Invasive Species Research Strategic Plan for the Upper Midwest Environmental Sciences Center[1]

May 2004

DRAFT

The Context

Most nonindigenous species established outside their native range do not cause observable changes in the invaded ecosystem, but a proportionately small number are perceived as a nuisance (Williamson 1996). These invasive species are economically costly (Pimentel et al., 1999, estimated this cost to be $137 billion annually in the United States alone), negatively affect human health (e.g., West Nile virus, malaria, Cholera), and have significant negative environmental effects (e.g., zebra mussels *Dreissena polymorpha*, leafy spurge *Euphorbia esula*, and kudzu *Pueraria montana* var. *lobata*). Each year thousands of species from microbes to mammals are intentionally or accidentally introduced into the United States (Ludke et al. 2002). The introduction and spread of invasive species are perhaps the least reversible human-induced global changes underway (Kolar and Lodge 2002).

> ***Definition of terms (modified from Executive Order 13112)***
>
> **Nonindigenous (or non-native, or alien) species**
> With respect to a given ecosystem, any species, including its seeds, eggs, spores, or other biological material capable of propagating that species, that is not native to that ecosystem
>
> **Invasive species**
> An invasive species is a nonindigenous species whose introduction does or is likely to cause economic or environmental harm or harm to human health

As the primary research agency within the Department of the Interior, the U.S. Geological Survey (USGS) fills an important niche in Federal efforts to combat invasive species in natural and semi-natural areas. The USGS Invasive Species Program Element supports cooperative efforts to document and monitor the introduction and spread of invasive species, study the ecology of invaders and factors in the resistance of habitats to invasion, forecast probabilities and locations of future invasions, and develop methods for minimizing their effects (USGS 2003). The Invasive Species Program Element is developing a virtual National Institute for Invasive Species Science that will include research conducted at other Science Centers in conjunction with the new National Institute for Invasive Species Science facility in Fort Collins, Colorado. In the future, the USGS Invasive Species Program Element will focus on developing predictive understanding of the relationships between invasive species and environmental drivers (e.g., extreme natural events and changes in physical disturbance regimes, climate, physicochemical pollution, and atmospheric conditions) operating at many spatial and temporal scales (USGS 2003).

The USGS Upper Midwest Environmental Sciences Center (UMESC), in La Crosse, Wisconsin, is close to two major North American watersheds that have been highly invaded by aquatic and wetland nonindigenous species, the Great Lakes and Mississippi River Basins (Figure 1). More than 160 nonindigenous aquatic species have arrived via an array of introduction vectors and a variety of physical pathways to become established in each of these ecosystems (Rasmussen 1998; NCRAIS 2004; USGS 2004). Ninety known aquatic and wetland nonindigenous species have been introduced into the Upper Mississippi River System (UMRS) alone (USGS 2004). Recent invaders to the Upper and Middle Mississippi River that have either become very abundant, have threatened native endangered species (e.g., the Higgins' eye pearly mussel, *Lampsilis higginsii*, and mapleleaf mussel, *Quadrula quadrula*), or have otherwise negatively altered the ecosystem include the zebra mussel, bighead carp (*Hypophthalmichthys*

[1] This is a draft document that will receive review by participants of a workshop of potential partners that will take place on June 23, 2004. The final document will incorporate perspectives and priorities of workshop participants.

nobilis), silver carp (*H. molitrix*), purple loosestrife (*Lythrum salicaria*), and reed canary grass (*Phalaris arundinacea*). Negative effects from historical invasions of the ecosystem, such as declines in native submersed plants and buffalo fishes caused by common carp (*Cyprinus carpio*), are only now beginning to be understood (Bellrichard 1994). Since the sea lamprey (*Petromyzon marinus*) invaded the Great Lakes in the 1940s, invasive species have shaped and defined the ecology of that ecosystem. The rate of invasion continues to increase in the Great Lakes, even after the institution of mid-water ballast water exchange regulations (Holeck et al. in review). The importance of artificial connecting waterways as corridors for species movement has been highlighted recently since several invasive species (e.g., the zebra mussel and white perch *Morone americana*) have used the Illinois Inland Waterway (IIWW) to spread from the Great Lakes to the Mississippi River Basin and several others (e.g., bighead and silver carps) are poised to spread to the Great Lakes from the other direction. The UMESC is particularly well-positioned to conduct research on aquatic invasive species within the UMRS, the Great Lakes, and the IIWW that artificially connects the two basins.

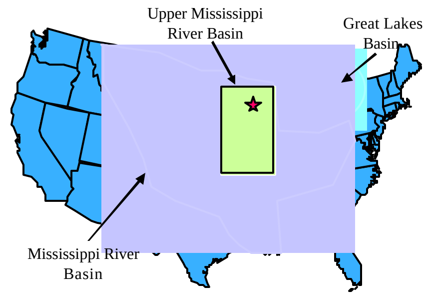

Figure 1. Location on the landscape of the Upper Midwest Environmental Sciences Center (indicated with a star).

