AQUATIC INVASIVE SPECIES INTERSTATE SURVEILLANCE FRAMEWORK FOR THE U.S. WATERS OF THE GREAT LAKES

2019

Citation

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The publication date acknowledges that the products published here (including the surveillance species lists and site prioritisation results) represents the outcome of analyses last updated in 2019. However, where relevant a small number of more recent publications have been added to update the text, reflecting the framework is a working document.

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Preface

The Great Lakes states of Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, and Wisconsin formed an Early Detection Rapid Response Team in 2014 to collaborate on the development of tools and guiding documents to support state aquatic invasive species (AIS) plans, and potential monitoring and response approaches that may be prudent in the Great Lakes, connecting channels, and Great Lakes tributaries. The planning aid (Framework) that follows was developed so states and partners can use their collective capacity for surveillance when appropriate, as well as develop clear and consentaneous priorities on AIS surveillance issues across the basin. The Framework supports the Great Lakes and St. Lawrence Governors and Premiers signed mutual aid agreement and calls for a collaborative structure in support of AIS surveillance and response not only across the Great Lakes states, but also to include local, regional, and federal agencies, along with tribes, provinces, and researchers. The Framework is intended to enable AIS surveillance actions that are complementary to existing work, prioritized appropriately, and informed by the most recent research while maintaining and recognizing decision-making authority.

The development of the Framework was funded through a Great Lakes Restoration Initiative (GLRI) grant from the U.S. Fish and Wildlife Service (USFWS) to the Michigan Department of Environmental Quality (MDEQ) now known as Michigan Department of Environment, Great Lakes, and Energy (MEGLE) via funding opportunity F14AS00095, April 21, 2014. The Framework was drafted between October 1, 2014 and December 30, 2016 and is the product of numerous face-to-face and web-based discussions among “core” team members, technical advisors, and “active” observers from Canadian partner agencies.

Core management team participants and affiliations included:

- Eric Fischer (Indiana Department of Natural Resources)
- Sarah LeSage (Michigan Department of Environmental Quality) – Project Manager
- Nick Popoff and Seth Herbst (Michigan Department of Natural Resources)
- Kelly Pennington and Heidi Wolf (Minnesota Department of Natural Resources)
- Catherine McGlynn (New York State Department of Environmental Conservation)
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- Michael Hoff (Grant officer), Katherine Wyman-Grothem, Amy McGovern, and Sandra Keppner (USFWS)

Active observers from Canadian partner agencies and affiliations included:

- Francine MacDonald (Ontario Ministry of Natural Resources and Forestry)
- Olivier Morissette and Isabelle Simard (Québec Ministère du Dévelopement durable, de l'Environnement et des Parcs)

The Framework and tools were developed with advice from a technical advisory group made up of leading researchers and practitioners working on AIS surveillance in the Great Lakes’ basin. These included:

- Anett Trebitz and Joel Hoffman (USEPA)
- Stephen Hensler, Tim Strakosh, Darin Simpkins, Robert Haltner and Ted Lewis (USFWS)
- Alisha Dahlstrom Davidson and Donna Kashian (Wayne State University)
- Jon Bossenbroek (University of Toledo)
- Erika Jensen (Great Lakes Commission)
- Lindsay Chadderton, Andrew Tucker (The Nature Conservancy, Great Lakes Project)
- Gust Annis (The Nature Conservancy, Michigan)

Logistic, contractual, and administrative support were provided by Berkley Ridenhour (The Nature Conservancy, Great Lakes Project) and Jamie Saxton (Great Lakes Environmental Center [GLEC]). The Framework was written by The Nature Conservancy under contract to GLEC. It was formally peer reviewed by John Darling (USEPA) and Jeff Tyson (Great Lakes Fisheries Commission) under the auspices of the USEPA Technical Manuscript Review Process. Their review improved the final document. Alisha Davidson completed a scientific review and edit of the revised framework. Final formatting was completed by Rebecca Reitemeier and Alicia Arkwright (The Nature Conservancy).

List of Acronyms

AIS: aquatic invasive species
GLAHF: Great Lakes Aquatic Habitat Framework
GLANSIS: Great Lakes Aquatic Nonindigenous Species Information System
GLANSRA: Great Lakes Aquatic Nonindigenous Species Risk Assessment
GLRI: Great Lakes Restoration Initiative
GLWQA: Great Lakes Water Quality Agreement
IEDRR Core Team: Interstate Early Detection and Rapid Response Core Team
MDEQ: Michigan Department of Environmental Quality
NANPCA: Nonindigenous Aquatic Nuisance Prevention and Control Act
NISC: National Invasive Species Council
USEPA: U.S. Environmental Protection Agency
USFWS: U.S. Fish and Wildlife Service

Executive Summary

The Great Lakes Aquatic Invasive Species Surveillance Framework (hereafter, the Framework) has been prepared to address the regional goal of establishing a comprehensive program for detecting and tracking newly identified invasive species in the U.S. waters of the Great Lakes. It fits within the context of safeguarding the ecological health of the Great Lakes because it aims to help prevent new non-native species (especially high-risk AIS) from establishing in the Great Lakes by facilitating a program to detect new introductions early. If fully implemented, the recommendations outlined in the Framework should provide the up-to-date critical information needed by decision makers to help inform potential management actions, and ultimately help to prevent establishment, spread, and impacts of AIS in the Great Lakes.

The Framework provides strategic guidance for decision makers on when, where, and how surveillance could be undertaken (Section 2). Consistent with the goal to develop and implement an early detection initiative, as outlined in the 2012 amendment to the Great Lakes Water Quality Agreement between Canada and the United States - Annex on Aquatic Invasive Species (GLWQA 2012 Annex 6), the Framework:

i. Develops a surveillance species list;
ii. Identifies priority locations for surveillance; and
iii. Provides guidance on monitoring protocols for surveillance.

In Section 3, the Framework provides guidance on how state (and federal) partners could work together to coordinate decision making, in order to implement and maintain an ongoing surveillance program. The Framework:

i. Establishes a process for regional decision making and coordination across state agencies;
ii. Establishes protocols for sharing information; and
iii. Identifies a collaborative adaptive management process of continual improvement based on surveillance results and new scientific understanding.

The data published here, including the surveillance species lists and site prioritisation results represents the outcome of the original analyses that were last updated in 2019. Sections of this Framework have subsequently been published as peer-reviewed manuscripts. Full citations are as follows:

Tucker, AJ, Chadderton WL, Annis G, Davidson AD, Hoffman J, Bossenbroek J, Hensler S, Hoff M, Jensen E, Kashian D, LeSage S (2020) A framework for aquatic invasive species surveillance site selection and prioritization in the US waters of the Laurentian Great Lakes. *Management of Biological Invasions*, 11(3): 607-632
https://www.reabic.net/journals/mbi/2020/3/MBI_2020_Tucker_etal.pdf

Davidson AD, Tucker AJ, Chadderton WL, Weibert C (2021) Development of a surveillance species list to inform aquatic invasive species management in the Laurentian Great Lakes. *Management of Biological Invasions* 12(2): 272-293.
https://www.reabic.net/journals/mbi/2021/2/MBI_2021_Davidson_etal.pdf

1. Introduction

1.1 Goal

Goal statement: Establish a comprehensive framework for 1) detecting and tracking invasive species in the U.S. waters of the Great Lakes and 2) providing up-to-date information needed by decision makers for evaluating potential response actions.

The Great Lakes States and the U.S. Fish and Wildlife Service (USFWS) are working collaboratively on species-specific AIS surveillance and response issues in the Great Lakes (e.g., Asian Carp response framework, ACRCC 2015). However, there remains a need to develop a comprehensive framework to guide and coordinate surveillance actions for any and all AIS threats within the U.S. waters of the Great Lakes. The Great Lakes Restoration Initiative (GLRI) Action Plan II calls for federal agencies and their partners "to increase the effectiveness of existing surveillance programs by establishing a coordinated, multi-species early detection network." This Framework has been prepared to address this goal. The Framework describes both the key technical components of a comprehensive surveillance program (Section 2) and a process to coordinate AIS surveillance activities among federal, state, tribal, and local natural resource management agencies (Section 3). If fully implemented, the Framework will help safeguard the ecological health of the Great Lakes and inform management actions.

1.2 Statutory Guidance

This Framework was developed to address the need for a comprehensive AIS early detection program, identified by numerous state, regional, federal, and binational plans and agreements. The National Invasive Species Council (NISC) Management Plan (NISC 2016), which directs Federal efforts to prevent, control and minimize invasive species and their impacts, includes as one of five goals the facilitation of effective coordination to limit the spread and impact of invasive species by, in part, promoting projects that explore multi-stakeholder approaches to early detection of invasive species. The previous National Invasive species management plan also called for "developing and enhancing the capacity in the United States to identify, report and effectively respond to newly discovered and localized invasive species" (NISC 2008).

Within the Great Lakes region, the Great Lakes Panel on Aquatic Nuisance Species (Great Lakes Panel) convened under the auspices of the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (NANPCA) to contribute to collective AIS management at regional and national levels, identifying the need for early detection and monitoring as one of several priorities (Great Lakes Panel 2016). In 2005, the Great Lakes Regional Collaboration strategy (GLRC 2005) created by Executive Order 13340 (Vol. 69 No. 98. Federal Register) to restore and protect the Great Lakes ecosystem for current and future generations, called for the establishment of a program to facilitate rapid response to AIS. In response to Executive Order 13340, the 2010-2014 GLRI Action Plan identified Invasive Species as a priority focus area and included the specific long-term goal (Goal 4) of developing a comprehensive detection program to inform response actions.

Most recently, the 2012 amendment to the Great Lakes Water Quality Agreement (GLWQA 2012) between Canada and the United States included an Annex on Aquatic Invasive Species (Annex 6) that requires parties to establish a binational strategy for AIS prevention in the Great Lakes basin.

Specifically, the Annex includes provisions to develop and implement an early detection initiative that:

- Develops surveillance species list.
- Identifies priority locations for surveillance.
- Develops monitoring protocols for surveillance; and
- Establishes protocols for sharing information.

This Framework primarily addresses the first of these Annex 6 provisions (i, ii), and identifies some minimum surveillance monitoring standards and processes to facilitate information sharing.

1.3 How to Use This Document

The Great Lakes states of Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania and Wisconsin formed an Early Detection Rapid Response Team to collaborate on the development of tools and guiding documents to further support state AIS plans, and potential monitoring and response approaches that may be prudent in the Great Lakes, connecting channels, and Great Lakes tributaries. This document was written to help states and partners develop clear and consentaneous priorities on AIS surveillance issues across the basin and when appropriate, ensure they can use their collective capacity to manage agreed-upon regional surveillance priorities. The Framework calls for a collaborative structure not only across the Great Lakes states, but also to include local, regional, and federal agencies, tribes, provinces, and researchers as well as supporting the Great Lakes and St. Lawrence Governors and Premiers signed mutual aid agreement. The Framework can enable AIS actions that are complementary to existing work, prioritized appropriately, and informed by the most recent research while maintaining and recognizing distributed decision-making authority.

1.3.1 Scope

i. Geographic

The scope of the framework is the Great Lakes, their connecting channels, and Great Lakes tributaries up to the first barrier to fish passage for United States waters of the Great Lakes. The plan is not limited to offshore or coastal waters but extends out to the Binational border with Canada and includes the U.S. waters of the Saint Lawrence Seaway down to Brockville, NY (Figure 1.3.1).

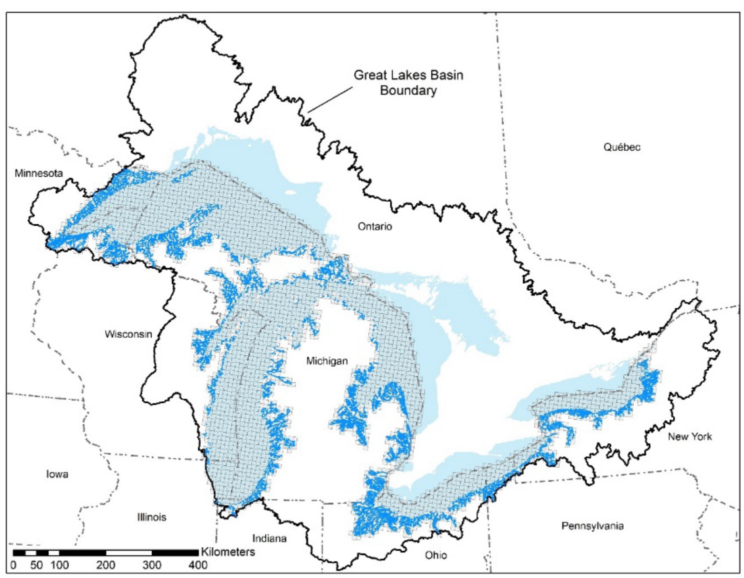


__Figure 1.3.1__. Spatial extent of the surveillance framework showing the U.S. waters of the Great Lakes connecting channels and rivers up to the first barrier. The boundaries of the Great Lakes Basin, and associated states and provinces are also shown.

ii. Biological

The surveillance program and sampling methods are designed to detect a full range of taxonomic groups. The species considered are restricted to obligate and facultative freshwater species and comprised those species that:

- represent novel introductions to the basin and established species with localized distribution in the Great Lakes (in ≤ 4 Great Lakes) but capable of range expansion;
- have a low, moderate or high probability of introduction score for at least one pathway;
- are able to establish in the Great Lakes based on GLANSRA establishment assessment (Davidson et al. 2017);
- pose a high or moderate ecological and/or socio-economic (including human health) risk if introduced to the basin or some portion of the basin not previously invaded.

The surveillance species list is organised around three high level taxonomic groups (fish, invertebrate, and plants including aquatic algae) recognising that distinct surveillance survey methods and sampling protocols are currently implemented around this taxonomy. Birds, reptiles, amphibians, mammals, viruses, bacteria, and unicellular parasites were not included. Furthermore, the plan does not cover monitoring within the pathways of introduction – i.e. monitoring of the vectors and pathways themselves before the release of propagules into the Great Lakes.

1.3.2 Document Layout

This document establishes a framework for AIS surveillance in the U.S. waters of the Great Lakes. Consistent with recommendations of Trebitz et al. (2017) the document is structured around the major decision points confronting state and federal management agencies charged with implementing an ongoing AIS surveillance program across the eight states, five lakes and connecting waters that comprise the U.S. waters of the Great Lakes.

Section 2 describes a surveillance program for the Great Lakes and provides specific technical guidance on:

- What species pose a risk (surveillance species list);
- Where monitoring should occur to detect the full range of high-risk species (site selection and prioritization);
- How the sample program should be designed (sampling design); and
- What sampling methods should be used (sampling methods).

Section 3 describes the processes that could be used to implement and sustain a surveillance program, including the assessment of surveillance results (sensu Trebitz et al. 2017). It identifies key participants, an overview of action items, and an adaptive management cycle to facilitate a process of continued improvement. The processes are as follows:

- Establishes a process for regional decision making and coordination across state agencies;
- Establishes protocols for sharing information; and
- Identifies a collaborative adaptive management process of continual improvement based on surveillance results and new scientific understanding.

The entire document is intended as a “living document” and is subject to revision. Yet the basic framework aims to provide a unifying approach that can be used to facilitate adaptive AIS surveillance across the basin, and a coordinating structure for local, regional, and federal agencies, tribes, provinces, and researchers, who can all play a role in supporting surveillance efforts in the Great Lakes and St Lawrence River.

The Framework does not assign responsibility for undertaking surveillance at any site. Rather, the Framework outlines planning, sharing, and adaptation steps that could facilitate allocation of surveillance tasks and duties. Surveillance implementation is always expected to be subject to jurisdictional capacity and available resources.

2. Elements of a Great Lakes Surveillance Framework: Species List, Site Selection, and Site Prioritization

2.1 Introduction

The North American Great Lakes is one of the most heavily invaded aquatic ecosystems in the world. Over 180 non-indigenous species have established in the Great Lakes, introduced through a variety of vectors and pathways (Pagnucco et al. 2015, Davidson et al. 2017). Aquatic invasive species in the Great Lakes have caused significant and ongoing ecological and economic impacts to the region (Rothlisberger et al. 2012, Rosaen et al. 2012). In recognition that prevention is often the most successful and cost-effective management investment to biological invasions (Lodge et al. 2006), federal, state, and provincial governments have implemented a variety of regulatory approaches, along with community and stakeholder engagement and education programs to try to prevent new introductions into the basin. Nevertheless, it is inevitable that prevention efforts will miss some species (Lodge et al. 2006). As such, adoption of early detection monitoring and response programs is an important management strategy that can effectively prevent the establishment and spread of newly introduced AIS.

Early detection monitoring in the Great Lakes is driven either by concerns about a specific species or by the threat of potential introduction of multiple species from one or more invasion pathways (Pagnucco et al. 2015, USFWS 2014). A small number of surveillance list fish species (silver carp, bighead carp, grass carp, and Eurasian ruffe) are currently the subject of species-specific surveillance efforts. Surveillance for invasive carp and Eurasian ruffe are effectively response-driven efforts to determine status following either eDNA evidence of potential presence within Great Lakes waters (silver and bighead carp; ACRCC 2014, Jerde et al. 2011, 2013), monitoring results that indicate presence of diploid fish and spawning success (grass carp; Whitman et al. 2014, Chapman 2013), or ongoing concern about range expansion (Eurasian ruffe; Bowen and Keppner 2013). These programs have existing surveillance monitoring plans that undergo annual review and refinement and therefore are not replicated here.

Targeted surveillance efforts for other high-risk invaders may also be warranted in instances where the most probable pathway(s) and points of introduction can be defined, when invasion appears imminent, and where general surveillance monitoring is not focussed on the areas with greatest potential for that species' introduction or spread. In addition, targeted surveillance may be established to support response efforts to contain or eradicate newly established species or range expansions species. An example of high-risk invertebrate species that may warrant targeted surveillance include the scud *Apocorophium lacustre*, a hull fouling species with potentially significant impacts and the potential to enter Lake Michigan via the Chicago Area Waterway System where it is established (Keller et al. 2017). While beyond the scope of this framework, species specific risk assessment data and site selection models described here could be adapted to inform these efforts.

Given that survey design and implementation guidance is already in place for some existing species-based monitoring efforts, this Framework is primarily designed to provide guidance on how to undertake monitoring for multiple species and taxa at introduction hotspots. The need for surveillance efforts to safeguard natural areas with especially rare species or with species, communities, or ecosystem services (including fisheries) of exceptional value that are vulnerable to AIS is recognized and will be addressed in future iterations of this plan.

This section of the Framework provides technical information organised around the key decision points confronting state and federal management agencies charged with implementing AIS surveillance in the waters of the Great Lakes (Figure 2.1.1). Specifically:

i. **What species pose a risk?** Section 2.2 puts forward a surveillance species list – comprised of those species with a relatively high probability of introduction to the Great Lakes and impact if introduced. The surveillance species list (in part) informs a goal setting process and explicitly sets out a rationale for surveillance (i.e., broader monitoring of entire taxonomic groups based on concerns about introductions from one or more invasion pathways).

ii. **Where should surveillance occur?** Species-specific surveillance is driven by knowledge about habitat preferences, dispersal pathways from areas of establishment or introduction, or potential points of aggregation (spawning, larval nursery areas etc.). The framework assumes that broad spectrum monitoring of multiple species or taxa should, in the first instance, target those areas where the initial invasion or secondary spread is most likely to occur. Section 2.3 identifies these areas for the Great Lakes, which are those locations with the highest points of intersection of all pathways of introduction.

iii. **How should sampling be undertaken to maximise detection sensitivity?** Section 2.4 provides recommendations on the combination of sampling methods, sampling effort and survey design to maximise the probability of detection cost-effectively.

