

GREAT LAKES: Lessons from aquatic invasive species cases to inform future invasive species policies and practice



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Table of Contents

Summary Findings and Recommendations	1
Project Overview	2
What We Found	5
Motivation	5
Science	7
Communication	8
Resources	9
Conclusion	10



SUMMARY FINDINGS AND RECOMMENDATIONS

Finding – Motivation: Where invasive species have been stopped or managed, the collective will to succeed is intense, focused and not prepared to concede. Where species have arrived, thrived and remain unchecked, the response has been more tentative and dispersed, without a strong, collective effort

Recommendation One: State, provincial, Tribal agencies with responsibility for managing invasives should invest time and resources on networking and integration within a regional community of practice

Recommendation Two: State, provincial, Tribal agencies with responsibility for managing invasives must strive for interjurisdictional cooperation at scale and from the outset

Recommendation Three: Federal authorities, working with state, provincial, Tribal and First Nations governments, must take every possible step to prevent all potential invaders from entering the system

Finding – Science: Successful AIS prevention or control requires targeted research focused on questions generated by the management or policy community

Recommendation Four: Public and private research agencies should prioritize resources for risk assessment to understand both the probability of invasion and prospective impact from potential invaders

Recommendation Five: Public and private research agencies should prioritize limited research resources on management or policy-informed questions over fundamental science

Finding – Communication: Successful AIS responses require clear, compelling and effective messages delivered by someone the target audience trusts

Recommendation Six: State, provincial, and Tribal agencies with responsibility for managing invasives must develop and deliver clear messages to managers and policy makers from trusted or influential sources

Recommendation Seven: State, provincial, Tribal agencies with responsibility for managing invasives working together must also promote cross-sector and cross-interest dialogue to identify a common, effective response

Recommendation Eight: Leverage all relevant non-governmental sectors and networks to deliver key messages adequate, shared resources, not only in the form of funds but also with facilities, equipment and skilled people

Finding: Resources: Successful AIS response requires adequate, shared resources, not only in the form of funds but also with facilities, equipment and skilled people

Recommendation Nine: Jurisdictions must find effective ways to share resources for invasive species policy and management to succeed

Recommendation Ten: Agencies need to identify the right organization to moderate resource and knowledge sharing to prevent establishment of invasive species

Conclusion

Agencies must have an effective plan coordinated with and integrated into a regional approach, possess or have access jointly to the necessary infrastructure and equipment, and be authorized and prepared to act collectively at appropriate scales for an effective invasive species response.



Trout River nesting male lamprey. Photo by Cory Brant

PROJECT OVERVIEW



Purple loosestrife . Photo by Cory Brant







The Laurentian Great Lakes are vulnerable to incursion by aquatic invasive species (AIS); officials need efficient and effective ways to protect this valuable freshwater resource from AIS destruction. To date, however, approaches to managing invasive species have most often been reactive, rather than proactive, and implemented inconsistently across jurisdictions. This study uses the sea lamprey control program to inform an analysis of five major invasive species—different types of species with unique life-histories and invasion or dispersion vectors—and identifies ten comprehensive recommendations for AIS policy and action.

The cases selected for this study include:

1. **Sea lampreys** (*Petromyzon marinus*) in the Great Lakes, our baseline case which revealed preliminary AIS policy themes and lessons that inspired this study;
2. **Invasive (Asian) carp spp.**, include silver carp (*Hypophthalmichthys molitrix*), bighead carp (*Hypophthalmichthys nobilis*), black carp (*Mylopharyngodon piceus*), and grass carp (*Ctenopharyngodon idella*). These four species constitute a partially successful AIS prevention program for the Great Lakes basin. Silver, bighead and black carp have thus far been prevented from entering the region, while grass carp have been discovered in Lake Erie but are not yet considered established;
3. **Dreissenid mussels** including zebra mussels (*Dreissena polymorpha*) and quagga mussels (*Dreissena bugensis*), both of which are commonly considered AIS policy failures in terms of prevention policy, outbreak responses, and control program in the Great Lakes basin;
4. **Black-striped mussel** (*Mytilopsis sallei*), an Australian invasion case with a successful rapid response and eradication;
5. **Purple loosestrife** (*Lythrum salicaria*), an ecologically destructive plant that has been established in the Great Lakes basin for over a century, and has had successful yet inconsistent control policies at local scales while remaining mostly unchecked at a continental scale; and
6. **Viral hemorrhagic septicemia** (VHS, *Oncorhynchus 2 novirhabdovirus*), a destructive fish disease case in the Great Lakes which triggered rapid responses during outbreaks, and rapid control policies to stop the spread.