The Stage

Research on aquatic invasive species has been an important and productive part of the research program at the UMESC since the inception of the facility in the 1950s and has resulted in over 170 publications (Appendix A). The vast majority of this research effort has focused on the Effect Stage of the invasion process (after the species becomes established and has negatively affected the invaded ecosystem; Figure 2)—more specifically on the chemical control of invasive fishes. Early efforts to develop chemical control for common carp (*Cyprinus carpio*) and other nuisance fishes expanded in the 1960s to a monumental and highly successful effort to control the invasive sea lamprey in the Great Lakes. These two efforts, in cooperation with the Great Lakes Fishery Commission (GLFC), constituted the Center's major research emphasis on invasive species through the early 1990s. After that time, the UMESC extended its chemical control talents to newly established nonindigenous species in the Great Lakes (e.g., Boogaard et al. 1996), and recently, to the use of taxon-specific chemicals and more integrated control of invasive fishes in the southwestern United States (Dawson and Kolar 2004). Other research efforts at the UMESC have examined the effects of invasive species such as zebra mussels and reed canary grass on the UMRS (Appendix A). Scientists at the UMESC have also conducted more limited research at other stages of the invasion process (Figure 2). For example, UMESC scientists have developed models to predict potential fish invaders in the Great Lakes (Introduction Stage; Kolar and Lodge 2002) and have been involved in the early detection and monitoring of invasive species in the UMRS (Establishment Stage; USGS 1999). The Long-Term Resource Monitoring Program (LTRMP) for the UMRS, under the guidance of the UMESC, for example, documented the introduction and expansion of bighead and silver carps in the UMRS. See Appendix B for a more thorough discussion of the history of invasive species research at the UMESC. Although research on aquatic invasive species at the UMESC has been productive, it has become more responsive and less strategic over time.

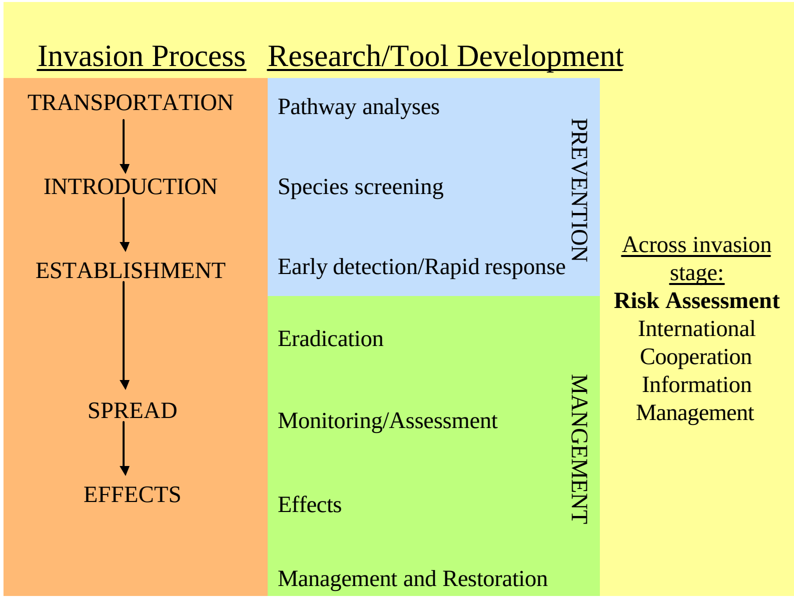

Figure 2. Stages of the invasion process (orange) with the associated research and tool development needs for the prevention (blue) and management (green) of invasive species. Risk assessments, international cooperation, and information management are needed across all invasion stages.

The purpose of this document is to lay out strategic research directions on invasive species at the UMESC to help Center Management to 1) assess new proposals for "base-funded" research, 2) encourage proposals for cyclical USGS funding, 3) focus Center activities in regional or national invasive species planning and advisory activities, and 4) enhance science leadership within existing partnerships (e.g., GLFC, LTRMP) related to impacts or control of invasive species.

The UMESC has made substantial contributions toward the better understanding of the prevention and control of aquatic invasive species. The culmination of a variety of factors will ensure that the UMESC will be well positioned to become a more visible player in invasive species research in the Upper Midwest and on the national front. These factors include (1) proximity to two highly invaded ecosystems; (2) the Center's extensive history on invasive species research; (3) management of the LTRMP; (4) close association with the GLFC; (5) strong quantitative focus; (6) strengths in geospatial, landscape, decision support tool development, and risk assessments; (7) the increasing awareness and concern of invasive species by partner entities; and (8) the development of a more cohesive and strategic research plan.

