redhorse	M	2			
Banded killifish		10	Goldeye	M	2			
Pumpkinseed		10	Silver redhorse	M	2			
Walleye	M/B	9	Bowfin	B	2			
Flathead catfish	M	9	Shortnose gar	B	2			
Central stoneroller		9	Bullhead minnow		2			
Common shiner		9	Mimic shiner		2			
Golden shiner	B	8	Redfin shiner		2			
Orangespotted sunfish	B	8	River redhorse		2			
Longear sunfish		8	Sand shiner		2			
Spotfin shiner		8	Silverjaw minnow		2			
Striped shiner		8	Spottail shiner		2			
Warmouth	B	7	Bigmouth buffalo	M/B	1			
Bluntnose minnow		7	Black redhorse	M	1			
Gizzard shad		7	Highfin carpsucker	M	1			
Red shiner		7	Mooneye	M	1			
American eel	M	6	Pirate perch	B	1			
Longnose gar	M	6	Redear sunfish	B	1			
Smallmouth bass	M	6	Weed shiner	B	1			
Black bullhead	B	6	Blackchin shiner		1			
Johnny darter	B	6	Brook silverside		1			
Blacknose dace		6	Emerald shiner		1			
Common carp		6	River carpsucker		1			
Logperch		6	Rosyface shiner		1			
Yellow bullhead		6	Stonecat		1			
White bass	M	5	Suckermouth minnow		1			
Brown bullhead		5	Trout perch		1			
Rainbow darter		5	White perch		1			
White sucker	M/B	4	Spotted sucker	M/B	0			
Mosquitofish (WESTERN)	B	4	Blackstripe topminnow	B	0			
Banded darter		4	Pugnose minnow	B	0			
Blackside darter		4	Yellow bass	B	0			
Fathead minnow		4	American brook lamprey		0			
Hornyhead chub		4	Bigmouth shiner		0			
Iowa darter		4	Black buffalo		0			
Round goby		4	Bluntnose darter		0			
Slenderhead darter		4	Creek chubsucker		0			
Steelcolor shiner		4	Grass carp		0			

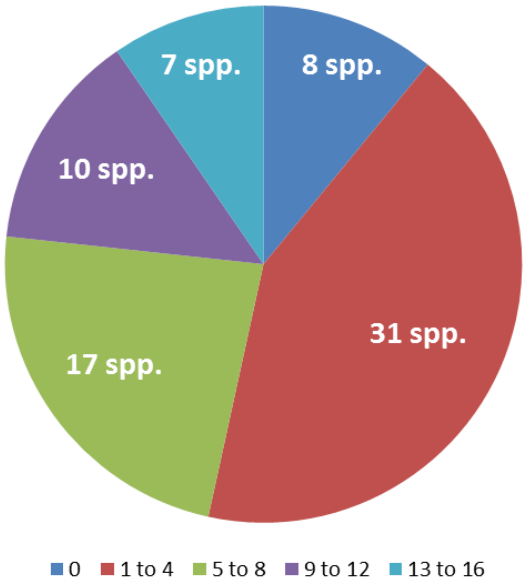

Figure 3. Number of fish species sampled in the Des Plaines River that may serve as potential hosts for 0 or between 1 – 4, 5 – 8, 9 – 12, and 13 – 16 species of freshwater mussels.

Discussion

The issue: upriver connectivity

The proposed BRLD fish barrier is designed to prevent upstream movement of invasive carps that may enter the lock chamber, either actively (e.g., as swimming adults and juveniles) or passively (e.g., as drifting eggs and larvae) (USACE 2017). A collateral effect of this will be the elimination of longitudinal connectivity for native fishes and mussels with the upper Des Plaines River and CAWS. The inability of desirable native fishes to supplement or recolonize the improved and improving portions of the upper Des Plaines River and CAWS may constrain recovering populations of key fish and mussel species while limiting approximately $27 million dollars in federal, state, and local (i.e. Forest Preserve Districts) efforts to rehabilitate the upper river and its biological community. Ultimately, the barrier project is assuming that fish species richness and abundance will be self-sustaining above BRLD, there will be no catastrophic events (disease, fish kills), there will be immigration of native fishes from Lake Michigan or small tributaries within the Des Plaines River watershed, or that supplementation via either hatchery production or quarantine and translocation can support the current upward trajectories as efficiently and economically as unconstrained upstream movement.

Currently the assumption of self-sustaining Des Plaines River fish populations cannot be assessed because of an absence of population data. Despite the lack of a comprehensive assessment there is evidence that some species-specific recruitment can occur; existing IDNR basin surveys document the presence of young-of-year (YOY) smallmouth bass and bluegill in tributary stations but not in the main channel habitat (Pescitelli 2013, Pescitelli 2017). This means there is a high degree of uncertainty in predicting whether the fish assemblage can be self-sustaining without continuing immigration from below BRLD.

Long-term survey data suggests that new species are immigrating and recolonizing the upper Des Plaines River and the other tributaries from the river below BRLD (Pescitelli 2013, Gibson-Reinemer et al. 2017, Pescitelli 2017). For instance, there is evidence that a fish barrier has prevented fish from taking advantage of recent water quality improvements in the DuPage River. This tributary has an impassable dam situated 1.5 rkm upriver from its confluence with the lower Des Plaines River. The DuPage River below the impassable dam hosts 16 species of fish that have not been surveyed above the dam in any of the four basin surveys conducted since 1983, suggesting the additional fish have not been able to move upriver to colonize. However, 81% of these same species have been observed above BRLD.

Long-term monitoring shows clearly that diversity has been improving substantially in the upper Illinois River basin and tributaries since the 1970's (McClelland et al. 2012; Gibson-Reinemer et al. 2017). This recovery includes many non-game species that are not reared or stocked in the basin, thus we conclude these fish populations are recovering passively through natural upstream dispersal and establishment. Many of the fish species are also returning to the tributaries such as the Kankakee and Fox Rivers below locks and dams or other barriers. While many of these fish are not yet present in the Des Plaines River, this basin was one of the most degraded and last to improve. Although the habitat and environment of the upper Des Plaines River and CAWS are different environments for fish than the Illinois River, data shows that native populations are still expanding upriver (e.g., Walleye, Smallmouth bass, and Redhorse spp. are present and expanding but would be blocked by the proposed project). An impassible barrier at BRLD means ongoing recovery would have to be through more active and intensive means, likely via expanded hatchery production or translocation of wild caught fish.