Across cases, the strongest common lessons are highlighted in the trend map below – effective ones are green, while ineffective ones are red (Figure 1). Bolded and numbered lessons provided the basis for each recommendation, which have been given corresponding numbers (1-10). The recommendations are grouped into four themes: motivation, science, communication and resources (Figure 2). As you can see from the trend map, many of these elements could easily be discussed under multiple themes, however they are described in the sections most applicable to them.

Figure 1: A trend map showing policy strengths and weaknesses relating to six aquatic invasive species

							
THEMES FROM SEA LAMPREYS CASE STUDY	AIS LESSONS FROM INTERVIEWS	SEA LAMPREYS (REFERENCE CASE)	ASIAN CARPS (SILVER, BIGHEAD, GRASS, BLACK)	DREISSENIID MUSSELS (ZEBRA AND QUAGGA)	VHS	BLACK STRIPED MUSSEL (AUSTRALIA)	PURPLE LOOSESTRIFE
MOTIVATION	1. Strong community of practice	Very strong	Very strong	Very strong	Very strong	Very strong	Very strong
	2. Immediate interjurisdictional cooperation	Very strong	Very strong	Very strong	Very strong	Very strong	Very strong
	3. Understanding that prevention is the best policy	Very strong	Very strong	Very strong	Very strong	Very strong	Very strong
	Communities responded to AIS impact	Very strong	Very strong	Very strong	Very strong	Very strong	Very strong
	Dedication and drive to succeed present	Very strong	Very strong	Very strong	Very strong	Very strong	Very strong
	Risk/clear causation shown (<i>i.e. damage easy to see</i>)	Very strong	Very strong	Very strong	Very strong	Very strong	Very strong
	No pessimism among experts	Very strong	Very strong	Very strong	Very strong	Very strong	Very strong
	Posed direct threat to industry (<i>e.g. fishing, plant nursery</i>)	Very strong	Very strong	Very strong	Very strong	Very strong	Very strong
	Culturally important to do something about AIS	Very strong	Very strong	Very strong	Very strong	Very strong	Very strong
SCIENCE	4. Science directed at risk before invasion occurred	Very strong	Very strong	Very strong	Very strong	Very strong	Very strong
	5. Science conducted for specific management goals	Very strong	Very strong	Very strong	Very strong	Very strong	Very strong
	Epistemic community of professionals	Very strong	Very strong	Very strong	Very strong	Very strong	Very strong
	Risk/clear causation demonstrated scientifically	Very strong	Very strong	Very strong	Very strong	Very strong	Very strong
	Interjurisdictional science sharing occurred	Very strong	Very strong	Very strong	Very strong	Very strong	Very strong
	Trust in scientists did not waver	Very strong	Very strong	Very strong	Very strong	Very strong	Very strong
	Science targets weak points in life history	Very strong	Very strong	Very strong	Very strong	Very strong	Very strong
COMMUNICATION	6. Clear messaging from trusted sources	Very strong	Very strong	Very strong	Very strong	Very strong	Very strong
	7. Meaningful interjurisdictional communication	Very strong	Very strong	Very strong	Very strong	Very strong	Very strong
	8. Leveraged relevant NGO agencies to deliver messages	Very strong	Very strong	Very strong	Very strong	Very strong	Very strong
	First-hand stories/personal impact used to lobby congress	Very strong	Very strong	Very strong	Very strong	Very strong	Very strong
	Key policy person/s got involved	Very strong	Very strong	Very strong	Very strong	Very strong	Very strong
	Authority to act was clearly communicated	Very strong	Very strong	Very strong	Very strong	Very strong	Very strong
	Clear risk and causation communicated	Very strong	Very strong	Very strong	Very strong	Very strong	Very strong
	Media stayed positive that something could be done	Very strong	Very strong	Very strong	Very strong	Very strong	Very strong
No single entity blamed (<i>e.g. industry/region/group</i>)	Very strong	Very strong	Very strong	Very strong	Very strong	Very strong	
RESOURCES	9. Found effective way to share resources cross-border	Very strong	Very strong	Very strong	Very strong	Very strong	Very strong
	10. Single organization to facilitate resource sharing	Very strong	Very strong	Very strong	Very strong	Very strong	Very strong
	Build on existing legislation to take action	Very strong	Very strong	Very strong	Very strong	Very strong	Very strong
	Allocation of resources to combat invader	Very strong	Very strong	Very strong	Very strong	Very strong	Very strong
	Epistemic community of professionals	Very strong	Very strong	Very strong	Very strong	Very strong	Very strong
	Pathway of invasion was clear	Very strong	Very strong	Very strong	Very strong	Very strong	Very strong
	Key policy person/s got involved	Very strong	Very strong	Very strong	Very strong	Very strong	Very strong
	Invasion treated like a disease outbreak	Very strong	Very strong	Very strong	Very strong	Very strong	Very strong
	Treaty and mandate to control invader	Very strong	Very strong	Very strong	Very strong	Very strong	Very strong