This plan was developed by Cindy Kolar (ecology and fisheries, Branch of Chemistry and Physiology), Michael Boogaard (chemistry, Branch of Chemistry and Physiology), Verdel Dawson (toxicology, Branch of Chemistry and Physiology, retired), Steven Gutreuter (ecology and statistics, Branch of Aquatic Sciences), Brian Ickes (ecology and fisheries, Branch of Aquatic Sciences), Eileen Kirsch (ecology and birds, Branch of Terrestrial Sciences), and Kirk Lohman (ecology, Geospatial Sciences and Decision Support Laboratory).

The Plan: Research Directions for the Next Five to Ten Years

Vision UMESC will play a more vital and cohesive role within the USGS in advancing the prevention and management of aquatic invasive species by building on our Center strengths, developing and growing current partnerships, and applying our collective talents to provide high quality management tools and scientific products

A focused research program at the UMESC on aquatic invasive species should take full advantage of Center facilities and human resources, such as field capabilities and tool development expertise, to meet partner and client needs at the regional and national level. The program, however, should look beyond current strengths at the Center to emerging invasive species issues. The research directions presented here were developed after consulting documents such as the National Invasive Species Management Plan (National Invasive Species Council 2001) and the Invasive Species Program Element Five Year Strategic Plan (USGS 2003), both important at the national level, and several documents regarding research priorities for invasive species at the regional level (see Appendix C for a listing of documents that were consulted). Research directions for invasive species at the UMESC are organized into primary and secondary areas of emphasis.

Primary areas of emphasis are those that should be pursued proactively and aggressively. These are areas in which sophisticated and holistic approaches should be taken to increase visibility of the UMESC regarding invasive species issues. They are areas in which the UMESC has existing capabilities and expertise, but that might require more focused development. They are areas that are or may become more important in invasive species research in the next several years. Two primary areas of emphasis are identified in this document: Ecological forecasting and risk assessment of invasive species and the Ecology of invasive species.

Secondary areas of emphasis are those in which UMESC scientists have substantial capabilities and reputation, but for reasons such as lack of potential for substantial funding or current political pressures and public attitudes, are not expected to be areas of growth for invasive species research in the next 5 years. They are areas in which the UMESC should maintain its capability, and perhaps even market its expertise. Research in these areas should proceed largely in response to partners seeking the expertise of the UMESC rather than by providing a basis for program development. Three secondary areas for emphasis are identified in this document: Science support for rapid response, Monitoring of invasive species, and the Science of invasive species management and ecological restoration of native habitats and taxa.

In the following section, each recommended area of emphasis will be discussed and described. For each, the issue, rationale for UMESC involvement (i.e., UMESC assets that can be applied to the problem), approach suggested for UMESC scientists to take, research goal, and objectives for each emphasis area are presented. With each objective are provided bulleted points as examples of the types of research possible at the UMESC given the strengths of the Center, current trends in research on invasive species, and partner needs. These examples are not intended to be a work plan; rather, they exemplify the types of questions envisioned under each objective.

Primary Areas of Emphasis

Ecological Forecasting and Risk Assessment of Invasive Species

Issue. Most research on invasive species has been reactive and occurred after a species is established, is spreading quickly, or is negatively affecting the invaded ecosystem (Kolar and Lodge 2002). In the past decade, however, growing emphasis has been placed on preventing the establishment and spread of invasive species. This change in research emphasis is evident in the published literature, in the stated needs of potential partners, in the National Invasive Species Management Plan (NISC 2001), and in proposed legislation regarding aquatic invasive species (National Aquatic Invasive Species Act). Perhaps the most important and overarching component of preventing invasions is being able to predict the success, distribution, and effects of potential invading species. Similarly, perhaps the most important component of providing viable management alternatives is being able to predict the outcome of such actions. Both of these ends require substantial abilities in ecological forecasting and risk assessment. Ecological forecasting and risk assessment are appropriate at all stages of the invasion process—broadly categorized as Prevention and Management (Figure 2)—and are capabilities needed within the Federal government to further progress in understanding invasive species issues. A substantial niche in ecological forecasting and risk assessment exists, particularly in freshwater and wetland ecosystems and species, within the USGS for the UMESC. These capabilities are also being developed for the more terrestrially focused research at the new USGS National Institute of Invasive Species Science in Fort Collins, Colorado.

Rationale (UMESC Assets). The UMESC has the following human, physical, and informational resources that would be of benefit researching ecological forecasting and risk assessment of invasive species: (1) Geospatial modeling capabilities, (2) Quantitative expertise, (3) Wide range of biological expertise, (4) Some past experience in risk assessments and ecological forecasting, and (5) Access to LTRMP and other relevant databases.