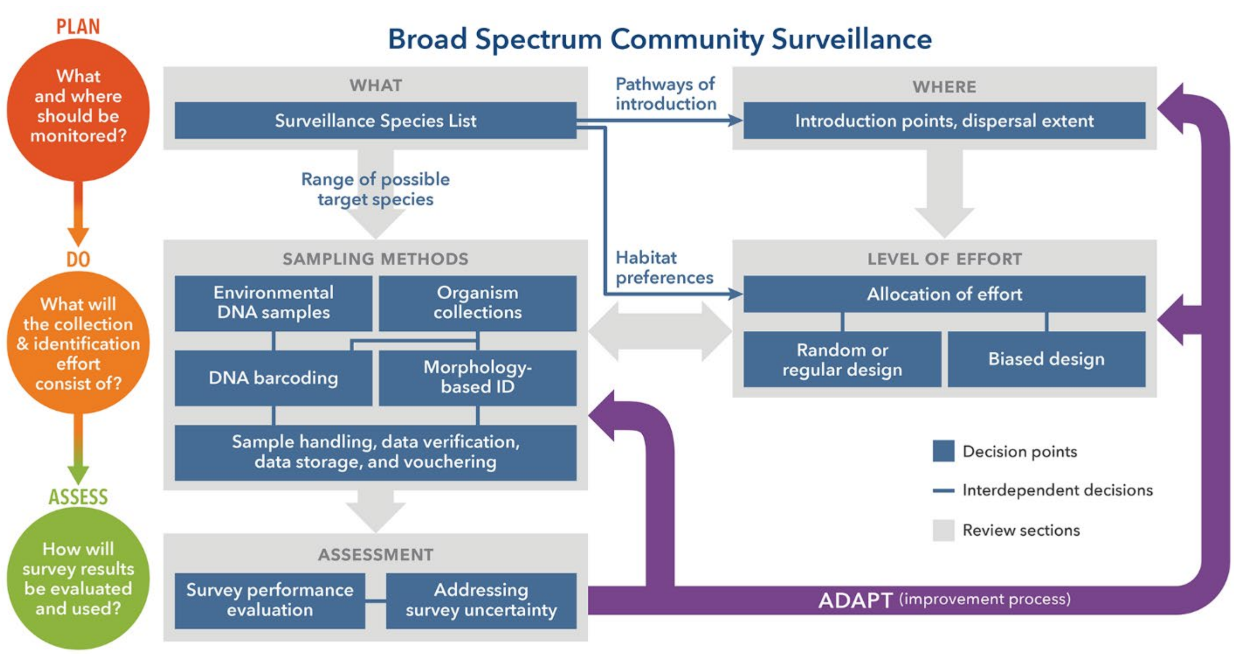


Figure 2.1.1. *Key components of an AIS surveillance framework for the Great Lakes (figure adapted from Trebitz et al. 2017)*

2.2 Surveillance Species List

2.2.1 Rationale and Development of a Great Lakes Surveillance Species List

The Framework provides guidance on where and how to undertake community level monitoring to detect a range of potential new introductions at the locations where these introductions are predicted to most likely occur. To do this, it is important to understand what species are most likely to be introduced and how they are likely to get here. Knowledge of the probable surveillance species targets (hereafter, "surveillance species list") also allows the sampling methods, sampling design, and habitat effort allocation to be tailored to maximise detection probabilities for groups of taxa.

The surveillance species list therefore forms the foundation for prioritizing AIS surveillance activities in the basin and underpins the surveillance Framework described here. The Framework uses the surveillance species list to quantify the relative risk of various pathways of primary introduction and secondary spread of those range expanding AIS that have only established in parts of the basin. Information on the relative risk of each pathway is used to inform the models that identify and prioritize locations where surveillance efforts are most likely to detect these or similar high-risk species (Section 2.3: Surveillance site selection and prioritization). Separate models can be developed for each major taxonomic groups to reflect differences in the relative importance of their pathways of introduction.

The surveillance species list also helps inform decisions around which habitats need to be sampled and what sampling methods, sampling strategies including effort, and sampling periodicity should be deployed to maximize detection sensitivity and the probability that new introductions are detected early (Section 2.4: Surveillance methods and survey design). Species on the surveillance list would also be priorities for collection of genomic sequence data to support adoption of high throughput sequencing surveillance methods that are likely to be increasingly important community monitoring approach (Trebitz et al. 2017). In addition, the risk assessment and pathway data that underpins the development of the surveillance species list provides a resource that can be used to inform policy prevention efforts and response determination processes (Davidson et al. 2021).

In the Laurentian Great Lakes, extensive work has been conducted on AIS-related risk assessments (Colautti et al. 2003, Grigorovich et al. 2003). More recently there has been increased emphasis placed upon the invasion risk associated with the trade in live organisms (Keller and Lodge 2007, Marson et al. 2009, Rixon et al. 2005, Mandrak et al. 2014, Gantz et al. 2014, USFWS ERSS (2024), Schroeder et al. 2014, Howeth et al. 2015), recreational boating (e.g., Rothlisberger et al. 2010) and canal pathways (U.S. Army Corps of Engineers 2014). These assessments were reviewed (see Davidson et al. 2021 for full list of assessments reviewed) to compile an inventory of 447 candidate species and then refined this list using a series of exclusion criteria (Box 1). All species in this refined list (303 species) were assessed using the Great Lakes Aquatic Nonindigenous Species Risk Assessment (GLANSRA) method (Davidson et al. 2017) to provide a likelihood of introduction and potential impact score.

The final list of surveillance species list is based on the probability of introduction, establishment, and impact in the Great Lakes (Davidson et al. 2021). The list is restricted to obligate and facultative freshwater species and comprised those species that:

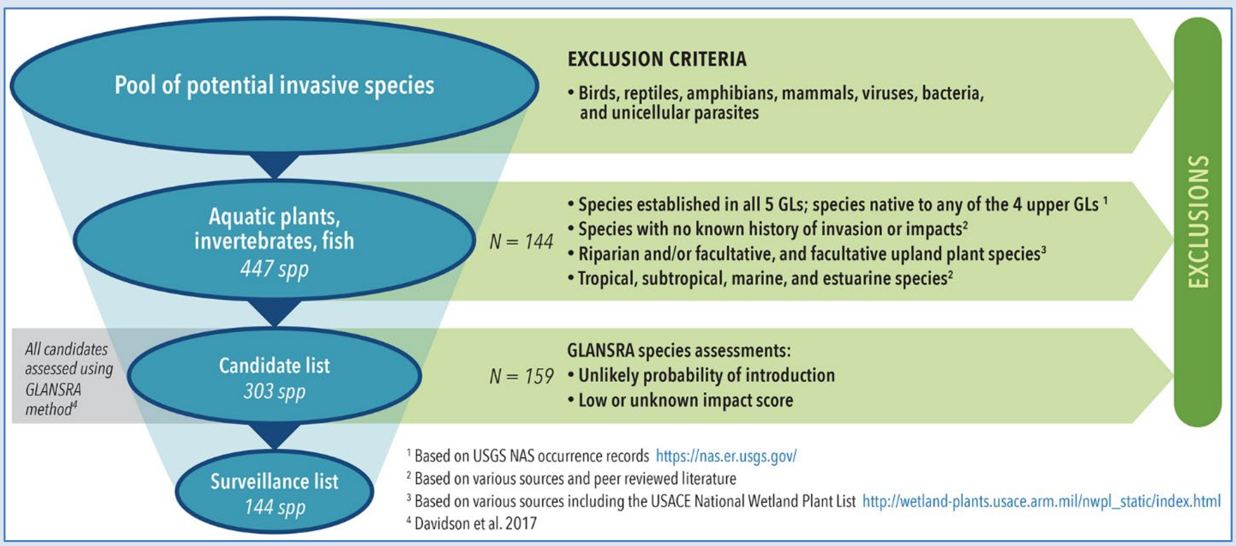
- represent novel introductions to the basin and established species with localized distribution in the Great Lakes (in ≤ 4 Great Lakes) but capable of range expansion;
- have a low, moderate or high probability of introduction score for at least one pathway;
- are able to establish in the Great Lakes based on GLANSRA establishment assessment (Davidson et al. 2017)
- pose a high or moderate ecological and/or socio-economic (including human health) risk if introduced to the basin or some portion of the basin not previously invaded,

The surveillance species list is organised around three high level taxonomic groups (fish, invertebrate, and plants including aquatic algae) and birds, reptiles, amphibians, mammals, viruses, bacteria, and unicellular parasites were not included.

The surveillance species list should not be a static list and should be updated at least annually and as either additional species are identified as having a pathway of introduction to the basin and assessed to pose a high or medium risk to the Great Lakes, or range expansion has resulted in established populations in all five lakes and their removal from the list.

Box 1. Surveillance Species List Compilation Method

A full description of methods used to develop surveillance species list is provided in Davidson et al. 2021. The flow diagram below sets out the process and series of exclusion criteria used to refine the original list of potential surveillance species.



The GLANSRA method (Davidson et al. 2017) was used to complete the final risk assessments because it provides a consistent approach across all taxonomic groups and incorporates measures of the relative potential for introduction, establishment, and impact to the Great Lakes Basin. Importantly it provides semi-quantitative information on socio-economic and ecological impacts (see Table 2.2.1), as well as introduction risk measures for each of the major invasion pathways (see Table 2.2.2). These data are important input variables used to identify the highest risk species, quantify risk across each pathway to help select priority surveillance sites. The GLANSRA assessments also collects data on habitat preferences for each species and this information can inform which habitats need to be sampled to maximize detection probability.
Figure from Davidson et al. 2021.

2.2.2 Surveillance Species List

A total of 144 species have been identified as Great Lakes surveillance priorities (Tables 2.2.3, 2.2.4, 2.2.5). Plants (n = 64) and fish (n = 40) constitute 72% of the surveillance list species. The invertebrate group is comprised primarily of crustaceans (n = 28) including seven crayfish species. Based on predicted per species impact scores, the highest risk taxonomic group is algae, followed by mollusks, and plants (Table 2.2.1). However, the large number of plant and fish species on the surveillance species list means that overall risk (from a taxonomic perspective) is greatest from these two groups.

The surveillance list species are native to five continents (Asia, Australia, Europe, North and South America), with the majority coming from Europe followed by Asia. Pathway risk varies by taxon and while various pathways could be responsible for introduction of surveillance list species (to the Great Lakes basin), the highest risk pathways across all taxonomic groups are natural dispersal, hitchhiking/fouling, and intentional release (Table 2.2.2).

Table 2.2.1. *Total and mean (± standard error) combined impact scores for each taxonomic group. Total number of species in each taxonomic group is indicated in parentheses. Maximum possible combined impact score (ecological + socio-economic) per species = 72.*

	Total combined impact score (all species)	**Mean ± SE combined impact score (per species basis)**
Plants/Algae (68)	1106	16.3 ± 1.5
Plants (64)	1002	15.7 ± 1.6
Algae (4)	104	26.0 ± 3.5
Fish (40)	407	10.2 ± 1.2
Invertebrates (36)	311	8.6 ± 1.4
Crustaceans (28)	192	6.8 ± 1.2
Mollusks (5)	88	17.6 ± 5.9
Bryozoan (2)	24	12.0 ± 8.0
Platyhelminthes (1)	7	--

Table 2.2.2. *Mean pathway score (± SE). Pathway scores reflect the probability of introduction for a species in a given pathway from 0-100. "Taxon score" is the sum of all pathway scores within each taxonomic group. "Pathway score" is the sum of all pathway scores within each pathway. Total number of species in each taxonomic group is in parentheses.*

	Natural dispersal	**Hitchhiking/Fouling**	**Shipping**	**Intentional release**	**Stocking, planting, escape**	**Commercial culture**	**Taxon score (all pathways combined)**
Plants/Algae (68)	47 ± 6	52 ± 5	7 ± 3	42 ± 6	41 ± 6	11 ± 4	13490
Plants (64)	45 ± 6	51 ± 6	4 ± 2	54 ± 6	44 ± 6	11 ± 4	12540
Algae (4)	75 ± 25	78 ± 23	60 ± 25	25 ± 25	0	0	950
Fish (40)	32 ± 7	19 ± 6	14 ± 4	28 ± 7	22 ± 7	5 ± 3	4798
Invertebrates (36)	30 ± 8	31 ± 7	45 ± 6	14 ± 6	3 ± 3	0	4369
Crustaceans (28)	27 ± 8	28 ± 8	39 ± 6	14 ± 6	4 ± 4	0	3076
Mollusks (5)	25 ± 19	24 ± 19	52 ± 15	20 ± 20	0	0	443
Platyhelminthes (1)	100 ± 0	100 ± 0	80 ± 0	0	0	0	280
Bryozoan (2)	50 ± 50	55 ± 45	100 ± 0	0	0	0	410
Pathway score (all taxa combined)	5575	5400	2692	4840	3250	900	

i. Fish

Fish account for just under one-third of all species identified and include six species that are established in the basin but with localised distributions. Established surveillance monitoring in the basin already target some specific fish species (e.g., the invasive carps (*Hypophthalmichthys nobilis, H. molitrix, Ctenopharyngodon idella*), Eurasian ruffe *Gymnocephalus cernua*). There is also a targeted sampling program for Tench (*Tinca tinca*) in the Saint Lawrence Seaway in a region of the river just outside the spatial extent of the current framework, that is driven by concern about the upstream range expansion of this species (Avlijaš et al. 2017). The fish surveillance species list also includes other high profile invasive species like blue catfish *Ictalurus furcatus*, European perch *Perca fluviatilis*, bleak *Alburnus alburnus*, stone moroko *Pseudorasbora parva*, northern snakehead *Channa argus*, and roach *Rutilus rutilus.* The large number of fish species on the surveillance list taken in combination with established species-specific monitoring efforts points to the importance of a community-level surveillance program for fish.

Natural dispersal (facilitated by human-modified connections like channels and navigation locks), intentional release, and hitchhiking/fouling are the three most important potential pathways of introduction for fish (Table 2.2.2).

Table 2.2.3. *Alphabetical list of fish on the surveillance species list. Categorical impact and pathway scores based on the GLANSRA are shown ([H]igh, [M]edium, or [L]ow). (*) indicates species that have been identified by previous assessments as in one or more invasion pathway – but data on their prevalence in these pathways is scarce. Species with localized Great Lakes distributions are in brackets.*

Species name	**Common name**	**Environmental Impact Category**	**Socio/Cultural Impact Category**	**Highest categorical pathway score (any pathway)**
Acanthogobius flavimanus	Yellowfin goby	H	L	H
Acipenseridae	Non-native sturgeon	H	H	H
Alburnus alburnus	Alver, bleak	H	L	M
Alosa aestivalis	Blueback herring	H	L	H
Atherina boyeri	Big-scale sand smelt	M	L	M
Babka gymnotrachelus	Racer goby	M	L	M
Benthophilus stellatus	Starry goby	M	L	L
Carassius gibelio	Prussian carp	H	H	U
Channa argus	Northern snakehead	H	M	M
[Ctenopharyngodon idella]	Grass carp	H	L	H
Cyprinella lutrensis	Red shiner	H	L	H
[Gambusia affinis]	Western mosquitofish	H	L	H
Gambusia holbrooki	Eastern mosquitofish	H	H	H
Gobio gobio	Gudgeon	H	L	L
[Gymnocephalus cernua]	Eurasian ruffe	H	H	H
Hypomesus nipponensis	Wakasagi	H	L	L
Hypophthalmichthys molitrix	Silver carp	H	H	M
Hypophthalmichthys nobilis	Bighead carp	H	H	M
Ictalurus furcatus	Blue catfish	M	L	H
Lepomis microlophus	Redear sunfish	H	L	H
Leuciscus leuciscus	Eurasian dace	H	H	M
Menidia beryllina	Inland silverside	H	L	H
[Misgurnus anguillicaudatus]	Oriental weatherfish	H	L	H
Morone saxatilis x chrysops	Hybrid striped bass	M	L	H
Mylopharyngodon piceus	Black carp	H	L	L
Neogobius fluviatilis	Babka goby	M	L	M
Oncorhynchus keta	Chum salmon	M	L	L
Osmerus eperlanus	European smelt	H	L	M
Perca fluviatilis	Eurasian perch	H	M	M
Perccottus glenii	Amur sleeper	H	L	M
Phoxinus phoxinus	Common minnow	M	L	M
Pseudorasbora parva	Stone moroko	H	L	L
Pylodictis olivaris	Flathead catfish	H	L	H
Rhodeus sericeus	Bitterling	H	L	H
Rutilus rutilus	Roach	H	M	M
Sander lucioperca	Zander	H	L	L

Species name	Common name	Environmental Impact Category	Socio/Cultural Impact Category	Highest categorical pathway score (any pathway)
[Scardinius erythropthalmus]	Rudd	M	L	H
Silurus glanis	Wels catfish	H	L	U
Siniperca chuatsi	Chinese perch	H	L	H
[Tinca tinca]	Tench	M	L	L

ii. Invertebrates

Invertebrates account for 25% of surveillance list species. Crustaceans account for over three-quarters of the invertebrate group (Table 2.2.4). For invertebrates there is often a paucity of data on impacts – hence many species assessed for the Framework had unknown or low impact scores and are not included on the surveillance species list.

Where pathways are known, invertebrate taxa are predominately associated with the shipping pathway (Table 2.2.2). The most obvious exception is the crayfish; red swamp crayfish, signal crayfish, marron, and yabby are all associated with intentional release. For the purposes of this plan, prioritization of surveillance sites for crayfish should follow recommendations for fish, which emphasize the importance of the intentional release pathway. The scud *Apocorophium lacustre* is another high-profile exception identified in the Great Lakes and Mississippi Inter-basin Study (USACE 2014), with its introduction linked to the canal pathway and potential for range expansion through the Chicago Area Waterway System.

Table 2.2.4. *Alphabetical list of aquatic invertebrates on the surveillance species list. Categorical impact and pathway scores based on the GLANSRA are shown ([H]igh, [M]edium, or [L]ow). Species with localized Great Lakes distributions are in brackets.*

Species name	Common name	Environmental Impact Category	Socio/Cultural Impact Category	Highest categorical pathway score (any pathway)
Bryozoan				
Fredericella sultana		H	H	H
Lophopodella carteri		M	L	H
Platyhelminthes				
[Ichthyocotylurus pileatus]	Digenean fluke	H	L	H
Mollusk				
Anodonta woodiana	Chinese pond mussel	H	L	H
Limnoperna fortunei	Golden mussel	H	H	L
Lithoglyphus naticoides	Gravel snail	H	L	M
Mytilopsis leucophaeata	Dark false mussel	H	H	M
[Potamopyrgus antipodarum]	New Zealand mudsnail	H	L	H
Crustacean				
Apocorophium lacustre		M	L	M
[Argulus japonicus]	Japanese fishlouse	H	H	H

Species name	Common name	Environmental Impact Category	Socio/Cultural Impact Category	Highest categorical pathway score (any pathway)
Chelicorophium curvispinum	Caspian mud shrimp	M	L	M
Cherax destructor	Yabby (crayfish)	M	L	M
Cherax tenuimanus	Hairy marron (crayfish)	M	L	L
Cyclops kolensis		M	L	M
[Daphnia galeata galeata]	Waterflea	H	L	H
[Daphnia lumholtzi]	Waterflea	M	L	H
Dikerogammarus haemobaphes		M	L	M
Dikerogammarus villosus	Killer shrimp	H	L	M
Echinogammarus warpachowskyi		M	L	M
Eriocheir sinensis	Chinese mitten crab	H	H	H
Gmelinoides fasciatus	Baikalian amphipod	H	L	M
[Hemimysis anomala]	Bloody red shrimp	H	L	H
Limnomysis benedeni		M	L	M
Obesogammarus crassus		H	L	M
Obesogammarus obesus		H	L	L
Orconectes (Faxonius) limosus	Spinycheek crayfish	L	M	L
Pacifastacus leniusculus	Signal crayfish	H	M	L
Paramysis (Metamysis) ullskyi		H	L	M
Paramysis (Serrapalpisis) lacustris		M	L	M
Podonevadne trigona ovum		M	L	L
Pontastacus leptodactylus	Danube crayfish	M	L	M
Pontogammarus robustoides		M	L	M
[Procambarus clarkii]	Red swamp crayfish	H	H	H
Procambarus fallax f. virginalis	Marmorkrebs, marbled crayfish	H	M	H
[Schizopera borutzkyi]	Oarsman	H	L	H

iii. Plants and Algae

Monitoring aquatic plant and algae communities has been a high priority for inland waters but historically limited surveillance has occurred for invasive aquatic plants in the Great Lakes and connecting waters themselves. However, aquatic plants and algae are the most prolific taxonomic group on the surveillance species list and almost one-third are already locally established in the Great Lakes Basin and have demonstrated significant impacts that warrant management concern. As a group, aquatic plants and algae have the highest average combined impact scores (i.e., negative environmental and socio-economic impacts).