■ Very strong (mentioned regularly across interviews as policy strength)
■ Strong (occasionally mentioned in interviews as policy strength)
■ Neutral (mentioned in at least 1 interview, in non-impactful context)
■ Weak (occasionally mentioned in interviews as a policy weakness)
■ Very weak (mentioned regularly across interviews as a policy weakness)

Four Themes: The lessons that emerged across cases fall into four areas, or themes. **Motivation** is the will to succeed among all actors engaged in the effort - a driver of all other aspects. Without sustained motivation the other elements will not succeed. The role of **science** here is deliberately focused on the management needs identified in the system. **Communication** supports the interjurisdictional and cross-sector engagement necessary for success. Finally, recommendations about **resources**, widely recognized as essential, are more nuanced, emphasizing resource-sharing and management across jurisdictions and sectors.

METHODS IN BRIEF

We collected 47 semi-structured interviews with experts in specific cases and with invasive species policy in general. Participants consisted of resource managers, scientists, academics, and non-government organization members. We transcribed and coded interviews using the software NVivo, a common tool for qualitative data analysis. Through the coding, themes emerged that contributed to the emergence of theory and the formulation of recommendations. The study also used literature and other documents to analyze the invasive species cases. Through the interviews with policy and management leaders in the execution of each of our species cases, and through the review of the literature, we identified both effective and ineffective policy and management approaches.