Approach. Increasing the capability of scientists to accurately predict potential invaders, their distribution, and potential effects on invaded ecosystems is central to successfully combating the damaging effects of some invasive species. Risk analysis, risk assessments, and ecological forecasting are important tools that can be used to increase predictive ability. These tools include an array of categorical, qualitative, and quantitative methods, some of which include geospatial applications. Developing a specialization in ecological forecasting and risk assessments, rather than being species or ecosystem focused, would allow the UMESC to apply them to a variety of ecosystems and species as well as to both basic and applied ecological problems. Although the UMESC is strong in quantitative expertise, key personnel may require additional training in risk assessment, risk analysis, and ecological forecasting. Collaboration may also fill some of this need.

Goal. Develop high quality, practical, science-based tools for managers and other decision makers to prevent and manage aquatic invasive species.

Objective 1. Use ecological forecasting and risk assessment information to develop priorities for implementing a program to prevent the introduction of aquatic invasive species.
Priorities in preventing introduction of aquatic invasive species:

- Establish a robust system for ranking risk assessment factors that could be used to determine the most critical pathways of entry, vectors of transport, species most likely to become established, and habitats most at risk
- Conduct risk assessments for individual species (e.g., bighead and silver carp risk assessments funded by FWS)

- Develop species screening tools to assess risk of potential new invaders

Objective 2. Use ecological forecasting and risk assessment information to develop a better understanding of factors that facilitate the spread, ecological effects, and management of aquatic invading species.

Factors associated with the species:

- Conduct risk assessment of the potential for established invaders to invade new areas (e.g., zebra mussels into inland lakes, bighead and silver carps into backwater habitats)
- Use existing life-history databases to identify species that may pose a particularly high risk (e.g., r-selected opportunistic strategists in all systems, periodic strategists in some rivers, etc.)
- Examine life history characteristics of invading species (i.e., Asian carps) in field and laboratory experiments to better determine the potential spread of the species
- Identify high-risk entry points for aquatic invasive species (e.g., ports, aquaculture facilities near highly connected inland waterways) in preparation for rapid response initiative
- Quantify risk of recently discovered invading species to determine appropriate action to take (i.e., in a given situation, should early detection lead to rapid response)
- Identify potential pathways and predict potential distributions of currently established invasive species
- Develop tools to choose appropriate management actions based on ecological forecasting and risk assessments

Factors associated with the vulnerability or sensitivity of ecosystems to invasion:

- Determine whether properties of ecosystems, such as food-web complexity, abundance of predators, potential pathogens and parasites, connectivity, resilience, nutrient enhancement, altered hydrology, altered fire regimes, roads, trails, climate change, and production affect vulnerability to invasion (e.g., are species-rich ecosystems generally more or less vulnerable to invasion than species-poor ecosystems? Does disturbance frequency affect vulnerability?)
- Develop geospatial management tool to determine regions or habitat types of the UMRS most vulnerable to invasion
- Use databases to model the spread of individual species through the UMRS over time to look for patterns—to identify pathways at greater risk of invasion, hindrances to spread (e.g., Lock and Dam 19), taxa that spread the most quickly, or habitats more prone to invasion
- Test theorized causes and correlates of invasibility with case studies

Ecology of Invasive Species

Issue. Once an invasive species is established, it is often necessary to determine the ecological effect, especially when such effects are perceived to be economically detrimental. Thus, determining the effects of an invasive species is critical for developing control strategies, management alternatives, or approaches that otherwise mitigate the negative effect. Additionally, investigation of the effects of invasive species on ecosystems provide an opportunity to learn, producing valuable lessons that can be applied to future invasions.

Ecologically, invasive species can affect the abundance, productivity, and survival of native species directly—by predation and competition—and indirectly—by altering nutrient and energy flow pathways or the physical environment by their presence or actions. Such effects often result in astounding economic and sociological consequences. Decisions concerning how to control invasive species—and where and at what spatial and temporal scales control can be effective in terms of supporting (restoring) native species and natural ecosystem processes—require an understanding of a full range of effects for some particularly harmful invasive species.

Rationale (UMESC Assets). The UMESC has the following human and physical resources that would benefit research on the ecology of invasive species: (1) Extensive ecological experience—many historical and on-going studies in terrestrial and aquatic ecosystems, (2) Scientists with diverse specializations, (3) Geospatial capabilities, (4) Statistical expertise, and (5) Extensive facilities, equipment, and infrastructure in place to conduct field and laboratory studies.

Approach. Ecosystems are increasingly under threat from certain invasive species; some invasions can have profound ecological and economic consequences. Comprehensive understanding of the effects of invasive species requires research on the basic biology of the invasive species (autecology) and how it interacts with its environment and the native biotic community (synecology). Experimental and observational studies will be conducted in both field and lab settings at scales appropriate for the research question.

Goal. Identify the effects of harmful invasive species on native systems and their components.