Downstream immigration of fishes from Lake Michigan into the CAWS and eventually into the upper Des Plaines River occurs, albeit on a limited basis. Examples include the non-native Round goby (*Neogobius melanostomus*) which was found along the Lake Michigan shoreline in the late 1990's but

was first surveyed in the Des Plaines River in 2003 (Charlebois et al. 2001, Irons et al. 2006), the Banded killifish, a state threatened species first surveyed in the upper Des Plaines River during an IDNR basin survey in 2013, and the Oriental weatherfish (Willink and Veraldi 2009, Tiemann et al. 2015). This indirect evidence is supported by source signatures measured by otolith $\delta^{13}C$, which revealed as much as 36% of fish sampled in the CAWS may have emigrated from Lake Michigan (Rude et al 2017). However, no fish sampled downstream of the CAWS in the Des Plaines River (including Emerald shiner, Green sunfish, Largemouth bass, and Round goby) during this study are thought to have originated in Lake Michigan. Thus, it appears emigration of fishes from Lake Michigan may supplement the fish community of the CAWS, but may not offset the losses resulting from a fish barrier at BRLD.

It is probable that some improvements in fish species richness on the Des Plaines River above BRLD also occurred as fishes moved out of small tributaries to the main stem. For example, nine species of fish sampled in the upper Des Plaines River watershed from 2002 – 2004 during summer base-flow conditions were observed only in headwater and/or main stem tributary sites (Slawski et al. 2008). These included Bowfin, Pirate perch, Brook stickleback, Iowa darter, Fantail darter, Common shiner, Redfin shiner, Yellow bass, and Western blacknose dace (Slawski et al. 2008). These nine species represented 21% of the 43 native species surveyed by Slawski et al. (2008) among main stem, main stem tributary, and headwater tributary waters. Future work could address the potential of main stem and headwater tributaries as sources of newly surveyed species above BRLD even if ANS controls are implemented. This could help address the knowledge gap associated with differentiating between fishes originating from below BRLD and those already present above.

Recent improvements in the mussel community of the upper Illinois River have largely been attributed to long-term enhancements in the fish community (Sietman et al. 2001). Despite its historically diverse mussel community, the increases in numbers and diversity seen below BRLD have not yet reached the upper Des Plaines River (Price et al. 2012a). However, the river below the proposed barrier at BRLD is a relatively rich source of mussels for recolonization hosting seventeen species still missing from the Des Plaines River above BRLD including two state threatened species (the Black Sandshell and Purple Wartyback). An ANS barrier at BRLD would limit longitudinal connectivity for potential species of fish hosts and which is critical for sustaining the recovery of these mussels (Sietman et al. 2001; Benson et al. 2017).

Anticipated changes in fish and mussel richness and presence over time

Steady improvements in fish species richness and abundance have occurred throughout the Illinois River basin (McClelland et al. 2012; Gibson-Reinemer et al. 2017). These are in large part due to improvements in water quality resulting from the Clean Water Act (1972) that allowed native species to reestablish in formerly uninhabitable main stem and tributary habitats. A similar trend of increasing species richness was also observed in the lower portions of the Des Plaines, DuPage, Kankakee, and Fox Rivers (Pescitelli 2013; Pescitelli 2017). However, the DuPage, Kankakee, and Fox Rivers all have impassable main stem dams that limit the upriver movement of fish to the first 1.5, 16, and 9 rkm respectively. On the DuPage River, the putative effects of limited habitat availability (i.e. 1.5 rkm below the first dam) on patterns in species richness could serve to illustrate the potential effects of a barrier at BRLD on fish.

The changes in fish species richness over time in the DuPage River provides us with a good idea of how the upper Des Plaines River might respond to a proposed barrier to fish movement. Of noteworthiness are the patterns in species richness over time as surveyed above and below the dam in Channahon, IL. Above the dam at Channahon, IL, only 3 species appear to have returned between 2002 and 2013 (Hornyhead chub, Stonecat, and Flathead catfish). In contrast, at least 13 newly observed native

species have returned to the DuPage River below the dam (Logperch, Northern hog sucker, River redhorse, Silver redhorse, Banded darter, Black redhorse, Mimic shiner, Smallmouth buffalo, Longnose gar, Pumpkinseed, River carpsucker, Walleye, and Yellow bullhead). The implication is that fish inhabiting the lower DuPage River are unable subsidize the upstream native community. If we think of this tributary dam example as analogous to the proposed main stem ANS barrier at BRLD, this suggests that over time the upstream assemblages would be negatively affected.

In some cases, certain species of fish may show little response to a fish barrier at BRLD if they are currently capable of maintaining self-sustaining populations. Though direct evidence of successful spawning and recruitment by most fishes inhabiting the upper Des Plaines River is lacking, trends in the temporal stability or consistency at which certain species of fish were sampled may provide indirect evidence of recruitment. For example, between 53% and 78%of fishes sampled in the Des Plaines River were surveyed during more than one basin survey spanning at least five years, and between 12% and 42% were sampled during all basin surveys that spanned from 1983 to 2013. Alternatively, in the case of the upper Des Plaines River, consistent fish presence may also indicate a degree of fish passage at BRLD. Therefore, greater uncertainty may exist regarding the anticipated consequences of a fish barrier for fish that are only intermittently surveyed, or that are thought to have only recently arrived above BRLD.

Although improvements in the mussel community of the upper Illinois River have been attributed to improvements in water quality and the rebound of their fish hosts over time (Sietman et al. 2001), the elimination of the only corridor for fish movement, and the glochidia they may be carrying, is anticipated to exclude any new species of mussels from naturally recolonizing the upper Des Plaines River. The DuPage River may again provide a good idea of how mussels might respond to a fish barrier at BRLD. For example, the DuPage River maintains a disparate mussel community of only 5 recently surveyed species (Price et al. 2012), despite its relatively close proximity (6 rkm) to the Dresden Island Nuclear Station on the upper Illinois River, where 25 species of mussels currently exist. As indicated by the inability of multiple species of fish to pass the lowest dam on the DuPage River, a fish barrier at BRLD might be expected to similarly stop upriver fish movement, thereby excluding mussels originating from more species rich downstream locations.

