Great Lakes Panel on Aquatic Nuisance Species
Aquatic Invasive Species Research Priorities for the Great Lakes - 2009

Background

Aquatic invasive species (AIS) significantly affect the ecological and economic integrity of the Great Lakes-St. Lawrence region. More than 180 aquatic nonindigenous species have been documented in the region as of April 2009, including well-known species such as zebra mussel, sea lamprey, purple loosestrife, Eurasian watermilfoil, round goby, ruffe, spiny water fleas, quagga mussel and rusty crayfish. Pathways of introduction include shipping (primarily through ballast water discharge), canals that artificially connect the Great Lakes to other watersheds (e.g., the Erie Canal), movement of recreational boats and equipment, stocking, the live and fresh fish industry, aquarium trade, biological control, recreational fisheries enhancement, live bait and horticultural practices. Introductions associated with these activities are both accidental and intentional.

More information and research is needed to prevent future unintentional AIS introductions, to respond to new introductions upon their discovery and to manage and control established invasive species populations. The Research Coordination Committee of the Great Lakes Panel on Aquatic Nuisance Species (hereafter the Great Lakes Panel) has compiled the following document to serve as a resource for, and provide guidance to, private foundations and local, state/provincial and federal agencies that provide funding for research on AIS prevention and control in the Great Lakes as well as those involved in the conduct of AIS research, management and control initiatives.

Various state and regional research and management plans and conference proceedings were reviewed to develop these priorities (*see References*). Research on some of these priorities is already underway or completed (*see Appendix*), yet some of the items remain priorities because there are gaps in knowledge that must be addressed before an item is stricken from the list. These research priorities were identified for the Great Lakes but in many instances they could be applied to the inland waters of the basin. The list is intended to be dynamic, changing as our knowledge expands and our focus varies.

Prevention - Maritime shipping (ballast water, hull fouling, anchor lockers etc.)

Transoceanic shipping has been the primary vector for AIS introductions in the Great Lakes-St. Lawrence River system. Based on the species listed in GLANSIS as of April 2009, 35 of 78 (44%) aquatic nonindigenous species first reported in the Great Lakes between 1960 and 2009 have been attributed to discharge of untreated ballast water. Intra-coastal and domestic Great Lakes vessels (e.g., lakers) can facilitate the spread of AIS already present within the Great Lakes-St. Lawrence River system, and nearshore waters of the east coast of Canada and United States. Research is underway to identify and develop means of treating ballast water and sediment to eliminate this mode of species introduction. Until shipboard treatment systems certified for use in the Great Lakes (i.e., effective in temperate, freshwater systems) are verified and in widespread operational use, research efforts should continue to be devoted to both advancing the implementation of shipboard treatment systems for ballast water (both pumpable and unpumpable (no ballast on board (NOBOB)) ballast water), and assessing the efficacy of a saltwater-based ballast management program. Research priorities include:

- Continue to develop methods and protocols to assess the effectiveness of shipboard ballast water treatment systems against specified discharge standards.
    - Continue efforts to purchase or lease vessels for full-scale ballast water treatment technology testing platforms. Make full-scale ballast water treatment test platforms available in the form of shore-based facilities or U.S. Department of Transportation - Maritime Administration (MARAD) vessels and conduct full-scale demonstrations of ballast water treatment technologies on shore or ship under actual operating conditions.
    - Evaluate on-board treatment systems on Lakers consistent with or as part of the US Coast Guard STEP program, to verify treatment performance standards across the range of environmental (temperature and salinity) conditions typical for the Great Lakes shipping season, and operational constraints of the Great Lakes shipping fleet.