The most important sources of introduction or range expansion for plants are associated with hitch hiking on boats or equipment, natural dispersal (through canals or headwater connections), intentional movement, and cultivation or stocking (Table 2.2.2). The commercial shipping pathway does not appear to be an important dispersal vector.

Table 2.2.5. *Alphabetical list of aquatic plants and algae on the surveillance species list. Categorical impact and pathway scores based on the GLANSRA are shown ([H]igh, [M]edium, [L]ow, or [U]nknown (ˆ) indicates algae. Species with localized Great Lakes distributions are in brackets.*

Species name	**Common name**	**Environmental Impact Category**	**Socio/Cultural Impact Category**	**Highest categorical pathway score (any pathway)**
Akebia quinata	Chocolate vine	H	L	H
[Alnus glutinosa]	Black alder	H	L	H
Alternanthera philoxeroides	Alligator weed	H	H	H
Alternantha sessilis	Sessile joyweed	L	H	M
Aponogeton distachyos	Cape pondweed	M	L	H
Artemesia absinthium	Absinthe wormwood	M	M	H
Arundo donax	Giant reed	H	M	H
Azolla filiculoides	Pacific mosquito fern	H	H	H
Azolla pinnata	Asian mosquito fern	H	M	L
[Butomus umbellatus]	Flowering rush	M	M	H
[Cabomba caroliniana]	Carolina fanwort	M	M	H
[Cirsium palustre]	Marsh thistle	H	L	H
Colocasia esculenta	Coco-yam	H	L	H
Crassula helmsii	New Zealand pygmy weed	H	M	U
Cyperus difformis	Variable flat sedge	L	H	L
*Didymosphenia geminata*ˆ	Didymo	H	H	H
Egeria densa	Brazilian waterweed	H	H	H
Egeria najas		M	M	H
Eichhornia azurea	Anchored water hyacinth	M	M	H
[Eichhornia crassipes]	Water hyacinth	H	H	H
[Epilobium hirsutum]	Great hairy willow herb	M	L	H
[Frangula alnus]	Glossy buckthorn	H	H	H
[Glyceria maxima]	Reed mannagrass	H	M	H
Hydrilla verticillata	Hydrilla	H	H	H
[Hydrocharis morus-ranae]	European frog-bit	H	H	H
Hydrocotyle ranunculoides	Floating marsh pennywort	H	H	H
Hygrophila polysperma	Indian hygrophila	M	H	M
Ipomoea aquatica	Swamp cabbage	H	H	H
[Juncus compressus]	Flattened rush	M	L	H
[Juncus gerardii]	Black-grass rush	H	M	H

Species name	Common name	Environmental Impact Category	Socio/Cultural Impact Category	Highest categorical pathway score (any pathway)
[Juncus inflexus]	European meadow rush	M	L	H
Lagarosiphon major	African elodea	H	H	L
Limnobium spongia	American spongeplant	M	M	L
Ludwigia adscendens	Water primrose	M	M	U
Ludwigia grandiflora		H	H	L
Ludwigia hexapetala	Uruguayan primrose willow	H	H	H
Ludwigia peploides	Floating primrose willow	H	H	H
[Lysimachia vulgaris]	Yellow loosestrife	H	L	H
Lythrum virgatum	Wanded loosestrife	H	H	H
Melaleuca quinquenervia	Punk tree	H	H	L
Murdannia keisak	Wart removing herb	H	M	L
Myriophyllum aquaticum	Parrot feather	H	M	H
Myriophyllum heterophyllum x M. laxum		H	H	L
[Najas minor]	Brittle waternymph	H	M	H
Nelumbo nucifera	Sacred lotus	H	L	H
[Nitellopsis obtusa]ˆ	Starry stonewort	H	H	H
Nymphaea spp (except Nymphaea odorata, and N. leibergii)	Non-native water lilies	M	L	H
Nymphoides peltata	Yellow floating heart	M	M	H
Oenanthe javanica	Water celery	M	M	H
Oxycaryum cubense	Cuban bulrush	H	L	L
[Pistia stratiotes]	Water lettuce	H	H	H
Prymnesium parvumˆ	Flagellated algae	H	H	M
Robinia pseudoacacia	Black locust	H	L	H
Rotala rotundifolia	Round leaf toothcup	M	L	H
Sagittaria platyphylla	Delta arrowhead	H	H	L
Sagittaria sagittifolia	Arrowhead	L	H	L
Salix atrocinerea	Smooth twig gray willow	H	L	H
Salvinia minima	Water spangles	H	H	H
Salvinia molesta	Kariba weed	H	H	L
Solanum tampicense	Wetland nightshade	M	L	U
Stratiotes aloides	Water soldier	M	M	H
[Trapa natans]	Water chestnut	H	H	H
Typha domingensis	Southern cattail	H	H	L
Typha laxmannii	Graceful cattail	H	L	H
Typha orientalis	Bullrush/raupo	H	L	U
Typha x glauca	Hybrid cattail	H	L	H
[Ulva species]ˆ	Green alga	H	M	H
Vallisneria spiralis	Eelgrass	H	M	H

2.3 Surveillance Site Selection and Prioritization

With a surface water area of 95,000 square miles (245,759 square km) and shoreline length of 10,210 miles (17,017 km), and just over 50% of the shoreline area occurring in U.S. territory, the Great Lakes represent a daunting challenge for sample site selection. Management resources are finite; hence it is important that monitoring efforts concentrate on those sites with the highest risk of introduction (Lodge et al. 2006, O'Malia et al. 2018). Furthermore, because the potential surveillance burden is unlikely to fall unevenly across jurisdictions given shoreline extent varies across each of the Great Lake's states, it is important that any process used to set priorities be objective, data driven, and based on testable transparent criteria and assumptions. The site prioritization method described in this Framework aims to address such challenges.

Accurate forecasting of invasion risk requires consideration of the probability of introduction/colonization (risk of introduction), the potential for establishment (site suitability), and a measure of potential impacts (Vander Zanden and Olden 2008). To determine the risk of introduction, pathway surrogates were combined to produce measures of cumulative propagule pressure at sites across the Great Lakes (Box 2: Tucker et al. 2020). Each surrogate is first weighted by the proportion of the total number of surveillance species (in a taxonomic group) known to be present in that pathway. As noted previously, the surveillance species list considers the combined potential for introduction, establishment, and impact of a species in the Great Lakes. To account for the measure of potential impact, only high and medium risk species were used to weight pathway surrogates to identify sites more likely to receive species predicted to have impacts in the Great Lakes. The potential for establishment was an inherent criterion for the surveillance species list as all species included in the site selection and prioritization process are environmentally suited to the Great Lakes. This approach does not consider the likelihood or scale of potential impacts at an individual site or the environmental suitability at individual sites.

The site selection process also accounts for introduction pathways that are drivers for both historic as well as projected future introductions, recognizing that there is typically a lag between introduction, establishment, and detection.

Finally, site selection priorities are organised around three high level taxonomic groups (fish, invertebrate, and plants including aquatic algae), recognising that distinct surveillance survey methods and sampling protocols are implemented around this taxonomy. A combined risk (all taxa) was published by Tucker et al. (2020).

2.3.1 Site Priorities

To facilitate the systematic and objective comparisons of risk and enable resources to be allocated to those sites with the highest risk, the site selection method outlined in this Framework divides the Great Lakes and connecting waters into a set of standardized survey units. These units have been ranked based on highest cumulative risk of invasion from all potential pathways of AIS introduction and secondary spread within the Great Lakes Basin. Separate ranked lists of high-risk management units were developed for fish, invertebrates, and plants because 1) optimal detection of each taxonomic group requires that different survey methods be used and 2) surveillance efforts for each taxonomic group are undertaken by independent sampling teams in most instances. As noted above, because they are vulnerable to detection using the same survey methods as for fish, crayfish are included within the fish model. For most introduction pathways the risk is highly skewed, hence a small number of units account for a disproportionate amount of the predicted invasion pressure. This is best illustrated by the shipping pathway, where a small number of ports account for a disproportionate number of the ship visits in the basin (Tucker et al. 2020, Supplementary Fig.1).

The prioritization system is designed so that priorities can be sorted to specific geographies or taxonomic groups. The grid squares were selected on the basis that they represent a standardized survey unit and should enable equitable allocation of resources across the highest risk sites. For instance, the USFWS (2014) identified Green Bay, the Huron-Erie Corridor and Western Lake Erie as large priority areas. But risk is not spread evenly across these large areas and this assessment indicates some areas contain multiple high-risk points of introduction. The current system does not extend down or consider the Saint Lawrence seaway primarily because of the boundaries of the GLAHF spatial framework, but future iterations should look to extending the framework down the length of the seaway.

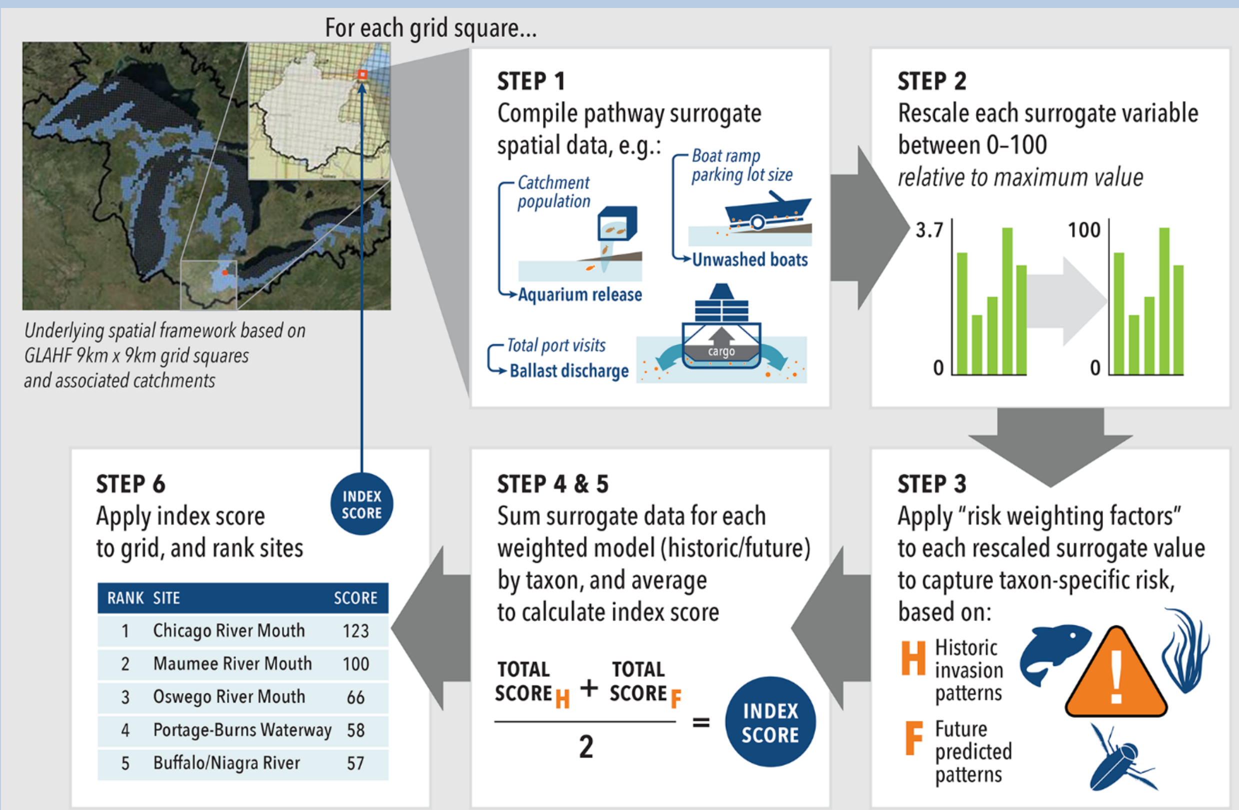
The site selection method outlined here focuses primarily on the most active points of introduction (nexus of multiple pathways), future iterations of the prioritization method should incorporate measures of irreplaceability or vulnerability (sensu Margules and Pressey 2000) to help identify the ecologically and economically important sites containing communities or ecosystem services that would be most impacted should they become invaded by the surveillance list species. Abiotic measures of habitat suitability (i.e. habitat invasibility, sensu Vander Zanden and Olden 2008) should also be more explicitly incorporated into future prioritization models. There is a rich array of abiotic spatial data associated with Great Lakes Aquatic Habitat Framework (GLAHF: Wang et al. 2015) and Great Lakes Environmental Assessment and Mapping project (GLEAM; Allan et al. 2013) and as species distribution data improves it should be possible to empirically model a combination of habitat and human disturbance measures that predict habitat suitability (Tucker et al. 2020).

Finally, consideration should also be given to including a measure of inter-lake connectivity (Kao et al. 2021), recognizing that some sites should they become invaded have far greater potential to contribute to future spread because of their location (connecting waters between lakes) or their connections through shipping to multiple disparate ports across the Great Lakes (Kvistad et al. 2019). A connectivity measure should also consider the potential for natural spread of established AIS into Lake Ontario from the Saint Lawrence River (seaway) as illustrated by the range expansion of Tench towards Lake Ontario (Avlijaš et al. 2017).

Box 2. Identifying Priority Sites for Surveillance

The Surveillance plan uses a systematic spatial prioritization method to identify site surveillance priorities (Tucker et al. 2020). The U.S. waters of the Great Lakes and tributaries were divided into standardized management units (each unit is 9 km by 9 km - 81km^2; 5, 953 units total) based on the Great Lakes Aquatic Habitat Framework (GLAHF; Wang et al. 2015). An index of invasion pressure was defined using a standardized set of spatial surrogates to estimate cumulative propagule pressure for each management unit. Human population density and number of constructed ponds were used as surrogates for the trade in living organisms. Number of ship visits and number of in-lake discharge events were used as surrogates for ballast water discharge. Marina and/or boat launch parking lot size were combined to produce a surrogate for the trailer boat pathway. Finally, the presence of canals or artificial headwater connections were attributed to each unit. Surrogate data was attributed within each spatial unit as well as catchments that drained into that unit (population, constructed ponds, and canals only) (Tucker et al. 2020).

Two kinds of weighting multipliers were applied to the attributed spatial surrogate data so that both historic patterns of introduction (H: based on the pathways associated with the introduction of established non-indigenous species) and future predicted patterns of introduction (F: based on the pathways predicted to be associated with the introduction of surveillance list species) were incorporated into the calculation of invasion pressure for each taxonomic group of interest. The spatial surrogate data for each of the weighted models was then summed to provide a quantitative estimate of potential invasion pressure in each management unit and a final cumulative risk score (index) was calculated for each grid square as the average of the two models.



2.3.2 Fish

Site selection for fish surveillance highlights those management units with larger population centres (associated with intentional release and aquarium pathways), and inland catchments with concentrations of constructed ponds and/or natural or artificial connections to either the Mississippi/Ohio or Mohawk/Hudson rivers (Table 2.3.1).

Recent AIS surveillance efforts by federal agencies (USFWS 2014) have focused on five areas previously identified by Grigorovich et al. (2003) as invasion hotspots: the Huron-Erie Corridor and western Lake Erie, southwestern Lake Michigan ports of Chicago and Indiana, the Buffalo-Niagara River, Duluth-Superior harbour and neighbouring ports, and St. Marys Locks and River. Multiple management units within four of these five broad locations were identified as priorities based on the AIS fish risk index rankings presented here (Figure 2.3.1). The Huron-Erie Corridor (from Port Huron, MI to Sandusky, OH) contains seven of the highest risk sites). Five high-risk sites in the Chicago area and along the section of southern Lake Michigan belonging to Indiana are considered high risk. Buffalo/Niagara River (ranked 5th) and Duluth/St Louis River (ranked 23rd) are also among the top 25 highest risk sites for fish. These sites are all associated with different combinations of high to moderate population density within their contributing catchments, large marinas and/or boat ramps, or in some cases moderate to high shipping activity.

The index of invasion pressure does not highlight the Lower Superior-Huron Corridor at the St. Marys River as especially high risk for fish. In general, the index down-weights the importance of some locations that have been emphasized in the past primarily because of their role as major shipping ports or locks with potentially sizeable ballast water discharge volumes (i.e. the Lower Superior-Huron corridor and Duluth/Superior harbour). Prioritizing surveillance based on patterns in shipping is understandable given that shipping has accounted for over 70% of introductions into the basin since the opening of the Welland Canal in 1959 (Ricciardi 2006, Grigorovich et al. 2003, Pugnacio et al. 2015). However, since the introduction of mandatory ballast water exchange in 2008, the importance of this pathway as a source of AIS appears to have declined (Bailey et al. 2011, O'Malia et al. 2018). Other high-risk sites include two sites each in the central basin of Lake Erie (Cleveland and Lorain in Ohio), the eastern Lake Michigan shoreline (Benton Harbor and Grand Haven in Michigan), and the southern shoreline of Lake Ontario (Rochester and Oswego in New York).

