

Risk and Consequence Analysis Focused on Biota Transfers Potentially Associated with Surface Water Diversions Between the Missouri River and Red River Basins: Appendices

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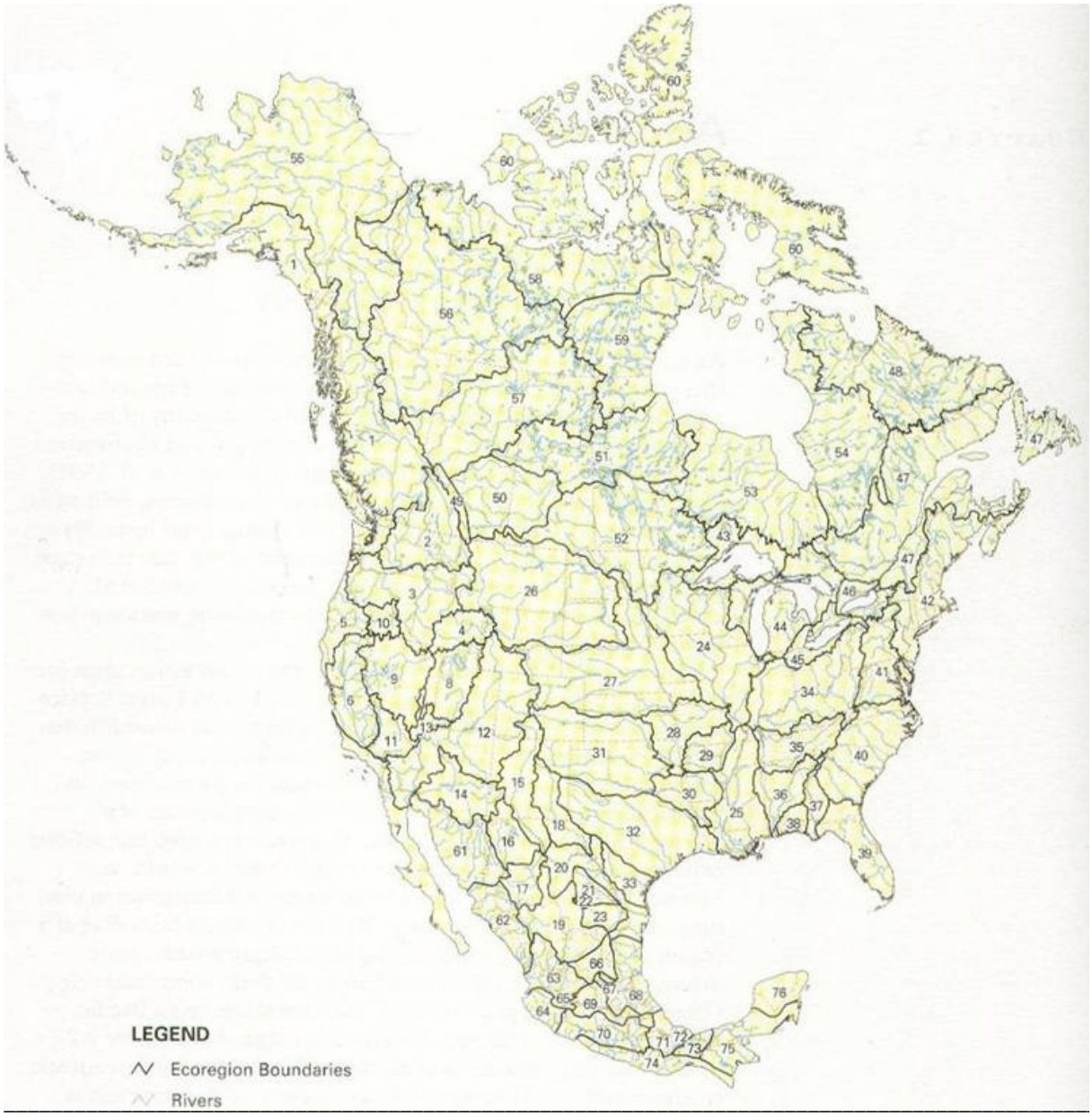
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Appendix 1. HUCs (2-digit and 4-digit) of particular interest in the evaluation of biota transfers between Missouri River and Red River basins. Not all subregions are listed for each region, but these subregions represent those most closely associated (spatially) with geographic locations likely serving as routes of entry (see http://water.usgs.gov/GIS/huc.html; NRC 1999).

Region	Subregion	Name or comment
Region 09		Souris-Red-Rainy basin
	Subregion 0901	Subregion includes the Souris River basin within North Dakota
	Subregion 0902	Subregion includes Red River basin within Minnesota, North Dakota, and South Dakota (including the closed basin of Devils Lake)
Region 10		Missouri River basin includes the drainage of the Missouri River basin, the Saskatchewan River basin (into Lake Winnipeg), and several small closed basins within the area
	Subregion 1003	Missouri-Marias subregion consists of the Missouri River basin below the confluence of the Gallatin, Jefferson, and Madison River basins to and including the Marias River basin of Montana
	Subregion 1006	Missouri-Poplar subregion covers the drainage from Fort Peck Dam to the confluence with the Yellowstone River basin in western Montana
	Subregion 1011	Missouri-Little Missouri subregion occurs below the confluence with Yellowstone River basin and extends to Garrison Dam, including Lake Sakakawea
	Subregion 1012	Sheyenne River subregion occurs above the normal operating pool of Lake Oahe and includes drainage in Montana, Nebraska, South Dakota, Wyoming
	Subregion 1013	Missouri-Oahe subregion of North Dakota and South Dakota includes the Missouri River basin from Garrison Dam to Oahe Dam, excluding the Sheyenne River basin above the normal operating pool of Lake Oahe
	Subregion 1014	Missouri-White subregion includes the basin from Oahe Dam to Fort Randall Dam within South Dakota and Nebraska
	Subregion 1015	Subregion includes Niobrara River basin and Ponca Creek basin of Nebraska, South Dakota, and Wyoming

Region	Subregion	Name or comment
	Subregion 1016	Subregion includes James River basin of North Dakota and South Dakota
	Subregion 1017	Subregion includes Missouri-Big Sioux basin (Missouri River basin from Fort Randall Dam to and including the Big Sioux River basin, but excluding the Ponca Creek, Niobrara River, and James River basins which includes portions of Iowa, Minnesota, Nebraska, South Dakota)
	Subregion 1018	Subregion includes North Platte River basin of Colorado, Nebraska, Wyoming
	Subregion 1019	Subregion includes South Platte River basin of Colorado, Nebraska, Wyoming
	Subregion 1020	Subregion includes Platte River basin below the confluence of the North and South Platte River basins, excluding the Elkhorn and Loup River Basins of Nebraska
	Subregion 1021	Subregion includes Loup River basin of Nebraska
	Subregion 1022	Subregion includes Elkhorn River basin of Nebraska
	Subregion 1023	Missouri-Little Sioux subregion which in Minnesota, Iowa, and Nebrasks and occupies the Missouri River basin below the confluence with the Big Sioux River basin to the confluence with the Platte River basin
	Subregion 1024	Missouri-Nishnabotna subregion of Iowa, Kansas, Missouri, and Nebraska which occurs below the confluence with the Platte River Basin to the confluence with the Kansas River Basin
	Subregion 1025	Republican River Basin of Colorado, Kansas, Nebraska
	Subregion 1026	Smoky Hill River Basin of Colorado and Kansas
	Subregion 1027	Kansas River basin of Kansas, Nebraska, and Missouri, excluding the Republican and Smoky Hill River basins
	Subregion 1028	Chariton, Grand, and Little Chariton River basins of Iowa and Missouri
	Subregion 1029	Gasconade-Osage subregion, which includes the Gasconade and Osage River basins of Kansas and Missouri
	Subregion 1030	Lower Missouri River basin which occurs in Kansas and Missouri below the confluence with the Kansas River Basin to the confluence with the Mississippi River, excluding the Chariton, Gasconade, Grand, and Osage River basins

Appendix 2. Aquatic ecoregions of North America (after Abell *et al*., 2000). HUCs identified in Figure 2 are defined hydrologically and spatially linked to ecoregions based on aquatic resources as detailed in (Abell, et al. 2000) where 2-digits HUCs of particular concern to this analysis (HUC 10 and HUC 09) occur within aquatic ecoregions identified as Mississippi (24), Upper Missouri (26), Middle Missouri (27), and English-Winnipeg Lakes (52).



Appendix 3A. Brief life histories for biota of concern: Aquatic invertebrates, fishes, and plants

Life history attributes are critical to the analysis and characterization of risk associated with biota transfers, be those biological invasions or shifts in metapopulations that are potentially influenced by interbasin water diversions. While a comprehensive characterization of life history for each biota of concern is precluded by the scope of this investigation and number of biota of concern identified during problem formulation, the life histories that follow are focused on invasive attributes, historical accounts of past invasions, and the current distribution of the species. Existing literature sources in the scientific literature and peer-reviewed public domain provide ample background on each species of interest to the current investigation, with natural resource agencies and the applied research community having disseminated a wealth of data and information for use in these initial investigations of risks associated with biota transfers potentially resulting from interbasin water diversions.

An ability to successfully translocate and accommodate to "new territory" is highly variable across species. Invasiveness depends on attributes related to physiological tolerance, and morphological and behavioral traits that directly or indirectly influence reproductive fitness of the species, thus enabling a species to establish and maintain sustainable populations in a region outside its current distribution. So called, "pioneer species" and invasive species share many of the same, if not identical attributes. Successful expansion of a species' distribution reflects an interrelated multi-step process regardless of whether that distribution expansion results from a "jump dispersal" event common to species invasions mediated directly or indirectly by "hitchhiking," e.g., involving anthropogenic or human cultural means to aid dispersal, or whether that expansion occurs without anthropogenic influences through diffusive mechanisms at the perimeter of existing distributions. Throughout many accounts of species movements and invasions, common attributes have been identified that characterize species as being "invasive" (see, e.g., Elton 1958 for early observations focused on invasive species). For example, Kolar and Lodge (2002) have characterized successful invasions as results of a complex adaptive process or series of events whose outcomes simplify to dependence on (1) transport, (2) establishment, and (3) demographic expansion. While these constituent processes of transport, establishment, and demographic expansion may be decomposed into many interrelated events, such a simplification of the invasion process serves the current investigation and helped focus the data mining activities summarized in the main body of this report and the appendices.

USGS/BRD recognizes the increasing awareness of invasive species and magnitude that species invasions may have on natural resources under the purview of Department of Interior (e.g., Bureau of Land Management, Bureau of Reclamation, National Park Service, and U.S. Fish and Wildlife Service). Invasive species threaten the nation's lands and waterways owing to the adverse effects organisms have on native plants and animals, ecosystems, and the collateral economic effects associated with species invasions (see, e.g., Perrings et al 2000 for overview). The wide range of habitats within the US, and the increased trade and commerce between states and with other countries having similar habitats and ecoregions provides many potential sources and pathways for movements (accidental and intentional) and introductions of biota to areas previously outside a species' distribution.

Invasive species, once established outside their native ecosystems, or repeated, sporadic invasions that may be long-term failures, may play a critical role in the invaded system's structure and function (e.g., sporadic outbreaks of emerging infectious disease may have population-level impacts). Invasive species may be of foreign (exotic species) or domestic origin, with the primary operational attributes shared by these species being their ability to become established in habitats outside their native range. As reflected in the current investigation focused on biota that may be introduced to previously uncharted locations through water diversions, all taxonomic groups – microbes, plants, and animals – include members whose life history attributes favor their being characterized as invasive species. Similar to attributes of invasives that cross-cut many phyla, some ecosystems in the U.S. appear more threatened by invasive species than others. Classically, islands have long been observed as "sensitive" to invasions by a wide assortment of microbes, plants, and animals, but "functional islands" such as habitat fragments, peninsular landforms, and mosaic wetlands exemplify how insular attributes influence the degree of success attained once species have been transported and gain footholds in "new" locations. In the U.S. many habitats are prone to invasion, including low latitude regions of North America characterized by relatively mild climates (e.g., absent extreme seasonal variations in temperature and precipitation), riparian systems across many ecoregions, and western grasslands and range lands. Aquatic habitats throughout the United States are also variously subject to species invasions regardless whether those are lotic or lentic systems. Expanded species distributions in aquatic habitats depend on linkages between sources and surface water habitats such as lakes and ponds, rivers and streams in receiving systems. Despite geographical differences (e.g., differences simply reflecting location or more complicated instances linked to differences between ecoregions characteristic of source and receiving systems), similar pathways may influence physical movement of many potential "invaders" between sources and "target areas" (e.g., open irrigation canals between adjacent low-

elevation water sheds). Contrastly, supposedly dissimilar pathways may actually represent relatively subtle differences in mechanisms of species transfer associated with vectors (e.g., dispersal via birds on seasonal migratory routes or overland transport via watercraft used in recreational fishing). Human-influenced pathways and natural pathways lacking human influences may compete as links between source and target areas, as suggested in Annex Figure 1 through Annex Figure 5 in Section 2. More importantly, the simplification of pathways as being "natural" or "human-mediated" may inevitably require recharacterization as a more complex element in the species invasion process when indirect relationships between supposedly independent events are considered (e.g., disturbance may influence the invasibility of habitats).

Biota of concern serving as representative species in USGS/BRD/CERC's interbasin water transfer project completed for U.S. Bureau of Reclamation's Dakota Area Office

An evaluation of risks potentially associated with biota transferred from the Missouri River basin to the Red River basin is daunting, but the risk assessment process, particularly that crafted for the evaluation of ecological risks, is amenable to technical support activities charged with such tasks. Those technical support activities ministering to natural resource managers and their risk management issues, however, must initially reflect a simplification that reflects a phased approach to risk analysis, an approach that varies from application to application, one guided by the stakeholders charged with management and administration responsibility. Hence, in the current investigation, the iterative process of "problem formulation" yielded a menu of biota of concern that were (1) species having a past history of varied discussions regarding their potential roles as "problem species" (see, e.g., http://www.invasivespecies.gov/ for frequently encountered problem species), but more importantly, (2) presented life histories that captured a range of species' attributes that suggested these biota of concern might be representative of species likely to move from one basin to the other as a result of water diversions. Each of these biota of concern – plants, animals, and microorganisms – are acknowledged as being invasive when introduced intentionally or unintentionally by humans and sometimes by natural means. As candidate representative species, these biota have established sustainable populations outside their native ecosystems and have proven to be threats (e.g., economically through displacement of native species) to ecosystems and native species in the US. As developed by Reclamation, stakeholders, and USGS/BRD/CERC through the iterative process of problem formulation, the list of biota of concern included exotic species (i.e., species of foreign origin) and species of domestic origin (i.e., North American), with some of the representative species having become widespread in other regions of the country and having caused significant ecological and economic impacts (e.g.,

zebra mussel, tamarisk). Through USGS and other resources (private and public such as Center for Disease Control and Prevention) brief life histories have been compiled and edited for Appendix 3A and Appendix 3B. These life histories suggest that existing information and available data for these representative species is documented with sufficient quantity and quality to support an analysis of risks (either qualitative or quantitative) and to help develop adaptive management programs focused on understanding, preventing, monitoring, controlling or eradicating, and predicting the impacts of invasive species in US.

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Biota of concern: Representative aquatic invertebrates

[1]***Dreissena polymorpha*** **(Pallas 1771)**

Common Name: zebra mussel

Size: Up to 50 mm

Native Distribution. Zebra mussels originated in the Balkans, Poland, and the former Soviet Union. In 1769, Pallas first described populations of this species from the Caspian Sea and Ural River.

Life History. Females generally reproduce in their second year. Fertilization is external and usually occurs in the spring or summer. Optimal temperature for spawning is 14-16 ºC which reflects peak reproduction occurring in early summer at mid-latitude locations. Spawning may last longer in waters that are warm throughout the year, and greater than 40,000 eggs may be laid in a single mating. Multiple matings may occur and up to one million eggs may be fertilized in a spawning season. After the eggs are fertilized, the larvae (veligers) emerge within 3 to 5 days and are free-swimming for up to a month. Optimal temperature for larval development is 20-22 ºC. Dispersal of larvae is normally passive by being carried downstream with the flow. The larvae begin their juvenile stage by settling to the bottom where they crawl about on a foot, searching for suitable substrate for attachment. Once suitable habitat is encountered, the veligers attach themselves to the substrate by means of a multiple-stranded "tether" – the byssus – located outside the body near the foot. Preferred habitats are characterized by hard or rocky substrates and have water velocities less than two meters per second. Although hard substrates are preferred, larvae and juveniles may also attach to vegetation. Zebra mussels are filter feeders, predominately feeding on phytoplankton while filtering nearly a liter of water per day.

Shells of zebra mussels range from dark- to light-colored, having a widely variable striped-pattern to the of their cuticle. Some individuals lack stripes on their shells. Zebra mussels can grow to a maximum length of about 50 mm (5-10 mm in the first year) and live four to five years. They

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[1]Original material accessed September 24, 2002 from USGS/BRD, Center for Aquatic Resource Studies. The Center is part of the Biological Resources Division of the U.S Geological Survey within the U. S. Department of the Interior (last access date, November-December 2004). Updated, expanded, and edited January, 2004.

inhabit fresh water, usually at depths of two to seven meters. Even though zebra mussels are freshwater animals, they have recently been found living in brackish water with salinity levels of one to two parts per thousand. Calcium is an important nutrient for survival with an optimal range of 25 -125 parts per million. Other environmental factors such as water temperature, pH, and dissolved oxygen also play a critical role in survival. Water temperatures of 17-25 ºC are optimal for survival across all life stages (veliger, juvenile, and adult). Temperature exceeding 30-31 ºC is usually lethal, and waters characterized by pH less than 7.4 or greater than 8.5 are commonly not sufficient to support growth and reproduction. Well-oxygenated waters having 8-10 parts per million dissolved oxygen are preferred. Under cool, humid conditions, zebra mussels can stay alive for several days out of water.

Nonindigenous Occurrences. Zebra mussels apparently originated in eastern Europe (e.g., Balkans, Poland, and Ukraine) but had spread to most all major drainages of Europe between the 1600's and 1700's because of widespread construction of canal systems. Great Britain was invaded in 1824 and currently has well-established populations of zebra mussel. Throughout the 19th and 20th centuries, zebra mussels have expanded throughout western Europe and countries of Scandinavia.

Figure 1 and Figure 2 summarize the geographic distribution of zebra mussels in North America. In 1988, zebra mussels were first recorded in an account of an established population in the Canadian waters of Lake St. Clair, a small water body connecting Lake Huron and Lake Erie. By 1990, zebra mussels occurred throughout all the Great Lakes, and in 1991, zebra mussels escaped the Great Lakes basin and found their way into the Illinois and Hudson rivers. The Illinois River was the key to their introduction into the Mississippi River drainage which covers over 1.2 million square miles. By 1992, the following rivers had established populations of zebra mussels: Arkansas, Cumberland, Hudson, Illinois, Mississippi, Ohio, and Tennessee. By 1994, the following states had reported records of zebra mussels within their borders or in water bodies adjacent to their borders: Alabama, Arkansas, Illinois, Indiana, Iowa, Kentucky, Louisiana, Michigan, Minnesota, Mississippi, Missouri, New York, Ohio, Oklahoma, Pennsylvania, Tennessee, Vermont, West Virginia, and Wisconsin. More recently, Connecticut has been added to the list of states where zebra mussels have been found. In 2002, zebra mussels were first recorded in a small isolated quarry in Virginia, and in 2003 Kansas and South Dakota recorded their first sightings of zebra mussels.

Method of Introduction. It is highly likely that the presence of zebra mussels in the Great Lakes

was a result of a ballast water introduction, and its dispersal throughout the Great Lakes and major river systems occurred relatively rapidly due to its ability to attach to boats navigating these lakes and rivers. Its rapid range expansion into interconnected waterways was probably due to barge traffic where it is theorized that attached mussels were scraped or fell off during routine navigation. Overland dispersal is also a strong possibility for aiding zebra mussel range expansion (see, e.g., Johnson et al 2001), and many small lakes in the Great Lakes basin have likely been accessed by mussels "hitch-hiking" as veligers and juveniles attached to watercraft transported from infested waters to uninfested waters where populations of zebra mussels have subsequently become established. Haphazard inspections throughout North America have found zebra mussels attached to hulls or in motor compartments of watercraft, including a documented observation outside Regina, Manitoba.

Ecological and economic impacts. Zebra mussels are notorious for their biofouling capabilities by colonizing water supply pipes of hydroelectric and nuclear power plants, public water supply plants, and industrial facilities (see, e.g., D'Itri 1997, Nalepa and Schloesser 1993). As veligers and juveniles, the species colonizes pipes and other hard substrates, then as adults, the established colonies reduce intake and restrict flow in water distribution and treatment systems, heat exchangers, condensers, fire fighting equipment, and air conditioning and cooling systems. For example, populations densities for zebra mussel have been recorded as high as 700,000 m^2 at power plants (e.g., in Michigan) and the diameters of pipes have been reduced by two-thirds at water treatment facilities. Although there is little information on zebra mussels affecting irrigation systems, farms and golf courses could be likely candidates for infestations, if their source waters are infested.

Navigational and recreational boating can be affected by increased drag due to attached mussels. Small mussels can get into engine cooling systems causing overheating and damage. Navigational buoys have been sunk under the weight of attached zebra mussels, and fishing gear can be fouled if left in the water for long periods. Deterioration of dock pilings has increased when they are encrusted with zebra mussels, and continued attachment of zebra mussel can cause corrosion of steel and concrete affecting its structural integrity.

Most of the biological impacts of zebra mussels in North America are poorly characterized, especially those indirect effects at higher levels of biological organization and those direct effects that stem from interactions with multiple-species in community settings. However, information from Europe tells us that zebra mussels have the potential to severely impact unionids (native

mussels) by interfering with their feeding, growth, locomotion, respiration, and reproduction. Researchers are observing some of these effects as they study interactions between zebra mussels and native unionids in the Great Lakes. In one study they determined that where zebra mussel densities were highest in Lake St. Clair and in the western basin of Lake Erie, the number of native unionids had dramatically declined (Schloesser and Nalepa 1994). This difference was seen after only two years of zebra mussel colonization. Other studies have shown an inverse correlation between zebra mussel biomass and unionid density (Nalepa 1994). Scientists in the Great Lakes region have been using models that may predict the degree of unionid mortality based on zebra mussel densities (Ricciardi 1995). Unfortunately, research shows zebra mussels prefer to attach to live unionids rather than to dead ones or to rocks (Schloesser and Kovalak 1991). Some unionids have been found with more than 10,000 zebra mussels attached to them. This represents a tripling or even a quadrupling of the unionid's own weight (Hebert et al. 1991). Native unionids may not survive if zebra mussels continue to colonize Lake St. Clair (Hunter and Bailey 1992). The St. Croix River, a federally designated wild and scenic river in the upper Mississippi River basin, is being heavily guarded by the National Park Service because it contains the only known viable population of the winged mapleleaf clam (*Quadrula frugosa*). Zebra mussels could wipe out these clams if they become established in the river. Placing the native unionids in temporary refugia or transplanting them in waters absent of zebra mussels is being used as an alternative to try and save them. Another exotic invader, the quagga mussel (*Dreissena bugensis*), probably arrived at the same time as the zebra mussel. Although the quagga mussel closely resembles its cousin, it is not expected to have as great an impact on unionids because it does not show a preference for unionids as substrates (Conn and Conn 1993).

According to early studies, zebra mussels are having a minimal effect on fish populations in the Great Lakes. It may be too soon to determine some of the effects which may take more time to develop. However, there has been a striking difference in water clarity improving dramatically in Lake Erie, sometimes four to six times what is was before the arrival of zebra mussels. With this increase in water clarity, more light is able to penetrate deeper allowing for an increase in aquatic plants (Skubinna et al. 1995). Some of these macrophyte beds have not been seen for many decades due to changing conditions of the lake mostly due to pollution. The macrophyte beds that have returned are providing cover and acting as nurseries for some species of fish.

Methods of Control. There are many methods that have been investigated to help control zebra mussels, and these listed below in no particular order. Some methods will work better than others in a particular situation.

- Chemical Molluscicides: Oxidizing (chlorine, chlorine dioxide) and non-oxidizing chemical treatments
- Manual Removal (pigging, high pressure wash)
- Dewatering/Desiccation (freezing, heated air)
- Thermal (steam injection, hot water > 32 oC*)*
- Acoustical Vibration
- Electrical Current
- Filters, Screens
- Coatings: Toxic (copper, zinc) and Non-toxic (silicone-based)
- Toxic Constructed Piping (copper, brass, galvanized metals)
- CO_2 Injection
- Ultraviolet Light
- Anoxia/Hypoxia
- Flushing
- Biological (predators, parasites, diseases)

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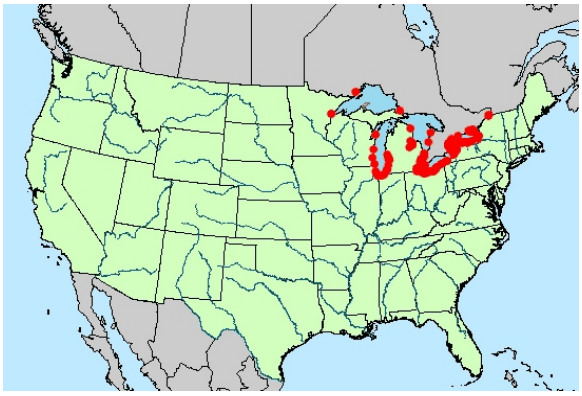
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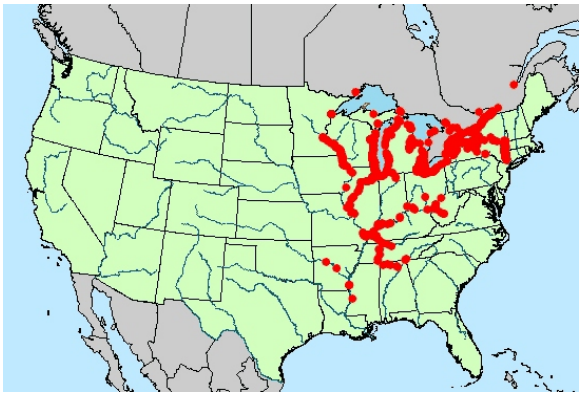
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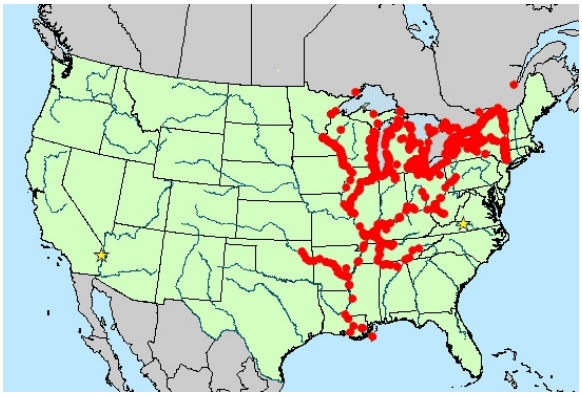
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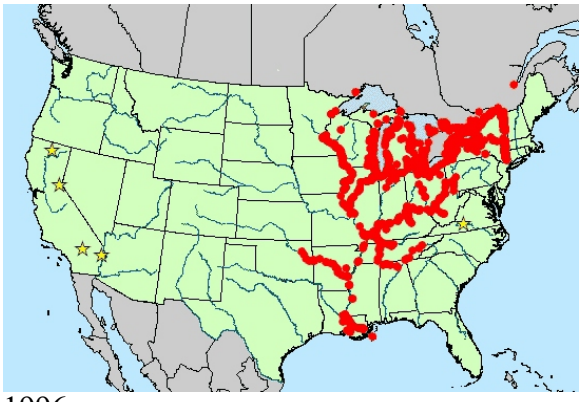
Figure 1. Distribution maps illustrating the progressive invasion of zebra mussel.

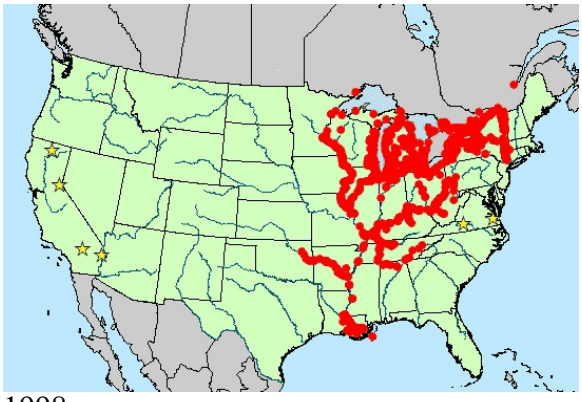

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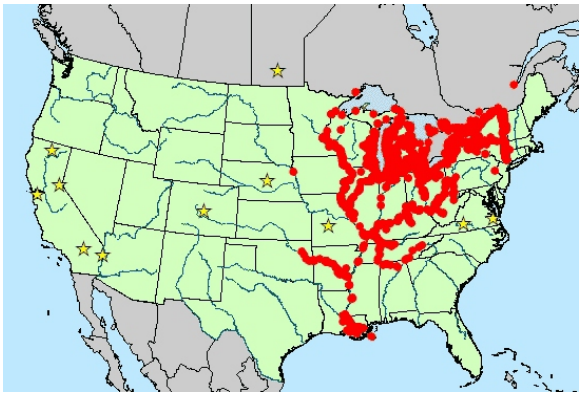

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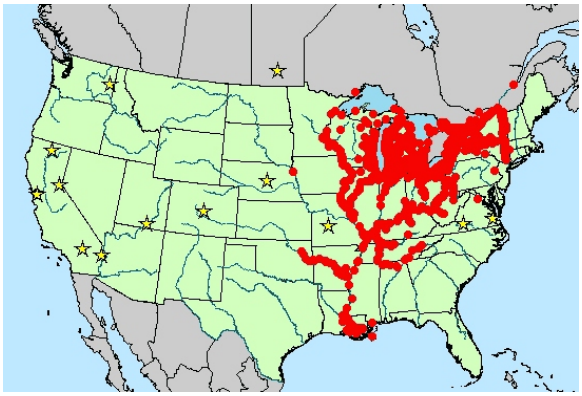

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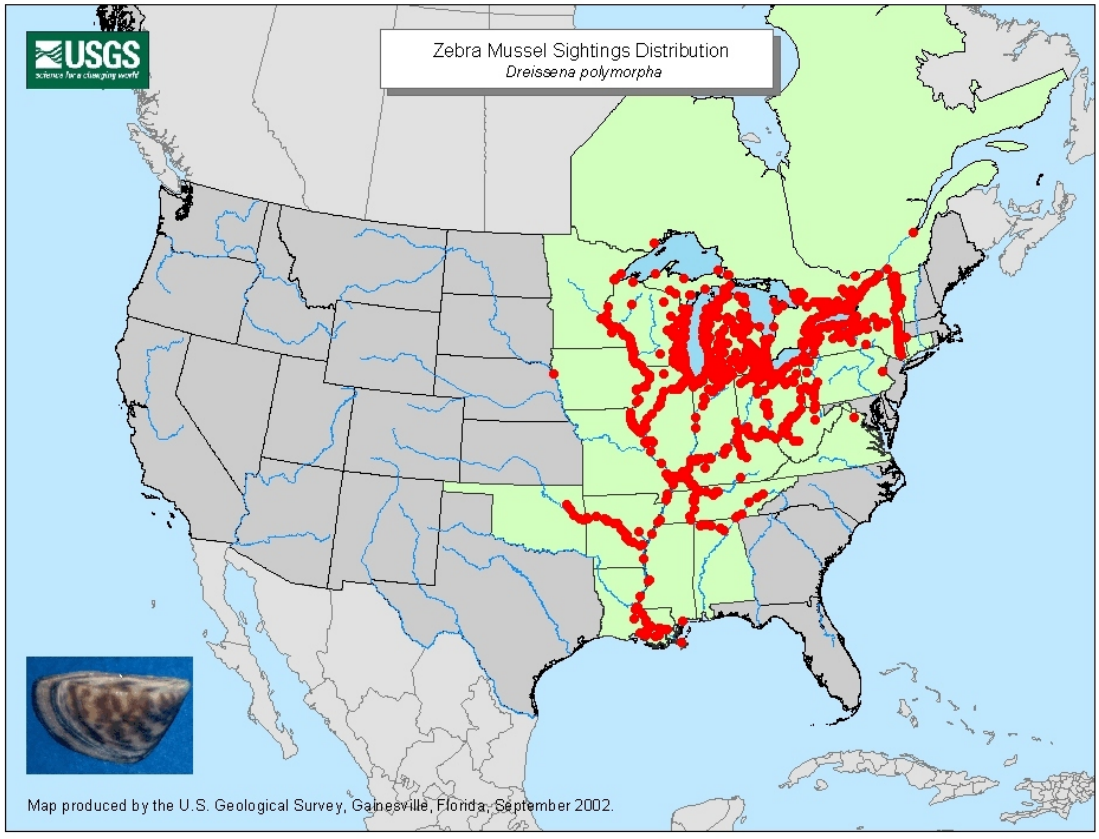
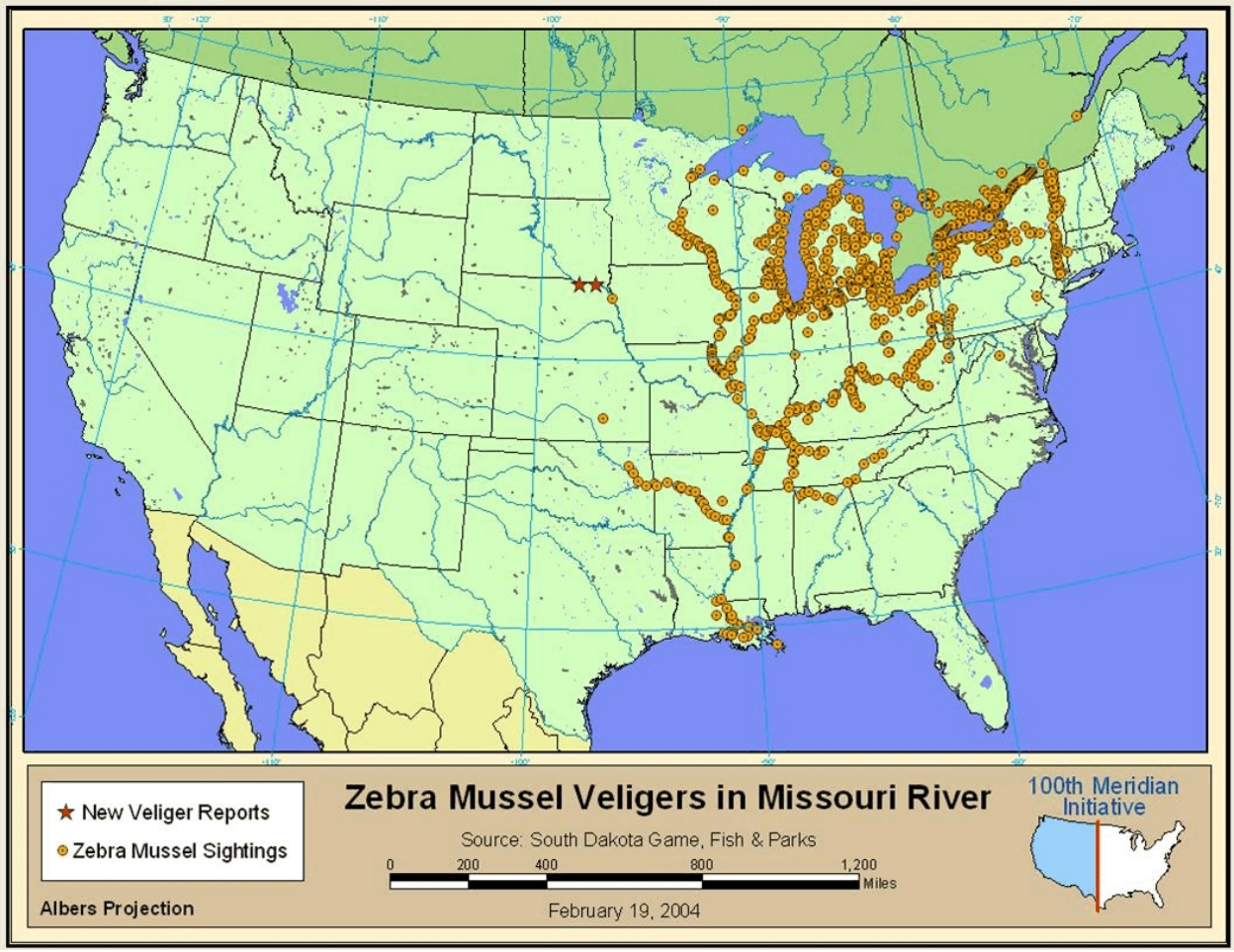

USGS
Zebra Mussel Sightings Distribution
Dreissena polymorpha
Map produced by the U.S. Geological Survey, Gainesville, Florida, September 2002.

Figure 2. Zebra mussel distribution as of February, 2004 (including locations of observations of veligers).



[2]***Corbicula fluminea* Müller 1774**

Other scientific names appearing in the literature for this species: *Corbicula manilensis* (Philippi, 1844), *C. leana* Prime, *C. fluminalis*.

Common Name: Asian clam, propensity clam; *Corbicula*

Similar species Fingernail clam.

Size: Generally less than 50 mm in length.

Taxonomy and distinguishing features. Throughout their native range and in the US, Asian clams are highly variable in their external morphology (Sinclair, 1971a; Britton and Morton, 1986; Morton, 1987). At least part of this variability is believed to be influenced by environmental factors (Sinclair, 1971a). Asian clams introduced into the United States were initially identified as *C. fluminea* (Müller, 1774) (Lachner et al., 1970; Carlton, 1992) and *Corbicula manilensis* Philippi, 1844 (Sinclair, 1971a). In addition to these descriptions, Hillis and Patton (1982) presented morphological and electrophoretic data that suggested two species of *Corbicula* occurred in the United States, which is also the interpretation of genetic data published by McLeod (1986). In contrast to these interpretations, electrophoretic data presented by Morton (Morton in Blalock and Herod, 1999) and morphometric data presented by Britton and Morton (1986) suggests that all North American populations are really *C. fluminea*. Presently *C. fluminea* is used for all species collected in the US, although additional work into the taxonomic status of introduced populations may be necessary to resolve this dispute. (All North American records are C. fluminea with synonyms *C. fluminea* and *C. manilensis* and *C. leana*.)

Description. Adults may reach 50 to 65 mm in shell length (Hall, 1984), but individuals above 25 mm are typically uncommon (Gottfried and Osborne, 1982). Shells are rounded to slightly triangular and inflated; anterior and posterior margins rounded. Young shells have a purple stripe

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[2]Original materials prepared May, 2001 by A. M. Foster, Pam Fuller, and Amy Benson at the Center for Aquatic Resource Studies. The Center is part of the Biological Resources Division of the Geological Survey within the U.S. Department of the Interior. Additional materials incorporated from Illinois Natural History Survey and Windsor Aguirre (currently, State University of New York at Stony Brook) and Stuart G. Poss at the University of Southern Mississippi, 15 September 1999 and 6 October 1999. Updated, expanded, and edited, January, 2004.

on the umbo. Shell interiors are layered with polished, light purple nacre, and in adults the umbo is high, centrally located, and elevated above the hinge line. Shell color varies with the periostracum ranging from yellowish-brown to black. Dark-shelled members of the species are generally found in the southwestern United States, with periostracum bing a dark olive-green to black and a deep royal blue nacre. Light-colored *C. fluminea* have shells having yellow-green to light brown periostracum and white to light blue or light purple nacre (McMahon 1991). Regardless of color, the shell is ornamented by distinct, concentric sulcations, anterior and posterior lateral teeth with many fine serations. The shell has three cardinal teeth in each valve below the umbo, two on each side of the umbo in the right valve, one on each side in the left valve. The presence of serrated lateral teeth separate *Corbicula* from the fingernail-clams.

Life History and biology. The sexes are normally separate, however, hermaphrodites exist and are capable of self-fertilization. The spawning season lasts about 6 months starting in early summer. Fertilization takes place in the inner gills. The larval stages of the Asian clam differ significantly from the larval stages of other types of bivalves. In contrast to most bivalves, larval development occurs predominately inside the gill compartments of the female clam, and the development of internal body structures, including the foot and siphon, occurs at a slightly different time during development relative to the pattern characteristic of free-living veliger larvae. While larvae of Dreissenidae are completely pelagic (i.e., free-floating in the water column), other freshwater bivalves (e.g., Corbiculidea, Unionidae, Sphaeriidea) brood their larvae through early, pre-shell developmental stages in marsupial sacs on the gill.

The first larval stage called a trochophore (15-20 microns) develops on the inner gill. The second larval stage called the veliger (~0.2 mm) is also incubated on the gill, and a characteristic D-shaped shell begins to develop. At a shell length of approximately 1 mm, the juvenile is released from the gill and begins life as an adult on the bottom. At this free-living early adult stage, pigments and growth rings should be visible on the shell; maturity should be reached when shell length is 6-10 mm. Life span varies with habitat, but is generally 1-4 years, with a maximum life span of approximately 7 years (Hall, 1984). These mussels are filter-feeder primarily foraging on phytoplankton.

As adults, *Corbicula fluminea* is found in lotic and lentic habitats throughout its native range in southeastern Asia, and in the United States, the species has been most successful in well-oxygenated, clear waters (Belanger et al., 1985; Stites et al., 1995). The clams typically occur at high densities and have a relatively high growth rate (Stites et al., 1995). Densities of *C. fluminea*

have been documented to occur by the thousands per square meter, often dominating the benthic community (Sickel 1986), with maximum densities reported to vary between 1000/m^2(Gotfried and Osborne, 1982; Stites et al., 1995) to 6000/ft^2 greater (Sinclair, 1971a; Sinclair, 1971b). Usually *C. fluminea* is more common and occurs at higher densities in stream pools than in stream runs (Blalock and Herod, 1999). Fine clean sand, clay, and coarse sand are preferred substrates, although this species may be found in lower numbers on most any substrate (Gottfried, and Osborne, 1982; Belanger et al., 1985; Blalock and Herod, 1999). Gottfried and Osborne (1982) reported density as lowest on bottoms composed of silty organic sediments. Factors that may affect population density and distribution of Asian clams include excessively high or low temperatures, salinity, drying, low pH, silt, hypoxia, pollution, bacterial, viral and parasitic infections, inter- and intraspecific competition, predators, and genetic changes (Evans et al. 1979; Sickel 1986).

Tolerance to reduced salinity and reduced water quality. Asian clams can tolerate salinities of up to 13ppt for short periods of time. If allowed to acclimate, they may tolerate salinities as high as 24ppt (King et al., 1986). Optimum is at lower salinities (Morton and Tong, 1985). In nature, Asian clams occur mostly in freshwaters, however, they have been reported from brackish and estuarine habitats, but are typically not as abudant in such habitats as in freshwaters (Carlton, 1992). In addition, Asian clams appear to be capable of tolerating polluted environments better than many native bivalves (Jenkinson, 1979).

Temperature Tolerance. This species appears to tolerate low temperatures well. Janech and Hunter (1995) reported a viable population surviving temperatures of 0-2˚C over winter in the Clinton River, Michigan (Janech and Hunter, 1984). Reproduction, on the other hand, is limited by low temperatures since velligers are typically released at temperatures of 16˚C or higher (Hall, 1984).

Reproduction and Fecundity. In North America, Asian clams breed from spring to fall. Reproductive activities are typically highest in the fall (Kraemer and Galloway, 1986). Asian clams are synchronous hermaphrodites and incubate their young within the inner demibranch of the ctenidium (branchial cavity). Self-fertilization may occur (Kraemer and Galloway, 1986). Sperm is ejected through the exhalent siphons (King et al., 1986). Egg cells are 120 to 170 µm in diameter just prior to fertilization (King et al., 1986). Trocophore larvae develop after 14 hours. Pediveligers are released from the parent in 4-5 days (King, 1979). Approximately between 320 (fall) and 387 (spring) pedivelligers are released daily per clam (Gottfried and Osborne, 1982;

Hall, 1984). Larval density has been reported to be as high as 1,000/ml (Sinclair, 1971b). When the pedivelligers are between 1.0 and 1.5mm in shell length, they attach to appropriate substrates with their byssus (Hall, 1984; Kraemer and Galloway, 1986). Larvae spawned in late spring and early summer may reach sexual maturity by the fall (Hall, 1984; King et al., 1986).

Trophic Interactions. Asian clams are consumed mainly by fish and crayfish. These clams have been found in the stomachs of black buffalo (*Ictiobus niger*; Minckley 1973); carp (*Cyprinus carpio*), channel catfish (*Ictalurus punctatus*), yellow bullhead (*Ameiurus natalis*), redear sunfish (*Lepomis microlophus*), largemouth bass (*Micropterus salmoides*), Mozambique tilapia (*Tilapia mossambica*; Minckley 1982); blue catfish (*Ictalurus furcatus*; M. Moser pers. comm. 1996); and spotted catfish (*Ameiurus serracanthus*; A. Foster pers. comm. 1996). In Florida, they have been reported as major prey items for the following species of fish: Redear sunfish, *Lepomis microlophus*, spotted bullhead, *Ameirus serracanthus* (Bass and Hitt, 1974), bluegill, *Lepomis macrochirus*, spotted sucker, *Minytrema melanops*, sturgeon, *Accipenser spp.*, channel catfish, *Ictalurus punctatus*, common carp, *Cyprinus carpio*, freshwater drum, *Aplodinotus grunniens*, smallmouth buffalo, *Ictiobus bubalus*, black buffalo, *I. niger*, and blue catfish, *Ictalurus furcatus* (McMahon, 1983).

Other predators of *Corbicula* include birds, raccoons, crayfish, and flatworms (Sickel 1986).

Habitat. Found in sandy and muddy bottomed streams and rivers, and in ponds and lakes of all sizes in silt, mud, sand, or gravel bottoms. Also, the species has also been recorded in man-made canals. *C. fluminea* can withstand habitats characterized by degraded water quality.

Native Range. The genus *Corbicula* is a freshwater species whose native range occupies temperate to tropical southern Asia west to the eastern Mediterranean (Russia, Thailand, Philippines, China, Hong Kong, Taiwan, Korea, and Japan) and Africa, except in the Sahara desert; southeast Asian islands south into central and eastern Australia (Morton 1986).

Nonindigenous Occurrences: The date and means of introduction of the Asian clam is not known. Generally, the introduction of this species is attributed to Chinese immigrants who used Asian clams as food (Sinclair, 1971a; Counts, 1981). The earliest verifiable record of this species in North America consists of three specimens found dead on the beach at Nanaimo, Vancouver Island, British Columbia in 1924 (USNM 363020; Counts, 1981). Asian clams are believed to have established a viable population on the west coast of the United States sometime prior to

1938 (Clench, 1970; Counts, 1981), perhaps established as early as the mid 1800's (Fox, 1969). Early records taken in the late 1930's and early 1940's exist for the Sacramento and San Joaquin River systems in California and the Columbia river system in Washington (Ingram, 1948). First documented in the US in California in 1938 where the species proliferated and spread by way of irrigation canals. A big migration east occurred when they were discovered in the Ohio River in 1957.

During this same period of "jump dispersal" eastward, the species rapidly invaded the Colorado, and spread throughout the Tennessee and Ohio River systems, spreading east along the Gulf states to the Florida panhandle by 1960, and to southern Florida by 1967 (Blalock and Herod, 1999). It was first reported for the Mobile River in 1962, where it was described as "abundant" (Hubricht, 1963). It was first reported for the Savannah River in 1972 (Stites et al., 1995) and reached Virginia that same year (Lachner et al., 1970). Transport on barges containing river gravel probably contributed to its rapid spread (Lachner, 1970; Sinclair, 1971a). Such gravel is often shipped great distances and maintains sufficient humidity to allow the clams to survive (Lachner et al., 1970). Other means of dispersal may have included transport on waterfowl, intentional releases by recreational aquarists, and intentional or accidental releases by fisherman who used this species as bait (Lachner et al., 1970; Sinclair, 1971a; Counts, 1981). Throughout the US, they can be found in many drainages except for the several states in the northern plains and the northeast. The Asian clam has long been recognized as a pest as far back as the 1950's in irrigation systems of California. *Corbicula* continues to expand its range into uninfested waters especially in the Midwest and Northeast. Asian clams have had one of the most rapid range expansions of any non-indigenous species in North America (Clench, 1970).

Status: Introduced, but widespread and common. *Corbicula fluminea* has become established in many states (see Figure 3).

Distribution. Asian clams naturally occur in southeast China, Korea, and in the Ussuri Basin, southeastern Russia (Lachner et al., 1970). Once translocated to North America, *C. fluminea* has flourished. The species is found in fresh waters throughout the United States including all five Gulf states and northern Mexico (Dundee, 1974; Carlton, 1992). Estuarine populations have been reported for the San Francisco Bay, California and Chesapeake Bay, Virginia, but none have yet been reported for the Gulf of Mexico ecosystem (Carlton, 1992). The species has been recorded in freshwater habits of the Gulf Coast states, however. In Alabama, besides the expanding populations from the west, *C. fluminea* may have been introduced into the Saugahatchee Creek

from experimental ponds of the Auburn University Department of Fisheries and Applied Aquaculture in the summer of 1972 (Jenkinson, 1979). Howells (1992) noted the history of introduction of *C. fluminea* into Texas is largely unknown. However, the Asian clam has been reported as common in freshwaters of Texas (Howells, 1992).

Means of Introduction. The first collection of *C. fluminea* in the United States occurred in 1938 along the banks of the Columbia River near Knappton, Washington (Counts 1986). Since this first introduction, it is now found in at least 38 states and the District of Columbia. *Corbicula fluminea*. With human intervention a primary agent of dispersal, no large-scale geographic features function as dispersal barriers (Counts 1986; Isom 1986). Current methods of introduction include bait-bucket introductions (Counts 1986), accidental introductions associated with imported aquaculture species (Counts 1986), and intentional introductions by people who buy them as a food item in markets (Devick 1991). The only other significant dispersal agent is thought to be passive movement via water currents (Isom 1986); fish and birds are not considered to be significant distribution vectors (Counts 1986; Isom 1986).

Impact of Introduction: Because of their reproductive success and high infestation, this species has become a serious pest throughout the United States, especially in irrigation and drainage canals, as well as water distribution and industrial water use systems (Lachner et al., 1970; Sinclair, 1971a; Sinclair, 1971b; Mattice, 1977; Hall, 1984; Kraemer and Galloway, 1986; Stites et al., 1995). Given their high growth and production rates, concerns have been raised over the capacity that Asian clams have to alter trophic and nutrient dynamics of aquatic systems, and to displace native bivalves (Gottfried and Osborne, 1982; Stites et al., 1995).

The most prominent effect of the introduction of the Asian clam into the United States has been biofouling, especially of complex power plant and industrial water systems (Isom et al. 1986; Williams and McMahon 1986). It has also be documented to cause problems in irrigation canals and pipes (Prokopovich and Hebert 1965; Devick 1991) and drinking water supplies (Smith et al. 1979). It also alters benthic substrate (Sickel 1986), and competes with native species for limited resources (Devick 1991).

Over its native range the Asian clam is marketed fresh or dry for human consumption and as feed for domestic fowl (Lachner et al., 1970; Sinclair, 1971b), and in the United States the species has gained commercial value as fish bait (Lachner, 1970; Burch, 1978).

Control and management. The Asian clam is likely to spread in North America until it reaches its lower temperature tolerance. In closed environments, such as power plants, mechanical or chemical control methods can be employed to reduce or eliminate this species where problems occur. To eliminate the source of many introductions, navigation and dredging activities should be investigated.

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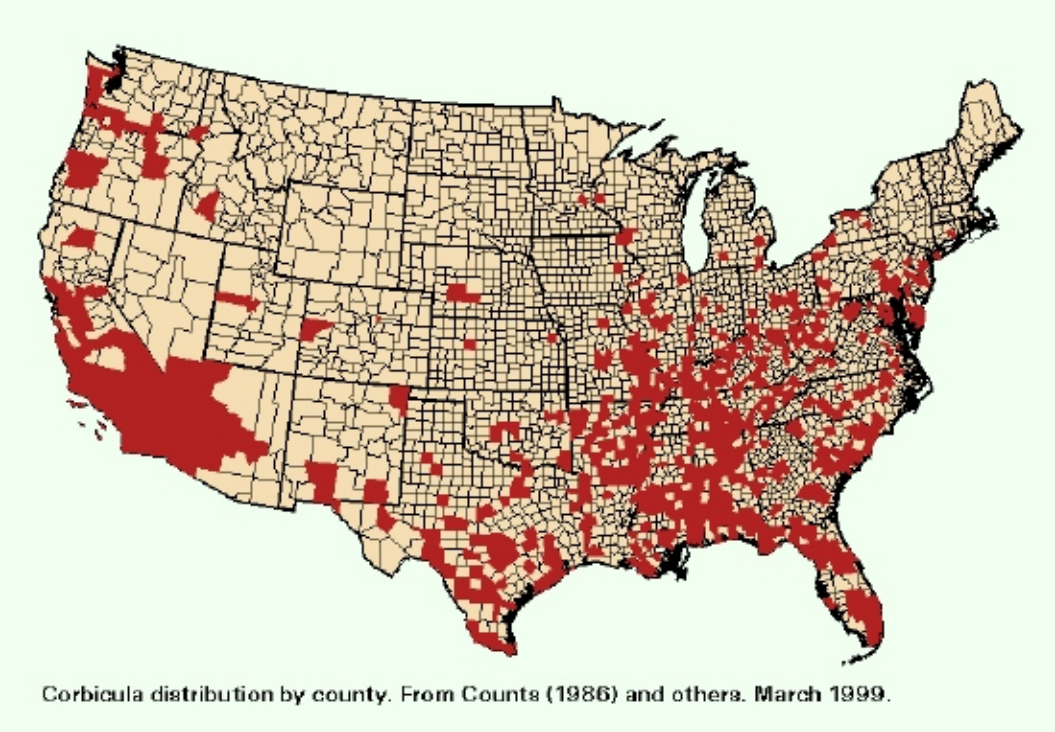
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Figure 3. Current distribution map and chronology of invasion. Based largely on the exhaustive taxonomic work of Counts (1981), the current distribution of *C. fluminea* is illustrated below (county records) and chronology summarized in legend..



Chronology of invasion. Since its documented introduction to the United States in 1938, *C. fluminea* has spread into many of the major waterways. The following location information briefly outlines where it is presently found. The [date: author publication date] format associated with each state identifies the first collection or record of *C. fluminea* in that state. The Asian clam has become established in the following states: Alabama [1962: Hubricht 1963] widespread (Counts 1991); Arizona [1958: Dundee and Dundee 1958] in the Aqua Fria, Colorado, Gila, Salt, and Verde rivers; Lake Martinez; and in several irrigation systems in Maricopa County (Counts 1991); Arkansas [1970: Fox 1970] widespread (Counts 1991); California [1945: Hanna 1966] in the Sacramento and San Joaquin drainages; Santa Barbara County south to San Diego County and west to the Salton Sea (Counts 1991); Colorado [1995: Livo 1996] in a northwestern reservoir; Connecticut [1990: Morgan, pers. comm.] in the Connecticut River; Delaware [1986: Counts 1986] in the Delaware River in New Castle County; the Nanticoke River in Sussex County; and the Nanticoke Wildlife Refuge (Counts 1991); District of Columbia [1979:Dressler and Cory 1980] in the Potomac River; Florida [1964: Heard 1964] widespread (Counts 1991; J. D.

Williams pers. comm. 1996); Georgia [1971: Sickel 1973] widespread (Counts 1991); Hawai`i [1982: Devick 1991] on the islands of O`ahu, Kaua`i, Maui, and Hawai`i; Idaho [1959: Ingram 1959] in the Snake River on the Idaho-Washington state line; Illinois [1962: Fetchner 1962] in the Illinois River south to the state line (Counts 1991); Indiana [1962: Fox 1969] in the White, lower Wabash, and Blue river drainages; Big Indian and Indian Creeks; and the Ohio River in Clark and Posey Counties (Counts 1991); Iowa [1974: Eckblad 1975] in the Mississippi River near Lansing; and the Cedar River in Linn County (Counts 1991); Kansas [1983: Mackie and Huggins 1983] in Perry Reservoir on the Delaware River; the Kansas River drainage; the North Fork of the Ninnescah River; Wilson Reservoir on the Saline River; and Cedar Bluff Reservoir on the Smoky Hill River (Counts 1991); Kentucky [1957: Sinclair and Isom 1961] widespread (Counts 1991); Louisiana [1961: Stein 1962] in the Pearl, Atchafalaya, Mississippi, and upper Red drainages (Counts 1991); Maryland [1975: Stotts et al. 1977] in the Choptank River near Goldsboro; Nassawango Creek near Snow Hill; the Susquehanna River below Conowingo Dam; the Wicomico River at Salisbury; the Potomac River in Charles, Prince Georges, and Montgomery Counties; Chesapeake Bay at Havre-de-Grace, and near the mouth of the Susquehanna River (Counts 1991); Michigan [1981: Clarke 1981] in Lake Michigan at the J. H. Campbell Power Plant; and Lake Erie at Detroit Beach, Sterling State Park and Bolles Harbor (Counts 1991); Minnesota [1975: Cummings and Jones 1978] in the Minnesota River near Burnsville; Mississippi [1963: Heard 1966] widespread (Counts 1991); Missouri [1969: Fox 1969] in the lower Missouri River drainage south to the state line; Nebraska [1991: Peyton and Maher 1995] in the Platte River in Lincoln and Dawson Counties; Nevada [1959: Ingram 1959] in Lake Meade (Counts 1991); New Jersey [1973: Fuller and Powell 1973] in the Raritan River in Middlesex and Somerset Counties; and the Delaware River near Newbold Island, Wright Point, and Trenton (Counts 1991); New Mexico [1966: Metcalf 1966] in Nemexas-West Drain in Dona Ana Co.; the Pecos River impoundment at Riverside Drive in Carlsbad; and the Rio Grande River from Caballo and Elephant Butte reservoirs, south to Percha Dam (Counts 1991); New York [1983: Raeihle 1983] in Massapequa Lake on Long Island; North Carolina [1970: Fox 1971] in the Cape Fear, Catawba, Chowan, Eden, Little, Meherrin, Neuse, Roanoke, Rocky, Tar, Uhwarrie, and Waccamaw rivers; and Richardsons Creek (Counts 1991); Ohio [1962: Pojeta 1964] in the Muskingum, upper Scioto, and upper Great Miami drainages; and the lower Hocking River (Counts 1991); Oklahoma [1969: Clench 1971] in the Arkansas River from Cherokee to Wagoner Counties; the Little River near Goodwater; Lake Texoma on the Red River; Lake Overholser; Lake Thunderbird; and Caddo Creek in Carter County (Counts 1991); Oregon [1948: Ingram 1948] in the Columbia drainage; the John Day River; the Smith River near Scottsburg; and at the mouth of the Siuslaw and Willamette rivers (Counts 1991); Pennsylvania [1973: Fuller and Powell

1973] in the Ohio and Delaware rivers; the Beaver River in Beaver County; the Monongahela River at Lock and Dam Number 8; and the Schuykill River at the Limerick Power Station and Fairmount Dam (Counts 1991); South Carolina [1972: Fuller and Powell 1973] in the Savannah, Cooper, Santee, Pee Dee, Little Pee Dee, Edisto, Waccamaw, and Salkahatchie rivers; the intracoastal waterway; and several industrial facilities in Aiken and Pickens counties (Counts 1991); Tennessee [1959: Sinclair and Isom 1961] in the Tennessee drainage (Counts 1991); Texas [1964: Metcalf 1966] in the Angelina, Colorado, Rio Grande, Guadalupe, San Antonio, San Jacinto, Sabine, Red, White, and Brazos drainages; the Clear and West Forks of the Trinity River (Counts 1991); Utah [1975: Counts 1985] in Sevier Reservoir; Virginia [1968: Diaz 1974] in the Appomattox, Clinch, Potomac, James, and New rivers; Lake Anna; the Chowan River at the mouths of the the Blackwater and Nottoway rivers; and the Chickahominy River at Lanexa; (Counts 1991); Washington [1938: Burch 1944] in the Columbia, Snake, Chehalis, and Willapa rivers; Hood Canal in Jefferson County; and Aberdeen Lake in Grays Harbor Lake County (Counts 1986, 1991); West Virginia [1964: Thomas and MacKenthum 1964] in the Elk and Kanawha drainages (Counts 1991); Wisconsin [1977: Cummings and Jones 1978] in the Mississippi River near Prairie du Chien and La Cross; and the St. Croix River near Hudson (Counts 1991).

[3]***Potamopyrgus antipodarum*** (J. E. Gray, 1853)

Common Name: New Zealand mudsnail

Size: Approximately 5mm in length, ranging to 12mm. The shell usually displays right-handed coiling with 7 to 8 whorls.

Native Distribution. The New Zealand mudsnail (*Potamopyrgus antipodarum*) is a small aquatic snail, native to freshwater lakes and streams of New Zealand and small islands immediately adjacent to New Zealand.

Life History. Mudsnail populations consist mostly of asexually reproducing females that are born with developing embryos in their reproductive system. New Zealand mudsnails are very small, operculate gastropods, and have a shell that varies from gray and dark brown to light brown in color.

This species can be found in all types of aquatic habitats from eutrophic mud bottom ponds to clear rocky streams. It can tolerate a wide range of water temperatures (except freezing), salinity, and turbidity in clean as well as degraded waters. They feed on dead and dying plant and animal material, algae, and bacteria. Mudsnail densities of over one-half million per meter square in western streams are a cause for concern. Because the West is known for abundant trout and productive fishing spots, there is concern that the mudsnails will impact the food chain for native trout and the physical characteristics of the streams themselves

Nonindigenous Occurrences: Outside New Zealand, the snail has relocated throughout the world, including Europe, Asia, and North America. The species has become naturalized in Australia and Europe. Movements of this aquatic snail to North America were likely associated with ship ballast in the Great Lakes or in the water of live gamefish shipped from infested waters to western rivers in the United States. New Zealand mudsnails were first discovered in the middle portion of the Snake River in Idaho in 1987, and currently occupy a disjunct distribution throughout North America (Figure 4). Since collection its collection in Idaho in the late 1980's, the species has spread to waters of Montana and Wyoming, including the waters of Yellowstone

[3]Original material prepared by staff at USGS/BRD/FISC, and Dan Gustafson and colleagues at Montana State University. Expanded, updated, and edited January, 2004.

National Park, as well as California, Arizona, Oregon, and Utah. New Zealand mudsnails have also been collected in Oregon near the mouth of the Columbia River and in a small lake in northwestern area of the state. Populations have been discovered in the Owens River and Central Valley of California in 2001 and 2002, and in the Colorado River in Arizona and the Green River in Utah in 2002. See Figure 4 for current distribution in western US and throughout the Missouri River watershed (HUC10). Populations in the eastern US occur in Great Lakes where a populations were discovered in the early 1990's in southwestern and northeastern Lake Ontario and the Welland Canal in Canada, and in 2003 New Zealand mudsnails were collected from Ontario's Thunder Bay immediately off Lake Superior.

Methods of Control: The species' parthenogenicity and its tolerance of a broad range of ecological factors make the possibility of further spread highly likely. As long as not completely desiccated, New Zealand mudsnails can withstand short periods out of the water. Precautionary measures should include education of the public to decontaminate fishing and sporting equipment so as not to spread existing populations or start new ones. Regulations on commercial shipping of this species are in effect. While the species supports a number of parasites in its native range, none have been found in any of the North American populations examined.

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Figure 4. Distribution map – Progression and current distribution (December 2003) of the New Zealand mudsnail, *Potamopyrgus antipodarum*, in the western U.S. (west of the 100th meridian).



1995



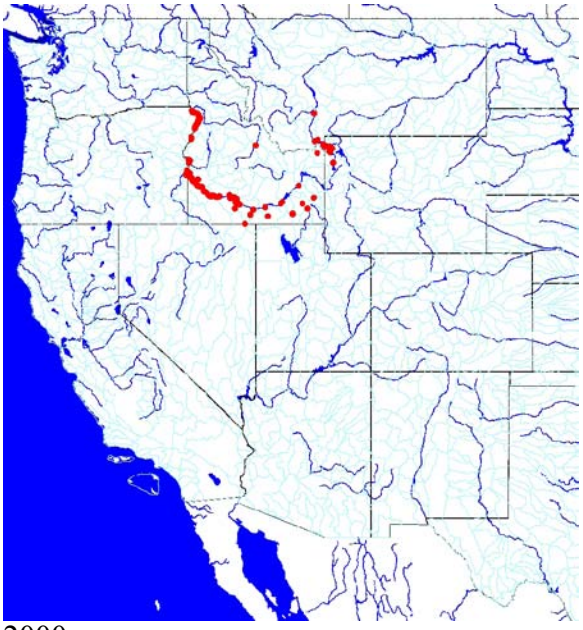
1997

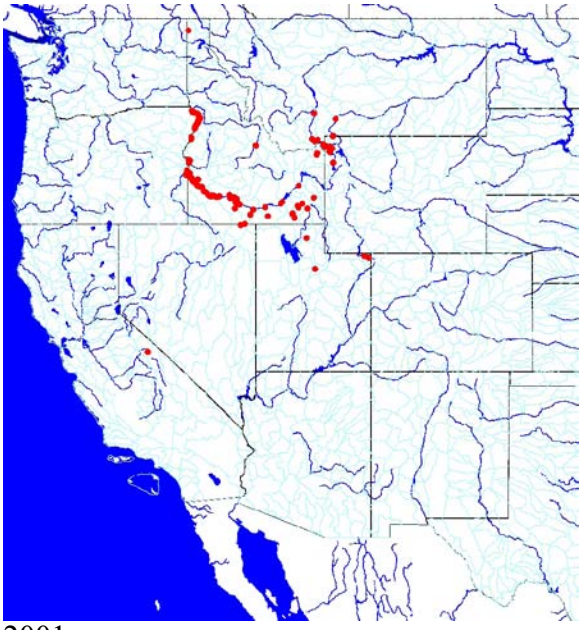


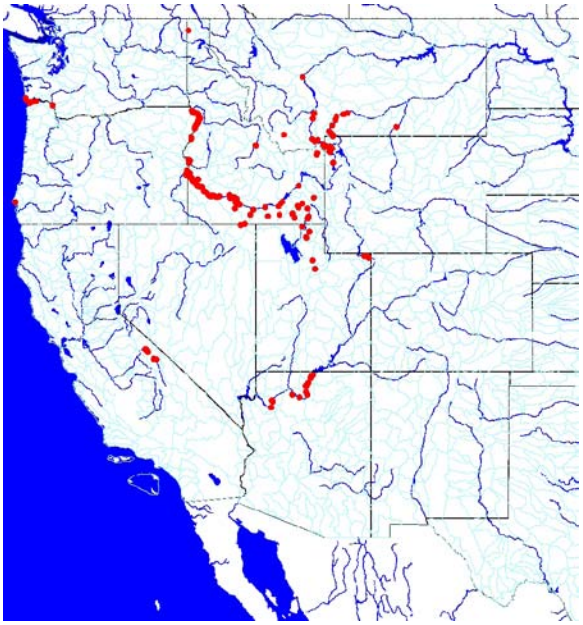
1998

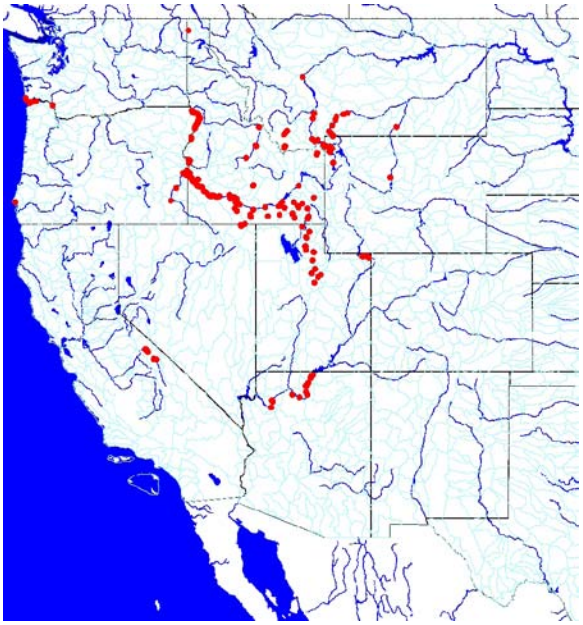


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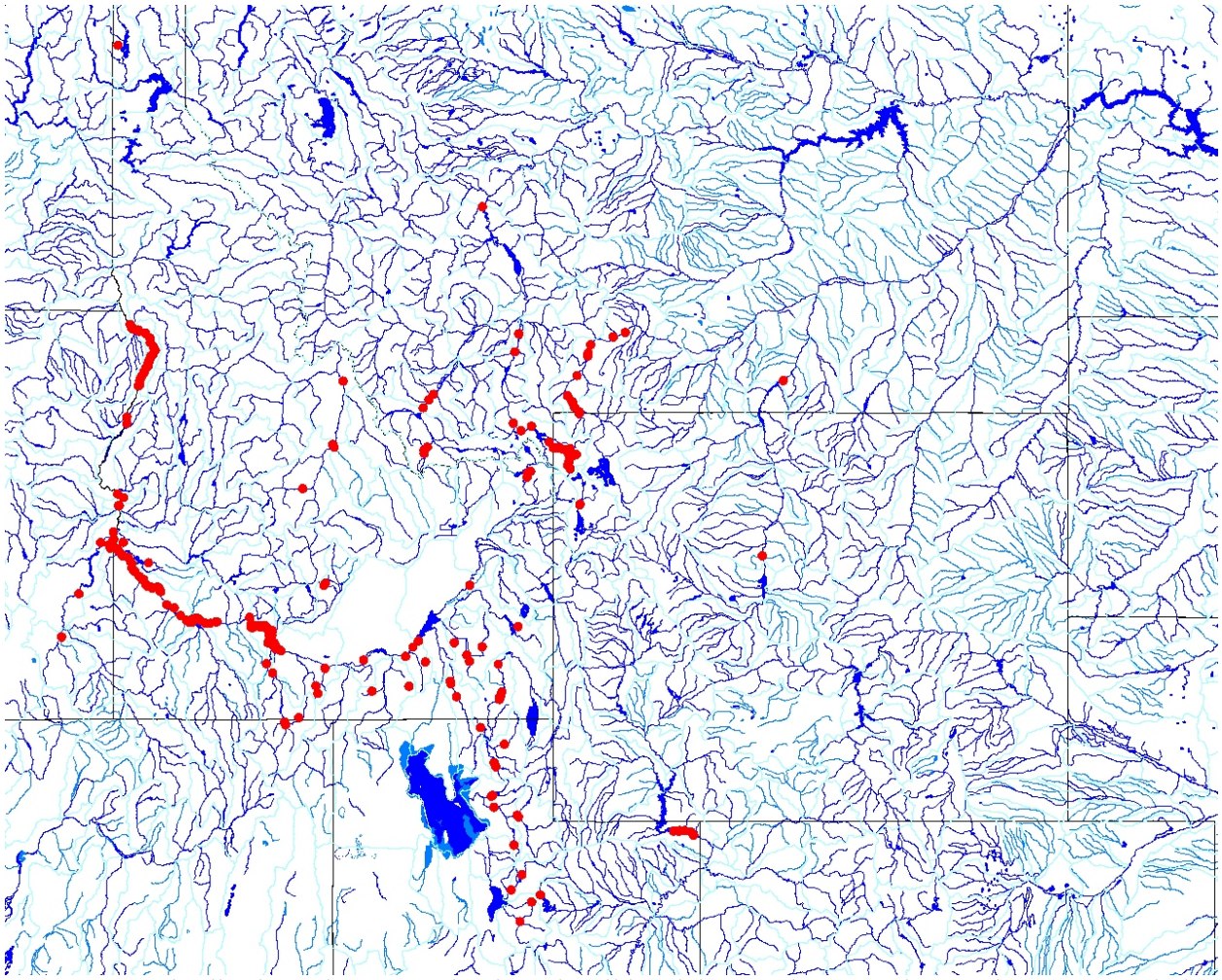
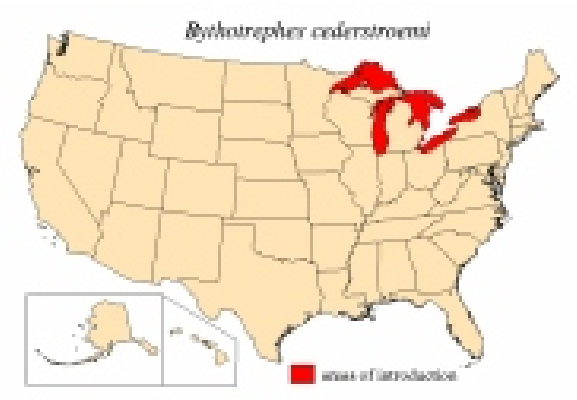


Figure 19. Distribution of New Zealand mudsnail in Idaho, Utah, Wyoming, and Montana relative to western reaches of the Missouri River headwaters.

[5]***Bythotrephes cederstroemi*** (Schodler, 1877)

Common name: Spiny water flea

Introduction: The native range of the spiny water flea, *Bythotrephes cederstroemi*, is the northern and central Palearctic (northern Europe to Caspian Sea). Although ballast water may have been the source of introduction, it is unclear whether this presumptive source was the root



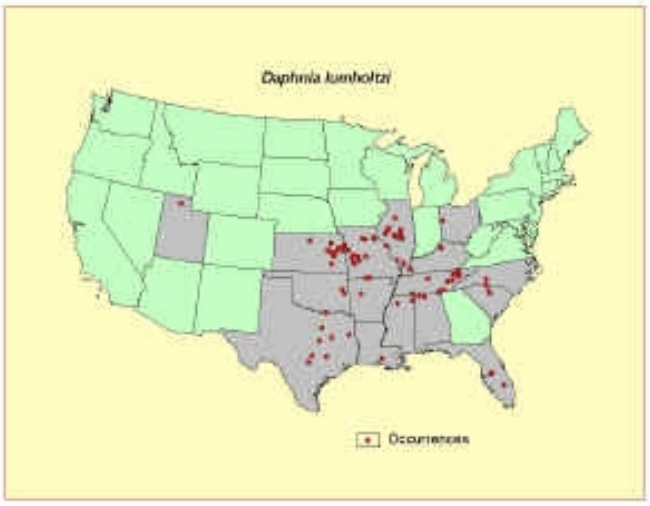
cause in the pioneering event, since most ocean-going ships do not carry freshwater in ballast. In North America, the spiny water flea was first collected in 1984 from Lake Huron (Bur et al.1986), followed in 1985 when the species was collected from Lake Erie and Lake Ontario. In 1986 the spiny water flea was collected from Lake Michigan, and in 1987 the species had successfully invaded Lake Superior. More recently it has been found in several small lakes in Minnesota and in more than a dozen lakes in Ontario, Canada. Researchers suspect *Bythotrephes cederstroemi* could be responsible for the decline of 3 daphnia species in Lake Michigan (Lehman 1991).

Other nonindigenous crustaceans in the United States. Besides *Bythotrephes cederstroemi*, there are numerous crusteceans that have gained increasing attention with respect to their being invasives and potentially having adverse impacts on native fauna. Here, we consider only a few species that might be considered in subsequent investigations of species invasions of the Red River basin. Throughout the US, there are no fewer than 77 species of crustaceans that are considered nonindigenous to the waters in which they occur, and of that number, 44 have become established in their new environment. Crustaceans are found in every kind of aquatic

[5]Original material authored by Amy Benson and Pam Fuller, USGS/BRD/FISC. Updated, expanded, and edited January, 2004.

habitat, and marine and estuarine habitats outnumber freshwater areas (lentic or lotic) habitats as far as species incursions, over two dozen introduced species are found in fresh water. Regardless of the receiving habitats, these introductions are linked to worldwide sources. Introductions of crustaceans as early as 1873, have typically occurred through aquaculture and research escapes and releases, ballast water discharge, ship fouling, stocking for food or gamefish forage, and stock contamination with fish or oyster species. Studies have shown that nonindigenous crustaceans impact food webs and fish communities, exclude native congeners, and alter habitats.

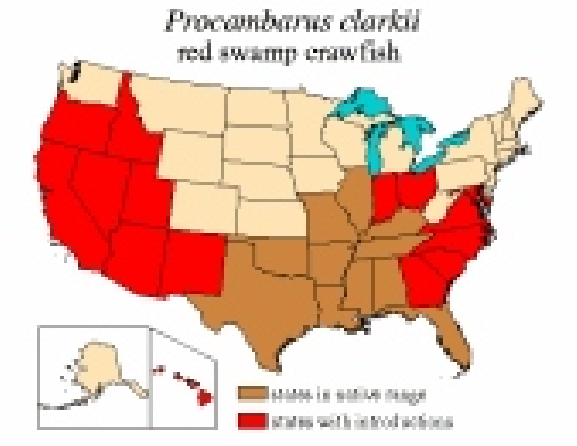
***Daphnia lumholtzi* Sars.** The native range of *Daphnia lumholtzi*are freshwater lakes of east Africa, southwest Asia, and east Australia (Havel 1993). It was first reported in Stockton Lake in southwest Missouri in 1991 and can be found in 13 states from Illinois and Ohio down to Texas



across to North Carolina and south to Florida. *D. lumholtzi* has spread much faster than another zooplankton invader, *Bythotrephes cederstroemi,* for reasons unknown. The method of introduction is uncertain. But, coincidentally, one of its first appearances was a lake in Texas where the Nile perch was first introduced to North America (Havel 1993). It is well established in the U.S. Effects or impacts are yet unknown (see USGS/BRD/FISC posting last accessed December 8, 2004 at http://nas.er.usgs.gov/crustaceans/docs/dlumholtzi.html).

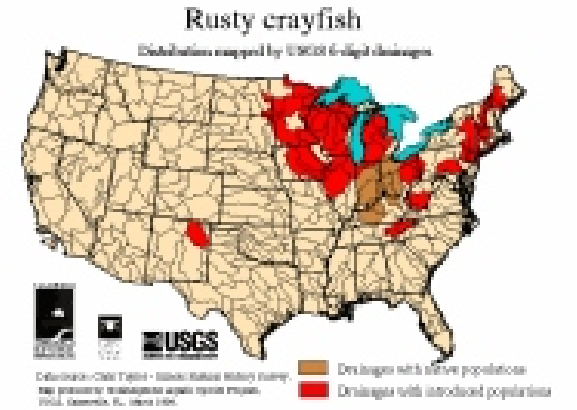
Procambarus clarkii (Red Swamp Crawfish). The red swamp crawfish is native to fresh waters from northern Mexico to the Florida panhandle and north to southern Illinois and Ohio (Hobbs 1989). This crayfish has been accidentally and deliberately introduced well outside its range in the Americas and in Africa and Asia (Fitzpatrick 1983). In the United States, it has been introduced into at least 15 states (Hobbs 1989). This species and one other, the white river crawfish (*P.*

acutus), are the cultured crawfish in "Cajun" crawfish dishes. The species are very similar and the two species comprise over 90% of the crawfish produced in the U.S. The way to distinguish the two species is the presence of a blue vein under the tail of the red swamp crawfish; it is absent in the white river crawfish. In California, wild populations of the red swamp crawfish eat rice crops (Pennak 1989). They have also been found to prey on California newts (*Taricha torosa*) and may



be responsible for their decline in some areas (Gamradt and Kats 1996).

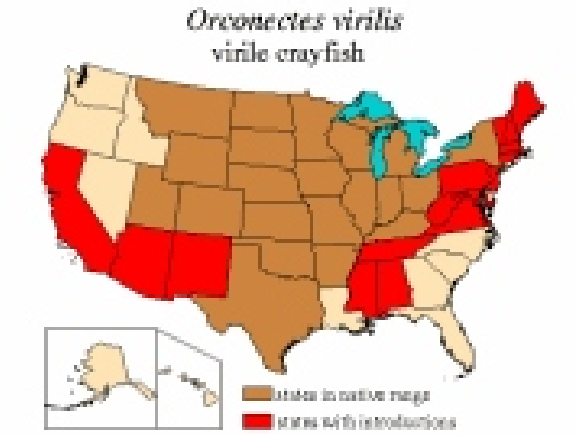
Orconectes rusticus (Rusty Crayfish). The rusty crayfish is native to western Ohio, eastern Indiana, and Kentucky. It has become established in 17 states outside of its native range, primarily through bait release by anglers. Contrary to some reports, it is not present in Missouri or central



Tennessee (C. Taylor, personal communication). Rusty crayfish often displace native crayfish including *O. propinquus, O. virilis*, and *O. sanborni*, reduce the amount and kinds of aquatic plants and invertebrates, and reduce some fish populations (Gunderson 1995). In Wisconsin,

where the rusty crayfish has been introduced, it is hybridizing with the blue crayfish (*O. propinquus*), another introduced species. The resulting hybrids are outcompeting both parental species for both food and shelter (Roush 1997). It has been estimated that rusty crayfish may consume twice as much food as the native virile crayfish, *O. virilis* (Momot 1992). This crayfish may affect fish populations by competing with juvenile fish for food and by preying on fish eggs (Gunderson 1995).

Orconectes virilis (Virile Crayfish). The virile crayfish is native from Saskatchewan to Ontario, Canada, and from Montana and Utah to Arkansas, New York, and possibly southwestern Maine. It has been introduced into 17 states outside its native range, largely through bait-bucket releases which are frequent modes of "jump" dispersal events for crusteceans and other aquatic biota. This species is also commonly sold by biological supply houses and could be dispersed this way as



well. In California, the virile crayfish may be responsible for the decline of native Shasta crayfish (*Pacifastacus fortis*). *O. virilis*was introduced into California in the early 1960s from east of the Continental Divide. It has a higher fecundity and more rapid growth rate than the native Shasta crayfish. The virile crayfish matures at one year and produces up to 443 eggs while the Shasta crayfish matures at 4 years and produces 10-70 eggs. As a result, the virile crayfish is replacing the native species (Light et al. 1995). Introductions of this species have also displaced native crayfish species in the Patapsco River, Maryland (Schwartz et al. 1963).

Representative biota of concern: Fishes

[6]*Dorosoma cepedianum* (Lesueur 1818)

Common Names: gizzard shad (hickory shad)

Size: 52 cm.

Taxonomy and identification. Various sources document the taxonomy of the gizzard shad, including Becker (1983); Whitehead (1985); Page and Burr (1991); Etnier and Starnes (1993).

Native Range. Figure 5 depicts the presumptive original distribution for the gizzard shad, although the historic distribution is unclear for certain localities, i.e. St. Lawrence-Great Lakes. The species remains widespread in the Mississippi, Atlantic, and Gulf Slope drainages from Quebec to central North Dakota and New Mexico, and south to central Florida and Mexico (Page

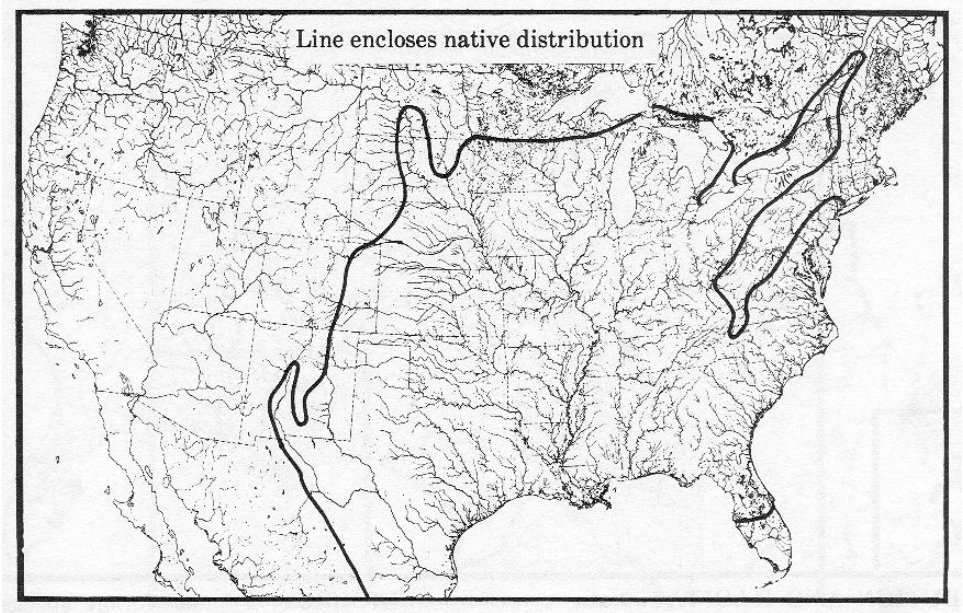


Figure 5. Presumptive native distribution of gizzard shad (after Lee et al 1980).

[6]Original material prepared by Pam Fuller (January 13, 2000) at the Center for Aquatic Resource Studies, USGS/BRD/FISC. The Center is part of the Biological Resources Division of the Geological Survey within the U.S. Department of the Interior. Updated and edited January, 2004.

and Burr 1991). Propst and Carlson (1986) believe the gizzard shad may be native to the South Platte drainage in Colorado. Since the 1600's, gizzard shad has expanded its range naturally to include Massachusetts (O'Leary and Smith 1987; Hartel 1992), and the species has been introduced to Lake Erie upon completion of the Ohio Canal (Jordan 1882). Cold weather apparently limits the species' northern range (Becker 1983).

Nonindigenous Occurrences. Figure 6 summarizes the presumptive native distribution overlain with the species' expanded range accountable as introduction. Gizzard shad were introduced into Colorado in the Arkansas, South Platte, and Republican drainages (Beckman 1952; Woodling

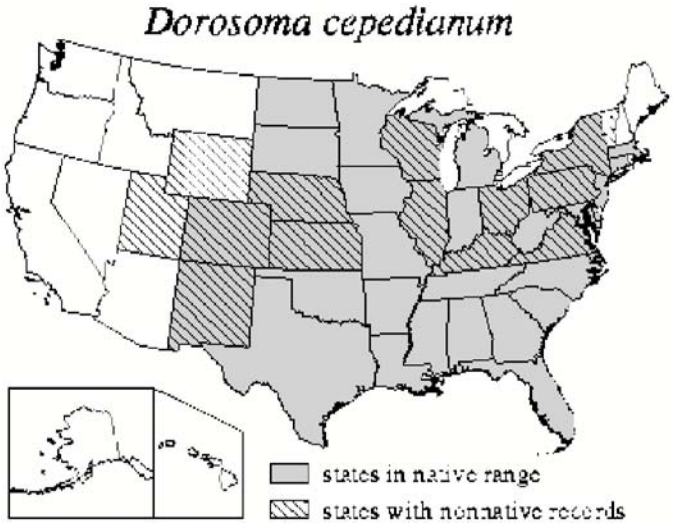


Figure 6. Native distribution overlain with expanded introduced range.

1985), although the species may have occurred in the South Platte drainage prior to the documented introduction. In Kansas, gizzard shad have been stocked in Fall River Reservoir, in sand pits along Prairie Dog Creek, and in Kirwin, Webster, and Cedar Bluff reservoirs (Cross 1967), and in Nebraska, one or more unspecified areas (presumably the Platte River) have also been stocked (Bouc 1987). The species has expanded its range into Wyoming from introductions into Nebraska (Baxter and Simon 1970), and from intentional stockings in the state east of the Continental Divide (Hubert 1994). Gizzard shad have become established in the upper Rio Grande River in New Mexico (J. Wilbur, personal communication), and the species has been stocked in Utah (B. Schmidt, personal communication).

East of the Mississippi River, the species, although native to Illinois, has expanded its range and abundance within the state due to construction of reservoirs (Smith 1979). Gizzard shad were

stocked in Martin's Fork Lake and in other small impoundments above Cumberland Falls in Kentucky (Minckley and Krumholz 1960; Burr and Warren 1986). It is unclear whether gizzard shad are native to the Great Lakes or gained access through canals and rivers in New York such as the Mohawk River, Oswego River, and Barge Canal (Smith 1985). The species has reached Lake Michigan (Wisconsin) either through the Chicago River Canal or the Fox-Wisconsin Canal at Portage (Becker 1983). Miller (1957) reviewed the evidence for native versus introduced status. As noted previously, gizzard shad gained access to Lake Erie, Ohio via the Ohio Canal (Jordan 1882). Gizzard shad were accidentally stocked in Conowingo Pond, Lancaster County, Pennsylvania (Denoncourt et al. 1975a). They have expanded into Lake Champlain and the Connecticut River, Vermont (K. Cox, personal communication). They were stocked in Lake Anna, Smith Mountain Lake, and Kerr, Philpot, and Leesville reservoirs, Virginia (Jenkins and Burkhead 1994).

Means of Introduction. These fish were stocked intentionally for forage. The Wyoming populations also spread from introductions into Nebraska (Baxter and Simon 1970). In Pennsylvania, gizzard shad were stocked accidentally with American shad (Denoncourt et al. 1975a). In Vermont, gizzard shad have expanded their range through the Connecticut River assisted by fishways that were constructed for American shad *Alosa sapidissima* and Atlantic salmon *Salmo salar* restoration (Cox, personal communication). The species has likely gained access to Lake Champlain through the Hudson Barge Canal that links the lake to the Hudson River (Cox, personal communication), and they have gained access to Lake Michigan through either the Chicago River Canal or the Fox-Wisconsin Canal (Becker 1983), and to Lake Erie through the Ohio Canal (Jordan 1882).

Status: Established in many states.

Impact of Introduction. Competition for food between gizzard shad and other fish species may occur (Burns 1966b; Moyle 1976a). Jenkins (1954) found that gizzard shad directly compete with centrarchids resulting in decreased growth and size of the centrarchids. Gizzard shad show tremendous invasion potential. After only two plantings totally 1020 fish in Lake Havasu, the species spread through the Colorado River from Davis Dam southward to the Mexican border, the Salton Sea, and associated irrigation ditches within only 18 months (Burns 1966b).

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[7]***Gila atraria*** **(Girard 1856)**

Common Name: Utah chub

Taxonomy and identification: Simpson and Wallace (1978); Sigler and Sigler (1987); Page and Burr (1991); Bond (1994).

Size: 56 cm (maximum length)

Native Range. Figure 7 indicates the native range of the Utah chub which includes the upper Snake River system in Wyoming and Idaho, and Lake Bonneville basin (including Great Salt Lake drainage and Sevier River system) in southeastern Idaho and Utah (Page and Burr 1991).

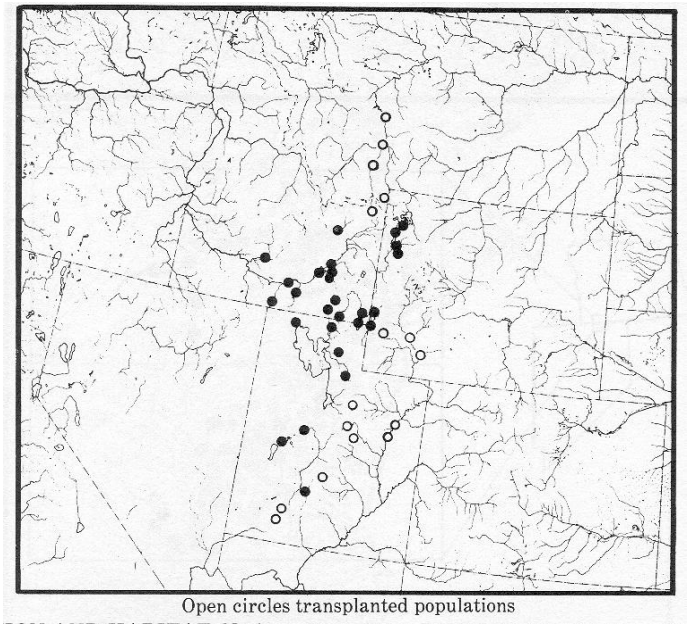


Figure 7. Native distribution of Utah chub.

Nonindigenous Occurrences: Figure 8 summarizes current distribution (native and introduced) projected from the dot map of Figure 7 which highlighted the species native distribution.

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[7] Original material prepared by Pam Fuller and Leo Nico (revised March 20, 2001) at the Center for Aquatic Resource Studies . The Center is part of the Biological Resources Division of the Geological Survey within the U.S. Department of the Interior. Updated and edited, January 2004.

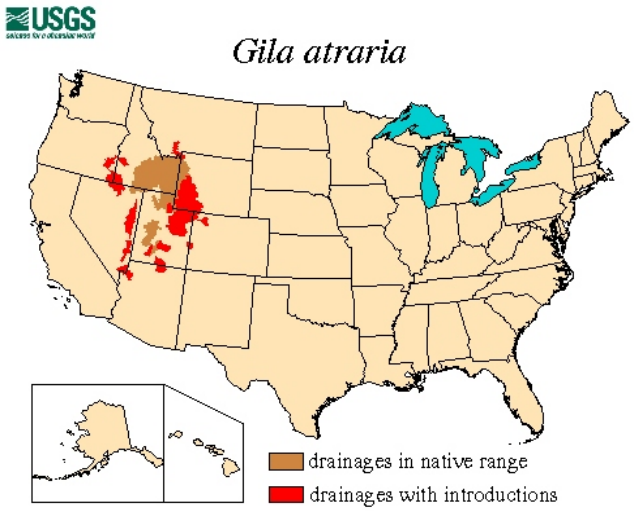


Figure 8. Native and introduced range of Utah chub.

The Utah chub is known from the Green and Yampa rivers in Colorado (Tyus et al. 1982). In Idaho, it has been recorded from the Snake River near Boise (circa 1970s) (Whitney and Wydoski 1979; Lee et al. 1980 et seq.), and Island Park Reservoir and several other small reservoirs in the upper part of Henrys Fork in the Snake River drainage (Simpson and Wallace 1978). The species was introduced into Hebgen Lake, Montana, where it became established and eventually spread to most of the Madison River and as far downstream as Canyon River Reservoir on the Missouri River (Brown 1971; Cross et al. 1986; Holton 1990), and it has been introduced into several sites in Nevada including Duck Lake (Lincoln County), Shoshone Springs (White Pine County), and both Murphy Spring and Comins Lake in Steptoe Valley (White Pine County) (Miller and Alcorn 1946; La Rivers 1962; Hubbs et al. 1974; Sigler and Sigler 1987; Miller et al. 1991). In Oregon, it was introduced to the Owyhee River system (Snake River drainage) (Bond 1994), and in Utah, Gila chub is has been collected from Panguitch Lake in the Sevier drainage, and from Fish Lake and reservoirs and streams in the Colorado River drainage (Sigler and Miller 1963; Vanicek et al. 1970; Holden and Stalnaker 1975b; Lee et al. 1980 et seq.; Tyus et al. 1982; Sigler and Sigler 1987). The species has also been recorded from the Green River in Wyoming (Baxter and Simon 1970; Lee et al. 1980 et seq.; Tyus et al. 1982; Hubert 1994).

Hubbs et al. (1974) detailed the introduction history of Utah chub in parts of the Great Basin of western North America. Tyus et al. (1982) gave a distribution map of this species in the upper Colorado basin. There is some uncertainty concerning the exact natural range of this species. For instance, Hubbs et al. (1974) stated that it might be theorized that an ancient outlet into the Bonneville system (where Utah chub is native), or some other stream connection, could have led

to the spread of this species into Spring Valley; however, they noted that there is no definitive evidence of such a discharge, and no other indication of the occurrence of Bonneville fishes in Spring Valley. Most authors (e.g., Lee et al. 1980 et seq.; Sigler and Sigler 1987, 1996) have concluded that the Utah chub is native to the Snake River above Shoshone Falls but not below. Simpson and Wallace (1978) noted that the native range of Utah chub in Henrys Fork of the Snake River was restricted to below Mesa Falls; however, the fish was later introduced to Island park Reservoir and several small reservoirs in the area. Many western states have outlawed the use of live fish as bait to prevent the spread of this and other bait fish (Sigler and Sigler 1987).

Means of Introduction. Many introductions have been the result of bait bucket releases (Holden and Stalnaker 1975b; Simpson and Wallace 1978; Sigler and Sigler 1987). Hubbs et al. (1974) found evidence that the species may have been introduced to certain sites in the Great Basin by early Mormon settlers. These researchers also speculated that Native Americans may have brought Utah chubs into Shoshone Spring. The species may have been introduced to Murphy Spring, in Steptoe Valley, as forage for sportfish, although its establishment may have resulted from bait bucket releases (Hubbs et al. 1974). In some areas the species has become widespread because of natural dispersal from original points of introduction (e.g., Madison and Missouri rivers in Montana). Holden (1991) stated that it first appeared in Flaming Gorge Reservoir on the Wyoming-Utah border in 1964.

Status. Established in Colorado, Idaho, Nevada, Montana, Utah, Wyoming, and apparently Oregon. In its native range in the Green River and Yampa River in Colorado, and in the Dolores, Green, and Price Rivers in Utah, the species is considered rare or incidental. Utah chub is considered abundant in Flaming Gorge Reservoir in Utah and Wyoming (Tyus et al. 1982).

Impact of Introduction. Introduced populations often reach great abundance and become serious competitors with sport fish, especially trout (Sigler and Miller 1963). For instance, this species has been found to depress growth of kokanee salmon *Oncorhynchus nerka* through competition for food (Teuscher and Luecke 1996). Hubbs et al. (1974) also noted that it has a tendency toward population explosion and habitat dominance in artificial impoundments. Utah chub became a major management concern in Flaming Gorge Reservoir by the late 1960s, in part, because it appeared to compete with trout for planktonic foods and because the species established growth records of its own (Holden 1991). Introduced Utah chub, along with other introduced species, may have replaced the relict dace *Relictus solitariu*s at Murphy Spring, Nevada (Hubbs et al. 1974). Predation by, and hybridization with, the Utah chub are considered

some of the most serious hazards to the least chub *Iotichthys phlegethontis* in Utah (Sigler and Sigler 1987), a species proposed for federal listing as an endangered species (U.S. Fish and Wildlife Service 1997). Attempts at eradication have been largely unsuccessful and costly (Sigler and Sigler 1987).

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[8]*Osmerus mordax* (Mitchill 1814)

Common Names: rainbow smelt

Taxonomy and identification: Scott and Crossman (1973); Becker (1983); Smith (1985); Page and Burr (1991).

Size: 33 cm

Native Range. Figure 9 illustrates the native range of the rainbow smelt. Atlantic drainages from Lake Melville, Newfoundland, to Delaware River, Pennsylvania, and west through Great Lakes; Arctic and Pacific drainages from Bathurst Inlet, Northwest Territories, to Vancouver Island, British Columbia. Also Pacific drainages of Asia (Page and Burr 1991).

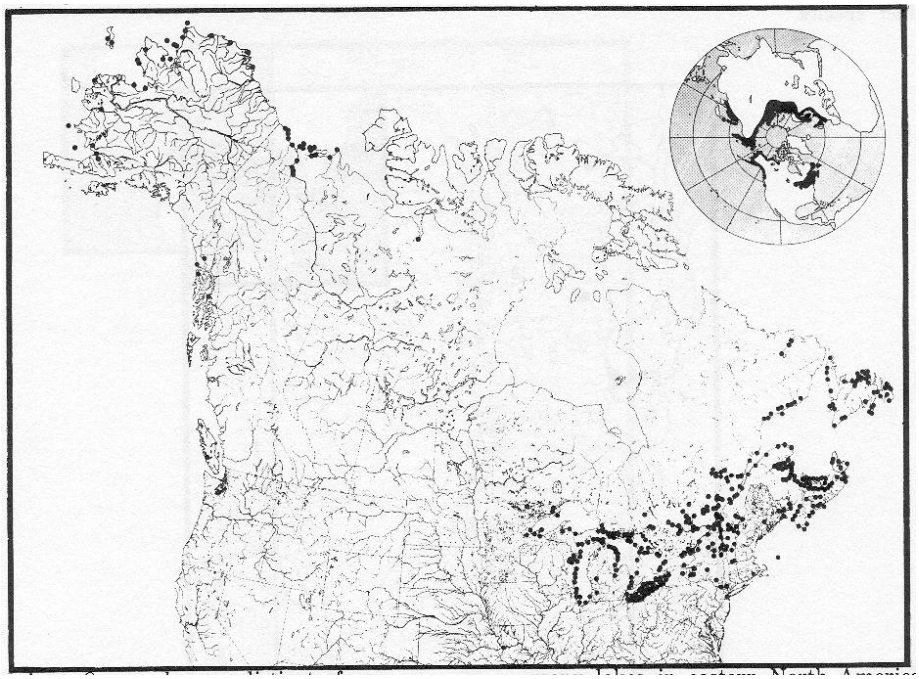


Figure 9. Native range of rainbow smelt (after Lee et al 1980).

[8]Original materials prepared by Pam Fuller (January 28, 2000) at the Center for Aquatic Resource Studies. The Center is part of the Biological Resources Division of the Geological Survey within the U.S. Department of the Interior. Updated and edited, January 2004.

Nonindigenous Occurrences: Figure 10 illustrates the distribution of rainbow smelt with introductions beyond the species' native range presented in the preceding dot map (Figure 9). Rainbow smelt occur in all five Great Lakes and also have been introduced or dispersed after introduction into several large rivers. Areas with introduced smelt include the Mississippi River,

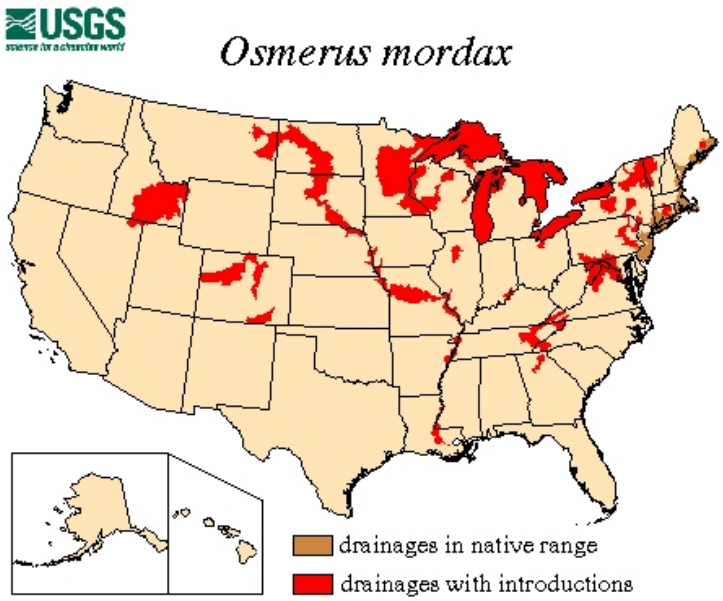


Figure 10. Expanded range (native plus introduced) of rainbow smelt.

Arkansas (Pennington et al. 1982; Mayden et al. 1987); reservoirs in the South Platte and Arkansas drainages and headwaters of the Colorado basin in Colorado (Woodling 1985; Propst and Carlson 1986); several lakes in Connecticut (Webster 1942); the Chattahoochee River below Lake Lanier, Georgia (Dahlberg and Scott 1971a, 1971b); lakes in the Sawtooth Mountains of Idaho (Linder 1963; Simpson and Wallace 1978); Lake Michigan (Emery 1985; Burr 1991), the Mississippi River, the Illinois River (Burr and Mayden 1980; Mayden et al. 1987; Burr 1991, Burr et al. 1996), and Ohio River (Burr 1991) in Illinois (Smith 1979; Burr and Page 1986); Lake Michigan and the Ohio River near Madison, Indiana (Emery 1985; Mayden et al. 1987); the Missouri River, Iowa (Harlan et al. 1987; Mayden et al. 1987); the Missouri River, Kansas (Mayden et al. 1987); the Mississippi River, Kentucky (Burr and Warren 1986; Mayden et al. 1987); the Mississippi River, Louisiana (Suttkus and Conner 1980; Mayden et al. 1987); Schoodic Lake, Maine (Havey 1973); Maryland (Ferguson 1876; Jenkins and Burkhead 1994); nonnative waters of Massachusetts (Smith 1833; Hartel 1992; Hartel et al. 1996); the Great Lakes in Michigan (Emery 1985); Lake Superior, Minnesota (Emery 1985; Burr and Page 1986); the

Missouri and Mississippi rivers, Missouri (Cross et al. 1986; Mayden et al. 1987; Pflieger 1997); the Missouri and Yellowstone rivers, Montana (Gould 1981; Cross et al. 1986; Mayden et al. 1987; Holton 1990); the Missouri River in Nebraska (Cross et al. 1986; Bouc 1987; Mayden et al. 1987); several dozen lakes in New Hampshire (Scarola 1973); Lake Erie (Emery 1985), Lake Ontario, the Finger Lakes, the Adirondack lakes, Neversink Reservoir, and Lake Champlain in New York (Werner 1980); Tennessee drainage, North Carolina (Menhinick 1991); Lake Sakakawea, North Dakota (Gould 1981; Bouc 1987; Harlan et al. 1987; Mayden et al. 1987; Holton 1990); Lake Erie, Ohio (Emery 1985); Lake Erie (Emery 1985) and Harvey's Lake (Susquehanna drainage), Pennsylvania (Denoncourt et al. 1975a; Hendricks et al. 1979; Cooper 1983; Hocutt et al. 1986); reservoirs on the Missouri River, South Dakota (Mayden et al. 1987; Hanten, personal communication); the Mississippi River, Watauga Reservoir, and South Fork Holston River, Tennessee (Mayden et al. 1987; Etnier and Starnes 1993); Lake Champlain, Vermont (Werner 1980); the Potomac River and Occoquan Reservoir, Virginia (Hocutt et al. 1986; Jenkins and Burkhead 1994); and Lake Superior, Wisconsin (Emery 1985; Burr and Page 1986).

Means of Introduction: The earliest known record is from 1912, when eggs were stocked in Crystal Lake, Michigan, which drains into Lake Michigan (Van Oosten 1937). Fish escaped into Lake Michigan and spread quickly throughout the Great Lakes and their tributaries (Creaser 1926; Gerking 1945; Hubbs and Lagler 1947; Nelson and Gerking 1968; Christie 1974; Eddy and Underhill 1974; Smith 1979; Morrow 1980; Phillips et al. 1982; Cooper 1983; Emery 1985). Early records documenting the smelt's range expansion in the Great Lakes include Lake Michigan, 1923 (Christie 1974; Emery 1985), Lake Erie, 1935 (Cooper 1983; Smith 1985), Lake Huron, 1925 (Christie 1974; Eddy and Underhill 1974), Lake Ontario, 1929 (Christie 1974; Smith 1985), and Lake Superior, 1923 (Emery 1985). The Lake Ontario population may be either native to this lake or gained access when the Welland Canal was built (Emery 1985; Smith 1985). Another possibility is that the species was introduced from the Finger Lakes via the Seneca-Cayuga, Erie and Oswego canals (Smith 1985).

Two means have been proposed to explain the introduction of rainbow smelt into the Missouri and Mississippi rivers. It may have spread from Lake Michigan via the Chicago sanitary canal to the Illinois River and then to the Mississippi and Missouri rivers (Burr and Mayden 1980). Alternatively, the species may have gained access to these rivers as a result of a stocking at Lake Sakakawea, North Dakota, in 1971 (Bouc 1987; Mayden et al. 1987; Holton 1990). The second explanation seems more plausible because of a lack of records from the Illinois River. Records of

first occurrence in other areas include the Mississippi River, Illinois and Kentucky, 1978; Mississippi River, Louisiana, 1979; Mississippi River, Tennessee and Arkansas, 1980; Missouri River, Missouri, 1980; Missouri River, Kansas, 1982 (Mayden et al. 1987). Mayden et al. (1987) provided a map of the species' distribution, dates of first observation in new areas, and possible introduction pathways. The species was originally introduced into Lake Sakakawea, North Dakota, as forage for salmonids (Mayden et al. 1987).

Status: Introduced populations of rainbow smelt have been very successful and the species is now established in the Great Lakes and in most rivers and lakes where introduced. In the Great Lakes a commercial fishery targeting smelt has been operating for many years (Smith 1985), and it is the most abundant fish in some locations on the Mississippi River (Pflieger 1997). To date, no adults of the rainbow smelt have been found in either Tennessee (Etnier and Starnes 1993) or Missouri (Pflieger 1997). The latter observation leads Pflieger (1997) to conclude that fish collected in Missouri are probabily maintained by continued escape of fish from upstream reservoirs on the Missouri River. As of 1987, only one specimen had been taken from the Ohio River (Mayden et al. 1987), and rainbow smelt are considered extirpated in Georgia, since none have been collected since its original release (Dahlberg and Scott 1971b).

Impact of Introduction: In the Great Lakes, rainbow smelt compete with lake herring *Coregonus artedii* for food (Becker 1983). In early studies, Havey (1973) had reported increased growth of landlocked Atlantic salmon following the introduction of smelt as a forage species in a lake in Maine, and Christie (1974) correlated lake herring decline with smelt increases in most of the lakes. Todd (1986b) also reported that smelt may be partially responsible for the decline of whitefish (*Coregonus* spp.) in the Great Lakes. Hrabik et al. (1998) found evidence of competition for food between introduced rainbow smelt and native yellow perch *Perca flavescens* in Wisconsin lake habitats. Rainbow smelt are eaten by humans and used as bait for salmonids and walleye (Pflieger 1997).

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Asian Carp

Asian carp are large fish (39-40 inch; 40-50 lb.) introduced into the U.S. by fish farmers in Southern states in the 1960's and 70's to control vegetation and algae blooms. Three of these species, bighead carp (*Hypophthalmichthys nobilis*), the grass carp (*Ctenopharyngodon idella*), and silver carp (*Hypophthalmichthys molitrix*) have been released or have escaped to the wild and are reproducing in many rivers and streams of the Mississippi River Basin. Black carp (*Mylopharyngodon piceus*) has also been included, since it remains in captivity in hatcheries, fish culture facilities, and fish farm ponds, primarily in Southeastern states. Common carp (*Cyprinus carpio*) has not been considered as part of this compilation.

[9]***Hypophthalmichthys (Aristichthys) nobilis*** (Richardson, 1845)

Common name: Bighead carp

Size: Maximum length generally falls between 100 to 150 cm TL and maximum weight varies from 20 to 50 kg.

Native distribution. *Hypophthalmichthys (Aristichthys) nobilis* is one of many carp species whose native distribution occurs in Asia, being particularly common to large rivers of eastern China (Figure 11).

Taxonomy and identification. Bighead carp are dark green to olive in color on their backs with gray to silvery sides and a white to cream colored belly, generally having small black blotches over their dorsolateral surfaces. Bighead carp lack barbels and are distinctive morphologically, having scales that are very tiny and eyes are set below the midline of the long and compressed body.

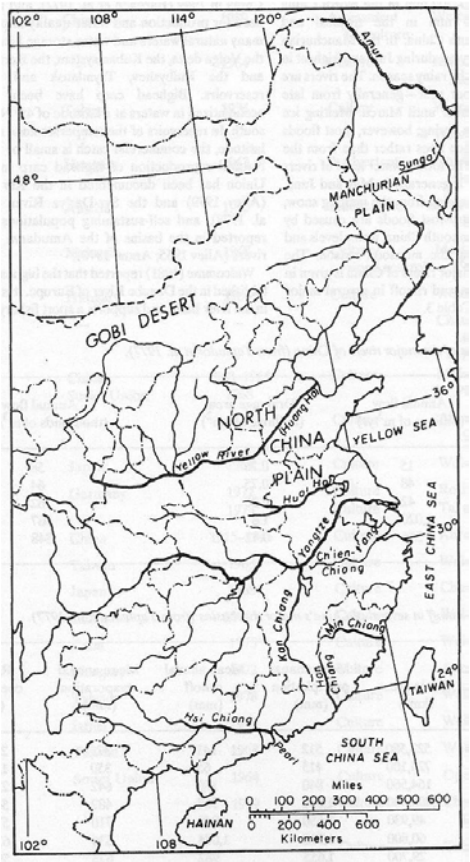


Figure 11. Native ranges of Asian carp occur in China.

[9]Original material prepared by Pam Fuller, USGS/BRD/FISC, with additional material obtained from FishBase (www.fishbase.org), access October through December, 2003. Updated and edited, November, 2004.

The head is very large compared to the body (hence, the species common name), and the fish can weigh from 55-110 lbs (25-50 kg) and measure nearly 60 inches (1.5 meters) long. The species is technically characterized by spine counts: dorsal spines (total): 3-3; dorsal soft rays (total): 7-7; anal spines: 1-3; anal soft rays: 12-14. The posterior margin of the last simple dorsal ray is not serrated, and branched anal rays number 13-14.5. A keel extend from base of the pelvis to anus.

Life history. Bighead carp are freshwater benthopelagic fishes that generally range between near surface to 5 m. Their apparent perferred temperatures range between 4 - 26˚C which are common to their native and introduced ranges that lie between latitude 64ºN to 18ºS. Populations of bighead carp are relatively resilient to adverse impacts, having a minimum population doubling time that ranges between 1.4 and 4.4 years. Preferred habitats include rivers and lakes where the fish feeds on the bottom, mainly on zooplankton. In its native range, the fish is marketed fresh and frozen.

Bighead carp have long gill rakers, which allow them to strain plankton from the water for food, which includes cyanobacteria, green algae, zooplankton, and aquatic insects and larva. The fish forage constantly, and are voracious feeders. Bighead carp will compete for food with fish that are still in the larval stage and fish populations decrease because the larval fish do not get enough food to survive.

Bighead carp spawn when the water temperature is between 25 to 30 ºC (77 to 86 ºF) which means active spawning at mid-latitudes occurs between April and June. Peak spawning season occurs in late May, with females carrying between 660,000 to 872,000 eggs. The number of eggs lain increases with age of female until senescence when production decreases.

Nonindigenous occurrences: The bighead carp was introduced to the Mississippi River when private hatchery ponds were washed out in the state of Arkansas in the 1970's or possibly they were let go into the wild when they were no longer needed on by the fish farmers. Fish appeared in open water in the early 1980's in the Ohio and Mississippi Rivers, and at present bighead carp have been found in at least 19 states including Lake Erie. Introductions of *Hypoopthalmichthys (Aristichthys) nobilis* have been documented worldwide [FishBase cites, n=71], ranging from locations near native distribution (e.g., China to Malaysia throughout the 1800's, and from China to Japan, southeast Asia from the end of the 19th through the 20th century) to releases throughout Europe in mid- to late 20th century that yielded sustained populations in eastern Europe. These eastern European populations in turn served as source regions for invasions, most unsuccessful,

into western Europe. Current distribution of commercial stock is worldwide, and releases from captivity regularly occur although establishment of sustainable populations is infrequent. The earliest documentation of release and establishment of sustainable populations in North America occurred in the mid-1980's (FishBase cites 1986), which resulted from ornamental fish being released from confinement. FishBase BiOSC cited point data for *Hypophthalmichthyes nobilis* (*Aristichthys nobilis*; n = 7) includes type specimens at University of Kansas (*Hypophthalmichthys nobilis*, 1993 at lat 38.98, long -96.77 (Catalog KU 23151), collected by T. Hall near Kansas River below Bowersock Dam at Lawrence). In North America, the increasing range of *Hypophthalmichthys nobilis* is apparent with increased reports as yet to be cataloged by museums and subscribers to BiOSC. Each citing in North America to date is compatible with the species current distribution (Figure 12).

Methods of introduction: Most introductions have been intentional, since the bighead carp

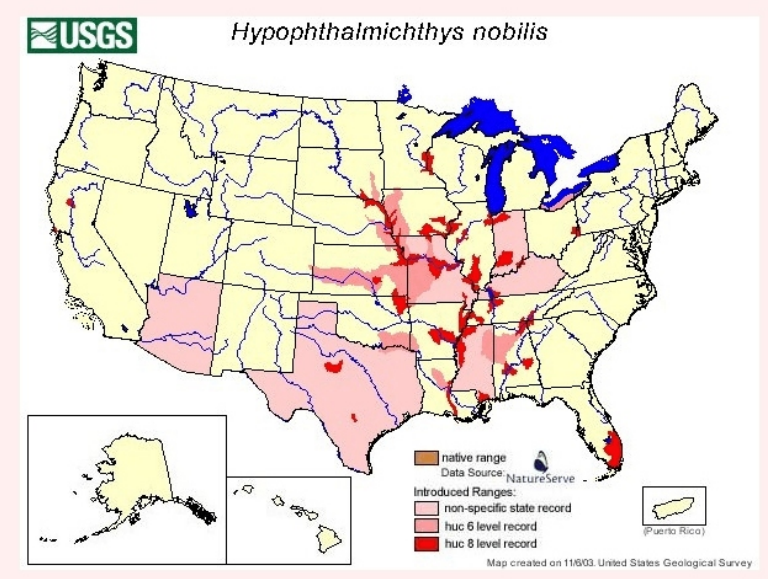


Figure 12. Current extent of bighead carp in the US.

supports a highly successful commercial fishery and aquaculture industry (e.g., commercial aquaria and show aquaria). Introduced populations occur in numerous countries, and the species has achieved a near global distribution. Many introductions, however, have not yielded sustainable populations outside culture facilities, since the species' breeding requirements are very specialized and commerical stocks are generally maintained by artificial reproduction or continuous importation. When the species does escape from captivity, several countries report adverse ecological impact after bighead carp are introduction to a region and establish sustainable

populations.

Impacts. Bighead carp is not included on the IUCN Red List, and is considered a potential pest. A number of diseases associated with *Hypophthalmichthys nobilis* have been observed and potentially threaten other carp and native cyprinids, if disease agents can jump from one species to another. These diseases include parasitic infections: parasitic protozoa and worms (such as White Spot Disease, Dactylogyrus Gill Flukes Disease, Trichodinosis, Cryptobia Infestation, Turbidity of the skin in freshwater fish, Myxidium Infection, Trichodina Infection 1, Trichodina Infection 2, Trichodina Infection 3, Tripartiella Infestation, Trichodinella Infection 2, Ichthyobodo Infection, Bothriocephalus Infestation), fungal disease (e.g., False Fungal Infection caused by *Apiosoma* spp.), and Fish Louse Infestation 2.

Methods of control. Currently, the best control technology is far from perfect, and currently it appears that big head carp are restricted only by high dams and electric barriers (also see, e.g., http://www.umesc.usgs.gov/invasive_species/asian_carp.html, http://www.glfc.org/fishmgmt/carp.asp, and http://www.epa.gov/glnpo/invasive/asiancarp/).

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[10]Hypophthalmichthys molitrix (Valenciennes 1844)

Common Name: silver carp

Size: Silver carp easily reach a maximum size of 100 cm TL and 27 kg with a published maximum size of 105 cm TL (male/unsexed) and 50.0 kg.

Taxonomy and identification. Silver carp are olivaceous to silvery in color and lack barbels. Distinguishing characteristics were initially summarized by Berg (1949), and currently published state and regional fish books provided detailed accounts of life history (e.g., Robison and Buchanan 1988; Etnier and Starnes 1993; Pflieger 1997). Diagnostically, the species presents spine counts: dorsal spines (total): 1-3; dorsal soft rays (total): 6-7; anal spines: 1-3; anal soft rays: 10-14 (branched 12-13.5). The edge of last simple dorsal ray is not serrated, and a keel extends from isthmus to anus.

Life history: *Hypopthalmichthyes moltrix* is requires standing or slow-flowing conditions such as in impoundments or the backwaters of large rivers, so tends to be benthopelagic and potamodromous and ranges between surface to 5m in depth. As one of the so-called "Chinese carps" or "Asian carps," the silver carp is a filter-feeder capable of taking large amounts of phytoplankton, zooplankton, bacteria, and detritus (Leventer 1987). In its native range, silver carp migrate upstream to breed, then fertilized eggs and larvae float downstream to floodplain zones. The species generally swims just beneath the water's surface, and is very active swimmer being well known for its habit of leaping clear of the water when disturbed.

In its native range (approximately bounded between 64ºN and 43ºS), temperatures range from 6 to 28ºC. As is characteristic of other "Asian carp," *Hypopthalmichthyes moltrix* is relative resilience and has a population doubling time that ranges between 1.4 to 4.4 years.

Native Range. Several major Pacific drainages in eastern Asia from the Amur River of far eastern Russia (Siberia) south through much of eastern half of China to Pearl River, possibly including northern Vietnam (Berg 1949; Li and Fang 1990).

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[10]Original material prepared by Leo Nico (October 3, 2003) at the USGS/BRD/FISC. Supplemental materials were also incorporated from FishBase, then expanded and edited, October, 2003 through November, 2004.

Nonindigenous Occurrences: Silver carp have been introduced around the world for aquaculture and control of algal blooms. In North America (Figure 13), the species has been recorded from the Black Warrior and Tallapoosa river drainages of the Mobile Basin, including Yates Reservoir, in Alabama (Mettee et al. 1996; J. Hornsby and M. Pierson, personal communication); from

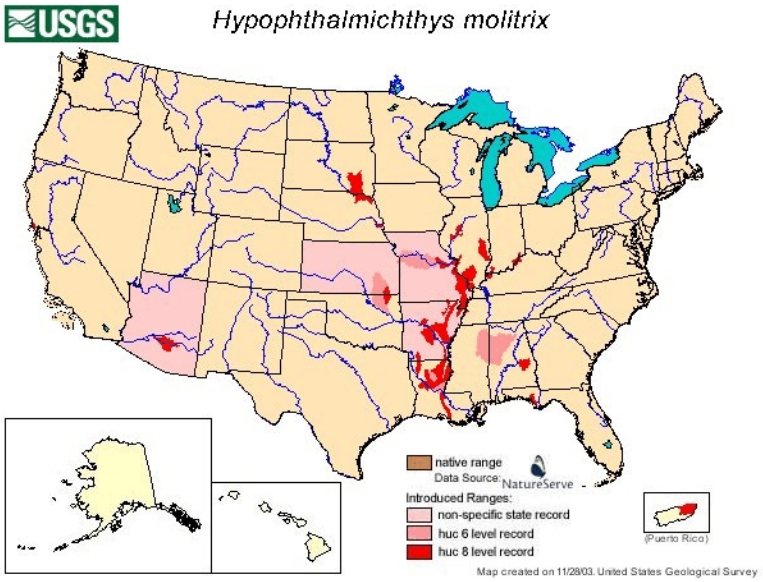


Figure 13. Current distribution of silver carp in US.

Arizona (Courtenay et al. 1991; Rinne 1995); and from the Arkansas and White River systems (including the the lower Cache River) and the Mississippi River mainstem in Arkansas (Freeze and Henderson 1982; Carter and Beadles 1983; Courtenay et al. 1984; Robison and Buchanan 1988). It has been stocked in water treatment ponds on the East Slope of Colorado (D. Horak, personal communication). A single specimen was taken in August 1994 from St. Andrews Bay at the Deer Point Lake spillway, Bay County, Florida (Middlemas 1994). It has been intentionally released in Hawaii (Davidson et al. 1992). It has also been collected or reported from several water bodies in, or bordering, Illinois, including the Mississippi and Ohio rivers and several of their tributaries, the Muddy River, Horseshoe Lake and vicinity in the Cache River drainage (Burr 1991; Burr et al. 1996; Laird and Page 1996) and the Embarras River below Lake Charleston (K. Cummings, personal communication). There are also records of this species from the southeastern part of Indiana (presumably the Ohio River; Courtenay et al. 1991; Simon et al. 1992); unspecified location(s) in Kansas (Courtenay et al. 1991) (possibly the Missouri River); from the Ohio River in Kentucky (Pearson and Krumholz 1984; Burr and Warren 1986); from the lower Mississippi River and many tributary sites in Louisiana including the Atchafalaya, Red, Boeuf, Old, Ouachita, and Little river drainages, LaFourche Canal, Miller Lake, and Loggy Bayou (Freeze and

Henderson 1982; Carp Task Force 1989; Douglas et al. 1996; F. Bryan and J. Hughes Little, personal communication); from the Mississippi and Missouri river mainstems in Missouri (Courtenay et al. 1991; Robinson 1995; Pflieger 1997); the Missouri River drainage and Elkhorn River Nebraska (Nebraska Game and Parks 2000); the Missouri River up to Gavins Point Dam in South Dakota (W. Stancill, pers. comm.), the mouth of the James River in South Dakota (R. Klumb, pers. comm.)and from a Mississippi River outflow in Tennessee (C. Saylor, personal communication). Voucher specimens are housed state museums in Florida (UF 98162); Illinois (SIUC 17716, 23043, 23046, 24415; INHS 88425); Louisiana (NLU 65811, 66858, 66859).

Means of introduction and status. Introductions of silver carp have historically been intentional, stemming from species' commercial fishery and aquaculture value. When released or escaped from culture, and sustained populations are subsequently attained, the species is frequently characterized as a potential pest. FishBase cites no fewer than 91 introductions of *Hypophthalmichthys molitrix* world-wide, which suggests the species is highly adaptable with life history attributes amenable to an invasive (see http://www.fishbase.org/search.cfm). Initial invasion and establishment in US poorly documented but the species has been imported and stocked for phytoplankton control in eutrophic water bodies. Silver carp have also been stocked as a food fish, e.g., the species was first brought into the United States in 1973 when a private fish farmer imported silver carp into Arkansas (Freeze and Henderson 1982). By the mid-1970's the silver carp was being raised at six state, federal, and private facilities, and by the late 1970s the species had been stocked in several municipal sewage lagoons (Robison and Buchanan 1988). By 1980 the species was discovered in natural waters, probably a result of escapes from fish hatcheries and other types of aquaculture facilities (Freeze and Henderson 1982). The occurrence of silver carp in the Ouachita River of the Red River system in Louisiana was likely the result of an escape from an aquaculture facility upstream in Arkansas (Freeze and Henderson 1982). The Florida introduction was probably a result of stock contamination, a silver carp having been inadvertently released with a stock of grass carp being used for aquatic plant control (Middlemas 1994). In a similar case, the species was apparently introduced accidentally to an Arizona lake as part of an intentional, albeit illegal, stock of diploid grass carp (W. Silvey, personal communication). Pearson and Krumholz (1984) suggested that individuals taken from the Ohio River may have come from plantings in local ponds or entered the Ohio River from populations originally introduced in Arkansas.

Impact of Introduction. Silver carp have been intensively cultured in many parts of the world, often raised in combination with other fishes, and the species is among 3 or 4 species of cyprinids

whose world production in aquaculture exceed 1 million tons/year, much as fresh fish for human consumption. The species has also been introduced to many countries where its ability to clean reservoirs and other waters of clogging algae is exploited, e.g., Jenkins and Burkhead (1994) reported on the use of silver carp in a wastewater treatment pond in the upper James River drainage of Virginia, yet no record of the species in Virginia open waters has occurred. Pflieger (1997) considered the impact of this species difficult to predict because of its place in the food web. In numbers, the silver carp has the potential to cause enormous damage to native species because it feeds on plankton required by larval fish and native mussels (Laird and Page 1996). Silver carp are also potential competitors with adults of some native fishes (e.g., gizzard shad) that also rely on plankton for food (Pflieger 1997).

Adverse ecological impacts have been observed after the species' introduction, e.g., increased incidence of fish disease associated with *Hypophthalmichthys molitrix* such as parasitic protozoa and parasitic worms (Bothriocephalus Infestation 2, Myxobolus Infection 4, Myxobolus Infection 2, Anchorworm Disease (Lernaea sp.), Dactylogyrus Gill Flukes Disease, and Trichodinosis) and bacterial diseases (e.g., enteric redmouth).

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[11]***Mylopharyngodon piceus*** (Richardson 1846)

Common Name: black carp

Taxonomy and identification. A few distinguishing characteristics were provided by Berg (1949), Masuda et al. (1984), and Howells (1992b). Black carp superficially resemble grass carp (*Ctenopharyngodon idella*), but there are no known voucher specimens in US museums.

Size: maximum size recorded 122 to 131 cm TL and 32 to 36 kg (males/unsexed individuals)

Life history and general biology. Black carp are demersal freshwater fish, ranging from near surface to a depth of 10m. As a bottom-dwelling molluscivore, black carp were imported into the United States in the early 1970's for use as a food fish and also as a biological control agent for snails that serve as an intermediate host for a trematode parasite in fish held captive on fish farms. More recently, this species has been proposed as a biological control for the introduced zebra mussel *Dreissena polymorpha*.

While adults preferentially prey on mollusk, black carp diet varies with age. Immatures forage on zooplankton and fingerling fishes, and adults will prey on benthic crustaceans, aquatic insects, and fish eggs when mollusks are not available. As immatures and adults, black carp, if established in the wild, could have serious adverse impacts, due to predation on native mollusc species (including threatened and endangered species) and on fingernail clams which are a primary food source of migrating waterfowl and fish. For example, black carp commonly feed on mollusks, using their pharyngeal teeth to crush the mollusks shells, then consuming the soft tissues, e.g., a 4-year old juveniles are capable of consuming ca. 1-2 kg of molluscs per day. Given their preference of mollusks, black carp were considered at biological control agents for zebra mussel (e.g., French 1993; Rubinshtein 1994; Ricciardi 1994), but there is little experimental evidence that indicates black carp would be effective in controlling zebra mussels. Because black carp do not have jaw teeth and their mouths are relatively small, it is unlikely that these fish are capable of breaking apart zebra mussel rafts (Nico and Williams 1996).

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[11]Original material posted to FishBase, Leo Nico and Pam Fuller (Center for Aquatic Resource Studies, USGS/BRD, Danielle M. Crosier and Daniel P. Molloy (New York State Museum) with assistance from Jerry Rasmussen (U.S. Fish and Wildlife Service). Last accessed November, 2004. Updated and edited, June, 2004 through November, 2004.

Mylopharyngodon piceus characteristically presents black-tipped scales that appear as cross-hatching upon viewing. Diagnostically, the dorsal fin is located above the pelvic fins, and is short and pointed, containing 7-8 rays. The anal fin is located closer to the caudal fin than in the native minnow. While the black carp resembles the grass carp in size, color, and appearance (e.g., shape of fins, and size and position of eyes), the species may be distinguished on the basis of their pharyngeal teeth (i.e., pharyngeal teeth of the grass carp possess deep parallel grooves and those of black carp appear molar-like).

Black carp are superficially very similar in appearance to grass carp, *Ctenopharyngodon idella*, specifically in terms of body size and shape, position and size of fins, and position and size of the eyes. Juveniles, in particular, are difficult to distinguish from grass carp young. As such, Nico and Williams (1996) expressed concern that if black carp become more common in U.S. aquaculture, there will be an increased risk that the species be misidentified and unintentionally introduced as "grass carp" to some areas. Available information indicates that the black carp is, or has been in the recent past, maintained in research or production facilities in six states including Arkansas, Louisiana, Mississippi, Missouri, North Carolina, Oklahoma, and Texas (Nico and Williams 1996). There is widespread concern, however, that black carp will escape captivity, establish wild populations, and cause major adverse environmental impacts. In addition, black carp are host to parasites, flukes, and bacterial and viral diseases and could possibly transfer these to other fish species.

The reproductive biology of the black carp is similar to other members of the family. Females are capable of producing between 129,000 and 1,180,000 eggs per year (depending upon body size), and are deposited on the bottom in a single batch. Fertilization occurs upstream and eggs drift downstream with the current until reaching areas with little current (e.g., floodplain lakes, smaller streams, and water channels). Following fertilization, the bathypelagic eggs become hydrated and swell 4- to 5-fold, and are carried by currents. Embryos typically pass through 8 embryonic stages, followed by 4 larval stages, and then two stages as fry. Early developmental stages are particularly sensitive to infections (bacterial and fungal), and growth rate before sexual maturation is determined especially by quality and quantity of food. Maturity is reached at 6 to 11 years of age in the species native habitat, and in captivity maximum lifespan is 15 years. Growth continues after sexual maturity is reached, and relatively large increments in length and weight occur annually. Once maturity has been reached, black carp are capable of annual reproductive activity. Population doubling times are relative low, with a minimum ranging between 4.5 and 14 years. While temperature preferences and lower temperature tolerances are poorly characterized, in the

species native range spawning begins when food is available, water levels are high, and water temperatures reach 26-30°C.

Native Range. Their native distribution is primarily subtropical, lying between 53°N to 15°N where the species occupies freshwater habitats in most major Pacific drainages of eastern Asia

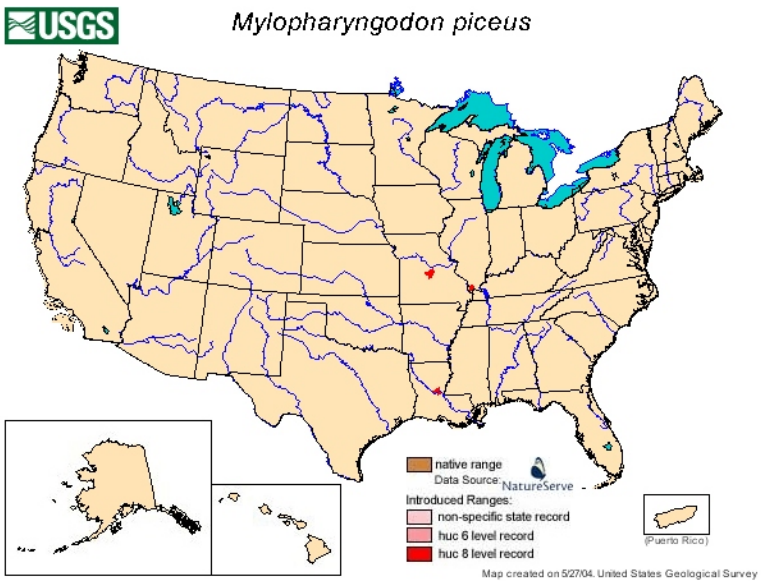


Figure 14. Known distribution of black carp in US.

from the Pearl River (Zhu Jiang) basin in the north of China to the Amur River (Heilong Jiang) and its major tributaries of China and far eastern Russia. Black carp may have been native to the Honghe or Red River of northern Vietnam (Nico and Williams 1996).

Nonindigenous occurrences and current status. Introductions of *Mylopharyngodon piceus* documented in FishBase (n = 31) clearly indicate that invasions of the species have occurred worldwide, although not all invasions develop sustainable populations subsequent to their release. From its native distribution in China, *Mylopharyngodon piceus* has expanded its disjunct distribution throughout Asia during the 19th and early 20th century. In the 1980's the species invaded the Nearctic region with documented releases occurring in the Carribbean, although establishment of sustainable populations are few, if any. In the US (Figure 14), black carp have been maintained in hatcheries, fish culture facilities, and fish farm ponds (mainly located in the southeastern United States). Both diploid (fertile) and triploid (sterile) fish have been used in fish farming applications, and some have escaped captivity. Approximately 30 black carp escaped from a fish farm in Missouri into the Osage River, Missouri River basin, during a flood event in

April 1994 (Anonymous 1994b; W. Pflieger, personal communication). The first specimen reported from the wild was captured by a commercial fisherman in March 2003 from Horseshoe Lake in Illinois near the confluence of the Mississippi and Ohio Rivers. Preliminary analyses indicate that this fish (4-year old; 783 mm, 5.8 kg) was a triploid individual. A second specimen was captured from the wild in the lower Red River, Louisiana in April 2004.

Means of Introduction. This species was first brought into the United States in the early 1970's with imported grass carp stocks. These fish came from Asia and were sent to a private fish farm in Arkansas (Nico and Williams 1996). The second introduction of black carp into this country occurred in the early 1980's. During this period it was imported as a a food fish and as a biological control agent to combat the spread of yellow grub *Clinostomum margaritum* in aquaculture ponds (Nico and Williams 1996). Current reports indicate that black carp are established in Illinois and Missouri, but it is not clear if the Illinois specimen resulted from the Missouri escape. As previously noted, the black carp captured from the wild may have escaped in Missouri and was thought to be triploid (Anonymous 1994b). However, it also was rumored that these fish may have been brood stock, and the commercial fisherman who captured the Louisiana specimen reported catching a “different-looking grass carp” for the past eight years. Capture of black carp in Louisiana probably stem from escape from an aquaculture facility.

Impact of introduction and control measures. Black carp are considered a potential pest species, particularly given its similarities to grass carp (*Ctenopharyngodon idella*) with respect to the species’ reproductive biology. Given that the grass carp has expanded its range since its introduction to the US in 1963, a current concern among those working with invasive species is, black carp might be capable of expanding their distribution in a similar manner to grass carp, if the opportunity were presented. If so, there is high potential that the black carp would negatively impact native aquatic communities by feeding on, and reducing, populations of native mussels and snails, many of which are considered endangered or threatened (Nico and Williams 1996). At present, steps have been taken to regulate the culture of black carp by placing it on the federal list of injurious wildlife species under the Lacey Act, which may help contain managed populations. Trade of the species is restricted in Germany, and several countries report adverse ecological impact after introduction of black carp.

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[12]***Ctenopharyngodon idella*** (Valenciennes 1844)

Common Name: grass carp, white amur

Size: Maximum size ranges between 125 to 150 cm TL (male/unsexed; Ref. 30578) with a maximum recorded weight of 45.0 kg (Ref. 7248)

Taxonomy and identification. Distinguishing characteristics for grass carp were given in Berg (1949), Shireman and Smith (1983), and Page and Burr (1991), and more recently published state and regional fish books provide life histories and photographs of the species (e.g., Robison and Buchanan 1988; Etnier and Starnes 1993; Jenkins and Burkhead 1994; Pflieger 1997). A few authors identify the scientific name as *Ctenopharyngodon idellus*, but that term is not valid.

Diagnotically, the species is well characterized, having dorsal spines (total): 3-3; dorsal soft rays (total): 7-8; anal spines: 3-3; and anal soft rays: 7-11. Barbels are absent from a very shout snout (length less than or equal to eye diameter) and the postorbital length is more than half the length of the head. The caudal fin has 18 soft rays.

Life history and biology. Grass carp occur in a wide range of aquatic habitats, ranging from those presenting relatively fast currents to lakes, ponds, pools and backwaters of large rivers where the species prefers large, slow-flowing or standing water bodies with vegetation. The species tends toward being demersal and usually ranges from near surface to a depth of 5 m. The native range of grass carp was temperate, mid-latitude (65˚N - 25˚N), with a normal temperature range from 10 - 26˚C. However, the species tolerants wide range of environmental conditions, which in part supports their invasiveness attributes. For example, grass carp are relatively tolerant to temperatures from 0º to 38ºC, salinities as greater as 10 ppt, and dissolved oxygen levels as low as 0.5 ppm. Grass carp feed on aquatic vascular plants, detritus, insects and other invertebrates. The species has a long history as an aquaculture species commonly used for weed control in rivers, fish ponds and reservoirs.

Reproduction biology of grass carp is typical of "Asian carp" with spawning generally initiated

[12]Original material prepared by Leo Nico and Pam Fuller (January 4, 2001) at USGS/BRD/FISC. Updated, expanded with FishBase output, and edited June, 2004 through November, 2004.

along riverbeds with relatively strong current. Embryo-larval development is similiar to other carp, with a maximum age recorded at 21 years. While used extensively throughout the world for aquatic vegetation control, the species is also used as food for human consumption. The species is widely regarded as a pest in most countries because of the damages made to submerged vegetation when the species escapes from its intended role control in nuisance aquatic vegetation.

Native Range. As with other "Asian carp," the original distribution of grass carp included eastern Asia from the Amur River of eastern Russia and China south to West River of southern China (Lee et al. 1980. Shireman and Smith 1983), China and Eastern Siberia (i.e., Amur River system) and widely transported around the world.

Nonindigenous Occurrences. Currently, in the US the grass carp occupies a wide, disjunct distribution (Figure 15) which in part reflects the species opportunistic dispersal associated with intentional releases. The distribution depicted in Figure 16 results from extrapolation of point-sourced releases documented in the literature and summarized in the dot map in Figure 15.

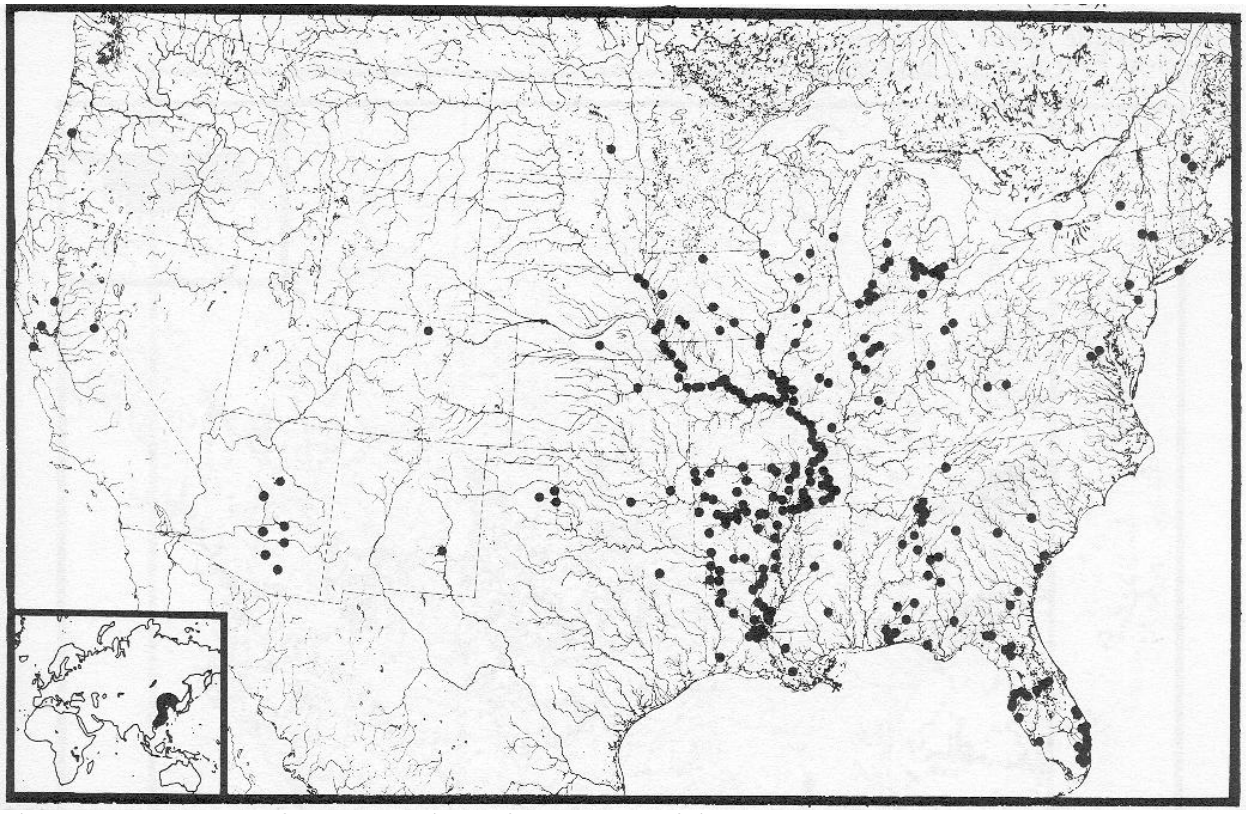


Figure 15. Dot map of grass carp in surface waters of the US.

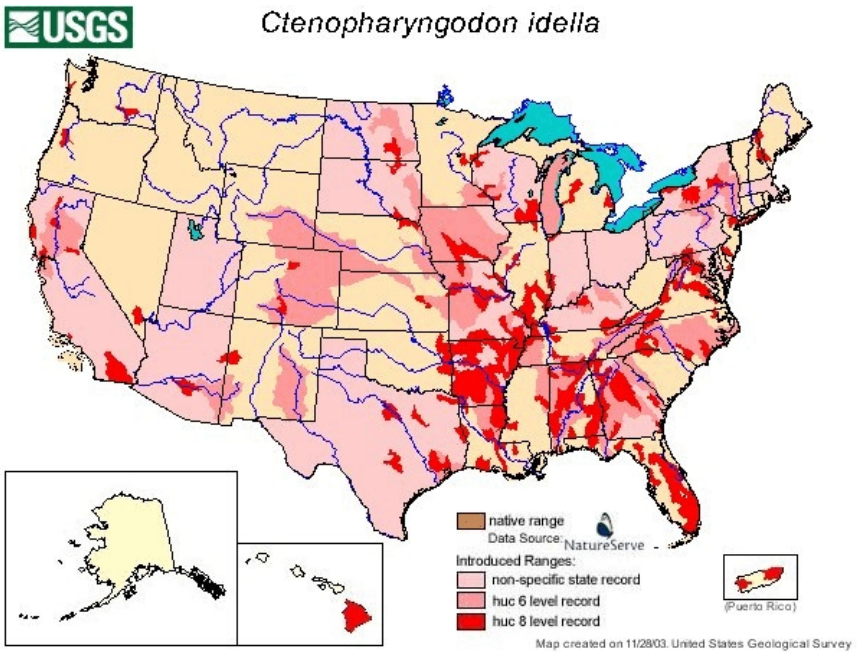


Figure 16. Projected current distributions for grass carp developed form dot map, e.g., in Figure 15.

Grass carp have been recorded from Alabama (Guillory and Gasaway 1978; Boschung 1992; Kirk et al. 1994; Mettee et al. 1996); Arizona (Minckley 1973; Guillory and Gasaway 1978; Courtenay et al. 1984, 1991); Arkansas (Buchanan 1973; Guillory and Gasaway 1978; Zimpfer et al. 1987); California (Guillory and Gasaway 1978; Courtenay et al. 1984, 1991; Dill and Cordone 1997); Colorado (Guillory and Gasaway 1978; Courtenay et al. 1984, 1991; Woodling 1985); Connecticut (Whitworth 1996); Delaware (Courtenay et al. 1984, 1991; Raasch and Altemus 1991; Rohde et al. 1994); Florida (Guillory and Gasaway 1978; Courtenay and Stauffer 1984; Florida Game and Freshwater Fish Commission 1989, 1994; Shafland 1995b); Georgia (Guillory and Gasaway 1978; Courtenay et al. 1984; Walters 1997); Hawaii (Maciolek 1984); Idaho (Courtenay et al. 1984, 1991; Idaho Fish and Game 1990); Illinois (Pflieger 1975; Anonymous 1977; Guillory and Gasaway 1978; Smith 1979; Phillips et al. 1982; Burr and Page 1986; Burr et al. 1996; Laird and Page 1996); Indiana (Anonymous 1977; Guillory and Gasaway 1978; Simon et al. 1992); Iowa (Guillory and Gasaway 1978; Burr and Page 1986; Harlan et al. 1987; Courtenay et al. 1991); Kansas (Guillory and Gasaway 1978; Courtenay and Williams 1992; Cross and Collins 1995); Kentucky (Conner et al. 1980; Courtenay et al. 1984, 1991; Burr and Page 1986; Burr and Warren 1986); Louisiana (Guillory and Gasaway 1978; Conner and Suttkus 1986; Zimpfer et al. 1987; Carp Task Force 1989); Maryland (Guillory and Gasaway 1978; Courtenay et al. 1984, 1991; Rohde et al. 1994); Massachusetts (Courtenay et al. 1984, 1991; Hartel 1992; Hartel et al. 1996); Michigan (Guillory and Gasaway 1978; Lee et al. 1980 et seq.;

Courtenay et al. 1984; Emery 1985); Minnesota (Phillips et al. 1982; Courtenay et al. 1984, 1991); Mississippi (Guillory and Gasaway 1978; Courtenay et al. 1991; Courtenay 1993); Missouri (Pflieger 1975, 1978, 1997; Guillory and Gasaway 1978; Brown and Coon 1991); Nebraska (Guillory and Gasaway 1978; Courtenay et al. 1984, 1991); Nevada (Courtenay et al. 1984, 1991; Deacon and Williams 1984); New Hampshire (Guillory and Gasaway 1978; Lee et al. 1980 et seq.; Schmidt 1986); New Jersey (Guillory and Gasaway 1978; D. Mitchell and Soldwedel, personal communication); New Mexico (Guillory and Gasaway 1978; Courtenay et al. 1984, 1991; Cowley and Sublette 1987; Sublette et al. 1990); New York (Guillory and Gasaway 1978; Courtenay et al. 1984, 1991; Smith 1985; Schmidt 1986); North Carolina (Guillory and Gasaway 1978; Courtenay et al. 1984, 1991; Menhinick 1991; Rohde et al. 1994); North Dakota (Lee et al. 1980 et seq.; Owen et al. 1981; Power and Ryckman 1998); Ohio (Guillory and Gasaway 1978; Courtenay et al. 1984, 1991); Oklahoma (Guillory and Gasaway 1978; Courtenay et al. 1984, Cashner and Matthews 1988; Pigg et al. 1992); Oregon (Lee et al. 1980 et seq.; Pauley et al. 1994); Pennsylvania (C. N. Shiffer, personal communication); South Carolina (Guillory and Gasaway 1978; Courtenay et al. 1984, 1991; Foltz and Kirk 1994; Rohde et al. 1994); South Dakota (Guillory and Gasaway 1978; Lee et al. 1980 et seq.; Owen et al. 1981); Tennessee (Guillory and Gasaway 1978; Ryon and Loar 1988; Etnier and Starnes 1993); Texas (Guillory and Gasaway 1978; Conner and Suttkus 1986; Trimm et al. 1989; Howells 1992a); Utah (Courtenay et al. 1984, 1991; Sigler and Sigler 1996); Virginia (Guillory and Gasaway 1978; Courtenay et al. 1984, 1991; Jenkins and Burkhead 1994; Rohde et al. 1994); Washington (Pauley et al. 1994; Fletcher, personal communication); West Virginia (Guillory and Gasaway 1978; Courtenay et al. 1991); Wisconsin (Guillory and Gasaway 1978; Becker 1983; Emery 1985; Burr and Page 1986; Mulvey 1990; Fago 1992); and Wyoming (Courtenay et al. 1984, 1991; Stone 1995).

Means of introduction and status. Both authorized and unauthorized stockings of grass carp have taken place for biological control of vegetation. This species was first imported to the United States in 1963 to aquaculture facilities in Auburn, Alabama, and Stuttgart, Arkansas. The Auburn stock came from Taiwan, and the Arkansas stock was imported from Malaysia (Courtenay et al. 1984).

The first release of this species into open waters took place at Stuttgart, Arkansas, when fish escaped the Fish Farming Experimental Station (Courtenay et al. 1984). However, many of the early stockings in Arkansas were in lakes or reservoirs open to stream systems, and by the early 1970s there were many reports of grass carp captured in the Missouri and Mississippi rivers

(Pflieger 1975, 1997). During the past few decades, the species has spread rapidly as a result of widely scattered research projects, stockings by federal, state, and local government agencies, legal and illegal interstate transport and release by individuals and private groups, escapes from farm ponds and aquaculture facilities; and natural dispersal from introduction sites (e.g., Pflieger 1975; Lee et al. 1980 et seq.; Dill and Cordone 1997). Some of the agencies that have stocked grass carp in the past include the Arkansas Game and Fish Commission, the Tennessee Valley Authority, the U.S. Fish and Wildlife Service, the Delaware Division of Fish and Wildlife, the Florida Game and Fresh Water Fish Commission, the Iowa Conservation Commission, the New Mexico Department of Fish and Game, and the Texas Parks and Wildlife Department. The species also has been stocked by private individuals and organizations. In some cases, grass carp have escaped from stocked waterbodies and appeared in nearby waterbodies. Stocking of grass carp as a biological control against nuisance aquatic plants in ponds and lakes continues. For instance, Pflieger (1997) stated that thousands of grass carp are reared and sold by fish farmers in Missouri and Arkansas.

In total, grass carp are presently reported from 45 states; there are no reports of introductions in Alaska, Maine, Montana, Rhode Island, and Vermont. It is known to have established populations in a number of states in the Mississippi River basin. Breeding populations have been recorded for the Mississippi River in Kentucky (Conner et al. 1980; Burr and Warren 1986), the Illinois and upper Mississippi rivers of Illinois and Missouri (Raibley et al. 1995), the lower Missouri River in Missouri (Raibley et al. 1995), the Mississippi River or its tributaries in the states of Arkansas (Conner et al. 1980), Louisiana (Conner et al. 1980; Zimpfer et al. 1987), Tennessee (Etnier and Starnes 1993), and presumably Mississippi (Courtenay et al. 1991). It is also established in the Ohio River in Illinois (Burr, personal communication); it was listed as established in Minnesota (Courtenay et al. 1991, but see Courtenay 1993), and in the Trinity River of Texas (Waldrip 1992; Webb et al. 1994; Elder and Murphy 1997). Courtenay (1993) listed grass carp as established in eight states, Arkansas, Kentucky, Illinois, Louisiana, Missouri, Mississippi, Tennessee, and Texas; an additional one, Minnesota, was included in an earlier listing of states with established populations (Courtenay et al. 1991). Stone (1995) listed this species as being established in Wyoming; however, Stone (personal communication) clarified his earlier report by stating that, as of early 1997, there is no evidence of natural reproduction in that state. Similar to a few other authors, he used the term “established” to indicate that grass carp populations have persisted for many years, presumably because of their long life span and because of long-term maintenance of wild populations through continued stockings. Pearson and Krumholz (1984) mentioned several records from the Ohio River, including river mile 963 on the Illinois-Kentucky

border and from the Falls of the Ohio, at Louisville, along the Kentucky-Ohio border. They also stated that the species had been stocked in many private ponds and lakes in the Ohio River basin. Sigler and Sigler (1996) stated that this species is no longer found in Utah, but they provide no details. Harvest of grass carp by commercial fishermen in the Missouri and Mississippi rivers of Missouri has exhibited a general climb. In 1996, the most recent available data, there was a record reported harvest, about 44,000 pounds, 8 percent of the total commercial fish harvest (J. W. Robinson, personal communication).

Impact of introduction. Outside the species' native range in China and Eastern Siberia (Amur River system), grass carp have been widely transported around the world, and several countries report adverse ecological impacts after introduction of grass carp. Various authors (e.g., Shireman and Smith 1983; Chilton and Muoneke 1992; Bain 1993) have reviewed the literature on grass carp, and most discuss actual and potential impacts caused by the species' introduction.

Shireman and Smith (1983) concluded that the effects of grass carp introduction on a water body are complex and apparently depend on the stocking rate, macrophyte abundance, and community structure of the ecosystem. The authors indicated that numerous contradictory results are reported in the literature concerning grass carp interaction with other species. Negative effects involving grass carp reported in the literature and summarized by these authors included interspecific competition for food with invertebrates (e.g., crayfish) and other fishes, significant changes in the composition of macrophyte, phytoplankton, and invertebrate communities, interference with the reproduction of other fishes, and decreases in refugia for other fishes.

In their overview, Chilton and Muoneke (1992) reported that grass carp seem to indirectly affect other animal species by modifying preferred habitat. However, the authors also indicated that grass carp may directly influence other animals through either predation or competition when plant food is scarce. Similarly, Bain (1993) stated that grass carp have significantly altered the food web and trophic structure of aquatic systems by inducing changes in plant, invertebrate, and fish communities. Bain (1993) indicated that effects are largely secondary consequences of decreases in the density and composition of aquatic plant communities. Organisms requiring limnetic habitats and food webs based on phytoplankton tend to benefit from the presence of grass carp. On the other hand, Bain (1993) also reported that declines have occurred in the diversity and density of organisms that require structured littoral habitats and food chains based on plant detritus, macrophytes, and attached algae.

Removal of vegetation can have negative effects on native fish, such as elimination of food sources, shelter, and spawning substrates (Taylor et al. 1984). Hubert (1994) similarly cited a study that found vegetation removal by grass carp lead to better growth of rainbow trout due to increases in phytoplankton and zooplankton production, but it also lead to higher predation on rainbow trout by cormorants *Phalacrocorax auritus* due to lack of cover, and changes in diet, densities, and growth of native fishes. Although grass carp are often used to control selected aquatic weeds, these fish sometimes feed on preferred rather than on target plant species (Taylor et al. 1984). Increases in phytoplankton populations is a secondary effect of grass carp presence. A single grass carp can digest only about half of the approximately 45 kg of plant material that it consumes each day. Collateral to these grazing effects, the deposition of undigested material and feces into aquatic habitats by grass carp promotes nutrient enrichment which often promotes algal blooms (Rose 1972). These blooms can subsequently reduce water clarity and decrease oxygen levels (Bain 1993).

In addition to problems related to switching of food sources, grass carp may also carry several parasites and diseases known to be transmissible or potentially transmissible to native fishes. For example, grass carp imported from China may have been the source of introduction of the Asian tapeworm *Bothriocephalus opsarichthydis* (Hoffman and Schubert 1984; Ganzhorn et al. 1992), and the species may have been indirectly responsible for infection of the endangered woundfin *Plagopterus argentissimus* (by way of the red shiner *Cyprinella lutrensis*; Moyle 1993). If parasites of the grass carp can jump to native cyprinidae, introductions of grass carp may have also present opportunity for other diseases of *Ctenopharyngodon idella* (see Table 1) to expand their range.

Although triploids are considered sterile and incapable of reproduction, some researchers have questioned the sterility of triploids. Howells (1992b) referred to a study in which milt from triploids was used to successfully fertilize normal diploid eggs, but he found no published information on the viability of eggs from triploid females. Available information (e.g., Chilton and Muoneke 1992; Exotic Species Workgroup 1994; W. Shelton, personal communication) indicate that triploid grass carp can produce some viable gametes, but the proportion of such gametes is extremely low; hence, the reproductive potential of triploids is considered to be very low (Chilton and Muoneke 1992). In general, triploid females never fully develop ovaries, but triploid males may present a superfiscal appearance of being fertile with a complement of fully developed testes in the adult. Techniques to induce triploidy are not always totally effective and every individual needs to be genetically checked. Triploid grass carp are indistinguishable in external morphology

from normal (fertile) diploids, so triploidy must be confirmed by blood or tissue analysis.

Case history suggests that grass carp management must be practiced cautiously. For example, although diploid grass carp are banned in Florida, in 1991 three adults, including a gravid female (UF 85587), were captured in the Suwannee River, Florida (Burkhead and Williams 1991). Similarly, Webb et al. (1994) reported on the capture of young grass carp in Texas whose ploidy and age indicated some were escapees from illegal stockings. Although triploids are generally allowed, many states no longer permit import of diploid grass carp. Some states, however, are exercising additional precautions, e.g., Texas restricts grass carp releases, given the species' history of excessive removal of vegetation and the subsequent destruction of fish and wildlife habitat. As of 1994, Alaska, Oregon, Montana, North Dakota, Minnesota, Wisconsin, Michigan, Massachusetts, Vermont, Maine, Maryland, and Rhode Island also prohibit grass carp, diploid and triploid, in their state. The states of Hawaii, Iowa, Kansas, Missouri, Oklahoma, Arkansas, Mississippi, and Alabama have no restrictions, meaning that both diploids and triploids can be used and there is no permit required. The remaining states have some type of restriction on the use of grass carp. Typical restrictions include one or more of the following: use of only verified triploids, use only in public waters, or use requires a permit (Wattendorf and Phillippy 1996).

The numbers of grass carp legally stocked in a region can be fairly high. For instance, in January 1992, the Texas Parks and Wildlife Commission approved the use of certified triploid grass carp for vegetation control in state waters. In March 1994, Durocher (1994) reported that the relatively new program already had issued nearly 2,900 permits and allowed the stocking of more than 78,000 grass carp. Foltz and Kirk (1994) indicated that 300,000 triploid grass carp were stocked into Lake Marion, South Carolina, between 1989 and 1991. Since the late 1970's more than 2,000 water bodies in Florida have been stocked with grass carp (Haller 1994). Lake Istokpoga, Florida, was stocked with 125,000 triploid grass carp during a two-year period in the early 1990s (Thomas 1994). Guillory and Gasaway (1978) gave dot map detailing the known distribution of grass carp at that time. Pflieger (1978) described the invasion of Missouri streams. Dill and Cordone (1997) detailed the history of grass carp introductions in California. As part of their account, the authors reported the removal of about 1,500 diploid grass carp from golf course ponds that had been illegally stocked during the 1980's.

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Table 1. Diseases common to grass carp.

Bacterial and Fungal Diseases	Parasites (Protozoan and Metazoan)
Water mold Disease (l.), Fungal diseases Columnaris Disease (l.), Bacterial diseases Water mold Disease (e.), Fungal diseases Columnaris Disease (e.), Bacterial diseases Columnaris Disease (m.), Bacterial diseases SVC, Viral diseases	Fish louse Infestation 1, Parasitic infestations (protozoa, worms, etc.) Myxidium Infection, Parasitic infestations (protozoa, worms, etc.) Trichodina Infection 1, Parasitic infestations (protozoa, worms, etc.) Trichodina Infection 2, Parasitic infestations (protozoa, worms, etc.) Trichodina Infection 3, Parasitic infestations (protozoa, worms, etc.) Tripartiella Infestation, Parasitic infestations (protozoa, worms, etc.) Bothriocephalus Infestation 2, Parasitic infestations (protozoa, worms, etc.) Trichodina Infection 5, Parasitic infestations (protozoa, worms, etc.) Trichodina Infection 5, Parasitic infestations (protozoa, worms, etc.) Myxobolus Infection 1, Parasitic infestations (protozoa, worms, etc.) Fish louse Infestation 1, Parasitic infestations (protozoa, worms, etc.) Dactylogyrus Gill Flukes Disease, Parasitic infestations (protozoa, worms, etc.) Trichodinosis, Parasitic infestations (protozoa, worms, etc.) Sporozoa-infection (Myxobolus sp.), Parasitic infestations (protozoa, worms, etc.) Anchorworm Disease (Lernaea sp.), Parasitic infestations (protozoa, worms, etc.) Capillaria Infestation, Parasitic infestations (protozoa, worms, etc.) Philometra Disease, Parasitic infestations (protozoa, worms, etc.) Spiroxys Infestation, Parasitic infestations (protozoa, worms, etc.)

[13]***Polyodon spathula*** (Walbaum, 1792)

Common Name: paddlefish

Size: FishBase lists the maximum recorded length of paddlefish as 221 cm (male/unsexed; FishBase Ref. 5723) and a maximum weight as 90.7 kg (Ref. 3221).

Taxonomy and identification. The typical summary of taxonomic and identification information for paddlefish is listed in various sources, but Robison and Buchanan (1988); Page and Burr (1991); Etnier and Starnes (1993); Jenkins and Burkhead (1994); Mettee et al. (1996) provide good background on the species. Paddlefish are an extremely primitive form of fish having a skeleton of cartilage rather than bones, and in many respects, paddlefish are one of the most unique fish species in North America.

Paddlefish have few scales and their skin is smooth. Their color varies gray-blue to blackish-blue above to a pale gray to white belly and lower sides, and their highly distinctive snout is elongated and flattened into a paddle. Opercula are pointed and extend far back on the sides of the body, and their mouth is extremely large and toothless except in very young fish.

Life history and biology. Paddlefish are strictly freshwater and characteristically inhabit slow-flowing waters of large rivers. The original habitat of the paddlefish consisted of large free-flowing rivers with high concentrations of zooplankton (floating, microscopic aquatic animals). Paddlefish primarily feed on plankton and aquatic insects by swimming through the water with their mouth open and their long paddle-like snout weaving back and forth. The paddle appears to contain sensory organs that enables the paddlefish to detect concentrations of food (the paddle is not used to "dig" for food as is commonly thought). Backwater areas and tributary streams with dense concentrations of plankton are important feeding and nursery areas.

The species is demersal, generally preferring deep water, usually greater than 1.25 to 1.5 meters in

[13]Original material prepared by Pam Fuller at USGS/BRD/FISC (October 11, 2000) and by U.S. Fish and Wildlife Service (North Dakota's federally listed endangered, threatened, and candidate species - 1995. U.S. Fish and Wildlife Service, Bismarck, ND. Jamestown, ND posted at Northern Prairie Wildlife Research Center Home Page. http://www.npwrc.usgs.gov/resource/distr/others/nddanger/nddanger.htm (Version 16JUL97). Edited and updated June to November, 2004.

depth. As a planktivore, paddlefish use their extended upper jaw, or "paddle," characteristic of the species to forage about the depths of their habitat and channel plankton into the mouth. Paddlefish present a highly disjoint native distribution with species in the family occurring in large rivers at mid-latitudes (50ºN - 30ºN) in China (*Psephurus gladius*) and in the Mississippi-Missouri River systems (*Polydon spathula*). The climate characteristic of their native distribution is temperate with average annual temperatures falling between 10 to 18ºC. The species presents relatively low resilience, with minimum population doubling times ranging from 4.5 to 14 years. Paddlefish are long-lived with a maximum age reported at 55 years.

Currently, populations of paddlefish occur in reservoirs where the fish have access to spawning areas that consist of deep, rocky rapids with swift currents. Paddlefish mature between 7 and 14 years of age, but do not spawn each year. Spawning occurs in the spring over gravel bars in swift currents at water temperatures of approximately 60º to 76º F. Successful paddlefish spawning has been positively correlated with water temperature and the length of spring flooding. Their eggs are a greenish-black color and during their first year of life paddlefish grow rapidly at over 1 inch per week. At maturity, adults reach nearly 7 feet in length and weigh 200 pounds.

Paddlefish populations have declined due to the destruction of spawning grounds, blockage of migratory movement by dams, channelization of rivers, loss of backwater habitat, stream water depletions, and pollution. Overharvest or mortalities due to commercial fishing with nets and traps may also be a leading cause of population declines. The paddlefish was formerly a candidate species for review by the U.S. Fish and Wildlife Service for official listing as an endangered or threatened, but as of February 28, 1996, the paddlefish is no longer listed as a candidate species. Regionally, however, paddlefish remains species of management concern. The species is listed as vulnerable by the IUCN (see IUCN Red List designation, C2b).

Native Range. In North America, the Mississippi River and major tributaries, including the Missouri River into Montana and the Ohio River to its headwaters, are the home of *Polydon*

spathula. Representative point data are summarized in FishBase and reflected in Figure 17 for their distribution in North America. As such, paddlefish occur throughout the Mississippi River basin from southwestern New York to central Montana and south to Louisiana. Gulf Slope

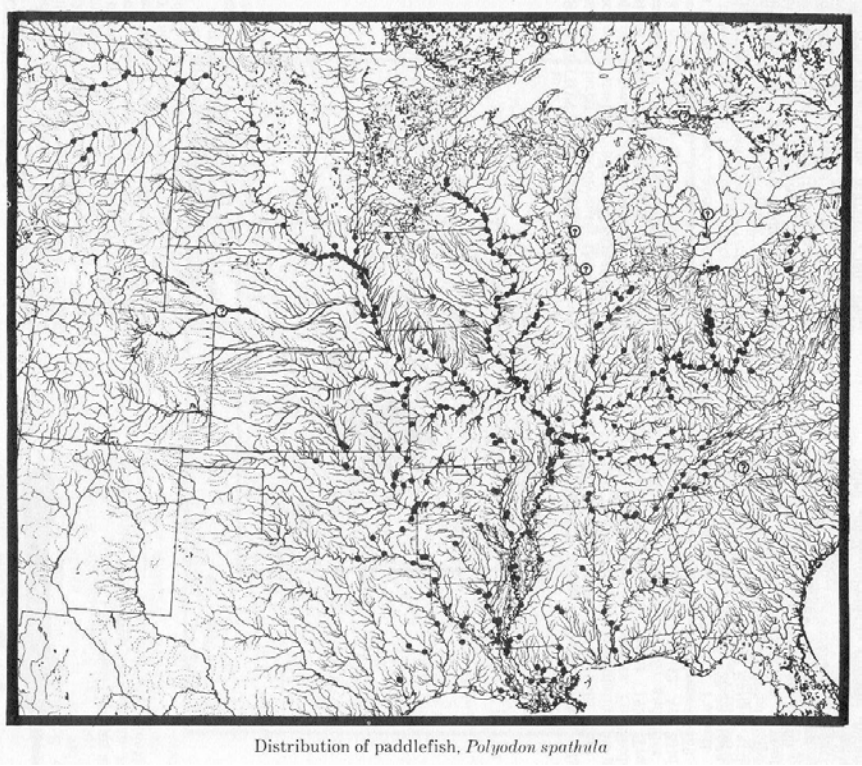


Figure 17. Point data for historic distribution of paddlefish.

drainages from Mobile Bay, Alabama, to Galveston Bay, Texas form the southern extent of the species, and formerly paddlefish occurred in the Lake Erie drainage of Ohio. Although records are incomplete, the species may have also occurred in the drainages of Lakes Huron and Michigan, but paddlefish have been extirpated from Great Lakes basin. Similarly, the species no longer occurs in drainages of Galveston Bay and Sabine River in Texas, and Calcasieu drainage in Louisiana (Page and Burr 1991).