    - Test efficacy of ballast water treatment systems for fresh water ballast over the range of environmental conditions (temperature and salinity) typical of both the Great Lakes ecosystem and ballast water carried during the Great Lakes shipping season for saltwater vessels, in order to prevent both new AIS introductions from foreign freshwater ports and/or secondary spread between Great Lakes ports by saltwater vessels.
    - Test efficacy of ballast water treatment systems for fresh water ballast over the range of environmental conditions (temperature and salinity) typical of both the Great Lakes ecosystem and ballast water carried during the Great Lakes shipping season by Lakers, considering physical and operational limitations of Great Lakes vessels, in order to prevent secondary spread between Great Lakes ports by Great Lakes vessels.
- Continue to develop technologies to reduce the number or concentration of AIS discharged with ballast water in accordance with applicable standards as they are developed.
- Continue to develop technologies to reduce entrained and accumulated sediment in ship ballast water and tanks in accordance with applicable standards as they are developed.
- Continue to conduct research on ballast in coastwise vessels.
- Continue to identify maritime transportation routes, such as has been done with the Ponto-Caspian region that have demonstrated or potential capability to transfer AIS to the Great Lakes.
- Continue to conduct research on factors affecting the resuspension of organisms in sediment in ballast tanks.
- Conduct research on the environmental soundness of alternative ballast water treatment technologies.
- Develop a program to identify, assess, and address potential high-threat invader organisms present in foreign fresh and brackish water systems.
- Quantify the relative risk of small vessels, including small commercial vessels that are not subject to U.S. Coast Guard inspection and larger recreational vessels that are not trailerable.
- Continue development of "ballast-free" ship designs, considering changing needs associated with economic factors, climate change, available draft and changing trade patterns.
- Continue to evaluate the risk of secondary spread of AIS associated with Lakers and their trade routes.
- Develop and evaluate practices (ballast water management tools) for reducing the risk of inter/intra lake transport of non-indigenous species by Lakers for immediate implementation.

Prevention - Canals and artificial waterways connecting Great Lakes to other watersheds

Canals and waterways facilitate the conveyance of bulk goods and commodities and are used for recreational activities, but they also facilitate the spread of AIS by allowing cross-basin transfer between watersheds. Closing canals and waterways can re-establish the natural geographic separation of the Great Lakes from other drainage basins. Existing canals and waterways in the Great Lakes -St. Lawrence River basin should include dispersal barriers, flood control barriers, physical barriers, and other provisions to ensure hydrologic separation of historically disconnected watersheds. Wherever possible, canals that are no longer in use should not be improved and, in fact, should contain physical barriers to prevent the free-flow of aquatic organisms. Similarly restoration of native fish passage to inland waters by the removal of dam or culvert barrier needs to be considered against the risk that this may open up previously uninvaded waters to AIS colonization. Specific recommendations include:

- Accelerate research efforts on different types of AIS barriers for canals and waterways.
- Examine options for permanent hydrological, ecological and/or biological separation of the Great Lakes and Mississippi River systems.
- Determine the feasibility of physical barriers or control structures in canals that have fallen into disuse or disrepair as a way to prevent the introduction and spread of AIS.
- Determine the potential of canals and waterways to spread AIS through intermittent flood-related connections or water level changes.
- Conduct research on dam removal and integrate research findings into dam removal planning and implementation activities to reduce the risk of creating new and unintentional AIS pathways.

Prevention - Commerce in live organisms

Introductions arising from the trade in live organisms are the second most significant source of new invasions into the Great Lakes. Species are imported directly for the aquarium and water garden trades, aquaculture, and live food industries. A small number of species are prohibited from sale and possession, but there is little consistency across jurisdictions within the basin. This allows the importation, interstate commerce, and widespread dispersal of numerous problem species including known invasive species, increasing the potential that some will eventually be either accidentally or deliberately released and become established in natural waterways. A more comprehensive and consistent approach to regulating the live trades is required and needs to be supported by robust science. Research needs include:

- Continue to review state of risk assessment globally to identify the most accurate and cost effective methods.
- Quantify the number of species, trade volume and economic values of organisms in trade.
- Develop a suite of risk assessment tools for fishes, plants, mollusks, amphibians, reptiles and crustaceans to identify a list of high and low risk species.
    - Support research to advance the understanding of aquatic invasion biology, particularly characteristics of successful/unsuccessful invasions and invaders.
    - Quantify life history characteristics that lead to successful invasions (e.g., propagule pressure and trophic disruption).
    - Research species attributes to complement the development of risk assessment tools.
- Consider global climate change in the development of future models.
- Quantify economic costs and benefits of different levels of management of live organism commerce.

