

**Horizon Scan to Identify Future Potential Aquatic
Invaders to the Northeast Region
Final Report, November 2024**

Executive Summary

Horizon scanning applied herein is a systematic approach to identifying risk of introduction of potential invasive species not yet established within a region. This approach can contribute to more effective prevention and early detection efforts. The U.S. Fish and Wildlife Service (“USFWS”) recognizes horizon scanning and the resulting species watch lists as the foundation of proactive aquatic invasive species (“AIS”) management because they help direct limited resources towards species most likely to cause harm, improving the efficiency and effectiveness of prevention and early detection activities. Horizon scanning and watch lists are also foundational to the implementation of the U.S. Department of the Interior (“DOI”) National Early Detection and Rapid Response Framework (“national framework”). In 2019, the USFWS initiated a series of regional horizon scanning efforts to identify species of fresh- and brackish water fish and other vertebrates, macroinvertebrates, and plants at risk of arriving in target regions of the United States, establishing populations there, and causing harm. Each of these regional efforts focuses on a subset of taxa and pathways based on regional priorities and capacity, with the process designed to be repeatable over time as priorities and capacities change. These regional horizon scans are part of a suite of complementary horizon scan projects being funded by DOI to support the national framework.

From October 2022 through November 2022, USFWS gathered 19 Federal, Regional, State, Tribal, and University partners to provide input on exact geography and priority introduction pathways and taxa groups on which to focus a regional horizon scan for the northeastern United States (“Northeast”). The range of expertise represented by this group allowed USFWS to hear many perspectives on AIS priorities in the Northeast. Based on the input of these regional experts, the scope of this initial Northeast horizon scan focused on identifying nonnative species within seven families of macroinvertebrates, eight families of aquatic plants that could be transported via recreational equipment; one family of crayfish, one family of shrimp, and 14 families of fish that could be introduced through the bait pathway; and introduced species in adjacent watersheds with permanent or temporary hydrologic connections. The target region of introduction itself was defined as including the States of Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont along with the Lake Champlain, Mohawk, and Hudson drainages in New York and New Jersey.

In the second phase of the project, data from regional and state boat inspection programs, state non-resident fishing licenses, and state bait importation regulations and records were used to determine the regions (U.S. States, Canadian Provinces, or other countries) contributing the highest volumes of AIS vector movement into the target region. Combining these data with climate matching analyses led to identification of a set of regions (“top donor regions”) from which species in the selected families of macroinvertebrates, aquatic plants, crayfish, or fish could arrive and then survive within the Northeast. Finally, global species occurrence datasets were used to generate a list of species that are present in the top donor regions but not yet present in the target region. Known species of AIS in watersheds with permanent or temporary hydrologic connections to the target region were also added to the species list.

Risk screening was conducted for a prioritized subset of the species list generated in the previous phase using the USFWS’ Ecological Risk Screening Summary tool. Five macroinvertebrate, seven plant, and seven fish species were identified as posing high risk to the Northeast based on both climate match and prior history of invasiveness in other locations: a waterflea (*Daphnia lumholtzi*), giant ramshorn snail (*Marisa cornuarietis*), channeled applesnail (*Pomacea canaliculata*), New Zealand mudsnail (*Potamopyrgus antipodarum*), common river

snail (*Viviparus viviparus*), haspan flatsedge (*Cyperus haspan*), limpoglass (*Hemarthria altissima*), wingleaf primrose-willow (*Ludwigia decurrens*), large-flower primrose-willow (*Ludwigia grandiflora*), marsh dewflower (*Murdannia keisak*), spiny naiad (*Najas marina*), Manchurian wild rice (*Zizania latifolia*), banded darter (*Etheostoma zonale*), ruffe (*Gymnocephalus cernua*), silver carp (*Hypophthalmichthys molitrix*), bighead carp (*Hypophthalmichthys nobilis*), spotted bass (*Micropterus punctulatus*), sailfin molly (*Poecilia latipinna*), and freshwater tubenose goby (*Proterorhinus semilunaris*). Fourteen of these species were documented to have been introduced to other areas outside their native range through the focal pathways.

These horizon scanning results can be used to inform regulatory decision-making, improve training resources, and refine detection tools and strategies on a local, regional, and national level. From a prevention perspective, there are many opportunities to increase the effectiveness of preventive regulations through cross-border consistency, as well as incorporating the high-risk species into existing watercraft inspection and outreach programs. From an early detection perspective, surveillance for these species can be incorporated into existing aquatic invasive species monitoring efforts with little additional effort. The watch list from this horizon scan will be incorporated into DOI's national framework efforts. Although the horizon scan described here is limited in scope, it provides a template for expanding horizon scanning to other pathways and taxonomic groups in the future.

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Introduction

Aquatic invasive species (“AIS”) are non-native plants, animals, and other living organisms that thrive in areas where they do not naturally live and that cause (or are likely to cause) economic or environmental harm, or harm to human, animal, or plant health (USFWS 2023). AIS are a significant burden to aquatic environments and economies. They negatively impact native species abundance and water quality across aquatic habitats (Gallardo et al. 2016) and are capable of re-engineering ecosystems (Fei et al. 2014). Costs to address AIS are growing over time. For example, the annual cost associated with damages and management for invasive species in the United States was \$2 billion in the 1960s and increased to \$21 billion annually in the 2010s (Fantle-Lepczyk et al. 2022). Costs directly attributable to the Northeast from the 1960s to 2010s were over \$630 million. Compared to other regions of the United States, the Northeast has the highest proportion of invasive species costs coming from aquatic species and two of the top three most costly invasive species in the Northeast are aquatic species: naval shipworm (*Teredo navalis*) and zebra mussel (*Dreissena polymorpha*) (Fantle-Lepczyk et al. 2022). Investing in proactive rather than reactive strategies to combat AIS reduces economic as well as ecological costs (Simberloff 2003; Keller et al. 2008; Lodge et al. 2016; Rouget et al. 2016).

Horizon scanning is a process used across sectors—from transportation (Tsakalidis et al. 2021) to healthcare (Clyne et al. 2014)—to systematically explore threats and opportunities at the edge of current knowledge. Applied to AIS, horizon scanning is a process for identifying unrecognized potential AIS threats (Roy et al. 2014). Specifically, this process seeks to identify species that are not the focus of current prevention or early detection activities, yet pose a risk of introduction, establishment, and negative impacts. In the absence of horizon scanning and other risk screening efforts, such species may be overlooked in the early phases of introduction and establishment, allowing them to become problematic and necessitating often costly eradication or control measures (Keller et al. 2007; Cuthbert et al. 2022).

Horizon scanning and the resulting species watch lists are foundational to a proactive approach to AIS because they help direct limited resources towards species most likely to cause harm (Reaser et al. 2020; Reaser 2020). The U.S. Fish and Wildlife Service (“USFWS”) initiated a series of regional horizon scans in 2019 to identify species of fresh- and brackish water fish and other vertebrates, macroinvertebrates, and plants at risk of arriving and establishing populations via unintentional or unassisted movement. This project is a part of that effort. Each regional scan focuses on a subset of taxa and pathways based on regional priorities as well as prevention and early detection capacity. The process is designed to be repeatable over time as priorities and capacity change. These projects are part of a suite of complementary horizon scans covering different introduction pathways and different groups of species, including multiple horizon scans focusing on international live trade pathways being led by the U.S. Geological Survey (“USGS”; W. Daniel, USGS, personal communication, 2022). The collective results of these horizon scans will be used to formulate regional species watch lists and identify hot spots for invasion risk within regions as part of a comprehensive national early detection and rapid response framework for AIS (figure 1; Reaser 2020; Kendig et al. 2022; W. Daniel, pers. comm.). This work directly supports Goals 2 (prevention) and 3 (rapid response) of the DOI Invasive Species Strategic Plan (DOI 2021).