At present, paddlefish numbers have been greatly reduced in their historic range, especially in the Mississippi and its upper tributaries. Formerly abundant in the Missouri, Mississippi and Gulf Coast drainages, paddlefish can presently be found in 22 states, including North Dakota (Figure 18). In North Dakota, they are present in the Missouri and Yellowstone Rivers. Juvenile paddlefish have been collected in North Dakota in the upper portion of Lake Sakakawea, which probably represents spawning events that most likely occur upstream in Montana with young

paddlefish subsequently carried downstream into North Dakota waters.

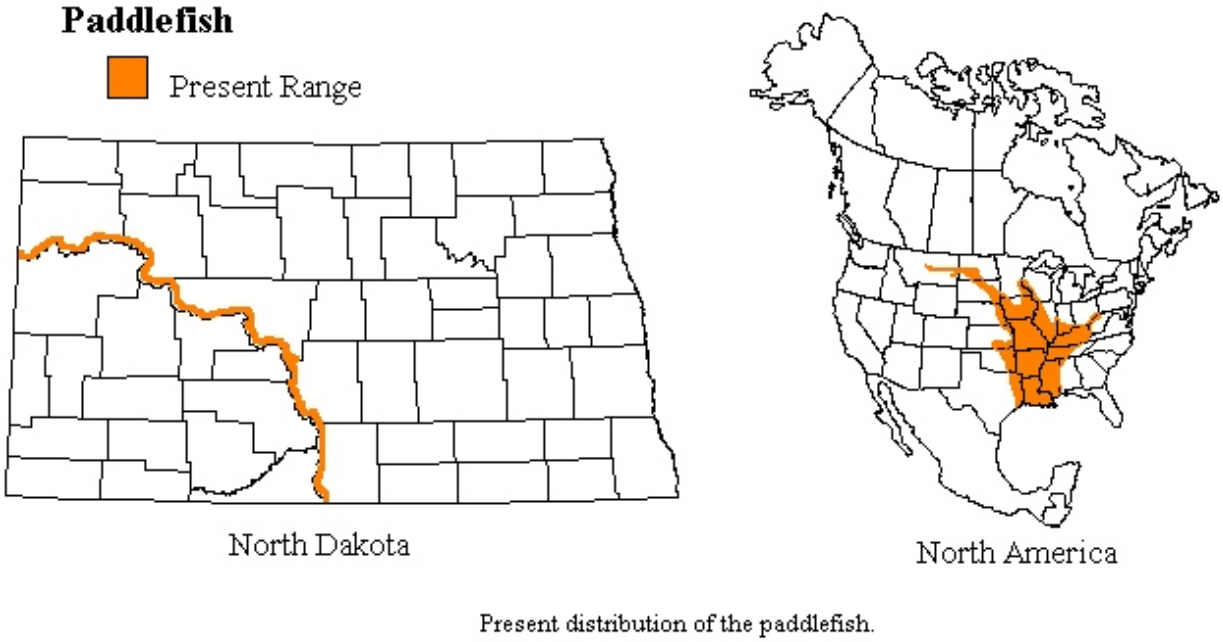


Figure 18. Potential present distribution of paddlefish throughout the Mississippi River-Missouri River basins (right), and within the Missouri River basin in North Dakota (left).

Nonindigenous Occurrences. Introductions of *Polyodon spathula* have occurred worldwide during the late 20th Century (e.g., Europe, Russia, and China), although the establishment of sustainable populations is poorly characterized. *Polyodon spathula* has a long list of presence data (n = 126, see "Occurrence Records from FishBase"), but range extensions throughout the Mississippi-Missouri Rivers system (Figure 19) require field validation with respect to suspect areas maintaining sustainable populations. For example, paddlefish were introduced into the Flint River below Newton, Georgia, and fish have dispersed downstream to Lake Seminole and the Apalachicola River, Florida (R. Ober and F. Paruka, personal communication).

Means of introduction and current status. Approximately 1,200 fish, 10 to 15" in length escaped an aquaculture facility along the Flint River in Georgia, during Tropical Storm Alberto in early July 1994 (Ober and Paruka, personal communication). Four or five fish have been collected from the stretch from Newton to the Apalachicola River with one individual collected in the

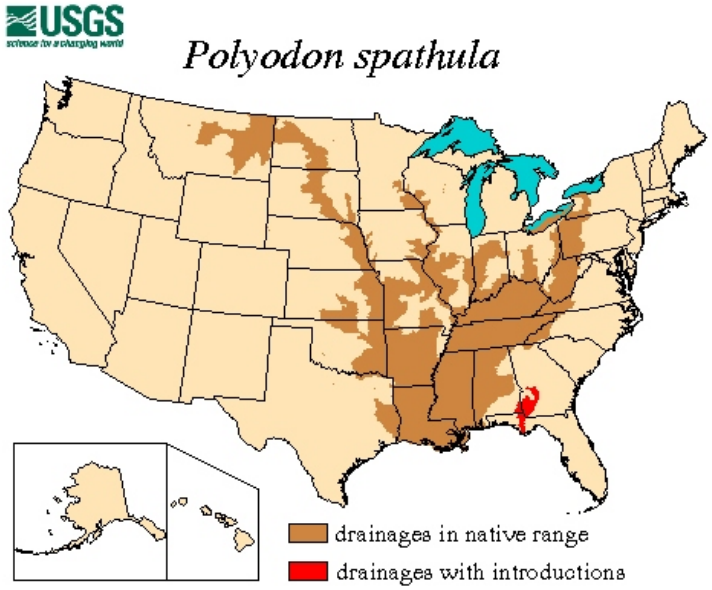


Figure 19. Drainages historically listing occurrences of paddlefish and range expansions previously noted.

spring of 1997 measuring 30" TL (Paruka, personal communication). Two paddlefish were also collected below Jim Woodruff Dam on the Apalachicola River in 1997 and weighed 10 to 11 pounds (Ober, personal communication).

Impact of Introduction. The impacts of these releases are currently unknown, however, FishBase notes that at least one country lists the species as a potential pest with adverse ecological impacts potentially expressed after introduction. International trade restrictions are in place for paddlefish (**CITES** II, since 11.6.92).

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[14]***Scaphirhynchus albus*** **(Forbes & Richardson, 1905)**

Common name: Pallid sturgeon

Maximum size. FishBase recorded a maximum length as 168 cm TL (male/unsexed), and pallid sturgeon can weigh up to 80 pounds (for comparison, shovelnose sturgeon which overlaps pallid sturgeon's range reaches a maximum weight of 5 pounds with an average weight of 2 pounds).

Taxonomy and identification. Pallid sturgeon were not identifed as a separate species until 1905, yet the species is an ancient lineage of cartilagenous fish, As are all sturgeons, the species is armored, having lengthwise rows of "bony" plates extending dorsoventrally. Their barbels are distinctive relative to other North American sturgeon, with the length of the inner barbels (4 whisker-like appendages in front of the mouth) only about 1/2 as long as the outer barbels. The fish are grayish-white in color; hence, their common name.

Life history and biology. Pallid sturgeon are demersal, freshwater fishes ranging in mid-latitudes between 44ºN - 30ºN. Within these northern latitudes the species inhabits relatively deep channels within large rivers, and prefers turbid waters, usually occupying locations with strong currents overlaying firm sand or gravel substrates. Pallid sturgeon feed on aquatic insects, mollusks and small fishes. Pallid sturgeon do not appear to reach sexually mature until they attain 3 to 4 years of age, and both male and female sturgeon may go 3 to 10 years between spawnings. In North Dakota, pallid sturgeon spawning occurs in May or June over gravel or other hard surfaces. The eggs take 5 to 8 days to hatch. The species presents relatively low resilience with a minimum population doubling time 4.5 - 14 years. Pallid sturgeon are long lived, with individuals reaching perhaps 50 years of age. Pallid sturgeons are known to hybridize with the smaller shovelnose sturgeon.

Of the 3,550 river miles the species potentially could occupy in North America, pallid sturgeon habitats have been significantly altered. For example, on the Missouri River, impoundments have created unsuitable lake-like habitat, and channelization has yielded deep, clear channels,

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[14]Original material collected from FishBase and U.S. Fish and Wildlife Service (North Dakota's federally listed endangered, threatened, and candidate species - 1995. U.S. Fish and Wildlife Service, Bismarck, ND posted at USGS/BRD/Northern Prairie Wildlife Research Center Home Page, http://www.npwrc.usgs.gov/resource/distr/others/nddanger/nddanger.htm (Version 16JUL97). Edited and updated June through November, 2004.

alterations believed detrimental to pallid sturgeon. Commercial fishing may have also played a role in the pallid sturgeon's decline. The species is listed as endangered and near extinction throughout all or a significant portion of their range (55 Federal Register 36641; September 6, 1990)[15], and international trade in the species has been restricted since 1998 under CITES II. Pallid sturgeon is also listed as endangered on the IUCN Red List (D).

Native distribution. The range of the pallid sturgeon in North Dakota overlaps with the range of the shovelnose sturgeon. Pallid sturgeon are found in the Mississippi and Missouri Rivers and their larger tributaries (Figure 20 and Figure 21 illustrate dot map of occurrences and continuous

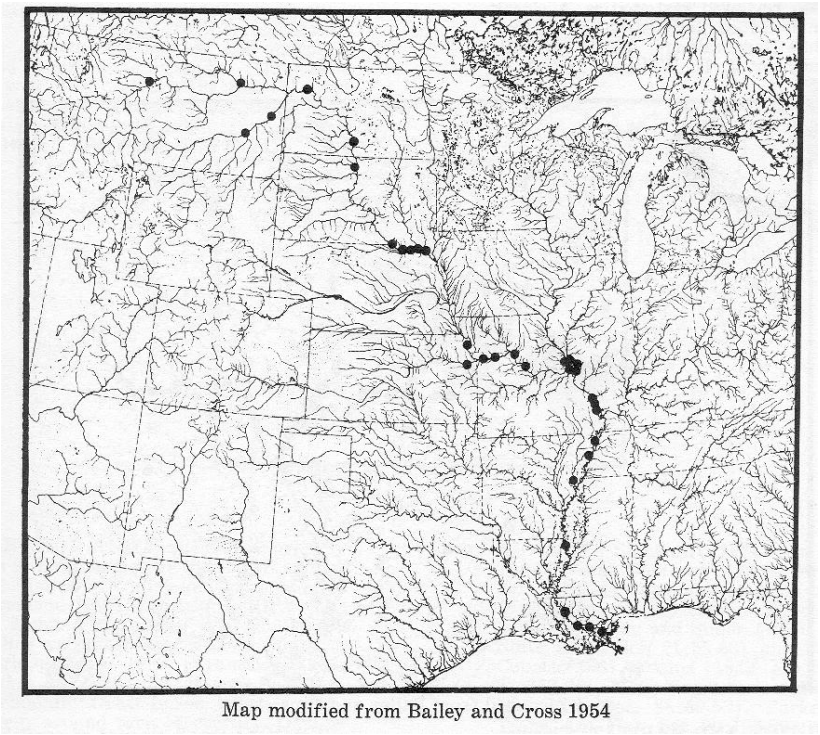


Figure 20. Dot map of locations for pallid sturgeon on the Missouri and Mississippi Rivers.

distribution map, respectively). In North America, suitable habitat is highly fragmented and restricted to main channels of Missouri River and lower Mississippi River from Montana to Louisina, and within their historic distribution, only portions of the range are presently suitable

[15]The *Pallid Sturgeon Recovery Plan* is in preparation by the North Dakota State Office of the U.S. Fish and Wildlife Service. A *Pallid Sturgeon Recovery Update* is available from the same office (1500 Capitol Ave., Bismarck, North Dakota 58501).

pallid sturgeon habitat, e.g., in North Dakota, the Missouri and Yellowstone Rivers remain relatively unaltered, but no reproduction has been documented in North Dakota in over a decade (Figure 21).

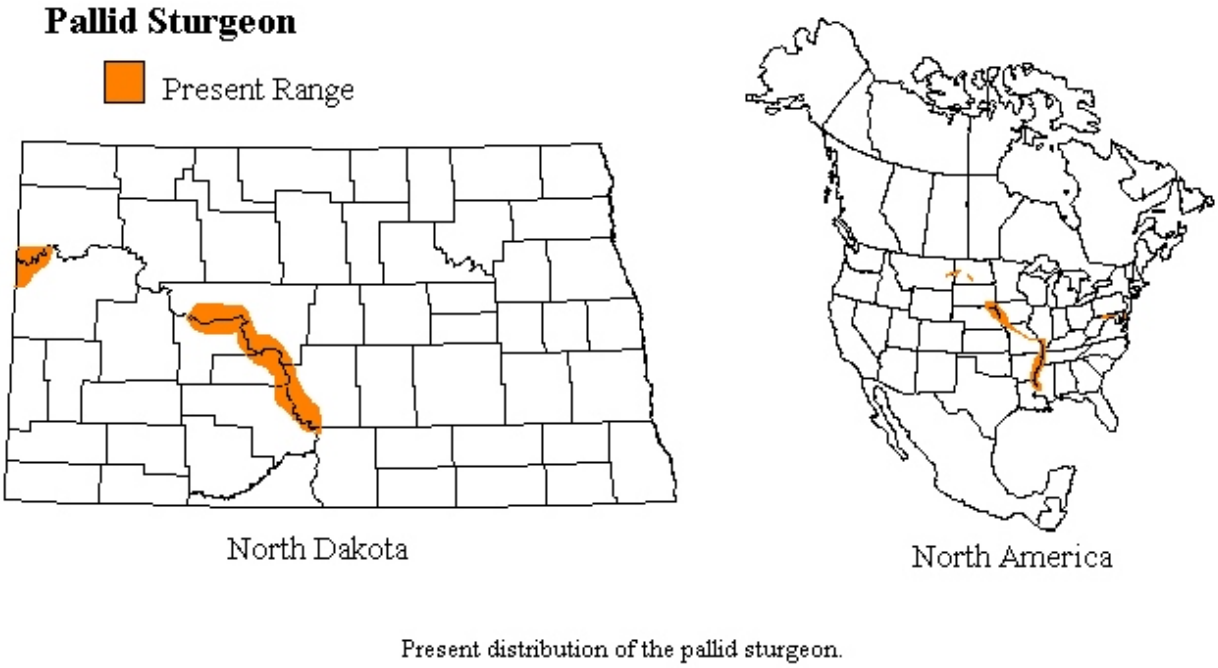


Figure 21. Projected distribution of pallid sturgeon throughout its historic range and within North Dakota.

Non-indigenous distribution. Pallid sturgeon do not occur outside its native range where the species continues to hover near extinction with dwindling numbers of individuals.

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[16]*Stizostedion lucioperca* (Linneaus 1758)

Common Name: zander, pike-perch

Size: The usual maximum length varies between 90 cm to 1.1 m with weights between 5 to 7 kg. The largest zander recorded was 1.3m and weighed 12 kg.

Taxonomy and identification. Various authors have summarized the taxonomy and identification of the species, including Berg (1949), Wheeler (1969, 1978), Maitland (1977), Howells (1992b). Zander, formerly known as *Lucioperca lucioperca* (e.g., Berg 1949), attains maximum lengths of 1.0 to 1.3 m and weights of 5 to 7 kg (Robins et al. 1991b). There are no known voucher specimens for fish occurring in the US.

Zander has small, finely toothed scales distributed over a long, torpedo-shaped body. The head is large, and powerful jaws bear several large, recurved teeth and many smaller teeth. A small, flat spine lies at the rear of the gill cover. Dorsal fin completely separated with the front part suppored by long, sharp spines, the rear part supported by branched fin rays. Tail fin is slightly forked, and anal fin is positioned well back on the tail opposite the rear dorsal. Pelvic fins are held forwards on the body close to the pectoral fins

Fish color varies from dorsal to ventral surfaces, being light olive-brown to drab brown on the back, then lightening down the sides to a cream or white belly. Color varies with water quality, with fish being darker in peaty waters and paler in turbid water. Young and small zander often have seven to 10 dusky grey bars running down their backs as far as the lateral line, but these markings fade with age. Juvenile forms have dark grey-brown fins, but the pectoral and pelvic fins are paler, sometimes with heavy brown-black spotting.

Life history and biology. In their native range, zander or perch-pike are predators of fish, including small zander, carp, crucian carp, dace, roach, rudd, bitterling, minnow, bream, silver bream, bleak gudgeon, stone loach, perch and ruffe. The wide mouth of a Zander is adopted for catching small fish, and its eyes are adapted for detecting prey in the murkiest of conditions, e.g.,

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[16] Original material prepared by Pam Fuller and Leo Nico (April 17, 2000) from the Center for Aquatic Resource Studies, which is part of the Biological Resources Division of the Geological Survey within the U. S. Department of the Interior. Edited, revised, and updated, December, 2004.

seeing in low light or turbid conditions. Small zander feed in loose shoals, but as they grow to become solitary feeders. Although feeding will occur throughout the day, foraging intensity increases at dusk and dawn, when shoals of prey are easier to approach in the changing light. Zander also feed heavily by day in turbid water. Feeding intensity declines with low water temperatures, but zander appears to feed throughout the year and only suspends feeding activities during spawning season.

In their native ranges in Europe, zander spawn in April to June in water 1 to 3 m deep. Adults congregate in suitable sites as soon as the water temperature rises above about 12°C, with weedy sites (e.g., open reed beds) preferred breeding habitats. Fish do not pair off; instead, several males will accompany one female as she spawns, depositing their milt in mass. Each female produces an equivalent of about 150,000 eggs per kilogram body weight. Eggs are sticky, pale yellow eggs and about 1.5 mm in diameter. Eggs are deposited among weeds, boulders or in hollows in the gravel bottom, and it has been reported that spawning areas are guarded until the eggs hatch. Hatching occurs after 7 to 10 days, and 5 to 6 mm larvae feed on the remains of their yolk sacs while their fins, mouths and teeth develop. As fry, the young fish disperse and feed actively on small crustaceans and insect larvae. By the end of their first year, zander range between 15 to 20 cm in length, and at the end of the second year, fish measure 20 to 30 cm. Females grow more quickly than males after the first year. Males mature at two to three years, females at three to four years, when they will have attained an average length of 45 cm and weight of about 1.1 kg. Maximum life span is about 20 years.

Native Range. Continental Europe to western Siberia (Figure 22; Berg 1949; Robins et al. 1991b).

Nonindigenous distribution. Figure 23 identifies areas in the US where zander has been release. In the late 1970's zander was illegally stocked in ponds near Cooperstown, New York, by an individual from Germany (J. Nickum, personal communication; Courtenay et al. 1988). Hatchery-reared zander fingerlings



Figure 22. Native distribution of zander included eastern Europe (light blue), with introduction to western Europe (dark blue). Figure from Greenhalgh 1999).

were stocked into Spiritwood Lake (Stutzman County), North Dakota in 1989; the fish were imported as fry from Finland (Lohman 1989; Anderson 1992). Only one survivor was recovered during a subsequent netting survey (Anderson 1992), and a sustainable population was thought not to have been established. However, the capture of a fish in August 1999, and another 2+ year old fish in 2000 shows that at least some survived and reproduced (Dokken 2004). Concern exists that zander and walleye could hybridize.

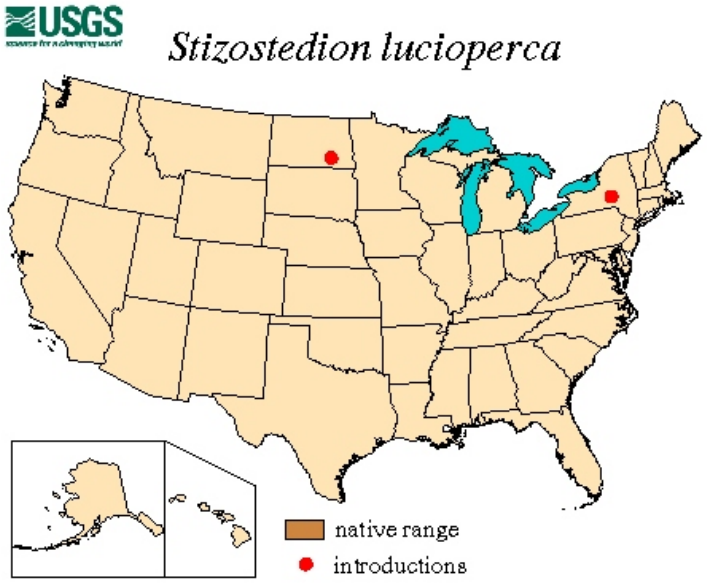


Figure 23. Distribution of known releases of zander in the US.

The history of the species introduction into North Dakota is not well documented in the scientific literature, but North Dakota Game and Fish Department had been interested in zander as a sport fish for many years. Spirit Lake had been selected as the site of an experimental release because the water body was completely enclosed (Anderson 1992). In 1987 an earlier attempt at introducing zander was aborted when fry hatched from eggs imported from Holland were destroyed for fear that they carried pike fry rhobdo virus (Anonymous 1987a; Lohman 1989). Those wanting to introduce zander thought that it would be a boon to the fisheries of North America (e.g., Anderson 1992), but others had strong reservations (e.g., Wright 1992). Some fisheries personnel in states surrounding North Dakota and nearby Canadian provinces expressed doubts concerning the species' introduction, particularly because its effect on native species was unknown and because of its potential to spread (e.g., Wingate 1992). Zander has been widely introduced into western Europe and the species was illegally introduced into portions of England.

According to Hickley (1986), the success of introduced populations seemed to be limited by the availability of the species' preferred habitat, characterized as "eutrophic, turbid, well oxygenated and of low mean depth, and, if a river, slow-flowing rather than turbulent."

Impact of Introduction: Zander stocks ore highly prized, but there is concern about the effects on native fish populations where it is introduced. Adverse effects are largely unknown, although there is concern among European fish resource managers that introduced zander may cause a collapse in resident prey fish stocks (Hickley 1986 and references therein).

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Representative biota of concern: Aquatic, wetland, and terrestrial vascular plants

[17]*Hydrilla verticillata* (L.f.) Royle (Hydrilla)

Common name: hydrilla

Taxonomy and identification. Hydrilla grows submersed. The species is generally perennial but sometimes annual, and have horizontal stems in the substrate forming tubers under certain conditions. Stems are ascending and usually are sparsely branched until the plants near the water surface and then become profusely branched. Under certain conditions, turions (actually bulbil-like structures) form in the leaf axils. Stems can be up to 8.5 m long and grow to the surface of the water where the branchlets extend horizontally. Leaves are 1-nerved, sessile, whorled, 3 to 12 at a node but mostly 5 or more, mostly shorter than 1.5 cm long, linear to lanceolate or rarely widely ovate, broadest at the base, the sides nearly paralleling to near the acute tip that terminates in a single spine cell. Leaf margins are serrate, the teeth visible to the naked eye. Fresh leaves are notably rough to the touch. The midrib on the upper surface is often tinged with red and on the lower surface, usually, has 1-celled sharp teeth or spines.

Flowers are unisexual, arising from the leaf axil; plants are monoecious or dioecious. The flowers are small, less than 6 mm in diameter, translucent to white; female flowers are usually produced in the fall and are on long thread-like stalks 2 to 4 cm long from leaf axils of the upper branches that carry the flowers to the water surface. Male flowers are solitary, small, on short stalks in the leaf axil and break off as buds, opening explosively on the water surface.

Hydrilla can usually be differentiated from Canadian elodea (*Elodea canadensis* Michx.) and egeria (*Egeria densa* Planch.) by the following characters:

- Leaves mostly in whorls of 4 at sterile nodes, leaves 1.4 to 2.5 cm long *Egeria densa*
- Leaves of stems at growing tips at water's surface usually in whorls of 3 or 5 or more; leaves not or mostly not exceeding 1.5 cm long, sometimes to 2 cm

[17]Original material prepared by C.C. Jacono and M.M. Richerson at the Center for Aquatic Resource Studies, USGS/BRD/FISC. Last accessed December, 2004; edited and revised December, 2004.

- Leaves mostly in whorls of 5 or more; margins of the leaves with teeth perceptible to the naked eye; midribs on lower leaf surface (when fresh) with a few conical protuberances tipped by sharp 1-celled teeth; fresh leaves notably rough to the touch *Hydrilla verticillata*
- Leaves mostly in whorls of 3; margins of the leaves not having teeth perceptible to the naked eye; midribs of lower leaf surface not pronounced, not bearing teeth; fresh leaves not rough to the touch *Elodea canadensis*

Habitat and growth characteristics. Hydrilla grows in canals, springs, streams, ponds, lakes and reservoirs. Most populations of hydrilla in the United States are dioecious, although populations of monoecious hydrilla occur in North Carolina and northward into the mid-Atlantic states (Langeland 1996). Hydrilla can reproduce by four methods: fragmentation, tubers, turions, and seed. Tubers in the hydrosoil can remain viable for several years (Langeland 1996) and allow the plant to survive cold temperatures and periods of drought (Tarver *et al.*1986). Although the importance of seed production in the spread of hydrilla has not been researched extensively, it is probably of minor importance compared to vegetative reproduction (Langeland 1996). Hydrilla has a high growth rate and lower light requirement for photosynthesis than most other submersed plants (Langeland 1996) which allows it to grow at greater depths and outcompete most other species. It also forms a dense canopy at the surface of the water and "shades out" other submersed plants (Tarver *et al*. 1986).

Native distribution and introduction to North America. *Hydrilla verticillata*(L.f.) Royle is an introduction from the Old World (Cook & Luond 1982) that was first discovered in the United States in 1960. The species is now abundantly naturalized in many parts of the United States (Langeland 1996). Plants have attractive foliage and are planted in aquaria which are often emptied into freshwater habitats. Hydrilla is easily confused with *Egeria densa* Planch., Brazilian elodea or Egeria, and *Elodea canadensis* Michx., Canadian elodea, Waterweed.

Non-indigenous distribution. The current distribution of hydrilla in the US is illustrated in Figure 24.

Control and management problems.[18] This species is probably the worst submersed aquatic

[18]Developed in part from guidance from The Western Aquatic Plant Management Society available from http://www.wapms.org/plants/hydrilla.html last accessed December, 2004.

weed in the United States. Plants form large, dense populations which displace native species, restrict flow, and impair small boat navigation and other recreational uses (Tarver *et al*. 1986, Langeland 1996). In addition to being spread by natural fragmentation, plants are sometimes spread from lake to lake by fragments attached to boat motors and trailers. Hydrilla also is thought to be intentionally introduced into "new" water bodies in an effort to enhance sport fishing for black bass.

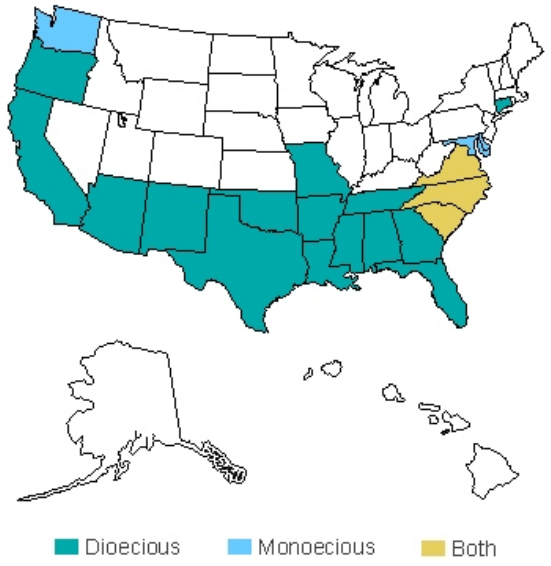


Figure 24a. Distribution of hydrilla as indicated by state records.

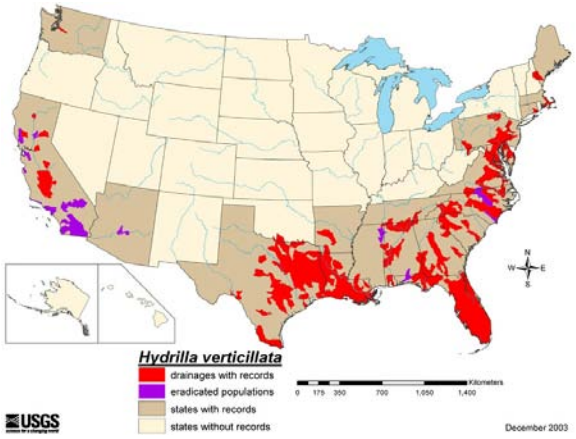


Figure 24b. Distribution of hydrilla as indicated by hydrological unit codes.

Management of hydrilla in waterways or ponds and lakes is generally intensive, owing to hydrilla's great reproductive potential. Tubers are particularly troublesome, since they serve as a source of regrowth in areas where the hydrilla shoots have been controlled by chemical or mechanical methods. Hydrilla can rapidly colonize an area devoid of aboveground vegetation.

Response to Herbicides. Three EPA-registered herbicides are effective against hydrilla growth that are permitted for use: fluridone (Sonar®), endothall (Aquathal®), and copper compounds. Fluridone is a systemic herbicide that has proven effective against hydrilla; however, drawbacks to using fluridone include its high cost, slow-action, and non-selectivity toward other macrophyte species. Endothall, a fast-acting contact herbicide, is used when immediate control of vegetation is needed. Copper compounds are often used in conjunction with endothall applications, although copper by itself exhibits herbicidal action against hydrilla. Copper is also used for its algicidal

properties when heavy periphytic growth on the hydrilla may interfere herbicide uptake. These herbicides do not affect hydrilla seeds, tubers, and turions and repeated applications are needed to control hydrilla regrowth.

Response to Cultural Methods. Localized control (in swimming areas and around docks) can be achieved by covering the sediment with a opaque fabric which blocks light from the plants. Managers of reservoirs and some lake systems may have the ability to lower the water level as a method of managing aquatic plants. This technique is sometimes successful in areas where the hydrosoil can thoroughly desiccate.

Response to Mechanical Methods. Because this plant spreads readily through fragmentation, mechanical controls such as cutting and harvesting should be used only when the infestation has reached a local maximum (e.g., dispersal is resource limited). Using mechanical controls while the plant is still invading, will tend to enhance its rate of spread.

In some states, e.g., Florida, specially designed aquatic plant harvesters are used to cut and collect hydrilla from waterways. Hydrilla harvesting is mainly performed to open boat lanes through hydrilla beds for navigation. Because hydrilla produces more biomass per square meter than most aquatic plants, the cost of harvesting hydrilla is generally higher than for harvesting other nuisance species such as Eurasian watermilfoil. For example, harvesting costs on the Potomac River were about $1,200 per acre (costs for harvesting milfoil in Washington average $600 to 800 per acre).

Biological Control. Worldwide surveys for natural hydrilla enemies were begun in 1981 in a cooperative study between the University of Florida, the United States Department of Agriculture, and the U.S. Army Corps of Engineers. A number of insects were identified, quarantined and tested, and eventually released in Florida and other states. Results from these insect releases are still being evaluated.

Although they have access to many biocontrol agents, grass carp have been deemed the most effective biological control for hydrilla by Florida lake managers. Grass carp have definite food preferences and hydrilla is a preferred plant species. Grass carp have proven to be an effective tool for hydrilla eradication, e.g., hydrilla infestation reached a maximum of 79 percent on Lake Baldwin, Florida, and was then eliminated by two successive grass carp stockings. Similarly, in California triploid grass carp have been introduced to the Imperial Irrigation District as an eradication tool for hydrilla.

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[19]***Myriophyllum spicatum*** L.

Common Name: Eurasian watermilfoil

Taxonomy and identification. A submersed, rooted, perennial herb. Consisting of long underwater stems that branch and produce many whorled, finely divided leaves upon nearing the surface. Distinguished from the native *M. sibiricum* primarily by the overall shape of the leaf and then by the number of leaflets. Leaves are divided in to threadlike leaflets, usually in pairs of more than 14 (Nichols 1975). Leaflets are uniformly tapered so that the leaf shape is more like an equilateral triangle with a curved base. Leaflets stand at acute angles (less than 45 degrees) to the rachis and are parallel to each other (Ceska 1985). Meanwhile, *M. sibiricum* has basal leaflets that are as long as the leaf. They curve over and extend almost to the top of the leaf, forming a more feathery shape. Aiken (1981) provides a detailed key for fertile specimens.

Life history and biology. Lakes, ponds, shallow reservoirs and low energy areas of rivers and streams. Brackish water of protected tidal creeks and bays. Particularly troublesome in waterbodies that have experienced disturbances such as nutrient loading, intense plant management, or abundant motorboat use (Nichols 1994).

Native distribution. Europe, Asia, and northern Africa

Nonindigenous Occurrences: Figure 25 illustrates the current distribution of Eurasian watermilfoil in the US. In the northeastern US, the species is expanding through New York, particularly into the Upper Hudson River-Albany region and into lakes in the foothills and mountains of the Adirondacks (Madsen 1994). In New England, Eurasian watermilfoil occurs in Vermont at 53 lakes, most concentrated in the western drainages, where *Myriophyllum spicatum* covers thousands of aquatic acres, including large bays in Lake Champlain and Lake Bomoseen (Crosson 2000). Eradication has been accomplished in some areas of New England; for example, the species has been successfully eradicated from the interior of New Hampshire by draining a site (Mountain Pond) in Brookfield, New Hampshire (R. Esterbrook, New Hampshire Dept. of Environmental Services, pers. comm. 1996). However, Eurasian watermilfoil has since found in

[19] Original material prepared by Colette C. Jacono and M.M. Richerson (April 15, 2003) from the Center for Aquatic Resource Studies which is part of the Biological Resources Division of the Geological Survey within the U.S. Department of the Interior. Updated January, 2004.

the Connecticut River, bordering Vermont and New Hampshire, and under New Hampshire jurisdiction (Engel 1998). The species is locally abundant and spreading rapidly in Massachusetts and Connecticut (Crow and Hellquist 1983), and occurs in lakes and ponds of Rhode Island

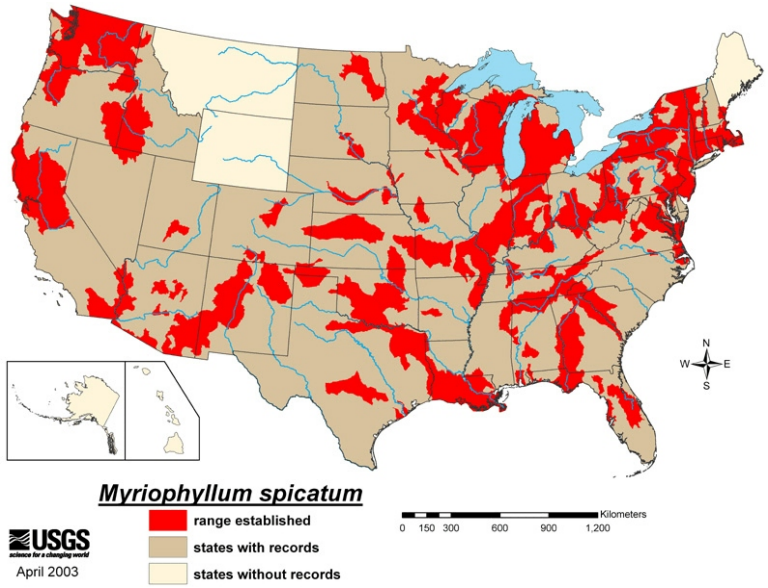


Figure 25. Map indicates recorded presence in at least one site within the drainage (USGS Hydrologic Unit 8) , but does not necessarily imply occurrence throughout that drainage.

(Sheath and Nerone 1988). The species is spreading rapidly through lakes and rivers in Pennsylvania, while the native *M. sibiricum* has been listed as endangered (Pennsylvania Flora Project 1998). Watermilfoil has become established in the tidal regions of the Delaware River, where salt intrusion and industrial pollution are eliminating native submersed plants (Schuyler et al. 1993). The species occurs in New Jersey's Upper Delaware drainage basin where specimens were collected as early as 1952 from Lake Musconetcong (Schuyler 1989), and now occurs in all major drainages in New Jersey. In New Jersey, Eurasian watermilfoil is very problematic in the state's northern lakes (Trudeau 1982), and the species is recently been observed in Delaware from a pond along the Chesapeake & Delaware Canal (C. Martin, Delaware Dept. of Natural Resources and Environmental Control, pers. comm. August 1997). In Maryland, the species is common in fresh to oligohaline waters of the Upper Chesapeake Bay and its tributaries (Orth et al. 1996).

In the southeast, Eurasian watermilfoil has occurred in the Potomac River esturary for over three decades, varying in abundance depending on location and seasonal influences in grow and vigor of plants in Virginia (Carter and Rybicki 1994). In North Carolina, the species has been declining in some waters; for example, Eurasian watermilfoil once dominated the shallow waters of Currituck Sound, but climatic factors and sediment suspension precipitated lead to the species' decline in 1990 (Carter and Rybicki 1994). Depending on site conditions, the species has covered at least 4000 acres in the Currituck and Albermarle Sounds, and has become established inland at Lake Gaston and the adjoining Roanoke Rapids Lake, North Carolina (NCDWR 1996). In neighboring South Carolina, Eurasian watermilfoil has been known since 1972 at a few public lakes (Lake Murray and Stevens Creek reservoirs; S. deKozlowski, South Carolina Dept. of Natural Resources, pers. comm. 1997). At Lake Seminole, Georgia, Eurasian watermilfoil was replaced by hydrilla following extensive 2,4-D treatment (Bates and Smith 1994), but the species remains widespread in private impoundments throughout Georgia (G. Lewis, Univ. of Georgia, pers. comm. 1999). Eurasian watermilfoil often dominates the vegetation community in the lower portions of the Apalachicola, Homosassa, Chassohowitzka and Crystal Rivers of Florida, where they meet the Gulf of Mexico (BAPM 1982-1994). Similar patterns of invasion occur throughout the Gulf Coast. In Alabama, Eurasian watermilfoil is the most abundant submersed species in bays and creeks of the Mobile River Delta (Zolczynski and Shearer 1997), and the species has occurred in freshwater reservoirs throughout the rest of the state for years (Bayne 1979). In Mississippi, Eurasian watermilfoil has occurred along the Tennessee-Tombigbee waterway since 1987 (Kight 1988).

West of the Appalachians, Eurasian watermilfoil occurs in West Virginia (Harmon et al 1996), and in Kentucky, populations of the species have declined in some areas (e.g., Kentucky Lake), while being maintained as large populations at other impoundments throughout the state (B. Kenman, Kentucky Fish and Wildlife, pers. comm. 1996). Populations have fluctuated in size throughout the the Tennessee River system (Smith and Barko 1996) where the species was initially introduced to the river at Watts Bar Reservoir, Tennessee in the 1950's (Couch and Nelson 1985). Eurasian watermilfoil has been spreading throughout the Cumberland River system in the late 1980's, in some instances as the result of deliberate planting (Simpson 1990).

In the Great Lakes Region, Eurasian watermilfoil is decreasing in some locations, e.g., Put-in-Bay Harbor, Lake Erie, Ohio, while native plants have returned, as nonindigenous mussels clear the once turbid waters of the harbor (Stuckey and Moore 1995). In the glacial lakes of Indiana, Eurasian watermilfoil has been repeatedly found to occur, with many of the sightings recorded for

lakes located in the northern St. Joseph drainage (INDNR 1997). The species is also known in reservoirs across central Indiana (IDNR 1997), including Monroe Reservoir, where the species thrives in silt laden zones (Landers and Frey 1980). In Illinois, the species has been declining in McCullom Lake in conjunction with the appearance of herbivorous *Euhrychiopsis* weevils (Weinberg 1995). Eurasian watermilfoil is well established in Wisconsin, where infestations have occurred in nutrient rich, recreational lakes since the 1960's. Southern Wisconsin has recorded large populations of Eurasian watermilfoil for over 40 years, and Wisconsin records the most occurrences of the species for any state (over 300 waterbodies infested; Engel 1999). In Lake Michigan the plant occurs sporadically in some bays, but it is spreading northward through lakes of Michigan's lower peninsula (Nichols 1994; Trudeau 1982). Eurasian watermilfoil has been spreading rapidly in Minnesota since the species' arrival in 1987 (e.g., Eurasian watermilfoil occurs in 75 lakes and 4 streams that radiate from the Twin Cites area (Bratager et al. 1996).

Across the Great Plains Eurasian watermilfoil is increasingly becoming a problem. The species is a relatively recent arrival to North Dakota, where it was initially observed in September 1996 as local populations in the Sheyenne River at Valley City (B. Alexander, Valley City State Univ., pers. comm. 1997). The species recurs sporadically but its occurrence is influenced by environmental conditions, e.g., the species was not found following flooding and drawdown of 1997 (Engel 1998). In South Dakota , Eurasian watermilfoil was recently observed at Lake Sharpe, a 61,010 acre impoundment of the Missouri River, and the species has been observed from Fort Thompson to Pierre, where a few small beds were found in August 1999 (D. Ode, South Dakota Game, Fish and Parks, pers. comm. 2000). The species is rare and of little concern in most of Nebraska, populations vary across the state (e.g., noted as declining at Wildwood Lake, Lancaster County while increasing in Hord Lake, Merrick County; R. Kaul, Univ. of Nebraska, pers. comm. 1997; T. LeGrange, Nebraska Game and Parks, pers. comm. 1996). In Kansas, reports of local populations are limited, but the species is long standing along the Kerr-McClellan waterway and in ponds and lakes of southern and central Oklahoma (Nelson and Couch 1985). Since 1993, the plant has occurred as various locations sites across Iowa, where nutrient loading, sedimentation and the maintenance of artificially high water levels have contributed to the absence of native vegetation. The species is currently established at Wilson Grove Lake and at Snyder Bend Lake, a shallow oxbow of the Missouri River (G. Phillips, Iowa Lakes Community College, and J. Wahl, Iowa Dept. of Natural Resources, pers. comm. 1997).

In the Ozark-Prairie of south central US, Eurasian watermilfoil has been collected since 1962 at various locations within 9 river drainages in Missouri (Padgett 2001). The plants are most

problematic in the southcentral and southeastern portions of the state, especially at major recreational water bodies including Lake of the Ozarks (Whitley et al. 1990) and the upper Gasconade River (Padgett 2001). In Arkansas, the species has been tentatively identified from vegetative specimens collected at Lake Ouachita (herbarium specimen UARK 1997), and the species probably occurs downstream in Lake Hamilton (M. Armstrong, Arkansas Dept. of Game and Fish, pers. comm. 1996). The species is found locally in lakes and bayous of western and southeastern Louisiana, and more commonly occurs in fresh to brackish marshes and bays of the Mississippi Delta and the southern Coastal zone (Montz 1980; Chabreck and Condrey 1979). Populations have been established at reservoirs in eastern and central Texas where the species is most troublesome at Lake Austin, Pat Mayse Reservoir and Buescher State Park (Helton and Hartmann 1996).

Throughout the west and northwest US, occurrence of Eurasian watermilfoil is sporadic. Early sightings of *Myriophyllum spicatum* from Montanta and Wyoming are not well documented (Engel 1998), but are likely the result of misidentification. However, the species has been observed in 1998 at the Pend Oreille River, Hayden Lake, Spirit Lake and Eagle Island State Park, in western Idaho (C. Holly and V. Mason, Idaho Dept. of Agric., pers. comm. 1998), which represents the first records for the state. These observations coincide with warm summers in the Pacific Northwest. In Oregon, Eurasian watermilfoil occurs in Devils Lake, where efforts to managed the plant have relied on releases of triploid grass carp (*Ctenopharyngodon idella*; Bonar et al. 1993). The species occurs in lakes across Washington and along the Columbia, Little Spokane, and Pend Orielle Rivers (Parsons 1996) where the invasive plant has replaced native vegetation, particularly in shallow lakes east of Puget Sound, Washington (Walton 1996).

In the intermountain west and southwest US, Eurasian watermilfoil was initially reported in 1998 from Colorado from the Rio Grande River near Alamosa (F. Nibling, U.S. Bureau of Reclamation, pers. comm. 1999) where its presence has caused concern for regional irrigation systems. In New Mexico, the species has been reported at ponds and lakes in four northern counties (Martin and Hutchins 1981), and more recent records have been noted for Abiquiu and Cochiti Lakes, impoundments on the Rio Chama and the Rio Grande Rivers (Charles Ashton, U.S. Army Corps of Engineers, pers. comm. 2000). In Arizona as in other areas of the southwest, Eurasian watermilfoil may be more a curiosity than a problem, given the warm, arid climate of the region. In Arizona, the speices occurs in a few ponds in the Colorado River Indian Tribe Reservation and in a small reservoir in the Verde Valley (E. Hall, Arizona Dept. of Agriculture, pers. comm. 1997). First observed in 1993, Eurasian watermilfoil occurs at Fish Lake and Otter

Creek Reservoir in Utah (UDWR 1993), and in Nevada, plants were first observed at marinas along the northern shore of Lake Tahoe in 1995 (Anderson and Ryan 1996). And, in California, the species occurs as an nncommon plant in ditches and at lake margins in regions surrounding San Francisco Bay and San Joaquin Valley (Hickman 1993).

Means of Introduction. In the US, Eurasian watermilfoil was first documented in 1942 from a pond in Washington D.C., where the species was probably intentionally introduced (Couch and Nelson 1985). From that point and other introduction, the species has spread into lakes and streams across the country. Once introduced, water currents potentially disseminate vegetative propagules throughout a drainage, and stem fragments are important for the colonization of new habitats. Within a stand, local populations generally expand through growth of stolons (Aiken et al. 1979; Madsen et al. 1988). Anthropogenic mechanisms such as motorboat traffic contribute to natural seasonal fragmentation and the distribution of fragments throughout lakes, and transport of watercraft plays the largest role in introducing fragments to new waterbodies. For example, road checks in Minnesota have found aquatic vegetation on 23% of all trailered watercraft inspected (Bratager 1996) where transport of any aquatic vegetation is now illegal.

Impact of introduction. Eurasian watermilfoil is one of the most widely distributed of all nonindigenous aquatic plants in the US, being confirmed in 45 states. In Canada, the species occurs British Columbia, Ontario and Quebec. The species is widespread primarily because it competes aggressively to displace and reduce the diversity of native aquatic plants, once introduced to an area. From a single to a few vegetative propagules, the plant becomes established, then its shoots elongate and vegetative growth continues. The plant effectively outcompetes native aquatic vegetation, since its growth in spring occurs much earlier than other aquatic plants. The species is tolerant of low water temperatures, and it quickly grows to the surface forming dense canopies that overtop and shade the surrounding vegetation (Madsen et al. 1991). Canopy formation and light reduction are significant factors in the decline of native plant abundance and diversity observed when Eurasian water-milfoil invades healthy plant communities (Smith and Barko 1990; Madsen 1994). Both eelgrass (*Vallisneria americana*) and southern naiad (*Najas guadalupensis*) are known to have been displaced by this nonindigenous species in the Mobile Delta of Alabama (Bates and Smith 1994), and its establishment in Lake George, New York, reduced native plants from 5.5 to 2.2 species per square meter, in just two years (Madsen et al 1991). Eurasian water-milfoil has less value as a food source for waterfowl than the native plants it replaces (Aiken et al. 1979). Fish may initially experience a favorable edge effect in early stages of Eurasian watermilfoil invasions, but the characteristic over abundant growth offsets any

short-term benefits that edge effect may provide fish in healthy waters. At high densities, the plant's foliage supports a lower abundance and diversity of invertebrates, organisms that serve as fish food (Keast 1984). Dense cover allows high survival rates of young fish, but larger predator fish lose foraging space and and are less efficient at obtaining their prey (Lillie and Budd 1992; Engel 1995). Madsen et al. (1995) found growth and vigor of a warm-water fishery reduced by dense Eurasian water-milfoil cover. The growth and senescence of thick vegetation degrades water quality and depletes dissolved oxygen levels (Honnell 1992; Engel 1995). Typical dense beds restrict swimming, fishing and boating, clog water intakes and result in decaying mats that foul lakeside beaches.

Control and management. The occurrence of sixteen species including *Potamogeton illinoensis* and *Potamogeton pectinatus* may be indicators of conditions suitable for Eurasian water-milfoil invasion. Searching areas colonized by these species may provide early detection, the best method for preventing new invasion (Nichols and Buchan 1997).

Chemical and physical control.[20] Most problems caused by milfoil can be managed with conventional methods such as treatment with herbicides or mechanical removal of plants. For example, in Minnesota, management of Eurasian watermilfoil is completed using methods that cause as little damage to native aquatic plants as possible. Native plants provide many benefits to lake ecosystems, such as stabilizing lake sediments, and increasing habitat for fish and wildlife. Also, widespread destruction of native plants can lead to an overall increase in the amount of Eurasian watermilfoil in a water body because milfoil is very effective at invading disturbed habitat.

Using herbicides to eradicate milfoil are "...rarely, if ever, likely to succeed" (Smith and Barko 1990), and in Minnesota, the use of herbicides to prevent the spread of milfoil within a lake has, at best, slowed the plant's local dispersion, but rarely yields eradication. Studies by Minnesota Department of Natural Resources (DNR) suggests that fluridone application to whole lakes or bays at an intermediate rate of 10 parts per billion (ppb) causes unavoidable damage to native vegetation and has the potential to affect other aspects of lake ecosystems (Welling et al 1997).

The results of subsequent investigations of fluridone in Michigan suggested that application of the herbicide at the low rate of 5 to 6 ppb may provide more selective control than has previously

[20]Source from http://www.dnr.state.mn.us/ecological_services/invasives/ewmprog.html.

been observed in Minnesota. Chemical control of Eurasian watermilfoil is variously successful, and should be considered along with other agents and management tools as indicated by case-specific factors.

For example, in the Washington state,[21][22] various eradication and control strategies have been developed to address a wide range of invasive plant management issues. These management tools include eradication and control strategies using physical and chemical controls, e.g., hand pulling and bottom barrier installation; diver dredging; rotovation and harvesting; water level drawdown; 2,4-D treatment; whole lake fluridone treatment, endothall treatment; and release of triploid grass carp.

Due to expense and the time intensive nature of manual methods, sites suitable for hand pulling and bottom screening are limited to lakes or ponds only lightly infested with Eurasian watermilfoil. This method is suitable for very early infestations of milfoil and for follow-up removal after a whole lake fluridone treatment, a 2,4-D treatment, or diver dredging. To be cost-effective, generally the total amount of milfoil in the waterbody should be three-acres or less in area, if all the milfoil plants were grouped together in one location. If the infestation has advanced beyond this point, it is more effective to consider other eradication techniques such as aquatic herbicides. This method may also be applicable in waterbodies where no herbicide use can be tolerated such as in a lake used as a municipal drinking water supply. These methods could be used in any waterbody to eradicate milfoil; however costs for large-scale projects would become prohibitive.

Response to Herbicides. Westerdahl and Getsinger (1988) reported excellent control with 2,4-D, diquat, diquat and complexed copper, endothall dipotassium salt, and endothall with complexed copper. They also report good control with fluridone, and in Washington, fluridone (Sonar®) has been successfully used to eradicate Eurasian watermilfoil in lakes. To be effective, fluridone concentrations of 10-15 ppb must be maintained in the water column for 10 to 12 weeks. Follow-up diver surveillance and hand-pulling of surviving plants is essential to the success of this technique. Some eradication attempts with fluridone have had mixed success in Washington. Factors such as surface and ground water inflows and development of land forms of Eurasian

[21]See http://www.ecy.wa.gov/programs/wq/plants/management/milfoil_strategies.html.

[22]See http://www.wapms.org/plants/milfoil.html.

watermilfoil all affect the success rate. The herbicide triclopyr is undergoing federal aquatic registration and holds great promise for Eurasian watermilfoil control. Unlike fluridone, triclopyr requires a short contact time (18 to 48 hours) and will selectively control Eurasian watermilfoil while leaving many native aquatic plants relatively unaffected.

Response to Cultural Methods. Localized control (in swimming areas and around docks) can be achieved by covering the sediment with a opaque fabric which blocks light from the plants (bottom barriers or screens). Managers of reservoirs and some lake systems may have the ability to lower the water level as a method of managing aquatic plants. The Tennessee Valley Authority (TVA) uses both winter and summer water level drawdowns as effective way of reducing Eurasian watermilfoil biomass. Drawdown of about 2 meters is effective in reducing excessive populations. Short-term dewatering for 2-3 days during period of freezing temperatures has been effective, but multiple exposures may improve control. A 1-week drawdown of a large TVA impoundment in July 1983 desiccated about 810 hectares of Eurasian watermilfoil. A narrow, relatively weed-free band occurred after refilling and control effects extended into the following two growing seasons. In Washington, the Bureau of Reclamation lowered the water level of Banks Lake in 1994 in an effort to manage Eurasian watermilfoil populations. The success of a drawdown on Eurasian watermilfoil is dependent on several factors such as degree of desiccation (drawdowns in rainy western Washington and Oregon are often ineffective), the composition of substrate (sand vs. clay), air temperature (the exposed sediments need to freeze down to 8-12 inches), and presence of snow.

Response to Mechanical Methods. Because Eurasian watermilfoil spreads readily through fragmentation, mechanical controls such as cutting, harvesting, and rotovation (underwater rototilling) should be used only when the extent of the infestation is such that space for further expansion is limited and, e.g., local within-lake dispersion is unlikely. Using mechanical controls while the plant is still invading, will tend to enhance its rate of spread. The British Columbia Ministry of Environment developed a barge mounted rototilling machine called a rotovator to remove Eurasian watermilfoil roots. The machine’s underwater tiller blades churn up to 8 inches into the sediment and dislodge buoyant Eurasian watermilfoil roots. Floating roots may then be collected from the water. Control with rotovation, generally extends 2 or more growing seasons.

Harvesting requires machinery that can cut plants below the water's surface, then collected, and stored harvested plant material for disposal on land. Harvesting removes surfacing mats and creates open areas of water. However because of its rapid growth rate Eurasian watermilfoil

generally needs to be harvested twice during the growing season.

Biological control. A range of biological control agents have been used in efforts to eradicate or control Eurasian watermilfoil. Insects have been evaluated by USDA and Corps of Engineers, and several insects have been considered as prospective biocontrol agents, e.g., pyralid moths and several stem-boring weevils. However, many of these insects were found to be non-specific to Eurasian watermilfoil or to offer little potential as effective biological control agents. In British Columbia, several insects were associated with Eurasian watermilfoil and a midge was investigated as a potential control agent. However, the midge proved to be extremely difficult to rear in the laboratory.

A North American weevil, *Euhrychiopsis lecontie*, may be associated with natural declines at northern lakes (Sheldon 1994, Bratager et al. 1996, Weinberg 1995). Studies have found the herbivorous weevil to cause significant damage to Eurasian water-milfoil while having little impact on native species (Sheldon and Creed 1995), suggesting the insect as a potential biological control agent. For example, *E. lecontei* has been found in Washington state feeding on both Eurasian watermilfoil and northern milfoil (*Myriophyllum sibericum*) plants, and studies have shown that this native weevil appears to be a milfoil specialist and will not feed on other macrophyte species. It can be easily raised in the laboratory and laboratory-reared weevils could be used to augment natural populations.

Although triploid grass carp will eat Eurasian watermilfoil, it is not a highly palatable or preferred species. To achieve control of Eurasian watermilfoil generally means the total removal of more palatable native aquatic species before the grass carp will consume Eurasian watermilfoil. In situations where Eurasian watermilfoil is the only aquatic plant species in the lake, this may be acceptable. However, generally grass carp are not recommended for Eurasian watermilfoil control.

Plant pathogens of Eurasian watermilfoil may be applicable to control and management of Eurasian watermilfoil, especially given observations of extensive mortality of Eurasian watermilfoil linked to a plant pathogenic fungus *Mycoleptodiscus terrestris*. In the late 1960s in Maryland, “Northeast Disease” was associated with declines in Eurasian watermilfoil, and *M. terrestris* was suspected as the causative agent. The pathogenic fungus has been shown to significantly reduce Eurasian watermilfoil biomass in laboratory studies, although control Eurasian watermilfoil in the field has not been achieved. The US Army Corps of Engineers is continuing

research on plant pathogens.

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[2324]***Eichhornia crassipes*** (Martius) Solms

Common name: Waterhyacinth

Taxonomy and identification. Taxonomy of waterhyacinth is detailed in on Cronquist (1988), Thorne (1992), and Takhtajan (1997). The English common names of the plant are waterhyacinth, water hyacinth, and water-hyacinth. Waterhyacinth is the standardized spelling adopted by the Weed Science Society of America (WSSA, 1984) to denote that it is not an aquatic relative of true "hyacinth" (*Hyacinthus* spp.), as the two-word spelling suggests.

Waterhyacinth is a member of the pickerelweed family (Pontederiaceae). Families most closely allied with the Pontederiaceae are Commelinaceae, Haemodoraceae (including Conostylidaceae [Takhtajan, 1997]), Philydraceae, and Hanguanaceae (Hahn, 1997; APG, 1998). The subclass Commelinidae includes the Arecales, Poales, Commelinales, and Zingiberales (APG, 1998).
The Pontederiaceae is a small family of herbaceous mono Cotyledons that includes six genera and 30 to 35 species (Eckenwalder and Barrett, 1986). All are palustrine or aquatic and most are confined to the Americas. All seven members of the genus *Eichhornia* originated in tropical America, except for *Eichhornia natans* (P. Beauv.), which is from tropical Africa. Fourteen species of Pontederiaceae occur in the flora of US and Canada (Table 2), six of which are adventive; none are considered threatened or endangered (USDA, NRCS, 1999).

Life history and biology. Waterhyacinth is an erect, free-floating, stoloniferous, perennial herb. The bouyant leaves vary in size and morphology. The short, bulbous leaf petioles produced in uncrowded conditions provide a stable platform for vertical growth. Plants in crowded conditions form elongate (up to 1.5 m) petioles (Center and Spencer, 1981). Leaves are arranged in whorls

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[23] Original material prepared by T. D. Center (U.S. Department of Agriculture, Agricultural Research Service, Invasive Plant Research Laboratory, Fort Lauderdale, Florida, USA, M. P. Hill - Plant Protection Research Institute, Pretoria, South Africa, H. Cordo - U.S. Department of Agriculture, Agricultural Research Service, South American Biological Control Laboratory, Hurlingham, Argentina, M. H. Julien - Commonwealth Scientific and Industrial Research Organization, Indooroopilly, Australia, and published in Van Driesche, R., *et al.*, 2002, Biological Control of Invasive Plants in the Eastern United States, USDA Forest Service Publication FHTET-2002-04, 413 p.

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of six to 10, and individual plants develop into Clones of attached rosettes (Center and Spencer, 1981).

Table 2. Species of Pontederiaceae in the United States.

Native Species	**Introduced Species**
Heteranthera dubia (Jacq.) MacM.	*Eichhornia azurea* (Sw.) Kunth
Heteranthera limosa (Sw.) Willd.	*Eichhornia crassipes* (Mart.) Solms.
Heteranthera mexicana Wats.	*Eichhornia diversifolia* (Vahl) Urban
Heteranthera multiflora (Griseb.) Horn	*Eichhornia paniculata* (Spreng.l) Solms
Heteranthera penduncularis Benth.	*Monochoria hastata* (L.) Solms
Heteranthera reniformis Ruiz Lopez & Pavon	*Monochoria vaginalis* (Burm. f.) K. Presl
Heteranthera rotundifolia (Kunth) Griseb.	
Pontederia cordata L.	

The lavender flowers display a central yellow fleck and are borne in clusters of up to 23 on a single spike (Barrett, 1980). The flowers may have short, medium, or long styles, but only the short- and long-style forms occur in the United States (Barrett, 1977). The 14-day flowering cycle concludes when the flower stalk bends, positioning the spike below the water surface where seeds are released (Kohji *et al.*, 1995). Seed capsules normally contain fewer than 50 seeds each (Barrett, 1980). Each inflorescence can produce more than 3,000 seeds and a single rosette can produce several inflorescences each year (Barrett, 1980). The small, long-lived seeds sink and remain viable in sediments for 15 to 20 years (Matthews, 1967; Gopal, 1987). Seeds germinate on moist sediments or in warm shallow water (Haigh, 1936; Hitchcock *et al.*, 1950) and flowering can occur 10 to 15 weeks thereafter (Barrett, 1980). Lack of germination sites limits seedling recruitment except during drought, on decaying mats after herbicide applications (Matthews, 1967), or at the margins of waterbodies. Populations increase mainly by vegetative means.

Weber (1950), Richards (1982), Watson (1984), and Watson and Cook (1982, 1987) describe waterhyacinth growth and population expansion as the result of differentiation of apical or axillary meristems. The single apical meristem on each stem tip can be vegetative, producing leaves with axillary buds, or reproductive, producing flowers. If an inflorescence develops, termination of the apical meristem halts leaf production. In this event, the axillary bud immediately below the inflorescence differentiates into a continuation shoot. This produces a new apical meristem that

allows leaf production to proceed. If the axillary bud does not form a continuation shoot, then it produces a stolon. Elongation of the stolon internode moves the axillary bud apex away from the parent rosette. It then produces short internodes that grow vertically into a new rosette.

Waterhyacinth grows best in neutral pH, water high in macronutrients, warm temperatures (28° to 30°C), and high light intensities. It tolerates pH 4.0 to 10.0 (Haller and Sutton, 1973), but not more than 20 to 25% sea water (Muramoto *et al.*, 1991). The plants survive frost if the rhizomes do not freeze, even though emergent portions may succumb (Webber, 1897). Prolonged cold kills the plants (Penfound and Earle, 1948), but reinfestation from seed follows during later warmer periods. Ueki (1978) matched the northern limit of waterhyacinth to the 1°C average January isotherm in Japan, and growth is inhibited at water temperatures above 33˚C (Knipling *et al.*, 1970). Plants stranded on moist sediments can survive several months (Parija, 1934).

Native distribution. The diversity of other species of *Eichhornia*, particularly the more primitive *Eichhornia paniculata* (Spreng.) Solms. and *Eichhornia paradoxa* (Mart.) Solms., and the overlapping range of the closely related *Eichhornia azurea* (Sw.) Kunth suggest that *E. crassipes* arose in tropical South America.

Non-indigenous distribution. Waterhyacinth was introduced into the United States around 1884 and has become pan-tropical. Worldwide, the limits of distribution are bound by 40°N and 40°S latititude (Gowanloch and Bajkov, 1948; Bock, 1968; Holm *et al.*, 1969; Ueki, 1978; Gopal, 1987). In the US, waterhyacinth is most abundant in the Southeast (Figure 26); it also occurs in California and Hawaii, with scattered records in other states (USDA, NRCS, 1999).

Impacts and control. Waterhyacinth, *Eichhornia crassipes* is one of the world's worst weeds (Holm *et al.*, 1977), invading lakes, ponds, canals, and rivers. It was introduced into many countries during the late 19th and early 20th centuries, where it spread and degraded aquatic ecosystems. The species is still rapidly spreading throughout Africa, where new infestations are creating life-threatening situations as well as environmental and cultural upheaval (Cock *et al.*, 2000). Control with herbicides, particularly 2,4-D, is feasible, but is costly and temporary.

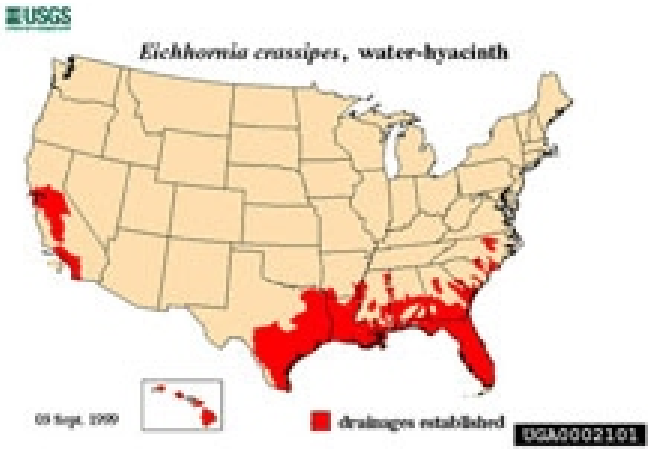


Figure 26. Drainages infested by waterhyacinth in the United States. (Map from USGS/BRD).

Adverse biological and ecological effects associated with waterhyacinth are numerous. Dense mats reduce light to submerged plants, thus depleting oxygen in aquatic communities (Ultsch, 1973). The resultant lack of phytoplankton (McVea and Boyd, 1975) alters the composition of invertebrate communities (O'Hara, 1967; Hansen *et al.*, 1971), ultimately affecting fisheries. Drifting mats scour vegetation, destroying native plants and wildlife habitat. Waterhyacinth also competes with other plants, often displacing wildlife forage and habitat (Gowanloch, 1944). Higher sediment loading occurs under waterhyacinth mats due to increased detrital production and siltation. Herbicidal treatment or mechanical harvesting of waterhyacinth often damages nearby desirable vegetation.

Economic impacts of waterhyacinth may be significant. Waterhyacinth grows rapidly (Penfound and Earle, 1948) forming expansive colonies of tall, interwoven floating plants that may blanket large waterbodies, and create impenetrable barriers and obstructing navigation (Gowanloch and Bajkov, 1948; Zeiger, 1962). Floating mats block drainage, causing flooding or preventing subsidence of floodwaters. Large rafts accumulate where water channels narrow, sometimes causing bridges to collapse. Waterhyacinth hinders irrigation by impeding water flow, by clogging irrigation pumps, and by interfering with weirs (Penfound and Earle, 1948). Multimillion-dollar flood control and water supply projects can be rendered useless by waterhyacinth infestations (Gowanloch and Bajkov, 1948).

Infestations block access to recreational areas and decrease waterfront property values, oftentimes

harming the economies of communities that depend upon fishing and water sports for revenue. Shifting waterhyacinth mats sometimes prevent boats from reaching shore, trapping the occupants and exposing them to environmental hazards (Gowanloch and Bajkov, 1948; Harley, 1990). Waterhyacinth infestations intensify mosquito problems by hindering insecticide application, interfering with predators, increasing habitat for species that attach to plants, and impeding runoff and water circulation (Seabrook, 1962).

Historically, annual losses associated with waterhyacinth-caused damages are often quite high, e.g., costs were estimated at $65 to 75 million in Louisiana during the 1940s (Gowanloch and Bajkov, 1948). During that same period, fish and wildlife losses alone in the six southeastern states exceeded $4 million per year in 1947 (Tabita and Woods, 1962). Holm *et al.*(1969) ascribed losses of $43 million in 1956 to waterhyacinth infestations in Florida, Mississippi, Alabama, and Louisiana, and early estimates from the US Army Corps of Engineers estimated benefits from waterhyacinth control programs at nearly $14 million in 1965 (Gordon and Coulson, 1974). Florida spent more than $43 million during 1980 to 1991 to suppress waterhyacinth and waterlettuce (Schmitz *et al.*, 1993), and more recently, annual costs for waterhyacinth management range from $500,000 in California to $3 million in Florida (Mullin *et al.*, 2000). The largest infestations occur in Louisiana, where the Department of Fisheries herbicidally treats about 25,000 acres of waterhyacinth per year, mostly at boat ramps, at an annual cost of $2 million (R. Brassette, pers. comm.).

Biological control measures have become increasingly attractive to manage waterhyacinth problems. Since the the early 1970s, USDA has studied biological control of waterhyacinth using the weevils *Neochetina eichhorniae* Warner, *Neochetina bruchi* Hustache, and the pyralid moth *Niphograpta (=Sameodes) albiguttalis* (Warren). These three agents and the mite, *Orthogalumna terebrantis* Wallwork, are now widely used in biological control programs targeted on waterhyacinth (Table 3).

Worldwide, biological control programs against waterhyacinth have reported successes (Julien and Griffiths, 1998), with the *Neochetina* weevils being successful. Biological control, however, often is not sufficient to adquate management of the waterhyacinth problem, since biological control agents tend to be slow-acting, which may not be acceptable for a particular application and biological control may not be compatible with other management practices (Center *et al.*, 1999a). Explosive growth of waterhyacinth stimulated by high nutrient levels may also limit the success of biological control measures (Heard and Winteron, 2000). Additional biological control

agents have been identified, but their effectiveness at controlling waterhyacinth is incompletely characterized.

Table 3. Arthropods potentially acting as biological control agents for waterhyacinth

Species	**Field and Laboratory Host Plants**	**Attributes, Limitations, and Current Status of Research**
Neochetina eichhorniae Warner (Col.: Curculionidae)	*E. crassipes*	In use in North America, Australia, Africa, and Asia (Julien and Griffiths, 1998)
Neochetina brunchi Hustache (Col.: Curculionidae)	*E. crassipes*	Ibid.
Niphograpta albiguttalis (Warren) (Lep.: Pyralidae)	*E. crassipes*	Ibid.
Orthogalumna terebrantis Wallwork (Acarina: Galumnidae)	*E. crassipes, E. azurea, Pontederia cordata, Reussia subovata*	Ibid.

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[25]*Lythrum salicaria* L.

Common name: Purple loosestrife

Taxonomy and identification. Purple loosestrife is an erect rhizomatous perennial herb in the loosestrife family, with a square to angular, woody stem having opposite or whorled leaves. The plant's native range was in Eurasia and Africa, but its introduction outside its native area has yielded plant infestations at a wide range of moist or marshy sites throughout North America. Stems are erect (1.5 to 8 or more feet tall), four to six angled, and can be smooth or pubescent with few branches. Leaves are simple (0.75 to 4 inches long, 0.2 to 0.5 inches wide), entire, and can be opposite or whorled. Leaves are lance-shaped, stalkless, and heart-shaped or rounded at the base. Plants are usually covered by a downy pubescence. Loosestrife plants grow from four to ten feet high, depending upon conditions, and produce a showy display of magenta-colored flower spikes throughout much of the summer. Flowers have five to seven petals. Mature plants can have from 30 to 50 stems arising from a single rootstock.

Life history and biology. The most identifiable characteristic of purple loosestrife is the striking rose to purple colored flowers. The flowers are arranged on a spike, which can be a few inches to 3 feet long. Each flower has five to seven petals arising from a cylindrical green tube. At mid-continent latitudes characteristic of the northern Great Plains, plants usually flower from early July to mid-September. The seed capsule is two celled and contains many very small seeds (1 mm long or less). The roots become thick and woody in mature plants. The aerial shoots die in the fall and new shoots arise the following spring from buds at the top of the root crown. Although the root crown expands and produces more shoots each year, the maximum growth of the root crown diameter is limited to about 20 inches.

Spread of purple loosestrife is primarily by seed, but the plant can also spread vegetatively from stem cuttings. Seed viability varies from 50 to 100 percent, and approximately 2.7 million seeds are produced per plant, giving purple loosestrife the potential to spread rapidly once established in an area.

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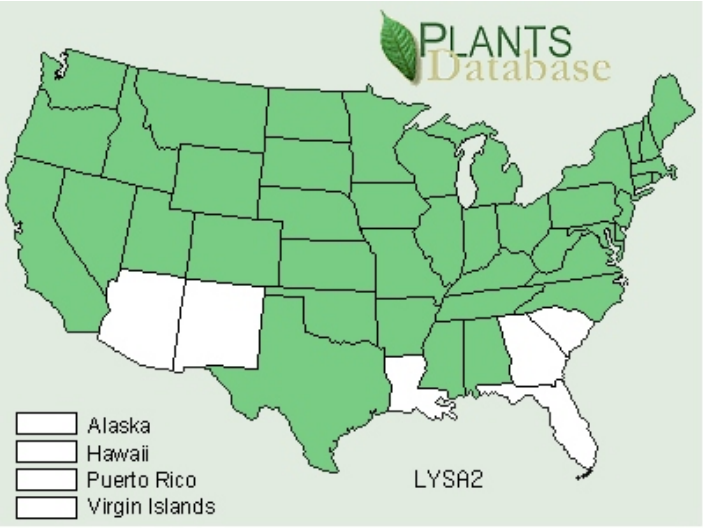
[25]Original material prepared by Jil M. Swearingen, U.S. National Park Service, Washington, DC; W-1132 (Revised) March 2002, Rodney G. Lym, Professor, Plant Sciences, North Dakota State University, NDSU Extension Service. Updated, edited, and revised November, 2004.

Purple loosestrife is capable of invading many wetland types, including freshwater wet meadows, tidal and non-tidal marshes, river and stream banks, pond edges, reservoirs, and ditches. Purple loosestrife has an extended flowering season, generally from June to September (depending on latitude and site-specific conditions), which allows it to produce vast quantities of seed. Flowers require pollination by insects, for which it supplies an abundant source of nectar. A mature plant may have as many as thirty flowering stems capable of producing an estimated two to three million, minute seeds per year. Purple loosestrife readily reproduces vegetatively through underground stems at a rate of about one foot per year. Many new stems may emerge vegetatively from a single rootstock of the previous year.

The most destructive impact of purple loosestrife invasions is adverse ecological effects associated with its dense monotypic stands as it displaces native wetland plants. Under optimum conditions, a small isolated group of purple loosestrife plants can spread to cover aquatic sites in just one growing season. When purple loosestrife replaces native vegetation, it also can displace wildlife. For example, songbirds do not consume the small hard seed. Muskrats use cattails to build their homes, and they show a preference for cattail over purple loosestrife for food. Waterfowl, especially ducks, avoid wetlands that have become dominated with purple loosestrife. In addition, overall waterfowl production decreases as suitable nesting habitat is eliminated. The plant's growth is generally too compact to offer cover, and cover may be as crucial to wildlife as food.

Native range. *Lythrum salicaria* has a native range throughou Eurasia, stretching from Great Britain, across central and southern Europe to central Russia, Japan, Manchuria China, then southeast Asia and northern India.

Non-indigenous range. According to the U.S. Fish and Wildlife Service and other survey records (e.g., BONAP, see Kartesz 1999), purple loosestrife now occurs in nearly every state of the US (Figure 27; states in green have records of local populations). The map in Figure 27 does not reflect relatively recent additions with the states of South Carolina, Georgia, Louisiana, New



Mexico, and Arizona. Currently, only Florida remains without a documented observation of purple loosestrife. Various states in the US and provinces in Canada have identified the species as a "noxious weed" or similar descriptor (Kartesz 1999). For example, North Dakota, Minnesota, and Manitoba each have programs dedicated to eradication of purple loosestrife, given the species current distribution within each's political boundaries (Figure 27 - Figure 29).

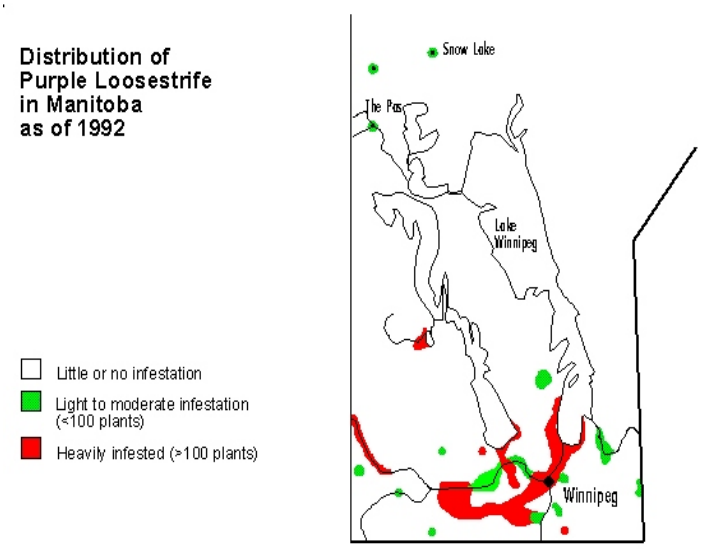


Figure 27. Purpleloosestrife in Manitoba.

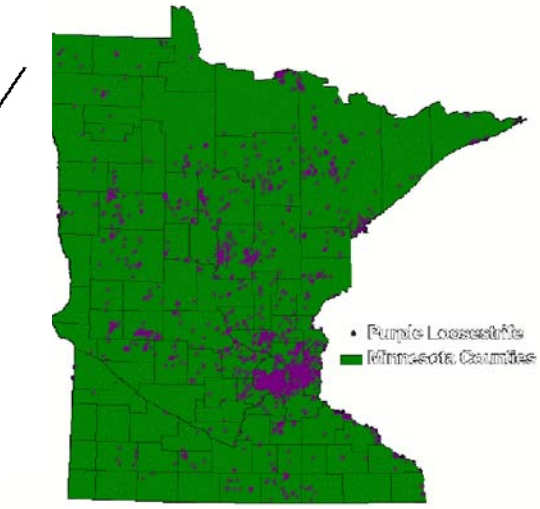


Figure 28. Purpleloosestrife in Minnesota.

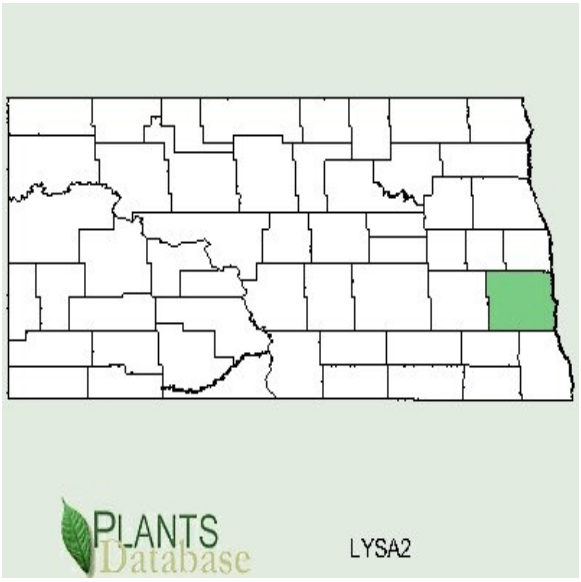


Figure 29. Purpleloosestrife in North Dakota (county record).

Impacts and control. Purple loosestrife was first introduced into North America in the early 1800's. Plants were sold throughout the US as various horticultural cultivars, all having striking colors and being easily grown perenniels (e.g., winter hardy and lack of insect or disease problems). These garden cultivars were thought to be sterile but have now been shown to cross-pollinate with the wild *Lythrum* type and sometimes with other *Lythrum* cultivars.

Purple loosestrife adapts readily to natural and disturbed wetlands. As it establishes and expands its local and regional range, the species out-competes and replaces native grasses, sedges, and other flowering plants that provide a higher quality source of nutrition for wildlife. The highly invasive nature of purple loosestrife allows it to form dense, homogeneous stands that restrict native wetland plant species, including some federally endangered orchids, and reduce habitat for waterfowl.

Several methods are available for purple loosestrife control, including mechanical, biological, and chemical. The size and location of a specific infestation will determine the best control methods. In general, small infestations of a few plants can be controlled by digging, especially when plants are only a few years old. Larger infestations require treatment with herbicides and/or biological control agents.

Mechanical control. Small infestations can be controlled by removing all roots and underground stems. It is difficult to remove all of the roots in a single digging, so monitor the area for several growing seasons to ensure that purple loosestrife has not regrown from roots or seed. This method is most useful on garden plantings or young infestations.

Dispose of plants and roots by drying and burning or by composting in an enclosed area. Take care to prevent further seed spread from clothing or equipment during the removal process. Removal of all plant material is important. Small segments of purple loosestrife stems can become rooted and reestablish the infestation.

Chemical control. Herbicides can be used to control purple loosestrife in areas too large to be controlled by digging. Also, herbicides can be applied to individual plants selectively in landscape situations to prevent killing desirable plants. Infestations growing along streams or in marshy areas may require specialized equipment and application by trained professionals.

Glyphosate (Rodeo® or Roundup®, various other trade names for glyphosate) will provide good

control of purple loosestrife when applied from July to early September. Many formulations of glyphosate are sold but only those labeled for aquatic use can be applied in or near water. For example, the Rodeo and Glypro formulations of glyphosate can be used in water. With the Rodeo or Glypro formulations, a nonionic surfactant approved for aquatic sites at 0.25% vol/vol must be added to the spray solution. Roundup and similar glyphosate formulations can be used to remove purple loosestrife from large plantings or infestations away from water. Glyphosate has no soil residual so it could be used to remove purple loosestrife located within an ornamental planting without having to dig in the flower bed. Best results have been obtained when glyphosate is applied as a 1 to 1.5% concentration (1 to 1.5 gallons glyphosate per 100 gallons of water) or (1.3 to 1.9 fl. oz./gallon of water) at bloom or shortly thereafter.

A variety of sprayers, including backpack sprayers and boat-mounted sprayers, can be used to control purple loosestrife in aquatic sites. Wick application is also effective but is labor intensive. Spray dye added to the tank may be useful to ensure uniform application to purple loosestrife with minimal herbicide applied to desirable plants.

Eliminating the entire vegetative cover will promote purple loosestrife seed germination, which can result in an increase in plant density rather than control. Since glyphosate does not provide residual control, treated areas will need to be monitored for regrowth from the roots or seedlings for several years. A 2,4-D formulation labeled for use near water applied as a 2% solution (2 gallons 2,4-D per 100 gallons of water) or (2.6 fl. oz./gallon of water) will prevent seedling establishment when applied in early fall or spring before the plants can establish perennial characteristics.

Triclopyr (trade name Garlon®) is a selective broadleaf herbicide that will not kill cattail or other desirable monocot species. However, Garlon is not labeled for use in water, and it can only be used up to the water's edge. Garlon will provide good to excellent purple loosestrife control when applied in the pre to early flower or late flower growth stages. Garlon should be applied as a 1 to 2% solution (1 to 2 gallons Garlon® per 100 gallons of water or 1.3 to 2.6 fl. oz./gallon of water) and will provide some residual seedling control. Garlon® can be applied in dryland sites but should not be used in landscapes or flower beds because soil residual of the herbicide may prevent establishment of other horticultural plants.

Regardless of the herbicide applied, the infested areas should be monitored to ensure that purple loosestrife does not reinfest from root or seed. Also, areas downstream from river or creek

infestations and on all sides of a lake or pond infestation should be monitored for purple loosestrife seedlings.

Biological control. While herbicides and hand removal may be useful for controlling individual plants or small populations, biological control is seen as the most likely candidate for effective long term control of large infestations of purple loosestrife. As of 1997, three insect species from Europe have been approved by the US Department of Agriculture for use as biological control agents. These plant-eating insects include a root-mining weevil (*Hylobius transversovittatus*), and two leaf-feeding beetles (*Galerucella calmariensis* and *Galerucella pusilla*). Two flower-feeding beetles (*Nanophyes*) that feed on various parts of purple loosestrife plants are still under investigation. *Galerucella* and *Hylobius* have been released experimentally in natural areas in 16 northern states, from Oregon to New York. Although these beetles have been observed occasionally feeding on native plant species, their potential impact to non-target species is considered to be low. Of these insects, the two *Galerucella* spp. leaf feeding beetles have been most successful. For example, in North Dakota these insects overwinter as adults and lay eggs in early June in North Dakota. The adults and especially the larvae feed on the leaves and flowers of purple loosestrife. Following several summers of heavy feeding, purple loosestrife infestations have been greatly reduced. However, since the largest infestations in North Dakota are in urban areas, mosquito control programs have kept these insects from becoming well established. Purple loosestrife infestations in North Dakota are generally small and isolated and should be controlled by chemical and/or mechanical methods.

Regardless of the control methods employed, successful weed management must limit future dispersal, and locally or regionally this may be accomplished using chemical controls such as herbicides, physical means such as mechanical removals, and biological controls. Depending upon the size and location of the outbreak to be control, a combination of these management tools may be applied to prevent or control spread of purple loosestrife. For small infestations of young purple loosestrife, mechanical removal, e.g., plants may be pulled by hand, should be completd before seed set. For older plants, spot treatments with glyphosate herbicide (e.g., Rodeo® for wetlands, Roundup® for uplands) is recommended. These herbicides may be most effective when applied late in the season when plant are preparing for dormancy. However, it may be best to do a mid-summer and a late season treatment, to reduce the amount of seed produced.

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[26]***Tamarix* spp.** (most likely species of concern include *Tamarix ramosissima* Ledebour, *Tamarix pentandra* Pallas, *Tamarix chinensis* Loureiro, *Tamarix parviflora* De Candolle and hybrids)

Common names: Saltcedar, Tamarisk

Taxonomy and identification. Commonly referred to as saltcedar or tamarisk, the plant is a member of the Tamaricaceae, and not unlike other invasive species issues, the plant's taxonomy clouds management issues as that relates to prevention and control of the plant's continued spread throughout North Ameria. For example, Robinson (1965) stated that two species of *Tamarix* have escaped cultivation in western North America, namely *T. pentandra* Pallas and *T. gallica* L., yet Horton and Campbell (1974) studied tamarisk collections from the southwestern United States and grew plants under controlled conditions, then proposed assigning all deciduous life-forms to a single species, *T. chinensis*. Yet another study (Welsh et al. 1987) classified deciduous tamarisk species in Utah as either *T. ramosissima* which has flower parts in 5's (5-merous) or *T. parviflora* which has flower parts in 4's (4-merous). According to Weber (1990), *T. ramosissima* Ledebour and *T. chinensis* Loureiro were taxonomic synonyms, and Sudbrock (1993) stated that *T. ramosissima* and *T. chinensis* were difficult to distinguish, appeared to hybridize, and may be lumped together as *T. chinensis*. Other researchers lump all deciduous tamarisk species into *T. pentandra*. In practice, little distinction is made among the deciduous tamarisk species for management purposes, and Carpenter (2004) followed an increasingly common practice of referring to all 5-merous deciduous tamarisk species that have become naturalized in western North America as *T. ramosissima*, and the 4-merous deciduous species as *T. parviflora*. The 5-merous deciduous tamarisk appears to be more widespread in North America than the 4-merous species.

Deciduous tamarisk species in the western United States – *T. ramosissima* or *T. parviflora* – can be distinguished using the characteristics in Table 4. Both species are deciduous, loosely branched shrubs or small trees. The branchlets are slender with minute, appressed scaly leaves. The leaves are rhombic to ovate, sharply pointed to gradually tapering, and 0.5 –3.0 mm long. The margins of the leaves are thin, dry and membranaceous. White to pink flowers are most abundant between

[26]Original material prepared by Alan T. Carpenter, Land Stewardship Consulting, Boulder CO, and maintained by The Nature Conservancy Wildland Weed Management and Research Program, University of California, Davis, CA (Ramona A. Robison and John M. Randall, The Nature Conservancy, Wildland Weeds Management and Research, 124 Robbins Hall, University of California, Davis, CA 95616). Updated January 2004.

April and August, but may be found any time of the year, and are borne on slender racemes 2-5 cm long on the current year's branches. Flowers are grouped together in terminal panicles borne on short pedicels. Petals are usually retained on the fruit, and seeds are borne in a lance-ovoid capsule 3-4 mm long. Seeds contain no endosperm, are about 0.45 mm long and 0.17 mm wide, and have unicellular hairs about 2 mm long at the apical end (Wilgus and Hamilton 1962; Stevens 1990).

Table 4. Distinguishing characteristics of *T. ramosissima* and *T. parviflora* based on Welsh et al. (1987).

Characteristic	***Tamarix ramosissima***	***Tamarix parviflora***
Size	< 5 m tall	< 6 m tall
Bark	reddish brown	dark brown to deep purple
Bracts	scarcely translucent	more or less translucent
Flowers	parts in 5s	parts in 4s
Sepals	outer two narrower than inner all more or less acute	outer two keeled and acute outer flat or slightly keeled and obtuse
Stamen filaments	inserted under the disc near the margin	arising gradually from disc lobes between the lobes
Petals	obovate, 1-1.8 mm long	oblong to ovate, 1.9-2.3 mm long

Life history and biology. Throughout the western US, various species of *Tamarix* are increasingly a management problem, especially in riparian areas where the plant has a long history of successful invasions and a correspondingly long history of adverse impacts to the system. Tamarisk is an aggressive, woody invasive plant species that has become established over as much as a million acres of floodplains, riparian areas, wetlands and lake margins in the western United States (Johnson 1986). Once established, the plant is a relatively long-lived and can tolerate a wide range of environmental conditions. Massive quantities of small seeds are produced annually by each plant, and asexual propagation occurs from buried or submerged stems.

Tamarisk displaces and eventually replaces native woody species such as cottonwood, willow and mesquite, which occupy habitats similar to those preferred by tamarisk. When riparian habitats are altered, for example, by augmented stream flows (e.g., when timing and amount of peak water discharge, salinity, temperature, and substrate texture have been altered by human activities),

tamarisk may be favored in competitive interactions with native species of riparian wood shrubs and trees. Stands of tamarisk generally have lower wildlife values compared to stands of native vegetation, although tamarisk can be important to some bird species as nesting habitat.

Tamarisk is a facultative phreatophyte, drawing on groundwater sources as available, but once established, access to groundwater is not required for its survival. Tamarisk translocates large quantities of water, possibly more than woody native plant species that occupy similar habitats. The species is a halophyte and can tolerant highly saline habitats, in part, by concentrating salts in its leaves (hence, the species common name). Over time, as leaf litter accumulates under tamarisk plants, the surface soil can become highly saline, thus impeding future colonization by many native plant species.

Although it grows mostly on fine-textured soils (Everitt 1980), tamarisk can grow in many different substrates from below sea level to about 2100 m elevation (Hoddenbach 1990). As a facultative phreatophyte, tamarisk occurs in areas where its roots can reach the water table, such as floodplains, along irrigation ditches and on lake shores. Plants usually grow where the depth to ground water does not exceed 3 to 5 m, and tamarisk forms dense thickets where the ground water lies from 1.5 to 6 m below the soil surface (Horton et al. 1960). Where ground water is deeper than 6 m, plants form an open shrubland (Horton and Campbell 1974).

Tamarisks have a wide tolerance of saline or alkaline soils (Robinson 1965), and Carmen and Brotherson (1980) found that tamarisk sites in Utah had higher soil salinity and pH than sites without tamarisk. Brotherson and Winkel (1986) identified the major factors that contribute to tamarisk success as alkaline soils, available soil moisture, and sufficient disturbance of native vegetation to facilitate tamarisk invasion. Ideal conditions for first-year survival for tamarisk seedlings are on gently sloping riverbanks, or sandbars and siltbars where water levels slowly recede during the period of seed fall (Everitt 1980).

Tamarisk is a highly fecund, relatively long-lived phreatophyte which is very tolerant of inundation, desiccation and nutrient stress (Stevens 1990). Tamarisk produces massive quantities of minute seeds that are readily dispersed by wind, and seeds are viable for up to 45 days under ideal conditions during summer. Once in contact with water, germination is completed within 24 hours following contract with water. Tamarisk seeds have no dormancy or after-ripening requirements.

Tamarisk flowers in two flushes, one in April-May and another in late July (in northern Arizona), presumably reflecting availability of spring high-water (e.g., linked to snowmelt) and summer moisture as rain. Tamarisk flowers continuously under favorable environmental conditions but the flowers required insect pollination to set seed. Tamarisk seed lived for only a few weeks during the summer; and the few seeds that might survive over winter under cooler conditions did not appear to form a persistent seed bank (Stevens 1990).

Tamarisk will produce roots from buried or submerged stems or stem fragments (Merkel and Hopkins 1957). Such a life history attribute allows tamarisk to produce new plants vegetatively following floods from stems torn from the parent plants and buried by sediment. Ideal conditions for first-year survival are saturated soil during the first few weeks of life, a high water table, and open sunny ground with little competition from other plants.

Hem (1967) studied the salts present in leaves and stems of *T. pentandra* at locations in Arizona and New Mexico. He found that the total concentration of calcium, magnesium, chloride, and sulfate in the leaves generally ranged from 5 to 15% of their dry weight. About 10% of the total ionic concentration consisted of inorganic ions that could be readily washed off the leaves by rainfall.

Native distribution. The family Tamaricaceae is native to Africa, Asia, and Europe (Robinson 1965), and the native range of the 5-merous tamarisk (*T. ramosissima*) is from the southern Europe to Asia minor and eastward to Mongolia, Tibet, central China and North Korea (Crins 1989). *T. parviflora*, the 4-merous tamarisk, has a native range lying in southern Europe, perhaps extending as far south as northern Algeria (Crins 1989). *T. aphylla* is a severe pest of riparian areas in arid central Australia where it impacts systems similarly to *T. ramosissima* and *T. parviflora* have in the southwestern U.S (Griffin et al. 1989); *T. aphylla* is not considered invasive in North America.

Non-indigenous distribution. Tamarisk has spread to all of the western and Great Plains states, with the greatest concentrations in Texas, Arizona and New Mexico (Robinson 1965; Figure 30). It is also abundant in California, Nevada, Utah and western Colorado. Wyoming and Montana have recently been invaded along with tributaries of the Missouri. North Dakota recorded its first observation of tamarisk in 2002 (Figure 31). It is not clear whether or not the 5-merous species (*T. ramosissima*) dominates in some areas and the 4-merous species (*T. parviflora*) in others. Both the 5-merous species and the 4-merous species also escape from cultivation occasionally in

the eastern U.S., particularly on sandy beaches and roadsides, but are not invasive there (Gleason and Cronquist 1991, Radford et al. 1968, Wunderlin 1998). Weber (1990) reported that the Spanish explorer Father Escalante mentioned tamarisk in his journals from his travels throughout the American Southwest in 1776. If this is correct, it means that the Spanish introduced this species at least 200 years ago, although Robinson (1965) provided evidence that contradicts this claim. Robinson (1965) stated that tamarisk was offered for sale to the public in California beginning in the 1850s. Apparently, tamarisk did not start to become invasive in the U.S. until about 1877 when collections of tamarisk started to appear in herbaria (Robinson 1965). The plant did not attract much attention in the United States until the 1920s, and its impact on ground water was not appreciated until years later (Robinson 1965).

Impacts and control. Since the mid- to late 1800's, tamarisk has become naturalized along river bottoms and lake margins in the western United States, particularly in Arizona, New Mexico, California, Texas, Colorado, Utah, Nevada, Oklahoma and Wyoming. The species was first reported in North Dakota in 2002. There are multiple, interacting factors involved in the invasion of tamarisk (Everitt 1980), including intentional tamarisk plantings designed to protect streambanks and control erosion; conversion of native riparian forests to agricultural uses; damming of rivers fed by snowmelt which has shifted the time of peak discharge below the dams from spring to summer; creation of large areas of fine sediment that provide the ideal substrate for tamarisk colonization along the margins of reservoirs; increased salinity of rivers due to irrigation return flows and evaporation from reservoirs; reduced flood frequency downstream of reservoirs; and more stabilized base flows in rivers due to reservoir construction. Everitt (1980) noted that tamarisk has not become established in all western rivers, particularly those that still experience large floods and those where spring, rather than summer flooding still predominates. The spread of tamarisk has been and continues to be greatly facilitated by human activities.

Tamarisk possesses a number of highly desirable attributes for a successful invasive species, including an ability to 1) crowd out native stands of riparian and wetland vegetation; 2) increase the salinity of surface soil rendering the soil inhospitable to native plant species; 3) dries up springs, wetlands, riparian areas and small streams by lowering surface water tables; 4) widens

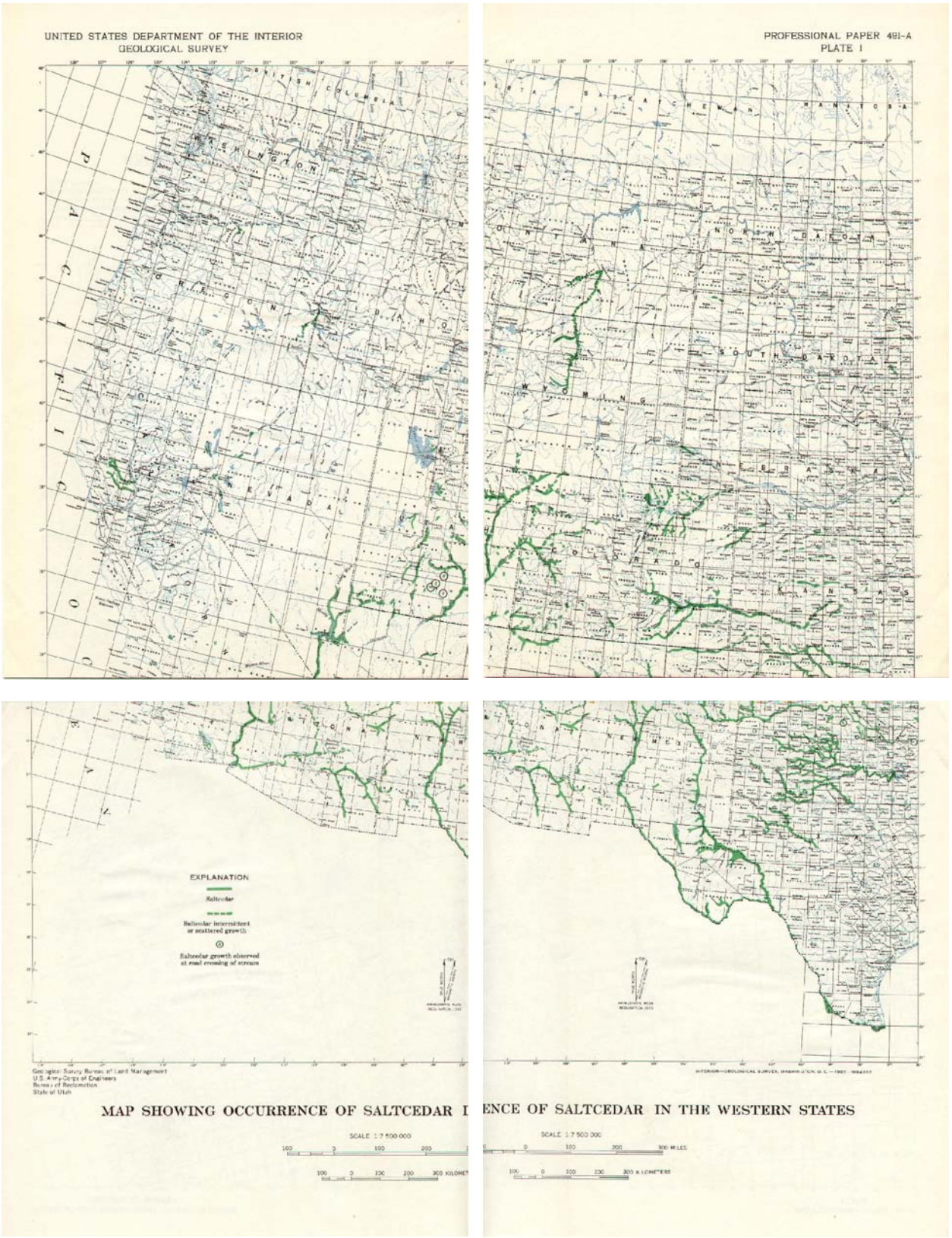


Figure 30. Sectional distribution map of *Tamarix* spp. as summarized in Robinson (1965).

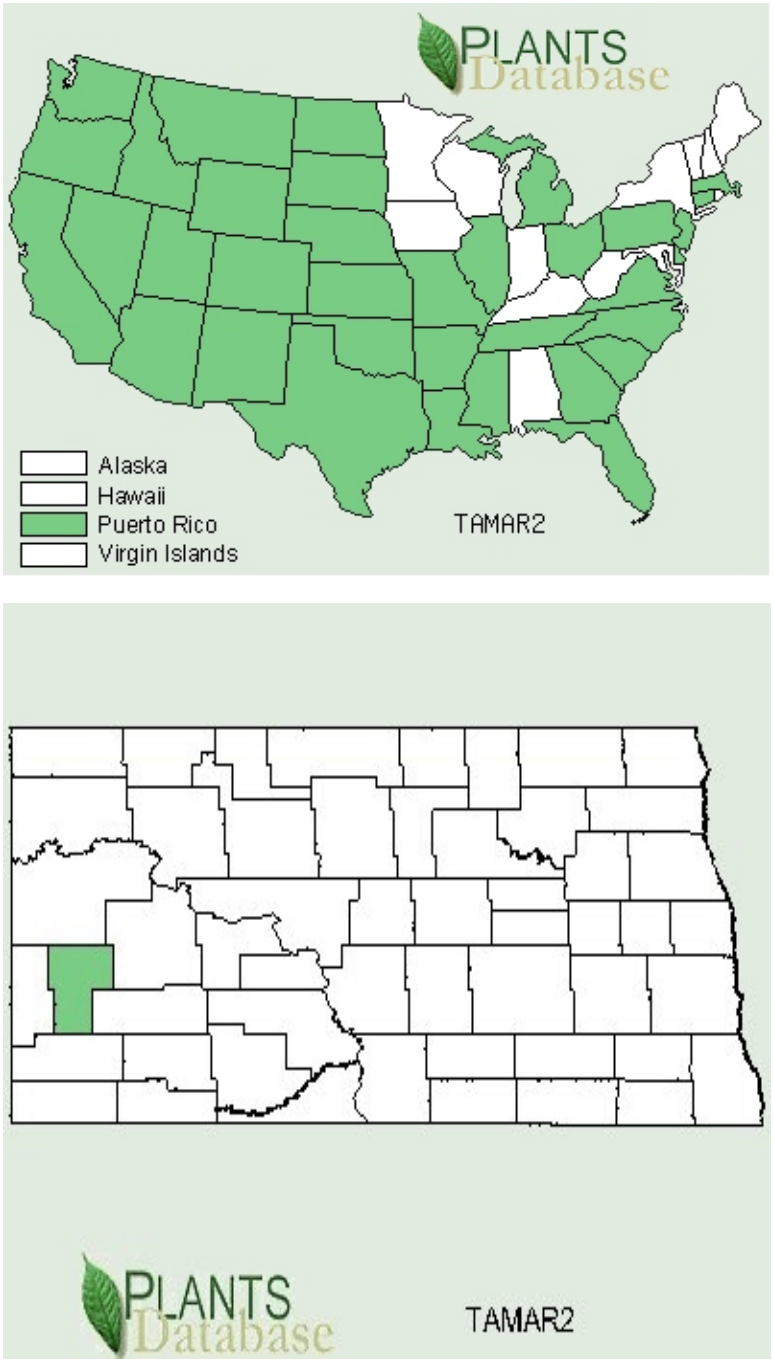


Figure 31. *Tamarix* spp. by state records (top) and county records (bottom). There are no confirmed observations of the plants in Canada.

floodplains by clogging stream channels; 5) increases sediment deposition due to the abundance of tamarisk stems in dense stands; and 6) uses more water than comparable native plant communities.

Crowding out native vegetation. A number of field observations clearly suggests that tamarisk can crowd out native riparian and wetland vegetation, yet human-induced changes in hydrologic regimes of rivers is likely not the only factor involved in the widespread invasion of tamarisk in the western US(Everitt 1980). Along some river courses in the southwest US, tamarisk is the dominant component in the vegetation community, e.g., along the lower Colorado River in Arizona and California, the elimination of flooding due to the construction of dams, the salinization of the soil and recurrent wildfires have virtually eliminated the cottonwood-willow riparian forests (R. D. Ohmart, personal communication). Tamarisk appears much less invasive along rivers where natural hydrologic processes are relatively intact. In many instances, tamarisk probably replaces rather than displaces native riparian vegetation, once native vegetation has been adversely effected by human activities. An outcome of a success invasion and the accompanying change in community structure is, wildlife habitat quality is generally diminished with increasing occurrence of tamarisk in the vegetation community.

Increasing salinity of surface soil. Tamarisk is a halophyte and actually mediates increases soil salinity. The plant's leaves and stems contain concentrations of soluble salts in the range of 5-15% (Hem 1967) which are absorbed by the roots from deeper soil layers, transported though the plant and concentrated in the leaves. With leaf fall, these salts are later deposited on the soil and become part of the soil litter.

Increased water consumption. Tamarisk stands in riparian ares translocate large amounts of ground water, an observation well documented nearly 40 years ago in a series of papers published by USGS (see Robinson 1965). Robinson (1965) cited studies which indicate tamarisk consumes on the order of 4 acre-feet of ground water annually. Sala et al. (1996) found that individual *Tamarix ramosissima* plants used about the same amount of water per unit of leaf area as did the native riparian species *Pluchea sericea*, *Prosopis pubescens* and *Salix exigua*, and their study confirmed previous work (Davenport et al.1982) that indicated evapotranspiration from riparian communities with high ground water availability is more dependent on stem density than on plant species composition. Sala et al. (1996) noted that tamarisk stands may have significantly more leaf area per unit of ground area than stands of native riparian vegetation. If so, the tamarisk stands would use more water per unit of ground area than the native stands and, replacing the tamarisk

stands with native species would save water.

Weeks et al. (1987) presented data that suggested that conversion of stands of native riparian forest to a tamarisk stand may result in increased consumptive use of ground water. Few studies have demonstrated increases in ground water levels or stream flows in the southwestern US following tamarisk removal, except on a very local scale in small streams or springs. Many land managers, however, cite cases of springs that dried up following invasion by tamarisk, then tamarisk removal, springs flowed again (Barrows 1993). Brotherson et al. (1982) found that the proportion of xerophytic plant species increased as the age of tamarisk stands increased, which suggests that the longer a community had been occupied by tamarisk, the drier it became.

Widening floodplains and increasing deposition of sediment. Robinson (1965) claimed that dense stands of tamarisk could increase areas inundated by floods, because dense stands of tamarisk choked overflow and lateral channels, reducing the capacity of a stream channel and associated flood plain to transport flood waters. Dense stands of tamarisk also tended to increase sediment deposition due the increased channel roughness caused by tamarisk stems. Everitt (1980) noted that vegetation can promote local sediment deposition, but likely play little role in increasing larger-scale regional deposition of sediment.

Tamarisk is commonly controlled in riparian areas and wetlands and along lake shores because of its potential to displace native vegetation and its lower value as wildlife habitat. However, control over large areas is difficult in situations where hydrologic processes have been greatly altered, due to the high control cost and the likelihood that tamarisk will re-invade areas from which it is eliminated. Areas where tamarisk is to be managed should be selected carefully to maximize the likelihood of success.

Alternatives for control. Tamarisk has two traits that might be exploited for its control. First, tamarisk seedlings grow more slowly than many native riparian plant species. Second, mature tamarisk plants are highly susceptible to shading (Stevens 1990)

Management options for control of tamarisk reflect various considerations including the spatial extent of infestation (e.g., less than an acre to many acres), federal and state restrictions on chemical control agents, co-occuring native vegetation that should be maintained, the presence or absence of open water, adjacent land uses (e.g., potentially limiting chemical use or prescribed burns), and the availability and cost of labor.

Tamarisk can be controlled by three principal methods: chemical control, mechanical removal, and biologica control. Chemical control of tamarisk is the most frequently applied management tool, and often times chemical controls are used in conjunction with mechanical removals to gain long-term success in preventing spread and controlling existing stands of tamarisk.

Chemical controls and mechanical removal. Herbicide use may occur at various times during the plant's life, and depending on habitat, various management options are available. For example, chemcial controls may be implemented by: 1) applying herbicide to foliage of intact plants; 2) removing aboveground stems by burning or mechanical means followed by foliar application of herbicide; 3) cutting stems close to the ground followed by application of herbicide to the cut stems; 4) spraying basal bark with herbicide and 5) digging or pulling plants.

For larger areas (> 1 to 2 acres) that are essentially monotypic stands of tamarisk, the best methods would likely be foliar application of imazapyr (Arsenal®) herbicide to the intact plants or burning or cutting plants followed by foliar application of imazapyr or triclopyr (e.g. Garlon4® or PathfinderII®) to the resprouted stems. Foliar application of imazapyr or imazapyr in combination with glyphosate (e.g. Rodeo®) can be effective at killing large, established plants. Over 95% control has been achieved in field trials during the late summer or early fall. Herbicide application may be accomplished from the ground (hand-held or truck-mounted equipment) or from the air. Foliar application of herbicide works especially well in monotypic stands of tamarisk, although experienced persons using ground equipment can spray around native trees and shrubs such as cottonwood and willow. As an alternative to herbicides, prescribed fire or a bulldozer can be used to open up large stands of tamarisk. Once opened, the resprouts can be sprayed when they are 1 to 2 m tall using imazapyr, or imazapyr plus glyphosate, or triclopyr.

Tamarisk eradication in areas that contain significant numbers of interspersed, desirable shrubs and trees is difficult, and it may not be possible to rapidly kill tamarisk plants without also killing desirable shrubs and trees. Depending on the site, manual removal of plants may be necessary, then tamarisk stumps would be treated with herbicide. While labor costs are high with manual removal and subsequent herbicide treatments, desirable woody plants will be spared. Depending on the vegetation mix characterizing the habitat, an alternative approach to managing mixed-species eradication programs is to kill all woody plants at a site, then replant with desirable species.

For modest-sized areas (< 1 acre), the "cut-stump" method (i.e., cutting the stem and applying herbicide) is used in stands where woody native plants are present and where their continued existence is desired. Individual tamarisk plants are cut as close to the ground as possible with chainsaws, loppers or axes, and herbicide is applied immediately thereafter to the perimeters of the cut stems. Triclopyr (e.g. Garlon4® or PathfinderII®) and imazapyr (Arsenal®) can be very effective when used in this fashion, and treatments are most effective in the fall when plants are translocating materials to their roots. The efficacy of treatments is enhanced by cutting the stems within 5 cm of the soil surface, applying herbicide within one minute of cutting, applying herbicide all around the perimeter of the cut stems, and retreating any resprouts 4 to 12 months following initial treatment.

Long-term success at eradication, or at least control, of tamarisk depends on an effective initial treatment and periodic re-treatments, especially when 100% "kill" was not attained in a first round of treatment. To assure long-term management success, monitor and control programs must be designed and implemented to control tamarisk and reduce the likelihood that it will re-invade treated areas. If initial control efforts are effective, subsequent monitoring and surveillence programs are relatively inexpensive.

Control with burning. Tamarisk plants typically resprout vigorously after burning. However, burning followed by herbicide application to the resprouts can achieve excellent control in monotypic stands of tamarisk. Burning opens dense tamarisk stands and greatly reduces tamarisk biomass. Jorgensen (1996) recommended felling 20 to 25% of the largest tamarisk plants in stands several months prior to burning to create enough dry ground fuel to propagate a fire. Burning during the hottest part of the summer, when plants experience the greatest water stress, is likely to yield the best results. Chavez (1996), West (1996) and Egan (1996, 1997) used prescribed fire in Afton Canyon, California, to open dense stands of tamarisk for resprout treatment with herbicides. Duncan (1994) stated that repeated yearly burns can suppress tamarisk and kill some of the plants after 3 to 4 years.

Wildfire may be highly detrimental to native riparian forests, since it is a relatively novel disturbance in riparian forests of the southwestern US (Busch and Smith 1993). The dominant woody plant in many southwestern native riparian forests, Fremont cottonwood (*Populus fremontii* ssp. *fremontii*), does not re-sprout vigorously following fire, while tamarisk does. Busch (1995) concluded that the invasion of the alien tamarisk coupled with the novel disturbance of fire completely change southwestern riparian forests, based on his study of burned and unburned

riparian forests along the lower Colorado River in Arizona. His results suggested that the native cottonwood – willow forest would be completely converted to tamarisk stands over the next several decades, and burning does not appear to be a reasonable control method for tamarisk where it occurs as a component of native communities.

Control with chemicals using foliar application to intact plants. Field studies in New Mexico by Duncan (1994) suggested that aerial application of the herbicide imazapyr (Arsenal®) alone or in combination with glyphosate (e.g. Roundup®, Rodeo®) is effective and practical for controlling tamarisk over thousands of hectares, particularly in dense stands where little on no native vegetation is present. Cost of aerial application of herbicide ranged from $70 to $90 per acre. Field trials along the Pecos River in New Mexico showed that fixed-wing aircraft could apply herbicide quite precisely, consistently following the 15 meter buffer line along the river bank. Several field trials have produced control rates of > 90% after one or two years. Alternatively, herbicide can be sprayed directly on tamarisk plants using truck-mounted equipment if stands are not too dense. This approach is appropriate where significant numbers of native trees and shrubs are interspersed with tamarisk plants. Duncan (personal communication) cautioned that sprayed plants should not be bulldozed or burned for two growing seasons, because disturbing the treated plants can induce some to resprout. Duncan and McDaniel (1996) have developed the following general guidelines:

- Focus treatment on young or regrowing tamarisk plants, because smaller plants are easier to kill than larger plants.
- Target areas previously plowed, mowed, burned or cleared, or areas where tamarisk appears to be invading.
- Target areas with tamarisk densities < 400 plants per hectare.

While the optimal herbicide proportions have not yet been developed, a mixture of 0.5% (v/v) imazapyr and 0.5% glyphosate (v/v) plus 0.25% (v/v) nonionic surfactant give satisfactory results. Kunzmann and Bennett (1990) stated that preliminary research indicates that the broad-spectrum herbicide imazapyr is the most cost-effective control technique known for tamarisk. However, they noted that more research is required to determine long-term effects of imazapyr on non-target plants and on other organisms.

Prescribed burning followed by foliar application of herbicide. This method is appropriate for larger areas, e.g., hundreds of hectares. Bureau of Land Management (BLM) has effectively used

the method in the deserts of the southwestern US to control tamarisk and restore riparian vegetation (Egan 1996, 1997). Costs of removing the tamarisk and restoring native vegetation costs $1500 to $3000 per acre. As of 1997, tamarisk abundance had declined dramatically in the areas where it had been controlled (Egan 1997).

Cut-stump method. The cut-stump method is appropriate for modest-sized areas 2 hectares or smaller. Neill (1990, 1996) summarized the details of cut-stump herbicide treatments for tamarisk. Based on Neill's work, the triclopyr herbicides Garlon4® or PathfinderII® appear to be the best choices for killing tamarisk due to higher phytotoxicity, low toxicity to humans, lack of restriction, and cost comparable to the other herbicides when diluted as directed. These herbicides contain the same active ingredient, triclopyr. Garlon4® is diluted 1:3 (v/v) in the field with cheap vegetable oil while PathfinderII® is sold already mixed and diluted with vegetable oil. PathfinderII® also contains a dye, which makes it easier to distinguish stumps that have been treated from those that have not. Dyes such as colorfast® purple, colorfast® red and basoil® red can be added to Garlon4®.

Diluted, Garlon4® costs about $26 per gallon, while PathfinderII® costs about $30 per gallon. One gallon is sufficient to treat hundreds of cut stumps. Neill (1990, 1996) stated that 95% mortality can be expected with either of these herbicides, with lower mortality probably being the result of not cutting close enough to ground level and/or not treating the circumference of the stump completely. However, Howard (1983) found that cuts 15 to 30 cm above the ground surface were effective when using Garlon4® in the autumn. Neill (1990, 1996) noted that tamarisk plants are best located in the spring or summer when their pink flowers are visible, and that control during this period may be advisable even though the plants are less susceptible to the herbicide. Neither Garlon4® nor PathfinderII® is labeled for aquatic use; however, stumps located near but not in or over open water can be treated with these herbicides provided that none of the herbicide enters the water. Garlon3A®, an amine-based, water-soluble formulation of triclopyr, is registered for use "to control vegetation in and around standing water sites, such as marshes, wetlands, and the banks of ponds and lakes" (see Garlon 3A® label).

Control with chemicals using basal bark treatment with herbicide. Neill (1996) reviewed the basal bark method of tamarisk control. This method precludes the need to cut the tamarisk plants, resulting in major savings in labor and produces no tamarisk debris to haul away or burn. Disadvantages are the higher amount of herbicide required, up to five times that needed for stump-cut control, and lower mortality than with stump-cut. Neill (1996) noted that the basal bark

method has been very effective at killing resprouts from debris piles left by a major flood. Jorgensen (1996) stated that basal bark application of Garlon4® was very effective on tamarisk plants with a basal diameter of less than 4 inches.

Carpet roller method. H.S. Mayeux with the USDA-ARS in Temple, Texas developed a carpet roller attachment for the front of a tractor. The roller is sprayed with herbicide, which is then applied to the tamarisk via the carpet roller as the tractor drives through the tamarisk stand. This method is an alternative in dense stands where desirable trees and shrubs are present. This method might also be useful in situations where standing water is interspersed with the tamarisk plants.

While a tabular summary of chemical control measures oversimplifies herbicide use for tamarisk control (see Table 5), these summary practices (see, e.g., Jackson (1996) for detail) provide starting points for use of various chemicals and their application to tamarisk control in western US.

Early reviews (Sisneros 1991) of herbicide control of tamarisk noted that Garlon® formulations were among the safest herbicides for mammals and other organisms, however, Garlon 4® is highly toxic to fish. Triclopyr, the active ingredient in all the Garlon® formulations decomposes rapidly after application, in less than one day in water and between 2 to 8 weeks in soil. Triclopyr will not kill grasses but it will kill native trees and shrubs.

Table 5. Summary of herbicide information relevant to tamarisk control (Jackson 1996).

Herbicide Trade Name	Active Ingredient	Formu-lation	Signal Word	Aquatic Registration	Foliar Applic?	Aerial Applic?	Stump Cut?	Basal bark Application
Arsenal®	Imazapyr	IPA-salt	Caution	No	Yes	Yes	Yes	No
Garlon 3A®	Triclopyr	Amine	Danger	No (applied for)	Yes	No	Yes	Yes
Garlon 4®	Triclopyr	Ester	Caution	No	Yes	No	Yes	Yes
Pathfinder II®	Triclopyr	Ester	Caution	No	No	No	Yes	Yes
Rodeo®	Glyphosate	IPA-salt	Caution	Yes	Yes	Yes	Yes	No
Roundup®	Glyphosate	IPA-salt	Caution	No	Yes	Yes	Yes	No

Control with cutting. A single cutting of tamarisk is ineffective, because tamarisks resprout vigorously. Cutting combined with herbicide treatment can be very effective at controlling tamarisk, and can reduce consumption of ground water through reduction of transpiring leaves. Resprouting from roots that remain is common, so repeated measures (e.g., cutting and burning, cutting and herbicide application) may be required to kill the root system.

Root plowing has been used to control tamarisk. It is important that the root plow cut the tamarisk root crowns well below the soil surface, e.g., 0.3 to 1.0 m. Root plowing works best during hot, dry conditions that help dry the cut roots. Root fragments left in the ground will often resprout after root plowing which means repeated measures to achieve control (e.g., hand-grubbing resprouts or spraying them with imazapyr or triclopyr). Root plowing is appropriate for large, dense stands that have little or no native vegetation and where prescribed burning or aerial application of herbicide is not feasible.

Control with grazing, dredging and draining. Tamarisk is able to extract water from deeper in the soil profile than the native species of cottonwood and willow. Therefore, draining and dredging that lead to local declines in water table depth could promote tamarisk at the expense of desirable native plants, rather than discourage tamarisk.

Cattle (and probably goats) will eat tamarisk, but grazing alone is probably not a feasible control method. However, goats might be able to control dense stands of tamarisk where little native vegetation is present, particularly if the stands are cut or burned first, with goats eating the regrowth.

Control with mowing, disking and pulling. Mowing might be a useful way to reduce the volume of tamarisk prior to treatment with herbicide, especially in relatively level sites where prescribed burning is not feasible. Hand pulling can be an effective way to control tamarisk in situations where the plants are small, where access is difficult, or where herbicides cannot be used. For example, hand pulling has been used to control new tamarisk plants around isolated desert springs in national parks after the larger tamarisk plants have been killed.

Biological control. In 1986, the U.S. Department of Agriculture's Agricultural Research Service (USDA-ARS) laboratory in Temple, Texas initiated a biological control program for tamarisk (DeLoach 1996). The goals for the program were to find and obtain insects that would damage *Tamarix ramosissima* without damaging native vegetation or *Tamarix aphylla*, the less invasive, evergreen species that is used for windbreaks and shade in the southwestern U.S. To date, two species of insect have been tested and proposed for release by USDA. One is a mealybug (*Trabutina mannipara*) from Israel and the other is a leaf beetle (*Diorhabda elongata*) from China. The leaf beetle defoliated tamarisks in greenhouse tests and the mealybug fed on twigs. DeLoach and Gould (1998) predict that these two insects may provide about 85% control of tamarisk and will take 3 to 5 years to control tamarisk at small sites and 5 to10 years to control tamarisks in small to medium watersheds.

Impacts. Early studies clearly suggested that tamarisk invasions of riparian habitats would be associated with adverse ecological effects. For example, Anderson et al. (1977) found that tamarisk stands along the lower Colorado River had lower bird density, bird species richness and diversity than did the native cottonwood-willow vegetation. Engel-Wilson and Ohmart (1978) found lower bird density and diversity in tamarisk stands along the lower Rio Grande River compared to native cottonwood-willow riparian forest. Kasprzyk and Bryant (1989) studied birds and small mammals along the Virgin River upstream from its inflow to Lake Mead in Nevada, and found that bird density and diversity were lower in tamarisk communities than native riparian vegetation. Ellis (1995) studied bird use of tamarisk and cottonwood vegetation in central New Mexico along the Rio Grande River where many bird species used both habitats, but three species used only tamarisk while six species using only cottonwood. Assuming the prediction by Howe and Knopf (1991) that tamarisk may completely supplant cottonwood habitat along the middle Rio Grande River in New Mexico over the next century, the richness of riparian bird species in that area would decline.

Brown and Johnson (1990) argued that, while tamarisk habitat along the lower Colorado River was much less valuable for breeding birds than native riparian habitat, the reverse was true along the Colorado River in Grand Canyon National Park. Hunter et al. (1988) proposed that bird nests in tamarisk along the lower Colorado River experienced higher heat loads than nests in multi-layered cottonwood forests that afford more shade. Anderson (1994) studied the Apache cicada in a native riparian community and a tamarisk stand along the lower Colorado River, and found that although cicadas were abundant in both communities, the insects emerged later in the native, cottonwood and willow-dominated communities when migrating and nesting birds were present. This change in temporal availability of this key food resource may help explain the low abundance of breeding birds in tamarisk communities.

Brown and Trosset (1988) stated that tamarisk stands in Grand Canyon National Park developed after construction of the of Glen Canyon Dam; comparable vegetation was not present along the river prior to construction of the Dam, so the tamarisk vegetation represented a new habitat type for that locale. In fact, black chinned hummingbirds (*Archilocus alexandri*) nested only in tamarisk-dominated habitats along the Colorado in the Grand Canyon (Brown 1992). Thus, Brown and Trosset (1988) argued that regional tamarisk management strategies must developed with respect to bird species.

Hunter et al. (1988) studied bird use in riparian vegetation along the middle Pecos River in New Mexico. There, birds used tamarisk as much as or more than other vegetation types year round. They noted that prior to invasion by tamarisk, this portion of the Pecos River had few tall, mature stands of vegetation. Thus, birds may have expanded their local ranges as tamarisk expanded. The lack of tall vegetation along the Pecos River contrasts with the condition of other desert riparian systems prior to Euro-American settlement (Ohmart and Anderson 1982).

The Federally Endangered Southwestern Willow Flycatcher (*Empidonax trailii extimus*) is known to nest in tamarisk-dominated areas (USFWS 1993). This subspecies of the Willow Flycatcher is widely distributed in scattered remnant populations across much of the area where tamarisk is invasive. Although it also feeds and breeds in riparian woodlands dominated by native plants including willows (*Salix* spp.) arrowweed (*Pluchea* spp.) and *Baccharis* species there has been concern that it might be further threatened if a biocontrol agent controls tamarisk over wide areas of the southwest. Others point out that even a highly successful biocontrol agent would not eliminate tamarisk and, that where it is reduced, native plants favored by breeding and feeding birds are likely to establish (Lovich and de Gouvenain 1998). Most published studies of the value

of tamarisk to wildlife in North America have focused on birds and purported benefits to certain bird species may or may not extend to other animals (Lovich and de Gouvenain 1998).

Restoration potential. Smith and Devitt (1996) concluded that riparian restoration efforts that involve removing dense stands of tamarisk without restoring historical flow regimes will not be successful without extensive follow-up management. Native cottonwood and willow species may fail to re-establish without intensive planting in areas where floods have been eliminated or where receding flood flows do not occur when short-lived cottonwood and willow seeds are produced. Another potential problem is the ability of tamarisk to increase the salinity of surface soil due to deposition of highly saline leaf litter. In areas subject to frequent flooding, increased soil salinity should be a fairly transient phenomenon. High salinities may persist, however, in higher terraces along rivers whose banks are dominated by tamarisk because floodwaters rarely reach these areas. This may make it difficult or impossible for native plants to colonize these areas once tamarisk is controlled. Another problem may be downcutting of stream channels downstream of dams. In such situations, surface water tables may decline to the point that cottonwood and willows can no longer survive or colonize. Wildfire may be a problem because tamarisk-dominated communities experience higher fire frequencies than native cottonwood-willow communities, eventually eliminating the fire-sensitive cottonwood and perhaps even the willows (Busch 1995; Busch and Smith 1993). A final problem may be lack of a thorough network of mycorrhizal hyphae in soils that have been dominated by tamarisk for many years (St. John 1997). Mycorrhizae are important for many native species and their absence or low abundance may impede colonization of desirable plant species.

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Appendix 3B. Diseases of fishes and water-borne diseases: Representative diseases of potential concern related to biota transfers associated with water diversions

The list of biota of concern developed in collaboration with Reclamation and Technical Team included species of microorganisms that are considered in this appendix as representative disease or toxin-producting agents. As a subset of biota of concern (Table 1), these species complement those species previously considered in Appendix 3A.

Table 1. Diseases of fishes and waterborne disease agents as representative biota of concern[1]

Protozoa and Myxozoa	***Bacteria and viruses***
Myxobolus (*Myxosoma*) *cerebralis*	Enteric redmouth (ERM)
Polypodium hydriforme	Infectious hemtopoietic necrosis virus (IHNV)
*Cryptosporidium parvum**	*Escherichia coli* (various serotypes)*
*Giardia lamblia**	*Legionella* spp.*
	Salmonella spp. (including, but not limited to
Cyanobacteria	*S. typhi, S. typhmurium,* other *Salmonella*
*Anabaena flos-aquae**	serotypes and other water-borne infectious
*Microcystis aeruginosa**	diseases)*
*Aphanizomenon flos-aquae**	

The species considered in this appendix represent biota which are dependent on dispersal of host (primary or intermediate) to expand their current range (e.g., fish diseases such as *Myxosoma cerebralis* and *Polypodium hydriforme*) or agents of waterborne disease that currently have a presence in both Missouri River and Red River watershed (hence, shifts in metapopulations may

[1]Asterisk "*" indicates that these species occur in both source and receiving systems, but interbasin water transfers may infer risks beyond baseline levels, if shifts in metapopulations are realized consequent to water diversion.

be related to interbasin water transfers). Here, we briefly summarize life history information for each representative, particularly those attributes that influence their potential for being transferred between Missouri River and Red River watersheds consequent to potential interbasin water diversions.

While considering the role of epizootic disease or low occurrence infection, and the potential for cross-species transmission of disease agents is always a possibility, interactions between hosts and infectious agent may be subject to stochastic events that influence cross-species infectivity and agents "jumping" from one species to another (see, e.g., Krauss et al 2003). For the current effort, we consider disease events as "simple" outcomes associated with interbasin water transfers, given the biota may move collaterally from source waters to receiving systems. The brief life histories of biota of concern that follow are intended to provide background and context for the evaluation of risks considered in this work (Section 3 and Section 4), and as such are organized as two major breakout groups: those disease agents primarily associated with fishes and those disease agents primarily associated with terrestrial and wetland vertebrates, including humans. The inclusion of disease agents having well-defined roles in human health should not be interpreted as public health issues being primary drivers in this analysis. Rather, agents of human disease, often being zoonotic in character, serve as representative biological agents included in the range of disease processes potentially of interest when biota transfers are concerned, especially when transfers could potentially be associated with increased likelihoods for occurrence of emerging infectious disease.

Overview: Disease of fishes

Fishes are susceptible to a number of parasites and infectious diseases which potentially yield individuals with reduced health and lifetimes, if not premature death. If apparent within populations, reductions in individual health can be expressed as increased morbidity and mortality within a region. If widespread, the disease may be characterized as an epizootic. From a quantitative perspective, disease-related mortality is best documented for hatcheries and aquaculture facilities, although field observations of disease outbreaks are not uncommon for

some diseases related to causal agents frequently associated with human interventions (e.g., intentional or accidental poisonings, fish-kills related to environmental conditions such as temperature extremes, toxic chemical releases). Diseases of freshwater fishes commonly associated with ichthyofauna of the Upper Missouri River and the Red River are listed in Table 1. Selected disease agents included in this list were considered as biota of concern from interbasin water transfers between these river basins.

Table 1. Commonly encountered fish diseases of concern to resource managers during biota transfers that potentially result from interbasin water diversions of various magnitudes.

● Lamprey infestation	● Sessile, solitary, ectocommensal ciliate infestations
● Leech infestation	● Sessile, colonial, ectocommensal ciliate infestations
● Copepod infestation/infection	● Typical water mold infection
● Branchiuran infestation	● Atypical water mold infection
● Monogenean infestation	● Branchiomycosis
● Protozoan ectoparasites: general features	● Columnaris infection
● Ich infection	● Bacterial cold water disease
● Trichodinosis	● Bacterial gill disease
● *Chilodonella* infestation	● Lymphocystis
● Tetrahymenosis	● Epitheliocystis
● Freshwater velvet disease	● Miscellaneous skin and gill diseases
● Ichthyobodosis	● Incidental findings (e.g., stressor interactions manifested as disease states)
● Gill Cryptobia infestations	
● Gill amoebic infestations	

External parasites of fishes. External parasites of fishes that could be transfered between watersheds interconnected by natural (e.g., flooding) or anthropogenic "bridges" are numerous, but following the lead of Noga (1996), the simple listing in Table 1 illustrates potential disease-

causing organisms as species spearheading biological invasion (e.g., an emerging disease previously not recorded to the receiving system) or shifts in metapopulations between watershed (e.g., an increase occurrence of a disease previously characterized for the receiving system). A facet of biota transfers that is incompletely understood is that associated with the loss of parasites and disease agents upon invasion – the so-called "Enemy Release Hypothesis" (see, e.g., Colautti et al 2004, Poulin and Mouillot 2003,Wolfe 2002) which may be similar to the loss of parasites observed when anadromous fishes move from freshwater to marine habitats. Subsequent to movements from one basin to another, other parasites are likely going to be acquired from the "new" environment, and the variety of parasites may increase among the invasive species emigrating to receiving waters.

Bacterial, viral, and fungal diseases of fishes. Fishes are susceptible to numerous bacterial, viral, and fungal diseases, and some of the more common bacterial diseases to North American waters include furunculosis, bacterial kidney disease (BKD), coldwater disease (CWD), vibriosis, and enteric redmouth disease (ERM) (see, e.g., Noga 1996, Hoffman 1999, Wolf 1988). Whether considering disease agents and their impacts on wild stocks or stocks in hatcheries or controlled facilities, the manifestations of disease can be conveniently assigned to categories, e.g., acute infectious disease, chronic infectious disease, diseases characterized by skin lesions, and diseases characterized at post-mortem conditions. For the most part, but especially in wild stocks, frank disease is difficult to characterize unless altered states of morbidity or mortality are evident (e.g, acute episodes manifested at "fish kills" or skin lesions presented as signs of acute or chronic disease). For example, fishes encounter a range of fungi during their various life stages with *Saprolegnia* spp. being a common opportunistic infection in a wide range of aquatic vertebrates and invertebrates. Similarly, furunculosis caused by *Aeromonas salmonicida*) can be a problem in freshwater fishes, and the disease is widespread across numerous species (see, e.g., Cipriano and Bullock 2001). No natural waters with resident fish populations are considered free of disease, and furunculosis can be a source of significant mortality in wild populations, e.g., if water temperatures in a river become unusually high for extended periods. And, bacterial kidney disease (BKD) is a chronic infection of salmonids fishes, especially in culture environments (e.g., hatchery

and aquaculture), which spreads both vertically and horizontally. Once established, BKD may be difficult to control and virtually impossible to cure. BKD is present in Canada as well as the US (see, e.g., Bullock and Herman 1988). Prevention, and in the absence of prevention, control of any disease process – bacterial, fungal, viral – under field conditions is challenging, and under cultured conditions, while more manageable, still requires time and resources that ultimately reflect investments that may not be fully appreciated in long-term gains anticipated by resource managers.

For the current investigation, biota of concern included Enteric redmouth (ERM) and Infectious hemtopoietic necrosis virus (IHNV).

[2]**Enteric Redmouth Disease.** Enteric redmouth disease (ERM) is a systemic bacterial disease caused by *Yersinia ruckeri* (Family Enterbacteriacae). Salmonids such as rainbow trout, *Oncorhynchus mykiss*, are particularly responsive to infection, and ERM occurs in salmonids throughout Canada and US waters in both wild populations and in culture environments. ERM generally expresses itself by sustained low-level mortality, eventually resulting in high losses. Epizootics can occur if chronically infected fish are stressed during hauling (e.g., transport of hatchery-reared fish), or exposed to other poor environmental conditions (e.g., altered water quality for wild populations) in the wild. In hatcheries, treatment for ERM is accomplished with medicated diets or by intraperitoneal injections for adult fish or through commercially-available vaccines and surface disinfection of eggs in culture facilities.

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[2]Original material derived from Fish Disease Leaflet 82: Enteric Redmouth Disease of Salmonids, G. L. Bullock and R. C. Cipriano, U.S. Fish and Wildlife Service, National Fisheries Research Center-Leetown, National Fish Health Research Laboratory, Box 700, Kearneysville, West Virginia. 25430 United States Department of the Interior, Fish and Wildlife Service. 1990 (Revision of Fish Disease Leaflet 57 (1979), same title, by G. L. Bullock and S. F. Snieszko and Fish Disease Leaflet 67 (1984) by G. L. Bullock.)

ERM was first reported in rainbow trout from Idaho in the 1950's, then described by Rucker in 1966 (Rucker, 1966). In epizootics fish typically present with clinical signs of lethargy, anorexia, and subcutaneous hemorrhages in and around the mouth, oral cavity, and isthmus (hence, the disease's common name), and at the base of fins. Gill filaments may be hemorrhagic, and petechial hemorrhages may occur on the surface of the liver, pancreas, pyloric caeca, and swim bladder, and in the lateral musculature. Splenomegaly is generally observed, with the organ being highly friable. Inflammation occurs throughout the gastrointestinal tract, with the lower intestine becoming charged with a thick, yellowish exudate. Exophthalmus occurs, commonly accompanied by hemorrhages around the ocular cavity and iris, with the eyes frequently becoming ruptured as the disease progresses. Histologically, tissues from infected trout display acute bacteremia and attendant inflammatory responses in virtually all tissues. Upon microscopic examination, bacteria are conspicuous in vascular tissues and in zones of petechial hemorrhage (Rucker 1966). Bacterial colonization occurs in the capillaries of highly vascularized tissue (e.g., gill and kidney) which is followed by dilation of small blood vessels; petechial hemorrhages; erythrocyte congestion; and edema of the kidneys, liver, spleen, heart, and gills. Focal necrosis may occur in the liver, and marked accumulations of mononuclear cells in periportal areas. Hemorrhages develop in outer portions of the digestive tract, and the lining or mucosa becomes edematous and necrotic, frequently sloughing off into the lumen (Busch 1983). Atypical infections sometimes occur, in which case hemorrhages do not develop on the mouth and gill cover, and fish merely become dark and swim near the surface (Frerichs et al. 1985). If fish survive, their skin darkens and their behavior becomes altered, e.g., the typical survivor shuns other fish and seeks shelter (Busch 1983; Rucker 1966). Busch and Lingg (1975) showed that 25% of the rainbow trout surviving an experimental ERM challenge became asymptomatic carriers in which the bacterium was localized in the lower intestine. Such trout serve as reservoirs of infection.

There are two serotypes of *Y. ruckeri*, the first isolated from salmonids in the Hagerman Valley, Idaho (Type I; Ross et al. 1966; Busch 1983). At present, most *Y. ruckeri* linked to ERM are Type I, although O'Leary (1977) has described another serotype of *Y. ruckeri* isolated from Pacific salmon (*Oncorhynchus* spp.; Type II). Additional research has characterized as many as

five distinct serotypes (Pyle et al. 1985, 1987; Stevenson and Airdrie 1984), but only Types I and II are causally linked to ERM epizootics. The original source of *Y. ruckeri* is uncertain, since the isolate from Idaho was contemporaneous with isolates in West Virginia and Australia in the 1950's (Bullock et al. 1977).

Natural infections spread from fish to fish by direct contact with infected fish or carriers. Rucker (1966) transmitted the disease by exposing healthy rainbow trout to waterborne bacteria shed by infected trout, but vertical transmission has yet to be documented and probably does not occur. Stressors have been shown to play a significant role in triggering ERM outbreaks (Hunter et al. 1980). Experimentally, incubation takes 5 to 10 days at13 to 15°C, although the time course for outbreaks in the wild are undoubtedly affected by temperature, pH, and dissolved oxygen among other chemical and physical stressors.

Since its early characterization, geographic ranges of host and disease have increased. Since its initial isolation in Idaho which was associated with transportation of carrier fish, ERM has spread to virtually all trout-producing regions of the United States and Canada. The host range has also expanded to include other salmonids (e.g., Atlantic salmon and Pacific salmon) and non-salmonids such as emerald shiners, *Notropis atherinoides* (Mitchum 1981); fathead minnows, *Pimephales promelas* (Michel et al. 1986); goldfish, *Carassius auratus* (McArdle and DooleyMartyn 1985); and farmed whitefish, *Coregonus* spp. (Rintamaki et al. 1986).

Given the nearly 50 years since its description, management tools have been developed to control, and when possible, prevent ERM. A practical and commercially available bacterin was developed in the early 1960's and 1970's (Klontz 1963; Ross and Klontz 1965; Anderson and Ross 1972; Anderson and Nelson (1974). Then, Croy and Amend (1978) demonstrated that fish could be immunized by immersion in a hyperosmotic solution of sodium chloride, followed by immersion in the bacterin. Commercial ERM bacterin was first licensed in 1976. Other management tools have also been developed, including antibacterials (e.g., oxytetracycline, erythromycin, quinolones (e.g., initial reports of Ceschia et al. 1987; Bullock et al. 1983).

Summary of occurrence of ERM in Missouri River and Red River watershed in the US and Canada. In Figure 1the dot map summarizes the current status of known occurrences of ERM (red dots are sample locations with known occurrence; green dots are sample locations known to be negative) in Missouri River (HUC 10) and Red River (HUC 09). ERM in Canada is widespread, but much of the data reflect disease occurrence in hatchery-reared salmonids and discussions regarding the risks potentially associated with infected hatchery stock entering wild

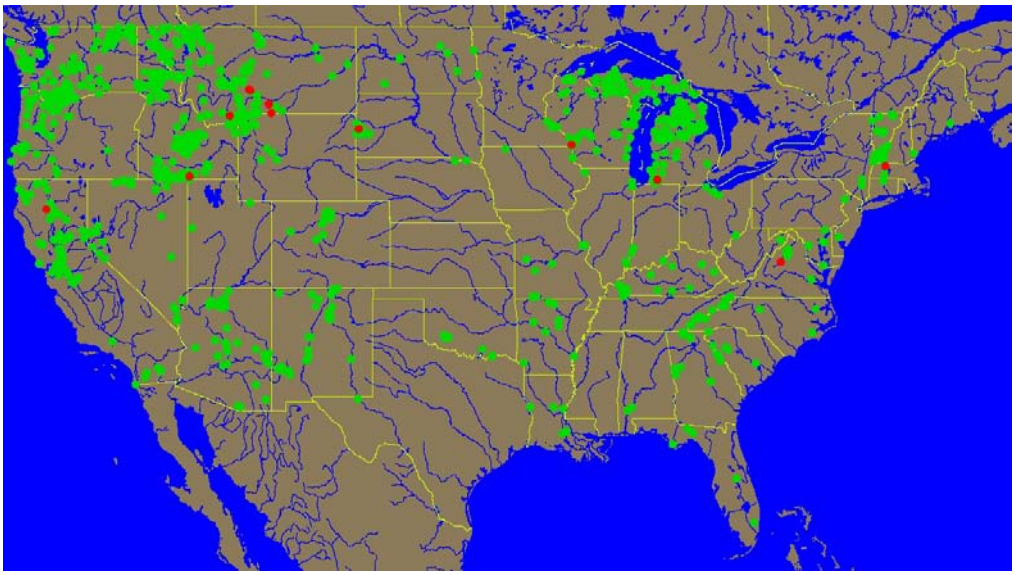


Figure 1. Dot map summarizing sampling locations (green dots) and known occurrences of ERM (red dots) in US surface waters (see US Fish and Wildlife Service, National Fish Health Survey, available online at http://wildfishsurvey.fws.gov/).

populations (see, e.g., http://www.intrafish.com/laws-and-regulations/report_bc/vol3-vi.htm; http://home.hisf.no/SVENJO/Undervis%20fra%20C/FISKESYK/fishhlth.htm#1).

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Viral diseases of fishes. Fishes exhibit a number of viral diseases manifested in the wild and under controlled conditions in hatcheries or other culture facilities (see, e.g., Wolf 1988, Hoole et al 2001 on cyprinds, Roberts and Shepherd 1997 on salmonids). For example, in hatchery culture salmonids frequently diagnosed viral diseases (see, e.g., Roberts and Shepherd 1997) include infectious pancreatic necrosis virus (IPN), salmon papilloma, and infectious hematopoietic necrosis virus (IHNV), the latter disease identified as one of the biota of concern in the current investigation. Each of these diseases may also be observed in wild stocks.

[3]**Infectious hematopoietic necrosis virus (IHNV)**. Infectious Hematopoietic Necrosis Virus (IHNV) is a bullet shape rhabdovirus that effects primarily in salmonid populations. IHNV is endemic to the Pacific Northwest where the virus was first isolated from a disease outbreak in 1953 at two fish hatcheries in the state of Washington. IHNV was reported through the remainder of 1950's and 1960's throughout the Pacific Northwest and caused unprecedented high mortality in salmon production (Wolf, 1988). IHNV received its name because the primary histological manifestation is the necrosis of hematopoietic tissue of the anterior kidney (Amend et al., 1969). However, this virus presents with an acute, systematic infection and causes viremia with hemorrhage and necrosis of many organs and tissues. Other names that have been given to this virus were: British Columbia Virus, the Oregon Sockeye Virus, and the Sacramento River Chinook Disease Virus. (Chiou, 1996).

Five serotypes of IHNV have been classified on the basis of the molecular weight differences of the viral components. The distribution of the virus first characterized from the Northwest has subsequently been observed throughout the United States and Canada and has been identified in

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[3]Original material prepared by Dr. Jo-Ann Leong from Oregon State Universiy, Dept. of Microbiology; Chiou, P.P. (1996), A Molecular Study of Viral Proteins in the Pathogenesis of IHNV, (PhD dissertation, Department of Microbiology, Oregon State University; Infectious Hematopoietic Necrosis Virus (IHNV): IHNV Factsheet (February 11, 2002); Linda Bootland, Assistant Professor at Oregon State University.

Minnesota, Montana, South Dakota, Alaska, West Virginia and British Columbia. It has also been observed in Europe and Asia with outbreaks reported in France, Italy, Belgium, Japan, Taiwan, and Korea. The spread of IHNV is believed to have originally been from the practice of feeding fry with meal composed of ground adult fish and viscera, but more recently it has been a consequence of shipping IHNV contaminated eggs and fry from the Pacific Northwest of the United States and from Canada (Wolf, 1988).

IHNV infections may cause severe mortalities in young fish, generally as fry or fingerlings. Survival and percent mortality from IHNV are directly correlated to the age and size of the fish. The younger the fish, the more susceptible they are to this disease. Young fish infected with the virus present with external signs of infection within a week of exposure. Moralities usually begin four or five days after exposure with peak counts about ten days after exposure. Generally, after 40 or 50 days there are usually no more moralities (Chiou, 1996).

The most accepted route of infection is through the gills, skin or GI track. When fish first contract IHNV, they may die without any clinical signs but usually they are moribund and lethargic with periods of sporadic whirling or hyperactivity (Wolf, 1988). Fry may also be dark in color, have a distended abdomen, pale gills, expothalmia, hemorrhaging of musculature and vase of fins, and cast-like excretion trails. Internally fish appear anemic, there is petechial hemorrhaging of mesenteries or visceral tissues and musculature, and the stomach or intestine is filled with milky or watery fluids (Reno, 1998). Additionally, there is extensive necrosis of the hematopoietic tissues of the anterior kidney and spleen. Necrosis is usually observed throughout most internal organs of infected fish.

The host range of IHNV is relatively broad and is known to naturally infect various salmonids, including rainbow trout (*Oncorhynchus mykiss*), chinook salmon (*O. tshawytscha*), sockeye salmon (*O. nerka*), pink salmon (*O. gorbuscha*), chum salmon (*O. keta*), coho salmon (*O. kisutch*), amago salmon (*O. rhodurus*), yamame salmon (*O. masou*), Atlantic salmon (*Salmo salar*), and cutthroat trout (*S. trutta*). Bull trout (*Salvelinus confluentus*), mountain whitefish

(*Prosopium williamsoni*) and the marine fish seabream (*Archosargus rhomboidalis*) and turbot (*Scopthalmus maximus*) have been experimentally infected with IHNV. Other hosts may include mayflies, copepods and leeches.

IHNV transmission. The epizootiology of IHNV is not completely understood and the source of the virus infecting salmonids is still unknown (Bootland and Leong, 1999). Transmission of fish diseases may occur through vertical or horizontal vectors. Horizontal transmission, from infected to uninfected fish, may occur through feces, urine, and ovarian or seminal fluid. Additionally, IHNV has demonstrated that it may survive for several months in water and infect fish (Mulcahy et al., 1983). IHNV is then either absorbed through the skin and gills or it is consumed orally. Therefore, infected water may also be a potential source of viral infections, but it is not likely that IHNV could survive a winter in the environment.

There are many factors that may influence transmission and virulence. Susceptibility to the virus decreases with an increase in fish age and weight (LaPatra et al., 1994). Other factors that influence virulence or transmission are geographic location, genetics, fish health or stress, fish density and temperature (Bootland and Leong, 1998). One of the most important factors that influence epizootics is temperature. IHNV outbreaks usually occur in water temperatures from 10^{o} C to 12^{o} C, but IHNV has been known to kill trout fry from 3 to 18 C^{o} (Bootland and Leong, 1998).

IHNV epizootics usually occur in very young salmonid fingerlings and fry, but may also infect older fish. It usually causes an acute disease in young fish with mortalities of fry and fingerlings as high as 90% (Bootland and Leong, 1998). Interestingly, the virus may only be isolated up to approximately fifty days after viral exposure and thereafter is usually not isolated again until the fish nears sexual maturity (Bootland and Leong, 1998). The survivors of epizootics are presumed to be carriers, apparently for life. However, the virus is difficult to isolate during this stage.

Horizontal transmission is a major component of viral spreading during an epizootic, both in

nature and in husbandry (Wolf, 1988). Horizontal transmission is most likely to occur from contact between adults during spawning, from fry to fry, or from eating fish excrement floating in the water. Vertical transmission, from an adult to its progeny, occurs through ovarian or seminal fluid. However, vertical transmission has not been well documented. Other sources of infection other than fish may exist and transmission may be occurring from an unknown reservoir or host. For example, several invertebrates have been shown to carry this virus. IHNV has been isolated from copepods, mayflies and salmon leaches (Mulcahy, 1990).

The most frequent evidence for vertical transmission is the association between the shipment of infected eggs into new geographic areas and resultant outbreaks of IHNV (Bootland and Leong, 1998). However, there are conflicting views as to how vertical transmission occurs. The controversy lies in whether the virus is on the egg surface or within the egg. Observations that disinfecting does not always prevent IHNV infection of progeny suggest that the virus is within the egg (Amend, 1975). However, examination of egg shells for IHNV has yet been done (Bootland and Leong, 1998).

There are two possible mechanisms for the observance of IHNV in spawning adults. The first possibility is that the virus may be entering a latent state in fish that survive an IHNV epizootic. Then the virus is reactivated when the fish becomes sexually mature. The second possibility is that fish surviving an epizootic are then completely clear of the virus but become reinfected prior or during their spawning migration. Currently, there is still much to be learned about the state of the virus in fry and smolts that survive IHNV epizootics. Some studies have shown that IHNV could be isolated from adult sockeye salmon during the ocean phase of their life cycle (Traxler et al., 1997). Other studies have also shown that IHNV survivors are latently infected with IHNV, but it has not been possible to show a reactiviation of the latent state or identify conditions that trigger reactivation (Bootland and Leong, 1998). Thus, there is a possibility that a combination of the two hypotheses accounts for the infection of sexually mature fish (Bootland and Leong, 1998). There is also the possibilty of alternate reseviors, both marine and fresh water.

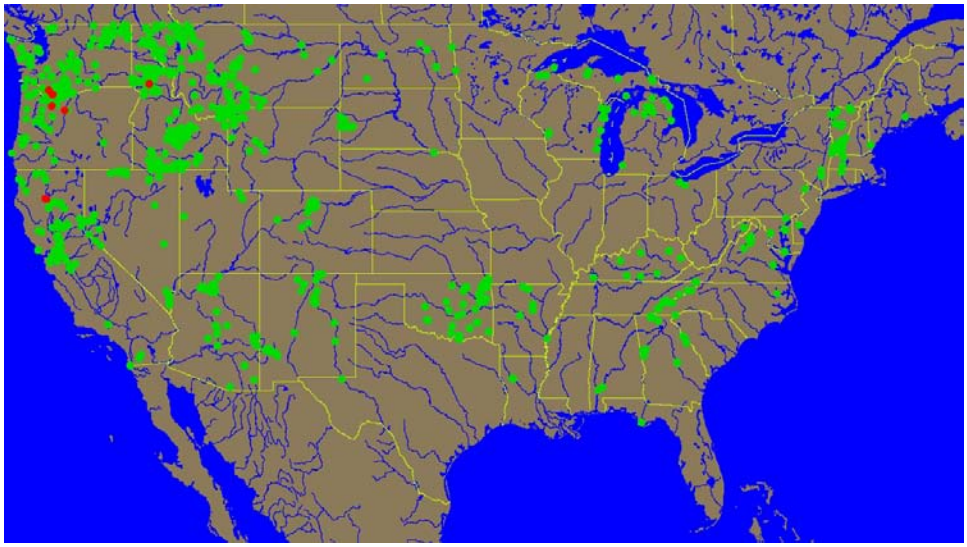
Sources of IHNV other than salmonid fish have not been identified, but potential sources include freshwater and marine invertebrates, sediment and other fish species (Bootland and Leong, 1998). IHNV has been isolated from several different types of invertebrates; such as parasitic copepods, mayflies and leeches. The virus has also been isolated from sturgeon and suckers. The transmission of the virus from these potential reseviors could occur through the salmonids actually eating the infected organisms or the virus could be transmitted through the water. Transmission from invertebrates to salmonid fish has not been demonstrated, but the role of alternate resevoirs can not be ruled out (Bootland and Leong, 1998).

Prevention and control. While IHNV primarily is a disease of salmonid fishes, commonly steelhead trout (*O. mykiss*), sockeye salmon (*O. nerka*), chinook (*O. tshawytscha*), chum (*O.keta*), coho (*O. kisutch*), and Atlantic salmon (*Salmo salar*), the disease has also been observed in pike fry (*Esox lucius*) and other species under experimental conditions. Historically, the geographic range of IHNV was limited to the Pacific Rim of North America but, more recently, the disease has spread to continental Europe and Asia. Disease control in the field is singly focused on prevention from stocked fish, but in hatchery settings, control methods currently rely on disinfection of fertilized eggs. Eggs, alevins and fry should be reared on virus-free water supplies in premises completely separated from possible IHNV-positive carriers. Broodstock from sources with a history of IHNV outbreaks should also be avoided wherever possible. At present, vaccination is only at an experimental stage. As with viral haemorrhagic septicaemia virus (VHSV), good over-all fish health condition seems to decrease the susceptibility to overt IHNV. Handling and other types of stress frequently cause sub-clinical infection to become overt.

In Canada, Fisheries and Oceans Canada maintains a complete listing of the occurrence of this virus in wild stocks in British Columbia. IHNV has been recently identified as the cause of significant mortalities in farmed and enhanced salmon in the Pacific Northwest. Outbreaks of the disease in wild salmon have been reported primarily in juvenile sockeye and occasionally chum salmon in freshwater. IHNV has also affected immature kokanee (freshwater sockeye) adults.

Outbreaks of this disease in Atlantic salmon farms in British Columbia occurred in 1992, 1995, 1996,1997 and 2001. All reported cases occurred within the Campbell River area. IHNV is present in wild fish stocks, in particular, sockeye salmon. It is likely that the disease is transferred from wild fish to farmed salmon, but given the disease is present in wild salmon, additional risk of impact on wild stocks from IHNV farm outbreaks is considered relatively low, provided health status of released fish is documented.

Current status of IHNV in Missouri River and Red River watersheds in the US and Canada. Figure 2 summarizes the current status of IHNV throughout the US (red dots are sample locations with known occurrence; green dots are sample locations without known occurrence).



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Iridovirus.[4] At the October 28, 2003 stakeholder meeting in Fargo, North Dakota, concerns of biota transfers of iridovirus of fishes were expressed. Request was made of USGS/BRD/CERC to briefly review existing information on these disease agents as potential biota of concern for interbasin biota transfers. In part, these concerns stemmed from observations of transfers potentially linked to hatchery-reared sturgeon from the fish hatchery located near Garrison Dam in North Dakota.

Numerous sturgeon species have been integral components of significant fisheries within North America and have played an important historical role in recreational and commercial fisheries of various riverine and Great Lakes communities throughout the United States. Present commercial fisheries for sturgeon species are virtually non-existent, in part due to overexploitation coupled with an inherently long period of time for sturgeon species to become sexually mature.

Two species within the Missouri River basin – pallid sturgeon (*Scaphirhynchus albus*), which was considered as biota of concern in the current investigation, and shovelnose sturgeon (*Scaphirhynchus platorynhus*) – have been recently found to harbor a suspect virus (currently being referred to as the Missouri River Sturgeon Iridovirus, or MRSIV), very similar to but different from the White Sturgeon Iridovirus (WSIV; see Figure 3). Currently, MRSIV has been detected only in captive propagated sturgeon in US Fish and Wildlife Service facilities and in wild shovelnose sturgeon collected in the Missouri River below Ft Peck. Both shovelnose and pallid

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[4]See also:

Williamson, D.F., 2003, Caviar and Conservation, Status, Management, and Trade of North American Sturgeon and Paddlefish, TRAFFIC North America, World Wildlife Fund, Washington, D.C., 252pp.

LaPatra, S.E., J.M Groff, G.R. Jones, B. Munn, T.L. Patterson, R.A. Holt, A.K. Hauck, and R.P. Hedrick. 1994. Occurrence of white sturgeon iridovirus infections among cultured white sturgeon in the Pacific Northwest. Aquaculture 126:201-210.

http://fwp.state.mt.us/fwppaperapps/wildthings/2002annualreport.pdf

sturgeon have been diagnosed with the iridovirus agent. In USFWS Region 6, three Service facilities have cultured sturgeon in which the iridovirus was detected: Gavins Point National Fish Hatchery, Valley City National Fish Hatchery, and Garrison Dam National Fish Hatchery.

Current information regarding the significance of the iridovirus in Missouri River sturgeon species is lacking in the following areas: a) its host and geographic range in wild populations, b) its transmissibility to other species of sturgeon and the question of vertical transmission from parents to progeny, c) the utility of existing sturgeon cell fines and primary cell cultures, and d) applicable diagnostic and monitoring procedures for both latent and patent infections.

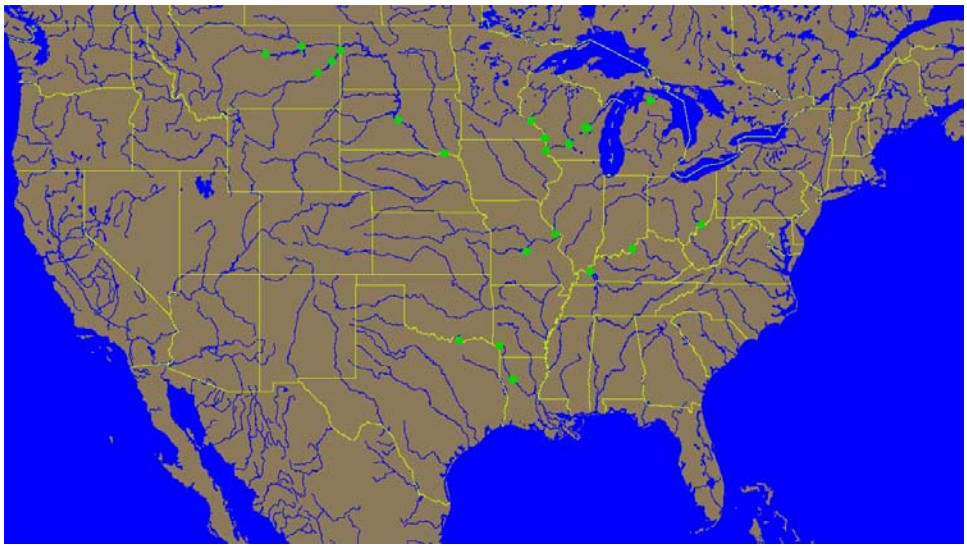


Figure 3. White sturgeon iridovirus sample locations (green dots, sampled but no record of occurrence for WSIV)

As noted in Appendix 3A and main body of this report, Pallid sturgeon are Federally listed as an endangered species, not legally catch-able and subject to a multi-agency recovery effort. The current recovery plan calls for supplemental propagation programs to provide absolutely essential recruitment in the Upper Missouri River basin where natural recruitment is non-existent and has been so for over 20 years. Without releasing hatchery propagated sturgeon into the wild, to pass on the gene pool from the aging pallid sturgeon population, the species will become extinct in the upper basin. Service facilities in Region 6 have implemented culture programs and management

activities to assist in the recovery effort. The intensive culture of the pallid and shovelnose sturgeon presents fish health concerns. As with most fish pathogens, the iridoviral agent can be associated with mortalities in cultured sturgeon but has not been identified as a mortality factor in the wild.

The significance of the iridoviral agent in shovelnose and pallid sturgeon is not entirely known, primarily as a function of our lack of knowledge regarding the epizootiology and life cycle of the viral agent. Management decisions relative to both species, must be based on good science with regard to pathogen detection and significance. Improved management decisions can be made if we have a good understanding of the naturally occurring presence of this virus in wild populations of both species. Lack of thorough information is currently resulting in management decisions that err on the side of caution regarding stocking of positive or suspect sturgeon. In the not too distant future, decisions will need to be based on the need to prevent extinction of the species as the wild population continues to age toward senility and death.

Fungal diseases of fishes[5]

Fungal diseases of fishes were not included as biota of concern, yet are briefly consider for completeness. While fungal disease agents potentially transferred as a consequent of interbasin water diversions are already present in both source and receiving basins, the potential for shifts in metapopulations does exists, although at a relatively low level. Fungi can become a problem, if fish are stressed by disease, by poor environmental conditions, receive poor nutrition, or are injured. If these factors weaken the fish or damage its tissue, fungus can infest the fish. Fungi can also prevent successful hatching when it invades fish eggs (see, e.g., Bruno and Wood 1999,

[5]Material as excerpt of: Technical Fact Sheet VM 97 (College of Veterinary Medicine, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida (February 1996); see http://edis.ifas.ufl.edu/BODY_VM033, last accessed December, 12, 2004.

McVicar 1999).

Fungi are grouped by the morphology of various life stages. All fungi produce spores which readily spread disease, since fungal spores are relatively resistant to heat, drying, disinfectants and the natural defense systems of fish. The three most common fungal diseases are Saprolegniasis (see Bruno and Wood 1999), Branchiomycosis, and Ichthyophonus disease (McVicar 1999).

Saprolegniasis. Saprolegniasis is a fungal disease of fish and fish eggs most commonly caused by the Saprolegnia species, the "water molds." The disease is common in fresh fishes, especially in species occupying warmer waters. *Saprolegnia* spp. can grow at temperatures ranging from 32˚ to 95˚F but seem to prefer temperatures of 59˚ to 86˚F. The disease will attack an existing injury on the fish and can spread to healthy tissue. Poor water quality (e.g., water with low circulation, low dissolved oxygen, or high ammonia) and high organic loads, including the presence of dead eggs, are often associated with *Saprolegnia* infections. The presence of *Columnaris* spp. bacteria or external parasites are also common with Saprolegniasis.

Disease Signs. Saprolegniasis is often observed as fluffy tufts of cotton-like material – colored white to shades of gray and brown – on skin, fins, gills, or eyes of fish or on fish eggs. These areas are scraped and mounted on a microscope slide for proper diagnosis. Under a microscope, Saprolegnia presents as hyphae.

Management and Control. Saprolegniasis is best prevented by good management practices – such as good water quality and circulation, avoidance of crowding to minimize injury (especially during spawning), and good nutrition. Once Saprolegnia is identified in an aquatic system, sanitation should be evaluated and corrected. Disease outbreaks are common under cultured conditions (e.g., hatcheries), and if mortality is observed under these conditions, medication is appropriate.

Branchiomycosis. Branchiomyces demigrans or "Gill Rot" is caused by the fungi *Branchiomyces*

sanguinis and *B. demigrans*. Branchiomycosis is a pervasive problem in Europe, but has been only occasionally reported by US fish farms. As with diseases in general, both species of fungi are found in fish suffering from an environmental stress, e.g., low pH (5.8 to 6.5), low dissolved oxygen, or a high algal bloom. *Branchiomyces* spp. grow at temperatures between 57˚ and 95˚F with optimal growth occurring between 77˚ and 90˚F. The main sources of infection are the fungal spores carried in the water and detritus on pond bottoms. Again, disease is infrequent observed in field settings, and is more commonly observed in culture facilities.

Disease Signs. *B. sanguinis* and *B. demigrans* infect the gill tissue of fish. Symptomatically fish may appear lethargic and may be seen gulping air at the water surface (or piping). Gills appear striated or marbled with the pale areas representing infected and dying tissue. High mortalities are often associated with this infection.

Management and Control. Avoidance is the best control for Branchiomycosis. Good management practices will create environmental conditions unacceptable for fungi growth. If the disease is present in hatchery stock, infected fish should not be transported, and care must be taken to prevent movement of the disease to uninfected areas. In hatcheries, formalin and copper sulfate have been used to control the disease, but all tanks, raceways, and aquaria must be disinfected and dried as prophylactic measures. Ponds should be dried and treated with quicklime (calcium oxide). Prevention in wild populations is the only practice management tool to avoid disease outbreaks.

Icthyophonus Disease. Icthyophonus disease is caused by the fungus, ***Icthyophonus hoferi*** . The fungus grows in fresh, and wild and cultured fish are equally likely to harbor the disease. The disease, however, tends to be restricted to cool temperatures (36˚ to 68˚F). Spread of the disease occurs via fungal cysts which are released in the feces and by cannibalism of infected fish.

Disease Signs. Because the primary route of transmission is through the ingestion of infective spores, fish with a mild to moderate infection will show no external signs of the disease. In severe

cases, the skin may have a "sandpaper texture" caused by infection under the skin and in muscle tissue. Some fish may show curvature of the spine. Internally, the organs may be swollen with white to gray-white sores.

Management and Control. There is no cure for fish with *I. hoferi*, and infected fish carry the disease for life. Prevention is the only control, and to avoid introduction of infective spores, never feed raw fish or raw fish products to cultured fish. In culture systems, complete disinfection of tanks, raceways, or aquaria must be completed, if eradication of disease agent is a management goal. For ponds with dirt or gravel bottoms, months of drying are required to totally eliminate the fungus.

Regardless of the water source, fish fungi disease agents are cosmopolitan in surface waters. Fungal diseases are often indicative of a more serious water quality problems. Saprolegniasis is the most common fungal disease, but can be eliminated easily after the primary cause of illness has been identified and corrected. On the other hand, Branchiomycosis, a relatively new problem in the US, has caused high mortalities in cultured fish, and is difficult to control. Ichthyophonus disease is a systemic fungal disease and once it enters the fish, there is no cure. The best control for all fungal infections is good management: good water quality, good nutrition and proper handling.

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CABI Publishing, A division of CAB International, Nosworthy Way, Wallingford, Oxfordshire, UK, pp. 661-688.

[6]Protozoan and myxozoan diseases of fishes

The taxonomy of the entire myxozoan group (Lom and Noble 1984) and the *Myxobolus*/*Myxosoma* group in particular (Landsberg and Lom 1991) is very dynamic and the object of much work. While a detailed review of the species current taxonomic status lies beyond the scope of the current investigation, a very brief summary provides the phylogenetic context beneficial to the analysis.

Myxozoa attained phyllum status from some workers, while others regard them as a highly specialized, reduced forms of parasites having complex life cycles as member of the Cnidaria (see, e.g., Roberts and Janovy 2005). Regardless of these higher level taxonomic disputes, the myxozoans are comprised of approximately 1200 species, with nearly 50 genera having been characterized. Regardless of the fundamental issues underlying the taxonomy of the group, the Myxozoa are all parasitic life forms, generally presenting parasitic life-cycles dependent on teleost fish, although representatives are also known from invertebrates, amphibia, and turtles. When fully characterized, their life cycles are relatively complex. A highly abridged overview of life cycle focuses on spores being multicellular in origin, with each spore comprised of 1 to 3 valves (rarely more), each containing one to many sporoplasms. Each sporoplasm contains one to many polar capsules, with each bearing a polar filament that is expelled during invasion of the host.

A generalized myxozoan life-cycle generally finds the earliest stages developmental stages of the parasite in fish (intermediate host) as trophozoites within cells. Depending upon species, the cell

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[6]Original material prepared by Maria E Markiw, U.S. Fish and Wildlife Service, National Fisheries Research Center-Leetown National Fish Health Research Laboratory, Box 700, Kearneysville, West Virginia 25430.

type targeted will tend to be specific, e.g., cartilage for the causative agent of whirling disease. Growth of the trophozoite yields amoeboid cytoplasm eventually increasing in size, while the nucleus undergoes repeated karyokinesis to form a plasmodium (large cytoplasmic mass with many nuclei). Plasmodia grow attached to the epithelium in the coelomic area (i.e. urinary bladder, swim bladder) in coelozoic forms or occur within tissues in species histozoic types. During winter, many coelomic forms (e.g., *Myxobilatus microspora* in urinary bladder of largemouth bass) plasmodia form sheet-like aggregates, then in late spring and summer form long, finger-like extensions that bud off as free-floating plasmodia. Spores then form within the fingers and buds which pass out with the urine (see Booker and Current 1981).