Evidence of fish passage

Comparisons of the fish assemblages above and below BRLD, where upriver passage through the lock chamber is possible, with fish assemblages in the adjacent tributaries where impassable dams are in place (e.g. the DuPage, Kankakee, and Fox Rivers), provides indirect evidence of how the native fishes might be affected. This is particularly evident when contrasting above and below the barrier on the DuPage River with above and below the prosed barrier at BRLD. In the case of the DuPage River, 16 species of fish surveyed below the dam have yet to be surveyed above. However, 13 of these 16 species have been surveyed above BRLD on the Des Plaines River. Additionally, 9 of these 13 species have only been surveyed since 2003 suggesting relatively recent movements above BRLD. Those nine recent arrivals include the moderately intolerant Logperch in 2008 (Grabarkiewicz and Davis 2008) and intolerant Rosyface Shiner in 2013 (Grabarkiewicz and Davis 2008), further suggesting water quality may now be suitable for hosting previously excluded pollution sensitive fishes. In the absence of studies tracking these native fish, these changes in distribution over time strongly suggest the species can pass upriver through BRLD.

Additionally, the total number of lock passages may also be associated with equalizing fish community similarity. On the Monongahela River, PA, a positive relationship was observed between the maximum number of lockages per year (2004 – 2008) at six main stem lock and dams and the degree of similarity (based on Jaccard's coefficient of similarity) in large-bodied fishes sampled above and below

these lock and dams (Argent and Kimmel 2011). The maximum number of lockages per year among the six structures on the Monongahela River varied between approximately 1,700 and 8,100 (Argent and Kimmel 2011). Between 1990 and 2016, the number of lockages at BRLD varied between 2,786 and 4,453 (USACE Navigation Data Center 2018) which falls within the range of lockages thought to facilitate increased community similarity in the Monongahela River.

Although some uncertainty exists regarding fish passage through the lock chamber at BRLD, a diverse array of fishes has been collected in lock chambers from other rivers (Margraf and Knight 2002; Hendrick et al. 2004). For example, twenty-five species were collected from the lock chamber at the Morgantown lock and dam on the Monongahela River, PA, after rotenone application in September of 2003 (Hendrick et al. 2004). The surveyed families included Cyprinidae (11 species), Ictaluridae (3 species), Percidae (3 species), Centrarchidae (2 species) Atherinopsidae (1 species), Catostomidae (1 species), Sciaenidae (1 species), Lepisosteidae (1 species), Moronidae (1 species), and Clupeidae (1 species). Rotenone surveys conducted at the same lock and dam between 1973 and 1990 also indicate additional Centrarchids (7 species), Ictalurids (2 species), a Catostomid (1 species), an Escosid (1 species), and un-classified redhorse and darter species had also been surveyed over time (Weller et al. 1991). The presence of these species in the lock does not automatically imply successful passage. However, combined with the observed positive relationship between maximum number of lockages and fish community similarity above and below locks observed by Argent and Kimmel (2011), it provides incremental information needed to support upriver lock passage as a mechanism facilitating rehabilitation of the fish community above BRLD.

Potential mitigation approach

Current trends in the upper Des Plaines River and other tributaries in the region indicate that fish species richness has improved over time, and that freshwater mussels while present, still require considerable rehabilitation (McClelland et al. 2012, Gibson-Reinemer et al. 2017, Pescitelli 2017). It is noteworthy that there appears to be still more potential for additional fish and mussel rehabilitation in the upper Des Plaines River: many species not currently found in the upper Des Plaines River do occur in downstream tributaries. Thus, the main effect of a proposed ANS barrier will be reducing upriver movement of native fish and by extension preventing further recovery of the fish and mussel assemblages. Ameliorating for the loss of connectivity should be the focus of any potential mitigation efforts.

Uncertainty exists regarding which species of fish inhabiting the upper Des Plaines River might be most at risk of decline or extirpation if a fish barrier were installed at BRLD. Moreover, even less is known about how mussels in this same area might respond. Much of this uncertainty stems from a paucity of direct evidence of successful reproduction and recruitment by the majority of native fishes or mussels in this section of river. This knowledge gap brings into question the sustainability of both communities without access to a downriver source of immigration. There is greater certainty however in the outcome that post ANS barrier implementation at BRLD, fewer new additions of fish or mussel species currently absent from the upper Des Plaines River would be possible via natural movements through the lock.

Prioritizing fish species for mitigation

Confirming reproduction and recruitment trends in over 50 species of native fish inhabiting the upper Des Plaines River may not be feasible on a species by species basis. Therefore, differentiating among species commonly observed, or observed in more than one basin survey spanning five or more years could serve as a starting point. Fish species not commonly observed or only recently observed in the upper Des Plaines River could then be given higher priority as missing or potentially underrepresented

(Pescitelli 2017). In contrast, those species of fish that are successfully spawning and recruiting in the upper Des Plaines River or are poor candidates for hatchery rearing could be prioritized for translocation efforts. While not all species currently raised in the Illinois fish hatchery system are applicable to mitigation efforts on the warm water Des Plaines River, the infrastructure could be used to supplement targeted species for mitigation. Translocation of wild fish immediately after capture to supplement the fish community of the upper Des Plaines River may not be permitted out of concern for unintended transfer of invasive species and disease (K. Irons *personal communication*). A quarantine period for wild fish could be recommended prior to release in the wild and implemented at currently operational hatchery systems in Illinois.