Objective 1. Study the physiology, ecology, and population dynamics of aquatic invasive species to develop possible avenues for control and mitigation (Autecology of invasive species).

- Identify areas or stages susceptible to control (chemical, physical, and biological)
- Determine specific life stage habitat requirements of invasive species and use such information to predict effects on native species, constraints to distributional spread, and areas where control could be implemented
- Determine native taxa most likely to be affected by invasive species

Objective 2: Determine the individual and cumulative effects of aquatic invasive species on ecosystem processes (Synecology).

- Investigate the effects of invasive species on energy pathways and food webs
- Investigate the effects of invasive species on the physical environment (e.g., increased suspended sediment resuspension, destruction of vegetation)
- Assess the direct and indirect effects of invasive species on habitats and species of management concern

Objective 3. Study ecosystem level processes and conditions that may control aquatic invasive species or keep them from spreading (Effects of Management).

- Study the efficacy of management techniques in controlling invasive species and reducing their spread such as fire, erosion, and deposition processes, atmospheric and climatological stresses, chemical pollution, land use changes and management practices, chemical applications, habitat manipulation, and habitat restoration
- Assess whether dams alter the rates or extent of effects of invasive species on native species

Secondary Areas of Emphasis

Science Support for Rapid Response

Issue. Growing evidence indicates early control of potentially harmful invasive species can prevent them from attaining nuisance levels. Therefore, detecting such nonindigenous species soon after their introduction may be key to preventing negative consequences from their introduction. Early detection and rapid response to newly invading species have been the focus of several regional and state management plans. After an invading species is detected and a risk assessment determines that a rapid response (control) effort is called for, a control plan must quickly be developed. Development of these plans requires technical expertise (e.g., of chemical efficacy and application) not widely available.

Rationale (UMESC Assets). The UMESC has the following human resources to benefit research on the science support for rapid response of partner and client agencies: (1) Extensive and unique expertise in chemical control of fishes, (2) Geospatial expertise, and (3) Expertise in developing chemical treatment plans for flowing waters.

Approach. Because of the expertise housed within the UMESC on chemical control and integrated pest management of fishes, partners previously have sought the help of UMESC scientists in developing chemical control plans. The facilities and expertise at the Center have made us the national leader in this field. We therefore expect UMESC personnel to be approached by funding partners to do additional work in this field. Given the importance of developing rapid response plans and the wealth of such knowledge at the Center, UMESC should continue to provide technical assistance in developing rapid response plans. It may be appropriate to market our expertise to potential partners. Developing these plans would be a collaborative effort.

Goal. Use current expertise at the UMESC to provide science support for partner clients to control the newly established or currently established aquatic invasive species with expanding range.

Objective: Maintain and demonstrate capability to develop rapid response plans for the control of invasive aquatic species.

- Produce synthetic paper on the current state of chemical control effectiveness for aquatic vertebrates or produce document for use in marketing the UMESC capabilities in chemical control plan development
- Develop and demonstrate the UMESC capabilities in providing science support for rapid response to invasive species (pilot project integrating geospatial and CAP expertise).
- Maintain existing advisory roles on rapid response committees (e.g. Chicago Rapid Response Committee)
- Provide scientific expertise for interagency rapid response teams
- Participate in multidisciplinary teams to provide assessment of impacts of new invaders and to provide sound scientific advice for biological “SWAT” teams responding to new invasions

Monitoring of Invasive Species

Issue. Accurate monitoring of invasive species is important to understanding their rate of spread, ecology, and population biology, and is important in developing control plans and management strategies. Monitoring of invasive species has been identified as a key area in need of improvement in the National Invasive Species Management Plan (NISC 2001). Standard survey methods employed by monitoring programs, however, were not developed to accurately detect rare species (relevant to early detection of invasive species) or particular invasive species due to unique behaviors or areas they inhabit. In addition, the behavior or habitats of some invasive species may make them particularly difficult to detect and monitor. Innovative, accurate, and reliable methods of monitoring invasive species are needed.

Rationale (UMESC Assets). The UMESC has the following human, physical, and informational resources that would benefit research on monitoring of aquatic invasive species: (1) Expertise within the LTRMP, (2) LTRMP datasets, (3) Statistical expertise, and (4) Geospatial capability.

Approach. The UMESC has taken on a national leadership role in the monitoring of riverine aquatic organisms with the administration of the LTRMP. As specialists in monitoring of aquatic organisms, UMESC personnel may be approached to develop methods to accurately monitor invasive species in particular situations.

Goal. Develop a better understanding of the spread of aquatic invasive species and refine methods for monitoring expanding populations for implementation by partner and client.

Objective 1. Develop and improve methods to reliably monitor invasive species.