Some cells are destined to form spores within the plasmodia, and a range of sporulation processes have been characterized (e.g., disporoblastic spore formation in *Henneguya exilis* in channel catfish; Current and Janovy 1977). In all types of sporulation, an envelope cell encapsulates a sporogonic cell where multiple cell divisions of sporogonic cell to form new cells that eventually form 2 separate spores within the envelope cell. The number of spores developing from the same cells varies, but ultimately spores liberated into environment where they are ingested by tubificid oligochaetes (definitive host). Once in the definitive host, polar filaments are expelled, valves of the spore separate, and sporoplasm invades gut (usually, intracellular spaces between intestinal epithelial cells). Sporoplasm subsequently undergoes asexual division, often times by multiple fission, which is then followed by gamogony where cells derived from the fusion of different plasmodia. Cell fusion yields 3-valved triactinomyxon spores which are subsequently released into the lumen of the gut and are eventually released upon defecation. Once the triactinomyon spores are reach water, they attach to fish via polar filaments, and sporoplasms invade cells of primary host. Fish can also become infected by ingesting the intermediate hosts, the infected oligochaetes.

Given the number of species in the Myxozoa, only a handful of species are completely characterized with respect to life cycle and identification of primary and intermediate hosts. In aquatic vertebrates (fishes and amphibians), representative genera and species of myxozoans include: *Chloromyxum trijugum* in the gall bladder of centrarchids in North America, *Henneguya*

exilis in the gill filaments of channel catfish in North America, *Myxidium serotinum* in the gall bladder of anurans in the Western hemisphere, *Myxobilatus mictospora* in the urinary bladder of large mouth bass in North America, *Myxobolus cyprini* in muscles of carp in Europe, *Sphaerospora renicola* in the renal tubuli of European carp, *Thelohanellus nikolskii* in cysts on the fins of carp in Europe, and *Myxosoma cerebralis* which infects cartilage tissues in young trout, causing deformities, neurological dysfunction, and death. The current investigation focuses on the causative agent of whirling disease which may have been introduced to North America with brown trout transplants from Europe (see Bartholomew and Wilson 2002).

Myxobolus cerebralis and whirling disease. Whirling disease is a parasitic infection of trout and salmon by the myxosporean protozoan *Myxobolus cerebralis* (Syn. *Myxosoma cerebralis*). This parasite targets cartilagenous tissue, and infection can cause deformities of the axial skeleton and neural damage that results in "blacktail." The disease is named for the erratic, tail-chasing, "whirling" in young fish that are startled or fed. Heavy infection of young fish can result in high mortalities or unmarketable, deformed individuals.

Although the parasite was first reported in 1903 in central Europe (Hofer 1903), its complete life cycle was not described until the early 1980's. Whirling disease occurs throughout Europe (Halliday 1976) where it probably originated. It occurs in the former Soviet Union (Uspenskaya 1955) and was seemingly introduced into British surface waters where it is now common (Elson 1969; O'Brien 1976; Hudson and Holliman 1985). It was accidentally introduced into New Zealand (Hewitt and Little 1972) and into the United States. The detailed history of the disease and its introduction into the United States (into Pennsylvania and Nevada in about 1955) were discussed in a recent review by Hoffman (1990). Although Hoffman provided an extensive list of the present worldwide distribution of the infection, the cited occurrence in several countries may be suspect, because of the methods applied in the detection and identification of spores in earlier studies. *Myxobolus cerebralis* was probably established in North America much earlier than reported because the parasite requires several years to become established at sufficiently high intensity for clinical signs to appear in fish.

In the United States, whirling disease has been detected in 22 states: Alabama, California, Colorado, Connecticut, Idaho, Maryland, Massachusetts, Michigan, Montana, Nevada, New Hampshire, New Jersey, New York, Ohio, Oregon, Pennsylvania, Utah, Virginia, Washington, West Virginia, and Wyoming (Figure 4). Figure 4 illustrates a state-based summary of whirling disease occurrence from its initial characterization in fish from Pennsylvania through its dispersal throughout surface waters of the US.

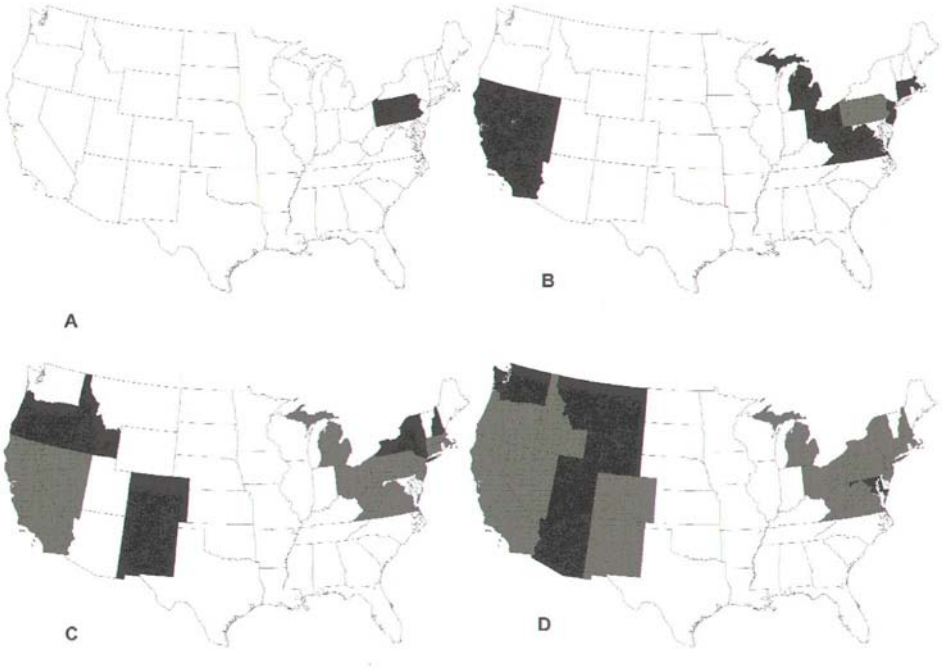


Figure 4. Spread of whirling disease as indicated by state records (from Bartholomew and Reno 2002)

Figure 5 and Figure 6 present dot maps capturing occurrence data, which illustrate uncertainties associated with "fish disease registration," given the spatial requirements of GIS-based predictive tools such as GARP. For example, the resolution of map projections such as those of Figure 4 are spatially biased and do not readily translate into decision-making processes focused on watershed level management models. Although more data intensive, the strengths of point data and its role in analysis, e.g., of invasive species and their potential for interbasin transfer and their subsequent establishing sustainable populations would be fully supported, if a formal registry of disease occurrence would be maintained for fish pathogens such as *M. cerebralis*.



Figure 5. Dot map ca 2002 supporting state-records map of Figure 4 (from Bartholomew and Reno 2002).

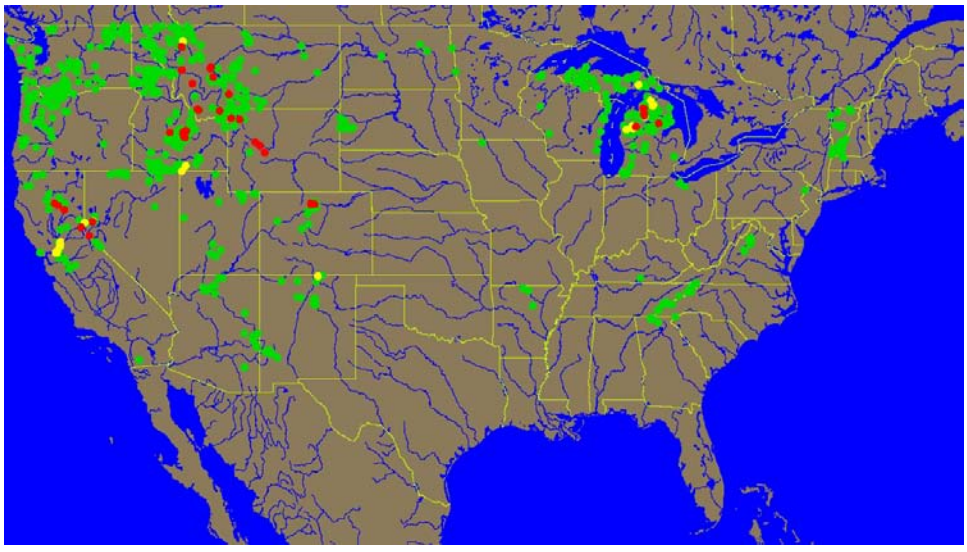


Figure 6. Dot map ca 2004 derived from US Fish and Wildlife Service, National Wild Fish Health Survey at http://wildfishsurvey.fws.gov/.

Diagnosis and clinical signs. Moderate or heavy clinical infection of fish with whirling disease can be presumptively diagnosed on the basis of changes in behavior and appearance. When

alarmed or feeding, some infected individuals show an abnormal whirling behavior. The caudal peduncle and tail may become dark or even black, but these characteristics fade in preserved specimens. The whirling behavior is believed to be the result of impaired coordination caused by neural damage from lesions and disintegration of cartilaginous tissue around the organs of equilibrium. These clinical signs appear, depending on temperature and intensity of the infection, about 35 to 80 days after initial infection and can persist for about a year. Deformities of the axial skeleton or head, shortening of the snout, and cranial depressions persist through the life of the infected fish. These signs are not conclusive, however, since injury, exposure to toxic chemicals, or deficiency in dietary tryptophan and ascorbic acid can evoke similar signs (Wolf et at. 1981). The collective appearance of all signs throughout a population are suggestive of a clinical infection with whirling disease.

To date, no reliable nondestructive serological procedures have been developed for detecting the causal organism of whirling disease in fish. Nonspecific, false positive, and false negative reactions have been found in tested fish (Griffin and Davis 1978; Markiw, unpublished data). The long life cycle of the parasite, about 3 months in fish and 3.5 months in tubificid worms, may result in continual changes of antigenic components.

In gross pathological examination, internal organs appear normal. Histological sections of cartilage, particularly skull, gill, and vertebrae, show areas of lysis and inflammation. Although hematoxylin and eosin stains are routinely used in histology, these stains do not enhance the appearance of spores of *M. cerebralis*, so methylene blue, Giemsa or May-Grünwald Giemsa, or Ziehl-Neelsen stains are recommended because the polar capsules react strongly and make the spores prominent. If the infection has existed for 3 to 4 months (depending on temperature), spores of the myxozoan *M. cerebralis* have had sufficient time to form in or around the cartilage lesions, and the presence of *M. cerebralis* spores in cartilage areas is pathognomonic for whirling disease.

Identification. *Myxobolus cerebralis* is the only myxosporean found in the cartilage of salmonids.

The mature spore is lenticular in side view and nearly circular in front view. The spores are 8 to 10 mm in greatest diameter and have two prominent ovate polar capsules with coiled filaments that may be extruded. Aberrant spores, either in shape or with unequal polar capsules, may be encountered (Lom and Hoffman 1971; Markiw and Wolf 1974a), and the iodinophilous vacuole may not be present. However, the absence of the iodinophilous vacuole is not always reliable taxonomically and can be observed only in fresh spores. Preserved spores are usually about 10% smaller than fresh spores, and may contribute to misidentification of species. Sole identification by morphology may be difficult because *M. cerebralis*-infected fish may have mixed infections with other myxosporeans from the central nervous system, muscle, or skin. For example, spores of other species of *Myxobolus* are similar to *M. cerebralis*, and can occasionally be isolated from the head, but not in the cartilage or bone, of salmonids. These species include:

Myxobolus kisutchi – in the central nervous system of coho salmon (*Oncorhynchus kisutch*) and chinook salmon (*Oncorhynchus tshawytscha*). The preserved spores (formalin) are 7 to 8 mm in diameter, appear uniform in shape, and contain an iodinophilous vacuole.

Myxobolus squamalis – in the scales of rainbow trout (*Oncorhynchus mykiss*) and salmon from the western United States. The preserved spores (formalin) are 8 to 9 mm in diameter and appear uniform, with equal polar capsules and with a narrow ridge that parallels either side of the sutural ridge.

Myxobolus arcticus – in the central nervous system of coho salmon, sockeye salmon (*Oncorhynchus nerka*), Dolly Varden char (*Salvelinus malma*), lake char ("Neyva," *Salvelinus neiva*), Arctic grayling (*Thymallus arcticus*), Arctic char (*Salvelinus alpinus*), and whitefish (*Coregonus clupeaformis*), the fresh spores are large, 14.3 to 16.5 x 7.6 to 7.7 mm, with large, elongated polar capsules (recent description by Pugachev and Khokhlov 1979).

Myxobolus neurobius – in the central nervous system of brown trout (*Salmo trutta*); Arctic grayling; European grayling (*Thymallus*) from central Europe, Eurasia, and North America; and arctic char and wild young Atlantic salmon (*Salmo salar*) in Newfoundland (Maloney et al. 1991). The preserved spores (glycerin) are oval and appear in a wide range of sizes, 10 to 12 x 8 mm (Schuberg and Schroeder 1905); but fresh spores are larger, 13.4 to 14 x 8.5 to 9.2 mm, according to a recent description by Pugachev and Khokhlov (1979).

Myxobolus insidiosus – in the muscle of cutthroat trout (*Oncorhynchus clarki*), chinook salmon, and coho salmon from the western United States. The fresh spores are about the same size and shape as *M. arcticus*, 12.8 to 17.3 x 9 to 11.5 mm.

Histological location and identification of *M. cerebralis* spores in lesions of skeletal tissue, particularly of the head, have been recommended for confirmation of diagnosis, but this may not be reliable for fish infected with only a few spores. A presumptive diagnosis may be based on location, size, and morphology of the spores and epizootiological data such as geographical location and history (e.g., of the reach or hatchery in wild or cultured fish, respectively), the species of fish, and the clinical signs. Diagnosis is usually confirmed by the identification of spores, generally from a direct fluorescent antibody test with rabbit antiserum against *M. cerebralis* or *Triactinomyxon* spores conjugated with fluorescein isothiocyanate (Markiw and Wolf 1978; Markiw 1989a; antiserum prepared at the National Fish Health Research Laboratory has shown cross reactivity with *Myxosoma cartilaginis* of bluegills, *Lepomis macrochirus*).

Life Cycle. Whirling disease presents a two-host life cycle (Figure 7) involving a fish and the aquatic oligochaete *Tubifex* (Markiw and Wolf 1983; Wolf and Markiw 1984; Wolf et al. 1986), and two separate stages of sporogony occur, one in each host. Antigenic homology of the two morphologically distinct spore forms has been demonstrated serologically (Markiw 1989a).

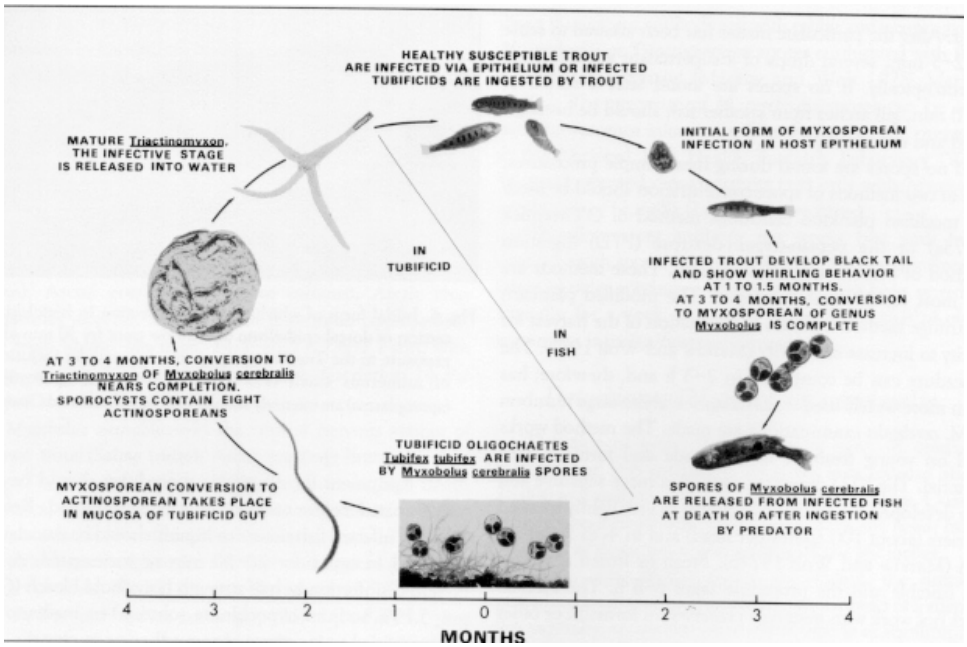


Figure 7. Diagram of 2-host life cycle of *Myxobolus cerebralis*, the causative agent of whirling disease (from Markiw 1992).

In brief, the life cycle of the causative agent of whirling disease begins with spores of *M. cerebralis* released to the aquatic environment when infected fish die and decompose or are consumed by predators or scavengers. The myxosporean-type spores are ingested by tubifex worms in whose gut epithelium the next phase of the life continues. In the oligochete gut epithelium, transformation into the actinosporean, or *Triactinomyxon*, occurs. This developmental stage is infective to fish, and takes about 3.5 months at 12.5°C to complete development. Once fully developed, Triactinomyxon are released from infected worms into the water for several weeks. The Triactinomyxon spores are much larger and have three polar capsules and three grapple-like appendages, 170 to 180 mm long. Triactinomyxon enter susceptible fish such as rainbow trout through the epithelial cells of the skin, fins, buccal cavity (particularly at the base of the gills), upper esophagus, and lining of the digestive tract. Once infection occurs, transformation into *M. cerebralis* spores takes about 2.6 months at a water temperature of 12.5°C. The life cycle for *M. cerebralis* was original documented by Markiew (see, e.g., Markiew and Wolf 1974a) and subsequently confirmed by El-Matbouli and Hoffmann (1989); a similar life cycle has been

characterized for *Myxobolus cotti* (El Matbouli and Hoffmann 1987). Although a two-host life cycle of the whirling disease organism is now widely accepted, the parasite has been recycled in fish or tubificids in the laboratory without loss of infectivity. Also, Hamilton and Canning (1987), Prihoda (1983), and Uspenskaya (1978) suggest direct transmission of the parasite from fish-to-fish by way of aged spores, although further study is indicated to detail fish-to-fish transmission.

Transmission. Salmonids contract whirling disease in two ways: by ingesting tubificids that harbor the specific actinosporean Triactinomyxon and by brief contact with waterborne Triactinomyxons released from infected tubificids. The experimentally produced actinosporean stage of *M. cerebralis* is short-lived, persisting 3 to 4 days at 12.5°C and fewer days at warmer temperatures (Markiw 1992b). Studies of the dynamics of the infective stage for fish (Markiw 1986) demonstrated that after a single exposure to *M. cerebralis* spores, a population of infected tubificids can release viable Triactinomyxon spores for as long as a year at a level detectable by only sentinel fish.

O'Grodnick (1975b) demonstrated that whirling disease cannot be transmitted vertically from infected brood stock to the egg. Shipments of salmonid eggs from waters contaminated with whirling disease are also unlikely to disseminate the parasite because rainbow trout are refractory to the infection during hatching and for a day afterward (Markiw 1991). Contrary to reports from eastern Europe and Russia (Prihoda 1983; Uspenskaya 1978), attempts to effect fish-to-fish transmission of whirling disease or through aged-spores of *M. cerebralis* in absence of tubificids have been unsuccessful in other studies.

Development. Development time for both stages of the whirling disease organism, myxosporean in fish and actinosporean in tubificids, is directly related to temperature. Trout fry fed infected worms or exposed to waterborne Triactinomyxon show blacktail after 35 to 45 days at a water temperature of 12.5°C. Whirling behavior first appears at about the same time or slightly later, and fully mature spores are detected after 2.6 to 3.5 months at 12.5°C. Under experimental conditions, following a 3-hour, single exposure to *M. cerebralis* to triactinomyxons, 2-month-old rainbow

trout became infected with spore counts in head cartilage ranging from less than 100 to nearly 2 million at 5 or 6 months and showed limitation of parasitism at the highest levels of infection (Markiw 1992a, 1992b). Development time is shortened or lengthened at temperatures above or below 12.5°C; about 50 days at 17°C and 120 days at 7°C (Halliday 1973).

Development time in the worm is defined as the interval between first contact with *M. cerebralis* spores and the release of the first Triactinomyxon. Experimentally, after single exposure of one population of tubificid worms to *M. cerebralis* spores at 12.5°C, Triactinomyxons were released in a consistent pattern that began at 104 to 113 days post exposure, subsequently peaking during the next 15 to 60 days. Spore production continued at trace levels for about 6 months, and during the next 3 months the infectivity was detectable by only sentinel fish (Markiw 1986). Whether the same infected worms are releasing Triactinomyxons for 11 months or a new generation of worms must become infected with *M. cerebralis* spores to produce infectivity is not known. One tubificid worm, at peak of productivity (about 130 days after exposure) can harbor 900 to 1,000 mature Triactinomyxons.

Reservoir of Infectivity. Trout and salmon can be infected with whirling disease and may harbor *M. cerebralis* spores. Predators and scavengers such as birds (Taylor and Lott 1978) that consume infected fish, can release viable *M. cerebralis* spores into the environment and may disseminate the parasite. The source of the infective agent for fish is usually the water supply or earthen ponds inhabited by aquatic tubificid worms. An outbreak of the disease can occur after stocking with infected fish or transferring fish from facilities where the infection had not yet been detected.

Susceptibility and Host Range. Young and adult trout and salmon are susceptible to *M. cerebralis* infection, but the severity of the infection decreases with age (Markiw 1992a). When fish are infected at an older age, they are usually asymptomatic, healthy-looking, and of normal size, but may carry the spores of *M. cerebralis*. Severe mortalities of 90% or more may occur among newly hatched fish exposed to the infective agent as sac fry; l-day-old rainbow trout are

refractory to the infection (Markiw 1991).

Not all salmonid species are equally susceptible to infection. For example, rainbow trout are most susceptible to the disease and brook trout much less so. Lake trout apparently cannot be infected and do not acquire the disease (O'Grodnick 1979). Other salmonids can be infected, but clinical signs of the disease may or may not develop. In the following list, species are ranked in descending order of apparent susceptibility (O'Grodnick 1979; Hoffman 1990): rainbow trout, sockeye salmon, golden trout (*Oncorhynchus aguabonita*), cutthroat trout, brook trout, steelhead (*Oncorhynchus mykiss*), chinook salmon, Atlantic salmon, brown trout, coho salmon, lake trout (*Salvelinus namaycush*) and splake (hybrids between brook trout and lake trout). Lake trout and splake are refractory to infection with whirling disease. Susceptibility not only varies among species but also among strains and may vary tremendously among individual fish within a population (Markiw 1992a). Grayling (*Thymallus* sp.) and whitefish (*Coregonus* sp. and *Prosopium* sp.), which are generally regarded as salmonids, have yet to be tested and their susceptibility or resistance to whirling disease remains undetermined. Early accounts of whirling disease (Halliday 1976) suggested that non-salmonids were susceptible, but these early reports may be erroneous, and reexamination and identification of spores by current serological methods are necessary for confirmation (Markiew, personal communication).

Tubifex is the only tubificid that has been identified as susceptible to *M. cerebralis* (Wolf et al. 1986), and species of *Limnodrilus*, *Quistadrilus*, and *Ilyodrilus* in mixed populations with *Tubifex* did not produce Triactinomyxon when exposed to *M. cerebralis* spores. Other genera of oligochaetes have also been tested (*Dero*, *Stylaria*, and *Aeolosoma*) but do not produce infectivity for whirling disease (Markiw and Wolf 1983).

Prevention and Control. At the present time, control of *M. cerebralis* infections is difficult. However, application of preventive measures can decrease the intensity of the disease in fish culture facilities and perhaps eliminate the spread to non-enzootic areas. Because tubificids are essential intermediate hosts for development of the infective stage in fish, the avoidance of earthen

ponds for rearing fish should be considered. Tubificids are normal inhabitants of aquatic environments, and are particularly abundant in rich organic soils, occurring as dense red patches in settling basins and streams that carry effluent from trout hatcheries. The life span of *T. tubifex* is about 2.5 to 3 years depending on environmental conditions (USSR Academy of Sciences 1972), and the seasonal variation of oligochaete biomass is commonly observed with the greatest biomass in fall and the least in spring. The phenomenon might correlate with the intensity of reproduction, given breeding and development of oligochaetes are directly associated with temperature (USSR Academy of Sciences 1972).

Earthen ponds and raceways stocked with fish where cleaning is difficult or neglected are ideal habitats for worms and, once introduced, the whirling disease parasite becomes established. Techniques for prevention are periodical disinfection of the facility and the rearing of small trout indoors in pathogen-free water. Smooth-faced concrete or plastic-lined raceways that are kept clean and free of contaminated water keep the facility free of the disease. Disinfection of waterborne infectivity has also been effective and can be achieved by combining filtration to remove or reduce suspended contaminants with ultraviolet-irradiation (Hoffman 1974, 1975). Some chemotherapeutants reduced losses and infection of young trout, but none prevented or totally eliminated whirling disease. Development of spores decreased when young trout were fed furazolidone (Taylor et al. 1973); furoxone, benomyl, and fumagillin (O'Grodnick and Gustafson 1974, 1975); or proguanil and clamoxyquin (AIderman 1986). El-Matbouli and Hoffmann (1991) reported recently that fumagillin, fed to experimentally infected rainbow trout, defected morphology of *M. cerebralis* spores and could prevent a clinical outbreak of whirling disease. Chlorine (sodium hypochlorite), administered weekly for 4 months at concentrations of 0.5 ppm for 2 h to control waterborne infectivity (triactinomyxons) and infected tubificids, suppressed the prevalence of infection by 73% in one group of young trout and by 63% in another group of concurrently exposed young trout (Markiw, unpublished). This chlorine treatment regime was not toxic to trout.

Immune response of fish to the whirling disease pathogen is critical for vaccination against the

disease under culture conditions. Immune response in rainbow trout to *M. cerebralis* was studied early by Halliday (1974), Pauley (1974), and Griffin and Davis (1978), and these studies revealed some evidence that rainbow trout produce antibodies against *M. cerebralis*. Protection against infection, however, has not been demonstrated and the immune response to Triactinomyxon has not been examined. Subsequent studies, however, indicate that host tissue reaction against the pathogen decreased or even eliminated myxosporean infection in lightly infected rainbow trout (Markiw 1992a), which suggests that immunization against whirling disease may work with common specific antigenic components of both stages for producing an immunogen by genetic engineering.

In the past, radical methods of controlling the disease in affected trout hatcheries were used. Infected fish stocks were destroyed and buried and the entire facility disinfected. Present methods of control are less drastic, and approaches to managing hatcheries with infected fish are comprehensively discussed by Hoffman (1990). When fish of a hatchery are infected, the intensity of infection determines what can be done with infected individuals. Infected fish may be slaughtered and smoked for table use (smoking kills the spores; Wolf and Markiw 1982) or placed in enzootic areas. Such arrangements may reduce economic loss to fish culturists. Survey of watersheds for the source of infectivity with susceptible sentinel trout in floating cages (Hnath 1970; Horsch 1987) and the use of more sensitive methods of spore detection help pinpoint contaminated areas.

An evaluation of whirling disease should emphasize the intensity of infection, not simply the presence or absence of *M. cerebralis* in the environment. While a initial characterization of presence-absence is critical in the "discovery process" in identifying dispersal, in part, this more quantitative, intensive characterization focused on "how much" rather than occurrence data reflects the observation that control measures do not need to eradicate the parasite completely to be effective. Measures such as culturing resistant species, filtering the water supply, chemotherapy, and periodical disinfection of culture facilities reduce the potential for establishment of myxosporean infection in fish and actinosporean infection in tubificids, which

greatly reduce the number of infected individuals and the intensity of the infection. Whirling disease can also be reduced if hatchery-reared fish are inspected and certified as disease-free before transfer between facilities.

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Metazoan diseases of fishes: Phylum Cnidaria (Coelenterata) and Myxozoans

The parasitic members of the Cnidaria (Coelenterata) are systematically interesting, since their interrelationships with other members of the phyla are clouded, poorly characterized and poorly understood (see preceding section on *Myxobolus cerebralis*, the causative agent of whirling disease). For the representative disease-causing organism of interest to the current investigation, the genus *Polypodium* is a member of the Phylum Cnidaria. Relative to whirling disease and the literature available on *M. cerebralis*, few publications occur for *P. hydriforme*, yet the work reported for the parasite indicates the species currently occupies areas in both Missouri River and Hudson drainages (see, e.g., Holloway et al 1991, Dick et al 1991).

Cnidaria are aquatic, and most of their number are marine, although the freshwater representatives are well published in the literature. The phyllum is characterized by its radial symmetry, with most of its members have a gastrovascular cavity and tentacles at some stage of development. Tentacles are derivatives of extensions of body wall, with most species being armed with nematocysts (stinging cells). Most species are characterized by alternation of generations, with an asexual phase being polyploid in character and sexual generations taking the form of medusae. As a general feature, most species have one phase dominant their life cycle with the other being reduced or even absent (see Roberts and Janovy 2005).

The parasitic members of the phyllum are found in two of the three classes[7] that comprise the

[7] Current convention lists Class Hydrozoa (four orders, including the hydras; Class Schyphozoa (four orders, including the jellyfish); and Class Anthozoa (two subclasses with 10-12 orders (depending upon authority), including sea anemones and corals). The current taxonomic status of the Myxozoa and their relationships to Cnidaria is uncertain. Herein, Myxozoa were considered separately in characterizing *Myxobolus cerebralis* as causative agent of whirling disease.

group, with *Polypodium hydriforme* being considered a hydrozoan. The taxonomic status of these parasitic forms remains disputed, but for our current investigation the "Myxozoa" includes the causative agent of whirling disease which was considered without particular attention afforded the basic research issues that suggests the group represents a fourth distinct class in the phyllum Cnidaria (Siddall et al 1995). As noted, *P. hydriforme* is a hydrozoan and infects the eggs of sturgeon and other primitive fish – *Acipenser* spp. (Acipenseridae), including sturgeon in Europe and North America, *Huso* spp. (Acipenseridae), the kaluga in Russia, and *Polyodon spathula* (Polydontidae), the paddlefish in North America (see, e.g., Hoffman et al 1974, Suppes and Meyer 1975, Holloway et al 1991, Dick et al 1991, Choudhury and Dick 1991, 2001; see Figures 8-10 for illustration of known occurrences).

In general, parasitic stages of the hydrozoans are found in oocytes throughout oogenesis, beginning with previtellogenesis up until spawning over one year later. Single cells in previtellogenic oocytes each have 2 nuclei (one large nucleus and one closely associated, but smaller haploid nucleus). As the life cycle progresses, the large nucleus engulfs the smaller nucleus which becomes enveloped within thin layer of cytoplasm within the larger nucleus. In essence, a small "cell" forms within a larger cell, where the engulfed nuclear content remaining haploid and the larger "cell" becomes polyploid. Eventually, the parasite becomes diploid, but it remains unclear when this nuclear event occurs.

Developmentally, the engulfed nuclear material divides within larger cell or trophamnion which serves as a nurse cell supporting its development. As the nuclear material of the small "cell" divides, it forms blastomeres which eventually forms a cluster embryoes within the trophamnion. Embryoes elongate, each eventually undergoing gastrulation, while the nucleus of trophamnion gradually becomes reticulate (undergoes senescence). In northern latitudes, in late May to late July of the year prior to spawning, when oocytes accumulate yolk, yielding a planula-type larva having two distinct epithelial layers forms. Infected eggs become darkly pigmented and larger in size than uninfected eggs, and the nucleus of the host egg is damaged as the parasite persists. Larvae of the parasite elongate and undergo multiple budding to form stolons in August as it

grows. Stolons continue to grow and elongate through the end of summer, when they become convoluted, typically possessing 30 to 40 buds. Buds continue to develop, and the typical

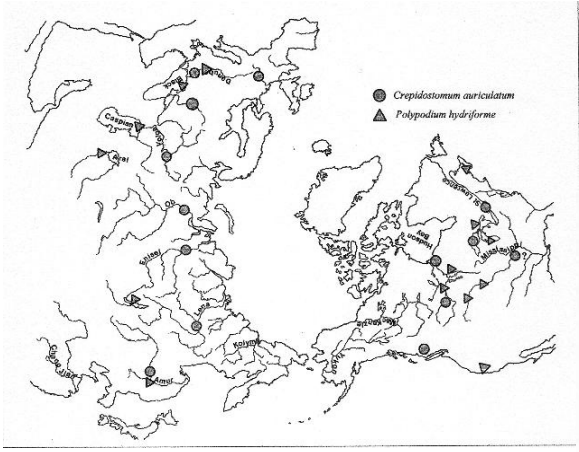


Figure 8. Circumpolar occurrences of *P. hydriforme* indicated by filled triangles (from Choudhury and Dick 2001).

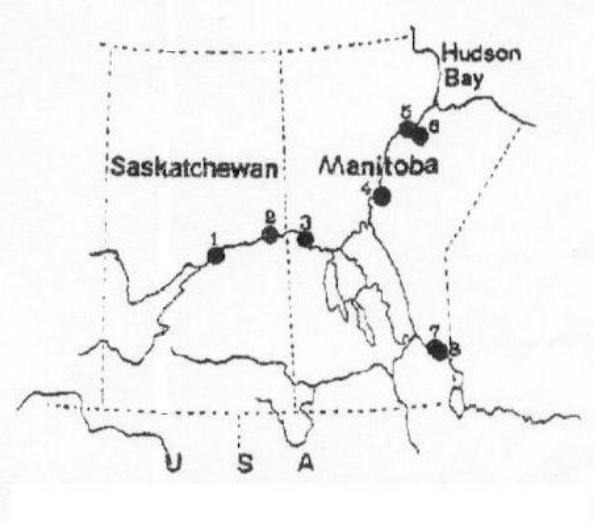


Figure 9. Sampling locations and occurrences in Hudson drainage at sites 2, 4, and 5 (see Dick et al 1991).

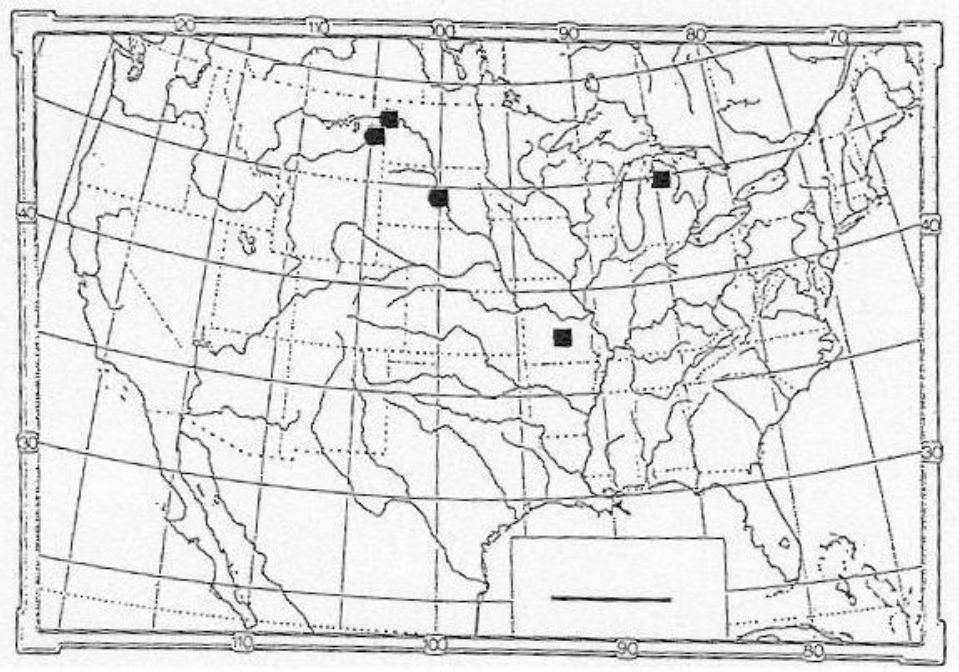


Figure 10. Occurrences of *P. hydriforme* in US indicated by filled circles and boxes (modified from Holloway et al 1991).

hydrozoan tentacles begin to form and eventually acquire nematocysts, generally by end of October. During winter, the parasite's development is arrested, but between March and May of following year, buds on stolons begin increase in size and tentacles elongate. Before the host spawns, stolons invert (turn inside out) and are released to the oviduct when the infected egg ruptures during spawning. Stolons with tentacles are subsequently released directly to the water, and once in water, stolons break into pieces. Fragmentation of stolons continues throughout summer until organisms with 6 tentacles or less predominate. As yolk reserves in stolons are depleted, each forms a typical hydrozoan mouth and feeds on small invertebrates, and growth of the individual continues. Growth results in more tentacles being developed, and the "free-living" stage of the organism reproduces by binary fission. Locomotion occurs in the typical hydrozoan fashion, e.g., "walking" about substrate using tentacles.

In August, male and female gonads form, generally with oogonia formed first. It is unclear whether reproduction involves self-fertilization or whether the organisms are parthenogenic. It is currently thought the free-living, sexual *Polypodium* spp. deposit gametophores onto larval fish where the parasites become attached to the yolk sac, head, body, tail, and fin fold of young sturgeon, and the parasite life-cycle is renewed (see review articles; Raikova 1994, 2002).

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Waterborne Diseases of Terrestrial and Wetland Vertebrates

Many diseases of terrestrial, avian and aquatic life are zoonotic, i.e., transmissible between humans and animals, causing infection in both species (Figure 11; see, e.g., Krauss et al 2003, Hugh-Jones et al 2000, Friend et al 1999, and http://www.vetmed.wisc.edu/pbs/zoonoses/ last accessed December 14, 2004). While humans are frequently involved as hosts in zoonotic disease processes, their inclusion in the current work was not reflective of an effort targeted on human health risks, but rather a recognition that terrestrial vertebrates, including humans, are

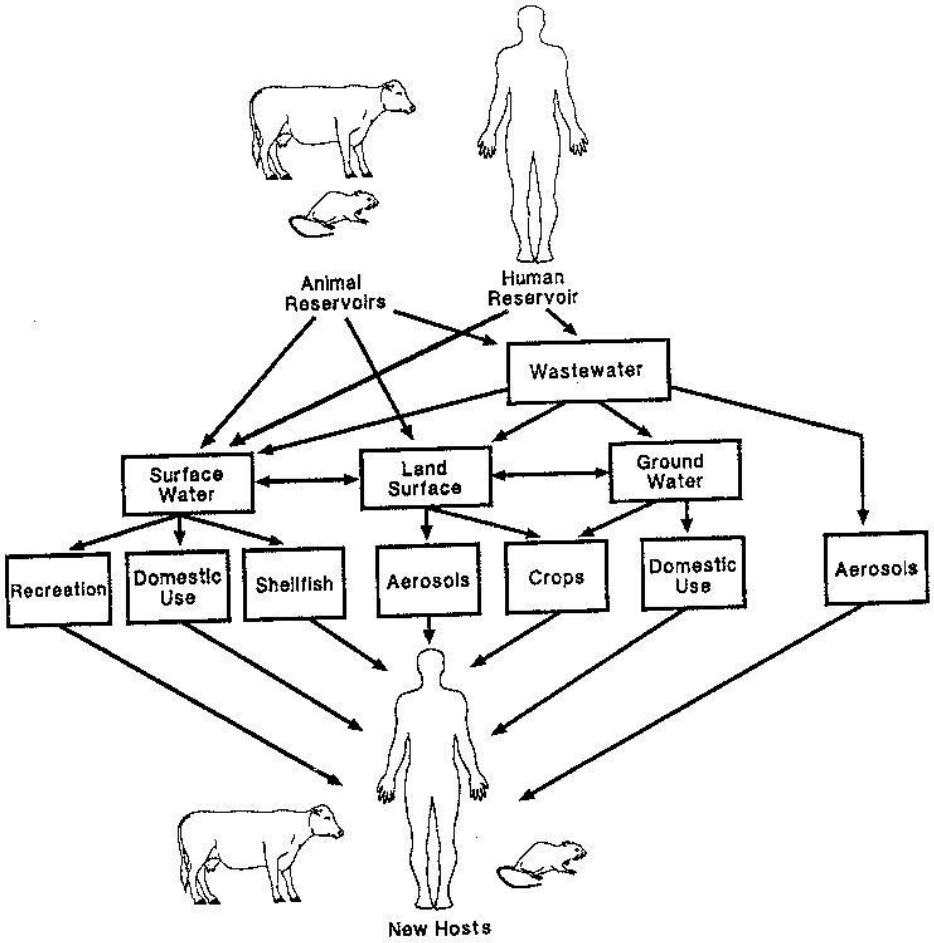


Figure 11. Illustration of interrelationships between hosts (here, illustrated by mammals) and pathogen sources in typical zoonotic diseases.

representative "targets" of disease agents potentially transferred collateral with interbasin water

diversions. The following groups of microorganisms have been linked with the occurrence of waterborne disease, and these broad categories have been used to summarize risks associated with representative biota of concern identified by Reclamation and Technical Team. All can be found in raw water or finished water, especially if the water is characterized by high turbidity. Broadly, these groups are:

- cyanobacteria
- bacteria
- fungi
- viruses
- protozoa

Cyanobacteria. While cyanobacteria have been linked to fish mortalities in the wild, these biota of concern for the current investigation are considered here, primarily for convenience. Cyanobacteria, especially when populations increase to problematic levels in ponds, lakes, and wetland habitats, are not predisposed to impact one group of receptors over another, e.g., cyanobacterial toxins are equally active with fishes, wildlife, and humans.

Bacteria. Bacteria are the most widely distributed life forms. Pathogenic bacteria range in length from approximately 0.4 to 14 micrometers and 0.2 to 1.2 micrometers in width. Some of the more common strains of bacteria that are associated with waterborne disease outbreaks are Legionella, Salmonella typhi and Cholera. These bacteria can be killed with proper disinfection practices associated with current water treatment techniques.

Fungi. Fungi can cause a variety of diseases in plants and animals, yet none were identified as biota of concern in this current investigation. Fungal diseases of animals can be categorized at infections or altered host responses consequent to exposure, most often manifested as allergies or toxicity reactions (e.g., to fungal toxins). Fungal allergies and toxic reactions are important concerns in agriculture and other industries where fungal contamination is common, but only

fungal infections are highlighted briefly given the primary focus of potential agents transferred as a consequence of an interbasin water diversion.

Fungal infections, or mycoses, result from invasion of living tissue by a fungus. Mycoses represent the most common form of fungal disease, yet of the more than 200,000 species of fungi, fewer than 200 are known to infect humans and other terrestrial vertebrates. As zoonotic infections, mycoses of terrestrial vertebrates may be categorized as superficial mycoses, cutaneous mycoses, subcutaneous mycoses, or systemic mycoses.

Viruses. Viruses are inactive when living outside of a host cell. Viruses linked to waterborne diseases range in size from 0.02 to 0.09 micrometers and have protein coats that provide protection from environmental hazards. Unlike bacteria, fungi, and protozoa, viruses contain only one type of nucleic acid (RNA or DNA). Key waterborne viral pathogens such as rotavirus and Norwalk virus among others, or those associated with water sources owing to vectors relying on surface water habitats common to their life cycle include emerging diseases such as West Nile virus, are problematic for water resource managers. Viruses can be killed with proper disinfection practices associated, with current water treatment techniques, and may be removed from finished water using certain filtration technologies.

Protozoa. Protozoa common in open bodies of water are much larger than bacteria and viruses. To survive harsh environmental conditions, some species can secrete a protective covering and form a resting stage called a “cyst.” Encystment can protect protozoa from drinking water disinfection efforts and facilitate the spread of disease.

Each of these broad categories will be considered in in the following synoptic life history overviews, which will focus on attributes presented by biota of concern that are primarily related to their being disease agents.

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Cyanobacteria[8]

Periodic blooms of algae, including true algae, dinoflagellates, and cyanobacteria or blue-green algae have been re-ported in marine and freshwater bodies throughout the world. Although many blooms are merely an aesthetic nuisance,some species of algae produce toxins that kill fish, shellfish, humans, livestock and wildlife. Proliferations of freshwater toxin-producing cyanobacteria are simply called “cyanobacterial blooms” or “toxic algal blooms.” Cyanobacterial blooms initially appear green and may later turn blue, sometimes forming a scum in the water. Although algal blooms historically have been considered a natural phenomenon, the frequency of

[8]Developed from: Creekmore, L.H., 1999, Algal toxins, In M. Friend, J.C. Franson (Technical editors), and E.A. Ciganovich (Editor), 1999, Field Manual of Wildlife Diseases: General Field Procedures and Diseases of Birds, Biological Resources Division, Information and Technology Report 1999–001, USGS, Biological Resources Division National Wildlife Health Center, Madison, Wisconsin, pp. 263-266.

occurrence of harmful algae appears to have increased in recent years. Agricultural runoff and other pollutants of freshwater wetlands and water bodies have resulted in increased nutrient loading of phosphorus and nitrogen, thus providing conditions favorable to the growth of potentially toxic algae. The detrimental impact of cyanobacterial blooms on wetland, shore, and pelagic species has long been suspected but not often been substantiated because information on the effects of these toxins in fish and wildlife species is lacking and diagnostic tools are limited.

Causative agents. Some dinoflagellates (in marine and estuarine habitats, especially) and cyanobacteria produce toxins that can affect domestic animals and humans. Some of these toxins such as domoic acid, saxitoxin (paralytic shellfishpoisoning or PSP toxin), brevetoxin, and cyanobacterial toxins (including anatoxins, microcystins, and nodularins) have been suspected, but they have rarely been documented, as the cause of wildlife mortality (Table 2).

Table 2. Documented instances of wildlife mortality caused by algal toxins in surface waters (modified from Creekmore 1999).

Toxin	Algal species	Toxin type(s)
Cyanobacterial	Microcystis spp. Anabaena spp. Aphanizomenon spp. Nodularia spp. Oscillatoria spp.	Heptatoxins (microcystins and nodularin) Neurotoxins (anatoxin-a and anatoxin-a(s))

Cyanobacterial toxins adversely affect wetland and terrestrial species such as amphibians, reptiles, birds, and mammals (including humans), as well as fish and other aquatic organisms exposed to these toxins (see, e.g., , Briand et al 2003, Meyer and Barclay 1990, Friend et al 1999). Many bird and mammal species can be affected by cyanobacterial toxins, most often noted as increased mortality in birds and wildlife ("die-offs") that occur in conjunction with a cyanobacterial bloom. Cyanobacterial toxins may be found in wildlife food items, but there have been very few instances in which the algal or cyanobacterial toxin has been isolated from the ingesta or tissues of affected

birds. For example, although exposure likely occurs through multiple pathways, cyanobacterial toxicosis has been suspected in mortalities of free-ranging ducks, geese, eared grebes, gulls, and songbirds.

Distribution. Many of the organisms responsible for algal and cyanobacterials blooms are widely distributed and not limited to either Missouri River or Red River watersheds. In recent years, the organisms or the occurrence of signs of toxicosis appear to be increasing in distribution, or at least in the occurrence of signs and symptoms of cyanobacterial toxicosis. Natural weather-related events can aid dispersal of these organisms, and it is suspected that some organisms may be transported long distances in waters of "fish wells" or other human-aided transport mechanisms. Increased nutrient loading in surface waters has also been strongly associated with the increased occurrence of algal and cyanbacterial blooms and toxicoses.

Field signs of algal and cyanobacterial blooms and toxicosis. While abiotic factors such as temperature, precipitation, and nutrient loading are highly likely to influence the development of algal and cyanobacterial blooms, there have not been enough confirmed instances of bird or wildlife mortality caused by cyanobacterial blooms to establish seasonal patterns of occurrence. Field signs reported are variable and they depend on the toxin involved. For example, cyanobacterial poisoning of birds and mammals leads to caused neurologic signs that include muscle tremors, a characteristic side-to-side head movement, pouch scratching, awkward flight in birds and abnormal gate in mammals, toe clenching, twisting of the head over the back, vomiting in mammals, and loss of the righting reflex just before death. Display of signs and symptoms is highly species dependent.

Characteristic gross lesions observed on necropsy are few, and none are particularly diagnostic. Many of the toxins, particularly the neurotoxins, do not produce a grossly observable lesion although the behavioral signs clearly indicate compromised nervous system function. For cyanobacterial toxins targeting liver function, e.g., birds exposed to toxic blooms of *Microcystis*, notable lesions of necrosis or tissue death and hemorrhage in the liver may be observed. Such

lesions have been reported in domestic mammals and birds, including ducks, that have died as a result of exposure to a toxic *Microcystis* bloom or that were experimentally dosed with microcystin.

Diagnosis. Definitive diagnosis of algal and cyanobacterial toxicosis is technically difficult, and reliance on circumstantial evidence such as the occurrence of a freshwater cyanobacterial bloom in conjunction with a die-off, supported by clinical and pathologic findings (e.g., evidence of neurological dysfunction or at worse, lack of evidence of the presence of other types of toxins or infectious disease) must frequently influence a presumptive diagnosis. In fish and wildlife, analysis of the upper gastrointestinal tract contents or tissues of affected individuals for toxins is possible but not widely practiced, owing to limited "off the shelf" tests. Even when levels of particular toxins can be measured it may be difficult to assess their significance. There are presently no established toxic thresholds for wildlife species. Recently developed methods using enzyme linked immunosorbent assay (ELISA) technologies permit detection of microcystins in animal tissues and gastrointestinal contents. Samples of suspect waters may be collected in the field, and may be diagnostic if collected at the time of the die-off event. Generally, collection of field samples, be those dead or dying animals or environmental samples such as surface water should be the routine practice.

Control and prevention. Because it is difficult to definitively identify algal and cyanobacterial toxins as the causeof wildlife mortalities, few control measures have been instituted. Currently, more interest has been expressed in the role that algal and cyanobacterial toxins play as threats to human water and food supplies (see, e.g., Chorus and Bartram 1999). Outside these public health settings which emphasize water treatment or source water controls to prevent problem blooms, identifying and characterizing the conditions that trigger harmful algal and cyanobacterial blooms may aid in developing strategies to prevent fish and wildlife mortality associated with these events. And, these control measures would benefit the problems more directly related to human health issues associated with algal and cyanobacterial blooms.

Regardless of whether receptors of concern are humans, domestic livestock, or fish and wildlife, controlling nutrient loading through reduced fertilizer use, improved animal waste control, and improved sewage treatment may reduce the number, or likely locations, of toxic algal or cyanobacterial blooms. Careful monitoring and early detection of potentially toxic blooms could allow time to initiate actions to prevent or reduce increased morbidity or mortality in populations associated with water sources displaying or tending to display algal or cyanobacterial population growth linked to toxin production. For humans, most toxic freshwater cyanobacteria are not problematic unless waterborne toxin is ingested. Some organisms irritate the skin and others release toxic compounds into the water and, if aerosolized by wave action, these compounds may cause problems when people inhale them. Similar exposures unlikely occur with wildlife, but are poorly documented. As in the investigation of all wildlife mortality events, wear rubber or latex gloves when handling carcasses.

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Legionella: Links between public health risks and ecological risks

Legionella pneumophila, the causative agent of Legionnaires' disease and related respiratory ailments (e.g., Pontiac fever), is a facultative intracellular pathogen, and represents but one species of bacteria whose role in public health is often dominated by proximal expressions of the disease while being poorly understood within the context of the species' life history (see, e.g.,

Fields 1996, 2002, Golovlev 2000, Segal and Shuman 1999, Steinert et al 2002). For many health professionals and the lay-public, the organism is known only as a well characterized public health problem. As a causative agent of human disease, route of exposure is predominately via inhalation of aerosols. Once inhaled, the organism is ingested by human macrophages where the it effectively evades microbicidal defenses of phagocytes by maintaining a vacuolar pH near neutrality, thus preventing phagosome-lysosome fusion. The organism in effect becomes an intracellular parasite, growing grows exponentially within a specialized vacuole borne within the phagocyte (see, e.g., Harb et al 2000, Fields 2002). These events are similar to those characteristic of other intracellular parasites such as *Toxoplasma gondii, Leishmania donovani,* and *Mycobacterium tuberculosis* (see, e.g., Roberts and Janovy 2005), but in contrast to these organisms, *L. pneumophila* can be cultivated in the laboratory using standard microbiological media and techniques (Fields 2002). Although Legionnaires disease and other forms of legionellosis have probably existed in the past, the clinical entities were not recognized until 1976 when several cases of Legionnaires disease occurred at a national convention of the American Legion in Philadelphia, Pennsylvania. In that initial outbreak and in subsequent occurrences of the disease, man-made devices such as air-conditioner cooling towers, showers, respirators, and other equipment that generate aerosols of standing water contributed to the spread of the organism from the environment and caused outbreaks of *Legionella* pneumonia (see, e.g., Lin et al 1998, Murga et al 2001).

Occurrence in natural and man-made environments. While the focus of most public health professionals resolves on proximal sources as roots of infection, the species of *Legionella* afford an opportunity to considered the ecology of an infectious disease agent within the context of source waters, e.g., potentially stemming from interbasin water diversions. *L. pneumophila* and related species has been isolated from almost any type of freshwater sample (see, e.g., Dutka and Ewan 1983, Atlas 1999), and it is quite evident that *Legionella* spp. are common in natural waters, especially those of high nutrient content and thermally polluted (Figure 12 and Figure 13). Waters of this type appear to serve as a reservoir of *Legionella* spp. from which the bacterium enters and colonizes water cooling systems, humidifiers, hot water systems, and similar structures. Some of these human-engineered systems provide a very favorable environment for *Legionella* in

terms of temperature, level of aeration, organic nutrients and iron concentration, yet these "habitats" afford similar conditions found in open-waters.

In natural or artificial systems the organism generally develops as a member of a biofilm (see, e.g., Armon et al 1997, Harb et al 2000, Marrão et al 1993, Murga et al 2001) but there is nearly always an association between *L. pneumophila* and the free-living protozoa *Acanthoameba polyphaga* (see, e.g., Cirillo et al 1994, Harf and Monteil 1988, Harb et al 2000, Kwalk et al 1998, Newsome et al 1998). In many respects, the intracellular mechanisms that assure survival of *L. pneumophilia* in human phagocytes are identical to those mechansisms that allow for an intracellular existence with its free-living protozoan "host." This involves the intracelluar growth of *L. pneumophila* inside amoebic trophozoites, an adaptation that enables *L. pneumophila* to survive chlorination of cooling water and similar systems. Aerial distribution inside amoebae, and as fragments of biofilm or as large droplets from natural or man-made systems, may represent a means by which the bacterium bypasses defense mechanisms in the lung. From a broader environmental viewpoint, intracellular growth is probably beneficial to *L. pneumophila* in preventing predation by other protozoa, ensuring a supply of nutrients, including iron, and protecting against UV irradiation to which *Legionella* is highly sensitive.

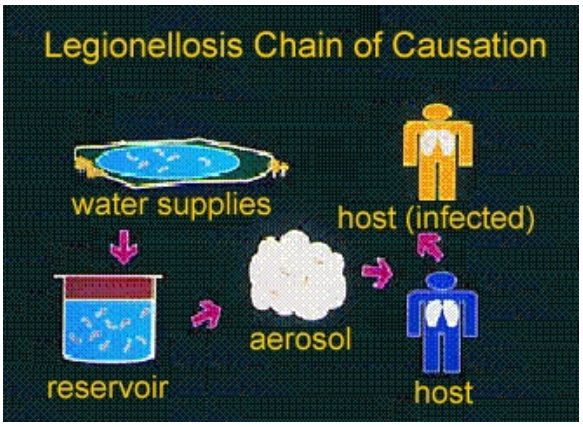


Figure 12. Conceptual model linking human host with *L. pneumophilia* (from CDC public domain sources).

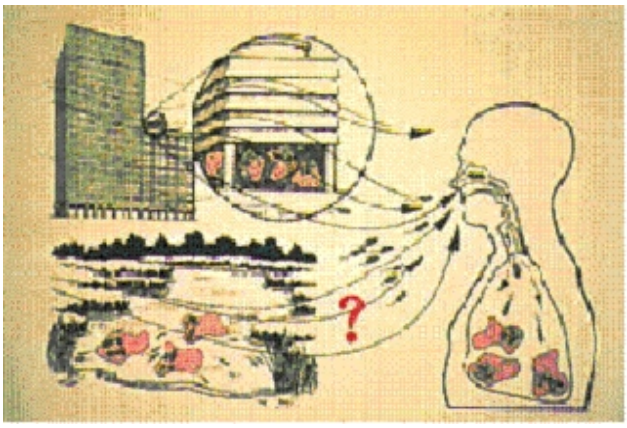


Figure 13. Graphic illustration linking human hosts with man-made devices that mediate exposure and presumptive links directly with native habitats of *L. pneumophilia* (from CDC public domain sources).

Frequently *Legionella* spp. are found in close association with algae and protozoa. Whether members of the Family Legionellaeae are capable of free-living is speculative, but several lines of evidence strongly suggest that legionellae grow exclusively within other organisms. Many amoebae have *Legionella*-like organisms growing intracellularly, and some protozoa, e.g., *Hartmanella vermiformis*, have been identified in several outbreaks of Legionnaires disease. *L. pneumophila* can reproduce within amoebae and ciliated protozoa such as *Tetrahymena pyriformis*, so mechanisms are clearly available for long-term populations in the wild.

Legionellosis is the direct consequence of the ability of *Legionella* spp. to gain access to human lungs by dispersal in aerosols. This occurs in a variety of ways, all of which involve a man-made device. Perhaps the most common device that has been responsible for introducing the organism into the human environment is the air-conditioning cooling tower. In this device, water returning from an air-conditioning system is allowed to evaporate. Due to the increased temperature and exposure to the external environment, water that contains legionellae can be co-colonized by protozoan hosts that under some conditions may facilitate explosive growth of the bacteria. Either bacteria or protozoa infected with bacteria are then aerosolized throughout the air-conditioning

system. Experiments in susceptible animals have shown that co-infection of *L. pneumophila* and *H. vermiformis* produces more-acute disease than infection with *L. pneumophila* alone.

Water distribution systems (public and private) and standard plumbing devices such as shower heads, pipes, and heat-exchange bumpers have also been shown to harbor the organism (see, e.g. Lin et al 1998), and in these structures, the role of biofilms is similar. Biofilms within these devices allow consortia of organisms to thrive, and it is likely that protozoan members of biofilms serve as hosts for *Legionella* spp. Other devices such as spas and whirlpools, respiratory therapy devices, and even grocery store produce misters have been shown to be a source of *Legionella* spp., diversity of habitats capturing the range of possibilities similar to those in the wild. Across all these habitats, however, the potential for legionellosis is only realized when water containing legionellae alone or in combination with a protozoan is aerosolized, then inhaled by a susceptible individual. Legionellae are frequently present in potable water supplies but pose a health threat only when conditions favor replication of the organism to large enough numbers, conditions generally captured by the formation of biofilms that contain a susceptible host, temperature, and the absence of added biocides.

Disease occurrence. Legionnaires' disease has been an emergent disease since the 1970's. In the last few years, the increased use of a test for detecting urinary antigen associated with *L. pneumophila*, Serogroup 1 in individuals presenting with pneumonia has facilitated diagnosis of legionellosis. Transmission of the disease agent continues to be dominated by exposure to aerosols, and evidence of *Legionella* in aerosols derived from cooling towers has been provided in various studies, although disputes in the epidemiological literature indicate that other sources may be acting as sources of the bacteria.

Legionnaires' disease is normally acquired by inhalation or aspiration of legionellae from a contaminated environmental source. Relatively little is known about sporadically occurring cases of community-acquired legionellosis, which accounts for most infections, although correlation analyses suggest that a substantial proportion of these cases may be residentially acquired and

associated with bacteria in hot water distribution systems. In households and other man-made systems (e.g., water handling systems within buildings, municipal water distribution systems), *Legionella* spp. have been isolated from water with a temperature as high as 63˚C, and the contamination is associated with other bacteria and protozoa. Biofilm formation can provide a means for survival and dissemination of *L. pneumophila*, interfering with efforts to eradicate bacteria from water systems. The accumulation of microorganisms on the pipeline surfaces and the formation of biofilms are influenced by many factors, such as surface materials, concentration and quality of nutrients and disinfectants, temperature and hydraulics of the system, and pipe surface roughness.

Figure 14 through Figure 16 illustrate data available from public health agencies (see, e.g., http://www.cdc.gov/mmwr/preview/mmwrhtml/mm4753a1.htm and similar summaries for other disease agents) that would serve as baseline data for evaluating risks potentially associated with interbasin water diversions. While state-wide data routinely reported would differ within a spatial context relative to our focus on Missouri River and Red River basins, if such assessment and monitoring efforts were identified for focused analysis, disease incidence data could be apportioned by HUCs and relative changes in incidence of disease could be monitored as baseline data and (potentially) post-diversion data. Data summarized as illustrations in Figure 14 through Figure 16 suggest apparent baseline for, e.g., Minnesota, North Dakota, and Manitoba across years is comparable with respect to variability, and upon collaboration with respective agencies within-state and within-province, data should be available for a river basin-based analysis.

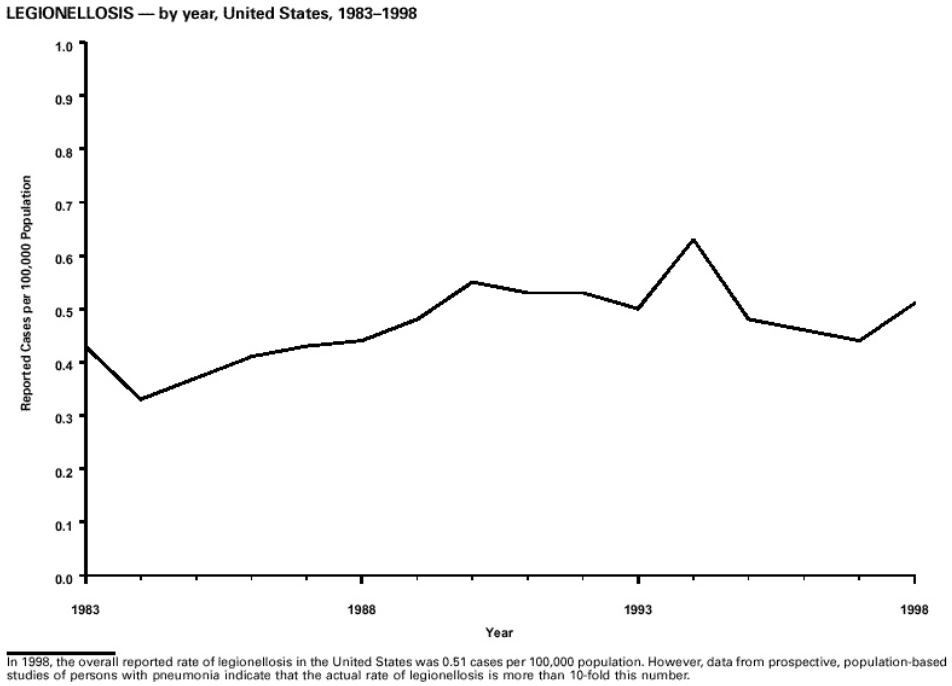


Figure 14. Typical summary data available from CDC through compilation of state-wide records.

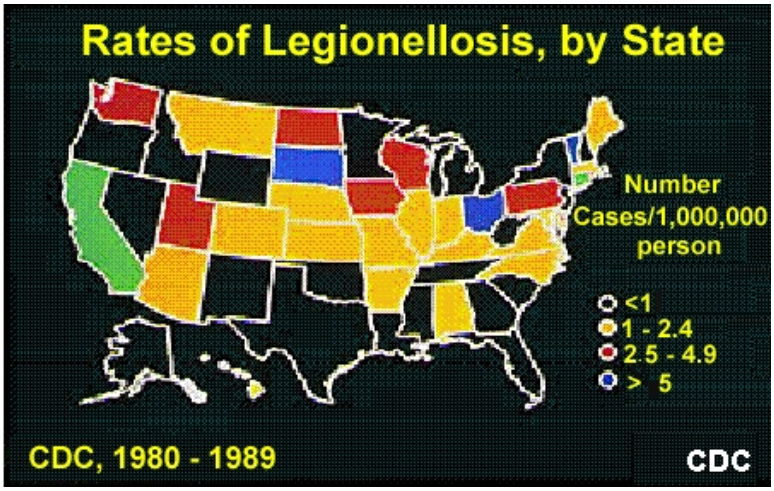
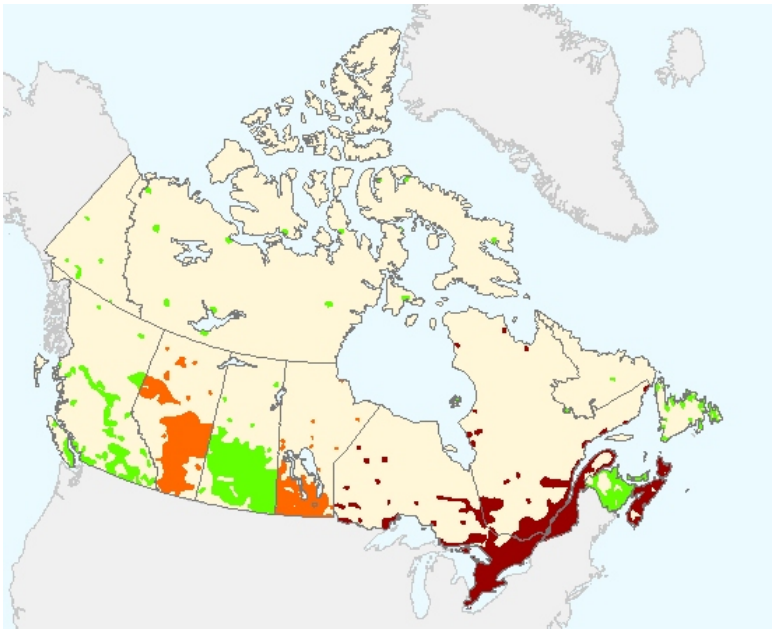


Figure 15. Illustration of disease rates derived by state, which could serve as preliminary data for evaluating baseline and "post-diversion" monitoring data focused on potential changes in disease rates associated with interbasin water diversions.

Notifiable Diseases On-Line

Population and Public Health Branch (PPHB)

Figure 16. Province-wide data compiled and report for legionellosis (both sexes combined, [including not specified], all ages [Incl. Not Specified] for 2000).



Rate per 100,000 population	**0.00 - < 0.01**	0.01 - < 0.02	0.02 - < 0.07	0.07 - < 0.11	0.11 - 0.36

Province	Rate per 100,000
Newfoundland	0.00
Prince Edward Island	0.00
Nova Scotia	0.11
New Brunswick	0.00
Quebec	0.16
Ontario	0.36
Manitoba	0.09

Province	Rate per 100,000
Saskatchewan	0.00
Alberta	0.07
British Columbia	0.00
Yukon	0.00
Northwest Territories	0.00
Nunavut	0.00

Data updated: 2003

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Enteric bacteria: *Escherichia coli* and *Salmonella* spp.

Escherichia coli and relationships to waterborne disease

Bacteria occur across a wide range of habitats, yet their ecology and interrelationships with disease processes are difficult to characterize and generally relies on indirect observations and measurement. Typically, the colons of mammals and birds have been regarded as natural habitat for *E. coli*; *E. coli* is one of the first bacterial species to colonize mammals after birth. Densities of *E. coli* in the large intestine of mammals (and birds) has been estimated from 1 million to 10 million cells per gram of colon (see, e.g., Hurst 2002, Quinn et al 2002). These population levels make *E. coli* a minor component of the microbiota of the colon, since this section of the intestine is largely anaerobic and has a total bacterial density calculated at some 100 billion cells per gram of colon. In the gut, *E. coli* passes through a single one cell division daily in contrast to growth in laboratory media which generally attains doublings six times a day or more (e.g., for *E. coli* K-12). Vertebrates other than mammals harbor *E. coli* as part of their normal gut flora, but generally occur as different strains or combinations of strains from those in birds and mammals and at lower population levels (see Quinn et al 2002). These observations suggest the species and its various serotypes are widespread beyond the often studied representatives considered in strictly a public health investigation.

Owing to the focus of our present-day diagnostic tools, when *E. coli* causes increase morbidity (or mortality), fecal contamination of water or food is commonly suspected, and environmental microbiologists, including public health and veterinary health professionals, primarily focus on characterizing pathways that link *E. coli* originating from vertebrate sources, usually mammalian or avian colon, to its introduction into a receptor's gastrointestinal system where the bacteria can reproduce. If pathogenic, the bacteria may present through signs and symptoms of disease. Strains of *E. coli* found in aquatic environments (natural or anthropogenic in character, e.g., water distribution systems) are generally more diverse than strains obtained directly from hosts. A number of studies have found that aquatic and soil bacterial populations of *E. coli* can increase

population density over time, indicating that these bacteria grow and survive in these external environments outside their host's gut. These studies suggest that *E. coli* infections can develop from sources other than fecal contamination of surface water (as well as groundwater and food).

E. coli in a nutrient-poor environment such as water or mud differs in many respects to its habitat in the vertebrate gut, e.g., bacteria in nutrient-poor environments divide at around 10% the rate achieved in the laboratory, and thrive via commensal relations with host animals (see, e.g., Rosenberg 1999). Generally, one strain of *E. coli* will dominant within a specific microhabitat (e.g., opportunistic host or microsite in aquatic or sediment habitat), but new genotypes appear to develop relatively quickly through the genetic drift that occurs under varying environmental conditions. Hence, dominance by any given strain is transitory.

As a member of the Enterobacteriaceae, molecular phylogeny studies with *E. coli* indicate that it is closely related to some other pathogens of vertebrates, including *Shigella* and *Salmonella*, *Vibrio cholera*, and *Haemophilus* spp. Enterobacteria are characterized by their capacity for facultative respiration, and are highly diverse in habitats supporting their populations, e.g., many members are free-living. Others live in commensal relationships with animals or plants. Strains of *E. coli* range from the relatively harmless K-12 serotype widely used in experimental laboratories to enterohemorrhagic *E. coli* such as O157:H7 which appears to have acquired many of its genes by horizontal transfer since diverging from K-12. Horizontal or lateral gene transfer is an attribute of bacteria that facilitates exchange of DNA within or across species lines. Such "gene-swapping" takes place through bacterial conjugation; through the intervention of bacteriophages; or through transformation, wherein bacteria acquire "loose" DNA from their environment.

E. coli O157:H7 follows a range of pathways in acquiring hosts, and it is becoming increasingly recognized as a waterborne pathogen, e.g., outbreaks involving drinking water supply or recreational water exposure illustrate the role of water in transmission (see, e.g., Mara and Horan 2003). Contaminated drinking water and recreational water have been associated with outbreaks of hemorrhagic colitis caused by E. coli O157:H7 in the areas of concern, but conventional water

treatment (e.g., chlorination) ensures that potable water and water used in recreational settings, if treated, are free of microbial pathogens. Studies focused on chlorine resistance of E. coli O157:H7 compared to wild-type E. coli suggests both pathogenic and nonpathogenic strains are significantly reduced within 1 minute of exposure to free chlorine, and that chlorine levels typically maintained in water systems are sufficient to inactivate these organisms (See Appendix 11 and Appendix 12).

Serotype O157:H7 has been the causative agent of several recent fatal outbreaks, with the more commonly recorded events linked to foodborne disease (see, e.g., NRC 2004). Pathogenicity is a function of virulence factors that *E. coli* K-12 lacks. These virulence factors influence metabolic pathways and prophages of the serotype, and enable DNA elements to move around on a chromosome which enables the enterobacteria to undergo genetic recombination more frequently than in other organisms. Lateral or horizontal gene transfer creates bacterial genomes that are mosaics of genes with different evolutionary histories, which in part enable the wide range of habitats the *E. coli* can occupy. "Pathogenic islands" are characterized as regions that present high rates of recombination; these regions are locations on the genome that confer pathogenicity to the organism (Lawrence and Ochman 1998 as cited in Souza et al 2002).

Plasmids and environmental plasticity. Bacteria carry some of their genetic information in the form of extrachromosomal elements known as plasmids, which are highly dynamic, circular DNA molecules that readily move between strains within species and (potentially) between species. Plasmids are common in *E. coli*, although bacteria can survive without a plasmid. The role of plasmids in bacterial life history varies, however, and some bacteria store a high percentage of its genome in these mobile genetic structures. Over 300 plasmids have been described in *E. coli* and confer genetic information for assimilating rare sugars and for producing colicins (substances that kill possible competitors of the same species); resistance to antibiotics and heavy metals; immunity against bacteria-targeting viruses and colicins; genes that code for genetic exchange; and filaments related to pathogenesis and the production of toxins. In general the distribution of a plasmid depends not only on its range of bacterial hosts, but also on a complex system of incompatibility

among plasmids of the same type. Conjugative plasmids rely on conjugation to mediate movement between bacteria and contain genes necessary for bacterium-to-bacterium recognition. Conjugative plasmids convey their genetic material between bacteria via formation of pili that allow for transfer of DNA, while nonconjugative plasmids may be transferred collaterally when conjugation.

Many plasmids are capable of transfers among different species, although the mechanisms mediating such interspecies transfers are incompletely characterized. Some plasmids readily undergo interspecies exchanges of genetic material and may be regarded as promiscuous. These plasmids tend to be over represented in bacterial populations, and have been referred to as "epidemic plasmids," since they often allow bacteria to acquire virulence factors or resistance to antibiotics by horizontal transfer. Promiscuous plasmids potentially contribute to coevolution, since the movement of extrachromosomal genomes of interacting species may evolve in parallel. In addition to these promiscuous or epidemic plasmids, there are clonal plasmids that are only transferred from "parent" to "child" as part of asexual reproduction, and plasmids that are transferred only between individuals of a species that have specific base sequences within their genome.

Ecological and population genetics implications of genomic plasticity. *E. coli* reflects genomic plasticity common to bacteria (and viruses) which confer on these organisms an extraordinary ecological plasticity. In bacteria, reproduction is not limited to sexual processes, since bacteria divide by binary fission to produce clones. Following a process of asexual reproduction through binary fission, genetic variation arises solely by way of mutations passed along to clones. Horizontal transfer, which involves exchange of genetic material between individuals through a parasexual process, also serves as a source of variability in populations, and in bacterial population, the balance between these two processes is called the degree of clonality, e.g., a highly clonal species is one reliant on binary fission and is distinguished by a collection of independently evolved lineages where adaptation to environmental factors relies primiarly on selection of complete lineages, most often manifested by genetic drift. In contrast, if a species

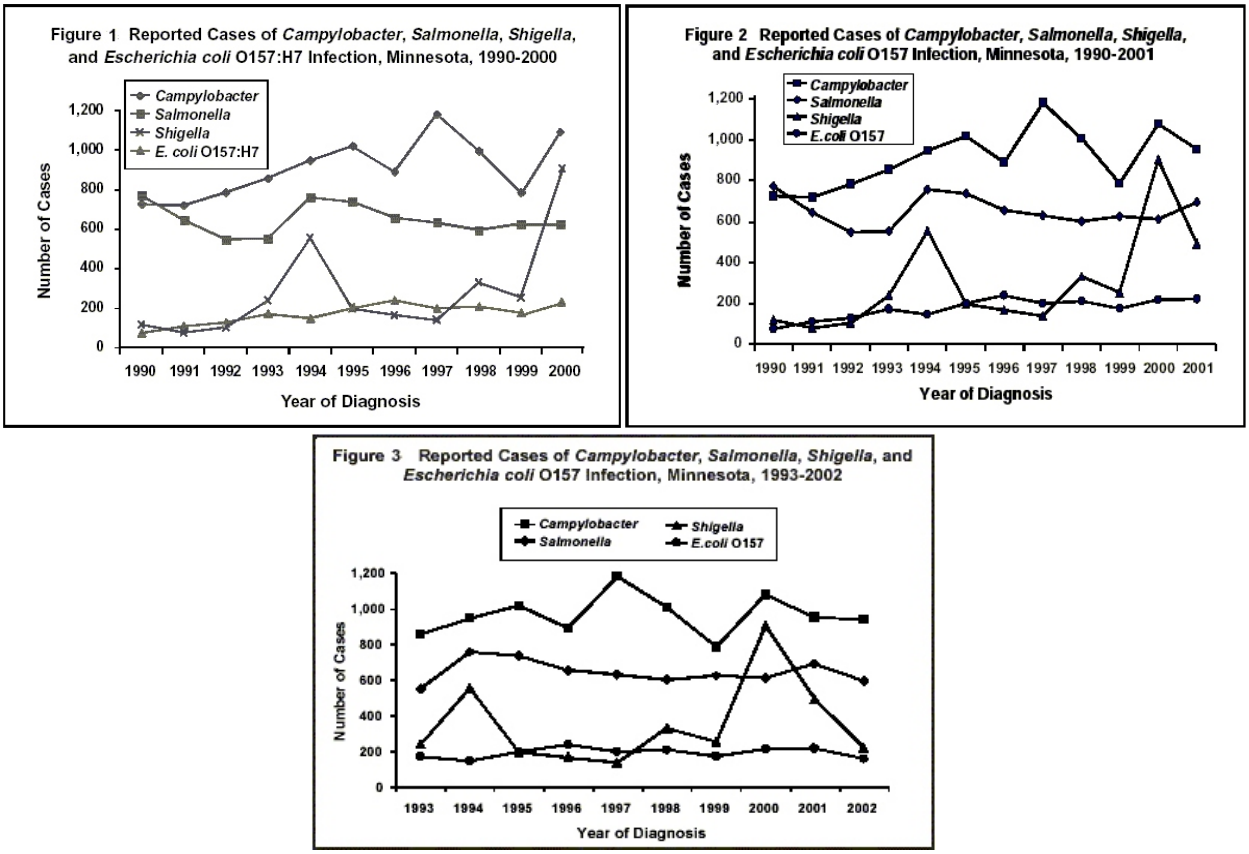
exhibits high rates of recombination, populations display attributes of randomly mating, "sexual" populations. Degrees of sexuality and clonality of bacterial populations vary, but the current characterization of *E. coli* reveals high levels of genetic variation within its populations, although research findings suggest that recombination is a rare phenomenon in *E. coli* associated with humans or domesticated animals. The high genetic diversity observed from *E. coli* probably stems from periodic selection where a genotype selectively displaces others present in the population, viz., in an asexual population, once a favored mutation spreads by natural selection, it replaces not just the gene involved, but a complete genotype. Such a mechanism would assure adaptation to particular niches, and the process would yield genetic diversity through the collection of very different strains, each adapted to a different environment.

E. coli is characterized by great genetic and ecological diversity, which reflects its high level of genetic recombination and exchange. These genetic mechanisms generate of a large quantity of genotypes, although they may not be expressed in each generation. Recombination of plasmids and gene fragments of genes also contribute to the species ability to invade "new" environmental niches and new hosts, and the spread of new variants of *E. coli* enable the species to be highly competitive across a range of environments, e.g., serotype O157:H7 was identified as a pathogen in 1982 (see, e.g., http://www.cdc.gov/ncidod/dbmd/diseaseinfo/escherichiacoli_g.htm). Given its genetic potential, *E. coli* has generated structured populations of various ecotypes or pathogenic strains that can live in a large number of environments that previously were thought secondary or atypical for the species.

As a representative disease agent potentially transferred between Missouri River and Red River watershed, *E. coli* has displayed abilities to rapidly adapt to a wide range of environmental conditions, e.g., existing as a free-living organism, in commensal mutualism in the colons of mammals and birds, and as a pathogen capable of infecting a wide range of hosts. As a pathogen, *E. coli* extends its ecological plasticity to invade other "niches" successfully, e.g., different tissues or organs across a range of species may be targets for infection beyond its normal occurrence as member of the gastrointestinal microbiota (see, e.g., Quinn et al 2002).

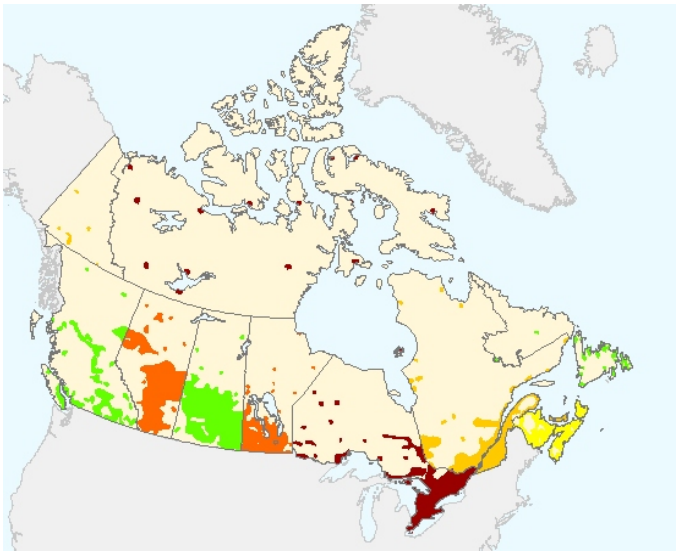
Occurrence of disease associated with pathogenic strains of *E. coli.* While the focus of the current investigation was not public health, the role of disease agents in the landscape was considered appropriate to the evaluation of risks of biota transfer associated with interbasin water diversions. As a disease agent, various strains of *E. coli* are infective for a wide range of fish and wildlife, and the species is not limited to those diseases tracked by federal, state, and county health offices. However, the available spatial and quantitative data for addressing disease occurrence is best developed for those serotypes presenting adverse effects in human populations. As with many health-related agencies, the majority of cases investigated and subsequently linked to E. coli O157:H7 exposure are food-related. Similarly, *Salmonella* occurrence in Minnesota over the same 3-year period was predominately food-related (see following section). Figure 17 and Figure 18 illustrate data typically available to baseline assessment or "post-diversion" monitoring. Again, while state-wide data routinely reported would differ within a spatial context relative to our focus on Missouri River and Red River basins, if such assessment and monitoring efforts were identified for focused analysis, disease incidence data could be apportioned by HUCs and relative changes in incidence of disease could be monitored as baseline data and (potentially) post-diversion data. Data summarized as illustrations in Figure 17 and Figure 18 (e.g., for Minnesota and Manitoba, respectively) suggest data are available to evaluate basin-wide incidence of disease, if collaboration with respective agencies within-state and within-province would be identified as data needs for monitoring programs.

Figure 17. *Escherichia coli* O157:H7 occurrence in Minnesota over a 3-year period (2000-2002; source, Minnesota Department of Health).



Notifiable Diseases On-Line Population and Public Health Branch (PPHB)

Figure 18. Province-wide incidence of "Verotoxigenic" *E. coli* in Canada (sexes combined, including not specified; all ages, including not specified), 2000.



Rate per 100,000 population	0.55 - < 4.50	4.50 - < 6.51	6.51 - < 7.59	7.59 - < 12.20	12.20 - 134.53

Province	Rate per 100,000
Newfoundland	0.56
Prince Edward Island	6.51
Nova Scotia	4.99
New Brunswick	4.50
Quebec	7.26
Ontario	12.20
Manitoba	7.59
Saskatchewan	4.11
Alberta	10.80

Province	Rate per 100,000
British Columbia	3.92
Yukon	6.54
Northwest Territories	14.69
Nunavut	134.53

Data updated: 2003

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Salmonella spp. as bacteria related to waterborne disease

Salmonellosis outbreaks in human populations generally result from ingestion of foods of animal origin that, but an increasing number of events have been associated with surface water exposures, consumption of fresh produce, person-to-person transmission, and commensal-to-human transmission (e.g., pets being the source of infectious agent). In part, these reports reflect sporadic infections rather than widespread outbreaks. For example, in the US from 1993 to 1997, the number of reported culture-confirmed *Salmonella* infections was approximately six-fold higher than the number of cases of salmonellosis reported associated with outbreaks (see CDC 2000).

As with many of the biota of concern considered in this current investigation, the nomenclature of the genus *Salmonella* has undergone considerable change in recent years, many of those changes directly reflecting the increasing use of genomic libraries to characterize phylogenetic relationships within a taxonomic system (CDC 2000, Hurst 2002). For example, based on DNA hybridization and other taxonomic studies, there are currently two recognized species in the genus *Salmonella* – *S. enterica and S. bongori* (Brenner et al 2000). *S. enterica* includes 6 subspecies: *enterica, salamae, arizonae, diarizonae, houtenae,* and *indica*, each with numerous serotypes (serotype names are written in Roman (not italicized) letters, and the first letter of the serotype name is capitalized; e.g., *Salmonella* serotype [ser.] Typhimurium or *Salmonella* Typhimurium). Over 2,400 serotypes have been identified, approximately 60% of which belong to *S. enterica* subsp. *enterica.*. Serotyping provides a consistent subtyping scheme that has changed little over time, permitting analysis of trends in *Salmonella* surveillance data. For example, infection with *Salmonella* Typhi (typhoid fever) was common in the United States in the late nineteenth and early twentieth centuries, but with widespread chlorination of drinking water supplies and improved sewage disposal practices, the incidence of *S. typhi* has declined dramatically (Tauxe 1996). Coincident with this decline has been the rise in the incidence of non-typhoidal salmonellosis, usually attributed to waterborne disease agents or foods of animal origin such as eggs, meats, and poultry.

A full summary of Salmonella serotypes and their association with disease occurrences (as sporadic infections or outbreaks) through 1998 is presented in CDC (2000), and for the current investigation we have presented selected serotypes that most closely match those specifications related to exposures associated with biota that may be transferred consequent to water diversions between the Missouri River and Red River basin. These epidemiologic summaries focus on graphical displays of data for common *Salmonella* serotypes reported in the United States during the 1968-1998 reporting period, and represent the type of data, when updated, that would be available to intensive baseline assessment or "post-diversion" monitoring activity.

Occurrence of salmonellosis. Figure 19 and Figure 20 summarize non-human sources of S. Typhimurium and S. Enterica, respectively, and Table 3 (CDC 2000) tallies *Salmonella* serotypes by record of occurrence throughout the US. These compiled data summarized by CDC represent input from states, generally reporting county-level data. For example, for state records, compiled data from Minnesota for 2002 (Table 4) illustrates available summary data for incidence of reported diseases aggregated by county into state regions, which could be applicable to future studies focused on river comparisons of disease incidence. Similarly, Manitoba presents summary maps and numeric data that could be similarly applied to subsequent analysis, if desired.

Trends in disease incidence. As in the large works from which these graphic summaries are derived (e.g., CDC 2000), it is beyond the scope of this narrative summary to comment on specific data for each serotype. General trends, however, are worth noting, particularly as those related to waterborne disease occurrence that might related to the current investigation's focus on interbasin biota transfers. Throughout the US, S. Typhimurium, S. Enteritidis, and S. Heidelberg were the three most frequently reported serotypes from 1968 to 1998 and accounted for over 50% of all reported *Salmonella* isolations in the United States during the period. While the rate of reported S. Typhimurium has recently been relatively stable, there has been a general increase in S. Enteritidis infections in the United States up until 1995 (Hargrett-Bean et al 1988, Rodrigue et al 1990, Angulo et al 1999).

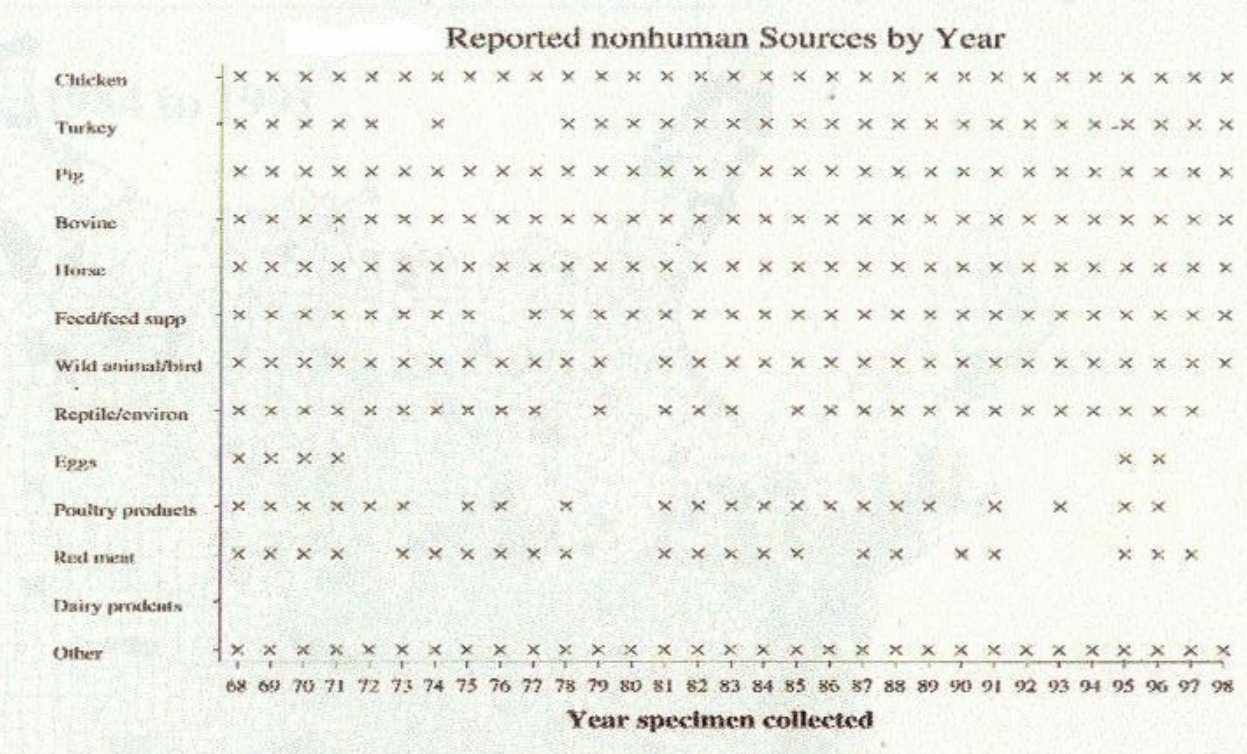


Figure 18. Non-human sources of S. Typhimurium (1968-1998).

Table 3. Summary of occurrence of *Salmonella* serotypes as percent of total cases in US.

Top 100 reported isolates of *Salmonella* serotypes
Ranking
United States, 1968-1998

Rank	Serotype	Count	Percent	Rank	Serotype	Count	Percent
1	*S.* Typhimurium	301548	29.4072	51	*S.* Miami	1901	0.1854
2	*S.* Enteritidis	145405	14.18	52	*S.* Hartford	1855	0.1809
3	*S.* Heidelberg	82442	8.0398	53	*S.* Havana	1730	0.1687
4	*S.* Newport	60983	5.9471	54	*S.* Rubislaw	1659	0.1618
5	*S.* Infantis	32392	3.1589	55	*S.* Worthington	1652	0.1611
6	*S.* Agona	27414	2.6734	56	*S.* Paratyphi A	1644	0.1603
7	*S.* Saintpaul	21646	2.1109	57	*S.* Adelaide	1633	0.1593
8	*S.* Hadar	20715	2.0201	58	*S.* Virchow	1630	0.159
9	*S.* Montevideo	19928	1.9434	59	*S.* Norwich	1596	0.1556
10	*S.* Group B	18991	1.852	60	*S.* Cubana	1477	0.144
11	*S.* Thompson	17858	1.7415	61	*S.* Johannesburg	1442	0.1406
12	*S.* Javiana	16622	1.621	62	*S.* Kentucky	1379	0.13448
13	*S.* Oranienburg	16339	1.5934	63	*S.* Bovismorbificans	137	0.1339
14	*S.* Typhi	16333	1.5928	64	*S.* Kottbus	1317	0.12843
15	*S.* Muenchen	14495	1.4136	65	*S.* Alachua	1282	0.12502
16	*S.* Derby	10680	1.0415	66	*S.* Haardt	1255	0.12239
17	*S.* Braenderup	10452	1.0193	67	*S.* Albany	1122	0.10942
18	*S.* Blockley	9734	0.9493	68	*S.* Gaminara	1054	0.10279
19	*S.* Anatum	7983	0.7785	69	*S.* Livingstone	1027	0.10015
20	*S.* Panama	7026	0.6852	70	*S.* Meleagridis	961	0.09372
21	*S.* Java	6865	0.6695	71	*S.* Newington	906	0.08835
22	*S.* Poona	5766	0.5623	72	*S.* Urbana	847	0.0826
23	*S.* Berta	5579	0.5441	73	*S.* Subspecies IIIA/IIIB	773	0.07538
24	*S.* Group D1	4862	0.4741	74	*S.* Oslo	769	0.07499
25	*S.* Manhattan	4852	0.4732	75	*S.* Siegburg	746	0.07275
26	*S.* Reading	4615	0.4501	76	*S.* Group E1	706	0.06885
27	*S.* Litchfield	456	0.445	77	*S.* Minnesota	673	0.06563
28	*S.* Schwarzengrund	4435	0.4325	78	*S.* Uganda	539	0.05256
29	*S.* Mississippi	4279	0.4173	79	*S.* Group G	530	0.05169
30	*S.* Paratyphi B	4262	0.4156	80	*S.* Drypool	516	0.05032
31	*S.* Bredeney	4230	0.4125	81	*S.* Duesseldorf	512	0.04993
32	*S.* Senftenberg	4090	0.3989	82	*S.* Inverness	448	0.04369
33	*S.* Group C1	4012	0.3913	83	*S.* Saphra	436	0.04252
34	*S.* Ohio	3887	0.3791	84	*S.* Ibadan	434	0.04232
35	*S.* Group C2	3613	0.3523	85	*S.* Newbrunswick	427	0.04164
36	*S.* Sandiego	3524	0.3437	86	*S.* Marina	377	0.03677
37	*S.* Mbandaka	3291	0.3209	87	*S.* Glostrup	369	0.03599
38	*S.* Bareilly	3243	0.3163	88	*S.* California	342	0.03335
39	*S.* Brandenburg	3055	0.2979	89	*S.* Eastbourne	337	0.03286
40	*S.* Weltevreden	2972	0.2898	90	*S.* Flint	321	0.0313
41	*S.* Give	2871	0.28	91	*S.* Hvittingfoss	303	0.02955
42	*S.* Tennessee	2847	0.2776	92	*S.* Stanleyville	291	0.02838
43	*S.* Stanley	2524	0.2461	93	*S.* Pomona	268	0.02614
44	*S.* London	2519	0.2457	94	*S.* Lindenburg	262	0.02555
45	*S.* Dublin	2503	0.2441	95	*S.* Irumu	256	0.02497
46	*S.* Cerro	2502	0.244	96	*S.* Istanbul	238	0.02321
47	*S.* Chester	2462	0.2401	97	*S.* Bardo	236	0.02301
48	*S.* Choleraesuis	2250	0.2194	98	*S.* Lomalinda	219	0.02136
49	*S.* Muenster	2063	0.2012	99	*S.* Madelia	216	0.02106
50	*S.* Indiana	1946	0.1898	100	*S.* Subspecies IIIA	212	0.02067

Note: *S.* Typhimurium includes var. copenhagen
S. Choleraesuis includes var. kunzendorf

Figure 19. Non-human sources of S. Enteritidis (1968-1998).

Figure 20. Summary maps for S. Typhimurium by county.

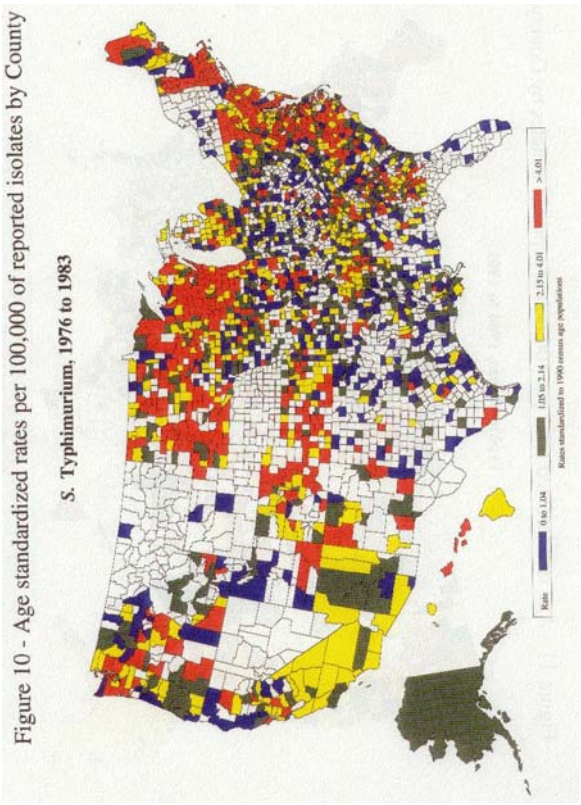


Figure 10 - Age standardized rates per 100,000 of reported isolates by County

***S.* Typhimurium, 1976 to 1983**

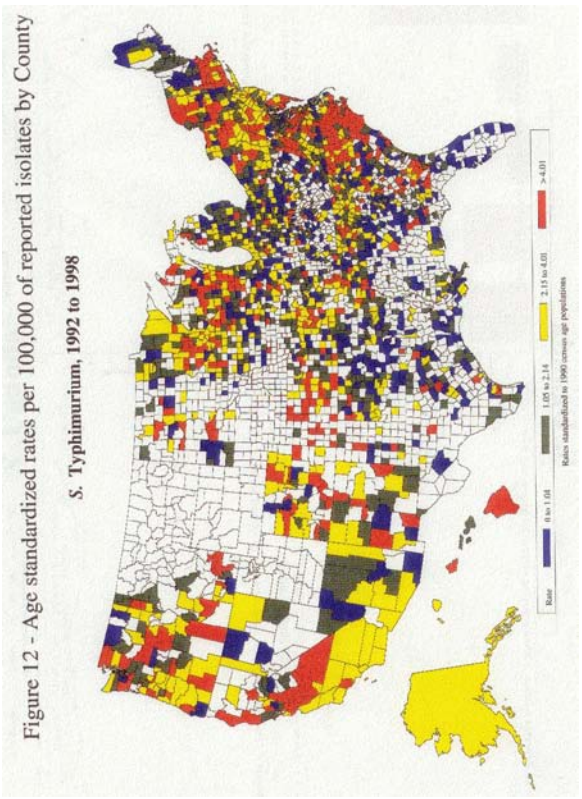


Figure 12 - Age standardized rates per 100,000 of reported isolates by County

***S.* Typhimurium, 1992 to 1998**

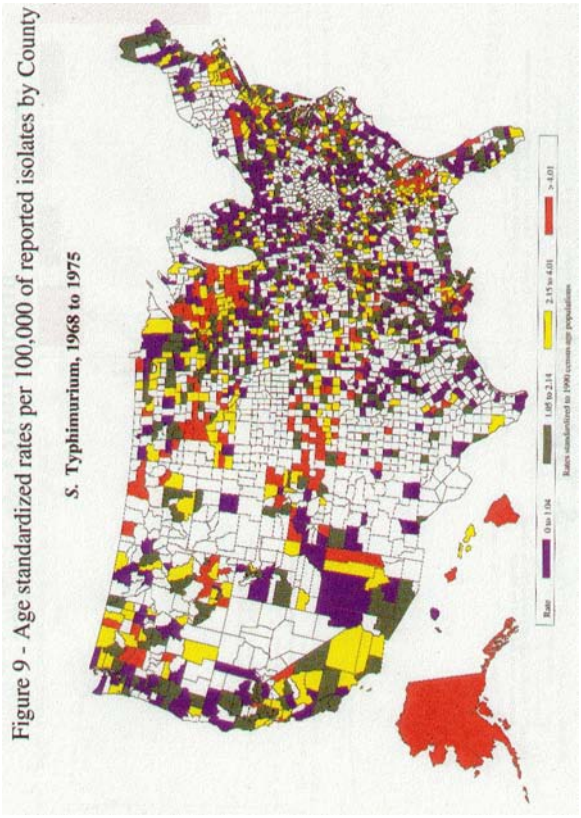


Figure 9 - Age standardized rates per 100,000 of reported isolates by County

***S.* Typhimurium, 1968 to 1975**

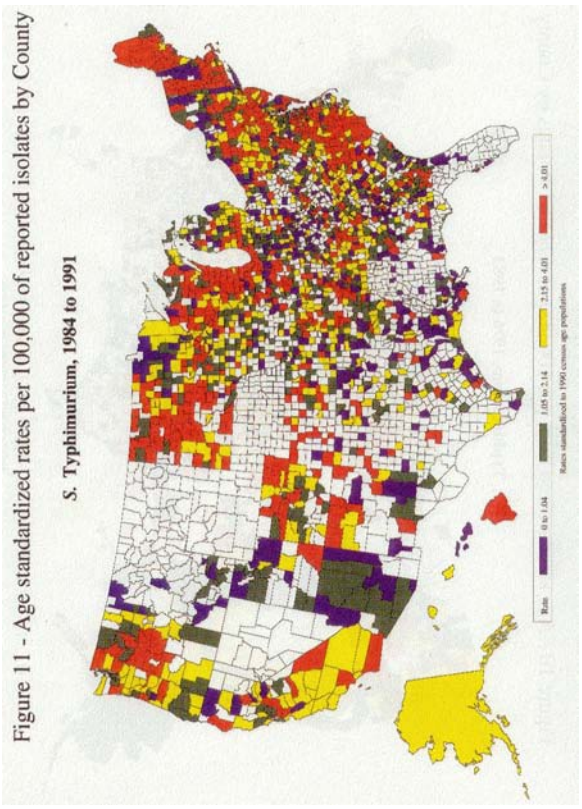


Figure 11 - Age standardized rates per 100,000 of reported isolates by County

***S.* Typhimurium, 1984 to 1991**

Figure 21. Summary maps for S. Enteritidis by county.

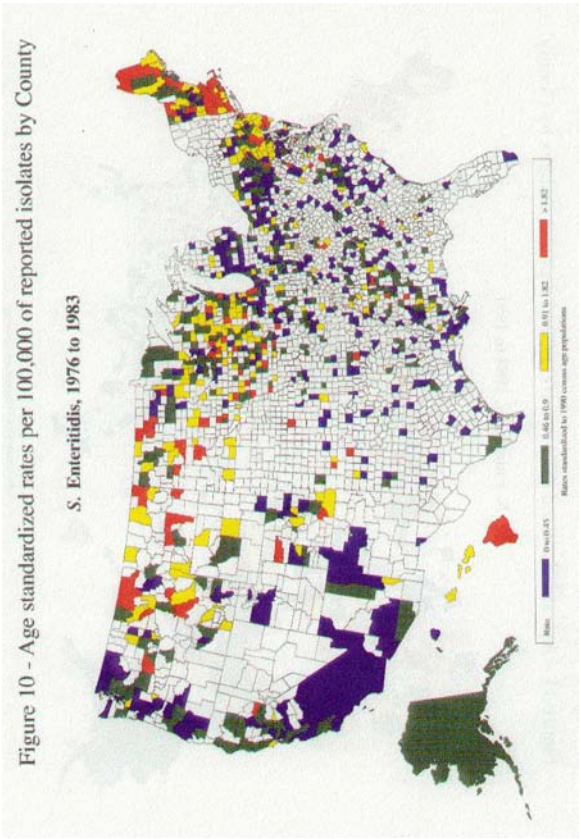


Figure 10 - Age standardized rates per 100,000 of reported isolates by County

S. Enteritidis, 1976 to 1983

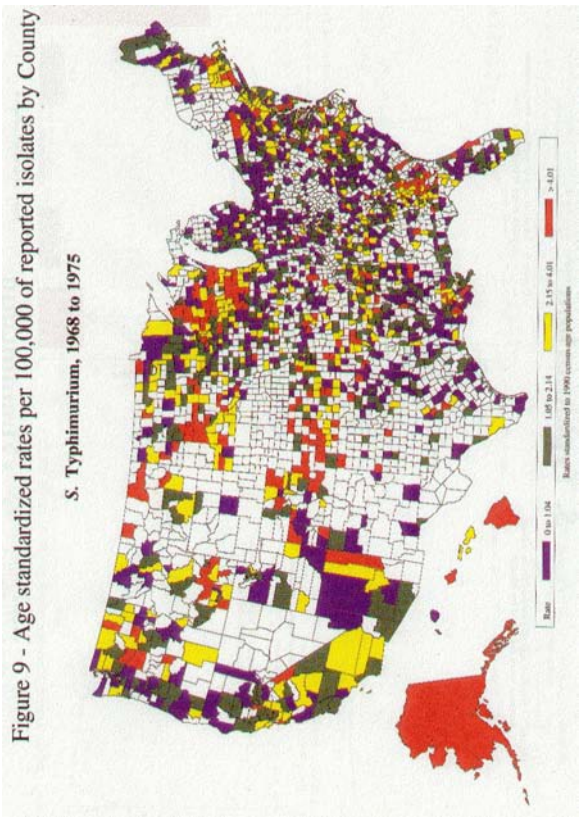


Figure 9 - Age standardized rates per 100,000 of reported isolates by County

S. Typhimurium, 1968 to 1975

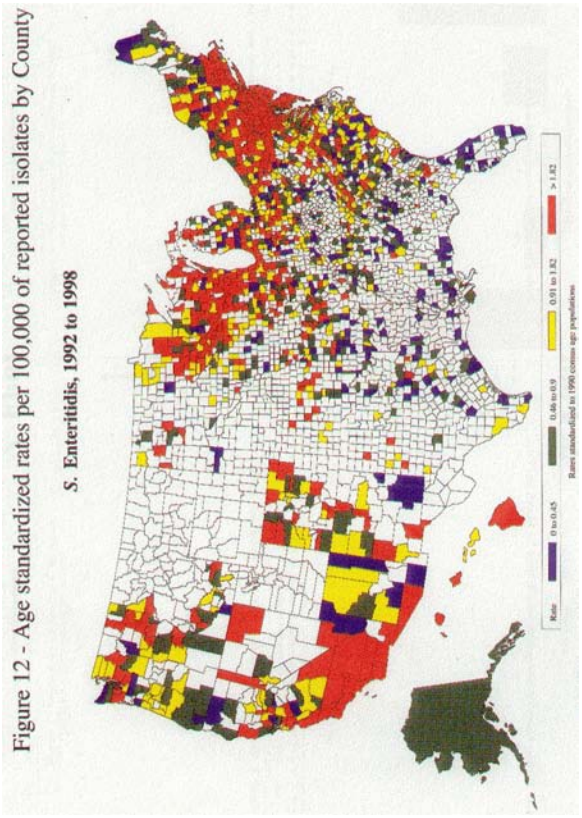


Figure 12 - Age standardized rates per 100,000 of reported isolates by County

S. Enteritidis, 1992 to 1998

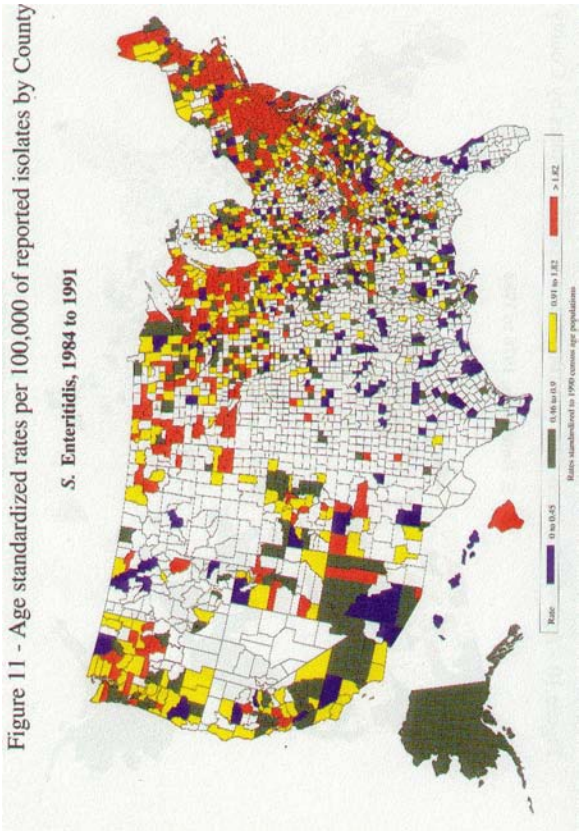


Figure 11 - Age standardized rates per 100,000 of reported isolates by County

S. Enteritidis, 1984 to 1991

Table 4. Example of Year, 2002 report from Minnesota illustrating available data for baseline and "post-diversion" monitoring.

Cases of Selected Communicable Diseases Reported to the Minnesota Department of Health, by District of Residence, 2002

Disease	District* (population per U.S. Census 2000)									
	Metropolitan (2,642,056)	Northwestern (152,001)	Northeastern (248,425)	Central (683,787)	West Central (222,691)	South Central (280,332)	Southeastern (460,102)	Southwestern (230,085)	Unknown Residence	Total (4,919,479)
Campylobacteriosis	480	22	37	127	52	50	104	69	0	941
Cryptosporidiosis	44	2	11	38	37	7	49	18	0	206
Ehrlichiosis	31	0	3	109	0	1	4	1	0	149
Encephalitis - viral										
LaCrosse	8	0	0	0	0	2	3	0	0	13
West Nile	13	4	0	4	10	4	5	8	0	48
Escherichia coli O157 infection	51	5	14	27	14	5	31	13	0	160
Hemolytic Uremic Syndrome	3	0	2	4	1	0	1	0	0	11
Giardiasis	533	13	32	133	23	59	125	64	0	982
Haemophilus influenzae invasive disease	24	3	4	6	4	2	7	2	0	52
HIV infection other than AIDS	189	1	4	8	1	2	5	0	1	211
AIDS (cases diagnosed in 2002)	135	1	2	7	1	1	3	0	1	151
Legionnaires' disease	12	0	5	0	0	0	1	0	0	18
Listeriosis	1	0	0	2	0	0	1	0	0	4
Lyme disease	401	11	22	358	5	14	52	4	0	867
Measles	2	0	0	0	0	0	0	0	0	2
Mumps	5	0	0	0	0	0	0	0	0	5
Neisseria meningitidis invasive disease	8	3	6	3	1	4	8	3	0	36
Pertussis	287	6	22	49	3	1	8	53	0	429
Rubella	0	0	0	0	0	0	0	0	0	0
Salmonellosis	349	14	31	61	27	26	54	31	0	593
Sexually transmitted diseases*	10,229	163	476	886	181	348	736	285	0	13,304
Chlamydia trachomatis - genital infections	7,402	152	423	755	158	314	640	263	0	10,107
Gonorrhea	2,697	10	53	123	22	34	91	19	0	3,049
Syphilis, total	130	1	0	8	1	0	5	3	0	148
primary/secondary	55	0	0	2	0	0	1	1	0	59
early latent**	23	0	0	0	0	0	0	0	0	23
late latent***	50	1	0	6	1	0	4	2	0	64
congenital	1	0	0	0	0	0	0	0	0	1
other	1	0	0	0	0	0	0	0	0	1
Chancroid	0	0	0	0	0	0	0	0	0	0
Shigellosis	169	10	1	13	14	5	6	4	0	222
Streptococcus pneumoniae invasive disease	300	22	38	88	31	38	56	25	0	598
Streptococcal invasive disease - Group A	82	4	10	14	4	5	23	5	0	147
Streptococcal invasive disease - Group B	187	7	26	31	10	10	31	9	0	311
Tuberculosis	184	0	5	10	5	7	20	6	0	237
Viral hepatitis, type A	39	0	3	2	2	1	6	0	0	53
Viral hepatitis, type B (acute infections only, not perinatal)	36	0	4	5	2	1	2	2	0	52
Viral hepatitis, type C (acute infections only)	2	0	6	5	1	0	0	0	0	14
Yersiniosis	7	1	1	5	1	1	2	1	0	19

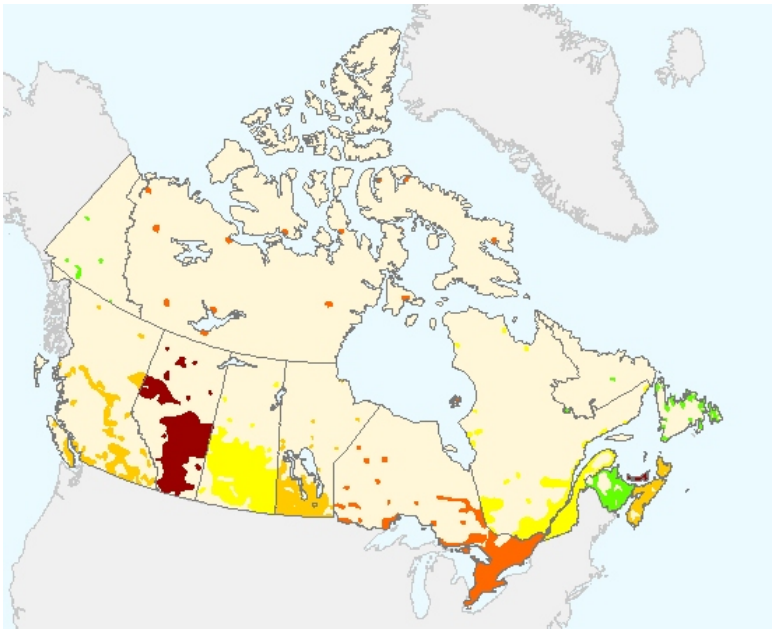
*Cases for which the patient's residence is unknown are assigned the geographic location of the reporting clinic.
**Duration ≤1 year
***Duration >1 year

County Distribution within Districts
Metropolitan - Anoka, Carver, Dakota, Hennepin, Ramsey, Scott, Washington
Northwestern - Beltrami, Clearwater, Hubbard, Kittson, Lake of the Woods, Marshall, Pennington, Polk, Red Lake, Roseau
Northeastern - Aitkin, Carlton, Cook, Itasca, Koochiching, Lake, St. Louis
Central - Benton, Cass, Chisago, Crow Wing, Isanti, Kanabec, Mille Lacs, Morrison, Pine, Sherburne, Stearns, Todd, Wadena, Wright
West Central - Becker, Clay, Douglas, Grant, Mahnomen, Norman, Otter Tail, Pope, Stevens, Traverse, Wilkin
South Central - Blue Earth, Brown, Faribault, LeSueur, McLeod, Martin, Meeker, Nicollet, Sibley, Waseca, Watonwan
Southeastern - Dodge, Fillmore, Freeborn, Goodhue, Houston, Mower, Olmsted, Rice, Steele, Wabasha, Winona
Southwestern - Big Stone, Chippewa, Cottonwood, Jackson, Kandiyohi, Lac Qui Parle, Lincoln, Lyon, Murray, Nobles, Pipestone, Redwood, Renville, Rock, Swift, Yellow Medicine

Notifiable Diseases On-Line

Population and Public Health Branch (PPHB)

Figure 22. Province-wide records for Salmonellosis (both sexes combined, including not specified); all ages, including not specified), 2000.



Rate per 100,000 population	6.53 - < 14.62	14.62 - < 16.75	16.75 - < 19.58	19.58 - < 23.85	23.85 - 65.45

Province	**Rate/100,000**
Newfoundland	7.62
Prince Edward Island	23.85
Nova Scotia	18.25
New Brunswick	13.63
Quebec	14.62
Ontario	19.96
Manitoba	16.75
Saskatchewan	16.15

Alberta	26.94
British Columbia	17.14
Yukon	6.54
Northwest Territories	19.58
Nunavut	65.45

Data last updated: 2003

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Protozoan infectious agents and waterborne disease. Key protozoa being considered as representative agents of waterborne disease in this investigation include:

- Cryptosporidium
- Giardia

[9]**Cryptosporidium parvum**. The current taxonomic status of *Cryptosporidium* aligns the genus with other coccidia, although recent molecular studies have shown that members of the genus are more closely related to the gregarines than to eimerians or even the malaria. The current taxonomic position of *Cryptosporidium* places the genus in the Phylum Apicomplexa, Class: Conoidasida (see Roberts and Janovy 2005).

Cryptosporidium parvum is a parasitic protozoan about 5 microns in diameter and spherical in shape. Members of the genus infect epithelial surfaces, especially those along the gut, and can be found in a wide range of vertebrates. *C. parvum* is predominately a parasite of neonate animals, and older animals generally develop milder infections, even when unexposed previously to this parasite.

Life-cycle. The life cycle of *C. parvum* is depicted in Figure 23 and begins with ingestion of the sporulated oocyst, the resistant stage found in the environment. The vertebrate intestine provides good "habitat" for these protozoan parasites, yet the number of oocysts needed to establish an infection in humans varies. For example, one study suggested that the 50% infectious dose in humans was around 132 oocysts, although one volunteer was infected with as few as 30 oocysts. In contrast, another study using a more aggressive isolate suggests that even lower numbers of oocysts (nine) can sometimes initiate infections and cause disease (see, e.g., Haas et al 1996, Gale

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[9]Original material developed by Steve J. Upton, Ph.D., Division of Biology, Ackert Hall. Kansas State University, Manhattan, Kansas; http://www.ksu.edu/parasitology/basicbio; revised and updated June, 2004 through November, 2004.

2000 and references therein, Teunis et al 2002 and references therein). Vertebrates present various degrees of susceptibility to the parasite, and the effective doses varies between individuals and among isolates.

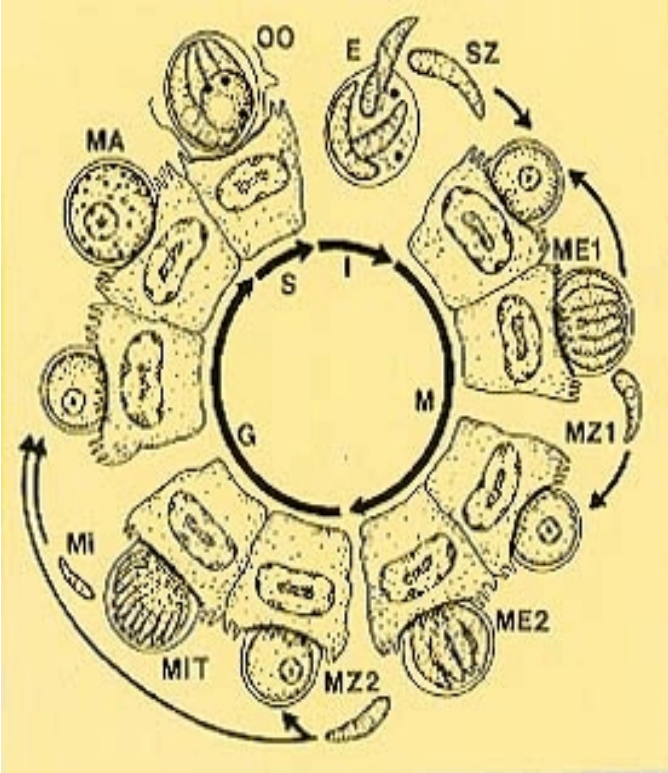


Figure 23. Life cycle of *Cryptosporidium parvum*. Abbreviations: (E) Excystation (either as thick-walled oocyst from environment or via thin-walled oocyst excysting in situ), resulting in release of 4 sporozoites through suture in wall; (G) Gamogony; (I) Infective phase; (M) Merogony; (ME1) Type I meront containing 8 merozoites; (ME2) Type II meront containing 4 merozoites; (MA) Macrogamete, containing wall forming bodies; (Mi) Microgamete; (MiT) Microgametocyte with 16 non-flagellated microgametes; (MZ1) Type I merozoite; (MZ2) Type II merozoite; (OO) oocyst; (S) Sporogony; (SZ) sporozoite. See 1986, J Protozool 33: 98-108.

Development of *Cryptosporidium* occurs rapidly, and each generation can develop and mature in as little as 12-14 hours. Due to the rapidity of the life cycle, plus the autoinfective cycles, huge numbers of organisms can colonize the intestinal tract in several days. The ileum is the primary target of infection, with secondary sites being the duodenum and large intestine. In individuals that are immunosuppressed (e.g., under medication or not immunocompetent), parasites can sometimes be found in the stomach, biliary and pancreatic ducts, and respiratory tract. Diarrhea, weight loss, and abdominal cramping are clinical signs of the disease and in immunosuppressed individuals electrolyte imbalance may occur. The prepatent period, which is the interval between infection and the first appearance of oocysts in the feces, is generally 4 days (3 days in heavy infections) in animals infected experimentally. In human outbreaks where lower numbers of oocysts are probably ingested, 4-6 days is probably typical. Patency, which is the length of time

oocysts are shed in the feces, generally lasts 6-18 days (4-10 days of diarrhea) in immunocompetent individuals but may be prolonged in immunosuppressed patients. Some individuals shed oocysts but appear asymptomatic.

Epidemiology. Oocysts of *Cryptosporidium* are widespread in the environment and can be found in freshwater surface waters such as rivers and streams, and lakes and ponds. Depending on type and location of freshwater habitat, *Cryptosporidium* oocysts may occur in high numbers. For example, surface waters receiving runoff from livestock operations characteristically present high oocysts counts, while relatively "pristine" areas may have very few oocysts. The extent of oocyst contamination, however, does not necessarily lessen the infectivity of a given "dose" of infective agent. The occurrence of *Cryptosporidium* in the environment also varies with season, e.g., *Cryptosporidium* becomes a problem in surface waters in most areas of North America is generally March-June, when spring rains increase run-off and many neonate animals are present in the environment to amplify oocyst numbers. Despite the seasonal variation in disease occurrence, studies suggest that many adult animals produce low levels of oocysts on a regular basis, which enhances the environmental load and serves as a source of infection year around. Ruminants, cervids, swine, cats, dogs, and other mammals may all contribute to numbers of *Cryptosporidium* oocysts in the environment both in rural and urban areas.

Failures or overloaded public water utilities have occasionally resulted in community outbreaks of cryptosporidiosis. In other cases, infections have been acquired from swimming pools and water parks because of fecal accidents. In most cases, various degrees of diarrhea, some weight loss and abdominal cramping were the extent of illness. In some individuals, however, specifically young children, the elderly, and immunosuppressed patients, cryptosporidiosis became chronic and life-threatening. It should be noted that it is nearly impossible to determine the origin of many individual cases of cryptosporidiosis.

Recent studies have shown that *C. parvum* exists as no less than two distinct species. Genotype 1 (or genotype H for human) is now termed *Cryptosporidium hominis* and is almost exclusively a

parasite of humans (with a few minor exceptions), while Genotype 2 (or genotype C for calf) is considered the traditional *Cryptosporidium parvum* and occurs in a wide range of animals, including humans. The former species tends to be more aggressive in humans, with a patent period nearly doubling that of genotype 2 and averaging just under 2 weeks. Rarely, both species can be found infecting the same person. Genetic markers on different chromosomes reveal there is little or no mixing between the two (i.e. isolates are not found that are composed of mixed genotypes), strongly supporting the notion that two distinct (but morphologically identical) species exist. Either species may cause an outbreak.

Cryptosporidiosis occurs throughout North America, and North Dakota, Minnesota, and Manitoba have documented cases of the disease (see Figure 24 and Figure 25). As illustrated by Figure 24 and Figure 25, epidemiologic data for *C. parvum* are available, but "as is," the data must be recompiled within the context of river basins in order to address intensive baseline

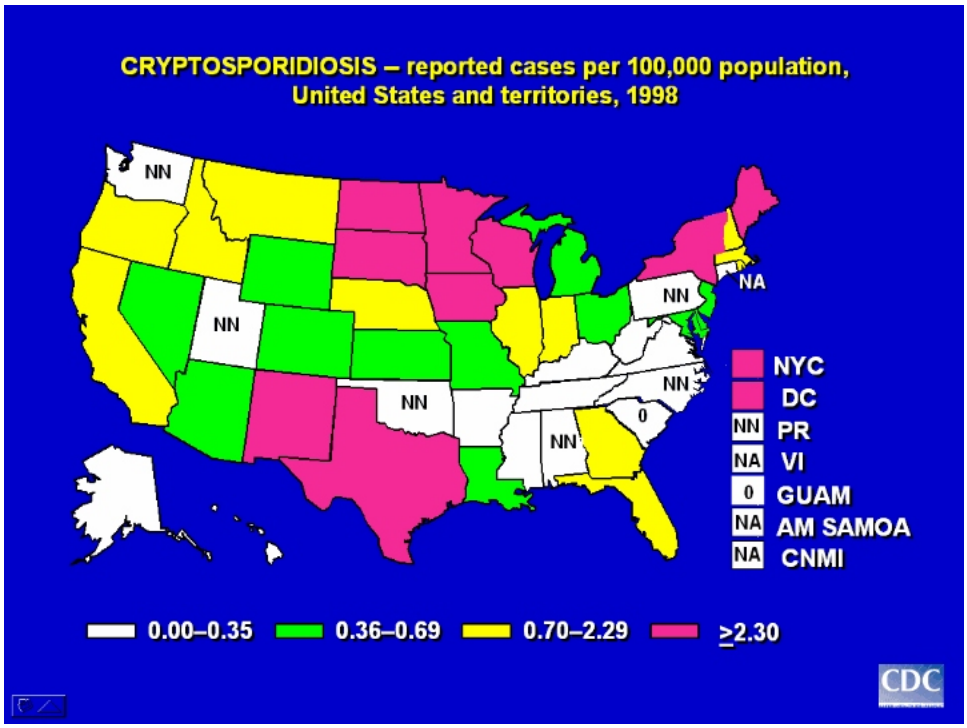


Figure 24. Incidence of cryptosporidiosis as compiled by CDC for 1998.

assessment or monitoring activity, as those relate to biota transfers that might manifest as disease

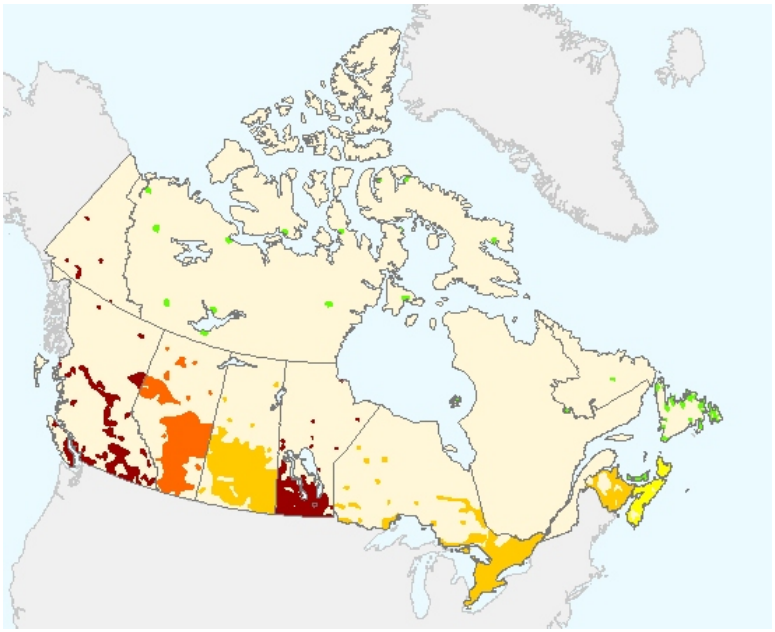
outbreaks associated with agents in source waters. Currently, available data across years suggest that incidence withing those states is similar, although statistic comparisons among states and provinces requires time-series data that presently were not incorporated into the current investigation.

Prevention and control. See Appendix 12 for overview of water treatment control technologies targeted on prevention and control of cryptosporidiosis. Because all *Cryptosporidium* infections are initiated though ingestion of environmentally resistant oocysts, control of this stage is the single most important factor in limiting the spread of the disease. Infected animals and humans will continue to contaminate the environment, and elimination of these sources is virtually impossible.

Numbers of *Cryptosporidium* oocysts reported by various groups from public water samples are highly variable. Concentration techniques for oocysts in environmental samples are relatively poor and detection methods often cross- react with algae or other debris. Hence, evaluation of disinfection is challenging. Numerous other species of *Cryptosporidium* incapable of infecting humans occur in the environment and may also cross-react in diagnostic tests. In addition, many oocysts detected are probably not viable due to age, freezing, or UV radiation. Current regulatory efforts, in part, focus on water treatment technologies targeted on preventing cryptosporidiosis (see Appendix 12).

Population and Public Health Branch (PPHB)

Figure 25. Province-wide incidence of cryptosporidiosis (both sexes combined, including not specified; all ages, including not specified), 2000.



Rate per 100,000 population	0.00 - < 0.01	0.01 - < 1.86	1.86 - < 3.19	3.19 - < 4.16	4.16 - 16.34

Province	Rate per100,000
Newfoundland	0.00
Prince Edward Island	0.00
Nova Scotia	0.64
New Brunswick	2.65
Quebec	
Ontario	1.86
Manitoba	5.76
Saskatchewan	3.13

Province	Rate per100,000
Alberta	3.19
British Columbia	4.16
Yukon	16.34
Northwest Territories	0.00
Nunavut	3.64

Data updated: 2003

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Giardia. Giardia is one of the most common protozoan parasites in vertebrates, including humans. In vertebrates, the passage of *Giardia* species from one host to another occurs predominately via a fecal-to-oral route, most frequently through ingestion of contaminated water (e.g., drinking water or water ingested with foods washed with contaminated water). *Giardia* spp. display alternation of generations and exists in two distinct life forms, the trophozoite and the cyst. The flagellated trophozoite moves about the host's gastrointestinal tract where it makes use of its adhesive disk to attach to intestinal cells lining the gut and feeds on cellular secretions of the small intestine. In contrast, the cyst stage is a thin-walled, but resistant stage of the life cycle capable of surviving in the external environment after passing from host. Both life stages can be shed by an infected host, but the trophozoite is not capable of surviving environmental conditions harsher than those characteristic of its host internal environment. Cysts can be transferred to new hosts by direct or indirect contact with the infected-host feces.

Under the Interim Enhanced Surface Water Treatment Rule (IESWTR; see guidance from EPA http://www.epa.gov/OGWDW/mdbp/ieswtr.html last accessed December 11, 2004), potable waters from water treatment facilities must meet performance criteria intended to eliminate threats of *Giardia* infections (See Text Box 1 summarizing drinking water regulatory guidance). Groundwater sourced by drinking-water wells and not be affected by leaking septic tanks or surface waters not adversely affected by land-use practices, e.g., pasture runoff, would not be expected to be contaminated with *Giardia* spp. or *Cryptosporidium* spp. Under IESWTR removal of *Giardia* should be assured, given the specified performance criteria targeted on *Cryptosporidium* which is much smaller then *Giardia*, and filtration practices intended to remove *Cryptosporidium* should remove *Giardia* cysts.

Text Box 1. Summary of EPA regulations regarding drinking water, including guidance pertinent to *Giardia* spp. and *Cryptosporidium* spp. disinfection.

Environmental Protection Agency (EPA) regulations regarding drinking water, 1974–2003

Regulation/date	Description
Safe Drinking Water Act/1974 and 1986 and 1996 amendments	Authorizes EPA to set national standards to protect drinking water and its sources
Total Coliform Rule (TCR)/and Maximum Contaminant Level (MCL)/1989	Requires routine monitoring for total coliforms of all public water systems plus periodic on-site inspections for systems that take <5 samples/month to evaluate and document treatment, storage, distribution network, operation and maintenance, and overall management. Systems that collect ≥40 samples/month (i.e., typically, systems that serve >33,000 persons) violate MCL if >5.0% of the samples collected during each month are positive for total coliforms; systems that collect <40 samples/month violate MCL if two samples during the month are positive for total coliforms. If a system has a total coliform-positive sample, then 1) that sample must be tested for the presence of fecal coliforms or *Escherichia coli*, and 2) three repeat samples must be collected (four, if the system collects ≤1 routine sample/month) within 24 hours and analyzed for total coliforms. If positive, the sample must be analyzed for fecal coliforms or *Es. coli*. In addition, ≥5 routine samples must be collected during the next month of sampling, regardless of system size. For any size system, if two consecutive total coliform-positive samples occur at one site during a month, and one of these samples is also fecal coliform-positive or *Es. coli*-positive, the system has an acute violation of the Maximum Contaminant Level and must notify the state and the public immediately.
Surface Water Treatment Rule (SWTR)/1989	Covers all water systems that use surface water or groundwater under the direct influence of surface water; all systems must disinfect their water, and the majority of systems must filter their water also, unless they meet EPA-specified filter-avoidance criteria that define high-quality source water. Specific requirements include • a combined filter-effluent–performance standard for turbidity (i.e., for rapid granular filters, 0.5 nephelometric turbidity unit [NTU] maximum for 95% of measurements [taken every 4 hours] during a month) and no single NTU reading >5.0; • watershed protection, redundant disinfection capability, and other requirements for unfiltered systems; • a 0.2-mg/L disinfectant residual entering the distribution system; and • maintenance of a detectable disinfectant residual in all parts of the distribution system. This rule requires that all such systems reduce the level of *Giardia* by 99.9% (3-log reduction) and viruses by 99.99% (4-log reduction) through a combination of removal (filtration) and inactivation (disinfection).
Information Collection Rule/ 1996–1998	Requires systems serving ≥100,000 persons to provide treatment data and monitor disinfection byproducts and source water quality parameters. Surface water systems are also required to monitor *Cryptosporidium*, *Giardia*, total culturable viruses, and total and fecal coliforms or *Es. coli* ≥1 time/month for 18 months. Results provided information to facilitate development of the Long Term 2 Enhanced SWTR, which is intended to protect against microbial risks by targeting those systems with suboptimal quality source water and to balance the health risks associated with disinfection byproducts and the anticipated Stage 2 Disinfection Byproduct Rule.
Interim Enhanced Surface Water Treatment Rule (IESWTR)/1998	Follow-up to SWTR that covers all public systems using surface water or groundwater under the direct influence of surface water and serving ≥10,000 persons. Key provisions include • a 2-log *Cryptosporidium*-removal requirement for filtered systems; • strengthened combined filter-effluent–turbidity performance standards for systems using conventional filtration treatment or direct filtration (0.3 NTU maximum for 95% of measurements during a month and no single NTU reading >1.0); • individual filter turbidity monitoring provisions;

Text Box 1 (continued). Summary of EPA regulations regarding drinking water, including guidance pertinent to *Giardia* spp. and *Cryptosporidium* spp. disinfection.

(*Continued*). Environmental Protection Agency (EPA) regulations regarding drinking water, 1974–2003

Regulation/date	Description
	• disinfection profile and benchmark provisions to ensure continued levels of microbial protection while facilities take necessary steps to comply with new disinfection byproduct standards; • revision of the definition of groundwater under the influence of surface water and the watershed-control requirements for unfiltered public water systems to include detection of *Cryptosporidium*; • requirements for covers on newly finished water reservoirs; • sanitary surveys for all surface water systems regardless of size; and • an MCL goal of zero oocysts for *Cryptosporidium*.
Lead and Copper Rule/2000 changes	Streamlines requirements, promotes consistent national implementation, and reduces the burden for water systems.
Long Term 1 Enhanced SWTR (LT1ESWTR)/2002 and the Filter Backwash Recycling Rule (FBRR)/2001	Companion regulations for 1ESWTR; LT1ESWTR applies to public water systems that use surface water or groundwater under the direct influence of surface water and that serve <10,000 persons. FBRR regulates how treatment plants recycle water that has been used to backwash a filter or that has been extracted from treatment plant sludge. FBRR regulates the point in the treatment plant at which the contaminated recycle water may be introduced, assuring that the water is subject to the entire particle and *Cryptosporidium parvum* removal process.
Long Term 2 Enhanced SWTR (LT2ESWTR)/expected in 2003	Applies to all systems using surface water or groundwater under the influence of surface water; will provide additional protection against *Cryptosporidium*. Systems will be assigned to a treatment category on the basis of their source-water *Cryptosporidium* levels; the category then determines how much additional treatment is required.
Stage 2 Disinfection Byproduct Rule (DBPR)/expected in 2003	Will apply to community water systems and nontransient noncommunity water systems that use an alternative to ultraviolet disinfection or deliver disinfected water; systems will be required to monitor for total trihalomethanes and the sum of five haloacetic acids and comply with MCLs at each monitoring location as a locational running annual average.
Ground Water Rule (GWR) (1996 amendment to EPA's Safe Drinking Water Act)/expected to be finalized in 2003	Applies to public groundwater systems (i.e., systems that have ≥15 service connections, or regularly serve ≥25 persons daily for ≥60 days/year) or any system that mixes surface and groundwater if the groundwater is added directly to the distribution system and provided to consumers without treatment. Establishes multiple barriers to protect against bacteria and viruses in drinking water from groundwater sources; establishes targeted strategy to identify groundwater systems at high risk for fecal contamination. Key areas include • system sanitary surveys; • hydrogeologic sensitivity assessments for nondisinfected systems; • source-water microbial monitoring by systems that do not disinfect and that draw from hydrogeologically sensitive aquifers or have detected fecal indicators within the system's distribution system; • corrective action by any system with substantial deficiencies or positive microbial samples indicating fecal contamination; and • compliance monitoring for systems that disinfect to ensure that they reliably achieve 4-log (99.99%) inactivation or removal of viruses. GWR does not apply to privately owned wells that serve <25 persons (e.g., individual homeowner wells).

[10]**Life history of *Giardia lamblia*.** A typical *G. lamblia* life cycle is illustrated in Figure 26. Infection occurs by the ingestion of cysts in contaminated water or food, and in the small intestine excystation releases trophozoites that multiply by longitudinal binary fission. The trophozoites

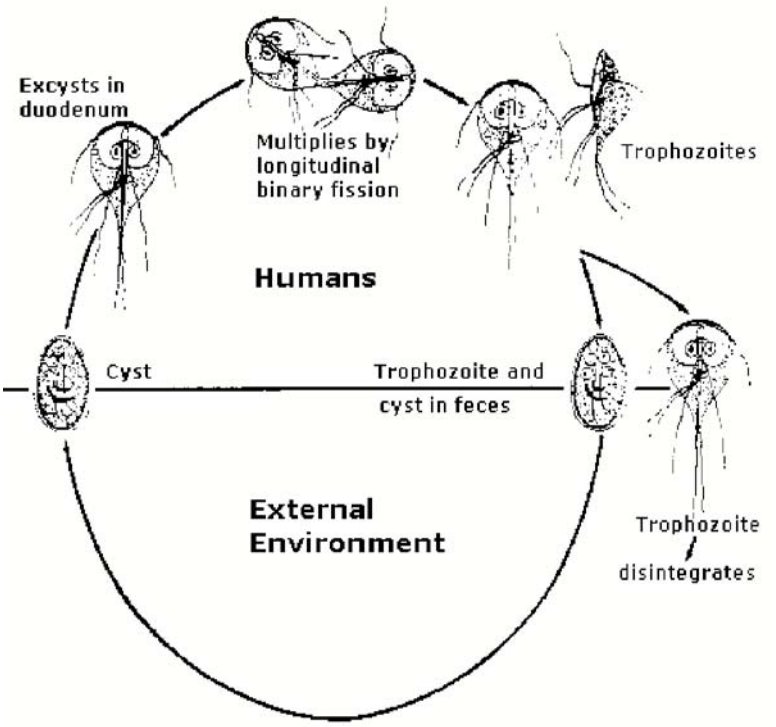


Figure 26. Life cycle of *Giardia lamblia*.

remain in the lumen of the proximal small bowel where they can be free or attached to the mucosa by a ventral sucking disk. Encystation occurs when the parasites transit toward the colon, and cysts are released to the environment with normal (non-diarrheal) feces. The cysts are hardy, can survive several months in cold water, and are responsible for transmission. Because the cysts are infectious when passed in the stool or shortly afterward, person-to-person transmission is possible. While animals are infected with *Giardia*, their importance as a reservoir is unclear, especially as that relates to the disease being a zoonosis.

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[10]Original material courtesy of the Division of Parasitic Diseases at the National Center for Infectious Diseases, Centers for Disease Control & Prevention; (accessed June, 2004 http://www.dpd.cdc.gov/DPDx/HTML/Giardiasis.htm).

Trophozoites of *G. lamblia* range from 12 to 15 µm in length and are pear-shaped. Two nuclei, median bodies, and four pairs of flagella are characteristic hallmarks of the species. Cysts of *Giardia* are the life form generally found in feces, and are ovoid, 6 to 12 µm long. Cysts contain two to four nuclei at one end and present prominent diagonal fibrils. Motile trophozoites live in the duodenum and jejunum and multiply by binary fission. As trophozoites transit the lower intestine, encystation occurs as the motile forms of the organisms enter the fecal stream, lose their motility, round up, and ultimately excreted as dormant, resistant cysts

Pathologically, the presence of intestinal trophozoites results in an increased turnover of intestinal epithelium, with replacement of mature cells by immature intestinal cells. The replacement of mature gastrointestinal epithelia with immature types reduces the gut's overall ability to digest and absorb fats and fat-soluble vitamins; hence, the diarrhea and steatorrhea observed during the course of the disease. Although antibodies are generally not produced in response to infections, both cellular and humoral host defenses are initiated consequent to infection.

Epidemiology. *Giardia* infection occurs worldwide, with an incidence usually ranging from 1.5 to 20 percent, with higher incidences generally occurring where sanitary standards are low. Although people of all ages may harbor these organisms, infants and children are more often infected than are adults. Carriers are probably more important in the spread of these organisms than symptomatic patients because cysts are less likely to be present in diarrheic stool. Recent outbreaks, some of epidemic proportions, have occurred in North America, generally linked to drinking contaminated water from community water supplies or directly from rivers and streams.

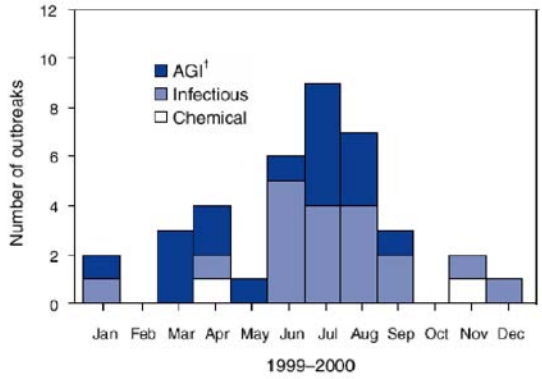
Many animals harbor *Giardia* organisms that are indistinguishable from *G. lamblia.* In the past, these isolates were assumed to be host-specific, but recent evidence suggests this is not always the case. At least some of the *Giardia* strains that parasitize animals may also infect humans and vice versa which complicates the problem of defining species in this genus. The role of animal reservoirs of *Giardia* and zoonotic mechanisms associated with human infections is also of increasing concern. For example, the finding of *Giardia*-infected animals in watersheds from

which humans acquired giardiasis, and the successful interspecies transfer of these organisms, strengthens the possibility that giardiasis is a zoonotic infection. In these settings, infected beavers are believed to be one source of water-borne giardiasis, since beaver *Giardia* isolates are capable of infecting dogs and humans. Hence, dogs may also be another source of human giardiasis. Many vertebrates harbor *Giardia* spp. indistinguishable from *G lamblia*, and there is evidence that *Giardia* strains isolated from domestic livestock or vertebrate wildlife (e.g., cattle, deer, beaver) may be infective for humans. Different strains of *G. lamblia* possibly vary in virulence. There are many sources of potentially infective agent; hence, fecal-oral transmission of disease can occur via drinking water and may be a problem wherever water treatment fails or is absent.

Multiple illustrations in Figure 27 summarize the national picture for waterborne diseases in the US for 1999-2000. Data compiled to yield graphic summaries in Figure 27 are given a regional focus on Minnesota, North Dakota, and Manitoba through summary Table 5through Table 9, and Figure 28 (with companion summary table). As such, available sources from, e.g., CDC and state, or provincial health agencies, indicate that data would be available for analysis of intensive baseline assessment or “post-diversion” monitoring studies, if interbasin water diversions are realized.

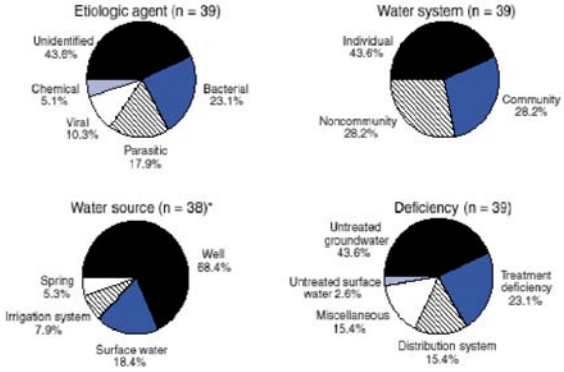
Figure 27. Multiple graphic summaries of waterborne disease occurrence in US and Canada (available from CDC at http://www.cdc.gov/ncidod/diseases/list_waterborne.htm last accessed December 14, 2004).

FIGURE 1. Number of waterborne-disease outbreaks associated with drinking water, by etiologic agent and month — United States, 1999–2000 (n = 38)*



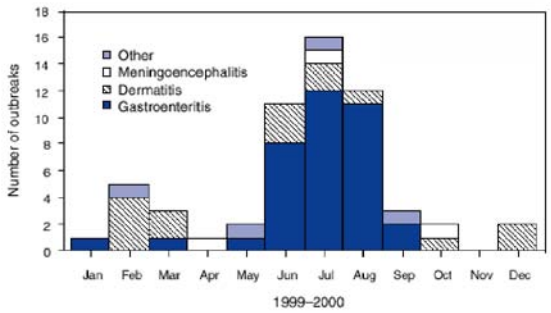
*One outbreak of *Salmonella* Bareilly was not included.
†Acute gastrointestinal illness of unknown etiology.

FIGURE 2. Waterborne-disease outbreaks associated with drinking water, by etiologic agent, water system, water source, and deficiency — United States, 1999–2000 (n = 39)



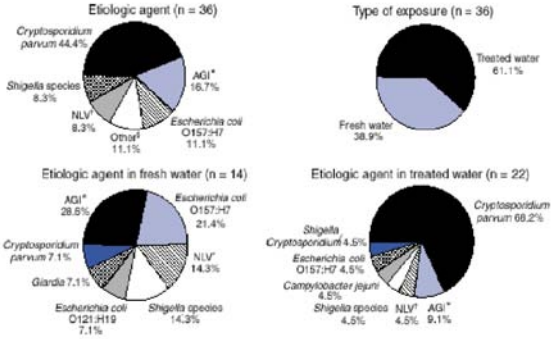
*One outbreak of *Salmonella* Bareilly was not included.

FIGURE 3. Number of waterborne-disease outbreaks associated with recreational water, by illness and month — United States, 1999–2000 (n = 58)*



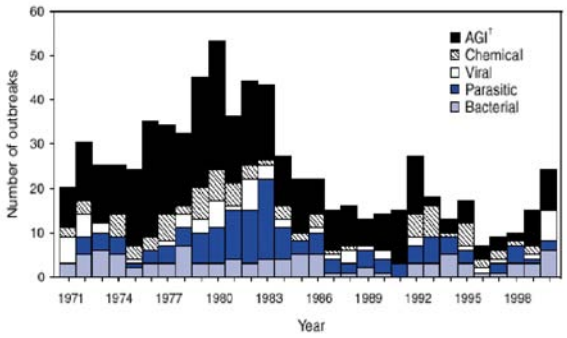
*Information regarding the month was not provided for one outbreak of meningoencephalitis.

FIGURE 4. Waterborne-disease outbreaks of gastroenteritis associated with recreational water, by etiologic agent and type of exposure — United States, 1999–2000



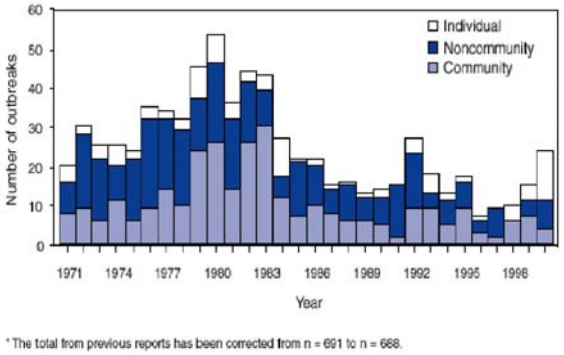
*Acute gastrointestinal illness of unknown etiology.
†Norwalk-like virus.
§These included outbreaks of *Campylobacter jejuni*, *Giardia*, *Escherichia coli* O121:H19 and one mixed *Shigella/Cryptosporidium* outbreak.

FIGURE 5. Number of waterborne-disease outbreaks associated with drinking water, by year and etiologic agent — United States, 1971–2000 (n = 730)*



*The total from previous reports has been corrected from n = 691 to n = 688.
†Acute gastrointestinal illness of unknown etiology.

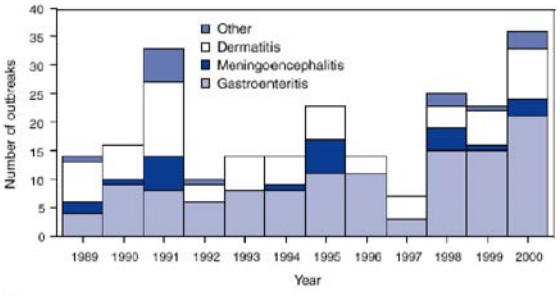
FIGURE 6. Number of waterborne-disease outbreaks associated with drinking water, by year and type of water system — United States, 1971–2000 (n = 730)*



*The total from previous reports has been corrected from n = 691 to n = 688.

Figure 27 (continued). Multiple graphic summaries of waterborne disease occurrence in US and Canada (available from CDC at http://www.cdc.gov/ncidod/diseases/list_waterborne.htm last accessed December 14, 2004).

FIGURE 7. Number of waterborne-disease outbreaks associated with recreational water, by year and illness — United States, 1989–2000 (n = 229)*



*The total from previous reports has been corrected from n = 171 to n = 170.

FIGURE 8. Number of outbreaks involving gastroenteritis associated with recreational water, by year and illness — United States, 1978–2000 (n = 146)

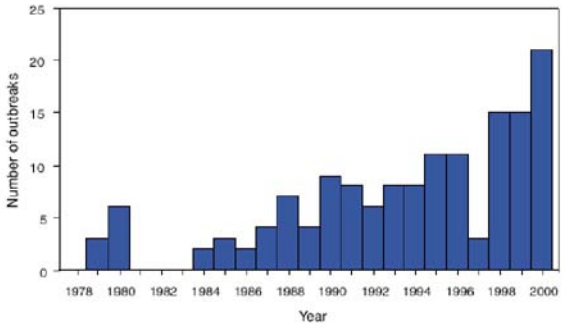


FIGURE 9. Number of outbreaks involving gastroenteritis associated with recreational water, by water type — United States, 1985–2000 (n = 135)

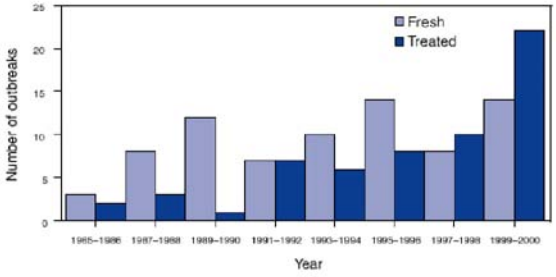


Table 5. State of Minnesota records of reportable communicable diseases, 2002.

Table 2. Cases of Selected Communicable Diseases Reported to the Minnesota Department of Health, by District of Residence, 2002

Disease	District* (population per U.S. Census 2000)									
	Metropolitan (2,642,056)	Northwestern (152,001)	Northeastern (248,425)	Central (683,787)	West Central (222,691)	South Central (280,332)	Southeastern (460,102)	Southwestern (230,085)	Unknown Residence	Total (4,919,479)
Campylobacteriosis	480	22	37	127	52	50	104	69	0	941
Cryptosporidiosis	44	2	11	38	37	7	49	18	0	206
Ehrlichiosis	31	0	3	109	0	1	4	1	0	149
Encephalitis - viral										
LaCrosse	8	0	0	0	0	2	3	0	0	13
West Nile	13	4	0	4	10	4	5	8	0	48
Escherichia coli O157 infection	51	5	14	27	14	5	31	13	0	160
Hemolytic Uremic Syndrome	3	0	2	4	1	0	1	0	0	11
Giardiasis	533	13	32	133	23	59	125	64	0	982
Haemophilus influenzae invasive disease	24	3	4	6	4	2	7	2	0	52
HIV infection other than AIDS	189	1	4	8	1	2	5	0	1	211
AIDS (cases diagnosed in 2002)	135	1	2	7	1	1	3	0	1	151
Legionnaires' disease	12	0	5	0	0	0	1	0	0	18
Listeriosis	1	0	0	2	0	0	1	0	0	4
Lyme disease	401	11	22	358	5	14	52	4	0	867
Measles	2	0	0	0	0	0	0	0	0	2
Mumps	5	0	0	0	0	0	0	0	0	5
Neisseria meningitidis invasive disease	8	3	6	3	1	4	8	3	0	36
Pertussis	287	6	22	49	3	1	8	53	0	429
Rubella	0	0	0	0	0	0	0	0	0	0
Salmonellosis	349	14	31	61	27	26	54	31	0	593
Sexually transmitted diseases*	10,229	163	476	886	181	348	736	285	0	13,304
Chlamydia trachomatis - genital infections	7,402	152	423	755	158	314	640	263	0	10,107
Gonorrhea	2,697	10	53	123	22	34	91	19	0	3,049
Syphilis, total	130	1	0	8	1	0	5	3	0	148
primary/secondary	55	0	0	2	0	0	1	1	0	59
early latent**	23	0	0	0	0	0	0	0	0	23
late latent***	50	1	0	6	1	0	4	2	0	64
congenital	1	0	0	0	0	0	0	0	0	1
other	1	0	0	0	0	0	0	0	0	1
Chancroid	0	0	0	0	0	0	0	0	0	0
Shigellosis	169	10	1	13	14	5	6	4	0	222
Streptococcus pneumoniae invasive disease	300	22	38	88	31	38	56	25	0	598
Streptococcal invasive disease - Group A	82	4	10	14	4	5	23	5	0	147
Streptococcal invasive disease - Group B	187	7	26	31	10	10	31	9	0	311
Tuberculosis	184	0	5	10	5	7	20	6	0	237
Viral hepatitis, type A	39	0	3	2	2	1	6	0	0	53
Viral hepatitis, type B (acute infections only, not perinatal)	36	0	4	5	2	1	2	2	0	52
Viral hepatitis, type C (acute infections only)	2	0	6	5	1	0	0	0	0	14
Yersiniosis	7	1	1	5	1	1	2	1	0	19

*Cases for which the patient's residence is unknown are assigned the geographic location of the reporting clinic.
**Duration ≤1 year
***Duration >1 year

County Distribution within Districts
Metropolitan - Anoka, Carver, Dakota, Hennepin, Ramsey, Scott, Washington
Northwestern - Beltrami, Clearwater, Hubbard, Kittson, Lake of the Woods, Marshall, Pennington, Polk, Red Lake, Roseau
Northeastern - Aitkin, Carlton, Cook, Itasca, Koochiching, Lake, St. Louis
Central - Benton, Cass, Chisago, Crow Wing, Isanti, Kanabec, Mille Lacs, Morrison, Pine, Sherburne, Stearns, Todd, Wadena, Wright
West Central - Becker, Clay, Douglas, Grant, Mahnomen, Norman, Otter Tail, Pope, Stevens, Traverse, Wilkin
South Central - Blue Earth, Brown, Faribault, LeSueur, McLeod, Martin, Meeker, Nicollet, Sibley, Waseca, Watonwan
Southeastern - Dodge, Fillmore, Freeborn, Goodhue, Houston, Mower, Olmsted, Rice, Steele, Wabasha, Winona
Southwestern - Big Stone, Chippewa, Cottonwood, Jackson, Kandiyohi, Lac Qui Parle, Lincoln, Lyon, Murray, Nobles, Pipestone, Redwood, Renville, Rock, Swift, Yellow Medicine

Table 6. State of Minnesota records of reportable communicable diseases, 2000.

Table 2. Cases of Selected Communicable Diseases Reported to the Minnesota Department of Health by District of Residence, 2000

Disease	District* (population; 2000 Census data)									
	Metropolitan (2,642,056)	Northwestern (152,001)	Northeastern (248,425)	Central (683,787)	West Central (222,691)	South Central (280,332)	Southeastern (460,102)	Southwestern (230,085)	Unknown Residence	Total (4,919,479)
Campylobacteriosis	589	12	26	146	43	52	140	71	0	1079
Cryptosporidiosis	43	0	28	27	5	22	60	12	0	197
Ehrlichiosis	24	2	2	48	0	0	2	1	0	79
Encephalitis - viral										
LaCrosse	5	0	0	1	0	0	2	0	0	8
Western	0	0	0	0	0	0	0	0	0	0
Escherichia coli O157:H7 infection	109	6	1	29	7	16	31	17	0	216
Hemolytic Uremic Syndrome	6	0	0	2	0	2	1	2	0	13
Giardiasis	605	6	21	178	33	17	122	38	207	1227
Haemophilus influenzae invasive disease	31	2	4	9	1	2	1	2	0	52
HIV infection other than AIDS	216	1	3	6	2	2	6	3	1	240
AIDS cases (diagnosed in 2000)	142	0	2	8	1	1	3	4	0	161
Legionnaires' disease	8	0	0	2	0	2	3	2	0	17
Listeriosis	6	0	0	1	0	0	0	0	0	7
Lyme disease	249	3	9	165	2	3	31	3	0	465
Measles	0	0	1	0	0	0	0	0	0	1
Mumps	3	0	0	2	1	0	1	0	0	7
Neisseria meningitidis invasive disease	13	0	4	0	4	0	1	0	0	22
Pertussis	460	14	3	38	11	11	23	15	0	575
Rubella	1	0	0	0	0	0	0	0	0	1
Salmonellosis	364	7	14	72	25	30	68	32	0	612
Sexually transmitted diseases*										
Chlamydia trachomatis - genital infections	6166	203	294	503	148	198	464	126	0	8102
Gonorrhea	2843	14	90	99	19	31	44	20	0	3160
Syphilis total	63	0	1	9	1	0	4	1	0	79
primary/secondary	13	0	1	1	1	0	0	0	0	16
early latent**	16	0	0	2	0	0	0	0	0	18
late latent***	32	0	0	6	0	0	4	1	0	43
congenital	2	0	0	0	0	0	0	0	0	2
Chancroid	0	0	0	0	0	0	0	0	0	0
Shigellosis	766	11	16	50	7	15	15	23	1	904
Streptococcus pneumoniae invasive disease (Twin Cities only)	439	--	--	--	--	--	--	--	--	439
Streptococcal invasive disease - Group A	96	4	12	14	5	5	8	5	0	149
Streptococcal invasive disease - Group B	175	8	24	21	9	23	24	10	0	294
Tetanus	0	0	0	1	0	0	1	0	0	2
Tuberculosis	137	5	1	6	3	2	18	6	0	178
Viral hepatitis, type A	131	0	6	10	1	19	26	4	0	197
Viral hepatitis, type B (acute infections only)	46	0	1	4	0	2	5	0	0	58
Viral hepatitis, type C (acute infections only)	5	0	4	1	1	0	3	1	0	15
Yersiniosis	4	0	0	1	1	1	3	0	0	10

*Cases for which the patient's residence is unknown are assigned the geographic location of the reporting clinic.
**Duration ≤1 year
***Duration >1 year

County Distribution within Districts
Metropolitan = Anoka, Carver, Dakota, Hennepin, Ramsey, Scott, Washington
Northwestern = Beltrami, Clearwater, Hubbard, Kittson, Lake of the Woods, Marshall, Pennington, Polk, Red Lake, Roseau
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Southwestern = Big Stone, Chippewa, Cottonwood, Jackson, Kandiyohi, Lac Qui Parle, Lincoln, Lyon, Murray, Nobles, Pipestone, Redwood, Renville, Rock, Swift, Yellow Medicine

Table 7. State of Minnesota records of reportable communicable diseases, 1998.

Table 2. Cases of Selected Communicable Diseases Reported to the Minnesota Department of Health by District of Residence, 1998

Disease	Metropolitan (2,482,858)	Northwestern (149,731)	Northeastern (244,750)	Central (634,199)	West Central (219,312)	South Central (277,691)	Southeastern (440,013)	Southwestern (234,194)	Unknown Residence	Total (4,682,748)
	District (population; 1996 estimates*)									
Campylobacteriosis	546	23	24	112	28	46	173	54	0	1006
Cryptosporidiosis	40	4	1	20	8	16	64	20	0	173
Encephalitis - viral										
LaCrosse	1	0	0	0	0	0	3	0	0	4
Western	0	0	0	0	0	0	0	0	0	0
Escherichia coli 0157:H7 infection	130	0	4	44	4	2	20	5	0	209
Hemolytic Uremic Syndrome	9	0	0	2	2	0	6	1	0	20
Giardiasis	644	11	36	131	40	31	113	47	271	1324
Haemophilus influenzae invasive disease	47	3	3	8	5	3	6	2	0	77
HIV infection other than AIDS	193	0	1	7	0	6	7	2	10	226
AIDS cases (diagnosed in 1998)	167	1	0	5	1	2	5	0	0	181
Legionnaires' disease	4	1	3	0	0	0	1	3	0	12
Listeriosis	11	1	0	0	0	2	3	2	0	19
Lyme disease	154	0	5	79	0	7	15	1	0	261
Measles	0	0	0	0	0	0	0	0	0	0
Mumps	11	0	0	0	0	1	1	0	0	13
Neisseria meningitidis invasive disease	19	1	4	6	2	0	3	1	0	36
Pertussis	313	0	18	26	5	10	15	52	0	439
Salmonellosis	328	6	18	84	28	23	80	32	2	601
Sexually transmitted diseases**										
Chlamydia trachomatis - genital infections	5438	105	234	481	113	121	385	93	0	6970
Gonorrhea	2527	7	33	60	9	16	37	19	0	2708
Syphilis total	62	0	1	3	0	1	4	4	0	75
primary/secondary	9	0	0	0	0	0	0	0	0	9
early latent***	7	0	0	1	0	0	0	0	0	8
late latent****	46	0	1	2	0	1	4	4	0	58
Shigellosis	237	4	2	20	6	9	46	7	0	331
Streptococcus pneumoniae invasive disease (Twin Cities only)	506	--	--	--	--	--	--	--	--	506
Streptococcal invasive disease - Group A	105	6	10	19	3	7	18	5	0	173
Streptococcal invasive disease - Group B	145	6	8	21	9	17	12	11	0	229
Tetanus	0	0	0	0	0	0	0	0	0	0
Tuberculosis	123	2	7	2	1	3	21	2	0	161
Vancomycin Resistant Enterococci	105	0	7	11	4	7	13	2	0	149
Viral hepatitis, type A	76	4	9	19	9	16	5	7	0	145
Viral hepatitis, type B	57	0	3	4	1	1	5	0	0	71
Viral hepatitis, type C	9	0	1	7	0	1	1	0	0	19

*For sexually transmitted diseases, 1997 population estimates from the U.S. Census Bureau are used.
**Cases for which residence is unknown are assigned the geographic location of the reporting clinic.
***Duration <1 year
****Duration >1 year

County Distribution within Districts
Metropolitan = Anoka, Carver, Dakota, Hennepin, Ramsey, Scott, Washington
Northwestern = Beltrami, Clearwater, Hubbard, Kittson, Lake of the Woods, Marshall, Pennington, Polk, Red Lake, Roseau
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Table 8. Illustrative summary of disease incidence data available for North Dakota, 2000-2001.

Summary of Reportable Conditions
North Dakota, January - June 2001 and 2000

Reportable Condition	May-Jun 2001*	Jan-Jun 2001*	May-Jun 2000	Jan-Jun 2000
AIDS	0	1	2	3
Campylobacteriosis	11	37	28	42
Chlamydia	200	501	159	452
Cryptosporidiosis	1	3	3	8
E.coli O157:H7	0	1	3	8
Giardiasis	2	28	11	32
Gonorrhea	4	16	19	35
Haemophilus influenzae (invasive)	2	4	1	2
Hantavirus Pulmonary Syndrome	0	0	0	2
Hepatitis A	0	2	2	2
Hepatitis B	0	0	0	2
HIV (without AIDS diagnosis)	1	6	1	5
Legionellosis	0	1	0	0
Malaria	0	0	0	2
Measles (Rubeola)	0	0	0	0
Meningitis, Bacterial (non meningococcal)	0	2▲	1	3
Meningococcal disease	0	5	0	1
MRSA (invasive)	0	1	0	3
Mumps	0	0	2	1
Pertussis	0	0	1	2
Q fever	0	1	0	0
Rabies (animal)	6	24	34	83
Rubella	0	0	0	0
Salmonellosis	3	15	14	35
Shigellosis	1	13	2	4
•Streptococcal Disease, Group A (invasive)	0	7	1	4
•Streptococcal Disease, Group B (infant < 3 months of age)	0	0	1	2
•Streptococcal Disease, Group B (invasive†)	0	9	2	7
•Streptococcal pneumoniae, (invasive, children < 5 years of age)	0	7	1	1
•Streptococcal pneumoniae (invasive‡)	1	11	7	14
•Streptococcus pneumoniae, drug resistant	0	4	3	7
Toxic Shock Syndrome	0	0	0	1
Tuberculosis	0	3	2	2
Tularemia	0	0	0	2

*Provisional data

▲Meningitis caused by *Staphylococcus aureus* and *Streptococcus pneumoniae*.

•Includes invasive infections caused by streptococcal disease not including those classified as meningitis.

†Includes invasive infections of streptococcal disease, Group B, in persons ≥ 3 months of age.

‡Includes invasive infections caused by *Streptococcus pneumoniae* in persons ≥ 5 years of age.

Animal Rabies by Species
January – June 2001

Animal Species	Number
Badger	1
Cat	3
Cow	5
Dog	1
Horse	1
Skunk	13

Table 9. Illustrative summary of disease incidence data available for North Dakota, 1996-2001.

Summary of Selected Reportable Conditions
North Dakota, Division of Disease Control, 1996-2001

Reportable Condition	Jan-Feb 2001*	Jan-Feb 2000	Total 2000*	Total 1999	Total 1998	Total 1997	Total 1996	5-Year median 1996-2000
AIDS	1	0	8	9	5	11	13	9
Amebiasis		1	4	5	1	1	7	4
Anthrax (human)			1	0	0	0	0	0
Botulism, infant			0	1	0	0	0	0
Botulism, other			0	1	0	0	0	0
Campylobacteriosis	8	5	106	63	57	59	75	63
Chlamydia	163	155	909	934	1036	887	1022	934
Cryptosporidiosis		1	18	20	34	15	12	18
E.coli , shiga toxin positive (non-O157)			2	NR	NR	NR	NR	2
E.coli O157:H7		3	23	19	12	15	19	19
Giardiasis	17	10	65	104	82	135	148	104
Gonorrhea	5	7	73	81	80	73	42	73
Haemophilus influenzae, invasive		1	4	2	1	0	0	1
Hantavirus Pulmonary Syndrome			2	0	0	0	0	0
Hepatitis A			4	3	4	14	140	4
Hepatitis B		2	3	2	4	7	2	3
Hepatitis C			1	1	0	4	0	1
HIV (Without AIDS diagnosis)	3	1	8	6	9	10	4	8
Legionellosis			1	2	0	2	0	1
Listeriosis			2	NR	NR	NR	NR	2
Lyme Disease			2	1	0	0	2	1
Malaria		1	3	0	3	3	1	3
Meningitis, Bacterial (not meningococcal)	1		4	6	7	6	3	6
Meningococcal disease	2	2	2	4	5	2	5	4
MRSA - invasive	1		11	NR	NR	NR	NR	11
Mumps			1	1	2	0	2	1
Pertussis		1	5	22	17	2	1	5
Q fever			0	0	2	0	0	0
Rabies (animal)	14	10	117	147	155	91	77	117
Rocky Mountain Spotted Fever			0	0	2	0	0	0
Salmonellosis	1	11	73	58	68	69	63	68
Shigellosis	9	1	61	3	11	10	80	11
Streptococcal Disease, infantile, Group B	2	1	15	6	9	7	4	7
Streptococcal Disease, invasive Group A	4	2	9	8	8	8	1	8
Streptococcal Disease, invasive°			2	NR	NR	NR	NR	2
Streptococcus pneumoniae, drug resistant	2	2	5	5	2	0	3	3
Toxic Shock Syndrome		1	1	0	1	1	2	1
Tuberculosis		1	5	7	10	12	8	8
Tularemia		2	2	NR	NR	NR	NR	2

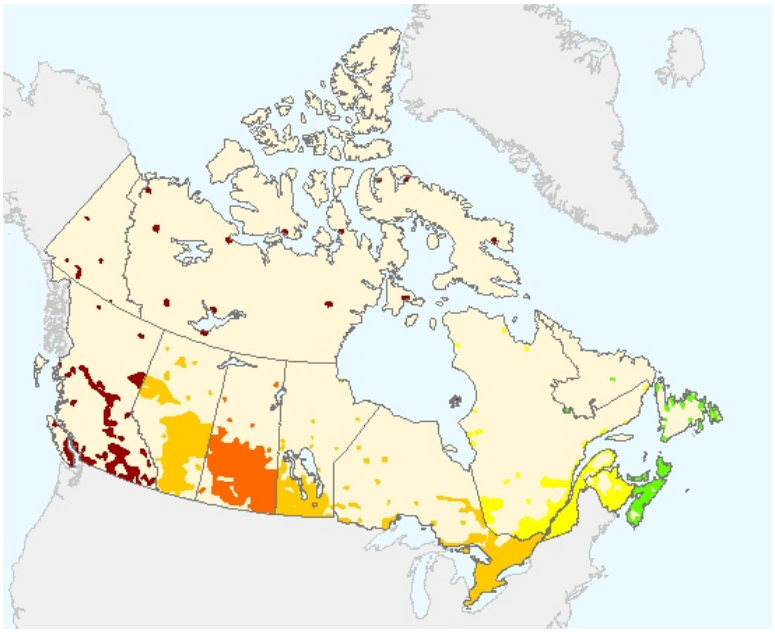
*Provisional data

NR: Not required to be reported during this year

° Includes invasive infections caused by all streptococcal organisms

On-Line Population and Public Health Branch (PPHB)

Figure 28. Province-wide incidence of giardiasis (both sexes combined, including not specified; all ages, including not specified), 2000.