Mitigation for freshwater mussels

There are relatively few documented instances of successful freshwater mussel mitigation. Often, reducing fragmentation and habitat restoration are noted as less expensive and more successful steps towards long-term rehabilitation of mussel populations (Haag and Williams 2014). However, hatchery propagation and release of mussels has been successful in the past. For example, Neves (2004) notes the successful propagation and release of nine species of endangered freshwater mussels in Tennessee and Virginia. Prioritizing mussel species for rehabilitation may be contingent on ensuring host fish are successfully reproducing, or for which mitigation is planned to occur. As such, attempts could be made to infest either quarantined wild fish or hatchery produced fish with glochidia from target mussel species. Given the potentially low success rate of laboratory fish infestation resulting in subsequent juvenile transformation in the wild, longer and intensive rearing of mussels to juveniles prior to release is another option (D. Shasteen *personal communication*). Our query of mussel host data revealed a paucity of information regarding the species of mussels many fish may serve as hosts for under natural conditions (INHS-FMHD 2018). Any wild fish taken with the purpose of eventual translocation (post quarantine) could opportunistically be surveyed for natural infestation of mussel glochidia. Such work could help close knowledge gaps regarding mussel host relationships and may help identify mussels most likely to have been transported naturally upriver of BRLD prior to barrier establishment.

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Appendix 1. Estimated costs associated with nine dam removals on the main stem Des Plaines River. Removals were carried out through collaborations with the IDNR, USACE, Forest Preserves of Cook County, and the Lake County Forest Preserve District.

Watershed	**Waterbody**	**Dam Name**	**Removal Cost**
Des Plaines River	Des Plaines River	Ryerson Dam	$397,727
Des Plaines River	Des Plaines River	Armitage Avenue Dam	$402,991
Des Plaines River	Des Plaines River	Fairbanks Avenue Dam	$400,000
Des Plaines River	Des Plaines River	Hoffman Dam	$2,500,000
Des Plaines River	Des Plaines River	Dam No. 2	$153,000
Des Plaines River	Des Plaines River	Dam No.1	$186,000
Des Plaines River	Des Plaines River	Wright Woods / Dam No.1A	$457,517
Des Plaines River	Des Plaines River	MacArther Woods/ Dam No.1B	$457,517
Des Plaines River	Des Plaines River	Dempster Street	$274,990
Des Planies River	Seavey Ditch	Golf Coarse Dam	$60,000
Des Plaines River	East Branch DuPage River	Churchill Woods	$1,062,000
Des Planies River	West Branch DuPage River	Warrenville Dam	$1,036,000
Des Planies River	West Branch DuPage River	McDowell Grove Dam	$1,427,540
		Dam Removal Costs	**$8,815,282**

Appendix 2. Estimated costs associated with additional habitat improvements and rehabilitation efforts in the upper Des Plaines River watershed. Habitat improvements and rehabilitation were carried out through collaborations with the IDNR, Forest Preserves of Cook County, and the Lake County Forest Preserve District.

Location	Adjacent Waterbody	Efforts	Cost
Des Plaines River watershed	Des Plaines River	IDNR willow plantings	$15,000
Santa Fe Prairie	Des Plaines River	IDNR rock bar habitat installation	$36,505
Lake County Forest Preserve District	Des Plaines River	Des Plaines River woodland restoration, flatwood and vernal pool inundation and water retention	$2,300,000
	Thorngate Creek, Des Plaines River triburary	Step pool structure installation and stabilization	$320,000
	Stoneroller Creek, Des Plaines River tributary	Creek stabilization	$425,000
	Unnamed tributary to Des Plaines River (Wright Woods Forest Preserve)	Creek stabilization	$75,000
	North Mill Creek, Des Plaines River tributary	Dam removal, stream channel and riparian habitat restoration	$4,200,000
Forest Preserves of Cook County	Des Plaines River (Portwine Woods)	Tree removal and brush clearing, native sedge, grass, and wildflower restoration	$1,100,000
	Salt Creek, Des Plaines River tributary (Bemis Woods)	Invasive species control, prescribed fire (2017)	$749,000
	Des Plaines River (Black Partridge Woods)		
	Salt Creek, Des Plaines River tributary (Brookfield Woods)		
	Salt Creek, Des Plaines River tributary (Busse Woods)		
	Des Plaines River (Cermak Woods)		
	Des Plaines River (Dam 1 Woods)		
	Buffalo Creek, Des Plaines River tributary (Deer Grove West)		
	Buffalo Creek, Des Plaines River tributary (Jens Jensen)		
	Des Plaines River (G.A.R. Woods)		
	Des Plaines River (Kloempken)		
	Des Plaines River (Lake Avenue Woods)		
	Des Plaines River (McCormick Woods)		
	Des Plaines River (River Trail Nature Center)		
	Des Plaines River (Robinson Woods)		
	Salt Creek, Des Plaines River tributary, (Salt Creek Nature Preserve)		
	Des Plaines River (Schiller Woods)		
	Des Plaines River (Thatcher Woods)		
	Salt Creek, Des Plaines River tributary (Wolf Road Paririe)		
	Buffalo Creek, Des Plaines River Tributary (Deer Grove)	Tree removal, shrub clearing, invasive species monitoring and clearing, hydrology repairs	$3,000,000
		Additional Habitat Improvement Costs	**$12,220,505**

Appendix 3. River specific fish sampling effort, gear, and station summaries for the Des Plaines, DuPage, Kankakee, and Fox Rivers carried out during IDNR-DF basin surveys.