***Table 2.3.1**. Fish, top 25 highest risk sites based on the AIS risk index score (see Box 2 for detail).*

Site Rank	**Location**	**State**	**Index Score**
1	Chicago/Chicago River Mouth	IL	123
2	Toledo/Maumee River Mouth	OH	100
3	Oswego/Oswego River Mouth	NY	66
4	Portage/Portage-Burns Waterway	IN	58
5	Buffalo/Niagara River	NY	57
6	Saginaw Bay/Saginaw River Mouth	MI	56
7	Benton Harbor/Saint Joseph River Mouth	MI	53
8	Calumet River Mouth/Lake Michigan	IN	50
9	Cleveland/Cuyahoga River Mouth	OH	48
10	East Chicago/Indiana Harbor Canal	IN	45
11	Evanston/North Shore Channel Mouth	IL	45
12	Rochester/Genesee River Mouth	NY	43
13	Grand Haven/Grand River Mouth	MI	43
14	West Harbor/Marblehead/Lake Erie	OH	42
15	Green Bay/Fox River Mouth	WI	41
16	Sandusky/Sandusky Bay	OH	39
17	Lakeside/ Lake St. Clair	MI	38
18	Grosse Pointe Shores/Lake St. Clair	MI	34
19	Detroit River/Rouge River Mouth	MI	34
20	Milwaukee/Kinnickinnic River Mouth	WI	32
21	Lake St. Clair/Clinton River Mouth	MI	31
22	Fairport Harbor/Grand River Mouth	OH	29
23	Duluth/St Louis River Mouth	MN	27
24	Lorain/Black River Mouth	OH	25
25	Toussaint River Mouth	OH	21

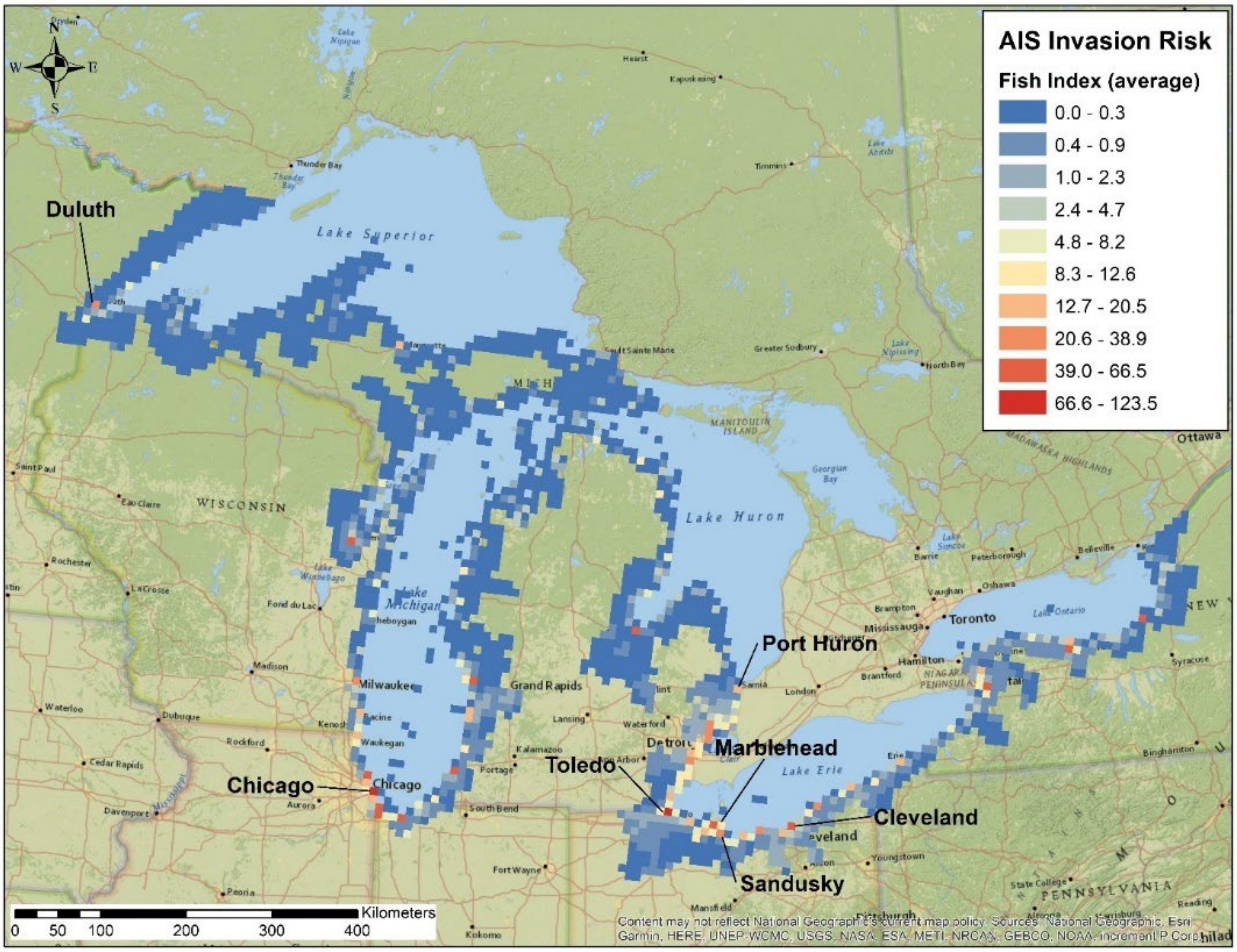


__Figure 2.3.1.__ Fish invasion risk pressure maps. Red represents highest risk sites and blue lowest risk sites. Sites highlighted in the offshore water of the Great Lakes represent areas of open water ballast water discharge.

2.3.3 Invertebrates

The rankings for invertebrate surveillance are driven almost entirely by the shipping pathway with only minor contributions from the other pathway surrogates. Hence all the top ranked sites are major ports with Duluth-Superior the highest ranked site (Table 2.3.2; Figure 2.3.2) because it typically receives about twice as many ship visits as the next highest ranked port. The number of ship visits, which was used here as the primary surrogate to estimate propagule pressure from the shipping pathway, does not take into consideration either temporal changes in abundance of AIS in the location where ballast water was taken up or the suitability of the receiving waters. However, it is the metric most correlated to AIS detections relative to other publicly available metrics of ship-based risk (O'Malia et al. 2018, Drake et al. 2015, Keller et al. 2010).

High risk crayfish species were included in invertebrate pathway weightings. But crayfish share many of the same pathways of introduction and are typically collected using traditional fisheries methods (traps, nets, visual observations). Hence future iterations of the site prioritisation model should consider including these as part of a combined fish and crayfish index.

Table 2.3.2. Invertebrates, top 25 highest risk sites based on the AIS risk index score (see Box 2 for detail).

Site Rank	Location	State	Index Score
1	Duluth/St. Louis River Mouth	MN	72
2	Toledo/Maumee River Mouth	OH	54
3	Chicago/Chicago River Mouth	IL	53
4	Cleveland/Cuyahoga River Mouth	OH	49
5	Portage/Portage-Burns Waterway	IN	42
6	Sandusky/Sandusky Bay	OH	38
7	Marquette/ Dead River Mouth	MI	37
8	Detroit/ Detroit River	MI	36
9	Oswego/Oswego River Mouth	NY	34
10	West Harbor/Marblehead/Lake Erie	OH	34
11	Buffalo/Niagara River	NY	33
12	Calumet River Mouth/Lake Michigan	IN	30
13	Chicago-Calumet Port	IL	30
14	Milwaukee/Kinnickinnic River Mouth	WI	28
15	Saginaw Bay/Saginaw River Mouth	MI	28
16	Grosse Pointe Shores/Lake St. Clair	MI	27
17	East Chicago/Indiana Harbor Canal	IN	26
18	Evanston/North Shore Channel Mouth	IL	26
19	Alpena/Thunder Bay River Mouth	MI	25
20	Rochester/Genesee River Mouth	NY	24
21	Lake St. Clair/Clinton River Mouth	MI	24
22	Rogers City/Calcite	MI	22
23	Ashtabula/Ashtabula River Mouth	OH	22
24	Two Harbors	MN	22
25	Green Bay/Fox River Mouth	WI	21

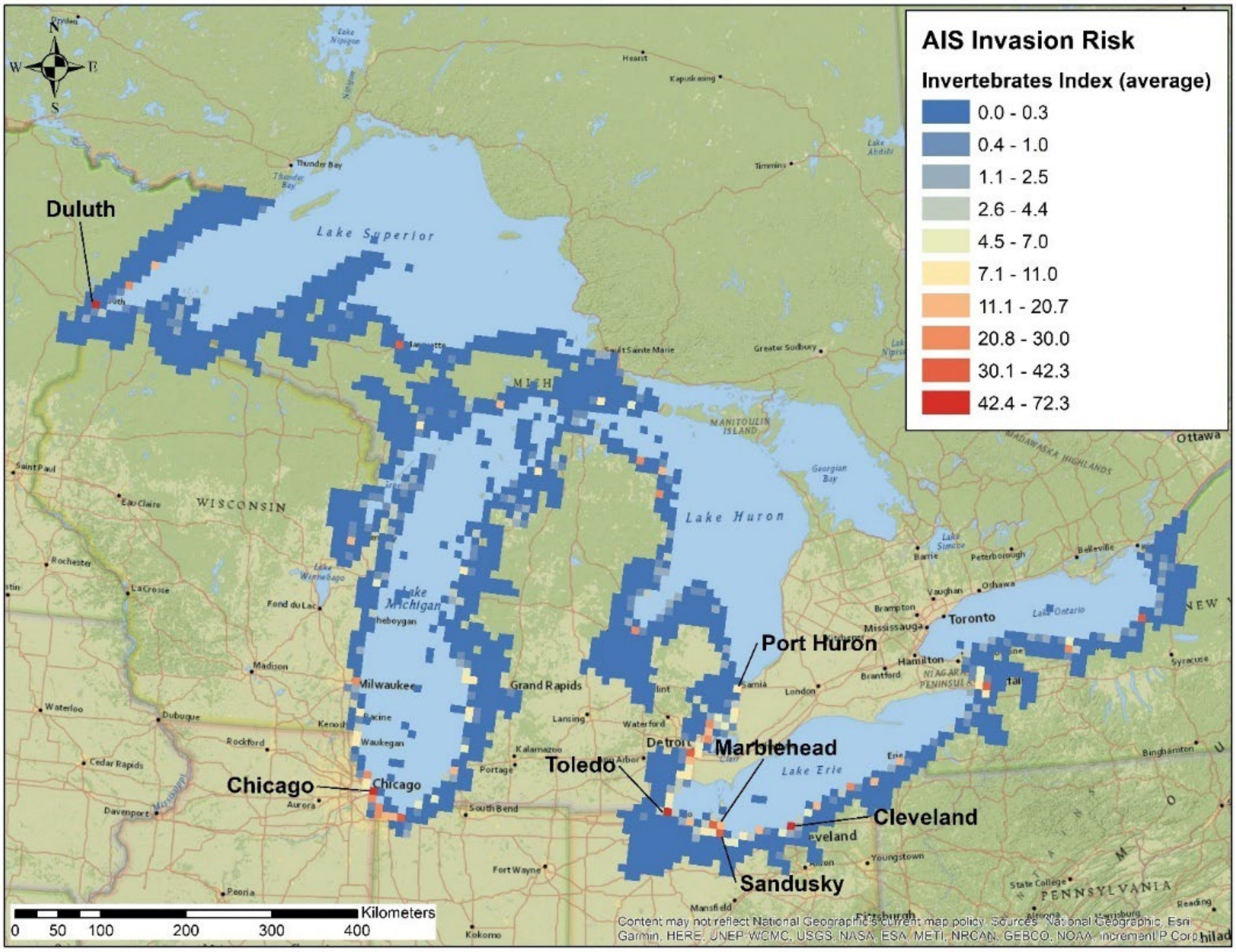


Figure 2.3.2. Invertebrate invasion risk pressure maps. Red represents highest risk sites and blue lowest risk sites.

2.3.4 Plants (vascular plants and algae)

The surveillance list pathways assessment indicates that the natural dispersal, hitchhiking/fouling, intentional release, and escape pathways are the most likely sources of aquatic vascular plant and algae introductions (Table 2.2.5). Thus, the site surveillance priorities for plants identify locations with the highest densities of natural and/or artificial connections (dispersal), boat launches/marinas (hitchhiking/fouling), and large population centres (intentional release from water gardens or aquaria) (Table 2.3.3, Figure 2.3.3). The shipping pathway is considered a low-risk pathway for introduction and spread of aquatic plants because macroscopic, vegetative life stages (e.g., plant fragments, seeds, and bulbils) should be screened during ballast water intake (within lake movement) and would not survive the high salinity associated with ballast water exchange or hull fouling (e.g., Hay 1990).

Limited surveillance has occurred for new non-native aquatic plants in the Great Lakes. The USFWS does not have a legislative responsibility for invasive plants and surveillance efforts for plants at the state level have largely been focused on inland waters. Nevertheless, the Great Lakes coastline has extensive and ecologically valuable coastal wetlands that have proven vulnerable to invasive aquatic plants, suggesting that plant surveillance in Great Lakes waters is justified. More than half of the highest risk sites for plant introductions are near the entrances to the Erie Canal (Oswego River, Niagara River, Genesee River) and CAWS (e.g., Chicago River, Calumet River, North Shore Channel), or within the Huron-Erie Corridor (eight sites). The recent discovery of surveillance list plant species (hydrilla *Hydrilla verticillata*, water chestnut *Trapa natans*, water lettuce *Pistia stratioties*, and water hyacinth *Eichhornia crassipes*) in the Erie Canal and sites in the Huron-Erie Corridor provide support for these predictions (Gatenby 2016, Adebayo et al. 2011).

As noted earlier, the large number of wetland plant species on the surveillance list indicates future iterations of plant site surveillance prioritization could be strengthened through the incorporation of measures of site value (e.g., wetlands) and consideration of habitat suitability using specific habitat measures (depth, substrate, exposure) available in the Great Lakes Aquatic Habitat Framework (GLAHF, http://ifr.snre.umich.edu/glahf/). Secondary spread via dispersal through natural corridors could also be explored in greater detail.

Table 2.3.3. *Plants, top 25 highest risk sites based on the AIS risk index score (see Box 2 for detail).*

Site Rank	**Location**	**State**	**Index Score**
1	Chicago/Chicago River Mouth	IL	138
2	Toledo/Maumee River Mouth	OH	115
3	West Harbor/Marblehead/Lake Erie	OH	75
4	Saginaw Bay/Saginaw River Mouth	MI	72
5	Benton Harbor/Saint Joseph River Mouth	MI	69
6	Sandusky/Sandusky Bay	OH	65
7	Grosse Pointe Shores/Lake St. Clair	MI	61
8	Oswego/Oswego River Mouth	NY	60
9	Cleveland/Cuyahoga River Mouth	OH	55
10	Lake St. Clair/Clinton River Mouth	MI	54
11	Lakeside/ Lake St. Clair	MI	52
12	Portage/Portage-Burns Waterway	IN	51
13	Grand Haven/Grand River Mouth	MI	50
14	Buffalo/Niagara River	NY	49
15	Detroit River/Rouge River Mouth	MI	48
16	Green Bay/Fox River Mouth	WI	47
17	Calumet River Mouth/Lake Michigan	IN	46
18	Fairport Harbor/Grand River Mouth	OH	40
19	Milwaukee/Kinnickinnic River Mouth	WI	39
20	East Chicago/Indiana Harbor Canal	IN	37
21	Evanston/North Shore Channel Mouth	IL	36
22	Erie/Presque Isle Bay	PA	35
23	Toussaint River Mouth	OH	35
24	Rochester/Genesee River Mouth	NY	33
25	Lorain/Black River Mouth	OH	32

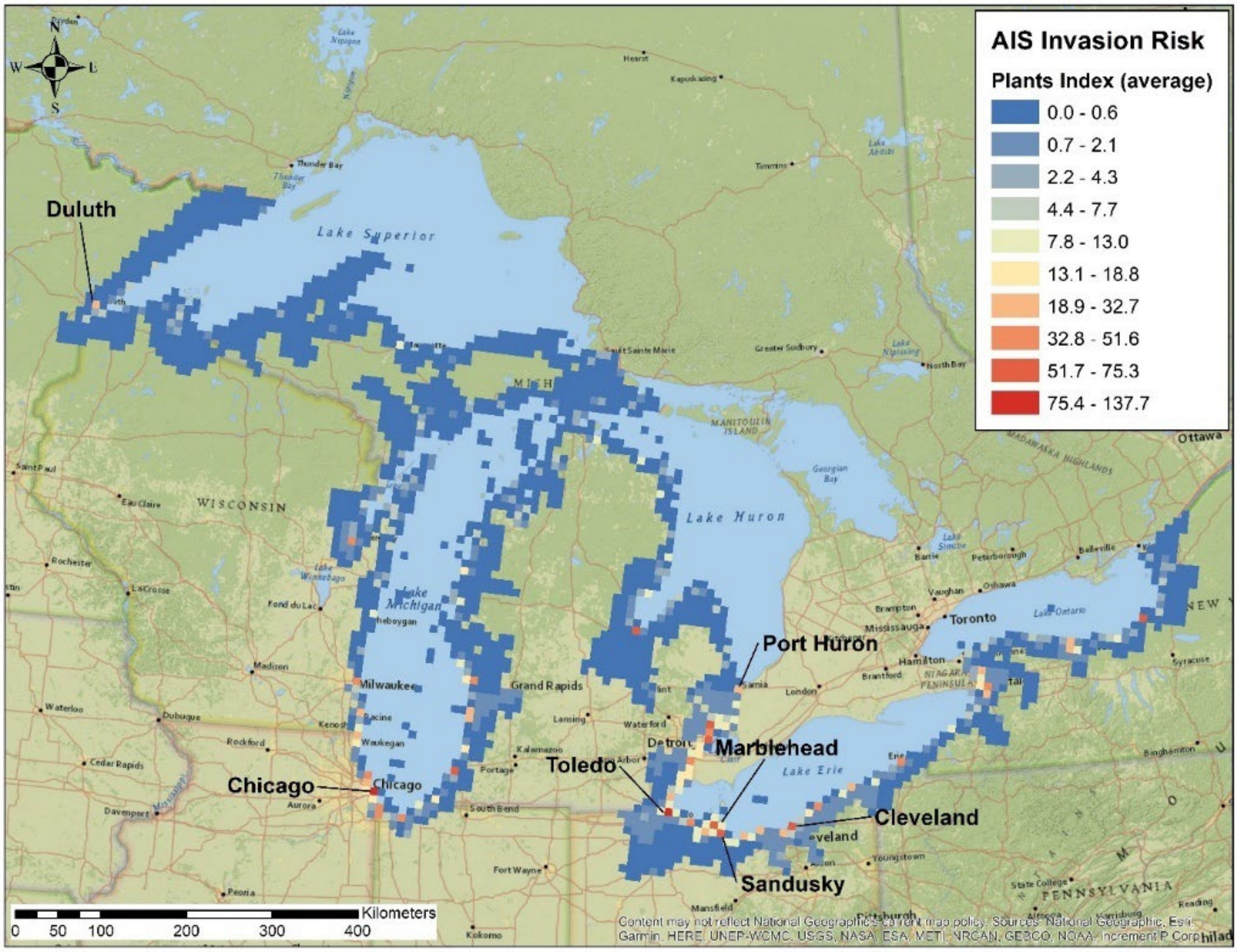


Figure 2.3.3. Plant invasion risk pressure maps. Red represents highest risk sites and blue lowest risk sites.

2.4 Surveillance Methods and Survey Design

The recommendations that follow are geared towards survey design and implementation of sampling within a single management unit. The surveillance framework is focused on improving early detection for as many species as possible given evolving resource constraints. The previous sections are therefore based on a risk management and prioritization approach. A surveillance species list of high and moderate risk species was developed to help direct surveillance activities to the sites that likely pose the most imminent threat for introduction of invasive species with predicted high or moderate impacts. Although the surveillance species list approach focuses surveillance effort on only a subset of all possible Great Lakes locations where non-native species might be introduced (hot spots), the surveillance species list is large enough (144 species) to encompass a wide range of taxa introduced by various pathways. These species inhabit a range of habitats, and survey methods optimized for the detection of this broad range of species will likely also facilitate detection of other species not currently on the surveillance species list but of potential interest to managers for other reasons.

Survey design and surveillance methodology should largely be based on the principles and best practices derived from previous EPA and USFWS surveillance studies (e.g., Trebitz et al. 2009, Hoffman et al. 2016, Harris et al. 2018). In general, the framework recommends that each survey should:

- Target multiple habitat types to detect the full range of surveillance list species.
- Employ multiple different gear types that can contribute unique sets of species to the surveillance effort (by exploiting gear-specific differences in species detection).
- Be quantitative and probabilistic (to facilitate evaluation of detection rates and optimization of sampling efficiency through oversampling and randomization techniques; and to decrease the likelihood that some habitats are not sampled at all or with little sampling effort).

Recommendations also assume that for now, the surveillance program will be developed with traditional gears, and through adaptive management new methods and technology will be incorporated moving forward.

2.4.1 Survey Design

Implementation of a Great Lakes surveillance program will by necessity be an adaptive process subject to changes in knowledge and resource availability. A key principle that underlines the plan is the idea of learning by doing. Hence as the survey program is implemented, the sampling design should enable an evaluation of sampling success to optimize sampling efficiency. Employing a probabilistic design and enough sample replicates within and across each sampling strata the first time a site is surveyed will enable an assessment of detection probability (number of sites where observed divided by total number of sites) and facilitate predictions of what may not be detected through species effort theory (Chao et al. 2009, Colwell 2013). Species-effort metrics also allow a lack of detection to be reported with an associated level of confidence, thereby helping to avoid the perception that new AIS were not detected simply for lack of effort. Another advantage of a probabilistic sampling design is that it decreases the likelihood that some habitats are not sampled at all or with little sampling effort. Spatially restricted non-native species are a formidable problem for early detection because a species could establish a viable population prior to detection if concentrated in a small area (Trebitz et al. 2009). Stratified random sampling is an excellent tool for covering space and for covering a range of unique habitats (with habitat appropriate gear). Survey teams should be careful not to assume they know where to look, especially when targeting a broad range of taxa (Trebitz et al. 2009).