Rate per 100,000 population	9.43 - < 11.51	11.51 - < 16.22	16.22 - < 20.35	20.35 - < 22.17	22.17 - 62.10

Province	**Rate/100,000**
Newfoundland	10.41
Prince Edward Island	10.84
Nova Scotia	9.44
New Brunswick	11.51
Quebec	12.61
Ontario	16.97
Manitoba	16.22
Saskatchewan	20.35
Alberta	17.24

Province	Rate/100,000
British Columbia	22.17
Yukon	62.10
Northwest Territories	34.27
Nunavut	21.82

Data updated: 2003

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Appendix 4. Analysis primer

While a comprehensive review of the tools used in analysis is not necessary to the management of risks, in this appendix we briefly discuss types of data, data distributions (especially as those relate to biota transfers), reliability and fault-tree analysis, and the evaluation of complex adaptive systems such as those characteristic of the exporting (Missouri River system), importing (Red River system), or engineering controls (e.g., water treatment and distribution system) considered in the current investigation within the context of risk reduction. For a more extensive treatment of any of the analytical tools the reader is referred to the references.

4.1 Types of Data: Categorical data and measurement data

Categorical data reflect objects being grouped into categories based on some qualitative trait, and the resulting data are merely labels (Figure 1). Common day examples of categorical data are hair color, flower colors, sex, and in our current investigation, species occurrence data (present/absent data or more precisely, found/not found data). A simple review of even these common day

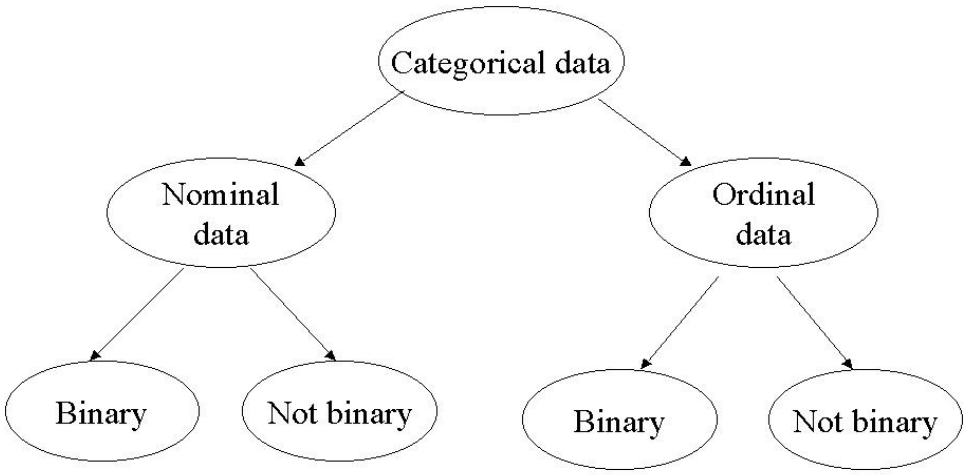


Figure 1. Types of categorical data.

examples indicates that categorical data can also be classified based upon the number of categories that are potentially characteristic of all members of the population. Categorical data are classified as being nominal, ordinal, or binary (dichotomous) in character. Nominal data are a type of categorical data in which objects fall into unordered categories (e.g., flower colors). In contrast, ordinal data are categorical data in which order is important, e.g., developmental stages of some invertebrates are an ordered set referred to as eggs, larvae, juveniles, and adults or pathological states such as morbidity may be scored as none, mild, moderate, and severe. Binary or dichotomous data are categorical data that occur as one of two possible states; that is, there are only two independent categories, e.g., species occurrence (e.g., present/absent). Binary data can either be nominal or ordinal.

Measurement data are those that are measured, based on some quantitative trait and the resulting data are set of numbers, e.g., height, weight, age, number of organisms in a region, or stream velocity (Figure 2). Measurement data are classified as discrete or continuous, where discrete

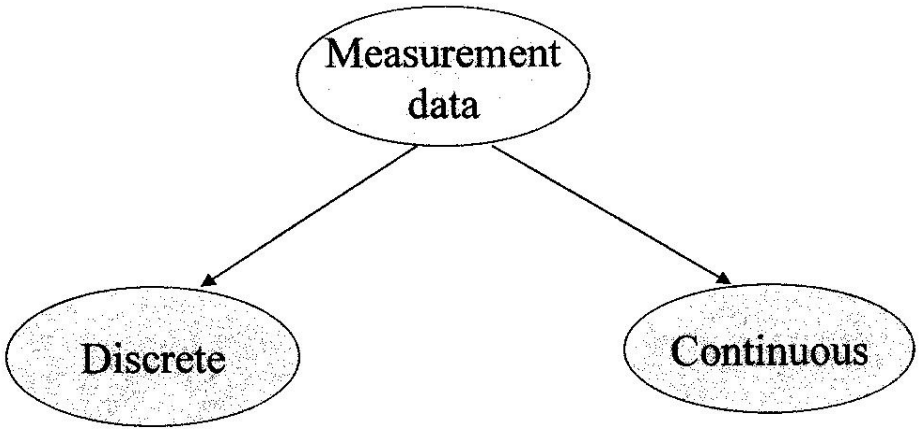


Figure 2. Types of measurement data.

measurement data occur as only certain values; that is, there are gaps between the values. Values for discrete data are generally whole numbers and occur at count data, e.g, population counts such as number of fish in a pond. In contrast to discrete measurement data, continuous measurement data may occur as any whole number plus take on any value in the interval between whole numbers, e.g., distance, height, and age. Categorical data are commonly summarized using

"percentages" (or "proportions"), and measurement data are typically summarized using "averages" (or "means") or some descriptive statistic that characterizes a particular attribute of a sample of numbers taken from a population of interest.

4.2 Data distributions encountered in the analysis of biota transfer

In data mining operations such as those implemented for the current investigation, an understanding of data and their characteristic distributions are necessary to conduct an analysis of risks, especially for probabilistic analyses (see, e.g, Bedford and Cooke 2001). Predicted or forecasted outcomes of risk scenarios, be those characterized by qualitative or quantitative methods, that capture the concerns of stakeholders reflect issues incorporated into conceptual models of alternative events (such as biota transfers yielding species invasions or shifts in metapopluations). Inevitably, data mining and the evaluation of encountered data has been completed in the absence of a fully characterized distribution of data, which is common in studies such as ours, in part, owing to dependence on diffuse data sources collected across multiple publications across a wide range of time. Our current work, however, frequently requires assumptions of data distributions likely characteristic of these data compiled during the course of the study; hence, a brief overview of frequently encountered data distributions and their interrelationships is included in this appendix in order to better characterize risks, and in particular uncertainties associated with these risks (see standard references and online sources such as Weisstein (1999), e.g., http://mathworld.wolfram.com/about/mathworld.html for source materials for this portion of Appendix 4 and additional detail on data distributions).

Bernoulli Distribution. The Bernoulli distribution is a discrete distribution having two possible outcomes labelled by $n = 0$ and $n = 1$ in which $n = 1$ ("success") occurs with probability p and $n = 0$ ("failure") occurs with probability $q \equiv 1 - p$, where $0 < p < 1$ (Figure 3; see, e.g., Evans, et al 2000; Balakrishnan and Nevzorov, 2003). As such, the distribution has probability function:

$$P(n) = \begin{cases} 1-p & \text{for } n = 0 \\ p & \text{for } n = 1, \end{cases}$$

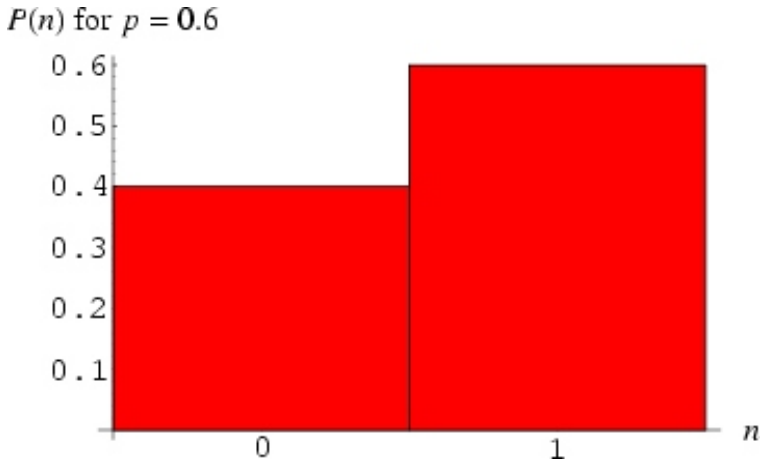


Figure 3. Bernoulli distribution.

which can also be written

$$P(n) = p^n(1-p)^{1-n}.$$

The corresponding distribution function is

$$D(n) = \begin{cases} 1-p & \text{for } n = 0 \\ 1 & \text{for } n = 1. \end{cases}$$

The performance of a fixed number of trials with fixed probability of success on each trial is known as a Bernoulli trial, which is an experiment in which *s* trials are made of an event with probability *p* of success in any given trial.

The distribution of heads and tails in coin tossing is an example of a Bernoulli distribution with $p = q = 1/2$. The Bernoulli distribution is the simplest discrete distribution and is the building block for other more complicated discrete distributions. The distributions of a number of variate types are based on sequences of independent Bernoulli trials that are constrained in some way, e.g., the binomial distribution is characterized by the number of successes in *n* trials (Evans et al 2000; Balakrishnan and Nevzorov 2003).

The characteristic Bernoulli function is

$$\phi(t) = 1 + p(e^{it} - 1),$$

and mean , variance , skewness , and kurtosis are then

$$\mu = p$$

$$\sigma^2 = p(1-p)$$

$$\gamma_1 = \frac{1-2p}{\sqrt{p(1-p)}}$$

$$\gamma_2 = \frac{6p^2-6p+1}{p(1-p)}.$$

To find an estimator $\hat{p}$ for the mean of a Bernoulli population with population mean p, let N be the sample size and suppose n successes are obtained from the N trials. Assume an estimator given by

$$\hat{p} \equiv \frac{n}{N},$$

so that the probability of obtaining the observed n successes in N trials is then

$$\binom{N}{n} p^n (1-p)^{N-n}.$$

The expectation value of the estimator $\hat{p}$ is therefore given by

$$\langle \hat{p} \rangle = \sum_{n=0}^{N} p \binom{N}{n} p^n (1-p)^{N-n}$$

$$= (1-p)^N \left(\frac{1}{1-p} \right)^N p = p,$$

so $\hat{p}$ is indeed an unbiased estimator for the population mean p.

Binomial Distribution. The binomial distribution gives the discrete probability distribution $P_p(n|N)$ of obtaining exactly *n* successes out of *N* Bernoulli trials, where the result of each Bernoulli trial is true with probability *p* and false with probability $q = 1 - p$ (see, e.g., Evans et al 2000; Balakrishnan and Nevzorov 2003). The binomial distribution is therefore given by:

$$P_p(n|N) = \binom{N}{n} p^n q^{N-n}$$

$$= \frac{N!}{n!(N-n)!} p^n (1-p)^{N-n},$$

where $\binom{N}{n}$ is a binomial coefficient . The following plot (Figure 4) shows the distribution of *n* successes out of $N = 20$ trials with $p = q = 1/2$.

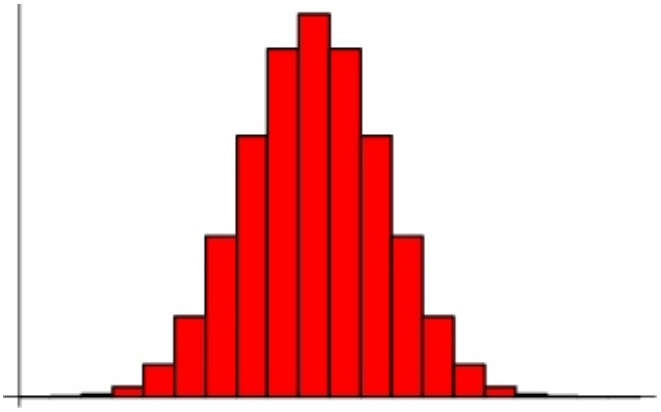


Figure 4. Binomial distribution.

The probability of obtaining *more* successes than the *n* observed in a binomial distribution is

$$P = \sum_{k=n+1}^{N} \binom{N}{k} p^k (1-p)^{N-k} = I_p(n+1, N-n),$$

where

$$I_x(a,b) \equiv \frac{B(x;a,b)}{B(a,b)},$$

$B(a,b)$ is the beta function , and $B(x;a,b)$ is the incomplete beta function.

The characteristic function for the binomial distribution is

$$\phi(t) = (q + pe^{it})^n$$

(see, e.g., Evans et al 2000; Balakrishnan and Nevzorov 2003), and the skewness and kurtosis are

$$\begin{aligned}\gamma_1 &= \frac{1-2p}{\sqrt{Np(1-p)}} \\ &= \frac{q-p}{\sqrt{Npq}} \\ \gamma_2 &= \frac{6p^2-6p+1}{Np(1-p)} \\ &= \frac{1-6pq}{Npq}.\end{aligned}$$

The mean deviation is given by

$$\mathrm{MD} = \sum_{k=0}^{N} |k - Np| \binom{N}{k} p^k (1-p)^{N-k}.$$

For the special case $p = q = 1/2$, this is equal to

$$\mathrm{MD} = 2^{-N} \sum_{k=0}^{N} \binom{N}{k} \left|k - \tfrac{1}{2}N\right|$$

$$= \begin{cases} \frac{N!!}{2(N-1)!!} & \text{for } N \text{ odd} \\ \frac{(N-1)!!}{2(N-2)!!} & \text{for } N \text{ even,} \end{cases}$$

where $N!!$ is a double factorial . For N = 1, 2, ..., the first few values are therefore 1/2, 1/2, 3/4, 3/4, 15/16, 15/16, ... A complete derivation is not included here. However, treating the distribution as continuous,

$$\lim_{N\to\infty} \sum_{n=0}^{N} P(n) \approx \int P(n)\, dn = \int_{-\infty}^{\infty} P(\tilde{n}+\eta)\, d\eta = 1.$$

Since each term is of order $1/N \sim 1/\sigma^2$ smaller than the previous, we can ignore terms higher than B_2, so

$$P(n) = P(\tilde{n}) e^{-|B_2|\eta^2/2}.$$

The probability must be normalized, so

$$\int_{-\infty}^{\infty} P(\tilde{n}) e^{-|B_2|\eta^2/2}\, d\eta = P(\tilde{n}) \sqrt{\frac{2\pi}{|B_2|}} = 1,$$

and

$$P(n) = \sqrt{\frac{|B_2|}{2\pi}} e^{-|B_2|(n-\tilde{n})^2/2}$$

$$= \frac{1}{\sqrt{2\pi Npq}} \exp\left[-\frac{(n-Np)^2}{2Npq}\right].$$

Defining $\sigma^2 \equiv Npq$,

$$P(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-(x-\mu)^2/(2\sigma^2)}$$

$$P(n) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left[-\frac{(n-\tilde{n})^2}{2\sigma^2}\right],$$

which is a normal distribution. For $p \ll 1$, a different approximation procedure shows that the binomial distribution approaches the Poisson distribution (see Haight 1967).

Normal distribution and the Central Limit Theorem. A normal distribution in a variate X with mean μ and variance σ^2 has probability function on the domain $x \in (-\infty, \infty)$. The term "normal distribution" or "Gaussian distribution" are commonly used in reference to this distribution, and because of its curved flaring shape, social scientists refer to it as the "bell curve" (Figure 5; see Patel and Read, 1982).

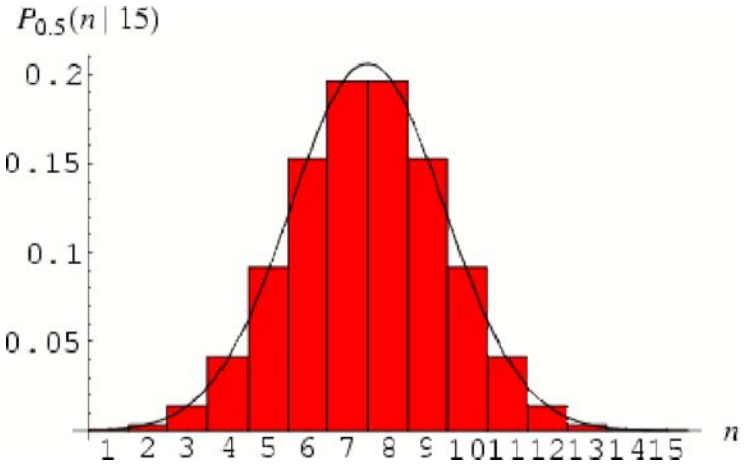


Figure 5. Normal distribution.

The so-called "standard normal distribution" is given by taking $\mu = 0$ and $\sigma^2 = 1$ in a general normal distribution. An arbitrary normal distribution can be converted to a standard normal

distribution by changing variables to $Z \equiv (X - \mu)/\sigma$, so $dz = dx/\sigma$, yielding:

$$P(x)\,dx = \frac{1}{\sqrt{2\pi}} e^{-z^2/2}\,dz.$$

The normal distribution function $\Phi(z)$ gives the probability that a standard normal variate assumes a value in the interval $[0, z]$,

$$\Phi(z) \equiv \frac{1}{\sqrt{2\pi}} \int_0^z e^{-x^2/2}\,dx = \tfrac{1}{2}\,\mathrm{erf}\left(\frac{z}{\sqrt{2}}\right),$$

where erf is a function sometimes called the error function; neither $\Phi(z)$ nor erf can be expressed in terms of finite additions, subtractions, multiplications, and root extractions. Consequently, both must be either computed numerically or otherwise approximated.

The normal distribution (Figure 5) is the limiting case of a discrete binomial distribution $P_p(n|N)$ as the sample size *N* becomes large, in which case $P_p(n|N)$ is normal with mean and variance

$$\mu = Np$$

$$\sigma^2 = Npq,$$

respectively, when $q \equiv 1 - p$.

The distribution *P*(*x*) is properly normalized since

$$\int_{-\infty}^{\infty} P(x)\,dx = 1.$$

The cumulative distribution function , which gives the probability that a variate will assume a value $\leq x$, is then the integral of the normal distribution,

$$D(x) \equiv \int_{-\infty}^{x} P(x')\,dx'$$

$$= \frac{1}{\sigma\sqrt{2\pi}} \int_{-\infty}^{x} e^{-(x'-\mu)^2/(2\sigma^2)}\,dx'.$$

$$= \frac{1}{2}\left[1 + \mathrm{erf}\left(\frac{x-\mu}{\sigma\sqrt{2}}\right)\right],$$

where erf is again called the error function.

Normal distributions have many convenient properties, so random variates with unknown distributions are often assumed to be normal. Although this can be a dangerous assumption, it is often a good approximation due to a surprising result known as the central limit theorem . This theorem states that the mean of any set of variates with any distribution having a finite mean and variance tends to the normal distribution. Many common attributes conform to a normal distribution, with few members at the high and low ends and many in the middle. Because the normal distribution occurs frequently, there is a tendency to invoke assumptions of normality in situations where they may not be applicable: "Everybody believes in the exponential law of errors: the experimenters, because they think it can be proved by mathematics; and the mathematicians, because they believe it has been established by observation" (Whittaker and Robinson 1967).

The unbiased estimator for the variance of a normal distribution is given by

$$\sigma^2 = \frac{N}{N-1} s^2,$$

where

$$s \equiv \frac{1}{N} \sum_{i=1}^{N} (x_i - \bar{x})^2,$$

so

$$\mathrm{var}(\bar{x}) = \frac{s^2}{N-1}.$$

The characteristic function for the normal distribution is

$$\phi(t) = e^{i\mu t - \sigma^2 t^2/2},$$

and the variance , skewness , and kurtosis excess are given by

$$\mathrm{var}(x) = \sigma^2$$

$$\gamma_1 = 0$$

$$\gamma_2 = 0.$$

The variance of the sample variance s^2 for a general distribution is given by

$$\mathrm{var}(s^2) = \frac{(N-1)[(N-1)\mu_4 - (N-3)\mu_2^2]}{N^3},$$

which simplifies in the case of a normal distribution to

$$\mathrm{var}(s^2) = \frac{2\sigma^4(N-1)}{N^2}$$

(Kenney and Keeping 1951). If $P(x)$ is a normal distribution, then

$$D(x) = \frac{1}{2}\left[1 + \mathrm{erf}\left(\frac{x-\mu}{\sigma\sqrt{2}}\right)\right],$$

so variates X_i with a normal distribution can be generated from variates Y_i having a uniform distribution in (0,1) via

$$X_i = \sigma\sqrt{2}\,\mathrm{erf}^{-1}(2Y_i - 1) + \mu.$$

The normal distribution is also a special case of the chi-squared distribution , since making the substitution

$$\tfrac{1}{2}z \equiv \frac{(x-\mu)^2}{2\sigma^2}$$

gives

$$d(\tfrac{1}{2}z) = \frac{(x-\mu)}{\sigma^2}\,dx = \frac{\sqrt{z}}{\sigma}\,dx.$$

Now, the real line $x \in (-\infty, \infty)$ is mapped onto the half-infinite interval $z \in [0, \infty)$ by this transformation, so an extra factor of 2 must be added to $d(z/2)$, transforming $P(x)\,dx$ into

$$P(z)\,dz = \frac{1}{\sigma\sqrt{2\pi}} e^{-z/2} \frac{\sigma}{\sqrt{z}}\, 2(\tfrac{1}{2}\,dz)$$

$$= \frac{e^{-z/2} z^{-1/2}}{2^{1/2}\Gamma(\frac{1}{2})}\,dz$$

(Kenney and Keeping 1951), where use has been made of the identity $\Gamma(1/2) = \sqrt{\pi}$.

Poisson distribution and rare events. A Poisson process is one that satisfies the following properties:

- The numbers of changes in nonoverlapping intervals are independent for all

intervals.

- The probability of exactly one change in a sufficiently small interval $h \equiv 1/n$ is

$$P = \nu h \equiv \nu / n,$$

where ν is the probability of one change and *n* is the number of trials.

- The probability of two or more changes in a sufficiently small interval *h* is essentially 0.

In the limit of the number of trials becoming large, the resulting distribution is called a Poisson distribution (Figure 6; see Haight 1967).

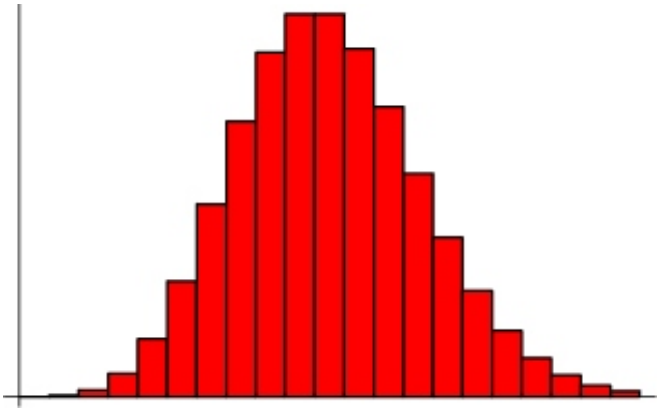


Figure 6. Poisson distribution.

Given a Poisson process, the probability of obtaining exactly *n* successes in *N* trials is given by the limit of a binomial distribution

$$P_p(n|N) = \frac{N!}{n!(N-n)!} p^n (1-p)^{N-n}.$$

Viewing the distribution as a function of the expected number of successes $\nu \equiv Np$ instead of the sample size *N* for fixed *p*, the equation then becomes

$$P_{\nu/N}(n|N) = \frac{N!}{n!(N-n)!}\left(\frac{\nu}{N}\right)^n\left(1-\frac{\nu}{N}\right)^{N-n},$$

Letting the sample size *N* become large, the distribution then approaches:

$$P_\nu(n) = \lim_{N\to\infty} P_B(n)$$

$$= \lim_{N\to\infty} \frac{N(N-1)\cdots(N-n+1)}{n!}\frac{\nu^n}{N^n}\left(1-\frac{\nu}{N}\right)^N\left(1-\frac{\nu}{N}\right)^{-n}$$

$$= \lim_{N\to\infty} \frac{N(N-1)\cdots(N-n+1)}{N^n}\frac{\nu^n}{n!}\left(1-\frac{\nu}{N}\right)^N\left(1-\frac{\nu}{N}\right)^{-n}$$

$$= 1\cdot\frac{\nu^n}{n!}\cdot e^{-\nu}\cdot 1$$

$$= \frac{\nu^n e^{-\nu}}{n!},$$

which is known as the Poisson distribution (see, e.g., Haight 1967; Papoulis 1984; Pfeiffer and Schum 1973). Note that the sample size *N* has completely dropped out of the probability function, which has the same functional form for all values of ν.

The Poisson distribution is normalized so that the sum of probabilities equals 1, since

$$\sum_{n=0}^{\infty} P_\nu(n) = e^{-\nu}\sum_{n=0}^{\infty}\frac{\nu^n}{n!} = e^{-\nu}e^{\nu} = 1.$$

The mean , variance , skewness , and kurtosis are

$$\mu = \nu$$

$$\sigma^2 = \nu$$

$$\gamma_1 \equiv \frac{\mu_3}{\sigma^3} = \frac{\nu}{\nu^{3/2}} = \nu^{-1/2}$$

$$\gamma_2 \equiv \frac{\mu_4}{\sigma^4} - 3 = \frac{\nu(1+3\nu)}{\nu^2} - 3$$

$$= \frac{\nu + 3\nu^2 - 3\nu^2}{\nu^2} = \nu^{-1}.$$

The characteristic function for the Poisson distribution is

$$\phi(t) = e^{\nu(e^{it}-1)}$$

(Haight 1967; Papoulis 1984), and the cumulative function is

$$K(h) = \nu(e^h - 1) = \nu(h + \tfrac{1}{2!}h^2 + \tfrac{1}{3!}h^3 + \ldots),$$

so

$$\kappa_r = \nu.$$

The Poisson distribution can also be expressed in terms of

$$\lambda \equiv \frac{\nu}{x},$$

the rate of changes, so that

$$P_\nu(n) = \frac{(\lambda x)^n e^{-\lambda x}}{n!}.$$

Biological implications of data types and data distributions. While the underlying mathematical principals excerpted from http://mathworld.wolfram.com/about/mathworld.html (see Weisstein (1999), last accessed November 16, 2004) and briefly summarized in this appendix are infrequently considered in the quantitative assessment of biological functions and processes,

the risk analysis and subsequent interpretation of risks must be completed and interpreted with an awareness of what these principals are and what they mean within the context of managing risks characterized by investigations such as the current effort dependent on existing data and available information from a wide variety of sources.

Species presence and absence data, or more appropriately stated, data that characterize species as found or not found, are binary or Bernoulli variables. As noted in the preceding sections of the primer, a Bernoulli random variable is formally described as a variable that results from an experiment in which *s* trials are made of an event, with probability *p* of success (i.e., found) in any given trial. By definition, a failure (i.e., not found) in any given trial is characterized as $q = 1 - p$. The classical example of a Bernoulli trial is a coin toss, preferably with a "fair coin," one where the probability of a head or tail is equal on any given trial. A binomial distribution will characterize the outcomes of repeated Bernoulli trials, where the binomial distribution gives the discrete probability distribution of obtaining exactly *n* successes out of *N* Bernoulli trials where the result of each Bernoulli trial is characterized by a probability $p + q = 1$. The binomial distribution is therefore given by

$$P_p(n|N) = \binom{N}{n} p^n q^{N-n}$$

$$= \frac{N!}{n!(N-n)!} p^n (1-p)^{N-n},$$

where $\binom{N}{n}$ is a binomial coefficient. While the intricacies of interrelationships between differing statistical distributions will not be developed further (see Evans et al 2000 and Balakrishnan and Nevzorov 2003 for additional details), there are two important distributions, the normal

distribution as specified,

$$P(n) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left[-\frac{(n-\tilde{n})^2}{2\sigma^2}\right],$$

and the Poisson distribution as specified,

$$P_\nu(n) = \frac{\nu^n e^{-\nu}}{n!},$$

which appear as the limits for sequences of binomial distributions. The differences between these limiting distributions reflects the contrasting asymptotic behaviors of alternative sequences of binomial random variables and reflect the influence of sample size and *p* values on system behavior (e.g., distributions of binomial random variables reflecting $p << 1$ approach limits captured by the Poisson distribution). Applications of these analytical tools to problems such as those of interest in the present investigation reflect these asymptotic behaviors and their boundary conditions.

The balance of this section will focus on an overview of how these distributional properties influence the work completed as part of this investigation focused on potential biota transfers between the Missouri River and Red River basins.

4.3 Reliabililty and fault-tree analysis: Fault-Probability Trees (FPTs)

Complex interactive systems, be those engineered systems designed and constructed following industry standards or biological systems at any level of organization (e.g., molecular, cellular, tissues and organs, organismic, populations, communities, or ecosystems), are subject to inevitable events commonly referred to as "failures." These failures potentially compromise the system's performance for various time periods, ranging from the inconsequential events to catastrophic terminal events. Failure analysis, especially within the context of biological systems and their relationships to alternative engineering systems, was a primary tool in the evaluation of

risks of biota transfers associated with water diversions between the Missouri River and Red River basin.

Failures range from the inconsequential to the catastrophic. But, from the point of view of assessing system reliability, catastrophic failures are handled no differently from failures that occur when a key parameter of a system of interdependent components drifts slightly out of specification. Regardless of the systems complexity, departures from nominal structure or function call for an unscheduled maintenance action or recovery process in engineering or ecological systems, respectively. Consequences associated with failure events vary widely, since the restoration of a system's performance is a function of magnitude of departure (e.g., more than one component fails) and the sensitivity of the system to failure of its various components (e.g., not all components may be equally sensitive to failure and some components may be more critical to system performance than others at various periods in a system's lifetime).

For the current investigation, problem formulation identified the "failures" that were the major concerns of Reclamation and Technical Team. From a system perspective, failures were considered to be biota transfers (both species invasions and shifts in metapopulations) that were variably affected by alternative control systems interjected into the water diversion to the attendant reduce risks. Failure analysis, then, was critical to the evaluation of risks, since the biological or ecological "failures" (e.g., a species invasion) associated with interbasin water transfers were influenced by "failures"in the alternative technologies incorporated into the proposed water distribution system linking Missouri River sources with importing areas in the Red River basin.

As background to the current investigation and to encourage future iterations of this analysis consider the critical interactions between biological and ecological systems and the role that engineering systems play in reducing risks, a brief overview of failure analysis follows. For more comprehensive technical guidance on failure analysis and its potential value in evaluating risks and consequences, the reader is referred to Barlow (1998), Blischke and Parbhakar Murthy (2000),

and NIST/SEMATECH (2004).

Repairable and non-repairable systems and lifetime distribution models. A repairable system is one which can be restored to satisfactory operation following some scheduled or unscheduled action to remedy a departure from acceptable performance (a failure), e.g., control systems involving water filtration will have a routine maintenance schedule to reduce risks of failure in treatment system, or ecosystems may recover following unsuccessful species invasions. When discussing the rate at which failures occur during system operation (and are then repaired), an engineer will define a "Rate Of Occurrence Of Failure" (ROCF) or "repair rate" which would be roughly equivalent to the restoration ecologist's term of "recovery rate." While the engineer actively develops corrective action plans (e.g., scheduled maintenance), restoration ecologists may assume active or passive roles in the recovery process (see, e.g., Jordan et al 1987; Manci 1989; FISRWG, 1998). For engineering systems, "failure rates" or "hazard rates" are terms applied to the first failure times for a population of non-repairable components or to non-repairable systems. Biological analogs of non-repairable components or non-repairable systems would be characterized as aging-related events (e.g., decreased fecundity) commonly measured as changes in survivorship (for example) in life-table analysis. A non-repairable population is one for which individual items that fail are removed permanently from the population. While the system may be repaired by replacing failed units from either a similar or a different population, the members of the original population dwindle over time until all have eventually failed. The comparison to cohorts and their passage through the population ecologist's life table are clearly evident (see, e.g., Caswell 2001).

Tools for evaluating non-repairable populations. In general, population models used to describe unit lifetimes are known as lifetime distribution models regardless of whether the populations of interest are biological or engineering in origin. A population is generally considered to be all of the possible unit lifetimes for all of the units, and a random sample of size n from this population is the collection of failure times observed for a randomly selected group of n units. A lifetime distribution model can be any probability density function (or PDF), $f(t)$, defined

over the range of time from $t = 0$ to $t =$ infinity. The corresponding cumulative distribution function (or CDF), $F(t)$, characterizes the probability that a randomly selected unit will fail by time t. Figure 7 that follows illustrates the relationship between $f(t)$ and $F(t)$. The lifetime CDF may be characterized by $F(t)$ as (1) $F(t)$ = the area under the PDF $f(t)$ to the left of t; (2) $F(t)$ = the probability that a single randomly chosen new unit will fail by time t; and (3) $F(t)$ = the proportion of the entire population that fails by time t.

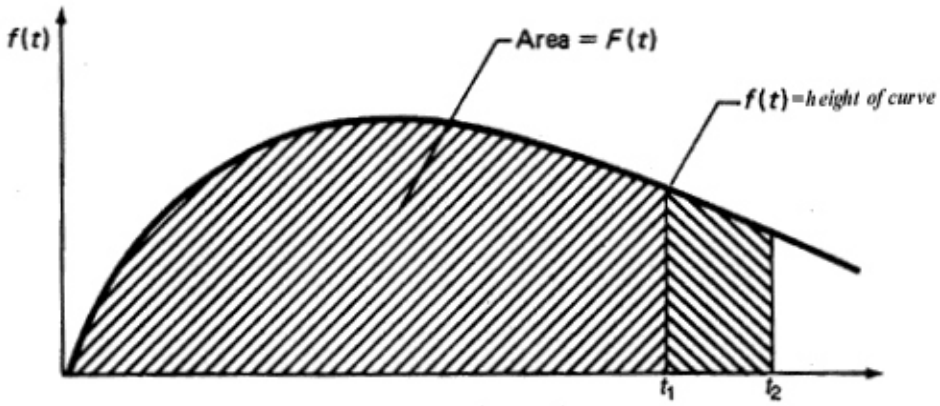


Figure 7. Cumulative distribution function for lifetime model.

The figure above also shows a shaded area under $f(t)$ between the two times t_1 and t_2. This area is $[F(t_2) - F(t_1)]$ and represents the proportion of the population that fails between times t_1 and t_2 (or the probability that a brand new randomly chosen unit will survive to time t_1 but fail before time t_2). It is worthy to note that the PDF $f(t)$ has only non-negative values and eventually either becomes 0 as t increases or decreases towards the origin. Ideally, the CDF $F(t)$ is monotonically increasing and goes from 0 to 1 as t approaches infinity. In other words, the total area under the curve is always 1.

A good example of a life distribution model is the 2-parameter Weibull distribution for $F(t)$. It has the CDF and PDF equations given by:

$$F(t) = 1 - e^{-\left(\frac{t}{\alpha}\right)^{\gamma}}, \quad f(t) = \frac{\gamma}{t}\left(\frac{t}{\alpha}\right)^{\gamma} e^{-\left(\frac{t}{\alpha}\right)^{\gamma}}$$

where γ is the "shape" parameter and α is a scale parameter called the characteristic life.

Survival is the complementary event to failure, and the reliability function, *R(t)*, also known as the survival function, *S(t)*, is defined by:

R(t) = *S(t)* = the probability a unit survives beyond time *t*.

Since a unit either fails or survives, and one of these two mutually exclusive alternatives must occur, we have

R(t) = 1 - F(t), F(t) = 1 - R(t)

Calculations using *R(t)* often occur when building up from single components to subsystems with many components. The reliability of a system is the product of the reliability functions of the components since both must survive in order for the system to survive. Building up to a "system" from the individual components is referred to as the "bottom-up" method. The bottom-up method is guided by the general rule: to calculate the reliability of a system of independent components, multiply the reliability functions of all the components.

Failure (or hazard) rate. The failure rate is the rate at which the population survivors at any given instant are "falling over the cliff," that is the failure rate is defined for non-repairable populations as the (instantaneous) rate of failure for the survivors to time *t* during the next instant of time. It is a rate per unit of time, and it represents a "snapshot" in time, since the next instant the failure rate may change and the units that have already failed play no further role since only the survivors count. The failure rate (or hazard rate) is denoted by *h(t)* and calculated from

$$h(t) = \frac{f(t)}{1 - F(t)} = \frac{f(t)}{R(t)} = \text{the instantaneous (conditional) failure rate.}$$

The failure rate is sometimes called a "conditional failure rate" since the denominator 1 - *F(t)* (i.e., the population survivors) converts the expression into a conditional rate, given survival past some time, *t*. Since *h(t)* is equal to the negative of the derivative of ln{*R(t)*}, we have the useful identity:

$$F(t) = 1 - \exp\left\{ -\int_0^t h(t)dt \right\}$$

If we let

$$H(t) = \int_0^t h(t)dt$$

be the cumulative hazard function, we then have $F(t) = 1 - e^{-H(t)}$. Two other useful identities that follow are:

$$h(t) = -\frac{d \ln R(t)}{dt}$$

$$H(t) = -\ln R(t).$$

A failure rate over any interval ($T_1 \rightarrow T_2$) characterizes an "average" failure rate for the interval and is denoted by $AFR(T_1, T_2)$. AFR's are calculated:

$$AFR(T_2 - T_1) = \frac{\left(\int_{T_1}^{T_2} h(t)dt \right)}{T_2 - T_1} = \frac{H(T_2) - H(T_1)}{T_2 - T_1} = \frac{\ln R(T_1) - \ln R(T_2)}{T_2 - T_1}$$

$$AFR(0, T) = AFR(T) = \frac{H(T)}{T} = \frac{-\ln R(T)}{T}$$

Graphical depictions of failure rates: "Bathtub" curve. A plot of the failure rate over time yields a curve that looks like a drawing of a bathtub (at least to an engineer; Figure 8). If enough units from a given population are observed operating and failing over time, it is relatively easy to compute estimates of the failure rate *h(t)*.

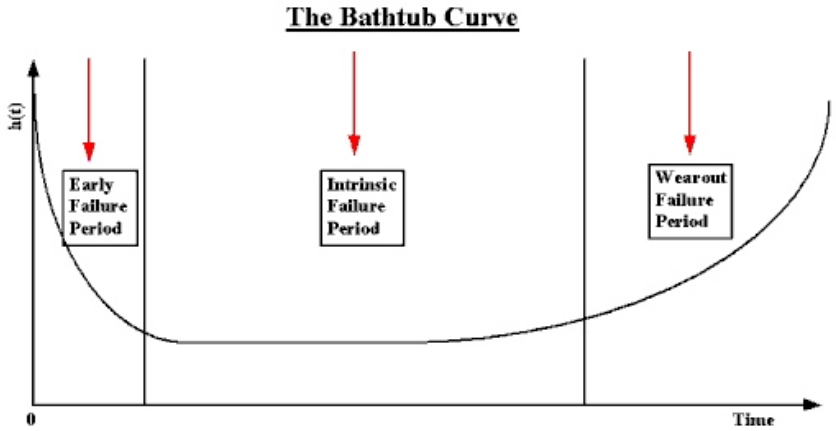


Figure 8. Typical "bathtub" curve of the reliability engineer.

In an idealized bathtub curve, the initial region begins at time zero (t_0) when a system's operation commences (which is analogous to birth in life table analysis). The system is initially characterized by a high but rapidly decreasing failure rate (e.g., early failure period for an engineering system, infant mortality period for biological populations and actuaries), with the decreasing failure rate typically lasting several weeks to a few months depending on the system. Following the initial, frequently transitory high failure rate, the failure rate levels off and remains roughly constant for throughout "useful life of the system." This long period of a relative constant failure rate is known as the intrinsic failure period or the stable failure period. The constant failure rate level during this period is referred to as the intrinsic failure rate. Most systems function most of their lifetimes in this flat portion of the bathtub curve. If units from the population remain in use long enough, the failure rate begins to increase as materials wear out and degradation failures occur at an ever increasing rate. This is the "wearout failure period."

Based on empirical observations, the bathtub curve also applies to repairable systems, but in this

instance, a "repair rate" or the "rate of occurrence of failures" (ROCOF) characterizes the ordinate of Figure 8. A different approach is used for modeling the repair rates for a repairable system, since failures occur at given system ages and the system, once repaired, be the same as new, or better, or worse than the original system. Frequency of repairs may be increasing, decreasing, or staying at a roughly constant rate, and may be characteristic of a given system.

Let *N(t)* be a counting function that keeps track of the cumulative number of failures a given system has had from t_0, t_1, t_2,. . .t_n, t_{n+1}. Then, *N(t)*is a step function that jumps up one every time a failure occurs and stays at the new level until the next failure. Every system will have its own observed *N(t)* function over time. If we observed the *N(t)* curves for a large number of similar systems and "averaged" these curves, we would have an estimate of *M(t)* = the expected number (average number) of cumulative failures by time *t* for these systems. Repair rate is the mean rate of failures per unit time, and the derivative of *M(t)*, denoted *m(t)*, is defined as the repair rate at time, *t*.

Lifetime distribution models. A handful of lifetime distribution models are commonly applied to investigations where data mining provides "starter sets" for an analysis. While empirical data sets developed as a direct result of observational or designed studies have contributed much to the literature for use in the current investigation focused on biota transfers, the inevitable stochastic character of the invasion process leads the analysis of risks to distribution models that have enjoyed great practical success in past investigations. There are a handful of distribution models that have successfully served as population models for lifetime distributions and failure times arising from a wide range of applications (e.g., engineering, biological, and ecological) and failure mechanisms. Sometimes there are probabilistic arguments based on the physics of the failure mode that tend to justify the choice of model. At other times the model is used solely because of its empirical success in fitting actual failure data. Six models frequently used are described in this appendix: Exponential, Weibull, Extreme Value, Lognormal, Gamma, and Proportional Hazards.

Exponential distribution. The exponential model with only one unknown parameter is the

simplest of all distribution models. The key equations for the exponential distribution are listed below, with the failure rate reducing to the constant λ for any time. As a consequence, another name for the exponential mean is the "mean time to fail" (MTTF) = $1/\lambda$. The exponential distribution is the only distribution to have a constant failure rate. The Cum Hazard function for the exponential is just the integral of the failure rate or $H(t) = \lambda t$. The PDF and CDF for the exponential have the familiar shapes shown below (Figure 9 and Figure 10, respectively).

$$\text{CDF: } F(t) = 1 - e^{-\lambda t}$$

$$\text{RELIABILITY: } R(t) = e^{-\lambda t}$$

$$\text{PDF: } f(t) = \lambda e^{-\lambda t}$$

$$\text{MEAN: } \frac{1}{\lambda}$$

$$\text{MEDIAN: } \frac{\ln 2}{\lambda} \cong \frac{.693}{\lambda}$$

$$\text{VARIANCE: } \frac{1}{\lambda^2}$$

$$\text{FAILURE RATE: } h(t) = \lambda$$

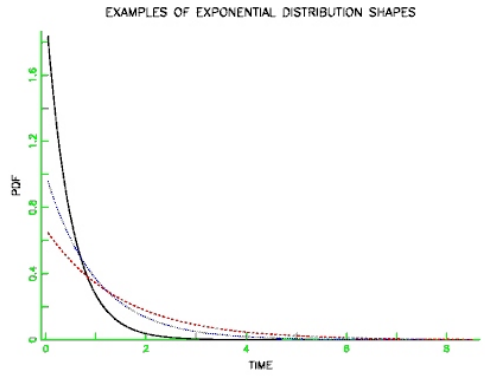


Figure 9. PDF for exponential distribution.

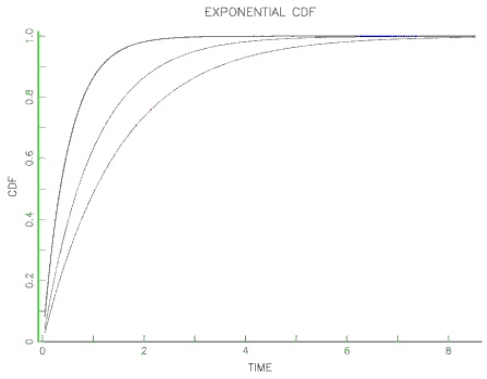


Figure 10. CDF for exponential distribution.

The exponential distribution models the flat portion of the "bathtub" curve, because of its

constant failure rate property. Since most components and systems spend most of their lifetimes in this portion of the Bathtub Curve, this justifies frequent use of the exponential distribution when early failures or wear out is not a concern.

Weibull distribution. The Weibull distribution is a very flexible life distribution model with two parameters, and has CDF and PDF and other key formulas given by:

$$\text{CDF: } F(t) = 1 - e^{-\left(\frac{t}{\alpha}\right)^{\gamma}}$$

$$\text{RELIABILITY: } e^{-\left(\frac{t}{\alpha}\right)^{\gamma}}$$

$$\text{PDF: } f(t) = \frac{\gamma}{t}\left(\frac{t}{\alpha}\right)^{\gamma} e^{-\left(\frac{t}{\alpha}\right)^{\gamma}}$$

$$\text{FAILURE RATE: } \frac{\gamma}{\alpha}\left(\frac{t}{\alpha}\right)^{\gamma-1}$$

$$\text{MEAN: } \alpha\Gamma\left(1+\frac{1}{\gamma}\right)$$

$$\text{MEDIAN: } \alpha(\ln 2)^{\frac{1}{\gamma}}$$

$$\text{VARIANCE: } \alpha^2\Gamma\left(1+\frac{2}{\gamma}\right) - \left[\alpha\Gamma\left(1+\frac{1}{\gamma}\right)\right]^2$$

with α the scale parameter (the characteristic life), γ (gamma) the shape parameter, and Γ is the Gamma function with $\Gamma(N) = (N\text{-}1)!$ for integer N. The Cum Hazard function for the Weibull is the integral of the failure rate or

$$H(t) = \left(\frac{t}{\alpha}\right)^{\gamma}$$

A more general 3-parameter form of the Weibull includes an additional waiting time parameter μ (sometimes called a shift or location parameter). The formulas for the 3-parameter Weibull are easily obtained from the above formulas by replacing t by $(t - \mu)$ wherever t appears. No failure can occur before μ hours, so the time scale starts at μ, and not 0. If a shift parameter μ is known (based, perhaps, on the physics of the failure mode), then all you have to do is subtract μ from all the observed failure times and/or readout times and analyze the resulting shifted data with a 2-parameter Weibull. When $\gamma = 1$, the Weibull reduces to the exponential model , with $\alpha = 1/\lambda$ = the "mean time to fail" (MTTF). Depending on the value of the shape parameter λ , the

Weibull model can empirically fit a wide range of data histogram shapes as illustrated below (Figure 11).

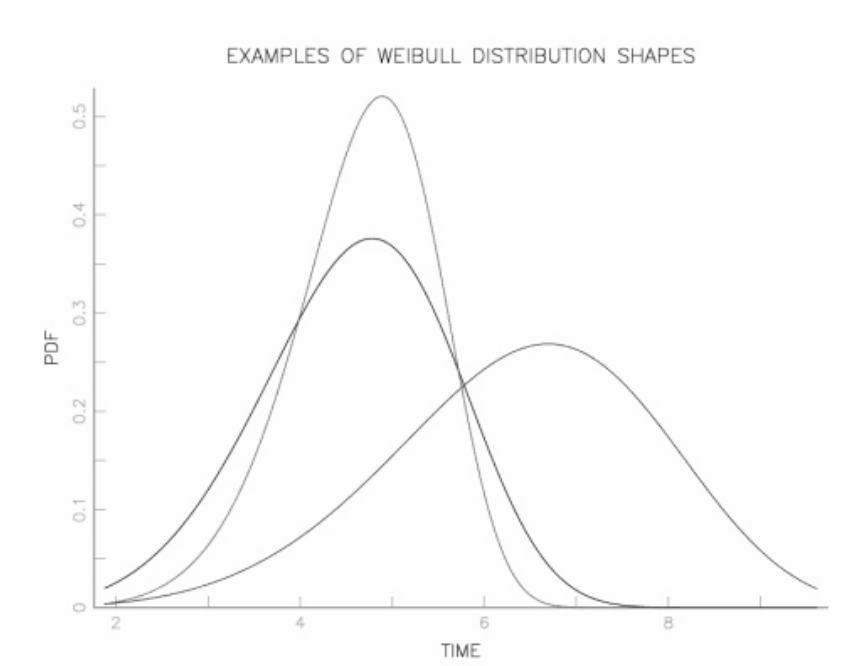


Figure 11. Illustrations of Weibull distribution.

As a failure rate model, the Weibull is a natural extension of the constant failure rate exponential model since the Weibull has a polynomial failure rate with exponent $\{\gamma - 1\}$. The Weibull has been applied to many failure analyses because of its flexible shape and ability to model a wide range of failure rates across a wide range of physical and biological systems.

Extreme value distributions. Extreme value distributions are the limiting distributions for the minimum or the maximum of a very large collection of random observations from the same arbitrary distribution (see Castillo et al, 2005). Gumbel (1958) showed that for any well-behaved initial distribution (i.e., *F(x)*is continuous and has an inverse), only a few models are needed, depending on whether you are interested in the maximum or the minimum, and also if the observations are bounded above or below. In the context of reliability modeling, extreme value distributions for the minimum are frequently encountered, e.g., if a system consists of *n* identical components in series, and the system fails when the first of these components fails, then system

failure times are the minimum of *n* random component failure times. Extreme value theory says that, independent of the choice of component model, the system model will approach a Weibull as *n* becomes large. The same reasoning can also be applied at a component level, if the component failure occurs when the first of many similar competing failure processes reaches a critical level.

The distribution often referred to as the extreme value distribution is the limiting distribution of the minimum of a large number of unbounded identically distributed random variables. The PDF and CDF are given by:

$$f(x) = \frac{1}{\beta} e^{\frac{x-\mu}{\beta}} e^{-e^{\frac{x-\mu}{\beta}}}, \quad -\infty < x < \infty, \beta > 0$$

$$F(x) = 1 - e^{-e^{\frac{x-\mu}{\beta}}}, \quad -\infty < x < \infty, \beta > 0$$

If the *x* values are bounded below (as is the case with times of failure) then the limiting distribution is the Weibull. PDF shapes for the (minimum) extreme value distribution are illustrated in Figure 12.

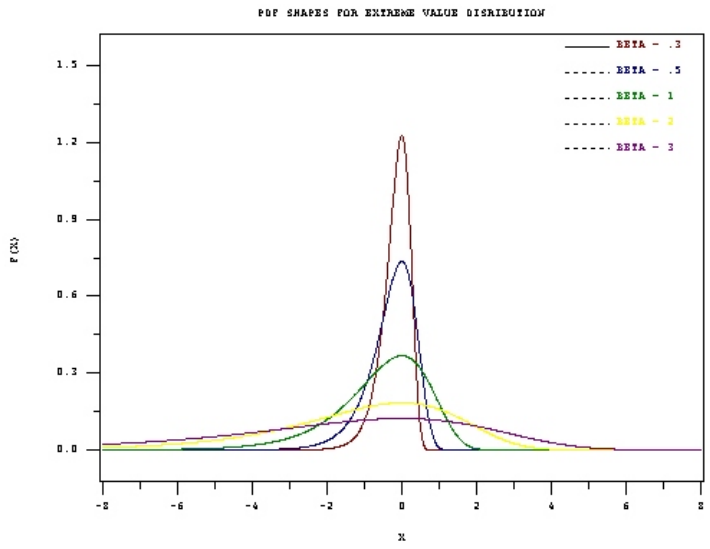


Figure 12. Illustrations of various Extreme Value distributions.

The Weibull distribution and the extreme value distribution have a useful mathematical relationship. If $t_1, t_2, \ldots, t_n$ are a sample of random times of failure from a Weibull distribution, then $\ln t_1, \ln t_2, \ldots, \ln t_n$ are random observations from the extreme value distribution. In other words, the natural log of a Weibull random time is an extreme value random observation. Because of this relationship, computer programs and graph papers designed for the extreme value distribution can be used to analyze Weibull data which is similar to using normal distribution programs to analyze lognormal data, after first taking natural logarithms of the data points.

Lognormal distribution. The lognormal life distribution, like the Weibull, is a very flexible model that can empirically fit many types of failure data. The two parameter form has parameters σ = the shape parameter and T_{50} = the median (a scale parameter). If time to failure, t_f, has a lognormal distribution, then the (natural) logarithm of time to failure has a normal distribution with mean $\mu = \ln T_{50}$ and standard deviation σ. This makes lognormal data convenient to work with; just take natural logarithms of all the failure times and censoring times and analyze the resulting normal data. Later on, convert back to real time and lognormal parameters using σ as the lognormal shape and $T_{50} = e^{\mu}$ as the (median) scale parameter. Below is a summary of the key formulas for the lognormal.

$$\text{PDF: } f(t) = \frac{1}{\sigma t \sqrt{2\pi}} e^{-\left(\frac{1}{2\sigma^2}\right)(\ln t - \ln T_{50})^2}$$

$$\text{CDF: } F(T) = \int_0^T \frac{1}{\sigma t \sqrt{2\pi}} e^{-\left(\frac{1}{2\sigma^2}\right)(\ln t - \ln T_{50})^2} dt = \Phi\left(\frac{\ln t - \ln T_{50}}{\sigma}\right)$$

with $\Phi(z)$ denoting the standard Normal CDF

$$\text{RELIABILITY: } R(T) = 1 - F(t)$$

$$\text{FAILURE RATE: } h(t) = \frac{f(t)}{R(t)}$$

$$\text{MEAN: } T_{50} e^{\frac{\sigma^2}{2}}$$

$$\text{MEDIAN: } T_{50}$$

$$\text{VARIANCE: } T_{50}^2 e^{\sigma^2}\left(e^{\sigma^2} - 1\right)$$

A more general 3-parameter form of the lognormal includes an additional waiting time parameter θ (sometimes called a shift or location parameter). The formulas for the 3-parameter

lognormal are easily obtained from the above formulas by replacing *t* by (*t* - θ) wherever *t* appears. No failure can occur before θ hours, so the time scale starts at θ and not 0. If a shift parameter θ is known (based, perhaps, on the physics of the failure mode), then all you have to do is subtract θ from all the observed failure times and/or readout times and analyze the resulting shifted data with a 2-parameter lognormal.

Examples of lognormal PDF and failure rate plots are shown in Figure 13 and Figure 14, respectively. Observe that lognormal shapes for small sigmas are very similar to Weibull shapes when the shape parameter γ is large and large sigmas give plots similar to small Weibull γ's. Both distributions are very flexible and it is often difficult to choose which to use based on empirical fits to small samples of (possibly censored) data.

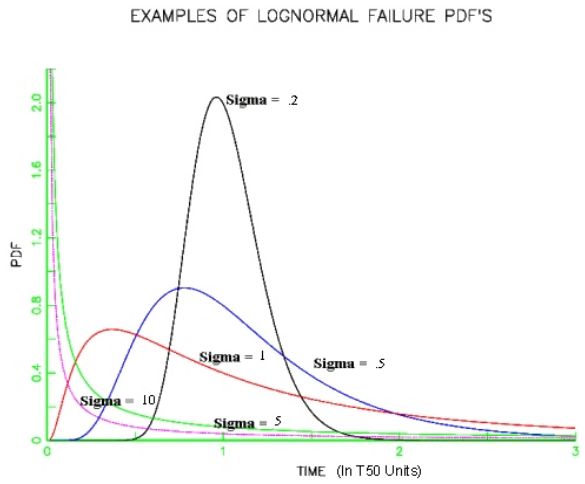


Figure 13. Illustrations of the lognormal distribution PDFs.

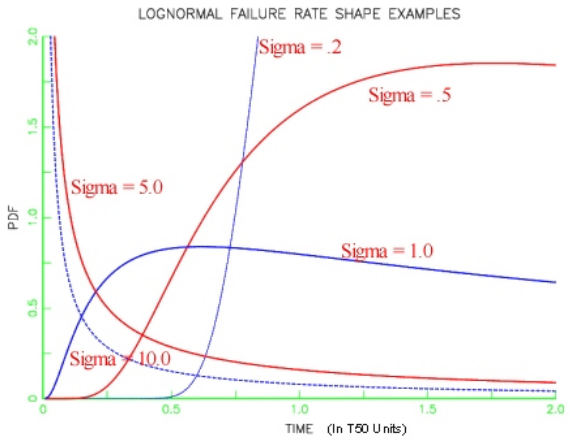
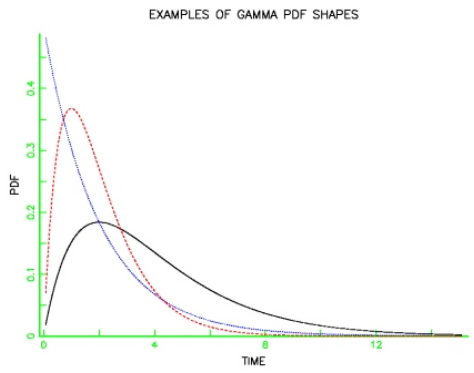


Figure 14. Illustrations of lognormal failure rates.

As suggested by the preceding plots, lognormal PDF and failure rate shapes are flexible enough to make the lognormal a very useful empirical model. Lognormal models can be theoretically derived under assumptions matching many common failure processes, which does not mean that the lognormal is always the correct model for these mechanisms, but it does perhaps explain why it has been empirically successful in so many cases.

Gamma distribution. In the literature, the gamma distribution is commonly presented in one of two forms, and different authors use different symbols for the shape and scale parameters. Below we show three ways of writing the gamma, with $a = \alpha = \gamma$, the "shape" parameter, and $b = 1/\beta$, the scale parameter. The exponential is a special case of the gamma when $a = 1$, the gamma reduces to an exponential distribution with $b = \lambda$. Another well-known statistical distribution, the Chi-Square, is also a special case of the gamma, where a Chi-Square distribution with n degrees of freedom is the same as a gamma with $a = n/2$ and $b = 0.5$ (or $\beta = 2$). Figure 15 illustrates of gamma PDFs, CDFs, and failure rate shapes.



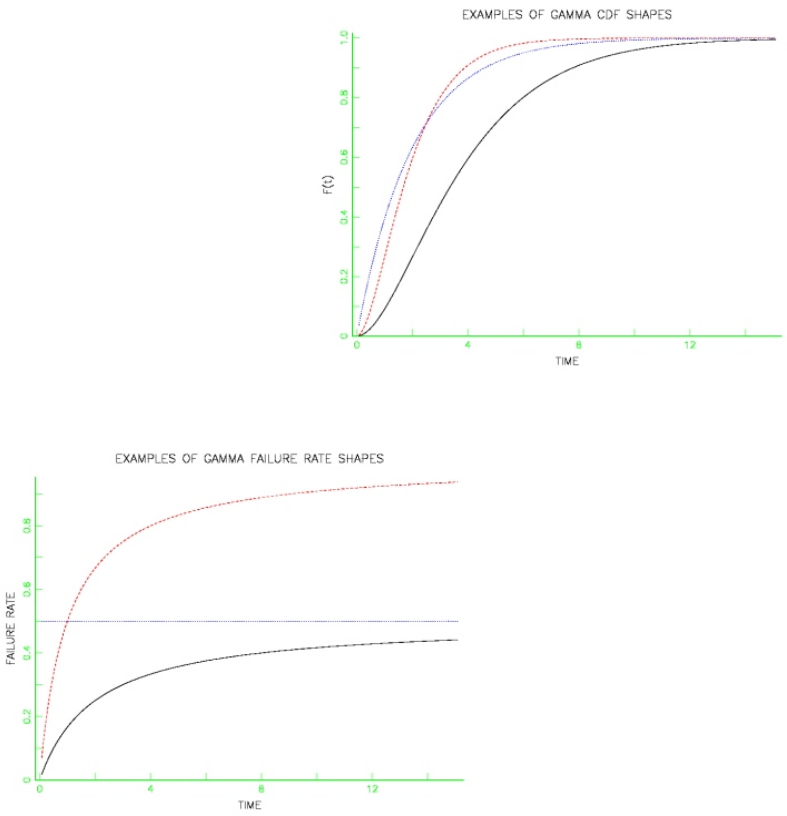


Figure 15. Illustrations of PDFs (top left), CDFs (top right), and failure rates (bottom) for gamma distribution.

The gamma distribution is commonly used for Bayesian reliability analysis, since it is a flexible life distribution model and frequently provides a good fit for failure data.

Proportional hazards model. The proportional hazards model is often used in survival analysis, but infrequently with engineering data. Cox's proportional hazards model (Cox 1972) has been used primarily to evaluate survival when secondary variables are likely exerting effects on the system. Its strength lies in its ability to model and test many inferences about survival without making any specific assumptions about the form of the life distribution model.

Proportional hazards model is based on an assumption that there are one or more explanatory variables (continuous, categorical, or binary) that affect lifetime. The hazard rate for a nominal (or baseline) set $z_0 = (x_0, y_0, \ldots)$ of these variables be given by $h_0(t)$, with $h_0(t)$ denoting legitimate hazard function (failure rate) for some unspecified life distribution model. The proportional hazard model assumes changing a stress variable (or explanatory variable) has the effect of multiplying the hazard rate by a constant. The proportional hazards model assumes we can write the changed hazard function for a new value of z as:

$$h_z(t) = g(z)h_0(t)$$

In other words, changing z, the explanatory variable vector, results in a new hazard function that is proportional to the nominal hazard function, and the proportionality constant is a function of z, $g(z)$, independent of the time variable t. A common and useful form for $f(z)$ is the log-linear model which has the equation: $g(x) = e^{ax}$ for one variable, $g(x,y) = e^{ax + by}$ for two variables.

The proportional hazards model is equivalent to the acceleration factor concept if and only if the life distribution model is a Weibull (which includes the exponential model, as a special case). For a Weibull with shape parameter γ, and an acceleration factor AF between nominal use fail time t_0 and high stress fail time t_s (with $t_0 = AFt_s$) we have $g(s) = AF^{\gamma}$. In other words, $h_s(t) = {}_{AFh0}(t)$. Under a log-linear model assumption for $g(z)$ without any further assumptions about the life

distribution model, it is possible to analyze experimental data and compute maximum likelihood estimates and use likelihood ratio tests to determine which explanatory variables are highly significant. More details on the theory and applications of the proportional hazards model may be found in Kalbfleisch and Prentice (2002) and Lawless (2003).

Data limitations and failure analysis. The more reliable a system is, the more difficult it is to gather failure data to predict its failure. Two closely related problems that are typical of reliability data and related types of statistical data encountered in invasion biology (e.g., species distribution data where "species not found" may be misinterpreted as "species absence"). First, data are generally censored (e.g., when an observation period ends, but not all units have failed). Failure data may be "right censored" or "left censored," depending on the way the data were collected (e.g., testing period of fixed time or fixed number of failures defines testing period, respectively; see Kalbfleisch and Prentice (2002), Lawless (2003), and Meeker and Escobar (1998) for a comprehensive review of the role of data censoring in limiting failure analysis). Data may also be "multicensored," since different studies may record observations differently for identical systems being considered, e.g., failure may be identified as a run-time endpoint, if the unit did not fail while under observation, or failure may be identified as an exact failure time, or failure may be identified as an interval of time during which the unit failed. Many statistical methods can be used to fit models and estimate failure rates even with censored data (e.g., probability plotting, maximum likelihood estimation; see Meeker and Escobar 1998).

Second, observed failures may be few in number or completely absent, if the system is highly reliable or inadequately sampled. Independently or in combination, these data limitations influence the uncertainty associated with analyzing failure data, particularly as those tools apply to evaluations for risk. Although serving as sources of uncertainty, solutions to these data limitations generally mean making additional assumptions in developing risk scenarios and using "best guess" models for characterizing failure events and their role in modifying risks (e.g., increasing or decreasing risk estimates).

Distinguishing Failure Modes. Failures are a generally a coarse measurement endpoint, and may result from several different failure modes (e.g., root cause of failure may differ from one occurrence to the next), and in the current investigation the discrimination between species invasions linked to interbasin water transfers and those linked with other pathways are considered within the context of competing risks in Section 4.

In general, the analysis of competing risks, regardless of the focus being on biological and ecological systems, or on engineering systems, revolves about failure mechanisms that are assumed to be independent, with the first "failure mode" that occurs causes the system to fail. For example, if a species invasion is considered a failure, then each of k different failure modes or ways a failure can occur are competing (e.g., for species invasions, different pathways may be interpreted as different failure modes), and underlying each failure mode is a failure mechanism (for a given pathway, each mode will have one to many different failure mechanisms).

In evaluating competing risks, a system's reliability is considered as a "build up" model, based on evaluations of the reliability of each failure mode. Three assumptions are generally specified in such an analysis of competing risks: (1) each failure mechanism leading to a particular type of failure (i.e., failure mode) proceeds independently of every other one at least until a failure occurs; (2) a failure event occurs when the first of all the competing failure mechanisms reaches a failed state; and (3) each of the k failure modes has a known life distribution model $F_i(t)$.

Quantitatively, the competing risk model is best applied when all three assumptions hold. If $R_c(t)$, $F_c(t)$, and $h_c(t)$ denote the reliability, CDF and failure rate for the component, respectively, and $R_i(t)$, $F_i(t)$and $h_i(t)$ are the reliability, CDF and failure rate for the i-th failure mode, respectively, then the competing risk model formulas are:

$$R_c(t) = \prod_{i=1}^{k} R_i(t)$$

$$F_c(t) = 1 - \prod_{i=1}^{k} \{1 - F_i(t)\}$$

$$h_c(t) = \sum_{i=1}^{k} h_i(t)$$

Multiply reliabilities and add failure rates. For evaluating competing risks, consider all failure mechanisms are racing to see which can reach failure first, e.g., which competing risk is most likely to yield a species invasion. If the failure mechanisms are assumed independent, then the component reliability is the product of the failure mode reliabilities and the component failure rate is the sum of the failure rates. This algorithm holds for any arbitrary life distribution model, as long as "independence" and "first mechanism failure causes the component to fail" assumptions are not violated.

Alternative "rules" associated with calculating risks for different types of systems are briefly reviewed below.

Failures in series models. The series model is used to go from individual components to the entire system, assuming the system fails when the first component fails and all components fail or survive independently of one another. The series model is a "build up" model where components are constructed to yield sub-assemblies and systems, and only applies to non-replaceable populations (or first failures of populations of systems). The assumptions and formulas for the series model are identical to those for the competing risk model, with the *k* failure modes within a component replaced by the *n* components within a system. In Figure 16, the entire system has *n* components in series, and the system operates when all components function or fails when at least one component fails. Each component is independent, but failure in one component means the system fais. Simplified, the system of 5 components in series may be represented by an equivalent

system (as far as reliability is concerned) with only one component.

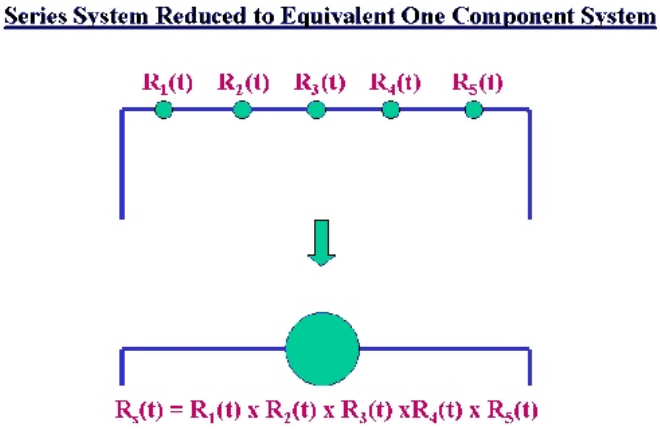


Figure 16. Illustration of a series system.

Failures in parallel or redundant systems. In parallel systems, all n components that make up the system operate independently and the system works as long as at least one component still works. Parallel systems are the opposite of a system operating in series in which the first component failure causes the system to fail. In a parallel system, all the components have to fail before the system fails. If there are *n* components, any (*n-1*) of them may be considered redundant to the remaining one (even if the components are all different). When the system is turned on, all the components operate until they fail. The system fails at the time of the last component failure.

In contrast to a system operating in series, the assumptions for a parallel model are: (1) all components operate independently of one another, as far as reliability is concerned; (2) the system operates as long as at least one component is still operating, and system failure only occurs at the time of the last component failure; and (3) the CDF for each component is known. For a system operating in parallel, the CDF $F_s(t)$ for the system is just the product of the CDF's $F_i(t)$ for the components or

$$F_s(t) = \prod_{i=1}^{n} F_i(t)$$

$R_s(t)$ and $h_s(t)$ can be evaluated using basic definitions, once we have $F_s(t)$. Figure 17 represents a parallel system with 5 components and the (reliability) equivalent 1 component system with a CDF F_s equal to the product of the 5 component CDFs.

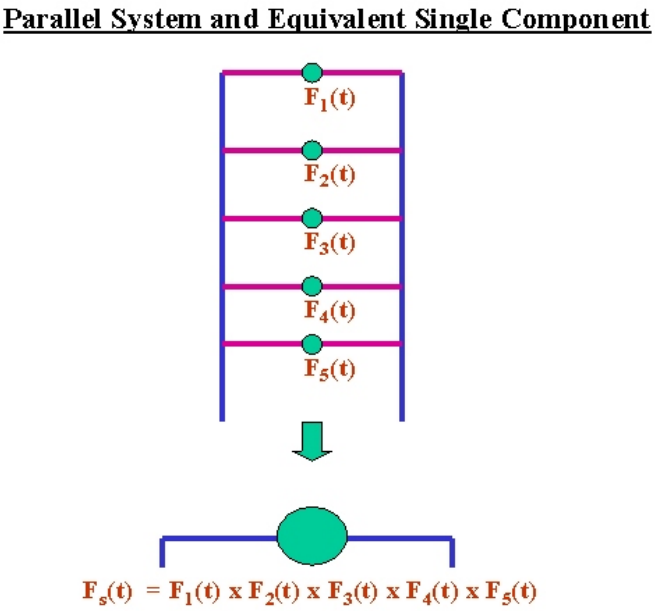


Figure 17. An illustration of a parallel system.

R out of N model. An "*r* out of *n*" system survives when at least *r* of its components are working (any *r*). An "*r* out of *n*" system contains includes the series system and the parallel system as special cases. The system has *n* components that operate or fail independently of one another and as long as at least *r* of these components (any *r*) survive, the system survives. System failure occurs when the [*n* - *(r+1)*] component failure occurs. When $r = n$, the *r* out of *n* model reduces to the series model, and when $r = 1$, the *r* out of *n* model becomes the parallel model. When all the components of the system (1) are identical and have the identical reliability function *R(t)*; (2) operate independently of one another (as far as failure is concerned); (3) the system can survive any (*n-r*) of the components failing, but fails upon the [(*n* - *(r+1)*] component failure, then system reliability is given by adding the probability of exactly *r* components surviving to time *t* to the probability of exactly (*r+1*) components surviving, and so on up to the probability of all

components surviving to time *t*. These are binomial probabilities (with $p = R(t)$), so the system reliability is given by:

$$R_s(t) = \sum_{i=r}^{n} \binom{n}{i} [R(t)]^i [1 - R(t)]^{n-i}$$

If all the components are not identical, then $R_s(t)$ would be the sum of probabilities evaluated for all possible terms that could be formed by picking at least *r* survivors and the corresponding failures. The probability for each term is evaluated as a product of *R(t)*'s and *F(t)*'s. For example, for $n = 4$ and $r = 2$, the system reliability would be (abbreviating the notation for *R(t)* and *F(t)* by using only *R* and *F)*:

$$R_s = R_1R_2F_3F_4 + R_1R_3F_2F_4 + R_1R_4F_2F_3 + R_2R_3F_1F_4 + R_2R_4F_1F_3 + R_3R_4F_1F2 + R_1R_2R_3F_4 + R_1R_3R_4F_2 + R_1R_2R_4F_3 + R_2R_3R_4F_1 + R_1R_2R_3R_4$$

Complex systems. For complex systems, reliability can be evaluated by successive applications of series and parallel models. Many complex systems can be diagramed as combinations of series components, parallel components, and *R* out of *N* components (see, e.g., Miller and Escobar 1998; Thompson 2000; Borgelt and Kruse 2002; Huzurbazar 2005; Banerjee et al 2004; Salthe 1985; Puccia and Levins 1985). While many engineering analyses, and indeed many evaluations of ecological systems, seek to reduce their complexity to "equivalent" simple systems, many systems with marked interdependence and interconnectedness, or with systems characterized by complicated operational logic structure, alternative tools such as event trees, Boolean representations, coherent structures, cut sets and decompositions may be involved. The reader is referred to those authors listed above for more comprehensive treatment of complex systems analysis[1].

[1] Graphics and excerpts from NIST/SEMATECH (2004), e-Handbook of Statistical Methods (available at http://www.itl.nist.gov/div898/handbook/) have been relied upon for peer-reviewed technical summaries incorporated into this overview of reliability analysis in this appendix.

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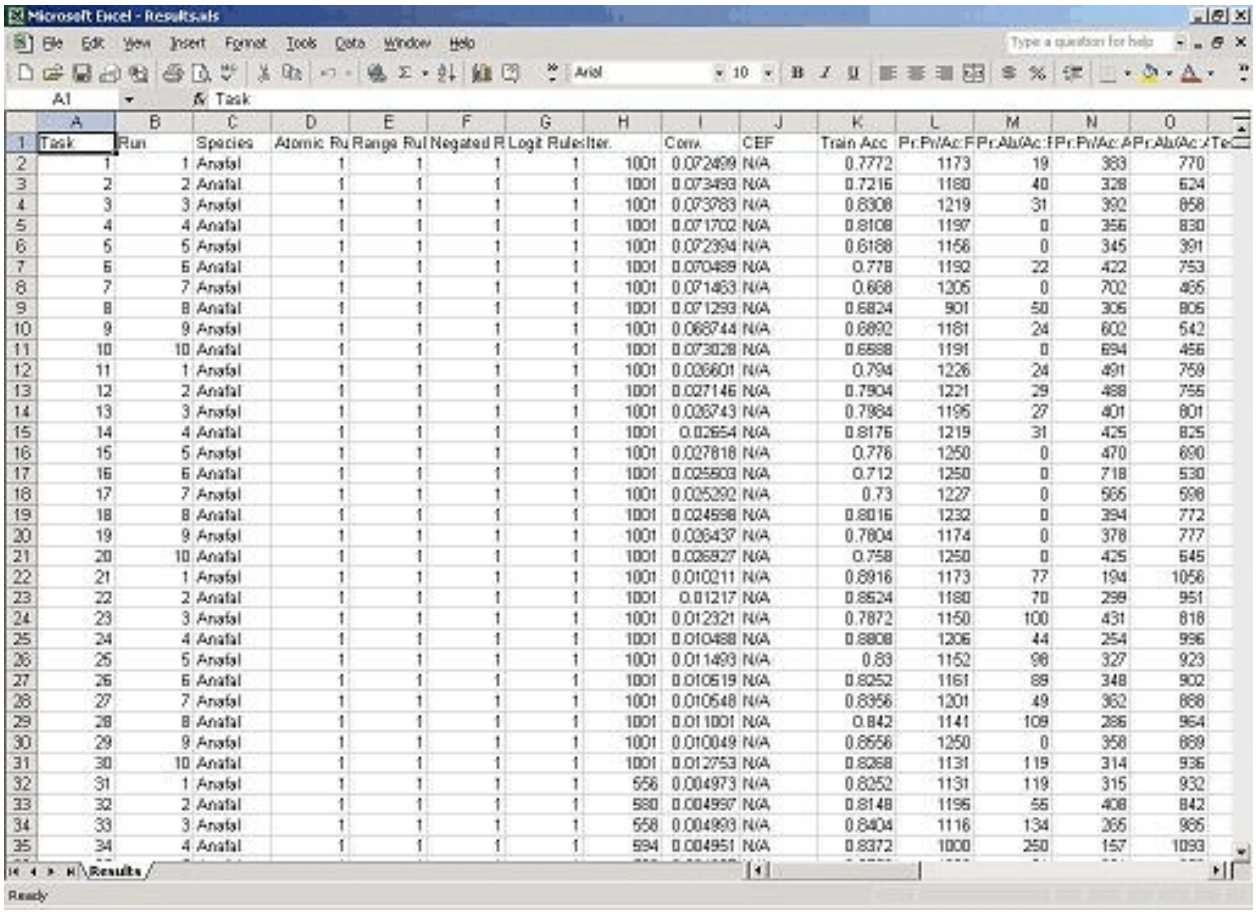
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Appendix 5. Summary tables for best subsets generated by GARP

All information generated as tabular output from the best subsets procedures are stored within GARP as an MS-Excel file. These files show a summary of all tasks, error messages, result parameters, preliminary statistical tests, and measures of accuracy (Figure 1) associated with predicted distributions maps included in Section 3.


Microsoft Excel - Resultsals

File Edit View Insert Format Tools Data Window Help

A1 Task

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	Task	Run	Species	Atomic Ru	Range Rul	Negated R	Logit Rule	Iter.	Conv.	CEF	Train Acc	Pr.Pr/Ac.F	Pr.Au/Ac.I	Pr.Pr/Ac.A	Pr.Au/Ac.A
2	1	1	Anafal	1	1	1	1	1001	0.072499	N/A	0.7772	1173	19	383	770
3	2	2	Anafal	1	1	1	1	1001	0.073493	N/A	0.7216	1180	40	328	624
4	3	3	Anafal	1	1	1	1	1001	0.073783	N/A	0.8308	1219	31	392	858
5	4	4	Anafal	1	1	1	1	1001	0.071702	N/A	0.8108	1197	0	356	830
6	5	5	Anafal	1	1	1	1	1001	0.072394	N/A	0.6188	1156	0	345	391
7	6	6	Anafal	1	1	1	1	1001	0.070489	N/A	0.778	1192	22	422	753
8	7	7	Anafal	1	1	1	1	1001	0.071453	N/A	0.668	1205	0	702	465
9	8	8	Anafal	1	1	1	1	1001	0.071293	N/A	0.6824	901	50	305	805
10	9	9	Anafal	1	1	1	1	1001	0.068744	N/A	0.6892	1181	24	602	542
11	10	10	Anafal	1	1	1	1	1001	0.073028	N/A	0.6888	1191	0	694	456
12	11	1	Anafal	1	1	1	1	1001	0.026601	N/A	0.794	1226	24	491	759
13	12	2	Anafal	1	1	1	1	1001	0.027146	N/A	0.7904	1221	29	488	756
14	13	3	Anafal	1	1	1	1	1001	0.026743	N/A	0.7984	1195	27	401	801
15	14	4	Anafal	1	1	1	1	1001	0.02654	N/A	0.8176	1219	31	425	825
16	15	5	Anafal	1	1	1	1	1001	0.027818	N/A	0.776	1250	0	470	690
17	16	6	Anafal	1	1	1	1	1001	0.025603	N/A	0.712	1250	0	718	530
18	17	7	Anafal	1	1	1	1	1001	0.025292	N/A	0.73	1227	0	566	598
19	18	8	Anafal	1	1	1	1	1001	0.024598	N/A	0.8016	1232	0	394	772
20	19	9	Anafal	1	1	1	1	1001	0.026437	N/A	0.7804	1174	0	378	777
21	20	10	Anafal	1	1	1	1	1001	0.026827	N/A	0.758	1250	0	425	645
22	21	1	Anafal	1	1	1	1	1001	0.010211	N/A	0.8916	1173	77	194	1056
23	22	2	Anafal	1	1	1	1	1001	0.01217	N/A	0.8524	1180	70	299	951
24	23	3	Anafal	1	1	1	1	1001	0.012321	N/A	0.7872	1150	100	431	818
25	24	4	Anafal	1	1	1	1	1001	0.010488	N/A	0.8808	1206	44	254	996
26	25	5	Anafal	1	1	1	1	1001	0.011493	N/A	0.83	1152	98	327	923
27	26	6	Anafal	1	1	1	1	1001	0.010619	N/A	0.8252	1161	89	348	902
28	27	7	Anafal	1	1	1	1	1001	0.010548	N/A	0.8356	1201	49	362	868
29	28	8	Anafal	1	1	1	1	1001	0.011001	N/A	0.842	1141	109	286	964
30	29	9	Anafal	1	1	1	1	1001	0.010049	N/A	0.8656	1250	0	358	869
31	30	10	Anafal	1	1	1	1	1001	0.012753	N/A	0.8268	1131	119	314	936
32	31	1	Anafal	1	1	1	1	556	0.004973	N/A	0.8252	1131	119	315	932
33	32	2	Anafal	1	1	1	1	580	0.004997	N/A	0.8148	1196	55	408	842
34	33	3	Anafal	1	1	1	1	558	0.004993	N/A	0.8404	1116	134	265	985
35	34	4	Anafal	1	1	1	1	594	0.004951	N/A	0.8372	1000	250	157	1093

Results

Ready

Figure 1. Screen snapshot of GARP results table.

The first line of the file holds a label for each column, and each subsequent line shows information on a single task within the experiment (see http://biodi.sdsc.edu/ and http://beta.lifernapper.org/desktopgarp/ for detail). Below are column descriptions captured in Figure 1.

Output item	Explanation of output item
Task	Sequential number or identifier assigned to each task. The task identifier is attached to each prediction map file name or directory as a link back to the task information.
Run	Sequential number assigned to a group of tasks that are repetition of the same input parameters. For example, if 5 runs are selected on the optimization parameters panel, each unique task will be repeated 5 times, and they will be represented with different numbers in this column, from 1 to 5 in this example.
Species	Species name as provided in the input file and displayed on the list box on the species data points panel.
Atomic Rules	Indicates whether the atomic rules were used on the experiment. Possible values for that column are 0 (false) or 1 (true).
Range Rules	Indicates whether the range rules were used on the experiment. Possible values for that column are 0 (false) or 1 (true).
Negated Rules	Indicates whether the negated rules were used on the experiment. Possible values for that column are 0 (false) or 1 (true).
Logit Rules	Indicates whether the logistic regression rules were used on the experiment. Possible values for that column are 0 (false) or 1 (true).
Iter.	Number of iterations executed by the GARP algorithm for that task. The value is limited by the maximum number of iterations. The value may be lower if the convergence limit was reached before the maximum number of iterations. Because the final iteration sums up optimization results, this column often brings the maximum number of iterations plus one.
Conv.	Value of the convergence control variable when the task finished. Can be slightly below the convergence limit specified on the optimization parameter panel in cases where the task ended because the limit was reached. Can also be greater than that limit in cases where the maximum number of iterations was reached before the convergence limit.
CEF	Not used.
Train Acc	Accuracy calculated using the training data points. Accuracy is calculated

Output item	Explanation of output item
	using the expression: (a+b)/(a+b+c+d), where the variables a, b, c and d are explained below.
Pr:Pr/Ac:Pr	Number of points where the model predicted presence and the input point (actual point) was a presence record. In this case, the model has predicted the point successfully. This is variable a on the accuracy expression. The mneumonics on the column label represents: Pr(edicted):Pr(esent)/Ac(tual record):Pr(esence).
Pr:Ab/Ac:Pr	Number of points where the model predicted absence and the input point (actual point) was a presence record. In this case, the model has predicted the point incorrectly. This value usually represents a real error, because of either low model quality or a misidentification of the specimen record. This is true when using presence only data, which is the case of the current release of DesktopGarp. This is variable c on the accuracy expression. The mneumonics on the column label represents: Pr(edicted):Ab(sent)/Ac(tual record):Pr(esence).
Pr:Pr/Ac:Ab	Number of points where the model predicted presence and the input point (actual point) was an absence record. At a first glance, the model has predicted the point incorrectly. However, when using presence points only, this error can be due to insufficient sampling of the interest area in cases where the point might be suitable for the species but no information is available about the occurrence of the species at this location. This is variable d on the accuracy expression. The mneumonics on the column label represents: Pr(edicted):Pr(esent)/Ac(tual record):Ab(sence).
Pr:Ab/Ac:Ab	Number of points where the model predicted absence and the input point (actual point) was an absence record. In this case, the model has predicted the point successfully. This is variable b on the accuracy expression. The mneumonics on the column label represents: Pr(edicted):Ab(sent)/Ac(tual record):Ab(sence).
Test Acc	These columns show the accuracy calculated using the data points set aside for

Output item	Explanation of output item
	accuracy testing, and that have not been used for training the model. The value is calculate by the same expression described for training points and the columns Pr:Pr/Ac:Pr, Pr:Ab/Ac:Pr, Pr:Pr/Ac:Ab and Pr:Ab/Ac:Ab represent the same concepts described above, applied to the test dataset.
Total Area	Total number of non-masked cells on the interest area.
Presence Area	Total number of cells where the species is predicted to be present.
Absence Area	Total number of cells where the species is predicted to be absent.
Non-predicted Area	Total number of cells where the algorithm could not define whether the species is present or absent; that is, no rule applied to that area.
Yes	Number of test points that fall inside the presence area.
No	Number of test points that fall outside the presence area.
ChiSq	Intermediate value for calculating the chi-square test value.
p	Chi-square test. Probability of a random predictions being similar, that is, having the same number of correct predicted points as the one generated by GARP on that task.
Commission	Percentage of the prediction area that exceeds the recorded occurrence.
Omission (int)	Intrinsic omission. Percentage of the training points that are omitted from the prediction; that is, those that are predicted absent but are presence records.
Omission (ext)	Extrinsic omission. Percentage of the test points that are omitted from the prediction; that is, those that are predicted absent but are presence records.
Status	Status of the task. Can be "Waiting to be processed," "Successfully processed" or "Failed."
Message	More detailed message to explain the status message.
Layers	Indicates which layers have been used on the prediction. Represented by 0 (false) or 1 (true) below the layer name.

For each of the biota of concern that presented data sufficient to developing a predicted species distribution, a summary results table for the best subsets implementation is included in this

appendix. Tabular output included in this appendix were generated for each of the models selected in the best subsets, and are associated with summary maps generated and included in figures of predicted species distributions included in Section 3.

Zebra mussel

Task	Run	Species	Atomic Rules	Range Rules	Negated Rules	Logit Rules	Iter.	Conv.	Train Acc
1	1	Zebra mussel	1	1	1	1	102	0.009685	0.4996
2	2	Zebra mussel	1	1	1	1	84	0.009406	0.4996
3	3	Zebra mussel	1	1	1	1	106	0.009017	0.4964
4	4	Zebra mussel	1	1	1	1	114	0.008987	0.4988
5	5	Zebra mussel	1	1	1	1	103	0.009662	0.4996
6	6	Zebra mussel	1	1	1	1	97	0.009761	0.5
7	7	Zebra mussel	1	1	1	1	97	0.009725	0.4992
8	8	Zebra mussel	1	1	1	1	99	0.009464	0.4988
9	9	Zebra mussel	1	1	1	1	114	0.008979	0.4996
10	10	Zebra mussel	1	1	1	1	92	0.009664	0.8816
11	11	Zebra mussel	1	1	1	1	108	0.009152	0.4988
12	12	Zebra mussel	1	1	1	1	104	0.008469	0.4984
13	13	Zebra mussel	1	1	1	1	97	0.009869	0.4992
14	14	Zebra mussel	1	1	1	1	103	0.009267	0.4972
15	15	Zebra mussel	1	1	1	1	96	0.009815	0.5
16	16	Zebra mussel	1	1	1	1	99	0.009554	0.7892
17	17	Zebra mussel	1	1	1	1	105	0.009985	0.498
18	18	Zebra mussel	1	1	1	1	91	0.009439	0.8476
19	19	Zebra mussel	1	1	1	1	112	0.009569	0.8512
20	20	Zebra mussel	1	1	1	1	88	0.008746	0.5

Task	Run	Pr:Pr/Ac:Pr	Pr:Ab/Ac:Pr	Pr:Pr/Ac:Ab	Pr:Ab/Ac:Ab	Test Acc	Pr:Pr/Ac:Pr	Pr:Ab/Ac:Pr	Pr:Pr/Ac:Ab	Pr:Ab/Ac:Ab	Total Area
1	1	1249	0	190	0	0.4996	1249	0	187	0	315910
2	2	1249	0	453	0	0.5	1250	0	459	0	315910
3	3	1241	0	172	0	0.4964	1241	0	150	0	315910
4	4	1247	0	160	0	0.4976	1244	0	183	0	315910

Task	Run	Pr:Pr/Ac:Pr	Pr:Ab/Ac:Pr	Pr:Pr/Ac:Ab	Pr:Ab/Ac:Ab	Test Acc	Pr:Pr/Ac:Pr	Pr:Ab/Ac:Pr	Pr:Pr/Ac:Ab	Pr:Ab/Ac:Ab	Total Area
5	5	1249	0	170	0	0.4992	1248	0	183	0	315910
6	6	1250	0	167	0	0.5	1250	0	174	0	315910
7	7	1248	0	174	0	0.4964	1241	0	177	0	315910
8	8	1247	0	141	0	0.4984	1246	0	176	0	315910
9	9	1249	0	166	0	0.4992	1248	0	176	0	315910
10	10	1242	5	176	962	0.8888	1246	4	160	976	315910
11	11	1247	0	180	0	0.4992	1248	0	194	0	315910
12	12	1246	0	190	0	0.5	1250	0	169	0	315910
13	13	1248	0	191	0	0.4972	1243	0	161	0	315910
14	14	1243	0	156	0	0.4996	1249	0	167	0	315910
15	15	1250	0	158	0	0.498	1245	0	153	0	315910
16	16	1244	4	184	729	0.7868	1241	0	182	726	315910
17	17	1245	0	169	0	0.5	1250	0	153	0	315910
18	18	1204	45	196	915	0.858	1222	28	169	923	315910
19	19	1249	0	149	879	0.858	1237	0	161	908	315910
20	20	1250	0	188	0	0.4972	1243	0	164	0	315910

Task	Run	Presence Area	Absence Area	Non-predicted Area	Yes	No	ChiSq	p
1	1	48211	0	267699	1214	1	6733.3756162	0
2	2	113954	0	201956	1216	0	2155.0669217	0
3	3	43344	0	272566	1212	3	7596.782535	0
4	4	45307	0	270603	1213	2	7228.9098631	0
5	5	44055	0	271855	1214	1	7483.198437	0
6	6	45098	0	270812	1216	0	7302.0398244	0
7	7	43483	0	272427	1212	3	7568.6143684	0
8	8	42524	0	273386	1213	2	7781.5245933	0
9	9	42617	0	273293	1215	1	7783.1092828	0
10	10	42388	246550	26972	1209	7	7742.6326955	0

Task	Run	Presence Area	Absence Area	Non-predicted Area	Yes	No	ChiSq	p
11	11	46060	0	269850	1214	1	7104.5643593	0
12	12	47600	0	268310	1214	0	6843.0323529	0
13	13	45292	0	270618	1213	2	7231.7063521	0
14	14	46173	0	269737	1215	1	7090.0456168	0
15	15	42074	0	273836	1213	2	7877.7463476	0
16	16	44987	187030	83893	1212	3	7274.9619589	0
17	17	42865	0	273045	1215	0	7739.4068587	0
18	18	45053	233515	37342	1177	38	6781.3463626	0
19	19	41162	223561	51187	1211	5	8039.9867816	0
20	20	46861	0	269049	1211	3	6929.7022239	0

Task	Run	Commission	Omission (int)	Omission (ext)	Status	Message
1	1	15.260992055	0	8.23e-02	Processed	Success (506 unique points used)
2	2	36.071665981	0	0	Processed	Success (563 unique points used)
3	3	13.720363395	0	0.24691358025	Processed	Success (563 unique points used)
4	4	14.341742901	0	0.1646090535	Processed	Success (526 unique points used)
5	5	13.945427495	0	8.23e-02	Processed	Success (534 unique points used)
6	6	14.275584818	0	0	Processed	Success (550 unique points used)
7	7	13.764363268	0	0.24691358025	Processed	Success (531 unique points used)
8	8	13.460795796	0	0.1646090535	Processed	Success (571 unique points used)
9	9	13.49023456	0	8.22e-02	Processed	Success (548 unique points used)
10	10	13.41774556	0.4	0.57565789474	Processed	Success (542 unique points used)
11	11	14.580101928	0	8.23e-02	Processed	Success (533 unique points used)
12	12	15.067582539	0	0	Processed	Success (541 unique points used)
13	13	14.336994714	0	0.1646090535	Processed	Success (536 unique points used)
14	14	14.615871609	0	8.22e-02	Processed	Success (553 unique points used)
15	15	13.318350163	0	0.1646090535	Processed	Success (541 unique points used)
16	16	14.240448229	0.32	0.24691358025	Processed	Success (523 unique points used)

Task	Run	Commission	Omission (int)	Omission (ext)	Status	Message
17	17	13.568737932	0	0	Processed	Success (557 unique points used)
18	18	14.261340255	3.6	3.12757201646	Processed	Success (527 unique points used)
19	19	13.029660346	0	0.41118421053	Processed	Success (541 unique points used)
20	20	14.833655155	0	0.2471169687	Processed	Success (554 unique points used)

New Zealand mudsnail

Task	Run	Species	Atomic Rules	Range Rules	Negated Rules	Logit Rules	Iter.	Conv.	Train Acc
1	1	New Zealand mudsnail	1	1	1	1	113	0.00828	0.5
2	2	New Zealand mudsnail	1	1	1	1	108	0.009405	0.4948
3	3	New Zealand mudsnail	1	1	1	1	95	0.009377	0.5
4	4	New Zealand mudsnail	1	1	1	1	78	0.009892	0.5
5	5	New Zealand mudsnail	1	1	1	1	99	0.009848	0.4928
6	6	New Zealand mudsnail	1	1	1	1	114	0.009266	0.5
7	7	New Zealand mudsnail	1	1	1	1	106	0.008523	0.838
8	8	New Zealand mudsnail	1	1	1	1	100	0.009925	0.5536
9	9	New Zealand mudsnail	1	1	1	1	105	0.009773	0.4976
10	10	New Zealand mudsnail	1	1	1	1	107	0.009555	0.4936
11	11	New Zealand mudsnail	1	1	1	1	109	0.008098	0.496
12	12	New Zealand mudsnail	1	1	1	1	98	0.009924	0.4956
13	13	New Zealand mudsnail	1	1	1	1	108	0.009743	0.5
14	14	New Zealand mudsnail	1	1	1	1	100	0.009934	0.5
15	15	New Zealand mudsnail	1	1	1	1	103	0.009214	0.4972
16	16	New Zealand mudsnail	1	1	1	1	112	0.009955	0.8588
17	17	New Zealand mudsnail	1	1	1	1	105	0.009887	0.4948
18	18	New Zealand mudsnail	1	1	1	1	113	0.009175	0.5
19	19	New Zealand mudsnail	1	1	1	1	100	0.009887	0.5204
20	20	New Zealand mudsnail	1	1	1	1	109	0.008015	0.8192

Task	Run	Pr:Pr/Ac:Pr	Pr:Ab/Ac:Pr	Pr:Pr/Ac:Ab	Pr:Ab/Ac:Ab	Test Acc	Pr:Pr/Ac:Pr	Pr:Ab/Ac:Pr	Pr:Pr/Ac:Ab	Pr:Ab/Ac:Ab	Total Area
1	1	1250	0	303	0	0.4928	1232	0	321	0	315910
2	2	1237	0	163	0	0.4832	1208	0	207	0	315910
3	3	1250	0	303	0	0.4828	1207	0	319	0	315910
4	4	1250	0	244	0	0.4892	1223	0	249	0	315910
5	5	1232	0	199	0	0.4852	1213	0	182	0	315910

Task	Run	Pr:Pr/Ac:Pr	Pr:Ab/Ac:Pr	Pr:Pr/Ac:Ab	Pr:Ab/Ac:Ab	Test Acc	Pr:Pr/Ac:Pr	Pr:Ab/Ac:Pr	Pr:Pr/Ac:Ab	Pr:Ab/Ac:Ab	Total Area
6	6	1250	0	285	0	0.4784	1196	0	281	0	315910
7	7	1250	0	159	845	0.8324	1212	38	158	869	315910
8	8	1239	0	186	145	0.5436	1222	8	189	137	315910
9	9	1244	0	247	0	0.4896	1224	0	224	0	315910
10	10	1234	0	228	0	0.4848	1212	0	261	0	315910
11	11	1240	0	289	0	0.4824	1206	0	255	0	315910
12	12	1239	0	195	0	0.492	1230	0	207	0	315910
13	13	1250	0	143	0	0.476	1190	0	166	0	315910
14	14	1250	0	230	0	0.4864	1216	0	268	0	315910
15	15	1243	0	298	0	0.494	1235	0	293	0	315910
16	16	1216	34	236	931	0.8668	1227	23	229	940	315910
17	17	1237	0	244	0	0.49	1225	0	261	0	315910
18	18	1250	0	345	0	0.4944	1236	0	354	0	315910
19	19	1241	0	140	60	0.502	1194	0	139	61	315910
20	20	1203	47	206	845	0.8356	1220	30	203	869	315910

Task	Run	Presence Area	Absence Area	Non-predicted Area	Yes	No	ChiSq	p
1	1	80436	0	235474	144	1	416.66458939	1.298508e-92
2	2	45139	0	270771	142	3	828.31281158	3.771190e-182
3	3	79730	0	236180	142	4	401.37097	2.770084e-89
4	4	64946	0	250964	142	2	537.15736455	7.831498e-119
5	5	48621	0	267289	139	3	742.13287748	2.060674e-163
6	6	73182	0	242728	139	4	440.39282192	8.891051e-98
7	7	43555	214935	57420	143	3	869.95656457	3.334462e-191
8	8	45828	35876	234206	138	3	790.12149802	7.583014e-174
9	9	61854	0	254056	141	2	567.09923474	2.400567e-125
10	10	62721	0	253189	140	3	547.43028344	4.560477e-121
11	11	70164	0	245746	141	3	477.700041	6.764132e-106

Task	Run	Presence Area	Absence Area	Non-predicted Area	Yes	No	ChiSq	p
12	12	50312	0	265598	143	2	740.54769415	4.557120e-163
13	13	38040	0	277870	140	4	986.48544696	1.555473e-216
14	14	65756	0	250154	141	3	519.36934154	5.804304e-115
15	15	76890	0	239020	144	1	442.56677785	2.991025e-98
16	16	57475	239360	19075	141	2	621.19820584	4.103478e-137
17	17	65208	0	250702	140	3	521.10139714	2.437355e-115
18	18	89158	0	226752	145	1	364.26329159	3.321081e-81
19	19	35960	16562	263388	140	4	1051.8667937	9.562593e-231
20	20	55850	215339	44721	141	2	643.43194959	5.991614e-142

Task	Run	Commission	Omission (int)	Omission (ext)	Status	Message
1	1	25.461682125	0	0.68965517241	Processed	Success (93 unique points used)
2	2	14.288563198	0	2.06896551724	Processed	Success (96 unique points used)
3	3	25.238200753	0	2.7397260274	Processed	Success (101 unique points used)
4	4	20.558386882	0	1.38888888889	Processed	Success (97 unique points used)
5	5	15.390775854	0	2.11267605634	Processed	Success (97 unique points used)
6	6	23.165458517	0	2.7972027972	Processed	Success (99 unique points used)
7	7	13.787154569	0	2.05479452055	Processed	Success (98 unique points used)
8	8	14.50666329	0	2.12765957447	Processed	Success (101 unique points used)
9	9	19.579627109	0	1.3986013986	Processed	Success (108 unique points used)
10	10	19.854072362	0	2.0979020979	Processed	Success (98 unique points used)
11	11	22.210123136	0	2.08333333333	Processed	Success (96 unique points used)
12	12	15.926054889	0	1.37931034483	Processed	Success (108 unique points used)
13	13	12.041404197	0	2.77777777778	Processed	Success (100 unique points used)
14	14	20.814789022	0	2.08333333333	Processed	Success (101 unique points used)
15	15	24.339210535	0	0.68965517241	Processed	Success (99 unique points used)
16	16	18.193472825	2.72	1.3986013986	Processed	Success (101 unique points used)
17	17	20.641321895	0	2.0979020979	Processed	Success (100 unique points used)

Task	Run	Commission	Omission (int)	Omission (ext)	Status	Message
18	18	28.222595043	0	0.68493150685	Processed	Success (100 unique points used)
19	19	11.382988826	0	2.77777777778	Processed	Success (98 unique points used)
20	20	17.679085816	3.76	1.3986013986	Processed	Success (92 unique points used)

New Zealand mudsnail (based on points from HUC10 only)

Task	Run	Species	Atomic Rules	Range Rules	Negated Rules	Logit Rules	Iter.	Conv.	Train Acc
1	1	New Zealand mudsnail	1	1	1	1	105	0.009468	0.5
2	2	New Zealand mudsnail	1	1	1	1	91	0.009272	0.5
3	3	New Zealand mudsnail	1	1	1	1	95	0.009152	0.5
4	4	New Zealand mudsnail	1	1	1	1	79	0.009271	0.5
5	5	New Zealand mudsnail	1	1	1	1	100	0.009511	0.5
6	6	New Zealand mudsnail	1	1	1	1	103	0.00872	0.5
7	7	New Zealand mudsnail	1	1	1	1	87	0.008962	0.5
8	8	New Zealand mudsnail	1	1	1	1	102	0.009844	0.5
9	9	New Zealand mudsnail	1	1	1	1	91	0.009911	0.5
10	10	New Zealand mudsnail	1	1	1	1	104	0.009546	0.5
11	11	New Zealand mudsnail	1	1	1	1	94	0.0099	0.5
12	12	New Zealand mudsnail	1	1	1	1	87	0.009954	0.5
13	13	New Zealand mudsnail	1	1	1	1	107	0.009482	0.9768
14	14	New Zealand mudsnail	1	1	1	1	86	0.009949	0.5348
15	15	New Zealand mudsnail	1	1	1	1	90	0.009987	0.5
16	16	New Zealand mudsnail	1	1	1	1	102	0.009258	0.5
17	17	New Zealand mudsnail	1	1	1	1	87	0.009886	0.5
18	18	New Zealand mudsnail	1	1	1	1	95	0.009889	0.5
19	19	New Zealand mudsnail	1	1	1	1	106	0.009899	0.5
20	20	New Zealand mudsnail	1	1	1	1	96	0.009274	0.5

Task	Run	Pr:Pr/Ac:Pr	Pr:Ab/Ac:Pr	Pr:Pr/Ac:Ab	Pr:Ab/Ac:Ab	Test Acc	Pr:Pr/Ac:Pr	Pr:Ab/Ac:Pr	Pr:Pr/Ac:Ab	Pr:Ab/Ac:Ab	Total Area
1	1	1250	0	10	0	0.5	1250	0	11	0	315910
2	2	1250	0	16	0	0.4728	1182	0	25	0	315910
3	3	1250	0	18	0	0.5	1250	0	16	0	315910
4	4	1250	0	20	0	0.5	1250	0	26	0	315910
5	5	1250	0	18	0	0.4736	1184	0	16	0	315910

Task	Run	Pr:Pr/Ac:Pr	Pr:Ab/Ac:Pr	Pr:Pr/Ac:Ab	Pr:Ab/Ac:Ab	Test Acc	Pr:Pr/Ac:Pr	Pr:Ab/Ac:Pr	Pr:Pr/Ac:Ab	Pr:Ab/Ac:Ab	Total Area
6	6	1250	0	16	0	0.4768	1192	0	14	0	315910
7	7	1250	0	16	0	0.5	1250	0	22	0	315910
8	8	1250	0	10	0	0.476	1190	0	19	0	315910
9	9	1250	0	16	0	0.5	1250	0	7	0	315910
10	10	1250	0	11	0	0.5	1250	0	10	0	315910
11	11	1250	0	15	0	0.4728	1182	0	12	0	315910
12	12	1250	0	16	0	0.4204	1051	0	20	0	315910
13	13	1250	0	16	1192	0.974	1250	0	14	1185	315910
14	14	1250	0	18	87	0.488	1114	0	14	106	315910
15	15	1250	0	24	0	0.4864	1216	0	27	0	315910
16	16	1250	0	20	0	0.4752	1188	0	15	0	315910
17	17	1250	0	17	0	0.5	1250	0	23	0	315910
18	18	1250	0	18	0	0.5	1250	0	20	0	315910
19	19	1250	0	14	0	0.476	1190	0	27	0	315910
20	20	1250	0	16	0	0.5	1250	0	17	0	315910

Task	Run	Presence Area	Absence Area	Non-predicted Area	Yes	No	ChiSq	p
1	1	3257	0	312653	37	0	3551.7841572	0
2	2	4526	0	311384	36	1	2407.8767588	0
3	3	3827	0	312083	37	0	3017.2644369	0
4	4	5645	0	310265	37	0	2033.6235607	0
5	5	4142	0	311768	35	2	2488.2622321	0
6	6	4272	0	311638	35	2	2411.4200846	0
7	7	4905	0	311005	37	0	2346.011213	0
8	8	4286	0	311624	35	2	2403.4228084	0
9	9	3780	0	312130	37	0	3055.2407407	0
10	10	3856	0	312054	37	0	2994.2940871	0
11	11	4172	0	311738	35	2	2470.1043853	0

Task	Run	Presence Area	Absence Area	Non-predicted Area	Yes	No	ChiSq	p
12	12	3499	0	312411	32	5	2462.4036498	0
13	13	4307	299389	12214	37	0	2676.8774089	0
14	14	3230	25131	287549	34	3	3018.9897104	0
15	15	5336	0	310574	35	2	1923.2266133	0
16	16	5073	0	310837	35	2	2024.8450257	0
17	17	4611	0	311299	37	0	2497.9533724	0
18	18	4066	0	311844	37	0	2837.7343827	0
19	19	4828	0	311082	35	2	2129.4690304	0
20	20	4459	0	311451	37	0	2584.3657771	0

Task	Run	Commission	Omission (int)	Omission (ext)	Status	Message
1	1	1.0309898389	0	0	Processed	Success (20 unique points used)
2	2	1.4326865246	0	2.7027027027	Processed	Success (19 unique points used)
3	3	1.2114209743	0	0	Processed	Success (21 unique points used)
4	4	1.7869013327	0	0	Processed	Success (21 unique points used)
5	5	1.3111329176	0	5.40540540541	Processed	Success (20 unique points used)
6	6	1.3522838783	0	5.40540540541	Processed	Success (19 unique points used)
7	7	1.5526574024	0	0	Processed	Success (22 unique points used)
8	8	1.3567155202	0	5.40540540541	Processed	Success (19 unique points used)
9	9	1.1965433193	0	0	Processed	Success (22 unique points used)
10	10	1.220600804	0	0	Processed	Success (21 unique points used)
11	11	1.3206292932	0	5.40540540541	Processed	Success (19 unique points used)
12	12	1.107593935	0	13.5135135135	Processed	Success (22 unique points used)
13	13	1.3633629831	0	0	Processed	Success (17 unique points used)
14	14	1.0224431009	0	8.10810810811	Processed	Success (18 unique points used)
15	15	1.6890886645	0	5.40540540541	Processed	Success (20 unique points used)
16	16	1.6058371055	0	5.40540540541	Processed	Success (20 unique points used)
17	17	1.459592922	0	0	Processed	Success (21 unique points used)

18	18	1.2870754329	0	0 Processed	Success (17 unique points used)
19	19	1.5282833718	0	5.40540540541 Processed	Success (17 unique points used)
20	20	1.4114779526	0	0 Processed	Success (19 unique points used)

Asian carp (prediction based on joint distributions of all carp)

Task	Run	Species	Atomic Rules	Range Rules	Negated Rules	Logit Rules	Iter.	Conv.	Train Acc
1	1	Asian carp	1	1	1	1	109	0.00911	0.5
2	2	Asian carp	1	1	1	1	107	0.00965	0.5
3	3	Asian carp	1	1	1	1	89	0.009727	0.5
4	4	Asian carp	1	1	1	1	102	0.009998	0.5
5	5	Asian carp	1	1	1	1	107	0.009094	0.5
6	6	Asian carp	1	1	1	1	102	0.008899	0.5
7	7	Asian carp	1	1	1	1	110	0.009807	0.7688
8	8	Asian carp	1	1	1	1	110	0.008994	0.5
9	9	Asian carp	1	1	1	1	115	0.009911	0.5
10	10	Asian carp	1	1	1	1	105	0.009988	0.5
11	11	Asian carp	1	1	1	1	87	0.009848	0.5
12	12	Asian carp	1	1	1	1	105	0.009306	0.5
13	13	Asian carp	1	1	1	1	87	0.009979	0.5
14	14	Asian carp	1	1	1	1	104	0.009112	0.5
15	15	Asian carp	1	1	1	1	115	0.009498	0.5572
16	16	Asian carp	1	1	1	1	109	0.00943	0.5
17	17	Asian carp	1	1	1	1	105	0.009704	0.5
18	18	Asian carp	1	1	1	1	96	0.009289	0.5
19	19	Asian carp	1	1	1	1	84	0.009805	0.5
20	20	Asian carp	1	1	1	1	111	0.009566	0.5324

Task	Run	Pr:Pr/Ac:Pr	Pr:Ab/Ac:Pr	Pr:Pr/Ac:Ab	Pr:Ab/Ac:Ab	Test Acc	Pr:Pr/Ac:Pr	Pr:Ab/Ac:Pr	Pr:Pr/Ac:Ab	Pr:Ab/Ac:Ab	Total Area
1	1	1250	0	278	0	0.45	1125	0	316	0	1470219
2	2	1250	0	233	0	0.4248	1062	0	243	0	1470219
3	3	1250	0	188	0	0.4292	1073	0	204	0	1470219
4	4	1250	0	353	0	0.4484	1121	0	322	0	1470219
5	5	1250	0	234	0	0.408	1020	0	237	0	1470219

Task	Run	Pr:Pr/Ac:Pr	Pr:Ab/Ac:Pr	Pr:Pr/Ac:Ab	Pr:Ab/Ac:Ab	Test Acc	Pr:Pr/Ac:Pr	Pr:Ab/Ac:Pr	Pr:Pr/Ac:Ab	Pr:Ab/Ac:Ab	Total Area
6	6	1250	0	207	0	0.394	985	0	217	0	1470219
7	7	1250	0	319	672	0.7236	1124	0	310	685	1470219
8	8	1250	0	241	0	0.4416	1104	0	240	0	1470219
9	9	1250	0	369	0	0.4112	1028	0	404	0	1470219
10	10	1250	0	191	0	0.4148	1037	0	184	0	1470219
11	11	1250	0	469	0	0.4516	1129	0	494	0	1470219
12	12	1250	0	294	0	0.3848	962	0	300	0	1470219
13	13	1250	0	275	0	0.438	1095	0	278	0	1470219
14	14	1250	0	286	0	0.4272	1068	0	319	0	1470219
15	15	1250	0	402	143	0.54	1173	0	376	177	1470219
16	16	1250	0	250	0	0.3888	972	0	236	0	1470219
17	17	1250	0	368	0	0.4724	1181	0	374	0	1470219
18	18	1250	0	228	0	0.4692	1173	0	258	0	1470219
19	19	1250	0	224	0	0.3992	998	0	200	0	1470219
20	20	1250	0	520	81	0.5468	1250	0	493	117	1470219

Task	Run	Presence Area	Absence Area	Non-predicted Area	Yes	No	ChiSq	p
1	1	342736	0	1127483	25	2	72.490738912	1.678176e-17
2	2	274630	0	1195589	23	3	83.34785967	6.881327e-20
3	3	240346	0	1229873	22	4	88.607696954	4.814124e-21
4	4	388465	0	1081754	24	2	58.054499057	2.549557e-14
5	5	275976	0	1194243	22	5	69.637465123	7.127023e-17
6	6	250937	0	1219282	22	5	79.14299634	5.777321e-19
7	7	378440	781958	309821	22	3	50.697342083	1.077654e-12
8	8	296251	0	1173968	24	2	84.136620628	4.617382e-20
9	9	446100	0	1024119	22	4	36.234467185	0.0000000017
10	10	222970	0	1247249	22	4	97.471470729	5.463785e-23
11	11	559720	0	910499	24	2	32.440027205	0.0000000123
12	12	338920	0	1131299	23	4	58.761868371	1.779569e-14

Task	Run	Presence Area	Absence Area	Non-predicted Area	Yes	No	ChiSq	p
13	13	304636	0	1165583	24	2	81.111837615	2.132985e-19
14	14	354444	0	1115775	21	4	49.013294177	2.542335e-12
15	15	465927	203311	800981	25	1	49.908966443	1.610470e-12
16	16	290409	0	1179810	22	4	69.008747869	9.802766e-17
17	17	428346	0	1041873	24	1	54.137015049	1.869855e-13
18	18	289984	0	1180235	26	1	99.983925184	1.536390e-23
19	19	259107	0	1211112	21	4	75.869406143	3.030593e-18
20	20	604700	117279	748240	26	0	37.214311229	0.0000000011

Task	Run	Commission	Omission (int)	Omission (ext)	Status	Message
1	1	23.311901152	0	7.40740740741	Processed	Success (18 unique points used)
2	2	18.679530056	0	11.5384615385	Processed	Success (19 unique points used)
3	3	16.347632564	0	15.3846153846	Processed	Success (17 unique points used)
4	4	26.4222541	0	7.69230769231	Processed	Success (19 unique points used)
5	5	18.771081043	0	18.5185185185	Processed	Success (15 unique points used)
6	6	17.068001434	0	18.5185185185	Processed	Success (18 unique points used)
7	7	25.740382895	0	12	Processed	Success (20 unique points used)
8	8	20.150127294	0	7.69230769231	Processed	Success (20 unique points used)
9	9	30.342418374	0	15.3846153846	Processed	Success (21 unique points used)
10	10	15.165767821	0	15.3846153846	Processed	Success (17 unique points used)
11	11	38.070518746	0	7.69230769231	Processed	Success (18 unique points used)
12	12	23.052347984	0	14.8148148148	Processed	Success (21 unique points used)
13	13	20.720450491	0	7.69230769231	Processed	Success (20 unique points used)
14	14	24.108245098	0	16	Processed	Success (17 unique points used)
15	15	31.690992975	0	3.84615384615	Processed	Success (21 unique points used)
16	16	19.752771526	0	15.3846153846	Processed	Success (19 unique points used)
17	17	29.134843176	0	4	Processed	Success (23 unique points used)
18	18	19.723864268	0	3.7037037037	Processed	Success (20 unique points used)

Task	Run	Commission	Omission (int)	Omission (ext)	Status	Message
19	19	17.623700959	0	16 Processed		Success (18 unique points used)
20	20	41.129926902	0	0 Processed		Success (18 unique points used)

Gizzard shad

Task	Run	Species	Atomic Rules	Range Rules	Negated Rules	Logit Rules	Iter.	Conv.	Train Acc
1	1	Gizzard shad	1	1	1	1	97	0.009974	0.498
2	2	Gizzard shad	1	1	1	1	96	0.009751	0.9404
3	3	Gizzard shad	1	1	1	1	104	0.009785	0.5
4	4	Gizzard shad	1	1	1	1	118	0.009547	0.4944
5	5	Gizzard shad	1	1	1	1	105	0.009592	0.886
6	6	Gizzard shad	1	1	1	1	114	0.009975	0.8856
7	7	Gizzard shad	1	1	1	1	116	0.009648	0.5
8	8	Gizzard shad	1	1	1	1	101	0.008692	0.4968
9	9	Gizzard shad	1	1	1	1	104	0.009922	0.8004
10	10	Gizzard shad	1	1	1	1	107	0.009608	0.5
11	11	Gizzard shad	1	1	1	1	98	0.009263	0.492
12	12	Gizzard shad	1	1	1	1	109	0.009878	0.4944
13	13	Gizzard shad	1	1	1	1	104	0.009775	0.5
14	14	Gizzard shad	1	1	1	1	118	0.009761	0.4956
15	15	Gizzard shad	1	1	1	1	96	0.009735	0.4924
16	16	Gizzard shad	1	1	1	1	116	0.009787	0.5
17	17	Gizzard shad	1	1	1	1	103	0.009226	0.4916
18	18	Gizzard shad	1	1	1	1	103	0.009167	0.9324
19	19	Gizzard shad	1	1	1	1	98	0.009847	0.5
20	20	Gizzard shad	1	1	1	1	104	0.009477	0.5

Task	Run	Pr:Pr/Ac:Pr	Pr:Ab/Ac:Pr	Pr:Pr/Ac:Ab	Pr:Ab/Ac:Ab	Test Acc	Pr:Pr/Ac:Pr	Pr:Ab/Ac:Pr	Pr:Pr/Ac:Ab	Pr:Ab/Ac:Ab	Total Area
1	1	1245	0	147	0	0.4928	1232	0	170	0	315910

Task	Run	Pr:Pr/Ac:Pr	Pr:Ab/Ac:Pr	Pr:Pr/Ac:Ab	Pr:Ab/Ac:Ab	Test Acc	Pr:Pr/Ac:Pr	Pr:Ab/Ac:Pr	Pr:Pr/Ac:Ab	Pr:Ab/Ac:Ab	Total Area
2	2	1234	16	133	1117	0.9348	1191	59	104	1146	315910
3	3	1250	0	185	0	0.4936	1234	0	155	0	315910
4	4	1236	0	194	0	0.5	1250	0	189	0	315910
5	5	1223	27	147	992	0.896	1211	36	137	1029	315910
6	6	1237	13	125	977	0.8592	1183	59	127	965	315910
7	7	1250	0	397	0	0.4944	1236	0	405	0	315910
8	8	1242	0	136	0	0.4916	1229	0	136	0	315910
9	9	1242	0	197	759	0.7976	1250	0	175	744	315910
10	10	1250	0	293	0	0.4952	1238	0	330	0	315910
11	11	1230	0	166	0	0.4936	1234	0	161	0	315910
12	12	1236	0	160	0	0.4952	1238	0	166	0	315910
13	13	1250	0	146	0	0.4904	1226	0	140	0	315910
14	14	1239	0	145	0	0.4804	1201	0	134	0	315910
15	15	1231	0	166	0	0.496	1240	0	172	0	315910
16	16	1250	0	152	0	0.4896	1224	0	162	0	315910
17	17	1229	0	124	0	0.4752	1188	0	142	0	315910
18	18	1250	0	167	1081	0.9092	1178	67	149	1095	315910
19	19	1250	0	359	0	0.4972	1243	0	349	0	315910
20	20	1250	0	161	0	0.486	1215	0	161	0	315910

Task	Run	Presence Area	Absence Area	Non-predicted Area	Yes	No	ChiSq	p
1	1	41373	0	274537	226	2	1482.541114	0
2	2	29731	286056	123	222	7	2058.0158766	0
3	3	43937	0	271973	227	2	1388.911089	5.396098e-304
4	4	46798	0	269112	231	0	1328.3659985	7.743607e-291
5	5	37470	251860	26580	224	7	1600.5585532	0
6	6	33708	243421	38781	221	8	1770.159401	0
7	7	98070	0	217840	226	1	497.80644637	2.852629e-110

Task	Run	Presence Area	Absence Area	Non-predicted Area	Yes	No	ChiSq	p
8	8	38727	0	277183	225	3	1583.3004471	0
9	9	45806	188866	81238	228	0	1344.4464044	2.480382e-294
10	10	82560	0	233350	228	1	639.62206393	4.037714e-141
11	11	42252	0	273658	229	2	1466.3843818	0
12	12	41515	0	274395	227	1	1491.7941756	0
13	13	37867	0	278043	227	3	1639.1178401	0
14	14	37497	0	278413	224	5	1617.1056318	0
15	15	42723	0	273187	229	1	1455.955301	0
16	16	39339	0	276571	228	2	1585.0419573	0
17	17	33265	0	282645	217	12	1724.512112	0
18	18	42247	272185	1478	218	9	1338.917526	3.944507e-293
19	19	88896	0	227014	229	1	580.26583172	3.282895e-128
20	20	38777	0	277133	226	4	1579.2444315	0

Task	Run	Commission	Omission (int)	Omission (ext)	Status	Message
1	1	13.096451521	0	0.87719298246	Processed	Success (125 unique points used)
2	2	9.4112247159	1.28	3.05676855895	Processed	Success (131 unique points used)
3	3	13.908075085	0	0.87336244541	Processed	Success (129 unique points used)
4	4	14.813712766	0	0	Processed	Success (123 unique points used)
5	5	11.860973062	2.16	3.0303030303	Processed	Success (127 unique points used)
6	6	10.670127568	1.04	3.49344978166	Processed	Success (125 unique points used)
7	7	31.043651673	0	0.44052863436	Processed	Success (130 unique points used)
8	8	12.258871197	0	1.31578947368	Processed	Success (128 unique points used)
9	9	14.499699281	0	0	Processed	Success (126 unique points used)
10	10	26.134025514	0	0.43668122271	Processed	Success (128 unique points used)
11	11	13.374695325	0	0.8658008658	Processed	Success (125 unique points used)
12	12	13.141401032	0	0.43859649123	Processed	Success (125 unique points used)
13	13	11.986641765	0	1.30434782609	Processed	Success (126 unique points used)

Task	Run	Commission	Omission (int)	Omission (ext)	Status	Message
14	14	11.8695198	0	2.18340611354	Processed	Success (125 unique points used)
15	15	13.523788421	0	0.4347826087	Processed	Success (129 unique points used)
16	16	12.452597259	0	0.86956521739	Processed	Success (128 unique points used)
17	17	10.529897756	0	5.24017467249	Processed	Success (120 unique points used)
18	18	13.373112595	0	3.96475770925	Processed	Success (118 unique points used)
19	19	28.13966003	0	0.4347826087	Processed	Success (118 unique points used)
20	20	12.27469849	0	1.73913043478	Processed	Success (121 unique points used)

Rainbow smelt

Task	Run	Species	Atomic Rules	Range Rules	Negated Rules	Logit Rules	Iter.	Conv.	Train Acc
1	1	Rainbow smelt	1	1	1	1	91	0.009969	0.5
2	2	Rainbow smelt	1	1	1	1	70	0.009809	0.494
3	3	Rainbow smelt	1	1	1	1	97	0.009928	0.5
4	4	Rainbow smelt	1	1	1	1	109	0.008601	0.5
5	5	Rainbow smelt	1	1	1	1	104	0.009121	0.4952
6	6	Rainbow smelt	1	1	1	1	113	0.008306	0.5
7	7	Rainbow smelt	1	1	1	1	99	0.009274	0.5
8	8	Rainbow smelt	1	1	1	1	110	0.009761	0.5
9	9	Rainbow smelt	1	1	1	1	104	0.009028	0.4956
10	10	Rainbow smelt	1	1	1	1	103	0.01	0.4932
11	11	Rainbow smelt	1	1	1	1	110	0.009165	0.8624
12	12	Rainbow smelt	1	1	1	1	112	0.008141	0.5
13	13	Rainbow smelt	1	1	1	1	109	0.009755	0.5
14	14	Rainbow smelt	1	1	1	1	99	0.009736	0.5
15	15	Rainbow smelt	1	1	1	1	110	0.009919	0.5
16	16	Rainbow smelt	1	1	1	1	109	0.009448	0.5
17	17	Rainbow smelt	1	1	1	1	103	0.009402	0.5
18	18	Rainbow smelt	1	1	1	1	107	0.009421	0.5
19	19	Rainbow smelt	1	1	1	1	103	0.008763	0.5
20	20	Rainbow smelt	1	1	1	1	102	0.00938	0.5

Task	Run	Pr:Pr/Ac:Pr	Pr:Ab/Ac:Pr	Pr:Pr/Ac:Ab	Pr:Ab/Ac:Ab	Test Acc	Pr:Pr/Ac:Pr	Pr:Ab/Ac:Pr	Pr:Pr/Ac:Ab	Pr:Ab/Ac:Ab	Total Area
1	1	1250	0	132	0	0.4856	1214	0	133	0	315910
2	2	1235	0	176	0	0.4812	1203	0	179	0	315910
3	3	1250	0	98	0	0.46	1150	0	93	0	315910
4	4	1250	0	146	0	0.4596	1149	0	174	0	315910
5	5	1238	0	153	0	0.4528	1132	0	123	0	315910

Task	Run	Pr:Pr/Ac:Pr	Pr:Ab/Ac:Pr	Pr:Pr/Ac:Ab	Pr:Ab/Ac:Ab	Test Acc	Pr:Pr/Ac:Pr	Pr:Ab/Ac:Pr	Pr:Pr/Ac:Ab	Pr:Ab/Ac:Ab	Total Area
6	6	1250	0	355	0	0.4932	1233	0	330	0	315910
7	7	1250	0	249	0	0.488	1220	0	223	0	315910
8	8	1250	0	187	0	0.464	1160	0	167	0	315910
9	9	1239	0	208	0	0.4796	1199	0	197	0	315910
10	10	1233	0	221	0	0.4904	1226	0	199	0	315910
11	11	1250	0	181	906	0.8352	1184	34	192	904	315910
12	12	1250	0	106	0	0.4624	1156	0	100	0	315910
13	13	1250	0	524	0	0.5	1250	0	497	0	315910
14	14	1250	0	146	0	0.4804	1201	0	149	0	315910
15	15	1250	0	130	0	0.474	1185	0	132	0	315910
16	16	1250	0	251	0	0.488	1220	0	225	0	315910
17	17	1250	0	251	0	0.4908	1227	0	249	0	315910
18	18	1250	0	152	0	0.4704	1176	0	142	0	315910
19	19	1250	0	217	0	0.4928	1232	0	219	0	315910
20	20	1250	0	237	0	0.4784	1196	0	229	0	315910

Task	Run	Presence Area	Absence Area	Non-predicted Area	Yes	No	ChiSq	p
1	1	32350	0	283560	112	4	940.16151215	1.825575e-206
2	2	43121	0	272789	119	4	720.60844825	9.870825e-159
3	3	27204	0	288706	115	6	1148.5572768	9.235124e-252
4	4	39368	0	276542	113	8	726.42506409	5.364761e-160
5	5	33435	0	282475	108	8	834.67819727	1.558096e-183
6	6	83977	0	231933	121	1	329.46560357	1.256550e-73
7	7	61077	0	254833	119	2	484.37381176	2.387926e-107
8	8	45356	0	270554	114	6	634.67282962	4.814261e-140
9	9	54032	0	261878	115	4	530.93427992	1.768852e-117
10	10	53071	0	262839	120	1	587.41755366	9.133334e-130
11	11	49819	229213	36878	114	4	580.54784526	2.850449e-128

Task	Run	Presence Area	Absence Area	Non-predicted Area	Yes	No	ChiSq	p
12	12	30471	0	285439	112	7	974.31879056	6.862901e-214
13	13	130524	0	185386	120	0	170.43854004	5.934521e-39
14	14	37565	0	278345	116	4	823.15788531	4.979765e-181
15	15	34801	0	281109	111	4	857.72388705	1.521899e-188
16	16	58415	0	257495	119	2	511.95870001	2.377164e-113
17	17	59303	0	256607	119	2	502.48155742	2.741802e-111
18	18	38943	0	276967	119	4	811.09655166	2.086852e-178
19	19	54303	0	261607	116	1	552.07740926	4.447037e-122
20	20	59375	0	256535	115	4	472.46637805	9.312575e-105

Task	Run	Commission	Omission (int)	Omission (ext)	Status	Message
1	1	10.240258301	0	3.44827586207	Processed	Success (77 unique points used)
2	2	13.64977367	0	3.25203252033	Processed	Success (77 unique points used)
3	3	8.6113133487	0	4.95867768595	Processed	Success (84 unique points used)
4	4	12.461777088	0	6.61157024793	Processed	Success (84 unique points used)
5	5	10.58371055	0	6.89655172414	Processed	Success (89 unique points used)
6	6	26.582570985	0	0.81967213115	Processed	Success (78 unique points used)
7	7	19.333670982	0	1.65289256198	Processed	Success (75 unique points used)
8	8	14.357253648	0	5	Processed	Success (85 unique points used)
9	9	17.103605457	0	3.36134453782	Processed	Success (80 unique points used)
10	10	16.799404894	0	0.82644628099	Processed	Success (78 unique points used)
11	11	15.769997784	0	3.38983050847	Processed	Success (80 unique points used)
12	12	9.6454686461	0	5.88235294118	Processed	Success (76 unique points used)
13	13	41.316830743	0	0	Processed	Success (78 unique points used)
14	14	11.891044918	0	3.33333333333	Processed	Success (75 unique points used)
15	15	11.016112184	0	3.47826086957	Processed	Success (85 unique points used)
16	16	18.491025925	0	1.65289256198	Processed	Success (82 unique points used)
17	17	18.772118641	0	1.65289256198	Processed	Success (81 unique points used)

Task	Run	Commission	Omission (int)	Omission (ext)	Status	Message
18	18	12.327245101	0	3.25203252033	Processed	Success (76 unique points used)
19	19	17.189389383	0	0.8547008547	Processed	Success (79 unique points used)
20	20	18.794909943	0	3.36134453782	Processed	Success (84 unique points used)

Rainbow trout (and associated whirling disease)

Task	Run	Species	Atomic Rules	Range Rules	Negated Rules	Logit Rules	Iter.	Conv.	Train Acc
1	1	Rainbow trout	1	1	1	1	110	0.009864	0.6488
2	2	Rainbow trout	1	1	1	1	108	0.009623	0.488
3	3	Rainbow trout	1	1	1	1	109	0.009918	0.496
4	4	Rainbow trout	1	1	1	1	120	0.009641	0.75
5	5	Rainbow trout	1	1	1	1	92	0.009712	0.7288
6	6	Rainbow trout	1	1	1	1	100	0.009483	0.7404
7	7	Rainbow trout	1	1	1	1	118	0.009954	0.668
8	8	Rainbow trout	1	1	1	1	110	0.009827	0.7056
9	9	Rainbow trout	1	1	1	1	106	0.009715	0.7636
10	10	Rainbow trout	1	1	1	1	99	0.009617	0.6484
11	11	Rainbow trout	1	1	1	1	97	0.009772	0.762
12	12	Rainbow trout	1	1	1	1	95	0.009251	0.7916
13	13	Rainbow trout	1	1	1	1	98	0.009873	0.606
14	14	Rainbow trout	1	1	1	1	100	0.009711	0.4952
15	15	Rainbow trout	1	1	1	1	103	0.009706	0.6712
16	16	Rainbow trout	1	1	1	1	108	0.009605	0.7356
17	17	Rainbow trout	1	1	1	1	111	0.008796	0.6596
18	18	Rainbow trout	1	1	1	1	108	0.009759	0.6692
19	19	Rainbow trout	1	1	1	1	95	0.009412	0.6956
20	20	Rainbow trout	1	1	1	1	93	0.009973	0.6764

Task	Run	Pr:Pr/Ac:Pr	Pr:Ab/Ac:Pr	Pr:Pr/Ac:Ab	Pr:Ab/Ac:Ab	Test Acc	Pr:Pr/Ac:Pr	Pr:Ab/Ac:Pr	Pr:Pr/Ac:Ab	Pr:Ab/Ac:Ab	Total Area
1	1	1223	4	608	399	0.6584	1216	12	584	430	315910
2	2	1220	0	465	0	0.48	1200	0	483	0	315910
3	3	1240	0	566	0	0.4956	1239	0	583	0	315910
4	4	1203	37	453	672	0.7524	1202	41	411	679	315910

Task	Run	Pr:Pr/Ac:Pr	Pr:Ab/Ac:Pr	Pr:Pr/Ac:Ab	Pr:Ab/Ac:Ab	Test Acc	Pr:Pr/Ac:Pr	Pr:Ab/Ac:Pr	Pr:Pr/Ac:Ab	Pr:Ab/Ac:Ab	Total Area
5	5	1220	22	448	602	0.7208	1206	30	484	596	315910
6	6	1233	12	501	618	0.7264	1194	29	503	622	315910
7	7	1221	8	466	449	0.676	1211	19	440	479	315910
8	8	1229	9	477	535	0.7012	1223	21	506	530	315910
9	9	1139	106	387	770	0.732	1065	170	410	765	315910
10	10	1238	6	560	383	0.6524	1232	18	541	399	315910
11	11	1200	46	424	705	0.7664	1188	56	405	728	315910
12	12	1173	77	441	806	0.802	1185	65	422	820	315910
13	13	1229	0	546	286	0.5892	1212	0	549	261	315910
14	14	1238	0	590	0	0.49	1225	0	556	0	315910
15	15	1209	19	514	469	0.6728	1193	46	482	489	315910
16	16	1211	32	464	628	0.7232	1200	38	478	608	315910
17	17	1234	4	488	415	0.644	1200	16	505	410	315910
18	18	1229	11	541	444	0.6796	1217	16	500	482	315910
19	19	1205	45	514	534	0.6728	1163	70	516	519	315910
20	20	1238	9	547	453	0.6948	1233	5	506	504	315910

Task	Run	Presence Area	Absence Area	Non-predicted Area	Yes	No	ChiSq	p
1	1	147394	105589	62927	405	9	435.53410456	1.014865e-96
2	2	120726	0	195184	409	15	609.24777481	1.630646e-134
3	3	147783	0	168127	409	3	455.9782306	3.606667e-101
4	4	111433	171484	32993	400	11	693.09555306	9.487070e-153
5	5	118147	149713	48050	404	11	637.077209	1.444132e-140
6	6	125539	156566	33805	399	14	557.8069959	2.521580e-123
7	7	115372	118180	82358	405	11	664.09994781	1.917346e-146
8	8	123548	130826	61536	411	6	618.94019541	1.271338e-136
9	9	99801	192538	23571	318	96	391.72427862	3.487400e-87
10	10	141791	99226	74893	395	7	462.95576971	1.093123e-102

Task	Run	Presence Area	Absence Area	Non-predicted Area	Yes	No	ChiSq	p
11	11	109150	176146	30614	400	15	701.6930328	1.280984e-154
12	12	105799	208455	1656	394	18	714.24590239	2.387169e-157
13	13	140209	65746	109955	401	7	480.22227063	1.911517e-106
14	14	142500	0	173410	402	10	458.00987234	1.303105e-101
15	15	122130	124776	69004	397	19	565.42063319	5.564921e-125
16	16	120130	156032	39748	408	12	622.82970038	1.812633e-137
17	17	124209	101282	90419	401	12	577.83404549	1.109740e-127
18	18	132002	114960	68948	406	9	535.9112465	1.461970e-118
19	19	126379	136907	52624	398	20	530.87492048	1.822239e-117
20	20	136853	118973	60084	415	5	526.68203228	1.488658e-116

Task	Run	Commission	Omission (int)	Omission (ext)	Status	Message
1	1	46.656959261	0.32	2.17391304348	Processed	Success (284 unique points used)
2	2	38.215314488	0	3.53773584906	Processed	Success (285 unique points used)
3	3	46.780095597	0	0.72815533981	Processed	Success (300 unique points used)
4	4	35.273653889	2.96	2.67639902676	Processed	Success (290 unique points used)
5	5	37.398942737	1.76	2.65060240964	Processed	Success (299 unique points used)
6	6	39.738849672	0.96	3.38983050847	Processed	Success (287 unique points used)
7	7	36.520527998	0.64	2.64423076923	Processed	Success (287 unique points used)
8	8	39.108606882	0.72	1.43884892086	Processed	Success (292 unique points used)
9	9	31.591592542	8.48	23.1884057971	Processed	Success (281 unique points used)
10	10	44.883352854	0.48	1.74129353234	Processed	Success (293 unique points used)
11	11	34.550979709	3.68	3.61445783133	Processed	Success (292 unique points used)
12	12	33.49023456	6.16	4.36893203883	Processed	Success (285 unique points used)
13	13	44.382577316	0	1.71568627451	Processed	Success (295 unique points used)
14	14	45.107783862	0	2.42718446602	Processed	Success (285 unique points used)
15	15	38.659744864	1.52	4.56730769231	Processed	Success (293 unique points used)
16	16	38.026653161	2.56	2.85714285714	Processed	Success (290 unique points used)

Task	Run	Commission	Omission (int)	Omission (ext)	Status	Message
17	17	39.31784369	0.32	2.90556900726	Processed	Success (295 unique points used)
18	18	41.784685512	0.88	2.1686746988	Processed	Success (286 unique points used)
19	19	40.004748188	3.6	4.78468899522	Processed	Success (282 unique points used)
20	20	43.320249438	0.72	1.19047619048	Processed	Success (289 unique points used)

Appendix 6, Listing of biota of concern documented as occurring in aquatic habitats in HUC10, HUC09, and immediately adjacent hydrological units (courtesy of Amy Benson, USGS/BRD/Florida Integrated Science Center, Gainesville FL).

Genus	Species	State	County	Locality	HUC	Comment
Bythotrephes	cederstroemii	ONT	Muskoka	Loon Lake (45o55'30W 79o26'N)	0	NULL
Bythotrephes	cederstroemii	MN	Carlton	St. Louis River downstream of the Cloquet River	4010201	St. Louis
Bythotrephes	cederstroemii	MN	St. Louis	Cloquet River from Island Lake to the St. Louis River	4010202	Cloquet
Bythotrephes	cederstroemii	MN	St. Louis	Fish Lake	4010202	Cloquet
Bythotrephes	cederstroemii	MN	St. Louis	Island Lake	4010202	Cloquet
Bythotrephes	cederstroemii	WI	Iron	Giles Flowage [a reservoir just S of Montreal, WI]	4010302	Bad-Montreal
Bythotrephes	cederstroemii	MI	Alger	Beaver Lake, Pictured Rocks National Lakeshore	4020201	Betsy-Chocolay
Bythotrephes	cederstroemii	MI	Chippewa	Monacle Lake	4020203	Waiska
Bythotrephes	cederstroemii	NULL	NULL	Lake Superior	4020300	Lake Superior
Bythotrephes	cederstroemii	MI	NULL	Lake Superior	4020300	Lake Superior
Bythotrephes	cederstroemii	MN	NULL	Lake Superior	4020300	Lake Superior
Bythotrephes	cederstroemii	MN	NULL	Lake Superior	4020300	Lake Superior
Bythotrephes	cederstroemii	WI	NULL	Lake Superior	4020300	Lake Superior
Bythotrephes	cederstroemii	MI	Marquette	Lake Michigamme	4030107	Michigamme
Bythotrephes	cederstroemii	NULL	NULL	Lake Michigan	4060200	Lake Michigan
Bythotrephes	cederstroemii	IL	NULL	Lake Michigan	4060200	Lake Michigan
Bythotrephes	cederstroemii	IL	NULL	Lake Michigan	4060200	Lake Michigan
Bythotrephes	cederstroemii	IN	NULL	Lake Michigan	4060200	Lake Michigan
Bythotrephes	cederstroemii	IN	NULL	Lake Michigan	4060200	Lake Michigan
Bythotrephes	cederstroemii	MI	NULL	Lake Michigan	4060200	Lake Michigan
Bythotrephes	cederstroemii	MI	NULL	Lake Michigan	4060200	Lake Michigan
Bythotrephes	cederstroemii	WI	NULL	Lake Michigan	4060200	Lake Michigan
Bythotrephes	cederstroemii	WI	NULL	Lake Michigan	4060200	Lake Michigan
Bythotrephes	cederstroemii	NULL	NULL	Lake Huron	4080300	Lake Huron
Bythotrephes	cederstroemii	MI	NULL	Lake Huron	4080300	Lake Huron
Bythotrephes	cederstroemii	MI	NULL	Lake Huron	4080300	Lake Huron

Appendix 6, Listing of current non-native species in Missour River (HUC10), Rainy-Red-Souris Rivers (HUC09), and immediately adjacent hydrological units.

Genus	Species	State	County	Locality	HUC	Comment
Bythotrephes	cederstroemii	NULL	NULL	Lake St. Clair	4090002	Lake St Clair
Bythotrephes	cederstroemii	PA	Erie	Presque Isle Bay	4120101	Chautauqua-Conneaut
Bythotrephes	cederstroemii	NULL	NULL	Lake Erie	4120200	Lake Erie
Bythotrephes	cederstroemii	MI	NULL	Lake Erie	4120200	Lake Erie
Bythotrephes	cederstroemii	NY	NULL	Lake Erie	4120200	Lake Erie
Bythotrephes	cederstroemii	NY	NULL	Lake Erie	4120200	Lake Erie
Bythotrephes	cederstroemii	OH	NULL	Lake Erie	4120200	Lake Erie
Bythotrephes	cederstroemii	OH	NULL	Lake Erie	4120200	Lake Erie
Bythotrephes	cederstroemii	PA	Erie	Lake Erie	4120200	Lake Erie
Bythotrephes	cederstroemii	PA	Erie	Lake Erie	4120200	Lake Erie
Bythotrephes	cederstroemii	NULL	NULL	Lake Ontario	4150200	Lake Ontario
Bythotrephes	cederstroemii	NULL	NULL	Lake Ontario	4150200	Lake Ontario
Bythotrephes	cederstroemii	NULL	NULL	Lake Ontario	4150200	Lake Ontario
Bythotrephes	cederstroemii	NY	Niagara	Lake Ontario at Somerset, NY (found in the cooling water intake of the NY State Electric and Gas Corporation-owned Somerset Coal Generating Station, 610 m offshore)	4150200	Lake Ontario
Bythotrephes	cederstroemii	ONT	NULL	Lake Saganaga at Seagull Island	9030001	Rainy Headwaters
Corbicula	fluminea	MN	St. Louis	St. Louis River near the Duluth Wastewater Treatment Plant	4010201	St. Louis
Corbicula	fluminea	WI	NULL	St. Louis River estuary	4010201	St Louis
Corbicula	fluminea	WI	NULL	St. Louis River estuary	4010201	St Louis
Corbicula	fluminea	MI	Marquette	Lake Superior in the warmwater effluent of the Upper Peninsula Power Company in Marquette.	4020300	Lake Superior
Corbicula	fluminea	MI	NULL	Lake Michigan, J. H. Campbell Power Plant	4060200	Lake Michigan
Corbicula	fluminea	MI	Monroe	Lake Erie, Bolles Harbor, Michigan Department of Natural Resources Access Area, 5.6 km E of Monroe	4100001	Ottawa-Stony
Corbicula	fluminea	MI	Monroe	Lake Erie, Detroit Beach, 6.4 km ENE of Monroe	4100001	Ottawa-Stony

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Genus	Species	State	County	Locality	HUC	Comment
Corbicula	fluminea	MI	Monroe	Lake Erie, Sterling State Park, 5.6 km E of Monroe, 9.6 km SSW of Newport	4100001	Ottawa-Stony
Corbicula	fluminea	MI	Monroe	Lake Erie, Sterling State Park, 5.6 km E of Monroe, 9.6 km SSW of Newport	4100001	Ottawa-Stony
Corbicula	fluminea	OH	Lucas	Lake Erie, Maumee Bay, Bay Shore Generating Station, shoreline adjacent to discharge	4100006	Tiffin
Corbicula	fluminea	OH	Lucas	Maumee River, Acme Generating Station discharge	4100009	Lower Maumee
Corbicula	fluminea	OH	Lucas	Lake Erie, outfall of Oregon Sewage Treatment Plant, Maumee Bay	4100010	Cedar-Portage
Corbicula	fluminea	NY	Chautauqua	Lake Erie at Dunkirk Harbor	4120200	Lake Erie
Corbicula	fluminea	NY	Niagara	Western end of Erie Canal, including Gasport	4130001	Oak Orchard-Twelvemile
Corbicula	fluminea	NY	Seneca	NYSEG generating station, Seneca Lake	4140201	Seneca
Corbicula	fluminea	WI	St. Croix	St. Croix River, Hudson Railroad Bridge, river km 25.4 - 29, near Hudson	7030005	Lower St. Croix
Corbicula	fluminea	IA	Alamakee	Mississippi River, Lansing	7060001	Coon-Yellow
Corbicula	fluminea	IA	Alamakee	Mississippi River, river km 1054.1, 4.2 km SW of Ferryville, 6.7 km SE of Lansing	7060001	Coon-Yellow
Corbicula	fluminea	WI	Crawford	Mississippi River, river km 1016, W side of each channel, north tip of island, 1.3 km W of Prairie du Chien	7060001	Coon-Yellow
Corbicula	fluminea	WI	Vernon	Mississippi River, 1.6 km downstream from LaCrosse Boiling Water Reactor, 32 km S of LaCrosse	7060001	Coon-Yellow
Corbicula	fluminea	IL	Rock Island	Commonwealth Edison Power Plant, near Rock Island	7080101	Copperas-Duck
Corbicula	fluminea	IL	Rock Island	Quad Cities Nuclear Plant, 32 km NE of Moline	7080101	Copperas-Duck
Corbicula	fluminea	IL	Hancock	Mississippi River, Keokuk Pool	7080104	Flint-Henderson
Corbicula	fluminea	IA	Linn	Cedar River, vicinity of Lewis Access, 6.4 km upstream from Duane Arnold Power Plant	7080205	West Fork Cedar
Corbicula	fluminea	IL	Pike	Mississippi River (Gulf of Mexico Drainage) River Mile 277.8, Cash Island, at toe, Pool 24	7110004	The Sny

Appendix 6, Listing of current non-native species in Missour River (HUC10), Rainy-Red-Souris Rivers (HUC09), and immediately adjacent hydrological units.

Genus	Species	State	County	Locality	HUC	Comment
Corbicula	fluminea	IL	Pike	Mississippi River (Gulf of Mexico Drainage) River Mile 285.5, 2 mi above Louisiana, MO, Hickory Chute Lower lights and daymark (just downstream of lights and daymark)	7110004	The Sny
Corbicula	fluminea	MO	Lincoln	Mississippi River, river km 386.4, 4.2 km E of Winfield	7110004	The Sny
Corbicula	fluminea	MO	Pike	Mississippi River (Gulf of Mexico Drainage) River mile 292.9-293.9, Blackbird Island side channel, Ted Shanks Wildlife Management Area	7110004	The Sny
Corbicula	fluminea	IL	Jersey	Mississippi River (Gulf of Mexico Drainage) River Mile 217, 1 mi E Grafton	7110009	Peruque-Piasa
Corbicula	fluminea	IL	Kankakee	Exline Slough (Baker Creek-Kankakee River Drainage) 1 mi N St. George, Co. Rd 6000N	7120001	Kankakee
Corbicula	fluminea	IL	Kankakee	Kankakee River (Illinois River Drainage) 1.5 mi NE Aroma Park, at McHie Ferry historical marker, 1870 Sandbar Rd.	7120001	Kankakee
Corbicula	fluminea	IL	Kankakee	Kankakee River (Illinois River Drainage) 2.75 mi E Momence	7120001	Kankakee
Corbicula	fluminea	IL	Kankakee	Kankakee River (Illinois River Drainage) 6.5 mi E Momence, E side of Woodland (South Shore)	7120001	Kankakee
Corbicula	fluminea	IL	Kankakee	Kankakee River (Illinois River Drainage) Altorf, Langham Island	7120001	Kankakee
Corbicula	fluminea	IL	Kankakee	Kankakee River (Illinois River Drainage) Aroma Park	7120001	Kankakee
Corbicula	fluminea	IL	Kankakee	Kankakee River (Illinois River Drainage) Momence, Island Park, downstream of RR bridge	7120001	Kankakee
Corbicula	fluminea	IL	Kankakee	Trim Creek (Kankakee River Drainage) 1 mi SW Grant Park, Co. Rd. 7000N bridge	7120001	Kankakee
Corbicula	fluminea	IL	Kankakee	Trim Creek (Kankakee River Drainage) 2.5 mi S Grant Park, Co. Rd. 5500N	7120001	Kankakee
Corbicula	fluminea	IL	Will	Dresden Lake, near Dresden Nuclear Station, 14.4 km E of Morris	7120001	Kankakee

Appendix 6, Listing of current non-native species in Missour River (HUC10), Rainy-Red-Souris Rivers (HUC09), and immediately adjacent hydrological units.

Genus	Species	State	County	Locality	HUC	Comment
Corbicula	fluminea	IL	Will	Dresden Nuclear Station, 14.4 km E of Morris	7120001	Kankakee
Corbicula	fluminea	IL	Will	Kankakee River, Custer Park	7120001	Kankakee
Corbicula	fluminea	IL	Will	Kankakee River, near Dresden Nuclear Station, 14.4 km E of Morris	7120001	Kankakee
Corbicula	fluminea	IL	Iroquois	Iroquois River (Kankakee River Drainage) 1.5 mi NE Watseka	7120002	Iroquois
Corbicula	fluminea	IL	Iroquois	Iroquois River (Kankakee River Drainage) 2 mi N Eastburn	7120002	Iroquois
Corbicula	fluminea	IL	Iroquois	Iroquois River (Kankakee River Drainage) 5 mi SW Iroquois, Co. Rd. 2500E bridge	7120002	Iroquois
Corbicula	fluminea	IL	Iroquois	Iroquois River (Kankakee River Drainage) Iroquois, Rt. 52 bridge (most individuals under bridge on N side)	7120002	Iroquois
Corbicula	fluminea	IL	Iroquois	Iroquois River (Kankakee River Drainage) Watseka, city boat ramp (downstream from ramp, E shoreline)	7120002	Iroquois
Corbicula	fluminea	IL	Iroquois	Mud Creek (Sugar Creek-Iroquois River Drainage) 2 mi SW Milford, Co. Rd. 900N bridge (downstream of bridge)	7120002	Iroquois
Corbicula	fluminea	IL	Iroquois	Shavetail Creek (Spring Creek-Iroquois River Drainage) 3 mi SSW Crescent City, Co. Rd. 1300E bridge (downstream of bridge)	7120002	Iroquois
Corbicula	fluminea	IL	Iroquois	Spring Creek (Iroquois River Drainage) 2 mi N Crescent City, Rt. 49 bridge	7120002	Iroquois
Corbicula	fluminea	IL	Iroquois	Sugar Creek (Iroquois River Drainage)-Kankakee River Drainage) 1 mi ESE Milford, Co. Rd. 2470E bridge (upstream from bridge)	7120002	Iroquois
Corbicula	fluminea	IL	Iroquois	Sugar Creek (Iroquois River-Kankakee River Drainage) 1.5 mi NW Milford, Co. Rd. 1100N bridge (downstream of bridge)	7120002	Iroquois

Appendix 6, Listing of current non-native species in Missour River (HUC10), Rainy-Red-Souris Rivers (HUC09), and immediately adjacent hydrological units.

Genus	Species	State	County	Locality	HUC	Comment
Corbicula	fluminea	IL	Kankakee	Iroquois River (Kankakee River Drainage) 4 mi E Chebanse, Sugar Island bridge (upstream of bridge, E side)	7120002	Iroquois
Corbicula	fluminea	MN	Hennepin	Minnesota River, Northern States Power Company Blackdog Plant near Burnsville	7120002	Iroquois
Corbicula	fluminea	IL	Cook	Des Plaines River (Illinois River Drainage) Riverside, Barrypoint Rd. bridge	7120004	Des Plaines
Corbicula	fluminea	IL	Cook	Des Plaines River (Illinois River Drainage) Riverside, Barrypoint Rd. bridge (300m downstream of bridge)	7120004	Des Plaines
Corbicula	fluminea	IL	Will	Kankakee River (lllinois River Drainage) Custer Park, mouth Horse Creek	7120004	Des Plaines
Corbicula	fluminea	IL	Grundy	Mazon River (Illinois River Drainage) 1.8 km SE Morris	7120005	Upper Illinois
Corbicula	fluminea	IL	Peoria	Catapillar Tractor Plant, Peoria	7130001	Lower Illinois-Senachw
Corbicula	fluminea	IL	Ford	North Fork Vermilion River (Illinois River Drainage) 1 mi E Piper City, Rt. 24	7130002	Vermilion
Corbicula	fluminea	IL	Livingston	Vermilion River (Illinois River Drainage) 2 mi W Cornell	7130002	Vermilion
Corbicula	fluminea	IL	Fulton	Illinois River, Turkey Island Chute above Kingston Mines, river km 237.3	7130003	Lower Illinois-Lake Ch
Corbicula	fluminea	IL	Mason	Illinois Power facility, Havanna	7130003	Lower Illinois-Lake Ch
Corbicula	fluminea	IL	Mason	Illinois River, Lake Chautauqua	7130003	Lower Illinois-Lake Ch
Corbicula	fluminea	IL	Mason	Illinois River, lower end of Bath Chute below Bath, river km 170.7	7130003	Lower Illinois-Lake Ch
Corbicula	fluminea	IL	Mason	Illinois River, Upper Bath Chute, river km 181.6	7130003	Lower Illinois-Lake Ch
Corbicula	fluminea	IL	Tazewell	Mackinaw River (Illinois River Drainage) 3 mi NE Talbot, Co. Rd. 1400N (Manito Rd.)	7130003	Lower Illinois-Lake Chautauqua
Corbicula	fluminea	IL	McLean	Henline Creek (Mackinaw River Drainage) 4 mi NW Colfax, Co. Rd. 2150N	7130004	Mackinaw

Appendix 6, Listing of current non-native species in Missour River (HUC10), Rainy-Red-Souris Rivers (HUC09), and immediately adjacent hydrological units.

Genus	Species	State	County	Locality	HUC	Comment
Corbicula	fluminea	IL	Tazewell	Mackinaw River (Illinois River Drainage) 2 mi SW Mackinaw, Ill Rt. 9	7130004	Mackinaw
Corbicula	fluminea	IL	Tazewell	Mackinaw River (Illinois River Drainage) 3 mi NNE Hopedale, Co. Rd. 2550E (= Levy Rd, at abandoned iron bridge)	7130004	Mackinaw
Corbicula	fluminea	IL	Tazewell	Mackinaw River (Illinois River Drainage) 4 mi SW Mackinaw, Co. Rd. 2675E	7130004	Mackinaw
Corbicula	fluminea	IL	Tazewell	Mackinaw River (Illinois River Drainage) Mackinaw River State Fish and Wildlife Area	7130004	Mackinaw
Corbicula	fluminea	IL	Knox	McMaster Lake (Snakeden Hollow-Spoon River Drainage) 1 mi SE Victoria, Snakeden Hollow State Fish and Wildlife Area	7130005	Spoon
Corbicula	fluminea	IL	Champaign	Big Ditch (Sagamon River Drainage) 5.5 mi NW Mahomet	7130006	Upper Sangamon
Corbicula	fluminea	IL	Champaign	Sangamon River (Illinois River Drainage) 0.5 mi E Mahomet, I-74 bridge (~ 200 m upstream of bridge)	7130006	Upper Sangamon
Corbicula	fluminea	IL	Champaign	Sangamon River (Illinois River Drainage) Mahomet, Lake of the Woods (upstream of wooden bridge)	7130006	Upper Sangamon
Corbicula	fluminea	IL	Christian	Kincaid Generating Station	7130007	South Fork Sangamon
Corbicula	fluminea	IL	Christian	South Fork Sangamon River [near Taylorsville, IL]	7130007	South Fork Sangamon
Corbicula	fluminea	IL	Christian/Sangam	Lake Sangchris, near Kincaid, Illinois	7130007	South Fork Sangamon
Corbicula	fluminea	IL	Christian/Sangam	Lake Sangchris, near Kincaid, Illinois	7130007	South Fork Sangamon
Corbicula	fluminea	IL	Sangamon	Lake Springfield, near Springfield, Illinois	7130007	South Fork Sangamon
Corbicula	fluminea	IL	Sangamon	Lick Creek, near confluence with Lake Springfield	7130007	South Fork Sangamon
Corbicula	fluminea	IL	Sangamon	Sugar Creek, near confluence with Lake Springfield	7130007	South Fork Sangamon
Corbicula	fluminea	IL	Mason	Illinois River, Sugar Creek Island Chute, river km 152	7130009	Salt
Corbicula	fluminea	IL	Calhoun	Illinois River, below mouth of Crawford Creek, 2.2 km S of Kampsville	7130011	Lower Illinois
Corbicula	fluminea	IL	Calhoun	Illinois River, just downstream from ferry landing at Kampsville, river km 51.5	7130011	Lower Illinois

Appendix 6, Listing of current non-native species in Missour River (HUC10), Rainy-Red-Souris Rivers (HUC09), and immediately adjacent hydrological units.

Genus	Species	State	County	Locality	HUC	Comment
Corbicula	fluminea	IL	Macoupin	Otter Creek (Hodges Creek-Macoupin Creek Drainage) 1 mi S Hettick, Ill, Rt. 111 bridge	7130012	Macoupin
Corbicula	fluminea	IL	Madison	Granite City Steel Company, Granite City	7140101	Cahokia-Joachim
Corbicula	fluminea	IL	Madison	Granite City Steel Company, Granite City	7140101	Cahokia-Joachim
Corbicula	fluminea	IL	Monroe	Mississippi River, river km 235.2 - 236.5, 5.6 km W of Maeys	7140101	Cahokia-Joachim
Corbicula	fluminea	MO	Mississippi	Mississippi River, confluence of Mississippi and Ohio rivers, under Illinois - Missouri bridge	7140101	Cahokia-Joachim
Corbicula	fluminea	MO	Ste. Genevieve	Mississippi River, Brickeys	7140101	Cahokia-Joachim
Corbicula	fluminea	MO	Ste. Genevieve	Mississippi River, river km 208 - 212, in Establishment Side Canal, 8.3 km NE of Bloomdale, 11.8 km NW of Ste. Genevieve	7140101	Cahokia-Joachim
Corbicula	fluminea	MO	Crawford	Meramec River, Blue Springs Birch State Park	7140102	Meramec
Corbicula	fluminea	MO	Crawford	Meramec River, Daniel Boone Camp	7140102	Meramec
Corbicula	fluminea	MO	Crawford	Meramec River, river km 190.1	7140102	Meramec
Corbicula	fluminea	MO	Crawford	Meramec River, river km 192.6	7140102	Meramec
Corbicula	fluminea	MO	Crawford	Meramec River, river km 200.3	7140102	Meramec
Corbicula	fluminea	MO	Crawford	Meramec River, river km 208.6	7140102	Meramec
Corbicula	fluminea	MO	Franklin	Meramec River, 7 km NE of Sullivan	7140102	Meramec
Corbicula	fluminea	MO	Franklin	Meramec River, river km 102.4	7140102	Meramec
Corbicula	fluminea	MO	Franklin	Meramec River, river km 109	7140102	Meramec
Corbicula	fluminea	MO	Franklin	Meramec River, river km 116.2	7140102	Meramec
Corbicula	fluminea	MO	Franklin	Meramec River, river km 126.4	7140102	Meramec
Corbicula	fluminea	MO	Franklin	Meramec River, river km 134.2)	7140102	Meramec
Corbicula	fluminea	MO	Franklin	Meramec River, river km 141.8	7140102	Meramec
Corbicula	fluminea	MO	Franklin	Meramec River, river km 146.1	7140102	Meramec
Corbicula	fluminea	MO	Franklin	Meramec River, river km 150.2	7140102	Meramec
Corbicula	fluminea	MO	Franklin	Meramec River, river km 160	7140102	Meramec
Corbicula	fluminea	MO	Franklin	Meramec River, river km 163.8	7140102	Meramec

Appendix 6, Listing of current non-native species in Missour River (HUC10), Rainy-Red-Souris Rivers (HUC09), and immediately adjacent hydrological units.

Genus	Species	State	County	Locality	HUC	Comment
Corbicula	fluminea	MO	Franklin	Meramec River, river km 170.4	7140102	Meramec
Corbicula	fluminea	MO	Franklin	Meramec River, river km 172.2	7140102	Meramec
Corbicula	fluminea	MO	Franklin	Meramec River, river km 175.2	7140102	Meramec
Corbicula	fluminea	MO	Franklin	Meramec River, river km 176.5	7140102	Meramec
Corbicula	fluminea	MO	Franklin	Meramec River, river km 177.8	7140102	Meramec
Corbicula	fluminea	MO	Franklin	Meramec River, river km 83.2	7140102	Meramec
Corbicula	fluminea	MO	Franklin	Meramec River, river km 87	7140102	Meramec
Corbicula	fluminea	MO	Franklin	Meramec River, river km 95.2	7140102	Meramec
Corbicula	fluminea	MO	Franklin	Meramec River, SR 30 to SR O	7140102	Meramec
Corbicula	fluminea	MO	Franklin	Meramec River, SR O to SR 44	7140102	Meramec
Corbicula	fluminea	MO	Franklin	Meramec River, SR O to Times Beach	7140102	Meramec
Corbicula	fluminea	MO	Jefferson	Meramec River, 1.1 km E of Paulina Hills	7140102	Meramec
Corbicula	fluminea	MO	Jefferson-St. Louis	Meramec River, 1.6 km above SR 21 bridge	7140102	Meramec
Corbicula	fluminea	MO	St. Louis	Meramec River, river km 16.8	7140102	Meramec
Corbicula	fluminea	MO	St. Louis	Meramec River, river km 28	7140102	Meramec
Corbicula	fluminea	MO	St. Louis	Meramec River, river km 3.2	7140102	Meramec
Corbicula	fluminea	MO	St. Louis	Meramec River, river km 34.4	7140102	Meramec
Corbicula	fluminea	MO	St. Louis	Meramec River, river km 45.4	7140102	Meramec
Corbicula	fluminea	MO	St. Louis	Meramec River, river km 53.6	7140102	Meramec
Corbicula	fluminea	MO	St. Louis	Meramec River, river km 60.3	7140102	Meramec
Corbicula	fluminea	MO	St. Louis	Meramec River, river km 63.7	7140102	Meramec
Corbicula	fluminea	MO	St. Louis	Meramec River, river km 67.7	7140102	Meramec
Corbicula	fluminea	MO	St. Louis	Meramec River, river km 78.1	7140102	Meramec
Corbicula	fluminea	MO	St. Louis	Meramec River, SR 44 bridge	7140102	Meramec
Corbicula	fluminea	MO	St. Louis	Meramec River, Times Beach	7140102	Meramec
Corbicula	fluminea	MO	St. Louis	Meramec River, Times Beach between I-44 and US 66 bridges, 9.9 km S of Ellisville	7140102	Meramec

Appendix 6, Listing of current non-native species in Missour River (HUC10), Rainy-Red-Souris Rivers (HUC09), and immediately adjacent hydrological units.

Genus	Species	State	County	Locality	HUC	Comment
Corbicula	fluminea	MO	Franklin	Bourbeuse River, below Reiker Ford, 9.3 km SW of Union	7140103	Bourbeuse
Corbicula	fluminea	MO	Franklin	Bourbeuse River, river km 0.6	7140103	Bourbeuse
Corbicula	fluminea	MO	Franklin	Bourbeuse River, river km 0.8	7140103	Bourbeuse
Corbicula	fluminea	MO	Franklin	Bourbeuse River, river km 18.6	7140103	Bourbeuse
Corbicula	fluminea	MO	Franklin	Bourbeuse River, river km 25.1	7140103	Bourbeuse
Corbicula	fluminea	MO	Franklin	Bourbeuse River, river km 57.8	7140103	Bourbeuse
Corbicula	fluminea	MO	Franklin	Bourbeuse River, river km 67.2	7140103	Bourbeuse
Corbicula	fluminea	MO	Franklin	Bourbeuse River, river km 75.5	7140103	Bourbeuse
Corbicula	fluminea	MO	Franklin	Bourbeuse River, river km 86.2	7140103	Bourbeuse
Corbicula	fluminea	MO	Franklin	Bourbeuse River, river km 94.2	7140103	Bourbeuse
Corbicula	fluminea	MO	Franklin	Bourbeuse River, Union Access	7140103	Bourbeuse
Corbicula	fluminea	MO	Gasconade	Bourbeuse River, river km 105.6	7140103	Bourbeuse
Corbicula	fluminea	MO	Gasconade	Bourbeuse River, river km 106.1	7140103	Bourbeuse
Corbicula	fluminea	MO	Gasconade	Bourbeuse River, river km 117.9	7140103	Bourbeuse
Corbicula	fluminea	MO	Gasconade	Bourbeuse River, river km 130.6	7140103	Bourbeuse
Corbicula	fluminea	MO	Gasconade	Bourbeuse River, river km 154.6	7140103	Bourbeuse
Corbicula	fluminea	MO	Jefferson	Big River, river km 0.1	7140104	Big
Corbicula	fluminea	MO	Jefferson	Big River, river km 111.8	7140104	Big
Corbicula	fluminea	MO	Jefferson	Big River, river km 115.4	7140104	Big
Corbicula	fluminea	MO	Jefferson	Big River, river km 120.8	7140104	Big
Corbicula	fluminea	MO	Jefferson	Big River, river km 16.5	7140104	Big
Corbicula	fluminea	MO	Jefferson	Big River, river km 23.0	7140104	Big
Corbicula	fluminea	MO	Jefferson	Big River, river km 32.3	7140104	Big
Corbicula	fluminea	MO	Jefferson	Big River, river km 45.3	7140104	Big
Corbicula	fluminea	MO	Jefferson	Big River, river km 48.8	7140104	Big
Corbicula	fluminea	MO	Jefferson	Big River, river km 7.7	7140104	Big
Corbicula	fluminea	MO	Washington	Big River, river km 182.7	7140104	Big

Appendix 6, Listing of current non-native species in Missour River (HUC10), Rainy-Red-Souris Rivers (HUC09), and immediately adjacent hydrological units.