River	Year	Site	River segment	Gear	Effort
DuPage River	1983	GB-01	Lower	1BE	45
DuPage River	1983	GB-11	Middle	1BE	40
DuPage River	1997	GB-01	Lower	1BE	30
DuPage River	1997	GB-11	Middle	1BE	35
DuPage River	2002	GB-11	Middle	1BE	60
DuPage River	2003	GB-01	Lower	1BE	30
DuPage River	2008	GB-01	Lower	1BE/1SH	60/na
DuPage River	2008	GB-11	Middle	1BE/1SH	60/na
DuPage River	2013	GB-01	Lower	1BE/2BE/1SH	30/30/na
DuPage River	2013	GB-11	Middle	1BE	60
Fox River	1996	DT-46	Lower	1BE	60
Fox River	1996	DT-36, 03, 69, 06, 22	Middle	1BE/2BE	30/30
Fox River	1996	DT-09	Middle	1BE/2BE	25/40
Fox River	2002	DT-36, 03, 69, 09, 06, 22	Middle	1BE/2BE/1SH	30/30/na
Fox River	2007	DT-46	Lower	1BE/2BE/1SH	30/30/na
Fox River	2007	DT-36, 03, 69, 09	Middle	1BE/2BE/1SH	30/30/na
Fox River	2007	DT-03, 22	Middle	1BE/2BE	30/30
Fox River	2007	DT-51, 23, 35	Upper	1BE/2BE	30/30
Fox River	2012	DT-46	Lower	1BE/2BE/1SH	30/30/na
Fox River	2012	DT-36, 03, 69, 09, 22	Middle	1BE/2BE/1SH	30/30/na
Fox River	2012	DT-06	Middle	1BE/2BE/1SH/2SH	30/30/na/na
Fox River	2007	DT-51, 23, 35	Upper	1BE/2BE/1SH	30/30/na
Kankakee River	1994	F-01	Lower	1BE	60
Kankakee River	1994	F-11	Lower	1BE/1SH	60/na
Kankakee River	1994	F-14	Lower	1BE/1SH	30/na
Kankakee River	1994	F-04, 07, 08, 12, 13	Middle	1BE/1SH	60/na
Kankakee River	1994	F-02, 03, 06, 09, 15	Upper	1BE/1SH	60/na
Kankakee River	2000	F-01, 14	Lower	1BE/2BE/1PE/1SH	30/30/30/na
Kankakee River	2000	F-11	Lower	1BE/1PE/1SH	30/30/na
Kankakee River	2000	F-04, 07, 08, 13	Middle	1BE/2BE/1PE/1SH	30/30/30/na
Kankakee River	2000	F-12	Middle	1BE/2BE/1PE/1SH	30/30/38.66/na
Kankakee River	2000	F-02, 06, 15	Upper	1BE/2BE/1PE/1SH	30/30/30/na
Kankakee River	2000	F-03	Upper	1BE/2BE/1PE/1SH	30/20/38.5/na
Kankakee River	2000	F-09	Upper	1BE/2BE/1PE/1SH	35/30/33.33/na
Kankakee River	2005	F-01, 11, 14	Lower	1BE/2BE/1PE/1SH	30/30/15/na
Kankakee River	2005	F-04, 07, 08, 12, 13	Middle	1BE/2BE/1PE/1SH	30/30/15/na
Kankakee River	2005	F-02, 03, 06, 09, 15	Upper	1BE/2BE/1PE/1SH	30/30/15/na
Kankakee River	2010	F-01, 11, 14	Lower	1BE/2BE/1SH	30/30/na
Kankakee River	2010	F-04, 07, 08, 12, 13	Middle	1BE/2BE/1SH	30/30/na
Kankakee River	2010	F-02, 03, 06, 09, 15	Upper	1BE/2BE/1SH	30/30/na

Appendix 3. (cont.)

River	Year	Site	River segment	Gear	Effort
Des Plaines River	1983	G-12	Lower	1BE	60
Des Plaines River	1983	G-03, 08, 18, 24, 30, 32	Upper	1BE	60
Des Plaines River	1983	G-07, 11, 33, 36	Upper	1BE	30
Des Plaines River	1983	G-25, 26, 34	Upper	1SH	.
Des Plaines River	1983	G-28, 35	Upper	1BE	45
Des Plaines River	1997	G-07, 28, 35	Upper	1BE	35
Des Plaines River	1997	G-08	Upper	1ES	14
Des Plaines River	1997	G-11	Upper	1BE	60
Des Plaines River	1997	G-18	Upper	1BE/1SH	30/na
Des Plaines River	1997	G-25	Upper	1BE	24
Des Plaines River	1997	G-33	Upper	1BE	30
Des Plaines River	2003	G-05	Upper	1BE	40
Des Plaines River	2003	G-06	Upper	1BE/1PE	30/30
Des Plaines River	2003	G-07, 11, 18, 25	Upper	1BE/2BE/1SH	30/30/na
Des Plaines River	2003	G-08	Upper	1ES	15
Des Plaines River	2003	G-14	Upper	1BE	45
Des Plaines River	2003	G-15, 16, 38, 39, 45	Upper	1BE	30
Des Plaines River	2003	G-30	Upper	1BE	20/23*
Des Plaines River	2003	G-33	Upper	1BE/2BE/1SH	30/23/na
Des Plaines River	2003	G-35	Upper	1BE/2BE/1SH	30/20/na
Des Plaines River	2003	G-46	Upper	1BE/1SH	30/na
Des Plaines River	2008	G-02, 33	Upper	1BE/1SH	60/na
Des Plaines River	2008	G-03	Upper	1BE/2BE	30/30
Des Plaines River	2008	G-07, 25, 35	Upper	1BE	60
Des Plaines River	2008	G-08	Upper	1ES	42
Des Plaines River	2008	G-11	Upper	1BE/1SH	60/na
Des Plaines River	2008	G-18	Upper	1BE/2BE/1SH	30/30/na
Des Plaines River	2008	G-01	Lower	1BE/2BE	30/30
Des Plaines River	2008	G-12	Lower	1BE/1SH	30/na
Des Plaines River	2013	G-01	Lower	1BE/2BE	30/30
Des Plaines River	2013	G-12	Lower	1BED	60
Des Plaines River	2013	G-25, 07, 35, 15, 30, 33, 18, 03)	Upper	1BE/1SH	60/na
Des Plaines River	2013	G-96	Upper	1BE	30
Des Plaines River	2013	G-06	Upper	1BE/1SH	40/na
Des Plaines River	2013	G-36	Upper	1BE/1SH	45/na
Des Plaines River	2013	G-38, 44, 01	Upper	1BE	60
Des Plaines River	2013	G-02	Upper	1BE/1SH	55/na
Des Plaines River	2013	G-11	Upper	1BE/1SH	50/na

*Two effort values reported under one gear designation.

Appendix 4. Cumulative fish species richness across all sampling periods as denoted in Appendix 3.