In allocating effort across a site, an important initial step is dividing the site into key habitats or strata to sample. This habitat classification will likely be based on combinations of depth, substrate, exposure, and the presence or absence of aquatic plants. As the surveillance program matures, with increased knowledge of individual sites and assessment of survey results (i.e., which habitats and sampling method yield the most novel information: e.g., Harris et al. 2018), the probabilistic sampling design (e.g., stratified random) can evolve towards a strategically biased design (non-probabilistic) over time. Efficiency can be gained by reducing effort in areas that produce little new information and targeting specific habitats where non-native or rare species are over-represented in a sample relative to their abundance (Trebitz 2009, Hoffman et al. 2016). Detection of rare native species provides a basis for gauging survey performance in the absence of information on AIS.

2.4.2 Survey Methods

Inherent variability in habitats, substrates, and biotic communities at priority management units across the Great Lakes basin requires that sample collection techniques be location-specific and fit within a flexible sample design (USFWS 2014, Hayer 2018). Sample gears must be selected that work in the habitats present in each priority site and that exploit the habitat preferences and life histories of targeted priority species. Previous studies have shown different gear types can contribute unique sets of species to a surveillance effort, hence sampling with multiple kinds of equipment is important to maximize species richness by exploiting gear-specific differences in species detection (e.g., Hoffman et al. 2016).

Once a sample location has been stratified based on habitat (e.g., depth, substrate, exposure, presence of aquatic vegetation), it should be sampled with gears and methods appropriate for the taxonomic group and habitats of interest. A range of methods have been identified by EPA, USFWS, and state management agencies for sampling each broad taxonomic group (Hayer 2018). Important considerations relevant to each method, including ideal habitat for deployment, timing of deployment, cost, time to results, and QA/QC considerations, are discussed below.

Comparable survey design and sampling methods across jurisdictions is recommended to maximize sampling efficiencies as part of a regional collaborative sampling program. The detection of new species is the goal of early detection monitoring, and such detections are more valuable than repeated encounters with known species. Thus, surveys should strive to sample in new areas, with new equipment and new methods as they become available. Future iterations of the Framework should consider new methods and new capacity as they develop in the basin.

i. Fish methods

Surveillance effort should be proportionally allocated to reflect the larger number of littoral and pelagic fish species on the surveillance species list (as compared to benthic fish species). Fish on the surveillance species list exhibit no dominant substrate preference with species attributed almost equally across soft, hard, and mixed substrates including aquatic plant communities so the sampling program should include gears capable of sampling a full range of substrates and vegetated habitats.

Sample effort should aim to detect at least 95% of the predicted species pool, and gears allocated in a way to maximize the information that can be gained from the system where multiple habitats contribute to the overall species pool. Absolute number and placement of gears will vary but should be consistent with the idea of deploying multiple gears to sample a full range of habitats and undertaking annual assessment of gear performance to optimize how these gears are allocated (Hoffman et al. 2016, Harris et al. 2018). Current best practice suggests fish surveillance should utilize three or more conventional gears and typically would involve a combination of fyke nets, boat electrofishing (all substrates in shallow water), multi-mesh gillnets (deeper water >2m), and bottom trawls (for soft substrates). For each site it is recommended that a minimum of two years of sampling effort be undertaken to provide an acceptable level of detection. In each year a minimum of fifty sample locations should be selected at random from across two depth strata, shallow and deep (based on photic zone depth, approximately 3m). Initially (baseline monitoring at a site), samples can be allocated equally across gear types. At a subset of sites, minnow traps, cloverleaf traps, trammel nets, and seines can also be deployed (Hayer 2018, Harris et al. 2018) as alternatives to target specific habitats or species. Gear performance should be evaluated on an annual basis by assessing species accumulation curves and the capture of rare species to optimize gear allocation for sampling in future years (Hoffman et al. 2016) and determine whether the addition of new gears improve performance (sensu Harris et al. 2018).

Additional sampling tools are likely to be identified by USFWS and fishing methods adapted as results of ongoing field trials become available. Recommended field sampling methods for these gears, including gear specifications, duration of sampling, and deployment methods are described in Hoffman et al. 2016 and Hayer 2018. Many of the gears used to detect fish will also be effective for crayfish surveillance (e.g., gee minnow traps: Smith 2020, Kvistad et al. 2021a).

Sampling should ideally occur in late summer to maximize the likelihood that all species (including YOY) can recruit to sampling gears. Rusty crayfish capture rates also appear to be higher in late summer within the Great Lakes waters (Kvistad et al. 2021b).

Fifty samples per site, when allocated across fyke nets, electrofishing, gill nets, and bottom trawl is roughly equivalent to about 5 days of effort per site (each year). Fish surveillance in Great Lakes' ports of comparable size to the 9 km x 9 km management units prescribed in this Framework indicates that two consecutive years of the above sampling effort is likely to get close to the desired 95% detection of the true fish species pool at any given site (assuming that combining independent years is a reasonable space-time substitution of effort; see Hoffman et al. 2016). Nevertheless, performance-based monitoring at each site will be needed to ensure these conclusions are valid, and to provide the relevant data needed to modify the sample plan. Ideally, the number of samples needed to detect rare species at each site in subsequent years can be reduced if performance metrics suggest that gear allocation can be optimized to target the most species-rich habitats at each site.

ii. Invertebrate methods

In general, the diversity of habitat associations for invertebrate taxa means that this information provides limited value for directing surveillance efforts, except that it emphasizes the importance of sampling across a full range of environments (benthic, pelagic, soft bottom, hard bottom, shallow, and deep). The sampling effort required to reliably detect most zooplankton and benthic invertebrate species at a site is typically much larger than for fish. The current reliance on morphological identification can be especially time consuming, and consequently traditional collection methods sample relatively small areas of habitat. Hence Hoffman et al. (2011) estimate that a 95% detection sensitivity for benthic invertebrates likely requires at least 150 samples per site (versus about 100 samples for fish), whereas 95% detection of zooplankton could require up to 750 samples per site (Hoffman et al. 2011). Harvey et al. (2009) concluded that invasive zooplankton monitoring was best done using large samples that were spaced well apart. For now, zooplankton monitoring remains a challenge and the level of effort required to provide an acceptable detection limit will likely not be feasible, especially considering the time required for species identification. Genetic identification methods offer considerable potential for speeding up sample processing times for mixed organism samples, although efficacy of this approach has been constrained by the lack of reference DNA sequences for many species (Trebitz et al. 2015). The use of environmental DNA metabarcoding methods to process the samples appears to offer considerable potential (see also section 2.4.3), and notwithstanding the need to build out gene libraries, agreed protocols for the genomic workflow including bioinformatic data processing and quality assurance protocols (Trebitz et al. 2017, Darling et al. 2017). While the requisite barcode libraries and ability to complete whole plankton community profiles are probably some years away (Darling et al. 2017), sequence information is available for some high-risk zooplankton, and metabarcoding analyses of samples could provide a means to screen mixed samples for at least these species.

In the short term, due to the lower number of samples necessary to achieve 95% detection sensitivity for benthic invertebrates versus zooplankton, surveillance with conventional gears should focus on detection of benthic invertebrates across a range of habitats. Sampling effort should again aim to detect at least 95% of the predicted species pool, with gears allocated to maximize the information that can be gained from the system where multiple habitats contribute to the overall species pool. Best practice suggests the use of conventional gears that enable sampling of both soft and hard substrates and comprised of the following: ponar grab samplers (for sediment-associated benthos in deeper habitats), sweep nets (for epiphytic benthos in shallow-vegetated habitats), and artificial colonization substrates (e.g. Hester-Dendy colonization plates) deployed on mixed (soft and hard substrates) and rocky habitats. Soft-bottom sampling can also be supplemented with benthic sleds designed to sample a larger area for larger high-risk species (Hayer 2018). For each site, a minimum of 75 sample locations should be selected at random from across various habitat types (e.g., 50% (~ 37 samples) from shallow-vegetated habitat, 35% (~26 samples) from deep habitat, and 15% (~12 samples) from rocky habitat). Recommended field sampling methods for these gears, including gear specifications, duration of sampling, and deployment methods are described in Hoffman et al. 2011 and Hayer 2018. It is important that the volume sampled, or area swept is documented so that the effectiveness of collection methods can be assessed (Trebitz et al. 2017). Specimens should be separated from sediments using a 500-um sieve and preserved for laboratory identification. Consideration should be given to preservation in ethanol rather than a 10% buffered formalin, to facilitate genetic identification (Darling 2015) and contribute to efforts to build out genetic libraries of Great Lakes communities and surveillance species. In the laboratory, organisms should be sorted (including possibly sub-sampling) with emphasis placed on searching for the full range of taxa, and especially novel taxa (rather than counts of individual organisms). Environmental DNA (eDNA) metabarcoding of the ethanol used to preserve samples has potential to facilitate a rapid screening of samples (Duarte et al. 2021) for surveillance species especially as genetic libraries become more comprehensive.

When gears are deployed as described above, detection of 95% of the true benthic invertebrate species pool at any given site is predicted after two consecutive years of sampling (based on detection rates from EPA sampling in Great Lakes' ports, and if combining independent years is a reasonable space-time substitution of effort; see Trebitz et al. 2009, Hoffman et al. 2011).

iii. Plant methods

Aquatic plant survey methods have been optimized for surveillance in shallow inland lakes, but historically, the waters of the Great Lakes themselves have received limited attention. This gap in plants surveillance coverage in the Great Lakes is beginning to be addressed, and comprehensive surveys have been to be completed for some high-risk sites across the basin (e.g., Tucker et al. 2021). Recent surveys have also formed the basis for the development of a standard monitoring protocol that is consistent with fish and invertebrate methods (Hoffman et al. 2011).

Specifically, the recommended protocol is designed to quantitatively assess survey performance for detection of the entire aquatic plant community, including rare and potentially invasive aquatic plants, in Great Lakes coastal areas (ports, harbours, drowned river mouths, and estuaries). The emphasis on a quantitative and probabilistic design aims to facilitate evaluation of survey performance using plant detection rates and ensure site coverage to decrease the likelihood that some habitats are not under sampled (or not sampled at all).

Aquatic plant surveys differ slightly from other taxonomic groups in that plants have a narrower range of suitable habitats (light limitations). Site survey should still target all major habitat types likely to support plants to detect the full range of watch list species. But it is recommended that effort should be allocated to those habitats able to support plants, recognizing differences in habitat preferences and life histories of the priority surveillance species, e.g., submerged vs. emergent vs. floating species. Within the constraints of a probabilistic, random sampling design, sample effort should be allocated proportionally towards shallow habitats most suitable for aquatic plants (i.e., < 6m water depth) and areas that also include the key points of introductions (e.g., boats ramps, marinas). Where resources allow, spatial models can be used to predict the areas of high species richness, based on habitat attributes associated with plant establishment and surrogates for aquatic plant pathways of introduction (i.e., depth and littoral areas, fetch exposure), distance to boat ramps, and distance to marinas (sensu Tucker et al. 2021). The focus on shallow or species-rich sites and introduction points of entry, aims to increase survey efficiency and limit (but not eliminate) sampling effort in areas likely to be devoid of plants. But it is still important to put some effort into habitats predicted to be unsuitable to confirm these habitat assumptions.

Consistent with other taxonomic groups, it is recommended that more than one sampling method is employed, and as a minimum these should include multiple rake tosses and visual inspections to characterize species presence both at each sampling station. Visual meander surveys and use of sonar between sample stations increases coverage and exploits method-specific differences to facilitate adequate sampling of various habitats and plant growth forms. But an adaptive sampling approach is important to allow survey teams to modify the location of sample units or stations during the survey based on the observation of potential species or plant communities of interest during visual meander between sample units and stations within a unit. This increases the probability of encountering areas of high plant abundance, or areas of floating or emergent plants that could be invasive species. Preservation of survey spatial data is important, to allow effort to be mapped, and survey coverage to be assessed, and sampling designs and species richness predictions to be refined. Maps of survey effort are also an effective means of communicating distributional data with stakeholders.

Scuba diver or snorkel meander surveys have not been tested in Great Lakes waters, and they may offer greater detection probability for some submerged species, but they will be effort intensive, probably limit the area that can be covered, and unsuitable in industrial areas, ports or marinas with poor water quality and other hazards. Application of eDNA metabarcoding approaches for plant community surveillance are still in the early stages of development and testing.

iv. Species verification and vouchering

Organisms should be identified to the best taxonomic resolution possible using current morphological keys, literature and/or genetic databases. If species cannot be identified, specimens should be vouchered and sent to taxonomic experts for verification, and potentially sequencing (Trebitz et al. 2017). Voucher specimens should be deposited in relevant state or federal museums that maintain taxonomic collections. Genetic material should also be collected, preserved, and made available for sequencing to contribute to ongoing efforts to build out genetic reference databases. A regionally coordinated surveillance monitoring program provides the ideal basis for the collection of native and non-native species specimens so gaps in genetic databases can be rapidly filled.

Final products from each survey include: 1) raw data indicating species composition and abiotic conditions (depth and secchi transparency) at each sample station and combined for each sample unit, 2) survey performance measures (including estimated species richness and proportion of the estimated richness sampled, based on the sample-based rarefaction curve), and 3) voucher specimens cataloguing species presence.

All non-native species detections should be shared to the Nonindigenous Aquatic Species information resource for the United States Geological Survey (USGS NAS; https://nas.er.usgs.gov/default.aspx).

2.4.3 Environmental DNA Meta Barcoding Surveillance Methods

The framework primarily concentrates on sampling with conventional gears for broad species surveys. But rapid advances in eDNA metabarcoding high throughput sequencing are showing how biodiversity can be effectively monitored across broad taxonomic scales (Thomsen et al. 2012, Olds et al. 2016, Trebitz et al. 2017, Darling et al. 2017, Sard et al. 2019). Furthermore, eDNA meta-barcoding surveillance approaches offer advantages over traditional collection methods including the ability to rapidly sample large spatial scales with potentially a greater level of detection sensitivity (Jerde et al. 2011, Olds et al. 2016, Sard et al. 2019) and for a broader range of taxonomic groups.

Integration of eDNA metabarcoding methods into a regional surveillance program is consistent with the principle of adaptation and improvement that underline the framework. The detection of physical specimens to verify presence will likely remain the gold standard because it provides additional information relevant to response efforts (e.g., age, life stage, condition, breeding status; Trebitz et al. 2017). And while an increasing number of studies in inland waters of the region are showing how eDNA metabarcoding methods have the potential to enhance estimations of community assemblages in both flowing water and standing water (e.g., Olds et al. 2016, Sard et al. 2019), it remains to be seen whether these benefits are also transferable to a regional surveillance program in the large and predominantly lentic waters of the Great Lakes. Nevertheless, because the same eDNA samples can be screened for multiple taxonomic groups (ie. fish, invertebrates and plants) there would be sampling efficiencies if site priorities based on the rank produced by combining the introduction risk for fish, invertebrates, and plants. The rank order of sites based on the average site rank for each taxonomic group (Table 2.4.1) is one way to prioritize sampling based on collective risk of introduction.

Trebitz et al. (2015) identify key impediments to the adoption and integration of eDNA metabarcoding survey methods into a regional surveillance program including: management acceptance, agreed and optimized sampling strategies (sample collection techniques, volumes, replicates, and spatial coverage), genomic workflows (extraction, markers, contamination, and quality assurance protocols), gaps in genetic libraries, and bioinformatic protocols.

Efforts to expand relevant genetic libraries for the Great Lakes are underway to address the mismatch between taxa inventories and DNA sequence libraries that have limited the broader efficacy of these eDNA metabarcoding methods (Trebitz et al. 2015). For some invertebrates it will likely be a few years before the requisite barcode libraries are available for complete community profiling (Darling et al. 2017). Nevertheless, existing genetic libraries have the potential to enable samples to be screened for a smaller subset of AIS species (Darling et al. 2017). By prioritizing the collection of sequence data for all species on the surveillance list (Davidson et al. 2021), the region can rapidly increase efficacy of genomic sample screening. Furthermore, while standardized sampling protocols, genomic workflows, quality assurance, and bioinformatic platforms are likely to refine and improve the efficiency of eDNA metabarcoding methods have advanced to the point that these could be developed adaptively as part of the process of integration into a regional surveillance program. There is increasing body of literature that provides guidance to managers on how to interpret and respond to eDNA invasive species detections (e.g. Darling et al. 2021, Sepulveda et al. 2023).

Table 2.4.1. *Rank order of sites based on Index scores for each taxon, inclusive of the top 25 sites in each taxa (1=highest risk). "Inverts" = invertebrates.*

Lake Basin	Location Name	State	Fish	Inverts	Plants	Average rank
Michigan	Chicago/Chicago River Mouth	IL	1	3	1	1.7
Erie	Toledo/Maumee River Mouth	OH	2	2	2	2
Ontario	Oswego/Oswego River Mouth	NY	3	9	8	6.7
Michigan	Portage/Portage-Burns Waterway	IN	4	5	12	7
Erie	Cleveland/Cuyahoga River Mouth	OH	9	4	9	7.3
Huron	Saginaw Bay/Saginaw River Mouth	MI	6	15	4	8.3
Erie	West Harbor/Marblehead/Lake Erie	OH	14	10	3	9
Erie	Sandusky/Sandusky Bay	OH	16	6	6	9.3
Erie	Buffalo/Niagara River	NY	5	11	14	10
Michigan	Calumet River Mouth/Lake Michigan	IN	8	12	17	12.3
Erie	Grosse Pointe Shores/Lake St. Clair	MI	18	16	7	13.7
Michigan	Benton Harbor/Saint Joseph River	MI	7	31	5	14.3
Michigan	East Chicago/Indiana Harbor Canal	IN	10	17	20	15.7
Michigan	Evanston/North Shore Channel	IL	11	18	21	16.7
Erie	Lake St. Clair/Clinton River Mouth	MI	21	21	10	17.3
Michigan	Milwaukee/Kinnickinnic River Mouth	WI	20	14	19	17.7
Ontario	Rochester/Genesee River Mouth	NY	12	20	24	18.7
Michigan	Green Bay/Fox River Mouth	WI	15	25	16	18.7
Erie	Lakeside/ Lake St. Clair	MI	17	35	11	21
Superior	Duluth/St. Louis River Mouth	MN	23	1	39	21
Erie	Detroit River/Rouge River Mouth	MI	19	32	15	22
Erie	Fairport Harbor/Grand River Mouth	OH	22	33	18	24.3
Erie	Erie/Presque Isle Bay	PA	26	28	22	25.3
Erie	Lorain/Black River Mouth	OH	24	30	25	26.3
Michigan	Grand Haven/Grand River Mouth	MI	13	54	13	26.7
Erie	Toussaint River Mouth	OH	25	37	23	28.3
Erie	Ashtabula/Ashtabula River Mouth	OH	30	23	40	31
Superior	Marquette/Dead River Mouth	MI	37	7	57	33.7
Michigan	Chicago-Calumet Port	IL	40	13	55	36
Erie	Detroit/ Detroit River	MI	38	8	64	36.7
Huron	Alpena/Thunder Bay River Mouth	MI	47	19	68	44.7
Huron	Rogers City/Calcite	MI	60	22	91	57.7
Superior	Two Harbors	MN	66	24	106	65.3

2.4.4 Basin Coverage, Sampling Periodicity, and a Comprehensive Surveillance Network

For a complex, large, and ecologically diverse region like the Great Lakes, resource constraints will always limit the number of locations that can be surveyed and how often each site can be monitored. How available resources should be allocated remains an unresolved issue. Because knowledge of non-native communities and introduction risk varies across the lakes and taxa. A combination of strategies that are adjusted adaptively as knowledge improves seem appropriate. These approaches can be broadly broken down into three potential allocation strategies:

- monitoring a small number of high-risk sites on an annual basis with effort optimized to maximise detection probability.

- monitoring a larger set of high-risk sites so that each site is monitored intensively every few years on a rotational basis; and
- allocating a smaller amount of effort annually across a larger number of sites to develop a baseline inventory while accepting a potentially reduced level of detection sensitivity.

The optimal time between sampling events is not well understood and the risk (i.e., failure to detect early) will vary across the three major taxonomic groups. In making site sampling decisions, some key principles that need to be considered include:

- Population growth - rate of recruitment of key species or taxonomic groups
- Dispersal distance (larval and adult)
- Management response potential – does species' biology (including dispersal mechanisms and habitat a species will colonize) and control tool availability lend themselves to an effective response.