Genus	Species	State	County	Locality	HUC	Comment
Corbicula	fluminea	MO	Washington	Big River, river km 190.9	7140104	Big
Corbicula	fluminea	MO	Washington	Big River, river km 192.6	7140104	Big
Corbicula	fluminea	IL	Randolph	Little Mary's River (Mary's River-Mississippi River Drainage) 2.5 mi NE Chester, Hwy. 150	7140105	Upper Mississippi-Cape Girardeau
Corbicula	fluminea	IL	Randolph	Mississippi River, 4.5 km NNW of Kaskaskia	7140105	Upper Mississippi-Cape
Corbicula	fluminea	IL	Union	Mississippi River, river km 114.7 - 117.9, 4.3 km W of LaRue	7140105	Upper Mississippi-Cape
Corbicula	fluminea	IL	Jackson	Beaucoup Creek (Big Muddy River Drainage) 4.5 mi N Murphysboro, Rt. 13/127 bridge	7140106	Big Muddy1
Corbicula	fluminea	IL	Jackson	Tributary Big Muddy River (Mississippi River Drainage) 2 mi SSE Gorham, Rt. 3 bridge	7140106	Big Muddy1
Corbicula	fluminea	IL	Jefferson	Casey Fork (Big Muddy River Drainage) NE edge Mt. Vernon, below small dam	7140106	Big Muddy1
Corbicula	fluminea	IL	Perry	Beaucoup Creek (Big Muddy River Drainage) 0.75 mi E Pinkneyville, Rt. 154 bridge (downstream from bridge at riffle)	7140106	Big Muddy1
Corbicula	fluminea	IL	Perry	Beaucoup Creek (Big Muddy River Drainage) 0.75 mi E Pinkneyville, Rt. 154 bridge (upstream from bridge)	7140106	Big Muddy1
Corbicula	fluminea	IL	Williamson	Grassy Creek (Crab Orchard Creek-Big Muddy River Drainage) 13.5 km SE Carbondale, Co. Rd. 25 (Bank 1 of 2)	7140106	Big Muddy1
Corbicula	fluminea	MO	Cape Girardeau	Mississippi River, 1.6 km S of Trail of Tears State Park	7140107	Whitewater
Corbicula	fluminea	MO	Cape Girardeau	Mississippi River, 1.6 km S of Trail of Tears State Park	7140107	Whitewater
Corbicula	fluminea	MO	Cape Girardeau	Mississippi River, 1.6 km S of Trail of Tears State Park	7140107	Whitewater
Corbicula	fluminea	MO	Cape Girardeau	Mississippi River, just above mouth of Indian Creek, 19.2 km NE of Jackson	7140107	Whitewater
Corbicula	fluminea	MO	Cape Girardeau	Whitewater River, Bollinger Mill	7140107	Whitewater

Appendix 6, Listing of current non-native species in Missour River (HUC10), Rainy-Red-Souris Rivers (HUC09), and immediately adjacent hydrological units.

Genus	Species	State	County	Locality	HUC	Comment
Corbicula	fluminea	IL	St. Clair	Silver Creek (Kaskaskia River Drainage) 2.5 mi SW Shiloh, Scott Air Force Base	7140204	Lower Kaskaskia
Corbicula	fluminea	WY	Laramie	Crystal Reservoir (near Curt Gowdy State Park)	10190009	Crow
Corbicula	fluminea	NE	Dawson	Dawson County R24W, T10N, sec 9	10200101	Middle Platte-Buffalo
Corbicula	fluminea	NE	Dawson-Lincoln	Platte River between Lexington and North Platte in irrigation canals	10200101	Middle Platte-Buffalo
Corbicula	fluminea	NE	Lincoln	Lincoln County R26W, T12N, sec 19,20,28	10200101	Middle Platte-Buffalo
Corbicula	fluminea	NE	Lincoln	Lincoln County R29W, T13N, sec 7&8	10200101	Middle Platte-Buffalo
Corbicula	fluminea	KS	Trego	Smoky Hill River, Cedar Bluff Reservoir	10260006	Middle Smoky Hill
Corbicula	fluminea	KS	Lincoln/Russell	Wilson Reservoir on the Saline River (NE of Russell, KS)	10260009	Upper Saline
Corbicula	fluminea	KS	Jefferson	Delaware River, Perry Reservoir	10270103	Delaware
Corbicula	fluminea	KS	Douglas-Johnson-	Kansas River, West from Kansas City to Eudora	10270104	Lower Kansas
Corbicula	fluminea	MO	Macon	Thomas Hill Reservoir, East arm at SR T	10280203	Little Chariton
Corbicula	fluminea	MO	Macon	Thomas Hill Reservoir, West arm at SR T	10280203	Little Chariton
Corbicula	fluminea	MO	Laclede	Osage Fork (Gasconade River Drainage) 11 mi E Lebanon, 11.75 mi SSE Stoutland, at Drynob Access (MO Dept. of Conservation Drynob Access)	10290109	Lake of the Ozarks
Corbicula	fluminea	MO	Laclede	Osage Fork (Gasconade River Drainage) 2.5 mi E Morgan, 11 mi S Lebanon, Hwy J. bridge	10290109	Lake of the Ozarks
Corbicula	fluminea	MO	Laclede	Osage Fork (Gasconade River Drainage) 9 mi E Lebanon, 7.5 mi S Stoutland, Co. Rd. bridge off Hwy N.	10290109	Lake of the Ozarks
Corbicula	fluminea	MO	Morgan	Lake of the Ozarks, Osage River, 8 km NW of Laurie	10290109	Lake of the Ozarks
Corbicula	fluminea	MO	Pulaski	Gasconade River (Missouri River Drainage) 3.5 mi S Richland, Hwy. 133 bridge	10290109	Lake of the Ozarks
Corbicula	fluminea	MO	Pulaski	Gasconade River (Missouri River Drainage) 6 mi E Richland, Hwy T bridge	10290109	Lake of the Ozarks

Appendix 6, Listing of current non-native species in Missour River (HUC10), Rainy-Red-Souris Rivers (HUC09), and immediately adjacent hydrological units.

Genus	Species	State	County	Locality	HUC	Comment
Corbicula	fluminea	MO	Pulaski	Gasconade River (Missouri River Drainage) 9.5 mi E Richland, Hwy. 17 brige, confluence with Roubidoux Creek	10290109	Lake of the Ozarks
Corbicula	fluminea	MO	Webster	Osage Fork (Gasconade River Drainage) 8 mi NE Niangua, 0.25 mi W Rader, Hwy 22 bridge	10290110	Niangua
Corbicula	fluminea	MO	Miller	Osage River, Bagnell Dam to county line [see Ozark, MO]	10290111	Lower Osage
Corbicula	fluminea	MO	Laclede	Gasconade River (Missouri River Drainage) 3.5 mi NE Competition Hwy. AD bridge	10290201	Upper Gasconade
Corbicula	fluminea	MO	Laclede	Gasconade River (Missouri River Drainage) 4 mi N Nebo, low water bridge crossing	10290201	Upper Gasconade
Corbicula	fluminea	MO	Laclede	Osage Fork (Gasconade River Drainage) 6.5 mi E Conway, 1.5 mi S Morgan Co. Rd. bridge	10290201	Upper Gasconade
Corbicula	fluminea	MO	Pulaski	Gasconade River (Missouri River Drainage) 5.5 mi NE St. Robert, Hwy. 28 bridge, approx. 1 mi upstream confluence with Big Piney River	10290201	Upper Gasconade
Corbicula	fluminea	MO	Pulaski	Gasconade River (Missouri River Drainage) 6 mi N St. Robert, 7 mi SE Crocker	10290201	Upper Gasconade
Corbicula	fluminea	MO	Wright	Gasconade River (Missouri River Drainage), 5.5 mi NE Hartville, 5 mi SSW Manes	10290201	Upper Gasconade
Corbicula	fluminea	MO	Wright	Woods Fork (Gasconade River Drainage) Hartville, near city limit, Hwy 38 bridge	10290201	Upper Gasconade
Corbicula	fluminea	MO	Gasconade	Gasconade River, below Frederickson Ferry	10290203	Lower Gasconade
Corbicula	fluminea	MO	Phelps	Little Piney Creek (Gasconade River Drainage) 0.25 mi S Newburg, Hwy. T bridge	10290203	Lower Gasconade
Corbicula	fluminea	MO	Cole	Moreau River, Jefferson City, SR B	10300102	Lower Missouri-Moreau
Corbicula	fluminea	MO	Camden	Lake of the Ozarks, Osage River	10300103	Lamine
Corbicula	fluminea	MO	Camden	Lake of the Ozarks, Osage River	10300103	Lamine

Appendix 6, Listing of current non-native species in Missour River (HUC10), Rainy-Red-Souris Rivers (HUC09), and immediately adjacent hydrological units.

Genus	Species	State	County	Locality	HUC	Comment
Corbicula	fluminea	MO	Camden	Lake of the Ozarks, Osage River, Niangua Arm, SR KJ	10300103	Lamine
Dreissena	polymorpha	----	----	----	4010102	Beaver-Lester
Dreissena	polymorpha	----	----	----	4010201	St Louis
Dreissena	polymorpha	----	----	----	4010201	St. Louis
Dreissena	polymorpha	----	----	----	4010301	Beartrap-Nemadji
Dreissena	polymorpha	----	----	----	4020102	Ontonagon
Dreissena	polymorpha	----	----	----	4020105	Dead-Kelsey
Dreissena	polymorpha	----	----	----	4020203	Waiska
Dreissena	polymorpha	----	----	----	4020300	Lake Superior
Dreissena	polymorpha	----	----	----	4030101	Manitowoc-Sheboygan
Dreissena	polymorpha	----	----	----	4030101	Manitowoc-Sheboygon
Dreissena	polymorpha	----	----	----	4030102	Door-Kewaunee
Dreissena	polymorpha	----	----	----	4030106	Brule
Dreissena	polymorpha	----	----	----	4030108	Menominee
Dreissena	polymorpha	----	----	----	4030109	Cedar-Ford
Dreissena	polymorpha	----	----	----	4030111	Tacoosh-Whitefish
Dreissena	polymorpha	----	----	----	4030112	Fishdam-Sturgeon
Dreissena	polymorpha	----	----	----	4030201	Upper Fox
Dreissena	polymorpha	----	----	----	4030202	Wolf
Dreissena	polymorpha	----	----	----	4030203	Lake Winnebago
Dreissena	polymorpha	----	----	----	4030204	Lower Fox
Dreissena	polymorpha	----	----	----	4040001	Little Calumet-Galien
Dreissena	polymorpha	----	----	----	4040002	Pike-Root
Dreissena	polymorpha	----	----	----	4040002	Pike-Root IL
Dreissena	polymorpha	----	----	----	4040003	Milwaukee

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Genus	Species	State	County	Locality	HUC	Comment
Dreissena	polymorpha	----	----	----	4050001	St Joseph
Dreissena	polymorpha	----	----	----	4050001	St. Joseph
Dreissena	polymorpha	----	----	----	4050002	Black-Macatawa
Dreissena	polymorpha	----	----	----	4050003	Kalamazoo
Dreissena	polymorpha	----	----	----	4050004	Upper Grand
Dreissena	polymorpha	----	----	----	4050005	Maple
Dreissena	polymorpha	----	----	----	4050006	Lower Grand
Dreissena	polymorpha	----	----	----	4060101	Pere Marquette-White
Dreissena	polymorpha	----	----	----	4060102	Muskegon
Dreissena	polymorpha	----	----	----	4060103	Manistee
Dreissena	polymorpha	----	----	----	4060104	Betsie-Platte
Dreissena	polymorpha	----	----	----	4060105	Boardman-Charlevoix
Dreissena	polymorpha	----	----	----	4060107	Brevoort-Millecoquins
Dreissena	polymorpha	----	----	----	4060200	Lake Michigan
Dreissena	polymorpha	----	----	----	4070002	Carp-Pine
Dreissena	polymorpha	----	----	----	4070003	Lone Lake-Ocqueoc
Dreissena	polymorpha	----	----	----	4070004	Cheboygan
Dreissena	polymorpha	----	----	----	4070006	Thunder Bay
Dreissena	polymorpha	----	----	----	4070007	Au Sable
Dreissena	polymorpha	----	----	----	4080101	Au Gres-Rifle
Dreissena	polymorpha	----	----	----	4080102	Kawkawlin-Pine
Dreissena	polymorpha	----	----	----	4080103	Pigeon-Wiscoggin
Dreissena	polymorpha	----	----	----	4080104	Birch-Willow
Dreissena	polymorpha	----	----	----	4080201	Tittabawassee
Dreissena	polymorpha	----	----	----	4080201	Tittawabassee
Dreissena	polymorpha	----	----	----	4080203	Shiawassee

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Genus	Species	State	County	Locality	HUC	Comment
Dreissena	polymorpha	----	----	----	4080204	Flint
Dreissena	polymorpha	----	----	----	4080206	Saginaw
Dreissena	polymorpha	----	----	----	4080300	Lake Huron
Dreissena	polymorpha	----	----	----	4090001	St. Clair
Dreissena	polymorpha	----	----	----	4090002	Lake St. Clair
Dreissena	polymorpha	----	----	----	4090003	Clinton
Dreissena	polymorpha	----	----	----	4090004	Detroit
Dreissena	polymorpha	----	----	----	4090005	Huron
Dreissena	polymorpha	----	----	----	4100000	Western Lake Erie
Dreissena	polymorpha	----	----	----	4100001	Ottawa-Stony
Dreissena	polymorpha	----	----	----	4100002	Raisin
Dreissena	polymorpha	----	----	----	4100003	St. Joseph
Dreissena	polymorpha	----	----	----	4100006	Tiffin
Dreissena	polymorpha	----	----	----	4100009	Lower Maumee
Dreissena	polymorpha	----	----	----	4100010	Cedar-Portage
Dreissena	polymorpha	----	----	----	4100011	Sandusky
Dreissena	polymorpha	----	----	----	4100012	Huron-Vermilion
Dreissena	polymorpha	----	----	----	4110000	Southern Lake Erie
Dreissena	polymorpha	----	----	----	4110001	Black-Rocky
Dreissena	polymorpha	----	----	----	4110003	Ashtabula-Chagrin
Dreissena	polymorpha	----	----	----	4110004	Grand
Dreissena	polymorpha	----	----	----	4120101	Chautauqua-Conneaut
Dreissena	polymorpha	----	----	----	4120103	Buffalo-Eighteenmile
Dreissena	polymorpha	----	----	----	4120104	Niagara
Dreissena	polymorpha	----	----	----	4120200	Lake Erie
Dreissena	polymorpha	----	----	----	4130001	Oak Orchard-Twelvemile

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Genus	Species	State	County	Locality	HUC	Comment
Dreissena	polymorpha	----	----	----	4130002	Upper Genesee
Dreissena	polymorpha	----	----	----	4130003	Lower Genesee
Dreissena	polymorpha	----	----	----	4130003	Lower Genessee
Dreissena	polymorpha	----	----	----	4140101	Irondequiot-Ninemile
Dreissena	polymorpha	----	----	----	4140101	Irondequoit-Ninemile
Dreissena	polymorpha	----	----	----	4140102	Salmon-Sandy
Dreissena	polymorpha	----	----	----	4140201	Seneca
Dreissena	polymorpha	----	----	----	4140202	Oneida
Dreissena	polymorpha	----	----	----	4140203	Oswego
Dreissena	polymorpha	----	----	----	4150000	NULL
Dreissena	polymorpha	----	----	----	4150102	Chaumont-Perch
Dreissena	polymorpha	----	----	----	4150200	Lake Ontario
Dreissena	polymorpha	----	----	----	4150301	Upper St Lawrence
Dreissena	polymorpha	----	----	----	4150301	Upper St. Lawrence
Eichhornia	crassipes	IL	Lake	Fox River Chain O' Lakes in a channel between Lake Marie and Channel Lake.	7120006	Upper Fox
Eichhornia	crassipes	MO	Pulaski	Big Piney River, west side; T36N R10W S13	10290202	Big Piney
Lythrum	salicaria	MI	NULL	Michigan	4000000	Great Lakes
Lythrum	salicaria	MI	NULL	non-specific	4000000	Great Lakes
Lythrum	salicaria	MI	Berrien	Berrien County	4000000	Great Lakes Region
Lythrum	salicaria	MI	Chippewa	Chippewa County	4000000	Great Lakes Region
Lythrum	salicaria	MI	Emmet	Emmet County	4000000	Great Lakes Region
Lythrum	salicaria	MI	Iosco	Iosco County	4000000	Great Lakes Region
Lythrum	salicaria	MI	Livingston	Shore of Strawberry Lake	4000000	Great Lakes
Lythrum	salicaria	MI	Mackinac	Mackinac County	4000000	Great Lakes Region
Lythrum	salicaria	MI	Oakland	Oakland County	4000000	Great Lakes Region

Appendix 6, Listing of current non-native species in Missour River (HUC10), Rainy-Red-Souris Rivers (HUC09), and immediately adjacent hydrological units.

Genus	Species	State	County	Locality	HUC	Comment
Lythrum	salicaria	MI	Shiawassee	Shiawassee County	4000000	Great Lakes Region
Lythrum	salicaria	WI	NULL	Wisconsin	4000000	Great Lakes
Lythrum	salicaria	WI	NULL	Wisconsin.	4000000	Great Lakes
Lythrum	salicaria	WI	Bayfield	Bayfield	4010300	Southwestern Lake Supe
Lythrum	salicaria	WI	Bayfield	Bayfield	4010300	Southwestern Lake Supe
Lythrum	salicaria	WI	Ashland	Ashland County	4010302	Southwestern Lake Supe
Lythrum	salicaria	MI	Houghton	Hougton	4020103	Keweenaw Peninsula
Lythrum	salicaria	MI	Keweenaw	Keweenaw County	4020103	Keweenaw Peninsula
Lythrum	salicaria	WI	Shawano	Shawano County	4030000	Northwestern Lake Mich
Lythrum	salicaria	MI	Delta	Delta County	4030100	Northwestern Lake Mich
Lythrum	salicaria	WI	Kewaunee	Kewaunee County	4030100	Northwestern Lake Mich
Lythrum	salicaria	WI	Milwaukee	Whitefish bay along Lake Michigan.	4030101	Manitowoc-Sheyboygen
Lythrum	salicaria	IN	Lake	Wabash railway west of Aetna	4040001	Little Calumet-Galien
Lythrum	salicaria	IN	Porter/Lake	Indiana Dunes National Lakeshore	4040001	Little Calumet-Galien
Lythrum	salicaria	WI	Milwaukee	Kletzsch Park	4040003	Millwaukee
Lythrum	salicaria	MI	Barry	Barry County	4050000	Southeastern Lake Mich
Lythrum	salicaria	MI	Calhoun	Calhoun County	4050000	Southeastern Lake Mich
Lythrum	salicaria	MI	Clinton	Clinton County	4050000	Southeastern Lake Mich
Lythrum	salicaria	MI	Eaton	Eaton County	4050000	Southeastern Lake Mich
Lythrum	salicaria	MI	Kalamazoo	Kalamazoo County	4050000	Southeastern Lake Mich
Lythrum	salicaria	MI	Ottawa	Ottawa County	4050000	Southeastern Lake Mich
Lythrum	salicaria	IN	Elkhart	Middlebury	4050001	St. Joseph
Lythrum	salicaria	MI	Cass	Cass County	4050001	St. Joseph
Lythrum	salicaria	MI	Hillsdale	Joneville	4050001	St. Joseph
Lythrum	salicaria	MI	Allegan	Saugatuck, coastal marsh on Lake Michigan.	4050002	Black-Macatawa
Lythrum	salicaria	MI	Ingham	Haslett	4050004	Upper Grand

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Genus	Species	State	County	Locality	HUC	Comment
Lythrum	salicaria	MI	Ingham	Lansing	4050004	Upper Grand
Lythrum	salicaria	MI	Antrim	Antrim County	4060100	Northeastern Lake Mich
Lythrum	salicaria	MI	Leelanau	Leelanau County	4060100	Northeastern Lake Mich
Lythrum	salicaria	MI	Newaygo	Newaygo County	4060100	Northeastern Lake Mich
Lythrum	salicaria	MI	Schoolcraft	Schoolcraft County	4060100	Northeastern Lake Mich
Lythrum	salicaria	MI	Muskegon	Muskegon, along the Shoreline of Lake Michigan.	4060101	Pere Marquette-White
Lythrum	salicaria	MI	Benzie	Benzie County	4060104	Betsie-Platte
Lythrum	salicaria	MI	Alpena	Alpena County	4070000	Northwestern Lake Huro
Lythrum	salicaria	MI	Presque Isle	Presque Isle County	4070000	Northwestern Lake Huro
Lythrum	salicaria	MI	Cheboygan	outlet of the Cheboygan River at the town of Cheboygan	4070004	Cheboygan
Lythrum	salicaria	MI	Crawford	Grayling	4070007	Au Sable
Lythrum	salicaria	MI	Huron	Huron County	4080100	Southwestern Lake Huro
Lythrum	salicaria	MI	Bay	Nayanquing Point Wildlife Area	4080102	Kawkawlin-Pine
Lythrum	salicaria	MI	Saginaw	Shiawassee River State Game Area	4080203	Shiawasee
Lythrum	salicaria	MI	Bay	Bay City	4080206	Saginaw
Lythrum	salicaria	MI	Bay	Crow Island State Game Area	4080206	Saginaw
Lythrum	salicaria	MI	Saginaw	Crow Island State Game Area	4080206	Saginaw
Lythrum	salicaria	MI	Saginaw	Saginaw	4080206	Saginaw
Lythrum	salicaria	MI	Macomb	Macomb County	4090000	St.Clair-Detroit
Lythrum	salicaria	MI	St. Clair	Port Huron	4090001	St. Clair
Lythrum	salicaria	MI	Wayne	Detroit	4090004	Detroit
Lythrum	salicaria	MI	Wayne	Sheldon	4090004	Detroit
Lythrum	salicaria	MI	Washtenaw	Along the Huron River northwest of Ann Arbor.	4090005	Huron
Lythrum	salicaria	MI	Lenawee	Lenawee County	4100000	Western Lake Erie
Lythrum	salicaria	MI	Monroe	Monroe County	4100000	Western Lake Erie

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Lythrum	salicaria	OH	Lucas	Metzger Marsh, 300 ha restored wetland in an embayment in western Lake Erie, approx. 18 km east of Toledo, within boundaries of refuges of the US Fish and Wildlife Service and the Ohio Division of Wildlife	4100010	Cedar-Portage
Lythrum	salicaria	OH	Cuyahoga	Cuyahoga County	4110000	Southern Lake Erie
Lythrum	salicaria	OH	Lake	Lake County.	4110000	Southern Lake Erie
Lythrum	salicaria	OH	Lake	Little Mountain	4110000	Southern Lake Erie
Lythrum	salicaria	NY	Cattaraugus	Cattaraugus County.	4120102	Cattaraugus
Lythrum	salicaria	NY	Erie	near Buffalo	4120103	Buffalo-Eighteenmile
Lythrum	salicaria	NY	Erie	Alden, swail located at SE corner of intersection of US Rte 20 and Two Rod Road	4120104	Niagara
Lythrum	salicaria	NY	Niagra	Niagra Falls	4120104	Niagra
Lythrum	salicaria	NY	Oswego	South shore of Lake Ontario	4140000	Southeastern Lake Onta
Lythrum	salicaria	NY	Monroe	Irondequoit Bay	4140101	Irondequoit-Ninemile
Lythrum	salicaria	NY	Cayuga	Motezuma National Wildlife Refuge, n end of Lake Cayuga	4140201	Seneca
Lythrum	salicaria	NY	Cayuga/Seneca/To	Cayuga lake	4140201	Seneca
Lythrum	salicaria	NY	Tompkins	Sapsucker Woods Sanctuary, Ithaca	4140201	Seneca
Lythrum	salicaria	NY	Wayne	3.2 km w of n from Savannah	4140201	Seneca
Lythrum	salicaria	NY	Wayne	Clyde	4140201	Seneca
Lythrum	salicaria	WI	Columbia	Columbia County	7000000	Upper Mississippi
Lythrum	salicaria	WI	Vernon	Vernon County	7000000	Upper Mississippi
Lythrum	salicaria	MN	Hennepin	Lake Minnetonka, north shore Brown's Bay	7010206	Twin Cities
Lythrum	salicaria	MN	Hennepin	west shore, Smith's Bay, Lake Minnetonka	7010206	Twin Cities
Lythrum	salicaria	MN	Stevens	Morris, one mile southeast of Morris.	7020002	Pomme de Terre
Lythrum	salicaria	MN	Goodhue	Red Wing	7040001	Rush-Vermillion

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Genus	Species	State	County	Locality	HUC	Comment
Lythrum	salicaria	MN	Wabasha	Mississippi River, Pool 5, near Weaver Landing, part of the Upper Mississippi River National Wildlife and Fish Refuge.	7040003	Buffalo-Whitewater
Lythrum	salicaria	WI	Sawyer	Sawyer County	7050000	Chippewa
Lythrum	salicaria	IA	Scott	Scott County.	7080100	Upper Miss-Skunk-Wapsi
Lythrum	salicaria	IA	Linn	Cedar Rapids	7080200	Iowa
Lythrum	salicaria	IL	Winnebago	Winnebago County	7090000	Rock
Lythrum	salicaria	WI	Jefferson	Rome	7090001	Upper Rock
Lythrum	salicaria	IA	Buena Vista	Racoon River	7100006	North Raccoon
Lythrum	salicaria	IA	Buena Vista	Storm Lake	7100006	North Raccoon
Lythrum	salicaria	IA	Buena Vista	Streams around Storm Lake	7100006	North Raccoon
Lythrum	salicaria	MO	NULL	Northeast corner of the state, at about 50 sites.	7110000	Upper Mississippi-Salt
Lythrum	salicaria	IL	Cook	Cook County.	7120000	Upper Illinois
Lythrum	salicaria	IL	Cook	Along the Wabash railway.	7120003	Chicago
Lythrum	salicaria	IL	Cook	Chicago area	7120003	Chicago
Lythrum	salicaria	MO	St. Louis City	St. Louis	7140101	Cahokia-Joachim
Lythrum	salicaria	IL	Jackson	Carbondale	7140106	Big Muddy
Lythrum	salicaria	IL	Jackson	South of Elkville	7140106	Big Muddy
Lythrum	salicaria	ND	Cass	Cass County	9020000	Red
Lythrum	salicaria	ND	Cass	Fargo	9020104	Upper Red
Lythrum	salicaria	MT	Cascade	Cascade County	10030100	Upper Missouri
Lythrum	salicaria	MT	Lewis and Clark	Lewis and Clark County	10030100	Upper Missouri
Lythrum	salicaria	MT	Teton	Teton County	10030205	Teton
Lythrum	salicaria	MT	Fergus	Fergus County	10040000	Missouri-Musselshell
Lythrum	salicaria	MT	Yellowstone	Yellowstone County	10070000	Upper Yellowstone
Lythrum	salicaria	WY	Big Horn/Park	Shoshone River	10080014	Shoshone
Lythrum	salicaria	WY	Park	6 km sw of Powell	10080014	Shoshone

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Genus	Species	State	County	Locality	HUC	Comment
Lythrum	salicaria	WY	Sheridan	Tongue River	10090101	Upper Tongue
Lythrum	salicaria	NE	NULL	Niobrara River	10150000	Niobrara
Lythrum	salicaria	WY	Niobrara	Niobrara River	10150002	Niobrara Headwaters
Lythrum	salicaria	SD	NULL	near Vermillion and Elk Point	10170000	Missouri-Big Sioux
Lythrum	salicaria	SD	Union	Union county	10170000	Missourri-Big Sioux
Lythrum	salicaria	WY	Goshen	Platte River	10180009	Middle North Platte-Sc
Lythrum	salicaria	CO	Park	South Platte River	10190001	South Platte Headwater
Lythrum	salicaria	CO	Jefferson	west of Hampden and Quincy, South Denver	10190002	Upper South Platte
Lythrum	salicaria	CO	Jefferson/Park	Bear Creek	10190002	Upper South Platte
Lythrum	salicaria	CO	NULL	Lakes in the Denver Metro Area	10190003	Middle South Platte/C
Lythrum	salicaria	CO	Denver	Federal Youth Correction Center, One mile south of Havana St. in northwest Denver	10190003	Middle South Platte-Ch
Lythrum	salicaria	CO	Clear Creek/Jeff	Clear Creek	10190004	Clear
Lythrum	salicaria	CO	Boulder	Boulder	10190005	St. Vrain
Lythrum	salicaria	CO	Larimer	Ft. Collins	10190007	Cache La Poudre
Lythrum	salicaria	WY	Laramie	Diamond Creek, off Crow Creek, at Warren Air Force Base.	10190009	South Platte Headwater
Lythrum	salicaria	WY	Laramie	in the city of Cheyenne	10190009	Crow
Lythrum	salicaria	CO	NULL	South Platte River, thrugh Northeast Colorado	10190012	Middle South Platte-St
Lythrum	salicaria	NE	NULL	Platte River	10200101	Middle Platte-Buffalo
Lythrum	salicaria	NE	NULL	Platte River, spreading up and down the river	10200101	Middle Platte-Buffalo
Lythrum	salicaria	NE	Buffalo	south rim of Blue Hole, near Elm Creek	10200101	Middle Platte-Buffalo
Lythrum	salicaria	NE	Sarpy/Cass	Platte River	10200202	Lower Platte
Lythrum	salicaria	IA	Page	Page County.	10240000	Missouri-Nishnabotna
Lythrum	salicaria	KS	NULL	the area around Topeka and Kansas City	10270100	Kansas
Lythrum	salicaria	NE	Fillmore	Fillmore County.	10270200	Big Blue
Lythrum	salicaria	NE	Fillmore	along a stream one mile east of Exeter	10270203	West Fork Big Blue

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Genus	Species	State	County	Locality	HUC	Comment
Lythrum	salicaria	MO	Macon	La Plata, in and around the town.	10280203	Little Chariton
Lythrum	salicaria	MO	Franklin	Franklin county	10300200	Lower Missouri
Myriophyllum	spicatum	MN	Itasca	Ice (Crystal) Lake	7010103	Prairie-Willow
Myriophyllum	spicatum	MN	Itasca	McKinney Lake	7010103	Prairie-Willow
Myriophyllum	spicatum	MN	Itasca	North Twin Lake	7010103	Prairie-Willow
Myriophyllum	spicatum	MN	Crow Wing	Bay Lake	7010104	Elk-Nokasippi
Myriophyllum	spicatum	MN	Crow Wing	Ripple River	7010104	Elk-Nokasippi
Myriophyllum	spicatum	MN	Crow Wing	Ossawinnamakee Lake	7010105	Pine
Myriophyllum	spicatum	MN	Crow Wing	Ruth Lake	7010105	Pine
Myriophyllum	spicatum	MN	Douglas	Oscar Lake	7010108	Long Prairie
Myriophyllum	spicatum	MN	Todd	Sauk Lake	7010202	Sauk
Myriophyllum	spicatum	MN	Sherburne	Little Elk Lake	7010203	Clearwater-Elk
Myriophyllum	spicatum	MN	Stearns	unnamed	7010203	Clearwater-Elk
Myriophyllum	spicatum	MN	Wright	Clearwater Lake	7010203	Clearwater-Elk
Myriophyllum	spicatum	MN	Wright	Clearwater River	7010203	Clearwater-Elk
Myriophyllum	spicatum	MN	Wright	Fish Lake	7010203	Clearwater-Elk
Myriophyllum	spicatum	MN	Wright	Mary Lake	7010203	Clearwater-Elk
Myriophyllum	spicatum	MN	Wright	Sugar Lake	7010203	Clearwater-Elk
Myriophyllum	spicatum	MN	Wright	Weigand Lake	7010203	Clearwater-Elk
Myriophyllum	spicatum	MN	Hennepin	Sarah Lake	7010204	Crow
Myriophyllum	spicatum	MN	Kandiyohi	Green Lake	7010204	Crow
Myriophyllum	spicatum	MN	Meeker	Ripley Lake	7010204	Crow
Myriophyllum	spicatum	MN	Meeker	Stella Lake	7010204	Crow
Myriophyllum	spicatum	MN	Meeker	Washington Lake	7010204	Crow
Myriophyllum	spicatum	MN	Wright	Beebe Lake	7010204	Crow
Myriophyllum	spicatum	MN	Wright	Buffalo Lake	7010204	Crow

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Genus	Species	State	County	Locality	HUC	Comment
Myriophyllum	spicatum	MN	Wright	Buffalo Lake	7010204	Crow
Myriophyllum	spicatum	MN	Wright	Deer Lake	7010204	Crow
Myriophyllum	spicatum	MN	Wright	French Lake	7010204	Crow
Myriophyllum	spicatum	MN	Wright	Goose Lake	7010204	Crow
Myriophyllum	spicatum	MN	Wright	Lake Pulaski	7010204	Crow
Myriophyllum	spicatum	MN	Wright	Little Waverly Lake	7010204	Crow
Myriophyllum	spicatum	MN	Wright	Rock Lake	7010204	Crow
Myriophyllum	spicatum	MN	Wright	Waverly Lake	7010204	Crow
Myriophyllum	spicatum	MN	Carver	Eagle Lake	7010205	South Fork Crow
Myriophyllum	spicatum	MN	Hennepin	Independence Lake	7010205	South Fork Crow
Myriophyllum	spicatum	MN	Hennepin	Rebecca Lake	7010205	South Fork Crow
Myriophyllum	spicatum	MN	Hennepin	Whaletail Lake	7010205	South Fork Crow
Myriophyllum	spicatum	MN	Anoka	Cenaiko Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Anoka	Centerville Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Anoka	Otter Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Anoka	Peltier Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Anoka	Spring Brook	7010206	Twin Cities
Myriophyllum	spicatum	MN	Carver	Auburn Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Carver	Minnewashta Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Carver	Parley Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Carver	Piersons Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Carver	Shutz Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Carver	Stieger Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Carver	Stone Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Carver	Virginia Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Carver	Wasserman Lake	7010206	Twin Cities

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Genus	Species	State	County	Locality	HUC	Comment
Myriophyllum	spicatum	MN	Carver	Zumbra Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Dakota	Sunset Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Hennepin	Bass Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Hennepin	Brownie Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Hennepin	Calhoun Lake	7010206	Twin Ciites
Myriophyllum	spicatum	MN	Hennepin	Cedar Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Hennepin	Christmas Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Hennepin	Dutch Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Hennepin	Eagle Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Hennepin	Fish Lake	7010206	Twin Ciites
Myriophyllum	spicatum	MN	Hennepin	Forest Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Hennepin	Galpin Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Hennepin	Gleason Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Hennepin	Harriet Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Hennepin	Hiawatha Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Hennepin	Lake of Isles	7010206	Twin Cities
Myriophyllum	spicatum	MN	Hennepin	Libbs Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Hennepin	Little Long Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Hennepin	Long Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Hennepin	Medicine Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Hennepin	Minnehaha Creek	7010206	Twin Cities
Myriophyllum	spicatum	MN	Hennepin	Minnetonka Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Hennepin	Niccum's Pond	7010206	Twin Cities
Myriophyllum	spicatum	MN	Hennepin	Nokomis Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Hennepin	Parkers Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Hennepin	Peavy Lake	7010206	Twin Cities

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Genus	Species	State	County	Locality	HUC	Comment
Myriophyllum	spicatum	MN	Hennepin	Schmidt Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Hennepin	Swan Pond	7010206	Twin Cities
Myriophyllum	spicatum	MN	Hennepin	Tanager Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Hennepin	unnamed wetland	7010206	Twin Cities
Myriophyllum	spicatum	MN	Hennepin	Wirth Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	many	Mississippi River	7010206	Twin Cities
Myriophyllum	spicatum	MN	many	St. Croix River	7010206	Twin Cities
Myriophyllum	spicatum	MN	Ramsey	Bald Eagle Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Ramsey	DNR pond	7010206	Twin Cities
Myriophyllum	spicatum	MN	Ramsey	Gervais Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Ramsey	Island Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Ramsey	Keller Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Ramsey	Kohlman Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Ramsey	McCarrons Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Ramsey	Owasso Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Ramsey	Phalen Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Ramsey	Round Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Ramsey	Silver Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Ramsey	Snail Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Ramsey	Spoon Creek	7010206	Twin Cities
Myriophyllum	spicatum	MN	Ramsey	Sucker Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Ramsey	Turtle Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Ramsey	Vadnais Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Ramsey	Wabasso Lake	7010206	Twin Ciites
Myriophyllum	spicatum	MN	Washington	Powers Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Washington	Sunset Lake	7010206	Twin Cities

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Genus	Species	State	County	Locality	HUC	Comment
Myriophyllum	spicatum	MN	Washington	White Bear Lake	7010206	Twin Cities
Myriophyllum	spicatum	MN	Anoka	Lake George	7010207	Rum
Myriophyllum	spicatum	MN	Isanti	Green Lake	7010207	Rum
Myriophyllum	spicatum	MN	Mille Lacs	Mille Lacs Lake	7010207	Rum
Myriophyllum	spicatum	MN	Kandiyohi	Norway Lake	7020005	Chippewa
Myriophyllum	spicatum	MN	Pope	Lake Minnewaska	7020005	Chippewa
Myriophyllum	spicatum	MN	Carver	Ann Lake	7020012	Lower Minnesota
Myriophyllum	spicatum	MN	Carver	Bavaria Lake	7020012	Lower Minnesota
Myriophyllum	spicatum	MN	Carver	Chaska Pond	7020012	Lower Minnesota
Myriophyllum	spicatum	MN	Carver	Lotus Lake	7020012	Lower Minnesota
Myriophyllum	spicatum	MN	Carver	Riley Lake	7020012	Lower Minnesota
Myriophyllum	spicatum	MN	Carver	Waconia Lake	7020012	Lower Minnesota
Myriophyllum	spicatum	MN	Dakota	Crystal Lake	7020012	Lower Minnesota
Myriophyllum	spicatum	MN	Dakota	Lac Lavon Lake	7020012	Lower Minnesota
Myriophyllum	spicatum	MN	Dakota	Schultz Lake	7020012	Lower Minnesota
Myriophyllum	spicatum	MN	Dakota	Twin Lake	7020012	Lower Minnesota
Myriophyllum	spicatum	MN	Hennepin	Arrowhead Lake	7020012	Lower Minnesota
Myriophyllum	spicatum	MN	Hennepin	Bryant Lake	7020012	Lower Minnesota
Myriophyllum	spicatum	MN	Hennepin	Bush Lake	7020012	Lower Minnesota
Myriophyllum	spicatum	MN	Hennepin	Mitchell Lake	7020012	Lower Minnesota
Myriophyllum	spicatum	MN	Hennepin	Rice Lake	7020012	Lower Minnesota
Myriophyllum	spicatum	MN	Hennepin	Round Lake	7020012	Lower Minnesota
Myriophyllum	spicatum	MN	Scott	Lower Prior Lake	7020012	Lower Minnesota
Myriophyllum	spicatum	MN	Scott	O'Dowd Lake	7020012	Lower Minnesota
Myriophyllum	spicatum	MN	Scott	Thole Lake	7020012	Lower Minnesota
Myriophyllum	spicatum	MN	Scott	Upper Prior Lake	7020012	Lower Minnesota

Appendix 6, Listing of current non-native species in Missour River (HUC10), Rainy-Red-Souris Rivers (HUC09), and immediately adjacent hydrological units.

Genus	Species	State	County	Locality	HUC	Comment
Myriophyllum	spicatum	MN	Kanabec	Knife Lake	7030004	Snake
Myriophyllum	spicatum	MN	Chisago	Ellen Lake	7030005	Lower St. Croix
Myriophyllum	spicatum	MN	Chisago	Rush Lake	7030005	Lower St. Croix
Myriophyllum	spicatum	MN	Dakota	Marion Lake	7040001	Rush-Vermillion
Myriophyllum	spicatum	MN	Le Sueur	East Jefferson Lake	7040002	Cannon
Myriophyllum	spicatum	MN	Le Sueur	German Lake	7040002	Cannon
Myriophyllum	spicatum	MN	Rice	Cedar Lake	7040002	Cannon
Myriophyllum	spicatum	MN	Olmsted	George Lake	7040004	Zumbro
Myriophyllum	spicatum	KS	NULL	western part of the state, mostly in farm ponds	10000000	Missouri
Myriophyllum	spicatum	SD	NULL	Lake Sharpe, a few small beds, scattered floating plant fregments in or near bays from near the dam all the way to near Pierre	10140101	Fort Randall Reservoir
Myriophyllum	spicatum	SD	Hughes	Lake Sharpe, Joe Creek Bay, ca. 31 air miles se of Pierre	10140101	Fort Randall Reservoir
Myriophyllum	spicatum	SD	Hughes	Lake Sharpe, West Bend Marina, 34 air miles SE of Pierre	10140101	Fort Randall Reservoir
Myriophyllum	spicatum	SD	Hughes	Lake Sharpe/Hipple Lake in Farm Island State Park, 3 mi se of Pierre	10140101	Fort Randall Reservoir
Myriophyllum	spicatum	SD	Hyde	Lake Sharpe, Cooper's Bay, ca. 2 miles downstream from North Bend Recreation Area	10140101	Fort Randall Reservoir
Myriophyllum	spicatum	SD	Lyman	Lake Sharpe, Grass Rope cutoff pond, streaight east across the reservoir from West Bend Recreation Area	10140101	Fort Randall Reservoir
Myriophyllum	spicatum	CO	Denver	Marston Lake	10190002	Upper South Platte
Myriophyllum	spicatum	CO	Jefferson	Standley Lake	10190003	Middle South Platte-Cherry Cre
Myriophyllum	spicatum	NE	Hall	Hall County	10200100	Middle Platte
Myriophyllum	spicatum	NE	Merrick	Hord Lake	10200103	Middle Platte-Prairie
Myriophyllum	spicatum	NE	Merrick	Hord Lake	10200103	Middle Platte-Prairie

Appendix 6, Listing of current non-native species in Missour River (HUC10), Rainy-Red-Souris Rivers (HUC09), and immediately adjacent hydrological units.

Genus	Species	State	County	Locality	HUC	Comment
Myriophyllum	spicatum	NE	Douglas	pond along the Platte River, near Omaha.	10200202	Lower Platte
Myriophyllum	spicatum	NE	Lancaster	Wildwood Lake, near the city of Lincoln.	10200203	Salt
Myriophyllum	spicatum	NE	Lancaster	Wildwood Lake, near the city of Lincoln.	10200203	Salt
Myriophyllum	spicatum	IA	Woodbury	Snyder Bend Lake.	10230001	Blackbird-Soldier
Myriophyllum	spicatum	KS	NULL	Kansas	10260000	Smoky Hill
Myriophyllum	spicatum	IA	Ringgold	Walnut Creek Marsh.	10280101	Upper Grand
Myriophyllum	spicatum	MO	Camden/Morgan/ Mi	Lake of the Ozarks	10290100	Osage
Myriophyllum	spicatum	MO	Camden	Toronto Springs, S30 R14W T38N	10290109	Lake of the Ozarks
Myriophyllum	spicatum	MO	Camden	Toronto Springs; T38N R14W Sec. 30	10290109	Lake of the Ozarks
Myriophyllum	spicatum	MO	Morgan	Gravois Arm of Lake Ozark	10290109	Lake of the Ozarks
Myriophyllum	spicatum	MO	Laclede	Osage River	10290201	Upper Gasconade
Myriophyllum	spicatum	MO	Wright	Gasconade River; east of Hwy E; Buzzard Bluff public fishing access	10290201	Upper Gasconade

Appendix 8, Listing of all non-native aquatic plant species documented as occurring in HUC04, HUC07, HUC09, and HUC10. 1

Hydrologic Unit Searched: 40101 - Northwestern Lake Superior Drainage

total records found: 1

Scientific Name	Common Name
Potamogeton crispus	curly pondweed

Hydrologic Unit Searched: 40103 - Southwestern Lake Superior Drainage

total records found: 2

Scientific Name	Common Name
Lythrum salicaria	purple loosestrife
Myriophyllum spicatum	Eurasian water-milfoil

Hydrologic Unit Searched: 40201 - Southcentral LakeSuperior Drainage

total records found: 3

Scientific Name	Common Name
Lythrum salicaria	purple loosestrife
Nasturtium officinale	water-cress
Veronica beccabunga	European brooklime

Hydrologic Unit Searched: 70101 - Mississippi Headwaters Drainage

total records found: 2

Scientific Name	Common Name
Myriophyllum spicatum	Eurasian water-milfoil
Potamogeton crispus	curly pondweed

Hydrologic Unit Searched: 70102 - Upper Mississippi-Crow-Rum Drainage

total records found: 4

Scientific Name	Common Name
Lythrum salicaria	purple loosestrife
Myriophyllum spicatum	Eurasian water-milfoil

Nasturtium officinale	water-cress
Potamogeton crispus	curly pondweed

Hydrologic Unit Searched: 70200 - Minnesota Drainage

total records found: 3

Scientific Name	Common Name
Lythrum salicaria	purple loosestrife
Myriophyllum spicatum	Eurasian water-milfoil
Potamogeton crispus	curly pondweed

Hydrologic Unit Searched: 70300 - St Croix Drainage

total records found: 2

Scientific Name	Common Name
Myriophyllum spicatum	Eurasian water-milfoil
Potamogeton crispus	curly pondweed

Hydrologic Unit Searched: 90100 - Souris Drainage

total records found: 1

Scientific Name	Common Name
Butomus umbellatus	flowering rush

Hydrologic Unit Searched: 90201 - Upper Red Drainage

total records found: 3

Scientific Name	Common Name
Butomus umbellatus	flowering rush
Lythrum salicaria	purple loosestrife
Potamogeton crispus	curly pondweed

Appendix 8, Listing of all non-native aquatic plant species documented as occurring in HUC04, HUC07, HUC09, and HUC10. 3

Hydrologic Unit Searched: 90202 - Devils Lake-Sheyenne Drainage

total records found: 3

Scientific Name	Common Name
Butomus umbellatus	flowering rush
Myriophyllum spicatum	Eurasian water-milfoil
Potamogeton crispus	curly pondweed

Hydrologic Unit Searched: 90203 - Lower Red Drainage

total records found: 1

Scientific Name	Common Name
Potamogeton crispus	curly pondweed

Hydrologic Unit Searched: 90300 - Rainy Drainage

No matches found!

Hydrologic Unit Searched: 101401 - Fort Randall Reservoir Drainage

total records found: 1

Scientific Name	Common Name
Myriophyllum spicatum	Eurasian water-milfoil

Hydrologic Unit Searched: 101500 - Niobrara Drainage

total records found: 1

Scientific Name	Common Name
Lythrum salicaria	purple loosestrife

Hydrologic Unit Searched: 101600 - James Drainage

total records found: 2

Scientific Name	Common Name
Butomus umbellatus	flowering rush
Iris pseudacorus	yellow iris

Appendix 8, Listing of all non-native aquatic plant species documented as occurring in HUC04, HUC07, HUC09, and HUC10. 4

Hydrologic Unit Searched: 101701 - Lewis Clark Lake Drainage

total records found: 1

Scientific Name	Common Name
Potamogeton crispus	curly pondweed

Hydrologic Unit Searched: **102001 - Middle Platte Drainage**

total records found: 2

Scientific Name	Common Name
Lythrum salicaria	purple loosestrife
Myriophyllum spicatum	Eurasian water-milfoil

Hydrologic Unit Searched: 102002 - Drainage

total records found: 3

Scientific Name	Common Name
Lythrum salicaria	purple loosestrife
Myriophyllum spicatum	Eurasian water-milfoil
Potamogeton crispus	curly pondweed

Hydrologic Unit Searched: 102300 - Missouri-Little Sioux Drainage

total records found: 2

Scientific Name	Common Name
Myriophyllum spicatum	Eurasian water-milfoil
Potamogeton crispus	curly pondweed

No matches found for any of these drainages

Hydrologic Unit Searched: 100600 - Missouri - Poplar Drainage

Hydrologic Unit Searched: 101000 - Lower Yellowstone Drainage

Hydrologic Unit Searched: 101101 - Lake Sakakawea Drainage

Hydrologic Unit Searched: 101102 - Little Missouri Drainage

Hydrologic Unit Searched: 101201 - Cheyenne Drainage

Hydrologic Unit Searched: 101202 - Belle Fourche Drainage

Hydrologic Unit Searched: 101301 - Lake Oahe Drainage

Hydrologic Unit Searched: 101302 - Cannonball-Heart-Knife Drainage

Hydrologic Unit Searched: 101303 - Grand-Moreau Drainage

Hydrologic Unit Searched: 101402 - White Drainage

Hydrologic Unit Searched: 101702 - Big Sioux Drainage

Hydrologic Unit Searched: 102200 - Elkhorn Drainage

MONTANA University System
WATER CENTER

December 15, 2003

Edward Little, Branch Chief
Ecology Branch, U.S.G.S. BRD/CERC
Columbia, MO 65201

Re: Request for Proposal

Dear Dr. Little:

I'm writing on behalf of the Whirling Disease Steering Committee, to request that you submit a full proposal for 2004-2005 research funding of your whirling disease vector assessment project. The RFP is enclosed. The submittal deadline will be February 13, 2004. Please review both the 5-year research plan and the request for preproposals before preparing your proposal; they can be found at:

http://water.montana.edu/mwc/programs/fisheries/whirling/

Here are specific comments of the Steering Committee regarding your full proposal: please review the work of Rick Barrows on bird vectors, as reported at the Whirling Disease Symposium a few years ago (http://www.whirling-disease.org/). The committee views your draft budget as quite high. There will be three full proposals on this topic, and the committee will select the one that shows the best experimental/observational design and the most judicious use of WD Initiative funding.

Please do not hesitate to contact me if you have any questions about this solicitation.

Sincerely,

Gretchen Rupp
Director

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MONTANA University System
WATER CENTER

December 15, 2003

Edward Little, Branch Chief
Ecology Branch, U.S.G.S.
BRD/CERC
Columbia, MO 65201

Re: Whirling Disease Initiative

Dear Mr. Little:

I am sorry to say that the Whirling Disease Steering Committee has decided not to request a full proposal from you for 2004-2005 research funding on filtration efficacy for whirling disease TAM removal. All of the membrane filtration techniques suggested for testing (with nominal pore sizes ranging from 0.08- 5 microns) would easily collect TAMs following exhaustive pre-filtration; thus there appears to be no reason to conduct such assays.

Please do not hesitate to contact me if you have any questions about this decision.

Sincerely,

Gretchen Rupp

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Director

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Appendix 11. A primer in disinfection characterization[1]

From technical and regulatory perspectives, water disinfection is routinely characterized on the basis of "contact time." Contact time and its kinetics are simply a measure of the inactivation expressed as a function of concentration of the disinfectant and time (as C*t, is C, residual concentration, and t, time). Under the regulatory auspices of the SDWA as amended, EPA has developed regulations for the minimum kill percentages (inactivation) necessary for public water to be considered potable, including regulations that specify minimum disinfection of (1) 3 log (99.9%) for *Giardia lamblia* cysts and (2) 4 log (99.99%) for enteric viruses (see Letterman 1999, see also http://www.epa.gov/safewater/sdwa/index.html last accessed December 8, 2004).

Derivation of C*t values. A relationship between disinfection and contact time was originally described by Chick (1908 as cited in Haas 1999). Her research yielded data characterizing a relationship between survival and exposure to disinfectant illustrated Figure 1, where N_0 represents the initial number of organisms and N_t is the number of organisms at time *t*. As contact time between water and disinfectant increases, the ratio of (N_t / N_0) decreases, a general outcome subsequently referred to as "Chick's Law."

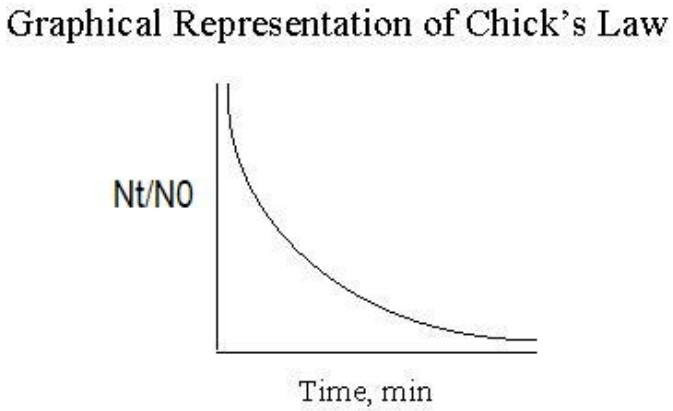


Figure 1. Typical plot of disinfection as measured by number of survivors exposed to C*t.

[1]Original source, Daniel Gallagher, Eric Karch and David Loftis, Virginia Technological Institute and State University, Blacksburg, VA. Updated June, 2004.

Chick's relatively simple equation was subsequently modified to account for various disinfectants or disinfection methods (e.g., physicochemical and physical barrier technologies; Watson 1908 as cited in Haas 1999), originally yielding the formulation of Chick-Watson Law. For example, the relatively simple relationship that characterizes the exponential decay curve in Figure 1 is modified to incorporate coefficients that account for the varying strengths of "disinfectant" and the dependence of disinfection on physicochemical attributes of water, e.g., pH. In water treatment technology, the coefficient of specific lethality (λ, lambda) captures these attributes mathematically, yielding Watson's modification of Chick's equation for a constant-mixed batch reactor (see, e.g., Haas 1999):

$$\ln(N_t / N_0) = -\lambda c^n t$$

where

N_t	=	number of viable organisms at time t,
N_0	=	number of viable organsims at time 0,
λ	=	coefficient of lethality,
c	=	concentration of disinfectant,
n	=	coefficient of media attributes (e.g., dilution, pH)
t	=	contact time (C*t; time elapsed between counts)

Factors affecting C*t.[2] Water quality characteristics will influence disinfection processes. For example, turbidity and pH strongly affect how long exposure must be in order to attain a desired rate of disinfection, e.g., as pH increases, the value of C*t must also increase in order to maintain a specific rate of disinfection ($\ln(N_t / N_0)$; see Table 1). For chlorination processes, this observation can be explained by noting the effects of pH on free chlorine. Similarly, as pH increases, the concentration of OCl^- (weak disinfectant) increases and $HOCl^-$ (strong disinfectant) decreases; thus, C*t must be increased to maintain a given rate of disinfection. Similarly, to

[2]Units of contact time, C*t, are (mg/l)(min)

increase disinfection (i.e., increase rate of log removal), C*t needs to be increased if other parameters in the process are held constant.

Table 1. C*t for removal of *Giardia* cysts in relation to log removal and pH

Log Removal	**pH <6**	**pH 6.5**	**pH 7.0**	**pH 7.5**
1.0	46	54	65	79
1.5	69	82	98	119
2.0	91	109	130	158
2.5	114	136	163	198

Not surprisingly, disinfectant strength directly affects C*t, e.g., for a weak disinfectant, C*t will have to be greater than for a strong disinfectant. Ozone is the strongest disinfectant, and C*t for ozonation is less when compared to chlorine and chlorine dioxide. Microorganisms have varying sensitivities to disinfectants, and if an organism has a high resistance to a certain disinfectant, C*t will be greater than for an organism with a low resistance (see Table 2).

Table 2. C*t Values for 99% inactivation at 5°C for various organisms subjected to various disinfectants[3]

Organism	**Free Chlorine (pH 6-7)**	**Chlorine Dioxide (pH 6-7)**	**Ozone (pH 6-7)**
E.coli	0.034-0.05	0.4-0.75	0.02
Rotavirus	0.01-0.05	0.2-2.1	0.006-0.06
Giardia lamblia cysts	47-150	-	0.5-0.6
Crytosporidium parvum	7200*	79*	5-10*

* 99% inactivation at 25°C

Depending on the specifications of the treatment system (e.g., regulatory requirements), various

[3]Hoff, J.C., Inactivation of microbial agents by chemical disinfectants, EPA/600/2-86/067, 1986

levels of disinfection can be attained by altering the type and concentration of disinfectant, and contact time. The selection of disinfection technology can be determined once regulatory and management needs are addressed, but once the level of disinfection is specified, then using the Chick-Watson relationship, engineering designs can be specified to yield the necessary contact time for a given level of disinfection. The time untreated water is exposed to the disinfectant and the concentration of that disinfectant are the main factors in the equation that influence management of water disinfection systems.

References

Chick, H., 1908, An investigation of the laws of disinfection, Journal of Hygiene 8:92-157.

Haas, C.H, 1999, Disinfection, In R.D. Letterman (editor), Water quality and treatment, Fifth edition, American Water Works Association, Denver, Colorado, pp. 14.1-14.60.

Letterman, R.D. (editor), 1999, Water quality and treatment, Fifth edition, American Water Works Association, Denver, Colorado, pagination by chapter.

Watson, H.E., 1908, A note on the variation of the rate of disinfection with change in the concentration of the disinfectant, Journal of Hygiene 8:536-542.

Appendix 12. Risk reduction technologies potentially supporting interbasin water transfers

Water diversions envisioned under the Flood Control Act of 1944 nearly 60 years ago markedly differ from those being considered as options under water management plans currently motivating this study. And, given the concerns related to biota transfers initially voiced by the International Joint Commission (IJC) in the late 1970's, control systems have been considered that minimize risks of biota transfers associated with water diversions between Missouri River source waters and the receiving systems, Red River of the North. Implementing interbasin water transfers in full compliance with the Safe Water Drinking Act (1974) as amended (including amendments promulgated in 1996) would bring to resource management discussions a system of control technologies that are effectively risk reduction tools. Within the context of risk reduction, these technologies as integrated components of control systems serving to implement interbasin water diversions are presently considered in this risk characterization. While these tools serve to reduce risks, in this case related to biota transfers, there are attendant uncertainties that must also be considered within an adaptive management context, and these uncertainties have also been considered briefly in the following sections.

Water treatment control systems as a risk reduction tool

Fifty to one-hundred years ago, waterborne diseases such as typhoid and cholera reached epidemic proportions in American cities (see, e.g., Percevial et al 2004), and the development of technologies to treat drinking water was one of the major public health advances in the 20th century. During that time interval, various control technologies have been developed to assure water disinfection is achieved and limited as a major factor in disease outbreaks and epidemics. These control technologies range from chemical and physicochemical treatments (e.g., chlorination and chloramination to ozonation) to physical barriers acting as filters (e.g., pressure-driven membrane technologies), each capable of reducing risks of biota transfers associated with interbasin water diversions (see Letterman 1999). These technologies may be used singly or in combination in control systems designed to meet user specifications, yet regardless configuration, the systems themselves present collateral risks that must be considered in any adaptive resource management plan, e.g., chemical treatments such as chlorination may yield unintended byproducts which may pose risks consequent to interaction with naturally-occurring materials in the water (see, e.g., Percival et al 2004, Letterman 1999).

Chemical treatments: Chlorination[1] and Chloramination

Disinfection in water treatment is required by the Surface Water Treatment Rule of 1990 and subsequent regulations (see, e.g., http://www.epa.gov/OGWDW/mdbp/ieswtr.html) which mandates effective disinfection through (1) filtration pre-treatment of source waters followed by (2) inactivation of organisms such as bacteria and viruses by disinfectants such as chlorine, chlorine dioxide, or ozone, and (3) as applicable, treatment requirements for waterborne pathogens, e.g., *Cryptosporidium* spp. in addition to meet existing requirements for *G. lamblia* and viruses.

Water is disinfected, not sterilized, in the water treatment process. As such, disinfection generally occurs as a two-step process wherein (1) particulate matter is removed by conventional filtration to reduce turbidity in source waters and thus, reduce "habitat" for viruses and bacteria adsorbed to particulate material, and then (2) pathogenic microorganisms are inactivated, e.g., by chemical treatments (such as chlorination and chloramination), physicochemical treatments (such as ozonation), or removed through physical treatments (such as membrane filtration; see, e.g., Letterman 1999 for overview of water treatment process; see also Mallevialle et al 1996, Duranceau 2001, Schippers et al 2004 for discussions of pressure-driven membrane systems).

Chlorination has been synonymous with disinfection, since the chemical's use as an agent for disinfection increased in the US over the past 100 years (see, e.g., Letterman 1999, and http://www.awwa.org/Advocacy/learn/info/HistoryofDrinkingWater.cfm last accessed December 8, 2004). Initially, chlorine was available for use only as hydrated lime, chloride of lime, or as bleaching powder, and in 1894 chlorine was first used as a disinfectant on a plant scale basis in Brewster, New York (see http://www.nywea.org/clearwaters/321011.html last accessed December 8, 2004). In Europe, chlorine gas was first used as a disinfectant in drinking water in 1903, and the first full scale chlorine installation at a drinking water plant in the United States occurred in 1908 (Pontius 1990). Numerous technologies were developed for the chlorination of drinking water, and in October, 1914 the Department of the Treasury enacted the first set of standards that required the use of disinfection for drinking water. These standards called for a maximum level of bacterial concentration of 2 coliforms per 100 millilters, and because

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[1]Updated and revised source materials originally developed by Eric Emenheiser, Chris Forstner, Matt Curtis & Erik Johnston, Becky Cheadle, Mark Smith, Daniel Gallagher, Virginia Polytechnic Institute and State University, Blacksburg, Virginia. Last updated December 8, 2004.

chlorination was the main disinfectant at the time, these standards dramatically increased the number of treatment plants using chlorine (White 1999). Then, in 1925 new drinking water standards were enacted that reduced the maximum permissible limit of coliforms from 2 to 1 coliform per 100 millilters. Advancements in chlorination as a primary means of disinfection occurred throughout the first half of the 20th century, but in 1972 the first published report of disinfection by-products (DBPs) in drinking water was published (EPA 1972), and focused on DBPs resulting from chlorination of source water polluted with organic chemicals (White 1999).

Much of the process of chlorination relies on technology developed in the 1950's and 1960's (see White 1999 and earlier editions of this reference). Although the tools for chlorination have continued to be refined, few innovations have been made recently. Other disinfection technologies have been developed (e.g., ozonation, UV irradiation), but chlorine remains widely used as a disinfectant throughout the US because of its low cost, ability to form a residual, and its effectiveness at low concentrations.

Chlorine gas, when exposed to water reacts readily to form hypochlorus acid, HOCl, and hydrochloric acid. $Cl_2 + H_2O \rightarrow HOCl + HCl$, and if pH exceeds 8, the hypochlorus acid will dissociate to yield hypochlorite ion, $HOCl^-$ which dissociates, H^+ and OCl^-. If pH is much less than 7, then HOCl will not dissociate. If ammonia is present in the system, hypochlorus acid will react to form one three types of chloramines depending on the pH, temperature, and reaction time. Monochloramine and dichloramine are formed in the pH range of 4.5 to 8.5, with monochloramine most common at pH > 8. When pH < 4.5, the most common form of chloramine is trichloramine. Chloramines are bacteriocidal, but are less effective as disinfectants for viruses.

Overall, chlorine presents numerous advantages for disinfection, including the chemical's ease of application and residual presence in the distribution system, its effectiveness at low concentrations, and its relatively simple conversion to chloramines which also provide strong residual effects with limited DBPs. From an engineering cost perspective, chlorine is a relatively inexpensive disinfecting agent. Despite these advantages, chlorine has "down side" characteristics that must be managed, if it is selected as a disinfection agent of choice. Chlorine reacts with organic materials in source waters, effectively reducing its concentration while creating trihalomethanes (THMs) and DBPs, compounds that may become health risks in drinking water distribution systems. More importantly from the perspective of its role as a disinfection chemical, chlorine provides poor disinfection levels for *Cryptosporidium* spp. and other microorganisms characterized by chlorine-resistant stages in their life history (e.g., spore formation; see Appendix

3B). For target organisms such as *Cryptosporidium* spp., filtration provides an alternative disinfection method used singly or in conjunction with chlorination (see, e.g., Schippers et al 2004, Duranceau 2001, Mallevialle et al 1996).

Water Disinfection with chlorine dioxide

Chlorine dioxide (ClO_2) has found increased use in drinking water treatment, since it is as good as, or better as chlorine as a disinfectant (see White 1999). From a water treatment perspective, chlorine dioxide is a good oxidant, reducing iron, manganese, sulfur compounds, and odor-causing organic substances in raw waters. The chemical's increased use, however, stems in part from its use as a pre-oxidant, since chlorine dioxide does not as readily chlorinate organic compounds in source waters. In addition to the chemical's reduced reactivity with natural organic matter (NOM) or organic pollutants to form trihalomethanes (THMs) or other chlorinated byproducts, chlorine dioxide has also found favor in water treatment, because ClO_2 will not oxidize bromide (Br^-) to bromate (BrO_3). Hypobromous acid (HOBr) can also form brominated DBPs in reactions with NOM. Regardless of the source of bromate, this constituent will be regulated at 0.010 mg/L by the Disinfectant-Disinfection By-Product (D-DBP) Rule, owing it the chemical's health risks (EPA 2001). As a disinfectant, ClO_2 is as good or better than chlorine for the inactivation of *Giardia* and is better than either chlorine or chloramines for the inactivation of *Cryptosporidium* (see Letterman 1999). While C*t values will vary depending on system design, comparative C*t values for chlorine, chloramines, ClO_2, and O_3 are summarized in Table 1 to illustrate range of disinfection realized under various technologies (see Connell 1996, Haas 1999 and White 1999 for discussion).

Table 1. Examples of C*t Values (mg/L * min) for various disinfectants (Connell 1996, Haas 1999, White 1999).

Indicator	Chloramines	Chlorine	Chlorine Dioxide	Ozone
Giardia 0.5 log inactivation pH 6-9, 5˚C	340-380	15-50	4.0-6.0	0.3-0.6
Viruses 2 log inactivation pH 6-9, 5˚C	825-900	4-7	5.0-6.0	0.6-0.9
Cryptosporidium pH 7, 25˚C	7200 2 log inactivation	7200 1 log inactivation	78 1 log inactivation	5 - 10 2 log inactivation

In contrast to chlorine, chlorine dioxide does not react as readily with organic constituents in source waters; hence, chlorinated by-products such as THMs are reduced in the post-processing stream. For drinking water treatment, typical ClO_2 treatments have been targeted at less than 1.5 mg/L, given the maxmium daily residue load (MDRL) for finished-water concentrations of ClO_2 0.8 mg/L. By-products of chlorine dioxide include chlorite ion (ClO_2^-) and chlorate ion (ClO_3^-), which have been linked to potential adverse health effects, and subject to regulatory levels mandated by Stage 1 Disinfectant/Disinfection By-Products (D/DBP) Rule. Maximum contaminant level (MCL) for ClO_2^- is 1.0 mg/L, with no ClO_3^- MCL yet proposed (EPA 2001a).

Treatment with chloramine. Chloramines are the product of chloride reacting with ammonia, as noted in the brief discussion of chlorine earlier in this section. Chloramines, particularly monochloramine, have also been used as disinfectants since the 1930's, and its use in drinking water disinfections is an increasingly common standard practice among water utilities (see also Haas 1999). In part, the increasing use of chloramine in water treatment stems from chlorine's disadvantages.

While chloramine is a weaker disinfectant than chlorine, it is more stable in water solutions under operating pH and the chemical's benefits as a disinfectant are available over longer periods of a system's operation. Chloramines primary use in water treatment is as a secondary disinfectant, since it helps maintain a disinfectant residual in the distribution system. Chloramine also provides the following benefits:

- Chloramine is not as reactive as chlorine with organic material in water, thereby producing substantially lower concentrations of DBPs such as THMs and haloacetic acids (HAAs) which have associated adverse health effects at high levels.

- Because the chloramine residual is more stable and longer lasting than free chlorine, it provides better protection against bacterial regrowth in systems with large storage tanks and dead-end water mains.

- Like chlorine, chloramine effectively controls the formation of biofilms within the distribution system. Controlling biofilms reduces microbial habitat in distribution systems, which reduces concentrations of coliforms and other microorganisms, and helps reduce biofilm-induced corrosion of pipes.

- Because chloramine does not tend to react with organic compounds, many systems will experience less incidence of taste and odor complaints when using chloramine.

In addition to these technical advantages of chloramine, many drinking water utilities in the US have switched to chloramine as their disinfectant residual, since regulatory limits for THMs in drinking water have been lowered with promulgation of the Stage I Disinfection Byproducts Rule and subsequent administrative targets for lowering standards of DBPs (see EPA 2001a for a quick reference, or EPA 2001b).

Membrane filtration

Membrane filtration technology has been increasingly applied to water treatment problems, where the range of membrane technologies have become efficient and safe water treatment alternatives. Water treatment systems singly dependent on membrane filtration, or incorporating membrane technology within a multiple-treatment process, yield product waters of consistent quality that meets or exceeds water quality standards, especially with respect to disinfection (see, e.g., Schippers et al 2004). Membrane separation technology removes substances largely based on size and shape, with pore size and particle-size exclusion typically measured in nanometers (nm, or 10^{-9} meters), Angstroms (Å, or 10^{-10} meters), or molecular weight (MW, often times expressed as units, D for daltons). A range of membranes have been developed with mass transfer properties and pore sizes such that ionic, molecular and organic substances measuring 1-1000 Å (MW between 100 and 500,000) are removed or rejected (Table 2).

As a "stand-alone" water treatment technology, membrane filtration is a physical process that may require little or no chemical treatment, depending on the choice of membrane device selected. Unlike ultraviolet radiation technology, membrane filtration allows not only the removal of pathogens, bacteria and viruses likely to be found in the water drawn, but also to reduces color, turbidity and mineral content. While various types of filtration are available, three general types are briefly considered: microfiltration, ultrafiltration, and nanofiltration (Figure 1; graphic after AWWA).

Table 2. Comparative rejection values for range of membrane technologies (modified from Water Technology, Latham. NY; see Mallevialle 1996, Duranceau 2001).

Species	RO	Loose RO	NF	UF
Sodium Chloride, NaCl	99%	70-95%	0-50%*	0%
Sodium Sulfate, Na_2SO_4	99%	80-95%	99%	0%
Calcium Chloride, $CaCl_2$	99%	80-95%	0-60%	0%
Magnesium Sulfate, $MgSO_4$	>99%	95-98%	>99%	0%
Sulfuric Acid, H_2SO_4	98%	80-90%	0%	0%
Hydrochloric Acid, HCl	90%	70-85%	0%	0%
Fructose, MW 180	>99%	>99%	>99%	0%
Sucrose, MW 360	>99%	>99%	>99%	0%
Humic Acid	>99%	>99%	>99%	0%
Viruses	99.99%	99.99%	99.99%	99%
Proteins	99.99%	99.99%	99.99%	99%
Bacteria	99.99%	99.99%	99.99%	99%

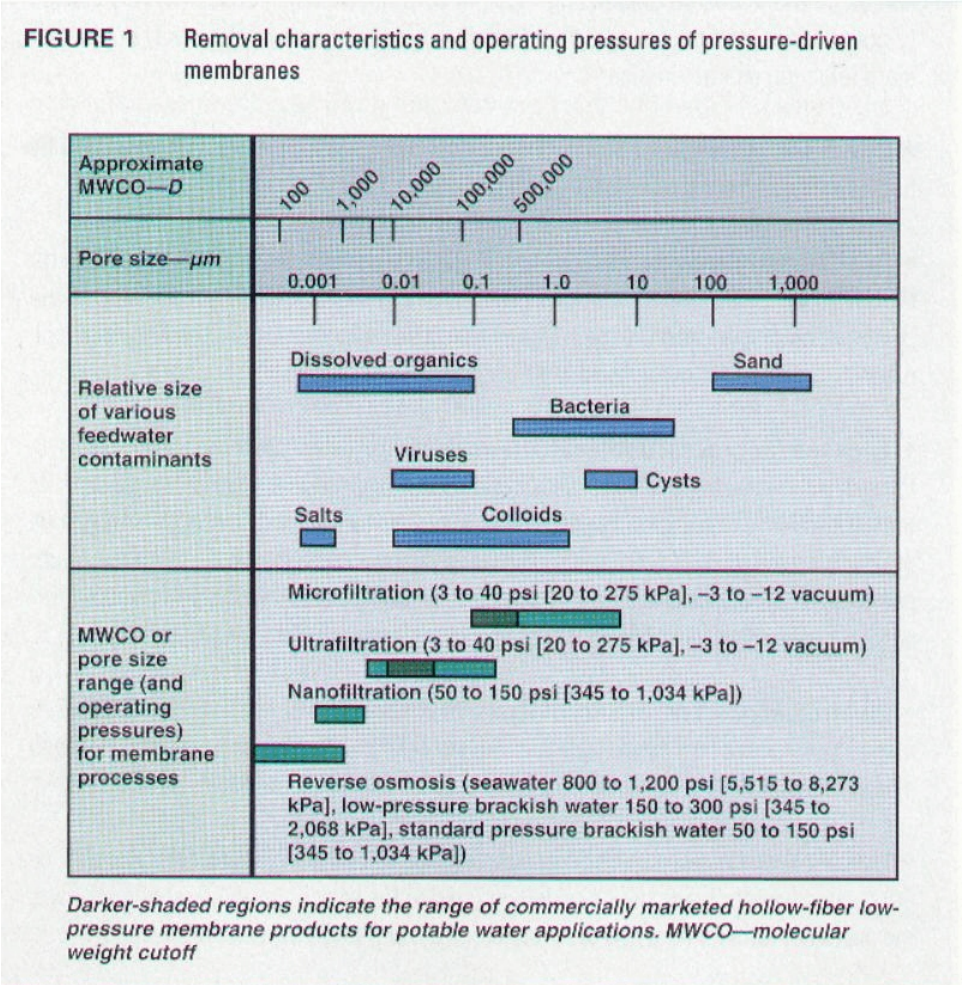
*values reflect controlled conditions where "0%" rejection is valid for a 30,000 parts per million (ppm) solutions occur as mixture of ions. Actual rejection of defined 30,000 ppm solution ranges from 5-15%, with the higher value valid for dilute solutions. Actual rejection will vary depending on the composition of the feed and membrane characteristics.

Microfiltration is characterized as a solid-liquid separation process with a molecular weight cut off between between 0.1 μm and 10 μm (Figure 1). Microfiltration reduces the passage of suspended particles, high-molecular weight lipids and fats, macromolecules, bacteria and protozoa (although *Cryptosporidium* spp. and *Giardia* spp. may not be removed completely). It is frequently used for the production of drinking water and waste water treatment.

Ultrafiltration allows the filtration of smaller particles than microfiltration with a molecular weight cut off between between 0.01 μm (micrometers, 10^{-6} meters) and 0.1 μm, which effectively excludes all protozoa, bacteria and virus particles, as well as most proteins and high molecular weight organic compounds (Figure 1). Ultrafiltration is finding widespread use for a variety of applications such as producing drinking water, treating waste water and treating

process water (e.g., discharges from agricultural, biotechnology, petrochemical, municipal waste streams).

Nanofiltration provides the greatest filtration capacity of the membrane technologies, with pore sizes less than 10 nm (Figure 1). As such, nanofiltration not only excludes those constituents separated by ultrafiltration, but also limits passage of divalent ions, dissolved organic material and sugars. Given the membranes characteristic molecular-weight cut off, nanofiltration provides for partial demineralisation, which tends to yield potable water from slightly brackish water or humic-stained surface water.



(Source: American Water Works Association)

Although not considered withing the context of alternatives pertinent to the current focus on reducing risks associated with interbasin biota transfer, reverse osmosis technologies have

numerous applications in industry, and it use in water treatment processes is most often associated with desalination projects. As a membrane technology, reverse osmosis allows for the separation of suspended solids and ionic species. A key difference between reverse osmosis and other filtration membranes lies in membrane pore size, with reverse osmosis membrane pores measuring between 1 to 15 Å (Angstroms). Membrane technologies are usually operated according to a cross-flow mode where source or "raw" water enters the treatment system via an inlet, product or filtered water (permeate) exists the system via an outlet, and rejected water (concentrate) is discharged through another outlet. Dead-end filtration modes are also designed as required for specific operations; in dead-end modes, rejected water is "recycled" to achieve higher rates of product recovery (see Malleviallen1996, Duranceau 2001).

Chemical treatment, membrane filtration, and disinfection of water

Chlorine disinfection has been effective in treating drinking water supplies in the US for most of the 20th century, especially with respect to protecting drinking water resources from bacterial and viral contamination (see Haas 1999 for brief history). Water-borne diseases such as typhoid fever (*Salmonella typhi*), cholera (*Vibrio cholerae*) and bacillary dysentery (*Shigella dysenteriae*) have been eliminated or dramatically reduced to sporadic outbreaks infrequently associated with failed treatment facilities in the developed countries. Three primary chemical agents are used in chlorine disinfection are free chlorine, chloramine, and chlorine dioxide. The disinfection capacity for these chemicals, however, reflects chemical properties of chloride that necessarily contribute to "trade offs" associated with the chemical's use. Chlorine is highly reactive, and when added to water in its various forms, disinfection occurs but in the process, chlorine reacts with other chemicals, including organic constituents, present in the water. These chemicals generally enter the water supply through natural plant and soil breakdown, or through anthropogenic chemicals such as agricultural or industrial chemicals released to the environment.

When chlorine reacts with organic constituents in source water, DBPs such as THMs (e.g., chloroform) and HAAs. Other disinfection chemicals also generate DBPs, but given chlorine's long record in water treatment, more is known regarding DBPs resulting from chlorination than by other disinfectants. Many DBPs resulting from chlorination have been characterized as health risks, e.g., animal studies with DBPs at high exposure concentration have been characterized by increased incidence of cancer, although mechanisms leading to these pathological responses is poorly understood (see Regli et al 1994).

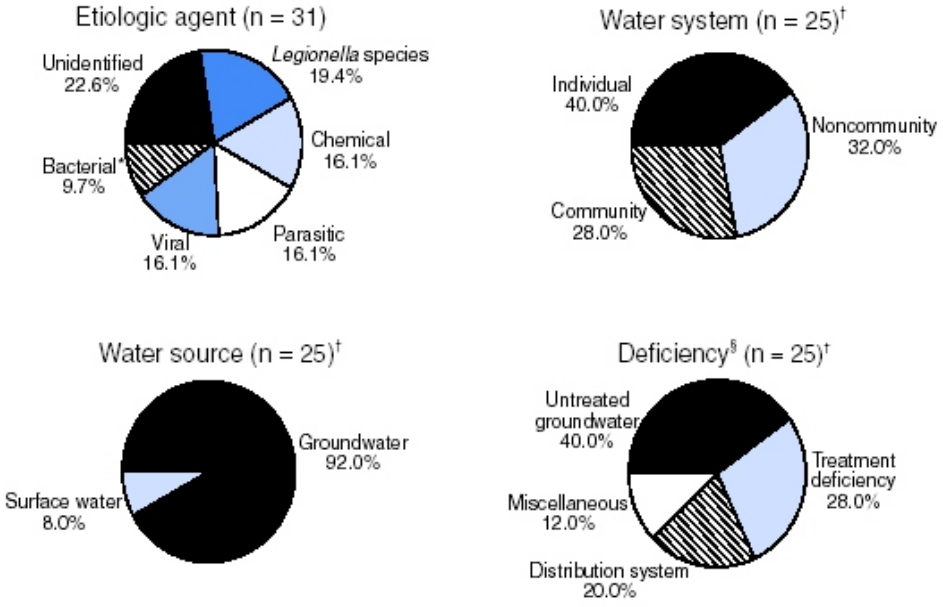
Given the health risks associated with DBPs, rather than use chlorine gas in the chlorination process, chloramine or chlorine dioxide may serve as alternative sources for chlorine disinfection. While these sources produce fewer DBPs than chlorine, these chemicals also have their attendant risks and technical shortcomings. For example, as a disinfectant, chloramine is not as strong as chlorine, and disinfection with chlorine dioxide produces its own DBPs (White 1999). Currently, DBPs occur in US drinking water at very low concentrations, and unequivocal links between exposures to DBPs at low concentrations and adverse health risks associated with these exposures is relatively poorly characterized (Regli et al 1994, Singer 1999). Under the authority of the Safe Drinking Water Act (SDWA), EPA has regulated acceptable levels of some DBPs since 1979. And, under the Safe Drinking Water Act Amendments of 1996, EPA has been charged to implement its initial Disinfectant and Disinfectant-By-Product (DDPB) rule and Interim Enhanced Surface Water Treatment Rule (IESWTR), both originally proposed in 1994.

The continued need for chemical disinfection of drinking water and the attendant risks associated with DBPs illustrates the trade-offs between benefits and risks associated with chlorination, given the characterization that microbial pathogens consistently present greater risks in drinking water sources than do DBPs resulting from chemical treatments such as chlorination (see, e.g., Regli et al 1994). Although most regulatory attention has focused on DBPs of chlorine, other disinfection processes also produce byproducts when chemicals used in treatment react with organic or inorganic constituents in raw water, e.g., ozonation has been used effectively in water disinfection, but bromate ion is a DBP resulting from ozonation of water high bromide. Bromate is being evaluated by EPA during the Stage I rule developed to support the SDWA as amended 1996.

Cryptosporidium. Another factor that is likely to impact the choice of primary disinfectants by utilities is the need to address disinfection focused on *Cryptosporidium*. Chlorine is not very effective in treating *Cryptosporidium*, but adequate filtration appears to be the best protection from the disease agent. In some areas with poor water quality, however, a combination of disinfection technologies may be necessary to provide disinfection of *Cryptosporidium* and other protozoan, bacterial, and viral agents of waterborne disease (see, e.g., Percival et al 2004). Chlorine dioxide and ozone have been shown to be relatively effective for inactivating *Cryptosporidium*, yet the literature suggests that these disinfectants can be even more effective when used sequentially with various membrane technologies (see, e.g., White 1999, Letterman 1999, Schippers et al 2004).

Groundwater Disinfection. According to the EPA there are over 150,000 groundwater systems in the US (see http://www.epa.gov/safewater/ last accessed December 8, 2004). The "Groundwater Rule" is intended to address microbial contamination of groundwaters (see http://www.epa.gov/fedrgstr/EPA-WATER/2000/May/Day-10/w10763.htm last accessed December 8, 2004). Groundwater, although filtered by natural processes, is often susceptible to microbial contamination, especially in rural communities, and source waters may need disinfection as part of the treatment process. Increasingly, sources of drinking water dependent on groundwater have been found vulnerable to microbial contamination, including indication of fecal contamination from tests for total coliform bacteria, *E. coli*, coliphage and human viruses (NRC 2003). Drinking water derived from groundwater sources has also been the source of nearly half of all waterborne disease outbreaks in the US, and with an increasing reliance on groundwater, inadequate disinfection of groundwater and untreated groundwater will continue to dominate as sources of waterborne disease outbreaks in the US (see CDC 2004; Figure 2).

FIGURE 2 Drinking water-associated outbreaks, by etiologic agent, water system, water source, and deficiency — United States, 2001–2002



*Other than *Legionella* species.
†Excludes outbreaks attributed to *Legionella* species.
§No outbreaks were attributed to untreated surface water.

(Source: Centers for Disease Control and Prevention)

[2]UV Disinfection of Drinking Water

In view of the "Best Available Technologies" being considered as part of the Groundwater Rule, brief summaries of UV and ozone disinfection technologies are considered in the following sections. As noted many times in past reports, the problem of unsafe drinking water is not an isolated technical problem, but interrelated to the problems of adequate water supply, community education in public hygiene, access to sanitation, and effective and safe disposal of human and animal wastes (see, e.g., Percival et al 2004).

Use of ultraviolet (UV) light to disinfect water of waterborne pathogens relies on the germicidal properties of a narrow range of the UV spectrum. Provided dosage is sufficient (e.g., exposure duration long enough to yield desired C*t values), UV wavelengths ranging from 240 to 280 nanometers (nm) deactivate, or effectively kill, microorganisms by damaging their DNA so as to prevent DNA repair. The organism, if not killed, is unable to replicate and thrive (see, e.g., McKey et al 2001, Jacangelo et al 2002). UV dose measured in microwatt-seconds per square centimeter is the product of UV intensity and exposure time, and exposures for 90% kill of most bacteria and viruses range from 2,000 to 8,000 $\mu W\text{-}s/cm^2$, and for disinfection targeted on *Giardia* spp., *Cryptosporidium* spp., and other large cysts and parasites, UV doses are an order of magnitude greater (approximately 60,000-80,000 $\mu W\text{-}s/cm^2$; see, e.g., McKey et al 2001, Jacangelo et al 2002). Most UV disinfection systems use a low-pressure or medium-pressure mercury vapor lamp and expose water to UV by pumping the water around a sleeve within which the UV lamp is supported. UV systems can also be coupled with a pre-filter to remove larger organisms that would otherwise pass through the UV system unaffected. The pre-filter also clarifies the water to improve light transmittance; therefore, UV dose is achieved throughout the entire water column. Proper handling and storage of UV-treated waters are a critical part of any UV treatment system. UV treatment alone offers no residual disinfection, and if bacteria are not killed as a result of UV exposure, the organisms may be able to repair their DNA and reactivate in a few days when exposed to visible light (see, e.g., Mara and Horan 2003).

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[2]Edited and updated from original source material prepared by Ashok Gadgil, Anushka Drescher, David Greene, Peter Miller, Cynthia Motau, and Frank Stevens and published by Lawrence Berkeley Laboratory Report Number LBNL 40360 (1997).

[3]Disinfection with Ozone

Ozone is a form of oxygen with the molecular formula O_3 which forms when O_2 or clean dry air is exposed to a powerful electric current. In nature, it forms in the upper atmosphere when lightning passes through the air. As a disinfectant, ozone is highly unstable and decomposes to O_2 and O^- shortly after its formation; O^- is the highly decomposition product responsible for ozone's disinfectant properties. As a highly reactive species, ozone is a powerful oxidant and one of the most powerful disinfectants available in water treatment.

Ozone was discovered late in in 1783, and by the close of the close of the 19th century, ozone was used for water disinfection in Europe. By 1980, there were over 1100 water treatment facilities using ozonation, with most of these facilities in Europe (see, e.g., Letterman 1999, White 1999). In the 1930's, several water treatment plants in New York, Pennsylvania, and Indiana experimented with ozone, but only recently has the use of ozone gained attention in the US. Although few water treatment facilities relied on ozonation in 1987 (Haas 1999), a few years later nearly 40 water treatment plants in the US were equipped with ozonation facilities. Water disinfection in the US currently remains more heavily dependent on less expensive disinfectants such as free chlorine, chlorine dioxide, and chloramines (see, Letterman 1999). However, recent legislation such as the Safe Drinking Water Act Amendments of 1996 and its associated rules or proposed rules (e.g., Surface Water Treatment Rule, Groundwater Rule) place more strict rules on both the range and amount of disinfection needed and the concentrations of DBPs allowed in drinking water. As a consequence, the use of free chlorine and other common disinfectants may become less cost-effective, and ozone disinfection has gained much attention, given the increasing awareness of public health risks associated with agents of waterborne disease and ozone to effectively inactivate *Cryptosporidium* and *Giardia* (see, Regli et al 1994, White 1999).

Disinfection is achieved when ozone reacts with source water upon entering a "reaction chamber" designed to allow for sufficient contact time, wherein ozone decays to form oxygen molecules and free hydroxyl radicals (Haas 1999). Both ozone and the highly reactive free radicals generated in its decomposition serve as strong oxidants, attacking organic molecules, including pollutants such as herbicides and pesticides, and biological compounds such as proteins,

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[3]Updated and edited from original material prepared by Rob Dunham, Hong He & Ken Woodard, Daniel Gallagher, Stacie Kramer and Susanna Leung, Virginia Technological Institute and State University, Blackburg, VA.

carbohydrates and humic acids, at double-bonded carbons to damage and destroy critical components of organisms found in the water. Contact times are relatively short duration, but highly effective at disinfection (Table 3), since the free hydroxyl is very reactive compared to other disinfectants (see White 1999).

Table 3. Summary of ranges of C*t-values for 99% inactivation of various waterborne disease agents by various disinfectants at 5°C (see White 1999)

Organism	Free Chlorine pH 6-7	Preformed Chloramine pH 8-9	Chlorine Dioxide pH 6-7	Ozone
E.coli	0.034-0.05	95-180	0.4-0.75	0.02
Polio I	0.1-2.5	768-3740	0.2-6.7	0.1-0.2
Rotavirus	0.01-0.05	3806-6476	0.2-2.1	0.006-0.06
Phage F2	0.08-0.18	---	---	---
Giardia lamblia cysts	47-150	---	---	0.5-0.6
Giardia muris cysts	36-630	1400	7.2-18.5	1.8-2.0
Cryptosporidium parvum	7200	7200	79	5-10

Precautions must be taken to assure that ozone and its highly reactive free radicals are eliminated from product water following disinfection, given the highly reactive decomposition products of ozone.

From an engineering perspective, ozone has its own set of benefits and risks as a disinfectant (Table 4). Currently, the primary drawbacks to ozonation are capital costs relative to alternative chlorination systems, and the increased cost of maintenance and operation over conventional water treatment facilities (see, e.g., http://www.awwa.org/Advocacy/pressroom/ozone.cfm; see also, EPRI 1996, 1999; http://www.epri.com/attachments/285588_WaterImperative.pdf). As with UV disinfection, ozonation does not yield disinfectant residuals in the water distribution system post-treatment; hence, long-term effectiveness of ozonation may also limit is adoption, since bacterial regrowth may occur in the distribution system following treatment, if bacteriocidal effects were not achieved in the ozonation process.

Table 4. Simplified summary of selected benefits and costs associated with ozone disinfection of source water.

Benefits	Costs
Extremely powerful disinfectant	Expensive option
Does not form trihalomethanes	Can form other hazardous disinfection-by-products such as bromate
Requires relatively short contact time	Requires high level of technology
Reduces taste, odor, and color in water by oxidizing the algae and humic material which causes these problems	Requires another disinfectant to achieve residual disinfection levels
Forms microfloc upon contact therefore improving coagulation and reducing the required coagulant dose	Unstable - must be generated on-site
- Can improve filtration rates. With improved coagulation, more material settles in the sedimentation basin. Hence, less material reaches the filters and the filters can be run longer before backwashing.	Climate control needed to maintain solubility
- Environmentally friendly - decays back to oxygen	Not widely used in US

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Appendix 13. Output from simulation analysis of invasion probabilities.

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
9.990e-01	9.990e-01	9.990e-01	9.990e-01	9.990e-01	9.990e-01	9.940e-01
9.900e-01	9.900e-01	9.900e-01	9.900e-01	9.900e-01	9.900e-01	9.415e-01
9.500e-01	9.500e-01	9.500e-01	9.500e-01	9.500e-01	9.500e-01	7.351e-01
9.000e-01	9.000e-01	9.000e-01	9.000e-01	9.000e-01	9.000e-01	5.314e-01
8.500e-01	8.500e-01	8.500e-01	8.500e-01	8.500e-01	8.500e-01	3.771e-01
8.000e-01	8.000e-01	8.000e-01	8.000e-01	8.000e-01	8.000e-01	2.621e-01
7.500e-01	7.500e-01	7.500e-01	7.500e-01	7.500e-01	7.500e-01	1.780e-01
7.000e-01	7.000e-01	7.000e-01	7.000e-01	7.000e-01	7.000e-01	1.176e-01
6.500e-01	6.500e-01	6.500e-01	6.500e-01	6.500e-01	6.500e-01	7.542e-02
8.500e-01	8.500e-01	9.990e-01	5.000e-01	4.000e-01	5.000e-01	7.218e-02
5.000e-01	4.500e-01	4.000e-01	9.900e-01	8.500e-01	6.500e-01	4.923e-02
6.000e-01	6.000e-01	6.000e-01	6.000e-01	6.000e-01	6.000e-01	4.666e-02
9.500e-01	6.000e-01	5.000e-01	7.500e-01	4.000e-01	5.000e-01	4.275e-02
9.990e-01	7.500e-01	4.000e-01	2.000e-01	6.500e-01	9.000e-01	3.506e-02
9.500e-01	7.000e-01	4.000e-01	7.000e-01	5.000e-01	3.500e-01	3.258e-02
5.500e-01	5.500e-01	5.500e-01	5.500e-01	5.500e-01	5.500e-01	2.768e-02
5.000e-01	8.000e-01	1.500e-01	3.000e-01	9.500e-01	9.900e-01	1.693e-02
4.000e-01	7.500e-01	9.990e-01	7.500e-01	1.000e-01	7.500e-01	1.686e-02
5.000e-01	5.000e-01	5.000e-01	5.000e-01	5.000e-01	5.000e-01	1.562e-02
7.500e-01	5.000e-02	7.500e-01	7.000e-01	8.500e-01	7.000e-01	1.171e-02
5.000e-01	9.990e-01	5.000e-01	9.900e-01	8.000e-01	5.000e-02	9.890e-03
4.500e-01	4.500e-01	4.500e-01	4.500e-01	4.500e-01	4.500e-01	8.304e-03
3.000e-01	4.500e-01	6.000e-01	9.000e-01	6.500e-01	1.500e-01	7.108e-03
9.500e-01	8.500e-01	4.000e-01	9.000e-01	4.500e-01	5.000e-02	6.541e-03
3.000e-01	6.000e-01	2.000e-01	5.000e-01	8.000e-01	4.500e-01	6.480e-03
9.990e-01	1.000e-01	3.500e-01	6.000e-01	6.000e-01	4.000e-01	5.035e-03
3.500e-01	1.500e-01	8.000e-01	4.500e-01	3.000e-01	8.500e-01	4.820e-03
9.500e-01	6.000e-01	7.500e-01	3.000e-01	1.000e-01	3.500e-01	4.489e-03

Probability of						
Missouri River Input	Transfer to Control System	Control System Failure	Establishing a Sustainable Population	Intersection of Transferred Biota & Receptor	Expression of Adverse Effect in Receptor	Outcome as "Successful Invasion"
4.000e-01	4.000e-01	4.000e-01	4.000e-01	4.000e-01	4.000e-01	4.096e-03
5.500e-01	4.000e-01	7.500e-01	1.000e-01	4.000e-01	5.500e-01	3.630e-03
5.500e-01	9.990e-01	8.500e-01	3.000e-01	1.000e-01	2.500e-01	3.503e-03
8.500e-01	1.500e-01	2.500e-01	2.000e-01	5.000e-01	8.500e-01	2.709e-03
3.500e-01	3.500e-01	3.500e-01	3.500e-01	3.500e-01	3.500e-01	1.838e-03
1.000e-01	1.000e-01	8.000e-01	3.000e-01	7.500e-01	9.900e-01	1.782e-03
5.000e-02	4.000e-01	9.500e-01	7.500e-01	3.000e-01	4.000e-01	1.710e-03
3.500e-01	4.000e-01	5.000e-01	1.000e-01	2.500e-01	9.500e-01	1.662e-03
4.500e-01	3.500e-01	7.500e-01	1.500e-01	4.500e-01	2.000e-01	1.595e-03
1.000e-01	9.990e-01	3.000e-01	7.500e-01	1.000e-01	7.000e-01	1.573e-03
5.000e-02	7.500e-01	4.000e-01	2.500e-01	9.500e-01	3.500e-01	1.247e-03
5.500e-01	8.500e-01	5.000e-02	5.000e-01	6.500e-01	1.500e-01	1.140e-03
9.000e-01	5.000e-02	2.000e-01	9.900e-01	4.000e-01	3.000e-01	1.069e-03
1.000e-01	3.000e-01	4.500e-01	3.000e-01	3.500e-01	7.500e-01	1.063e-03
2.000e-01	1.500e-01	8.500e-01	4.000e-01	1.000e-01	9.900e-01	1.010e-03
4.000e-01	4.000e-01	4.000e-01	9.900e-01	1.000e-01	1.500e-01	9.504e-04
8.000e-01	4.000e-01	2.000e-01	1.500e-01	1.000e-01	8.500e-01	8.160e-04
5.500e-01	8.500e-01	7.500e-01	3.000e-01	7.500e-01	1.000e-02	7.889e-04
3.000e-01	3.000e-01	3.000e-01	3.000e-01	3.000e-01	3.000e-01	7.290e-04
3.500e-01	4.500e-01	5.000e-02	9.900e-01	8.000e-01	1.000e-01	6.237e-04
5.000e-01	1.500e-01	5.000e-02	5.000e-01	4.500e-01	7.000e-01	5.906e-04
1.500e-01	1.500e-01	3.000e-01	9.990e-01	2.000e-01	3.500e-01	4.720e-04
8.500e-01	9.990e-01	4.500e-01	1.500e-01	7.500e-01	1.000e-02	4.299e-04
2.000e-01	3.500e-01	7.500e-01	1.500e-01	5.000e-01	1.000e-01	3.937e-04
4.000e-01	3.500e-01	7.500e-01	8.500e-01	7.500e-01	5.000e-03	3.347e-04
3.000e-01	9.990e-01	7.500e-01	2.500e-01	5.500e-01	1.000e-02	3.091e-04
8.000e-01	4.000e-01	1.000e-02	1.500e-01	8.000e-01	7.500e-01	2.880e-04
2.500e-01	2.500e-01	2.500e-01	2.500e-01	2.500e-01	2.500e-01	2.441e-04
3.000e-01	4.500e-01	3.000e-01	6.500e-01	6.500e-01	1.000e-02	1.711e-04
2.000e-01	9.990e-01	5.000e-02	1.500e-01	6.500e-01	1.500e-01	1.461e-04

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
2.000e-01	5.000e-02	1.500e-01	3.000e-01	4.500e-01	7.000e-01	1.418e-04
9.900e-01	6.500e-01	5.000e-02	5.000e-03	8.000e-01	8.500e-01	1.094e-04
4.000e-01	7.500e-01	1.000e-02	2.500e-01	2.000e-01	7.000e-01	1.050e-04
9.500e-01	8.500e-01	8.500e-01	3.000e-01	1.000e-02	5.000e-02	1.030e-04
1.000e-03	9.990e-01	5.000e-01	7.500e-01	9.500e-01	2.500e-01	8.897e-05
5.000e-02	3.500e-01	9.500e-01	9.900e-01	5.000e-03	9.900e-01	8.147e-05
4.000e-01	1.500e-01	1.000e-02	3.000e-01	6.000e-01	7.000e-01	7.560e-05
2.000e-01	2.000e-01	2.000e-01	2.000e-01	2.000e-01	2.000e-01	6.400e-05
4.000e-01	7.500e-01	9.990e-01	3.500e-01	9.500e-01	5.000e-04	4.983e-05
8.500e-01	1.000e-01	7.500e-01	1.000e-01	1.000e-02	7.500e-01	4.781e-05
9.000e-01	1.000e-03	6.500e-01	9.000e-01	3.500e-01	2.500e-01	4.607e-05
4.000e-01	3.500e-01	1.000e-02	1.000e-01	4.000e-01	8.000e-01	4.480e-05
8.500e-01	1.000e-03	3.000e-01	2.500e-01	9.900e-01	7.000e-01	4.418e-05
3.500e-01	1.000e-03	7.500e-01	8.500e-01	4.000e-01	4.500e-01	4.016e-05
6.500e-01	5.000e-02	1.000e-02	2.500e-01	7.500e-01	6.500e-01	3.961e-05
1.500e-01	4.500e-01	6.500e-01	1.000e-03	9.500e-01	8.500e-01	3.543e-05
5.000e-01	1.000e-03	7.500e-01	2.500e-01	3.000e-01	9.500e-01	2.672e-05
8.500e-01	7.500e-01	8.500e-01	5.000e-05	9.000e-01	9.500e-01	2.317e-05
7.500e-01	5.000e-02	4.000e-01	1.000e-01	3.000e-01	5.000e-02	2.250e-05
2.500e-01	7.500e-01	5.000e-04	9.000e-01	7.500e-01	3.500e-01	2.215e-05
1.000e-02	6.000e-01	6.000e-01	1.000e-01	3.000e-01	2.000e-01	2.160e-05
8.000e-01	1.000e-02	7.500e-01	9.990e-01	6.500e-01	5.000e-03	1.948e-05
9.500e-01	7.500e-01	8.500e-01	3.000e-01	2.000e-01	5.000e-04	1.817e-05
9.990e-01	7.000e-01	5.000e-02	2.000e-01	5.000e-01	5.000e-03	1.748e-05
1.000e-02	3.000e-01	3.500e-01	1.500e-01	3.000e-01	3.500e-01	1.654e-05
9.000e-01	1.000e-04	7.500e-01	7.000e-01	9.500e-01	3.500e-01	1.571e-05
9.990e-01	6.000e-01	9.990e-01	7.500e-01	6.500e-01	5.000e-05	1.460e-05
1.500e-01	1.500e-01	1.500e-01	1.500e-01	1.500e-01	1.500e-01	1.139e-05
7.500e-01	4.000e-01	1.000e-02	1.000e-02	6.500e-01	5.500e-01	1.073e-05
4.000e-01	7.500e-01	8.000e-01	6.000e-01	1.000e-04	7.000e-01	1.008e-05

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
5.000e-02	1.500e-01	1.000e-02	2.000e-01	9.500e-01	7.000e-01	9.975e-06
5.000e-01	3.000e-01	8.500e-01	7.500e-01	9.990e-01	1.000e-04	9.553e-06
1.500e-01	1.000e-01	9.990e-01	8.000e-01	7.500e-01	1.000e-03	8.991e-06
3.000e-01	8.500e-01	2.000e-01	7.000e-01	5.000e-01	5.000e-04	8.925e-06
9.990e-01	8.500e-01	1.000e-02	1.000e-01	9.990e-01	1.000e-02	8.483e-06
2.500e-01	7.500e-01	7.500e-01	1.000e-04	6.000e-01	9.900e-01	8.353e-06
3.500e-01	7.500e-01	7.500e-01	6.000e-01	1.000e-04	7.000e-01	8.269e-06
5.500e-01	5.000e-02	8.500e-01	1.000e-03	7.500e-01	4.500e-01	7.889e-06
8.000e-01	5.000e-02	7.500e-01	5.000e-02	9.500e-01	5.000e-03	7.125e-06
1.000e-01	4.000e-01	8.500e-01	9.900e-01	5.000e-04	4.000e-01	6.732e-06
5.000e-05	8.500e-01	9.500e-01	3.000e-01	7.500e-01	7.000e-01	6.359e-06
4.500e-01	1.000e-02	1.500e-01	1.500e-01	4.000e-01	1.500e-01	6.075e-06
2.500e-01	7.500e-01	6.500e-01	9.990e-01	9.500e-01	5.000e-05	5.783e-06
9.500e-01	6.000e-01	5.000e-05	5.000e-01	5.000e-01	8.000e-01	5.700e-06
9.000e-01	1.500e-01	4.000e-01	1.000e-01	1.000e-01	1.000e-02	5.400e-06
4.000e-01	5.000e-04	5.000e-01	7.500e-01	4.500e-01	1.500e-01	5.063e-06
1.000e-03	1.500e-01	2.000e-01	8.500e-01	3.500e-01	5.000e-01	4.462e-06
1.000e-04	2.500e-01	6.500e-01	4.000e-01	7.500e-01	8.500e-01	4.144e-06
5.500e-01	5.500e-01	3.000e-01	1.000e-03	4.500e-01	1.000e-01	4.084e-06
1.500e-01	4.500e-01	3.500e-01	7.500e-01	2.000e-01	1.000e-03	3.544e-06
5.000e-01	1.000e-01	2.000e-01	1.000e-03	4.000e-01	8.000e-01	3.200e-06
5.000e-02	4.500e-01	4.000e-01	3.000e-01	5.000e-03	2.000e-01	2.700e-06
1.500e-01	8.500e-01	5.000e-05	6.000e-01	9.900e-01	6.500e-01	2.461e-06
9.000e-01	1.000e-04	1.500e-01	2.500e-01	7.500e-01	9.500e-01	2.405e-06
9.500e-01	7.500e-01	7.500e-01	1.000e-01	9.000e-01	5.000e-05	2.405e-06
7.500e-01	4.500e-01	9.990e-01	1.000e-03	1.000e-02	7.000e-01	2.360e-06
9.500e-01	9.000e-01	4.000e-01	1.000e-02	1.000e-03	6.500e-01	2.223e-06
5.000e-05	6.000e-01	7.000e-01	3.000e-01	9.500e-01	3.500e-01	2.095e-06
9.500e-01	8.500e-01	1.000e-05	7.000e-01	4.500e-01	8.000e-01	2.035e-06
4.000e-01	1.000e-01	5.000e-01	2.000e-01	1.000e-01	5.000e-03	2.000e-06

Probability of						
Missouri River Input	Transfer to Control System	Control System Failure	Establishing a Sustainable Population	Intersection of Transferred Biota & Receptor	Expression of Adverse Effect in Receptor	Outcome as "Successful Invasion"
5.000e-03	5.000e-03	6.500e-01	4.000e-01	4.000e-01	6.500e-01	1.690e-06
9.000e-01	7.500e-01	7.000e-01	5.000e-05	1.000e-01	7.000e-01	1.654e-06
5.000e-05	5.500e-01	8.500e-01	1.500e-01	5.500e-01	8.000e-01	1.543e-06
8.000e-01	4.500e-01	1.000e-02	1.500e-01	5.000e-03	4.500e-01	1.215e-06
7.500e-01	6.500e-01	1.000e-02	3.500e-01	6.000e-01	1.000e-03	1.024e-06
1.000e-01	1.000e-01	1.000e-01	1.000e-01	1.000e-01	1.000e-01	1.000e-06
9.000e-01	2.500e-01	5.000e-05	1.500e-01	9.000e-01	6.500e-01	9.872e-07
5.500e-01	3.000e-01	6.000e-01	1.000e-03	9.500e-01	1.000e-02	9.405e-07
9.500e-01	4.500e-01	1.000e-01	5.000e-02	7.500e-01	5.000e-04	8.016e-07
9.900e-01	9.900e-01	2.500e-01	5.000e-06	6.500e-01	9.900e-01	7.884e-07
5.500e-01	6.500e-01	5.000e-06	7.500e-01	6.500e-01	8.500e-01	7.407e-07
9.000e-01	1.000e-02	8.500e-01	4.000e-01	4.500e-01	5.000e-04	6.885e-07
9.500e-01	5.000e-05	9.500e-01	5.000e-02	8.000e-01	3.500e-01	6.318e-07
8.500e-01	3.500e-01	6.000e-01	5.000e-01	1.000e-05	7.000e-01	6.248e-07
9.990e-01	1.000e-05	2.000e-01	7.500e-01	9.900e-01	4.000e-01	5.934e-07
1.000e-01	1.000e-03	5.000e-02	8.000e-01	2.000e-01	7.000e-01	5.600e-07
6.500e-01	7.500e-01	3.000e-01	8.000e-01	4.500e-01	1.000e-05	5.265e-07
3.500e-01	1.500e-01	2.000e-01	5.000e-05	9.500e-01	9.900e-01	4.938e-07
5.000e-03	1.000e-02	1.000e-01	9.900e-01	9.900e-01	1.000e-01	4.901e-07
5.000e-05	7.500e-01	9.900e-01	2.500e-01	1.500e-01	3.500e-01	4.873e-07
3.500e-01	6.500e-01	4.500e-01	1.000e-03	9.500e-01	5.000e-03	4.863e-07
5.000e-01	8.500e-01	7.500e-01	5.000e-01	3.000e-01	1.000e-05	4.781e-07
4.000e-01	9.500e-01	4.000e-01	3.000e-01	9.900e-01	1.000e-05	4.514e-07
1.500e-01	2.000e-01	3.000e-01	1.000e-01	1.000e-01	5.000e-03	4.500e-07
9.500e-01	5.500e-01	7.500e-01	2.500e-01	4.500e-01	1.000e-05	4.409e-07
1.500e-01	3.000e-01	2.000e-01	5.000e-04	1.000e-01	9.500e-01	4.275e-07
1.500e-01	8.000e-01	7.500e-01	1.000e-03	9.500e-01	5.000e-03	4.275e-07
1.000e-05	5.500e-01	3.000e-01	7.000e-01	4.500e-01	8.000e-01	4.158e-07
6.500e-01	1.000e-05	9.500e-01	2.000e-01	5.000e-01	6.500e-01	4.014e-07
9.500e-01	4.500e-01	1.000e-05	3.000e-01	6.500e-01	4.500e-01	3.751e-07

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
1.500e-01	6.000e-01	4.500e-01	2.500e-01	5.000e-05	7.000e-01	3.544e-07
1.000e-03	5.500e-01	9.500e-01	1.000e-03	7.500e-01	8.500e-01	3.331e-07
1.000e-03	8.500e-01	4.000e-01	1.500e-01	6.500e-01	1.000e-02	3.315e-07
8.500e-01	9.900e-01	5.000e-06	3.000e-01	3.000e-01	8.500e-01	3.219e-07
5.000e-01	5.500e-01	4.500e-01	5.000e-06	6.000e-01	8.500e-01	3.156e-07
5.000e-01	8.000e-01	1.000e-05	1.500e-01	6.500e-01	7.000e-01	2.730e-07
9.500e-01	1.000e-03	8.500e-01	1.000e-03	7.500e-01	4.500e-01	2.725e-07
8.000e-01	1.500e-01	9.900e-01	1.000e-05	3.500e-01	6.500e-01	2.703e-07
5.000e-02	4.500e-01	4.500e-01	5.000e-05	6.500e-01	8.000e-01	2.633e-07
4.500e-01	4.500e-01	8.500e-01	5.000e-05	3.000e-01	1.000e-01	2.582e-07
4.500e-01	3.000e-01	9.000e-01	5.000e-06	5.000e-01	8.500e-01	2.582e-07
1.000e-01	4.500e-01	1.000e-05	9.000e-01	9.500e-01	6.500e-01	2.501e-07
2.000e-01	1.000e-05	8.500e-01	3.000e-01	4.500e-01	9.500e-01	2.180e-07
9.500e-01	4.500e-01	6.500e-01	1.500e-01	1.000e-01	5.000e-05	2.084e-07
1.000e-05	9.000e-01	9.990e-01	5.000e-01	3.000e-01	1.500e-01	2.023e-07
1.000e-01	2.000e-01	8.500e-01	5.000e-01	4.500e-01	5.000e-05	1.913e-07
4.000e-01	7.500e-01	7.500e-01	1.000e-06	9.500e-01	8.000e-01	1.710e-07
5.000e-03	4.000e-01	4.000e-01	1.000e-03	6.500e-01	3.000e-01	1.560e-07
8.500e-01	6.000e-01	4.000e-01	1.000e-06	8.000e-01	9.500e-01	1.550e-07
4.000e-01	1.000e-04	2.500e-01	5.000e-01	3.000e-01	1.000e-01	1.500e-07
2.000e-01	5.000e-04	8.500e-01	5.000e-02	1.000e-01	3.500e-01	1.488e-07
3.500e-01	2.000e-01	1.000e-05	7.500e-01	3.500e-01	8.000e-01	1.470e-07
9.000e-01	4.500e-01	1.000e-05	2.000e-01	2.000e-01	8.500e-01	1.377e-07
8.500e-01	1.000e-05	1.500e-01	5.000e-01	6.500e-01	3.000e-01	1.243e-07
5.000e-01	1.500e-01	8.500e-01	8.500e-01	2.000e-01	1.000e-05	1.084e-07
5.000e-06	7.000e-01	3.000e-01	3.000e-01	9.500e-01	3.500e-01	1.047e-07
8.000e-01	3.500e-01	7.500e-01	1.000e-03	5.000e-04	9.900e-01	1.039e-07
1.000e-02	6.000e-01	4.500e-01	5.000e-02	5.000e-03	1.500e-01	1.013e-07
9.990e-01	9.000e-01	5.500e-01	3.000e-01	6.500e-01	1.000e-06	9.643e-08
4.500e-01	3.000e-01	5.000e-04	3.000e-01	9.500e-01	5.000e-03	9.619e-08

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
3.000e-01	7.500e-01	4.000e-01	6.000e-01	5.000e-06	3.500e-01	9.450e-08
6.500e-01	9.990e-01	6.500e-01	2.000e-01	1.000e-06	9.990e-01	8.433e-08
5.000e-01	7.500e-01	1.500e-01	3.000e-01	9.500e-01	5.000e-06	8.016e-08
2.500e-01	7.500e-01	8.500e-01	1.000e-03	1.000e-01	5.000e-03	7.969e-08
5.000e-03	6.000e-01	5.000e-01	3.000e-01	5.000e-04	3.500e-01	7.875e-08
3.500e-01	7.500e-01	1.000e-05	6.000e-01	9.900e-01	5.000e-02	7.796e-08
9.000e-01	4.500e-01	6.500e-01	8.500e-01	5.000e-07	6.500e-01	7.272e-08
1.000e-03	5.500e-01	2.000e-01	6.000e-01	2.000e-01	5.000e-03	6.600e-08
1.500e-01	5.500e-01	1.000e-05	3.000e-01	3.500e-01	6.500e-01	5.631e-08
3.000e-01	5.000e-05	7.500e-01	5.000e-02	5.000e-01	2.000e-01	5.625e-08
4.000e-01	5.500e-01	1.000e-02	5.000e-02	5.000e-01	1.000e-03	5.500e-08
1.000e-05	4.000e-01	2.000e-01	1.500e-01	4.500e-01	9.000e-01	4.860e-08
8.000e-01	1.000e-01	2.000e-01	8.000e-01	6.500e-01	5.000e-06	4.160e-08
9.990e-01	4.500e-01	3.000e-01	5.000e-06	4.000e-01	1.500e-01	4.046e-08
3.000e-01	7.500e-01	5.000e-01	6.000e-01	1.000e-02	5.000e-05	3.375e-08
9.500e-01	4.000e-01	5.000e-07	3.500e-01	5.000e-01	9.900e-01	3.292e-08
2.500e-01	3.000e-01	4.500e-01	5.000e-06	9.500e-01	2.000e-01	3.206e-08
1.000e-03	1.000e-03	7.500e-01	8.500e-01	9.900e-01	5.000e-02	3.156e-08
9.990e-01	8.500e-01	7.500e-01	6.000e-01	8.000e-01	1.000e-07	3.057e-08
9.990e-01	1.000e-06	4.500e-01	3.000e-01	3.000e-01	7.500e-01	3.034e-08
1.000e-06	6.000e-01	3.000e-01	6.000e-01	8.000e-01	3.500e-01	3.024e-08
5.000e-05	5.000e-02	6.500e-01	1.000e-01	3.500e-01	5.000e-01	2.844e-08
2.000e-01	6.000e-01	4.500e-01	1.000e-06	7.500e-01	7.000e-01	2.835e-08
5.500e-01	2.500e-01	4.000e-01	1.000e-04	5.000e-01	1.000e-02	2.750e-08
1.500e-01	4.000e-01	1.000e-05	2.500e-01	4.000e-01	4.500e-01	2.700e-08
3.500e-01	7.500e-01	3.000e-01	1.000e-06	7.500e-01	4.500e-01	2.658e-08
9.500e-01	9.990e-01	7.000e-01	1.000e-06	6.500e-01	5.000e-02	2.159e-08
5.500e-01	9.900e-01	1.500e-01	2.500e-01	1.000e-02	1.000e-04	2.042e-08
4.500e-01	5.000e-05	4.000e-01	7.500e-01	3.000e-01	1.000e-02	2.025e-08

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
9.500e-01	1.000e-01	8.500e-01	1.000e-06	3.000e-01	7.500e-01	1.817e-08
1.000e-02	6.000e-01	5.000e-05	8.000e-01	1.000e-01	7.500e-01	1.800e-08
9.990e-01	5.000e-07	5.000e-01	5.000e-01	4.000e-01	3.500e-01	1.748e-08
6.500e-01	1.000e-01	7.500e-01	3.500e-01	1.000e-05	1.000e-01	1.706e-08
5.000e-03	9.000e-01	1.500e-01	5.000e-01	5.000e-03	1.000e-02	1.688e-08
5.000e-02	5.000e-02	5.000e-02	5.000e-02	5.000e-02	5.000e-02	1.563e-08
1.000e-07	9.990e-01	4.000e-01	9.900e-01	4.500e-01	8.000e-01	1.424e-08
2.500e-01	1.000e-06	4.000e-01	4.000e-01	9.900e-01	3.500e-01	1.386e-08
9.500e-01	9.000e-01	5.000e-08	9.900e-01	4.500e-01	7.000e-01	1.333e-08
5.000e-06	1.500e-01	7.500e-01	1.000e-01	3.000e-01	7.500e-01	1.266e-08
1.000e-04	7.500e-01	7.500e-01	1.000e-02	4.500e-01	5.000e-02	1.266e-08
2.500e-01	4.500e-01	2.500e-01	8.500e-01	1.000e-03	5.000e-04	1.195e-08
9.990e-01	1.500e-01	7.500e-01	4.000e-01	5.000e-03	5.000e-05	1.124e-08
5.000e-01	9.000e-01	1.000e-07	3.500e-01	9.990e-01	7.000e-01	1.101e-08
4.500e-01	4.000e-01	6.000e-01	5.000e-06	4.000e-01	5.000e-02	1.080e-08
1.500e-01	9.000e-01	2.000e-01	7.500e-01	5.000e-01	1.000e-06	1.013e-08
1.500e-01	1.500e-01	8.500e-01	5.000e-06	1.500e-01	7.000e-01	1.004e-08
1.000e-03	1.000e-01	6.000e-01	6.500e-01	5.000e-01	5.000e-04	9.750e-09
3.500e-01	4.500e-01	5.000e-02	3.500e-01	5.000e-06	7.000e-01	9.647e-09
8.000e-01	6.000e-01	4.000e-01	9.990e-01	1.000e-04	5.000e-04	9.590e-09
9.500e-01	6.000e-01	8.500e-01	5.000e-06	5.000e-03	7.500e-01	9.084e-09
5.000e-05	7.500e-01	4.000e-01	6.000e-01	2.000e-01	5.000e-03	9.000e-09
9.000e-01	9.500e-01	2.500e-01	6.000e-01	1.000e-07	7.000e-01	8.978e-09
5.500e-01	5.000e-07	4.000e-01	1.500e-01	6.500e-01	7.500e-01	8.044e-09
7.500e-01	1.000e-01	4.500e-01	1.500e-01	3.000e-01	5.000e-06	7.594e-09
1.000e-01	9.000e-01	9.990e-01	3.500e-01	5.000e-07	4.500e-01	7.080e-09
5.000e-03	4.000e-01	8.500e-01	8.000e-01	5.000e-06	9.990e-01	6.793e-09
9.990e-01	7.500e-01	9.990e-01	8.500e-01	1.000e-06	1.000e-02	6.362e-09

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
9.990e-01	5.000e-03	4.500e-01	7.500e-01	7.500e-01	5.000e-06	6.322e-09
9.900e-01	4.000e-01	7.000e-01	1.000e-07	3.000e-01	7.000e-01	5.821e-09
7.500e-01	1.000e-05	6.000e-01	2.500e-01	5.000e-01	1.000e-02	5.625e-09
4.000e-01	1.000e-07	8.500e-01	3.000e-01	7.500e-01	7.000e-01	5.355e-09
1.000e-05	8.500e-01	7.500e-01	2.500e-01	6.500e-01	5.000e-03	5.180e-09
5.500e-01	4.000e-01	1.000e-07	7.500e-01	3.000e-01	9.900e-01	4.901e-09
2.500e-01	6.000e-01	1.000e-05	5.000e-03	9.000e-01	7.000e-01	4.725e-09
5.000e-05	9.500e-01	6.500e-01	3.000e-01	5.000e-01	1.000e-03	4.631e-09
1.000e-01	7.500e-01	5.000e-05	3.500e-01	1.000e-02	3.500e-01	4.594e-09
3.500e-01	1.000e-01	6.500e-01	5.000e-06	8.000e-01	5.000e-02	4.550e-09
9.500e-01	2.500e-01	9.500e-01	2.000e-01	1.000e-07	9.990e-01	4.508e-09
4.000e-01	7.500e-01	9.000e-01	3.500e-01	9.500e-01	5.000e-08	4.489e-09
9.000e-01	1.000e-06	6.000e-01	8.500e-01	9.500e-01	1.000e-02	4.360e-09
1.000e-01	6.000e-01	1.000e-04	1.500e-01	5.000e-03	9.000e-01	4.050e-09
6.500e-01	6.000e-01	7.500e-01	2.000e-01	6.500e-01	1.000e-07	3.802e-09
9.000e-01	8.500e-01	1.000e-01	5.000e-01	9.900e-01	1.000e-07	3.787e-09
5.500e-01	1.000e-02	1.000e-05	2.000e-01	4.000e-01	8.500e-01	3.740e-09
4.500e-01	9.990e-01	2.500e-01	9.990e-01	5.000e-08	6.500e-01	3.649e-09
6.000e-01	6.500e-01	1.500e-01	5.000e-07	3.500e-01	3.500e-01	3.583e-09
5.000e-02	5.000e-02	7.500e-01	5.000e-06	4.500e-01	7.500e-01	3.164e-09
9.000e-01	5.000e-05	5.000e-02	8.000e-01	5.000e-03	3.500e-01	3.150e-09
4.500e-01	1.000e-01	4.000e-01	7.000e-01	1.000e-06	2.500e-01	3.150e-09
3.000e-01	6.000e-01	1.000e-02	5.000e-06	7.500e-01	4.500e-01	3.038e-09
9.990e-01	1.000e-01	5.000e-02	6.000e-01	2.000e-01	5.000e-06	2.997e-09
9.990e-01	9.990e-01	7.500e-01	1.000e-04	8.000e-01	5.000e-05	2.994e-09
6.500e-01	4.500e-01	1.000e-06	3.000e-01	6.500e-01	5.000e-02	2.852e-09
7.000e-01	1.000e-01	6.000e-01	5.000e-07	4.500e-01	3.000e-01	2.835e-09
8.500e-01	5.000e-05	7.500e-01	2.500e-01	1.000e-03	3.500e-01	2.789e-09

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
4.000e-01	5.000e-05	1.500e-01	1.000e-02	2.000e-01	4.500e-01	2.700e-09
4.000e-01	4.000e-01	5.000e-08	4.500e-01	7.500e-01	9.900e-01	2.673e-09
2.000e-01	3.000e-01	3.500e-01	5.000e-02	5.000e-01	5.000e-06	2.625e-09
6.500e-01	5.000e-07	1.000e-02	9.900e-01	9.500e-01	8.500e-01	2.598e-09
1.500e-01	6.000e-01	7.000e-01	9.900e-01	1.000e-07	4.000e-01	2.495e-09
5.000e-01	3.500e-01	3.000e-01	1.000e-02	9.500e-01	5.000e-06	2.494e-09
1.000e-07	2.000e-01	4.500e-01	3.500e-01	9.500e-01	8.000e-01	2.394e-09
8.000e-01	8.500e-01	2.000e-01	5.000e-08	9.990e-01	3.500e-01	2.378e-09
3.000e-01	4.500e-01	1.000e-07	8.500e-01	4.500e-01	4.500e-01	2.324e-09
1.000e-01	7.500e-01	6.500e-01	1.000e-05	9.500e-01	5.000e-03	2.316e-09
6.500e-01	7.000e-01	5.000e-08	7.000e-01	9.500e-01	1.500e-01	2.269e-09
1.500e-01	6.000e-01	5.000e-05	5.000e-03	6.500e-01	1.500e-01	2.194e-09
4.000e-01	9.990e-01	6.000e-01	5.000e-08	4.500e-01	4.000e-01	2.158e-09
9.990e-01	1.000e-08	4.000e-01	9.000e-01	7.000e-01	8.500e-01	2.140e-09
7.500e-01	4.500e-01	5.000e-02	5.000e-02	5.000e-04	5.000e-03	2.109e-09
4.000e-01	4.000e-01	1.000e-02	3.500e-01	7.500e-01	5.000e-06	2.100e-09
1.000e-02	6.000e-01	4.000e-01	5.000e-01	3.500e-01	5.000e-06	2.100e-09
9.500e-01	4.000e-01	1.000e-07	2.500e-01	3.000e-01	7.000e-01	1.995e-09
7.500e-01	4.500e-01	1.500e-01	5.000e-07	1.000e-01	7.500e-01	1.898e-09
3.500e-01	8.500e-01	8.500e-01	1.000e-05	7.500e-01	1.000e-03	1.897e-09
7.500e-01	8.500e-01	3.000e-01	5.000e-08	2.000e-01	9.000e-01	1.721e-09
9.500e-01	1.000e-06	4.000e-01	1.500e-01	6.000e-01	5.000e-02	1.710e-09
4.000e-01	4.000e-01	7.500e-01	1.000e-07	3.500e-01	4.000e-01	1.680e-09
5.000e-03	1.000e-01	1.000e-05	4.000e-01	9.500e-01	8.500e-01	1.615e-09
1.000e-05	4.500e-01	1.500e-01	5.000e-03	5.000e-01	9.500e-01	1.603e-09
7.500e-01	5.000e-07	3.000e-01	5.000e-02	9.500e-01	3.000e-01	1.603e-09
1.500e-01	6.500e-01	1.000e-07	7.500e-01	3.000e-01	7.000e-01	1.536e-09
2.500e-01	9.990e-01	1.000e-02	5.000e-06	2.000e-01	6.000e-01	1.499e-09

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
9.500e-01	9.990e-01	6.500e-01	9.000e-01	5.000e-06	5.000e-04	1.388e-09
1.000e-02	9.990e-01	4.500e-01	6.000e-01	1.000e-02	5.000e-05	1.349e-09
2.000e-01	8.500e-01	5.000e-08	7.500e-01	3.000e-01	7.000e-01	1.339e-09
1.000e-07	1.500e-01	7.500e-01	8.500e-01	4.000e-01	3.500e-01	1.339e-09
3.500e-01	6.500e-01	1.000e-05	1.000e-03	8.000e-01	7.000e-01	1.274e-09
5.000e-02	9.990e-01	5.000e-01	1.000e-04	5.000e-02	1.000e-02	1.249e-09
3.000e-01	1.500e-01	3.000e-01	6.000e-01	3.000e-01	5.000e-07	1.215e-09
1.000e-01	1.000e-07	4.500e-01	7.500e-01	9.990e-01	3.500e-01	1.180e-09
1.000e-04	1.000e-03	8.500e-01	2.500e-01	3.500e-01	1.500e-01	1.116e-09
9.990e-01	1.000e-05	8.500e-01	3.500e-01	7.500e-01	5.000e-04	1.115e-09
8.000e-01	6.000e-01	4.000e-01	7.500e-01	5.000e-08	1.500e-01	1.080e-09
1.000e-02	4.500e-01	7.500e-01	9.000e-01	5.000e-07	7.000e-01	1.063e-09
8.000e-01	5.000e-09	6.000e-01	8.500e-01	6.500e-01	8.000e-01	1.061e-09
8.500e-01	4.500e-01	1.000e-07	4.000e-01	4.500e-01	1.500e-01	1.033e-09
3.500e-01	1.000e-01	6.500e-01	4.500e-01	1.000e-01	1.000e-06	1.024e-09
2.000e-01	8.500e-01	5.000e-08	4.000e-01	4.500e-01	6.500e-01	9.945e-10
1.000e-02	8.500e-01	5.000e-07	7.000e-01	8.000e-01	4.000e-01	9.520e-10
3.000e-01	4.000e-01	9.990e-01	1.500e-01	1.000e-01	5.000e-07	8.991e-10
5.000e-01	3.000e-01	5.000e-01	5.000e-05	5.000e-04	4.500e-01	8.438e-10
1.500e-01	5.000e-05	5.000e-04	5.000e-01	9.900e-01	4.500e-01	8.353e-10
5.000e-03	1.000e-03	1.000e-02	3.500e-01	9.500e-01	5.000e-02	8.312e-10
2.500e-01	6.000e-01	1.000e-03	5.000e-04	2.000e-01	5.000e-02	7.500e-10
1.000e-02	7.500e-01	5.000e-02	5.000e-06	9.500e-01	4.000e-01	7.125e-10
4.000e-01	6.000e-01	4.500e-01	2.500e-01	5.000e-04	5.000e-05	6.750e-10
8.500e-01	2.500e-01	1.000e-06	7.000e-01	1.000e-02	4.500e-01	6.694e-10
1.000e-03	4.000e-01	5.500e-01	1.000e-05	4.000e-01	7.500e-01	6.600e-10
5.000e-01	6.500e-01	6.000e-01	1.000e-02	6.500e-01	5.000e-07	6.338e-10
5.000e-02	6.000e-01	1.000e-06	6.000e-01	1.000e-01	3.500e-01	6.300e-10

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
4.000e-01	1.000e-02	5.000e-05	5.000e-03	9.500e-01	6.500e-01	6.175e-10
3.500e-01	3.000e-01	4.000e-01	5.000e-08	9.500e-01	3.000e-01	5.985e-10
9.900e-01	5.000e-02	3.000e-01	8.000e-01	1.000e-03	5.000e-05	5.940e-10
3.000e-01	1.000e-01	8.500e-01	9.000e-01	5.000e-01	5.000e-08	5.738e-10
3.000e-01	9.990e-01	5.000e-04	5.000e-05	5.000e-01	1.500e-01	5.619e-10
3.000e-01	5.000e-07	4.000e-01	6.000e-01	1.000e-01	1.500e-01	5.400e-10
9.990e-01	5.000e-07	6.000e-01	6.000e-01	3.000e-01	1.000e-02	5.395e-10
1.000e-01	1.000e-01	7.500e-01	1.000e-06	1.000e-01	7.000e-01	5.250e-10
4.000e-01	3.500e-01	2.000e-01	5.000e-07	2.500e-01	1.500e-01	5.250e-10
5.000e-02	1.000e-01	5.000e-06	1.500e-01	3.000e-01	4.500e-01	5.063e-10
5.000e-01	5.000e-02	5.000e-02	4.000e-01	1.000e-06	9.990e-01	4.995e-10
6.500e-01	6.000e-01	7.500e-01	3.000e-01	1.000e-01	5.000e-08	4.387e-10
3.000e-01	9.990e-01	5.000e-02	1.000e-07	4.500e-01	6.500e-01	4.383e-10
8.000e-01	4.500e-01	1.000e-03	1.000e-05	8.000e-01	1.500e-01	4.320e-10
9.500e-01	2.500e-01	7.500e-01	3.000e-01	5.000e-08	1.500e-01	4.008e-10
5.000e-05	7.500e-01	3.000e-01	1.000e-03	5.000e-02	7.000e-01	3.938e-10
9.990e-01	1.000e-08	7.000e-01	7.500e-01	5.000e-01	1.500e-01	3.934e-10
4.000e-01	9.500e-01	2.000e-01	5.000e-06	9.900e-01	1.000e-03	3.762e-10
1.500e-01	1.000e-06	7.500e-01	1.000e-01	6.500e-01	5.000e-02	3.656e-10
9.500e-01	6.000e-01	5.000e-08	6.000e-01	4.000e-01	5.000e-02	3.420e-10
3.000e-01	1.500e-01	5.000e-06	3.500e-01	5.000e-03	8.500e-01	3.347e-10
1.500e-01	1.000e-06	1.000e-02	7.500e-01	3.500e-01	8.500e-01	3.347e-10
1.500e-01	4.500e-01	7.500e-01	1.000e-05	1.000e-03	6.500e-01	3.291e-10
9.900e-01	7.500e-01	6.500e-01	1.000e-01	6.500e-01	1.000e-08	3.137e-10
5.500e-01	6.000e-01	5.000e-07	4.000e-01	9.500e-01	5.000e-03	3.135e-10
1.000e-04	4.500e-01	1.000e-02	3.000e-01	4.500e-01	5.000e-03	3.038e-10
1.500e-01	8.000e-01	9.990e-01	5.000e-07	1.000e-01	5.000e-02	2.997e-10
1.500e-01	1.500e-01	5.000e-06	2.500e-01	1.000e-01	1.000e-01	2.813e-10

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
9.900e-01	6.000e-01	1.000e-08	3.000e-01	4.500e-01	3.500e-01	2.807e-10
1.000e-04	4.000e-01	3.500e-01	1.000e-03	4.000e-01	5.000e-02	2.800e-10
9.500e-01	5.500e-01	1.000e-02	7.000e-01	5.000e-07	1.500e-01	2.743e-10
4.000e-01	1.000e-04	1.000e-04	4.000e-01	2.000e-01	8.500e-01	2.720e-10
1.000e-03	1.000e-05	4.000e-01	3.000e-01	3.000e-01	7.500e-01	2.700e-10
1.000e-01	4.000e-01	2.000e-01	5.000e-08	9.500e-01	7.000e-01	2.660e-10
7.500e-01	8.000e-01	2.000e-01	5.000e-08	5.000e-02	8.500e-01	2.550e-10
3.500e-01	1.000e-01	5.000e-08	2.500e-01	8.000e-01	7.000e-01	2.450e-10
1.000e-03	4.000e-01	2.000e-01	1.000e-04	5.500e-01	5.000e-02	2.200e-10
1.500e-01	5.500e-01	7.500e-01	5.000e-08	1.000e-01	7.000e-01	2.166e-10
3.000e-01	5.500e-01	2.500e-01	3.500e-01	3.000e-01	5.000e-08	2.166e-10
5.000e-01	1.000e-07	8.000e-01	7.500e-01	1.000e-02	7.000e-01	2.100e-10
9.000e-01	1.000e-04	5.000e-05	4.000e-01	4.500e-01	2.500e-01	2.025e-10
3.000e-01	5.000e-08	6.000e-01	1.000e-01	8.000e-01	2.500e-01	1.800e-10
9.990e-01	6.000e-01	4.000e-01	1.500e-01	9.500e-01	5.000e-09	1.708e-10
4.000e-01	9.000e-01	5.000e-01	7.500e-01	5.000e-09	2.500e-01	1.688e-10
9.990e-01	4.500e-01	7.500e-01	1.000e-02	9.900e-01	5.000e-08	1.669e-10
1.000e-04	7.500e-01	9.900e-01	5.000e-06	9.500e-01	4.500e-01	1.587e-10
5.000e-01	1.000e-07	6.000e-01	1.500e-01	6.500e-01	5.000e-02	1.463e-10
1.000e-03	4.000e-01	7.500e-01	7.500e-01	1.000e-06	6.500e-01	1.463e-10
8.500e-01	3.500e-01	1.000e-02	1.000e-06	9.500e-01	5.000e-02	1.413e-10
1.000e-04	5.500e-01	1.000e-01	3.000e-01	1.000e-04	8.500e-01	1.403e-10
1.500e-01	8.500e-01	4.000e-01	2.500e-01	1.000e-02	1.000e-06	1.275e-10
5.000e-01	9.000e-01	5.000e-07	2.500e-01	5.000e-03	4.500e-01	1.266e-10
4.000e-01	1.500e-01	1.000e-07	3.000e-01	1.000e-01	6.500e-01	1.170e-10
9.000e-01	6.500e-01	5.000e-09	4.000e-01	6.500e-01	1.500e-01	1.141e-10
4.000e-01	5.000e-06	6.500e-01	3.500e-01	2.500e-01	1.000e-03	1.138e-10
1.500e-01	9.990e-01	5.000e-03	6.000e-01	5.000e-05	5.000e-03	1.124e-10

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
1.000e-04	3.000e-01	6.500e-01	7.500e-01	7.500e-01	1.000e-05	1.097e-10
1.000e-02	9.500e-01	7.500e-01	5.000e-08	7.500e-01	4.000e-01	1.069e-10
8.000e-01	5.000e-06	2.000e-01	8.500e-01	3.000e-01	5.000e-04	1.020e-10
9.990e-01	4.000e-01	2.500e-01	1.000e-02	1.000e-02	1.000e-05	9.990e-11
9.990e-01	1.000e-01	3.000e-01	5.000e-05	6.500e-01	1.000e-04	9.740e-11
3.500e-01	3.500e-01	1.000e-08	3.000e-01	7.500e-01	3.500e-01	9.647e-11
5.000e-05	8.500e-01	7.000e-01	5.000e-06	6.500e-01	9.500e-01	9.185e-11
8.000e-01	4.000e-01	5.000e-06	1.500e-01	7.500e-01	5.000e-04	9.000e-11
6.000e-01	1.000e-03	7.500e-01	5.000e-05	8.000e-01	5.000e-03	9.000e-11
8.500e-01	9.990e-01	5.000e-06	9.900e-01	4.000e-01	5.000e-05	8.407e-11
5.500e-01	5.500e-01	1.000e-05	5.000e-05	6.500e-01	8.500e-01	8.357e-11
9.900e-01	4.500e-01	4.000e-01	1.000e-06	4.500e-01	1.000e-03	8.019e-11
9.900e-01	5.000e-09	4.000e-01	3.000e-01	3.000e-01	4.500e-01	8.019e-11
5.000e-02	1.000e-01	7.500e-01	2.500e-01	1.000e-07	8.500e-01	7.969e-11
3.500e-01	1.000e-01	3.500e-01	1.000e-06	6.500e-01	1.000e-02	7.963e-11
1.000e-03	7.000e-01	4.500e-01	5.000e-06	9.500e-01	5.000e-02	7.481e-11
9.900e-01	4.000e-01	5.000e-06	4.500e-01	8.000e-01	1.000e-04	7.128e-11
5.000e-03	1.000e-01	1.000e-05	3.500e-01	5.000e-02	8.000e-01	7.000e-11
9.990e-01	4.000e-01	5.000e-06	9.990e-01	5.000e-05	7.000e-01	6.986e-11
1.500e-01	4.500e-01	1.000e-02	5.000e-05	5.000e-03	4.000e-01	6.750e-11
1.000e-05	4.500e-01	1.000e-02	3.000e-01	5.000e-02	1.000e-01	6.750e-11
4.000e-01	6.000e-01	5.000e-09	1.000e-01	8.000e-01	7.000e-01	6.720e-11
4.500e-01	3.500e-01	5.000e-06	2.000e-01	5.000e-04	8.500e-01	6.694e-11
9.500e-01	1.000e-09	7.000e-01	9.900e-01	1.000e-01	9.900e-01	6.518e-11
2.500e-01	6.500e-01	5.000e-06	1.000e-03	2.000e-01	4.000e-01	6.500e-11
5.000e-02	8.000e-01	1.000e-08	2.500e-01	6.500e-01	9.990e-01	6.494e-11
4.500e-01	5.000e-09	2.000e-01	8.000e-01	2.000e-01	9.000e-01	6.480e-11
5.000e-02	9.500e-01	1.500e-01	1.000e-07	2.000e-01	4.500e-01	6.412e-11

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
1.000e-05	4.500e-01	1.000e-02	7.000e-01	2.000e-01	1.000e-02	6.300e-11
9.500e-01	4.500e-01	6.500e-01	5.000e-03	4.500e-01	1.000e-07	6.252e-11
2.500e-01	5.000e-02	5.000e-08	8.000e-01	3.500e-01	3.500e-01	6.125e-11
5.000e-01	1.000e-05	5.000e-05	3.000e-01	9.500e-01	8.500e-01	6.056e-11
5.000e-02	3.000e-01	1.000e-02	5.000e-06	1.000e-01	7.000e-01	5.250e-11
9.500e-01	5.000e-04	3.500e-01	1.000e-06	6.500e-01	4.500e-01	4.863e-11
9.500e-01	1.000e-01	1.000e-02	1.000e-02	5.000e-02	1.000e-04	4.750e-11
1.500e-01	1.000e-05	5.000e-01	6.000e-01	9.990e-01	1.000e-04	4.496e-11
4.000e-01	5.500e-01	5.000e-08	8.500e-01	9.500e-01	5.000e-03	4.441e-11
1.000e-05	1.500e-01	9.500e-01	3.000e-01	1.000e-02	1.000e-02	4.275e-11
4.000e-01	4.500e-01	1.000e-05	5.000e-05	6.000e-01	7.500e-01	4.050e-11
9.900e-01	8.500e-01	1.000e-02	2.500e-01	3.500e-01	5.000e-08	3.682e-11
1.000e-05	2.500e-01	1.000e-03	3.500e-01	1.000e-01	4.000e-01	3.500e-11
9.500e-01	2.500e-01	1.000e-08	6.500e-01	4.500e-01	5.000e-02	3.473e-11
3.000e-01	1.000e-07	1.500e-01	7.500e-01	9.500e-01	1.000e-02	3.206e-11
1.000e-01	9.990e-01	5.000e-02	5.000e-08	8.500e-01	1.500e-01	3.184e-11
5.000e-05	9.000e-01	1.000e-02	1.000e-01	1.000e-03	7.000e-01	3.150e-11
3.000e-01	9.000e-01	5.000e-08	1.000e-02	6.500e-01	3.500e-01	3.071e-11
9.990e-01	2.500e-01	3.500e-01	1.000e-02	7.000e-01	5.000e-08	3.059e-11
9.500e-01	5.000e-05	6.000e-01	1.000e-03	5.000e-03	2.000e-01	2.850e-11
8.000e-01	1.000e-07	5.000e-03	7.500e-01	9.500e-01	1.000e-01	2.850e-11
8.000e-01	7.500e-01	9.500e-01	1.000e-06	9.990e-01	5.000e-05	2.847e-11
1.000e-03	7.500e-01	8.000e-01	2.000e-01	5.000e-07	4.500e-01	2.700e-11
3.500e-01	6.000e-01	5.000e-05	2.500e-01	1.000e-02	1.000e-03	2.625e-11
1.000e-01	1.000e-06	7.500e-01	5.000e-03	6.500e-01	1.000e-01	2.438e-11
3.500e-01	6.500e-01	4.000e-01	5.000e-02	9.500e-01	5.000e-09	2.161e-11
4.000e-01	6.000e-01	5.000e-05	5.000e-06	3.500e-01	9.500e-01	1.995e-11
6.000e-01	4.500e-01	1.000e-04	5.000e-06	9.500e-01	1.500e-01	1.924e-11

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
1.000e-01	1.000e-08	3.000e-01	7.500e-01	1.000e-01	8.500e-01	1.913e-11
2.500e-01	6.000e-01	1.500e-01	1.000e-08	5.000e-01	1.500e-01	1.688e-11
6.500e-01	6.000e-01	1.000e-02	1.000e-02	5.000e-07	8.500e-01	1.658e-11
1.500e-01	4.500e-01	6.500e-01	5.000e-07	1.000e-03	7.500e-01	1.645e-11
9.900e-01	1.000e-03	1.000e-05	5.000e-03	4.000e-01	7.500e-01	1.485e-11
7.000e-01	2.500e-01	7.500e-01	5.000e-08	5.000e-03	4.500e-01	1.477e-11
9.900e-01	9.990e-01	7.000e-01	5.000e-03	5.000e-09	8.500e-01	1.471e-11
3.000e-01	5.000e-02	2.000e-01	5.000e-08	6.500e-01	1.500e-01	1.462e-11
9.500e-01	5.000e-09	5.000e-02	3.000e-01	4.500e-01	4.500e-01	1.443e-11
9.500e-01	4.500e-01	5.000e-06	1.000e-05	9.000e-01	7.000e-01	1.347e-11
5.500e-01	3.000e-01	5.000e-07	1.000e-03	4.500e-01	3.500e-01	1.299e-11
8.500e-01	6.000e-01	1.000e-02	5.000e-08	1.000e-01	5.000e-01	1.275e-11
3.000e-01	1.000e-05	8.500e-01	1.000e-03	5.000e-01	1.000e-02	1.275e-11
1.000e-09	1.000e-01	4.500e-01	9.500e-01	4.500e-01	6.500e-01	1.250e-11
3.000e-01	1.000e-04	9.900e-01	5.000e-07	9.900e-01	8.500e-01	1.250e-11
2.000e-01	7.500e-01	6.500e-01	2.500e-01	1.000e-05	5.000e-05	1.219e-11
2.000e-01	1.000e-02	1.000e-02	3.000e-01	4.000e-01	5.000e-06	1.200e-11
1.000e-04	9.500e-01	3.000e-01	5.000e-03	8.000e-01	1.000e-04	1.140e-11
1.000e-01	1.000e-01	6.500e-01	3.500e-01	5.000e-06	1.000e-03	1.138e-11
6.000e-01	5.000e-09	8.000e-01	9.900e-01	9.500e-01	5.000e-03	1.129e-11
1.000e-02	5.000e-02	4.500e-01	5.000e-05	1.000e-01	1.000e-02	1.125e-11
1.000e-05	7.500e-01	9.900e-01	7.500e-01	1.000e-05	2.000e-01	1.114e-11
9.990e-01	5.500e-01	1.000e-02	5.000e-04	8.000e-01	5.000e-06	1.099e-11
1.000e-05	6.000e-01	5.000e-02	1.000e-01	1.000e-03	3.500e-01	1.050e-11
9.500e-01	8.500e-01	5.000e-05	3.000e-01	1.000e-06	8.500e-01	1.030e-11
5.000e-05	1.000e-05	1.500e-01	1.500e-01	9.990e-01	8.500e-01	9.553e-12
4.500e-01	5.000e-07	7.500e-01	1.000e-02	5.500e-01	1.000e-02	9.281e-12
2.500e-01	3.000e-01	1.000e-05	3.500e-01	5.000e-05	7.000e-01	9.188e-12

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
9.000e-01	1.000e-06	5.000e-04	9.990e-01	1.000e-01	2.000e-01	8.991e-12
8.500e-01	1.500e-01	5.000e-08	5.000e-03	8.000e-01	3.500e-01	8.925e-12
1.000e-07	4.000e-01	2.000e-01	7.000e-01	3.000e-01	5.000e-03	8.400e-12
4.500e-01	1.000e-02	1.000e-08	9.990e-01	6.000e-01	3.000e-01	8.092e-12
9.000e-01	1.000e-08	7.500e-01	2.500e-01	4.500e-01	1.000e-02	7.594e-12
1.000e-01	5.000e-05	8.500e-01	3.500e-01	5.000e-04	1.000e-02	7.438e-12
1.000e-05	5.500e-01	5.000e-02	6.000e-01	4.500e-01	1.000e-04	7.425e-12
4.000e-01	5.000e-09	1.500e-01	2.500e-01	1.000e-01	9.900e-01	7.425e-12
9.500e-01	2.500e-01	1.000e-04	7.500e-01	4.000e-01	1.000e-06	7.125e-12
4.000e-01	1.500e-01	5.000e-03	1.000e-05	4.500e-01	5.000e-03	6.750e-12
5.000e-01	6.500e-01	1.000e-05	8.000e-01	4.500e-01	5.000e-06	5.850e-12
5.500e-01	1.000e-01	8.500e-01	1.000e-07	5.000e-03	2.500e-01	5.844e-12
5.500e-01	9.990e-01	5.000e-07	6.500e-01	6.500e-01	5.000e-05	5.804e-12
5.500e-01	9.990e-01	1.000e-08	3.000e-01	5.000e-03	7.000e-01	5.769e-12
5.000e-01	5.000e-05	1.000e-03	1.000e-02	4.500e-01	5.000e-02	5.625e-12
5.000e-08	1.500e-01	7.500e-01	5.000e-03	3.000e-01	6.500e-01	5.484e-12
5.000e-03	5.000e-08	5.000e-01	6.000e-01	2.000e-01	3.500e-01	5.250e-12
1.000e-07	6.500e-01	4.000e-01	2.000e-01	9.900e-01	1.000e-03	5.148e-12
9.500e-01	4.500e-01	5.000e-06	5.000e-01	9.500e-01	5.000e-06	5.077e-12
5.000e-01	2.500e-01	1.000e-07	1.000e-02	1.000e-01	4.000e-01	5.000e-12
1.000e-03	4.000e-01	1.000e-02	2.500e-01	5.000e-04	1.000e-02	5.000e-12
1.000e-03	3.500e-01	7.500e-01	7.500e-01	5.000e-07	5.000e-02	4.922e-12
1.000e-02	9.000e-01	5.500e-01	1.000e-06	1.000e-03	9.900e-01	4.901e-12
3.000e-01	5.000e-05	1.000e-02	6.500e-01	1.000e-03	5.000e-02	4.875e-12
9.500e-01	1.000e-03	4.500e-01	5.000e-07	4.500e-01	5.000e-02	4.809e-12
1.500e-01	4.500e-01	3.500e-01	5.000e-05	5.000e-06	8.000e-01	4.725e-12
6.500e-01	1.000e-05	5.000e-02	5.000e-05	9.500e-01	3.000e-01	4.631e-12
5.000e-06	8.500e-01	6.500e-01	5.000e-01	6.500e-01	5.000e-06	4.489e-12

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
4.500e-01	8.500e-01	5.000e-06	3.000e-01	1.000e-05	7.500e-01	4.303e-12
8.500e-01	4.500e-01	4.500e-01	5.000e-02	1.000e-04	5.000e-06	4.303e-12
5.000e-03	1.000e-05	7.500e-01	5.000e-03	4.500e-01	5.000e-02	4.219e-12
9.990e-01	5.000e-02	7.500e-01	5.000e-02	4.500e-01	5.000e-09	4.215e-12
3.500e-01	1.000e-03	5.000e-01	1.000e-07	6.500e-01	3.500e-01	3.981e-12
1.000e-03	4.000e-01	1.000e-04	1.000e-04	9.900e-01	9.900e-01	3.920e-12
1.000e-01	6.000e-01	9.990e-01	1.000e-06	1.000e-04	6.500e-01	3.896e-12
1.000e-04	1.000e-01	4.500e-01	5.000e-06	2.000e-01	8.500e-01	3.825e-12
8.000e-01	9.500e-01	1.000e-07	1.000e-03	2.000e-01	2.500e-01	3.800e-12
4.000e-01	5.000e-02	1.000e-02	5.000e-05	7.500e-01	5.000e-04	3.750e-12
1.000e-03	9.990e-01	6.000e-01	5.000e-08	3.500e-01	3.500e-01	3.671e-12
1.500e-01	1.000e-09	8.500e-01	1.000e-01	4.000e-01	7.000e-01	3.570e-12
4.000e-01	4.500e-01	3.000e-01	1.000e-02	6.500e-01	1.000e-08	3.510e-12
1.000e-02	1.000e-05	1.500e-01	3.500e-01	1.000e-03	6.500e-01	3.413e-12
1.000e-05	9.990e-01	7.500e-01	5.000e-07	9.500e-01	9.500e-01	3.381e-12
1.500e-01	5.000e-02	6.000e-01	5.000e-08	1.000e-01	1.500e-01	3.375e-12
1.000e-02	9.990e-01	7.500e-01	5.000e-07	1.000e-03	8.500e-01	3.184e-12
3.500e-01	4.000e-01	6.000e-01	5.000e-09	7.500e-01	1.000e-02	3.150e-12
1.000e-04	5.000e-07	6.500e-01	2.500e-01	5.500e-01	7.000e-01	3.128e-12
3.000e-01	1.000e-05	2.000e-01	1.000e-01	5.000e-03	1.000e-02	3.000e-12
5.000e-01	6.000e-01	4.000e-01	1.000e-07	5.000e-03	5.000e-02	3.000e-12
5.000e-01	8.500e-01	1.000e-06	1.000e-01	1.000e-04	6.500e-01	2.763e-12
3.500e-01	1.000e-01	5.000e-02	1.000e-08	4.500e-01	3.500e-01	2.756e-12
1.000e-09	3.500e-01	3.000e-01	8.000e-01	2.000e-01	1.500e-01	2.520e-12
3.500e-01	6.000e-01	5.000e-08	2.500e-01	1.000e-03	9.500e-01	2.494e-12
1.000e-03	8.000e-01	1.000e-04	7.500e-01	4.000e-01	1.000e-04	2.400e-12
6.000e-01	1.000e-02	8.500e-01	5.000e-02	9.000e-01	1.000e-08	2.295e-12
9.500e-01	9.500e-01	5.000e-02	1.000e-07	9.500e-01	5.000e-04	2.143e-12

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
5.000e-01	7.500e-01	5.000e-06	5.000e-02	5.000e-05	4.500e-01	2.109e-12
3.500e-01	3.000e-01	8.500e-01	9.000e-01	5.000e-03	5.000e-09	2.008e-12
3.000e-01	9.900e-01	5.000e-06	6.000e-01	4.500e-01	5.000e-06	2.005e-12
5.000e-06	6.500e-01	1.000e-04	5.000e-02	3.500e-01	3.500e-01	1.991e-12
4.000e-01	3.000e-01	1.000e-01	2.500e-01	1.000e-09	6.500e-01	1.950e-12
9.500e-01	4.500e-01	3.000e-01	1.000e-06	3.000e-01	5.000e-05	1.924e-12
1.000e-03	7.500e-01	1.000e-02	1.000e-01	5.000e-03	5.000e-04	1.875e-12
2.500e-01	4.500e-01	6.500e-01	1.000e-05	5.000e-01	5.000e-06	1.828e-12
1.000e-01	2.500e-01	2.500e-01	1.000e-09	4.500e-01	6.500e-01	1.828e-12
3.000e-01	4.500e-01	9.990e-01	5.000e-02	5.000e-05	5.000e-06	1.686e-12
7.500e-01	8.500e-01	1.000e-03	1.000e-03	5.000e-01	5.000e-06	1.594e-12
1.000e-06	9.990e-01	9.990e-01	1.000e-04	3.000e-01	5.000e-02	1.497e-12
5.000e-06	5.500e-01	4.500e-01	6.000e-01	4.000e-01	5.000e-06	1.485e-12
3.000e-01	1.500e-01	5.000e-06	1.500e-01	8.000e-01	5.000e-05	1.350e-12
1.000e-06	5.000e-02	5.000e-05	9.900e-01	7.500e-01	7.000e-01	1.299e-12
5.500e-01	8.500e-01	1.000e-02	5.000e-03	1.000e-05	5.000e-03	1.169e-12
1.000e-02	1.500e-01	7.000e-01	1.000e-06	9.900e-01	1.000e-03	1.040e-12
3.000e-01	1.000e-06	5.000e-01	1.000e-04	1.500e-01	4.500e-01	1.013e-12
1.000e-02	1.000e-02	1.000e-02	1.000e-02	1.000e-02	1.000e-02	1.000e-12
6.500e-01	2.000e-01	5.000e-07	5.000e-01	5.000e-05	6.000e-01	9.750e-13
5.000e-05	7.500e-01	9.900e-01	3.500e-01	7.500e-01	1.000e-07	9.745e-13
1.000e-07	1.000e-04	7.500e-01	4.500e-01	3.000e-01	9.500e-01	9.619e-13
5.000e-05	4.000e-01	9.500e-01	9.990e-01	1.000e-07	5.000e-01	9.491e-13
9.000e-01	3.500e-01	5.000e-06	6.000e-01	1.000e-03	1.000e-03	9.450e-13
2.000e-01	1.000e-01	1.000e-07	7.000e-01	1.000e-03	6.500e-01	9.100e-13
5.000e-02	6.000e-01	1.000e-04	1.000e-06	6.500e-01	4.500e-01	8.775e-13
5.000e-03	9.000e-01	5.000e-05	5.000e-06	9.500e-01	8.000e-01	8.550e-13
4.000e-01	4.500e-01	1.500e-01	3.000e-01	1.000e-03	1.000e-07	8.100e-13

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
9.990e-01	1.000e-04	2.000e-01	1.000e-06	8.000e-01	5.000e-02	7.992e-13
5.000e-05	4.500e-01	3.000e-01	5.000e-07	6.500e-01	3.500e-01	7.678e-13
2.500e-01	6.000e-01	9.990e-01	1.000e-05	5.000e-01	1.000e-06	7.493e-13
1.500e-01	8.500e-01	5.000e-08	3.500e-01	5.000e-04	6.500e-01	7.252e-13
2.000e-01	1.000e-04	1.000e-03	5.000e-05	8.500e-01	8.500e-01	7.225e-13
1.000e-06	4.500e-01	4.500e-01	7.500e-01	9.500e-01	5.000e-06	7.214e-13
7.500e-01	4.000e-01	8.500e-01	1.000e-05	5.000e-07	5.500e-01	7.013e-13
3.500e-01	6.500e-01	6.500e-01	1.000e-06	1.000e-05	4.500e-01	6.654e-13
1.000e-05	4.500e-01	6.500e-01	4.000e-01	5.500e-01	1.000e-06	6.435e-13
5.000e-06	7.500e-01	5.000e-06	2.000e-01	2.000e-01	8.500e-01	6.375e-13
1.000e-09	7.500e-01	5.000e-01	5.000e-03	4.000e-01	8.500e-01	6.375e-13
4.500e-01	1.000e-09	4.000e-01	5.000e-02	1.000e-01	7.000e-01	6.300e-13
5.000e-06	5.000e-07	4.000e-01	8.000e-01	9.500e-01	8.000e-01	6.080e-13
1.000e-04	9.990e-01	8.500e-01	1.000e-08	8.000e-01	8.000e-01	5.435e-13
9.900e-01	9.500e-01	5.000e-01	4.500e-01	5.000e-08	5.000e-05	5.290e-13
1.000e-03	7.500e-01	1.000e-05	1.000e-03	2.000e-01	3.500e-01	5.250e-13
9.900e-01	1.000e-03	1.000e-08	3.000e-01	4.500e-01	3.500e-01	4.678e-13
1.000e-04	6.500e-01	1.500e-01	5.000e-06	9.500e-01	1.000e-02	4.631e-13
1.000e-03	4.000e-01	1.500e-01	5.000e-06	1.500e-01	1.000e-02	4.500e-13
8.500e-01	1.000e-06	5.000e-06	1.500e-01	9.900e-01	7.000e-01	4.418e-13
8.500e-01	4.500e-01	5.000e-07	5.000e-02	4.500e-01	1.000e-04	4.303e-13
5.000e-06	4.500e-01	6.000e-01	2.000e-01	3.000e-01	5.000e-06	4.050e-13
1.000e-03	3.500e-01	5.000e-04	1.000e-01	4.500e-01	5.000e-05	3.938e-13
6.500e-01	6.500e-01	1.000e-05	6.000e-01	1.000e-06	1.500e-01	3.803e-13
5.000e-01	2.000e-01	7.500e-01	5.000e-08	1.000e-01	1.000e-03	3.750e-13
5.000e-01	9.990e-01	1.000e-02	1.500e-01	1.000e-07	5.000e-03	3.746e-13
5.000e-05	1.000e-05	1.000e-02	2.500e-01	3.000e-01	9.000e-01	3.375e-13
1.000e-05	2.000e-01	5.000e-01	5.000e-06	1.000e-01	6.500e-01	3.250e-13

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
1.000e-01	6.000e-01	5.000e-04	1.500e-01	1.000e-07	7.000e-01	3.150e-13
9.990e-01	1.000e-04	9.500e-01	6.000e-01	1.000e-03	5.000e-06	2.847e-13
5.000e-06	5.000e-05	7.500e-01	1.000e-02	7.500e-01	2.000e-01	2.813e-13
1.000e-08	8.500e-01	1.000e-04	6.500e-01	6.500e-01	7.500e-01	2.693e-13
5.000e-05	5.000e-06	3.500e-01	6.000e-01	9.990e-01	5.000e-03	2.622e-13
5.000e-05	3.500e-01	8.500e-01	3.500e-01	1.000e-06	5.000e-02	2.603e-13
5.000e-05	1.000e-04	2.000e-01	4.000e-01	6.500e-01	1.000e-03	2.600e-13
9.990e-01	6.500e-01	1.000e-02	4.000e-01	1.000e-03	1.000e-07	2.597e-13
5.000e-02	3.000e-01	1.500e-01	4.500e-01	5.000e-06	5.000e-05	2.531e-13
5.000e-03	5.000e-07	4.500e-01	5.000e-04	9.990e-01	4.500e-01	2.529e-13
8.000e-01	2.500e-01	2.500e-01	5.000e-03	1.000e-04	1.000e-05	2.500e-13
1.500e-01	1.000e-03	2.500e-01	1.000e-07	1.000e-01	6.500e-01	2.438e-13
4.000e-01	8.500e-01	4.000e-01	1.000e-06	3.500e-01	5.000e-06	2.380e-13
4.000e-01	8.000e-01	3.000e-01	9.900e-01	5.000e-05	5.000e-08	2.376e-13
9.500e-01	1.000e-01	1.000e-02	5.000e-02	1.000e-02	5.000e-07	2.375e-13
2.500e-01	1.000e-08	1.000e-02	1.000e-01	1.000e-01	9.000e-01	2.250e-13
9.990e-01	1.000e-03	1.500e-01	3.000e-01	5.000e-07	1.000e-02	2.248e-13
1.000e-05	5.000e-07	6.000e-01	9.900e-01	1.000e-01	7.000e-01	2.079e-13
4.000e-01	6.000e-01	4.000e-01	5.000e-08	5.000e-05	8.500e-01	2.040e-13
3.000e-01	3.000e-01	5.000e-02	5.000e-05	1.000e-06	9.000e-01	2.025e-13
5.000e-01	1.000e-09	4.000e-01	9.900e-01	2.000e-01	5.000e-03	1.980e-13
5.500e-01	4.000e-01	4.000e-01	4.500e-01	1.000e-05	5.000e-07	1.980e-13
1.000e-06	6.000e-01	1.000e-06	3.500e-01	9.500e-01	9.500e-01	1.895e-13
5.000e-01	7.500e-01	5.000e-01	1.000e-06	1.000e-01	1.000e-05	1.875e-13
5.000e-02	6.000e-01	1.000e-06	5.000e-03	5.000e-03	2.500e-01	1.875e-13
7.500e-01	1.000e-05	1.000e-05	7.500e-01	3.000e-01	1.000e-02	1.688e-13
1.000e-02	1.000e-03	5.000e-02	5.000e-06	4.500e-01	1.500e-01	1.688e-13
4.500e-01	5.000e-07	5.000e-02	1.500e-01	9.900e-01	1.000e-04	1.671e-13

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
3.000e-01	1.500e-01	1.000e-07	4.500e-01	8.000e-01	1.000e-04	1.620e-13
5.500e-01	4.500e-01	6.500e-01	1.000e-02	1.000e-05	1.000e-05	1.609e-13
1.000e-03	8.500e-01	5.000e-01	5.000e-05	5.000e-05	1.500e-01	1.594e-13
5.000e-05	6.000e-01	3.000e-01	1.000e-07	5.000e-01	3.500e-01	1.575e-13
8.500e-01	1.000e-06	4.000e-01	1.500e-01	1.000e-05	3.000e-01	1.530e-13
9.500e-01	6.500e-01	1.000e-04	5.000e-05	5.000e-05	9.900e-01	1.528e-13
8.000e-01	3.000e-01	1.000e-02	1.000e-07	6.000e-01	1.000e-03	1.440e-13
1.500e-01	6.000e-01	4.500e-01	1.000e-03	1.000e-08	3.500e-01	1.418e-13
1.500e-01	6.000e-01	5.000e-04	5.000e-08	2.000e-01	3.000e-01	1.350e-13
1.500e-01	8.500e-01	7.000e-01	5.000e-06	1.000e-06	3.000e-01	1.339e-13
9.500e-01	5.000e-05	1.000e-02	1.000e-06	6.000e-01	4.500e-01	1.283e-13
5.500e-01	3.500e-01	1.000e-04	1.000e-07	1.000e-01	6.500e-01	1.251e-13
1.000e-05	3.500e-01	5.000e-02	1.000e-03	1.000e-03	7.000e-01	1.225e-13
1.000e-07	8.500e-01	1.000e-05	2.000e-01	9.000e-01	8.000e-01	1.224e-13
8.000e-01	1.000e-08	5.000e-05	8.500e-01	9.990e-01	3.500e-01	1.189e-13
1.000e-01	5.000e-09	7.000e-01	4.500e-01	1.000e-03	7.500e-01	1.181e-13
6.000e-01	5.000e-09	1.000e-02	7.500e-01	9.900e-01	5.000e-03	1.114e-13
5.000e-02	5.000e-03	8.500e-01	5.000e-08	1.000e-01	1.000e-01	1.063e-13
9.500e-01	9.500e-01	5.000e-05	5.000e-08	3.000e-01	1.500e-01	1.015e-13
1.500e-01	5.000e-09	5.000e-04	8.000e-01	5.000e-01	6.500e-01	9.750e-14
5.500e-01	9.990e-01	5.000e-02	1.000e-09	1.000e-02	3.500e-01	9.615e-14
1.500e-01	5.000e-06	7.500e-01	3.000e-01	1.000e-06	5.500e-01	9.281e-14
8.500e-01	1.000e-05	9.500e-01	1.500e-01	1.000e-07	7.500e-01	9.084e-14
5.000e-01	9.000e-01	5.000e-02	1.000e-09	8.000e-01	5.000e-03	9.000e-14
5.000e-05	5.500e-01	6.500e-01	5.000e-01	1.000e-05	1.000e-03	8.938e-14
5.000e-06	4.000e-01	5.000e-07	2.500e-01	9.900e-01	3.500e-01	8.663e-14
9.000e-01	1.000e-05	1.000e-02	5.000e-06	5.500e-01	3.500e-01	8.663e-14
1.000e-05	5.000e-07	4.000e-01	5.000e-01	1.000e-01	8.500e-01	8.500e-14

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
5.000e-05	1.000e-04	1.000e-02	7.500e-01	5.000e-03	4.500e-01	8.438e-14
1.500e-01	1.500e-01	5.000e-02	1.500e-01	1.000e-04	5.000e-06	8.438e-14
8.500e-01	5.500e-01	5.000e-06	5.000e-08	9.990e-01	7.000e-01	8.173e-14
1.000e-04	1.000e-01	2.000e-01	5.000e-05	8.000e-01	1.000e-03	8.000e-14
8.500e-01	5.000e-07	5.000e-02	7.500e-01	9.900e-01	5.000e-06	7.889e-14
1.000e-07	6.500e-01	3.000e-01	2.000e-01	2.000e-01	1.000e-04	7.800e-14
7.500e-01	1.000e-04	4.000e-01	3.000e-01	1.000e-08	8.500e-01	7.650e-14
8.500e-01	6.500e-01	2.500e-01	1.000e-08	1.000e-01	5.000e-04	6.906e-14
1.500e-01	5.000e-09	4.000e-01	1.000e-01	5.000e-03	4.500e-01	6.750e-14
9.000e-01	1.000e-03	1.000e-09	9.900e-01	1.500e-01	5.000e-01	6.683e-14
5.000e-09	3.500e-01	9.500e-01	5.000e-02	1.000e-03	8.000e-01	6.650e-14
9.500e-01	1.500e-01	1.000e-04	1.000e-04	1.000e-04	4.500e-01	6.413e-14
8.000e-01	1.000e-06	5.000e-07	6.500e-01	3.500e-01	7.000e-01	6.370e-14
1.000e-04	6.000e-01	3.000e-01	1.000e-04	3.500e-01	1.000e-04	6.300e-14
1.000e-07	1.000e-05	8.500e-01	7.500e-01	6.500e-01	1.500e-01	6.216e-14
5.500e-01	9.000e-01	3.500e-01	5.000e-06	1.000e-07	7.000e-01	6.064e-14
3.000e-01	5.000e-07	4.500e-01	2.500e-01	5.000e-06	7.000e-01	5.906e-14
1.000e-06	6.500e-01	3.000e-01	6.000e-01	1.000e-01	5.000e-06	5.850e-14
3.500e-01	4.500e-01	1.500e-01	5.000e-06	9.900e-01	5.000e-07	5.847e-14
5.000e-01	1.000e-05	5.000e-06	7.500e-01	3.000e-01	1.000e-02	5.625e-14
8.500e-01	1.000e-05	6.500e-01	5.000e-07	4.000e-01	5.000e-02	5.525e-14
3.500e-01	4.500e-01	6.500e-01	5.000e-02	1.000e-08	1.000e-03	5.119e-14
5.000e-06	3.000e-01	1.500e-01	6.000e-01	5.000e-07	7.500e-01	5.063e-14
9.990e-01	4.000e-01	5.000e-09	5.000e-03	9.900e-01	5.000e-03	4.945e-14
5.000e-05	3.000e-01	1.000e-02	9.900e-01	5.000e-07	6.500e-01	4.826e-14
1.000e-04	8.500e-01	1.000e-07	5.000e-02	7.000e-01	1.500e-01	4.463e-14
1.000e-01	1.000e-03	4.500e-01	1.000e-07	9.900e-01	1.000e-02	4.455e-14
5.000e-06	4.500e-01	7.500e-01	5.000e-07	1.500e-01	3.500e-01	4.430e-14