Species	Des Plaines River	DuPage River	Kankakee River	Fox River	Species	Des Plaines River	DuPage River	Kankakee River	Fox River
American brook lamprey			X		Mooneye			X	X
American eel			X		Mosquitofish	X		X	
Banded darter		X	X	X	Muskellunge	X			X
Banded killifish	X				Northern hog sucker		X	X	X
Bigmouth buffalo	X		X		Northern pike	X	X	X	X
Bigmouth shiner	X	X		X	Orangespotted sunfish	X	X	X	X
Black buffalo			X	X	Pirate perch			X	
Black bullhead	X	X	X	X	Pugnose minnow				X
Black crappie	X	X	X	X	Pumpkinseed	X	X	X	X
Black redhorse		X	X	X	Quillback	X	X	X	X
Blackchin shiner	X				Rainbow darter			X	
Blacknose dace			X	X	Red shiner	X	X	X	
Blackside darter	X	X	X	X	Redear sunfish	X		X	
Blackstripe topminnow	X	X	X	X	Redfin shiner	X	X	X	
Bluegill	X	X	X	X	River carpsucker	X	X	X	X
Bluntnose darter			X		River redhorse		X	X	X
Bluntnose minnow	X	X	X	X	Rock bass	X	X	X	X
Bowfin	X		X	X	Rosyface shiner	X		X	X
Brook silverside	X		X	X	Round goby	X		X	
Brown bullhead			X		Sand shiner	X	X	X	X
Bullhead minnow	X		X	X	Sauger	X		X	X
Common carp	X	X	X	X	Shorthead redhorse	X	X	X	X
Central mudminnow	X	X	X		Shortnose gar			X	X
Central stoneroller	X	X	X	X	Silver carp				X
Channel catfish	X	X	X	X	Silver redhorse	X	X	X	X
Common shiner	X	X	X	X	Silverjaw minnow			X	
Creek chub	X	X	X	X	Skipjack herring			X	X
Creek chubsucker			X		Slenderhead darter			X	X
Emerald shiner	X	X	X	X	Smallmouth bass	X	X	X	X
Fantail darter			X		Smallmouth buffalo	X	X	X	X
Fathead minnow	X	X	X	X	Spotfin shiner	X	X	X	X
Flathead catfish	X	X	X	X	Spottail shiner	X	X	X	X
Freshwater drum	X	X	X	X	Spotted sucker	X		X	
Gizzard shad	X	X	X	X	Starhead topminnow			X	X
Golden redhorse	X	X	X	X	Steelcolor shiner			X	
Golden shiner	X	X	X	X	Stonecat	X	X	X	X
Goldeye			X		Striped shiner	X	X	X	X
Goldfish	X	X	X	X	Suckermouth minnow	X	X	X	X
Grass carp	X			X	Tadpole madtom	X		X	X
Grass pickerel	X		X	X	Threadfin shad	X		X	
Green sunfish	X	X	X	X	Trout perch			X	
Highfin carpsucker			X	X	Walleye	X	X	X	X
Hornyhead chub	X	X	X	X	Warmouth	X		X	X
Iowa darter	X				Weed shiner			X	
Ironcolor shiner			X		White bass	X		X	X
Johnny darter	X	X	X	X	White crappie	X		X	X
Lake chubsucker			X		White perch			X	
Largemouth bass	X	X	X	X	White sucker	X	X	X	X
Logperch	X	X	X	X	Yellow bass	X			X
Longear sunfish	X	X	X		Yellow bullhead	X	X	X	X
Longnose gar	X	X	X	X	Yellow perch	X	X		X
Mimic shiner	X	X	X	X	**TOTALS**	**73**	**55**	**93**	**74**

Appendix 5. Mussel fish-host relationships documented for the 32 mussel species and 109 fish species (hybrids included) surveyed throughout the Des Plaines, DuPage, Kankakee, and Fox Rivers. Relationships identified using the Illinois Natural History Survey Freshwater Mussel Host Database. Grey highlighted cells indicate mussel fish-host relationships where either natural infestation or natural transformation was noted in the database.

	Freshwater Mussels																																
Fish Species (common name)	**Black Sandshell** (*Ligumia recta*)	**Creeper** (*Strophitus undulatus*)	**Deertoe** (*Truncilla truncata*)	**Elktoe** (*Alasmidonta marginata*)	**Ellipse** (*Venustaconcha ellipsiformis*)	**Fatmucket** (*Lampsilis siliquoidea*)	**Fawnsfoot** (*Truncilla donaciformis*)	**Flutedshell** (*Lasmigona costata*)	**Fragile Papershell** (*Leptodea fragilis*)	**Giant Floater** (*Pyganodon grandis*)	**Hickorynut** (*Obovaria olivaria*)	**Lilliput** (*Toxolasma parvum*)	**Mapleleaf** (*Quadrula quadrula*)	**Monkeyface** (*Quadrula metanevra*)	**Mucket** (*Actinonaias ligamentina*)	**Paper Pondshell** (Utterbackia imbecillis)	**Pimpleback** (*Amphinaias pustulosa*)	**Pink Heelsplitter** (*Potamilus alatus*)	**Pink Papershell** (*Potamilus ohiensis*)	**Pistolgrip** (*Tritogonia verrucosa*)	**Plain Pocketbook** (*Lampsilis cardium*)	**Purple Wartyback** (*Cyclonaias tuberculata*)	**Rock Pocketbook** (*Arcidens confragosus*)	**Round Pigtoe** (*Pleurobema sintoxia*)	**Sheepnose** (*Plethobasus cyphyus*)	**Spike** (*Elliptio dilatata*)	**Threehorn Wartyback** (*Obliquaria reflexa*)	**Threeridge** (*Amblema plicata*)	**Wabash Pigtoe** (*Fusconaia flava*)	**Washboard** (*Megalonaias nervosa*)	**White Heelsplitter** (*Lasmigona complanata*)	**Yellow Sandshell** (*Lampsilis teres*)	**Potential # of Mussel Species Hosted**
American brook lamprey																																	0
American eel	X							X							X								X		X				X			6
Banded darter		X			X			X																	X							4
Banded killifish	X			X				X		X					X	X							X		X	X				X		10
Bigmouth buffalo								X																									1
Bigmouth shiner																																	0
Black buffalo																																	0
Black bullhead		X						X									X			X		X							X				6
Black crappie	X	X				X		X		X					X	X					X					X		X	X	X	X	X	14
Black redhorse																												X					1
Blackchin shiner										X																							1
Blacknose dace		X								X				X	X										X	X							6
Blackside darter		X			X			X																			X						4
Blackstripe topminnow																																	0
Bluegill	X	X				X		X		X		X		X	X	X					X				X		X		X	X	X		X	16
Bluegill x Green sunfish hybrid																																	0
Bluntnose darter																																	0
Bluntnose minnow		X				X		X		X				X											X	X							7
Bowfin								X																						X			2
Brook silverside										X																							1
Brown bullhead		X						X									X			X										X			5
Bullhead minnow								X																		X							2
Carp	X							X		X					X								X								X		6
Carp x Goldfish hybrid																																	0
Central mudminnow		X						X															X										3
Central stoneroller	X	X						X		X				X	X									X	X					X			9
Channel catfish		X						X					X			X	X			X		X	X					X		X			10
Common shiner		X		X		X		X		X				X										X	X			X					9
Creek chub		X		X				X		X				X	X	X				X			X	X	X				X				12
Creek chubsucker																																	0