Prevention - Trailer craft including recreational boaters

Boats that are capable of being trailered and moved across natural watershed boundaries are an important vector of primary and secondary spread of AIS into and around the Great Lakes basin. The problem is large with millions of boaters and tens of thousands of lakes and water bodies that could be invaded and act as stepping stones for the invasion of the Great Lakes or neighboring watersheds. Large amounts of operational and voluntary resources are expended on this invasion pathway with a strong emphasis placed upon boater education. Research needs include:

- Continue to quantify boater movement patterns and develop spread models that more accurately predict high risk invasion sites, and the most important source waters for AIS around the basin.
- Continue to conduct environmental niche modeling for priority invasive species localized or absent in the Great Lakes basin to identify vulnerable waters.
- Continue to measure the effectiveness of boater AIS education programs by quantifying behaviors and compliance (at landings) with "Clean Boat" education programs.
- Continue to determine the relative invasion risk posed by different small craft boating groups (e.g., yachts, jet skis, recreational and small boat commercial fishers, guides, etc.).

Preventing and managing new invasions (general cross cutting themes)

Prevention of new AIS introductions must remain a top priority. Efforts should focus on pathways, origins, technologies and methods that will prevent both entrainment of organisms into transport vectors and their release and establishment in the Great Lakes. Research needs include:

- Determine the relative risk for introducing new AIS of pathways and vectors other than ballast water.
- Continue to apply genetic tools to identify relationships among source communities and newly established AIS populations to identify high risk trade routes.
- Develop tools to measure the effectiveness and/or difference that AIS management strategies are making.
- Quantify community and species patterns at high risk invasion sites to provide baseline reference measurements that will (1) enable ecological change to be measured if new AIS become

established; (2) aid identification of new invasive species; and (3) help quantify differences resulting from management efforts.

Detection, Monitoring and Rapid Response

Effective early detection and rapid response (EDRR) requires that new introductions are detected in the early phases of establishment while populations are still susceptible to management. It also requires that effective containment, control and eradication tools are available once founding populations are detected to ensure that they can be eradicated. Work is required to develop effective rapid response tools (chemical and physical) and to ensure that the appropriate legal mandates are in place to allow their application. EDRR requires effective monitoring tools that can detect species at low abundances with known detection limits. Effective EDRR will also require regionally coordinated surveillance monitoring programs undertaken over appropriate time scales. Specific recommendations include:

- Identify policy and management barriers to effective assessment or response and better ways to optimize informed management decisions following the discovery of new AIS.
- Continue to compile a "hot list" of high risk invasive species that are predicted to be the next pest species to invade the Great Lakes. Conduct research as needed to verify and expand the "hot list" of high risk species, potential source locations, and probable impacts.
- Review and develop standardized surveillance monitoring techniques for high risk invasive species (see previous bullet), quantifying detection limits and appropriate sampling periodicity.
- Review availability (legal, specificity, toxicity) and effectiveness of existing control tools for the range of taxonomic groups and species that may invade the Great Lakes.
- Develop environmentally acceptable chemical (e.g. selective biocides) and physical control and eradication tools for localized rapid response for those taxonomic groups (e.g., crustacean) for which no tools exist.
- Continue to develop genetic markers for all high risk invasive species predicted to invade the Great Lakes.
- Establish coordinated monitoring programs focusing on high risk areas to provide surveillance for (early detection) new introductions.
- Develop coordinated rapid response plans.