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
3.500e-01	5.500e-01	1.000e-05	7.000e-01	6.500e-01	5.000e-08	4.379e-14
5.000e-02	4.500e-01	2.000e-01	1.000e-03	9.500e-01	1.000e-08	4.275e-14
1.000e-04	8.500e-01	5.000e-08	5.000e-02	3.000e-01	6.500e-01	4.144e-14
9.900e-01	5.000e-02	5.000e-07	3.000e-01	1.000e-01	5.000e-05	3.713e-14
3.000e-01	8.000e-01	5.000e-05	6.000e-01	1.000e-06	5.000e-03	3.600e-14
6.500e-01	5.000e-07	4.500e-01	5.000e-07	6.000e-01	8.000e-01	3.510e-14
9.990e-01	6.000e-01	5.000e-05	1.000e-08	7.500e-01	1.500e-01	3.372e-14
8.000e-01	1.000e-05	1.000e-07	1.500e-01	4.000e-01	7.000e-01	3.360e-14
3.500e-01	1.000e-01	7.500e-01	5.000e-03	5.000e-08	5.000e-03	3.281e-14
1.000e-04	1.500e-01	8.500e-01	5.000e-06	1.000e-01	5.000e-03	3.188e-14
5.500e-01	8.500e-01	1.500e-01	1.000e-07	9.000e-01	5.000e-06	3.156e-14
3.000e-01	5.000e-09	1.000e-03	1.000e-01	9.500e-01	2.000e-01	2.850e-14
5.000e-06	6.000e-01	4.000e-01	5.000e-08	4.500e-01	9.990e-01	2.697e-14
9.990e-01	4.500e-01	6.000e-01	9.900e-01	1.000e-05	1.000e-08	2.670e-14
5.000e-08	8.500e-01	5.000e-05	1.500e-01	5.500e-01	1.500e-01	2.630e-14
1.000e-04	3.500e-01	1.000e-05	7.500e-01	1.000e-01	1.000e-03	2.625e-14
4.000e-01	7.500e-01	1.000e-09	2.000e-01	5.000e-04	8.000e-01	2.400e-14
4.000e-01	1.000e-06	5.000e-06	1.500e-01	1.000e-01	8.000e-01	2.400e-14
9.990e-01	5.500e-01	1.000e-06	1.000e-06	1.000e-01	4.000e-01	2.198e-14
1.000e-05	6.000e-01	5.000e-06	1.000e-03	9.500e-01	7.500e-01	2.138e-14
5.000e-05	6.000e-01	5.000e-09	6.000e-01	9.500e-01	2.500e-01	2.138e-14
1.000e-01	1.000e-04	2.000e-01	3.500e-01	3.000e-01	1.000e-07	2.100e-14
5.000e-01	1.000e-07	5.000e-06	1.500e-01	8.000e-01	7.000e-01	2.100e-14
4.500e-01	5.000e-03	8.000e-01	5.000e-05	4.500e-01	5.000e-07	2.025e-14
1.500e-01	4.500e-01	7.500e-01	1.000e-06	4.000e-01	1.000e-06	2.025e-14
3.000e-01	8.500e-01	3.000e-01	5.000e-07	1.000e-01	5.000e-06	1.913e-14
7.500e-01	8.500e-01	6.000e-01	1.000e-06	1.000e-03	5.000e-05	1.913e-14
2.500e-01	5.000e-05	1.000e-02	3.000e-01	1.000e-05	5.000e-02	1.875e-14

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
9.500e-01	5.000e-07	7.500e-01	7.000e-01	1.000e-07	7.500e-01	1.870e-14
5.000e-05	5.000e-06	1.500e-01	1.500e-01	5.000e-03	6.500e-01	1.828e-14
2.000e-01	8.500e-01	6.000e-01	1.000e-04	5.000e-09	3.500e-01	1.785e-14
9.000e-01	3.500e-01	1.500e-01	7.500e-01	1.000e-04	5.000e-09	1.772e-14
9.000e-01	5.000e-07	3.500e-01	2.500e-01	1.000e-06	4.500e-01	1.772e-14
3.000e-01	3.500e-01	1.500e-01	5.000e-08	5.000e-05	4.000e-01	1.575e-14
5.000e-03	5.000e-03	5.000e-03	5.000e-03	5.000e-03	5.000e-03	1.563e-14
1.500e-01	1.000e-04	2.000e-01	2.000e-01	5.000e-03	5.000e-06	1.500e-14
5.000e-01	5.000e-02	6.500e-01	5.000e-06	5.000e-07	3.500e-01	1.422e-14
1.500e-01	5.000e-06	2.500e-01	5.000e-06	1.500e-01	1.000e-01	1.406e-14
5.000e-06	2.000e-01	1.000e-02	4.000e-01	5.000e-06	7.000e-01	1.400e-14
3.500e-01	1.000e-01	4.000e-01	5.000e-08	5.000e-05	4.000e-01	1.400e-14
5.000e-06	9.900e-01	5.000e-01	5.000e-08	7.500e-01	1.500e-01	1.392e-14
8.500e-01	5.000e-02	7.500e-01	5.000e-08	1.000e-05	8.500e-01	1.355e-14
9.900e-01	1.000e-04	5.000e-04	2.500e-01	9.990e-01	1.000e-06	1.236e-14
5.000e-01	5.000e-05	5.500e-01	2.500e-01	3.500e-01	1.000e-08	1.203e-14
8.000e-01	1.000e-09	1.000e-02	2.000e-01	7.500e-01	1.000e-02	1.200e-14
1.000e-08	5.000e-02	4.000e-01	4.000e-01	1.500e-01	1.000e-03	1.200e-14
1.000e-05	1.000e-03	3.000e-01	1.000e-01	8.000e-01	5.000e-05	1.200e-14
5.000e-06	7.500e-01	1.500e-01	5.000e-06	5.000e-03	8.500e-01	1.195e-14
1.000e-04	1.000e-03	3.500e-01	4.500e-01	1.500e-01	5.000e-06	1.181e-14
8.000e-01	1.000e-06	4.000e-01	8.000e-01	4.500e-01	1.000e-07	1.152e-14
4.000e-01	6.500e-01	8.500e-01	1.000e-08	9.990e-01	5.000e-06	1.104e-14
6.500e-01	1.000e-03	1.000e-02	7.500e-01	5.000e-09	4.500e-01	1.097e-14
8.000e-01	4.500e-01	9.500e-01	1.000e-06	6.000e-01	5.000e-08	1.026e-14
7.500e-01	1.000e-04	1.000e-05	4.000e-01	6.500e-01	5.000e-05	9.750e-15
5.000e-09	6.500e-01	4.500e-01	6.500e-01	1.000e-02	1.000e-03	9.506e-15
9.500e-01	5.000e-09	1.000e-02	2.000e-01	2.000e-01	5.000e-03	9.500e-15

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
1.000e-09	4.500e-01	8.500e-01	5.000e-01	9.900e-01	5.000e-05	9.467e-15
7.500e-01	5.500e-01	1.000e-08	5.000e-06	6.500e-01	7.000e-01	9.384e-15
5.000e-09	3.000e-01	1.500e-01	8.000e-01	1.000e-02	5.000e-03	9.000e-15
9.500e-01	5.000e-05	7.500e-01	5.000e-08	5.000e-01	1.000e-02	8.906e-15
1.000e-01	5.000e-07	1.000e-05	3.500e-01	1.000e-01	5.000e-01	8.750e-15
2.500e-01	5.000e-07	1.000e-05	3.500e-01	4.000e-01	5.000e-02	8.750e-15
3.000e-01	6.000e-01	9.990e-01	5.000e-06	9.500e-01	1.000e-08	8.541e-15
5.000e-05	8.500e-01	1.000e-02	5.000e-07	4.000e-01	1.000e-01	8.500e-15
3.000e-01	2.500e-01	1.000e-07	2.500e-01	1.000e-05	4.500e-01	8.438e-15
8.000e-01	5.000e-07	6.500e-01	1.000e-07	4.500e-01	7.000e-01	8.190e-15
9.000e-01	7.500e-01	5.000e-08	5.000e-01	5.000e-07	9.500e-01	8.016e-15
6.500e-01	6.000e-01	5.000e-05	1.000e-05	8.000e-01	5.000e-05	7.800e-15
1.000e-05	1.000e-08	6.500e-01	1.500e-01	9.900e-01	8.000e-01	7.722e-15
9.000e-01	1.000e-04	8.500e-01	1.000e-01	1.000e-05	1.000e-04	7.650e-15
1.000e-05	5.000e-06	9.500e-01	8.500e-01	5.000e-04	3.500e-01	7.066e-15
1.000e-04	3.500e-01	5.000e-06	4.000e-01	2.000e-01	5.000e-04	7.000e-15
3.500e-01	5.000e-09	4.500e-01	5.000e-05	5.000e-01	3.500e-01	6.891e-15
8.000e-01	1.000e-08	5.000e-06	2.500e-01	8.000e-01	8.500e-01	6.800e-15
9.990e-01	4.500e-01	1.000e-06	6.000e-01	5.000e-07	5.000e-02	6.743e-15
4.000e-01	5.000e-09	7.500e-01	4.500e-01	9.900e-01	1.000e-05	6.683e-15
1.500e-01	5.000e-05	5.000e-02	1.000e-01	5.000e-07	3.500e-01	6.563e-15
5.000e-01	1.000e-08	1.000e-05	3.000e-01	6.000e-01	7.000e-01	6.300e-15
8.000e-01	5.000e-07	3.500e-01	1.000e-01	1.000e-06	4.500e-01	6.300e-15
9.900e-01	5.000e-09	4.500e-01	6.000e-01	1.000e-05	4.500e-01	6.014e-15
8.000e-01	5.000e-05	7.500e-01	5.000e-09	1.000e-01	4.000e-01	6.000e-15
5.000e-03	5.000e-09	6.500e-01	9.900e-01	3.500e-01	1.000e-03	5.631e-15
1.000e-02	5.000e-05	5.000e-02	5.000e-07	5.000e-01	9.000e-01	5.625e-15
1.000e-01	1.000e-07	5.000e-06	2.000e-01	6.500e-01	8.500e-01	5.525e-15

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
5.000e-05	5.500e-01	9.990e-01	1.000e-06	2.000e-01	1.000e-03	5.495e-15
3.000e-01	5.000e-07	8.500e-01	5.000e-08	9.990e-01	8.500e-01	5.413e-15
9.000e-01	1.000e-04	1.500e-01	5.000e-08	8.000e-01	1.000e-02	5.400e-15
5.500e-01	5.000e-08	6.500e-01	1.000e-04	3.000e-01	1.000e-02	5.363e-15
1.000e-04	5.000e-09	7.500e-01	1.500e-01	9.500e-01	1.000e-01	5.344e-15
1.000e-07	1.000e-06	5.000e-01	1.500e-01	9.990e-01	7.000e-01	5.245e-15
1.000e-06	4.500e-01	7.500e-01	1.000e-06	1.000e-01	1.500e-01	5.063e-15
9.500e-01	1.000e-01	7.000e-01	5.000e-08	1.000e-05	1.500e-01	4.988e-15
3.000e-01	1.000e-03	4.000e-01	5.000e-06	8.000e-01	1.000e-05	4.800e-15
1.000e-03	1.000e-03	7.500e-01	1.000e-08	7.500e-01	8.500e-01	4.781e-15
9.500e-01	1.000e-03	1.000e-03	1.000e-06	5.000e-01	1.000e-02	4.750e-15
3.000e-01	4.500e-01	4.000e-01	5.000e-05	5.000e-09	3.500e-01	4.725e-15
5.000e-05	2.000e-01	1.000e-05	9.900e-01	9.500e-01	5.000e-05	4.703e-15
1.000e-08	7.000e-01	7.500e-01	2.500e-01	1.000e-05	3.500e-01	4.594e-15
1.000e-01	5.000e-09	7.500e-01	3.500e-01	6.500e-01	5.000e-05	4.266e-15
1.500e-01	5.000e-06	1.000e-07	1.500e-01	5.000e-01	7.500e-01	4.219e-15
5.500e-01	5.000e-05	3.000e-01	1.000e-02	1.000e-06	5.000e-02	4.125e-15
5.000e-05	4.000e-01	6.500e-01	1.000e-04	6.000e-01	5.000e-06	3.900e-15
9.990e-01	1.000e-03	5.000e-06	8.000e-01	9.500e-01	1.000e-06	3.796e-15
1.500e-01	5.000e-06	2.000e-01	1.000e-06	1.000e-01	2.500e-01	3.750e-15
5.000e-05	8.000e-01	1.000e-02	1.000e-06	1.000e-02	9.000e-01	3.600e-15
1.000e-04	8.500e-01	5.000e-07	9.900e-01	8.500e-01	1.000e-04	3.576e-15
9.500e-01	1.000e-06	5.000e-02	5.000e-03	3.000e-01	5.000e-05	3.563e-15
3.000e-01	1.000e-06	8.500e-01	1.000e-07	3.000e-01	4.500e-01	3.443e-15
1.000e-08	9.990e-01	7.500e-01	8.500e-01	5.000e-01	1.000e-06	3.184e-15
5.000e-09	1.500e-01	6.500e-01	8.500e-01	1.000e-05	7.500e-01	3.108e-15
1.000e-02	1.000e-04	9.990e-01	5.000e-09	6.500e-01	9.500e-01	3.084e-15
5.000e-02	5.000e-02	1.000e-06	3.500e-01	5.000e-06	7.000e-01	3.063e-15

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
1.000e-09	1.000e-01	1.000e-04	4.500e-01	9.500e-01	7.000e-01	2.993e-15
1.000e-01	9.500e-01	3.000e-01	5.000e-05	2.000e-01	1.000e-08	2.850e-15
8.000e-01	1.000e-06	1.000e-02	1.000e-06	3.500e-01	9.990e-01	2.797e-15
5.000e-06	5.500e-01	1.000e-08	3.000e-01	9.500e-01	3.500e-01	2.743e-15
9.000e-01	5.000e-09	4.000e-01	5.000e-02	6.000e-01	5.000e-05	2.700e-15
3.000e-01	1.000e-05	1.000e-02	2.000e-01	5.000e-07	8.500e-01	2.550e-15
5.500e-01	5.000e-09	1.000e-05	2.000e-01	9.900e-01	4.500e-01	2.450e-15
9.500e-01	6.000e-01	1.000e-07	5.000e-06	8.500e-01	1.000e-02	2.423e-15
9.500e-01	8.000e-01	5.000e-08	6.000e-01	1.000e-06	1.000e-01	2.280e-15
1.500e-01	5.000e-07	4.000e-01	1.000e-07	9.500e-01	8.000e-01	2.280e-15
2.000e-01	4.500e-01	5.000e-07	1.000e-03	5.000e-03	1.000e-02	2.250e-15
9.990e-01	3.000e-01	5.000e-09	1.000e-02	1.000e-03	1.500e-01	2.248e-15
8.500e-01	5.000e-09	3.000e-01	1.000e-01	5.000e-05	3.500e-01	2.231e-15
5.500e-01	8.000e-01	1.000e-05	1.000e-03	1.000e-02	5.000e-05	2.200e-15
1.000e-06	7.500e-01	5.000e-08	2.000e-01	3.000e-01	9.500e-01	2.138e-15
5.000e-03	9.990e-01	1.000e-05	5.000e-05	8.500e-01	1.000e-03	2.123e-15
1.000e-04	6.000e-01	1.000e-02	5.000e-06	1.000e-03	7.000e-01	2.100e-15
4.000e-01	1.000e-06	1.000e-02	1.500e-01	3.500e-01	1.000e-05	2.100e-15
2.500e-01	1.000e-05	5.500e-01	5.000e-02	6.000e-01	5.000e-08	2.063e-15
9.000e-01	6.000e-01	5.000e-05	5.000e-08	3.000e-01	5.000e-03	2.025e-15
3.000e-01	5.000e-06	1.000e-08	3.000e-01	9.990e-01	4.500e-01	2.023e-15
5.000e-05	4.000e-01	1.000e-02	5.000e-06	4.000e-01	5.000e-03	2.000e-15
4.000e-01	1.000e-01	2.000e-01	5.000e-07	1.000e-02	5.000e-05	2.000e-15
5.000e-02	1.000e-02	2.000e-01	5.000e-05	5.000e-07	8.000e-01	2.000e-15
1.000e-03	1.000e-04	6.000e-01	3.500e-01	9.500e-01	1.000e-07	1.995e-15
6.500e-01	5.000e-02	5.000e-07	1.000e-06	3.500e-01	3.500e-01	1.991e-15
1.000e-01	5.000e-05	1.000e-03	6.000e-01	1.000e-06	6.500e-01	1.950e-15
6.500e-01	1.000e-06	2.000e-01	1.000e-06	5.000e-02	3.000e-01	1.950e-15

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
8.500e-01	1.000e-04	5.000e-02	3.000e-01	1.500e-01	1.000e-08	1.913e-15
3.000e-01	1.000e-06	3.000e-01	5.000e-02	5.000e-07	8.500e-01	1.913e-15
1.500e-01	5.000e-02	5.000e-07	2.500e-01	4.000e-01	5.000e-06	1.875e-15
4.000e-01	4.000e-01	1.000e-05	5.000e-07	4.500e-01	5.000e-03	1.800e-15
1.000e-01	3.500e-01	1.000e-02	5.000e-08	9.900e-01	1.000e-04	1.733e-15
6.500e-01	1.000e-05	6.500e-01	1.000e-02	5.000e-08	8.000e-01	1.690e-15
4.500e-01	1.000e-05	6.000e-01	2.500e-01	5.000e-03	5.000e-07	1.688e-15
1.000e-02	8.500e-01	1.000e-07	4.000e-01	9.500e-01	5.000e-06	1.615e-15
5.000e-09	5.000e-03	1.000e-02	4.000e-01	1.000e-01	1.500e-01	1.500e-15
9.900e-01	6.000e-01	5.000e-02	9.900e-01	5.000e-05	1.000e-09	1.470e-15
1.000e-07	5.000e-06	9.500e-01	9.500e-01	5.000e-03	6.500e-01	1.467e-15
4.000e-01	3.000e-01	5.000e-08	5.000e-03	9.500e-01	5.000e-05	1.425e-15
3.500e-01	5.000e-02	5.000e-08	7.000e-01	4.500e-01	5.000e-06	1.378e-15
1.000e-01	1.000e-06	5.000e-06	5.000e-01	5.500e-01	1.000e-02	1.375e-15
4.000e-01	5.000e-07	3.000e-01	3.000e-01	1.000e-07	7.500e-01	1.350e-15
1.000e-04	8.500e-01	1.000e-03	1.000e-06	3.000e-01	5.000e-02	1.275e-15
9.990e-01	5.000e-07	6.500e-01	7.500e-01	1.000e-05	5.000e-04	1.218e-15
9.500e-01	1.000e-08	4.000e-01	3.000e-01	9.990e-01	1.000e-06	1.139e-15
2.000e-01	1.000e-05	4.500e-01	5.000e-02	5.000e-04	5.000e-05	1.125e-15
5.000e-03	1.000e-08	7.500e-01	6.000e-01	5.000e-01	1.000e-04	1.125e-15
1.000e-03	5.000e-02	1.000e-08	5.000e-01	4.500e-01	1.000e-02	1.125e-15
1.000e-07	4.000e-01	5.000e-02	1.000e-05	3.500e-01	1.500e-01	1.050e-15
1.000e-08	5.000e-05	1.000e-02	6.000e-01	5.000e-01	7.000e-01	1.050e-15
9.990e-01	1.000e-05	5.000e-07	1.000e-03	3.000e-01	6.500e-01	9.740e-16
1.500e-01	5.000e-09	8.500e-01	3.000e-01	9.990e-01	5.000e-06	9.553e-16
9.500e-01	4.000e-01	1.000e-02	5.000e-08	9.900e-01	5.000e-06	9.405e-16
4.000e-01	5.000e-06	9.990e-01	5.000e-06	1.000e-04	9.000e-01	8.991e-16
1.000e-01	1.000e-01	1.000e-05	5.000e-07	5.000e-02	3.500e-01	8.750e-16

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
8.500e-01	2.000e-01	1.000e-02	1.000e-07	9.990e-01	5.000e-06	8.492e-16
5.000e-03	3.500e-01	5.000e-08	9.900e-01	1.000e-05	9.500e-01	8.229e-16
2.000e-01	6.500e-01	5.000e-05	5.000e-06	5.000e-01	5.000e-05	8.125e-16
1.000e-04	2.500e-01	1.000e-01	5.000e-08	6.500e-01	1.000e-02	8.125e-16
9.500e-01	5.000e-07	7.500e-01	5.000e-09	6.500e-01	7.000e-01	8.105e-16
5.000e-06	5.000e-02	7.500e-01	8.500e-01	1.000e-07	5.000e-02	7.969e-16
8.000e-01	4.000e-01	5.000e-07	1.000e-03	9.900e-01	5.000e-06	7.920e-16
3.000e-01	3.000e-01	1.000e-07	1.000e-06	2.000e-01	4.000e-01	7.200e-16
1.000e-05	4.000e-01	4.500e-01	5.000e-08	8.000e-01	1.000e-02	7.200e-16
1.000e-02	9.000e-01	5.000e-06	5.000e-08	7.000e-01	4.500e-01	7.088e-16
1.000e-05	5.000e-06	9.500e-01	3.500e-01	5.000e-05	8.500e-01	7.066e-16
1.000e-05	7.500e-01	3.000e-01	6.000e-01	1.000e-05	5.000e-05	6.750e-16
3.500e-01	1.000e-06	1.500e-01	2.000e-01	1.000e-07	6.000e-01	6.300e-16
1.000e-01	6.500e-01	1.000e-04	1.000e-04	9.000e-01	1.000e-06	5.850e-16
5.000e-06	1.000e-06	3.000e-01	4.000e-01	9.500e-01	1.000e-03	5.700e-16
8.000e-01	1.000e-06	7.500e-01	1.000e-07	9.500e-01	1.000e-02	5.700e-16
7.500e-01	1.000e-01	1.000e-02	5.000e-04	3.000e-01	5.000e-09	5.625e-16
5.000e-05	5.000e-07	8.500e-01	4.000e-01	6.500e-01	1.000e-04	5.525e-16
9.990e-01	5.000e-09	5.000e-06	4.000e-01	1.000e-01	5.500e-01	5.495e-16
1.000e-09	1.000e-05	6.500e-01	4.000e-01	6.500e-01	3.000e-01	5.070e-16
1.000e-01	4.500e-01	5.000e-06	1.000e-02	5.000e-07	4.500e-01	5.063e-16
5.000e-02	5.000e-07	4.500e-01	2.000e-01	5.000e-07	4.500e-01	5.063e-16
1.000e-04	5.000e-09	5.000e-02	4.000e-01	1.000e-01	5.000e-01	5.000e-16
4.000e-01	1.000e-02	1.000e-05	5.000e-07	1.000e-01	2.500e-01	5.000e-16
6.500e-01	4.000e-01	5.000e-08	1.000e-02	5.000e-06	7.500e-01	4.875e-16
5.000e-05	7.500e-01	5.000e-05	6.000e-01	5.000e-07	8.500e-01	4.781e-16
3.000e-01	5.500e-01	6.000e-01	5.000e-06	9.500e-01	1.000e-09	4.703e-16
9.500e-01	5.000e-07	4.500e-01	5.000e-07	8.500e-01	5.000e-03	4.542e-16

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
9.500e-01	5.000e-05	1.000e-05	6.000e-01	1.000e-05	1.500e-01	4.275e-16
7.500e-01	6.000e-01	1.000e-07	1.000e-06	1.000e-02	9.500e-01	4.275e-16
3.000e-01	1.000e-05	7.500e-01	3.500e-01	1.000e-01	5.000e-09	3.938e-16
3.000e-01	5.000e-09	9.900e-01	5.000e-06	1.500e-01	3.500e-01	3.898e-16
5.000e-09	3.000e-01	7.500e-01	5.000e-07	8.000e-01	8.500e-01	3.825e-16
9.500e-01	1.000e-04	4.000e-01	4.000e-01	5.000e-07	5.000e-05	3.800e-16
9.990e-01	1.000e-04	1.000e-02	5.000e-08	1.000e-02	7.500e-01	3.746e-16
1.000e-04	3.000e-01	5.000e-06	1.000e-05	3.000e-01	8.000e-01	3.600e-16
8.000e-01	1.000e-06	1.000e-02	9.990e-01	1.000e-07	4.500e-01	3.596e-16
1.000e-08	5.000e-02	2.000e-01	5.000e-04	7.000e-01	1.000e-02	3.500e-16
4.000e-01	5.000e-07	1.500e-01	5.000e-08	6.500e-01	3.500e-01	3.413e-16
8.500e-01	1.000e-08	1.000e-02	5.000e-06	9.900e-01	8.000e-01	3.366e-16
1.000e-09	7.500e-01	1.500e-01	5.000e-06	6.000e-01	9.500e-01	3.206e-16
2.500e-01	1.000e-06	7.500e-01	8.500e-01	2.000e-01	1.000e-08	3.188e-16
5.000e-02	1.500e-01	8.500e-01	5.000e-02	1.000e-07	1.000e-05	3.188e-16
1.000e-06	1.000e-01	4.000e-01	5.000e-08	3.000e-01	5.000e-01	3.000e-16
4.000e-01	3.000e-01	5.000e-06	5.000e-08	9.900e-01	1.000e-02	2.970e-16
3.500e-01	7.500e-01	5.000e-01	5.000e-07	1.000e-08	4.500e-01	2.953e-16
9.000e-01	1.000e-01	1.000e-08	5.000e-05	6.500e-01	1.000e-02	2.925e-16
9.900e-01	5.000e-07	2.500e-01	1.000e-06	4.500e-01	5.000e-03	2.784e-16
1.500e-01	3.500e-01	3.500e-01	1.000e-07	1.000e-06	1.500e-01	2.756e-16
1.000e-02	5.000e-06	5.000e-02	5.500e-01	1.000e-06	2.000e-01	2.750e-16
4.000e-01	5.000e-07	5.000e-08	5.000e-02	5.000e-01	9.900e-01	2.475e-16
1.000e-07	3.000e-01	7.500e-01	1.000e-01	1.000e-01	1.000e-06	2.250e-16
5.500e-01	6.000e-01	6.500e-01	1.000e-07	1.000e-06	1.000e-02	2.145e-16
7.000e-01	2.000e-01	7.500e-01	1.000e-07	1.000e-07	2.000e-01	2.100e-16
9.500e-01	8.500e-01	1.000e-02	5.000e-08	5.000e-05	1.000e-02	2.019e-16
1.500e-01	5.500e-01	7.500e-01	5.000e-08	6.500e-01	1.000e-07	2.011e-16

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
1.000e-01	5.000e-06	6.500e-01	3.000e-01	2.000e-01	1.000e-08	1.950e-16
1.000e-04	5.000e-05	5.000e-07	1.000e-01	8.000e-01	9.500e-01	1.900e-16
5.000e-02	1.000e-03	7.500e-01	9.990e-01	1.000e-07	5.000e-05	1.873e-16
1.000e-04	6.000e-01	1.000e-03	5.000e-08	3.000e-01	2.000e-01	1.800e-16
4.000e-01	1.500e-01	1.000e-03	6.000e-01	1.000e-05	5.000e-07	1.800e-16
9.900e-01	7.000e-01	5.000e-06	1.000e-04	5.000e-01	1.000e-06	1.733e-16
5.000e-05	3.000e-01	5.000e-06	5.000e-03	4.500e-01	1.000e-03	1.688e-16
1.000e-02	5.500e-01	2.000e-01	6.000e-01	5.000e-07	5.000e-07	1.650e-16
7.500e-01	5.000e-05	8.500e-01	1.000e-09	5.000e-01	1.000e-02	1.594e-16
3.500e-01	3.000e-01	1.000e-05	3.000e-01	1.000e-07	5.000e-03	1.575e-16
5.000e-06	2.000e-01	7.500e-01	5.000e-07	8.000e-01	5.000e-04	1.500e-16
2.500e-01	1.500e-01	8.000e-01	5.000e-08	1.000e-06	1.000e-01	1.500e-16
9.990e-01	5.000e-09	5.000e-05	1.500e-01	8.000e-01	5.000e-03	1.499e-16
5.000e-05	8.500e-01	1.000e-08	5.000e-01	1.000e-03	7.000e-01	1.488e-16
4.000e-01	1.000e-09	5.000e-01	5.000e-06	9.900e-01	1.500e-01	1.485e-16
9.900e-01	1.000e-09	9.990e-01	2.000e-01	1.000e-06	7.000e-01	1.385e-16
5.000e-06	1.000e-03	5.000e-02	1.000e-05	1.000e-01	5.500e-01	1.375e-16
3.000e-01	5.000e-07	6.000e-01	1.000e-03	3.000e-01	5.000e-06	1.350e-16
5.000e-05	4.000e-01	5.000e-05	1.000e-06	2.000e-01	6.500e-01	1.300e-16
4.000e-01	9.990e-01	6.500e-01	5.000e-08	1.000e-05	1.000e-03	1.299e-16
1.000e-04	5.000e-06	5.000e-06	7.500e-01	1.500e-01	4.500e-01	1.266e-16
4.000e-01	9.000e-01	1.000e-09	1.000e-06	9.500e-01	3.500e-01	1.197e-16
2.000e-01	7.500e-01	6.000e-01	5.000e-07	5.000e-05	5.000e-05	1.125e-16
3.500e-01	1.000e-08	9.500e-01	5.000e-07	4.500e-01	1.500e-01	1.122e-16
2.500e-01	9.500e-01	5.000e-07	1.000e-09	9.500e-01	9.500e-01	1.072e-16
1.000e-08	4.500e-01	6.000e-01	5.000e-06	1.000e-02	7.000e-01	9.450e-17
1.000e-01	7.500e-01	5.000e-08	2.500e-01	5.000e-07	2.000e-01	9.375e-17
9.500e-01	4.500e-01	5.000e-07	1.000e-03	5.000e-07	8.500e-01	9.084e-17

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
4.000e-01	8.500e-01	2.500e-01	5.000e-07	4.000e-01	5.000e-09	8.500e-17
6.500e-01	6.500e-01	1.000e-05	5.000e-06	8.000e-01	5.000e-06	8.450e-17
5.000e-01	1.000e-05	7.500e-01	9.000e-01	5.000e-05	5.000e-07	8.438e-17
7.500e-01	6.000e-01	7.500e-01	5.000e-08	5.000e-01	1.000e-08	8.438e-17
9.500e-01	1.000e-08	1.000e-02	5.000e-06	5.000e-01	3.500e-01	8.313e-17
1.000e-05	5.500e-01	5.000e-01	6.000e-01	1.000e-05	5.000e-06	8.250e-17
5.000e-03	6.500e-01	1.000e-02	1.000e-03	5.000e-05	5.000e-05	8.125e-17
1.000e-01	8.000e-01	5.000e-08	5.000e-06	1.000e-02	3.500e-01	7.000e-17
1.000e-09	6.000e-01	3.000e-01	7.500e-01	1.000e-01	5.000e-06	6.750e-17
6.000e-01	1.000e-09	5.000e-01	5.000e-02	4.500e-01	1.000e-05	6.750e-17
8.500e-01	4.500e-01	5.000e-07	2.000e-01	3.500e-01	5.000e-09	6.694e-17
5.000e-02	5.000e-02	5.000e-08	5.000e-06	1.000e-01	9.900e-01	6.188e-17
1.000e-06	2.500e-01	5.000e-07	9.900e-01	1.000e-01	5.000e-03	6.188e-17
5.500e-01	7.500e-01	1.000e-02	1.000e-08	3.000e-01	5.000e-06	6.188e-17
1.000e-01	1.000e-03	1.000e-08	1.000e-04	9.500e-01	6.500e-01	6.175e-17
1.000e-03	6.000e-01	5.000e-06	1.000e-06	2.000e-01	1.000e-01	6.000e-17
4.000e-01	3.500e-01	1.000e-07	8.500e-01	1.000e-03	5.000e-06	5.950e-17
1.000e-05	1.000e-01	2.000e-01	9.900e-01	3.000e-01	1.000e-09	5.940e-17
1.000e-02	5.000e-05	1.000e-02	1.000e-07	7.500e-01	1.500e-01	5.625e-17
1.000e-07	8.500e-01	6.500e-01	5.000e-07	2.000e-01	1.000e-02	5.525e-17
8.500e-01	5.000e-09	7.000e-01	3.500e-01	5.000e-01	1.000e-07	5.206e-17
5.000e-06	4.500e-01	1.000e-06	9.000e-01	5.000e-05	5.000e-01	5.063e-17
4.000e-01	5.000e-07	1.000e-02	5.000e-05	1.000e-01	5.000e-03	5.000e-17
9.900e-01	5.000e-02	5.000e-08	5.000e-06	1.000e-02	4.000e-01	4.950e-17
9.000e-01	1.000e-05	1.000e-05	3.500e-01	1.000e-05	1.500e-01	4.725e-17
4.500e-01	2.000e-01	5.000e-08	5.000e-02	2.000e-01	1.000e-06	4.500e-17
8.000e-01	5.000e-07	4.500e-01	5.000e-01	1.000e-02	5.000e-08	4.500e-17
5.000e-05	5.000e-05	7.500e-01	5.000e-07	9.500e-01	5.000e-02	4.453e-17

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
5.000e-02	1.000e-04	2.500e-01	1.000e-07	1.000e-03	3.500e-01	4.375e-17
3.500e-01	5.000e-05	5.000e-06	5.000e-03	9.900e-01	1.000e-04	4.331e-17
1.000e-05	8.500e-01	1.000e-08	2.000e-01	5.000e-01	5.000e-03	4.250e-17
5.000e-02	5.000e-07	5.000e-04	1.000e-05	4.500e-01	7.500e-01	4.219e-17
5.000e-05	1.000e-05	7.500e-01	2.500e-01	1.000e-06	4.500e-01	4.219e-17
5.000e-06	8.500e-01	1.000e-02	1.000e-05	1.000e-04	9.900e-01	4.208e-17
3.500e-01	1.000e-06	1.000e-09	4.000e-01	9.990e-01	3.000e-01	4.196e-17
3.000e-01	5.000e-09	6.500e-01	1.000e-07	6.500e-01	6.500e-01	4.119e-17
1.000e-08	1.000e-07	1.500e-01	7.000e-01	7.500e-01	4.500e-01	3.544e-17
5.000e-06	1.000e-05	5.000e-01	5.000e-06	3.500e-01	8.000e-01	3.500e-17
5.000e-06	4.000e-01	7.000e-01	5.000e-08	1.000e-01	5.000e-03	3.500e-17
1.500e-01	1.000e-08	5.000e-06	8.000e-01	5.500e-01	1.000e-02	3.300e-17
9.500e-01	5.000e-07	1.000e-03	1.000e-07	8.000e-01	8.500e-01	3.230e-17
4.500e-01	1.000e-09	2.000e-01	5.000e-02	1.000e-05	7.000e-01	3.150e-17
3.500e-01	5.000e-02	5.000e-08	9.000e-01	5.000e-08	8.000e-01	3.150e-17
9.900e-01	7.500e-01	7.500e-01	5.000e-08	1.000e-09	9.900e-01	2.757e-17
1.500e-01	4.500e-01	1.000e-09	1.000e-06	5.000e-01	7.500e-01	2.531e-17
2.000e-01	5.000e-02	5.000e-04	1.000e-09	5.000e-02	1.000e-01	2.500e-17
5.500e-01	1.000e-08	2.000e-01	5.000e-06	5.000e-03	9.000e-01	2.475e-17
9.990e-01	1.000e-05	5.000e-08	5.000e-02	1.000e-03	9.900e-01	2.473e-17
9.900e-01	5.000e-06	9.990e-01	5.000e-04	1.000e-03	1.000e-05	2.473e-17
6.500e-01	6.000e-01	1.000e-07	2.500e-01	5.000e-07	5.000e-03	2.438e-17
6.500e-01	9.990e-01	5.000e-08	1.000e-08	3.000e-01	2.500e-01	2.435e-17
4.000e-01	1.000e-06	5.000e-01	1.500e-01	1.000e-09	8.000e-01	2.400e-17
4.000e-01	8.500e-01	1.000e-08	5.000e-08	2.000e-01	7.000e-01	2.380e-17
9.000e-01	1.000e-06	5.000e-06	5.000e-02	1.000e-01	1.000e-03	2.250e-17
1.000e-02	8.500e-01	1.000e-09	5.000e-06	7.500e-01	7.000e-01	2.231e-17
1.500e-01	6.500e-01	5.000e-08	1.000e-06	9.000e-01	5.000e-03	2.194e-17

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
1.500e-01	3.000e-01	1.000e-02	5.000e-08	9.500e-01	1.000e-06	2.138e-17
1.000e-01	8.500e-01	5.000e-08	9.990e-01	1.000e-01	5.000e-08	2.123e-17
1.500e-01	9.500e-01	5.000e-07	3.000e-01	9.900e-01	1.000e-09	2.116e-17
5.500e-01	1.000e-08	6.000e-01	5.000e-06	2.500e-01	5.000e-03	2.063e-17
3.000e-01	1.000e-05	4.500e-01	1.500e-01	1.000e-08	1.000e-02	2.025e-17
3.500e-01	3.500e-01	5.000e-04	1.000e-07	6.500e-01	5.000e-06	1.991e-17
9.990e-01	3.000e-01	6.500e-01	1.000e-09	9.900e-01	1.000e-07	1.929e-17
5.000e-05	4.000e-01	5.000e-08	7.000e-01	5.500e-01	5.000e-05	1.925e-17
1.000e-02	4.000e-01	9.500e-01	5.000e-09	1.000e-06	9.900e-01	1.881e-17
3.000e-01	5.000e-06	5.000e-02	1.000e-06	2.500e-01	1.000e-03	1.875e-17
9.990e-01	5.000e-02	7.500e-01	1.000e-03	5.000e-04	1.000e-09	1.873e-17
3.000e-01	7.500e-01	6.500e-01	5.000e-07	5.000e-02	5.000e-09	1.828e-17
1.000e-02	4.000e-01	1.000e-05	1.000e-02	4.500e-01	1.000e-07	1.800e-17
4.000e-01	1.000e-04	5.500e-01	5.000e-05	3.000e-01	5.000e-08	1.650e-17
1.000e-09	1.000e-03	5.000e-05	3.500e-01	9.500e-01	9.900e-01	1.646e-17
5.000e-03	1.000e-04	1.000e-05	7.500e-01	5.000e-06	8.500e-01	1.594e-17
9.900e-01	1.000e-01	1.000e-09	1.000e-06	4.000e-01	4.000e-01	1.584e-17
6.000e-01	1.000e-04	5.000e-01	5.000e-05	1.000e-05	1.000e-03	1.500e-17
1.000e-08	5.000e-02	1.000e-02	1.000e-05	3.500e-01	8.500e-01	1.488e-17
5.000e-05	3.500e-01	1.000e-08	2.000e-01	5.000e-04	8.500e-01	1.488e-17
5.000e-09	9.990e-01	3.000e-01	1.000e-07	6.500e-01	1.500e-01	1.461e-17
4.000e-01	5.000e-09	1.000e-07	3.000e-01	3.000e-01	7.500e-01	1.350e-17
4.000e-01	1.000e-06	5.000e-06	5.000e-05	3.000e-01	4.500e-01	1.350e-17
1.500e-01	9.000e-01	1.000e-03	1.000e-06	1.000e-05	1.000e-02	1.350e-17
3.000e-01	1.000e-08	9.900e-01	3.000e-01	1.000e-07	1.500e-01	1.337e-17
1.000e-08	1.000e-03	9.990e-01	5.000e-02	5.000e-05	5.000e-01	1.249e-17
5.000e-09	5.000e-07	5.000e-02	1.500e-01	9.990e-01	6.500e-01	1.218e-17
9.000e-01	1.000e-06	7.500e-01	5.000e-06	1.000e-05	3.500e-01	1.181e-17

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
1.000e-08	8.500e-01	5.500e-01	5.000e-09	6.500e-01	7.500e-01	1.140e-17
1.000e-05	5.000e-03	5.000e-02	4.500e-01	1.000e-08	9.900e-01	1.114e-17
5.500e-01	1.000e-01	5.000e-08	4.000e-01	1.000e-07	1.000e-01	1.100e-17
1.000e-08	4.500e-01	1.000e-08	4.000e-01	6.000e-01	9.900e-01	1.069e-17
1.500e-01	5.000e-07	1.000e-04	3.000e-01	9.500e-01	5.000e-06	1.069e-17
4.000e-01	1.000e-01	5.000e-05	1.000e-06	1.000e-01	5.000e-05	1.000e-17
1.000e-04	5.000e-06	2.000e-01	5.000e-05	5.000e-03	4.000e-01	1.000e-17
7.500e-01	7.000e-01	9.500e-01	5.000e-08	1.000e-09	4.000e-01	9.975e-18
7.500e-01	5.000e-07	1.000e-09	3.500e-01	3.000e-01	2.500e-01	9.844e-18
6.500e-01	7.500e-01	5.000e-08	1.000e-05	7.500e-01	5.000e-05	9.141e-18
5.000e-05	5.000e-07	1.000e-04	5.000e-03	9.500e-01	7.500e-01	8.906e-18
9.990e-01	7.000e-01	5.000e-04	5.000e-07	5.000e-02	1.000e-06	8.741e-18
2.000e-01	5.000e-07	1.000e-02	5.000e-08	2.000e-01	8.500e-01	8.500e-18
2.000e-01	8.000e-01	5.000e-08	5.000e-08	2.000e-01	1.000e-01	8.000e-18
1.000e-07	4.000e-01	4.000e-01	1.000e-05	9.990e-01	5.000e-05	7.992e-18
1.000e-01	5.000e-09	4.500e-01	7.000e-01	1.000e-05	5.000e-03	7.875e-18
1.000e-03	6.000e-01	7.500e-01	1.000e-08	3.500e-01	5.000e-06	7.875e-18
1.000e-05	6.000e-01	5.000e-08	5.000e-04	5.000e-01	1.000e-01	7.500e-18
5.000e-01	3.000e-01	1.000e-07	1.000e-02	1.000e-01	5.000e-07	7.500e-18
1.000e-03	4.000e-01	5.000e-02	5.000e-06	1.000e-07	7.500e-01	7.500e-18
8.500e-01	1.000e-06	1.000e-01	8.000e-01	1.000e-04	1.000e-06	6.800e-18
1.000e-09	4.500e-01	1.000e-05	9.900e-01	3.000e-01	5.000e-03	6.683e-18
1.000e-09	4.500e-01	7.500e-01	5.000e-08	4.000e-01	9.900e-01	6.683e-18
5.000e-06	3.500e-01	5.000e-06	3.000e-01	5.000e-01	5.000e-06	6.563e-18
5.000e-05	1.000e-09	6.500e-01	1.000e-02	4.000e-01	5.000e-02	6.500e-18
5.000e-05	5.000e-09	9.990e-01	5.000e-03	5.000e-03	9.990e-01	6.238e-18
9.500e-01	5.000e-07	1.000e-05	2.000e-01	1.000e-05	6.500e-01	6.175e-18
3.000e-01	4.000e-01	5.000e-09	4.500e-01	5.000e-08	4.500e-01	6.075e-18

Probability of						
Missouri River Input	Transfer to Control System	Control System Failure	Establishing a Sustainable Population	Intersection of Transferred Biota & Receptor	Expression of Adverse Effect in Receptor	Outcome as "Successful Invasion"
4.000e-01	4.000e-01	5.000e-09	1.500e-01	1.000e-02	5.000e-06	6.000e-18
4.000e-01	3.000e-01	5.000e-06	1.000e-08	9.500e-01	1.000e-03	5.700e-18
5.000e-03	6.000e-01	5.000e-04	1.000e-05	5.000e-07	7.500e-01	5.625e-18
2.500e-01	5.000e-07	2.000e-01	5.000e-05	1.000e-05	4.500e-01	5.625e-18
5.500e-01	5.000e-05	5.000e-04	1.000e-06	4.000e-01	1.000e-03	5.500e-18
4.000e-01	4.500e-01	5.000e-08	7.500e-01	5.000e-09	1.500e-01	5.063e-18
4.000e-01	1.000e-05	5.000e-05	1.000e-03	5.000e-04	5.000e-02	5.000e-18
5.000e-06	5.000e-02	1.000e-04	7.500e-01	5.000e-05	5.000e-03	4.688e-18
5.000e-09	9.000e-01	5.000e-07	1.000e-01	4.000e-01	5.000e-02	4.500e-18
5.000e-05	9.990e-01	1.000e-09	1.000e-02	9.000e-01	1.000e-02	4.496e-18
4.500e-01	1.000e-04	9.990e-01	1.000e-06	9.500e-01	1.000e-07	4.271e-18
2.500e-01	6.500e-01	1.000e-05	5.000e-06	1.000e-03	5.000e-04	4.063e-18
1.000e-09	5.000e-07	9.500e-01	5.000e-02	8.500e-01	2.000e-01	4.038e-18
5.000e-05	5.000e-02	4.500e-01	1.000e-06	5.000e-06	7.000e-01	3.938e-18
1.500e-01	1.000e-01	1.000e-02	1.000e-07	5.000e-03	5.000e-05	3.750e-18
5.000e-06	1.000e-04	7.500e-01	5.000e-08	2.000e-01	9.900e-01	3.713e-18
9.990e-01	8.500e-01	5.000e-08	1.000e-03	1.000e-07	8.500e-01	3.609e-18
1.000e-03	5.000e-07	2.500e-01	8.000e-01	5.000e-08	7.000e-01	3.500e-18
1.000e-05	9.990e-01	1.000e-06	7.000e-01	1.000e-01	5.000e-06	3.497e-18
3.500e-01	5.000e-09	4.000e-01	9.000e-01	5.500e-01	1.000e-08	3.465e-18
1.500e-01	5.000e-05	4.000e-01	5.000e-06	5.000e-07	4.500e-01	3.375e-18
8.000e-01	6.000e-01	5.000e-08	2.000e-01	1.000e-09	7.000e-01	3.360e-18
5.000e-06	8.000e-01	5.000e-05	5.000e-01	5.000e-08	6.500e-01	3.250e-18
1.000e-07	2.500e-01	4.000e-01	1.000e-03	5.000e-07	6.500e-01	3.250e-18
3.000e-01	1.000e-09	6.500e-01	3.500e-01	9.500e-01	5.000e-08	3.242e-18
5.500e-01	1.500e-01	1.000e-07	1.500e-01	5.000e-04	5.000e-06	3.094e-18
7.500e-01	1.000e-08	7.500e-01	5.000e-02	1.000e-01	1.000e-07	2.813e-18
2.500e-01	6.000e-01	5.000e-08	1.000e-05	7.500e-01	5.000e-05	2.813e-18

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
3.000e-01	8.000e-01	5.000e-08	1.000e-07	4.500e-01	5.000e-03	2.700e-18
5.000e-03	7.500e-01	5.000e-07	4.000e-01	1.000e-08	3.500e-01	2.625e-18
1.500e-01	4.000e-01	5.000e-05	1.000e-06	1.000e-06	8.500e-01	2.550e-18
5.000e-05	1.000e-07	4.500e-01	5.000e-05	4.500e-01	5.000e-02	2.531e-18
9.500e-01	5.000e-09	5.000e-01	1.000e-06	5.000e-03	2.000e-01	2.375e-18
9.000e-01	1.000e-02	5.000e-08	7.500e-01	1.000e-08	7.000e-01	2.363e-18
1.000e-05	1.000e-06	7.000e-01	1.500e-01	4.500e-01	5.000e-06	2.363e-18
1.000e-02	5.000e-06	5.000e-04	7.500e-01	5.000e-07	2.500e-01	2.344e-18
4.000e-01	5.000e-05	5.000e-02	1.000e-07	4.500e-01	5.000e-05	2.250e-18
1.500e-01	1.000e-07	5.000e-02	1.000e-03	5.000e-06	6.000e-01	2.250e-18
1.000e-02	1.000e-05	7.500e-01	3.000e-01	1.000e-02	1.000e-08	2.250e-18
8.000e-01	1.000e-07	1.000e-09	2.000e-01	3.500e-01	4.000e-01	2.240e-18
5.000e-02	5.000e-04	5.000e-07	1.000e-03	3.500e-01	5.000e-04	2.188e-18
9.500e-01	6.500e-01	7.000e-01	1.000e-07	1.000e-05	5.000e-06	2.161e-18
4.000e-01	8.500e-01	5.000e-09	5.000e-07	5.000e-01	5.000e-03	2.125e-18
1.000e-05	4.000e-01	5.000e-07	3.000e-01	1.000e-05	3.500e-01	2.100e-18
5.000e-06	6.000e-01	1.000e-02	5.000e-05	5.000e-06	2.500e-01	1.875e-18
1.000e-05	1.000e-01	1.500e-01	5.000e-04	5.000e-04	5.000e-05	1.875e-18
5.000e-06	5.000e-03	2.500e-01	1.500e-01	1.000e-08	2.000e-01	1.875e-18
5.000e-05	1.500e-01	5.000e-02	5.000e-08	1.000e-02	1.000e-02	1.875e-18
5.000e-06	1.000e-03	5.000e-08	3.000e-01	1.000e-01	2.500e-01	1.875e-18
3.000e-01	5.000e-09	9.900e-01	2.500e-01	1.000e-07	5.000e-02	1.856e-18
1.000e-01	1.000e-09	5.000e-08	5.500e-01	9.500e-01	7.000e-01	1.829e-18
1.000e-05	3.000e-01	6.500e-01	9.000e-01	1.000e-09	1.000e-03	1.755e-18
5.500e-01	7.500e-01	1.000e-07	1.000e-06	5.000e-05	8.500e-01	1.753e-18
1.000e-07	1.000e-09	8.500e-01	9.990e-01	2.000e-01	1.000e-01	1.698e-18
1.000e-09	1.000e-05	5.000e-01	5.000e-03	4.500e-01	1.500e-01	1.688e-18
5.500e-01	6.000e-01	5.000e-07	9.900e-01	1.000e-07	1.000e-04	1.634e-18

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
1.000e-06	1.000e-07	1.000e-02	6.500e-01	1.000e-02	2.500e-01	1.625e-18
9.990e-01	8.500e-01	5.000e-08	1.500e-01	5.000e-06	5.000e-05	1.592e-18
1.500e-01	1.000e-04	1.000e-04	1.000e-01	2.000e-01	5.000e-08	1.500e-18
4.000e-01	5.000e-07	1.000e-06	3.000e-01	5.000e-05	5.000e-01	1.500e-18
1.000e-05	1.500e-01	5.000e-04	1.000e-08	9.900e-01	2.000e-01	1.485e-18
1.000e-08	8.500e-01	4.000e-01	1.000e-03	5.000e-07	8.500e-01	1.445e-18
9.500e-01	1.000e-05	5.000e-07	1.000e-03	3.000e-01	1.000e-03	1.425e-18
1.000e-09	1.000e-08	8.000e-01	2.500e-01	9.900e-01	7.000e-01	1.386e-18
1.000e-05	5.500e-01	5.000e-04	5.000e-02	9.500e-01	1.000e-08	1.306e-18
5.000e-02	2.000e-01	5.000e-08	5.000e-01	5.000e-07	1.000e-02	1.250e-18
2.500e-01	5.000e-07	5.000e-08	5.000e-04	4.000e-01	9.900e-01	1.238e-18
5.000e-02	1.000e-05	6.500e-01	5.000e-05	5.000e-07	1.500e-01	1.219e-18
1.000e-07	5.000e-06	6.000e-01	1.000e-03	8.000e-01	5.000e-03	1.200e-18
1.000e-04	8.000e-01	5.000e-09	1.000e-05	3.500e-01	8.500e-01	1.190e-18
5.000e-03	1.000e-04	5.000e-02	1.000e-09	9.500e-01	5.000e-02	1.188e-18
9.500e-01	1.000e-05	5.000e-03	5.000e-02	1.000e-07	5.000e-03	1.188e-18
4.000e-01	1.000e-09	5.000e-08	4.000e-01	9.500e-01	1.500e-01	1.140e-18
9.500e-01	9.500e-01	5.000e-08	5.000e-08	5.000e-04	9.990e-01	1.127e-18
1.000e-07	5.000e-02	7.500e-01	6.000e-01	1.000e-06	5.000e-04	1.125e-18
7.500e-01	1.000e-07	3.000e-01	5.000e-06	9.500e-01	1.000e-05	1.069e-18
5.000e-06	5.000e-07	5.000e-05	8.500e-01	2.000e-01	5.000e-02	1.063e-18
1.000e-09	1.000e-04	1.500e-01	1.000e-03	1.000e-01	7.000e-01	1.050e-18
1.500e-01	3.500e-01	5.000e-08	6.000e-01	1.000e-09	6.500e-01	1.024e-18
1.000e-01	1.000e-05	5.000e-05	5.000e-05	4.000e-01	1.000e-03	1.000e-18
1.000e-03	1.000e-03	1.000e-03	1.000e-03	1.000e-03	1.000e-03	1.000e-18
5.000e-05	5.000e-04	8.500e-01	5.000e-06	9.000e-01	1.000e-05	9.563e-19
1.000e-03	1.000e-04	9.500e-01	1.000e-03	9.900e-01	1.000e-08	9.405e-19
5.000e-09	1.000e-01	7.500e-01	9.900e-01	5.000e-05	5.000e-05	9.281e-19

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
1.500e-01	3.000e-01	1.000e-05	5.000e-06	5.000e-07	8.000e-01	9.000e-19
1.000e-03	4.500e-01	5.000e-08	5.000e-06	1.000e-02	8.000e-01	9.000e-19
3.000e-01	5.000e-07	5.000e-05	5.000e-06	1.500e-01	1.500e-01	8.438e-19
5.000e-06	5.000e-06	6.500e-01	2.500e-01	5.000e-07	4.000e-01	8.125e-19
5.000e-02	4.000e-01	5.000e-06	1.000e-03	8.000e-01	1.000e-08	8.000e-19
1.000e-09	1.000e-07	2.500e-01	3.500e-01	1.000e-01	9.000e-01	7.875e-19
4.500e-01	3.500e-01	1.000e-08	5.000e-06	9.900e-01	1.000e-04	7.796e-19
1.000e-04	1.000e-03	2.000e-01	5.000e-04	7.500e-01	1.000e-07	7.500e-19
1.000e-08	4.500e-01	2.000e-01	1.000e-09	9.500e-01	8.500e-01	7.268e-19
6.500e-01	5.000e-07	4.500e-01	5.000e-06	9.900e-01	1.000e-06	7.239e-19
5.000e-01	3.500e-01	1.000e-02	1.000e-08	4.000e-01	1.000e-07	7.000e-19
5.500e-01	2.500e-01	1.000e-08	5.000e-02	9.990e-01	1.000e-08	6.868e-19
1.500e-01	4.500e-01	5.000e-08	2.000e-01	1.000e-01	1.000e-08	6.750e-19
1.000e-05	1.000e-05	6.000e-01	2.500e-01	1.000e-07	4.500e-01	6.750e-19
5.000e-05	9.000e-01	5.000e-06	1.000e-02	1.000e-06	3.000e-01	6.750e-19
3.500e-01	5.000e-09	1.000e-07	1.000e-02	4.500e-01	8.500e-01	6.694e-19
1.000e-03	1.000e-08	4.000e-01	3.500e-01	9.500e-01	5.000e-07	6.650e-19
1.000e-07	5.000e-06	1.000e-04	1.500e-01	3.500e-01	2.500e-01	6.563e-19
1.000e-06	7.000e-01	7.500e-01	5.000e-06	5.000e-05	5.000e-03	6.563e-19
5.000e-01	1.000e-05	1.500e-01	1.000e-07	1.000e-05	8.500e-01	6.375e-19
1.000e-08	6.500e-01	6.500e-01	3.000e-01	1.000e-07	5.000e-03	6.338e-19
1.000e-01	5.000e-02	5.000e-02	5.000e-04	5.000e-09	1.000e-03	6.250e-19
5.000e-05	5.000e-07	2.000e-01	3.500e-01	1.000e-06	3.500e-01	6.125e-19
1.000e-05	1.000e-06	4.000e-01	5.000e-06	2.000e-01	1.500e-01	6.000e-19
5.000e-05	6.000e-01	8.500e-01	1.000e-08	4.500e-01	5.000e-06	5.738e-19
1.000e-05	5.000e-07	3.000e-01	5.000e-04	7.500e-01	1.000e-03	5.625e-19
7.500e-01	6.000e-01	5.000e-08	1.000e-03	5.000e-07	5.000e-02	5.625e-19
8.000e-01	1.500e-01	5.000e-06	1.000e-05	1.000e-07	9.000e-01	5.400e-19

Probability of						
Missouri River Input	Transfer to Control System	Control System Failure	Establishing a Sustainable Population	Intersection of Transferred Biota & Receptor	Expression of Adverse Effect in Receptor	Outcome as "Successful Invasion"
5.000e-05	5.000e-07	1.000e-02	5.000e-06	9.500e-01	4.500e-01	5.344e-19
1.500e-01	5.500e-01	5.000e-02	5.000e-07	5.000e-05	5.000e-06	5.156e-19
1.000e-03	9.990e-01	8.500e-01	6.000e-01	1.000e-07	1.000e-08	5.095e-19
5.000e-02	4.500e-01	1.000e-05	5.000e-09	4.500e-01	1.000e-03	5.063e-19
1.000e-09	7.500e-01	3.000e-01	9.000e-01	5.000e-05	5.000e-05	5.063e-19
4.000e-01	5.000e-05	2.000e-01	1.000e-06	5.000e-07	2.500e-01	5.000e-19
1.000e-04	5.000e-07	5.000e-01	8.000e-01	5.000e-01	5.000e-08	5.000e-19
9.900e-01	1.000e-06	2.000e-01	5.000e-01	1.000e-05	5.000e-07	4.950e-19
1.000e-01	1.000e-03	5.000e-07	1.000e-06	9.900e-01	1.000e-02	4.950e-19
1.000e-03	5.000e-07	2.000e-01	1.000e-04	9.500e-01	5.000e-05	4.750e-19
5.000e-05	1.000e-03	5.000e-05	7.500e-01	5.000e-03	5.000e-05	4.688e-19
4.000e-01	6.000e-01	5.000e-05	5.000e-06	7.500e-01	1.000e-08	4.500e-19
9.990e-01	1.000e-09	6.000e-01	7.500e-01	9.990e-01	1.000e-09	4.491e-19
1.500e-01	5.000e-07	1.000e-08	1.000e-03	9.900e-01	6.000e-01	4.455e-19
3.500e-01	5.000e-06	5.000e-02	1.000e-07	5.000e-03	1.000e-02	4.375e-19
1.000e-04	1.000e-01	5.000e-02	1.000e-07	1.000e-05	8.500e-01	4.250e-19
9.990e-01	8.500e-01	1.000e-05	1.000e-05	5.000e-07	1.000e-02	4.246e-19
5.000e-01	4.500e-01	5.000e-02	5.000e-08	1.500e-01	5.000e-09	4.219e-19
1.500e-01	5.000e-07	3.000e-01	7.500e-01	5.000e-07	5.000e-05	4.219e-19
5.000e-04	5.000e-09	5.000e-06	1.500e-01	4.500e-01	4.500e-01	3.797e-19
9.000e-01	1.000e-09	5.000e-08	2.000e-01	1.000e-01	4.000e-01	3.600e-19
1.000e-02	5.000e-07	9.500e-01	1.000e-07	7.500e-01	1.000e-03	3.563e-19
6.500e-01	8.500e-01	5.000e-06	5.000e-08	5.000e-05	5.000e-02	3.453e-19
2.500e-01	1.000e-08	8.500e-01	5.000e-07	6.500e-01	5.000e-04	3.453e-19
1.000e-04	1.000e-09	2.000e-01	7.500e-01	4.500e-01	5.000e-05	3.375e-19
9.500e-01	1.000e-06	1.000e-05	2.000e-01	5.000e-07	3.500e-01	3.325e-19
5.000e-07	1.000e-03	7.500e-01	1.000e-08	8.500e-01	1.000e-01	3.188e-19
1.000e-08	3.500e-01	4.000e-01	5.000e-03	9.000e-01	5.000e-08	3.150e-19

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
4.000e-01	5.000e-07	1.000e-08	7.000e-01	4.000e-01	5.000e-04	2.800e-19
5.000e-05	6.000e-01	2.000e-01	1.000e-08	4.500e-01	1.000e-05	2.700e-19
1.000e-01	5.000e-02	9.500e-01	1.000e-09	1.000e-07	5.500e-01	2.613e-19
1.000e-08	1.500e-01	1.000e-08	1.000e-01	8.000e-01	2.000e-01	2.400e-19
1.000e-02	1.000e-05	1.000e-05	3.000e-01	8.000e-01	1.000e-06	2.400e-19
1.000e-04	4.500e-01	1.000e-05	1.000e-08	2.000e-01	2.500e-01	2.250e-19
5.000e-06	3.000e-01	7.500e-01	1.000e-05	4.000e-01	5.000e-08	2.250e-19
1.000e-07	4.500e-01	1.000e-05	5.000e-01	9.500e-01	1.000e-06	2.138e-19
9.990e-01	5.000e-07	1.000e-05	8.500e-01	1.000e-05	5.000e-03	2.123e-19
1.000e-09	1.000e-05	1.000e-03	5.000e-02	6.500e-01	6.000e-01	1.950e-19
9.000e-01	1.000e-02	4.500e-01	5.000e-08	9.500e-01	1.000e-09	1.924e-19
5.500e-01	1.000e-06	4.500e-01	1.000e-03	7.500e-01	1.000e-09	1.856e-19
1.000e-07	4.500e-01	9.990e-01	1.000e-06	5.000e-06	8.000e-01	1.798e-19
5.500e-01	1.000e-05	1.000e-05	1.000e-06	6.500e-01	5.000e-03	1.788e-19
1.000e-01	1.000e-01	3.500e-01	5.000e-08	1.000e-09	9.900e-01	1.733e-19
5.000e-09	6.000e-01	1.500e-01	7.500e-01	1.000e-07	5.000e-03	1.688e-19
7.500e-01	8.500e-01	1.000e-05	1.000e-06	5.000e-07	5.000e-02	1.594e-19
1.000e-05	7.500e-01	5.000e-06	5.000e-08	8.000e-01	1.000e-01	1.500e-19
2.500e-01	5.000e-07	7.500e-01	6.000e-01	5.000e-07	5.000e-06	1.406e-19
5.000e-08	1.000e-05	5.000e-02	8.000e-01	7.000e-01	1.000e-05	1.400e-19
5.000e-05	8.500e-01	5.000e-09	2.500e-01	5.000e-04	5.000e-03	1.328e-19
3.500e-01	1.000e-09	5.000e-06	5.000e-02	1.500e-01	1.000e-02	1.313e-19
5.000e-06	1.000e-04	6.500e-01	5.000e-08	8.000e-01	1.000e-02	1.300e-19
9.990e-01	5.000e-07	1.000e-01	1.000e-05	5.000e-01	5.000e-07	1.249e-19
9.500e-01	5.500e-01	5.000e-09	5.000e-08	1.000e-03	9.500e-01	1.241e-19
1.000e-04	7.000e-01	2.000e-01	5.000e-07	5.000e-08	3.500e-01	1.225e-19
8.500e-01	1.000e-05	9.500e-01	1.000e-08	1.000e-05	1.500e-01	1.211e-19
3.000e-01	1.000e-04	8.000e-01	5.000e-03	1.000e-09	1.000e-03	1.200e-19

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
1.000e-09	6.000e-01	4.000e-01	1.000e-02	9.900e-01	5.000e-08	1.188e-19
5.000e-02	1.000e-09	5.000e-03	1.000e-05	4.500e-01	1.000e-01	1.125e-19
1.000e-02	1.000e-04	7.500e-01	1.000e-06	1.000e-06	1.500e-01	1.125e-19
3.000e-01	3.000e-01	5.000e-04	5.000e-07	1.000e-05	5.000e-04	1.125e-19
9.990e-01	1.500e-01	3.000e-01	5.000e-08	1.000e-05	5.000e-06	1.124e-19
1.000e-08	4.500e-01	5.000e-08	5.000e-03	6.500e-01	1.500e-01	1.097e-19
9.500e-01	5.000e-09	7.500e-01	6.000e-01	5.000e-06	1.000e-05	1.069e-19
1.000e-05	1.000e-01	3.000e-01	7.000e-01	5.000e-09	1.000e-04	1.050e-19
5.000e-05	1.000e-04	1.000e-05	4.000e-01	1.000e-01	5.000e-05	1.000e-19
4.000e-01	5.000e-06	1.000e-02	9.900e-01	1.000e-06	5.000e-06	9.900e-20
4.000e-01	1.000e-09	7.500e-01	1.000e-04	6.500e-01	5.000e-06	9.750e-20
9.990e-01	5.000e-09	1.000e-02	3.000e-01	1.000e-08	6.500e-01	9.740e-20
1.000e-09	5.000e-05	2.000e-01	2.000e-01	9.500e-01	5.000e-05	9.500e-20
9.500e-01	9.500e-01	4.000e-01	5.000e-06	5.000e-08	1.000e-06	9.025e-20
5.000e-06	1.000e-05	1.000e-02	5.000e-07	9.990e-01	3.500e-01	8.741e-20
5.000e-06	1.000e-08	7.500e-01	5.000e-06	4.500e-01	9.900e-01	8.353e-20
4.000e-01	4.000e-01	1.000e-05	1.000e-07	9.500e-01	5.000e-07	7.600e-20
5.500e-01	8.500e-01	5.000e-06	1.000e-05	5.000e-09	6.500e-01	7.597e-20
5.000e-05	5.000e-07	5.000e-08	2.000e-01	4.000e-01	7.500e-01	7.500e-20
2.500e-01	4.000e-01	1.000e-07	1.000e-06	1.500e-01	5.000e-05	7.500e-20
9.990e-01	5.000e-09	7.500e-01	1.000e-06	4.000e-01	5.000e-05	7.493e-20
3.000e-01	1.000e-06	1.000e-04	5.000e-07	5.000e-03	9.990e-01	7.493e-20
3.500e-01	1.000e-07	5.000e-05	5.000e-05	7.500e-01	1.000e-03	6.563e-20
5.000e-03	1.000e-08	7.500e-01	5.000e-08	1.000e-01	3.500e-01	6.563e-20
1.000e-01	3.500e-01	7.500e-01	5.000e-06	1.000e-07	5.000e-06	6.563e-20
5.000e-05	4.500e-01	7.500e-01	5.000e-07	1.500e-01	5.000e-08	6.328e-20
9.500e-01	7.000e-01	5.000e-08	7.500e-01	5.000e-07	5.000e-06	6.234e-20
5.000e-06	7.500e-01	1.000e-02	5.000e-08	6.500e-01	5.000e-05	6.094e-20

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
5.000e-06	5.500e-01	5.000e-08	6.000e-01	1.000e-06	7.000e-01	5.775e-20
5.500e-01	5.000e-09	1.000e-04	1.000e-03	1.000e-03	2.000e-01	5.500e-20
5.000e-09	4.000e-01	6.500e-01	1.000e-06	8.000e-01	5.000e-05	5.200e-20
1.000e-01	1.000e-01	5.000e-09	1.000e-08	9.500e-01	1.000e-01	4.750e-20
5.000e-09	4.500e-01	1.000e-02	9.990e-01	2.000e-01	1.000e-08	4.496e-20
5.000e-06	7.500e-01	3.500e-01	1.000e-07	5.000e-07	6.500e-01	4.266e-20
5.000e-05	5.000e-09	4.500e-01	3.500e-01	5.000e-06	2.000e-01	3.938e-20
1.000e-01	5.000e-07	5.000e-02	3.000e-01	5.000e-07	1.000e-04	3.750e-20
1.000e-09	5.000e-05	5.000e-02	3.000e-01	9.990e-01	5.000e-05	3.746e-20
9.990e-01	1.000e-06	5.000e-08	3.000e-01	5.000e-01	5.000e-06	3.746e-20
1.000e-03	8.500e-01	1.000e-01	1.000e-08	5.000e-08	8.500e-01	3.613e-20
5.000e-06	9.000e-01	5.000e-06	5.000e-06	1.000e-03	3.000e-01	3.375e-20
4.000e-01	1.000e-04	5.000e-07	7.000e-01	5.000e-09	4.500e-01	3.150e-20
5.000e-02	5.000e-09	5.000e-06	2.000e-01	2.500e-01	5.000e-04	3.125e-20
8.000e-01	7.500e-01	1.000e-07	5.000e-04	2.000e-01	5.000e-09	3.000e-20
8.000e-01	1.500e-01	5.000e-08	5.000e-08	1.000e-01	1.000e-03	3.000e-20
4.000e-01	3.000e-01	1.000e-07	1.000e-08	2.500e-01	1.000e-03	3.000e-20
6.500e-01	1.000e-09	5.000e-08	1.000e-02	2.500e-01	3.500e-01	2.844e-20
5.000e-09	5.000e-02	1.500e-01	5.000e-05	3.000e-01	5.000e-05	2.813e-20
5.000e-05	1.000e-06	1.500e-01	7.500e-01	1.000e-07	5.000e-02	2.813e-20
1.000e-05	5.000e-07	7.500e-01	1.000e-06	1.000e-02	7.000e-01	2.625e-20
1.000e-09	9.990e-01	1.000e-03	5.000e-05	1.000e-01	5.000e-03	2.498e-20
1.000e-07	7.000e-01	7.000e-01	1.000e-07	1.000e-04	5.000e-02	2.450e-20
5.000e-06	1.000e-08	5.500e-01	5.000e-02	5.000e-05	3.500e-01	2.406e-20
5.000e-09	1.000e-04	3.000e-01	1.000e-06	7.500e-01	2.000e-01	2.250e-20
8.500e-01	5.000e-07	5.000e-08	4.000e-01	5.000e-01	5.000e-06	2.125e-20
3.000e-01	7.000e-01	5.000e-08	8.000e-01	5.000e-07	5.000e-06	2.100e-20
6.000e-01	1.000e-03	1.000e-04	1.000e-07	3.500e-01	1.000e-05	2.100e-20

Probability of						
Missouri River Input	Transfer to Control System	Control System Failure	Establishing a Sustainable Population	Intersection of Transferred Biota & Receptor	Expression of Adverse Effect in Receptor	Outcome as "Successful Invasion"
1.500e-01	5.000e-09	5.000e-06	3.500e-01	3.000e-01	5.000e-05	1.969e-20
1.000e-08	1.000e-06	4.500e-01	8.500e-01	1.000e-03	5.000e-03	1.913e-20
4.500e-01	1.000e-08	2.000e-01	2.000e-01	1.000e-04	1.000e-06	1.800e-20
1.500e-01	7.500e-01	1.000e-09	4.000e-01	1.000e-09	4.000e-01	1.800e-20
9.500e-01	1.000e-05	1.000e-02	3.500e-01	1.000e-07	5.000e-06	1.663e-20
5.000e-03	1.000e-02	1.000e-04	1.000e-07	6.500e-01	5.000e-05	1.625e-20
1.000e-09	4.000e-01	1.000e-07	2.000e-01	2.000e-01	1.000e-02	1.600e-20
5.000e-04	5.000e-04	5.000e-04	5.000e-04	5.000e-04	5.000e-04	1.563e-20
1.000e-04	1.000e-04	1.000e-02	3.000e-01	5.000e-07	1.000e-03	1.500e-20
3.000e-01	5.000e-06	9.900e-01	1.000e-07	1.000e-04	1.000e-03	1.485e-20
5.000e-01	1.000e-04	5.000e-08	8.000e-01	6.500e-01	1.000e-08	1.300e-20
5.500e-01	1.000e-09	9.000e-01	5.000e-07	9.900e-01	5.000e-05	1.225e-20
5.000e-01	5.000e-09	5.000e-07	1.000e-03	9.500e-01	1.000e-02	1.188e-20
5.500e-01	8.500e-01	1.000e-08	1.000e-03	5.000e-04	5.000e-06	1.169e-20
2.500e-01	1.000e-05	5.000e-02	1.000e-06	1.000e-07	9.000e-01	1.125e-20
9.500e-01	5.000e-07	1.000e-09	5.000e-03	4.000e-01	1.000e-02	9.500e-21
9.500e-01	5.000e-02	5.000e-07	4.000e-01	1.000e-09	1.000e-03	9.500e-21
5.000e-05	6.000e-01	5.000e-05	5.000e-06	5.000e-06	2.500e-01	9.375e-21
5.000e-01	1.000e-06	5.000e-06	1.500e-01	1.000e-07	2.500e-01	9.375e-21
5.000e-01	5.000e-07	5.000e-05	1.000e-07	1.500e-01	5.000e-02	9.375e-21
5.000e-06	4.000e-01	1.000e-02	4.500e-01	1.000e-06	1.000e-06	9.000e-21
9.990e-01	5.000e-07	9.990e-01	5.000e-08	3.500e-01	1.000e-06	8.733e-21
1.000e-06	8.500e-01	1.000e-02	1.000e-06	1.000e-06	9.900e-01	8.415e-21
4.000e-01	1.000e-06	5.000e-08	8.000e-01	1.000e-01	5.000e-06	8.000e-21
5.000e-02	1.000e-04	7.500e-01	4.000e-01	1.000e-08	5.000e-07	7.500e-21
5.000e-05	1.000e-09	5.000e-07	4.500e-01	9.500e-01	7.000e-01	7.481e-21
1.000e-09	7.000e-01	4.500e-01	5.000e-05	5.000e-07	9.500e-01	7.481e-21
1.000e-03	5.000e-07	1.000e-02	3.000e-01	1.000e-08	4.500e-01	6.750e-21

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
4.000e-01	1.000e-09	1.000e-08	6.000e-01	5.500e-01	5.000e-03	6.600e-21
6.500e-01	1.000e-08	1.000e-06	4.000e-01	5.000e-01	5.000e-06	6.500e-21
9.990e-01	5.000e-02	5.000e-02	5.000e-06	5.000e-08	1.000e-05	6.244e-21
1.500e-01	5.000e-09	1.000e-08	3.000e-01	5.500e-01	5.000e-03	6.188e-21
4.000e-01	3.000e-01	1.000e-04	1.000e-07	5.000e-06	1.000e-03	6.000e-21
4.000e-01	9.990e-01	1.000e-04	5.000e-08	3.000e-01	1.000e-08	5.994e-21
2.000e-01	8.500e-01	1.000e-05	5.000e-08	1.000e-07	7.000e-01	5.950e-21
5.000e-05	4.500e-01	1.000e-05	5.000e-02	1.000e-04	5.000e-06	5.625e-21
7.500e-01	5.000e-09	1.000e-02	6.000e-01	5.000e-05	5.000e-06	5.625e-21
1.000e-07	3.000e-01	1.000e-08	7.500e-01	5.000e-01	5.000e-05	5.625e-21
5.000e-02	6.000e-01	5.000e-08	7.500e-01	5.000e-06	1.000e-06	5.625e-21
3.500e-01	1.000e-04	3.000e-01	5.000e-04	1.000e-09	1.000e-03	5.250e-21
1.000e-01	3.000e-01	1.000e-02	3.500e-01	1.000e-08	5.000e-09	5.250e-21
4.000e-01	1.000e-06	5.000e-05	3.500e-01	1.500e-01	5.000e-09	5.250e-21
1.500e-01	1.000e-09	1.500e-01	4.500e-01	1.000e-05	5.000e-05	5.063e-21
5.000e-05	1.000e-05	1.000e-05	1.000e-03	1.000e-01	1.000e-02	5.000e-21
5.000e-06	5.000e-06	2.000e-01	1.000e-07	9.990e-01	1.000e-02	4.995e-21
5.000e-05	7.500e-01	5.000e-09	9.900e-01	5.000e-05	5.000e-04	4.641e-21
1.000e-09	1.000e-03	4.500e-01	5.000e-06	1.000e-02	2.000e-01	4.500e-21
5.000e-05	5.000e-02	5.000e-08	1.000e-03	7.000e-01	5.000e-05	4.375e-21
5.000e-06	1.000e-01	5.000e-05	1.000e-02	3.500e-01	5.000e-08	4.375e-21
5.000e-06	1.000e-09	8.500e-01	1.000e-03	1.000e-03	9.500e-01	4.038e-21
2.000e-01	5.000e-09	5.000e-05	1.000e-06	1.000e-01	8.000e-01	4.000e-21
1.000e-05	7.500e-01	1.000e-04	1.000e-06	1.000e-03	5.000e-03	3.750e-21
1.000e-04	1.000e-08	7.500e-01	1.000e-05	5.000e-04	9.900e-01	3.713e-21
1.000e-09	4.500e-01	5.000e-05	7.000e-01	5.000e-07	4.500e-01	3.544e-21
5.000e-06	1.000e-01	1.000e-07	2.000e-01	5.000e-07	7.000e-01	3.500e-21
1.000e-07	9.990e-01	1.000e-05	5.000e-07	7.000e-01	1.000e-02	3.497e-21

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
5.000e-09	1.000e-02	7.500e-01	5.000e-06	3.500e-01	5.000e-05	3.281e-21
1.000e-08	5.000e-07	6.500e-01	9.990e-01	2.000e-01	5.000e-06	3.247e-21
5.000e-01	1.000e-05	5.000e-08	2.500e-01	1.000e-02	5.000e-06	3.125e-21
5.000e-08	1.000e-08	1.000e-03	3.500e-01	3.500e-01	5.000e-02	3.063e-21
1.000e-09	5.000e-02	1.000e-06	4.000e-01	3.000e-01	5.000e-04	3.000e-21
5.000e-03	1.000e-05	3.000e-01	1.000e-07	4.000e-01	5.000e-06	3.000e-21
1.000e-01	6.000e-01	5.000e-04	1.000e-07	1.000e-07	1.000e-02	3.000e-21
9.990e-01	5.000e-05	3.000e-01	1.000e-07	4.000e-01	5.000e-09	2.997e-21
1.000e-08	2.500e-01	1.000e-04	5.000e-07	4.500e-01	5.000e-02	2.813e-21
1.000e-09	4.500e-01	9.990e-01	5.000e-07	2.500e-01	5.000e-05	2.810e-21
5.000e-02	1.000e-09	1.000e-04	9.990e-01	5.000e-07	9.990e-01	2.495e-21
1.000e-09	5.000e-07	1.000e-02	5.000e-03	6.500e-01	1.500e-01	2.438e-21
8.000e-01	1.000e-05	1.000e-05	1.000e-03	3.000e-01	1.000e-07	2.400e-21
1.000e-07	1.000e-05	2.000e-01	6.000e-01	1.000e-07	2.000e-01	2.400e-21
7.500e-01	7.500e-01	1.000e-05	1.000e-08	1.000e-07	4.000e-01	2.250e-21
9.000e-01	1.000e-01	5.000e-06	5.000e-07	1.000e-08	9.990e-01	2.248e-21
1.000e-04	1.000e-05	8.500e-01	5.000e-04	1.000e-03	5.000e-06	2.125e-21
4.500e-01	4.500e-01	4.000e-01	5.000e-06	1.000e-06	5.000e-09	2.025e-21
9.000e-01	4.500e-01	1.000e-07	5.000e-08	1.000e-05	1.000e-01	2.025e-21
5.000e-02	1.000e-07	1.000e-02	1.000e-05	8.000e-01	5.000e-06	2.000e-21
1.000e-01	4.000e-01	4.000e-01	5.000e-08	5.000e-07	5.000e-06	2.000e-21
9.500e-01	1.000e-08	5.000e-04	1.000e-06	8.000e-01	5.000e-04	1.900e-21
1.000e-04	7.000e-01	5.000e-07	1.000e-06	9.500e-01	5.000e-05	1.663e-21
8.000e-01	6.500e-01	5.000e-08	2.500e-01	5.000e-05	5.000e-09	1.625e-21
1.000e-02	1.000e-05	1.000e-05	3.000e-01	5.000e-08	1.000e-01	1.500e-21
1.000e-09	1.000e-05	1.000e-04	3.000e-01	9.990e-01	5.000e-03	1.499e-21
1.000e-06	5.000e-06	1.000e-02	6.000e-01	9.990e-01	5.000e-08	1.499e-21
9.500e-01	1.000e-05	3.000e-01	5.000e-08	1.000e-07	1.000e-01	1.425e-21

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
1.000e-04	4.000e-01	1.000e-02	1.000e-06	5.000e-09	7.000e-01	1.400e-21
1.000e-07	5.500e-01	1.000e-05	1.000e-01	5.000e-05	5.000e-04	1.375e-21
8.000e-01	5.000e-09	5.000e-06	1.000e-06	6.500e-01	1.000e-01	1.300e-21
1.000e-04	4.000e-01	1.000e-04	1.000e-07	6.500e-01	5.000e-06	1.300e-21
1.000e-01	1.000e-03	5.000e-04	5.000e-02	1.000e-06	5.000e-07	1.250e-21
1.000e-01	1.000e-08	5.000e-08	2.500e-01	9.500e-01	1.000e-04	1.188e-21
7.500e-01	1.000e-04	1.000e-08	3.000e-01	5.000e-05	1.000e-04	1.125e-21
1.000e-09	1.000e-03	5.000e-01	1.000e-06	4.500e-01	5.000e-03	1.125e-21
5.000e-09	6.000e-01	7.500e-01	1.000e-01	5.000e-03	1.000e-09	1.125e-21
1.500e-01	1.000e-05	5.000e-01	3.000e-01	1.000e-06	5.000e-09	1.125e-21
4.500e-01	6.000e-01	1.000e-09	1.000e-07	1.000e-04	4.000e-01	1.080e-21
1.000e-03	4.500e-01	5.000e-04	5.000e-08	9.500e-01	1.000e-07	1.069e-21
5.000e-05	1.500e-01	9.500e-01	1.500e-01	1.000e-07	1.000e-08	1.069e-21
1.000e-05	4.000e-01	5.000e-08	1.000e-06	1.000e-01	5.000e-02	1.000e-21
5.000e-09	6.000e-01	6.500e-01	1.000e-06	1.000e-01	5.000e-06	9.750e-22
5.000e-06	5.000e-07	7.500e-01	2.000e-01	5.000e-06	5.000e-04	9.375e-22
1.000e-05	4.000e-01	5.000e-08	5.000e-07	8.000e-01	1.000e-02	8.000e-22
4.000e-01	4.500e-01	5.000e-07	5.000e-09	3.500e-01	5.000e-06	7.875e-22
1.000e-02	5.000e-09	5.000e-04	6.500e-01	5.000e-08	9.500e-01	7.719e-22
5.000e-06	6.000e-01	6.000e-01	5.000e-08	1.000e-08	8.500e-01	7.650e-22
1.500e-01	5.000e-07	5.000e-06	9.000e-01	5.000e-09	4.500e-01	7.594e-22
1.500e-01	1.000e-09	1.500e-01	1.000e-06	6.500e-01	5.000e-05	7.313e-22
3.500e-01	4.500e-01	5.000e-08	3.500e-01	5.000e-08	5.000e-06	6.891e-22
4.000e-01	8.500e-01	1.000e-06	2.000e-01	1.000e-05	1.000e-09	6.800e-22
5.000e-05	5.000e-02	1.000e-04	5.000e-06	5.000e-03	1.000e-04	6.250e-22
5.000e-05	7.500e-01	5.000e-05	3.000e-01	1.000e-03	1.000e-09	5.625e-22
6.500e-01	1.000e-05	5.000e-08	5.000e-07	6.500e-01	5.000e-03	5.281e-22
3.500e-01	7.500e-01	1.000e-05	1.000e-06	2.000e-01	1.000e-09	5.250e-22

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
6.500e-01	1.000e-05	1.000e-02	8.000e-01	1.000e-07	1.000e-07	5.200e-22
1.000e-09	4.500e-01	3.000e-01	1.000e-07	7.500e-01	5.000e-05	5.063e-22
7.500e-01	5.000e-05	6.500e-01	2.000e-01	1.000e-09	1.000e-07	4.875e-22
8.500e-01	5.000e-05	5.000e-09	5.000e-09	6.500e-01	7.000e-01	4.834e-22
1.000e-01	5.000e-06	5.000e-09	5.000e-06	1.500e-01	2.500e-01	4.688e-22
6.500e-01	1.000e-09	7.000e-01	5.000e-08	4.000e-01	5.000e-05	4.550e-22
1.000e-09	1.000e-01	4.000e-01	5.000e-08	5.000e-04	4.500e-01	4.500e-22
4.500e-01	1.000e-09	1.000e-07	5.000e-05	6.500e-01	3.000e-01	4.388e-22
2.500e-01	1.000e-08	3.500e-01	5.000e-05	1.000e-03	1.000e-05	4.375e-22
5.000e-03	7.500e-01	4.500e-01	1.000e-08	5.000e-06	5.000e-06	4.219e-22
9.000e-01	5.000e-07	7.500e-01	5.000e-08	5.000e-03	5.000e-06	4.219e-22
8.000e-01	5.000e-06	9.990e-01	1.000e-08	1.000e-06	1.000e-02	3.996e-22
1.000e-01	9.990e-01	5.000e-08	1.000e-08	1.000e-05	7.500e-01	3.746e-22
1.000e-09	3.500e-01	1.000e-03	3.000e-01	3.500e-01	1.000e-08	3.675e-22
8.000e-01	5.000e-09	1.000e-05	1.000e-03	1.000e-05	8.500e-01	3.400e-22
4.500e-01	1.000e-03	1.000e-08	7.500e-01	1.000e-03	1.000e-07	3.375e-22
8.500e-01	9.990e-01	5.000e-07	1.000e-07	1.000e-08	7.500e-01	3.184e-22
8.500e-01	1.500e-01	5.000e-06	9.990e-01	1.000e-08	5.000e-08	3.184e-22
6.000e-01	1.000e-06	9.990e-01	1.000e-02	1.000e-09	5.000e-05	2.997e-22
2.500e-01	8.500e-01	5.000e-07	5.000e-06	1.000e-05	5.000e-05	2.656e-22
2.000e-01	1.000e-02	5.000e-05	5.000e-08	1.000e-01	5.000e-07	2.500e-22
5.000e-06	1.000e-08	1.000e-02	1.000e-04	9.900e-01	5.000e-03	2.475e-22
8.500e-01	5.000e-09	7.500e-01	1.000e-06	7.500e-01	1.000e-07	2.391e-22
9.990e-01	1.000e-05	5.000e-09	6.000e-01	5.000e-08	1.500e-01	2.248e-22
5.000e-05	5.000e-09	1.000e-02	1.000e-06	1.000e-01	8.500e-01	2.125e-22
5.500e-01	1.000e-06	9.500e-01	1.000e-09	8.000e-01	5.000e-07	2.090e-22
1.000e-01	4.000e-01	5.000e-08	9.900e-01	1.000e-06	1.000e-07	1.980e-22
1.000e-08	7.500e-01	1.000e-08	7.500e-01	1.000e-05	3.500e-01	1.969e-22

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
9.500e-01	5.000e-09	4.000e-01	5.000e-08	4.000e-01	5.000e-06	1.900e-22
1.000e-05	5.000e-04	1.500e-01	5.000e-06	1.000e-03	5.000e-05	1.875e-22
1.500e-01	9.000e-01	5.000e-08	5.000e-08	1.000e-06	5.500e-01	1.856e-22
5.500e-01	1.000e-09	5.000e-05	8.500e-01	5.000e-08	1.500e-01	1.753e-22
1.500e-01	1.000e-05	4.500e-01	1.000e-08	5.000e-01	5.000e-08	1.688e-22
1.000e-06	5.000e-09	8.500e-01	5.000e-05	7.500e-01	1.000e-03	1.594e-22
4.000e-01	5.000e-07	1.500e-01	1.000e-06	5.000e-04	1.000e-05	1.500e-22
5.000e-05	4.000e-01	7.500e-01	4.000e-01	5.000e-09	5.000e-09	1.500e-22
1.000e-08	3.500e-01	8.500e-01	1.000e-06	1.000e-03	5.000e-05	1.488e-22
1.000e-03	5.500e-01	5.000e-08	1.000e-03	5.000e-03	1.000e-06	1.375e-22
1.000e-05	1.000e-01	5.000e-02	5.000e-09	5.000e-06	1.000e-01	1.250e-22
3.500e-01	5.000e-06	1.000e-09	5.000e-07	1.500e-01	9.500e-01	1.247e-22
1.000e-09	1.000e-03	5.000e-08	4.000e-01	5.500e-01	1.000e-02	1.100e-22
5.000e-09	1.500e-01	6.500e-01	5.000e-08	1.000e-05	4.500e-01	1.097e-22
5.000e-05	5.000e-06	1.000e-02	1.000e-08	5.000e-03	8.500e-01	1.063e-22
1.000e-04	5.000e-07	5.000e-03	6.000e-01	1.000e-09	7.000e-01	1.050e-22
5.000e-09	5.000e-06	4.000e-01	1.000e-06	9.900e-01	1.000e-02	9.900e-23
5.000e-06	5.000e-06	1.000e-05	1.500e-01	5.000e-01	5.000e-06	9.375e-23
5.000e-06	1.000e-03	7.000e-01	5.000e-05	1.000e-05	5.000e-05	8.750e-23
9.990e-01	3.500e-01	5.000e-07	5.000e-08	1.000e-06	1.000e-02	8.741e-23
9.500e-01	1.000e-05	1.000e-07	1.000e-01	1.000e-09	8.500e-01	8.075e-23
8.500e-01	5.000e-09	1.000e-03	7.500e-01	5.000e-06	5.000e-06	7.969e-23
5.000e-06	7.500e-01	1.000e-05	5.000e-08	5.000e-05	8.500e-01	7.969e-23
3.000e-01	1.000e-06	1.000e-02	5.000e-06	1.000e-05	5.000e-04	7.500e-23
1.000e-01	5.000e-07	5.000e-07	3.000e-01	1.000e-02	1.000e-06	7.500e-23
1.000e-07	1.000e-05	7.000e-01	3.000e-01	3.500e-01	1.000e-09	7.350e-23
1.000e-09	8.500e-01	8.500e-01	5.000e-07	2.000e-01	1.000e-06	7.225e-23
5.000e-08	1.000e-09	9.990e-01	6.000e-01	4.000e-01	5.000e-06	5.994e-23

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
1.000e-05	1.000e-09	1.000e-02	2.500e-01	5.000e-06	4.500e-01	5.625e-23
1.000e-07	1.000e-01	1.500e-01	5.000e-07	5.000e-07	1.500e-01	5.625e-23
8.000e-01	1.000e-06	1.000e-05	1.000e-06	1.000e-05	7.000e-01	5.600e-23
9.500e-01	1.000e-09	5.000e-05	5.000e-05	4.500e-01	5.000e-05	5.344e-23
5.000e-01	1.000e-08	5.000e-08	3.000e-01	1.000e-06	7.000e-01	5.250e-23
1.000e-03	1.000e-09	1.000e-09	8.000e-01	6.500e-01	1.000e-01	5.200e-23
1.000e-02	1.000e-03	1.000e-05	1.000e-06	1.000e-01	5.000e-06	5.000e-23
4.000e-01	1.000e-03	1.000e-08	5.000e-05	1.000e-06	2.500e-01	5.000e-23
5.000e-05	5.000e-05	5.000e-03	5.000e-08	8.000e-01	1.000e-04	5.000e-23
5.000e-06	5.000e-09	5.000e-06	1.000e-03	4.500e-01	8.500e-01	4.781e-23
1.000e-04	4.500e-01	5.000e-08	1.000e-05	1.000e-05	2.000e-01	4.500e-23
1.000e-09	1.000e-02	9.990e-01	5.000e-06	1.000e-06	8.500e-01	4.246e-23
5.000e-05	1.000e-05	6.000e-01	5.500e-01	5.000e-09	5.000e-05	4.125e-23
5.500e-01	1.000e-03	5.000e-08	5.000e-08	6.000e-01	5.000e-05	4.125e-23
8.000e-01	1.000e-03	1.000e-08	1.000e-03	5.000e-01	1.000e-08	4.000e-23
5.000e-08	4.500e-01	5.000e-06	1.000e-07	3.500e-01	1.000e-02	3.938e-23
3.000e-01	1.000e-08	1.000e-05	5.000e-09	4.500e-01	5.500e-01	3.713e-23
1.000e-05	1.000e-09	5.000e-05	1.000e-04	9.500e-01	7.500e-01	3.563e-23
5.000e-08	5.000e-06	8.000e-01	3.500e-01	5.000e-03	1.000e-07	3.500e-23
9.990e-01	1.000e-01	1.000e-08	5.000e-08	1.000e-06	7.000e-01	3.497e-23
5.000e-06	1.000e-08	1.000e-08	2.000e-01	4.500e-01	7.500e-01	3.375e-23
5.000e-06	1.000e-04	5.000e-03	5.000e-02	5.000e-07	5.000e-04	3.125e-23
5.000e-02	4.000e-01	1.000e-07	6.000e-01	5.000e-07	5.000e-08	3.000e-23
1.000e-09	5.000e-09	5.000e-01	2.500e-01	5.000e-05	9.500e-01	2.969e-23
1.000e-09	9.000e-01	5.000e-07	9.900e-01	1.000e-07	6.500e-01	2.896e-23
9.000e-01	2.500e-01	5.000e-08	5.000e-07	5.000e-07	1.000e-02	2.813e-23
1.000e-07	7.500e-01	5.000e-05	1.500e-01	5.000e-05	1.000e-06	2.813e-23
1.500e-01	4.000e-01	1.000e-08	1.000e-06	4.500e-01	1.000e-07	2.700e-23

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
4.000e-01	5.000e-09	5.000e-08	6.000e-01	1.000e-06	4.500e-01	2.700e-23
4.000e-01	1.000e-08	5.000e-02	5.000e-08	5.000e-01	5.000e-06	2.500e-23
4.000e-01	1.000e-08	2.500e-01	5.000e-02	5.000e-04	1.000e-09	2.500e-23
1.000e-07	5.000e-09	1.500e-01	5.000e-07	8.500e-01	7.500e-01	2.391e-23
1.000e-07	5.000e-09	4.000e-01	5.000e-07	9.500e-01	2.500e-01	2.375e-23
9.990e-01	5.000e-05	5.000e-07	1.000e-07	9.500e-01	1.000e-05	2.373e-23
5.000e-09	2.500e-01	7.500e-01	5.000e-08	5.000e-06	1.000e-01	2.344e-23
9.500e-01	1.000e-08	1.000e-05	5.000e-07	9.500e-01	5.000e-04	2.256e-23
4.500e-01	5.000e-09	1.000e-06	1.000e-03	2.000e-01	5.000e-05	2.250e-23
5.000e-06	1.000e-04	1.000e-08	1.000e-03	4.500e-01	1.000e-02	2.250e-23
5.000e-06	1.000e-05	7.000e-01	2.500e-01	5.000e-05	5.000e-08	2.188e-23
1.000e-02	5.000e-06	5.000e-09	1.000e-07	9.990e-01	8.500e-01	2.123e-23
5.000e-06	5.000e-09	1.000e-08	2.500e-01	4.500e-01	7.000e-01	1.969e-23
1.000e-09	5.000e-07	2.500e-01	4.000e-01	1.000e-06	3.500e-01	1.750e-23
1.000e-06	5.000e-09	9.500e-01	1.000e-06	1.000e-02	3.500e-01	1.663e-23
1.000e-01	1.000e-08	1.000e-05	5.000e-07	6.500e-01	5.000e-03	1.625e-23
1.000e-05	5.000e-07	9.990e-01	5.000e-06	6.500e-01	1.000e-06	1.623e-23
1.000e-09	5.000e-07	6.500e-01	5.000e-08	9.900e-01	9.900e-01	1.593e-23
4.000e-01	1.000e-07	5.000e-09	3.500e-01	5.000e-07	4.500e-01	1.575e-23
3.500e-01	1.000e-09	1.000e-05	1.000e-01	4.500e-01	1.000e-07	1.575e-23
2.000e-01	1.000e-06	5.000e-08	3.500e-01	4.500e-01	1.000e-08	1.575e-23
1.000e-08	2.000e-01	5.000e-05	1.000e-03	1.500e-01	1.000e-06	1.500e-23
1.000e-04	1.000e-09	2.500e-01	1.500e-01	8.000e-01	5.000e-09	1.500e-23
1.000e-02	5.000e-08	1.000e-02	6.000e-01	5.000e-07	1.000e-05	1.500e-23
1.000e-07	7.500e-01	1.000e-02	5.000e-06	7.500e-01	5.000e-09	1.406e-23
1.000e-01	1.000e-05	1.000e-09	4.000e-01	1.000e-07	3.500e-01	1.400e-23
1.000e-05	1.000e-09	1.000e-08	3.500e-01	5.000e-01	7.500e-01	1.313e-23
1.000e-05	3.000e-01	8.000e-01	5.000e-06	1.000e-05	1.000e-07	1.200e-23

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
1.000e-04	1.000e-05	5.000e-02	1.000e-09	4.500e-01	5.000e-04	1.125e-23
4.000e-01	5.000e-09	5.000e-07	5.000e-08	7.500e-01	3.000e-01	1.125e-23
5.500e-01	5.000e-09	5.000e-08	1.000e-05	8.000e-01	1.000e-02	1.100e-23
5.500e-01	5.000e-09	8.000e-01	5.000e-08	1.000e-06	1.000e-01	1.100e-23
5.000e-05	5.000e-06	1.000e-05	5.000e-06	1.000e-03	8.500e-01	1.063e-23
1.000e-09	1.000e-04	3.000e-01	3.500e-01	1.000e-05	1.000e-04	1.050e-23
1.000e-04	1.000e-05	7.500e-01	5.000e-08	5.500e-01	5.000e-07	1.031e-23
5.000e-06	5.000e-02	6.000e-01	5.000e-08	1.000e-03	1.000e-06	7.500e-24
1.000e-09	5.000e-08	5.000e-06	3.000e-01	6.500e-01	1.500e-01	7.313e-24
1.000e-05	7.500e-01	5.000e-07	1.000e-03	3.500e-01	5.000e-09	6.563e-24
1.000e-09	1.000e-05	5.000e-07	2.000e-01	6.500e-01	1.000e-02	6.500e-24
1.000e-04	5.000e-09	9.990e-01	5.000e-07	5.000e-01	5.000e-05	6.244e-24
3.500e-01	5.000e-09	7.000e-01	5.000e-08	1.000e-06	1.000e-01	6.125e-24
1.000e-07	5.000e-07	2.500e-01	5.000e-02	9.500e-01	1.000e-08	5.938e-24
3.000e-01	1.000e-08	5.000e-05	1.000e-05	7.500e-01	5.000e-06	5.625e-24
9.990e-01	1.000e-09	7.500e-01	1.500e-01	5.000e-06	1.000e-08	5.619e-24
5.000e-06	1.000e-08	1.000e-02	2.000e-01	5.500e-01	1.000e-07	5.500e-24
5.000e-07	8.500e-01	5.000e-03	5.000e-06	1.000e-07	5.000e-03	5.313e-24
4.000e-01	3.500e-01	1.000e-08	1.000e-08	5.000e-07	7.500e-01	5.250e-24
1.000e-04	5.000e-07	5.000e-07	5.000e-07	7.500e-01	5.500e-01	5.156e-24
9.990e-01	1.000e-05	1.000e-05	1.000e-07	1.000e-03	5.000e-04	4.995e-24
1.000e-09	1.000e-05	4.500e-01	3.000e-01	3.500e-01	1.000e-08	4.725e-24
3.500e-01	1.000e-07	2.000e-01	1.000e-07	1.000e-08	6.500e-01	4.550e-24
5.000e-05	5.000e-09	8.000e-01	5.000e-09	5.000e-03	8.500e-01	4.250e-24
9.000e-01	5.000e-05	5.000e-08	1.000e-07	3.500e-01	5.000e-05	3.938e-24
9.500e-01	1.000e-09	5.000e-08	1.000e-06	8.000e-01	1.000e-01	3.800e-24
9.500e-01	5.000e-07	4.000e-01	2.000e-01	1.000e-09	1.000e-07	3.800e-24
1.000e-08	5.000e-05	3.000e-01	5.000e-06	5.000e-01	1.000e-05	3.750e-24

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
2.500e-01	1.000e-04	1.000e-07	1.000e-07	3.000e-01	5.000e-05	3.750e-24
6.500e-01	1.000e-09	2.000e-01	5.000e-08	5.000e-05	1.000e-02	3.250e-24
5.000e-05	1.000e-04	1.000e-09	9.990e-01	1.000e-05	5.000e-02	2.498e-24
4.000e-01	1.000e-05	1.000e-02	1.000e-03	5.000e-05	1.000e-09	2.000e-24
5.000e-05	1.000e-09	4.000e-01	9.900e-01	1.000e-04	1.000e-06	1.980e-24
9.500e-01	5.000e-06	5.000e-08	1.000e-04	1.000e-07	8.000e-01	1.900e-24
1.000e-07	5.000e-02	5.000e-08	5.000e-08	9.500e-01	1.500e-01	1.781e-24
3.500e-01	1.000e-09	1.000e-06	5.000e-02	1.000e-01	1.000e-06	1.750e-24
9.500e-01	5.000e-09	5.000e-09	5.000e-07	4.000e-01	3.500e-01	1.663e-24
5.000e-02	6.500e-01	5.000e-07	1.000e-06	1.000e-06	1.000e-04	1.625e-24
1.000e-04	1.000e-09	5.000e-06	3.000e-01	1.000e-03	1.000e-02	1.500e-24
1.000e-02	9.990e-01	5.000e-04	5.000e-07	1.000e-05	5.000e-08	1.249e-24
1.000e-07	7.500e-01	1.000e-02	1.500e-01	1.000e-09	1.000e-05	1.125e-24
9.500e-01	9.000e-01	5.000e-08	1.000e-05	5.000e-07	5.000e-06	1.069e-24
8.500e-01	5.000e-07	1.000e-05	1.000e-07	5.000e-04	5.000e-03	1.063e-24
1.000e-04	1.000e-04	1.000e-04	1.000e-04	1.000e-04	1.000e-04	1.000e-24
4.000e-01	1.000e-09	5.000e-08	1.000e-06	5.000e-02	9.500e-01	9.500e-25
1.000e-08	5.000e-09	1.000e-03	5.000e-03	7.500e-01	5.000e-03	9.375e-25
5.000e-06	1.000e-05	1.000e-08	1.000e-05	4.000e-01	4.500e-01	9.000e-25
2.000e-01	5.000e-09	1.000e-02	1.000e-04	1.000e-09	8.500e-01	8.500e-25
5.000e-05	5.000e-06	1.000e-08	5.000e-07	9.500e-01	6.500e-01	7.719e-25
1.000e-03	1.000e-05	5.000e-06	5.000e-06	5.000e-03	5.000e-04	6.250e-25
1.000e-05	9.990e-01	5.000e-09	1.000e-08	1.000e-03	9.900e-01	4.945e-25
1.000e-09	5.000e-09	6.500e-01	5.000e-07	4.000e-01	7.500e-01	4.875e-25
5.000e-03	5.000e-09	2.500e-01	7.500e-01	1.000e-04	1.000e-09	4.688e-25
5.000e-03	9.000e-01	1.000e-07	1.000e-06	1.000e-01	1.000e-08	4.500e-25
1.000e-08	5.000e-02	1.500e-01	5.000e-08	1.000e-03	1.000e-04	3.750e-25
8.500e-01	3.500e-01	1.000e-02	5.000e-08	5.000e-09	5.000e-07	3.719e-25

Probability of						
Missouri River Input	Transfer to Control System	Control System Failure	Establishing a Sustainable Population	Intersection of Transferred Biota & Receptor	Expression of Adverse Effect in Receptor	Outcome as "Successful Invasion"
1.000e-07	5.000e-09	7.500e-01	1.000e-07	9.500e-01	1.000e-02	3.563e-25
3.500e-01	1.000e-05	1.000e-09	3.500e-01	5.000e-07	5.000e-04	3.063e-25
5.000e-05	5.000e-09	2.500e-01	5.000e-07	1.000e-05	9.500e-01	2.969e-25
1.000e-03	1.000e-08	6.500e-01	1.000e-07	5.000e-07	8.500e-01	2.763e-25
1.000e-01	1.000e-09	5.000e-05	1.000e-05	5.000e-04	1.000e-02	2.500e-25
9.500e-01	1.000e-03	1.000e-06	5.000e-08	5.000e-03	1.000e-06	2.375e-25
1.000e-04	1.000e-06	5.000e-05	5.000e-08	9.500e-01	1.000e-03	2.375e-25
3.500e-01	1.000e-05	6.500e-01	1.000e-07	1.000e-06	1.000e-06	2.275e-25
3.000e-01	1.000e-04	5.000e-08	3.000e-01	1.000e-07	5.000e-06	2.250e-25
1.000e-09	3.000e-01	1.500e-01	1.000e-08	5.000e-05	1.000e-02	2.250e-25
1.000e-04	1.000e-07	8.500e-01	5.000e-08	1.000e-04	5.000e-03	2.125e-25
5.000e-06	1.000e-09	5.000e-09	9.900e-01	8.500e-01	1.000e-02	2.104e-25
5.000e-07	1.000e-03	1.000e-08	5.000e-05	8.000e-01	1.000e-03	2.000e-25
1.000e-02	1.000e-08	1.000e-08	6.000e-01	5.000e-07	6.500e-01	1.950e-25
5.000e-03	5.000e-08	1.000e-03	5.000e-05	1.500e-01	1.000e-07	1.875e-25
1.000e-09	1.000e-01	1.000e-07	3.500e-01	1.000e-06	5.000e-02	1.750e-25
5.000e-07	4.000e-01	1.000e-02	1.000e-07	6.500e-01	1.000e-09	1.300e-25
1.000e-09	5.000e-09	2.000e-01	5.000e-05	5.000e-01	5.000e-03	1.250e-25
5.000e-06	5.000e-09	3.000e-01	5.000e-07	6.500e-01	5.000e-05	1.219e-25
5.000e-09	8.500e-01	5.000e-02	5.000e-02	1.000e-06	1.000e-08	1.063e-25
5.000e-01	1.000e-09	8.000e-01	1.000e-05	5.000e-07	5.000e-05	1.000e-25
1.500e-01	1.000e-08	1.000e-09	6.500e-01	9.500e-01	1.000e-07	9.263e-26
5.000e-06	1.000e-08	5.000e-06	2.000e-01	3.500e-01	5.000e-06	8.750e-26
1.000e-08	5.000e-07	1.000e-02	3.500e-01	9.900e-01	5.000e-09	8.663e-26
1.000e-08	1.000e-01	1.000e-08	1.000e-01	5.000e-07	1.500e-01	7.500e-26
1.000e-06	1.000e-06	6.500e-01	1.000e-01	1.000e-08	1.000e-04	6.500e-26
1.000e-07	5.000e-04	5.000e-03	1.000e-01	5.000e-05	5.000e-08	6.250e-26
1.000e-09	4.000e-01	1.000e-07	3.000e-01	1.000e-01	5.000e-08	6.000e-26

Probability of						
Missouri River Input	Transfer to Control System	Control System Failure	Establishing a Sustainable Population	Intersection of Transferred Biota & Receptor	Expression of Adverse Effect in Receptor	Outcome as "Successful Invasion"
9.990e-01	1.000e-04	1.000e-05	1.000e-03	5.000e-07	1.000e-07	4.995e-26
5.000e-05	5.000e-05	5.000e-08	5.000e-05	1.000e-05	7.500e-01	4.688e-26
8.000e-01	1.000e-09	1.000e-02	5.000e-08	1.000e-01	1.000e-06	4.000e-26
1.000e-09	5.000e-03	5.000e-08	4.000e-01	7.500e-01	5.000e-07	3.750e-26
5.000e-02	5.000e-07	3.000e-01	1.000e-06	5.000e-06	1.000e-06	3.750e-26
5.000e-06	5.000e-06	1.000e-08	5.000e-07	3.500e-01	8.500e-01	3.719e-26
3.500e-01	5.000e-07	5.000e-07	1.000e-07	5.000e-06	8.500e-01	3.719e-26
5.000e-05	1.000e-03	4.000e-01	3.500e-01	1.000e-09	5.000e-09	3.500e-26
5.500e-01	5.000e-05	1.000e-05	5.000e-06	5.000e-07	5.000e-05	3.438e-26
1.000e-01	6.500e-01	1.000e-04	5.000e-08	1.000e-07	1.000e-06	3.250e-26
3.000e-01	8.000e-01	1.000e-08	5.000e-06	5.000e-07	5.000e-06	3.000e-26
1.000e-01	5.000e-09	3.000e-01	1.000e-07	5.000e-09	4.000e-01	3.000e-26
1.000e-09	7.500e-01	7.500e-01	5.000e-08	1.000e-09	9.990e-01	2.810e-26
1.000e-09	5.000e-02	1.000e-09	3.500e-01	1.000e-05	1.500e-01	2.625e-26
1.000e-08	5.000e-06	1.000e-02	1.000e-06	1.000e-03	5.000e-02	2.500e-26
5.000e-02	1.000e-03	1.000e-07	1.000e-07	5.000e-07	1.000e-01	2.500e-26
5.000e-03	1.000e-03	1.000e-03	5.000e-08	1.000e-07	1.000e-03	2.500e-26
9.500e-01	5.000e-06	5.000e-07	2.000e-01	5.000e-07	1.000e-07	2.375e-26
1.000e-08	1.000e-09	1.000e-03	7.500e-01	5.500e-01	5.000e-06	2.063e-26
8.000e-01	1.000e-09	1.000e-02	5.000e-06	5.000e-07	1.000e-03	2.000e-26
1.000e-04	1.000e-04	8.000e-01	5.000e-03	5.000e-08	1.000e-08	2.000e-26
1.000e-05	5.000e-09	3.000e-01	5.000e-06	5.000e-06	5.000e-02	1.875e-26
1.500e-01	5.000e-07	1.000e-05	1.000e-03	5.000e-06	5.000e-06	1.875e-26
5.000e-09	1.000e-04	5.000e-03	1.000e-06	1.500e-01	5.000e-05	1.875e-26
5.000e-05	5.000e-05	5.000e-05	5.000e-05	5.000e-05	5.000e-05	1.563e-26
3.000e-01	1.000e-04	1.000e-08	9.000e-01	5.000e-06	1.000e-08	1.350e-26
1.000e-07	6.000e-01	8.500e-01	5.000e-05	1.000e-07	5.000e-08	1.275e-26
1.000e-03	5.000e-05	1.000e-02	5.000e-04	5.000e-07	1.000e-07	1.250e-26

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
1.000e-04	2.500e-01	1.000e-08	9.900e-01	1.000e-05	5.000e-09	1.238e-26
1.000e-09	1.000e-08	6.500e-01	5.000e-03	5.000e-07	7.000e-01	1.138e-26
5.000e-06	3.000e-01	1.000e-06	5.000e-06	1.000e-08	1.500e-01	1.125e-26
1.000e-04	1.000e-09	1.500e-01	1.000e-09	5.000e-03	1.500e-01	1.125e-26
1.000e-09	5.000e-07	5.000e-07	5.000e-05	9.500e-01	8.500e-01	1.009e-26
1.000e-09	8.500e-01	5.000e-07	5.000e-06	4.500e-01	1.000e-05	9.563e-27
9.500e-01	4.000e-01	1.000e-03	1.000e-08	5.000e-07	5.000e-09	9.500e-27
5.000e-01	1.000e-06	5.000e-06	7.500e-01	1.000e-06	5.000e-09	9.375e-27
5.000e-05	7.500e-01	9.500e-01	5.000e-06	1.000e-09	5.000e-08	8.906e-27
5.000e-06	5.000e-09	1.000e-07	3.500e-01	1.000e-01	1.000e-04	8.750e-27
5.000e-05	1.000e-04	5.000e-09	6.000e-01	4.000e-01	1.000e-09	6.000e-27
5.000e-05	4.500e-01	5.000e-05	1.000e-07	5.000e-07	1.000e-04	5.625e-27
5.000e-05	1.000e-08	4.000e-01	5.000e-08	5.500e-01	1.000e-06	5.500e-27
1.000e-08	5.000e-07	6.000e-01	5.000e-07	1.000e-05	3.500e-01	5.250e-27
1.000e-08	5.000e-06	4.000e-01	1.000e-07	5.000e-01	5.000e-06	5.000e-27
1.000e-03	5.000e-06	1.000e-04	9.900e-01	1.000e-06	1.000e-08	4.950e-27
5.000e-06	9.000e-01	5.000e-08	1.000e-06	2.000e-01	1.000e-07	4.500e-27
3.500e-01	1.000e-04	5.000e-07	5.000e-03	1.000e-09	5.000e-05	4.375e-27
5.000e-03	5.000e-05	5.000e-07	1.000e-06	1.000e-07	3.500e-01	4.375e-27
5.500e-01	1.000e-09	3.000e-01	5.000e-08	5.000e-08	1.000e-02	4.125e-27
1.000e-09	1.000e-01	4.000e-01	1.000e-07	1.000e-02	1.000e-07	4.000e-27
1.000e-01	5.000e-09	3.000e-01	5.000e-06	5.000e-03	1.000e-09	3.750e-27
5.000e-09	4.000e-01	1.000e-06	5.000e-06	6.500e-01	5.000e-07	3.250e-27
1.000e-01	1.000e-09	4.000e-01	5.000e-08	1.000e-08	1.500e-01	3.000e-27
9.500e-01	1.000e-05	1.000e-09	5.000e-08	5.500e-01	1.000e-05	2.613e-27
9.990e-01	5.000e-09	5.000e-08	5.000e-05	4.000e-01	5.000e-07	2.498e-27
1.000e-09	9.990e-01	5.000e-02	1.000e-03	5.000e-07	1.000e-07	2.498e-27
1.000e-07	1.000e-02	1.000e-06	5.000e-06	1.000e-06	4.500e-01	2.250e-27

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
1.000e-06	1.000e-08	1.000e-04	3.000e-01	7.500e-01	1.000e-08	2.250e-27
1.500e-01	1.000e-06	1.000e-03	1.500e-01	1.000e-08	1.000e-08	2.250e-27
1.000e-07	4.500e-01	1.000e-02	1.000e-03	5.000e-09	1.000e-06	2.250e-27
1.000e-09	1.000e-08	8.500e-01	1.000e-03	5.000e-06	5.000e-02	2.125e-27
5.000e-06	8.500e-01	1.000e-05	5.000e-09	9.900e-01	1.000e-08	2.104e-27
5.000e-05	5.500e-01	3.000e-01	5.000e-09	1.000e-06	5.000e-08	2.063e-27
9.990e-01	1.000e-09	1.000e-09	5.000e-05	6.500e-01	5.000e-05	1.623e-27
5.500e-01	5.000e-05	1.000e-08	1.000e-03	5.000e-04	1.000e-08	1.375e-27
4.000e-01	5.000e-05	5.000e-06	5.000e-07	5.000e-03	5.000e-09	1.250e-27
1.500e-01	1.000e-04	5.000e-07	1.000e-07	3.000e-01	5.000e-09	1.125e-27
5.000e-06	1.000e-04	7.500e-01	5.000e-08	1.000e-03	5.000e-08	9.375e-28
1.000e-04	1.000e-03	1.000e-05	1.500e-01	1.000e-09	5.000e-06	7.500e-28
1.000e-09	4.000e-01	7.500e-01	5.000e-07	5.000e-07	1.000e-05	7.500e-28
1.000e-04	1.000e-09	2.000e-01	1.000e-05	1.000e-08	3.500e-01	7.000e-28
1.000e-09	5.000e-08	1.000e-06	5.000e-05	4.000e-01	6.500e-01	6.500e-28
8.500e-01	1.000e-08	5.000e-08	5.000e-08	5.000e-01	5.000e-05	5.313e-28
1.000e-04	1.000e-06	1.000e-09	5.000e-06	1.000e-01	1.000e-02	5.000e-28
1.000e-09	1.000e-09	2.000e-01	1.000e-03	5.000e-03	5.000e-04	5.000e-28
5.000e-06	1.000e-06	1.000e-08	8.000e-01	1.000e-06	1.000e-02	4.000e-28
1.000e-09	1.000e-01	5.000e-08	3.000e-01	5.000e-07	5.000e-04	3.750e-28
9.990e-01	5.000e-09	5.000e-06	5.000e-04	5.000e-07	5.000e-05	3.122e-28
1.000e-09	8.500e-01	1.000e-05	1.000e-06	5.000e-08	6.500e-01	2.763e-28
1.000e-09	9.990e-01	1.000e-08	1.000e-02	5.500e-01	5.000e-09	2.747e-28
1.000e-04	1.000e-03	5.000e-06	5.000e-06	1.000e-06	1.000e-04	2.500e-28
1.000e-09	1.000e-04	1.000e-02	1.000e-08	5.000e-03	5.000e-03	2.500e-28
1.000e-01	2.000e-01	1.000e-08	1.000e-08	1.000e-01	1.000e-09	2.000e-28
4.000e-01	1.000e-03	5.000e-08	5.000e-08	1.000e-09	2.000e-01	2.000e-28
4.000e-01	1.000e-09	1.000e-07	5.000e-08	9.500e-01	1.000e-04	1.900e-28

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
1.000e-04	5.000e-09	6.500e-01	1.000e-07	5.000e-01	1.000e-08	1.625e-28
5.000e-05	1.000e-06	1.000e-08	5.500e-01	1.000e-05	5.000e-05	1.375e-28
9.500e-01	1.000e-01	5.000e-05	5.000e-09	1.000e-09	5.000e-06	1.188e-28
3.000e-01	1.000e-08	6.500e-01	1.000e-07	5.000e-09	1.000e-04	9.750e-29
1.000e-07	1.000e-08	2.500e-01	1.500e-01	5.000e-05	5.000e-08	9.375e-29
3.500e-01	5.000e-07	5.000e-07	1.000e-07	1.000e-05	1.000e-03	8.750e-29
5.000e-09	7.000e-01	1.000e-08	5.000e-07	9.500e-01	5.000e-06	8.313e-29
1.000e-06	1.000e-09	1.500e-01	1.000e-08	9.500e-01	5.000e-05	7.125e-29
1.000e-02	1.000e-03	1.000e-09	1.000e-03	5.000e-07	1.000e-05	5.000e-29
1.000e-08	1.000e-05	9.990e-01	5.000e-08	1.000e-05	1.000e-03	4.995e-29
1.000e-09	1.500e-01	1.000e-08	1.000e-07	2.000e-01	1.000e-03	3.000e-29
1.000e-09	1.000e-08	5.000e-01	5.000e-05	9.900e-01	1.000e-07	2.475e-29
5.000e-08	1.000e-08	1.000e-08	7.500e-01	9.900e-01	5.000e-06	1.856e-29
1.000e-01	1.000e-08	1.000e-07	3.500e-01	5.000e-05	1.000e-08	1.750e-29
5.000e-09	5.000e-09	1.000e-04	1.000e-06	1.000e-02	6.500e-01	1.625e-29
1.000e-09	1.500e-01	5.000e-08	5.000e-08	7.000e-01	5.000e-05	1.313e-29
5.000e-03	5.000e-09	1.500e-01	5.000e-06	5.000e-06	1.000e-07	9.375e-30
3.500e-01	5.000e-09	1.000e-02	1.000e-06	1.000e-06	5.000e-07	8.750e-30
1.000e-05	1.000e-09	4.500e-01	7.500e-01	5.000e-07	5.000e-09	8.438e-30
5.000e-05	5.000e-09	6.000e-01	1.000e-02	5.000e-07	1.000e-08	7.500e-30
1.000e-03	5.000e-07	5.000e-07	5.000e-05	1.000e-05	5.000e-05	6.250e-30
1.000e-05	1.000e-05	5.000e-08	5.000e-07	5.000e-01	5.000e-06	6.250e-30
5.000e-05	1.000e-06	5.000e-08	5.000e-08	5.000e-03	1.000e-02	6.250e-30
5.000e-06	1.000e-08	1.000e-08	1.000e-07	3.500e-01	3.500e-01	6.125e-30
5.000e-09	1.000e-08	1.000e-07	1.500e-01	6.500e-01	1.000e-05	4.875e-30
4.500e-01	1.000e-04	1.000e-08	1.000e-08	1.000e-07	1.000e-02	4.500e-30
1.000e-03	5.000e-05	1.000e-08	5.000e-08	5.000e-07	3.500e-01	4.375e-30
5.000e-05	3.000e-01	5.000e-08	1.000e-06	1.000e-06	5.000e-06	3.750e-30

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
5.000e-09	1.000e-03	1.500e-01	1.000e-03	1.000e-07	5.000e-08	3.750e-30
5.000e-05	1.000e-06	7.500e-01	1.000e-06	1.000e-06	1.000e-07	3.750e-30
5.000e-06	5.000e-02	1.000e-09	5.000e-02	5.000e-08	5.000e-06	3.125e-30
5.000e-09	2.500e-01	1.000e-06	1.000e-07	4.000e-01	5.000e-08	2.500e-30
5.000e-02	5.000e-09	2.000e-01	5.000e-08	1.000e-06	1.000e-06	2.500e-30
9.500e-01	1.000e-03	1.000e-08	1.000e-03	5.000e-08	5.000e-09	2.375e-30
1.000e-05	1.000e-09	5.000e-09	3.000e-01	1.000e-06	1.500e-01	2.250e-30
1.000e-05	1.000e-06	3.000e-01	1.000e-05	1.000e-08	5.000e-06	1.500e-30
5.000e-05	1.000e-09	2.000e-01	5.000e-06	5.000e-07	5.000e-05	1.250e-30
5.000e-09	1.000e-05	4.500e-01	5.000e-06	1.000e-07	1.000e-04	1.125e-30
1.000e-05	1.000e-05	1.000e-05	1.000e-05	1.000e-05	1.000e-05	1.000e-30
2.000e-01	1.000e-08	5.000e-04	1.000e-08	1.000e-06	1.000e-04	1.000e-30
1.000e-09	1.000e-05	9.990e-01	1.000e-05	1.000e-06	1.000e-05	9.990e-31
1.500e-01	5.000e-09	5.000e-09	5.000e-06	1.000e-05	5.000e-03	9.375e-31
1.000e-09	3.500e-01	1.000e-07	1.000e-04	5.000e-03	5.000e-08	8.750e-31
1.500e-01	5.000e-09	5.000e-08	3.500e-01	5.000e-07	1.000e-07	6.563e-31
5.000e-06	1.000e-09	9.990e-01	1.000e-07	1.000e-09	9.900e-01	4.945e-31
1.000e-01	1.000e-05	4.500e-01	1.000e-09	1.000e-07	1.000e-08	4.500e-31
5.000e-09	2.500e-01	3.000e-01	1.000e-06	1.000e-06	1.000e-09	3.750e-31
5.000e-07	5.000e-09	5.000e-07	5.000e-08	5.000e-01	1.000e-02	3.125e-31
1.000e-09	5.000e-06	1.000e-02	5.000e-03	1.000e-05	5.000e-08	1.250e-31
1.000e-09	1.000e-05	5.000e-08	1.000e-03	5.000e-06	5.000e-02	1.250e-31
5.000e-09	5.000e-09	1.000e-01	5.000e-05	2.000e-01	5.000e-09	1.250e-31
5.000e-08	9.990e-01	5.000e-07	1.000e-06	1.000e-06	5.000e-06	1.249e-31
1.000e-08	5.000e-07	5.000e-07	1.000e-06	9.500e-01	5.000e-05	1.188e-31
5.000e-05	5.000e-09	5.000e-08	1.000e-06	8.500e-01	5.000e-06	5.313e-32
8.000e-01	1.000e-07	1.000e-08	5.000e-06	1.000e-09	1.000e-02	4.000e-32
1.000e-09	1.000e-09	1.000e-05	1.500e-01	1.000e-07	2.500e-01	3.750e-32

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
1.000e-09	5.000e-09	1.000e-08	3.000e-01	3.000e-01	5.000e-06	2.250e-32
5.000e-06	5.000e-06	5.000e-06	5.000e-06	5.000e-06	5.000e-06	1.563e-32
1.000e-08	1.000e-06	1.000e-09	1.000e-06	1.000e-03	7.000e-01	7.000e-33
1.500e-01	5.000e-09	5.000e-06	5.000e-09	1.000e-09	3.500e-01	6.563e-33
5.000e-03	1.000e-09	2.000e-01	1.000e-06	1.000e-09	5.000e-06	5.000e-33
5.000e-03	5.000e-09	5.000e-08	5.000e-08	5.000e-07	1.500e-01	4.688e-33
5.000e-06	2.500e-01	1.000e-08	1.000e-07	5.000e-09	5.000e-04	3.125e-33
1.000e-08	1.000e-04	6.000e-01	5.000e-08	1.000e-07	1.000e-06	3.000e-33
5.000e-09	6.500e-01	1.000e-07	1.000e-05	1.000e-05	5.000e-08	1.625e-33
1.000e-09	5.000e-04	1.000e-02	1.000e-03	5.000e-09	5.000e-08	1.250e-33
5.000e-01	1.000e-09	2.000e-01	5.000e-07	5.000e-09	5.000e-09	1.250e-33
5.000e-09	1.000e-05	6.000e-01	5.000e-08	1.000e-08	5.000e-05	7.500e-34
1.000e-07	1.000e-04	3.000e-01	5.000e-09	1.000e-09	5.000e-05	7.500e-34
5.000e-09	5.000e-09	1.500e-01	1.000e-03	1.000e-05	1.000e-08	3.750e-34
1.000e-06	5.000e-02	5.000e-06	5.000e-08	5.000e-07	5.000e-08	3.125e-34
5.000e-06	9.500e-01	1.000e-05	1.000e-09	1.000e-09	5.000e-06	2.375e-34
1.000e-08	1.000e-09	5.000e-06	5.000e-03	1.000e-09	8.500e-01	2.125e-34
3.500e-01	1.000e-05	1.000e-09	1.000e-06	1.000e-08	5.000e-06	1.750e-34
5.000e-06	5.000e-07	1.000e-09	5.000e-09	1.000e-05	8.500e-01	1.063e-34
1.000e-08	5.000e-02	5.000e-08	5.000e-08	1.000e-09	5.000e-02	6.250e-35
5.500e-01	5.000e-09	5.000e-07	1.000e-08	5.000e-08	5.000e-05	3.438e-35
1.000e-03	1.000e-09	5.000e-05	5.000e-06	1.000e-05	1.000e-08	2.500e-35
1.000e-09	1.000e-06	5.000e-08	1.000e-08	5.000e-05	5.000e-01	1.250e-35
5.000e-05	9.000e-01	5.000e-08	5.000e-08	1.000e-07	1.000e-09	1.125e-35
1.000e-09	5.000e-07	5.000e-05	1.000e-06	5.000e-05	5.000e-06	6.250e-36
1.000e-04	1.000e-05	1.000e-03	5.000e-08	5.000e-09	5.000e-09	1.250e-36
1.000e-06	1.000e-06	1.000e-06	1.000e-06	1.000e-06	1.000e-06	1.000e-36
5.000e-09	5.000e-05	5.000e-07	1.000e-06	1.000e-06	1.000e-06	1.250e-37

Probability of						
Missouri River Input	**Transfer to Control System**	**Control System Failure**	**Establishing a Sustainable Population**	**Intersection of Transferred Biota & Receptor**	**Expression of Adverse Effect in Receptor**	**Outcome as "Successful Invasion"**
5.000e-06	5.000e-09	1.000e-05	1.000e-03	1.000e-09	1.000e-07	2.500e-38
5.000e-07	5.000e-07	5.000e-07	5.000e-07	5.000e-07	5.000e-07	1.563e-38
5.000e-01	1.000e-09	5.000e-08	1.000e-07	5.000e-07	1.000e-08	1.250e-38
1.000e-08	1.000e-05	5.000e-07	1.000e-06	1.000e-08	5.000e-06	2.500e-39
1.000e-07	1.000e-07	1.000e-07	1.000e-07	1.000e-07	1.000e-07	1.000e-42
5.000e-08	5.000e-08	5.000e-08	5.000e-08	5.000e-08	5.000e-08	1.563e-44
1.000e-08	1.000e-08	1.000e-08	1.000e-08	1.000e-08	1.000e-08	1.000e-48
5.000e-09	5.000e-09	5.000e-09	5.000e-09	5.000e-09	5.000e-09	1.563e-50
1.000e-09	1.000e-09	1.000e-09	1.000e-09	1.000e-09	1.000e-09	1.000e-54

Appendix 14. As a statistical tool within the ArcView (see Lee and Wong 2001, Hutchinson 2004), **CORRELATION** calculates the cross correlation between two input grids, prints the correlation coefficient to the screen, and sets an AML variable with the output value.

Discussion: Spatial autocorrelation is a measure of the similarity of objects within an area. An object can have at least two types of descriptive elements; 1) aspatial attributes (i.e., soil parameters, elevation, slope), and 2) spatial attributes (i.e., the x, y location in a specified coordinate system). From an object based view of spatial data, spatial autocorrelation measures the relationship between the difference of the aspatial attributes of objects with the distance between the objects.

For example, two objects which are close together and that have very similar aspatial descriptors are highly spatially correlated. Two objects close together that have very different aspatial descriptors are not very spatially autocorrelated (the objects are considered spatially independent). However, a negative spatial autocorrelation exists when objects that are close together have very different aspatial attributes than objects that are farther apart (Goodchild, 1986).

In the context of GRID, the objects correspond to cells and the aspatial descriptors or attributes correspond to cell values. The importance and usefulness of the spatial autocorrelation indices are:

> The spatial autocorrelation index is a single value describing the spatial distribution of the objects in space.
>
> It can be used to explore the cause of the spatial distribution of objects in space.
>
> The index can be used to determine the degree of adjustment necessary when modeling phenomena (Goodchild, 1986).
>
> The spatial autocorrelation index can aid in the process of extracting random, unbiased samples that will be fed into a classical statistical package.

GRID provides several spatial autocorrelation techniques. Two of the most widely accepted spatial autocorrelation indices are the Geary and Moran indices (both of which are available in GRID). The GEARY and MORAN indices for a grid test for spatial autocorrelation between directly adjacent cells in a grid and do not yield correlation between cells as a function of lag (beyond a cell's immediate neighborhood).

A third autocorrelation technique is incorporated in the CORRELATION atool. The CORRELATION atool measures the cross correlation between two grids, allowing for one of the grids to be offset with respect to the other. By using the same grid for both inputs, an (auto) correlation index as a function of lag can be computed. This technique

is particularly useful for determining the interval sample distance for purposes of random sampling.

The general notation used in correlation formulas and their GRID interpretation are the following:

n - the total number of cells in a grid: NROWS * NCOLS

i - any cell on the first input grid

j - any cell on the second input grid that is offset from i's location by the specified x-, y-offset

z_i -the value of the attribute of cell i

z_j -the value of the attribute of cell j

$\bar{z}_i$ -the mean value of the attribute of the first grid

$\bar{z}_j$ -the mean value of the attribute of the second grid

c_{ij} -the similarity of i's and j's attributes: $(z_i - \bar{z}_i) * (z_j - \bar{z}_j)$

In the terms of the above notation, spatial autocorrelation is simply a measure of the attribute similiarites in the set of c_{ij} with the locational similarities, and then summing the results into a single coefficient (Goodchild, 1986).

The formula for calculating the CORRELATION index is:

$$c = \sum_{k}^{n} c_{ij} / \left(\text{sqrt}\left(\sum_{k}^{n} (z_i - \bar{z}_i)^2\right) * \text{sqrt}\left(\sum_{k}^{n} (z_j - \bar{z}_j)^2\right)\right)$$

CORRELATION <grid1> {grid2} {xoffset} {yoffset}

Arguments

<grid1> - an input integer or floating-point grid.

{grid2} - an input integer or floating-point grid. If no second input grid is specified, the cross correlation will be performed on the first grid shifted on itself by the specified offset.

{xoffset} - the number of cells in the x-axis or direction to offset the second input grid from the first input grid. The default x-offset is zero cells.

{yoffset} - the number of cells in the y-axis or direction to offset the second input grid from the first input grid. The default y-offset is zero cells.

Notes:

(1) The output from the CORRELATION atool is a coefficient (a floating-point value) that is printed to the screen and set into a global AML variable .correlation_out.

(2) The spatial autocorrelation index is calculated best on non-categorical data.

(3) The use of the grid.item syntax is not supported for this command. The input values must reside in the value attribute of the grid(s).

(4) When the second input grid is the same as the first, the CORRELATION atool returns a spatial autocorrelation index for the input grid based on the specified x-, y-offset.

(4) The resulting correlation coefficient will be from -1 to 1. If the two grids at the given offset are highly cross correlated the coefficient will equal one, if they are independent, zero, and if there is a strong negative correlation the output value will equal -1.

References

Goodchild, M.F., 1986, Spatial Autocorrelation, Catmog 47, Geo Books, Norwich.

Hutchinson, S., 2004, Inside ArcView GIS 8.3, Thomson/Delmar Learning, Clifton Park, NY, 510pp.

Lee, J., and D.W.S. Wong, 2001, Statistical analysis with ArcView GIS, John Wiley and Sons, New York, 192pp.

Appendix 15A. Habitat Equivalency Analysis of Risk Consequences: Summary of Results

Section 1 Offsetting Restoration for One Organism

Section 1.1 Red River from Fargo to Lake Winnipeg - Progressive Dispersal

Risk Category	Probability of Successful Invasion	Percent Outcomes	<---Offsetting Restoration for One Organism---> Slow Invasion (River-Miles)	Fast Invasion (River-Miles)
Very Low	1.00E-09	87.0%	0.0000000805	0.000000470
Low	1.00E-06	7.6%	0.0000805	0.000470
Moderate	1.00E-03	3.7%	0.0805	0.470
High	1.00E-02	1.7%	0.805	4.70
Very High	1.00E+00	0.0%	80.5	470
Weighted Average (a)			0.02	0.10

Section 1.2 Lake Winnipeg - Jump Dispersal

Risk Category	Probability of Successful Invasion	Percent Outcomes	<---Offsetting Restoration for One Organism---> Slow Invasion (Acres)	Fast Invasion (Acres)
Very Low	1.00E-09	87.0%	0.00173	0.00708
Low	1.00E-06	7.6%	1.73	7.08
Moderate	1.00E-03	3.7%	1,730	7,080
High	1.00E-02	1.7%	17,300	70,800
Very High	1.00E+00	0.0%	1,730,000	7,080,000
Weighted Average (a)			358.24	1,466.10

Section 1.3 Lake Winnipeg - Progressive Dispersal

Risk Category	Probability of Successful Invasion	Percent Outcomes	<---Offsetting Restoration for One Organism---> Slow Invasion (Acres)	Fast Invasion (Acres)
Very Low	1.00E-09	87.0%	0.000000291	0.00301
Low	1.00E-06	7.6%	0.000291	3.01
Moderate	1.00E-03	3.7%	0.291	3,010
High	1.00E-02	1.7%	2.91	30,100
Very High	1.00E+00	0.0%	291	3,010,000
Weighted Average (a)			0.06	623.30

Section 2 Offsetting Restoration for 31 Biota

Section 2.1 Slow Invasion

	<----Offsetting Restoration for 31 Biota (b)---->	
Dispersal Scenario for Lake Winnipeg	Red River (River-Miles)	Lake Winnipeg (Acres)
0 Jump - 31 Progressive	0.6	1.9
1 Jump - 30 Progressive	0.6	360.0
10 Jump - 21 Progressive	0.6	3,583.7

Section 2.2 Fast Invasion

	<----Offsetting Restoration for 31 Biota (b)---->	
Dispersal Scenario for Lake Winnipeg	Red River (River-Miles)	Lake Winnipeg (Acres)
0 Jump - 31 Progressive	3.1	19,322.3
1 Jump - 30 Progressive	3.1	20,165.1
10 Jump - 21 Progressive	3.1	27,750.3

Section 3 Notes

(a) Weighted by the percent outcomes of respective risk categories

(b) Multiples of the weighted averages of the respective offsetting restoration levels for one organism, combined according to the dispersal scenarios for Lake Winnipeg

Appendix 15B. Habitat Equivalency Analysis of Risk Consequences: Slow Invasion - Very Low Risk (One Organism)

Probability of successful invasion: 1.00E-09

Annual discount rate: 3.0%

Present year: 0

Section 1 Quantification of Expected Lost Services

Section 1.1 Red River from Fargo to Lake Winnipeg - Progressive Dispersal

Affected habitat (river-miles): 455.40

	<----------(Percentage)---------->		<----------(River-Mile Years)---------->	
Year	Certain (a)	Expected (b)	Current Value	Present Value
0	0.00%	0.00000000000%	0.00000000000	0.00000000000
1	0.34%	0.00000000034%	0.00000000155	0.00000000150
2	0.68%	0.00000000068%	0.00000000310	0.00000000292
3	1.02%	0.00000000102%	0.00000000465	0.00000000425
4	1.36%	0.00000000136%	0.00000000620	0.00000000550
5	1.70%	0.00000000170%	0.00000000774	0.00000000668
6	2.04%	0.00000000204%	0.00000000929	0.00000000778
7	2.38%	0.00000000238%	0.00000001084	0.00000000882
8	2.72%	0.00000000272%	0.00000001239	0.00000000978
9	3.06%	0.00000000306%	0.00000001394	0.00000001068
10	3.40%	0.00000000340%	0.00000001549	0.00000001153
11	3.74%	0.00000000374%	0.00000001704	0.00000001231
12	4.08%	0.00000000408%	0.00000001859	0.00000001304
13	4.42%	0.00000000442%	0.00000002014	0.00000001371
14	4.76%	0.00000000476%	0.00000002169	0.00000001434
15	5.10%	0.00000000510%	0.00000002323	0.00000001491
16	5.44%	0.00000000544%	0.00000002478	0.00000001544
17	5.78%	0.00000000578%	0.00000002633	0.00000001593
18	6.12%	0.00000000612%	0.00000002788	0.00000001638
19	6.46%	0.00000000646%	0.00000002943	0.00000001678
20	6.80%	0.00000000680%	0.00000003098	0.00000001715
21	7.14%	0.00000000714%	0.00000003253	0.00000001749
22	7.48%	0.00000000748%	0.00000003408	0.00000001778
23	7.82%	0.00000000782%	0.00000003563	0.00000001805
24	8.16%	0.00000000816%	0.00000003718	0.00000001829
25	8.50%	0.00000000850%	0.00000003872	0.00000001850
26	8.84%	0.00000000884%	0.00000004027	0.00000001867
27	9.18%	0.00000000918%	0.00000004182	0.00000001883
28	9.52%	0.00000000952%	0.00000004337	0.00000001896
29	9.86%	0.00000000986%	0.00000004492	0.00000001906

30	10.20%	0.00000001020%	0.00000004647	0.00000001914
31	10.54%	0.00000001054%	0.00000004802	0.00000001921
32	10.88%	0.00000001088%	0.00000004957	0.00000001925
33	11.22%	0.00000001122%	0.00000005112	0.00000001927
34	11.56%	0.00000001156%	0.00000005267	0.00000001928
35	11.90%	0.00000001190%	0.00000005421	0.00000001927
36	12.24%	0.00000001224%	0.00000005576	0.00000001924
37	12.59%	0.00000001259%	0.00000005731	0.00000001920
38	12.93%	0.00000001293%	0.00000005886	0.00000001914
39	13.27%	0.00000001327%	0.00000006041	0.00000001907
40	13.61%	0.00000001361%	0.00000006196	0.00000001899
41	13.95%	0.00000001395%	0.00000006351	0.00000001890
42	14.29%	0.00000001429%	0.00000006506	0.00000001880
43	14.63%	0.00000001463%	0.00000006661	0.00000001869
44	14.97%	0.00000001497%	0.00000006816	0.00000001856
45	15.31%	0.00000001531%	0.00000006970	0.00000001843
46	15.65%	0.00000001565%	0.00000007125	0.00000001829
47	15.99%	0.00000001599%	0.00000007280	0.00000001815
48	16.33%	0.00000001633%	0.00000007435	0.00000001799
49	16.67%	0.00000001667%	0.00000007590	0.00000001783
50	17.01%	0.00000001701%	0.00000007745	0.00000001767
51	17.35%	0.00000001735%	0.00000007900	0.00000001750
52	17.69%	0.00000001769%	0.00000008055	0.00000001732
53	18.03%	0.00000001803%	0.00000008210	0.00000001714
54	18.37%	0.00000001837%	0.00000008364	0.00000001695
55	18.71%	0.00000001871%	0.00000008519	0.00000001676
56	19.05%	0.00000001905%	0.00000008674	0.00000001657
57	19.39%	0.00000001939%	0.00000008829	0.00000001638
58	19.73%	0.00000001973%	0.00000008984	0.00000001618
59	20.07%	0.00000002007%	0.00000009139	0.00000001598
60	20.41%	0.00000002041%	0.00000009294	0.00000001577
61	20.75%	0.00000002075%	0.00000009449	0.00000001557
62	21.09%	0.00000002109%	0.00000009604	0.00000001536
63	21.43%	0.00000002143%	0.00000009759	0.00000001516
64	21.77%	0.00000002177%	0.00000009913	0.00000001495
65	22.11%	0.00000002211%	0.00000010068	0.00000001474
66	22.45%	0.00000002245%	0.00000010223	0.00000001453
67	22.79%	0.00000002279%	0.00000010378	0.00000001432
68	23.13%	0.00000002313%	0.00000010533	0.00000001411
69	23.47%	0.00000002347%	0.00000010688	0.00000001390
70	23.81%	0.00000002381%	0.00000010843	0.00000001369
71	24.15%	0.00000002415%	0.00000010998	0.00000001349
72	24.49%	0.00000002449%	0.00000011153	0.00000001328
73	24.83%	0.00000002483%	0.00000011308	0.00000001307
74	25.17%	0.00000002517%	0.00000011462	0.00000001286
75	25.51%	0.00000002551%	0.00000011617	0.00000001266
76	25.85%	0.00000002585%	0.00000011772	0.00000001245
77	26.19%	0.00000002619%	0.00000011927	0.00000001225
78	26.53%	0.00000002653%	0.00000012082	0.00000001205
79	26.87%	0.00000002687%	0.00000012237	0.00000001184
80	27.21%	0.00000002721%	0.00000012392	0.00000001165
81	27.55%	0.00000002755%	0.00000012547	0.00000001145

82	27.89%	0.00000002789%	0.00000012702	0.00000001125
83	28.23%	0.00000002823%	0.00000012857	0.00000001106
84	28.57%	0.00000002857%	0.00000013011	0.00000001086
85	28.91%	0.00000002891%	0.00000013166	0.00000001067
86	29.25%	0.00000002925%	0.00000013321	0.00000001048
87	29.59%	0.00000002959%	0.00000013476	0.00000001030
88	29.93%	0.00000002993%	0.00000013631	0.00000001011
89	30.27%	0.00000003027%	0.00000013786	0.00000000993
90	30.61%	0.00000003061%	0.00000013941	0.00000000975
91	30.95%	0.00000003095%	0.00000014096	0.00000000957
92	31.29%	0.00000003129%	0.00000014251	0.00000000939
93	31.63%	0.00000003163%	0.00000014406	0.00000000922
94	31.97%	0.00000003197%	0.00000014560	0.00000000905
95	32.31%	0.00000003231%	0.00000014715	0.00000000888
96	32.65%	0.00000003265%	0.00000014870	0.00000000871
97	32.99%	0.00000003299%	0.00000015025	0.00000000854
98	33.33%	0.00000003333%	0.00000015180	0.00000000838
99	33.67%	0.00000003367%	0.00000015335	0.00000000822
100	34.01%	0.00000003401%	0.00000015490	0.00000000806
101	34.35%	0.00000003435%	0.00000015645	0.00000000790
102	34.69%	0.00000003469%	0.00000015800	0.00000000775
103	35.03%	0.00000003503%	0.00000015954	0.00000000760
104	35.37%	0.00000003537%	0.00000016109	0.00000000745
105	35.71%	0.00000003571%	0.00000016264	0.00000000730
106	36.05%	0.00000003605%	0.00000016419	0.00000000715
107	36.39%	0.00000003639%	0.00000016574	0.00000000701
108	36.73%	0.00000003673%	0.00000016729	0.00000000687
109	37.07%	0.00000003707%	0.00000016884	0.00000000673
110	37.41%	0.00000003741%	0.00000017039	0.00000000660
111	37.76%	0.00000003776%	0.00000017194	0.00000000646
112	38.10%	0.00000003810%	0.00000017349	0.00000000633
113	38.44%	0.00000003844%	0.00000017503	0.00000000620
114	38.78%	0.00000003878%	0.00000017658	0.00000000607
115	39.12%	0.00000003912%	0.00000017813	0.00000000595
116	39.46%	0.00000003946%	0.00000017968	0.00000000583
117	39.80%	0.00000003980%	0.00000018123	0.00000000571
118	40.14%	0.00000004014%	0.00000018278	0.00000000559
119	40.48%	0.00000004048%	0.00000018433	0.00000000547
120	40.82%	0.00000004082%	0.00000018588	0.00000000536
121	41.16%	0.00000004116%	0.00000018743	0.00000000524
122	41.50%	0.00000004150%	0.00000018898	0.00000000513
123	41.84%	0.00000004184%	0.00000019052	0.00000000502
124	42.18%	0.00000004218%	0.00000019207	0.00000000492
125	42.52%	0.00000004252%	0.00000019362	0.00000000481
126	42.86%	0.00000004286%	0.00000019517	0.00000000471
127	43.20%	0.00000004320%	0.00000019672	0.00000000461
128	43.54%	0.00000004354%	0.00000019827	0.00000000451
129	43.88%	0.00000004388%	0.00000019982	0.00000000441
130	44.22%	0.00000004422%	0.00000020137	0.00000000432
131	44.56%	0.00000004456%	0.00000020292	0.00000000422
132	44.90%	0.00000004490%	0.00000020447	0.00000000413
133	45.24%	0.00000004524%	0.00000020601	0.00000000404

134	45.58%	0.00000004558%	0.00000020756	0.00000000395
135	45.92%	0.00000004592%	0.00000020911	0.00000000387
136	46.26%	0.00000004626%	0.00000021066	0.00000000378
137	46.60%	0.00000004660%	0.00000021221	0.00000000370
138	46.94%	0.00000004694%	0.00000021376	0.00000000362
139	47.28%	0.00000004728%	0.00000021531	0.00000000354
140	47.62%	0.00000004762%	0.00000021686	0.00000000346
141	47.96%	0.00000004796%	0.00000021841	0.00000000338
142	48.30%	0.00000004830%	0.00000021996	0.00000000331
143	48.64%	0.00000004864%	0.00000022150	0.00000000323
144	48.98%	0.00000004898%	0.00000022305	0.00000000316
145	49.32%	0.00000004932%	0.00000022460	0.00000000309
146	49.66%	0.00000004966%	0.00000022615	0.00000000302
147	50.00%	0.00000005000%	0.00000022770	0.00000000295
148	50.34%	0.00000005034%	0.00000022925	0.00000000289
149	50.68%	0.00000005068%	0.00000023080	0.00000000282
150	51.02%	0.00000005102%	0.00000023235	0.00000000276
151	51.36%	0.00000005136%	0.00000023390	0.00000000270
152	51.70%	0.00000005170%	0.00000023544	0.00000000263
153	52.04%	0.00000005204%	0.00000023699	0.00000000257
154	52.38%	0.00000005238%	0.00000023854	0.00000000252
155	52.72%	0.00000005272%	0.00000024009	0.00000000246
156	53.06%	0.00000005306%	0.00000024164	0.00000000240
157	53.40%	0.00000005340%	0.00000024319	0.00000000235
158	53.74%	0.00000005374%	0.00000024474	0.00000000229
159	54.08%	0.00000005408%	0.00000024629	0.00000000224
160	54.42%	0.00000005442%	0.00000024784	0.00000000219
161	54.76%	0.00000005476%	0.00000024939	0.00000000214
162	55.10%	0.00000005510%	0.00000025093	0.00000000209
163	55.44%	0.00000005544%	0.00000025248	0.00000000204
164	55.78%	0.00000005578%	0.00000025403	0.00000000199
165	56.12%	0.00000005612%	0.00000025558	0.00000000195
166	56.46%	0.00000005646%	0.00000025713	0.00000000190
167	56.80%	0.00000005680%	0.00000025868	0.00000000186
168	57.14%	0.00000005714%	0.00000026023	0.00000000181
169	57.48%	0.00000005748%	0.00000026178	0.00000000177
170	57.82%	0.00000005782%	0.00000026333	0.00000000173
171	58.16%	0.00000005816%	0.00000026488	0.00000000169
172	58.50%	0.00000005850%	0.00000026642	0.00000000165
173	58.84%	0.00000005884%	0.00000026797	0.00000000161
174	59.18%	0.00000005918%	0.00000026952	0.00000000157
175	59.52%	0.00000005952%	0.00000027107	0.00000000154
176	59.86%	0.00000005986%	0.00000027262	0.00000000150
177	60.20%	0.00000006020%	0.00000027417	0.00000000146
178	60.54%	0.00000006054%	0.00000027572	0.00000000143
179	60.88%	0.00000006088%	0.00000027727	0.00000000140
180	61.22%	0.00000006122%	0.00000027882	0.00000000136
181	61.56%	0.00000006156%	0.00000028037	0.00000000133
182	61.90%	0.00000006190%	0.00000028191	0.00000000130
183	62.24%	0.00000006224%	0.00000028346	0.00000000127
184	62.59%	0.00000006259%	0.00000028501	0.00000000124
185	62.93%	0.00000006293%	0.00000028656	0.00000000121

186	63.27%	0.00000006327%	0.00000028811	0.00000000118
187	63.61%	0.00000006361%	0.00000028966	0.00000000115
188	63.95%	0.00000006395%	0.00000029121	0.00000000112
189	64.29%	0.00000006429%	0.00000029276	0.00000000110
190	64.63%	0.00000006463%	0.00000029431	0.00000000107
191	64.97%	0.00000006497%	0.00000029586	0.00000000105
192	65.31%	0.00000006531%	0.00000029740	0.00000000102
193	65.65%	0.00000006565%	0.00000029895	0.00000000100
194	65.99%	0.00000006599%	0.00000030050	0.00000000097
195	66.33%	0.00000006633%	0.00000030205	0.00000000095
196	66.67%	0.00000006667%	0.00000030360	0.00000000093
197	67.01%	0.00000006701%	0.00000030515	0.00000000090
198	67.35%	0.00000006735%	0.00000030670	0.00000000088
199	67.69%	0.00000006769%	0.00000030825	0.00000000086
200	68.03%	0.00000006803%	0.00000030980	0.00000000084
201	68.37%	0.00000006837%	0.00000031134	0.00000000082
202	68.71%	0.00000006871%	0.00000031289	0.00000000080
203	69.05%	0.00000006905%	0.00000031444	0.00000000078
204	69.39%	0.00000006939%	0.00000031599	0.00000000076
205	69.73%	0.00000006973%	0.00000031754	0.00000000074
206	70.07%	0.00000007007%	0.00000031909	0.00000000072
207	70.41%	0.00000007041%	0.00000032064	0.00000000071
208	70.75%	0.00000007075%	0.00000032219	0.00000000069
209	71.09%	0.00000007109%	0.00000032374	0.00000000067
210	71.43%	0.00000007143%	0.00000032529	0.00000000066
211	71.77%	0.00000007177%	0.00000032683	0.00000000064
212	72.11%	0.00000007211%	0.00000032838	0.00000000062
213	72.45%	0.00000007245%	0.00000032993	0.00000000061
214	72.79%	0.00000007279%	0.00000033148	0.00000000059
215	73.13%	0.00000007313%	0.00000033303	0.00000000058
216	73.47%	0.00000007347%	0.00000033458	0.00000000056
217	73.81%	0.00000007381%	0.00000033613	0.00000000055
218	74.15%	0.00000007415%	0.00000033768	0.00000000054
219	74.49%	0.00000007449%	0.00000033923	0.00000000052
220	74.83%	0.00000007483%	0.00000034078	0.00000000051
221	75.17%	0.00000007517%	0.00000034232	0.00000000050
222	75.51%	0.00000007551%	0.00000034387	0.00000000049
223	75.85%	0.00000007585%	0.00000034542	0.00000000047
224	76.19%	0.00000007619%	0.00000034697	0.00000000046
225	76.53%	0.00000007653%	0.00000034852	0.00000000045
226	76.87%	0.00000007687%	0.00000035007	0.00000000044
227	77.21%	0.00000007721%	0.00000035162	0.00000000043
228	77.55%	0.00000007755%	0.00000035317	0.00000000042
229	77.89%	0.00000007789%	0.00000035472	0.00000000041
230	78.23%	0.00000007823%	0.00000035627	0.00000000040
231	78.57%	0.00000007857%	0.00000035781	0.00000000039
232	78.91%	0.00000007891%	0.00000035936	0.00000000038
233	79.25%	0.00000007925%	0.00000036091	0.00000000037
234	79.59%	0.00000007959%	0.00000036246	0.00000000036
235	79.93%	0.00000007993%	0.00000036401	0.00000000035
236	80.27%	0.00000008027%	0.00000036556	0.00000000034
237	80.61%	0.00000008061%	0.00000036711	0.00000000033

238	80.95%	0.00000008095%	0.00000036866	0.00000000032
239	81.29%	0.00000008129%	0.00000037021	0.00000000032
240	81.63%	0.00000008163%	0.00000037176	0.00000000031
241	81.97%	0.00000008197%	0.00000037330	0.00000000030
242	82.31%	0.00000008231%	0.00000037485	0.00000000029
243	82.65%	0.00000008265%	0.00000037640	0.00000000029
244	82.99%	0.00000008299%	0.00000037795	0.00000000028
245	83.33%	0.00000008333%	0.00000037950	0.00000000027
246	83.67%	0.00000008367%	0.00000038105	0.00000000026
247	84.01%	0.00000008401%	0.00000038260	0.00000000026
248	84.35%	0.00000008435%	0.00000038415	0.00000000025
249	84.69%	0.00000008469%	0.00000038570	0.00000000025
250	85.03%	0.00000008503%	0.00000038724	0.00000000024
251	85.37%	0.00000008537%	0.00000038879	0.00000000023
252	85.71%	0.00000008571%	0.00000039034	0.00000000023
253	86.05%	0.00000008605%	0.00000039189	0.00000000022
254	86.39%	0.00000008639%	0.00000039344	0.00000000022
255	86.73%	0.00000008673%	0.00000039499	0.00000000021
256	87.07%	0.00000008707%	0.00000039654	0.00000000021
257	87.41%	0.00000008741%	0.00000039809	0.00000000020
258	87.76%	0.00000008776%	0.00000039964	0.00000000019
259	88.10%	0.00000008810%	0.00000040119	0.00000000019
260	88.44%	0.00000008844%	0.00000040273	0.00000000019
261	88.78%	0.00000008878%	0.00000040428	0.00000000018
262	89.12%	0.00000008912%	0.00000040583	0.00000000018
263	89.46%	0.00000008946%	0.00000040738	0.00000000017
264	89.80%	0.00000008980%	0.00000040893	0.00000000017
265	90.14%	0.00000009014%	0.00000041048	0.00000000016
266	90.48%	0.00000009048%	0.00000041203	0.00000000016
267	90.82%	0.00000009082%	0.00000041358	0.00000000015
268	91.16%	0.00000009116%	0.00000041513	0.00000000015
269	91.50%	0.00000009150%	0.00000041668	0.00000000015
270	91.84%	0.00000009184%	0.00000041822	0.00000000014
271	92.18%	0.00000009218%	0.00000041977	0.00000000014
272	92.52%	0.00000009252%	0.00000042132	0.00000000014
273	92.86%	0.00000009286%	0.00000042287	0.00000000013
274	93.20%	0.00000009320%	0.00000042442	0.00000000013
275	93.54%	0.00000009354%	0.00000042597	0.00000000013
276	93.88%	0.00000009388%	0.00000042752	0.00000000012
277	94.22%	0.00000009422%	0.00000042907	0.00000000012
278	94.56%	0.00000009456%	0.00000043062	0.00000000012
279	94.90%	0.00000009490%	0.00000043217	0.00000000011
280	95.24%	0.00000009524%	0.00000043371	0.00000000011
281	95.58%	0.00000009558%	0.00000043526	0.00000000011
282	95.92%	0.00000009592%	0.00000043681	0.00000000010
283	96.26%	0.00000009626%	0.00000043836	0.00000000010
284	96.60%	0.00000009660%	0.00000043991	0.00000000010
285	96.94%	0.00000009694%	0.00000044146	0.00000000010
286	97.28%	0.00000009728%	0.00000044301	0.00000000009
287	97.62%	0.00000009762%	0.00000044456	0.00000000009
288	97.96%	0.00000009796%	0.00000044611	0.00000000009
289	98.30%	0.00000009830%	0.00000044766	0.00000000009

290	98.64%	0.00000009864%	0.00000044920	0.00000000009
291	98.98%	0.00000009898%	0.00000045075	0.00000000008
292	99.32%	0.00000009932%	0.00000045230	0.00000000008
293	99.66%	0.00000009966%	0.00000045385	0.00000000008
294	100.00%	0.00000010000%	0.00000045540	0.00000000008
Beyond (c)				0.00000000255
Total				0.00000177242

Section 1.2 Lake Winnipeg - Jump Dispersal

Affected habitat (acres): 5,868,625.00

	<----------(Percentage)---------->		<----------(Acre Years)---------->	
Year	Certain (a)	Expected (b)	Current Value	Present Value
0	0.00%	0.00000000000%	0.00000000000	0.00000000000
1	0.57%	0.00000000057%	0.00003353500	0.00003255825
2	1.14%	0.00000000114%	0.00006707000	0.00006321991
3	1.71%	0.00000000171%	0.00010060500	0.00009206783
4	2.29%	0.00000000229%	0.00013414000	0.00011918165
5	2.86%	0.00000000286%	0.00016767500	0.00014463793
6	3.43%	0.00000000343%	0.00020121000	0.00016851021
7	4.00%	0.00000000400%	0.00023474500	0.00019086917
8	4.57%	0.00000000457%	0.00026828000	0.00021178271
9	5.14%	0.00000000514%	0.00030181500	0.00023131607
10	5.71%	0.00000000571%	0.00033535000	0.00024953189
11	6.29%	0.00000000629%	0.00036888500	0.00026649037
12	6.86%	0.00000000686%	0.00040242000	0.00028224929
13	7.43%	0.00000000743%	0.00043595500	0.00029686414
14	8.00%	0.00000000800%	0.00046949000	0.00031038820
15	8.57%	0.00000000857%	0.00050302500	0.00032287261
16	9.14%	0.00000000914%	0.00053656000	0.00033436645
17	9.71%	0.00000000971%	0.00057009500	0.00034491685
18	10.29%	0.00000001029%	0.00060363000	0.00035456901
19	10.86%	0.00000001086%	0.00063716500	0.00036336630
20	11.43%	0.00000001143%	0.00067070000	0.00037135033
21	12.00%	0.00000001200%	0.00070423500	0.00037856101
22	12.57%	0.00000001257%	0.00073777000	0.00038503663
23	13.14%	0.00000001314%	0.00077130500	0.00039081388
24	13.71%	0.00000001371%	0.00080484000	0.00039592795
25	14.29%	0.00000001429%	0.00083837500	0.00040041257
26	14.86%	0.00000001486%	0.00087191000	0.00040430007
27	15.43%	0.00000001543%	0.00090544500	0.00040762143
28	16.00%	0.00000001600%	0.00093898000	0.00041040633
29	16.57%	0.00000001657%	0.00097251500	0.00041268320
30	17.14%	0.00000001714%	0.00100605000	0.00041447928
31	17.71%	0.00000001771%	0.00103958500	0.00041582064
32	18.29%	0.00000001829%	0.00107312000	0.00041673224
33	18.86%	0.00000001886%	0.00110665500	0.00041723798
34	19.43%	0.00000001943%	0.00114019000	0.00041736073
35	20.00%	0.00000002000%	0.00117372500	0.00041712238

36	20.57%	0.00000002057%	0.00120726000	0.00041654385
37	21.14%	0.00000002114%	0.00124079500	0.00041564515
38	21.71%	0.00000002171%	0.00127433000	0.00041444544
39	22.29%	0.00000002229%	0.00130786500	0.00041296301
40	22.86%	0.00000002286%	0.00134140000	0.00041121535
41	23.43%	0.00000002343%	0.00137493500	0.00040921916
42	24.00%	0.00000002400%	0.00140847000	0.00040699040
43	24.57%	0.00000002457%	0.00144200500	0.00040454432
44	25.14%	0.00000002514%	0.00147554000	0.00040189546
45	25.71%	0.00000002571%	0.00150907500	0.00039905772
46	26.29%	0.00000002629%	0.00154261000	0.00039604434
47	26.86%	0.00000002686%	0.00157614500	0.00039286796
48	27.43%	0.00000002743%	0.00160968000	0.00038954063
49	28.00%	0.00000002800%	0.00164321500	0.00038607384
50	28.57%	0.00000002857%	0.00167675000	0.00038247855
51	29.14%	0.00000002914%	0.00171028500	0.00037876516
52	29.71%	0.00000002971%	0.00174382000	0.00037494362
53	30.29%	0.00000003029%	0.00177735500	0.00037102337
54	30.86%	0.00000003086%	0.00181089000	0.00036701341
55	31.43%	0.00000003143%	0.00184442500	0.00036292229
56	32.00%	0.00000003200%	0.00187796000	0.00035875813
57	32.57%	0.00000003257%	0.00191149500	0.00035452867
58	33.14%	0.00000003314%	0.00194503000	0.00035024123
59	33.71%	0.00000003371%	0.00197856500	0.00034590279
60	34.29%	0.00000003429%	0.00201210000	0.00034151995
61	34.86%	0.00000003486%	0.00204563500	0.00033709898
62	35.43%	0.00000003543%	0.00207917000	0.00033264582
63	36.00%	0.00000003600%	0.00211270500	0.00032816609
64	36.57%	0.00000003657%	0.00214624000	0.00032366512
65	37.14%	0.00000003714%	0.00217977500	0.00031914795
66	37.71%	0.00000003771%	0.00221331000	0.00031461934
67	38.29%	0.00000003829%	0.00224684500	0.00031008379
68	38.86%	0.00000003886%	0.00228038000	0.00030554554
69	39.43%	0.00000003943%	0.00231391500	0.00030100860
70	40.00%	0.00000004000%	0.00234745000	0.00029647674
71	40.57%	0.00000004057%	0.00238098500	0.00029195351
72	41.14%	0.00000004114%	0.00241452000	0.00028744227
73	41.71%	0.00000004171%	0.00244805500	0.00028294614
74	42.29%	0.00000004229%	0.00248159000	0.00027846807
75	42.86%	0.00000004286%	0.00251512500	0.00027401083
76	43.43%	0.00000004343%	0.00254866000	0.00026957699
77	44.00%	0.00000004400%	0.00258219500	0.00026516899
78	44.57%	0.00000004457%	0.00261573000	0.00026078907
79	45.14%	0.00000004514%	0.00264926500	0.00025643934
80	45.71%	0.00000004571%	0.00268280000	0.00025212175
81	46.29%	0.00000004629%	0.00271633500	0.00024783813
82	46.86%	0.00000004686%	0.00274987000	0.00024359016
83	47.43%	0.00000004743%	0.00278340500	0.00023937939
84	48.00%	0.00000004800%	0.00281694000	0.00023520726
85	48.57%	0.00000004857%	0.00285047500	0.00023107509
86	49.14%	0.00000004914%	0.00288401000	0.00022698410
87	49.71%	0.00000004971%	0.00291754500	0.00022293539

88	50.29%	0.00000005029%	0.00295108000	0.00021892997
89	50.86%	0.00000005086%	0.00298461500	0.00021496874
90	51.43%	0.00000005143%	0.00301815000	0.00021105255
91	52.00%	0.00000005200%	0.00305168500	0.00020718211
92	52.57%	0.00000005257%	0.00308522000	0.00020335810
93	53.14%	0.00000005314%	0.00311875500	0.00019958108
94	53.71%	0.00000005371%	0.00315229000	0.00019585156
95	54.29%	0.00000005429%	0.00318582500	0.00019216999
96	54.86%	0.00000005486%	0.00321936000	0.00018853673
97	55.43%	0.00000005543%	0.00325289500	0.00018495209
98	56.00%	0.00000005600%	0.00328643000	0.00018141633
99	56.57%	0.00000005657%	0.00331996500	0.00017792962
100	57.14%	0.00000005714%	0.00335350000	0.00017449213
101	57.71%	0.00000005771%	0.00338703500	0.00017110393
102	58.29%	0.00000005829%	0.00342057000	0.00016776508
103	58.86%	0.00000005886%	0.00345410500	0.00016447557
104	59.43%	0.00000005943%	0.00348764000	0.00016123536
105	60.00%	0.00000006000%	0.00352117500	0.00015804436
106	60.57%	0.00000006057%	0.00355471000	0.00015490248
107	61.14%	0.00000006114%	0.00358824500	0.00015180953
108	61.71%	0.00000006171%	0.00362178000	0.00014876535
109	62.29%	0.00000006229%	0.00365531500	0.00014576972
110	62.86%	0.00000006286%	0.00368885000	0.00014282238
111	63.43%	0.00000006343%	0.00372238500	0.00013992308
112	64.00%	0.00000006400%	0.00375592000	0.00013707150
113	64.57%	0.00000006457%	0.00378945500	0.00013426733
114	65.14%	0.00000006514%	0.00382299000	0.00013151023
115	65.71%	0.00000006571%	0.00385652500	0.00012879984
116	66.29%	0.00000006629%	0.00389006000	0.00012613576
117	66.86%	0.00000006686%	0.00392359500	0.00012351761
118	67.43%	0.00000006743%	0.00395713000	0.00012094497
119	68.00%	0.00000006800%	0.00399066500	0.00011841740
120	68.57%	0.00000006857%	0.00402420000	0.00011593447
121	69.14%	0.00000006914%	0.00405773500	0.00011349572
122	69.71%	0.00000006971%	0.00409127000	0.00011110068
123	70.29%	0.00000007029%	0.00412480500	0.00010874888
124	70.86%	0.00000007086%	0.00415834000	0.00010643982
125	71.43%	0.00000007143%	0.00419187500	0.00010417302
126	72.00%	0.00000007200%	0.00422541000	0.00010194796
127	72.57%	0.00000007257%	0.00425894500	0.00009976415
128	73.14%	0.00000007314%	0.00429248000	0.00009762106
129	73.71%	0.00000007371%	0.00432601500	0.00009551818
130	74.29%	0.00000007429%	0.00435955000	0.00009345498
131	74.86%	0.00000007486%	0.00439308500	0.00009143094
132	75.43%	0.00000007543%	0.00442662000	0.00008944552
133	76.00%	0.00000007600%	0.00446015500	0.00008749819
134	76.57%	0.00000007657%	0.00449369000	0.00008558842
135	77.14%	0.00000007714%	0.00452722500	0.00008371567
136	77.71%	0.00000007771%	0.00456076000	0.00008187940
137	78.29%	0.00000007829%	0.00459429500	0.00008007908
138	78.86%	0.00000007886%	0.00462783000	0.00007831418
139	79.43%	0.00000007943%	0.00466136500	0.00007658415