Appendix 5. (cont.)

	Freshwater Mussels																															
Fish Species (common name)	**Black Sandshell** (*Ligumia recta*)	**Creeper** (*Strophitus undulatus*)	**Deertoe** (*Truncilla truncata*)	**Elktoe** (*Alasmidonta marginata*)	**Ellipse** (*Venustaconcha ellipsiformis*)	**Fatmucket** (*Lampsilis siliquoidea*)	**Fawnsfoot** (*Truncilla donaciformis*)	**Flutedshell** (*Lasmigona costata*)	**Fragile Papershell** (*Leptodea fragilis*)	**Giant Floater** (*Pyganodon grandis*)	**Hickorynut** (*Obovaria olivaria*)	**Lilliput** (*Toxolasma parvum*)	**Mapleleaf** (*Quadrula quadrula*)	**Monkeyface** (*Quadrula metanevra*)	**Mucket** (*Actinonaias ligamentina*)	**Paper Pondshell** (Utterbackia imbecillis)	**Pimpleback** (*Amphinaias pustulosa*)	**Pink Heelsplitter** (*Potamilus alatus*)	**Pink Papershell** (*Potamilus ohiensis*)	**Pistolgrip** (*Tritogonia verrucosa*)	**Plain Pocketbook** (*Lampsilis cardium*)	**Purple Wartyback** (*Cyclonaias tuberculata*)	**Rock Pocketbook** (*Arcidens confragosus*)	**Round Pigtoe** (*Pleurobema sintoxia*)	**Sheepnose** (*Plethobasus cyphyus*)	**Spike** (*Elliptio dilatata*)	**Threehorn Wartyback** (*Obliquaria reflexa*)	**Threeridge** (*Amblema plicata*)	**Wabash Pigtoe** (*Fusconaia flava*)	**Washboard** (*Megalonaias nervosa*)	**White Heelsplitter** (*Lasmigona complanata*)	**Yellow Sandshell** (*Lampsilis teres*)	**Potential # of Mussel Species Hosted**
Emerald shiner					**X**			X																				**X**					1
Fantail darter		X			**X**			X																									3
Fathead minnow		X						X						X											X								4
Flathead catfish		X						X					**X**				**X**			X		**X**				**X**		X		**X**			9
Freshwater drum			**X**				**X**	X	**X**	**X**								**X**	**X**				**X**				X	**X**		**X**			11
Gizzard shad								**X**		**X**													**X**			**X**	X			**X**	**X**		7
Golden redhorse				X																								**X**					2
Golden shiner		X		X				**X**		X													X		X	X			X			8
Goldeye																											**X**			X			2
Goldfish								X		X						X																	3
Grass carp																																	0
Grass pickerel																																	0
Green sunfish	X	X				X		X		**X**		X		**X**	**X**	X					X		X			X		X		X	X	**X**	16
Highfin carpsucker																																X	1
Hornyhead chub				X				X						X											X								4
Iowa darter		X			X					**X**																X							4
Ironcolor shiner																																	0
Johnny darter		X			**X**			X		**X**		X														X							6
Lake chubsucker																																	0
Largemouth bass	X	X				X		X		**X**					**X**	X					X					X		**X**	X	X	X	**X**	14
Logperch		X			X			X																		X		**X**		X			6
Longear sunfish	X	X				X		X		X						X														X	X		8
Longear sunfish x Bluegill hybrid																																	0
Longnose gar								X		X																X				**X**	**X**	**X**	6
Mimic shiner								X																	X								2
Mooneye																												**X**					1
Mosquitofish (WESTERN)								X								**X**				**X**					X								4
Muskellunge																																	0
Northern hog sucker				**X**				X																				**X**					3
Northern pike								X																		X		**X**					3
Orangespotted sunfish	X							X		X		X			X								X								X	**X**	8
Pirate perch								X																									1
Pugnose minnow																																	0
Pumpkinseed	X	X				**X**		X		X						X					X					X		**X**	X				10
Quillback				X				X															X										3

Appendix 5. (cont.)