Control and Management

Advances in AIS control and management have and are being made, but such progress is often slower than species movement. Management and, if possible, containment of existing populations will help provide researchers time to develop new methods to eradicate and better control invasive species. Sea lamprey control remains a high priority. For example, recent developments in pheromone research are expected to augment lamprey control efforts but rising abundance of lamprey in Lake Michigan underscores the need for additional control efforts. Environmentally acceptable chemical, physical, and biological control methods including attractant and repellents need to be developed to address other established invasive species.

- Develop environmentally acceptable chemical and physical control and eradication tools for priority established invasive species.
- Develop and refine containment systems for recently introduced invasive species to slow or prevent dispersal of established species.
- Develop ecological forecast methods that identify areas vulnerable to newly introduced species and predict likely dispersal pathways and potential natural barriers that might impede or slow dispersal.
- Conduct life history and basic biology studies of established invasive species to identify behaviors, life history traits or physiologies that might make them responsive to management.
- Study priority invasive species in their native and introduced range (within and outside Great Lakes basin) to identify natural species specific pathogens or parasites that could be safely applied as possible biological control agents.

- Develop decision support tools to quantify the efficacy of different eradication, control or containment approaches to identify strategies that have greatest impact on rates of spread and establishment to minimize economic and ecological impacts.

Coordination and Information Management

Coordination among research efforts should be strongly encouraged to help avoid duplication of efforts and concomitant dilution of research funds. Researchers and funding agencies are encouraged to utilize existing internet-based resources to allow collaboration and data sharing among projects.

- Ensure genetic markers developed for priority AIS are deposited online using the GenBank genetic sequence database in a timely manner to enable rapid identification of newly discovered AIS.
- Develop and widely share the AIS hot list (*referenced above under Detection, Monitoring and Rapid Response*) with entities responsible for rapid response and monitoring efforts.
- Determine and map potential ranges and habitat for AIS in the Great Lakes region.
- Continue to develop and promote use of Internet-based research coordination and information system such as the Great Lakes-St. Lawrence Research Inventory and the Great Lakes Aquatic Nuisance Species Information System (GLANSIS) to foster timely communication and information sharing among researchers, policy makers, extension agents, stakeholders and the general public.
- Provide funding for translation of foreign research articles on newly introduced species for use in rapid response efforts and other needs.
- Monitor ecological studies reported in international donor regions (i.e., those regions identified as posing the greatest risk to the Great Lakes (e.g., environmentally similar, high ship traffic volume)) to identify potentially new "hot" or high risk AIS.

Threats and Impacts to Ecosystems, Human Health and Economic Values

A stronger understanding of the ecosystem and economic impacts of invasive species is required by decision and policy makers to inform public and private investment in AIS management. The economic and ecosystem impacts of invasive species need to be quantified in order to justify increased investment in AIS prevention and control. We need to understand what species have caused the greatest changes to Great Lakes ecology; how ecosystems have responded to invasive species; what is the potential for resisting or facilitating invasion by introduced species; and can the natural invasion resistance of Great Lakes ecosystems be improved. A recognized challenge is that damage to ecosystems and natural resources as a result of invasive species is not immediately apparent unless an economically important resource has been significantly affected.

- Determine impacts of AIS on economically important species and aquatic biodiversity.
- Continue to conduct food web disruption studies, including mechanisms and trophic levels.
- Support research on potential human health and ecosystem issues from pathogens and parasites (e.g., Type E botulism, VHSv).
- Develop better economic models to quantify the impacts of AIS on the Great Lakes ecosystem and economy.
- Develop and validate approaches for assessing economic impacts of AIS and cost-benefit analyses of various management scenarios including control and eradication of individual species.
- Evaluate current and historical damage (e.g., physical, biological, industrial, recreational, ecosystem, beneficial uses) to the Great Lakes caused by AIS to provide decision makers with information to balance the cost of prevention with the costs of control and management.
- Conduct cost-benefit studies on all potential vectors for AIS introduction and spread, including hydrologic and ecological separation of canals and waterways.

References

Appendix