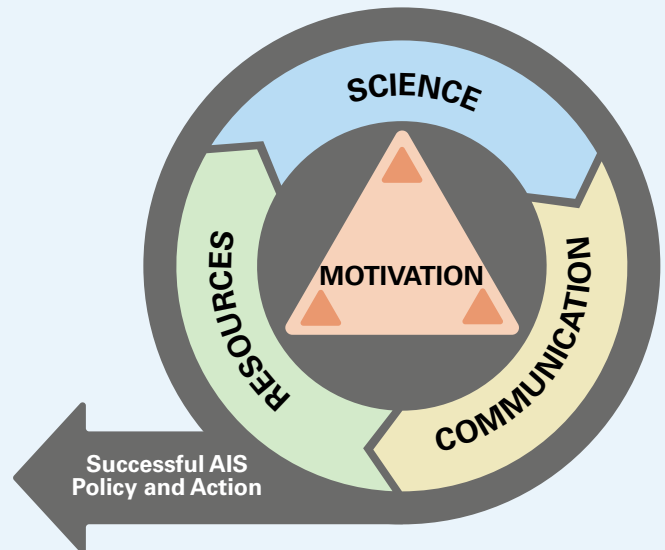


Figure 2: The four key themes for successful AIS policy and management



Adult Silver Carp. Photo courtesy of Asian Carp Regional Coordinating Committee (ACRCC)

WHAT WE FOUND

A closer look at the sea lamprey case in the Great Lakes

The sea lamprey invasion of the Great Lakes was one of the worst invasive species disasters to afflict the basin. The invasion caused major economic harm to commercial, tribal, and recreational fishers, and set in motion negatively cascading ecological impacts that still scar the lakes. The response to sea lampreys is the best, and perhaps only, example of a large-scale integrated control program of a major aquatic invasive species. Beginning with the creation of the Great Lakes Fishery Commission by treaty in 1954, Canada and the US enabled motivated biologists to work together, across borders, to understand the life history of the lamprey, discover effective control tools (many of which failed, yet no one gave up), and implement these tools to rehabilitate the fishery and save it from further loss.

The success is the result of a concerted effort by several generations of sea lamprey control experts and partners taking the program to the level of “calling,” not just a job. Key attributes of the successful sea lamprey case include:

1. Time and resources to network and integrate an intra-regional professional community to carry out the management program.
2. Interjurisdictional cooperation at scale and from the outset, with an understanding that sea lampreys do not recognize boundaries.
3. Intense military-like drive, especially at the outset, to prevent further spread of sea lampreys. Pioneers of the sea lamprey control program believed prevention was the best policy.
4. Priority of resources initially to understand the invader: map sea lamprey spread, understand life history and vulnerabilities, define economic and ecological impact.
5. Priority of limited resources for management or policy-informed research questions over fundamental science to rapidly move the program into an operational mode.
6. Delivery of clear and consistent messaging over 60+ years, making Great Lakes Fishery Commission a trusted source for policy makers, stakeholders, and managers.
7. Promoting cross-sector and cross-interest dialogue to carry out sea lamprey control.
8. Key messaging delivered through multiple, relevant partners, e.g., non-governmental actors, industry representatives, and the engaged public.
9. Effective cross-jurisdiction resource sharing, coordinated by the Great Lakes Fishery Commission in its authorized, multijurisdictional function.

The sea lamprey control program maintains participant motivation, an effective and long-standing plan to combat sea lampreys, the necessary infrastructure and equipment to carry out the plan, the authority to act, a communications program that secures resources and overall support for the program, and a scientific backbone to support sea lamprey control in the Great Lakes.



MOTIVATION

Where invasive species have been stopped or managed, the collective will to succeed is intense, focused and not prepared to concede. Where species have arrived, thrived and remain unchecked, the response has been more tentative and dispersed, without a strong, collective effort.

Recommendation One: State, provincial, Tribal agencies with responsibility for managing invasives should invest time and resources on networking and integration within a regional community of practice.

Successful AIS policy and action is driven by a strong community of practice that is able and willing to share resources, ideas, knowledge and innovation. The community shares challenges and successes, provides mutual support, and contributes strategic approaches to other members. The importance of this to successful AIS control is apparent in the sea lamprey control case, where professionals from jurisdictions around the basin regularly come together to share ideas, knowledge and innovative ideas for better control. The sea lamprey control community is built upon strong relationships and a dedicated focus on combatting the invader.