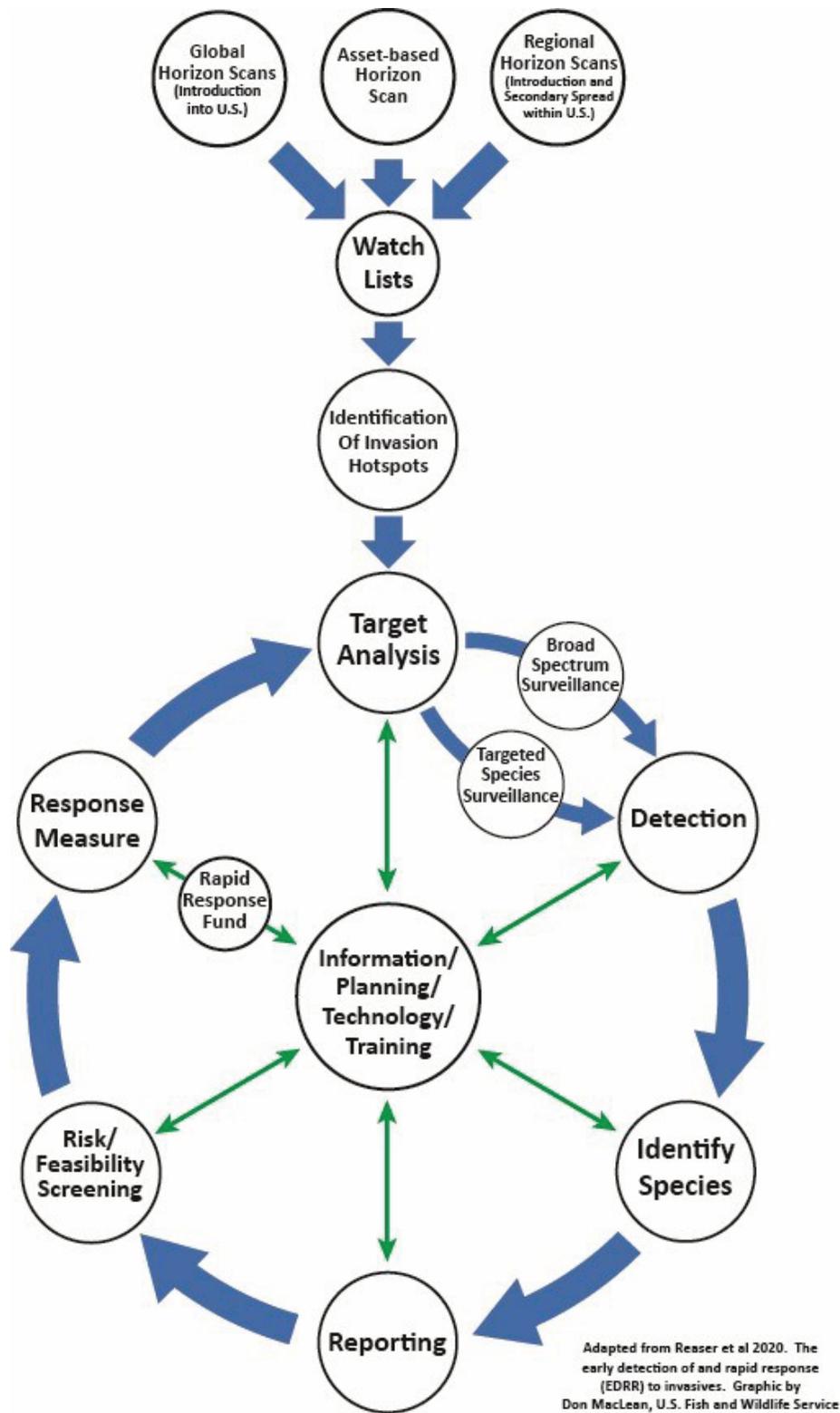


Figure 1. Diagram of the National Early Detection and Rapid Response framework being developed and implemented within the U.S. Department of the Interior. The project described in this report is part of the Regional Horizon Scan bubble which, with other horizon scans, provides foundational knowledge for the framework.

The Northeast was selected for horizon scanning because of its treasured coastal and inland resources. As home to some of the earliest European settlements within what is now the United States, introductions of non-native species have played an important role in shaping the taxa we find inhabiting these waters still today. In Massachusetts, 48% of the primary fish species are not native (Hartel et al. 2002). Likewise, in Maine, approximately 34% of the freshwater fish species are non-native (ME DIFW 2002). From the days of colonization to now, the waters of the Northeast have been affected by change. From industrialization to climate change, the global nature of these challenges has affected the landscape and vulnerability of the waters of the Northeast. Preventing further harm from species transported and introduced into local waters will minimize future impacts to the integrity and diversity of species and their habitats. Horizon scanning is a tool resource managers can rely on to help define potential threats and improve early detection and rapid response capability.

The objective for this regional horizon scan was to identify species from selected taxonomic groups with high risk of negative impacts in the Northeast but that are currently unrecognized as posing a risk of arriving in the Northeast, establishing populations, and causing harm in the region. The project was divided into three phases (figure 2): (1) scope definition, with participation from regional experts and stakeholders; (2) species list generation, which used pathway, climate, and species occurrence data to identify species at risk of transport to the Northeast via select pathways; and (3) risk screening, which identified a subset of species from the list developed in phase 2 that pose a high risk of establishment and harm if introduced to the Northeast.

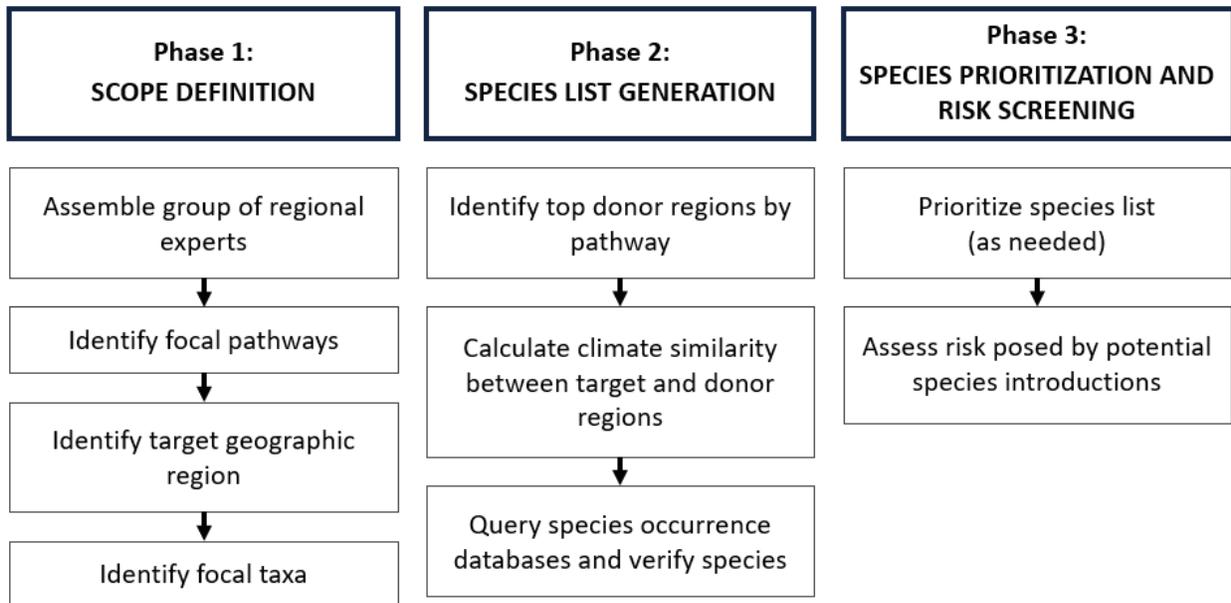


Figure 2. Three-phase method for U.S. Fish and Wildlife Service regional horizon scanning projects.

Methods

Phase 1: Scope Definition

Regional experts and stakeholders in AIS issues in the Northeast were invited to participate in the project scope development. Invitations were made via email in early fall 2022. Gathering a group of regional experts allowed the USFWS to hear AIS perspectives and concerns from partners and stakeholders across the Northeast. The role of the regional experts was primarily to assist with Phase 1 of the project: delineate the boundaries of the target geographic region into which new species could be introduced, select the introduction pathways on which to focus, and select the groups of species on which to focus that could be transported in those pathways. The regional experts were also asked for input on how to prioritize identified species for further risk screening. All introduction pathways were open for consideration except intentionally traded species. There were two reasons for the exception of this well documented pathway. The first was to prevent overlap with ongoing complementary work covering international organisms in trade pathways through horizon scans conducted by USGS (W. Daniel, pers. comm., 2022). The second was due to limitations of our climate matching methodology (described below). Similar methodological limitations in subsequent phases of the project limited focal taxa to those that could survive in freshwater or brackish water environments (see Phase 2, below, for more information). Asking the regional experts to define focal taxonomic groups rather than focal species was an intentional choice to reduce bias towards familiar species. Once focal taxonomic groups were identified, all species within those groups were included in the horizon scan regardless of whether they had attracted attention from biologists in the past.

There were four general opportunities for regional experts to provide input on the project. An initial meeting was held virtually in October 2022 to introduce the project, answer questions, and gather initial reactions from the regional experts. A series of follow-up questions (appendix A) was delivered to the experts along with a recording of the initial meeting. These questions were intended to help facilitators better understand the breadth and level of consensus on AIS priorities among the regional experts. A second meeting was held virtually in November 2022 to share and discuss the responses to the questionnaire. The responses to the questionnaire and input from the meetings were used to produce a written description of the project scope in terms of focal pathways, taxa, and target geography. Finally, the regional experts had the opportunity to review a draft of the project scope document to verify consensus on the decisions made during the second meeting. Not all regional experts participated in all opportunities to provide input.

Phase 2: Species List Generation

Identification of Top Donor Regions

Regions serving as potential donors of nonnative species were determined based on three introduction pathways: recreation activities, live bait, and hydrologic connections (see Results, below).

For the recreation activities pathway, potential donor regions were identified using boat inspection data and out-of-state fishing licenses issued by States within the target region. Boat inspection data for the previous five years and information on out-of-state fishing licenses from the same period were requested from all States within the target region. All data provided by states were anonymized. Boat inspection data were received from the Lake Champlain Basin Program (2022), Massachusetts (2021-2022), Maine (2017-2022), New Hampshire (2018-2022),

New York (2019-2021), Rhode Island (2012-2019), and Vermont (2017-2022). Rhode Island did not have a currently ongoing boat inspection program but did provide data from one that ended in 2019 (years 2012–2018). The data from New York were filtered so that only data from boat launches within the target region were used. Data were aggregated and summed by the State (United States), Province (Canada), or country where the equipment was last used. Areas identified as top outliers using the interquartile range method (Walfish 2006) were added to the potential donor region list. Out-of-state fishing license information for the last five years was requested from all States within the region. Data were provided by Connecticut (2020-2022), New Hampshire (2022), and Vermont (2021-2022). No personal information was provided, just summary numbers by the home State of the licensees. Similar to the boat inspection data, the fishing license data were aggregated and summed by home State of the licensee. Top outliers were identified using the interquartile range method and added to the potential donor region list.