140	80.00%	0.00000008000%	0.00469490000	0.00007488846
141	80.57%	0.00000008057%	0.00472843500	0.00007322658
142	81.14%	0.00000008114%	0.00476197000	0.00007159798
143	81.71%	0.00000008171%	0.00479550500	0.00007000212
144	82.29%	0.00000008229%	0.00482904000	0.00006843849
145	82.86%	0.00000008286%	0.00486257500	0.00006690656
146	83.43%	0.00000008343%	0.00489611000	0.00006540581
147	84.00%	0.00000008400%	0.00492964500	0.00006393573
148	84.57%	0.00000008457%	0.00496318000	0.00006249579
149	85.14%	0.00000008514%	0.00499671500	0.00006108550
150	85.71%	0.00000008571%	0.00503025000	0.00005970433
151	86.29%	0.00000008629%	0.00506378500	0.00005835181
152	86.86%	0.00000008686%	0.00509732000	0.00005702742
153	87.43%	0.00000008743%	0.00513085500	0.00005573068
154	88.00%	0.00000008800%	0.00516439000	0.00005446110
155	88.57%	0.00000008857%	0.00519792500	0.00005321820
156	89.14%	0.00000008914%	0.00523146000	0.00005200150
157	89.71%	0.00000008971%	0.00526499500	0.00005081053
158	90.29%	0.00000009029%	0.00529853000	0.00004964481
159	90.86%	0.00000009086%	0.00533206500	0.00004850391
160	91.43%	0.00000009143%	0.00536560000	0.00004738734
161	92.00%	0.00000009200%	0.00539913500	0.00004629467
162	92.57%	0.00000009257%	0.00543267000	0.00004522545
163	93.14%	0.00000009314%	0.00546620500	0.00004417924
164	93.71%	0.00000009371%	0.00549974000	0.00004315561
165	94.29%	0.00000009429%	0.00553327500	0.00004215413
166	94.86%	0.00000009486%	0.00556681000	0.00004117438
167	95.43%	0.00000009543%	0.00560034500	0.00004021594
168	96.00%	0.00000009600%	0.00563388000	0.00003927840
169	96.57%	0.00000009657%	0.00566741500	0.00003836136
170	97.14%	0.00000009714%	0.00570095000	0.00003746442
171	97.71%	0.00000009771%	0.00573448500	0.00003658719
172	98.29%	0.00000009829%	0.00576802000	0.00003572927
173	98.86%	0.00000009886%	0.00580155500	0.00003489029
174	99.43%	0.00000009943%	0.00583509000	0.00003406987
175	100.00%	0.00000010000%	0.00586862500	0.00003326764
Beyond (d)				0.00110892144
Total				0.03816138462

Section 1.3 Lake Winnipeg - Progressive Dispersal

Affected habitat (acres): 5,868,625.00

	<----------(Percentage)---------->		<----------(Acre Years)---------->	
Year	Certain (a)	Expected (b)	Current Value	Present Value
294	0.00%	0.00000000000%	0.00000000000	0.00000000000
295	0.57%	0.00000000057%	0.00003353500	0.00000000548
296	1.14%	0.00000000114%	0.00006707000	0.00000001063
297	1.71%	0.00000000171%	0.00010060500	0.00000001549
298	2.29%	0.00000000229%	0.00013414000	0.00000002005

299	2.86%	0.00000000286%	0.00016767500	0.00000002433
300	3.43%	0.00000000343%	0.00020121000	0.00000002835
301	4.00%	0.00000000400%	0.00023474500	0.00000003211
302	4.57%	0.00000000457%	0.00026828000	0.00000003562
303	5.14%	0.00000000514%	0.00030181500	0.00000003891
304	5.71%	0.00000000571%	0.00033535000	0.00000004197
305	6.29%	0.00000000629%	0.00036888500	0.00000004483
306	6.86%	0.00000000686%	0.00040242000	0.00000004748
307	7.43%	0.00000000743%	0.00043595500	0.00000004994
308	8.00%	0.00000000800%	0.00046949000	0.00000005221
309	8.57%	0.00000000857%	0.00050302500	0.00000005431
310	9.14%	0.00000000914%	0.00053656000	0.00000005624
311	9.71%	0.00000000971%	0.00057009500	0.00000005802
312	10.29%	0.00000001029%	0.00060363000	0.00000005964
313	10.86%	0.00000001086%	0.00063716500	0.00000006112
314	11.43%	0.00000001143%	0.00067070000	0.00000006247
315	12.00%	0.00000001200%	0.00070423500	0.00000006368
316	12.57%	0.00000001257%	0.00073777000	0.00000006477
317	13.14%	0.00000001314%	0.00077130500	0.00000006574
318	13.71%	0.00000001371%	0.00080484000	0.00000006660
319	14.29%	0.00000001429%	0.00083837500	0.00000006735
320	14.86%	0.00000001486%	0.00087191000	0.00000006801
321	15.43%	0.00000001543%	0.00090544500	0.00000006857
322	16.00%	0.00000001600%	0.00093898000	0.00000006904
323	16.57%	0.00000001657%	0.00097251500	0.00000006942
324	17.14%	0.00000001714%	0.00100605000	0.00000006972
325	17.71%	0.00000001771%	0.00103958500	0.00000006995
326	18.29%	0.00000001829%	0.00107312000	0.00000007010
327	18.86%	0.00000001886%	0.00110665500	0.00000007018
328	19.43%	0.00000001943%	0.00114019000	0.00000007020
329	20.00%	0.00000002000%	0.00117372500	0.00000007016
330	20.57%	0.00000002057%	0.00120726000	0.00000007007
331	21.14%	0.00000002114%	0.00124079500	0.00000006992
332	21.71%	0.00000002171%	0.00127433000	0.00000006971
333	22.29%	0.00000002229%	0.00130786500	0.00000006947
334	22.86%	0.00000002286%	0.00134140000	0.00000006917
335	23.43%	0.00000002343%	0.00137493500	0.00000006884
336	24.00%	0.00000002400%	0.00140847000	0.00000006846
337	24.57%	0.00000002457%	0.00144200500	0.00000006805
338	25.14%	0.00000002514%	0.00147554000	0.00000006760
339	25.71%	0.00000002571%	0.00150907500	0.00000006713
340	26.29%	0.00000002629%	0.00154261000	0.00000006662
341	26.86%	0.00000002686%	0.00157614500	0.00000006608
342	27.43%	0.00000002743%	0.00160968000	0.00000006553
343	28.00%	0.00000002800%	0.00164321500	0.00000006494
344	28.57%	0.00000002857%	0.00167675000	0.00000006434
345	29.14%	0.00000002914%	0.00171028500	0.00000006371
346	29.71%	0.00000002971%	0.00174382000	0.00000006307
347	30.29%	0.00000003029%	0.00177735500	0.00000006241
348	30.86%	0.00000003086%	0.00181089000	0.00000006174
349	31.43%	0.00000003143%	0.00184442500	0.00000006105
350	32.00%	0.00000003200%	0.00187796000	0.00000006035

351	32.57%	0.00000003257%	0.00191149500	0.00000005964
352	33.14%	0.00000003314%	0.00194503000	0.00000005891
353	33.71%	0.00000003371%	0.00197856500	0.00000005818
354	34.29%	0.00000003429%	0.00201210000	0.00000005745
355	34.86%	0.00000003486%	0.00204563500	0.00000005670
356	35.43%	0.00000003543%	0.00207917000	0.00000005595
357	36.00%	0.00000003600%	0.00211270500	0.00000005520
358	36.57%	0.00000003657%	0.00214624000	0.00000005444
359	37.14%	0.00000003714%	0.00217977500	0.00000005368
360	37.71%	0.00000003771%	0.00221331000	0.00000005292
361	38.29%	0.00000003829%	0.00224684500	0.00000005216
362	38.86%	0.00000003886%	0.00228038000	0.00000005140
363	39.43%	0.00000003943%	0.00231391500	0.00000005063
364	40.00%	0.00000004000%	0.00234745000	0.00000004987
365	40.57%	0.00000004057%	0.00238098500	0.00000004911
366	41.14%	0.00000004114%	0.00241452000	0.00000004835
367	41.71%	0.00000004171%	0.00244805500	0.00000004759
368	42.29%	0.00000004229%	0.00248159000	0.00000004684
369	42.86%	0.00000004286%	0.00251512500	0.00000004609
370	43.43%	0.00000004343%	0.00254866000	0.00000004535
371	44.00%	0.00000004400%	0.00258219500	0.00000004460
372	44.57%	0.00000004457%	0.00261573000	0.00000004387
373	45.14%	0.00000004514%	0.00264926500	0.00000004314
374	45.71%	0.00000004571%	0.00268280000	0.00000004241
375	46.29%	0.00000004629%	0.00271633500	0.00000004169
376	46.86%	0.00000004686%	0.00274987000	0.00000004097
377	47.43%	0.00000004743%	0.00278340500	0.00000004027
378	48.00%	0.00000004800%	0.00281694000	0.00000003956
379	48.57%	0.00000004857%	0.00285047500	0.00000003887
380	49.14%	0.00000004914%	0.00288401000	0.00000003818
381	49.71%	0.00000004971%	0.00291754500	0.00000003750
382	50.29%	0.00000005029%	0.00295108000	0.00000003683
383	50.86%	0.00000005086%	0.00298461500	0.00000003616
384	51.43%	0.00000005143%	0.00301815000	0.00000003550
385	52.00%	0.00000005200%	0.00305168500	0.00000003485
386	52.57%	0.00000005257%	0.00308522000	0.00000003421
387	53.14%	0.00000005314%	0.00311875500	0.00000003357
388	53.71%	0.00000005371%	0.00315229000	0.00000003294
389	54.29%	0.00000005429%	0.00318582500	0.00000003233
390	54.86%	0.00000005486%	0.00321936000	0.00000003171
391	55.43%	0.00000005543%	0.00325289500	0.00000003111
392	56.00%	0.00000005600%	0.00328643000	0.00000003052
393	56.57%	0.00000005657%	0.00331996500	0.00000002993
394	57.14%	0.00000005714%	0.00335350000	0.00000002935
395	57.71%	0.00000005771%	0.00338703500	0.00000002878
396	58.29%	0.00000005829%	0.00342057000	0.00000002822
397	58.86%	0.00000005886%	0.00345410500	0.00000002767
398	59.43%	0.00000005943%	0.00348764000	0.00000002712
399	60.00%	0.00000006000%	0.00352117500	0.00000002658
400	60.57%	0.00000006057%	0.00355471000	0.00000002606
401	61.14%	0.00000006114%	0.00358824500	0.00000002554
402	61.71%	0.00000006171%	0.00362178000	0.00000002502

403	62.29%	0.00000006229%	0.00365531500	0.00000002452
404	62.86%	0.00000006286%	0.00368885000	0.00000002402
405	63.43%	0.00000006343%	0.00372238500	0.00000002354
406	64.00%	0.00000006400%	0.00375592000	0.00000002306
407	64.57%	0.00000006457%	0.00378945500	0.00000002259
408	65.14%	0.00000006514%	0.00382299000	0.00000002212
409	65.71%	0.00000006571%	0.00385652500	0.00000002167
410	66.29%	0.00000006629%	0.00389006000	0.00000002122
411	66.86%	0.00000006686%	0.00392359500	0.00000002078
412	67.43%	0.00000006743%	0.00395713000	0.00000002034
413	68.00%	0.00000006800%	0.00399066500	0.00000001992
414	68.57%	0.00000006857%	0.00402420000	0.00000001950
415	69.14%	0.00000006914%	0.00405773500	0.00000001909
416	69.71%	0.00000006971%	0.00409127000	0.00000001869
417	70.29%	0.00000007029%	0.00412480500	0.00000001829
418	70.86%	0.00000007086%	0.00415834000	0.00000001790
419	71.43%	0.00000007143%	0.00419187500	0.00000001752
420	72.00%	0.00000007200%	0.00422541000	0.00000001715
421	72.57%	0.00000007257%	0.00425894500	0.00000001678
422	73.14%	0.00000007314%	0.00429248000	0.00000001642
423	73.71%	0.00000007371%	0.00432601500	0.00000001607
424	74.29%	0.00000007429%	0.00435955000	0.00000001572
425	74.86%	0.00000007486%	0.00439308500	0.00000001538
426	75.43%	0.00000007543%	0.00442662000	0.00000001505
427	76.00%	0.00000007600%	0.00446015500	0.00000001472
428	76.57%	0.00000007657%	0.00449369000	0.00000001440
429	77.14%	0.00000007714%	0.00452722500	0.00000001408
430	77.71%	0.00000007771%	0.00456076000	0.00000001377
431	78.29%	0.00000007829%	0.00459429500	0.00000001347
432	78.86%	0.00000007886%	0.00462783000	0.00000001317
433	79.43%	0.00000007943%	0.00466136500	0.00000001288
434	80.00%	0.00000008000%	0.00469490000	0.00000001260
435	80.57%	0.00000008057%	0.00472843500	0.00000001232
436	81.14%	0.00000008114%	0.00476197000	0.00000001204
437	81.71%	0.00000008171%	0.00479550500	0.00000001178
438	82.29%	0.00000008229%	0.00482904000	0.00000001151
439	82.86%	0.00000008286%	0.00486257500	0.00000001125
440	83.43%	0.00000008343%	0.00489611000	0.00000001100
441	84.00%	0.00000008400%	0.00492964500	0.00000001075
442	84.57%	0.00000008457%	0.00496318000	0.00000001051
443	85.14%	0.00000008514%	0.00499671500	0.00000001028
444	85.71%	0.00000008571%	0.00503025000	0.00000001004
445	86.29%	0.00000008629%	0.00506378500	0.00000000982
446	86.86%	0.00000008686%	0.00509732000	0.00000000959
447	87.43%	0.00000008743%	0.00513085500	0.00000000937
448	88.00%	0.00000008800%	0.00516439000	0.00000000916
449	88.57%	0.00000008857%	0.00519792500	0.00000000895
450	89.14%	0.00000008914%	0.00523146000	0.00000000875
451	89.71%	0.00000008971%	0.00526499500	0.00000000855
452	90.29%	0.00000009029%	0.00529853000	0.00000000835
453	90.86%	0.00000009086%	0.00533206500	0.00000000816
454	91.43%	0.00000009143%	0.00536560000	0.00000000797

455	92.00%	0.00000009200%	0.00539913500	0.00000000779
456	92.57%	0.00000009257%	0.00543267000	0.00000000761
457	93.14%	0.00000009314%	0.00546620500	0.00000000743
458	93.71%	0.00000009371%	0.00549974000	0.00000000726
459	94.29%	0.00000009429%	0.00553327500	0.00000000709
460	94.86%	0.00000009486%	0.00556681000	0.00000000693
461	95.43%	0.00000009543%	0.00560034500	0.00000000676
462	96.00%	0.00000009600%	0.00563388000	0.00000000661
463	96.57%	0.00000009657%	0.00566741500	0.00000000645
464	97.14%	0.00000009714%	0.00570095000	0.00000000630
465	97.71%	0.00000009771%	0.00573448500	0.00000000615
466	98.29%	0.00000009829%	0.00576802000	0.00000000601
467	98.86%	0.00000009886%	0.00580155500	0.00000000587
468	99.43%	0.00000009943%	0.00583509000	0.00000000573
469	100.00%	0.00000010000%	0.00586862500	0.00000000560
Beyond (e)				0.00000018653
Total				0.00000641919

Section 2 Quantification of Replacement Services

	<----------(Percentage)---------->	
Year	Current Value	Present Value
5	0.0%	0.0%
6	5.0%	4.2%
7	10.0%	8.1%
8	15.0%	11.8%
9	20.0%	15.3%
10	25.0%	18.6%
11	30.0%	21.7%
12	35.0%	24.5%
13	40.0%	27.2%
14	45.0%	29.8%
15	50.0%	32.1%
16	55.0%	34.3%
17	60.0%	36.3%
18	65.0%	38.2%
19	70.0%	39.9%
20	75.0%	41.5%
21	80.0%	43.0%
22	85.0%	44.4%
23	90.0%	45.6%
24	95.0%	46.7%
25	100.0%	47.8%
Beyond (f)		1592.0%
Total		2203.1%

Section 3 Offsetting Restoration for One Organism

Red River - Progressive Dispersal (river-miles):	0.0000000805
Lake Winnipeg - Jump Dispersal (acres):	0.00173
Lake Winnipeg - Progressive Dispersal (acres):	0.000000291

Section 4 Notes

(a) Percent loss given certain invasion

(b) Percent loss given probability of successful invasion

(c) From year 295 into perpetuity

(d) From year 176 into perpetuity

(e) From year 470 into perpetuity

(f) From year 26 into perpetuity

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Appendix 15C. Habitat Equivalency Analysis of Risk Consequences: Slow Invasion - Low Risk (One Organism)

Probability of successful invasion: 1.00E-06

Annual discount rate: 3.0%

Present year: 0

Section 1 Quantification of Expected Lost Services

Section 1.1 Red River from Fargo to Lake Winnipeg - Progressive Dispersal

Affected habitat (river-miles): 455.40

	<----------(Percentage)---------->		<----------(River-Mile Years)---------->	
Year	Certain (a)	Expected (b)	Current Value	Present Value
0	0.00%	0.00000000%	0.00000000	0.00000000
1	0.34%	0.00000034%	0.00000155	0.00000150
2	0.68%	0.00000068%	0.00000310	0.00000292
3	1.02%	0.00000102%	0.00000465	0.00000425
4	1.36%	0.00000136%	0.00000620	0.00000550
5	1.70%	0.00000170%	0.00000774	0.00000668
6	2.04%	0.00000204%	0.00000929	0.00000778
7	2.38%	0.00000238%	0.00001084	0.00000882
8	2.72%	0.00000272%	0.00001239	0.00000978
9	3.06%	0.00000306%	0.00001394	0.00001068
10	3.40%	0.00000340%	0.00001549	0.00001153
11	3.74%	0.00000374%	0.00001704	0.00001231
12	4.08%	0.00000408%	0.00001859	0.00001304
13	4.42%	0.00000442%	0.00002014	0.00001371
14	4.76%	0.00000476%	0.00002169	0.00001434
15	5.10%	0.00000510%	0.00002323	0.00001491
16	5.44%	0.00000544%	0.00002478	0.00001544
17	5.78%	0.00000578%	0.00002633	0.00001593
18	6.12%	0.00000612%	0.00002788	0.00001638
19	6.46%	0.00000646%	0.00002943	0.00001678
20	6.80%	0.00000680%	0.00003098	0.00001715
21	7.14%	0.00000714%	0.00003253	0.00001749
22	7.48%	0.00000748%	0.00003408	0.00001778
23	7.82%	0.00000782%	0.00003563	0.00001805
24	8.16%	0.00000816%	0.00003718	0.00001829
25	8.50%	0.00000850%	0.00003872	0.00001850
26	8.84%	0.00000884%	0.00004027	0.00001867
27	9.18%	0.00000918%	0.00004182	0.00001883
28	9.52%	0.00000952%	0.00004337	0.00001896
29	9.86%	0.00000986%	0.00004492	0.00001906

30	10.20%	0.00001020%	0.00004647	0.00001914
31	10.54%	0.00001054%	0.00004802	0.00001921
32	10.88%	0.00001088%	0.00004957	0.00001925
33	11.22%	0.00001122%	0.00005112	0.00001927
34	11.56%	0.00001156%	0.00005267	0.00001928
35	11.90%	0.00001190%	0.00005421	0.00001927
36	12.24%	0.00001224%	0.00005576	0.00001924
37	12.59%	0.00001259%	0.00005731	0.00001920
38	12.93%	0.00001293%	0.00005886	0.00001914
39	13.27%	0.00001327%	0.00006041	0.00001907
40	13.61%	0.00001361%	0.00006196	0.00001899
41	13.95%	0.00001395%	0.00006351	0.00001890
42	14.29%	0.00001429%	0.00006506	0.00001880
43	14.63%	0.00001463%	0.00006661	0.00001869
44	14.97%	0.00001497%	0.00006816	0.00001856
45	15.31%	0.00001531%	0.00006970	0.00001843
46	15.65%	0.00001565%	0.00007125	0.00001829
47	15.99%	0.00001599%	0.00007280	0.00001815
48	16.33%	0.00001633%	0.00007435	0.00001799
49	16.67%	0.00001667%	0.00007590	0.00001783
50	17.01%	0.00001701%	0.00007745	0.00001767
51	17.35%	0.00001735%	0.00007900	0.00001750
52	17.69%	0.00001769%	0.00008055	0.00001732
53	18.03%	0.00001803%	0.00008210	0.00001714
54	18.37%	0.00001837%	0.00008364	0.00001695
55	18.71%	0.00001871%	0.00008519	0.00001676
56	19.05%	0.00001905%	0.00008674	0.00001657
57	19.39%	0.00001939%	0.00008829	0.00001638
58	19.73%	0.00001973%	0.00008984	0.00001618
59	20.07%	0.00002007%	0.00009139	0.00001598
60	20.41%	0.00002041%	0.00009294	0.00001577
61	20.75%	0.00002075%	0.00009449	0.00001557
62	21.09%	0.00002109%	0.00009604	0.00001536
63	21.43%	0.00002143%	0.00009759	0.00001516
64	21.77%	0.00002177%	0.00009913	0.00001495
65	22.11%	0.00002211%	0.00010068	0.00001474
66	22.45%	0.00002245%	0.00010223	0.00001453
67	22.79%	0.00002279%	0.00010378	0.00001432
68	23.13%	0.00002313%	0.00010533	0.00001411
69	23.47%	0.00002347%	0.00010688	0.00001390
70	23.81%	0.00002381%	0.00010843	0.00001369
71	24.15%	0.00002415%	0.00010998	0.00001349
72	24.49%	0.00002449%	0.00011153	0.00001328
73	24.83%	0.00002483%	0.00011308	0.00001307
74	25.17%	0.00002517%	0.00011462	0.00001286
75	25.51%	0.00002551%	0.00011617	0.00001266
76	25.85%	0.00002585%	0.00011772	0.00001245
77	26.19%	0.00002619%	0.00011927	0.00001225
78	26.53%	0.00002653%	0.00012082	0.00001205
79	26.87%	0.00002687%	0.00012237	0.00001184
80	27.21%	0.00002721%	0.00012392	0.00001165
81	27.55%	0.00002755%	0.00012547	0.00001145

82	27.89%	0.00002789%	0.00012702	0.00001125
83	28.23%	0.00002823%	0.00012857	0.00001106
84	28.57%	0.00002857%	0.00013011	0.00001086
85	28.91%	0.00002891%	0.00013166	0.00001067
86	29.25%	0.00002925%	0.00013321	0.00001048
87	29.59%	0.00002959%	0.00013476	0.00001030
88	29.93%	0.00002993%	0.00013631	0.00001011
89	30.27%	0.00003027%	0.00013786	0.00000993
90	30.61%	0.00003061%	0.00013941	0.00000975
91	30.95%	0.00003095%	0.00014096	0.00000957
92	31.29%	0.00003129%	0.00014251	0.00000939
93	31.63%	0.00003163%	0.00014406	0.00000922
94	31.97%	0.00003197%	0.00014560	0.00000905
95	32.31%	0.00003231%	0.00014715	0.00000888
96	32.65%	0.00003265%	0.00014870	0.00000871
97	32.99%	0.00003299%	0.00015025	0.00000854
98	33.33%	0.00003333%	0.00015180	0.00000838
99	33.67%	0.00003367%	0.00015335	0.00000822
100	34.01%	0.00003401%	0.00015490	0.00000806
101	34.35%	0.00003435%	0.00015645	0.00000790
102	34.69%	0.00003469%	0.00015800	0.00000775
103	35.03%	0.00003503%	0.00015954	0.00000760
104	35.37%	0.00003537%	0.00016109	0.00000745
105	35.71%	0.00003571%	0.00016264	0.00000730
106	36.05%	0.00003605%	0.00016419	0.00000715
107	36.39%	0.00003639%	0.00016574	0.00000701
108	36.73%	0.00003673%	0.00016729	0.00000687
109	37.07%	0.00003707%	0.00016884	0.00000673
110	37.41%	0.00003741%	0.00017039	0.00000660
111	37.76%	0.00003776%	0.00017194	0.00000646
112	38.10%	0.00003810%	0.00017349	0.00000633
113	38.44%	0.00003844%	0.00017503	0.00000620
114	38.78%	0.00003878%	0.00017658	0.00000607
115	39.12%	0.00003912%	0.00017813	0.00000595
116	39.46%	0.00003946%	0.00017968	0.00000583
117	39.80%	0.00003980%	0.00018123	0.00000571
118	40.14%	0.00004014%	0.00018278	0.00000559
119	40.48%	0.00004048%	0.00018433	0.00000547
120	40.82%	0.00004082%	0.00018588	0.00000536
121	41.16%	0.00004116%	0.00018743	0.00000524
122	41.50%	0.00004150%	0.00018898	0.00000513
123	41.84%	0.00004184%	0.00019052	0.00000502
124	42.18%	0.00004218%	0.00019207	0.00000492
125	42.52%	0.00004252%	0.00019362	0.00000481
126	42.86%	0.00004286%	0.00019517	0.00000471
127	43.20%	0.00004320%	0.00019672	0.00000461
128	43.54%	0.00004354%	0.00019827	0.00000451
129	43.88%	0.00004388%	0.00019982	0.00000441
130	44.22%	0.00004422%	0.00020137	0.00000432
131	44.56%	0.00004456%	0.00020292	0.00000422
132	44.90%	0.00004490%	0.00020447	0.00000413
133	45.24%	0.00004524%	0.00020601	0.00000404

134	45.58%	0.00004558%	0.00020756	0.00000395
135	45.92%	0.00004592%	0.00020911	0.00000387
136	46.26%	0.00004626%	0.00021066	0.00000378
137	46.60%	0.00004660%	0.00021221	0.00000370
138	46.94%	0.00004694%	0.00021376	0.00000362
139	47.28%	0.00004728%	0.00021531	0.00000354
140	47.62%	0.00004762%	0.00021686	0.00000346
141	47.96%	0.00004796%	0.00021841	0.00000338
142	48.30%	0.00004830%	0.00021996	0.00000331
143	48.64%	0.00004864%	0.00022150	0.00000323
144	48.98%	0.00004898%	0.00022305	0.00000316
145	49.32%	0.00004932%	0.00022460	0.00000309
146	49.66%	0.00004966%	0.00022615	0.00000302
147	50.00%	0.00005000%	0.00022770	0.00000295
148	50.34%	0.00005034%	0.00022925	0.00000289
149	50.68%	0.00005068%	0.00023080	0.00000282
150	51.02%	0.00005102%	0.00023235	0.00000276
151	51.36%	0.00005136%	0.00023390	0.00000270
152	51.70%	0.00005170%	0.00023544	0.00000263
153	52.04%	0.00005204%	0.00023699	0.00000257
154	52.38%	0.00005238%	0.00023854	0.00000252
155	52.72%	0.00005272%	0.00024009	0.00000246
156	53.06%	0.00005306%	0.00024164	0.00000240
157	53.40%	0.00005340%	0.00024319	0.00000235
158	53.74%	0.00005374%	0.00024474	0.00000229
159	54.08%	0.00005408%	0.00024629	0.00000224
160	54.42%	0.00005442%	0.00024784	0.00000219
161	54.76%	0.00005476%	0.00024939	0.00000214
162	55.10%	0.00005510%	0.00025093	0.00000209
163	55.44%	0.00005544%	0.00025248	0.00000204
164	55.78%	0.00005578%	0.00025403	0.00000199
165	56.12%	0.00005612%	0.00025558	0.00000195
166	56.46%	0.00005646%	0.00025713	0.00000190
167	56.80%	0.00005680%	0.00025868	0.00000186
168	57.14%	0.00005714%	0.00026023	0.00000181
169	57.48%	0.00005748%	0.00026178	0.00000177
170	57.82%	0.00005782%	0.00026333	0.00000173
171	58.16%	0.00005816%	0.00026488	0.00000169
172	58.50%	0.00005850%	0.00026642	0.00000165
173	58.84%	0.00005884%	0.00026797	0.00000161
174	59.18%	0.00005918%	0.00026952	0.00000157
175	59.52%	0.00005952%	0.00027107	0.00000154
176	59.86%	0.00005986%	0.00027262	0.00000150
177	60.20%	0.00006020%	0.00027417	0.00000146
178	60.54%	0.00006054%	0.00027572	0.00000143
179	60.88%	0.00006088%	0.00027727	0.00000140
180	61.22%	0.00006122%	0.00027882	0.00000136
181	61.56%	0.00006156%	0.00028037	0.00000133
182	61.90%	0.00006190%	0.00028191	0.00000130
183	62.24%	0.00006224%	0.00028346	0.00000127
184	62.59%	0.00006259%	0.00028501	0.00000124
185	62.93%	0.00006293%	0.00028656	0.00000121

186	63.27%	0.00006327%	0.00028811	0.00000118
187	63.61%	0.00006361%	0.00028966	0.00000115
188	63.95%	0.00006395%	0.00029121	0.00000112
189	64.29%	0.00006429%	0.00029276	0.00000110
190	64.63%	0.00006463%	0.00029431	0.00000107
191	64.97%	0.00006497%	0.00029586	0.00000105
192	65.31%	0.00006531%	0.00029740	0.00000102
193	65.65%	0.00006565%	0.00029895	0.00000100
194	65.99%	0.00006599%	0.00030050	0.00000097
195	66.33%	0.00006633%	0.00030205	0.00000095
196	66.67%	0.00006667%	0.00030360	0.00000093
197	67.01%	0.00006701%	0.00030515	0.00000090
198	67.35%	0.00006735%	0.00030670	0.00000088
199	67.69%	0.00006769%	0.00030825	0.00000086
200	68.03%	0.00006803%	0.00030980	0.00000084
201	68.37%	0.00006837%	0.00031134	0.00000082
202	68.71%	0.00006871%	0.00031289	0.00000080
203	69.05%	0.00006905%	0.00031444	0.00000078
204	69.39%	0.00006939%	0.00031599	0.00000076
205	69.73%	0.00006973%	0.00031754	0.00000074
206	70.07%	0.00007007%	0.00031909	0.00000072
207	70.41%	0.00007041%	0.00032064	0.00000071
208	70.75%	0.00007075%	0.00032219	0.00000069
209	71.09%	0.00007109%	0.00032374	0.00000067
210	71.43%	0.00007143%	0.00032529	0.00000066
211	71.77%	0.00007177%	0.00032683	0.00000064
212	72.11%	0.00007211%	0.00032838	0.00000062
213	72.45%	0.00007245%	0.00032993	0.00000061
214	72.79%	0.00007279%	0.00033148	0.00000059
215	73.13%	0.00007313%	0.00033303	0.00000058
216	73.47%	0.00007347%	0.00033458	0.00000056
217	73.81%	0.00007381%	0.00033613	0.00000055
218	74.15%	0.00007415%	0.00033768	0.00000054
219	74.49%	0.00007449%	0.00033923	0.00000052
220	74.83%	0.00007483%	0.00034078	0.00000051
221	75.17%	0.00007517%	0.00034232	0.00000050
222	75.51%	0.00007551%	0.00034387	0.00000049
223	75.85%	0.00007585%	0.00034542	0.00000047
224	76.19%	0.00007619%	0.00034697	0.00000046
225	76.53%	0.00007653%	0.00034852	0.00000045
226	76.87%	0.00007687%	0.00035007	0.00000044
227	77.21%	0.00007721%	0.00035162	0.00000043
228	77.55%	0.00007755%	0.00035317	0.00000042
229	77.89%	0.00007789%	0.00035472	0.00000041
230	78.23%	0.00007823%	0.00035627	0.00000040
231	78.57%	0.00007857%	0.00035781	0.00000039
232	78.91%	0.00007891%	0.00035936	0.00000038
233	79.25%	0.00007925%	0.00036091	0.00000037
234	79.59%	0.00007959%	0.00036246	0.00000036
235	79.93%	0.00007993%	0.00036401	0.00000035
236	80.27%	0.00008027%	0.00036556	0.00000034
237	80.61%	0.00008061%	0.00036711	0.00000033

238	80.95%	0.00008095%	0.00036866	0.00000032
239	81.29%	0.00008129%	0.00037021	0.00000032
240	81.63%	0.00008163%	0.00037176	0.00000031
241	81.97%	0.00008197%	0.00037330	0.00000030
242	82.31%	0.00008231%	0.00037485	0.00000029
243	82.65%	0.00008265%	0.00037640	0.00000029
244	82.99%	0.00008299%	0.00037795	0.00000028
245	83.33%	0.00008333%	0.00037950	0.00000027
246	83.67%	0.00008367%	0.00038105	0.00000026
247	84.01%	0.00008401%	0.00038260	0.00000026
248	84.35%	0.00008435%	0.00038415	0.00000025
249	84.69%	0.00008469%	0.00038570	0.00000025
250	85.03%	0.00008503%	0.00038724	0.00000024
251	85.37%	0.00008537%	0.00038879	0.00000023
252	85.71%	0.00008571%	0.00039034	0.00000023
253	86.05%	0.00008605%	0.00039189	0.00000022
254	86.39%	0.00008639%	0.00039344	0.00000022
255	86.73%	0.00008673%	0.00039499	0.00000021
256	87.07%	0.00008707%	0.00039654	0.00000021
257	87.41%	0.00008741%	0.00039809	0.00000020
258	87.76%	0.00008776%	0.00039964	0.00000019
259	88.10%	0.00008810%	0.00040119	0.00000019
260	88.44%	0.00008844%	0.00040273	0.00000019
261	88.78%	0.00008878%	0.00040428	0.00000018
262	89.12%	0.00008912%	0.00040583	0.00000018
263	89.46%	0.00008946%	0.00040738	0.00000017
264	89.80%	0.00008980%	0.00040893	0.00000017
265	90.14%	0.00009014%	0.00041048	0.00000016
266	90.48%	0.00009048%	0.00041203	0.00000016
267	90.82%	0.00009082%	0.00041358	0.00000015
268	91.16%	0.00009116%	0.00041513	0.00000015
269	91.50%	0.00009150%	0.00041668	0.00000015
270	91.84%	0.00009184%	0.00041822	0.00000014
271	92.18%	0.00009218%	0.00041977	0.00000014
272	92.52%	0.00009252%	0.00042132	0.00000014
273	92.86%	0.00009286%	0.00042287	0.00000013
274	93.20%	0.00009320%	0.00042442	0.00000013
275	93.54%	0.00009354%	0.00042597	0.00000013
276	93.88%	0.00009388%	0.00042752	0.00000012
277	94.22%	0.00009422%	0.00042907	0.00000012
278	94.56%	0.00009456%	0.00043062	0.00000012
279	94.90%	0.00009490%	0.00043217	0.00000011
280	95.24%	0.00009524%	0.00043371	0.00000011
281	95.58%	0.00009558%	0.00043526	0.00000011
282	95.92%	0.00009592%	0.00043681	0.00000010
283	96.26%	0.00009626%	0.00043836	0.00000010
284	96.60%	0.00009660%	0.00043991	0.00000010
285	96.94%	0.00009694%	0.00044146	0.00000010
286	97.28%	0.00009728%	0.00044301	0.00000009
287	97.62%	0.00009762%	0.00044456	0.00000009
288	97.96%	0.00009796%	0.00044611	0.00000009
289	98.30%	0.00009830%	0.00044766	0.00000009

290	98.64%	0.00009864%	0.00044920	0.00000009
291	98.98%	0.00009898%	0.00045075	0.00000008
292	99.32%	0.00009932%	0.00045230	0.00000008
293	99.66%	0.00009966%	0.00045385	0.00000008
294	100.00%	0.00010000%	0.00045540	0.00000008
Beyond (c)				0.00000255
Total				0.00177242

Section 1.2 Lake Winnipeg - Jump Dispersal

Affected habitat (acres): 5,868,625.00

	<----------(Percentage)---------->		<----------(Acre Years)---------->	
Year	Certain (a)	Expected (b)	Current Value	Present Value
0	0.00%	0.00000000%	0.00000000	0.00000000
1	0.57%	0.00000057%	0.03353500	0.03255825
2	1.14%	0.00000114%	0.06707000	0.06321991
3	1.71%	0.00000171%	0.10060500	0.09206783
4	2.29%	0.00000229%	0.13414000	0.11918165
5	2.86%	0.00000286%	0.16767500	0.14463793
6	3.43%	0.00000343%	0.20121000	0.16851021
7	4.00%	0.00000400%	0.23474500	0.19086917
8	4.57%	0.00000457%	0.26828000	0.21178271
9	5.14%	0.00000514%	0.30181500	0.23131607
10	5.71%	0.00000571%	0.33535000	0.24953189
11	6.29%	0.00000629%	0.36888500	0.26649037
12	6.86%	0.00000686%	0.40242000	0.28224929
13	7.43%	0.00000743%	0.43595500	0.29686414
14	8.00%	0.00000800%	0.46949000	0.31038820
15	8.57%	0.00000857%	0.50302500	0.32287261
16	9.14%	0.00000914%	0.53656000	0.33436645
17	9.71%	0.00000971%	0.57009500	0.34491685
18	10.29%	0.00001029%	0.60363000	0.35456901
19	10.86%	0.00001086%	0.63716500	0.36336630
20	11.43%	0.00001143%	0.67070000	0.37135033
21	12.00%	0.00001200%	0.70423500	0.37856101
22	12.57%	0.00001257%	0.73777000	0.38503663
23	13.14%	0.00001314%	0.77130500	0.39081388
24	13.71%	0.00001371%	0.80484000	0.39592795
25	14.29%	0.00001429%	0.83837500	0.40041257
26	14.86%	0.00001486%	0.87191000	0.40430007
27	15.43%	0.00001543%	0.90544500	0.40762143
28	16.00%	0.00001600%	0.93898000	0.41040633
29	16.57%	0.00001657%	0.97251500	0.41268320
30	17.14%	0.00001714%	1.00605000	0.41447928
31	17.71%	0.00001771%	1.03958500	0.41582064
32	18.29%	0.00001829%	1.07312000	0.41673224
33	18.86%	0.00001886%	1.10665500	0.41723798
34	19.43%	0.00001943%	1.14019000	0.41736073
35	20.00%	0.00002000%	1.17372500	0.41712238

36	20.57%	0.00002057%	1.20726000	0.41654385
37	21.14%	0.00002114%	1.24079500	0.41564515
38	21.71%	0.00002171%	1.27433000	0.41444544
39	22.29%	0.00002229%	1.30786500	0.41296301
40	22.86%	0.00002286%	1.34140000	0.41121535
41	23.43%	0.00002343%	1.37493500	0.40921916
42	24.00%	0.00002400%	1.40847000	0.40699040
43	24.57%	0.00002457%	1.44200500	0.40454432
44	25.14%	0.00002514%	1.47554000	0.40189546
45	25.71%	0.00002571%	1.50907500	0.39905772
46	26.29%	0.00002629%	1.54261000	0.39604434
47	26.86%	0.00002686%	1.57614500	0.39286796
48	27.43%	0.00002743%	1.60968000	0.38954063
49	28.00%	0.00002800%	1.64321500	0.38607384
50	28.57%	0.00002857%	1.67675000	0.38247855
51	29.14%	0.00002914%	1.71028500	0.37876516
52	29.71%	0.00002971%	1.74382000	0.37494362
53	30.29%	0.00003029%	1.77735500	0.37102337
54	30.86%	0.00003086%	1.81089000	0.36701341
55	31.43%	0.00003143%	1.84442500	0.36292229
56	32.00%	0.00003200%	1.87796000	0.35875813
57	32.57%	0.00003257%	1.91149500	0.35452867
58	33.14%	0.00003314%	1.94503000	0.35024123
59	33.71%	0.00003371%	1.97856500	0.34590279
60	34.29%	0.00003429%	2.01210000	0.34151995
61	34.86%	0.00003486%	2.04563500	0.33709898
62	35.43%	0.00003543%	2.07917000	0.33264582
63	36.00%	0.00003600%	2.11270500	0.32816609
64	36.57%	0.00003657%	2.14624000	0.32366512
65	37.14%	0.00003714%	2.17977500	0.31914795
66	37.71%	0.00003771%	2.21331000	0.31461934
67	38.29%	0.00003829%	2.24684500	0.31008379
68	38.86%	0.00003886%	2.28038000	0.30554554
69	39.43%	0.00003943%	2.31391500	0.30100860
70	40.00%	0.00004000%	2.34745000	0.29647674
71	40.57%	0.00004057%	2.38098500	0.29195351
72	41.14%	0.00004114%	2.41452000	0.28744227
73	41.71%	0.00004171%	2.44805500	0.28294614
74	42.29%	0.00004229%	2.48159000	0.27846807
75	42.86%	0.00004286%	2.51512500	0.27401083
76	43.43%	0.00004343%	2.54866000	0.26957699
77	44.00%	0.00004400%	2.58219500	0.26516899
78	44.57%	0.00004457%	2.61573000	0.26078907
79	45.14%	0.00004514%	2.64926500	0.25643934
80	45.71%	0.00004571%	2.68280000	0.25212175
81	46.29%	0.00004629%	2.71633500	0.24783813
82	46.86%	0.00004686%	2.74987000	0.24359016
83	47.43%	0.00004743%	2.78340500	0.23937939
84	48.00%	0.00004800%	2.81694000	0.23520726
85	48.57%	0.00004857%	2.85047500	0.23107509
86	49.14%	0.00004914%	2.88401000	0.22698410
87	49.71%	0.00004971%	2.91754500	0.22293539

88	50.29%	0.00005029%	2.95108000	0.21892997
89	50.86%	0.00005086%	2.98461500	0.21496874
90	51.43%	0.00005143%	3.01815000	0.21105255
91	52.00%	0.00005200%	3.05168500	0.20718211
92	52.57%	0.00005257%	3.08522000	0.20335810
93	53.14%	0.00005314%	3.11875500	0.19958108
94	53.71%	0.00005371%	3.15229000	0.19585156
95	54.29%	0.00005429%	3.18582500	0.19216999
96	54.86%	0.00005486%	3.21936000	0.18853673
97	55.43%	0.00005543%	3.25289500	0.18495209
98	56.00%	0.00005600%	3.28643000	0.18141633
99	56.57%	0.00005657%	3.31996500	0.17792962
100	57.14%	0.00005714%	3.35350000	0.17449213
101	57.71%	0.00005771%	3.38703500	0.17110393
102	58.29%	0.00005829%	3.42057000	0.16776508
103	58.86%	0.00005886%	3.45410500	0.16447557
104	59.43%	0.00005943%	3.48764000	0.16123536
105	60.00%	0.00006000%	3.52117500	0.15804436
106	60.57%	0.00006057%	3.55471000	0.15490248
107	61.14%	0.00006114%	3.58824500	0.15180953
108	61.71%	0.00006171%	3.62178000	0.14876535
109	62.29%	0.00006229%	3.65531500	0.14576972
110	62.86%	0.00006286%	3.68885000	0.14282238
111	63.43%	0.00006343%	3.72238500	0.13992308
112	64.00%	0.00006400%	3.75592000	0.13707150
113	64.57%	0.00006457%	3.78945500	0.13426733
114	65.14%	0.00006514%	3.82299000	0.13151023
115	65.71%	0.00006571%	3.85652500	0.12879984
116	66.29%	0.00006629%	3.89006000	0.12613576
117	66.86%	0.00006686%	3.92359500	0.12351761
118	67.43%	0.00006743%	3.95713000	0.12094497
119	68.00%	0.00006800%	3.99066500	0.11841740
120	68.57%	0.00006857%	4.02420000	0.11593447
121	69.14%	0.00006914%	4.05773500	0.11349572
122	69.71%	0.00006971%	4.09127000	0.11110068
123	70.29%	0.00007029%	4.12480500	0.10874888
124	70.86%	0.00007086%	4.15834000	0.10643982
125	71.43%	0.00007143%	4.19187500	0.10417302
126	72.00%	0.00007200%	4.22541000	0.10194796
127	72.57%	0.00007257%	4.25894500	0.09976415
128	73.14%	0.00007314%	4.29248000	0.09762106
129	73.71%	0.00007371%	4.32601500	0.09551818
130	74.29%	0.00007429%	4.35955000	0.09345498
131	74.86%	0.00007486%	4.39308500	0.09143094
132	75.43%	0.00007543%	4.42662000	0.08944552
133	76.00%	0.00007600%	4.46015500	0.08749819
134	76.57%	0.00007657%	4.49369000	0.08558842
135	77.14%	0.00007714%	4.52722500	0.08371567
136	77.71%	0.00007771%	4.56076000	0.08187940
137	78.29%	0.00007829%	4.59429500	0.08007908
138	78.86%	0.00007886%	4.62783000	0.07831418
139	79.43%	0.00007943%	4.66136500	0.07658415

140	80.00%	0.00008000%	4.69490000	0.07488846
141	80.57%	0.00008057%	4.72843500	0.07322658
142	81.14%	0.00008114%	4.76197000	0.07159798
143	81.71%	0.00008171%	4.79550500	0.07000212
144	82.29%	0.00008229%	4.82904000	0.06843849
145	82.86%	0.00008286%	4.86257500	0.06690656
146	83.43%	0.00008343%	4.89611000	0.06540581
147	84.00%	0.00008400%	4.92964500	0.06393573
148	84.57%	0.00008457%	4.96318000	0.06249579
149	85.14%	0.00008514%	4.99671500	0.06108550
150	85.71%	0.00008571%	5.03025000	0.05970433
151	86.29%	0.00008629%	5.06378500	0.05835181
152	86.86%	0.00008686%	5.09732000	0.05702742
153	87.43%	0.00008743%	5.13085500	0.05573068
154	88.00%	0.00008800%	5.16439000	0.05446110
155	88.57%	0.00008857%	5.19792500	0.05321820
156	89.14%	0.00008914%	5.23146000	0.05200150
157	89.71%	0.00008971%	5.26499500	0.05081053
158	90.29%	0.00009029%	5.29853000	0.04964481
159	90.86%	0.00009086%	5.33206500	0.04850391
160	91.43%	0.00009143%	5.36560000	0.04738734
161	92.00%	0.00009200%	5.39913500	0.04629467
162	92.57%	0.00009257%	5.43267000	0.04522545
163	93.14%	0.00009314%	5.46620500	0.04417924
164	93.71%	0.00009371%	5.49974000	0.04315561
165	94.29%	0.00009429%	5.53327500	0.04215413
166	94.86%	0.00009486%	5.56681000	0.04117438
167	95.43%	0.00009543%	5.60034500	0.04021594
168	96.00%	0.00009600%	5.63388000	0.03927840
169	96.57%	0.00009657%	5.66741500	0.03836136
170	97.14%	0.00009714%	5.70095000	0.03746442
171	97.71%	0.00009771%	5.73448500	0.03658719
172	98.29%	0.00009829%	5.76802000	0.03572927
173	98.86%	0.00009886%	5.80155500	0.03489029
174	99.43%	0.00009943%	5.83509000	0.03406987
175	100.00%	0.00010000%	5.86862500	0.03326764
Beyond (d)				1.10892144
Total				38.16138462

Section 1.3 Lake Winnipeg - Progressive Dispersal

Affected habitat (acres): 5,868,625.00

	<----------(Percentage)---------->		<----------(Acre Years)---------->	
Year	Certain (a)	Expected (b)	Current Value	Present Value
294	0.00%	0.00000000%	0.00000000	0.00000000
295	0.57%	0.00000057%	0.03353500	0.00000548
296	1.14%	0.00000114%	0.06707000	0.00001063
297	1.71%	0.00000171%	0.10060500	0.00001549
298	2.29%	0.00000229%	0.13414000	0.00002005

299	2.86%	0.00000286%	0.16767500	0.00002433
300	3.43%	0.00000343%	0.20121000	0.00002835
301	4.00%	0.00000400%	0.23474500	0.00003211
302	4.57%	0.00000457%	0.26828000	0.00003562
303	5.14%	0.00000514%	0.30181500	0.00003891
304	5.71%	0.00000571%	0.33535000	0.00004197
305	6.29%	0.00000629%	0.36888500	0.00004483
306	6.86%	0.00000686%	0.40242000	0.00004748
307	7.43%	0.00000743%	0.43595500	0.00004994
308	8.00%	0.00000800%	0.46949000	0.00005221
309	8.57%	0.00000857%	0.50302500	0.00005431
310	9.14%	0.00000914%	0.53656000	0.00005624
311	9.71%	0.00000971%	0.57009500	0.00005802
312	10.29%	0.00001029%	0.60363000	0.00005964
313	10.86%	0.00001086%	0.63716500	0.00006112
314	11.43%	0.00001143%	0.67070000	0.00006247
315	12.00%	0.00001200%	0.70423500	0.00006368
316	12.57%	0.00001257%	0.73777000	0.00006477
317	13.14%	0.00001314%	0.77130500	0.00006574
318	13.71%	0.00001371%	0.80484000	0.00006660
319	14.29%	0.00001429%	0.83837500	0.00006735
320	14.86%	0.00001486%	0.87191000	0.00006801
321	15.43%	0.00001543%	0.90544500	0.00006857
322	16.00%	0.00001600%	0.93898000	0.00006904
323	16.57%	0.00001657%	0.97251500	0.00006942
324	17.14%	0.00001714%	1.00605000	0.00006972
325	17.71%	0.00001771%	1.03958500	0.00006995
326	18.29%	0.00001829%	1.07312000	0.00007010
327	18.86%	0.00001886%	1.10665500	0.00007018
328	19.43%	0.00001943%	1.14019000	0.00007020
329	20.00%	0.00002000%	1.17372500	0.00007016
330	20.57%	0.00002057%	1.20726000	0.00007007
331	21.14%	0.00002114%	1.24079500	0.00006992
332	21.71%	0.00002171%	1.27433000	0.00006971
333	22.29%	0.00002229%	1.30786500	0.00006947
334	22.86%	0.00002286%	1.34140000	0.00006917
335	23.43%	0.00002343%	1.37493500	0.00006884
336	24.00%	0.00002400%	1.40847000	0.00006846
337	24.57%	0.00002457%	1.44200500	0.00006805
338	25.14%	0.00002514%	1.47554000	0.00006760
339	25.71%	0.00002571%	1.50907500	0.00006713
340	26.29%	0.00002629%	1.54261000	0.00006662
341	26.86%	0.00002686%	1.57614500	0.00006608
342	27.43%	0.00002743%	1.60968000	0.00006553
343	28.00%	0.00002800%	1.64321500	0.00006494
344	28.57%	0.00002857%	1.67675000	0.00006434
345	29.14%	0.00002914%	1.71028500	0.00006371
346	29.71%	0.00002971%	1.74382000	0.00006307
347	30.29%	0.00003029%	1.77735500	0.00006241
348	30.86%	0.00003086%	1.81089000	0.00006174
349	31.43%	0.00003143%	1.84442500	0.00006105
350	32.00%	0.00003200%	1.87796000	0.00006035

351	32.57%	0.00003257%	1.91149500	0.00005964
352	33.14%	0.00003314%	1.94503000	0.00005891
353	33.71%	0.00003371%	1.97856500	0.00005818
354	34.29%	0.00003429%	2.01210000	0.00005745
355	34.86%	0.00003486%	2.04563500	0.00005670
356	35.43%	0.00003543%	2.07917000	0.00005595
357	36.00%	0.00003600%	2.11270500	0.00005520
358	36.57%	0.00003657%	2.14624000	0.00005444
359	37.14%	0.00003714%	2.17977500	0.00005368
360	37.71%	0.00003771%	2.21331000	0.00005292
361	38.29%	0.00003829%	2.24684500	0.00005216
362	38.86%	0.00003886%	2.28038000	0.00005140
363	39.43%	0.00003943%	2.31391500	0.00005063
364	40.00%	0.00004000%	2.34745000	0.00004987
365	40.57%	0.00004057%	2.38098500	0.00004911
366	41.14%	0.00004114%	2.41452000	0.00004835
367	41.71%	0.00004171%	2.44805500	0.00004759
368	42.29%	0.00004229%	2.48159000	0.00004684
369	42.86%	0.00004286%	2.51512500	0.00004609
370	43.43%	0.00004343%	2.54866000	0.00004535
371	44.00%	0.00004400%	2.58219500	0.00004460
372	44.57%	0.00004457%	2.61573000	0.00004387
373	45.14%	0.00004514%	2.64926500	0.00004314
374	45.71%	0.00004571%	2.68280000	0.00004241
375	46.29%	0.00004629%	2.71633500	0.00004169
376	46.86%	0.00004686%	2.74987000	0.00004097
377	47.43%	0.00004743%	2.78340500	0.00004027
378	48.00%	0.00004800%	2.81694000	0.00003956
379	48.57%	0.00004857%	2.85047500	0.00003887
380	49.14%	0.00004914%	2.88401000	0.00003818
381	49.71%	0.00004971%	2.91754500	0.00003750
382	50.29%	0.00005029%	2.95108000	0.00003683
383	50.86%	0.00005086%	2.98461500	0.00003616
384	51.43%	0.00005143%	3.01815000	0.00003550
385	52.00%	0.00005200%	3.05168500	0.00003485
386	52.57%	0.00005257%	3.08522000	0.00003421
387	53.14%	0.00005314%	3.11875500	0.00003357
388	53.71%	0.00005371%	3.15229000	0.00003294
389	54.29%	0.00005429%	3.18582500	0.00003233
390	54.86%	0.00005486%	3.21936000	0.00003171
391	55.43%	0.00005543%	3.25289500	0.00003111
392	56.00%	0.00005600%	3.28643000	0.00003052
393	56.57%	0.00005657%	3.31996500	0.00002993
394	57.14%	0.00005714%	3.35350000	0.00002935
395	57.71%	0.00005771%	3.38703500	0.00002878
396	58.29%	0.00005829%	3.42057000	0.00002822
397	58.86%	0.00005886%	3.45410500	0.00002767
398	59.43%	0.00005943%	3.48764000	0.00002712
399	60.00%	0.00006000%	3.52117500	0.00002658
400	60.57%	0.00006057%	3.55471000	0.00002606
401	61.14%	0.00006114%	3.58824500	0.00002554
402	61.71%	0.00006171%	3.62178000	0.00002502

403	62.29%	0.00006229%	3.65531500	0.00002452
404	62.86%	0.00006286%	3.68885000	0.00002402
405	63.43%	0.00006343%	3.72238500	0.00002354
406	64.00%	0.00006400%	3.75592000	0.00002306
407	64.57%	0.00006457%	3.78945500	0.00002259
408	65.14%	0.00006514%	3.82299000	0.00002212
409	65.71%	0.00006571%	3.85652500	0.00002167
410	66.29%	0.00006629%	3.89006000	0.00002122
411	66.86%	0.00006686%	3.92359500	0.00002078
412	67.43%	0.00006743%	3.95713000	0.00002034
413	68.00%	0.00006800%	3.99066500	0.00001992
414	68.57%	0.00006857%	4.02420000	0.00001950
415	69.14%	0.00006914%	4.05773500	0.00001909
416	69.71%	0.00006971%	4.09127000	0.00001869
417	70.29%	0.00007029%	4.12480500	0.00001829
418	70.86%	0.00007086%	4.15834000	0.00001790
419	71.43%	0.00007143%	4.19187500	0.00001752
420	72.00%	0.00007200%	4.22541000	0.00001715
421	72.57%	0.00007257%	4.25894500	0.00001678
422	73.14%	0.00007314%	4.29248000	0.00001642
423	73.71%	0.00007371%	4.32601500	0.00001607
424	74.29%	0.00007429%	4.35955000	0.00001572
425	74.86%	0.00007486%	4.39308500	0.00001538
426	75.43%	0.00007543%	4.42662000	0.00001505
427	76.00%	0.00007600%	4.46015500	0.00001472
428	76.57%	0.00007657%	4.49369000	0.00001440
429	77.14%	0.00007714%	4.52722500	0.00001408
430	77.71%	0.00007771%	4.56076000	0.00001377
431	78.29%	0.00007829%	4.59429500	0.00001347
432	78.86%	0.00007886%	4.62783000	0.00001317
433	79.43%	0.00007943%	4.66136500	0.00001288
434	80.00%	0.00008000%	4.69490000	0.00001260
435	80.57%	0.00008057%	4.72843500	0.00001232
436	81.14%	0.00008114%	4.76197000	0.00001204
437	81.71%	0.00008171%	4.79550500	0.00001178
438	82.29%	0.00008229%	4.82904000	0.00001151
439	82.86%	0.00008286%	4.86257500	0.00001125
440	83.43%	0.00008343%	4.89611000	0.00001100
441	84.00%	0.00008400%	4.92964500	0.00001075
442	84.57%	0.00008457%	4.96318000	0.00001051
443	85.14%	0.00008514%	4.99671500	0.00001028
444	85.71%	0.00008571%	5.03025000	0.00001004
445	86.29%	0.00008629%	5.06378500	0.00000982
446	86.86%	0.00008686%	5.09732000	0.00000959
447	87.43%	0.00008743%	5.13085500	0.00000937
448	88.00%	0.00008800%	5.16439000	0.00000916
449	88.57%	0.00008857%	5.19792500	0.00000895
450	89.14%	0.00008914%	5.23146000	0.00000875
451	89.71%	0.00008971%	5.26499500	0.00000855
452	90.29%	0.00009029%	5.29853000	0.00000835
453	90.86%	0.00009086%	5.33206500	0.00000816
454	91.43%	0.00009143%	5.36560000	0.00000797

455	92.00%	0.00009200%	5.39913500	0.00000779
456	92.57%	0.00009257%	5.43267000	0.00000761
457	93.14%	0.00009314%	5.46620500	0.00000743
458	93.71%	0.00009371%	5.49974000	0.00000726
459	94.29%	0.00009429%	5.53327500	0.00000709
460	94.86%	0.00009486%	5.56681000	0.00000693
461	95.43%	0.00009543%	5.60034500	0.00000676
462	96.00%	0.00009600%	5.63388000	0.00000661
463	96.57%	0.00009657%	5.66741500	0.00000645
464	97.14%	0.00009714%	5.70095000	0.00000630
465	97.71%	0.00009771%	5.73448500	0.00000615
466	98.29%	0.00009829%	5.76802000	0.00000601
467	98.86%	0.00009886%	5.80155500	0.00000587
468	99.43%	0.00009943%	5.83509000	0.00000573
469	100.00%	0.00010000%	5.86862500	0.00000560
Beyond (e)				0.00018653
Total				0.00641919

Section 2 Quantification of Replacement Services

	<----------(Percentage)---------->	
Year	Current Value	Present Value
5	0.0%	0.0%
6	5.0%	4.2%
7	10.0%	8.1%
8	15.0%	11.8%
9	20.0%	15.3%
10	25.0%	18.6%
11	30.0%	21.7%
12	35.0%	24.5%
13	40.0%	27.2%
14	45.0%	29.8%
15	50.0%	32.1%
16	55.0%	34.3%
17	60.0%	36.3%
18	65.0%	38.2%
19	70.0%	39.9%
20	75.0%	41.5%
21	80.0%	43.0%
22	85.0%	44.4%
23	90.0%	45.6%
24	95.0%	46.7%
25	100.0%	47.8%
Beyond (f)		1592.0%
Total		2203.1%

Section 3 Offsetting Restoration for One Organism

Red River - Progressive Dispersal (river-miles):	0.0000805
Lake Winnipeg - Jump Dispersal (acres):	1.73
Lake Winnipeg - Progressive Dispersal (acres):	0.000291

Section 4 Notes

(a) Percent loss given certain invasion

(b) Percent loss given probability of successful invasion

(c) From year 295 into perpetuity

(d) From year 176 into perpetuity

(e) From year 470 into perpetuity

(f) From year 26 into perpetuity

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Appendix 15D. Habitat Equivalency Analysis of Risk Consequences: Slow Invasion - Moderate Risk (One Organism)

Probability of successful invasion: 1.00E-03

Annual discount rate: 3.0%

Present year: 0

Section 1 Quantification of Expected Lost Services

Section 1.1 Red River from Fargo to Lake Winnipeg - Progressive Dispersal

Affected habitat (river-miles): 455.40

	<----------(Percentage)---------->		<----------(River-Mile Years)---------->	
Year	Certain (a)	Expected (b)	Current Value	Present Value
0	0.00%	0.00000%	0.00000	0.00000
1	0.34%	0.00034%	0.00155	0.00150
2	0.68%	0.00068%	0.00310	0.00292
3	1.02%	0.00102%	0.00465	0.00425
4	1.36%	0.00136%	0.00620	0.00550
5	1.70%	0.00170%	0.00774	0.00668
6	2.04%	0.00204%	0.00929	0.00778
7	2.38%	0.00238%	0.01084	0.00882
8	2.72%	0.00272%	0.01239	0.00978
9	3.06%	0.00306%	0.01394	0.01068
10	3.40%	0.00340%	0.01549	0.01153
11	3.74%	0.00374%	0.01704	0.01231
12	4.08%	0.00408%	0.01859	0.01304
13	4.42%	0.00442%	0.02014	0.01371
14	4.76%	0.00476%	0.02169	0.01434
15	5.10%	0.00510%	0.02323	0.01491
16	5.44%	0.00544%	0.02478	0.01544
17	5.78%	0.00578%	0.02633	0.01593
18	6.12%	0.00612%	0.02788	0.01638
19	6.46%	0.00646%	0.02943	0.01678
20	6.80%	0.00680%	0.03098	0.01715
21	7.14%	0.00714%	0.03253	0.01749
22	7.48%	0.00748%	0.03408	0.01778
23	7.82%	0.00782%	0.03563	0.01805
24	8.16%	0.00816%	0.03718	0.01829
25	8.50%	0.00850%	0.03872	0.01850
26	8.84%	0.00884%	0.04027	0.01867
27	9.18%	0.00918%	0.04182	0.01883
28	9.52%	0.00952%	0.04337	0.01896
29	9.86%	0.00986%	0.04492	0.01906

30	10.20%	0.01020%	0.04647	0.01914
31	10.54%	0.01054%	0.04802	0.01921
32	10.88%	0.01088%	0.04957	0.01925
33	11.22%	0.01122%	0.05112	0.01927
34	11.56%	0.01156%	0.05267	0.01928
35	11.90%	0.01190%	0.05421	0.01927
36	12.24%	0.01224%	0.05576	0.01924
37	12.59%	0.01259%	0.05731	0.01920
38	12.93%	0.01293%	0.05886	0.01914
39	13.27%	0.01327%	0.06041	0.01907
40	13.61%	0.01361%	0.06196	0.01899
41	13.95%	0.01395%	0.06351	0.01890
42	14.29%	0.01429%	0.06506	0.01880
43	14.63%	0.01463%	0.06661	0.01869
44	14.97%	0.01497%	0.06816	0.01856
45	15.31%	0.01531%	0.06970	0.01843
46	15.65%	0.01565%	0.07125	0.01829
47	15.99%	0.01599%	0.07280	0.01815
48	16.33%	0.01633%	0.07435	0.01799
49	16.67%	0.01667%	0.07590	0.01783
50	17.01%	0.01701%	0.07745	0.01767
51	17.35%	0.01735%	0.07900	0.01750
52	17.69%	0.01769%	0.08055	0.01732
53	18.03%	0.01803%	0.08210	0.01714
54	18.37%	0.01837%	0.08364	0.01695
55	18.71%	0.01871%	0.08519	0.01676
56	19.05%	0.01905%	0.08674	0.01657
57	19.39%	0.01939%	0.08829	0.01638
58	19.73%	0.01973%	0.08984	0.01618
59	20.07%	0.02007%	0.09139	0.01598
60	20.41%	0.02041%	0.09294	0.01577
61	20.75%	0.02075%	0.09449	0.01557
62	21.09%	0.02109%	0.09604	0.01536
63	21.43%	0.02143%	0.09759	0.01516
64	21.77%	0.02177%	0.09913	0.01495
65	22.11%	0.02211%	0.10068	0.01474
66	22.45%	0.02245%	0.10223	0.01453
67	22.79%	0.02279%	0.10378	0.01432
68	23.13%	0.02313%	0.10533	0.01411
69	23.47%	0.02347%	0.10688	0.01390
70	23.81%	0.02381%	0.10843	0.01369
71	24.15%	0.02415%	0.10998	0.01349
72	24.49%	0.02449%	0.11153	0.01328
73	24.83%	0.02483%	0.11308	0.01307
74	25.17%	0.02517%	0.11462	0.01286
75	25.51%	0.02551%	0.11617	0.01266
76	25.85%	0.02585%	0.11772	0.01245
77	26.19%	0.02619%	0.11927	0.01225
78	26.53%	0.02653%	0.12082	0.01205
79	26.87%	0.02687%	0.12237	0.01184
80	27.21%	0.02721%	0.12392	0.01165
81	27.55%	0.02755%	0.12547	0.01145

82	27.89%	0.02789%	0.12702	0.01125
83	28.23%	0.02823%	0.12857	0.01106
84	28.57%	0.02857%	0.13011	0.01086
85	28.91%	0.02891%	0.13166	0.01067
86	29.25%	0.02925%	0.13321	0.01048
87	29.59%	0.02959%	0.13476	0.01030
88	29.93%	0.02993%	0.13631	0.01011
89	30.27%	0.03027%	0.13786	0.00993
90	30.61%	0.03061%	0.13941	0.00975
91	30.95%	0.03095%	0.14096	0.00957
92	31.29%	0.03129%	0.14251	0.00939
93	31.63%	0.03163%	0.14406	0.00922
94	31.97%	0.03197%	0.14560	0.00905
95	32.31%	0.03231%	0.14715	0.00888
96	32.65%	0.03265%	0.14870	0.00871
97	32.99%	0.03299%	0.15025	0.00854
98	33.33%	0.03333%	0.15180	0.00838
99	33.67%	0.03367%	0.15335	0.00822
100	34.01%	0.03401%	0.15490	0.00806
101	34.35%	0.03435%	0.15645	0.00790
102	34.69%	0.03469%	0.15800	0.00775
103	35.03%	0.03503%	0.15954	0.00760
104	35.37%	0.03537%	0.16109	0.00745
105	35.71%	0.03571%	0.16264	0.00730
106	36.05%	0.03605%	0.16419	0.00715
107	36.39%	0.03639%	0.16574	0.00701
108	36.73%	0.03673%	0.16729	0.00687
109	37.07%	0.03707%	0.16884	0.00673
110	37.41%	0.03741%	0.17039	0.00660
111	37.76%	0.03776%	0.17194	0.00646
112	38.10%	0.03810%	0.17349	0.00633
113	38.44%	0.03844%	0.17503	0.00620
114	38.78%	0.03878%	0.17658	0.00607
115	39.12%	0.03912%	0.17813	0.00595
116	39.46%	0.03946%	0.17968	0.00583
117	39.80%	0.03980%	0.18123	0.00571
118	40.14%	0.04014%	0.18278	0.00559
119	40.48%	0.04048%	0.18433	0.00547
120	40.82%	0.04082%	0.18588	0.00536
121	41.16%	0.04116%	0.18743	0.00524
122	41.50%	0.04150%	0.18898	0.00513
123	41.84%	0.04184%	0.19052	0.00502
124	42.18%	0.04218%	0.19207	0.00492
125	42.52%	0.04252%	0.19362	0.00481
126	42.86%	0.04286%	0.19517	0.00471
127	43.20%	0.04320%	0.19672	0.00461
128	43.54%	0.04354%	0.19827	0.00451
129	43.88%	0.04388%	0.19982	0.00441
130	44.22%	0.04422%	0.20137	0.00432
131	44.56%	0.04456%	0.20292	0.00422
132	44.90%	0.04490%	0.20447	0.00413
133	45.24%	0.04524%	0.20601	0.00404

134	45.58%	0.04558%	0.20756	0.00395
135	45.92%	0.04592%	0.20911	0.00387
136	46.26%	0.04626%	0.21066	0.00378
137	46.60%	0.04660%	0.21221	0.00370
138	46.94%	0.04694%	0.21376	0.00362
139	47.28%	0.04728%	0.21531	0.00354
140	47.62%	0.04762%	0.21686	0.00346
141	47.96%	0.04796%	0.21841	0.00338
142	48.30%	0.04830%	0.21996	0.00331
143	48.64%	0.04864%	0.22150	0.00323
144	48.98%	0.04898%	0.22305	0.00316
145	49.32%	0.04932%	0.22460	0.00309
146	49.66%	0.04966%	0.22615	0.00302
147	50.00%	0.05000%	0.22770	0.00295
148	50.34%	0.05034%	0.22925	0.00289
149	50.68%	0.05068%	0.23080	0.00282
150	51.02%	0.05102%	0.23235	0.00276
151	51.36%	0.05136%	0.23390	0.00270
152	51.70%	0.05170%	0.23544	0.00263
153	52.04%	0.05204%	0.23699	0.00257
154	52.38%	0.05238%	0.23854	0.00252
155	52.72%	0.05272%	0.24009	0.00246
156	53.06%	0.05306%	0.24164	0.00240
157	53.40%	0.05340%	0.24319	0.00235
158	53.74%	0.05374%	0.24474	0.00229
159	54.08%	0.05408%	0.24629	0.00224
160	54.42%	0.05442%	0.24784	0.00219
161	54.76%	0.05476%	0.24939	0.00214
162	55.10%	0.05510%	0.25093	0.00209
163	55.44%	0.05544%	0.25248	0.00204
164	55.78%	0.05578%	0.25403	0.00199
165	56.12%	0.05612%	0.25558	0.00195
166	56.46%	0.05646%	0.25713	0.00190
167	56.80%	0.05680%	0.25868	0.00186
168	57.14%	0.05714%	0.26023	0.00181
169	57.48%	0.05748%	0.26178	0.00177
170	57.82%	0.05782%	0.26333	0.00173
171	58.16%	0.05816%	0.26488	0.00169
172	58.50%	0.05850%	0.26642	0.00165
173	58.84%	0.05884%	0.26797	0.00161
174	59.18%	0.05918%	0.26952	0.00157
175	59.52%	0.05952%	0.27107	0.00154
176	59.86%	0.05986%	0.27262	0.00150
177	60.20%	0.06020%	0.27417	0.00146
178	60.54%	0.06054%	0.27572	0.00143
179	60.88%	0.06088%	0.27727	0.00140
180	61.22%	0.06122%	0.27882	0.00136
181	61.56%	0.06156%	0.28037	0.00133
182	61.90%	0.06190%	0.28191	0.00130
183	62.24%	0.06224%	0.28346	0.00127
184	62.59%	0.06259%	0.28501	0.00124
185	62.93%	0.06293%	0.28656	0.00121

186	63.27%	0.06327%	0.28811	0.00118
187	63.61%	0.06361%	0.28966	0.00115
188	63.95%	0.06395%	0.29121	0.00112
189	64.29%	0.06429%	0.29276	0.00110
190	64.63%	0.06463%	0.29431	0.00107
191	64.97%	0.06497%	0.29586	0.00105
192	65.31%	0.06531%	0.29740	0.00102
193	65.65%	0.06565%	0.29895	0.00100
194	65.99%	0.06599%	0.30050	0.00097
195	66.33%	0.06633%	0.30205	0.00095
196	66.67%	0.06667%	0.30360	0.00093
197	67.01%	0.06701%	0.30515	0.00090
198	67.35%	0.06735%	0.30670	0.00088
199	67.69%	0.06769%	0.30825	0.00086
200	68.03%	0.06803%	0.30980	0.00084
201	68.37%	0.06837%	0.31134	0.00082
202	68.71%	0.06871%	0.31289	0.00080
203	69.05%	0.06905%	0.31444	0.00078
204	69.39%	0.06939%	0.31599	0.00076
205	69.73%	0.06973%	0.31754	0.00074
206	70.07%	0.07007%	0.31909	0.00072
207	70.41%	0.07041%	0.32064	0.00071
208	70.75%	0.07075%	0.32219	0.00069
209	71.09%	0.07109%	0.32374	0.00067
210	71.43%	0.07143%	0.32529	0.00066
211	71.77%	0.07177%	0.32683	0.00064
212	72.11%	0.07211%	0.32838	0.00062
213	72.45%	0.07245%	0.32993	0.00061
214	72.79%	0.07279%	0.33148	0.00059
215	73.13%	0.07313%	0.33303	0.00058
216	73.47%	0.07347%	0.33458	0.00056
217	73.81%	0.07381%	0.33613	0.00055
218	74.15%	0.07415%	0.33768	0.00054
219	74.49%	0.07449%	0.33923	0.00052
220	74.83%	0.07483%	0.34078	0.00051
221	75.17%	0.07517%	0.34232	0.00050
222	75.51%	0.07551%	0.34387	0.00049
223	75.85%	0.07585%	0.34542	0.00047
224	76.19%	0.07619%	0.34697	0.00046
225	76.53%	0.07653%	0.34852	0.00045
226	76.87%	0.07687%	0.35007	0.00044
227	77.21%	0.07721%	0.35162	0.00043
228	77.55%	0.07755%	0.35317	0.00042
229	77.89%	0.07789%	0.35472	0.00041
230	78.23%	0.07823%	0.35627	0.00040
231	78.57%	0.07857%	0.35781	0.00039
232	78.91%	0.07891%	0.35936	0.00038
233	79.25%	0.07925%	0.36091	0.00037
234	79.59%	0.07959%	0.36246	0.00036
235	79.93%	0.07993%	0.36401	0.00035
236	80.27%	0.08027%	0.36556	0.00034
237	80.61%	0.08061%	0.36711	0.00033

238	80.95%	0.08095%	0.36866	0.00032
239	81.29%	0.08129%	0.37021	0.00032
240	81.63%	0.08163%	0.37176	0.00031
241	81.97%	0.08197%	0.37330	0.00030
242	82.31%	0.08231%	0.37485	0.00029
243	82.65%	0.08265%	0.37640	0.00029
244	82.99%	0.08299%	0.37795	0.00028
245	83.33%	0.08333%	0.37950	0.00027
246	83.67%	0.08367%	0.38105	0.00026
247	84.01%	0.08401%	0.38260	0.00026
248	84.35%	0.08435%	0.38415	0.00025
249	84.69%	0.08469%	0.38570	0.00025
250	85.03%	0.08503%	0.38724	0.00024
251	85.37%	0.08537%	0.38879	0.00023
252	85.71%	0.08571%	0.39034	0.00023
253	86.05%	0.08605%	0.39189	0.00022
254	86.39%	0.08639%	0.39344	0.00022
255	86.73%	0.08673%	0.39499	0.00021
256	87.07%	0.08707%	0.39654	0.00021
257	87.41%	0.08741%	0.39809	0.00020
258	87.76%	0.08776%	0.39964	0.00019
259	88.10%	0.08810%	0.40119	0.00019
260	88.44%	0.08844%	0.40273	0.00019
261	88.78%	0.08878%	0.40428	0.00018
262	89.12%	0.08912%	0.40583	0.00018
263	89.46%	0.08946%	0.40738	0.00017
264	89.80%	0.08980%	0.40893	0.00017
265	90.14%	0.09014%	0.41048	0.00016
266	90.48%	0.09048%	0.41203	0.00016
267	90.82%	0.09082%	0.41358	0.00015
268	91.16%	0.09116%	0.41513	0.00015
269	91.50%	0.09150%	0.41668	0.00015
270	91.84%	0.09184%	0.41822	0.00014
271	92.18%	0.09218%	0.41977	0.00014
272	92.52%	0.09252%	0.42132	0.00014
273	92.86%	0.09286%	0.42287	0.00013
274	93.20%	0.09320%	0.42442	0.00013
275	93.54%	0.09354%	0.42597	0.00013
276	93.88%	0.09388%	0.42752	0.00012
277	94.22%	0.09422%	0.42907	0.00012
278	94.56%	0.09456%	0.43062	0.00012
279	94.90%	0.09490%	0.43217	0.00011
280	95.24%	0.09524%	0.43371	0.00011
281	95.58%	0.09558%	0.43526	0.00011
282	95.92%	0.09592%	0.43681	0.00010
283	96.26%	0.09626%	0.43836	0.00010
284	96.60%	0.09660%	0.43991	0.00010
285	96.94%	0.09694%	0.44146	0.00010
286	97.28%	0.09728%	0.44301	0.00009
287	97.62%	0.09762%	0.44456	0.00009
288	97.96%	0.09796%	0.44611	0.00009
289	98.30%	0.09830%	0.44766	0.00009

290	98.64%	0.09864%	0.44920	0.00009
291	98.98%	0.09898%	0.45075	0.00008
292	99.32%	0.09932%	0.45230	0.00008
293	99.66%	0.09966%	0.45385	0.00008
294	100.00%	0.10000%	0.45540	0.00008
Beyond (c)				0.00255
Total				1.77242

Section 1.2 Lake Winnipeg - Jump Dispersal

Affected habitat (acres): 5,868,625.00

	<----------(Percentage)---------->		<----------(Acre Years)---------->	
Year	Certain (a)	Expected (b)	Current Value	Present Value
0	0.00%	0.00000%	0.00000	0.00000
1	0.57%	0.00057%	33.53500	32.55825
2	1.14%	0.00114%	67.07000	63.21991
3	1.71%	0.00171%	100.60500	92.06783
4	2.29%	0.00229%	134.14000	119.18165
5	2.86%	0.00286%	167.67500	144.63793
6	3.43%	0.00343%	201.21000	168.51021
7	4.00%	0.00400%	234.74500	190.86917
8	4.57%	0.00457%	268.28000	211.78271
9	5.14%	0.00514%	301.81500	231.31607
10	5.71%	0.00571%	335.35000	249.53189
11	6.29%	0.00629%	368.88500	266.49037
12	6.86%	0.00686%	402.42000	282.24929
13	7.43%	0.00743%	435.95500	296.86414
14	8.00%	0.00800%	469.49000	310.38820
15	8.57%	0.00857%	503.02500	322.87261
16	9.14%	0.00914%	536.56000	334.36645
17	9.71%	0.00971%	570.09500	344.91685
18	10.29%	0.01029%	603.63000	354.56901
19	10.86%	0.01086%	637.16500	363.36630
20	11.43%	0.01143%	670.70000	371.35033
21	12.00%	0.01200%	704.23500	378.56101
22	12.57%	0.01257%	737.77000	385.03663
23	13.14%	0.01314%	771.30500	390.81388
24	13.71%	0.01371%	804.84000	395.92795
25	14.29%	0.01429%	838.37500	400.41257
26	14.86%	0.01486%	871.91000	404.30007
27	15.43%	0.01543%	905.44500	407.62143
28	16.00%	0.01600%	938.98000	410.40633
29	16.57%	0.01657%	972.51500	412.68320
30	17.14%	0.01714%	1,006.05000	414.47928
31	17.71%	0.01771%	1,039.58500	415.82064
32	18.29%	0.01829%	1,073.12000	416.73224
33	18.86%	0.01886%	1,106.65500	417.23798
34	19.43%	0.01943%	1,140.19000	417.36073
35	20.00%	0.02000%	1,173.72500	417.12238

36	20.57%	0.02057%	1,207.26000	416.54385
37	21.14%	0.02114%	1,240.79500	415.64515
38	21.71%	0.02171%	1,274.33000	414.44544
39	22.29%	0.02229%	1,307.86500	412.96301
40	22.86%	0.02286%	1,341.40000	411.21535
41	23.43%	0.02343%	1,374.93500	409.21916
42	24.00%	0.02400%	1,408.47000	406.99040
43	24.57%	0.02457%	1,442.00500	404.54432
44	25.14%	0.02514%	1,475.54000	401.89546
45	25.71%	0.02571%	1,509.07500	399.05772
46	26.29%	0.02629%	1,542.61000	396.04434
47	26.86%	0.02686%	1,576.14500	392.86796
48	27.43%	0.02743%	1,609.68000	389.54063
49	28.00%	0.02800%	1,643.21500	386.07384
50	28.57%	0.02857%	1,676.75000	382.47855
51	29.14%	0.02914%	1,710.28500	378.76516
52	29.71%	0.02971%	1,743.82000	374.94362
53	30.29%	0.03029%	1,777.35500	371.02337
54	30.86%	0.03086%	1,810.89000	367.01341
55	31.43%	0.03143%	1,844.42500	362.92229
56	32.00%	0.03200%	1,877.96000	358.75813
57	32.57%	0.03257%	1,911.49500	354.52867
58	33.14%	0.03314%	1,945.03000	350.24123
59	33.71%	0.03371%	1,978.56500	345.90279
60	34.29%	0.03429%	2,012.10000	341.51995
61	34.86%	0.03486%	2,045.63500	337.09898
62	35.43%	0.03543%	2,079.17000	332.64582
63	36.00%	0.03600%	2,112.70500	328.16609
64	36.57%	0.03657%	2,146.24000	323.66512
65	37.14%	0.03714%	2,179.77500	319.14795
66	37.71%	0.03771%	2,213.31000	314.61934
67	38.29%	0.03829%	2,246.84500	310.08379
68	38.86%	0.03886%	2,280.38000	305.54554
69	39.43%	0.03943%	2,313.91500	301.00860
70	40.00%	0.04000%	2,347.45000	296.47674
71	40.57%	0.04057%	2,380.98500	291.95351
72	41.14%	0.04114%	2,414.52000	287.44227
73	41.71%	0.04171%	2,448.05500	282.94614
74	42.29%	0.04229%	2,481.59000	278.46807
75	42.86%	0.04286%	2,515.12500	274.01083
76	43.43%	0.04343%	2,548.66000	269.57699
77	44.00%	0.04400%	2,582.19500	265.16899
78	44.57%	0.04457%	2,615.73000	260.78907
79	45.14%	0.04514%	2,649.26500	256.43934
80	45.71%	0.04571%	2,682.80000	252.12175
81	46.29%	0.04629%	2,716.33500	247.83813
82	46.86%	0.04686%	2,749.87000	243.59016
83	47.43%	0.04743%	2,783.40500	239.37939
84	48.00%	0.04800%	2,816.94000	235.20726
85	48.57%	0.04857%	2,850.47500	231.07509
86	49.14%	0.04914%	2,884.01000	226.98410
87	49.71%	0.04971%	2,917.54500	222.93539

88	50.29%	0.05029%	2,951.08000	218.92997
89	50.86%	0.05086%	2,984.61500	214.96874
90	51.43%	0.05143%	3,018.15000	211.05255
91	52.00%	0.05200%	3,051.68500	207.18211
92	52.57%	0.05257%	3,085.22000	203.35810
93	53.14%	0.05314%	3,118.75500	199.58108
94	53.71%	0.05371%	3,152.29000	195.85156
95	54.29%	0.05429%	3,185.82500	192.16999
96	54.86%	0.05486%	3,219.36000	188.53673
97	55.43%	0.05543%	3,252.89500	184.95209
98	56.00%	0.05600%	3,286.43000	181.41633
99	56.57%	0.05657%	3,319.96500	177.92962
100	57.14%	0.05714%	3,353.50000	174.49213
101	57.71%	0.05771%	3,387.03500	171.10393
102	58.29%	0.05829%	3,420.57000	167.76508
103	58.86%	0.05886%	3,454.10500	164.47557
104	59.43%	0.05943%	3,487.64000	161.23536
105	60.00%	0.06000%	3,521.17500	158.04436
106	60.57%	0.06057%	3,554.71000	154.90248
107	61.14%	0.06114%	3,588.24500	151.80953
108	61.71%	0.06171%	3,621.78000	148.76535
109	62.29%	0.06229%	3,655.31500	145.76972
110	62.86%	0.06286%	3,688.85000	142.82238
111	63.43%	0.06343%	3,722.38500	139.92308
112	64.00%	0.06400%	3,755.92000	137.07150
113	64.57%	0.06457%	3,789.45500	134.26733
114	65.14%	0.06514%	3,822.99000	131.51023
115	65.71%	0.06571%	3,856.52500	128.79984
116	66.29%	0.06629%	3,890.06000	126.13576
117	66.86%	0.06686%	3,923.59500	123.51761
118	67.43%	0.06743%	3,957.13000	120.94497
119	68.00%	0.06800%	3,990.66500	118.41740
120	68.57%	0.06857%	4,024.20000	115.93447
121	69.14%	0.06914%	4,057.73500	113.49572
122	69.71%	0.06971%	4,091.27000	111.10068
123	70.29%	0.07029%	4,124.80500	108.74888
124	70.86%	0.07086%	4,158.34000	106.43982
125	71.43%	0.07143%	4,191.87500	104.17302
126	72.00%	0.07200%	4,225.41000	101.94796
127	72.57%	0.07257%	4,258.94500	99.76415
128	73.14%	0.07314%	4,292.48000	97.62106
129	73.71%	0.07371%	4,326.01500	95.51818
130	74.29%	0.07429%	4,359.55000	93.45498
131	74.86%	0.07486%	4,393.08500	91.43094
132	75.43%	0.07543%	4,426.62000	89.44552
133	76.00%	0.07600%	4,460.15500	87.49819
134	76.57%	0.07657%	4,493.69000	85.58842
135	77.14%	0.07714%	4,527.22500	83.71567
136	77.71%	0.07771%	4,560.76000	81.87940
137	78.29%	0.07829%	4,594.29500	80.07908
138	78.86%	0.07886%	4,627.83000	78.31418
139	79.43%	0.07943%	4,661.36500	76.58415

140	80.00%	0.08000%	4,694.90000	74.88846
141	80.57%	0.08057%	4,728.43500	73.22658
142	81.14%	0.08114%	4,761.97000	71.59798
143	81.71%	0.08171%	4,795.50500	70.00212
144	82.29%	0.08229%	4,829.04000	68.43849
145	82.86%	0.08286%	4,862.57500	66.90656
146	83.43%	0.08343%	4,896.11000	65.40581
147	84.00%	0.08400%	4,929.64500	63.93573
148	84.57%	0.08457%	4,963.18000	62.49579
149	85.14%	0.08514%	4,996.71500	61.08550
150	85.71%	0.08571%	5,030.25000	59.70433
151	86.29%	0.08629%	5,063.78500	58.35181
152	86.86%	0.08686%	5,097.32000	57.02742
153	87.43%	0.08743%	5,130.85500	55.73068
154	88.00%	0.08800%	5,164.39000	54.46110
155	88.57%	0.08857%	5,197.92500	53.21820
156	89.14%	0.08914%	5,231.46000	52.00150
157	89.71%	0.08971%	5,264.99500	50.81053
158	90.29%	0.09029%	5,298.53000	49.64481
159	90.86%	0.09086%	5,332.06500	48.50391
160	91.43%	0.09143%	5,365.60000	47.38734
161	92.00%	0.09200%	5,399.13500	46.29467
162	92.57%	0.09257%	5,432.67000	45.22545
163	93.14%	0.09314%	5,466.20500	44.17924
164	93.71%	0.09371%	5,499.74000	43.15561
165	94.29%	0.09429%	5,533.27500	42.15413
166	94.86%	0.09486%	5,566.81000	41.17438
167	95.43%	0.09543%	5,600.34500	40.21594
168	96.00%	0.09600%	5,633.88000	39.27840
169	96.57%	0.09657%	5,667.41500	38.36136
170	97.14%	0.09714%	5,700.95000	37.46442
171	97.71%	0.09771%	5,734.48500	36.58719
172	98.29%	0.09829%	5,768.02000	35.72927
173	98.86%	0.09886%	5,801.55500	34.89029
174	99.43%	0.09943%	5,835.09000	34.06987
175	100.00%	0.10000%	5,868.62500	33.26764
Beyond (d)				1,108.92144
Total				38,161.38462

Section 1.3 Lake Winnipeg - Progressive Dispersal

Affected habitat (acres): 5,868,625.00

	<----------(Percentage)---------->		<----------(Acre Years)---------->	
Year	Certain (a)	Expected (b)	Current Value	Present Value
294	0.00%	0.00000%	0.00000	0.00000
295	0.57%	0.00057%	33.53500	0.00548
296	1.14%	0.00114%	67.07000	0.01063
297	1.71%	0.00171%	100.60500	0.01549
298	2.29%	0.00229%	134.14000	0.02005

299	2.86%	0.00286%	167.67500	0.02433
300	3.43%	0.00343%	201.21000	0.02835
301	4.00%	0.00400%	234.74500	0.03211
302	4.57%	0.00457%	268.28000	0.03562
303	5.14%	0.00514%	301.81500	0.03891
304	5.71%	0.00571%	335.35000	0.04197
305	6.29%	0.00629%	368.88500	0.04483
306	6.86%	0.00686%	402.42000	0.04748
307	7.43%	0.00743%	435.95500	0.04994
308	8.00%	0.00800%	469.49000	0.05221
309	8.57%	0.00857%	503.02500	0.05431
310	9.14%	0.00914%	536.56000	0.05624
311	9.71%	0.00971%	570.09500	0.05802
312	10.29%	0.01029%	603.63000	0.05964
313	10.86%	0.01086%	637.16500	0.06112
314	11.43%	0.01143%	670.70000	0.06247
315	12.00%	0.01200%	704.23500	0.06368
316	12.57%	0.01257%	737.77000	0.06477
317	13.14%	0.01314%	771.30500	0.06574
318	13.71%	0.01371%	804.84000	0.06660
319	14.29%	0.01429%	838.37500	0.06735
320	14.86%	0.01486%	871.91000	0.06801
321	15.43%	0.01543%	905.44500	0.06857
322	16.00%	0.01600%	938.98000	0.06904
323	16.57%	0.01657%	972.51500	0.06942
324	17.14%	0.01714%	1,006.05000	0.06972
325	17.71%	0.01771%	1,039.58500	0.06995
326	18.29%	0.01829%	1,073.12000	0.07010
327	18.86%	0.01886%	1,106.65500	0.07018
328	19.43%	0.01943%	1,140.19000	0.07020
329	20.00%	0.02000%	1,173.72500	0.07016
330	20.57%	0.02057%	1,207.26000	0.07007
331	21.14%	0.02114%	1,240.79500	0.06992
332	21.71%	0.02171%	1,274.33000	0.06971
333	22.29%	0.02229%	1,307.86500	0.06947
334	22.86%	0.02286%	1,341.40000	0.06917
335	23.43%	0.02343%	1,374.93500	0.06884
336	24.00%	0.02400%	1,408.47000	0.06846
337	24.57%	0.02457%	1,442.00500	0.06805
338	25.14%	0.02514%	1,475.54000	0.06760
339	25.71%	0.02571%	1,509.07500	0.06713
340	26.29%	0.02629%	1,542.61000	0.06662
341	26.86%	0.02686%	1,576.14500	0.06608
342	27.43%	0.02743%	1,609.68000	0.06553
343	28.00%	0.02800%	1,643.21500	0.06494
344	28.57%	0.02857%	1,676.75000	0.06434
345	29.14%	0.02914%	1,710.28500	0.06371
346	29.71%	0.02971%	1,743.82000	0.06307
347	30.29%	0.03029%	1,777.35500	0.06241
348	30.86%	0.03086%	1,810.89000	0.06174
349	31.43%	0.03143%	1,844.42500	0.06105
350	32.00%	0.03200%	1,877.96000	0.06035

351	32.57%	0.03257%	1,911.49500	0.05964
352	33.14%	0.03314%	1,945.03000	0.05891
353	33.71%	0.03371%	1,978.56500	0.05818
354	34.29%	0.03429%	2,012.10000	0.05745
355	34.86%	0.03486%	2,045.63500	0.05670
356	35.43%	0.03543%	2,079.17000	0.05595
357	36.00%	0.03600%	2,112.70500	0.05520
358	36.57%	0.03657%	2,146.24000	0.05444
359	37.14%	0.03714%	2,179.77500	0.05368
360	37.71%	0.03771%	2,213.31000	0.05292
361	38.29%	0.03829%	2,246.84500	0.05216
362	38.86%	0.03886%	2,280.38000	0.05140
363	39.43%	0.03943%	2,313.91500	0.05063
364	40.00%	0.04000%	2,347.45000	0.04987
365	40.57%	0.04057%	2,380.98500	0.04911
366	41.14%	0.04114%	2,414.52000	0.04835
367	41.71%	0.04171%	2,448.05500	0.04759
368	42.29%	0.04229%	2,481.59000	0.04684
369	42.86%	0.04286%	2,515.12500	0.04609
370	43.43%	0.04343%	2,548.66000	0.04535
371	44.00%	0.04400%	2,582.19500	0.04460
372	44.57%	0.04457%	2,615.73000	0.04387
373	45.14%	0.04514%	2,649.26500	0.04314
374	45.71%	0.04571%	2,682.80000	0.04241
375	46.29%	0.04629%	2,716.33500	0.04169
376	46.86%	0.04686%	2,749.87000	0.04097
377	47.43%	0.04743%	2,783.40500	0.04027
378	48.00%	0.04800%	2,816.94000	0.03956
379	48.57%	0.04857%	2,850.47500	0.03887
380	49.14%	0.04914%	2,884.01000	0.03818
381	49.71%	0.04971%	2,917.54500	0.03750
382	50.29%	0.05029%	2,951.08000	0.03683
383	50.86%	0.05086%	2,984.61500	0.03616
384	51.43%	0.05143%	3,018.15000	0.03550
385	52.00%	0.05200%	3,051.68500	0.03485
386	52.57%	0.05257%	3,085.22000	0.03421
387	53.14%	0.05314%	3,118.75500	0.03357
388	53.71%	0.05371%	3,152.29000	0.03294
389	54.29%	0.05429%	3,185.82500	0.03233
390	54.86%	0.05486%	3,219.36000	0.03171
391	55.43%	0.05543%	3,252.89500	0.03111
392	56.00%	0.05600%	3,286.43000	0.03052
393	56.57%	0.05657%	3,319.96500	0.02993
394	57.14%	0.05714%	3,353.50000	0.02935
395	57.71%	0.05771%	3,387.03500	0.02878
396	58.29%	0.05829%	3,420.57000	0.02822
397	58.86%	0.05886%	3,454.10500	0.02767
398	59.43%	0.05943%	3,487.64000	0.02712
399	60.00%	0.06000%	3,521.17500	0.02658
400	60.57%	0.06057%	3,554.71000	0.02606
401	61.14%	0.06114%	3,588.24500	0.02554
402	61.71%	0.06171%	3,621.78000	0.02502

403	62.29%	0.06229%	3,655.31500	0.02452
404	62.86%	0.06286%	3,688.85000	0.02402
405	63.43%	0.06343%	3,722.38500	0.02354
406	64.00%	0.06400%	3,755.92000	0.02306
407	64.57%	0.06457%	3,789.45500	0.02259
408	65.14%	0.06514%	3,822.99000	0.02212
409	65.71%	0.06571%	3,856.52500	0.02167
410	66.29%	0.06629%	3,890.06000	0.02122
411	66.86%	0.06686%	3,923.59500	0.02078
412	67.43%	0.06743%	3,957.13000	0.02034
413	68.00%	0.06800%	3,990.66500	0.01992
414	68.57%	0.06857%	4,024.20000	0.01950
415	69.14%	0.06914%	4,057.73500	0.01909
416	69.71%	0.06971%	4,091.27000	0.01869
417	70.29%	0.07029%	4,124.80500	0.01829
418	70.86%	0.07086%	4,158.34000	0.01790
419	71.43%	0.07143%	4,191.87500	0.01752
420	72.00%	0.07200%	4,225.41000	0.01715
421	72.57%	0.07257%	4,258.94500	0.01678
422	73.14%	0.07314%	4,292.48000	0.01642
423	73.71%	0.07371%	4,326.01500	0.01607
424	74.29%	0.07429%	4,359.55000	0.01572
425	74.86%	0.07486%	4,393.08500	0.01538
426	75.43%	0.07543%	4,426.62000	0.01505
427	76.00%	0.07600%	4,460.15500	0.01472
428	76.57%	0.07657%	4,493.69000	0.01440
429	77.14%	0.07714%	4,527.22500	0.01408
430	77.71%	0.07771%	4,560.76000	0.01377
431	78.29%	0.07829%	4,594.29500	0.01347
432	78.86%	0.07886%	4,627.83000	0.01317
433	79.43%	0.07943%	4,661.36500	0.01288
434	80.00%	0.08000%	4,694.90000	0.01260
435	80.57%	0.08057%	4,728.43500	0.01232
436	81.14%	0.08114%	4,761.97000	0.01204
437	81.71%	0.08171%	4,795.50500	0.01178
438	82.29%	0.08229%	4,829.04000	0.01151
439	82.86%	0.08286%	4,862.57500	0.01125
440	83.43%	0.08343%	4,896.11000	0.01100
441	84.00%	0.08400%	4,929.64500	0.01075
442	84.57%	0.08457%	4,963.18000	0.01051
443	85.14%	0.08514%	4,996.71500	0.01028
444	85.71%	0.08571%	5,030.25000	0.01004
445	86.29%	0.08629%	5,063.78500	0.00982
446	86.86%	0.08686%	5,097.32000	0.00959
447	87.43%	0.08743%	5,130.85500	0.00937
448	88.00%	0.08800%	5,164.39000	0.00916
449	88.57%	0.08857%	5,197.92500	0.00895
450	89.14%	0.08914%	5,231.46000	0.00875
451	89.71%	0.08971%	5,264.99500	0.00855
452	90.29%	0.09029%	5,298.53000	0.00835
453	90.86%	0.09086%	5,332.06500	0.00816
454	91.43%	0.09143%	5,365.60000	0.00797

455	92.00%	0.09200%	5,399.13500	0.00779
456	92.57%	0.09257%	5,432.67000	0.00761
457	93.14%	0.09314%	5,466.20500	0.00743
458	93.71%	0.09371%	5,499.74000	0.00726
459	94.29%	0.09429%	5,533.27500	0.00709
460	94.86%	0.09486%	5,566.81000	0.00693
461	95.43%	0.09543%	5,600.34500	0.00676
462	96.00%	0.09600%	5,633.88000	0.00661
463	96.57%	0.09657%	5,667.41500	0.00645
464	97.14%	0.09714%	5,700.95000	0.00630
465	97.71%	0.09771%	5,734.48500	0.00615
466	98.29%	0.09829%	5,768.02000	0.00601
467	98.86%	0.09886%	5,801.55500	0.00587
468	99.43%	0.09943%	5,835.09000	0.00573
469	100.00%	0.10000%	5,868.62500	0.00560
Beyond (e)				0.18653
Total				6.41919

Section 2 Quantification of Replacement Services

	<----------(Percentage)---------->	
Year	Current Value	Present Value
5	0.0%	0.0%
6	5.0%	4.2%
7	10.0%	8.1%
8	15.0%	11.8%
9	20.0%	15.3%
10	25.0%	18.6%
11	30.0%	21.7%
12	35.0%	24.5%
13	40.0%	27.2%
14	45.0%	29.8%
15	50.0%	32.1%
16	55.0%	34.3%
17	60.0%	36.3%
18	65.0%	38.2%
19	70.0%	39.9%
20	75.0%	41.5%
21	80.0%	43.0%
22	85.0%	44.4%
23	90.0%	45.6%
24	95.0%	46.7%
25	100.0%	47.8%
Beyond (f)		1592.0%
Total		2203.1%

Section 3 Offsetting Restoration for One Organism

Red River - Progressive Dispersal (river-miles):	0.0805
Lake Winnipeg - Jump Dispersal (acres):	1,730
Lake Winnipeg - Progressive Dispersal (acres):	0.291

Section 4 Notes

(a) Percent loss given certain invasion

(b) Percent loss given probability of successful invasion

(c) From year 295 into perpetuity

(d) From year 176 into perpetuity

(e) From year 470 into perpetuity

(f) From year 26 into perpetuity

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Appendix 15E. Habitat Equivalency Analysis of Risk Consequences: Slow Invasion - High Risk (One Organism)

Probability of successful invasion: 1.00E-02

Annual discount rate: 3.0%

Present year: 0

Section 1 Quantification of Expected Lost Services

Section 1.1 Red River from Fargo to Lake Winnipeg - Progressive Dispersal

Affected habitat (river-miles): 455.40

	<----------(Percentage)---------->		<----------(River-Mile Years)---------->	
Year	Certain (a)	Expected (b)	Current Value	Present Value
0	0.00%	0.0000%	0.0000	0.0000
1	0.34%	0.0034%	0.0155	0.0150
2	0.68%	0.0068%	0.0310	0.0292
3	1.02%	0.0102%	0.0465	0.0425
4	1.36%	0.0136%	0.0620	0.0550
5	1.70%	0.0170%	0.0774	0.0668
6	2.04%	0.0204%	0.0929	0.0778
7	2.38%	0.0238%	0.1084	0.0882
8	2.72%	0.0272%	0.1239	0.0978
9	3.06%	0.0306%	0.1394	0.1068
10	3.40%	0.0340%	0.1549	0.1153
11	3.74%	0.0374%	0.1704	0.1231
12	4.08%	0.0408%	0.1859	0.1304
13	4.42%	0.0442%	0.2014	0.1371
14	4.76%	0.0476%	0.2169	0.1434
15	5.10%	0.0510%	0.2323	0.1491
16	5.44%	0.0544%	0.2478	0.1544
17	5.78%	0.0578%	0.2633	0.1593
18	6.12%	0.0612%	0.2788	0.1638
19	6.46%	0.0646%	0.2943	0.1678
20	6.80%	0.0680%	0.3098	0.1715
21	7.14%	0.0714%	0.3253	0.1749
22	7.48%	0.0748%	0.3408	0.1778
23	7.82%	0.0782%	0.3563	0.1805
24	8.16%	0.0816%	0.3718	0.1829
25	8.50%	0.0850%	0.3872	0.1850
26	8.84%	0.0884%	0.4027	0.1867
27	9.18%	0.0918%	0.4182	0.1883
28	9.52%	0.0952%	0.4337	0.1896
29	9.86%	0.0986%	0.4492	0.1906

30	10.20%	0.1020%	0.4647	0.1914
31	10.54%	0.1054%	0.4802	0.1921
32	10.88%	0.1088%	0.4957	0.1925
33	11.22%	0.1122%	0.5112	0.1927
34	11.56%	0.1156%	0.5267	0.1928
35	11.90%	0.1190%	0.5421	0.1927
36	12.24%	0.1224%	0.5576	0.1924
37	12.59%	0.1259%	0.5731	0.1920
38	12.93%	0.1293%	0.5886	0.1914
39	13.27%	0.1327%	0.6041	0.1907
40	13.61%	0.1361%	0.6196	0.1899
41	13.95%	0.1395%	0.6351	0.1890
42	14.29%	0.1429%	0.6506	0.1880
43	14.63%	0.1463%	0.6661	0.1869
44	14.97%	0.1497%	0.6816	0.1856
45	15.31%	0.1531%	0.6970	0.1843
46	15.65%	0.1565%	0.7125	0.1829
47	15.99%	0.1599%	0.7280	0.1815
48	16.33%	0.1633%	0.7435	0.1799
49	16.67%	0.1667%	0.7590	0.1783
50	17.01%	0.1701%	0.7745	0.1767
51	17.35%	0.1735%	0.7900	0.1750
52	17.69%	0.1769%	0.8055	0.1732
53	18.03%	0.1803%	0.8210	0.1714
54	18.37%	0.1837%	0.8364	0.1695
55	18.71%	0.1871%	0.8519	0.1676
56	19.05%	0.1905%	0.8674	0.1657
57	19.39%	0.1939%	0.8829	0.1638
58	19.73%	0.1973%	0.8984	0.1618
59	20.07%	0.2007%	0.9139	0.1598
60	20.41%	0.2041%	0.9294	0.1577
61	20.75%	0.2075%	0.9449	0.1557
62	21.09%	0.2109%	0.9604	0.1536
63	21.43%	0.2143%	0.9759	0.1516
64	21.77%	0.2177%	0.9913	0.1495
65	22.11%	0.2211%	1.0068	0.1474
66	22.45%	0.2245%	1.0223	0.1453
67	22.79%	0.2279%	1.0378	0.1432
68	23.13%	0.2313%	1.0533	0.1411
69	23.47%	0.2347%	1.0688	0.1390
70	23.81%	0.2381%	1.0843	0.1369
71	24.15%	0.2415%	1.0998	0.1349
72	24.49%	0.2449%	1.1153	0.1328
73	24.83%	0.2483%	1.1308	0.1307
74	25.17%	0.2517%	1.1462	0.1286
75	25.51%	0.2551%	1.1617	0.1266
76	25.85%	0.2585%	1.1772	0.1245
77	26.19%	0.2619%	1.1927	0.1225
78	26.53%	0.2653%	1.2082	0.1205
79	26.87%	0.2687%	1.2237	0.1184
80	27.21%	0.2721%	1.2392	0.1165
81	27.55%	0.2755%	1.2547	0.1145

82	27.89%	0.2789%	1.2702	0.1125
83	28.23%	0.2823%	1.2857	0.1106
84	28.57%	0.2857%	1.3011	0.1086
85	28.91%	0.2891%	1.3166	0.1067
86	29.25%	0.2925%	1.3321	0.1048
87	29.59%	0.2959%	1.3476	0.1030
88	29.93%	0.2993%	1.3631	0.1011
89	30.27%	0.3027%	1.3786	0.0993
90	30.61%	0.3061%	1.3941	0.0975
91	30.95%	0.3095%	1.4096	0.0957
92	31.29%	0.3129%	1.4251	0.0939
93	31.63%	0.3163%	1.4406	0.0922
94	31.97%	0.3197%	1.4560	0.0905
95	32.31%	0.3231%	1.4715	0.0888
96	32.65%	0.3265%	1.4870	0.0871
97	32.99%	0.3299%	1.5025	0.0854
98	33.33%	0.3333%	1.5180	0.0838
99	33.67%	0.3367%	1.5335	0.0822
100	34.01%	0.3401%	1.5490	0.0806
101	34.35%	0.3435%	1.5645	0.0790
102	34.69%	0.3469%	1.5800	0.0775
103	35.03%	0.3503%	1.5954	0.0760
104	35.37%	0.3537%	1.6109	0.0745
105	35.71%	0.3571%	1.6264	0.0730
106	36.05%	0.3605%	1.6419	0.0715
107	36.39%	0.3639%	1.6574	0.0701
108	36.73%	0.3673%	1.6729	0.0687
109	37.07%	0.3707%	1.6884	0.0673
110	37.41%	0.3741%	1.7039	0.0660
111	37.76%	0.3776%	1.7194	0.0646
112	38.10%	0.3810%	1.7349	0.0633
113	38.44%	0.3844%	1.7503	0.0620
114	38.78%	0.3878%	1.7658	0.0607
115	39.12%	0.3912%	1.7813	0.0595
116	39.46%	0.3946%	1.7968	0.0583
117	39.80%	0.3980%	1.8123	0.0571
118	40.14%	0.4014%	1.8278	0.0559
119	40.48%	0.4048%	1.8433	0.0547
120	40.82%	0.4082%	1.8588	0.0536
121	41.16%	0.4116%	1.8743	0.0524
122	41.50%	0.4150%	1.8898	0.0513
123	41.84%	0.4184%	1.9052	0.0502
124	42.18%	0.4218%	1.9207	0.0492
125	42.52%	0.4252%	1.9362	0.0481
126	42.86%	0.4286%	1.9517	0.0471
127	43.20%	0.4320%	1.9672	0.0461
128	43.54%	0.4354%	1.9827	0.0451
129	43.88%	0.4388%	1.9982	0.0441
130	44.22%	0.4422%	2.0137	0.0432
131	44.56%	0.4456%	2.0292	0.0422
132	44.90%	0.4490%	2.0447	0.0413
133	45.24%	0.4524%	2.0601	0.0404

134	45.58%	0.4558%	2.0756	0.0395
135	45.92%	0.4592%	2.0911	0.0387
136	46.26%	0.4626%	2.1066	0.0378
137	46.60%	0.4660%	2.1221	0.0370
138	46.94%	0.4694%	2.1376	0.0362
139	47.28%	0.4728%	2.1531	0.0354
140	47.62%	0.4762%	2.1686	0.0346
141	47.96%	0.4796%	2.1841	0.0338
142	48.30%	0.4830%	2.1996	0.0331
143	48.64%	0.4864%	2.2150	0.0323
144	48.98%	0.4898%	2.2305	0.0316
145	49.32%	0.4932%	2.2460	0.0309
146	49.66%	0.4966%	2.2615	0.0302
147	50.00%	0.5000%	2.2770	0.0295
148	50.34%	0.5034%	2.2925	0.0289
149	50.68%	0.5068%	2.3080	0.0282
150	51.02%	0.5102%	2.3235	0.0276
151	51.36%	0.5136%	2.3390	0.0270
152	51.70%	0.5170%	2.3544	0.0263
153	52.04%	0.5204%	2.3699	0.0257
154	52.38%	0.5238%	2.3854	0.0252
155	52.72%	0.5272%	2.4009	0.0246
156	53.06%	0.5306%	2.4164	0.0240
157	53.40%	0.5340%	2.4319	0.0235
158	53.74%	0.5374%	2.4474	0.0229
159	54.08%	0.5408%	2.4629	0.0224
160	54.42%	0.5442%	2.4784	0.0219
161	54.76%	0.5476%	2.4939	0.0214
162	55.10%	0.5510%	2.5093	0.0209
163	55.44%	0.5544%	2.5248	0.0204
164	55.78%	0.5578%	2.5403	0.0199
165	56.12%	0.5612%	2.5558	0.0195
166	56.46%	0.5646%	2.5713	0.0190
167	56.80%	0.5680%	2.5868	0.0186
168	57.14%	0.5714%	2.6023	0.0181
169	57.48%	0.5748%	2.6178	0.0177
170	57.82%	0.5782%	2.6333	0.0173
171	58.16%	0.5816%	2.6488	0.0169
172	58.50%	0.5850%	2.6642	0.0165
173	58.84%	0.5884%	2.6797	0.0161
174	59.18%	0.5918%	2.6952	0.0157
175	59.52%	0.5952%	2.7107	0.0154
176	59.86%	0.5986%	2.7262	0.0150
177	60.20%	0.6020%	2.7417	0.0146
178	60.54%	0.6054%	2.7572	0.0143
179	60.88%	0.6088%	2.7727	0.0140
180	61.22%	0.6122%	2.7882	0.0136
181	61.56%	0.6156%	2.8037	0.0133
182	61.90%	0.6190%	2.8191	0.0130
183	62.24%	0.6224%	2.8346	0.0127
184	62.59%	0.6259%	2.8501	0.0124
185	62.93%	0.6293%	2.8656	0.0121

186	63.27%	0.6327%	2.8811	0.0118
187	63.61%	0.6361%	2.8966	0.0115
188	63.95%	0.6395%	2.9121	0.0112
189	64.29%	0.6429%	2.9276	0.0110
190	64.63%	0.6463%	2.9431	0.0107
191	64.97%	0.6497%	2.9586	0.0105
192	65.31%	0.6531%	2.9740	0.0102
193	65.65%	0.6565%	2.9895	0.0100
194	65.99%	0.6599%	3.0050	0.0097
195	66.33%	0.6633%	3.0205	0.0095
196	66.67%	0.6667%	3.0360	0.0093
197	67.01%	0.6701%	3.0515	0.0090
198	67.35%	0.6735%	3.0670	0.0088
199	67.69%	0.6769%	3.0825	0.0086
200	68.03%	0.6803%	3.0980	0.0084
201	68.37%	0.6837%	3.1134	0.0082
202	68.71%	0.6871%	3.1289	0.0080
203	69.05%	0.6905%	3.1444	0.0078
204	69.39%	0.6939%	3.1599	0.0076
205	69.73%	0.6973%	3.1754	0.0074
206	70.07%	0.7007%	3.1909	0.0072
207	70.41%	0.7041%	3.2064	0.0071
208	70.75%	0.7075%	3.2219	0.0069
209	71.09%	0.7109%	3.2374	0.0067
210	71.43%	0.7143%	3.2529	0.0066
211	71.77%	0.7177%	3.2683	0.0064
212	72.11%	0.7211%	3.2838	0.0062
213	72.45%	0.7245%	3.2993	0.0061
214	72.79%	0.7279%	3.3148	0.0059
215	73.13%	0.7313%	3.3303	0.0058
216	73.47%	0.7347%	3.3458	0.0056
217	73.81%	0.7381%	3.3613	0.0055
218	74.15%	0.7415%	3.3768	0.0054
219	74.49%	0.7449%	3.3923	0.0052
220	74.83%	0.7483%	3.4078	0.0051
221	75.17%	0.7517%	3.4232	0.0050
222	75.51%	0.7551%	3.4387	0.0049
223	75.85%	0.7585%	3.4542	0.0047
224	76.19%	0.7619%	3.4697	0.0046
225	76.53%	0.7653%	3.4852	0.0045
226	76.87%	0.7687%	3.5007	0.0044
227	77.21%	0.7721%	3.5162	0.0043
228	77.55%	0.7755%	3.5317	0.0042
229	77.89%	0.7789%	3.5472	0.0041
230	78.23%	0.7823%	3.5627	0.0040
231	78.57%	0.7857%	3.5781	0.0039
232	78.91%	0.7891%	3.5936	0.0038
233	79.25%	0.7925%	3.6091	0.0037
234	79.59%	0.7959%	3.6246	0.0036
235	79.93%	0.7993%	3.6401	0.0035
236	80.27%	0.8027%	3.6556	0.0034
237	80.61%	0.8061%	3.6711	0.0033

238	80.95%	0.8095%	3.6866	0.0032
239	81.29%	0.8129%	3.7021	0.0032
240	81.63%	0.8163%	3.7176	0.0031
241	81.97%	0.8197%	3.7330	0.0030
242	82.31%	0.8231%	3.7485	0.0029
243	82.65%	0.8265%	3.7640	0.0029
244	82.99%	0.8299%	3.7795	0.0028
245	83.33%	0.8333%	3.7950	0.0027
246	83.67%	0.8367%	3.8105	0.0026
247	84.01%	0.8401%	3.8260	0.0026
248	84.35%	0.8435%	3.8415	0.0025
249	84.69%	0.8469%	3.8570	0.0025
250	85.03%	0.8503%	3.8724	0.0024
251	85.37%	0.8537%	3.8879	0.0023
252	85.71%	0.8571%	3.9034	0.0023
253	86.05%	0.8605%	3.9189	0.0022
254	86.39%	0.8639%	3.9344	0.0022
255	86.73%	0.8673%	3.9499	0.0021
256	87.07%	0.8707%	3.9654	0.0021
257	87.41%	0.8741%	3.9809	0.0020
258	87.76%	0.8776%	3.9964	0.0019
259	88.10%	0.8810%	4.0119	0.0019
260	88.44%	0.8844%	4.0273	0.0019
261	88.78%	0.8878%	4.0428	0.0018
262	89.12%	0.8912%	4.0583	0.0018
263	89.46%	0.8946%	4.0738	0.0017
264	89.80%	0.8980%	4.0893	0.0017
265	90.14%	0.9014%	4.1048	0.0016
266	90.48%	0.9048%	4.1203	0.0016
267	90.82%	0.9082%	4.1358	0.0015
268	91.16%	0.9116%	4.1513	0.0015
269	91.50%	0.9150%	4.1668	0.0015
270	91.84%	0.9184%	4.1822	0.0014
271	92.18%	0.9218%	4.1977	0.0014
272	92.52%	0.9252%	4.2132	0.0014
273	92.86%	0.9286%	4.2287	0.0013
274	93.20%	0.9320%	4.2442	0.0013
275	93.54%	0.9354%	4.2597	0.0013
276	93.88%	0.9388%	4.2752	0.0012
277	94.22%	0.9422%	4.2907	0.0012
278	94.56%	0.9456%	4.3062	0.0012
279	94.90%	0.9490%	4.3217	0.0011
280	95.24%	0.9524%	4.3371	0.0011
281	95.58%	0.9558%	4.3526	0.0011
282	95.92%	0.9592%	4.3681	0.0010
283	96.26%	0.9626%	4.3836	0.0010
284	96.60%	0.9660%	4.3991	0.0010
285	96.94%	0.9694%	4.4146	0.0010
286	97.28%	0.9728%	4.4301	0.0009
287	97.62%	0.9762%	4.4456	0.0009
288	97.96%	0.9796%	4.4611	0.0009
289	98.30%	0.9830%	4.4766	0.0009

290	98.64%	0.9864%	4.4920	0.0009
291	98.98%	0.9898%	4.5075	0.0008
292	99.32%	0.9932%	4.5230	0.0008
293	99.66%	0.9966%	4.5385	0.0008
294	100.00%	1.0000%	4.5540	0.0008
Beyond (c)				0.0255
Total				17.7242

Section 1.2 Lake Winnipeg - Jump Dispersal

Affected habitat (acres): 5,868,625.00

	<----------(Percentage)---------->		<----------(Acre Years)---------->	
Year	Certain (a)	Expected (b)	Current Value	Present Value
0	0.00%	0.0000%	0.0000	0.0000
1	0.57%	0.0057%	335.3500	325.5825
2	1.14%	0.0114%	670.7000	632.1991
3	1.71%	0.0171%	1,006.0500	920.6783
4	2.29%	0.0229%	1,341.4000	1,191.8165
5	2.86%	0.0286%	1,676.7500	1,446.3793
6	3.43%	0.0343%	2,012.1000	1,685.1021
7	4.00%	0.0400%	2,347.4500	1,908.6917
8	4.57%	0.0457%	2,682.8000	2,117.8271
9	5.14%	0.0514%	3,018.1500	2,313.1607
10	5.71%	0.0571%	3,353.5000	2,495.3189
11	6.29%	0.0629%	3,688.8500	2,664.9037
12	6.86%	0.0686%	4,024.2000	2,822.4929
13	7.43%	0.0743%	4,359.5500	2,968.6414
14	8.00%	0.0800%	4,694.9000	3,103.8820
15	8.57%	0.0857%	5,030.2500	3,228.7261
16	9.14%	0.0914%	5,365.6000	3,343.6645
17	9.71%	0.0971%	5,700.9500	3,449.1685
18	10.29%	0.1029%	6,036.3000	3,545.6901
19	10.86%	0.1086%	6,371.6500	3,633.6630
20	11.43%	0.1143%	6,707.0000	3,713.5033
21	12.00%	0.1200%	7,042.3500	3,785.6101
22	12.57%	0.1257%	7,377.7000	3,850.3663
23	13.14%	0.1314%	7,713.0500	3,908.1388
24	13.71%	0.1371%	8,048.4000	3,959.2795
25	14.29%	0.1429%	8,383.7500	4,004.1257
26	14.86%	0.1486%	8,719.1000	4,043.0007
27	15.43%	0.1543%	9,054.4500	4,076.2143
28	16.00%	0.1600%	9,389.8000	4,104.0633
29	16.57%	0.1657%	9,725.1500	4,126.8320
30	17.14%	0.1714%	10,060.5000	4,144.7928
31	17.71%	0.1771%	10,395.8500	4,158.2064
32	18.29%	0.1829%	10,731.2000	4,167.3224
33	18.86%	0.1886%	11,066.5500	4,172.3798
34	19.43%	0.1943%	11,401.9000	4,173.6073
35	20.00%	0.2000%	11,737.2500	4,171.2238

36	20.57%	0.2057%	12,072.6000	4,165.4385
37	21.14%	0.2114%	12,407.9500	4,156.4515
38	21.71%	0.2171%	12,743.3000	4,144.4544
39	22.29%	0.2229%	13,078.6500	4,129.6301
40	22.86%	0.2286%	13,414.0000	4,112.1535
41	23.43%	0.2343%	13,749.3500	4,092.1916
42	24.00%	0.2400%	14,084.7000	4,069.9040
43	24.57%	0.2457%	14,420.0500	4,045.4432
44	25.14%	0.2514%	14,755.4000	4,018.9546
45	25.71%	0.2571%	15,090.7500	3,990.5772
46	26.29%	0.2629%	15,426.1000	3,960.4434
47	26.86%	0.2686%	15,761.4500	3,928.6796
48	27.43%	0.2743%	16,096.8000	3,895.4063
49	28.00%	0.2800%	16,432.1500	3,860.7384
50	28.57%	0.2857%	16,767.5000	3,824.7855
51	29.14%	0.2914%	17,102.8500	3,787.6516
52	29.71%	0.2971%	17,438.2000	3,749.4362
53	30.29%	0.3029%	17,773.5500	3,710.2337
54	30.86%	0.3086%	18,108.9000	3,670.1341
55	31.43%	0.3143%	18,444.2500	3,629.2229
56	32.00%	0.3200%	18,779.6000	3,587.5813
57	32.57%	0.3257%	19,114.9500	3,545.2867
58	33.14%	0.3314%	19,450.3000	3,502.4123
59	33.71%	0.3371%	19,785.6500	3,459.0279
60	34.29%	0.3429%	20,121.0000	3,415.1995
61	34.86%	0.3486%	20,456.3500	3,370.9898
62	35.43%	0.3543%	20,791.7000	3,326.4582
63	36.00%	0.3600%	21,127.0500	3,281.6609
64	36.57%	0.3657%	21,462.4000	3,236.6512
65	37.14%	0.3714%	21,797.7500	3,191.4795
66	37.71%	0.3771%	22,133.1000	3,146.1934
67	38.29%	0.3829%	22,468.4500	3,100.8379
68	38.86%	0.3886%	22,803.8000	3,055.4554
69	39.43%	0.3943%	23,139.1500	3,010.0860
70	40.00%	0.4000%	23,474.5000	2,964.7674
71	40.57%	0.4057%	23,809.8500	2,919.5351
72	41.14%	0.4114%	24,145.2000	2,874.4227
73	41.71%	0.4171%	24,480.5500	2,829.4614
74	42.29%	0.4229%	24,815.9000	2,784.6807
75	42.86%	0.4286%	25,151.2500	2,740.1083
76	43.43%	0.4343%	25,486.6000	2,695.7699
77	44.00%	0.4400%	25,821.9500	2,651.6899
78	44.57%	0.4457%	26,157.3000	2,607.8907
79	45.14%	0.4514%	26,492.6500	2,564.3934
80	45.71%	0.4571%	26,828.0000	2,521.2175
81	46.29%	0.4629%	27,163.3500	2,478.3813
82	46.86%	0.4686%	27,498.7000	2,435.9016
83	47.43%	0.4743%	27,834.0500	2,393.7939
84	48.00%	0.4800%	28,169.4000	2,352.0726
85	48.57%	0.4857%	28,504.7500	2,310.7509
86	49.14%	0.4914%	28,840.1000	2,269.8410
87	49.71%	0.4971%	29,175.4500	2,229.3539

88	50.29%	0.5029%	29,510.8000	2,189.2997
89	50.86%	0.5086%	29,846.1500	2,149.6874
90	51.43%	0.5143%	30,181.5000	2,110.5255
91	52.00%	0.5200%	30,516.8500	2,071.8211
92	52.57%	0.5257%	30,852.2000	2,033.5810
93	53.14%	0.5314%	31,187.5500	1,995.8108
94	53.71%	0.5371%	31,522.9000	1,958.5156
95	54.29%	0.5429%	31,858.2500	1,921.6999
96	54.86%	0.5486%	32,193.6000	1,885.3673
97	55.43%	0.5543%	32,528.9500	1,849.5209
98	56.00%	0.5600%	32,864.3000	1,814.1633
99	56.57%	0.5657%	33,199.6500	1,779.2962
100	57.14%	0.5714%	33,535.0000	1,744.9213
101	57.71%	0.5771%	33,870.3500	1,711.0393
102	58.29%	0.5829%	34,205.7000	1,677.6508
103	58.86%	0.5886%	34,541.0500	1,644.7557
104	59.43%	0.5943%	34,876.4000	1,612.3536
105	60.00%	0.6000%	35,211.7500	1,580.4436
106	60.57%	0.6057%	35,547.1000	1,549.0248
107	61.14%	0.6114%	35,882.4500	1,518.0953
108	61.71%	0.6171%	36,217.8000	1,487.6535
109	62.29%	0.6229%	36,553.1500	1,457.6972
110	62.86%	0.6286%	36,888.5000	1,428.2238
111	63.43%	0.6343%	37,223.8500	1,399.2308
112	64.00%	0.6400%	37,559.2000	1,370.7150
113	64.57%	0.6457%	37,894.5500	1,342.6733
114	65.14%	0.6514%	38,229.9000	1,315.1023
115	65.71%	0.6571%	38,565.2500	1,287.9984
116	66.29%	0.6629%	38,900.6000	1,261.3576
117	66.86%	0.6686%	39,235.9500	1,235.1761
118	67.43%	0.6743%	39,571.3000	1,209.4497
119	68.00%	0.6800%	39,906.6500	1,184.1740
120	68.57%	0.6857%	40,242.0000	1,159.3447
121	69.14%	0.6914%	40,577.3500	1,134.9572
122	69.71%	0.6971%	40,912.7000	1,111.0068
123	70.29%	0.7029%	41,248.0500	1,087.4888
124	70.86%	0.7086%	41,583.4000	1,064.3982
125	71.43%	0.7143%	41,918.7500	1,041.7302
126	72.00%	0.7200%	42,254.1000	1,019.4796
127	72.57%	0.7257%	42,589.4500	997.6415
128	73.14%	0.7314%	42,924.8000	976.2106
129	73.71%	0.7371%	43,260.1500	955.1818
130	74.29%	0.7429%	43,595.5000	934.5498
131	74.86%	0.7486%	43,930.8500	914.3094
132	75.43%	0.7543%	44,266.2000	894.4552
133	76.00%	0.7600%	44,601.5500	874.9819
134	76.57%	0.7657%	44,936.9000	855.8842
135	77.14%	0.7714%	45,272.2500	837.1567
136	77.71%	0.7771%	45,607.6000	818.7940
137	78.29%	0.7829%	45,942.9500	800.7908
138	78.86%	0.7886%	46,278.3000	783.1418
139	79.43%	0.7943%	46,613.6500	765.8415

140	80.00%	0.8000%	46,949.0000	748.8846
141	80.57%	0.8057%	47,284.3500	732.2658
142	81.14%	0.8114%	47,619.7000	715.9798
143	81.71%	0.8171%	47,955.0500	700.0212
144	82.29%	0.8229%	48,290.4000	684.3849
145	82.86%	0.8286%	48,625.7500	669.0656
146	83.43%	0.8343%	48,961.1000	654.0581
147	84.00%	0.8400%	49,296.4500	639.3573
148	84.57%	0.8457%	49,631.8000	624.9579
149	85.14%	0.8514%	49,967.1500	610.8550
150	85.71%	0.8571%	50,302.5000	597.0433
151	86.29%	0.8629%	50,637.8500	583.5181
152	86.86%	0.8686%	50,973.2000	570.2742
153	87.43%	0.8743%	51,308.5500	557.3068
154	88.00%	0.8800%	51,643.9000	544.6110
155	88.57%	0.8857%	51,979.2500	532.1820
156	89.14%	0.8914%	52,314.6000	520.0150
157	89.71%	0.8971%	52,649.9500	508.1053
158	90.29%	0.9029%	52,985.3000	496.4481
159	90.86%	0.9086%	53,320.6500	485.0391
160	91.43%	0.9143%	53,656.0000	473.8734
161	92.00%	0.9200%	53,991.3500	462.9467
162	92.57%	0.9257%	54,326.7000	452.2545
163	93.14%	0.9314%	54,662.0500	441.7924
164	93.71%	0.9371%	54,997.4000	431.5561
165	94.29%	0.9429%	55,332.7500	421.5413
166	94.86%	0.9486%	55,668.1000	411.7438
167	95.43%	0.9543%	56,003.4500	402.1594
168	96.00%	0.9600%	56,338.8000	392.7840
169	96.57%	0.9657%	56,674.1500	383.6136
170	97.14%	0.9714%	57,009.5000	374.6442
171	97.71%	0.9771%	57,344.8500	365.8719
172	98.29%	0.9829%	57,680.2000	357.2927
173	98.86%	0.9886%	58,015.5500	348.9029
174	99.43%	0.9943%	58,350.9000	340.6987
175	100.00%	1.0000%	58,686.2500	332.6764
Beyond (d)				11,089.2144
Total				381,613.8462

Section 1.3 Lake Winnipeg - Progressive Dispersal

Affected habitat (acres): 5,868,625.00

	<----------(Percentage)---------->		<----------(Acre Years)---------->	
Year	Certain (a)	Expected (b)	Current Value	Present Value
294	0.00%	0.0000%	0.0000	0.0000
295	0.57%	0.0057%	335.3500	0.0548
296	1.14%	0.0114%	670.7000	0.1063
297	1.71%	0.0171%	1,006.0500	0.1549
298	2.29%	0.0229%	1,341.4000	0.2005

299	2.86%	0.0286%	1,676.7500	0.2433
300	3.43%	0.0343%	2,012.1000	0.2835
301	4.00%	0.0400%	2,347.4500	0.3211
302	4.57%	0.0457%	2,682.8000	0.3562
303	5.14%	0.0514%	3,018.1500	0.3891
304	5.71%	0.0571%	3,353.5000	0.4197
305	6.29%	0.0629%	3,688.8500	0.4483
306	6.86%	0.0686%	4,024.2000	0.4748
307	7.43%	0.0743%	4,359.5500	0.4994
308	8.00%	0.0800%	4,694.9000	0.5221
309	8.57%	0.0857%	5,030.2500	0.5431
310	9.14%	0.0914%	5,365.6000	0.5624
311	9.71%	0.0971%	5,700.9500	0.5802
312	10.29%	0.1029%	6,036.3000	0.5964
313	10.86%	0.1086%	6,371.6500	0.6112
314	11.43%	0.1143%	6,707.0000	0.6247
315	12.00%	0.1200%	7,042.3500	0.6368
316	12.57%	0.1257%	7,377.7000	0.6477
317	13.14%	0.1314%	7,713.0500	0.6574
318	13.71%	0.1371%	8,048.4000	0.6660
319	14.29%	0.1429%	8,383.7500	0.6735
320	14.86%	0.1486%	8,719.1000	0.6801
321	15.43%	0.1543%	9,054.4500	0.6857
322	16.00%	0.1600%	9,389.8000	0.6904
323	16.57%	0.1657%	9,725.1500	0.6942
324	17.14%	0.1714%	10,060.5000	0.6972
325	17.71%	0.1771%	10,395.8500	0.6995
326	18.29%	0.1829%	10,731.2000	0.7010
327	18.86%	0.1886%	11,066.5500	0.7018
328	19.43%	0.1943%	11,401.9000	0.7020
329	20.00%	0.2000%	11,737.2500	0.7016
330	20.57%	0.2057%	12,072.6000	0.7007
331	21.14%	0.2114%	12,407.9500	0.6992
332	21.71%	0.2171%	12,743.3000	0.6971
333	22.29%	0.2229%	13,078.6500	0.6947
334	22.86%	0.2286%	13,414.0000	0.6917
335	23.43%	0.2343%	13,749.3500	0.6884
336	24.00%	0.2400%	14,084.7000	0.6846
337	24.57%	0.2457%	14,420.0500	0.6805
338	25.14%	0.2514%	14,755.4000	0.6760
339	25.71%	0.2571%	15,090.7500	0.6713
340	26.29%	0.2629%	15,426.1000	0.6662
341	26.86%	0.2686%	15,761.4500	0.6608
342	27.43%	0.2743%	16,096.8000	0.6553
343	28.00%	0.2800%	16,432.1500	0.6494
344	28.57%	0.2857%	16,767.5000	0.6434
345	29.14%	0.2914%	17,102.8500	0.6371
346	29.71%	0.2971%	17,438.2000	0.6307
347	30.29%	0.3029%	17,773.5500	0.6241
348	30.86%	0.3086%	18,108.9000	0.6174
349	31.43%	0.3143%	18,444.2500	0.6105
350	32.00%	0.3200%	18,779.6000	0.6035

351	32.57%	0.3257%	19,114.9500	0.5964
352	33.14%	0.3314%	19,450.3000	0.5891
353	33.71%	0.3371%	19,785.6500	0.5818
354	34.29%	0.3429%	20,121.0000	0.5745
355	34.86%	0.3486%	20,456.3500	0.5670
356	35.43%	0.3543%	20,791.7000	0.5595
357	36.00%	0.3600%	21,127.0500	0.5520
358	36.57%	0.3657%	21,462.4000	0.5444
359	37.14%	0.3714%	21,797.7500	0.5368
360	37.71%	0.3771%	22,133.1000	0.5292
361	38.29%	0.3829%	22,468.4500	0.5216
362	38.86%	0.3886%	22,803.8000	0.5140
363	39.43%	0.3943%	23,139.1500	0.5063
364	40.00%	0.4000%	23,474.5000	0.4987
365	40.57%	0.4057%	23,809.8500	0.4911
366	41.14%	0.4114%	24,145.2000	0.4835
367	41.71%	0.4171%	24,480.5500	0.4759
368	42.29%	0.4229%	24,815.9000	0.4684
369	42.86%	0.4286%	25,151.2500	0.4609
370	43.43%	0.4343%	25,486.6000	0.4535
371	44.00%	0.4400%	25,821.9500	0.4460
372	44.57%	0.4457%	26,157.3000	0.4387
373	45.14%	0.4514%	26,492.6500	0.4314
374	45.71%	0.4571%	26,828.0000	0.4241
375	46.29%	0.4629%	27,163.3500	0.4169
376	46.86%	0.4686%	27,498.7000	0.4097
377	47.43%	0.4743%	27,834.0500	0.4027
378	48.00%	0.4800%	28,169.4000	0.3956
379	48.57%	0.4857%	28,504.7500	0.3887
380	49.14%	0.4914%	28,840.1000	0.3818
381	49.71%	0.4971%	29,175.4500	0.3750
382	50.29%	0.5029%	29,510.8000	0.3683
383	50.86%	0.5086%	29,846.1500	0.3616
384	51.43%	0.5143%	30,181.5000	0.3550
385	52.00%	0.5200%	30,516.8500	0.3485
386	52.57%	0.5257%	30,852.2000	0.3421
387	53.14%	0.5314%	31,187.5500	0.3357
388	53.71%	0.5371%	31,522.9000	0.3294
389	54.29%	0.5429%	31,858.2500	0.3233
390	54.86%	0.5486%	32,193.6000	0.3171
391	55.43%	0.5543%	32,528.9500	0.3111
392	56.00%	0.5600%	32,864.3000	0.3052
393	56.57%	0.5657%	33,199.6500	0.2993
394	57.14%	0.5714%	33,535.0000	0.2935
395	57.71%	0.5771%	33,870.3500	0.2878
396	58.29%	0.5829%	34,205.7000	0.2822
397	58.86%	0.5886%	34,541.0500	0.2767
398	59.43%	0.5943%	34,876.4000	0.2712
399	60.00%	0.6000%	35,211.7500	0.2658
400	60.57%	0.6057%	35,547.1000	0.2606
401	61.14%	0.6114%	35,882.4500	0.2554
402	61.71%	0.6171%	36,217.8000	0.2502

403	62.29%	0.6229%	36,553.1500	0.2452
404	62.86%	0.6286%	36,888.5000	0.2402
405	63.43%	0.6343%	37,223.8500	0.2354
406	64.00%	0.6400%	37,559.2000	0.2306
407	64.57%	0.6457%	37,894.5500	0.2259
408	65.14%	0.6514%	38,229.9000	0.2212
409	65.71%	0.6571%	38,565.2500	0.2167
410	66.29%	0.6629%	38,900.6000	0.2122
411	66.86%	0.6686%	39,235.9500	0.2078
412	67.43%	0.6743%	39,571.3000	0.2034
413	68.00%	0.6800%	39,906.6500	0.1992
414	68.57%	0.6857%	40,242.0000	0.1950
415	69.14%	0.6914%	40,577.3500	0.1909
416	69.71%	0.6971%	40,912.7000	0.1869
417	70.29%	0.7029%	41,248.0500	0.1829
418	70.86%	0.7086%	41,583.4000	0.1790
419	71.43%	0.7143%	41,918.7500	0.1752
420	72.00%	0.7200%	42,254.1000	0.1715
421	72.57%	0.7257%	42,589.4500	0.1678
422	73.14%	0.7314%	42,924.8000	0.1642
423	73.71%	0.7371%	43,260.1500	0.1607
424	74.29%	0.7429%	43,595.5000	0.1572
425	74.86%	0.7486%	43,930.8500	0.1538
426	75.43%	0.7543%	44,266.2000	0.1505
427	76.00%	0.7600%	44,601.5500	0.1472
428	76.57%	0.7657%	44,936.9000	0.1440
429	77.14%	0.7714%	45,272.2500	0.1408
430	77.71%	0.7771%	45,607.6000	0.1377
431	78.29%	0.7829%	45,942.9500	0.1347
432	78.86%	0.7886%	46,278.3000	0.1317
433	79.43%	0.7943%	46,613.6500	0.1288
434	80.00%	0.8000%	46,949.0000	0.1260
435	80.57%	0.8057%	47,284.3500	0.1232
436	81.14%	0.8114%	47,619.7000	0.1204
437	81.71%	0.8171%	47,955.0500	0.1178
438	82.29%	0.8229%	48,290.4000	0.1151
439	82.86%	0.8286%	48,625.7500	0.1125
440	83.43%	0.8343%	48,961.1000	0.1100
441	84.00%	0.8400%	49,296.4500	0.1075
442	84.57%	0.8457%	49,631.8000	0.1051
443	85.14%	0.8514%	49,967.1500	0.1028
444	85.71%	0.8571%	50,302.5000	0.1004
445	86.29%	0.8629%	50,637.8500	0.0982
446	86.86%	0.8686%	50,973.2000	0.0959
447	87.43%	0.8743%	51,308.5500	0.0937
448	88.00%	0.8800%	51,643.9000	0.0916
449	88.57%	0.8857%	51,979.2500	0.0895
450	89.14%	0.8914%	52,314.6000	0.0875
451	89.71%	0.8971%	52,649.9500	0.0855
452	90.29%	0.9029%	52,985.3000	0.0835
453	90.86%	0.9086%	53,320.6500	0.0816
454	91.43%	0.9143%	53,656.0000	0.0797

455	92.00%	0.9200%	53,991.3500	0.0779
456	92.57%	0.9257%	54,326.7000	0.0761
457	93.14%	0.9314%	54,662.0500	0.0743
458	93.71%	0.9371%	54,997.4000	0.0726
459	94.29%	0.9429%	55,332.7500	0.0709
460	94.86%	0.9486%	55,668.1000	0.0693
461	95.43%	0.9543%	56,003.4500	0.0676
462	96.00%	0.9600%	56,338.8000	0.0661
463	96.57%	0.9657%	56,674.1500	0.0645
464	97.14%	0.9714%	57,009.5000	0.0630
465	97.71%	0.9771%	57,344.8500	0.0615
466	98.29%	0.9829%	57,680.2000	0.0601
467	98.86%	0.9886%	58,015.5500	0.0587
468	99.43%	0.9943%	58,350.9000	0.0573
469	100.00%	1.0000%	58,686.2500	0.0560
Beyond (e)				1.8653
Total				64.1919

Section 2 Quantification of Replacement Services

	<----------(Percentage)---------->	
Year	Current Value	Present Value
5	0.0%	0.0%
6	5.0%	4.2%
7	10.0%	8.1%
8	15.0%	11.8%
9	20.0%	15.3%
10	25.0%	18.6%
11	30.0%	21.7%
12	35.0%	24.5%
13	40.0%	27.2%
14	45.0%	29.8%
15	50.0%	32.1%
16	55.0%	34.3%
17	60.0%	36.3%
18	65.0%	38.2%
19	70.0%	39.9%
20	75.0%	41.5%
21	80.0%	43.0%
22	85.0%	44.4%
23	90.0%	45.6%
24	95.0%	46.7%
25	100.0%	47.8%
Beyond (f)		1592.0%
Total		2203.1%

Section 3 Offsetting Restoration for One Organism

Red River - Progressive Dispersal (river-miles):	0.805
Lake Winnipeg - Jump Dispersal (acres):	17,300
Lake Winnipeg - Progressive Dispersal (acres):	2.91

Section 4 Notes

(a) Percent loss given certain invasion

(b) Percent loss given probability of successful invasion

(c) From year 295 into perpetuity

(d) From year 176 into perpetuity

(e) From year 470 into perpetuity

(f) From year 26 into perpetuity

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Appendix 15F. Habitat Equivalency Analysis of Risk Consequences: Slow Invasion - Very High Risk (One Organism)

Probability of successful invasion: 1.00E+00

Annual discount rate: 3.0%

Present year: 0

Section 1 Quantification of Expected Lost Services

Section 1.1 Red River from Fargo to Lake Winnipeg - Progressive Dispersal

Affected habitat (river-miles): 455.40

	<----------(Percentage)---------->		<----------(River-Mile Years)---------->	
Year	Certain (a)	Expected (b)	Current Value	Present Value
0	0.00%	0.00%	0.00	0.00
1	0.34%	0.34%	1.55	1.50
2	0.68%	0.68%	3.10	2.92
3	1.02%	1.02%	4.65	4.25
4	1.36%	1.36%	6.20	5.50
5	1.70%	1.70%	7.74	6.68
6	2.04%	2.04%	9.29	7.78
7	2.38%	2.38%	10.84	8.82
8	2.72%	2.72%	12.39	9.78
9	3.06%	3.06%	13.94	10.68
10	3.40%	3.40%	15.49	11.53
11	3.74%	3.74%	17.04	12.31
12	4.08%	4.08%	18.59	13.04
13	4.42%	4.42%	20.14	13.71
14	4.76%	4.76%	21.69	14.34
15	5.10%	5.10%	23.23	14.91
16	5.44%	5.44%	24.78	15.44
17	5.78%	5.78%	26.33	15.93
18	6.12%	6.12%	27.88	16.38
19	6.46%	6.46%	29.43	16.78
20	6.80%	6.80%	30.98	17.15
21	7.14%	7.14%	32.53	17.49
22	7.48%	7.48%	34.08	17.78
23	7.82%	7.82%	35.63	18.05
24	8.16%	8.16%	37.18	18.29
25	8.50%	8.50%	38.72	18.50
26	8.84%	8.84%	40.27	18.67
27	9.18%	9.18%	41.82	18.83
28	9.52%	9.52%	43.37	18.96
29	9.86%	9.86%	44.92	19.06

30	10.20%	10.20%	46.47	19.14
31	10.54%	10.54%	48.02	19.21
32	10.88%	10.88%	49.57	19.25
33	11.22%	11.22%	51.12	19.27
34	11.56%	11.56%	52.67	19.28
35	11.90%	11.90%	54.21	19.27
36	12.24%	12.24%	55.76	19.24
37	12.59%	12.59%	57.31	19.20
38	12.93%	12.93%	58.86	19.14
39	13.27%	13.27%	60.41	19.07
40	13.61%	13.61%	61.96	18.99
41	13.95%	13.95%	63.51	18.90
42	14.29%	14.29%	65.06	18.80
43	14.63%	14.63%	66.61	18.69
44	14.97%	14.97%	68.16	18.56
45	15.31%	15.31%	69.70	18.43
46	15.65%	15.65%	71.25	18.29
47	15.99%	15.99%	72.80	18.15
48	16.33%	16.33%	74.35	17.99
49	16.67%	16.67%	75.90	17.83
50	17.01%	17.01%	77.45	17.67
51	17.35%	17.35%	79.00	17.50
52	17.69%	17.69%	80.55	17.32
53	18.03%	18.03%	82.10	17.14
54	18.37%	18.37%	83.64	16.95
55	18.71%	18.71%	85.19	16.76
56	19.05%	19.05%	86.74	16.57
57	19.39%	19.39%	88.29	16.38
58	19.73%	19.73%	89.84	16.18
59	20.07%	20.07%	91.39	15.98
60	20.41%	20.41%	92.94	15.77
61	20.75%	20.75%	94.49	15.57
62	21.09%	21.09%	96.04	15.36
63	21.43%	21.43%	97.59	15.16
64	21.77%	21.77%	99.13	14.95
65	22.11%	22.11%	100.68	14.74
66	22.45%	22.45%	102.23	14.53
67	22.79%	22.79%	103.78	14.32
68	23.13%	23.13%	105.33	14.11
69	23.47%	23.47%	106.88	13.90
70	23.81%	23.81%	108.43	13.69
71	24.15%	24.15%	109.98	13.49
72	24.49%	24.49%	111.53	13.28
73	24.83%	24.83%	113.08	13.07
74	25.17%	25.17%	114.62	12.86
75	25.51%	25.51%	116.17	12.66
76	25.85%	25.85%	117.72	12.45
77	26.19%	26.19%	119.27	12.25
78	26.53%	26.53%	120.82	12.05
79	26.87%	26.87%	122.37	11.84
80	27.21%	27.21%	123.92	11.65
81	27.55%	27.55%	125.47	11.45

82	27.89%	27.89%	127.02	11.25
83	28.23%	28.23%	128.57	11.06
84	28.57%	28.57%	130.11	10.86
85	28.91%	28.91%	131.66	10.67
86	29.25%	29.25%	133.21	10.48
87	29.59%	29.59%	134.76	10.30
88	29.93%	29.93%	136.31	10.11
89	30.27%	30.27%	137.86	9.93
90	30.61%	30.61%	139.41	9.75
91	30.95%	30.95%	140.96	9.57
92	31.29%	31.29%	142.51	9.39
93	31.63%	31.63%	144.06	9.22
94	31.97%	31.97%	145.60	9.05
95	32.31%	32.31%	147.15	8.88
96	32.65%	32.65%	148.70	8.71
97	32.99%	32.99%	150.25	8.54
98	33.33%	33.33%	151.80	8.38
99	33.67%	33.67%	153.35	8.22
100	34.01%	34.01%	154.90	8.06
101	34.35%	34.35%	156.45	7.90
102	34.69%	34.69%	158.00	7.75
103	35.03%	35.03%	159.54	7.60
104	35.37%	35.37%	161.09	7.45
105	35.71%	35.71%	162.64	7.30
106	36.05%	36.05%	164.19	7.15
107	36.39%	36.39%	165.74	7.01
108	36.73%	36.73%	167.29	6.87
109	37.07%	37.07%	168.84	6.73
110	37.41%	37.41%	170.39	6.60
111	37.76%	37.76%	171.94	6.46
112	38.10%	38.10%	173.49	6.33
113	38.44%	38.44%	175.03	6.20
114	38.78%	38.78%	176.58	6.07
115	39.12%	39.12%	178.13	5.95
116	39.46%	39.46%	179.68	5.83
117	39.80%	39.80%	181.23	5.71
118	40.14%	40.14%	182.78	5.59
119	40.48%	40.48%	184.33	5.47
120	40.82%	40.82%	185.88	5.36
121	41.16%	41.16%	187.43	5.24
122	41.50%	41.50%	188.98	5.13
123	41.84%	41.84%	190.52	5.02
124	42.18%	42.18%	192.07	4.92
125	42.52%	42.52%	193.62	4.81
126	42.86%	42.86%	195.17	4.71
127	43.20%	43.20%	196.72	4.61
128	43.54%	43.54%	198.27	4.51
129	43.88%	43.88%	199.82	4.41
130	44.22%	44.22%	201.37	4.32
131	44.56%	44.56%	202.92	4.22
132	44.90%	44.90%	204.47	4.13
133	45.24%	45.24%	206.01	4.04

134	45.58%	45.58%	207.56	3.95
135	45.92%	45.92%	209.11	3.87
136	46.26%	46.26%	210.66	3.78
137	46.60%	46.60%	212.21	3.70
138	46.94%	46.94%	213.76	3.62
139	47.28%	47.28%	215.31	3.54
140	47.62%	47.62%	216.86	3.46
141	47.96%	47.96%	218.41	3.38
142	48.30%	48.30%	219.96	3.31
143	48.64%	48.64%	221.50	3.23
144	48.98%	48.98%	223.05	3.16
145	49.32%	49.32%	224.60	3.09
146	49.66%	49.66%	226.15	3.02
147	50.00%	50.00%	227.70	2.95
148	50.34%	50.34%	229.25	2.89
149	50.68%	50.68%	230.80	2.82
150	51.02%	51.02%	232.35	2.76
151	51.36%	51.36%	233.90	2.70
152	51.70%	51.70%	235.44	2.63
153	52.04%	52.04%	236.99	2.57
154	52.38%	52.38%	238.54	2.52
155	52.72%	52.72%	240.09	2.46
156	53.06%	53.06%	241.64	2.40
157	53.40%	53.40%	243.19	2.35
158	53.74%	53.74%	244.74	2.29
159	54.08%	54.08%	246.29	2.24
160	54.42%	54.42%	247.84	2.19
161	54.76%	54.76%	249.39	2.14
162	55.10%	55.10%	250.93	2.09
163	55.44%	55.44%	252.48	2.04
164	55.78%	55.78%	254.03	1.99
165	56.12%	56.12%	255.58	1.95
166	56.46%	56.46%	257.13	1.90
167	56.80%	56.80%	258.68	1.86
168	57.14%	57.14%	260.23	1.81
169	57.48%	57.48%	261.78	1.77
170	57.82%	57.82%	263.33	1.73
171	58.16%	58.16%	264.88	1.69
172	58.50%	58.50%	266.42	1.65
173	58.84%	58.84%	267.97	1.61
174	59.18%	59.18%	269.52	1.57
175	59.52%	59.52%	271.07	1.54
176	59.86%	59.86%	272.62	1.50
177	60.20%	60.20%	274.17	1.46
178	60.54%	60.54%	275.72	1.43
179	60.88%	60.88%	277.27	1.40
180	61.22%	61.22%	278.82	1.36
181	61.56%	61.56%	280.37	1.33
182	61.90%	61.90%	281.91	1.30
183	62.24%	62.24%	283.46	1.27
184	62.59%	62.59%	285.01	1.24
185	62.93%	62.93%	286.56	1.21

186	63.27%	63.27%	288.11	1.18
187	63.61%	63.61%	289.66	1.15
188	63.95%	63.95%	291.21	1.12
189	64.29%	64.29%	292.76	1.10
190	64.63%	64.63%	294.31	1.07
191	64.97%	64.97%	295.86	1.05
192	65.31%	65.31%	297.40	1.02
193	65.65%	65.65%	298.95	1.00
194	65.99%	65.99%	300.50	0.97
195	66.33%	66.33%	302.05	0.95
196	66.67%	66.67%	303.60	0.93
197	67.01%	67.01%	305.15	0.90
198	67.35%	67.35%	306.70	0.88
199	67.69%	67.69%	308.25	0.86
200	68.03%	68.03%	309.80	0.84
201	68.37%	68.37%	311.34	0.82
202	68.71%	68.71%	312.89	0.80
203	69.05%	69.05%	314.44	0.78
204	69.39%	69.39%	315.99	0.76
205	69.73%	69.73%	317.54	0.74
206	70.07%	70.07%	319.09	0.72
207	70.41%	70.41%	320.64	0.71
208	70.75%	70.75%	322.19	0.69
209	71.09%	71.09%	323.74	0.67
210	71.43%	71.43%	325.29	0.66
211	71.77%	71.77%	326.83	0.64
212	72.11%	72.11%	328.38	0.62
213	72.45%	72.45%	329.93	0.61
214	72.79%	72.79%	331.48	0.59
215	73.13%	73.13%	333.03	0.58
216	73.47%	73.47%	334.58	0.56
217	73.81%	73.81%	336.13	0.55
218	74.15%	74.15%	337.68	0.54
219	74.49%	74.49%	339.23	0.52
220	74.83%	74.83%	340.78	0.51
221	75.17%	75.17%	342.32	0.50
222	75.51%	75.51%	343.87	0.49
223	75.85%	75.85%	345.42	0.47
224	76.19%	76.19%	346.97	0.46
225	76.53%	76.53%	348.52	0.45
226	76.87%	76.87%	350.07	0.44
227	77.21%	77.21%	351.62	0.43
228	77.55%	77.55%	353.17	0.42
229	77.89%	77.89%	354.72	0.41
230	78.23%	78.23%	356.27	0.40
231	78.57%	78.57%	357.81	0.39
232	78.91%	78.91%	359.36	0.38
233	79.25%	79.25%	360.91	0.37
234	79.59%	79.59%	362.46	0.36
235	79.93%	79.93%	364.01	0.35
236	80.27%	80.27%	365.56	0.34
237	80.61%	80.61%	367.11	0.33

238	80.95%	80.95%	368.66	0.32
239	81.29%	81.29%	370.21	0.32
240	81.63%	81.63%	371.76	0.31
241	81.97%	81.97%	373.30	0.30
242	82.31%	82.31%	374.85	0.29
243	82.65%	82.65%	376.40	0.29
244	82.99%	82.99%	377.95	0.28
245	83.33%	83.33%	379.50	0.27
246	83.67%	83.67%	381.05	0.26
247	84.01%	84.01%	382.60	0.26
248	84.35%	84.35%	384.15	0.25
249	84.69%	84.69%	385.70	0.25
250	85.03%	85.03%	387.24	0.24
251	85.37%	85.37%	388.79	0.23
252	85.71%	85.71%	390.34	0.23
253	86.05%	86.05%	391.89	0.22
254	86.39%	86.39%	393.44	0.22
255	86.73%	86.73%	394.99	0.21
256	87.07%	87.07%	396.54	0.21
257	87.41%	87.41%	398.09	0.20
258	87.76%	87.76%	399.64	0.19
259	88.10%	88.10%	401.19	0.19
260	88.44%	88.44%	402.73	0.19
261	88.78%	88.78%	404.28	0.18
262	89.12%	89.12%	405.83	0.18
263	89.46%	89.46%	407.38	0.17
264	89.80%	89.80%	408.93	0.17
265	90.14%	90.14%	410.48	0.16
266	90.48%	90.48%	412.03	0.16
267	90.82%	90.82%	413.58	0.15
268	91.16%	91.16%	415.13	0.15
269	91.50%	91.50%	416.68	0.15
270	91.84%	91.84%	418.22	0.14
271	92.18%	92.18%	419.77	0.14
272	92.52%	92.52%	421.32	0.14
273	92.86%	92.86%	422.87	0.13
274	93.20%	93.20%	424.42	0.13
275	93.54%	93.54%	425.97	0.13
276	93.88%	93.88%	427.52	0.12
277	94.22%	94.22%	429.07	0.12
278	94.56%	94.56%	430.62	0.12
279	94.90%	94.90%	432.17	0.11
280	95.24%	95.24%	433.71	0.11
281	95.58%	95.58%	435.26	0.11
282	95.92%	95.92%	436.81	0.10
283	96.26%	96.26%	438.36	0.10
284	96.60%	96.60%	439.91	0.10
285	96.94%	96.94%	441.46	0.10
286	97.28%	97.28%	443.01	0.09
287	97.62%	97.62%	444.56	0.09
288	97.96%	97.96%	446.11	0.09
289	98.30%	98.30%	447.66	0.09

290	98.64%	98.64%	449.20	0.09
291	98.98%	98.98%	450.75	0.08
292	99.32%	99.32%	452.30	0.08
293	99.66%	99.66%	453.85	0.08
294	100.00%	100.00%	455.40	0.08
Beyond (c)				2.55
Total				1,772.42

Section 1.2 Lake Winnipeg - Jump Dispersal

Affected habitat (acres): 5,868,625.00

	<----------(Percentage)---------->		<----------(Acre Years)---------->	
Year	Certain (a)	Expected (b)	Current Value	Present Value
0	0.00%	0.00%	0.00	0.00
1	0.57%	0.57%	33,535.00	32,558.25
2	1.14%	1.14%	67,070.00	63,219.91
3	1.71%	1.71%	100,605.00	92,067.83
4	2.29%	2.29%	134,140.00	119,181.65
5	2.86%	2.86%	167,675.00	144,637.93
6	3.43%	3.43%	201,210.00	168,510.21
7	4.00%	4.00%	234,745.00	190,869.17
8	4.57%	4.57%	268,280.00	211,782.71
9	5.14%	5.14%	301,815.00	231,316.07
10	5.71%	5.71%	335,350.00	249,531.89
11	6.29%	6.29%	368,885.00	266,490.37
12	6.86%	6.86%	402,420.00	282,249.29
13	7.43%	7.43%	435,955.00	296,864.14
14	8.00%	8.00%	469,490.00	310,388.20
15	8.57%	8.57%	503,025.00	322,872.61
16	9.14%	9.14%	536,560.00	334,366.45
17	9.71%	9.71%	570,095.00	344,916.85
18	10.29%	10.29%	603,630.00	354,569.01
19	10.86%	10.86%	637,165.00	363,366.30
20	11.43%	11.43%	670,700.00	371,350.33
21	12.00%	12.00%	704,235.00	378,561.01
22	12.57%	12.57%	737,770.00	385,036.63
23	13.14%	13.14%	771,305.00	390,813.88
24	13.71%	13.71%	804,840.00	395,927.95
25	14.29%	14.29%	838,375.00	400,412.57
26	14.86%	14.86%	871,910.00	404,300.07
27	15.43%	15.43%	905,445.00	407,621.43
28	16.00%	16.00%	938,980.00	410,406.33
29	16.57%	16.57%	972,515.00	412,683.20
30	17.14%	17.14%	1,006,050.00	414,479.28
31	17.71%	17.71%	1,039,585.00	415,820.64
32	18.29%	18.29%	1,073,120.00	416,732.24
33	18.86%	18.86%	1,106,655.00	417,237.98
34	19.43%	19.43%	1,140,190.00	417,360.73
35	20.00%	20.00%	1,173,725.00	417,122.38

36	20.57%	20.57%	1,207,260.00	416,543.85
37	21.14%	21.14%	1,240,795.00	415,645.15
38	21.71%	21.71%	1,274,330.00	414,445.44
39	22.29%	22.29%	1,307,865.00	412,963.01
40	22.86%	22.86%	1,341,400.00	411,215.35
41	23.43%	23.43%	1,374,935.00	409,219.16
42	24.00%	24.00%	1,408,470.00	406,990.40
43	24.57%	24.57%	1,442,005.00	404,544.32
44	25.14%	25.14%	1,475,540.00	401,895.46
45	25.71%	25.71%	1,509,075.00	399,057.72
46	26.29%	26.29%	1,542,610.00	396,044.34
47	26.86%	26.86%	1,576,145.00	392,867.96
48	27.43%	27.43%	1,609,680.00	389,540.63
49	28.00%	28.00%	1,643,215.00	386,073.84
50	28.57%	28.57%	1,676,750.00	382,478.55
51	29.14%	29.14%	1,710,285.00	378,765.16
52	29.71%	29.71%	1,743,820.00	374,943.62
53	30.29%	30.29%	1,777,355.00	371,023.37
54	30.86%	30.86%	1,810,890.00	367,013.41
55	31.43%	31.43%	1,844,425.00	362,922.29
56	32.00%	32.00%	1,877,960.00	358,758.13
57	32.57%	32.57%	1,911,495.00	354,528.67
58	33.14%	33.14%	1,945,030.00	350,241.23
59	33.71%	33.71%	1,978,565.00	345,902.79
60	34.29%	34.29%	2,012,100.00	341,519.95
61	34.86%	34.86%	2,045,635.00	337,098.98
62	35.43%	35.43%	2,079,170.00	332,645.82
63	36.00%	36.00%	2,112,705.00	328,166.09
64	36.57%	36.57%	2,146,240.00	323,665.12
65	37.14%	37.14%	2,179,775.00	319,147.95
66	37.71%	37.71%	2,213,310.00	314,619.34
67	38.29%	38.29%	2,246,845.00	310,083.79
68	38.86%	38.86%	2,280,380.00	305,545.54
69	39.43%	39.43%	2,313,915.00	301,008.60
70	40.00%	40.00%	2,347,450.00	296,476.74
71	40.57%	40.57%	2,380,985.00	291,953.51
72	41.14%	41.14%	2,414,520.00	287,442.27
73	41.71%	41.71%	2,448,055.00	282,946.14
74	42.29%	42.29%	2,481,590.00	278,468.07
75	42.86%	42.86%	2,515,125.00	274,010.83
76	43.43%	43.43%	2,548,660.00	269,576.99
77	44.00%	44.00%	2,582,195.00	265,168.99
78	44.57%	44.57%	2,615,730.00	260,789.07
79	45.14%	45.14%	2,649,265.00	256,439.34
80	45.71%	45.71%	2,682,800.00	252,121.75
81	46.29%	46.29%	2,716,335.00	247,838.13
82	46.86%	46.86%	2,749,870.00	243,590.16
83	47.43%	47.43%	2,783,405.00	239,379.39
84	48.00%	48.00%	2,816,940.00	235,207.26
85	48.57%	48.57%	2,850,475.00	231,075.09
86	49.14%	49.14%	2,884,010.00	226,984.10
87	49.71%	49.71%	2,917,545.00	222,935.39

88	50.29%	50.29%	2,951,080.00	218,929.97
89	50.86%	50.86%	2,984,615.00	214,968.74
90	51.43%	51.43%	3,018,150.00	211,052.55
91	52.00%	52.00%	3,051,685.00	207,182.11
92	52.57%	52.57%	3,085,220.00	203,358.10
93	53.14%	53.14%	3,118,755.00	199,581.08
94	53.71%	53.71%	3,152,290.00	195,851.56
95	54.29%	54.29%	3,185,825.00	192,169.99
96	54.86%	54.86%	3,219,360.00	188,536.73
97	55.43%	55.43%	3,252,895.00	184,952.09
98	56.00%	56.00%	3,286,430.00	181,416.33
99	56.57%	56.57%	3,319,965.00	177,929.62
100	57.14%	57.14%	3,353,500.00	174,492.13
101	57.71%	57.71%	3,387,035.00	171,103.93
102	58.29%	58.29%	3,420,570.00	167,765.08
103	58.86%	58.86%	3,454,105.00	164,475.57
104	59.43%	59.43%	3,487,640.00	161,235.36
105	60.00%	60.00%	3,521,175.00	158,044.36
106	60.57%	60.57%	3,554,710.00	154,902.48
107	61.14%	61.14%	3,588,245.00	151,809.53
108	61.71%	61.71%	3,621,780.00	148,765.35
109	62.29%	62.29%	3,655,315.00	145,769.72
110	62.86%	62.86%	3,688,850.00	142,822.38
111	63.43%	63.43%	3,722,385.00	139,923.08
112	64.00%	64.00%	3,755,920.00	137,071.50
113	64.57%	64.57%	3,789,455.00	134,267.33
114	65.14%	65.14%	3,822,990.00	131,510.23
115	65.71%	65.71%	3,856,525.00	128,799.84
116	66.29%	66.29%	3,890,060.00	126,135.76
117	66.86%	66.86%	3,923,595.00	123,517.61
118	67.43%	67.43%	3,957,130.00	120,944.97
119	68.00%	68.00%	3,990,665.00	118,417.40
120	68.57%	68.57%	4,024,200.00	115,934.47
121	69.14%	69.14%	4,057,735.00	113,495.72
122	69.71%	69.71%	4,091,270.00	111,100.68
123	70.29%	70.29%	4,124,805.00	108,748.88
124	70.86%	70.86%	4,158,340.00	106,439.82
125	71.43%	71.43%	4,191,875.00	104,173.02
126	72.00%	72.00%	4,225,410.00	101,947.96
127	72.57%	72.57%	4,258,945.00	99,764.15
128	73.14%	73.14%	4,292,480.00	97,621.06
129	73.71%	73.71%	4,326,015.00	95,518.18
130	74.29%	74.29%	4,359,550.00	93,454.98
131	74.86%	74.86%	4,393,085.00	91,430.94
132	75.43%	75.43%	4,426,620.00	89,445.52
133	76.00%	76.00%	4,460,155.00	87,498.19
134	76.57%	76.57%	4,493,690.00	85,588.42
135	77.14%	77.14%	4,527,225.00	83,715.67
136	77.71%	77.71%	4,560,760.00	81,879.40
137	78.29%	78.29%	4,594,295.00	80,079.08
138	78.86%	78.86%	4,627,830.00	78,314.18
139	79.43%	79.43%	4,661,365.00	76,584.15

140	80.00%	80.00%	4,694,900.00	74,888.46
141	80.57%	80.57%	4,728,435.00	73,226.58
142	81.14%	81.14%	4,761,970.00	71,597.98
143	81.71%	81.71%	4,795,505.00	70,002.12
144	82.29%	82.29%	4,829,040.00	68,438.49
145	82.86%	82.86%	4,862,575.00	66,906.56
146	83.43%	83.43%	4,896,110.00	65,405.81
147	84.00%	84.00%	4,929,645.00	63,935.73
148	84.57%	84.57%	4,963,180.00	62,495.79
149	85.14%	85.14%	4,996,715.00	61,085.50
150	85.71%	85.71%	5,030,250.00	59,704.33
151	86.29%	86.29%	5,063,785.00	58,351.81
152	86.86%	86.86%	5,097,320.00	57,027.42
153	87.43%	87.43%	5,130,855.00	55,730.68
154	88.00%	88.00%	5,164,390.00	54,461.10
155	88.57%	88.57%	5,197,925.00	53,218.20
156	89.14%	89.14%	5,231,460.00	52,001.50
157	89.71%	89.71%	5,264,995.00	50,810.53
158	90.29%	90.29%	5,298,530.00	49,644.81
159	90.86%	90.86%	5,332,065.00	48,503.91
160	91.43%	91.43%	5,365,600.00	47,387.34
161	92.00%	92.00%	5,399,135.00	46,294.67
162	92.57%	92.57%	5,432,670.00	45,225.45
163	93.14%	93.14%	5,466,205.00	44,179.24
164	93.71%	93.71%	5,499,740.00	43,155.61
165	94.29%	94.29%	5,533,275.00	42,154.13
166	94.86%	94.86%	5,566,810.00	41,174.38
167	95.43%	95.43%	5,600,345.00	40,215.94
168	96.00%	96.00%	5,633,880.00	39,278.40
169	96.57%	96.57%	5,667,415.00	38,361.36
170	97.14%	97.14%	5,700,950.00	37,464.42
171	97.71%	97.71%	5,734,485.00	36,587.19
172	98.29%	98.29%	5,768,020.00	35,729.27
173	98.86%	98.86%	5,801,555.00	34,890.29
174	99.43%	99.43%	5,835,090.00	34,069.87
175	100.00%	100.00%	5,868,625.00	33,267.64
Beyond (d)				1,108,921.44
Total				38,161,384.62

Section 1.3 Lake Winnipeg - Progressive Dispersal

Affected habitat (acres): 5,868,625.00

	<----------(Percentage)---------->		<----------(Acre Years)---------->	
Year	Certain (a)	Expected (b)	Current Value	Present Value
294	0.00%	0.00%	0.00	0.00
295	0.57%	0.57%	33,535.00	5.48
296	1.14%	1.14%	67,070.00	10.63
297	1.71%	1.71%	100,605.00	15.49
298	2.29%	2.29%	134,140.00	20.05

299	2.86%	2.86%	167,675.00	24.33
300	3.43%	3.43%	201,210.00	28.35
301	4.00%	4.00%	234,745.00	32.11
302	4.57%	4.57%	268,280.00	35.62
303	5.14%	5.14%	301,815.00	38.91
304	5.71%	5.71%	335,350.00	41.97
305	6.29%	6.29%	368,885.00	44.83
306	6.86%	6.86%	402,420.00	47.48
307	7.43%	7.43%	435,955.00	49.94
308	8.00%	8.00%	469,490.00	52.21
309	8.57%	8.57%	503,025.00	54.31
310	9.14%	9.14%	536,560.00	56.24
311	9.71%	9.71%	570,095.00	58.02
312	10.29%	10.29%	603,630.00	59.64
313	10.86%	10.86%	637,165.00	61.12
314	11.43%	11.43%	670,700.00	62.47
315	12.00%	12.00%	704,235.00	63.68
316	12.57%	12.57%	737,770.00	64.77
317	13.14%	13.14%	771,305.00	65.74
318	13.71%	13.71%	804,840.00	66.60
319	14.29%	14.29%	838,375.00	67.35
320	14.86%	14.86%	871,910.00	68.01
321	15.43%	15.43%	905,445.00	68.57
322	16.00%	16.00%	938,980.00	69.04
323	16.57%	16.57%	972,515.00	69.42
324	17.14%	17.14%	1,006,050.00	69.72
325	17.71%	17.71%	1,039,585.00	69.95
326	18.29%	18.29%	1,073,120.00	70.10
327	18.86%	18.86%	1,106,655.00	70.18
328	19.43%	19.43%	1,140,190.00	70.20
329	20.00%	20.00%	1,173,725.00	70.16
330	20.57%	20.57%	1,207,260.00	70.07
331	21.14%	21.14%	1,240,795.00	69.92
332	21.71%	21.71%	1,274,330.00	69.71
333	22.29%	22.29%	1,307,865.00	69.47
334	22.86%	22.86%	1,341,400.00	69.17
335	23.43%	23.43%	1,374,935.00	68.84
336	24.00%	24.00%	1,408,470.00	68.46
337	24.57%	24.57%	1,442,005.00	68.05
338	25.14%	25.14%	1,475,540.00	67.60
339	25.71%	25.71%	1,509,075.00	67.13
340	26.29%	26.29%	1,542,610.00	66.62
341	26.86%	26.86%	1,576,145.00	66.08
342	27.43%	27.43%	1,609,680.00	65.53
343	28.00%	28.00%	1,643,215.00	64.94
344	28.57%	28.57%	1,676,750.00	64.34
345	29.14%	29.14%	1,710,285.00	63.71
346	29.71%	29.71%	1,743,820.00	63.07
347	30.29%	30.29%	1,777,355.00	62.41
348	30.86%	30.86%	1,810,890.00	61.74
349	31.43%	31.43%	1,844,425.00	61.05
350	32.00%	32.00%	1,877,960.00	60.35