Participants in this study pointed out that AIS policy and management in the Great Lakes would be stronger if greater emphasis was placed on the development and enhancement of the existing community of practice. Built upon the existing relationships among AIS professionals across jurisdictions and sectors, such a community would consist of strong and coordinated partnerships of knowledge-based experts who share information and resources and, thus, would better help decision-makers define threats, identify policy solutions and appropriate actions, assess the success of outcomes, and iterate on the next policy or action round.

Energizing the community of practice leads to strong motivation to take action, many participants noted. That motivation among the community is important to motivating policy makers.

“It’s fairly simplistic: if you’ve experienced an actual [AIS] infestation, or are aware of the risk level to your jurisdictional authority, or your state, or your property, or your territory, or your province, then you pay attention to this.”

—Senior federal agency AIS advisor

Recommendation Two: State, provincial, Tribal agencies with responsibility for managing invasives must strive for interjurisdictional cooperation at scale and from the outset.

Across all interviews and cases, the single factor identified as key to successful AIS prevention or control is interjurisdictional cooperation at the appropriate scale. In the case

of sea lamprey management, cooperation across jurisdictions occurred binationally and basinwide, which reflected the proper scale and allowed for leveraging of resources. The same level of binational cooperation is currently identified as integral to the prevention of bighead and silver carp. In the black-striped mussel case, interjurisdictional cooperation occurred at a continental scale in Australia, allowing for rapid quarantine and eradication of the species shortly after it was discovered.

Conversely, cases generally considered unsuccessful in their policy and management response lack effective interjurisdictional cooperation. Participants often mentioned that the states and/or provinces furthest from the outbreak, which do not directly see themselves threatened, are often less motivated to react or less prepared to address the threat. These jurisdictions, while still at risk due to geo-physical connection to the Great Lakes, are also less likely to cooperate in outbreak response or other prevention programs.



Silver Carp. Photo by D O’Keefe of Michigan Sea Grant

Recommendation Three: Federal authorities, working with state, provincial, Tribal and First Nations governments, must take every possible step to prevent all potential invaders from entering the system.

Strong interjurisdictional cooperation, built on a solid community of practice, will sustain the effort necessary to develop and deploy supra-regional prevention policies and practices. Species specific control programs are substantially more expensive than programs to keep all AIS from the system in the first place. The sea lamprey control program alone requires an annual appropriation of nearly \$25 million. Participants agree such a level of funding and effort cannot be sustained for every destructive species we allow into the Great Lakes.¹

Perhaps the strongest evidence of motivation is the willingness to be proactive in preventing species from reaching the continent in the first place. Nearly every participant mentioned that prevention is the most important AIS policy. Equally important is the disposition to prepare for a potential invasion, act when a threat is identified and take action

before the species is able to become established. When prevention and rapid response fails, and when a species becomes established, the motivation to respond to the subsequent outbreak often evaporates, as officials tend to see further efforts as futile.

The necessary, region-wide elements include: risk analysis to understand what species are most likely to appear in which locations, a surveillance program addressing these invasion “hot spots,” and a rapid response protocol with clear roles, responsibilities and authorities to act. In most cases, a response will need to be species-specific and, therefore, activities are closely linked with management-focused research questions.

“I think in many cases, or in most cases, you do need at least a genus-specific, if not species-specific, approach to how you’re [going to] suppress or kill that particular organism. I don’t think you can get away from that. But that makes it all the more important to [implement prevention measures] to stop more stuff from being moved around.”

—Invasive species policy researcher

¹For more information on invasive species costs, see <https://www.fws.gov/verobeach/pythonpdf/costofinvasivesfactsheet.pdf>

The black-striped mussel case, Australia's Northern Territory

On March 27th, 1999, divers with the Commonwealth Scientific and Industrial Research Organization (CSIRO), an independent agency of the Australian federal government responsible for research protecting Australia's economy, made a shocking discovery. Divers reported an infestation of small striped mussels in Cullen Bay Marina, Darwin, NT. Early detection was possible because CSIRO had established a program years earlier which included monitoring for invasive species threats in areas with a high likelihood of invasion, such as marinas and ports. Trained divers immediately recognized that these mussels resemble the invasive zebra and quagga mussels then plaguing North America.