For the live bait pathway, potential donor regions were identified using information provided by States within the target region regarding bait importation and out-of-state fishing licenses. Information on bait importation and licensing for the previous five years was requested from all States within the target region. The out-of-state fishing license data were also used to identify donor regions for the live bait pathway. All data provided by States were anonymized. The same top outliers identified in the fishing license data for the recreation activities pathway were also added to the potential donor region list for the live bait pathway. Information on bait importation was provided by Connecticut, Massachusetts, New Hampshire, and Vermont. Specific species listed in the bait information were considered for inclusion on the species list (see Species List, below). Source locations for bait imported into the target region were added to the potential donor region list.

The potential donor regions for the hydrological connection pathway were all drainages surrounding the target geographic region or those that had a direct hydrologic connection to the target region (e.g., via the New York State Canal System). Inside the United States these were defined as the adjacent or connected HUC4 drainages (Seaber et al. 1987). In Canada, they were defined as the adjacent or connected “drainage regions” (Pearse et al. 1985).

Climate matching analyses were conducted to determine the similarity between the climate of a potential donor region and the climate of the Northeast target region using the USFWS’ Risk Assessment Mapping Program (“RAMP”; Sanders et al. 2023). Within RAMP, climate is quantified with 16 bioclimatic variables that characterize maximums, minimums, and changes in air temperature and precipitation on a monthly or annual basis. Despite the use of air temperature data, the algorithm used by RAMP to quantify climate match has been demonstrated to successfully predict establishment based on climate for freshwater aquatic species (Bomford et al. 2010; Howeth et al. 2016). RAMP cannot account for artificially altered climate conditions such as may be found in a greenhouse or aquaculture facility (this limitation is one of the reasons that the organisms in trade pathways was outside the scope of this project). All climate stations within the geographic boundaries of the potential donor region were used as source locations for each potential donor region’s climate matching analysis. The algorithm implemented in RAMP calculated a climate similarity score between 0 (low similarity) and 10 (high similarity) for each climate station in the target region relative to the potential donor region (USFWS 2024a). The Climate 6 score is calculated as: (count of target points with scores ≥ 6)/(count of all target points). When evaluating a species, establishment concern is warranted if the Climate 6 score is greater than or equal to 0.002 based on an analysis of the establishment success of 356 nonnative aquatic species introduced to the United States (USFWS 2024b). In this project, the climate

match for the potential donor region was used as a coarse surrogate for establishment concern for species present in the potential donor region. Therefore, potential donor regions with a Climate 6 score greater than or equal to 0.002 were considered to possibly have species that could be an establishment concern for the Northeast.

Donor regions were selected to use in the following species list generation steps if they had both a relatively high level of pathway activity (i.e., top outlier for a given pathway) and a climate match that indicated species present in the donor region might pose an establishment concern to the Northeast as determined by Climate 6 scores.

Species List

The set of species in the focal taxa present in top donor regions was generated using species occurrence data from the Global Biodiversity Information Facility (“GBIF”; GBIF Secretariat 2022). The database was queried for an initial list of species within the focal taxonomic groups (see Results, below, for list of target taxa) reported in each of the top donor regions for each focal pathway. The process was repeated to obtain the set of species reported within the Northeast target region. The validity of each species name was checked using World Flora Online (2022, for plants), Catalog of Fishes (Fricke et al. 2022, for fish), or the World Register of Marine Species (“WoRMS”; WoRMS Editorial Board 2022, for all other taxa) and only the accepted scientific name for a given species was maintained on the species list. The aim of this project was to identify species unrecognized as posing a risk of introduction and harm to the Northeast. To achieve that, any species with known records of occurrence in the Northeast target region were excluded from the final species list regardless of current establishment status as these species would already be known to managers. Species for which “fresh” or “brackish” water were not listed as an environment in WoRMS were also excluded from the final list.

Queries were conducted using R (R Core Team 2021) with the ‘rgbif’ (Chamberlain et al. 2021) package. The packages ‘stringr’ (Wickham 2019), and ‘dplyr’ (Wickham et al. 2020) were used for data processing, and the packages ‘WorldFlora’ (Kindt 2020) and ‘taxizedb’ (Chamberlain and Arendsee 2021) were used for verification of valid taxonomic names with World Flora Online (2022).

Phase 3: Species Prioritization and Risk Screening

As part of the questionnaire distributed to the regional experts between the first and second virtual meetings (appendix A), respondents were asked to indicate conditions or characteristics to guide prioritization of species for risk screening. Five such conditions or characteristics were supplied for ranking and there was an open-ended question where respondents could indicate other factors that they would prefer to use for prioritization. Responses to the questionnaire were discussed as part of the second meeting with the regional experts. Resources used to prioritize species based on the chosen prioritization factors included USGS Nonindigenous Aquatic Species Database (USGS 2022), USDA PLANTS (USDA NRCS 2022), World Register of Marine Species (WoRMS Editorial Board 2022), SeaLifeBase (Palomares and Pauly 2022), and FishBase (Froese and Pauly 2022) to determine if a species had a history of introduction outside its native range. The Aquarium Wiki (2012) and general online searches were used to determine if the species was present in a trade pathway (in addition to the unintentional movement pathway).

Individual species risk screening was conducted using the USFWS’ Ecological Risk Screening Summary tool (“ERSS”; USFWS 2024b), which includes climate matching for those

individual species. Using this tool, a species is classified as high-risk if the climate match analysis indicates there is establishment concern for the species, as determined by Climate 6 score, within the target geographic region (see Species List Generation, above, for a description of Climate 6 scores and establishment concern) and a high history of invasiveness (i.e., history of nonnative introductions and negative impacts). The contiguous United States is the default target geographic region for climate matching in ERSS reports. The climate matching results within the target region were considered when generating the horizon scan watch list. History of invasiveness categories were determined based on the availability of “clear, convincing, and reliable documentation of negative impacts of introduction” (USFWS 2024b) including those affecting native species, the environment, the economy, or human health. If such documentation was available, the history of invasiveness was categorized as “high.” Definitions of the remaining history of invasiveness categories are available from USFWS (2024b).

Results

Phase 1: Scope Definition

Twenty-two regional experts or stakeholders participated in one or more aspects of the scope definition process. These individuals represented 19 entities including Federal and State government; Tribes; and regional organizations (see Acknowledgments).

Focal Pathway

The focal pathway choice was based on consideration of individual pathways of concern to the regional experts as well as criteria that would identify a high priority pathway for horizon scanning. The one prioritization criterion most preferred by the experts was that the pathway had a historically high volume of introductions (figure 3). This was closely followed by pathways that have a greater number of past introductions that caused harm and a greater ability to regulate or manage the pathway.

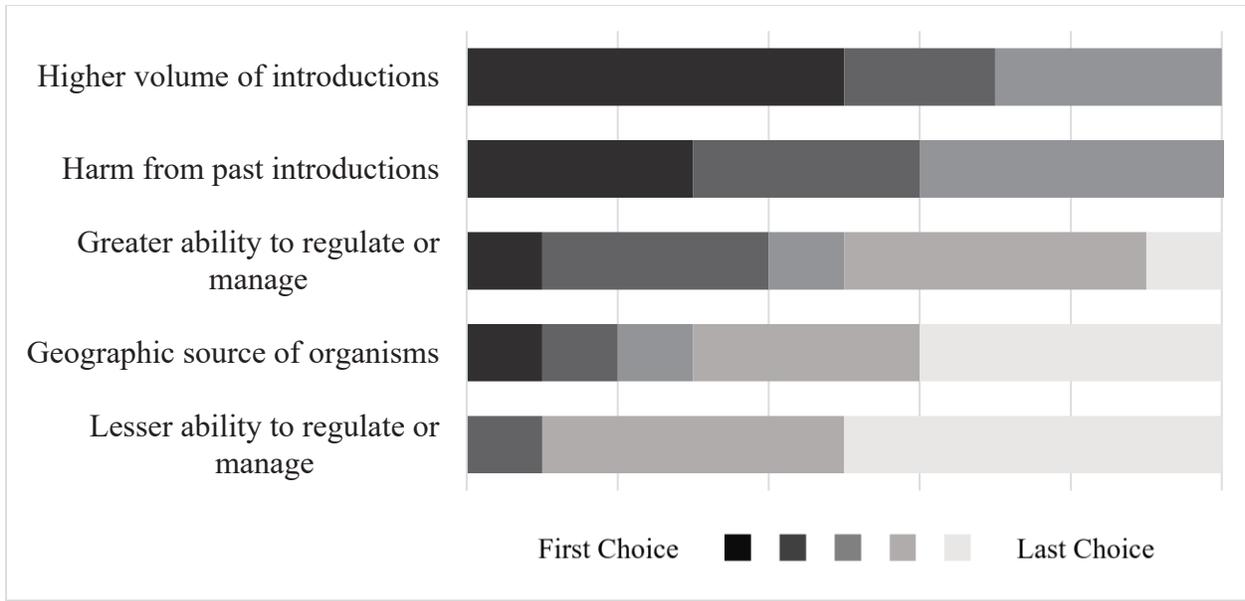


Figure 3. Regional expert ranking of pathway characteristics. The regional experts were asked to rank five pathway characteristics that they felt were most important to consider in prioritizing potential pathways of introduction for the scope of the horizon scan.

The most mentioned pathway in the questionnaire responses was recreation activities. The question asking about pathways was open ended (see appendix A) and 100% of respondents mentioned that pathway. Other pathways mentioned were live ornamental trade (and associated releases, 70% of responses), live bait and hitchhiking on commercial equipment (30% of responses each), and hydrologic connections (20% of responses). Live trade was outside the scope of this project (see Methods), but the responses did illustrate the high concern managers have for the pathway. Discussion during the second meeting reinforced recreation activities as a pathway that was extremely important to the regional experts.