351	32.57%	32.57%	1,911,495.00	59.64
352	33.14%	33.14%	1,945,030.00	58.91
353	33.71%	33.71%	1,978,565.00	58.18
354	34.29%	34.29%	2,012,100.00	57.45
355	34.86%	34.86%	2,045,635.00	56.70
356	35.43%	35.43%	2,079,170.00	55.95
357	36.00%	36.00%	2,112,705.00	55.20
358	36.57%	36.57%	2,146,240.00	54.44
359	37.14%	37.14%	2,179,775.00	53.68
360	37.71%	37.71%	2,213,310.00	52.92
361	38.29%	38.29%	2,246,845.00	52.16
362	38.86%	38.86%	2,280,380.00	51.40
363	39.43%	39.43%	2,313,915.00	50.63
364	40.00%	40.00%	2,347,450.00	49.87
365	40.57%	40.57%	2,380,985.00	49.11
366	41.14%	41.14%	2,414,520.00	48.35
367	41.71%	41.71%	2,448,055.00	47.59
368	42.29%	42.29%	2,481,590.00	46.84
369	42.86%	42.86%	2,515,125.00	46.09
370	43.43%	43.43%	2,548,660.00	45.35
371	44.00%	44.00%	2,582,195.00	44.60
372	44.57%	44.57%	2,615,730.00	43.87
373	45.14%	45.14%	2,649,265.00	43.14
374	45.71%	45.71%	2,682,800.00	42.41
375	46.29%	46.29%	2,716,335.00	41.69
376	46.86%	46.86%	2,749,870.00	40.97
377	47.43%	47.43%	2,783,405.00	40.27
378	48.00%	48.00%	2,816,940.00	39.56
379	48.57%	48.57%	2,850,475.00	38.87
380	49.14%	49.14%	2,884,010.00	38.18
381	49.71%	49.71%	2,917,545.00	37.50
382	50.29%	50.29%	2,951,080.00	36.83
383	50.86%	50.86%	2,984,615.00	36.16
384	51.43%	51.43%	3,018,150.00	35.50
385	52.00%	52.00%	3,051,685.00	34.85
386	52.57%	52.57%	3,085,220.00	34.21
387	53.14%	53.14%	3,118,755.00	33.57
388	53.71%	53.71%	3,152,290.00	32.94
389	54.29%	54.29%	3,185,825.00	32.33
390	54.86%	54.86%	3,219,360.00	31.71
391	55.43%	55.43%	3,252,895.00	31.11
392	56.00%	56.00%	3,286,430.00	30.52
393	56.57%	56.57%	3,319,965.00	29.93
394	57.14%	57.14%	3,353,500.00	29.35
395	57.71%	57.71%	3,387,035.00	28.78
396	58.29%	58.29%	3,420,570.00	28.22
397	58.86%	58.86%	3,454,105.00	27.67
398	59.43%	59.43%	3,487,640.00	27.12
399	60.00%	60.00%	3,521,175.00	26.58
400	60.57%	60.57%	3,554,710.00	26.06
401	61.14%	61.14%	3,588,245.00	25.54
402	61.71%	61.71%	3,621,780.00	25.02

403	62.29%	62.29%	3,655,315.00	24.52
404	62.86%	62.86%	3,688,850.00	24.02
405	63.43%	63.43%	3,722,385.00	23.54
406	64.00%	64.00%	3,755,920.00	23.06
407	64.57%	64.57%	3,789,455.00	22.59
408	65.14%	65.14%	3,822,990.00	22.12
409	65.71%	65.71%	3,856,525.00	21.67
410	66.29%	66.29%	3,890,060.00	21.22
411	66.86%	66.86%	3,923,595.00	20.78
412	67.43%	67.43%	3,957,130.00	20.34
413	68.00%	68.00%	3,990,665.00	19.92
414	68.57%	68.57%	4,024,200.00	19.50
415	69.14%	69.14%	4,057,735.00	19.09
416	69.71%	69.71%	4,091,270.00	18.69
417	70.29%	70.29%	4,124,805.00	18.29
418	70.86%	70.86%	4,158,340.00	17.90
419	71.43%	71.43%	4,191,875.00	17.52
420	72.00%	72.00%	4,225,410.00	17.15
421	72.57%	72.57%	4,258,945.00	16.78
422	73.14%	73.14%	4,292,480.00	16.42
423	73.71%	73.71%	4,326,015.00	16.07
424	74.29%	74.29%	4,359,550.00	15.72
425	74.86%	74.86%	4,393,085.00	15.38
426	75.43%	75.43%	4,426,620.00	15.05
427	76.00%	76.00%	4,460,155.00	14.72
428	76.57%	76.57%	4,493,690.00	14.40
429	77.14%	77.14%	4,527,225.00	14.08
430	77.71%	77.71%	4,560,760.00	13.77
431	78.29%	78.29%	4,594,295.00	13.47
432	78.86%	78.86%	4,627,830.00	13.17
433	79.43%	79.43%	4,661,365.00	12.88
434	80.00%	80.00%	4,694,900.00	12.60
435	80.57%	80.57%	4,728,435.00	12.32
436	81.14%	81.14%	4,761,970.00	12.04
437	81.71%	81.71%	4,795,505.00	11.78
438	82.29%	82.29%	4,829,040.00	11.51
439	82.86%	82.86%	4,862,575.00	11.25
440	83.43%	83.43%	4,896,110.00	11.00
441	84.00%	84.00%	4,929,645.00	10.75
442	84.57%	84.57%	4,963,180.00	10.51
443	85.14%	85.14%	4,996,715.00	10.28
444	85.71%	85.71%	5,030,250.00	10.04
445	86.29%	86.29%	5,063,785.00	9.82
446	86.86%	86.86%	5,097,320.00	9.59
447	87.43%	87.43%	5,130,855.00	9.37
448	88.00%	88.00%	5,164,390.00	9.16
449	88.57%	88.57%	5,197,925.00	8.95
450	89.14%	89.14%	5,231,460.00	8.75
451	89.71%	89.71%	5,264,995.00	8.55
452	90.29%	90.29%	5,298,530.00	8.35
453	90.86%	90.86%	5,332,065.00	8.16
454	91.43%	91.43%	5,365,600.00	7.97

455	92.00%	92.00%	5,399,135.00	7.79
456	92.57%	92.57%	5,432,670.00	7.61
457	93.14%	93.14%	5,466,205.00	7.43
458	93.71%	93.71%	5,499,740.00	7.26
459	94.29%	94.29%	5,533,275.00	7.09
460	94.86%	94.86%	5,566,810.00	6.93
461	95.43%	95.43%	5,600,345.00	6.76
462	96.00%	96.00%	5,633,880.00	6.61
463	96.57%	96.57%	5,667,415.00	6.45
464	97.14%	97.14%	5,700,950.00	6.30
465	97.71%	97.71%	5,734,485.00	6.15
466	98.29%	98.29%	5,768,020.00	6.01
467	98.86%	98.86%	5,801,555.00	5.87
468	99.43%	99.43%	5,835,090.00	5.73
469	100.00%	100.00%	5,868,625.00	5.60
Beyond (e)				186.53
Total				6,419.19

Section 2 Quantification of Replacement Services

	<----------(Percentage)---------->	
Year	Current Value	Present Value
5	0.0%	0.0%
6	5.0%	4.2%
7	10.0%	8.1%
8	15.0%	11.8%
9	20.0%	15.3%
10	25.0%	18.6%
11	30.0%	21.7%
12	35.0%	24.5%
13	40.0%	27.2%
14	45.0%	29.8%
15	50.0%	32.1%
16	55.0%	34.3%
17	60.0%	36.3%
18	65.0%	38.2%
19	70.0%	39.9%
20	75.0%	41.5%
21	80.0%	43.0%
22	85.0%	44.4%
23	90.0%	45.6%
24	95.0%	46.7%
25	100.0%	47.8%
Beyond (f)		1592.0%
Total		2203.1%

Section 3 Offsetting Restoration for One Organism

Red River - Progressive Dispersal (river-miles):	80.5
Lake Winnipeg - Jump Dispersal (acres):	1,730,000
Lake Winnipeg - Progressive Dispersal (acres):	291

Section 4 Notes

(a) Percent loss given certain invasion

(b) Percent loss given probability of successful invasion

(c) From year 295 into perpetuity

(d) From year 176 into perpetuity

(e) From year 470 into perpetuity

(f) From year 26 into perpetuity

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Appendix 15G. Habitat Equivalency Analysis of Risk Consequences: Fast Invasion - Very Low Risk (One Organism)

Probability of successful invasion: 1.00E-09

Annual discount rate: 3.0%

Present year: 0

Section 1 Quantification of Expected Lost Services

Section 1.1 Red River from Fargo to Lake Winnipeg - Progressive Dispersal

Affected habitat (river-miles): 455.40

	<----------(Percentage)---------->		<----------(River-Mile Years)---------->	
Year	Certain (a)	Expected (b)	Current Value	Present Value
0	0.00%	0.00000000000%	0.00000000000	0.00000000000
1	3.45%	0.00000000345%	0.00000001570	0.00000001525
2	6.90%	0.00000000690%	0.00000003141	0.00000002960
3	10.34%	0.00000001034%	0.00000004711	0.00000004311
4	13.79%	0.00000001379%	0.00000006281	0.00000005581
5	17.24%	0.00000001724%	0.00000007852	0.00000006773
6	20.69%	0.00000002069%	0.00000009422	0.00000007891
7	24.14%	0.00000002414%	0.00000010992	0.00000008938
8	27.59%	0.00000002759%	0.00000012563	0.00000009917
9	31.03%	0.00000003103%	0.00000014133	0.00000010832
10	34.48%	0.00000003448%	0.00000015703	0.00000011685
11	37.93%	0.00000003793%	0.00000017274	0.00000012479
12	41.38%	0.00000004138%	0.00000018844	0.00000013217
13	44.83%	0.00000004483%	0.00000020414	0.00000013901
14	48.28%	0.00000004828%	0.00000021985	0.00000014535
15	51.72%	0.00000005172%	0.00000023555	0.00000015119
16	55.17%	0.00000005517%	0.00000025126	0.00000015657
17	58.62%	0.00000005862%	0.00000026696	0.00000016151
18	62.07%	0.00000006207%	0.00000028266	0.00000016603
19	65.52%	0.00000006552%	0.00000029837	0.00000017015
20	68.97%	0.00000006897%	0.00000031407	0.00000017389
21	72.41%	0.00000007241%	0.00000032977	0.00000017727
22	75.86%	0.00000007586%	0.00000034548	0.00000018030
23	79.31%	0.00000007931%	0.00000036118	0.00000018301
24	82.76%	0.00000008276%	0.00000037688	0.00000018540
25	86.21%	0.00000008621%	0.00000039259	0.00000018750
26	89.66%	0.00000008966%	0.00000040829	0.00000018932
27	93.10%	0.00000009310%	0.00000042399	0.00000019088
28	96.55%	0.00000009655%	0.00000043970	0.00000019218
29	100.00%	0.00000010000%	0.00000045540	0.00000019325

Beyond (c)	0.00000644158
Total	0.00001034549

Section 1.2 Lake Winnipeg - Jump Dispersal

Affected habitat (acres): 5,868,625.00

	<----------(Percentage)---------->		<----------(Acre Years)---------->	
Year	Certain (a)	Expected (b)	Current Value	Present Value
0	0.00%	0.00000000000%	0.00000000000	0.00000000000
1	5.88%	0.00000000588%	0.00034521324	0.00033515848
2	11.76%	0.00000001176%	0.00069042647	0.00065079317
3	17.65%	0.00000001765%	0.00103563971	0.00094775704
4	23.53%	0.00000002353%	0.00138085294	0.00122686995
5	29.41%	0.00000002941%	0.00172606618	0.00148891985
6	35.29%	0.00000003529%	0.00207127941	0.00173466390
7	41.18%	0.00000004118%	0.00241649265	0.00196482966
8	47.06%	0.00000004706%	0.00276170588	0.00218011613
9	52.94%	0.00000005294%	0.00310691912	0.00238119480
10	58.82%	0.00000005882%	0.00345213235	0.00256871068
11	64.71%	0.00000006471%	0.00379734559	0.00274328325
12	70.59%	0.00000007059%	0.00414255882	0.00290550741
13	76.47%	0.00000007647%	0.00448777206	0.00305595440
14	82.35%	0.00000008235%	0.00483298529	0.00319517263
15	88.24%	0.00000008824%	0.00517819853	0.00332368859
16	94.12%	0.00000009412%	0.00552341176	0.00344200760
17	100.00%	0.00000010000%	0.00586862500	0.00355061464
Beyond (d)				0.11835382132
Total				0.15604906348

Section 1.3 Lake Winnipeg - Progressive Dispersal

Affected habitat (acres): 5,868,625.00

	<----------(Percentage)---------->		<----------(Acre Years)---------->	
Year	Certain (a)	Expected (b)	Current Value	Present Value
29	0.00%	0.00000000000%	0.00000000000	0.00000000000
30	5.88%	0.00000000588%	0.00034521324	0.00014222328
31	11.76%	0.00000001176%	0.00069042647	0.00027616171
32	17.65%	0.00000001765%	0.00103563971	0.00040217725
33	23.53%	0.00000002353%	0.00138085294	0.00052061780
34	29.41%	0.00000002941%	0.00172606618	0.00063181772
35	35.29%	0.00000003529%	0.00207127941	0.00073609832
36	41.18%	0.00000004118%	0.00241649265	0.00083376832
37	47.06%	0.00000004706%	0.00276170588	0.00092512435
38	52.94%	0.00000005294%	0.00310691912	0.00101045135
39	58.82%	0.00000005882%	0.00345213235	0.00109002303
40	64.71%	0.00000006471%	0.00379734559	0.00116410227

41	70.59%	0.00000007059%	0.00414255882	0.00123294150
42	76.47%	0.00000007647%	0.00448777206	0.00129678313
43	82.35%	0.00000008235%	0.00483298529	0.00135585988
44	88.24%	0.00000008824%	0.00517819853	0.00141039516
45	94.12%	0.00000009412%	0.00552341176	0.00146060341
46	100.00%	0.00000010000%	0.00586862500	0.00150669041
Beyond (e)				0.05022301354
Total				0.06621885243

Section 2 Quantification of Replacement Services

	<----------(Percentage)---------->	
Year	Current Value	Present Value
5	0.0%	0.0%
6	5.0%	4.2%
7	10.0%	8.1%
8	15.0%	11.8%
9	20.0%	15.3%
10	25.0%	18.6%
11	30.0%	21.7%
12	35.0%	24.5%
13	40.0%	27.2%
14	45.0%	29.8%
15	50.0%	32.1%
16	55.0%	34.3%
17	60.0%	36.3%
18	65.0%	38.2%
19	70.0%	39.9%
20	75.0%	41.5%
21	80.0%	43.0%
22	85.0%	44.4%
23	90.0%	45.6%
24	95.0%	46.7%
25	100.0%	47.8%
Beyond (f)		1592.0%
Total		2203.1%

Section 3 Offsetting Restoration for One Organism

Red River - Progressive Dispersal (river-miles):	0.000000470
Lake Winnipeg - Jump Dispersal (acres):	0.00708
Lake Winnipeg - Progressive Dispersal (acres):	0.00301

Section 4 Notes

(a) Percent loss given certain invasion

(b) Percent loss given probability of successful invasion

(c) From year 30 into perpetuity

(d) From year 18 into perpetuity

(e) From year 47 into perpetuity

(f) From year 26 into perpetuity

Appendix 15H. Habitat Equivalency Analysis of Risk Consequences: Fast Invasion - Low Risk (One Organism)

Probability of successful invasion: 1.00E-06

Annual discount rate: 3.0%

Present year: 0

Section 1 Quantification of Expected Lost Services

Section 1.1 Red River from Fargo to Lake Winnipeg - Progressive Dispersal

Affected habitat (river-miles): 455.40

	<----------(Percentage)---------->		<----------(River-Mile Years)---------->	
Year	Certain (a)	Expected (b)	Current Value	Present Value
0	0.00%	0.00000000%	0.00000000	0.00000000
1	3.45%	0.00000345%	0.00001570	0.00001525
2	6.90%	0.00000690%	0.00003141	0.00002960
3	10.34%	0.00001034%	0.00004711	0.00004311
4	13.79%	0.00001379%	0.00006281	0.00005581
5	17.24%	0.00001724%	0.00007852	0.00006773
6	20.69%	0.00002069%	0.00009422	0.00007891
7	24.14%	0.00002414%	0.00010992	0.00008938
8	27.59%	0.00002759%	0.00012563	0.00009917
9	31.03%	0.00003103%	0.00014133	0.00010832
10	34.48%	0.00003448%	0.00015703	0.00011685
11	37.93%	0.00003793%	0.00017274	0.00012479
12	41.38%	0.00004138%	0.00018844	0.00013217
13	44.83%	0.00004483%	0.00020414	0.00013901
14	48.28%	0.00004828%	0.00021985	0.00014535
15	51.72%	0.00005172%	0.00023555	0.00015119
16	55.17%	0.00005517%	0.00025126	0.00015657
17	58.62%	0.00005862%	0.00026696	0.00016151
18	62.07%	0.00006207%	0.00028266	0.00016603
19	65.52%	0.00006552%	0.00029837	0.00017015
20	68.97%	0.00006897%	0.00031407	0.00017389
21	72.41%	0.00007241%	0.00032977	0.00017727
22	75.86%	0.00007586%	0.00034548	0.00018030
23	79.31%	0.00007931%	0.00036118	0.00018301
24	82.76%	0.00008276%	0.00037688	0.00018540
25	86.21%	0.00008621%	0.00039259	0.00018750
26	89.66%	0.00008966%	0.00040829	0.00018932
27	93.10%	0.00009310%	0.00042399	0.00019088
28	96.55%	0.00009655%	0.00043970	0.00019218
29	100.00%	0.00010000%	0.00045540	0.00019325

Beyond (c)	0.00644158
Total	0.01034549

Section 1.2 Lake Winnipeg - Jump Dispersal

Affected habitat (acres): 5,868,625.00

	<----------(Percentage)---------->		<----------(Acre Years)---------->	
Year	Certain (a)	Expected (b)	Current Value	Present Value
0	0.00%	0.00000000%	0.00000000	0.00000000
1	5.88%	0.00000588%	0.34521324	0.33515848
2	11.76%	0.00001176%	0.69042647	0.65079317
3	17.65%	0.00001765%	1.03563971	0.94775704
4	23.53%	0.00002353%	1.38085294	1.22686995
5	29.41%	0.00002941%	1.72606618	1.48891985
6	35.29%	0.00003529%	2.07127941	1.73466390
7	41.18%	0.00004118%	2.41649265	1.96482966
8	47.06%	0.00004706%	2.76170588	2.18011613
9	52.94%	0.00005294%	3.10691912	2.38119480
10	58.82%	0.00005882%	3.45213235	2.56871068
11	64.71%	0.00006471%	3.79734559	2.74328325
12	70.59%	0.00007059%	4.14255882	2.90550741
13	76.47%	0.00007647%	4.48777206	3.05595440
14	82.35%	0.00008235%	4.83298529	3.19517263
15	88.24%	0.00008824%	5.17819853	3.32368859
16	94.12%	0.00009412%	5.52341176	3.44200760
17	100.00%	0.00010000%	5.86862500	3.55061464
Beyond (d)				118.35382132
Total				156.04906348

Section 1.3 Lake Winnipeg - Progressive Dispersal

Affected habitat (acres): 5,868,625.00

	<----------(Percentage)---------->		<----------(Acre Years)---------->	
Year	Certain (a)	Expected (b)	Current Value	Present Value
29	0.00%	0.00000000%	0.00000000	0.00000000
30	5.88%	0.00000588%	0.34521324	0.14222328
31	11.76%	0.00001176%	0.69042647	0.27616171
32	17.65%	0.00001765%	1.03563971	0.40217725
33	23.53%	0.00002353%	1.38085294	0.52061780
34	29.41%	0.00002941%	1.72606618	0.63181772
35	35.29%	0.00003529%	2.07127941	0.73609832
36	41.18%	0.00004118%	2.41649265	0.83376832
37	47.06%	0.00004706%	2.76170588	0.92512435
38	52.94%	0.00005294%	3.10691912	1.01045135
39	58.82%	0.00005882%	3.45213235	1.09002303
40	64.71%	0.00006471%	3.79734559	1.16410227

41	70.59%	0.00007059%	4.14255882	1.23294150
42	76.47%	0.00007647%	4.48777206	1.29678313
43	82.35%	0.00008235%	4.83298529	1.35585988
44	88.24%	0.00008824%	5.17819853	1.41039516
45	94.12%	0.00009412%	5.52341176	1.46060341
46	100.00%	0.00010000%	5.86862500	1.50669041
Beyond (e)				50.22301354
Total				66.21885243

Section 2 Quantification of Replacement Services

	<----------(Percentage)---------->	
Year	Current Value	Present Value
5	0.0%	0.0%
6	5.0%	4.2%
7	10.0%	8.1%
8	15.0%	11.8%
9	20.0%	15.3%
10	25.0%	18.6%
11	30.0%	21.7%
12	35.0%	24.5%
13	40.0%	27.2%
14	45.0%	29.8%
15	50.0%	32.1%
16	55.0%	34.3%
17	60.0%	36.3%
18	65.0%	38.2%
19	70.0%	39.9%
20	75.0%	41.5%
21	80.0%	43.0%
22	85.0%	44.4%
23	90.0%	45.6%
24	95.0%	46.7%
25	100.0%	47.8%
Beyond (f)		1592.0%
Total		2203.1%

Section 3 Offsetting Restoration for One Organism

Red River - Progressive Dispersal (river-miles):	0.000470
Lake Winnipeg - Jump Dispersal (acres):	7.08
Lake Winnipeg - Progressive Dispersal (acres):	3.01

Section 4 Notes

(a) Percent loss given certain invasion

(b) Percent loss given probability of successful invasion

(c) From year 30 into perpetuity

(d) From year 18 into perpetuity

(e) From year 47 into perpetuity

(f) From year 26 into perpetuity

Appendix 15I. Habitat Equivalency Analysis of Risk Consequences: Fast Invasion - Moderate Risk (One Organism)

Probability of successful invasion: 1.00E-03

Annual discount rate: 3.0%

Present year: 0

Section 1 Quantification of Expected Lost Services

Section 1.1 Red River from Fargo to Lake Winnipeg - Progressive Dispersal

Affected habitat (river-miles): 455.40

	<----------(Percentage)---------->		<----------(River-Mile Years)---------->	
Year	Certain (a)	Expected (b)	Current Value	Present Value
0	0.00%	0.00000%	0.00000	0.00000
1	3.45%	0.00345%	0.01570	0.01525
2	6.90%	0.00690%	0.03141	0.02960
3	10.34%	0.01034%	0.04711	0.04311
4	13.79%	0.01379%	0.06281	0.05581
5	17.24%	0.01724%	0.07852	0.06773
6	20.69%	0.02069%	0.09422	0.07891
7	24.14%	0.02414%	0.10992	0.08938
8	27.59%	0.02759%	0.12563	0.09917
9	31.03%	0.03103%	0.14133	0.10832
10	34.48%	0.03448%	0.15703	0.11685
11	37.93%	0.03793%	0.17274	0.12479
12	41.38%	0.04138%	0.18844	0.13217
13	44.83%	0.04483%	0.20414	0.13901
14	48.28%	0.04828%	0.21985	0.14535
15	51.72%	0.05172%	0.23555	0.15119
16	55.17%	0.05517%	0.25126	0.15657
17	58.62%	0.05862%	0.26696	0.16151
18	62.07%	0.06207%	0.28266	0.16603
19	65.52%	0.06552%	0.29837	0.17015
20	68.97%	0.06897%	0.31407	0.17389
21	72.41%	0.07241%	0.32977	0.17727
22	75.86%	0.07586%	0.34548	0.18030
23	79.31%	0.07931%	0.36118	0.18301
24	82.76%	0.08276%	0.37688	0.18540
25	86.21%	0.08621%	0.39259	0.18750
26	89.66%	0.08966%	0.40829	0.18932
27	93.10%	0.09310%	0.42399	0.19088
28	96.55%	0.09655%	0.43970	0.19218
29	100.00%	0.10000%	0.45540	0.19325

Beyond (c)	6.44158
Total	10.34549

Section 1.2 Lake Winnipeg - Jump Dispersal

Affected habitat (acres): 5,868,625.00

	<----------(Percentage)---------->		<----------(Acre Years)---------->	
Year	Certain (a)	Expected (b)	Current Value	Present Value
0	0.00%	0.00000%	0.00000	0.00000
1	5.88%	0.00588%	345.21324	335.15848
2	11.76%	0.01176%	690.42647	650.79317
3	17.65%	0.01765%	1,035.63971	947.75704
4	23.53%	0.02353%	1,380.85294	1,226.86995
5	29.41%	0.02941%	1,726.06618	1,488.91985
6	35.29%	0.03529%	2,071.27941	1,734.66390
7	41.18%	0.04118%	2,416.49265	1,964.82966
8	47.06%	0.04706%	2,761.70588	2,180.11613
9	52.94%	0.05294%	3,106.91912	2,381.19480
10	58.82%	0.05882%	3,452.13235	2,568.71068
11	64.71%	0.06471%	3,797.34559	2,743.28325
12	70.59%	0.07059%	4,142.55882	2,905.50741
13	76.47%	0.07647%	4,487.77206	3,055.95440
14	82.35%	0.08235%	4,832.98529	3,195.17263
15	88.24%	0.08824%	5,178.19853	3,323.68859
16	94.12%	0.09412%	5,523.41176	3,442.00760
17	100.00%	0.10000%	5,868.62500	3,550.61464
Beyond (d)				118,353.82132
Total				156,049.06348

Section 1.3 Lake Winnipeg - Progressive Dispersal

Affected habitat (acres): 5,868,625.00

	<----------(Percentage)---------->		<----------(Acre Years)---------->	
Year	Certain (a)	Expected (b)	Current Value	Present Value
29	0.00%	0.00000%	0.00000	0.00000
30	5.88%	0.00588%	345.21324	142.22328
31	11.76%	0.01176%	690.42647	276.16171
32	17.65%	0.01765%	1,035.63971	402.17725
33	23.53%	0.02353%	1,380.85294	520.61780
34	29.41%	0.02941%	1,726.06618	631.81772
35	35.29%	0.03529%	2,071.27941	736.09832
36	41.18%	0.04118%	2,416.49265	833.76832
37	47.06%	0.04706%	2,761.70588	925.12435
38	52.94%	0.05294%	3,106.91912	1,010.45135
39	58.82%	0.05882%	3,452.13235	1,090.02303
40	64.71%	0.06471%	3,797.34559	1,164.10227

41	70.59%	0.07059%	4,142.55882	1,232.94150
42	76.47%	0.07647%	4,487.77206	1,296.78313
43	82.35%	0.08235%	4,832.98529	1,355.85988
44	88.24%	0.08824%	5,178.19853	1,410.39516
45	94.12%	0.09412%	5,523.41176	1,460.60341
46	100.00%	0.10000%	5,868.62500	1,506.69041
Beyond (e)				50,223.01354
Total				66,218.85243

Section 2 Quantification of Replacement Services

	<----------(Percentage)---------->	
Year	Current Value	Present Value
5	0.0%	0.0%
6	5.0%	4.2%
7	10.0%	8.1%
8	15.0%	11.8%
9	20.0%	15.3%
10	25.0%	18.6%
11	30.0%	21.7%
12	35.0%	24.5%
13	40.0%	27.2%
14	45.0%	29.8%
15	50.0%	32.1%
16	55.0%	34.3%
17	60.0%	36.3%
18	65.0%	38.2%
19	70.0%	39.9%
20	75.0%	41.5%
21	80.0%	43.0%
22	85.0%	44.4%
23	90.0%	45.6%
24	95.0%	46.7%
25	100.0%	47.8%
Beyond (f)		1592.0%
Total		2203.1%

Section 3 Offsetting Restoration for One Organism

Red River - Progressive Dispersal (river-miles):	0.470
Lake Winnipeg - Jump Dispersal (acres):	7,080
Lake Winnipeg - Progressive Dispersal (acres):	3,010

Section 4 Notes

(a) Percent loss given certain invasion

(b) Percent loss given probability of successful invasion

(c) From year 30 into perpetuity

(d) From year 18 into perpetuity

(e) From year 47 into perpetuity

(f) From year 26 into perpetuity

Appendix 15J. Habitat Equivalency Analysis of Risk Consequences: Fast Invasion - High Risk (One Organism)

Probability of successful invasion: 1.00E-02

Annual discount rate: 3.0%

Present year: 0

Section 1 Quantification of Expected Lost Services

Section 1.1 Red River from Fargo to Lake Winnipeg - Progressive Dispersal

Affected habitat (river-miles): 455.40

	<----------(Percentage)---------->		<----------(River-Mile Years)---------->	
Year	Certain (a)	Expected (b)	Current Value	Present Value
0	0.00%	0.0000%	0.0000	0.0000
1	3.45%	0.0345%	0.1570	0.1525
2	6.90%	0.0690%	0.3141	0.2960
3	10.34%	0.1034%	0.4711	0.4311
4	13.79%	0.1379%	0.6281	0.5581
5	17.24%	0.1724%	0.7852	0.6773
6	20.69%	0.2069%	0.9422	0.7891
7	24.14%	0.2414%	1.0992	0.8938
8	27.59%	0.2759%	1.2563	0.9917
9	31.03%	0.3103%	1.4133	1.0832
10	34.48%	0.3448%	1.5703	1.1685
11	37.93%	0.3793%	1.7274	1.2479
12	41.38%	0.4138%	1.8844	1.3217
13	44.83%	0.4483%	2.0414	1.3901
14	48.28%	0.4828%	2.1985	1.4535
15	51.72%	0.5172%	2.3555	1.5119
16	55.17%	0.5517%	2.5126	1.5657
17	58.62%	0.5862%	2.6696	1.6151
18	62.07%	0.6207%	2.8266	1.6603
19	65.52%	0.6552%	2.9837	1.7015
20	68.97%	0.6897%	3.1407	1.7389
21	72.41%	0.7241%	3.2977	1.7727
22	75.86%	0.7586%	3.4548	1.8030
23	79.31%	0.7931%	3.6118	1.8301
24	82.76%	0.8276%	3.7688	1.8540
25	86.21%	0.8621%	3.9259	1.8750
26	89.66%	0.8966%	4.0829	1.8932
27	93.10%	0.9310%	4.2399	1.9088
28	96.55%	0.9655%	4.3970	1.9218
29	100.00%	1.0000%	4.5540	1.9325

Beyond (c)	64.4158
Total	103.4549

Section 1.2 Lake Winnipeg - Jump Dispersal

Affected habitat (acres): 5,868,625.00

	<----------(Percentage)---------->		<----------(Acre Years)---------->	
Year	Certain (a)	Expected (b)	Current Value	Present Value
0	0.00%	0.0000%	0.0000	0.0000
1	5.88%	0.0588%	3,452.1324	3,351.5848
2	11.76%	0.1176%	6,904.2647	6,507.9317
3	17.65%	0.1765%	10,356.3971	9,477.5704
4	23.53%	0.2353%	13,808.5294	12,268.6995
5	29.41%	0.2941%	17,260.6618	14,889.1985
6	35.29%	0.3529%	20,712.7941	17,346.6390
7	41.18%	0.4118%	24,164.9265	19,648.2966
8	47.06%	0.4706%	27,617.0588	21,801.1613
9	52.94%	0.5294%	31,069.1912	23,811.9480
10	58.82%	0.5882%	34,521.3235	25,687.1068
11	64.71%	0.6471%	37,973.4559	27,432.8325
12	70.59%	0.7059%	41,425.5882	29,055.0741
13	76.47%	0.7647%	44,877.7206	30,559.5440
14	82.35%	0.8235%	48,329.8529	31,951.7263
15	88.24%	0.8824%	51,781.9853	33,236.8859
16	94.12%	0.9412%	55,234.1176	34,420.0760
17	100.00%	1.0000%	58,686.2500	35,506.1464
Beyond (d)				1,183,538.2132
Total				1,560,490.6348

Section 1.3 Lake Winnipeg - Progressive Dispersal

Affected habitat (acres): 5,868,625.00

	<----------(Percentage)---------->		<----------(Acre Years)---------->	
Year	Certain (a)	Expected (b)	Current Value	Present Value
29	0.00%	0.0000%	0.0000	0.0000
30	5.88%	0.0588%	3,452.1324	1,422.2328
31	11.76%	0.1176%	6,904.2647	2,761.6171
32	17.65%	0.1765%	10,356.3971	4,021.7725
33	23.53%	0.2353%	13,808.5294	5,206.1780
34	29.41%	0.2941%	17,260.6618	6,318.1772
35	35.29%	0.3529%	20,712.7941	7,360.9832
36	41.18%	0.4118%	24,164.9265	8,337.6832
37	47.06%	0.4706%	27,617.0588	9,251.2435
38	52.94%	0.5294%	31,069.1912	10,104.5135
39	58.82%	0.5882%	34,521.3235	10,900.2303
40	64.71%	0.6471%	37,973.4559	11,641.0227

41	70.59%	0.7059%	41,425.5882	12,329.4150
42	76.47%	0.7647%	44,877.7206	12,967.8313
43	82.35%	0.8235%	48,329.8529	13,558.5988
44	88.24%	0.8824%	51,781.9853	14,103.9516
45	94.12%	0.9412%	55,234.1176	14,606.0341
46	100.00%	1.0000%	58,686.2500	15,066.9041
Beyond (e)				502,230.1354
Total				662,188.5243

Section 2 Quantification of Replacement Services

	<----------(Percentage)---------->	
Year	Current Value	Present Value
5	0.0%	0.0%
6	5.0%	4.2%
7	10.0%	8.1%
8	15.0%	11.8%
9	20.0%	15.3%
10	25.0%	18.6%
11	30.0%	21.7%
12	35.0%	24.5%
13	40.0%	27.2%
14	45.0%	29.8%
15	50.0%	32.1%
16	55.0%	34.3%
17	60.0%	36.3%
18	65.0%	38.2%
19	70.0%	39.9%
20	75.0%	41.5%
21	80.0%	43.0%
22	85.0%	44.4%
23	90.0%	45.6%
24	95.0%	46.7%
25	100.0%	47.8%
Beyond (f)		1592.0%
Total		2203.1%

Section 3 Offsetting Restoration for One Organism

Red River - Progressive Dispersal (river-miles):	4.70
Lake Winnipeg - Jump Dispersal (acres):	70,800
Lake Winnipeg - Progressive Dispersal (acres):	30,100

Section 4 Notes

(a) Percent loss given certain invasion

(b) Percent loss given probability of successful invasion

(c) From year 30 into perpetuity

(d) From year 18 into perpetuity

(e) From year 47 into perpetuity

(f) From year 26 into perpetuity

Appendix 15K. Habitat Equivalency Analysis of Risk Consequences: Fast Invasion - Very High Risk (One Organism)

Probability of successful invasion: 1.00E+00

Annual discount rate: 3.0%

Present year: 0

Section 1 Quantification of Expected Lost Services

Section 1.1 Red River from Fargo to Lake Winnipeg - Progressive Dispersal

Affected habitat (river-miles): 455.40

	<----------(Percentage)---------->		<----------(River-Mile Years)---------->	
Year	Certain (a)	Expected (b)	Current Value	Present Value
0	0.00%	0.00%	0.00	0.00
1	3.45%	3.45%	15.70	15.25
2	6.90%	6.90%	31.41	29.60
3	10.34%	10.34%	47.11	43.11
4	13.79%	13.79%	62.81	55.81
5	17.24%	17.24%	78.52	67.73
6	20.69%	20.69%	94.22	78.91
7	24.14%	24.14%	109.92	89.38
8	27.59%	27.59%	125.63	99.17
9	31.03%	31.03%	141.33	108.32
10	34.48%	34.48%	157.03	116.85
11	37.93%	37.93%	172.74	124.79
12	41.38%	41.38%	188.44	132.17
13	44.83%	44.83%	204.14	139.01
14	48.28%	48.28%	219.85	145.35
15	51.72%	51.72%	235.55	151.19
16	55.17%	55.17%	251.26	156.57
17	58.62%	58.62%	266.96	161.51
18	62.07%	62.07%	282.66	166.03
19	65.52%	65.52%	298.37	170.15
20	68.97%	68.97%	314.07	173.89
21	72.41%	72.41%	329.77	177.27
22	75.86%	75.86%	345.48	180.30
23	79.31%	79.31%	361.18	183.01
24	82.76%	82.76%	376.88	185.40
25	86.21%	86.21%	392.59	187.50
26	89.66%	89.66%	408.29	189.32
27	93.10%	93.10%	423.99	190.88
28	96.55%	96.55%	439.70	192.18
29	100.00%	100.00%	455.40	193.25

Beyond (c)	6,441.58
Total	10,345.49

Section 1.2 Lake Winnipeg - Jump Dispersal

Affected habitat (acres): 5,868,625.00

	<----------(Percentage)---------->		<----------(Acre Years)---------->	
Year	Certain (a)	Expected (b)	Current Value	Present Value
0	0.00%	0.00%	0.00	0.00
1	5.88%	5.88%	345,213.24	335,158.48
2	11.76%	11.76%	690,426.47	650,793.17
3	17.65%	17.65%	1,035,639.71	947,757.04
4	23.53%	23.53%	1,380,852.94	1,226,869.95
5	29.41%	29.41%	1,726,066.18	1,488,919.85
6	35.29%	35.29%	2,071,279.41	1,734,663.90
7	41.18%	41.18%	2,416,492.65	1,964,829.66
8	47.06%	47.06%	2,761,705.88	2,180,116.13
9	52.94%	52.94%	3,106,919.12	2,381,194.80
10	58.82%	58.82%	3,452,132.35	2,568,710.68
11	64.71%	64.71%	3,797,345.59	2,743,283.25
12	70.59%	70.59%	4,142,558.82	2,905,507.41
13	76.47%	76.47%	4,487,772.06	3,055,954.40
14	82.35%	82.35%	4,832,985.29	3,195,172.63
15	88.24%	88.24%	5,178,198.53	3,323,688.59
16	94.12%	94.12%	5,523,411.76	3,442,007.60
17	100.00%	100.00%	5,868,625.00	3,550,614.64
Beyond (d)				118,353,821.32
Total				156,049,063.48

Section 1.3 Lake Winnipeg - Progressive Dispersal

Affected habitat (acres): 5,868,625.00

	<----------(Percentage)---------->		<----------(Acre Years)---------->	
Year	Certain (a)	Expected (b)	Current Value	Present Value
29	0.00%	0.00%	0.00	0.00
30	5.88%	5.88%	345,213.24	142,223.28
31	11.76%	11.76%	690,426.47	276,161.71
32	17.65%	17.65%	1,035,639.71	402,177.25
33	23.53%	23.53%	1,380,852.94	520,617.80
34	29.41%	29.41%	1,726,066.18	631,817.72
35	35.29%	35.29%	2,071,279.41	736,098.32
36	41.18%	41.18%	2,416,492.65	833,768.32
37	47.06%	47.06%	2,761,705.88	925,124.35
38	52.94%	52.94%	3,106,919.12	1,010,451.35
39	58.82%	58.82%	3,452,132.35	1,090,023.03
40	64.71%	64.71%	3,797,345.59	1,164,102.27

41	70.59%	70.59%	4,142,558.82	1,232,941.50
42	76.47%	76.47%	4,487,772.06	1,296,783.13
43	82.35%	82.35%	4,832,985.29	1,355,859.88
44	88.24%	88.24%	5,178,198.53	1,410,395.16
45	94.12%	94.12%	5,523,411.76	1,460,603.41
46	100.00%	100.00%	5,868,625.00	1,506,690.41
Beyond (e)				50,223,013.54
Total				66,218,852.43

Section 2 Quantification of Replacement Services

	<----------(Percentage)---------->	
Year	Current Value	Present Value
5	0.0%	0.0%
6	5.0%	4.2%
7	10.0%	8.1%
8	15.0%	11.8%
9	20.0%	15.3%
10	25.0%	18.6%
11	30.0%	21.7%
12	35.0%	24.5%
13	40.0%	27.2%
14	45.0%	29.8%
15	50.0%	32.1%
16	55.0%	34.3%
17	60.0%	36.3%
18	65.0%	38.2%
19	70.0%	39.9%
20	75.0%	41.5%
21	80.0%	43.0%
22	85.0%	44.4%
23	90.0%	45.6%
24	95.0%	46.7%
25	100.0%	47.8%
Beyond (f)		1592.0%
Total		2203.1%

Section 3 Offsetting Restoration for One Organism

Red River - Progressive Dispersal (river-miles):	470
Lake Winnipeg - Jump Dispersal (acres):	7,080,000
Lake Winnipeg - Progressive Dispersal (acres):	3,010,000

Section 4 Notes

(a) Percent loss given certain invasion

(b) Percent loss given probability of successful invasion

(c) From year 30 into perpetuity

(d) From year 18 into perpetuity

(e) From year 47 into perpetuity

(f) From year 26 into perpetuity

Appendix 16A. Economic Impact Analysis of Lake Winnipeg Commercial Fishery: Summary of Results

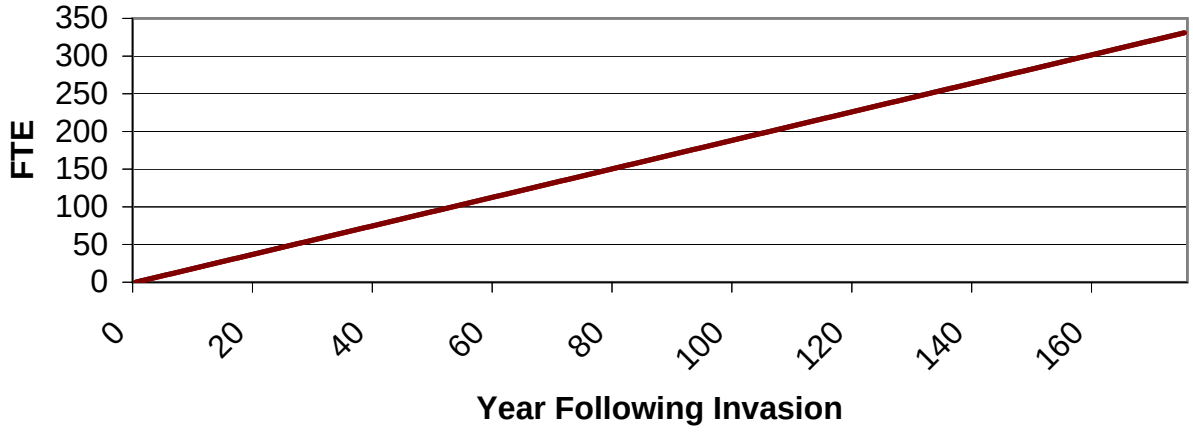
Assumed number of years until successful invasion begins: 0

Expected Direct and Indirect Output Impacts for All Canadian Provinces Given a Jump Dispersal Event

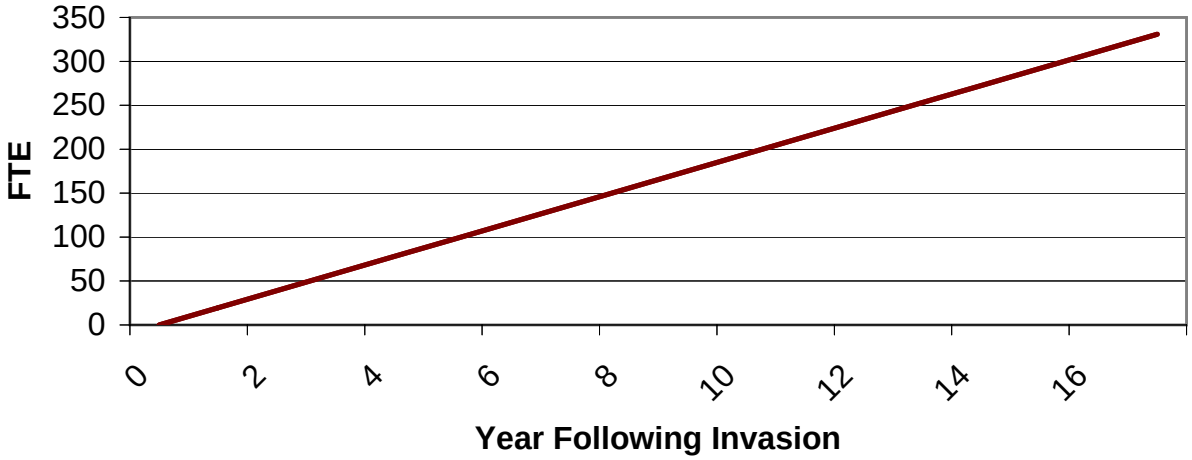
Risk Category	Probability of Successful Invasion	Percent Outcomes	Total Expected Present Value of <---Direct and Indirect Output Impacts---> Slow Invasion (Canadian 2003 $)	Fast Invasion (Canadian 2003 $)
Very Low	1.00E-09	87.0%	$0.160	$0.655
Low	1.00E-06	7.6%	$160	$655
Moderate	1.00E-03	3.7%	$160,000	$655,000
High	1.00E-02	1.7%	$1,600,000	$6,550,000
Very High	1.00E+00	0.0%	$160,000,000	$655,000,000
Weighted Average (a)			$33,000	$136,000

(a) Weighted by the percent outcomes of respective risk categories

Direct and Indirect Employment Impacts for All Canadian Provinces: Slow Invasion, Jump Dispersal Event, and Very High Risk



Direct and Indirect Employment Impacts for All Canadian Provinces: Fast Invasion, Jump Dispersal Event, and Very High Risk



Appendix 16B. Economic Impact Analysis of Lake Winnipeg Commercial Fishery: Slow Invasion - Very Low Risk

Probability of successful invasion:	1.00E-09	
Annual discount rate:	3.0%	
Present year:	0	
Invasion year:	0	
Annual landed value (10-year average):	$14,838,754	
Economic impact multipliers		
Output (direct effects):	1.00	
Output (direct & indirect effects - all provinces):	1.66	
Employment (direct effects):	17.41	FTE/million $ direct output
Employment (direct & indirect effects - all provinces):	22.30	FTE/million $ direct output

			<----------(Output Impacts)---------->			
	<-----(Fishery Displacement)----->		<----------(Direct Effects)---------->		<----(Direct & Indirect Effects)---->	
Year	Certain (a)	Expected (b)	Current Value	Present Value	Current Value	Present Value
0	0.0%	0.0000000000%	$0.00000	$0.00000	$0.00000	$0.00000
1	0.6%	0.0000000006%	$0.00008	$0.00008	$0.00014	$0.00014
2	1.1%	0.0000000011%	$0.00017	$0.00016	$0.00028	$0.00027
3	1.7%	0.0000000017%	$0.00025	$0.00023	$0.00042	$0.00039
4	2.3%	0.0000000023%	$0.00034	$0.00030	$0.00056	$0.00050
5	2.9%	0.0000000029%	$0.00042	$0.00037	$0.00070	$0.00061
6	3.4%	0.0000000034%	$0.00051	$0.00043	$0.00084	$0.00071
7	4.0%	0.0000000040%	$0.00059	$0.00048	$0.00099	$0.00080
8	4.6%	0.0000000046%	$0.00068	$0.00054	$0.00113	$0.00089
9	5.1%	0.0000000051%	$0.00076	$0.00058	$0.00127	$0.00097
10	5.7%	0.0000000057%	$0.00085	$0.00063	$0.00141	$0.00105
11	6.3%	0.0000000063%	$0.00093	$0.00067	$0.00155	$0.00112
12	6.9%	0.0000000069%	$0.00102	$0.00071	$0.00169	$0.00118

13	7.4%	0.0000000074%	$0.00110	$0.00075	$0.00183	$0.00125
14	8.0%	0.0000000080%	$0.00119	$0.00078	$0.00197	$0.00130
15	8.6%	0.0000000086%	$0.00127	$0.00082	$0.00211	$0.00136
16	9.1%	0.0000000091%	$0.00136	$0.00085	$0.00225	$0.00140
17	9.7%	0.0000000097%	$0.00144	$0.00087	$0.00239	$0.00145
18	10.3%	0.0000000103%	$0.00153	$0.00090	$0.00253	$0.00149
19	10.9%	0.0000000109%	$0.00161	$0.00092	$0.00267	$0.00153
20	11.4%	0.0000000114%	$0.00170	$0.00094	$0.00282	$0.00156
21	12.0%	0.0000000120%	$0.00178	$0.00096	$0.00296	$0.00159
22	12.6%	0.0000000126%	$0.00187	$0.00097	$0.00310	$0.00162
23	13.1%	0.0000000131%	$0.00195	$0.00099	$0.00324	$0.00164
24	13.7%	0.0000000137%	$0.00204	$0.00100	$0.00338	$0.00166
25	14.3%	0.0000000143%	$0.00212	$0.00101	$0.00352	$0.00168
26	14.9%	0.0000000149%	$0.00220	$0.00102	$0.00366	$0.00170
27	15.4%	0.0000000154%	$0.00229	$0.00103	$0.00380	$0.00171
28	16.0%	0.0000000160%	$0.00237	$0.00104	$0.00394	$0.00172
29	16.6%	0.0000000166%	$0.00246	$0.00104	$0.00408	$0.00173
30	17.1%	0.0000000171%	$0.00254	$0.00105	$0.00422	$0.00174
31	17.7%	0.0000000177%	$0.00263	$0.00105	$0.00436	$0.00175
32	18.3%	0.0000000183%	$0.00271	$0.00105	$0.00450	$0.00175
33	18.9%	0.0000000189%	$0.00280	$0.00105	$0.00464	$0.00175
34	19.4%	0.0000000194%	$0.00288	$0.00106	$0.00479	$0.00175
35	20.0%	0.0000000200%	$0.00297	$0.00105	$0.00493	$0.00175
36	20.6%	0.0000000206%	$0.00305	$0.00105	$0.00507	$0.00175
37	21.1%	0.0000000211%	$0.00314	$0.00105	$0.00521	$0.00174
38	21.7%	0.0000000217%	$0.00322	$0.00105	$0.00535	$0.00174
39	22.3%	0.0000000223%	$0.00331	$0.00104	$0.00549	$0.00173
40	22.9%	0.0000000229%	$0.00339	$0.00104	$0.00563	$0.00173
41	23.4%	0.0000000234%	$0.00348	$0.00103	$0.00577	$0.00172
42	24.0%	0.0000000240%	$0.00356	$0.00103	$0.00591	$0.00171
43	24.6%	0.0000000246%	$0.00365	$0.00102	$0.00605	$0.00170
44	25.1%	0.0000000251%	$0.00373	$0.00102	$0.00619	$0.00169
45	25.7%	0.0000000257%	$0.00382	$0.00101	$0.00633	$0.00167
46	26.3%	0.0000000263%	$0.00390	$0.00100	$0.00647	$0.00166
47	26.9%	0.0000000269%	$0.00399	$0.00099	$0.00662	$0.00165
48	27.4%	0.0000000274%	$0.00407	$0.00098	$0.00676	$0.00164
49	28.0%	0.0000000280%	$0.00415	$0.00098	$0.00690	$0.00162

50	28.6%	0.0000000286%	$0.00424	$0.00097	$0.00704	$0.00161
51	29.1%	0.0000000291%	$0.00432	$0.00096	$0.00718	$0.00159
52	29.7%	0.0000000297%	$0.00441	$0.00095	$0.00732	$0.00157
53	30.3%	0.0000000303%	$0.00449	$0.00094	$0.00746	$0.00156
54	30.9%	0.0000000309%	$0.00458	$0.00093	$0.00760	$0.00154
55	31.4%	0.0000000314%	$0.00466	$0.00092	$0.00774	$0.00152
56	32.0%	0.0000000320%	$0.00475	$0.00091	$0.00788	$0.00151
57	32.6%	0.0000000326%	$0.00483	$0.00090	$0.00802	$0.00149
58	33.1%	0.0000000331%	$0.00492	$0.00089	$0.00816	$0.00147
59	33.7%	0.0000000337%	$0.00500	$0.00087	$0.00830	$0.00145
60	34.3%	0.0000000343%	$0.00509	$0.00086	$0.00845	$0.00143
61	34.9%	0.0000000349%	$0.00517	$0.00085	$0.00859	$0.00141
62	35.4%	0.0000000354%	$0.00526	$0.00084	$0.00873	$0.00140
63	36.0%	0.0000000360%	$0.00534	$0.00083	$0.00887	$0.00138
64	36.6%	0.0000000366%	$0.00543	$0.00082	$0.00901	$0.00136
65	37.1%	0.0000000371%	$0.00551	$0.00081	$0.00915	$0.00134
66	37.7%	0.0000000377%	$0.00560	$0.00080	$0.00929	$0.00132
67	38.3%	0.0000000383%	$0.00568	$0.00078	$0.00943	$0.00130
68	38.9%	0.0000000389%	$0.00577	$0.00077	$0.00957	$0.00128
69	39.4%	0.0000000394%	$0.00585	$0.00076	$0.00971	$0.00126
70	40.0%	0.0000000400%	$0.00594	$0.00075	$0.00985	$0.00124
71	40.6%	0.0000000406%	$0.00602	$0.00074	$0.00999	$0.00123
72	41.1%	0.0000000411%	$0.00611	$0.00073	$0.01013	$0.00121
73	41.7%	0.0000000417%	$0.00619	$0.00072	$0.01028	$0.00119
74	42.3%	0.0000000423%	$0.00627	$0.00070	$0.01042	$0.00117
75	42.9%	0.0000000429%	$0.00636	$0.00069	$0.01056	$0.00115
76	43.4%	0.0000000434%	$0.00644	$0.00068	$0.01070	$0.00113
77	44.0%	0.0000000440%	$0.00653	$0.00067	$0.01084	$0.00111
78	44.6%	0.0000000446%	$0.00661	$0.00066	$0.01098	$0.00109
79	45.1%	0.0000000451%	$0.00670	$0.00065	$0.01112	$0.00108
80	45.7%	0.0000000457%	$0.00678	$0.00064	$0.01126	$0.00106
81	46.3%	0.0000000463%	$0.00687	$0.00063	$0.01140	$0.00104
82	46.9%	0.0000000469%	$0.00695	$0.00062	$0.01154	$0.00102
83	47.4%	0.0000000474%	$0.00704	$0.00061	$0.01168	$0.00100
84	48.0%	0.0000000480%	$0.00712	$0.00059	$0.01182	$0.00099
85	48.6%	0.0000000486%	$0.00721	$0.00058	$0.01196	$0.00097
86	49.1%	0.0000000491%	$0.00729	$0.00057	$0.01211	$0.00095

87	49.7%	0.0000000497%	$0.00738	$0.00056	$0.01225	$0.00094
88	50.3%	0.0000000503%	$0.00746	$0.00055	$0.01239	$0.00092
89	50.9%	0.0000000509%	$0.00755	$0.00054	$0.01253	$0.00090
90	51.4%	0.0000000514%	$0.00763	$0.00053	$0.01267	$0.00089
91	52.0%	0.0000000520%	$0.00772	$0.00052	$0.01281	$0.00087
92	52.6%	0.0000000526%	$0.00780	$0.00051	$0.01295	$0.00085
93	53.1%	0.0000000531%	$0.00789	$0.00050	$0.01309	$0.00084
94	53.7%	0.0000000537%	$0.00797	$0.00050	$0.01323	$0.00082
95	54.3%	0.0000000543%	$0.00806	$0.00049	$0.01337	$0.00081
96	54.9%	0.0000000549%	$0.00814	$0.00048	$0.01351	$0.00079
97	55.4%	0.0000000554%	$0.00822	$0.00047	$0.01365	$0.00078
98	56.0%	0.0000000560%	$0.00831	$0.00046	$0.01379	$0.00076
99	56.6%	0.0000000566%	$0.00839	$0.00045	$0.01393	$0.00075
100	57.1%	0.0000000571%	$0.00848	$0.00044	$0.01408	$0.00073
101	57.7%	0.0000000577%	$0.00856	$0.00043	$0.01422	$0.00072
102	58.3%	0.0000000583%	$0.00865	$0.00042	$0.01436	$0.00070
103	58.9%	0.0000000589%	$0.00873	$0.00042	$0.01450	$0.00069
104	59.4%	0.0000000594%	$0.00882	$0.00041	$0.01464	$0.00068
105	60.0%	0.0000000600%	$0.00890	$0.00040	$0.01478	$0.00066
106	60.6%	0.0000000606%	$0.00899	$0.00039	$0.01492	$0.00065
107	61.1%	0.0000000611%	$0.00907	$0.00038	$0.01506	$0.00064
108	61.7%	0.0000000617%	$0.00916	$0.00038	$0.01520	$0.00062
109	62.3%	0.0000000623%	$0.00924	$0.00037	$0.01534	$0.00061
110	62.9%	0.0000000629%	$0.00933	$0.00036	$0.01548	$0.00060
111	63.4%	0.0000000634%	$0.00941	$0.00035	$0.01562	$0.00059
112	64.0%	0.0000000640%	$0.00950	$0.00035	$0.01576	$0.00058
113	64.6%	0.0000000646%	$0.00958	$0.00034	$0.01591	$0.00056
114	65.1%	0.0000000651%	$0.00967	$0.00033	$0.01605	$0.00055
115	65.7%	0.0000000657%	$0.00975	$0.00033	$0.01619	$0.00054
116	66.3%	0.0000000663%	$0.00984	$0.00032	$0.01633	$0.00053
117	66.9%	0.0000000669%	$0.00992	$0.00031	$0.01647	$0.00052
118	67.4%	0.0000000674%	$0.01001	$0.00031	$0.01661	$0.00051
119	68.0%	0.0000000680%	$0.01009	$0.00030	$0.01675	$0.00050
120	68.6%	0.0000000686%	$0.01018	$0.00029	$0.01689	$0.00049
121	69.1%	0.0000000691%	$0.01026	$0.00029	$0.01703	$0.00048
122	69.7%	0.0000000697%	$0.01034	$0.00028	$0.01717	$0.00047
123	70.3%	0.0000000703%	$0.01043	$0.00027	$0.01731	$0.00046

124	70.9%	0.0000000709%	$0.01051	$0.00027	$0.01745	$0.00045
125	71.4%	0.0000000714%	$0.01060	$0.00026	$0.01759	$0.00044
126	72.0%	0.0000000720%	$0.01068	$0.00026	$0.01774	$0.00043
127	72.6%	0.0000000726%	$0.01077	$0.00025	$0.01788	$0.00042
128	73.1%	0.0000000731%	$0.01085	$0.00025	$0.01802	$0.00041
129	73.7%	0.0000000737%	$0.01094	$0.00024	$0.01816	$0.00040
130	74.3%	0.0000000743%	$0.01102	$0.00024	$0.01830	$0.00039
131	74.9%	0.0000000749%	$0.01111	$0.00023	$0.01844	$0.00038
132	75.4%	0.0000000754%	$0.01119	$0.00023	$0.01858	$0.00038
133	76.0%	0.0000000760%	$0.01128	$0.00022	$0.01872	$0.00037
134	76.6%	0.0000000766%	$0.01136	$0.00022	$0.01886	$0.00036
135	77.1%	0.0000000771%	$0.01145	$0.00021	$0.01900	$0.00035
136	77.7%	0.0000000777%	$0.01153	$0.00021	$0.01914	$0.00034
137	78.3%	0.0000000783%	$0.01162	$0.00020	$0.01928	$0.00034
138	78.9%	0.0000000789%	$0.01170	$0.00020	$0.01942	$0.00033
139	79.4%	0.0000000794%	$0.01179	$0.00019	$0.01957	$0.00032
140	80.0%	0.0000000800%	$0.01187	$0.00019	$0.01971	$0.00031
141	80.6%	0.0000000806%	$0.01196	$0.00019	$0.01985	$0.00031
142	81.1%	0.0000000811%	$0.01204	$0.00018	$0.01999	$0.00030
143	81.7%	0.0000000817%	$0.01213	$0.00018	$0.02013	$0.00029
144	82.3%	0.0000000823%	$0.01221	$0.00017	$0.02027	$0.00029
145	82.9%	0.0000000829%	$0.01229	$0.00017	$0.02041	$0.00028
146	83.4%	0.0000000834%	$0.01238	$0.00017	$0.02055	$0.00027
147	84.0%	0.0000000840%	$0.01246	$0.00016	$0.02069	$0.00027
148	84.6%	0.0000000846%	$0.01255	$0.00016	$0.02083	$0.00026
149	85.1%	0.0000000851%	$0.01263	$0.00015	$0.02097	$0.00026
150	85.7%	0.0000000857%	$0.01272	$0.00015	$0.02111	$0.00025
151	86.3%	0.0000000863%	$0.01280	$0.00015	$0.02125	$0.00024
152	86.9%	0.0000000869%	$0.01289	$0.00014	$0.02139	$0.00024
153	87.4%	0.0000000874%	$0.01297	$0.00014	$0.02154	$0.00023
154	88.0%	0.0000000880%	$0.01306	$0.00014	$0.02168	$0.00023
155	88.6%	0.0000000886%	$0.01314	$0.00013	$0.02182	$0.00022
156	89.1%	0.0000000891%	$0.01323	$0.00013	$0.02196	$0.00022
157	89.7%	0.0000000897%	$0.01331	$0.00013	$0.02210	$0.00021
158	90.3%	0.0000000903%	$0.01340	$0.00013	$0.02224	$0.00021
159	90.9%	0.0000000909%	$0.01348	$0.00012	$0.02238	$0.00020
160	91.4%	0.0000000914%	$0.01357	$0.00012	$0.02252	$0.00020

161	92.0%	0.0000000920%	$0.01365	$0.00012	$0.02266	$0.00019
162	92.6%	0.0000000926%	$0.01374	$0.00011	$0.02280	$0.00019
163	93.1%	0.0000000931%	$0.01382	$0.00011	$0.02294	$0.00019
164	93.7%	0.0000000937%	$0.01391	$0.00011	$0.02308	$0.00018
165	94.3%	0.0000000943%	$0.01399	$0.00011	$0.02322	$0.00018
166	94.9%	0.0000000949%	$0.01408	$0.00010	$0.02337	$0.00017
167	95.4%	0.0000000954%	$0.01416	$0.00010	$0.02351	$0.00017
168	96.0%	0.0000000960%	$0.01425	$0.00010	$0.02365	$0.00016
169	96.6%	0.0000000966%	$0.01433	$0.00010	$0.02379	$0.00016
170	97.1%	0.0000000971%	$0.01441	$0.00009	$0.02393	$0.00016
171	97.7%	0.0000000977%	$0.01450	$0.00009	$0.02407	$0.00015
172	98.3%	0.0000000983%	$0.01458	$0.00009	$0.02421	$0.00015
173	98.9%	0.0000000989%	$0.01467	$0.00009	$0.02435	$0.00015
174	99.4%	0.0000000994%	$0.01475	$0.00009	$0.02449	$0.00014
175	100.0%	0.0000001000%	$0.01484	$0.00008	$0.02463	$0.00014
Beyond (c)				$0.00280		$0.00465
Total				$0.09649		$0.16017

	<--(Employment Impacts - FTE-->	
Year	Direct Effects	Direct & Indirect Effects
0	0	0
1	0	0
2	0	0
3	0	0
4	0	0
5	0	0
6	0	0
7	0	0
8	0	0
9	0	0
10	0	0
11	0	0
12	0	0
13	0	0
14	0	0

15	0	0
16	0	0
17	0	0
18	0	0
19	0	0
20	0	0
21	0	0
22	0	0
23	0	0
24	0	0
25	0	0
26	0	0
27	0	0
28	0	0
29	0	0
30	0	0
31	0	0
32	0	0
33	0	0
34	0	0
35	0	0
36	0	0
37	0	0
38	0	0
39	0	0
40	0	0
41	0	0
42	0	0
43	0	0
44	0	0
45	0	0
46	0	0
47	0	0
48	0	0
49	0	0
50	0	0
51	0	0

52	0	0
53	0	0
54	0	0
55	0	0
56	0	0
57	0	0
58	0	0
59	0	0
60	0	0
61	0	0
62	0	0
63	0	0
64	0	0
65	0	0
66	0	0
67	0	0
68	0	0
69	0	0
70	0	0
71	0	0
72	0	0
73	0	0
74	0	0
75	0	0
76	0	0
77	0	0
78	0	0
79	0	0
80	0	0
81	0	0
82	0	0
83	0	0
84	0	0
85	0	0
86	0	0
87	0	0
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89	0	0
90	0	0
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115	0	0
116	0	0
117	0	0
118	0	0
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120	0	0
121	0	0
122	0	0
123	0	0
124	0	0
125	0	0

126	0	0
127	0	0
128	0	0
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130	0	0
131	0	0
132	0	0
133	0	0
134	0	0
135	0	0
136	0	0
137	0	0
138	0	0
139	0	0
140	0	0
141	0	0
142	0	0
143	0	0
144	0	0
145	0	0
146	0	0
147	0	0
148	0	0
149	0	0
150	0	0
151	0	0
152	0	0
153	0	0
154	0	0
155	0	0
156	0	0
157	0	0
158	0	0
159	0	0
160	0	0
161	0	0
162	0	0

163	0	0
164	0	0
165	0	0
166	0	0
167	0	0
168	0	0
169	0	0
170	0	0
171	0	0
172	0	0
173	0	0
174	0	0
175	0	0

Notes

(a) Percent displacement given certain invasion

(b) Percent displacement given probability of successful invasion

(c) From year 176 into perpetuity

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Appendix 16C. Economic Impact Analysis of Lake Winnipeg Commercial Fishery: Slow Invasion - Low Risk

Probability of successful invasion:	1.00E-06	
Annual discount rate:	3.0%	
Present year:	0	
Invasion year:	0	
Annual landed value (10-year average):	$14,838,754	
Economic impact multipliers		
Output (direct effects):	1.00	
Output (direct & indirect effects - all provinces):	1.66	
Employment (direct effects):	17.41	FTE/million $ direct output
Employment (direct & indirect effects - all provinces):	22.30	FTE/million $ direct output

			<----------(Output Impacts)---------->			
	<-----(Fishery Displacement)----->		<----------(Direct Effects)---------->		<----(Direct & Indirect Effects)---->	
Year	Certain (a)	Expected (b)	Current Value	Present Value	Current Value	Present Value
0	0.0%	0.0000000%	$0.00	$0.00	$0.00	$0.00
1	0.6%	0.0000006%	$0.08	$0.08	$0.14	$0.14
2	1.1%	0.0000011%	$0.17	$0.16	$0.28	$0.27
3	1.7%	0.0000017%	$0.25	$0.23	$0.42	$0.39
4	2.3%	0.0000023%	$0.34	$0.30	$0.56	$0.50
5	2.9%	0.0000029%	$0.42	$0.37	$0.70	$0.61
6	3.4%	0.0000034%	$0.51	$0.43	$0.84	$0.71
7	4.0%	0.0000040%	$0.59	$0.48	$0.99	$0.80
8	4.6%	0.0000046%	$0.68	$0.54	$1.13	$0.89
9	5.1%	0.0000051%	$0.76	$0.58	$1.27	$0.97
10	5.7%	0.0000057%	$0.85	$0.63	$1.41	$1.05
11	6.3%	0.0000063%	$0.93	$0.67	$1.55	$1.12
12	6.9%	0.0000069%	$1.02	$0.71	$1.69	$1.18

13	7.4%	0.0000074%	$1.10	$0.75	$1.83	$1.25
14	8.0%	0.0000080%	$1.19	$0.78	$1.97	$1.30
15	8.6%	0.0000086%	$1.27	$0.82	$2.11	$1.36
16	9.1%	0.0000091%	$1.36	$0.85	$2.25	$1.40
17	9.7%	0.0000097%	$1.44	$0.87	$2.39	$1.45
18	10.3%	0.0000103%	$1.53	$0.90	$2.53	$1.49
19	10.9%	0.0000109%	$1.61	$0.92	$2.67	$1.53
20	11.4%	0.0000114%	$1.70	$0.94	$2.82	$1.56
21	12.0%	0.0000120%	$1.78	$0.96	$2.96	$1.59
22	12.6%	0.0000126%	$1.87	$0.97	$3.10	$1.62
23	13.1%	0.0000131%	$1.95	$0.99	$3.24	$1.64
24	13.7%	0.0000137%	$2.04	$1.00	$3.38	$1.66
25	14.3%	0.0000143%	$2.12	$1.01	$3.52	$1.68
26	14.9%	0.0000149%	$2.20	$1.02	$3.66	$1.70
27	15.4%	0.0000154%	$2.29	$1.03	$3.80	$1.71
28	16.0%	0.0000160%	$2.37	$1.04	$3.94	$1.72
29	16.6%	0.0000166%	$2.46	$1.04	$4.08	$1.73
30	17.1%	0.0000171%	$2.54	$1.05	$4.22	$1.74
31	17.7%	0.0000177%	$2.63	$1.05	$4.36	$1.75
32	18.3%	0.0000183%	$2.71	$1.05	$4.50	$1.75
33	18.9%	0.0000189%	$2.80	$1.05	$4.64	$1.75
34	19.4%	0.0000194%	$2.88	$1.06	$4.79	$1.75
35	20.0%	0.0000200%	$2.97	$1.05	$4.93	$1.75
36	20.6%	0.0000206%	$3.05	$1.05	$5.07	$1.75
37	21.1%	0.0000211%	$3.14	$1.05	$5.21	$1.74
38	21.7%	0.0000217%	$3.22	$1.05	$5.35	$1.74
39	22.3%	0.0000223%	$3.31	$1.04	$5.49	$1.73
40	22.9%	0.0000229%	$3.39	$1.04	$5.63	$1.73
41	23.4%	0.0000234%	$3.48	$1.03	$5.77	$1.72
42	24.0%	0.0000240%	$3.56	$1.03	$5.91	$1.71
43	24.6%	0.0000246%	$3.65	$1.02	$6.05	$1.70
44	25.1%	0.0000251%	$3.73	$1.02	$6.19	$1.69
45	25.7%	0.0000257%	$3.82	$1.01	$6.33	$1.67
46	26.3%	0.0000263%	$3.90	$1.00	$6.47	$1.66
47	26.9%	0.0000269%	$3.99	$0.99	$6.62	$1.65
48	27.4%	0.0000274%	$4.07	$0.98	$6.76	$1.64
49	28.0%	0.0000280%	$4.15	$0.98	$6.90	$1.62

50	28.6%	0.0000286%	$4.24	$0.97	$7.04	$1.61
51	29.1%	0.0000291%	$4.32	$0.96	$7.18	$1.59
52	29.7%	0.0000297%	$4.41	$0.95	$7.32	$1.57
53	30.3%	0.0000303%	$4.49	$0.94	$7.46	$1.56
54	30.9%	0.0000309%	$4.58	$0.93	$7.60	$1.54
55	31.4%	0.0000314%	$4.66	$0.92	$7.74	$1.52
56	32.0%	0.0000320%	$4.75	$0.91	$7.88	$1.51
57	32.6%	0.0000326%	$4.83	$0.90	$8.02	$1.49
58	33.1%	0.0000331%	$4.92	$0.89	$8.16	$1.47
59	33.7%	0.0000337%	$5.00	$0.87	$8.30	$1.45
60	34.3%	0.0000343%	$5.09	$0.86	$8.45	$1.43
61	34.9%	0.0000349%	$5.17	$0.85	$8.59	$1.41
62	35.4%	0.0000354%	$5.26	$0.84	$8.73	$1.40
63	36.0%	0.0000360%	$5.34	$0.83	$8.87	$1.38
64	36.6%	0.0000366%	$5.43	$0.82	$9.01	$1.36
65	37.1%	0.0000371%	$5.51	$0.81	$9.15	$1.34
66	37.7%	0.0000377%	$5.60	$0.80	$9.29	$1.32
67	38.3%	0.0000383%	$5.68	$0.78	$9.43	$1.30
68	38.9%	0.0000389%	$5.77	$0.77	$9.57	$1.28
69	39.4%	0.0000394%	$5.85	$0.76	$9.71	$1.26
70	40.0%	0.0000400%	$5.94	$0.75	$9.85	$1.24
71	40.6%	0.0000406%	$6.02	$0.74	$9.99	$1.23
72	41.1%	0.0000411%	$6.11	$0.73	$10.13	$1.21
73	41.7%	0.0000417%	$6.19	$0.72	$10.28	$1.19
74	42.3%	0.0000423%	$6.27	$0.70	$10.42	$1.17
75	42.9%	0.0000429%	$6.36	$0.69	$10.56	$1.15
76	43.4%	0.0000434%	$6.44	$0.68	$10.70	$1.13
77	44.0%	0.0000440%	$6.53	$0.67	$10.84	$1.11
78	44.6%	0.0000446%	$6.61	$0.66	$10.98	$1.09
79	45.1%	0.0000451%	$6.70	$0.65	$11.12	$1.08
80	45.7%	0.0000457%	$6.78	$0.64	$11.26	$1.06
81	46.3%	0.0000463%	$6.87	$0.63	$11.40	$1.04
82	46.9%	0.0000469%	$6.95	$0.62	$11.54	$1.02
83	47.4%	0.0000474%	$7.04	$0.61	$11.68	$1.00
84	48.0%	0.0000480%	$7.12	$0.59	$11.82	$0.99
85	48.6%	0.0000486%	$7.21	$0.58	$11.96	$0.97
86	49.1%	0.0000491%	$7.29	$0.57	$12.11	$0.95

87	49.7%	0.0000497%	$7.38	$0.56	$12.25	$0.94
88	50.3%	0.0000503%	$7.46	$0.55	$12.39	$0.92
89	50.9%	0.0000509%	$7.55	$0.54	$12.53	$0.90
90	51.4%	0.0000514%	$7.63	$0.53	$12.67	$0.89
91	52.0%	0.0000520%	$7.72	$0.52	$12.81	$0.87
92	52.6%	0.0000526%	$7.80	$0.51	$12.95	$0.85
93	53.1%	0.0000531%	$7.89	$0.50	$13.09	$0.84
94	53.7%	0.0000537%	$7.97	$0.50	$13.23	$0.82
95	54.3%	0.0000543%	$8.06	$0.49	$13.37	$0.81
96	54.9%	0.0000549%	$8.14	$0.48	$13.51	$0.79
97	55.4%	0.0000554%	$8.22	$0.47	$13.65	$0.78
98	56.0%	0.0000560%	$8.31	$0.46	$13.79	$0.76
99	56.6%	0.0000566%	$8.39	$0.45	$13.93	$0.75
100	57.1%	0.0000571%	$8.48	$0.44	$14.08	$0.73
101	57.7%	0.0000577%	$8.56	$0.43	$14.22	$0.72
102	58.3%	0.0000583%	$8.65	$0.42	$14.36	$0.70
103	58.9%	0.0000589%	$8.73	$0.42	$14.50	$0.69
104	59.4%	0.0000594%	$8.82	$0.41	$14.64	$0.68
105	60.0%	0.0000600%	$8.90	$0.40	$14.78	$0.66
106	60.6%	0.0000606%	$8.99	$0.39	$14.92	$0.65
107	61.1%	0.0000611%	$9.07	$0.38	$15.06	$0.64
108	61.7%	0.0000617%	$9.16	$0.38	$15.20	$0.62
109	62.3%	0.0000623%	$9.24	$0.37	$15.34	$0.61
110	62.9%	0.0000629%	$9.33	$0.36	$15.48	$0.60
111	63.4%	0.0000634%	$9.41	$0.35	$15.62	$0.59
112	64.0%	0.0000640%	$9.50	$0.35	$15.76	$0.58
113	64.6%	0.0000646%	$9.58	$0.34	$15.91	$0.56
114	65.1%	0.0000651%	$9.67	$0.33	$16.05	$0.55
115	65.7%	0.0000657%	$9.75	$0.33	$16.19	$0.54
116	66.3%	0.0000663%	$9.84	$0.32	$16.33	$0.53
117	66.9%	0.0000669%	$9.92	$0.31	$16.47	$0.52
118	67.4%	0.0000674%	$10.01	$0.31	$16.61	$0.51
119	68.0%	0.0000680%	$10.09	$0.30	$16.75	$0.50
120	68.6%	0.0000686%	$10.18	$0.29	$16.89	$0.49
121	69.1%	0.0000691%	$10.26	$0.29	$17.03	$0.48
122	69.7%	0.0000697%	$10.34	$0.28	$17.17	$0.47
123	70.3%	0.0000703%	$10.43	$0.27	$17.31	$0.46

124	70.9%	0.0000709%	$10.51	$0.27	$17.45	$0.45
125	71.4%	0.0000714%	$10.60	$0.26	$17.59	$0.44
126	72.0%	0.0000720%	$10.68	$0.26	$17.74	$0.43
127	72.6%	0.0000726%	$10.77	$0.25	$17.88	$0.42
128	73.1%	0.0000731%	$10.85	$0.25	$18.02	$0.41
129	73.7%	0.0000737%	$10.94	$0.24	$18.16	$0.40
130	74.3%	0.0000743%	$11.02	$0.24	$18.30	$0.39
131	74.9%	0.0000749%	$11.11	$0.23	$18.44	$0.38
132	75.4%	0.0000754%	$11.19	$0.23	$18.58	$0.38
133	76.0%	0.0000760%	$11.28	$0.22	$18.72	$0.37
134	76.6%	0.0000766%	$11.36	$0.22	$18.86	$0.36
135	77.1%	0.0000771%	$11.45	$0.21	$19.00	$0.35
136	77.7%	0.0000777%	$11.53	$0.21	$19.14	$0.34
137	78.3%	0.0000783%	$11.62	$0.20	$19.28	$0.34
138	78.9%	0.0000789%	$11.70	$0.20	$19.42	$0.33
139	79.4%	0.0000794%	$11.79	$0.19	$19.57	$0.32
140	80.0%	0.0000800%	$11.87	$0.19	$19.71	$0.31
141	80.6%	0.0000806%	$11.96	$0.19	$19.85	$0.31
142	81.1%	0.0000811%	$12.04	$0.18	$19.99	$0.30
143	81.7%	0.0000817%	$12.13	$0.18	$20.13	$0.29
144	82.3%	0.0000823%	$12.21	$0.17	$20.27	$0.29
145	82.9%	0.0000829%	$12.29	$0.17	$20.41	$0.28
146	83.4%	0.0000834%	$12.38	$0.17	$20.55	$0.27
147	84.0%	0.0000840%	$12.46	$0.16	$20.69	$0.27
148	84.6%	0.0000846%	$12.55	$0.16	$20.83	$0.26
149	85.1%	0.0000851%	$12.63	$0.15	$20.97	$0.26
150	85.7%	0.0000857%	$12.72	$0.15	$21.11	$0.25
151	86.3%	0.0000863%	$12.80	$0.15	$21.25	$0.24
152	86.9%	0.0000869%	$12.89	$0.14	$21.39	$0.24
153	87.4%	0.0000874%	$12.97	$0.14	$21.54	$0.23
154	88.0%	0.0000880%	$13.06	$0.14	$21.68	$0.23
155	88.6%	0.0000886%	$13.14	$0.13	$21.82	$0.22
156	89.1%	0.0000891%	$13.23	$0.13	$21.96	$0.22
157	89.7%	0.0000897%	$13.31	$0.13	$22.10	$0.21
158	90.3%	0.0000903%	$13.40	$0.13	$22.24	$0.21
159	90.9%	0.0000909%	$13.48	$0.12	$22.38	$0.20
160	91.4%	0.0000914%	$13.57	$0.12	$22.52	$0.20

161	92.0%	0.0000920%	$13.65	$0.12	$22.66	$0.19
162	92.6%	0.0000926%	$13.74	$0.11	$22.80	$0.19
163	93.1%	0.0000931%	$13.82	$0.11	$22.94	$0.19
164	93.7%	0.0000937%	$13.91	$0.11	$23.08	$0.18
165	94.3%	0.0000943%	$13.99	$0.11	$23.22	$0.18
166	94.9%	0.0000949%	$14.08	$0.10	$23.37	$0.17
167	95.4%	0.0000954%	$14.16	$0.10	$23.51	$0.17
168	96.0%	0.0000960%	$14.25	$0.10	$23.65	$0.16
169	96.6%	0.0000966%	$14.33	$0.10	$23.79	$0.16
170	97.1%	0.0000971%	$14.41	$0.09	$23.93	$0.16
171	97.7%	0.0000977%	$14.50	$0.09	$24.07	$0.15
172	98.3%	0.0000983%	$14.58	$0.09	$24.21	$0.15
173	98.9%	0.0000989%	$14.67	$0.09	$24.35	$0.15
174	99.4%	0.0000994%	$14.75	$0.09	$24.49	$0.14
175	100.0%	0.0001000%	$14.84	$0.08	$24.63	$0.14
Beyond (c)				$2.80		$4.65
Total				$96.49		$160.17

	<--(Employment Impacts - FTE)-->	
Year	Direct Effects	Direct & Indirect Effects
0	0	0
1	0	0
2	0	0
3	0	0
4	0	0
5	0	0
6	0	0
7	0	0
8	0	0
9	0	0
10	0	0
11	0	0
12	0	0
13	0	0
14	0	0

15	0	0
16	0	0
17	0	0
18	0	0
19	0	0
20	0	0
21	0	0
22	0	0
23	0	0
24	0	0
25	0	0
26	0	0
27	0	0
28	0	0
29	0	0
30	0	0
31	0	0
32	0	0
33	0	0
34	0	0
35	0	0
36	0	0
37	0	0
38	0	0
39	0	0
40	0	0
41	0	0
42	0	0
43	0	0
44	0	0
45	0	0
46	0	0
47	0	0
48	0	0
49	0	0
50	0	0
51	0	0

52	0	0
53	0	0
54	0	0
55	0	0
56	0	0
57	0	0
58	0	0
59	0	0
60	0	0
61	0	0
62	0	0
63	0	0
64	0	0
65	0	0
66	0	0
67	0	0
68	0	0
69	0	0
70	0	0
71	0	0
72	0	0
73	0	0
74	0	0
75	0	0
76	0	0
77	0	0
78	0	0
79	0	0
80	0	0
81	0	0
82	0	0
83	0	0
84	0	0
85	0	0
86	0	0
87	0	0
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89	0	0
90	0	0
91	0	0
92	0	0
93	0	0
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97	0	0
98	0	0
99	0	0
100	0	0
101	0	0
102	0	0
103	0	0
104	0	0
105	0	0
106	0	0
107	0	0
108	0	0
109	0	0
110	0	0
111	0	0
112	0	0
113	0	0
114	0	0
115	0	0
116	0	0
117	0	0
118	0	0
119	0	0
120	0	0
121	0	0
122	0	0
123	0	0
124	0	0
125	0	0

126	0	0
127	0	0
128	0	0
129	0	0
130	0	0
131	0	0
132	0	0
133	0	0
134	0	0
135	0	0
136	0	0
137	0	0
138	0	0
139	0	0
140	0	0
141	0	0
142	0	0
143	0	0
144	0	0
145	0	0
146	0	0
147	0	0
148	0	0
149	0	0
150	0	0
151	0	0
152	0	0
153	0	0
154	0	0
155	0	0
156	0	0
157	0	0
158	0	0
159	0	0
160	0	0
161	0	0
162	0	0

163	0	0
164	0	0
165	0	0
166	0	0
167	0	0
168	0	0
169	0	0
170	0	0
171	0	0
172	0	0
173	0	0
174	0	0
175	0	0

Notes

(a) Percent displacement given certain invasion

(b) Percent displacement given probability of successful invasion

(c) From year 176 into perpetuity

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Appendix 16D. Economic Impact Analysis of Lake Winnipeg Commercial Fishery: Slow Invasion - Moderate Risk

Probability of successful invasion:	1.00E-03	
Annual discount rate:	3.0%	
Present year:	0	
Invasion year:	0	
Annual landed value (10-year average):	$14,838,754	
Economic impact multipliers		
Output (direct effects):	1.00	
Output (direct & indirect effects - all provinces):	1.66	
Employment (direct effects):	17.41	FTE/million $ direct output
Employment (direct & indirect effects - all provinces):	22.30	FTE/million $ direct output

			<----------(Output Impacts)---------->			
	<-----(Fishery Displacement)----->		<----------(Direct Effects)---------->		<----(Direct & Indirect Effects)---->	
Year	Certain (a)	Expected (b)	Current Value	Present Value	Current Value	Present Value
0	0.0%	0.0000%	$0	$0	$0	$0
1	0.6%	0.0006%	$85	$82	$141	$137
2	1.1%	0.0011%	$170	$160	$282	$265
3	1.7%	0.0017%	$254	$233	$422	$386
4	2.3%	0.0023%	$339	$301	$563	$500
5	2.9%	0.0029%	$424	$366	$704	$607
6	3.4%	0.0034%	$509	$426	$845	$707
7	4.0%	0.0040%	$594	$483	$985	$801
8	4.6%	0.0046%	$678	$535	$1,126	$889
9	5.1%	0.0051%	$763	$585	$1,267	$971
10	5.7%	0.0057%	$848	$631	$1,408	$1,047
11	6.3%	0.0063%	$933	$674	$1,548	$1,119
12	6.9%	0.0069%	$1,018	$714	$1,689	$1,185

13	7.4%	0.0074%	$1,102	$751	$1,830	$1,246
14	8.0%	0.0080%	$1,187	$785	$1,971	$1,303
15	8.6%	0.0086%	$1,272	$816	$2,111	$1,355
16	9.1%	0.0091%	$1,357	$845	$2,252	$1,403
17	9.7%	0.0097%	$1,441	$872	$2,393	$1,448
18	10.3%	0.0103%	$1,526	$897	$2,534	$1,488
19	10.9%	0.0109%	$1,611	$919	$2,674	$1,525
20	11.4%	0.0114%	$1,696	$939	$2,815	$1,559
21	12.0%	0.0120%	$1,781	$957	$2,956	$1,589
22	12.6%	0.0126%	$1,865	$974	$3,097	$1,616
23	13.1%	0.0131%	$1,950	$988	$3,237	$1,640
24	13.7%	0.0137%	$2,035	$1,001	$3,378	$1,662
25	14.3%	0.0143%	$2,120	$1,012	$3,519	$1,681
26	14.9%	0.0149%	$2,205	$1,022	$3,660	$1,697
27	15.4%	0.0154%	$2,289	$1,031	$3,800	$1,711
28	16.0%	0.0160%	$2,374	$1,038	$3,941	$1,723
29	16.6%	0.0166%	$2,459	$1,043	$4,082	$1,732
30	17.1%	0.0171%	$2,544	$1,048	$4,223	$1,740
31	17.7%	0.0177%	$2,629	$1,051	$4,363	$1,745
32	18.3%	0.0183%	$2,713	$1,054	$4,504	$1,749
33	18.9%	0.0189%	$2,798	$1,055	$4,645	$1,751
34	19.4%	0.0194%	$2,883	$1,055	$4,786	$1,752
35	20.0%	0.0200%	$2,968	$1,055	$4,926	$1,751
36	20.6%	0.0206%	$3,053	$1,053	$5,067	$1,748
37	21.1%	0.0211%	$3,137	$1,051	$5,208	$1,745
38	21.7%	0.0217%	$3,222	$1,048	$5,349	$1,740
39	22.3%	0.0223%	$3,307	$1,044	$5,489	$1,733
40	22.9%	0.0229%	$3,392	$1,040	$5,630	$1,726
41	23.4%	0.0234%	$3,477	$1,035	$5,771	$1,718
42	24.0%	0.0240%	$3,561	$1,029	$5,912	$1,708
43	24.6%	0.0246%	$3,646	$1,023	$6,053	$1,698
44	25.1%	0.0251%	$3,731	$1,016	$6,193	$1,687
45	25.7%	0.0257%	$3,816	$1,009	$6,334	$1,675
46	26.3%	0.0263%	$3,900	$1,001	$6,475	$1,662
47	26.9%	0.0269%	$3,985	$993	$6,616	$1,649
48	27.4%	0.0274%	$4,070	$985	$6,756	$1,635
49	28.0%	0.0280%	$4,155	$976	$6,897	$1,620

50	28.6%	0.0286%	$4,240	$967	$7,038	$1,605
51	29.1%	0.0291%	$4,324	$958	$7,179	$1,590
52	29.7%	0.0297%	$4,409	$948	$7,319	$1,574
53	30.3%	0.0303%	$4,494	$938	$7,460	$1,557
54	30.9%	0.0309%	$4,579	$928	$7,601	$1,540
55	31.4%	0.0314%	$4,664	$918	$7,742	$1,523
56	32.0%	0.0320%	$4,748	$907	$7,882	$1,506
57	32.6%	0.0326%	$4,833	$896	$8,023	$1,488
58	33.1%	0.0331%	$4,918	$886	$8,164	$1,470
59	33.7%	0.0337%	$5,003	$875	$8,305	$1,452
60	34.3%	0.0343%	$5,088	$864	$8,445	$1,433
61	34.9%	0.0349%	$5,172	$852	$8,586	$1,415
62	35.4%	0.0354%	$5,257	$841	$8,727	$1,396
63	36.0%	0.0360%	$5,342	$830	$8,868	$1,377
64	36.6%	0.0366%	$5,427	$818	$9,008	$1,359
65	37.1%	0.0371%	$5,512	$807	$9,149	$1,340
66	37.7%	0.0377%	$5,596	$796	$9,290	$1,321
67	38.3%	0.0383%	$5,681	$784	$9,431	$1,302
68	38.9%	0.0389%	$5,766	$773	$9,571	$1,282
69	39.4%	0.0394%	$5,851	$761	$9,712	$1,263
70	40.0%	0.0400%	$5,936	$750	$9,853	$1,244
71	40.6%	0.0406%	$6,020	$738	$9,994	$1,225
72	41.1%	0.0411%	$6,105	$727	$10,134	$1,206
73	41.7%	0.0417%	$6,190	$715	$10,275	$1,188
74	42.3%	0.0423%	$6,275	$704	$10,416	$1,169
75	42.9%	0.0429%	$6,359	$693	$10,557	$1,150
76	43.4%	0.0434%	$6,444	$682	$10,697	$1,131
77	44.0%	0.0440%	$6,529	$670	$10,838	$1,113
78	44.6%	0.0446%	$6,614	$659	$10,979	$1,095
79	45.1%	0.0451%	$6,699	$648	$11,120	$1,076
80	45.7%	0.0457%	$6,783	$637	$11,260	$1,058
81	46.3%	0.0463%	$6,868	$627	$11,401	$1,040
82	46.9%	0.0469%	$6,953	$616	$11,542	$1,022
83	47.4%	0.0474%	$7,038	$605	$11,683	$1,005
84	48.0%	0.0480%	$7,123	$595	$11,824	$987
85	48.6%	0.0486%	$7,207	$584	$11,964	$970
86	49.1%	0.0491%	$7,292	$574	$12,105	$953

87	49.7%	0.0497%	$7,377	$564	$12,246	$936
88	50.3%	0.0503%	$7,462	$554	$12,387	$919
89	50.9%	0.0509%	$7,547	$544	$12,527	$902
90	51.4%	0.0514%	$7,631	$534	$12,668	$886
91	52.0%	0.0520%	$7,716	$524	$12,809	$870
92	52.6%	0.0526%	$7,801	$514	$12,950	$854
93	53.1%	0.0531%	$7,886	$505	$13,090	$838
94	53.7%	0.0537%	$7,971	$495	$13,231	$822
95	54.3%	0.0543%	$8,055	$486	$13,372	$807
96	54.9%	0.0549%	$8,140	$477	$13,513	$791
97	55.4%	0.0554%	$8,225	$468	$13,653	$776
98	56.0%	0.0560%	$8,310	$459	$13,794	$761
99	56.6%	0.0566%	$8,394	$450	$13,935	$747
100	57.1%	0.0571%	$8,479	$441	$14,076	$732
101	57.7%	0.0577%	$8,564	$433	$14,216	$718
102	58.3%	0.0583%	$8,649	$424	$14,357	$704
103	58.9%	0.0589%	$8,734	$416	$14,498	$690
104	59.4%	0.0594%	$8,818	$408	$14,639	$677
105	60.0%	0.0600%	$8,903	$400	$14,779	$663
106	60.6%	0.0606%	$8,988	$392	$14,920	$650
107	61.1%	0.0611%	$9,073	$384	$15,061	$637
108	61.7%	0.0617%	$9,158	$376	$15,202	$624
109	62.3%	0.0623%	$9,242	$369	$15,342	$612
110	62.9%	0.0629%	$9,327	$361	$15,483	$599
111	63.4%	0.0634%	$9,412	$354	$15,624	$587
112	64.0%	0.0640%	$9,497	$347	$15,765	$575
113	64.6%	0.0646%	$9,582	$339	$15,905	$564
114	65.1%	0.0651%	$9,666	$333	$16,046	$552
115	65.7%	0.0657%	$9,751	$326	$16,187	$541
116	66.3%	0.0663%	$9,836	$319	$16,328	$529
117	66.9%	0.0669%	$9,921	$312	$16,468	$518
118	67.4%	0.0674%	$10,006	$306	$16,609	$508
119	68.0%	0.0680%	$10,090	$299	$16,750	$497
120	68.6%	0.0686%	$10,175	$293	$16,891	$487
121	69.1%	0.0691%	$10,260	$287	$17,031	$476
122	69.7%	0.0697%	$10,345	$281	$17,172	$466
123	70.3%	0.0703%	$10,430	$275	$17,313	$456

124	70.9%	0.0709%	$10,514	$269	$17,454	$447
125	71.4%	0.0714%	$10,599	$263	$17,595	$437
126	72.0%	0.0720%	$10,684	$258	$17,735	$428
127	72.6%	0.0726%	$10,769	$252	$17,876	$419
128	73.1%	0.0731%	$10,853	$247	$18,017	$410
129	73.7%	0.0737%	$10,938	$242	$18,158	$401
130	74.3%	0.0743%	$11,023	$236	$18,298	$392
131	74.9%	0.0749%	$11,108	$231	$18,439	$384
132	75.4%	0.0754%	$11,193	$226	$18,580	$375
133	76.0%	0.0760%	$11,277	$221	$18,721	$367
134	76.6%	0.0766%	$11,362	$216	$18,861	$359
135	77.1%	0.0771%	$11,447	$212	$19,002	$351
136	77.7%	0.0777%	$11,532	$207	$19,143	$344
137	78.3%	0.0783%	$11,617	$202	$19,284	$336
138	78.9%	0.0789%	$11,701	$198	$19,424	$329
139	79.4%	0.0794%	$11,786	$194	$19,565	$321
140	80.0%	0.0800%	$11,871	$189	$19,706	$314
141	80.6%	0.0806%	$11,956	$185	$19,847	$307
142	81.1%	0.0811%	$12,041	$181	$19,987	$301
143	81.7%	0.0817%	$12,125	$177	$20,128	$294
144	82.3%	0.0823%	$12,210	$173	$20,269	$287
145	82.9%	0.0829%	$12,295	$169	$20,410	$281
146	83.4%	0.0834%	$12,380	$165	$20,550	$275
147	84.0%	0.0840%	$12,465	$162	$20,691	$268
148	84.6%	0.0846%	$12,549	$158	$20,832	$262
149	85.1%	0.0851%	$12,634	$154	$20,973	$256
150	85.7%	0.0857%	$12,719	$151	$21,113	$251
151	86.3%	0.0863%	$12,804	$148	$21,254	$245
152	86.9%	0.0869%	$12,889	$144	$21,395	$239
153	87.4%	0.0874%	$12,973	$141	$21,536	$234
154	88.0%	0.0880%	$13,058	$138	$21,676	$229
155	88.6%	0.0886%	$13,143	$135	$21,817	$223
156	89.1%	0.0891%	$13,228	$131	$21,958	$218
157	89.7%	0.0897%	$13,312	$128	$22,099	$213
158	90.3%	0.0903%	$13,397	$126	$22,239	$208
159	90.9%	0.0909%	$13,482	$123	$22,380	$204
160	91.4%	0.0914%	$13,567	$120	$22,521	$199

161	92.0%	0.0920%	$13,652	$117	$22,662	$194
162	92.6%	0.0926%	$13,736	$114	$22,803	$190
163	93.1%	0.0931%	$13,821	$112	$22,943	$185
164	93.7%	0.0937%	$13,906	$109	$23,084	$181
165	94.3%	0.0943%	$13,991	$107	$23,225	$177
166	94.9%	0.0949%	$14,076	$104	$23,366	$173
167	95.4%	0.0954%	$14,160	$102	$23,506	$169
168	96.0%	0.0960%	$14,245	$99	$23,647	$165
169	96.6%	0.0966%	$14,330	$97	$23,788	$161
170	97.1%	0.0971%	$14,415	$95	$23,929	$157
171	97.7%	0.0977%	$14,500	$93	$24,069	$154
172	98.3%	0.0983%	$14,584	$90	$24,210	$150
173	98.9%	0.0989%	$14,669	$88	$24,351	$146
174	99.4%	0.0994%	$14,754	$86	$24,492	$143
175	100.0%	0.1000%	$14,839	$84	$24,632	$140
Beyond (c)				$2,804		$4,654
Total				$96,491		$160,174

	<--(Employment Impacts - FTE)-->	
Year	Direct Effects	Direct & Indirect Effects
0	0	0
1	0	0
2	0	0
3	0	0
4	0	0
5	0	0
6	0	0
7	0	0
8	0	0
9	0	0
10	0	0
11	0	0
12	0	0
13	0	0
14	0	0

15	0	0
16	0	0
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167	0	0
168	0	0
169	0	0
170	0	0
171	0	0
172	0	0
173	0	0
174	0	0
175	0	0

Notes

(a) Percent displacement given certain invasion

(b) Percent displacement given probability of successful invasion

(c) From year 176 into perpetuity

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Appendix 16E. Economic Impact Analysis of Lake Winnipeg Commercial Fishery: Slow Invasion - High Risk

Probability of successful invasion:	1.00E-02	
Annual discount rate:	3.0%	
Present year:	0	
Invasion year:	0	
Annual landed value (10-year average):	$14,838,754	
Economic impact multipliers		
Output (direct effects):	1.00	
Output (direct & indirect effects - all provinces):	1.66	
Employment (direct effects):	17.41	FTE/million $ direct output
Employment (direct & indirect effects - all provinces):	22.30	FTE/million $ direct output

			<----------(Output Impacts)---------->			
	<-----(Fishery Displacement)----->		<----------(Direct Effects)---------->		<----(Direct & Indirect Effects)---->	
Year	Certain (a)	Expected (b)	Current Value	Present Value	Current Value	Present Value
0	0.0%	0.000%	$0	$0	$0	$0
1	0.6%	0.006%	$848	$823	$1,408	$1,367
2	1.1%	0.011%	$1,696	$1,599	$2,815	$2,654
3	1.7%	0.017%	$2,544	$2,328	$4,223	$3,864
4	2.3%	0.023%	$3,392	$3,013	$5,630	$5,002
5	2.9%	0.029%	$4,240	$3,657	$7,038	$6,071
6	3.4%	0.034%	$5,088	$4,261	$8,445	$7,073
7	4.0%	0.040%	$5,936	$4,826	$9,853	$8,011
8	4.6%	0.046%	$6,783	$5,355	$11,260	$8,889
9	5.1%	0.051%	$7,631	$5,849	$12,668	$9,709
10	5.7%	0.057%	$8,479	$6,309	$14,076	$10,474
11	6.3%	0.063%	$9,327	$6,738	$15,483	$11,185
12	6.9%	0.069%	$10,175	$7,137	$16,891	$11,847

13	7.4%	0.074%	$11,023	$7,506	$18,298	$12,460
14	8.0%	0.080%	$11,871	$7,848	$19,706	$13,028
15	8.6%	0.086%	$12,719	$8,164	$21,113	$13,552
16	9.1%	0.091%	$13,567	$8,454	$22,521	$14,034
17	9.7%	0.097%	$14,415	$8,721	$23,929	$14,477
18	10.3%	0.103%	$15,263	$8,965	$25,336	$14,882
19	10.9%	0.109%	$16,111	$9,188	$26,744	$15,252
20	11.4%	0.114%	$16,959	$9,390	$28,151	$15,587
21	12.0%	0.120%	$17,807	$9,572	$29,559	$15,889
22	12.6%	0.126%	$18,654	$9,736	$30,966	$16,161
23	13.1%	0.131%	$19,502	$9,882	$32,374	$16,404
24	13.7%	0.137%	$20,350	$10,011	$33,781	$16,618
25	14.3%	0.143%	$21,198	$10,124	$35,189	$16,806
26	14.9%	0.149%	$22,046	$10,223	$36,597	$16,970
27	15.4%	0.154%	$22,894	$10,307	$38,004	$17,109
28	16.0%	0.160%	$23,742	$10,377	$39,412	$17,226
29	16.6%	0.166%	$24,590	$10,435	$40,819	$17,322
30	17.1%	0.171%	$25,438	$10,480	$42,227	$17,397
31	17.7%	0.177%	$26,286	$10,514	$43,634	$17,453
32	18.3%	0.183%	$27,134	$10,537	$45,042	$17,491
33	18.9%	0.189%	$27,982	$10,550	$46,450	$17,513
34	19.4%	0.194%	$28,830	$10,553	$47,857	$17,518
35	20.0%	0.200%	$29,678	$10,547	$49,265	$17,508
36	20.6%	0.206%	$30,525	$10,532	$50,672	$17,484
37	21.1%	0.211%	$31,373	$10,510	$52,080	$17,446
38	21.7%	0.217%	$32,221	$10,479	$53,487	$17,395
39	22.3%	0.223%	$33,069	$10,442	$54,895	$17,333
40	22.9%	0.229%	$33,917	$10,398	$56,302	$17,260
41	23.4%	0.234%	$34,765	$10,347	$57,710	$17,176
42	24.0%	0.240%	$35,613	$10,291	$59,118	$17,083
43	24.6%	0.246%	$36,461	$10,229	$60,525	$16,980
44	25.1%	0.251%	$37,309	$10,162	$61,933	$16,869
45	25.7%	0.257%	$38,157	$10,090	$63,340	$16,750
46	26.3%	0.263%	$39,005	$10,014	$64,748	$16,623
47	26.9%	0.269%	$39,853	$9,934	$66,155	$16,490
48	27.4%	0.274%	$40,701	$9,849	$67,563	$16,350
49	28.0%	0.280%	$41,549	$9,762	$68,971	$16,205

50	28.6%	0.286%	$42,396	$9,671	$70,378	$16,054
51	29.1%	0.291%	$43,244	$9,577	$71,786	$15,898
52	29.7%	0.297%	$44,092	$9,480	$73,193	$15,737
53	30.3%	0.303%	$44,940	$9,381	$74,601	$15,573
54	30.9%	0.309%	$45,788	$9,280	$76,008	$15,405
55	31.4%	0.314%	$46,636	$9,176	$77,416	$15,233
56	32.0%	0.320%	$47,484	$9,071	$78,823	$15,058
57	32.6%	0.326%	$48,332	$8,964	$80,231	$14,881
58	33.1%	0.331%	$49,180	$8,856	$81,639	$14,701
59	33.7%	0.337%	$50,028	$8,746	$83,046	$14,519
60	34.3%	0.343%	$50,876	$8,635	$84,454	$14,335
61	34.9%	0.349%	$51,724	$8,524	$85,861	$14,149
62	35.4%	0.354%	$52,572	$8,411	$87,269	$13,962
63	36.0%	0.360%	$53,420	$8,298	$88,676	$13,774
64	36.6%	0.366%	$54,267	$8,184	$90,084	$13,585
65	37.1%	0.371%	$55,115	$8,070	$91,492	$13,396
66	37.7%	0.377%	$55,963	$7,955	$92,899	$13,205
67	38.3%	0.383%	$56,811	$7,840	$94,307	$13,015
68	38.9%	0.389%	$57,659	$7,726	$95,714	$12,825
69	39.4%	0.394%	$58,507	$7,611	$97,122	$12,634
70	40.0%	0.400%	$59,355	$7,496	$98,529	$12,444
71	40.6%	0.406%	$60,203	$7,382	$99,937	$12,254
72	41.1%	0.411%	$61,051	$7,268	$101,344	$12,065
73	41.7%	0.417%	$61,899	$7,154	$102,752	$11,876
74	42.3%	0.423%	$62,747	$7,041	$104,160	$11,688
75	42.9%	0.429%	$63,595	$6,928	$105,567	$11,501
76	43.4%	0.434%	$64,443	$6,816	$106,975	$11,315
77	44.0%	0.440%	$65,291	$6,705	$108,382	$11,130
78	44.6%	0.446%	$66,138	$6,594	$109,790	$10,946
79	45.1%	0.451%	$66,986	$6,484	$111,197	$10,764
80	45.7%	0.457%	$67,834	$6,375	$112,605	$10,582
81	46.3%	0.463%	$68,682	$6,267	$114,013	$10,402
82	46.9%	0.469%	$69,530	$6,159	$115,420	$10,224
83	47.4%	0.474%	$70,378	$6,053	$116,828	$10,047
84	48.0%	0.480%	$71,226	$5,947	$118,235	$9,872
85	48.6%	0.486%	$72,074	$5,843	$119,643	$9,699
86	49.1%	0.491%	$72,922	$5,739	$121,050	$9,527

87	49.7%	0.497%	$73,770	$5,637	$122,458	$9,357
88	50.3%	0.503%	$74,618	$5,536	$123,865	$9,189
89	50.9%	0.509%	$75,466	$5,435	$125,273	$9,023
90	51.4%	0.514%	$76,314	$5,336	$126,681	$8,858
91	52.0%	0.520%	$77,162	$5,239	$128,088	$8,696
92	52.6%	0.526%	$78,009	$5,142	$129,496	$8,536
93	53.1%	0.531%	$78,857	$5,046	$130,903	$8,377
94	53.7%	0.537%	$79,705	$4,952	$132,311	$8,220
95	54.3%	0.543%	$80,553	$4,859	$133,718	$8,066
96	54.9%	0.549%	$81,401	$4,767	$135,126	$7,913
97	55.4%	0.554%	$82,249	$4,676	$136,533	$7,763
98	56.0%	0.560%	$83,097	$4,587	$137,941	$7,615
99	56.6%	0.566%	$83,945	$4,499	$139,349	$7,468
100	57.1%	0.571%	$84,793	$4,412	$140,756	$7,324
101	57.7%	0.577%	$85,641	$4,326	$142,164	$7,182
102	58.3%	0.583%	$86,489	$4,242	$143,571	$7,042
103	58.9%	0.589%	$87,337	$4,159	$144,979	$6,904
104	59.4%	0.594%	$88,185	$4,077	$146,386	$6,768
105	60.0%	0.600%	$89,033	$3,996	$147,794	$6,634
106	60.6%	0.606%	$89,880	$3,917	$149,202	$6,502
107	61.1%	0.611%	$90,728	$3,838	$150,609	$6,372
108	61.7%	0.617%	$91,576	$3,762	$152,017	$6,244
109	62.3%	0.623%	$92,424	$3,686	$153,424	$6,118
110	62.9%	0.629%	$93,272	$3,611	$154,832	$5,995
111	63.4%	0.634%	$94,120	$3,538	$156,239	$5,873
112	64.0%	0.640%	$94,968	$3,466	$157,647	$5,753
113	64.6%	0.646%	$95,816	$3,395	$159,054	$5,636
114	65.1%	0.651%	$96,664	$3,325	$160,462	$5,520
115	65.7%	0.657%	$97,512	$3,257	$161,870	$5,406
116	66.3%	0.663%	$98,360	$3,189	$163,277	$5,294
117	66.9%	0.669%	$99,208	$3,123	$164,685	$5,184
118	67.4%	0.674%	$100,056	$3,058	$166,092	$5,076
119	68.0%	0.680%	$100,904	$2,994	$167,500	$4,970
120	68.6%	0.686%	$101,751	$2,931	$168,907	$4,866
121	69.1%	0.691%	$102,599	$2,870	$170,315	$4,764
122	69.7%	0.697%	$103,447	$2,809	$171,723	$4,663
123	70.3%	0.703%	$104,295	$2,750	$173,130	$4,565

124	70.9%	0.709%	$105,143	$2,691	$174,538	$4,468
125	71.4%	0.714%	$105,991	$2,634	$175,945	$4,372
126	72.0%	0.720%	$106,839	$2,578	$177,353	$4,279
127	72.6%	0.726%	$107,687	$2,523	$178,760	$4,187
128	73.1%	0.731%	$108,535	$2,468	$180,168	$4,097
129	73.7%	0.737%	$109,383	$2,415	$181,575	$4,009
130	74.3%	0.743%	$110,231	$2,363	$182,983	$3,923
131	74.9%	0.749%	$111,079	$2,312	$184,391	$3,838
132	75.4%	0.754%	$111,927	$2,262	$185,798	$3,754
133	76.0%	0.760%	$112,775	$2,212	$187,206	$3,673
134	76.6%	0.766%	$113,622	$2,164	$188,613	$3,592
135	77.1%	0.771%	$114,470	$2,117	$190,021	$3,514
136	77.7%	0.777%	$115,318	$2,070	$191,428	$3,437
137	78.3%	0.783%	$116,166	$2,025	$192,836	$3,361
138	78.9%	0.789%	$117,014	$1,980	$194,244	$3,287
139	79.4%	0.794%	$117,862	$1,936	$195,651	$3,214
140	80.0%	0.800%	$118,710	$1,894	$197,059	$3,143
141	80.6%	0.806%	$119,558	$1,852	$198,466	$3,074
142	81.1%	0.811%	$120,406	$1,810	$199,874	$3,005
143	81.7%	0.817%	$121,254	$1,770	$201,281	$2,938
144	82.3%	0.823%	$122,102	$1,730	$202,689	$2,873
145	82.9%	0.829%	$122,950	$1,692	$204,096	$2,808
146	83.4%	0.834%	$123,798	$1,654	$205,504	$2,745
147	84.0%	0.840%	$124,646	$1,617	$206,912	$2,684
148	84.6%	0.846%	$125,493	$1,580	$208,319	$2,623
149	85.1%	0.851%	$126,341	$1,545	$209,727	$2,564
150	85.7%	0.857%	$127,189	$1,510	$211,134	$2,506
151	86.3%	0.863%	$128,037	$1,475	$212,542	$2,449
152	86.9%	0.869%	$128,885	$1,442	$213,949	$2,394
153	87.4%	0.874%	$129,733	$1,409	$215,357	$2,339
154	88.0%	0.880%	$130,581	$1,377	$216,765	$2,286
155	88.6%	0.886%	$131,429	$1,346	$218,172	$2,234
156	89.1%	0.891%	$132,277	$1,315	$219,580	$2,183
157	89.7%	0.897%	$133,125	$1,285	$220,987	$2,133
158	90.3%	0.903%	$133,973	$1,255	$222,395	$2,084
159	90.9%	0.909%	$134,821	$1,226	$223,802	$2,036
160	91.4%	0.914%	$135,669	$1,198	$225,210	$1,989

161	92.0%	0.920%	$136,517	$1,171	$226,617	$1,943
162	92.6%	0.926%	$137,364	$1,144	$228,025	$1,898
163	93.1%	0.931%	$138,212	$1,117	$229,433	$1,854
164	93.7%	0.937%	$139,060	$1,091	$230,840	$1,811
165	94.3%	0.943%	$139,908	$1,066	$232,248	$1,769
166	94.9%	0.949%	$140,756	$1,041	$233,655	$1,728
167	95.4%	0.954%	$141,604	$1,017	$235,063	$1,688
168	96.0%	0.960%	$142,452	$993	$236,470	$1,649
169	96.6%	0.966%	$143,300	$970	$237,878	$1,610
170	97.1%	0.971%	$144,148	$947	$239,286	$1,572
171	97.7%	0.977%	$144,996	$925	$240,693	$1,536
172	98.3%	0.983%	$145,844	$903	$242,101	$1,500
173	98.9%	0.989%	$146,692	$882	$243,508	$1,464
174	99.4%	0.994%	$147,540	$861	$244,916	$1,430
175	100.0%	1.000%	$148,388	$841	$246,323	$1,396
Beyond (c)				$28,039		$46,545
Total				$964,906		$1,601,745

	<--(Employment Impacts - FTE-->	
Year	Direct Effects	Direct & Indirect Effects
0	0	0
1	0	0
2	0	0
3	0	0
4	0	0
5	0	0
6	0	0
7	0	0
8	0	0
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11	0	0
12	0	0
13	0	0
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170	3	3
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174	3	3
175	3	3

Notes

(a) Percent displacement given certain invasion

(b) Percent displacement given probability of successful invasion

(c) From year 176 into perpetuity

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Appendix 16F. Economic Impact Analysis of Lake Winnipeg Commercial Fishery: Slow Invasion - Very High Risk

Probability of successful invasion:	1.00E+00	
Annual discount rate:	3.0%	
Present year:	0	
Invasion year:	0	
Annual landed value (10-year average):	$14,838,754	
Economic impact multipliers		
Output (direct effects):	1.00	
Output (direct & indirect effects - all provinces):	1.66	
Employment (direct effects):	17.41	FTE/million $ direct output
Employment (direct & indirect effects - all provinces):	22.30	FTE/million $ direct output

			<----------(Output Impacts)---------->			
	<-----(Fishery Displacement)----->		<----------(Direct Effects)---------->		<----(Direct & Indirect Effects)---->	
Year	Certain (a)	Expected (b)	Current Value	Present Value	Current Value	Present Value
0	0.0%	0.0%	$0	$0	$0	$0
1	0.6%	0.6%	$84,793	$82,323	$140,756	$136,656
2	1.1%	1.1%	$169,586	$159,851	$281,512	$265,352
3	1.7%	1.7%	$254,379	$232,792	$422,269	$386,436
4	2.3%	2.3%	$339,172	$301,350	$563,025	$500,240
5	2.9%	2.9%	$423,964	$365,715	$703,781	$607,088
6	3.4%	3.4%	$508,757	$426,076	$844,537	$707,287
7	4.0%	4.0%	$593,550	$482,611	$985,293	$801,134
8	4.6%	4.6%	$678,343	$535,490	$1,126,049	$888,914
9	5.1%	5.1%	$763,136	$584,880	$1,266,806	$970,901
10	5.7%	5.7%	$847,929	$630,939	$1,407,562	$1,047,358
11	6.3%	6.3%	$932,722	$673,818	$1,548,318	$1,118,538
12	6.9%	6.9%	$1,017,515	$713,664	$1,689,074	$1,184,683

13	7.4%	7.4%	$1,102,307	$750,618	$1,829,830	$1,246,025
14	8.0%	8.0%	$1,187,100	$784,813	$1,970,587	$1,302,790
15	8.6%	8.6%	$1,271,893	$816,380	$2,111,343	$1,355,191
16	9.1%	9.1%	$1,356,686	$845,442	$2,252,099	$1,403,434
17	9.7%	9.7%	$1,441,479	$872,118	$2,392,855	$1,447,717
18	10.3%	10.3%	$1,526,272	$896,524	$2,533,611	$1,488,230
19	10.9%	10.9%	$1,611,065	$918,768	$2,674,367	$1,525,154
20	11.4%	11.4%	$1,695,858	$938,955	$2,815,124	$1,558,666
21	12.0%	12.0%	$1,780,650	$957,187	$2,955,880	$1,588,931
22	12.6%	12.6%	$1,865,443	$973,561	$3,096,636	$1,616,111
23	13.1%	13.1%	$1,950,236	$988,169	$3,237,392	$1,640,360
24	13.7%	13.7%	$2,035,029	$1,001,099	$3,378,148	$1,661,825
25	14.3%	14.3%	$2,119,822	$1,012,439	$3,518,905	$1,680,648
26	14.9%	14.9%	$2,204,615	$1,022,268	$3,659,661	$1,696,965
27	15.4%	15.4%	$2,289,408	$1,030,666	$3,800,417	$1,710,906
28	16.0%	16.0%	$2,374,201	$1,037,708	$3,941,173	$1,722,595
29	16.6%	16.6%	$2,458,994	$1,043,465	$4,081,929	$1,732,152
30	17.1%	17.1%	$2,543,786	$1,048,006	$4,222,685	$1,739,690
31	17.7%	17.7%	$2,628,579	$1,051,398	$4,363,442	$1,745,321
32	18.3%	18.3%	$2,713,372	$1,053,703	$4,504,198	$1,749,147
33	18.9%	18.9%	$2,798,165	$1,054,982	$4,644,954	$1,751,270
34	19.4%	19.4%	$2,882,958	$1,055,292	$4,785,710	$1,751,785
35	20.0%	20.0%	$2,967,751	$1,054,689	$4,926,466	$1,750,784
36	20.6%	20.6%	$3,052,544	$1,053,227	$5,067,223	$1,748,356
37	21.1%	21.1%	$3,137,337	$1,050,954	$5,207,979	$1,744,584
38	21.7%	21.7%	$3,222,129	$1,047,921	$5,348,735	$1,739,548
39	22.3%	22.3%	$3,306,922	$1,044,172	$5,489,491	$1,733,326
40	22.9%	22.9%	$3,391,715	$1,039,753	$5,630,247	$1,725,991
41	23.4%	23.4%	$3,476,508	$1,034,706	$5,771,003	$1,717,612
42	24.0%	24.0%	$3,561,301	$1,029,071	$5,911,760	$1,708,257
43	24.6%	24.6%	$3,646,094	$1,022,886	$6,052,516	$1,697,991
44	25.1%	25.1%	$3,730,887	$1,016,188	$6,193,272	$1,686,873
45	25.7%	25.7%	$3,815,680	$1,009,013	$6,334,028	$1,674,962
46	26.3%	26.3%	$3,900,472	$1,001,394	$6,474,784	$1,662,314
47	26.9%	26.9%	$3,985,265	$993,362	$6,615,540	$1,648,981
48	27.4%	27.4%	$4,070,058	$984,949	$6,756,297	$1,635,016
49	28.0%	28.0%	$4,154,851	$976,183	$6,897,053	$1,620,465

50	28.6%	28.6%	$4,239,644	$967,093	$7,037,809	$1,605,374
51	29.1%	29.1%	$4,324,437	$957,704	$7,178,565	$1,589,788
52	29.7%	29.7%	$4,409,230	$948,041	$7,319,321	$1,573,748
53	30.3%	30.3%	$4,494,023	$938,129	$7,460,078	$1,557,293
54	30.9%	30.9%	$4,578,816	$927,989	$7,600,834	$1,540,462
55	31.4%	31.4%	$4,663,608	$917,645	$7,741,590	$1,523,291
56	32.0%	32.0%	$4,748,401	$907,116	$7,882,346	$1,505,813
57	32.6%	32.6%	$4,833,194	$896,422	$8,023,102	$1,488,060
58	33.1%	33.1%	$4,917,987	$885,581	$8,163,858	$1,470,065
59	33.7%	33.7%	$5,002,780	$874,611	$8,304,615	$1,451,855
60	34.3%	34.3%	$5,087,573	$863,529	$8,445,371	$1,433,459
61	34.9%	34.9%	$5,172,366	$852,351	$8,586,127	$1,414,903
62	35.4%	35.4%	$5,257,159	$841,091	$8,726,883	$1,396,212
63	36.0%	36.0%	$5,341,951	$829,764	$8,867,639	$1,377,409
64	36.6%	36.6%	$5,426,744	$818,384	$9,008,396	$1,358,517
65	37.1%	37.1%	$5,511,537	$806,962	$9,149,152	$1,339,557
66	37.7%	37.7%	$5,596,330	$795,512	$9,289,908	$1,320,549
67	38.3%	38.3%	$5,681,123	$784,043	$9,430,664	$1,301,512
68	38.9%	38.9%	$5,765,916	$772,569	$9,571,420	$1,282,464
69	39.4%	39.4%	$5,850,709	$761,097	$9,712,176	$1,263,421
70	40.0%	40.0%	$5,935,502	$749,638	$9,852,933	$1,244,399
71	40.6%	40.6%	$6,020,294	$738,201	$9,993,689	$1,225,414
72	41.1%	41.1%	$6,105,087	$726,795	$10,134,445	$1,206,479
73	41.7%	41.7%	$6,189,880	$715,426	$10,275,201	$1,187,607
74	42.3%	42.3%	$6,274,673	$704,103	$10,415,957	$1,168,812
75	42.9%	42.9%	$6,359,466	$692,833	$10,556,714	$1,150,103
76	43.4%	43.4%	$6,444,259	$681,622	$10,697,470	$1,131,493
77	44.0%	44.0%	$6,529,052	$670,477	$10,838,226	$1,112,992
78	44.6%	44.6%	$6,613,845	$659,402	$10,978,982	$1,094,608
79	45.1%	45.1%	$6,698,638	$648,404	$11,119,738	$1,076,351
80	45.7%	45.7%	$6,783,430	$637,487	$11,260,494	$1,058,229
81	46.3%	46.3%	$6,868,223	$626,656	$11,401,251	$1,040,249
82	46.9%	46.9%	$6,953,016	$615,915	$11,542,007	$1,022,419
83	47.4%	47.4%	$7,037,809	$605,268	$11,682,763	$1,004,745
84	48.0%	48.0%	$7,122,602	$594,719	$11,823,519	$987,234
85	48.6%	48.6%	$7,207,395	$584,271	$11,964,275	$969,890
86	49.1%	49.1%	$7,292,188	$573,927	$12,105,032	$952,719

87	49.7%	49.7%	$7,376,981	$563,690	$12,245,788	$935,725
88	50.3%	50.3%	$7,461,773	$553,562	$12,386,544	$918,913
89	50.9%	50.9%	$7,546,566	$543,546	$12,527,300	$902,287
90	51.4%	51.4%	$7,631,359	$533,644	$12,668,056	$885,849
91	52.0%	52.0%	$7,716,152	$523,858	$12,808,812	$869,604
92	52.6%	52.6%	$7,800,945	$514,189	$12,949,569	$853,553
93	53.1%	53.1%	$7,885,738	$504,639	$13,090,325	$837,700
94	53.7%	53.7%	$7,970,531	$495,209	$13,231,081	$822,046
95	54.3%	54.3%	$8,055,324	$485,900	$13,371,837	$806,594
96	54.9%	54.9%	$8,140,116	$476,713	$13,512,593	$791,344
97	55.4%	55.4%	$8,224,909	$467,649	$13,653,350	$776,298
98	56.0%	56.0%	$8,309,702	$458,709	$13,794,106	$761,457
99	56.6%	56.6%	$8,394,495	$449,893	$13,934,862	$746,823
100	57.1%	57.1%	$8,479,288	$441,201	$14,075,618	$732,394
101	57.7%	57.7%	$8,564,081	$432,634	$14,216,374	$718,173
102	58.3%	58.3%	$8,648,874	$424,192	$14,357,130	$704,159
103	58.9%	58.9%	$8,733,667	$415,875	$14,497,887	$690,352
104	59.4%	59.4%	$8,818,460	$407,682	$14,638,643	$676,752
105	60.0%	60.0%	$8,903,252	$399,613	$14,779,399	$663,358
106	60.6%	60.6%	$8,988,045	$391,669	$14,920,155	$650,171
107	61.1%	61.1%	$9,072,838	$383,849	$15,060,911	$637,189
108	61.7%	61.7%	$9,157,631	$376,152	$15,201,668	$624,412
109	62.3%	62.3%	$9,242,424	$368,577	$15,342,424	$611,838
110	62.9%	62.9%	$9,327,217	$361,125	$15,483,180	$599,467
111	63.4%	63.4%	$9,412,010	$353,794	$15,623,936	$587,298
112	64.0%	64.0%	$9,496,803	$346,584	$15,764,692	$575,329
113	64.6%	64.6%	$9,581,595	$339,493	$15,905,448	$563,559
114	65.1%	65.1%	$9,666,388	$332,522	$16,046,205	$551,987
115	65.7%	65.7%	$9,751,181	$325,669	$16,186,961	$540,610
116	66.3%	66.3%	$9,835,974	$318,933	$16,327,717	$529,429
117	66.9%	66.9%	$9,920,767	$312,313	$16,468,473	$518,439
118	67.4%	67.4%	$10,005,560	$305,808	$16,609,229	$507,641
119	68.0%	68.0%	$10,090,353	$299,417	$16,749,986	$497,032
120	68.6%	68.6%	$10,175,146	$293,139	$16,890,742	$486,611
121	69.1%	69.1%	$10,259,938	$286,973	$17,031,498	$476,375
122	69.7%	69.7%	$10,344,731	$280,917	$17,172,254	$466,322
123	70.3%	70.3%	$10,429,524	$274,970	$17,313,010	$456,451

124	70.9%	70.9%	$10,514,317	$269,132	$17,453,766	$446,759
125	71.4%	71.4%	$10,599,110	$263,400	$17,594,523	$437,245
126	72.0%	72.0%	$10,683,903	$257,774	$17,735,279	$427,905
127	72.6%	72.6%	$10,768,696	$252,253	$17,876,035	$418,739
128	73.1%	73.1%	$10,853,489	$246,834	$18,016,791	$409,744
129	73.7%	73.7%	$10,938,282	$241,517	$18,157,547	$400,918
130	74.3%	74.3%	$11,023,074	$236,300	$18,298,304	$392,258
131	74.9%	74.9%	$11,107,867	$231,182	$18,439,060	$383,762
132	75.4%	75.4%	$11,192,660	$226,162	$18,579,816	$375,429
133	76.0%	76.0%	$11,277,453	$221,238	$18,720,572	$367,255
134	76.6%	76.6%	$11,362,246	$216,409	$18,861,328	$359,240
135	77.1%	77.1%	$11,447,039	$211,674	$19,002,084	$351,379
136	77.7%	77.7%	$11,531,832	$207,031	$19,142,841	$343,672
137	78.3%	78.3%	$11,616,625	$202,479	$19,283,597	$336,115
138	78.9%	78.9%	$11,701,417	$198,017	$19,424,353	$328,707
139	79.4%	79.4%	$11,786,210	$193,642	$19,565,109	$321,446
140	80.0%	80.0%	$11,871,003	$189,355	$19,705,865	$314,329
141	80.6%	80.6%	$11,955,796	$185,153	$19,846,621	$307,353
142	81.1%	81.1%	$12,040,589	$181,035	$19,987,378	$300,518
143	81.7%	81.7%	$12,125,382	$177,000	$20,128,134	$293,819
144	82.3%	82.3%	$12,210,175	$173,046	$20,268,890	$287,256
145	82.9%	82.9%	$12,294,968	$169,173	$20,409,646	$280,826
146	83.4%	83.4%	$12,379,760	$165,378	$20,550,402	$274,527
147	84.0%	84.0%	$12,464,553	$161,661	$20,691,159	$268,357
148	84.6%	84.6%	$12,549,346	$158,020	$20,831,915	$262,313
149	85.1%	85.1%	$12,634,139	$154,454	$20,972,671	$256,394
150	85.7%	85.7%	$12,718,932	$150,962	$21,113,427	$250,597
151	86.3%	86.3%	$12,803,725	$147,542	$21,254,183	$244,920
152	86.9%	86.9%	$12,888,518	$144,193	$21,394,939	$239,361
153	87.4%	87.4%	$12,973,311	$140,914	$21,535,696	$233,918
154	88.0%	88.0%	$13,058,104	$137,704	$21,676,452	$228,589
155	88.6%	88.6%	$13,142,896	$134,562	$21,817,208	$223,372
156	89.1%	89.1%	$13,227,689	$131,485	$21,957,964	$218,265
157	89.7%	89.7%	$13,312,482	$128,474	$22,098,720	$213,267
158	90.3%	90.3%	$13,397,275	$125,526	$22,239,477	$208,374
159	90.9%	90.9%	$13,482,068	$122,642	$22,380,233	$203,585
160	91.4%	91.4%	$13,566,861	$119,818	$22,520,989	$198,898

161	92.0%	92.0%	$13,651,654	$117,056	$22,661,745	$194,312
162	92.6%	92.6%	$13,736,447	$114,352	$22,802,501	$189,824
163	93.1%	93.1%	$13,821,239	$111,707	$22,943,257	$185,433
164	93.7%	93.7%	$13,906,032	$109,118	$23,084,014	$181,137
165	94.3%	94.3%	$13,990,825	$106,586	$23,224,770	$176,933
166	94.9%	94.9%	$14,075,618	$104,109	$23,365,526	$172,821
167	95.4%	95.4%	$14,160,411	$101,686	$23,506,282	$168,798
168	96.0%	96.0%	$14,245,204	$99,315	$23,647,038	$164,863
169	96.6%	96.6%	$14,329,997	$96,996	$23,787,795	$161,014
170	97.1%	97.1%	$14,414,790	$94,728	$23,928,551	$157,249
171	97.7%	97.7%	$14,499,582	$92,510	$24,069,307	$153,567
172	98.3%	98.3%	$14,584,375	$90,341	$24,210,063	$149,966
173	98.9%	98.9%	$14,669,168	$88,220	$24,350,819	$146,445
174	99.4%	99.4%	$14,753,961	$86,145	$24,491,575	$143,001
175	100.0%	100.0%	$14,838,754	$84,117	$24,632,332	$139,634
Beyond (c)				$2,803,896		$4,654,467
Total				$96,490,643		$160,174,467

	<--(Employment Impacts - FTE)-->	
Year	Direct Effects	Direct & Indirect Effects
0	0	0
1	1	2
2	3	4
3	4	6
4	6	8
5	7	9
6	9	11
7	10	13
8	12	15
9	13	17
10	15	19
11	16	21
12	18	23
13	19	25
14	21	26

15	22	28
16	24	30
17	25	32
18	27	34
19	28	36
20	30	38
21	31	40
22	32	42
23	34	43
24	35	45
25	37	47
26	38	49
27	40	51
28	41	53
29	43	55
30	44	57
31	46	59
32	47	61
33	49	62
34	50	64
35	52	66
36	53	68
37	55	70
38	56	72
39	58	74
40	59	76
41	61	78
42	62	79
43	63	81
44	65	83
45	66	85
46	68	87
47	69	89
48	71	91
49	72	93
50	74	95
51	75	96

52	77	98
53	78	100
54	80	102
55	81	104
56	83	106
57	84	108
58	86	110
59	87	112
60	89	113
61	90	115
62	92	117
63	93	119
64	94	121
65	96	123
66	97	125
67	99	127
68	100	129
69	102	130
70	103	132
71	105	134
72	106	136
73	108	138
74	109	140
75	111	142
76	112	144
77	114	146
78	115	147
79	117	149
80	118	151
81	120	153
82	121	155
83	123	157
84	124	159
85	125	161
86	127	163
87	128	165
88	130	166

89	131	168
90	133	170
91	134	172
92	136	174
93	137	176
94	139	178
95	140	180
96	142	182
97	143	183
98	145	185
99	146	187
100	148	189
101	149	191
102	151	193
103	152	195
104	154	197
105	155	199
106	156	200
107	158	202
108	159	204
109	161	206
110	162	208
111	164	210
112	165	212
113	167	214
114	168	216
115	170	217
116	171	219
117	173	221
118	174	223
119	176	225
120	177	227
121	179	229
122	180	231
123	182	233
124	183	234
125	185	236

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163	241	308
164	242	310
165	244	312
166	245	314
167	247	316
168	248	318
169	249	320
170	251	321
171	252	323
172	254	325
173	255	327
174	257	329
175	258	331

Notes

(a) Percent displacement given certain invasion

(b) Percent displacement given probability of successful invasion

(c) From year 176 into perpetuity

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Appendix 16G. Economic Impact Analysis of Lake Winnipeg Commercial Fishery: Fast Invasion - Very Low Risk

Probability of successful invasion:	1.00E-09	
Annual discount rate:	3.0%	
Present year:	0	
Invasion year:	0	
Annual landed value (10-year average):	$14,838,754	
Economic impact multipliers		
Output (direct effects):	1.00	
Output (direct & indirect effects - all provinces):	1.66	
Employment (direct effects):	17.41	FTE/million $ direct output
Employment (direct & indirect effects - all provinces):	22.30	FTE/million $ direct output

			<----------(Output Impacts)---------->			
	<-----(Fishery Displacement)----->		<----------(Direct Effects)---------->		<----(Direct & Indirect Effects)---->	
Year	Certain (a)	Expected (b)	Current Value	Present Value	Current Value	Present Value
0	0.0%	0.0000000000%	$0.0000	$0.0000	$0.0000	$0.0000
1	5.9%	0.0000000059%	$0.0009	$0.0008	$0.0014	$0.0014
2	11.8%	0.0000000118%	$0.0017	$0.0016	$0.0029	$0.0027
3	17.6%	0.0000000176%	$0.0026	$0.0024	$0.0043	$0.0040
4	23.5%	0.0000000235%	$0.0035	$0.0031	$0.0058	$0.0051
5	29.4%	0.0000000294%	$0.0044	$0.0038	$0.0072	$0.0062
6	35.3%	0.0000000353%	$0.0052	$0.0044	$0.0087	$0.0073
7	41.2%	0.0000000412%	$0.0061	$0.0050	$0.0101	$0.0082
8	47.1%	0.0000000471%	$0.0070	$0.0055	$0.0116	$0.0092
9	52.9%	0.0000000529%	$0.0079	$0.0060	$0.0130	$0.0100
10	58.8%	0.0000000588%	$0.0087	$0.0065	$0.0145	$0.0108
11	64.7%	0.0000000647%	$0.0096	$0.0069	$0.0159	$0.0115
12	70.6%	0.0000000706%	$0.0105	$0.0073	$0.0174	$0.0122

13	76.5%	0.0000000765%	$0.0113	$0.0077	$0.0188	$0.0128
14	82.4%	0.0000000824%	$0.0122	$0.0081	$0.0203	$0.0134
15	88.2%	0.0000000882%	$0.0131	$0.0084	$0.0217	$0.0140
16	94.1%	0.0000000941%	$0.0140	$0.0087	$0.0232	$0.0144
17	100.0%	0.0000001000%	$0.0148	$0.0090	$0.0246	$0.0149
Beyond (c)				$0.2993		$0.4968
Total				$0.3946		$0.6550

	<--(Employment Impacts - FTE)-->	
Year	Direct Effects	Direct & Indirect Effects
0	0	0
1	0	0
2	0	0
3	0	0
4	0	0
5	0	0
6	0	0
7	0	0
8	0	0
9	0	0
10	0	0
11	0	0
12	0	0
13	0	0
14	0	0
15	0	0
16	0	0
17	0	0

Notes

(a) Percent displacement given certain invasion

(b) Percent displacement given probability of successful invasion

(c) From year 18 into perpetuity

Appendix 16H. Economic Impact Analysis of Lake Winnipeg Commercial Fishery: Fast Invasion - Low Risk

Probability of successful invasion:	1.00E-06	
Annual discount rate:	3.0%	
Present year:	0	
Invasion year:	0	
Annual landed value (10-year average):	$14,838,754	
Economic impact multipliers		
Output (direct effects):	1.00	
Output (direct & indirect effects - all provinces):	1.66	
Employment (direct effects):	17.41	FTE/million $ direct output
Employment (direct & indirect effects - all provinces):	22.30	FTE/million $ direct output

			<----------(Output Impacts)---------->			
	<-----(Fishery Displacement)----->		<----------(Direct Effects)---------->		<----(Direct & Indirect Effects)---->	
Year	Certain (a)	Expected (b)	Current Value	Present Value	Current Value	Present Value
0	0.0%	0.0000000%	$0	$0	$0	$0
1	5.9%	0.0000059%	$1	$1	$1	$1
2	11.8%	0.0000118%	$2	$2	$3	$3
3	17.6%	0.0000176%	$3	$2	$4	$4
4	23.5%	0.0000235%	$3	$3	$6	$5
5	29.4%	0.0000294%	$4	$4	$7	$6
6	35.3%	0.0000353%	$5	$4	$9	$7
7	41.2%	0.0000412%	$6	$5	$10	$8
8	47.1%	0.0000471%	$7	$6	$12	$9
9	52.9%	0.0000529%	$8	$6	$13	$10
10	58.8%	0.0000588%	$9	$6	$14	$11
11	64.7%	0.0000647%	$10	$7	$16	$12
12	70.6%	0.0000706%	$10	$7	$17	$12

13	76.5%	0.0000765%	$11	$8	$19	$13
14	82.4%	0.0000824%	$12	$8	$20	$13
15	88.2%	0.0000882%	$13	$8	$22	$14
16	94.1%	0.0000941%	$14	$9	$23	$14
17	100.0%	0.0001000%	$15	$9	$25	$15
Beyond (c)				$299		$497
Total				$395		$655

	<--(Employment Impacts - FTE)-->	
Year	Direct Effects	Direct & Indirect Effects
0	0	0
1	0	0
2	0	0
3	0	0
4	0	0
5	0	0
6	0	0
7	0	0
8	0	0
9	0	0
10	0	0
11	0	0
12	0	0
13	0	0
14	0	0
15	0	0
16	0	0
17	0	0

Notes

(a) Percent displacement given certain invasion

(b) Percent displacement given probability of successful invasion

(c) From year 18 into perpetuity

Appendix 16I. Economic Impact Analysis of Lake Winnipeg Commercial Fishery: Fast Invasion - Moderate Risk

Probability of successful invasion:	1.00E-03	
Annual discount rate:	3.0%	
Present year:	0	
Invasion year:	0	
Annual landed value (10-year average):	$14,838,754	
Economic impact multipliers		
Output (direct effects):	1.00	
Output (direct & indirect effects - all provinces):	1.66	
Employment (direct effects):	17.41	FTE/million $ direct output
Employment (direct & indirect effects - all provinces):	22.30	FTE/million $ direct output

			<----------(Output Impacts)---------->			
	<-----(Fishery Displacement)----->		<----------(Direct Effects)---------->		<----(Direct & Indirect Effects)---->	
Year	Certain (a)	Expected (b)	Current Value	Present Value	Current Value	Present Value
0	0.0%	0.0000%	$0	$0	$0	$0
1	5.9%	0.0059%	$873	$847	$1,449	$1,407
2	11.8%	0.0118%	$1,746	$1,646	$2,898	$2,732
3	17.6%	0.0176%	$2,619	$2,396	$4,347	$3,978
4	23.5%	0.0235%	$3,491	$3,102	$5,796	$5,150
5	29.4%	0.0294%	$4,364	$3,765	$7,245	$6,249
6	35.3%	0.0353%	$5,237	$4,386	$8,694	$7,281
7	41.2%	0.0412%	$6,110	$4,968	$10,143	$8,247
8	47.1%	0.0471%	$6,983	$5,512	$11,592	$9,151
9	52.9%	0.0529%	$7,856	$6,021	$13,041	$9,995
10	58.8%	0.0588%	$8,729	$6,495	$14,490	$10,782
11	64.7%	0.0647%	$9,602	$6,936	$15,939	$11,514
12	70.6%	0.0706%	$10,474	$7,347	$17,388	$12,195

13	76.5%	0.0765%	$11,347	$7,727	$18,836	$12,827
14	82.4%	0.0824%	$12,220	$8,079	$20,285	$13,411
15	88.2%	0.0882%	$13,093	$8,404	$21,734	$13,950
16	94.1%	0.0941%	$13,966	$8,703	$23,183	$14,447
17	100.0%	0.1000%	$14,839	$8,978	$24,632	$14,903
Beyond (c)				$299,256		$496,766
Total				$394,568		$654,983

	<--(Employment Impacts - FTE)-->	
Year	Direct Effects	Direct & Indirect Effects
0	0	0
1	0	0
2	0	0
3	0	0
4	0	0
5	0	0
6	0	0
7	0	0
8	0	0
9	0	0
10	0	0
11	0	0
12	0	0
13	0	0
14	0	0
15	0	0
16	0	0
17	0	0

Notes

(a) Percent displacement given certain invasion

(b) Percent displacement given probability of successful invasion

(c) From year 18 into perpetuity

Appendix 16J. Economic Impact Analysis of Lake Winnipeg Commercial Fishery: Fast Invasion - High Risk

Probability of successful invasion:	1.00E-02	
Annual discount rate:	3.0%	
Present year:	0	
Invasion year:	0	
Annual landed value (10-year average):	$14,838,754	
Economic impact multipliers		
Output (direct effects):	1.00	
Output (direct & indirect effects - all provinces):	1.66	
Employment (direct effects):	17.41	FTE/million $ direct output
Employment (direct & indirect effects - all provinces):	22.30	FTE/million $ direct output

			<----------(Output Impacts)---------->			
	<-----(Fishery Displacement)----->		<----------(Direct Effects)---------->		<----(Direct & Indirect Effects)---->	
Year	Certain (a)	Expected (b)	Current Value	Present Value	Current Value	Present Value
0	0.0%	0.000%	$0	$0	$0	$0
1	5.9%	0.059%	$8,729	$8,474	$14,490	$14,068
2	11.8%	0.118%	$17,457	$16,455	$28,979	$27,316
3	17.6%	0.176%	$26,186	$23,964	$43,469	$39,780
4	23.5%	0.235%	$34,915	$31,021	$57,958	$51,495
5	29.4%	0.294%	$43,643	$37,647	$72,448	$62,494
6	35.3%	0.353%	$52,372	$43,861	$86,938	$72,809
7	41.2%	0.412%	$61,101	$49,681	$101,427	$82,470
8	47.1%	0.471%	$69,829	$55,124	$115,917	$91,506
9	52.9%	0.529%	$78,558	$60,208	$130,406	$99,946
10	58.8%	0.588%	$87,287	$64,950	$144,896	$107,816
11	64.7%	0.647%	$96,015	$69,364	$159,386	$115,144
12	70.6%	0.706%	$104,744	$73,465	$173,875	$121,953

13	76.5%	0.765%	$113,473	$77,269	$188,365	$128,267
14	82.4%	0.824%	$122,202	$80,790	$202,854	$134,111
15	88.2%	0.882%	$130,930	$84,039	$217,344	$139,505
16	94.1%	0.941%	$139,659	$87,031	$231,834	$144,471
17	100.0%	1.000%	$148,388	$89,777	$246,323	$149,030
Beyond (c)				$2,992,563		$4,967,655
Total				$3,945,683		$6,549,835

	<--(Employment Impacts - FTE)-->	
Year	Direct Effects	Direct & Indirect Effects
0	0	0
1	0	0
2	0	0
3	0	1
4	1	1
5	1	1
6	1	1
7	1	1
8	1	2
9	1	2
10	2	2
11	2	2
12	2	2
13	2	3
14	2	3
15	2	3
16	2	3
17	3	3

Notes

(a) Percent displacement given certain invasion

(b) Percent displacement given probability of successful invasion

(c) From year 18 into perpetuity

Appendix 16K. Economic Impact Analysis of Lake Winnipeg Commercial Fishery: Fast Invasion - Very High Risk

Probability of successful invasion:	1.00E+00	
Annual discount rate:	3.0%	
Present year:	0	
Invasion year:	0	
Annual landed value (10-year average):	$14,838,754	
Economic impact multipliers		
Output (direct effects):	1.00	
Output (direct & indirect effects - all provinces):	1.66	
Employment (direct effects):	17.41	FTE/million $ direct output
Employment (direct & indirect effects - all provinces):	22.30	FTE/million $ direct output

			<----------(Output Impacts)---------->			
	<-----(Fishery Displacement)----->		<----------(Direct Effects)---------->		<----(Direct & Indirect Effects)---->	
Year	Certain (a)	Expected (b)	Current Value	Present Value	Current Value	Present Value
0	0.0%	0.0%	$0	$0	$0	$0
1	5.9%	5.9%	$872,868	$847,445	$1,448,961	$1,406,758
2	11.8%	11.8%	$1,745,736	$1,645,523	$2,897,921	$2,731,569
3	17.6%	17.6%	$2,618,604	$2,396,393	$4,346,882	$3,978,013
4	23.5%	23.5%	$3,491,472	$3,102,127	$5,795,843	$5,149,531
5	29.4%	29.4%	$4,364,339	$3,764,718	$7,244,803	$6,249,431
6	35.3%	35.3%	$5,237,207	$4,386,079	$8,693,764	$7,280,891
7	41.2%	41.2%	$6,110,075	$4,968,050	$10,142,725	$8,246,963
8	47.1%	47.1%	$6,982,943	$5,512,400	$11,591,685	$9,150,584
9	52.9%	52.9%	$7,855,811	$6,020,825	$13,040,646	$9,994,569
10	58.8%	58.8%	$8,728,679	$6,494,957	$14,489,607	$10,781,628
11	64.7%	64.7%	$9,601,547	$6,936,362	$15,938,568	$11,514,360
12	70.6%	70.6%	$10,474,415	$7,346,544	$17,387,528	$12,195,262

13	76.5%	76.5%	$11,347,282	$7,726,947	$18,836,489	$12,826,732
14	82.4%	82.4%	$12,220,150	$8,078,959	$20,285,450	$13,411,072
15	88.2%	88.2%	$13,093,018	$8,403,910	$21,734,410	$13,950,491
16	94.1%	94.1%	$13,965,886	$8,703,079	$23,183,371	$14,447,110
17	100.0%	100.0%	$14,838,754	$8,977,690	$24,632,332	$14,902,966
Beyond (c)				$299,256,340		$496,765,525
Total				$394,568,347		$654,983,456

	<--(Employment Impacts - FTE)-->	
Year	Direct Effects	Direct & Indirect Effects
0	0	0
1	15	19
2	30	39
3	46	58
4	61	78
5	76	97
6	91	117
7	106	136
8	122	156
9	137	175
10	152	195
11	167	214
12	182	234
13	198	253
14	213	273
15	228	292
16	243	311
17	258	331

Notes

(a) Percent displacement given certain invasion

(b) Percent displacement given probability of successful invasion

(c) From year 18 into perpetuity

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Appendix 18. Paleoecological Context and Characterization of Risks Associated with Potential Interbasin Biota Transfers

Of those biota of concern identified by Reclamation and stakeholders on the Technical Team, the fishes and aquatic invertebrates provided a relatively data-rich source of existing information georeferenced locations for records of occurrence (e.g., FishBase, http://www.fishbase.org/ and similar data sources). Owing to the long-standing academic interest, historic and ongoing efforts by resource management agencies, and past interbasin water diversion studies, the current analysis benefitted from a diffuse collection of life history and distribution accounts (see Appendix 3A, Appendix 6, and Appendix 7) upon which the analysis of risk could be implemented quantitatively through a categorical and spatial analysis, which is summarized in Section 4 as part of the narrative analysis of risks associated with potential transfers of fishes collateral to an interbasin water diversion between Missouri River (exporting source area) and Red River (importing receiving area). For the fishes, as well as other biota of concern, placing our current "snapshot" of species distributions in ecological context requires a background in the dynamic character of biogeography, and past climate regimes and the distribution of fishes in the northern Great Plains illustrates the temporal considerations of the risk analysis.

Paleoecology of North American fishes: An illustration of changing species distributions through time. Numerous authors (see Mayden 1992) have considered various aspects of the biogeography of the fishes of North America, with distribution histories of North American fishes considered in detail by Burr and Mayden (1992), which serves as our primary source for this characterization. In early biogeographical analysis of fishes of North America, Gilbert (1976) suggested the Cyprinidae, Percidae, Catostomidae, Esocidae, and Umbridae came to North America from Eurasia; the Poeciliidae are of Central American derivation; the Cichlidae, Characidae, and Pimelodidae have reached the Nearctic region through relatively recent dispersals northward; the archaic Acipenseridae, Polyodontidae, Lepisosteidae, and Amiidae have a mixed origin; and the remainder of the families are of marine origin. Only eight families—Hiodontiade, Ictaluridae, Percopsidae, Aphredoderidae, Amblyopsidae, Coodeidae, Centrarchidae, and Elassomatidae—originated in North America, according to Gilbert's work of over 35 years ago. During the intervening years, alternative hypotheses (see, e.g., Patterson, 1981 and others cited in Burr and Mayden 1992) have been developed and the origins of North American icthyofauna remain a topic of keen research interest.

North Dakota, Minnesota, Manitoba, and Ontario occur in the Nearctic which includes many hydrological units and ecoregions (see Appendix 1 and Appendix 2, respectively), and biogeographic provinces throughout the continent (Figure 1 after Burr and Mayden 1992). Following Burr and Mayden (1992), a relatively coarse-grained mapping of fish fauna provinces suggests that the origin of fishes in the areas of concern is likely easily confounded, if resolution at a 2-digit HUC perspective is desired. Although survey works completed over the past 15 years support a higher resolution analysis (see Petreka and Koel 1996; Koel 1997), faunistic differences between HUC09 and HUC10 are incompletely documented in the current biogeographic literature. Hence, the fishes identified by Reclamation and members of the Technical Team generally represented species whose native distribution (or current distribution, if the species was already considered "invasive") did not reach Red River basin surface waters and sufficiently characterized them as species potentially of concern for being transfers from Missouri River source waters to Red River, if water diversion between watersheds occurred.

At the spatial scale of the faunal province, the Hudson Bay Province and Mississippi River Province were most pertinent to our analysis, although provinces immediately adjacent to these coarse-scaled regions (coarse-scaled relative to a 2- or 4-digit HUC) should not be completely dismissed as potential sources. For example, the Yukon-Mackenzie Province and Hudson Bay Province (see Figure 5 for location) display a common species composition, characterized by freshwater fishes that have apparently invaded from the Mississippi Province (or other more southern provinces). Hudson Bay Province includes all watersheds of Hudson and Ungava Bays in much of Canada and in the north-central US (see Crossman and McAllister 1986), with the species' composition displaying strong affinities with both Mississippi and Great Lakes Provinces. No species are endemic to the Hudson Bay Province, and many fish species occur only at the southern edges of the province. Burr and Mayden (1992) note of the Hudson Bay Province:

> "As a result of Pleistocene glaciation the [fish] fauna has occupied the province for less than 14,000 years. The distribution patterns of fishes reflect mainly the postglacial reinvasion of these drainages with dispersal through glacial lakes and rivers, shifting, watersheds, and coastal waters (Crossman and McAllister, 1986)."

From a faunistics perspective, Missouri River drainage (HUC10) is part of the Mississippi Province which consists of areas of the US and Canada currently drained by the Mississippi-Missouri-Ohio Rivers. In North America the Mississippi Province presents the richest ichthyofauna, including families thought to have phylogenetic origins in North America.

Mississippi Province has served as a refuge during glaciation and has been a source area for fishes characteristic of past faunal assemblages. Burr and Mayden (1992) have gone as far to state that the

> "Mississippi fauna is clearly the "mother" fauna of North America and much of the diversity of surrounding provinces can be accounted for by spillover from this cradle of temperate freshwater fish diversity."

From the perspective of a paleoecologist, late Pleistocene and early Holcene were dynamic landscapes where current day boundaries between biogeographic provinces and their constituent watersheds differed, in some instances markedly differed, from our present-day snapshots of these systems, including landscape features as the continental divide for waters flowing to Hudson Bay and waters flowing to the Gulf of Mexico (see Teller and Clayton 1983; Figure 2). Results of geological and paleoecological studies also suggest that not only were glacial lakes such as Lake Agassiz interconnected with surface waters of Mississippi Province but several connections with Great Lakes-St. Lawrence Province also existed (Figure 3), yielding a mixing of fish fauna (and other aquatic biota) across current boundaries, especially during periods of glacial retreat. As a consequence, the ichthyofaunas of these regions are similar, particularly when fishes of the northern part of the Mississippi Province are compared to the Hudson Bay and Great Lakes-St. Lawrence fish fauna (see Burr and Mayden 1992). The areas of concern in the Red River and adjacent areas of the Great Lakes-St. Lawrence Province were variously covered with ice of the Wisconsin Age until about 15,000 years ago (see Teller and Clayton 1983; Underhill 1986), with surface waters of the Mississippi Province serving as refugia and future source areas for repopulating what had been a depauperate region (Figure 4). As Wisconsin Age glaciations diminished and as Lake Agassiz filled, then retreated, various current day watersheds gained a biological signature strongly influenced by past geologic events, which have subsequently served as a foundation upon which current landscapes have been shaped.

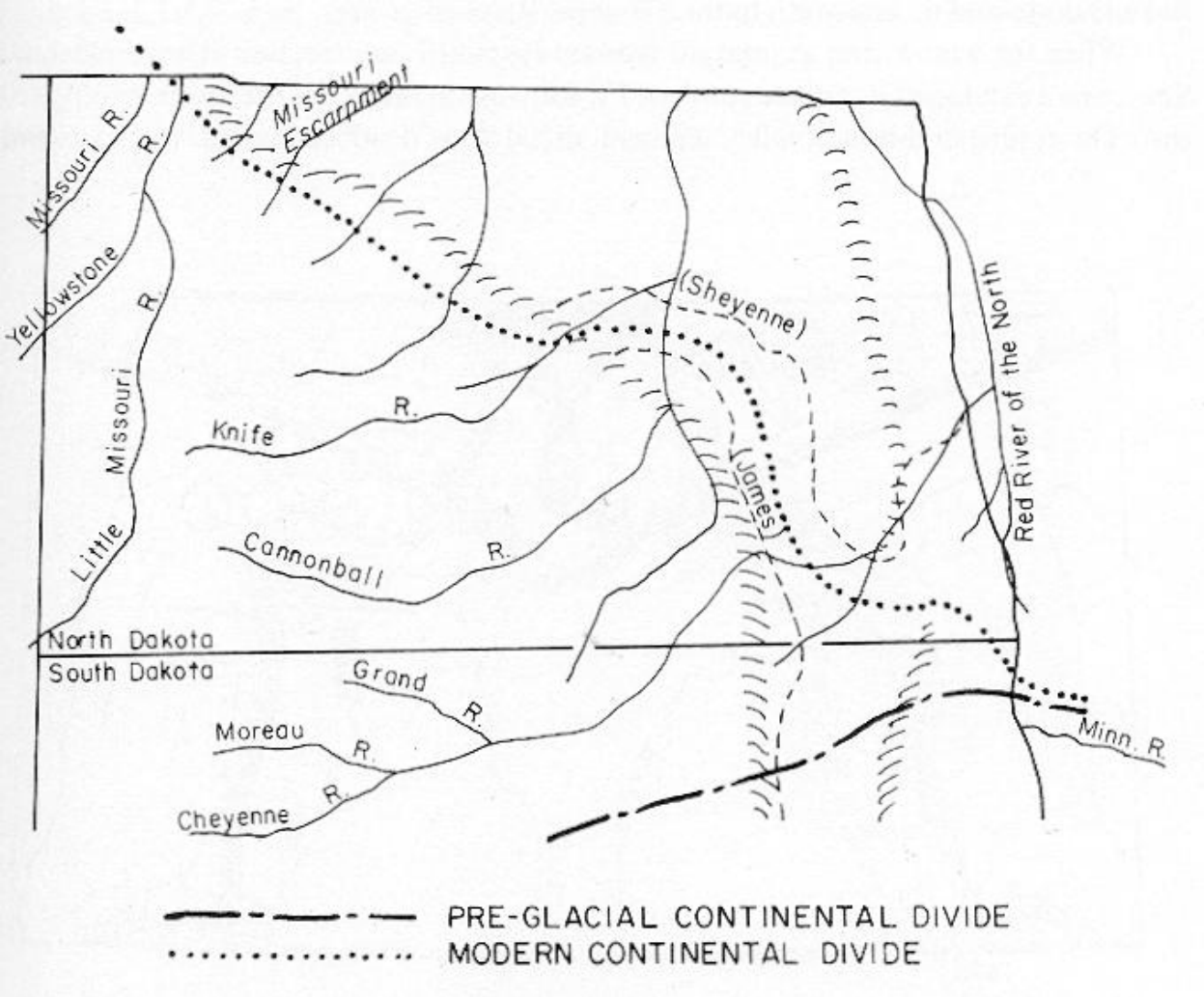


Figure 1. Landscape features such as continental divides are not fixed, and ecological attributes related to current species distributions must be interpreted within that dynamic context (from Brophy and Bluemle 1983).

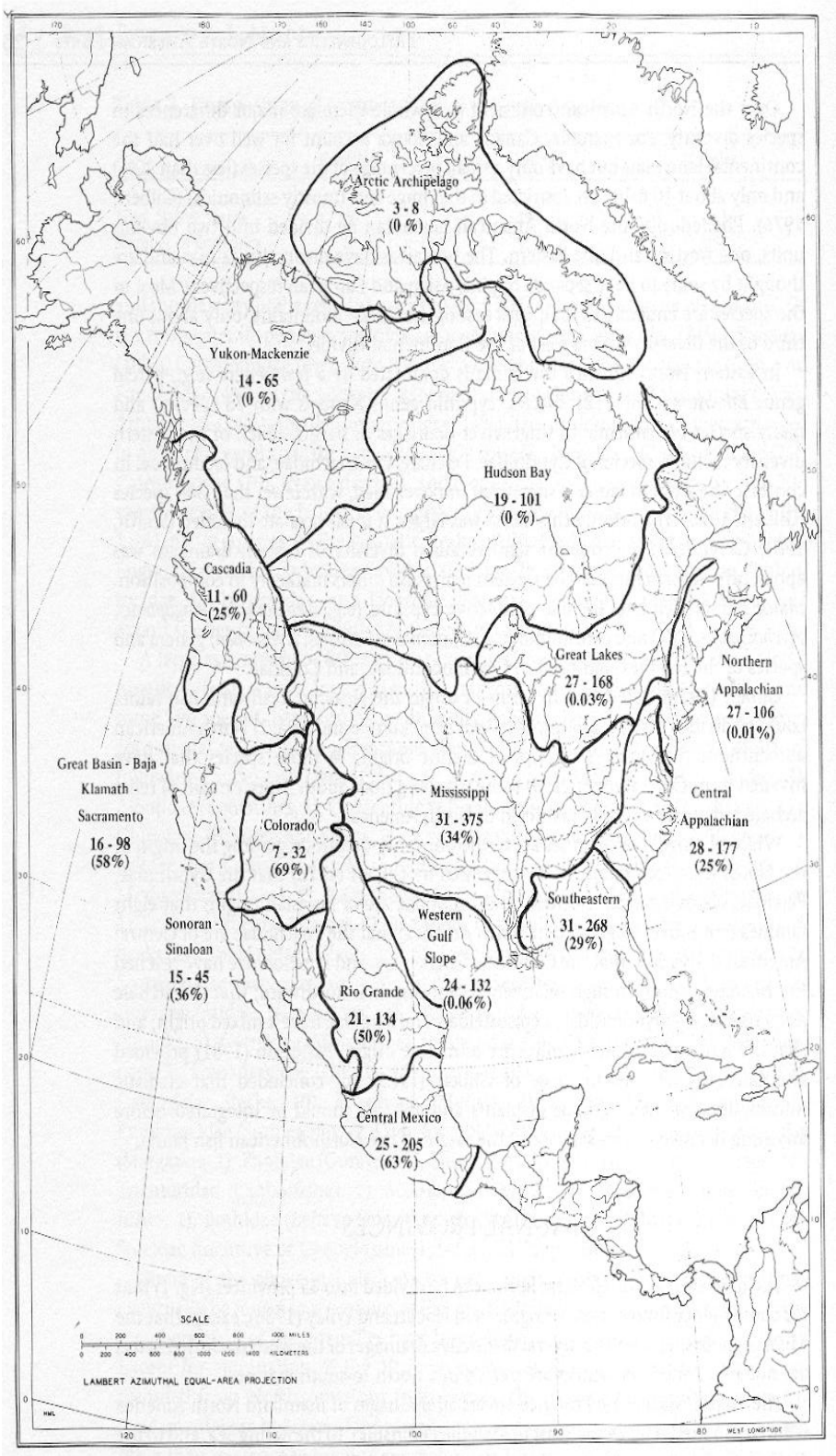


Figure 2. Provinces of Nearctic freshwater fishes with number of families listed, followed by number of species (percent endemics in province; after Burr and Mayden, 1992).

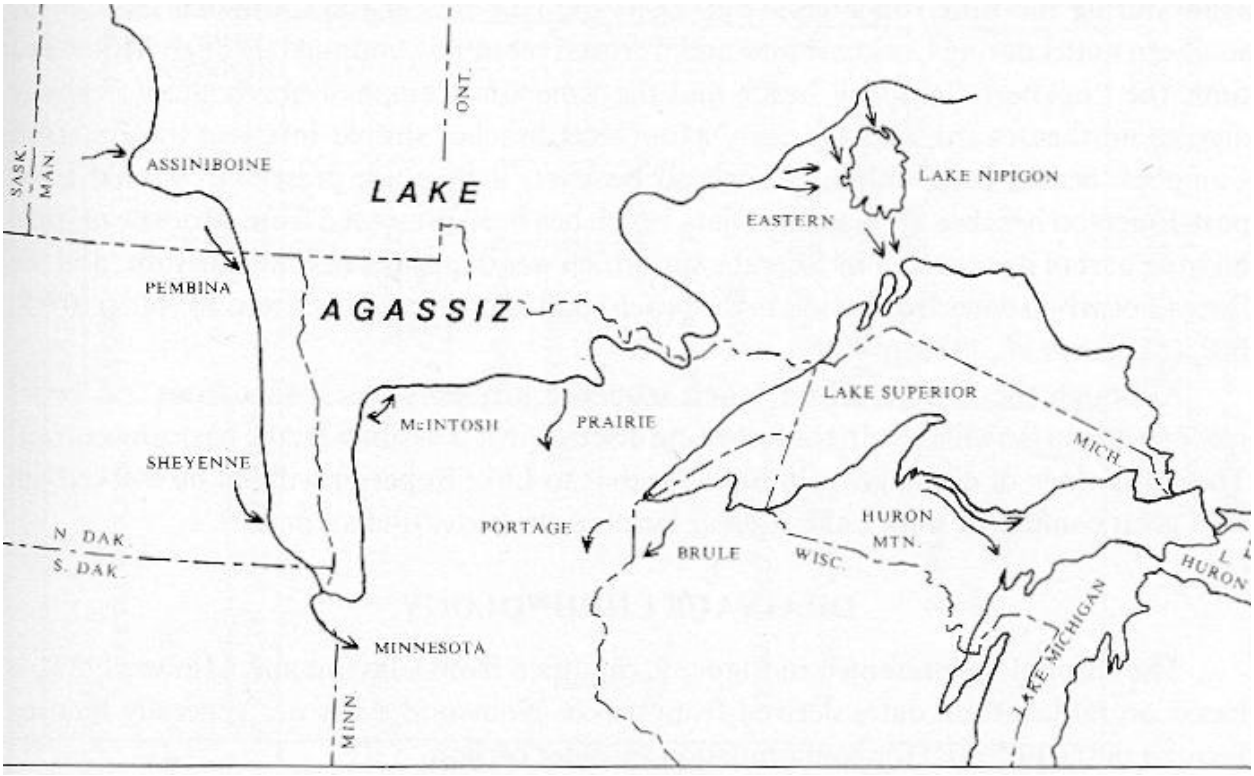


Figure 3. Spillways from glacial Lake Agassiz that historically linked nascent Red River basin flora and fauna with Upper Missouri River, Upper Mississippi River, and Great Lakes basins (from Clayton 1983).

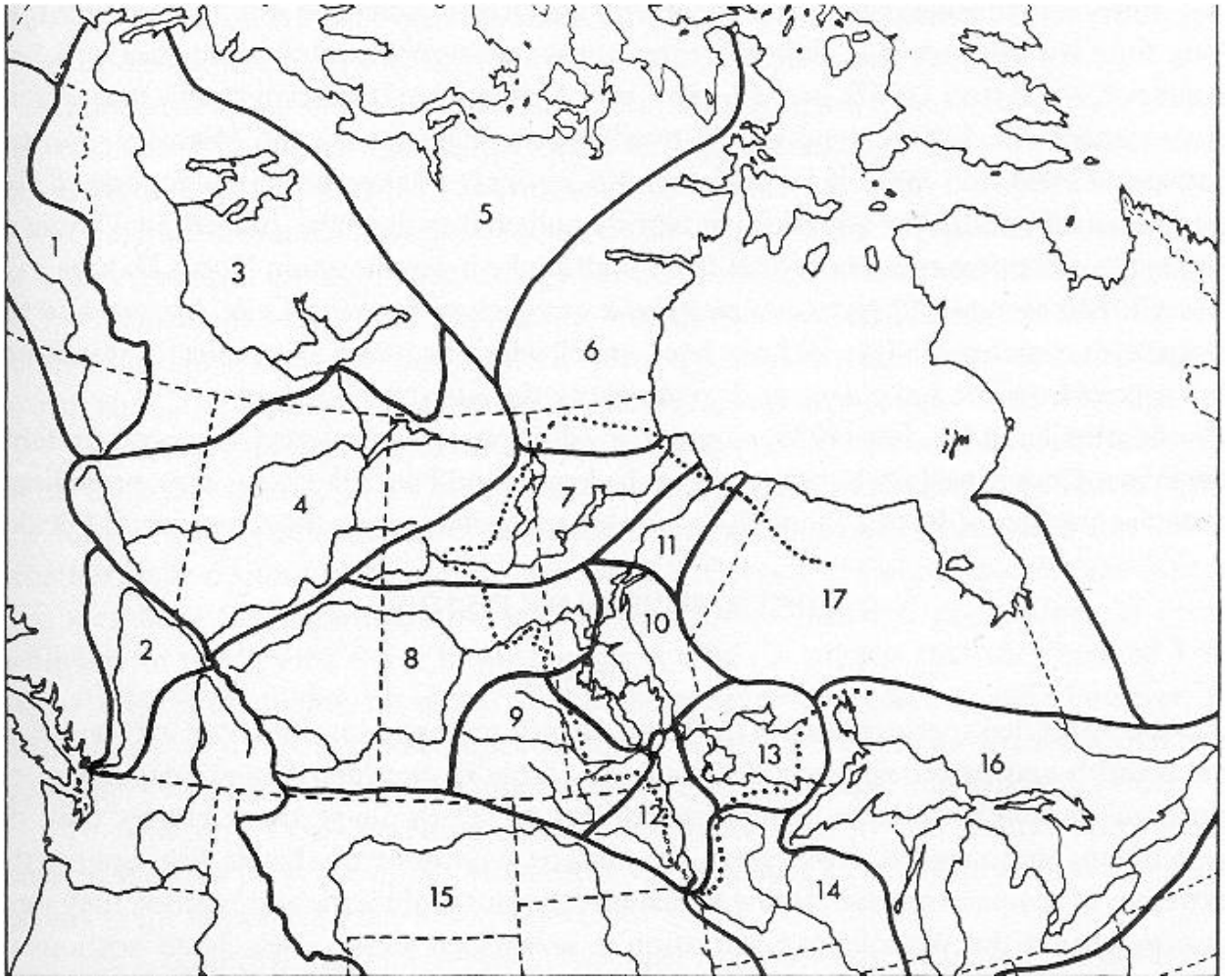


Figure 4. Recent surface drainages associated with glacial Lake Agassiz. Watersheds numbered 7–13 and 17 were directly influenced by glaciers of the Wisconsin Age and Lake Agassiz. In postglacial periods, other watersheds listed (Numbers 1–16) were colonized by species which dispersed via the Lake Agassiz and environs or contained glacial refugia from which species dispersed into the Lake Agassiz region (watersheds numbered 1, 14, and 15). The maximum extent of Lake Agassiz is indicated by a dotted line. (1) Yukon, (2) Fraser, (3) Mackenzie, (4) Athabasca, (5) Arctic Coast, (6) Hudson Bay, north of Churchill River, (7) Churchill, (8) Saskatchewan, (9) Qu'Appelle/Assiniboine, (10) Manitoba Lakes, (11) Nelson, (12) Red, (13) Rainy, (14) Upper Mississippi, (15) Upper Missouri, (16) Great Lakes, (17) Hudson and James Bay, south of Nelson River (after Stewart and Lindsay 1983).

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