Immediately notified, the Minister and Chief Executive Officer of the Department of Primary Industry and Fisheries, called a special meeting with the Northern Territory cabinet where the cabinet declared the black stripe mussel an aquatic pest, freeing the authorities to act. They declared the infested marinas quarantined. Any movement of aquatic life in or out of the areas, as well as any boat traffic, was prohibited by law. The cabinet then authorized the use of any funds necessary (no limited) to combat and eradicate the quarantined mussel invasion.

Officials at CSIRO entered an Alert Phase and formed an incident management task force. The task force included teams responsible for media/ communications, vessel tracking, public health, diving surveys, eradication research, and treatment. Teams assembled in a matter of a few weeks, at which time officials entered an Operational Phase. They conducted surveys to map the extent of the AIS outbreak and federally quarantined areas infested with the mussel. Affected marinas (three total) were treated first with chlorine, and later with copper sulfate. All vessels in the marinas and at sea (hundreds of vessels) were tracked down, boarded, and disinfected.

The treatment of the three infested harbors, requiring a total 187 tons of liquid sodium hypochlorite and 7.5 tons of copper sulfate, resulted in 100% mortality and full eradication of the AIS threat within a two-week period.

Australians are much more motivated to take action against AIS threats than the U.S. or Canada. Authorities, and to a large extent society, in Australia, New Zealand and Tasmania have the perspective that "no one can fully predict the destructive potential of a new invasive species, so all must be stopped."



Quagga mussel from Lake Michigan. Photo courtesy of NOAA.



Zebra mussels on freshwater. Photo courtesy of John Van Oosten Library of USGS.

SCIENCE

Successful AIS prevention or control requires targeted research focused on questions generated by the management or policy community.

Recommendation Four: Public and private research agencies should prioritize resources for risk assessment to understand both the probability of invasion and prospective impact from potential invaders.

Humans are more likely to view ugly, weird or visibly destructive species as more threatening than "covert," or apparently benign species. However, basing this assessment on superficial aspects such as appearance, leads to unfortunate results. Participants noted that often, "covert species," such as the somewhat attractive purple loosestrife, have more economic and ecological impact than species initially viewed with more alarm. In the case of the black-striped mussel, for example, Australian participants were familiar with the destructive behavior of their zebra and quagga mussel cousins, knowledge which propelled Australians to action. Aware of findings on the ecological impact of dreissenids in the Great Lakes, the Australians were prepared to act when the first black-striped mussel, another



Mytilopsis sallei, black striped mussel. Photo courtesy of The Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia.

dreissenid species, appeared in one of their bustling sea ports. Australians were prepared because they had assessed the potential for a black-stripe invasion, understood the mussel's potential impact on their ecosystem and invested the time and resources to prepare an appropriately robust response. For these reasons, black-striped mussels were treated with the same response as an agricultural pest or disease, whereby government scientists and policy makers acted quickly and aggressively to isolate and eradicate the threat.

Recommendation Five: Public and private research agencies should prioritize limited research resources on management or policy-informed questions over fundamental science.

Successful prevention and control policies and actions are informed by research that addresses specific questions

“When you’re dealing with an organism that you’re trying to eradicate or suppress, you have to study it in order to find out where it’s vulnerable, and what tools you might use. That takes time. Some [AIS] studies these days appear to be kind of off base, or just answering somebody’s curiosity.... Studies with no clear management implications don’t really stand out to policy makers.”

—Retired NGO staff scientist

identified by the managers and policy makers. Participants stressed that most agencies lack the “luxury” of investing in the development of scientific knowledge not directly tied to management or policy need. Further, they expressed concern that the academic publishing process, which focuses more on the development of new knowledge and less on the application of existing knowledge, can lead researchers away from a management or policy-based focus.