	Freshwater Mussels																															
Fish Species (common name)	**Black Sandshell** (*Ligumia recta*)	**Creeper** (*Strophitus undulatus*)	**Deertoe** (*Truncilla truncata*)	**Elktoe** (*Alasmidonta marginata*)	**Ellipse** (*Venustaconcha ellipsiformis*)	**Fatmucket** (*Lampsilis siliquoidea*)	**Fawnsfoot** (*Truncilla donaciformis*)	**Flutedshell** (*Lasmigona costata*)	**Fragile Papershell** (*Leptodea fragilis*)	**Giant Floater** (*Pyganodon grandis*)	**Hickorynut** (*Obovaria olivaria*)	**Lilliput** (*Toxolasma parvum*)	**Mapleleaf** (*Quadrula quadrula*)	**Monkeyface** (*Quadrula metanevra*)	**Mucket** (*Actinonaias ligamentina*)	**Paper Pondshell** (Utterbackia imbecillis)	**Pimpleback** (*Amphinaias pustulosa*)	**Pink Heelsplitter** (*Potamilus alatus*)	**Pink Papershell** (*Potamilus ohiensis*)	**Pistolgrip** (*Tritogonia verrucosa*)	**Plain Pocketbook** (*Lampsilis cardium*)	**Purple Wartyback** (*Cyclonaias tuberculata*)	**Rock Pocketbook** (*Arcidens confragosus*)	**Round Pigtoe** (*Pleurobema sintoxia*)	**Sheepnose** (*Plethobasus cyphyus*)	**Spike** (*Elliptio dilatata*)	**Threehorn Wartyback** (*Obliquaria reflexa*)	**Threeridge** (*Amblema plicata*)	**Wabash Pigtoe** (*Fusconaia flava*)	**Washboard** (*Megalonaias nervosa*)	**White Heelsplitter** (*Lasmigona complanata*)	**Yellow Sandshell** (*Lampsilis teres*)	**Potential # of Mussel Species Hosted**
Rainbow darter		X			**X**			X		**X**														X							5
Red shiner	X							X		X				X										X	X		**X**				7
Red shiner x Spotfin shiner hybrid																															0
Redear sunfish								X																							1
Redfin shiner	X									X																					2
River carpsucker				X																											1
River redhorse								**X**																						**X**		2
Rock bass	X	X		X		X		X		**X**					X	X							**X**			X		X			X	12
Rosyface shiner	X																															1
Round goby	X					X				X					X																	4
Sand shiner		X				X																										2
Sauger	X		**X**			X	**X**	X						**X**	**X**						**X**			**X**	**X**		**X**		X	**X**		13
Shorthead redhorse				**X**				X															X									3
Shortnose gar																												X			**X**	2
Silver carp																																0
Silver redhorse				X				X																								2
Silverjaw minnow															X												X					2
Skipjack herring										**X**																	**X**			**X**		3
Slenderhead darter		X						X																		X			X			4
Smallmouth bass		X				X		X							**X**						X					X						6
Smallmouth buffalo				X																			X									2
Spotfin shiner		X						X						X		X								**X**	X			**X**	**X**			8
Spottail shiner								X																	X							2
Spotted sucker																																0
Starhead topminnow																																0
Steelcolor shiner								X						X											X			**X**				4
Stonecat								X																								1
Striped bass x White bass hybrid (Wiper)																																0
Striped shiner				X		X		X		**X**				X									X		X		X					8
Suckermouth minnow																									X							1
Tadpole madtom						**X**									**X**															**X**		3
Threadfin shad																																0
Trout-perch								X																								1

Appendix 5. (cont.)

	Freshwater Mussels																																
Fish Species (common name)	**Black Sandshell** (*Ligumia recta*)	**Creeper** (*Strophitus undulatus*)	**Deertoe** (*Truncilla truncata*)	**Elktoe** (*Alasmidonta marginata*)	**Ellipse** (*Venustaconcha ellipsiformis*)	**Fatmucket** (*Lampsilis siliquoidea*)	**Fawnsfoot** (*Truncilla donaciformis*)	**Flutedshell** (*Lasmigona costata*)	**Fragile Papershell** (*Leptodea fragilis*)	**Giant Floater** (*Pyganodon grandis*)	**Hickorynut** (*Obovaria olivaria*)	**Lilliput** (*Toxolasma parvum*)	**Mapleleaf** (*Quadrula quadrula*)	**Monkeyface** (*Quadrula metanevra*)	**Mucket** (*Actinonaias ligamentina*)	**Paper Pondshell** (Utterbackia imbecillis)	**Pimpleback** (*Amphinaias pustulosa*)	**Pink Heelsplitter** (*Potamilus alatus*)	**Pink Papershell** (*Potamilus ohiensis*)	**Pistolgrip** (*Tritogonia verrucosa*)	**Plain Pocketbook** (*Lampsilis cardium*)	**Purple Wartyback** (*Cyclonaias tuberculata*)	**Rock Pocketbook** (*Arcidens confragosus*)	**Round Pigtoe** (*Pleurobema sintoxia*)	**Sheepnose** (*Plethobasus cyphyus*)	**Spike** (*Elliptio dilatata*)	**Threehorn Wartyback** (*Obliquaria reflexa*)	**Threeridge** (*Amblema plicata*)	**Wabash Pigtoe** (*Fusconaia flava*)	**Washboard** (*Megalonaias nervosa*)	**White Heelsplitter** (*Lasmigona complanata*)	**Yellow Sandshell** (*Lampsilis teres*)	**Potential # of Mussel Species Hosted**
Walleye	X	X				**X**		X							**X**								X			X	X						1
Walleye x Sauger hybrid (Saugeye)																																	1
Warmouth				**X**		**X**						**X**				**X**												**X**		**X**		**X**	1
Weed shiner																				**X**													1
White bass						X				**X**					**X**													**X**		**X**			1
White crappie	**X**	X				**X**				**X**		X			**X**		**X**		**X**		**X**		**X**			**X**		**X**	**X**	X	X	**X**	1
White perch	X																																1
White sucker				**X**				**X**															X								X		1
Yellow bass																																	1
Yellow bullhead		X						X		**X**										X		X								X			1
Yellow perch	X	X				**X**		X		**X**					**X**	X					X					X		X		X	X	X	1
Number of potential host species	**4**	**4**	**0**	**2**	**0**	**5**	**0**	**4**	**0**	**4**	**0**	**2**	**0**	**0**	**4**	**2**	**1**	**0**	**1**	**2**	**3**	**1**	**3**	**0**	**0**	**3**	**1**	**4**	**1**	**5**	**3**	**3**	1
Number of hosts displaying NI and/or NT	**3**	**2**	**2**	**4**	**4**	**9**	**2**	**4**	**1**	**22**	**0**	**2**	**1**	**3**	**11**	**4**	**4**	**1**	**2**	**2**	**3**	**1**	**5**	**2**	**1**	**5**	**2**	**20**	**4**	**11**	**4**	**8**	1