- Develop scientifically sound monitoring techniques that could provide multi-scale data with less demand on human resources
- Determine the degree to which such methods (developed above) can be applied to a different taxa
- Develop methods to assess populations of bighead and silver carps in the UMRS and round goby in the IIWW

Objective 2. Use existing monitoring expertise at UMESC, particularly in relation to the LTRMP, to develop effective strategies for tracking the status and trend of invading populations.

- Synthesize existing LTRMP data sources for information on nonindigenous species within the UMRS and identify hotspots of invasion
- Evaluate methods developed for native species to monitor invasive species
- Integrate historical records, remote sensing data, and field sampling data in geographic information systems to document spatial and temporal patterns of expanding invasions at landscape and regional scales

Science of Management of Invasive Species Ecological Restoration of Native Habitats and Taxa

Issue. By the time a nonindigenous species is reported to have invaded a new habitat, it is usually already well established and has begun to negatively affect native species and their ecosystem. Managers are then faced with the problem of ecological restoration and management of a highly disrupted system. Options for restoration and management of native species and ecosystem function are limited. Technical expertise is required to evaluate alternatives and assist with development of a viable management plan.

Rationale (UMESC Assets). The UMESC has the following human, physical, and informational resources that would benefit research on managing aquatic invasive species and restoration of native habitats and taxa: 1) Expertise in controlling invasive species (e.g. UMESC involvement with the GLFC); 2) Geospatial expertise; 3) Scientists with diverse backgrounds; 4) Extensive facilities, equipment, and infrastructure to enable laboratory and field research

Approach. Involvement by the UMESC in these questions will be driven by client needs. Scientists at the UMESC have a long history of developing tools and operational plans for restoration and management of invasive species. As a result, they have often been approached by funding partners to provide assistance in this area. With the continuing spread of invasive species, the UMESC should expect to be called upon to continue collaborating on research aimed at developing new approaches to controlling invasive species and restoring native habitats.

Goal. Work with partners to study and evaluate alternatives for restoration and management of native species and ecosystem function.

Objective 1. To collaborate on research aimed at understanding the ecological processes most in need of restoration in the Mississippi River System to mitigate the effects of aquatic invasive species.

- Identify sites and processes most in need of restoration
- Develop adaptive management frameworks for restoring native species in the face of invaders
- Evaluate whether floodplain restoration differentially benefit invasive species or native species

Objective 2. To develop scientifically valid procedures to help guide managers in effectively manage aquatic invasive species.

- Develop protocols for rapid response when invasions are first reported, for preventing range expansion, for selecting tools for reducing populations of invasive species, for restoration of habitats altered by invasive species, or for protection and restoration of threatened and endangered species

Objective 3. To collaborate with interdisciplinary teams in developing new approaches to controlling populations of aquatic invasive species.

- Develop new formulations of general or selective chemical toxicants
- Develop new biological control methods
- Develop innovative genetic or transgenic management techniques
- Develop integrated pest management strategies

Objective 4. To provide technical assistance to clients and partner agencies

- Provide technical assistance to agencies responsible for the control of invasive species, for the restoration of native species or critical habitat, or for the restoration of threatened and endangered species

Recommendations

The following recommendations are made to help focus the invasive species research program at the UMESC and to better ensure its success:

1. As stated in the National Invasive Species Management Plan (NISC 2001), "the first line of defense for invasive species is prevention". The invasive species research program at the UMESC should target prevention, in the context of the USGS mission, in a significant portion of research conducted at the Center.

2. Because the resulting ecological and physiological shifts and changes caused by invasive species are intrinsically complex, the most productive and efficient research on invasive species integrates across disciplines and spatial and temporal scales. A significant portion of invasive species research conducted at the UMESC should be interdisciplinary, making full use of the talents of UMESC staff (toxicologists, ecologists, chemists, statisticians, geospatial specialists, and those with mapping capabilities), and including collaborations within the Biological Resources Discipline, the USGS, the Department of the Interior, academic institutions, and other entities as needed.

3. Most of the example research questions listed as bulleted points under objectives in this document are not watershed or taxon focused. Given current and emerging species issues, research focused on species such as the bighead, silver, black (*Mylopharyngodon piceus*), and grass carps

(*Ctenopharyngodon idellus*), round goby, ruffe, Eurasian water milfoil, purple loosestrife, and reed canary grass, would be recommended. Also, given the geographic location of the UMESC, research will likely focus on the UMRS and Midwestern and eastern river systems for riverine questions, as well as on the Great Lakes and Midwestern lakes and wetlands. Specific species and ecosystems or ecosystems studied should be driven by regional concerns, partner and client needs, and USGS research priorities.

4. To optimize both this strategic plan and the ensuing research, it will be important to leverage research done at the UMESC with other efforts underway in the USGS and to foster new collaborations both within the BRD and in the other disciplines of the Bureau. Full advantage of applicable USGS programs such as the Invasive Species Program Element and the focus areas of the Upper Mississippi River and the Great Lakes should also be taken.