The regional experts then considered live bait, commercial activities, and hydrologic connections as additional focal pathways in light of the pathway prioritization criteria. Specifically, the remaining pathways were evaluated on the number of past introductions through that pathway and the number of introductions that resulted in harm. Data from the USGS Nonindigenous Aquatic Species Database (“NAS”; USGS 2022) were used to estimate the number of introductions and introductions with harm (known impacts) for each of the mentioned pathways. Live bait had a much higher rate of introductions and introductions with harm than either of the remaining pathways and so was chosen as a focal pathway. In considering the two remaining pathways of commercial activities and hydrologic connections, the inability to regulate hydrologic connections was of high concern to the regional experts after discussion. It was identified that if the project included hydrologic connections as a pathway the resulting watch list would be highly applicable to early detection work in the region. That high level of concern combined with the long history of waterway modification in the region resulted in hydrologic connections being chosen as a third focal pathway.

Ultimately, three focal pathways for introduction of invasive species were included in the scope of the horizon scan: recreation activities, live bait, and direct hydrologic connections.

Focal Taxa

There were diverse taxonomic interests among the regional experts, but plants and invertebrates were most mentioned in the questionnaire responses with eleven mentions each. The taxonomic focus for the recreation activities pathway echoed the overall responses with the majority of responses mentioning plants and invertebrates. In relation to the live bait pathway, fish and invertebrates were the focus. For hydrologic connections, there were single mentions of plants and fish with one response indicating ‘all’ species that were present in donor areas of that pathway. During the second meeting, the regional experts reviewed this information but then went on to talk about why those taxa groups were most concerning to them. The main reasons they were concerned were that there were known species in those taxa groups that had been transported through the pathway and caused harm. The regional experts decided to focus on families of species that have been known to move through the recreation activity and live bait pathways. Data from the USGS NAS database (USGS 2022) and the CABI Species Discovery Tool (CABI 2022) were used to determine species that are known to be moved through those pathways. Families that contained more than one species known to be moved through the pathway were selected to be focal taxa. One additional plant family, Pontederiaceae, was added to the focal taxa for the recreation activities pathway as it was of special concern to the regional experts.

The final list of focal taxa for the recreation activities pathway included seven families of invertebrates (Cercopagididae, Daphniidae, Cyclopidae, Dreissenidae, Viviparidae, Cyrenidae, Ampullariidae) and eight families of aquatic plants (Haloragaceae, Hydrocharitaceae, Lythraceae, Onagraceae, Poaceae, Salviniaceae, Cyperaceae, Typhaceae). The live bait pathway had a focal taxa list including the crayfish family Cambaridae, shrimp family Palaemonidae, and 14 families of fish (Atherinopsidae, Catostomidae, Centrarchidae, Cichlidae, Clupeidae, Cottidae, Cyprinidae, Fundulidae, Gasterosteidae, Gobiidae, Ictaluridae, Percidae, Poeciliidae, Umbridae). The direct hydrologic connections pathway focused on species of fish, aquatic plants, and macroinvertebrates that had records of introduction in neighboring basins or those directly connected to the target region (see Methods: Identification of Top Donor Regions for more details).

Target Geographic Region

The regional experts came to consensus on defining the target region of the horizon scan as the entire States of Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont; and the Lake Champlain, Mohawk River, and Hudson River drainages, including the Hudson estuary in New York and New Jersey (figure 4). The participants were asked in the questionnaire whether natural (e.g., watershed) or political boundaries would be more meaningful for them. Out of 10 responses, 80% said that a combination of political and hydrologic boundaries would be more significant to their work. The reasons given for this choice included that it reflected shared priorities and how species naturally occur, balancing hydrological and biological realities with the ability to use the watch list produced for prevention activities that would follow political lines, such as regulations.

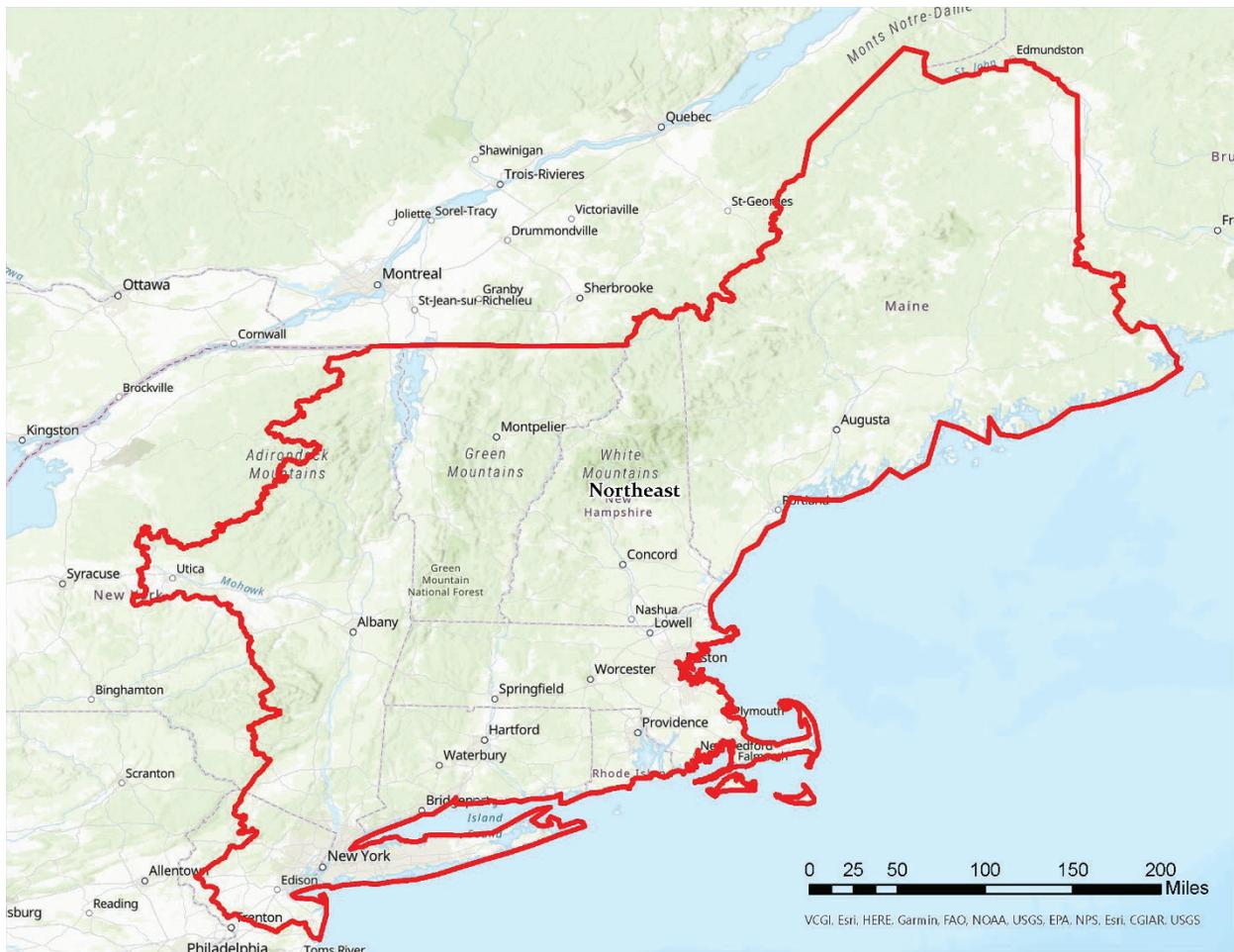


Figure 4. Map of the geographic scope of the Northeast regional horizon scan, outlined in red, including the States of Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont, along with portions of eastern New York and northern New Jersey. Map image is the intellectual property of Esri (Redlands, California) and is used herein under license.

Phase 2: Species List Generation

Identification of Top Donor Regions

Of the 55 source localities (U.S. States, Canadian provinces, or countries) reported as the previous location of the waterbody visited by recreational watercraft entering the target region, the top 10 source localities accounted for almost 90% of the watercraft traffic. Those 10 locations were identified as top outliers and added to the top donor region list for the recreation activities pathway (table 1). The out of state fishing license data identified 58 home jurisdictions for people that purchased licenses. Nine were identified as top outliers and accounted for over 65% of the licenses. Those nine were added to the top donor region list for the recreation pathway (table 1). There were seven regions in common between both sets of top outliers. California and Texas were unique to the fishing license data and Delaware, Ontario (Canada), and Michigan were unique to the watercraft inspection data. This resulted in 12 top donor regions for the recreation activities pathway.

The nine donor regions identified using out-of-state fishing license data were also added to the top donor region list for the live bait pathway (table 1). The data provided on bait

importations indicated that bait was only imported from two states outside of the target region, Arkansas and Minnesota; both States were added to the top donor region list. The final top donor region list for the live bait pathway, using both the information from out-of-state fishing license data and bait importation, included 11 regions.

There were six HUC4 watersheds (Seaber et al. 1987) in the United States and four adjacent drainage regions in Canada (Pearse et al. 1985) that met the criteria to be a donor region for the hydrologic connection pathway (table 2).

Of the top 24 potential donor regions across all pathways, 22 states, provinces, or watersheds had a climate match result that indicated a species present in that region could become established in the Northeast as determined by Climate 6 score (tables 1, 2). These 22 regions were used to develop the species list.