For example, the time between aquatic plant monitoring events can probably be longer than the gap for fish and invertebrates because population growth is generally slower, dispersal distance smaller, and there are a range of management tools available for plants. In most circumstances, this will translate into a longer lag period between establishment of an incipient AIS plant population and its spread beyond the point where containment and or eradication cease to be possible.

As the surveillance program, spatial coverage, and community knowledge improve it may be possible to focus more surveillance effort on fewer high-risk sites. But in the absence of a baseline inventory in areas with many high-risk sites, there is value in allocation of surveillance monitoring effort to maximises coverage and the number of sites within the surveillance network. A comprehensive invasive species surveillance program would also eventually include sampling at lower risks sites, both to recognise the inherent stochasticity of introduction events and the need to assess the generality of the monitoring strategies (Trebitz et al. 2017) and model predictions (Tucker et al. 2020). Such an approach could also provide coverage of sites with high ecological or economic value that are vulnerable to future invasions. These considerations should be incorporated into future iterations of the framework as understanding of these issues improves and as resources allow.

3. Implementation of a Great Lakes Surveillance Program

3.1 Introduction

An effective Great Lakes surveillance program requires that multiple agencies and entities work together to maximize coverage and the probability that new introductions are detected while they are still vulnerable to management. Finite resources necessitate collective learning, to ensure that there is an ongoing process of improvement and optimization of methods. The framework cannot be a static prescription. Rather, surveillance priorities will change, and survey techniques and invasion hotspots will continue to evolve as new knowledge of invasion pathways or vectors becomes available, new invasive species are detected, or survey methods improve. Ideally, an adaptive management process should guide implementation of the surveillance framework. This section sets out the key components of an adaptive management process that can be used to implement the Great Lakes surveillance program. The components of the Regional AIS Surveillance adaptive management planning cycle (Figure 3.1.1), are:

I. **Annual planning**
Annual surveillance objectives are identified – including what sites and/or taxonomic groups will be monitored and how surveillance tasks and responsibilities will be allocated.

II. **Surveillance implementation**
Monitoring or priority taxonomic groups, at agreed-upon high-priority sites and other sites of interest is implemented.

III. **Evaluate**
Surveillance results at site and regional scales are assessed and evaluated to ensure that the program is meeting agreed regional goals and objectives.

IV. **Communicate**
Surveillance results are shared with internal and external audiences. Advances in surveillance methods, data analyses, and newly identified invasive species threats are shared regionally.

V. **Adaptation (refinement process)**
All aspects of the AIS surveillance framework, including surveillance priorities and methods are reviewed and, where appropriate, refined and adapted on an annual basis, considering new knowledge or relevant independent research and outcomes of survey evaluations.

VI. **Information management**
Data are stored and shared in a manner that facilitates learning across jurisdictions and provides information to key science advisors.

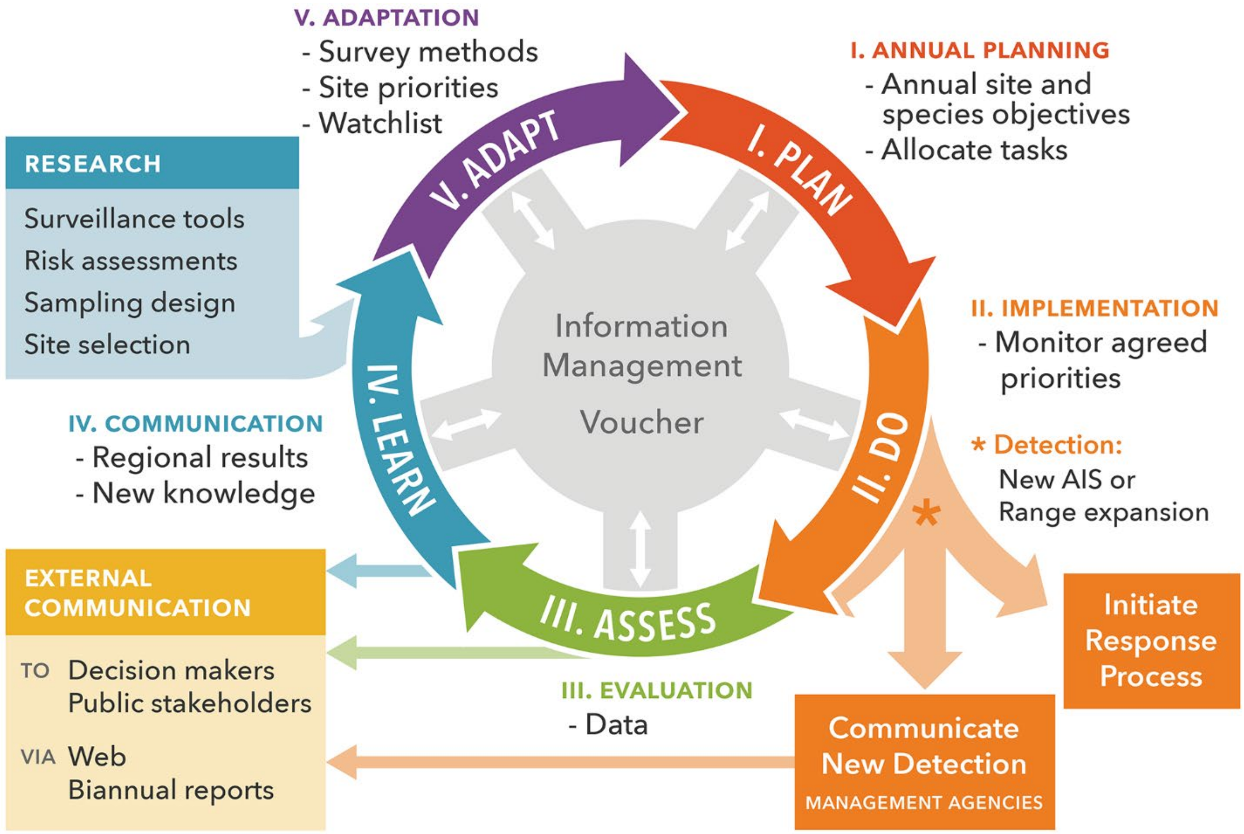


Figure 3.1.1. *Regional AIS Surveillance annual adaptive management planning cycle.*

3.2 Annual Planning

On an annual basis, agency managers with responsibility for AIS surveillance from the states, tribes, USFWS, and USEPA (hereafter referred to as EDRR Core team) should convene to review the results of the previous year's surveillance monitoring efforts and to discuss priorities for the following field season. The intended outcome of the meeting should be to identify an agreed set of surveillance priorities and allocate surveillance tasks and responsibilities according to available capacity.

A. *Who:* State, tribal, and federal agencies undertaking surveillance monitoring (IEDRR Core Team). Participation by each jurisdiction is important. Project consultants and technical advisors should be engaged as needed.

B. *What:* The IEDRR Core Team should agree on priority taxonomic or species surveillance targets and a list of sites where surveillance will be implemented for the year. Surveillance activities for each jurisdiction should be assigned.

C. *When:* Preparation for this activity should be ongoing throughout the year and may consist of informal calls/webinars to discuss planning challenges and opportunities. A face-to-face meeting of the IEDRR Core Team (and consultants/advisors as needed) should occur at least once annually at a time agreeable to all parties. An early spring meeting would be appropriate because it would provide time for data analysis and interpretation of the previous year's summer/fall surveillance activities while also leaving sufficient time to prepare for implementation of surveillance activities in the coming field season.

D. *How:*
   i. The IEDRR Core Team should consult the surveillance species list (section 2.2) and updated distribution data as a guide to inform decisions regarding priority taxa and species to target for surveillance. This could include making sure field crews are familiar with target species, adapting method effort allocation or inclusion of additional survey methods that have higher probability of detecting target species and ensuring relevant taxonomic expertise is available, and/or modifying survey strategy to target specific species (e.g., based on habitat preference or other relevant considerations).
   ii. The IEDRR Core Team should use the ranked list of high-risk AIS sites (Section 2.3) and data from at least two years of previous surveillance effort as a guide to inform selection of an optimal set of priority sites for AIS surveillance.
   iii. Gaps in existing surveillance activities and agency capacity and available resources should be considered.
   iv. Prior to the meeting, site prioritization models should be updated (if warranted) and driven by availability of new invasive species records, or spatial data on pathways that would materially improve or shift risk across the region. Spatial data on the last two years of sampling effort should be compiled and mapped against overall surveillance priorities identified above. An optimization analysis should be completed to down-weight areas adequately sampled and identify the next high-risk areas that warrant monitoring effort.

The annual planning meeting can also be used as a venue to provide updates on recent advances in surveillance methods or knowledge of new or recently detected invaders. For example, results from previous survey efforts, updates to the surveillance species list, reports of new AIS that have been identified in the Great Lakes region, or recent evidence of impacts from new species at important points of entry into North America could all be presented. The annual meeting is also an important venue to share results of relevant survey results, or surveillance activities being undertaken by entities outside the Surveillance Framework and IEDRR Core Team.

3.3 Surveillance Implementation

A. *Who:* The IEDRR Core Team leads the implementation component. Surveillance implementation responsibilities for each jurisdiction should be designated as part of the annual planning meeting. Jurisdictions should solicit additional help (e.g., staff from state, federal, tribal agencies, and other management entities) as needed.

B. *What*: The most suitable methods for targeting priority taxa/species should be implemented at each site and surveillance activities should follow recommended best practices and guidelines for standardized data collection and management (including collection and verification of voucher specimens).

C. *When:* Timing of surveys will vary across taxonomic groups, and for some, sampling may occur multiple times in a single year. Seasonal peaks in the most abundant life stages (e.g. larval fish) as well as logistics and capacity may necessitate surveillance in both summer and fall to capture a full range of species and to maximize the likelihood that all species (including young of year) are able to recruit to sampling gears. However, for plants, sampling should occur in late summer to allow peak development of aquatic vegetation.

D. *How:*
   i. The IEDRR Core Team should consult the survey design and sampling recommendations (Section 2.5), EPA publications, and USFWS best practice documents (e.g., Hayer 2018) as guides to inform preferred surveillance methods and survey design for priority sites and taxa. The recommended methods should be employed as appropriate to target priority taxa at each surveillance site.
   ii. Standardized data recording and data QA/QC procedures adapted from USFWS and EPA protocols should be adopted and implemented by all jurisdictions during surveillance activities.
   iii. The time lag between collection of specimens in the field and identification in the lab should be minimized.
   iv. Voucher specimens for all new detections and/or range expanding species should be retained, including the vouchering of tissue/DNA for sequencing. Shared protocols for authoritative taxonomic identification (to meet international standards) and voucher curation should be adopted and implemented.
   v. Where a new species or significant range expansion is detected, collections should be analysed to provide information on the status of the new population, population structure, evidence of recruitment, and range extent.

3.4 Evaluation – Evaluating and Optimizing Surveillance Effort

Surveillance at any given site should be initiated under an adaptive monitoring approach that includes annual surveillance, evaluation, and improvement (Figure 3.4.1). The adaptive monitoring approach facilitates quantitative analysis of survey performance (i.e., detection of rare taxa with a given level of confidence) and assessment of potential efficiencies in survey effort that could improve performance (e.g., optimal allocation of gear types or identification of most species-rich habitats at a given site).

A. *Who*: The IEDRR Core Team leads. Project consultants and technical advisors should be engaged as needed.

B. *What*: A plan to optimize sample effort and survey design should be developed as needed for each surveillance site.

C. *When*: Preparation for this activity should be ongoing as surveillance data is collected. Ideally, assessments of survey performance (and resulting outcomes for subsequent surveillance at a given site) will be completed in advance of the annual planning meeting to help inform discussions related to jurisdictional capacity and available resources.

D. *How*: Standard protocols for evaluation of survey performance should be used as a guide to optimize surveillance activities at all sites (e.g., recommendations from EPA-FWS pilot studies; see Box 3).

Standard protocols for survey performance evaluation and optimization should accomplish these basic aims:

1) Patterns of species richness and rareness should be evaluated to gauge survey performance (i.e., the ability to detect rare non-native taxa).
2) Randomization analyses should be implemented to identify the most effective allocation of some fixed sampling effort among different combinations of gear and/or habitat types.
3) Descriptive analyses of patterns in fish, invertebrate, or plant composition related to environmental or sampling attributes should be conducted (in support of randomization analyses).

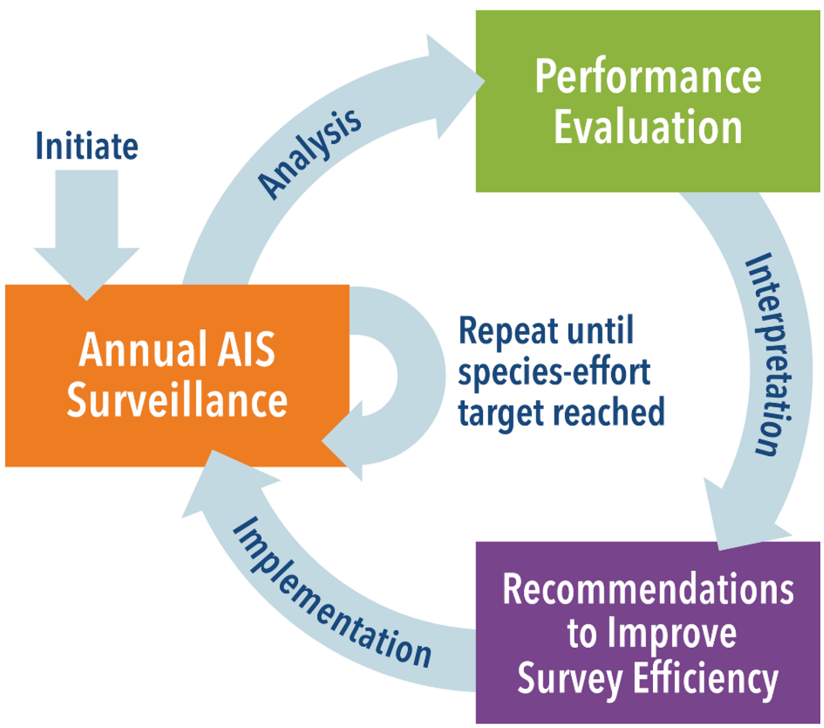


Figure 3.4.1. *Adaptive monitoring framework for evaluating and optimizing surveillance effort (adapted from Hoffman et al. 2016).*

Box 3. Recommendations for Survey Performance Evaluation and Optimization

Performance metrics
The probabilistic survey designs recommended in the surveillance program are a key element for assessing performance as they facilitate quantitative analyses of how many species may not have been detected, through species-effort theory. EPA and FWS have developed procedures for evaluating survey performance for non-native taxa in the Great Lakes. The EPA-FWS recommendations "use rarefaction curves (statistical expressions of the taxa accumulation pattern over multiple random re-orderings of the sampling sequence), to examine the rate at which taxa are detected" (Trebitz et al. 2009). These rarefaction curves allow for a lack of new detection to be reported with an associated level of confidence, "thereby helping to avoid the perception that new AIS were not detected simply for lack of effort" (Hoffman et al. 2016). Surveys undertaken under this surveillance framework should aim to evaluate survey performance in accordance with these species' richness-based performance metrics.

Randomization analyses
Probabilistic sampling designs can evolve towards strategically biased designs (non-probabilistic) over time as new information is compiled and assessed (e.g., which habitats yield the most information). Efficiency can be gained over time by reducing effort in areas that produce little new information and over-representing rare species in a sample relative to their abundance by targeting specific habitats (Trebitz et al. 2009). Randomization analyses that optimize the mix of gear and/or habitat types to maximize non-native species/rare species richness are a key component of any decision making along these lines. In pilot studies, EPA and FWS have evaluated optimal allocation of gear types to detect non-native taxa in the Great Lakes using a process that randomizes survey location combinations and then quantifies species richness metrics across the randomized survey location combinations (Trebitz et al. 2009). Surveys undertaken under this surveillance framework should aim to evaluate opportunities for survey optimization based on similar randomization approaches.

Descriptive analyses
Descriptive statistical analyses can help to inform randomization analyses by focusing effort allocation analyses on the habitat variables or gears that are significantly correlated with non-native taxa. These descriptive analyses include mapping of non-native richness against categorical variables (gear type or vegetation type) or continuous variables (water quality, distance to introduction points). Various quantitative approaches can be useful here including scatter plots and Pearson correlation analyses (for continuous variables) or box plots, ANOVA, and non-metric multidimensional scaling (for categorical variables). Surveys undertaken under this surveillance framework should be assessed using some combination of these descriptive statistical tools.

These performance evaluation methods are primarily designed to assess monitoring at a site scale; completion of an optimization exercise across the various taxon groups could also allow for effort allocation across those taxa to be optimized.

3.5 Communication

Effective communication across the network of IEDRR Core Team agencies and with other relevant public and private organisations will be an important component of regional surveillance collaboration and will help reaffirm the regional commitment to a collective surveillance impact (sensu Braun et al. 2016). In addition, communication with key decision makers and the broader stakeholder community will help ensure ongoing support for the program.

The order of communication will typically be hierarchical with a central group of core agencies with direct responsibility likely to be the starting point and included in most regional communication efforts (Figure 3.6.1). Engagement with partners in the middle and outer rings (Figure 3.6.1) will vary based on the specific factors of a detection and response program. It is not necessary to communicate with every partner listed, and in all scenarios and activities, who and when to communicate will be up to the best judgment of the responding lead state agency.

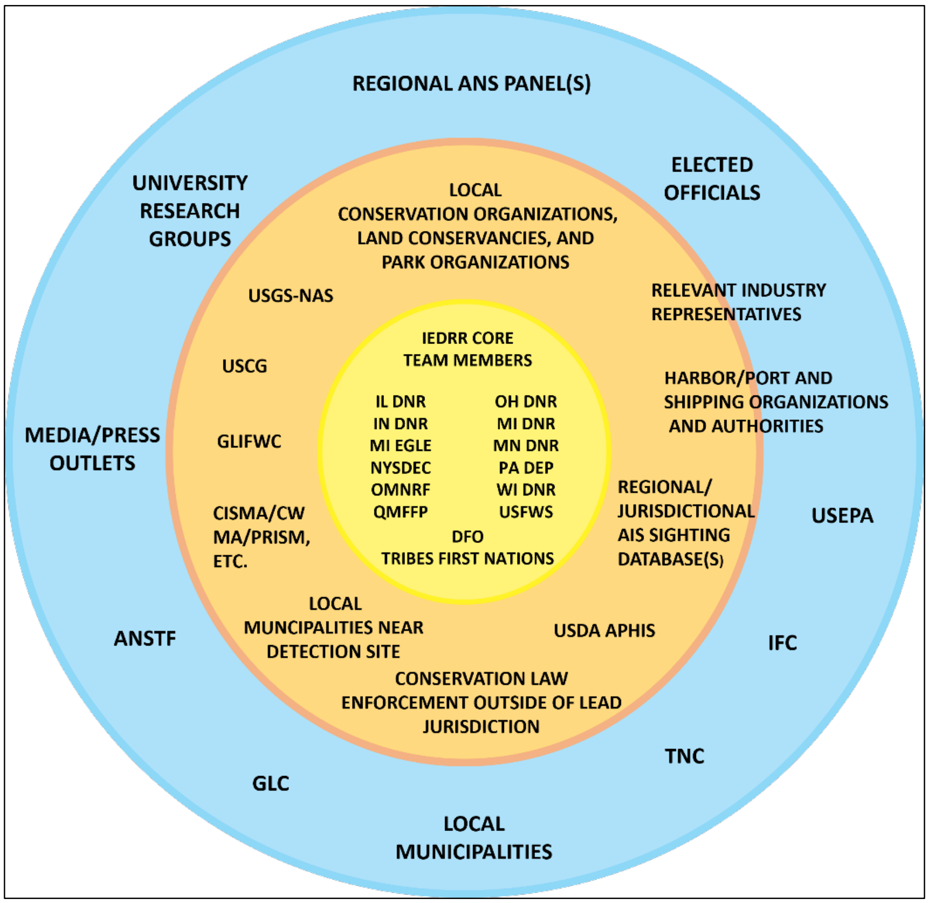


Figure 3.6.1. *A checklist and potential hierarchy of partners and stakeholder to consider when developing communication plans following confirmation of the detection of a novel invasive species. The inner ring includes all IEDRR core members who have response management decision authority and would likely lead any response program following the detection of a novel AIS or range expansion surveillance species. The second ring represents key management partners whose assistance may be required to support response actions. The outer ring represents stakeholder and entities whose support may be necessary to ensure there is public and political backing to sustain the resources and authorities necessary to underpin the response program, as well as any community led efforts to delimitation the extent of a novel invasive species.*

It is recommended that the lead state agency refrain from communicating a new detection until species identification has been confirmed to avoid confusion. Following the confirmation of a new species report, communications protocols should be followed based on the taxa and status of the new species.