COMMUNICATION

Successful AIS responses require clear, compelling and effective messages delivered by someone the target audience trusts

Recommendation Six: State, provincial, and Tribal agencies with responsibility for managing invasives must develop and deliver clear messages to managers and policy makers from trusted or influential sources.

Across cases, interview participants often mentioned that clearly articulated threats to an important industry is a strong motivator in generating effective AIS prevention and control policies. For example, sea lampreys threatened the Great Lakes commercial fishery, and it was the industry's persuasive reaction to the threat that generated policy support for the necessary research investment to find solutions. Members of the Great Lakes commercial fishing industry, from jurisdictions around the Great Lakes basin, lobbied congress, gave personal testimony to congressional committees, and worked with fishery managers and scientists to request federal resources for sea lamprey control research in the 1950s. Without such support, sea lamprey control would not have succeeded.

In Australia, the farmed pearl industry drove policy and rallied support for planning and preparation against the black-striped mussel. Pearl industry advocacy resulted in the responsible cabinet minister pushing for appropriate preparation and finding the resources to support action. Thus, when black-striped mussels did appear, the country was ready to act.

“So we have a...pearl oyster industry around northern Australia, which is probably one of the top five fisheries of value in Australia. And they were quite active in saying, “Something needs to be done.”

—Senior research scientist with CSIRO, Australia

Recommendation Seven: State, provincial, Tribal agencies with responsibility for managing invasives working together must also promote cross-sector and cross-interest dialogue to identify a common, effective response.

While the support of industry and key policy individuals are vital for the advancement of effective AIS policy, participants also mentioned that the expression of legitimate, competing interests can impede progress. For example, many interviewees mentioned that the maritime industry was concerned about species prevention techniques that could compromise the industry. As a result, decisive action that could affect industry operations undermined the will to take action, sometimes even with evidence that the lack of action would lead to a near-certain introduction of a new species. Industry, for instance, could easily demonstrate negative effects on their operations while proponents of AIS actions could not make the same economic claims with certainty, as prevention is abstract, akin to proving a negative. To get beyond such situations, meaningful cross-sector and cross-interest dialogue is imperative, and many participants recalled situations that were resolved through effective dialogue.

Recommendation Eight: Leverage all relevant non-governmental sectors and networks to deliver key messages.

Non-governmental organizations and industry associations can speak on behalf of important government programs and policy changes in ways that are not available to agency personnel. These non-agency actors also have access to individuals who control resources and authorities necessary for managing AIS. When communication is working well, decision makers hear the same message from multiple sources, which reinforces and strengthens the resolve to act. A good example is the messaging that has occurred related to preventing Asian carps from entering the Great Lakes. The environmental NGO community has worked hard to formulate a uniform message of urgency and need, which has resonated both with management agencies and with elected officials in Canada and the United States.

“For the plant pests like ash borer, the US, Canada, and Mexico have formed a tri-lateral organization called NAPPO, North American Plant Protection Organization. They collaborate fairly well on all kinds of plant pests. And certainly, they have tried to coordinate efforts. It’s been a forum through which APHIS [Animal and Plant Health Inspection Service] and its Canadian counterpart have coordinated efforts on emerald ash borer and Asian longhorn beetles and a lot of the other things that we share. It’s not a governing body, per se, although it issues regional standards, which then the agencies have to implement by adopting their own regulations. It provides a forum for a lot of cooperation and coordination and efforts to harmonize approaches.” —Invasive insect and plant policy expert

RESOURCES

Resources Successful AIS response requires adequate, shared resources, not only in the form of funds but also with facilities, equipment and skilled people

Recommendation Nine: Jurisdictions must find effective ways to share resources for invasive species policy and management to succeed.