Table 1. Climate matching results for the top 14 regions acting as source areas for the recreation activities and live bait pathways. Climate match analysis and associated Climate 6 scores were used to determine if, in general, species present in the donor region could be an establishment concern for the Northeast (see Species List Generation in Methods for a description of Climate 6 scores). Climate 6 scores greater than or equal to 0.002 indicate an establishment concern. The pathways that the source jurisdiction corresponds to are indicated by R – recreation activities or B – live bait. Source jurisdictions in bold are those that had a suitable climate match to the Northeast.

Donor Region	Climate 6 Score	Establishment Concern?	Focal Pathways
Arkansas	0.474	Yes	B
California	0	Doubtful	R, B
Delaware	0.285	Yes	R
Florida	0	Doubtful	R, B
Maryland	0.725	Yes	R, B
Michigan	0.872	Yes	R
Minnesota	0.180	Yes	B
North Carolina	0.513	Yes	R, B
Ohio	0.943	Yes	R, B
Ontario, Canada	0.981	Yes	R
Pennsylvania	0.964	Yes	R, B
Quebec, Canada	0.982	Yes	R, B
Texas	0.024	Yes	R, B
Virginia	0.710	Yes	R, B

Table 2. Climate matching results for the adjacent watersheds identified as potential donor regions for the hydrologic connections pathway. All source watersheds had a climate match analysis indicating species present in the region may pose an establishment concern to the Northeast. Climate 6 scores greater than or equal to 0.002 indicate an establishment concern.

Donor Region	Country	Climate 6 Score	Establishment Concern?
Delaware – Mid-Atlantic Central	United States	0.905	Yes
Eastern Lake Erie – Lake Erie	United States	0.953	Yes
Great Lakes	Canada	0.979	Yes
Ottawa	Canada	0.872	Yes
Northeastern Lake Ontario – Lake Ontario – St. Lawrence	United States	0.976	Yes
Southeastern Lake Ontario	United States	0.992	Yes
Southwest Lake Ontario	United States	0.799	Yes
St. Lawrence	Canada	0.920	Yes
St. John – St. Croix	Canada	0.978	Yes
Susquehanna	United States	0.894	Yes

Species List

The final species list included 676 species present in one or more of the 22 climate-matched top donor regions but not yet recorded in the Northeast target region (appendix B). The list included 15 families of fish (represented by 335 species), 2 families of crayfish (represented by 172 species), 8 families of plants (represented by 123 species), 4 families of mollusks (represented by 11 species), and 7 families of other invertebrates (represented by 35 species; table 3). Focal taxa groups that were not represented in the final species list included Dreissenidae, Gasterosteidae, Pontederiaceae, Salviniaceae, Typhaceae, and Umbridae. No species were identified as present in the donor regions but not present in the target region from these families. All species directly mentioned within the provided bait importation data and regulations were either native or already present within the target region and were not included in the species list.

Table 3. Families and associated number of species in the full species list for the Northeast. Families indicated with a ‘*’ are those that were identified for the recreation activities and live bait pathways. All other families came from the hydrologic connections pathway.

Family	Organism Type	Number of Species
Atherinopsidae*	Fish	4
Catostomidae*	Fish	21
Centrarchidae*	Fish	11
Cichlidae*	Fish	10
Clupeidae*	Fish	3
Cottidae*	Fish	9
Cyprinidae*	Fish	114
Dorosomatidae	Fish	2
Ehiravidae	Fish	1
Fundulidae*	Fish	18
Gobiidae	Fish	14
Ictaluridae*	Fish	20
Percidae*	Fish	90
Poeciliidae*	Fish	17
Synbranchidae	Fish	1
Commelinaceae	Plant	1
Cyperaceae*	Plant	61
Haloragaceae*	Plant	1
Hydrocharitaceae*	Plant	2
Lythraceae*	Plant	1
Onagraceae*	Plant	14
Plantaginaceae	Plant	1
Poaceae*	Plant	42
Ampullariidae*	Mollusk	4
Cyrenidae*	Mollusk	1
Hydrobiidae	Mollusk	1
Viviparidae*	Mollusk	5
Cambaridae	Crayfish	161
Palaemonidae	Shrimp	11
Ameiridae	Other Invertebrate	1
Cercopagididae*	Other Invertebrate	1
Cyclopidae*	Other Invertebrate	24
Daphniidae*	Other Invertebrate	6
Ergasilidae	Other Invertebrate	1
Gammaridae	Other Invertebrate	1
Miraciidae	Other Invertebrate	1

Phase 3: Species Prioritization and Risk Screening

The top three species attributes to use for prioritizing species for risk screening, as selected by the regional experts, were presence in a trade pathway (in addition to the focal pathways), past history of introductions, and if a species had a relative larger native range (figure 5). After setting aside 46 species from the species list for which ERSSs had been completed previously and for which results were already available, 20 additional species were prioritized for risk screening based on presence in a trade pathway in addition to a history of previous introductions. Summarized risk screening results are available in table 5 for the 20 species for which risk screening was conducted as part of this project and the 46 species on the final species list for which an ERSS had been completed as part of previous projects. To understand how changing climate may impact the establishment concern of potential invasive species, climate matching under projected future climate scenarios was conducted as part of the screening for the 20 species screened as part of this project and species screened as part of past horizon scans. Full risk screening results for those species, including climate matching under current climate conditions, are available online at <https://www.fws.gov/library/ecological-risk-screening-summaries>.

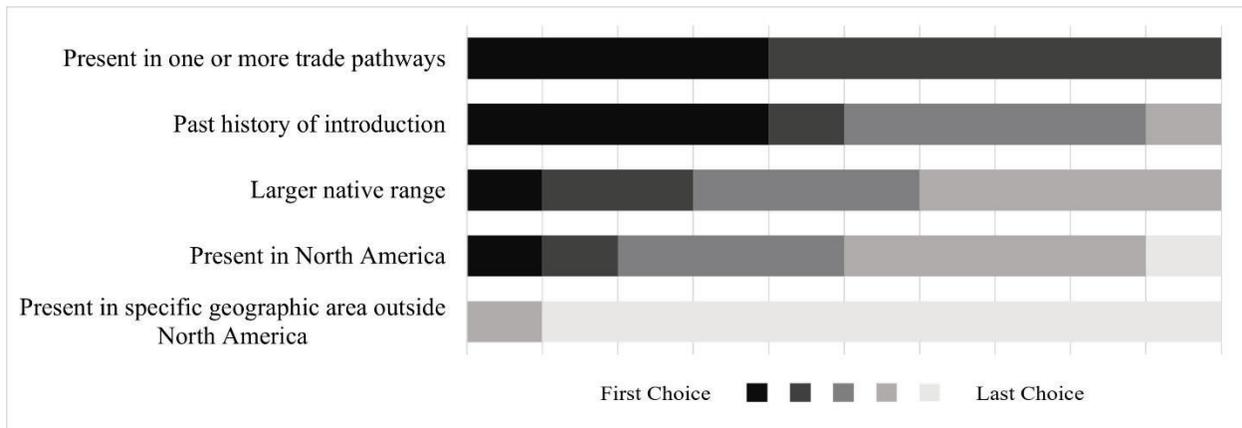


Figure 5. Regional expert ranking of species attributes to be used in prioritization of species for risk screening. Rankings were given by ten of the Northeast horizon scan regional experts.

Risk screening identified 19 high-risk species for the Northeast within the focal taxa and pathways (table 4). The high-risk designation indicates the species has documented negative impacts of introduction as well as a climate match result suggesting establishment concern (see Methods) for at least one State wholly or partially within the Northeast target region. The watch list contained seven fish species, seven plant species, and five non-crayfish invertebrates.

Table 4. Watch list of high-risk fish, plant, and invertebrate species not yet present in the Northeast identified through the recreational activities (R), live bait (B), and hydrologic connection (H) introduction pathways.

Scientific Name	Common Name	Organism Type	Pathway
<i>Etheostoma zonale</i>	Banded Darter	Fish	H
<i>Gymnocephalus cernua</i>	Ruffe	Fish	B, H
<i>Hypophthalmichthys molitrix</i>	Silver Carp	Fish	B
<i>Hypophthalmichthys nobilis</i>	Bighead Carp	Fish	B
<i>Micropterus punctulatus</i>	Spotted Bass	Fish	H
<i>Poecilia latipinna</i>	Sailfin Molly	Fish	B
<i>Proterorhinus semilunaris</i>	Freshwater Tubenose Goby	Fish	H
<i>Cyperus haspan</i>	Haspan Flatsedge	Plant	R
<i>Hemarthria altissima</i>	Limpograss	Plant	R
<i>Ludwigia decurrens</i>	Wingleaf Primrose-willow	Plant	H
<i>Ludwigia grandiflora</i>	Large-flower Primrose Willow	Plant	H
<i>Murdannia keisak</i>	Marsh Dewflower	Plant	H
<i>Najas marina</i>	Spiny Naiad	Plant	H
<i>Zizania latifolia</i>	Manchurian Wildrice	Plant	R
<i>Daphnia lumholtzi</i>	a water flea	Invertebrate	R, H
<i>Marisa cornuarietis</i>	Giant Ramshorn Snail	Invertebrate	R
<i>Pomacea canaliculata</i>	Channeled Applesnail	Invertebrate	R
<i>Potamopyrgus antipodarum</i>	New Zealand Mudsnailed	Invertebrate	H
<i>Viviparus viviparus</i>	Common River Snail	Invertebrate	R