The communication steps described below are designed to provide guidance that is relevant and appropriate to a wide variety of possible species detections. It is not an exhaustive guide, and it is recommended that when in doubt, state and provincial agencies err on the side of communicating. Furthermore, this guidance does not supersede any other state or federal communications plans, including communications guidelines laid out in the Invasive Fishes Communications protocol, or the Great Lakes St. Lawrence Governors & Premiers' Mutual Aid Agreement for Combating Aquatic Invasive Species Threats to the Great Lakes - St. Lawrence River Basin should that agreement be utilized.

A. *Who*: The IEDRR Core Team leads (Figure 3.6.1). Communication specialists should be consulted as needed to help develop messages and communication products. Key audiences include: the public, decision makers (including elected officials and funding agency personnel), and other stakeholders (including natural resource management agencies, academic institutions, and NGOs).

B. *What*: Timely and candid communication is critical for effective management. Information regarding surveillance priorities, methods, and results should be communicated internally (among IEDRR Core Team members) and externally (to the general public, decision makers, and other stakeholders). Standard communication protocols, regional databases, and outlets for mass communication (including web portals and comprehensive print and/or online reports) will help to facilitate the sharing process.

C. *When*: Communication of confirmed new detections and/or range expansions of a surveillance list species to IEDRR Core Team members should follow the Invasive Fishes Communication Protocol timeline (unless otherwise stipulated by a responsible agency), meaning that a good-faith effort should be made to report detections within five (5) business days of the species confirmation/risk assessment determination. But if the species is new to North America, and a known surveillance species, the detection should be communicated to U.S. Fish and Wildlife Service and the IEDRR Core Team as soon as possible after confirmation.

   For species known to be a low-risk determinations, it is recommended that the lead state agency share annual reports on the status of the species/population with the IEDRR Core Team membership. This may include monitoring updates, follow-up response activities, etc., and is at the discretion of the lead state agency.

D. *How*:
   i. Confirmation that the detection represents a novel invasive species:
      - The observer should be contacted and interviewed to validate the detection. The specific location, date and time of sighting should be recorded as well as an estimate from the observer of the extent of the infestation.

- A specimen and a digital photograph with an indication of scale should be secured. This may require a follow up survey.
- Species identification should be confirmed by reputable taxonomic expert.

Where the detection arises from an eDNA program, confirmation of the likely presence of a novel invasive species (in the absence of a physical specimen) should be based upon the weight of evidence, reliability, and confidence in the eDNA program including eDNA signal, assay and experimental design, QA/QC, and analysis: sensu Jerde 2019) and management implications of a detection (Sepulveda et al. 2023). Formalised guidance on confirmation processes, reporting and communication of eDNA results are in development across the region.

ii. Reporting of new detections and/or range expansions should be in accordance with a regionally agreed communication protocol for new and range expanding species.
    - If the species is a **fish**, the responsible state agency should follow the Invasive Fishes Communications protocol throughout this response process.
    - If the species is a **plant, algae, invertebrate**, or other non-fish species, the responsible state agency should follow the communications procedures outlined in the regional communication plan appended here (Appendix I).

A Novel AIS Detection Response Description Form (Appendix II) provides guidance on the type of information and detail necessary to provide an initial description of a new AIS detection.

iii. Programmatic results (including survey effort, species detections, and routine evaluations of survey performance) should be communicated to the IEDRR Core Team at the annual planning meeting in conventional formats (e.g. print reports or PowerPoint presentations). A regional database for information sharing could be considered to facilitate more regular and timely communication of survey progress and results.

iv. Broader communication of programmatic results (to the general public and other stakeholders) should occur at least annually through print or online reports but could also be facilitated on a more regular basis through a web portal.

It will also be important to capture survey results and surveillance activities undertaken by entities outside the surveillance framework. The annual surveillance planning meetings provides a venue to highlight such work including relevant results, advances in surveillance methods or any lessons learned. The onus is IEDRR core members to identify relevant work occurring within their jurisdiction, bring this to the attention of the regional surveillance community and ensure relevant work is integrated into the regional information space, and where appropriate shared at the annual regional surveillance meeting.

3.6 Adaptation – Annual Refinement Process

A. *Who*: The IEDRR Core Team leads. Project consultants and technical advisors should be engaged as needed.

B. *What*: Modifying the surveillance framework as new information is gathered and analysed will be essential for continued progress and improvement in surveillance outcomes.

C. *When*: Evaluation of the Framework and its contents should be a continuous process, and the Framework should be revised periodically to reflect new information as it becomes available.

D. *How:*

   i. *Review the science.* As part of the annual meeting and/or an existing regional process (e.g., GLWQA Annex 6 or GLANSP) the IEDRR Core Team and consultants should review and share the latest developments in AIS surveillance information (including detection methods and species or pathway risks).

   ii. *Revise the surveillance species list.* Based on new detections or knowledge of new and imminent invasion threats, the surveillance species list should be revised.

   iii. *Revise the list of high-risk surveillance locations.* To incorporate new information on pathways, surveillance list species, or other measures (e.g., site vulnerability, proximity to dispersal corridors, and/or site suitability) the ranked list of high-risk surveillance locations should be revised.

   iv. *Revise surveillance methods and survey design.* Survey methods and sample design for priority surveillance locations should be refined annually. New surveillance methods should be incorporated as standard operating procedures become available and implementation is feasible (e.g., eDNA metabarcoding technology).

   v. *Update surveillance priorities [and re-allocate tasks].* Surveillance locations and activities should be revised annually based on new science and information as described above.

   vi. *Review data management, assessment, and communication protocols.*

3.7 Information Management – Data Collection and Management

Effective data collection and management will be critical for successful implementation of a basin-wide surveillance program and for timely and accurate communication of programmatic results. Data collection and management procedures modelled after USFWS and EPA protocols for field and lab operations should be considered, including:

3.7.1 Field Operations Quality Assurance

i. Sample collection records

   a. Sample collection records should show that appropriate sampling protocols were implemented during field operations. At a minimum, these records should include names of persons conducting the activity, sample number, identification and counts of all fish, invertebrates, or plants encountered, sample collection dates and points, maps/diagrams, equipment/method used, weather conditions, and unusual observations. Count data is preferred to presence absence data. Where data is recorded on paper, records should be kept in bound notebooks and should be formatted to include pre-numbered pages with dates. The increasing adoption of tablets or computers for field data entry offers real time efficiencies but data entry quality assurance protocols need to be established and formalized to identify potential input errors during the data entry process so these can be identified and corrected in real time.

ii. Sample handling, processing and chain-of-custody records

   a. Details of how a sample is physically treated and handled are important, and data collection activities should indicate events during sampling handling that could affect the integrity of the samples. Checks for the integrity of the sample containers and sample labels as well as proper physical/chemical storage conditions should be made. Sample labels should be appropriately detailed. Field logs documenting events occurring during field sampling should be kept. Attention to preservation of samples to allow for future inspection and possibly DNA analysis is important (see section on vouchering, below).

   b. Chain-of-custody records should be maintained. These records document the progression of the samples as they travel from the original sampling location to the laboratory.

iii. Data transmittal

   a. Data from field logs should be entered electronically into a standard software package (e.g., Microsoft Excel, Microsoft Access, SAS) or regional relational database (as available; see section 3.7.D). Procedures for internal checks that will be used to ensure data quality during the data entry process (including verification and validation and correction procedures) should be identified and implemented.

iv. Data storage

   a. Original sample collection records and field logs should be kept at each state/federal office.

   b. All records should be electronically scanned and retained at state/federal offices.

3.7.2 Lab Operations Quality Assurance

i. Sample receipt records
   a. Documentation of the chain of custody and receipt of samples for laboratory analysis should be maintained.

ii. Sample handling and processing
   a. Data collection activities should indicate events during laboratory sampling handling that could affect the integrity of the samples. Checks for the integrity of the sample as well as appropriate hold times and sample preservation should be made and recorded.
   b. Sample processing records/bench sheets should be maintained and include at a minimum, names of persons conducting the activity, date and time of activity, sample ID, method, observations/tallies by taxa. Records should be kept in bound notebooks.
   c. Sample processing methods should be based on standard practices. Quality assurance procedures should ensure that agreed upon measurement data quality objectives are achieved. A series of random checks of sorted samples is recommended (e.g., one of every ten samples processed is verified). QA/QC reports (including records of analytical performance) should be maintained.

iii. Data transmittal
   a. All data (from sample processing and quality control, including bench sheets and records of analytical performance) should be entered electronically into a standard software package (e.g. Microsoft Excel, Microsoft Access, SAS). Procedures for internal checks that will be used to ensure data quality during the data entry process (including verification and validation and correction procedures) should be identified and implemented.

iv. Data storage
   a. Original sample receipt and sample handling records along with all bench sheets should be kept at each state office or laboratory.
   b. All records should be electronically scanned and retained at the state office or laboratory.

3.7.3 Quality Assurance and Quality Control

Field and laboratory data collection and management procedures should develop a "Quality Assurance and Project Plan" that is peer-reviewed and include processes and methods for independent auditing. Guidance on Quality Assurance Project Plans are provided by USEPA.

3.7.4 Data Storage/Management and Accessibility

Numerous online information systems provide general invasive species occurrence data and information services (Wallace et al. 2019, Reaser et al. 2019). It is recommended that all verified and spatially referenced occurrence data of new nonindigenous aquatic species populations should be submitted in a timely manner to the Nonindigenous Aquatic Species (NAS) information database (https://nas.er.usgs.gov/) maintained by United States Geological Survey. The Great Lakes Aquatic Nonindigenous Species Information System staff (oar.glerl.glansis@noaa.gov) can facilitate data formatting and upload for reports from the Great Lakes region, including both U.S. and Canadian data.

Furthermore, the vast amounts of data being collected as part of a regional surveillance program has the potential to answer a range of invasive species research and management questions, including questions that can help improve surveillance performance, sampling design and species detection efforts. In addition, the data being collected can also contribute to Great Lakes resource research and management questions. But the potential power of these regional datasets will only be realized if reports and data are broadly accessible, easy to use, and able to be routinely exchanged among interested parties (Invasive Species Council Management Plan 2001). This should include posting and maintaining copies of reports on public websites and publishing scientific literature as open-access articles. For the connected waters of the Great Lakes, data sharing needs to include the information routinely collected on native species as part of these invasive species sampling programs. This biodiversity information is important in terms of assessing potential inter-species interactions and to inform interpretation of sampling effectiveness because native species are often used as surrogates for rare novel non-native species. To this end, the region needs to facilitate sharing of a full range of surveillance data including, but not limited to, spatial information on sampling location and effort, non-native and native species occurrence and abundance data, sample gear types, sampling effort, and environmental covariates.

Existing biodiversity data standards, formats, and protocols for both data management and to improve information sharing among species information platforms are extensively summarized by Wallace et al. (2019) and Reaser et al. (2019). They argue that adequate data standards exist, and that the priority should be to overcome policy, culture, technology, or operational barriers to information sharing. This Great Lakes surveillance framework concurs with their recommendation to focus on fostering data access and delivery rather than the creation of a single information sharing system.

To that end, the annual surveillance planning meetings play an important role in developing and maintaining a collaborative culture and will help identify management and research needs and common ground. The Interstate Early Detection and Rapid response Website (Interstate Early Detection and Rapid Response - Great Lakes Commission (glc.org)) can also serve to provide a clearinghouse for key reports and documentation on meetings and ongoing projects.

3.7.5 Vouchering

The National Invasive Species Council's National Invasive Species Management Plan guidelines (2001) note, "it is essential for voucher specimens to be obtained and subsequent actions be based upon authoritative taxonomic identifications that meet international standards."

Authoritative verification of reported invasive populations is especially important when the initial report is obtained from people with minimal technical training. Verification can be used to authoritatively determine the presence or absence of a species in an area, whether it is an initial introduction into the Great Lakes basin or the movement of previously reported species into a new area, and other essential information.

If a species' identity cannot be confirmed in the field and/or laboratory or when a species is believed to be a new non-native species (to the Great Lakes basin), the specimen should be preserved and vouchered. Preservation and vouchering of genetic material are also critical to the development of comprehensive gene libraries to enable sequence confirmation of future specimens and facilitate development of eDNA metabarcoding surveillance program. Recommendations for preservation and vouchering include the following:

1. Agreed protocols for preservation should be developed, including protocols for what is preserved (e.g., organism, DNA, photograph, etc.) and how it is preserved.
2. Chain of custody documentation should be maintained.
3. Voucher specimens (preserved organism or DNA) should be maintained at institutions within a jurisdiction that have relevant taxonomic expertise (e.g., museums, university collections).
4. Vouchered specimen-based data should be sent to the iDigBio.org portal to add value for broader/national efforts in research and management of aquatic invasive species.

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Appendix I. Regional Communication Plan

<u>Great Lakes Regional AIS Response Framework Communications Plan</u>

Adopted: December 2021

Introduction

Development of this communications plan was initiated in 2019 when it became apparent that specific, detailed guidance surrounding communications was necessary for effective implementation of the Aquatic Invasive Species Interstate Response Framework (Response Framework). The Response Framework lays out a general process (Figure 2) for state agencies to systematically quantify risk and assess feasibility of response actions to newly discovered AIS. This process included determinations of when communication is necessary but did not provide direction about what information was expected to be communicated, how it should be communicated, or to whom it should be communicated.

This appendix serves as an extension of the Surveillance Framework, providing the specific expectations for each point in the response process where communication is required. It is intended to guide communications as they are called for within the Surveillance and Response Frameworks through explicit explanations of roles, responsibilities, and timeline for each communication step. The plan provides an outline of how to communicate with the understanding that responsible State Incident or Unified Command team member(s) will likely require some flexibility to shape communications around specific findings and incidents, and that specific communications will likely differ between different scenarios and different steps within the Framework. As such, we have tried to keep communication steps as consistent as possible with each other while still fulfilling the specific communication needs at each point in the response process.

The development of the communications plan was funded through a GLRI grant from the US Fish and Wildlife Service (USFWS) to the Michigan Department of Environmental Quality (MDEQ) (funding opportunity F18AP00560). This communications plan was developed between August 22, 2019 and June 30, 2021 and is the product of face-to-face and web-based discussions among "core" team members, technical advisors, and "active" observers from Canadian partner agencies as well as a mock desktop response exercise.

Core management team participants and affiliations included:

- Kevin Irons and Vic Santucci (Illinois Department of Natural Resources)
- Eric Fischer (Indiana Department of Natural Resources)
- Sarah LeSage (MDEQ) – Project Manager
- Seth Herbst and Lucas Nathan (Michigan Department of Natural Resources)
- Kelly Pennington (Minnesota Department of Natural Resources)
- Catherine McGlynn, and Dave Adams (New York State Department of Environmental Conservation)
- John Navarro (Ohio Department of Natural Resources)
- James Grazio (Pennsylvania Department of Environmental Protection)
- Robert Wakeman and Maureen Ferry (Wisconsin Department of Natural Resources)
- Amy McGovern (USFWS – Grant officer) Kate Wyman-Grothem, and Rob Simmons (USFWS)

Representatives from Canadian provinces also participated as active observers on the management agency team. These included:

- Francine MacDonald and Jeff Brinsmead (Ontario Ministry of Natural Resources and Forestry)
- Olivier Morissette (Ministère des Forêts, de la Faune et des Parcs)

This communications plan is based on the Invasive Fishes Communications Protocol developed by the Council of Great Lakes Fisheries Agencies. Press release guidance is based on the Asian Carp Regional Coordinating Committee's Communications Workgroup's Communication Strategic Plan. By building on elements from these well-established and successful communications strategies, we aim to continue improving regional coordination.

How To Use This Document

First and foremost, this plan lays out suggested communications guidance as a best practice, not a mandatory requirement. The guidance presented here was developed with the IEDRR core team to more clearly define the parameters of communication relevant to a response action. The IEDRR Core team represent the agencies and tribal authorities who have lead response management authority (Fig. A1). While the plan is designed to provide communication guidance that is relevant and appropriate to a wide variety of possible species detections and response actions, it is not an exhaustive guide and should not be treated as such. When in doubt about whether or how to communicate, it is always best for users to err on the side of overcommunicating than under communicating. This mindset should also extend to new detections made by a third party unrelated to a state agency or the IEDRR core team. While this plan does not provide guidance specific to this scenario, it is recommended that the lead state agency that receives the report from the third party share that report with the IEDRR core team as soon as they become aware of it.

Further, this plan is not designed to be restrictive in its guidance; rather than outlining a limit of communication that should occur at each step, the plan recommends an aspirational baseline of communication. Users should not feel as though they are restricted to only the guidance laid out in each step and should feel free to go beyond it. Notably, the plan recommends that a press release be drafted and shared at least as part of the final steps of the Surveillance Framework, and when developing and implementing a response plan. A press release can occur at any other point at the discretion of the lead state agency, but the IEDRR core team should always be notified informally and/or under embargo prior to the public notice of a press release.

Communications guidance in this appendix are designed to be paired with the existing Framework flowchart determination process for response activities (Figure A2). The flowchart has been reprinted in this appendix for reference. Blue stars accompany steps in the flowchart where specific communication guidance is necessary, and guidance corresponding to each numbered star follows the flowchart. Scope and responsibilities follow those laid out in the Framework, namely that all steps designated with an S are expected to be undertaken by a state incident command team, whereas steps designated with an R are expected to be completed by a regional unified command team.

Communication guidance given in this plan is designed to be specific to the Framework. Agencies conducting response activities may choose to implement other relevant communications protocols alongside this one; it is assumed that agencies and partners operating through the Framework will follow the communication guidance given in this appendix in addition to any other parallel communication plans, as this appendix does not supersede any other state or federal communications plans, including communications guidelines laid out in the Great Lakes St. Lawrence Governors & Premiers' Mutual Aid Agreement for Combating Aquatic Invasive Species Threats to the Great Lakes - St. Lawrence River Basin should that agreement be utilized.

The geographic scope of this plan covers the Great Lakes basin, i.e., all the streams, rivers, lakes, and other bodies of water within the drainage basin of the Great Lakes. At the discretion of the lead state agency for a response action, this plan may also be applied to detections outside of the Great Lakes basin, particularly for discoveries that may be of interest to the IEDRR core team or geographically close to waters within the Great Lakes basin.

While the Framework is designed to cover a full taxonomic scope of aquatic invasive species, including plants, algae, invertebrates, and fish, the taxonomic scope of this communications plan is limited to plants, algae, invertebrates, and other non-fish species. **In the event that the species identified through step S1 of the framework is a fish species, communications should follow the Invasive Fishes Communications Protocol, even as state incident and regional unified command teams continue to work through the Framework for response activities.** If the fish species identified through step S1 is an invasive carp (i.e., bighead carp *Hypophthalmichthys nobilis*, black carp *Mylopharyngodon piceus*, grass carp *Ctenopharyngodon idella*, or silver carp *Hypophthalmichthys molitrix*), response and communications activities should be managed through the Invasive Carp Regional Coordinating Committee. Further, the guidance provided in this communications plan is designed only for detections of organisms, alive or dead. The detection of eDNA is not considered within the scope of this plan, and communication of eDNA results should follow any relevant state/federal communications plans. In the absence of a relevant communication plan for eDNA, reporting agencies may consider following the guidance provided in the U.S Fish and Wildlife Service's Quality Assurance Project Plan for eDNA Monitoring of Bighead and Silver Carps.