If an AIS response is to be effective, jurisdictions must find ways to share resources effectively. The willingness to share resources first depends on all agencies agreeing on the level of risk associated with a species. Institutional or structural barriers to sharing sometimes exist, though multijurisdictional organizations, such as the Great Lakes Fishery Commission, the Great Lakes Commission, or the International Joint Commission, can be valuable. State, provincial and federal agencies are limited by their political boundaries but AIS are not. Treaty-based or legislatively-authorized multilateral organizations can provide the “common table” around which all jurisdictions can solve collective challenges, such as an AIS outbreak.

Recommendation Ten: Agencies need to identify the right organization to moderate resource and knowledge sharing to prevent establishment of invasive species.

A key challenge to interjurisdictional cooperation is the reality that most decisions about AIS prevention or management occur at the state, provincial, or tribal level while the Great Lakes span multiple jurisdictions and have direct hydrological connections to the others. By the time an invasive species is detected locally it is often considered too late to prevent establishment.

Sea lamprey control, which enjoys consistent success, is a multinational and interjurisdictional program based on the understanding that invasive species do not stop at the border. Participants often suggested that invasive species prevention and action need to be considered on a continental scale, and coordinated by a single agency. Such a body does not need to have regulatory authority, per se, but it does

require appropriate authority to facilitate and synchronize cross-border efforts.

CONCLUSION

Agencies must have an effective plan coordinated with and integrated into a regional approach, possess or have access jointly to the necessary infrastructure and equipment, and be authorized and prepared to act collectively at appropriate scales for an effective invasive species response

In the Great Lakes basin, all states, provinces, tribes, First Nations and federal agencies have AIS plans in place to cover either specific species or the jurisdiction's waters, or both. Although these plans may be complementary, not all are consistent. In some cases, for example, jurisdictions do not share the same objectives for a species. In other cases, some jurisdictions have better resources or authorities in place to facilitate action. A single AIS plan for the Great Lakes region is not necessary, as individual jurisdictional approaches are necessary to address particular circumstances. However, information exchange and resource sharing, will allow individual jurisdictions to harmonize their AIS plans so that any regional response will exceed the sum of the parts. An example of subnational actions that resulted in a coherent, regional outcome is the work prohibiting the interstate trade of live Asian carp. In the first decade of the 21st Century, individual states and the Province of Ontario promulgated restrictions on the possession of live Asian carp. They coordinated some of their work through a shared forum—the Joint Strategic Plan for Management of Great Lakes Fisheries and its Law Enforcement Committee. Thus, in the absence of a federal listing of some Asian carp species as “injurious” which would have prevented interstate movement, the states created a de facto “injurious” listing by having similar policies within each jurisdiction. A similar approach should be taken more broadly to ensure that individual AIS plans are complementary and reflect regionally agreed-upon objectives.

Appendix 1: Sea lamprey (*Petromyzon marinus*): a foundational case study in the Great Lakes.

Appendix 2: Silver carp (*Hypophthalmichthys molitrix*), bighead carp (*Hypophthalmichthys nobilis*), black carp (*Mylopharyngodon piceus*), and grass carp (*Ctenopharyngodon idella*): an escalating threat to the Great Lakes.

Appendix 3: Zebra mussel (*Dreissena polymorpha*) and quagga mussel (*Dreissena bugensis*): The Dreissenid mussel case in the Great Lakes.

Appendix 4: Black-striped mussel (*Mytilopsis sallei*): an invasive Dreissenid mussel case in Australia's Northern Territory.

Appendix 5: Purple loosestrife (*Lythrum salicaria*): a terrestrial plant case in the Great Lakes basin.

Appendix 6: Viral hemorrhagic septicemia (VHS, *Oncorhynchus 2 novirhabdovirus*): a fish-killing disease case in the Great Lakes.

“I don't think one agency can tackle AIS issues that are going on in the Great Lakes. It has to be everybody working together. It has to be binational, because Canada is our partner in this whole thing.”

—Advisor to the Great Lakes Fishery Commission

Sea lamprey, Photo by Cory Brant