All 19 high risk species were documented to have been introduced through at least one of the focal pathways or through a live trade pathway, one of the species prioritization criteria. Four of the high risk species, *Daphnia lumholtzi*, channeled applesnail (*Pomacea canaliculata*), New Zealand mudsnail (*Potamopyrgus antipodarum*), and common river snail (*Viviparus viviparus*) were all documented to have been introduced through hitchhiking on recreation equipment (USFWS 2015a, 2018a,b, 2022a). An additional four species were documented to have been introduced through the live bait pathway: banded darter (*Etheostoma zonale*), ruffe (*Gymnocephalus cernua*), sailfin molly (*Poecilia latipinna*), and freshwater tubenose goby (*Proterorhinus semilunaris*; USFWS 2015b, 2018c, 2021a, 2024c). Eleven species were documented to have spread through natural dispersal, making them candidates to easily spread through hydrologic connections. These 11 were *D. lumholtzi*, banded darter, silver carp (*Hypophthalmichthys molitrix*), bighead carp (*H. nobilis*), wingleaf primrose-willow (*Ludwigia decurrens*), large-flower primrose willow (*Ludwigia grandiflora*), marsh dewflower (*Murdannia keisak*), spiny naiad (*Najas marina*), channeled applesnail, New Zealand mudsnail, and freshwater tubenose goby (USFWS 2015a, 2018a,b,d, 2019a,b, 2021a,b,c, 2024c,d). Eleven species have been documented as introduced through a live trade pathway: channeled applesnail, common river snail, silver and bighead carp, large-flower primrose willow, sailfin molly, haspan flatsedge (*Cyperus haspan*), giant ramshorn snail (*Marisa cornuarietis*), Manchurian wildrice (*Zizania latifolia*), limpograss (*Hemarthria altissima*), and spotted bass (*Micropterus punctulatus*) (USFWS 2018b,c,d, 2019a,b, 2021c, 2022a, 2024e,f,g). Additional introduction

pathways documented for the 19 high risk species included contamination of agricultural and aquacultural products, ballast, hitchhiking on commercial equipment, and hitchhiking in the ornamental and aquarium trade.

Of the species that were subjects of risk screening via ERSS, three species had a high history of invasiveness but did not have a Climate 6 score above the establishment concern threshold for any State wholly or partially within the target region. They were pike killifish (*Belonesox belizanus*), Rio Grande cichlid (*Herichthys cyanoguttatus*), and blue tilapia (*Oreochromis aureus*; table 5) and so were not included on the list of high-risk species. These species, while not evaluated as high risk for the Northeast were evaluated to be high risk to the contiguous United States.

The remaining 44 species had an overall risk assessment category of ‘Uncertain.’ In the cases of these species, the ‘Uncertain’ category designation is largely due to the lack of information regarding the species’ history of invasiveness. This lack of information falls into two general categories indicated by the history of invasiveness classification (table 5). Thirty-three of those species with a history of invasiveness classified as ‘Data Deficient’ had records of established nonnative populations but information on impacts was lacking: there was no information regarding impacts or the information available was vague or anecdotal and did not meet the standard for ‘scientifically defensible information’ as outlined in the ERSS SOP (USFWS 2024b). Ten of these species had some information regarding impacts but it did not meet standards for a classification of ‘High’ or the information concerned potential impacts and a suitable climate match to at least one state in the target region (table 5). These species were: coastal waterhyssop (*Bacopa monnieri*), papyrus (*Cyperus papyrus*), blacktail shiner (*Cyprinella venusta*), bigmouth buffalo (*Ictiobus cyprinellus*), yerba de jicotea (*Ludwigia erecta*), *Mesocyclops pehpeiensis* (a copepod), redeye bass (*Micropterus coosae*), Asian swamp eel (*Monopterus albus*), black carp (*Mylopharyngodon piceus*), and spiked-topped applesnail (*Pomacea diffusa*). Another three species, Mexican molly (*Poecilia sphenops*), green swordtail (*Xiphophorus hellerii*), and variable platyfish (*Xiphophorus variatus*), also had some limited impact information but did not have climate matches above the establishment concern threshold within the target region. For the remaining 20 species with a history of invasiveness classified as ‘Data Deficient,’ there was no information regarding any sort of impacts.

Eleven uncertain-risk species had a history of invasiveness classified as ‘No Known Nonnative Population,’ indicating that no records of established nonnative populations could be confirmed. The ERSS process, as a rapid screening tool, relies heavily on evidence of past invasive behavior to designate a species as high risk for invasiveness in the United States. Without a known nonnative population, there is no opportunity to gather such evidence.

Future climate conditions may impact the risk of establishment for some species (table 5). Seven species had expanded establishment concern, based on State-specific Climate 6 scores (see Methods above) under at least some future climate projections. Two of those species are on the high-risk species list: limpgrass (expanded establishment concern to New Hampshire and Vermont) and giant ramshorn snail (expanded establishment concern to Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont).

Table 5. Summary of risk screening results for 66 species in focal taxa with potential for future introduction into the Northeast via the recreational activities, live bait, and hydrologic connections pathways. Species in bold are those determined to be high-risk to the Northeast. History of invasiveness categories represented the evidence for past introduction and harm caused by the species outside its native range (“High” if established and documented to cause harm, “Data Deficient” if established but harm is unknown, “No Known Nonnative Population” if no confirmed establishment outside native range). States in the Northeast target region with establishment concern for each species is based on RAMP (Sanders et al. 2014, 2018, 2021, 2023) state-specific Climate 6 scores. Brackets around state abbreviations indicate that establishment concern is classified as Doubtful under current climate conditions but is predicted to be above the Establishment Concern threshold under projected future conditions. A [*] indicates that future climate matching has not been conducted for this species to date. Full reports for each species are available at: <https://fws.gov/library/categories/ecological-risk-screening>.

Scientific Name	Common Name	History of Invasiveness	Establishment Concern	Certainty	Overall Risk for Northeast	Overall Risk for Contig. US
<i>Ameiurus serracanthus</i>	Spotted Bullhead	No Known Nonnative Population [^]	CT, MA, NJ, NY, RI, [*]	Low	Uncertain	Uncertain
<i>Belonesox belizanus</i>	Pike Killifish	High	--	High	Uncertain	High
<i>Cottus gobio</i>	European Bullhead	Data Deficient [^]	CT, MA, NH, NJ, NY, RI, VT, [*]	Low	Uncertain	Uncertain
<i>Cyprinella venusta</i>	Blacktail Shiner	Data Deficient ⁺	CT, MA, ME, NH, NJ, NY, RI, VT	Low	Uncertain	Uncertain
<i>Etheostoma zonale</i>	Banded Darter	High	CT, MA, ME, NH, NJ, NY, RI, VT	Medium	High	High
<i>Evorthodus lyricus</i>	Lyre Goby	No Known Nonnative Population [^]	NJ, [*]	Low	Uncertain	Uncertain
<i>Fundulus chrysotus</i>	Golden Topminnow	Data Deficient	CT, MA, ME, NH, NJ, NY, RI, VT	Low	Uncertain	Uncertain
<i>Fundulus notatus</i>	Blackstripe Topminnow	Data Deficient	CT, MA, ME, NH, NJ, NY, RI, VT	Low	Uncertain	Uncertain
<i>Fundulus pubereus</i>	Bayou Killifish	No Known Nonnative Population [^]	-- [*]	Low	Uncertain	Uncertain
<i>Fundulus seminolis</i>	Seminole Killifish	Data Deficient [^]	NJ, [*]	Low	Uncertain	Uncertain
<i>Gambusia geiseri</i>	Largespring Gambia	No Known Nonnative Population [^]	-- [*]	Low	Uncertain	Uncertain
<i>Gymnocephalus cernua</i>	Ruffe	High	CT, MA, ME, NH, NJ, NY, RI, VT	High	High	High
<i>Herichthys cyanoguttatus</i>	Rio Grande Cichlid	High	-- [*]	Medium	Uncertain	High
<i>Hypophthalmichthys molitrix</i>	Silver Carp	High	CT, MA, ME, NH, NJ, NY, RI, VT	Medium	High	High