Finally, this plan operates on an understanding that communication will always take place in the event of the detection of a species on the Regional Surveillance Species List (see Section 2.2. above) or range expansion or new introduction of species on the Great Lakes St. Lawrence Governors & Premiers' AIS Least Wanted list. While it is possible that a detection of one of these species may not lead to a response action, communicating these reports to the IEDRR core team is still valuable for information sharing and relevant research efforts.

Determining Who to Communicate with Through This Plan

As stated above, this plan lays out suggested communications guidance as a best practice, not a mandatory requirement. Figure A1, below, provides some initial suggestions of who to communicate with at the various steps within this plan. As a general consideration, when communicating with partners in outer rings, that communication should also be shared with relevant partners in inner rings. Figure 1 is not prescriptive and does not require communication with every partner listed; it is likely that specific scenarios will include communication to partners not listed and that partners may shift between rings based on the specific factors of a detection or response. In all scenarios and activities, it is up to the best judgment of the responding lead state agency. Finally, when in doubt about who to communicate with, it is always best for users to err on the side of overcommunicating than under communicating.

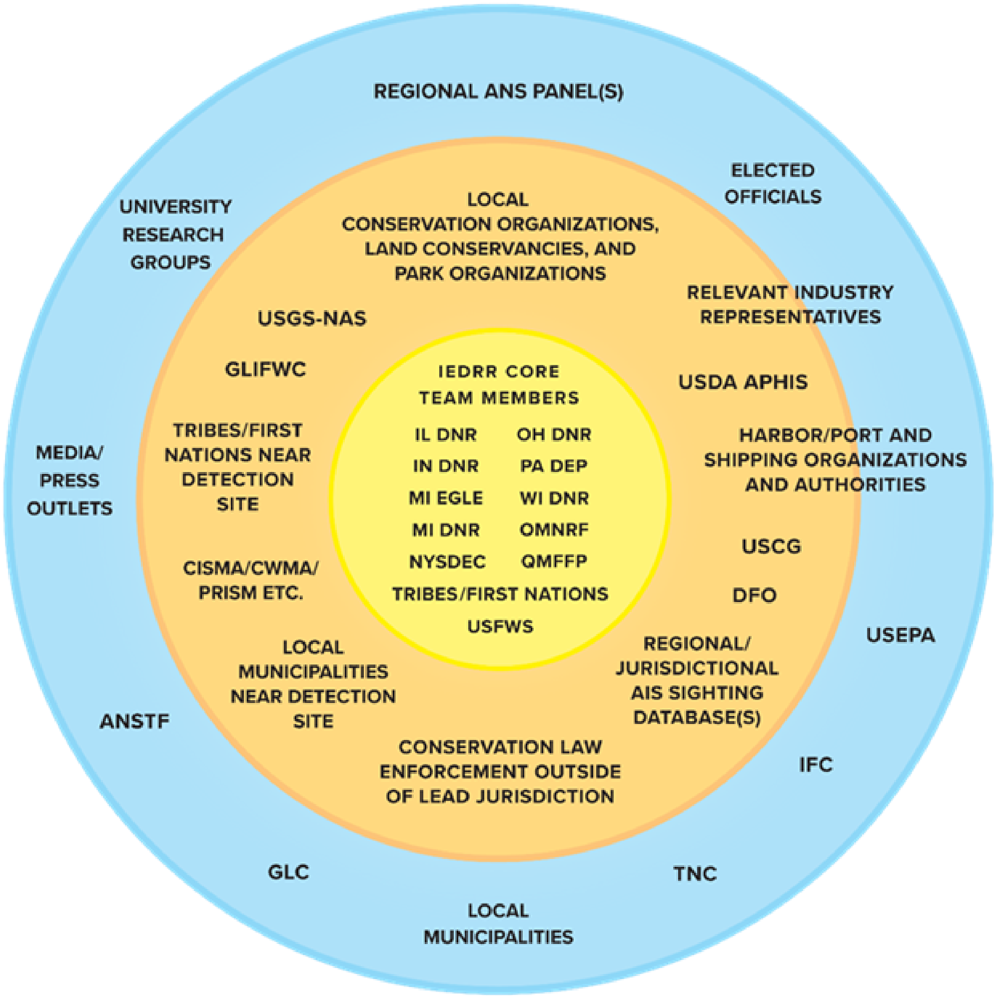

Figure A1. *Partners to consider communicating with throughout use of this plan.*

Great Lakes Regional AIS Response Framework

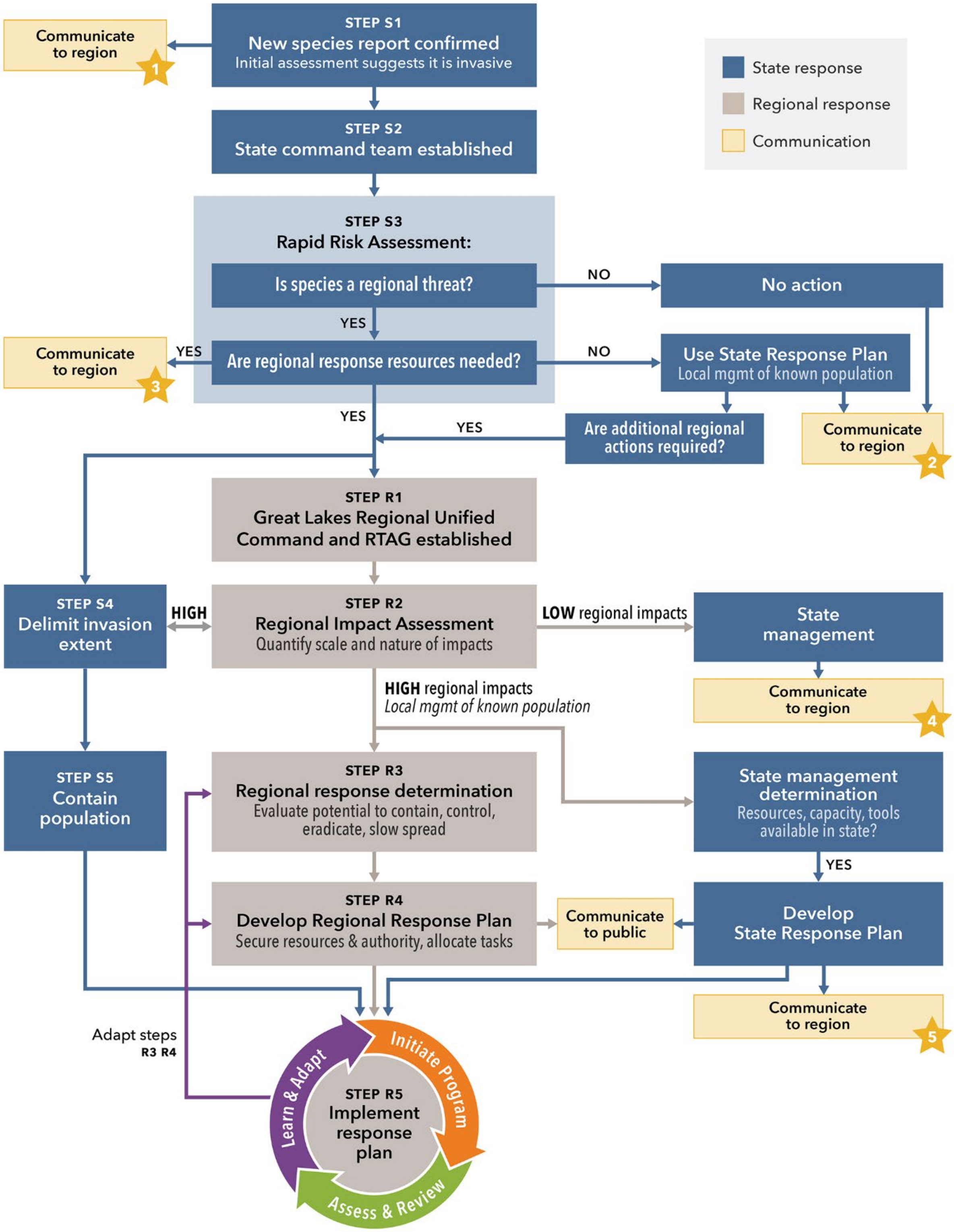

***Figure A2**. The Great Lakes Regional AIS Response Framework process for state agencies to systematically quantify risk and assess feasibility of response actions to newly discovered AIS. Blue stars accompany steps in the flowchart where specific communication guidance is necessary, and guidance corresponding to each numbered star follows the flowchart. Scope and responsibilities follow those laid out in the Response Framework, namely that all steps designated with an **S** are expected to be undertaken by a state incident command team, whereas steps designated with an **R** are expected to be completed by a regional unified command team.*

Steps requiring communication action (blue stars) are detailed below:

Step S1: New species report confirmed. Following the confirmation of a new species report, communications procedure should be determined based on the taxa and status of the new species:

- **If the species is a fish, the responsible state agency should follow the Invasive Fishes Communications Protocol throughout this response process** https://www.glfc.org/pubs/cglfa/Quick%20reference%20guide%20for%20protocol%20use_April_2022.pdf
- If the species is a plant, algae, invertebrate, or other non-fish species, the responsible state agency should follow the communications procedures outlined in this appendix
- If the species is new to North America, the detection should be communicated to U.S. Fish and Wildlife Service and the IEDRR core team as soon as possible after confirmation

Communication at this step is at the discretion of the lead state agency and may include informal notification of IEDRR core team members, relevant local partners, and/or conservation law enforcement (particularly for detections within a pathway, rather than a waterbody). It is recommended that the lead state agency refrain from communicating a new detection until species identification has been confirmed to avoid confusion.

Step S3: Rapid risk assessment. Following the state-initiated rapid risk assessment, communication to at least IEDRR core team members will take place in the case of a **low risk** determination or a **high risk** determination where a regional response is not warranted and the incursion can be addressed through implementation of a state's response plan:

Who: Relevant State Incident Command team member(s) with communications responsibility

What: Develop a Response Description Form describing the detection and risk assessment determination

How:

- Respond to prompts in the Response Description Form (Appendix II)
- Supporting documents that should be attached to the form include:
  - Narrative description of the detection
  - Any risk assessments completed as part of the IEDRR Response Framework
  - Additional files or links as necessary, including details from species confirmation
- Talking points should be drafted according to Invasive Fishes Communication Protocol guidance per step 2 in the Invasive Fishes Communication Protocol
- Once complete, the form should be emailed to at least all IEDRR core team members with a high priority email flag
- Partners should refrain from external communication until the lead state agency chooses to share a press release or otherwise communicate to the public
- In the event that comments are received from partners and a feedback loop is initiated, the lead state agency may choose to repeat this step as recommended above, convene the IEDRR core team via phone/video call, or continue conversation in another format

When: Unless otherwise stipulated by a responsible agency, the Invasive Fishes Communication Protocol timeline should be followed, meaning that a good-faith effort should be made to report

IMPORTANT events to at least IEDRR core team members within five (5) business days of the species confirmation/risk assessment determination. Partners that receive communication will then have three (3) business days from initial email notification to respond to the notification with comments.
For these low-risk determinations, it is recommended that the lead state agency share annual reports on the status of the species/population with the IEDRR core team membership. This may include monitoring updates, follow-up response activities, etc., and is at the discretion of the lead state agency.

Step S3: Rapid risk assessment. Following the state-initiated rapid risk assessment, communication to at least IEDRR core team members will take place in the case of a **high risk** determination **PRIOR** to initiating Step R1:

Who: Relevant State Incident Command team member(s) with communications responsibility

What: Develop a Response Description Form describing the detection and risk assessment determination

How:

- Respond to prompts in the Response Description Form (Appendix II)
- Supporting documents that should be attached to the form include:
  - Narrative description of the detection
  - Any risk assessments completed as part of the IEDRR Response Framework
  - Additional files or links as necessary, including details from species confirmation
- Talking points should be drafted according to Invasive Fishes Communication Protocol guidance per step 2 in the Invasive Fishes Communication Protocol
- Once complete, the form should be emailed to at least IEDRR core team members with a high priority email flag

When: Unless otherwise stipulated by a responsible agency, the Invasive Fishes Communication Protocol timeline should be followed, meaning that **URGENT** events should be communicated at least to IEDRR core team members within 24 hours of the species confirmation/risk assessment determination

Step R2: Regional risk assessment. Following the assessment of risk to the Great Lakes region, communication to at least IEDRR core team members and relevant local partners will take place in the case of a **low risk** determination:

Who: Relevant Unified Command team member(s) with communications responsibility

What: Develop a Response Description Form describing the regional risk assessment determination

How:

- Respond to prompts in the Response Description Form (Appendix II).
- Supporting documents that should be attached to the form include:
  - Narrative description of the detection
  - Any risk assessments completed as part of the IEDRR Response Framework
  - Additional files or links as necessary, including details from species confirmation

- Talking points should be drafted according to Invasive Fishes Communication Protocol guidance per step 2 in the Invasive Fishes Communication Protocol.
- Once finalized, the form should be emailed to at least IEDRR core team members and relevant local partners with a high priority email flag.

When:
- The Unified Command team should finalize the Response Description Form and talking points and disseminate it to at least IEDRR core team members and relevant local partners within five (5) business days of the risk assessment determination.

Step R4: Develop response plan. Following the development of a regional response plan to a specific incursion, communication to all relevant partners and public entities will take place.

Who: Relevant Unified Command team member(s) with communications responsibility

What:
- Develop a Response Description Form outlining the regional response plan.
- Develop a press release to be distributed to public entities.
- In the case of response actions planned in an area with federal threatened/endangered species, communication should be coordinated with U.S. Fish and Wildlife Service (USFWS), and all communication products and talking points should be shared with USFWS as well.

How:
- Respond to prompts in the Response Description Form (Appendix II)
- Supporting documents that should be attached to the form include:
    - Narrative description of the detection
    - Any risk assessments completed as part of the IEDRR Response Framework
    - Additional files or links as necessary, including details from species confirmation
- Talking points should be drafted according to Invasive Fishes Communication Protocol guidance per step 2 in the Invasive Fishes Communication Protocol
- Once finalized, the form should be emailed to at least IEDRR core team members and relevant local partners with a high priority email flag.
- A press release should be drafted and include the following as applicable (per Asian Carp Regional Coordinating Committee Live Fish Notification Protocol guidance):
    - Where the species was found
    - How many, and what species
    - Size of individual(s), and adult or juvenile
    - Who found the individual(s)
    - Who confirmed the identification
    - Date and time found
    - Current location of individual(s) now (e.g., removed from system or still present)
- Once finalized, the press release should be distributed to all other contacts. The press release may also be sent to additional public entity contacts as necessary based on the nature of findings (e.g., additional media outlets or specific elected officials in the jurisdiction where the detection was made)

When:

- The Unified Command team should finalize the Response Description Form and talking points and disseminate it to at least IEDRR core team members and relevant local partners within five (5) business days of finalizing the regional response plan.
- The Unified Command team should draft the press release and provide it to the IEDRR core team members within three (3) business days of finalizing the regional response plan. IEDRR core team members will be under embargo not to share the press release until it is disseminated publicly by the lead state agency.
- The Unified Command team should finalize the press release and talking points and disseminate it to public entities within two (2) additional business days following distribution of the press release to IEDRR core team members

Appendix II. Response Description Form

NOVEL AIS DETECTION DESCRIPTION FORM GUIDANCE

Adapted from the Great Lakes Fishery Commission Invasive Fishes Committee

Below is an example of a standard description form that could be used to communicate the new detection of a Novel AIS or major AIS range expansion within the Great Lakes. This form is provided to assist in framing the type of information and amount of detail that a fully complete detection description form should include. Those using the Interstate Surveillance Framework and Response Plan should refer to this guidance when filling out their own description forms.

NOTE: This information is confidential, not for distribution or use beyond intended audiences.

Draft Talking Points[1] ☐	**Final Talking Points**[1] ☐	
URGENT[2] ☐	**Important**[2] ☐	**Routine**[2] ☐

Species[3] ______________________________

Is species on the regional surveillance list?[4] Yes ☐ No ☐

Is species regulated in your jurisdiction?[5] Yes ☐ No ☐

Is this species considered a serious threat by your agency?[6] Yes ☐ No ☐

Location[7] ______________________________

Date of detection[8] ______________________________

Timeline of any related activities[9] ______________________________

Species voucher confirmed by[10] ______________________________

Sensitive information not to be shared with others[11] ______________________________

Responsible agency[12] ______________________________

Contact person/e-mail[13] ______________________________

Is species a known pathogen host and/or human health/reportable disease vector?[14] Yes ☐ No ☐

If yes, for what pathogen(s)?[15] ______________________________

Talking Points (bullets)[16]

Supporting information: (attach additional files or links as necessary, including narrative description of the detection and any risk assessments completed as part of the IEDRR Response Framework

[1] Information surrounding detection and/or response activities may change quickly. Space has been provided here to indicate if the information included in this response description form should be considered draft or final.

[2] Qualifiers:

- **Urgent**. New detection of a Surveillance Species, previously not known to be present within the Great Lakes or connecting channels. Would also include any novel non-native species to the Great Lakes for which no formal risk assessed data is available.

- **Important**. Major Range expansion (new Great Lakes) of a surveillance species that has a limited (present in 3 or less Great Lakes) distribution within the Great Lakes or connecting channels. The detection of a surveillance species that has been assessed unknown.

- **Routine**. Minor range expansion of a surveillance species (<100km from other known population within a Lake), or detection of a new non-native species that has been assessed to have a low risk to the great Lakes.

[3] The species detected. Multiple species detections at a single site may be reported on the same description form, but multiple sites should be reported in separate forms.

[4] The regional surveillance list is a list of species not yet detected throughout the Great Lakes basin for which early detection is a high priority. It also includes a small number of high-risk species that have established in the basin but are as of yet not widespread (present in all Great Lakes). (see section xx)

[5] Species' regulatory status may impact the kind of activities that agency staff may take regarding detections and subsequent response activities.

[6] The level of threat posed by a species detection will be highly dependent on the detection location and characteristics of that location, including connections to other waterways, potential impact to local food web dynamics, climactic conditions, etc. A serious threat is one that may require additional personnel and/or resources outside of the detecting agency, up to and including the invocation of the Great Lakes St. Lawrence Governors & Premiers' Mutual Aid Agreement for Combating Aquatic Invasive Species Threats to the Great Lakes - St. Lawrence River Basin. In that mutual aid agreement, a "serious threat" means potentially harmful effects, as determined by the Requesting Party, that may result from an AIS in the Basin. Thus, it is up to the detecting agency to make the determination for themselves on if a new detection represents a serious threat or not.

[7] The site where the detection was made. This should include spatial coordinates that allow the site to be mapped in GIS.

[8] The date the detection was made in the field, and the date the detection was confirmed.

[9] Scope of any monitoring activity that detected the species (that might help inform spatial extent of the population), any follow up survey effort and containment measures in place.

[10] Identify the experts and where appropriate the process (e.g. DNA sequence confirmation, taxonomic keys) used to confirm the voucher species identification.

[11] Space is provided here to record what information about this detection is considered sensitive and why (as possible). These response description forms should always be

considered confidential, but any information that should remain in strict confidence should be included here.

[12] The agency will be lead for any response activities and incident command structure.

[13] Who should be contacted for further information about the detection and/or response. This may change as response activities progress and should always be updated as subsequent versions of the response description form are shared in accordance with the communications protocol.

[14] Pathogens and/or diseases associated with a detected species may require involvement from fish health staff, public health staff, etc. who may be outside the typical personnel involved with detections and response activities.

[15] Providing information about associated pathogens and/or diseases will help to identify what other personnel may need to be involved in planning subsequent response activities and communications, as well as provide partners with further information about possible threats associated with a detection.

[16] What information are recipients of this response description form allowed to share with their interested and/or concerned partners? Recipients of the response description form are expected to never share information with media platforms or the general public prior to a formal press release issued by the responsible agency (see 12, above)