5. Foster a relationship with the new National Institute for Invasive Species Science in Fort Collins, Colorado.

6. The UMESC invasive species program should make full use of contacts within the Center for further research on invasive species such as the administration of the LTRMP at UMESC, Pat Heglund as USFWS contact, Kirk Lohman as NPS contact, David Kennedy as the Congressional contact, and Cindy Kolar as chair of the Research and Risk Assessment Committee of the Mississippi River Basin Panel on Aquatic Nuisance Species.

7. A UMESC representative should visit field offices in the Great Lakes and UMRS of potential funding partners (e.g., USEPA and USFWS) to keep current on their research needs and interests.

8. Determine the efficacy of economic cost or benefit approaches (e.g., determine when it is beneficial to take action against an invasive species)

9. Progress made by the new and focused research program on invasive species at the UMESC should be reviewed annually during the assessment of other teams at the Center. This strategic plan also should be reexamined periodically through program implementation (mid-FY2006).

Program Needs

The wealth and diversity of scientific expertise, facilities, equipment, and infrastructure at the UMESC put the Center in a good position to further develop an invasive species research program. Assigning personnel dedicated to implementing the plan is essential. Additional training may be necessary for several UMESC scientists to further develop expertise in risk assessment and ecological forecasting. Hiring an ecosystem modeler could strengthen the risk assessment and environmental effects aspects of the proposed program. Similarly, research conducted at the UMESC on the environmental effects of invasive species are limited by the facilities and equipment currently housed at the Center, particularly for terrestrial species (e.g., lack of greenhouse, laboratory facilities for terrestrial vertebrates). All of these needs can be met through collaboration or contract with state agencies or universities, however. If the focus of invasive species research at UMESC is expected to have a greater focus on terrestrial species, these limitations should be addressed in a long-term plan.

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Glossary

BOR	Bureau of Reclamation
BRD	Biological Resources Discipline
CAP	Branch of Chemistry and Physiology
GLFC	Great Lakes Fishery Commission
IAFWA	International Association of Fish and Wildlife Agencies
IIWW	Illinois Inland Waterway
LTRMP	Long Term Resource Monitoring Program
NASA	National Aeronautics and Space Administration
NPS	National Park Service
UMESC	Upper Midwest Environmental Sciences Center
UMRS	Upper Mississippi River System
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

Appendices to the Invasive Species Research Strategic Plan for the Upper Midwest Environmental Sciences Center

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Appendix A. *Invasive Species Publications of the Upper Midwest Environmental Sciences Center: 1964 – 2004*

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Appendix B. *History of Invasive Species Research at the Upper Midwest Environmental Sciences Center*

The study of invasive species at the Upper Midwest Environmental Sciences Center (UMESC) dates back to the formation of a federal research presence in La Crosse, Wisconsin in the 1950s. The American Fisheries Society resolved at its 88th annual meeting in 1958 to recommend an expansion of research in fish control to the Secretary of the Interior. In that same year, Congress made the first appropriation for establishment of the Fish Control Laboratory at La Crosse, Wisconsin. The Bureau of Sport Fisheries and Wildlife established the laboratory in 1959. The initial mission of the laboratory was to develop means for efficient manipulation of freshwater fish. In particular, safe and economical controls (chemical, biological, electrical, or mechanical) were sought for undesirable populations in standing and flowing waters. The objectives were sufficiently broad to encompass investigation and development of any new tools that may be useful in fishery management, fish culture, or fishery research. Early recognition was given to the potentials of chemical control agents such as general and selective toxicants, attractants, repellants, anesthetics, sterilants, spawning inducers, osmoregulators, marking dyes, medications for diseases, and sedatives and decontaminants for fish distribution. Emphasis was on finding selective toxicants for longnose and shortnose gars, gizzard shad, goldfish, carp, squawfish, white sucker, black bullhead, rock bass, green sunfish, pumpkinseed, yellow perch, and freshwater drum.

Early studies involved evaluations of various chemicals such as toxaphene and antimycin as piscicides. Much of the research focused on development of general toxicants, but the laboratory soon became involved in the effort for selective control of sea lamprey in the Great Lakes. The Fish Control Laboratory at La Crosse and the Hammond Bay Biological Station at Hammond Bay,Michigan, ooperated in the development and registration of the lampricides TFM and Bayluscide that are still being used as the primary means of managing sea lamprey populations in the Great Lakes. In the 1960s and 1970s, the laboratory concentrated its invasive species research on the efficacy and environmental safety of the lampricides. These studies included toxicity to target and non-target organisms, analytical methodologies, residue studies, uptake, metabolism, and elimination studies, photolysis studies, and microbial degradation studies. During this time, rotenone was also being developed and registered as a piscicide. New piscicidal candidates were being evaluated such as juglone, isobornyl thiocyanoacetate (Thanite), Salicylanilide I, and the selective toxicants, Squoxin and 2-(digeranylamino)-ethanol (GD-174).