Scientific Name	Common Name	History of Invasiveness	Establishment Concern	Certainty	Overall Risk for Northeast	Overall Risk for Contig. US
<i>Hypophthalmichthys nobilis</i>	Bighead Carp	High	CT, MA, ME, NH, NJ, NY, RI, VT	Medium	High	High
<i>Ictalurus lupus</i>	Headwater Catfish	Data Deficient [^]	--, [*]	Low	Uncertain	Uncertain
<i>Ictiobus bubalus</i>	Smallmouth Buffalo	Data Deficient	CT, MA, ME, NH, NJ, NY, RI, VT	Low	Uncertain	Uncertain
<i>Ictiobus cyprinellus</i>	Bigmouth Buffalo	Data Deficient ⁺	CT, MA, ME, NH, NJ, NY, RI, VT	Low	Uncertain	Uncertain
<i>Ictiobus niger</i>	Black Buffalo	Data Deficient	CT, MA, ME, NH, NJ, NY, RI, VT	Low	Uncertain	Uncertain
<i>Lepomis miniatus</i>	Redspotted Sunfish	Data Deficient	CT, MA, ME, NH, NJ, NY, RI, VT	Low	Uncertain	Uncertain
<i>Lucania goodei</i>	Bluefin Killifish	Data Deficient [^]	NJ, [*]	Low	Uncertain	Uncertain
<i>Lythrurus fasciolaris</i>	Scarlet Shiner	No Known Nonnative Population	CT, MA, ME, NH, NJ, NY, RI, VT	Low	Uncertain	Uncertain
<i>Maylandia zebra</i>	Nyassa Blue Cichlid	Data Deficient [^]	--, [*]	Low	Uncertain	Uncertain
<i>Micropterus coosae</i>	Redeye Bass	Data Deficient ⁺	CT, MA, ME, NH, NJ, NY, RI, VT	Low	Uncertain	Uncertain
<i>Micropterus punctulatus</i>	Spotted Bass	High	CT, MA, ME, NH, NJ, NY, RI, VT	High	High	High
<i>Monopterus albus</i>	Asian Swamp Eel	Data Deficient ^{^+}	CT, MA, ME, NH, NJ, NY, RI, VT	Low	Uncertain	Uncertain
<i>Mylopharyngodon piceus</i>	Black Carp	Data Deficient ^{^+}	CT, MA, NH, NJ, NY, VT, [*]	Low	Uncertain	Uncertain
<i>Notropis xaenocephalus</i>	Coosa Shiner	No Known Nonnative Population [^]	CT, MA, NJ, NY, RI, [*]	Low	Uncertain	Uncertain
<i>Oreochromis aureus</i>	Blue Tilapia	High	--, [*]	High	Uncertain	High
<i>Platygobio gracilis</i>	Fathead Chub	Data Deficient	CT, MA, ME, NH, NJ, NY, RI, VT	Low	Uncertain	Uncertain
<i>Poecilia latipinna</i>	Sailfin Molly	High	NJ, [*]	Medium	High	High
<i>Poecilia sphenops</i>	Mexican Molly	Data Deficient ^{^+}	--, [*]	Low	Uncertain	Uncertain
<i>Proterorhinus semilunaris</i>	Western Tubenose Goby	High	CT, MA, ME, NH, NJ, NY, RI, VT	High	High	High
<i>Rhinichthys osculus</i>	Speckled Dace	Data Deficient ⁺	CT, MA, ME, NH, NY, VT	Low	Uncertain	Uncertain
<i>Xiphophorus helleri</i>	Green Swordtail	Data Deficient ^{^+}	--, [*]	Low	Uncertain	Uncertain
<i>Xiphophorus variatus</i>	Variable Platyfish	Data Deficient ^{^+}	--, [*]	Low	Uncertain	Uncertain

Scientific Name	Common Name	History of Invasiveness	Establishment Concern	Certainty	Overall Risk for Northeast	Overall Risk for Contig. US
<i>Ammannia robusta</i>	Grand Redstem	Data Deficient	CT, MA, ME, NH, NJ, NY, RI, VT	Low	Uncertain	Uncertain
<i>Bacopa monnieri</i>	Coastal Waterhyssop	Data Deficient ⁺	CT, MA, ME, NH, NJ, NY, RI, VT	Low	Uncertain	Uncertain
<i>Cyperus albosriatus</i>	Umbrella Sedge	Data Deficient	CT, MA, ME, NH, NJ, NY, RI, VT	Low	Uncertain	Uncertain
<i>Cyperus haspan</i>	Haspan Flatsedge	High	CT, MA, ME, NH, NJ, NY, RI, VT	High	High	High
<i>Cyperus papyrus</i>	Papyrus	Data Deficient ⁺	CT, MA, ME, NH, NJ, NY, RI, VT	Low	Uncertain	Uncertain
<i>Hemarthria altissima</i>	Limpogress	High	CT, MA, ME, NJ, NY, RI, [NH, VT]	Medium	High	High
<i>Hopia obtusa</i>	Vine Mesquite	No Known Nonnative Population	CT, MA, ME, NH, NJ, NY, VT, [RI]	Low	Uncertain	Uncertain
<i>Ludwigia decurrens</i>	Wingleaf Primrose-willow	High	CT, MA, ME, NH, NJ, NY, RI, VT	High	High	High
<i>Ludwigia erecta</i>	Yerba de Jicotea	Data Deficient ⁺	--, [CT, MA, ME, NH, NJ, NY, RI, VT]	Low	Uncertain	Uncertain
<i>Ludwigia grandiflora</i>	Large-flower Primrose-willow	High	CT, MA, NH, NJ, NY, RI, VT	Medium	High	High
<i>Ludwigia hyssopifolia</i>	Seedbox	Data Deficient	CT, MA, ME, NH, NY, RI, [NJ]	Low	Uncertain	Uncertain
<i>Ludwigia linifolia</i>	Southeastern Primrose-willow	Data Deficient	CT, NJ, NY, [MA, ME, NH, VT]	Low	Uncertain	Uncertain
<i>Murdannia keisak</i>	Marsh Dewflower	High	CT, MA, ME, NH, NJ, NY, RI, VT	Medium	High	High
<i>Najas marina</i>	Holly-leaf Waternymph	High	CT, MA, ME, NH, NJ, NY, RI, VT	Medium	High	High
<i>Rhynchospora colorata</i>	Starrush Whitetop	No Known Nonnative Population	CT, MA, ME, NH, NJ, NY, RI, VT	Low	Uncertain	Uncertain
<i>Stratiotes aloides</i>	Water Soldier	Data Deficient ⁺	CT, MA, ME, NH, NJ, NY, RI, VT	Low	Uncertain	Uncertain
<i>Zizania latifolia</i>	Manchurian Wildrice	High	CT, MA, ME, NH, NJ, NY, RI, VT	Medium	High	High
<i>Cambarellus puer</i>	Swamp Dwarf Crayfish	No Known Nonnative Population [^]	CT, NJ, [*]	Low	Uncertain	Uncertain

Scientific Name	Common Name	History of Invasiveness	Establishment Concern	Certainty	Overall Risk for Northeast	Overall Risk for Contig. US
<i>Corbicula fluminalis</i>	a clam	Data Deficient [^]	CT, MA, NJ, NY, RI, [*]	Low	Uncertain	Uncertain
<i>Daphnia lumholzi</i>	a water flea	High	CT, MA, ME, NH, NJ, NY, RI, VT	Medium	High	High
<i>Faxonius nana</i>	Midget Crayfish	No Known Nonnative Population [^]	CT, NJ, NY, [*]	Low	Uncertain	Uncertain
<i>Macrobrachium ohione</i>	Ohio Shrimp	No Known Nonnative Population	CT, MA, ME, NH, NJ, NY, RI, VT	Low	Uncertain	Uncertain
<i>Marisa cornuarietis</i>	Giant Ramshorn Snail	High	CT, NJ, NY, [MA, ME, NH, RI, VT]	High	High	High
<i>Mesocyclops pehpeiensis</i>	a copepod	Data Deficient ^{+^}	NJ, NY, VT, [*]	Low	Uncertain	Uncertain
<i>Pomacea canaliculata</i>	Channeled Applesnail	High	NJ, NY, [*]	High	High	High
<i>Pomacea diffusa</i>	Spiked-topped Applesnail	Data Deficient ^{+^}	CT, MA, ME, NJ, NY, RI, VT, [NH]	Low	Uncertain	Uncertain
<i>Pomacea paludosa</i>	Florida Applesnail	Data Deficient [^]	--, [*]	Low	Uncertain	Uncertain
<i>Potamopyrgus antipodarum</i>	New Zealand Mudsnail	High	CT, MA, ME, NH, NJ, NY, VT	High	High	High
<i>Procambarus spiculifer</i>	White Tubercled Crayfish	No Known Nonnative Population	CT, MA, NH, NJ, NY, RI, VT, [*]	Low	Uncertain	Uncertain
<i>Viviparus viviparus</i>	Common River Snail	High	CT, MA, ME, NH, NJ, NY, RI, VT	Medium	High	High

[^]The ERSs for these species were completed under a previous SOP and the history of invasiveness classification listed in the ERSs uses different terms than currently used. ‘Uncertain’ is equivalent to ‘No Known Nonnative Population’ and ‘Not Documented’ is equivalent to ‘Data Deficient.’

⁺Species has some indication of impacts or potential impacts from introduction, but the information does not meet the standards needed for a classification of ‘High’.

Discussion

The results of this scan and complementary projects will be used by the USFWS to inform watch lists as part of the National Early Detection and Rapid Response Framework (figure 1). The national framework is an organizational structure which works to prevent the establishment and spread of AIS. This horizon scan identified 19 species within priority taxa that may pose high risk to the Northeast if introduced to the region in the future: five macroinvertebrate, seven plant, and seven fish species. As climate change increasingly impacts the Northeast it will be important to know which potential invasive species may still be of priority concern or which species that were previously not a concern may become one. The species lists and screenings produced as part of this project will help inform that effort. Species other than the proposed watch list species (table 4) may also be determined to pose significant risk of introduction and harm in the Northeast if more comprehensive risk assessments are performed. More comprehensive risk assessments may include study of population genetics, biotic interactions, and functional species traits that may influence the capacity for organisms to adjust to changing environmental conditions. Thirty-four species in table 5 were classified as having a history of invasiveness of ‘Data Deficient’; these species have known, established nonnative populations but insufficient information was found documenting the introduced populations’ impacts. Thirteen of those 34 species had some impact or potential impact information, but that information did not meet the standards required for a classification of ‘High.’ Published information regarding impacts, or the lack of impacts, from those populations would have allowed for better classification of the species’ risk with increased certainty in the results.