In 1947, Congress passed the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) that regulated the licensing and application of pesticides, primarily for agriculture. Initially the USDA was given the responsibility of registering pesticides. The responsibility passed to the United States Environmental Protection Agency (EPA) when it was created in 1970. Amendments to FIFRA were made in 1980 and 1988, with the latter amendment requiring that all pesticides registered prior to 1984 undergo a reregistration process. This was largely done because testing methodology had improved significantly, and Congress felt this necessitated repeating the registration process for older chemicals. Consequently, in the late 1980s and 1990s research effort was once again centered on the previously registered piscicides, antimycin, rotenone, TFM, and Bayluscide. New data, primarily involving safety studies, were collected and submitted to the EPA in support of the reregistration process.

Thus, development of chemical controls for nuisance fishes such as common carp at the UMESC was expanded in the 1960s to the control of invasive sea lamprey in the Great Lakes. These two efforts constituted the Center's major research emphasis on invasive species through the 1980s. The late 1980s brought a rapid expansion of the number of nonindigenous species in the aquatic systems of the Upper Midwest. New invasive organisms found their way into the Great Lakes, presumably by way of ballast water discharges from ocean-going vessels. These included the zebra mussel, Eurasian ruffe, and round goby. The range of the zebra mussel expanded considerably in the 1990s, and the species became a serious ecological threat throughout the Great Lakes and the Mississippi River Basin. As a result of these new invasions and range expansions, the UMESC expanded its success with sea lamprey and focused its chemical control talents on new Great Lakes invasive species. In response to the zebra mussel invasion of the Upper Mississippi River System, UMESC scientists also examined food web effects of zebra mussels on native fishes and birds, their ability to bioaccumulate toxins, and on ways to minimize the likelihood of introducing zebra mussels concurrent with native mussel conservation activities. Also from the 1990s until currently, the Long Term Resource Monitoring Program for the Upper Mississippi River, under the guidance of the UMESC, has documented the introduction and expansion of bighead and silver carps and other fishes such as white perch in the system.

In 2002, the UMESC stepped out of its regional focus to partner with the Bureau of Reclamation to assess integrated strategies to control invasive fishes in the southwestern United States. The native fish fauna of the southwestern United States, including that in the Gila River Basin in Arizona and New Mexico, is critically imperiled as a result of the introduction and establishment of nonindigenous fishes. As a result, UMESC scientists assembled a comprehensive review of integrated management techniques to control nonnative fishes.

Appendix C. *Strategic Documents of Other Entities for Invasive Species Research at the National or Regional Scale Consulted in Developing This Strategic Plan*

1. Great Lakes Panel on Aquatic Nuisance Species Research Committee ANS Research Priorities for the Great Lakes (draft) July 2003
2. Species of concern: Midwest Natural Resource Group. Partner Responses for Early Detection and Rapid Response
3. National Invasive Species Council. 2001. Meeting the invasive species challenge: National Invasive Species Management Plan. 80p. http://www.invasivespecies.gov.
4. U.S. Geological Survey Invasive Species Program Element Five Year Strategic Plan. 2003 (draft). 50p.
5. Mississippi River Basin Panel on Aquatic Nuisance Species Risk Assessment and Research Committee ANS Research Priorities for the Mississippi River Basin (draft) January 2004
6. U.S. Fish and Wildlife Service. 2002. Fish and Wildlife Resource Conservation Priorities. Region 3. January 2002. Version 2.0. 34p.
7. U.S. Geological Survey Eastern Region Integrated Science Priorities
8. Research priorities for aquatic invasive species. Hearing before the Subcommittee on Environment, Technology, and Standards Committee on Science. House of Representatives, One hundred seventh Congress, Second Session. June 20, 2002. Serial Number 107-72. Available via the World Wide Web: http://www.house.gov/science.
9. Non-Native Invasive Species Framework for Plants and Animals in the U.S. Forest Service, Eastern Region. 2003. R9 Regional Leadership Team, April 11, 2003.
10. Strategic plan for the U.S. Geological Survey Program on the Status and Trends of Biological Resources, 2004-2009.
11. The Nature Conservancy. 2003. Aquatic invasive species role definition. Information developed during a meeting to discuss the role that the TNC may have for combating aquatic invasive species. Draft.
12. Weitzell, R.E., M.L. Khoury, P. Gagnon, B. Schreurs, D. Grossman and J. Higgins. 2003. Conservation Priorities for Freshwater Biodiversity in the Upper Mississippi River Basin**.** Nature Serve and The Nature Conservancy. July 2003.
13. International Association of Fish and Wildlife Agencies Strategic Plan. December 15, 2003.