The results of this project can be applied to AIS prevention and early detection activities within the region to reduce the probability of introduction and establishment of these high-risk species. One common method of invasive species prevention is regulation at the local, state, or federal level. The possibility to consider additional regulations or new legislation was mentioned more than once when the regional experts were asked what prevention activities their organization may conduct within the next five years. Two of the high-risk species, silver and bighead carp, are listed as Federal Injurious Species (USFWS 2024h). None of the 19 high-risk species are regulated by all eight States within the target region. The two carp species that are federally listed are also regulated in four States within the target region: Connecticut (Connecticut DEEP 2020), New Hampshire (NHFG 2022), New Jersey (NJFW 2022), and New York (New York DEC 2022). Another seven high-risk species are regulated by at least one State (Connecticut DEEP 2020, New York DEC 2022, NHFG 2022, NJFW 2022, Rhode Island DEM 2022; table 6). The remaining 10 high-risk species are not regulated federally or by any of the States. Highlighting potentially harmful species through this process and gaps or inconsistencies in regulations is an opportunity for the region to improve the effectiveness of this prevention tool through increasing cross border consistency and issuing regulations proactively instead of reactively for the high-risk species (Beaury et al. 2021, Bradley et al. 2022).

Table 6. High-risk species that are regulated by States within the Northeast target region.

Scientific Name	Common Name	Regulating Jurisdictions
<i>Gymnocephalus cernua</i>	Ruffe	New Hampshire, New York, Rhode Island
<i>Hypophthalmichthys molitrix</i>	Silver Carp	United States (Lacey Act), Connecticut, New Hampshire, New Jersey, New York
<i>Hypophthalmichthys nobilis</i>	Bighead Carp	United States (Lacey Act), Connecticut, New Hampshire, New Jersey, New York
<i>Micropterus punctulatus</i>	Spotted Bass	New Jersey
<i>Proterorhinus semilunaris</i>	Freshwater Tubenose Goby	New York
<i>Ludwigia grandiflora</i>	Large-flower Primrose-willow	New York
<i>Murdannia keisak</i>	Marsh Dewflower	Delaware, New York
<i>Daphnia lumholtzi</i>	Waterflea	New York
<i>Potamopyrgus antipodarum</i>	New Zealand Mudsnaail	Connecticut, New York

Additional prevention activities may take the form of public education or outreach to the aquarium, aquaculture, and bait industries. Ten of the high-risk species are directly traded either domestically or internationally and nine species have been known to be contaminants in live trade of other species. Outreach and education regarding these species may result in alternative lower risk species being chosen for trade or result in screening for and reporting these organisms as contaminants. The high-risk species identified here may be an easy addition to ongoing outreach work in the region. General or targeted outreach was mentioned in more than half the responses when the regional experts were asked about their organization's ongoing or potential prevention activities. At least half of the responding organizations planned to conduct watercraft inspections or provide cleaning stations as well. Training inspection station staff or volunteers to improve awareness and recognition of identified high-risk species potentially transported through the recreation activities pathway would be an easy way to increase prevention effectiveness.

For early detection, application of project findings will be facilitated by the existing capacity for monitoring across the region. Regional experts representing nine organizations indicated that their organizations planned to conduct early detection work for plants and fish over the next five years. The taxa targeted by those surveys could easily be expanded to include many of the 19 high-risk species identified in this scan. Workshops and training materials for field technicians and boat inspectors could be updated to include information on identifying and reporting possible sightings of the high-risk species to individuals with expertise to confirm the identification. In the recreational activities pathway, monitoring for plant and invertebrate species could take place using the same tools and strategies already used for boat inspections conducted by the regional experts' organizations and others in the region (e.g., the Lake Champlain Lake Steward program).

Newer methods of early detection such as eDNA and remote sensing are being used by organizations in the region. Proactive early detection steps could include determining if the high-risk species identified have existing, validated genetic markers or if new markers need to be developed. Similarly, if remote sensing methods would be suitable for the species of concern,

determining beforehand if the species has any phenological characteristics that might increase the chances of detection or if specific spectral capabilities in equipment are needed could reduce lead time and increase effectiveness of a rapid response or monitoring.

The horizon scan described here only addresses a fraction of the potential future risk to the Northeast from AIS. Limiting the scope of the project to the introduction pathways of recreation activities, live bait, and hydrologic connections, and a limited number of nonmarine fish, crayfish, plant, and other invertebrate taxa was necessary given the limited resources for this study. Additional physical pathways, taxa, and biological capacity for change in response to new and changing environments remain unaddressed. However, this project provides a blueprint for conducting future horizon scanning and risk screening work with different focal pathways or taxa using the straightforward, repeatable approach employed here (figure 2). Advances in detection technology will continue to open new opportunities to monitor for introductions of AIS (Martinez et al. 2020, Singh et al. 2020, Stevens and Parsley 2023), making horizon scanning even more important for predicting and preparing for potentially harmful future introductions so they can be detected and managed as early in the invasion process as possible.

The area targeted in this horizon scan effort, the States of Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont, and the drainages of Lake Champlain, the Mohawk and Hudson Rivers and estuary in New York and New Jersey, represents a region that has been heavily impacted by human activities and introduced species for over 300 years (Mangiante et al. 2018). With continued pressure from global stressors including climate change and trade and transport technology, the waters of the Northeast remain at risk. Industries that inherently move species such as aquaculture and the bait industry as well as recreation activities continue to grow in popularity and efficiency giving rise to increased likelihood to advance introduction opportunities. Continued vigilance and emphasis on prevention are paramount to successful management of AIS and conservation of native species and their habitats. For these reasons, tools such as horizon scans are needed to forecast invasive species introductions and more effectively design prevention and monitoring strategies and prioritize early detection and rapid response actions.

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Appendix A: Scoping Questionnaire

The following instructions and series of questions were distributed to the regional experts for the Northeast regional horizon scan following an introductory meeting on the project. Responses were used to guide discussion leading to consensus on the four dimensions of the horizon scan's scope (geographic, pathway, taxonomic, temporal).

“Background: Over the next few months, members of our USFWS Nonnative Aquatic Species Risk Assessment Program will be scanning global and national species occurrence databases to identify nonnative freshwater vertebrate, macroinvertebrate, or plant species that are at risk of arrival and establishment in the Northeast through unintentional or unassisted movement. This project is part of a national, multi-agency effort to expand federal leadership and capacity for early detection and rapid response activities. The results could also be used to inform regional aquatic invasive species prevention and early detection priorities.

Purpose of the Survey: We would like your help to determine focal introduction pathways, focal taxonomic groups, and the precise geographic boundaries for the horizon scan. The following questions will give us insight into your priorities and a starting point for further discussion. You are welcome to consult with colleagues in your organization when responding to the questions.

Thank you for your time! Please contact Heidi Himes (heidi_himes@fws.gov) with any questions.

You and Your Organization

These questions will help us understand who is represented in the responses to the following sections.

1. First and Last Name
2. Organization
3. Email

Organizational Prevention and Early Detection Activities

The following questions will help us identify areas where horizon scan results may have useful applications within the Northeast. Thinking about potential applications now may be helpful in selecting the scope of the horizon scan.

4. Within the next five years, is your organization likely to be involved in activities to PREVENT new introductions of nonnative aquatic species to the Northeast region?
 Yes
 No
 Uncertain
5. Please briefly describe the aquatic invasive species prevention activities that will be undertaken by your organization in the Northeast region.
Include geographic area, time frame, and pathways or taxonomic groups to be targeted. If your organization is involved in many activities, please choose a few of the most significant ones to describe.
6. Within the next five years, is your organization likely to be involved in activities to DETECT newly introduced nonnative aquatic species in the Northeast region?

- Yes
- No
- Uncertain

7. Please briefly describe the AIS monitoring activities that will be undertaken by your organization in the Northeast region. Include geographic area, time frame and frequency of monitoring, species or taxonomic groups to be targeted, and the general methods to be used (traditional sampling gear, environmental DNA samples, or both). If your organization is involved in many activities, please choose a few of the most significant ones to describe.

Geographic Scope

In this project, we will be concerned with species introductions to our “target geographic region” from other areas of the country or world. The following questions ask about desired boundaries for the target geographic region, which we have been referring to as the “Northeast.”

8. The map on the right shows both potential political and hydrological boundaries that could be used to define the Northeast geographic region. What type(s) of boundaries do you think we should use to define the Northeast target geographic region for the horizon scan? (You will have an opportunity to provide more details below.)



- Political boundaries only
- Hydrologic boundaries only
- Combination

9. Would you use the political boundaries shown on the map above to define the target region? Are there areas that should be excluded? Are there other areas that should be included?
10. Would you use the hydrologic boundaries shown on the map above to define the target region? Are there areas that should be excluded? Are there other areas that should be included?
11. Please describe which political and which hydrologic boundaries you would like to use.
12. Why do you think these boundaries should be used for the Northeast horizon scan?

Introduction Pathway Priorities

Our horizon scan will focus on one or more introduction pathways into the target geographic region. The following questions ask how you would prioritize pathways based on their characteristics.

Definitions:

introduction pathway = means and routes by which organisms are moved (e.g., commercial shipping)

introduction vector = physical mode of organism transport (e.g., ballast water)

Examples of introduction pathways can be found here:

<https://www.invasivespeciesinfo.gov/subject/pathways>

13. What factors should we use to prioritize introduction pathways for horizon scanning?
Please rank the following options. (Drag to reorder.)
 - Higher volume of introduction through pathway
 - Greater documented harm from introductions through pathway
 - Great ability to regulate or manage the pathway effectively
 - Lesser ability to regulate or manage the pathway effectively
 - Geographic source of the organism in pathway
 - Other (enter below)
14. If there is another factor that is important to you, please name it here:

Introduction Pathways and Focal Taxa

The following questions ask about your knowledge and perceptions of introduction pathways to the Northeast. Please remember that live trade pathways are being addressed by a separate horizon scanning effort and will not be included in our project.

Definitions:

introduction pathway = means and routes by which organisms are moved (e.g., commercial shipping)

introduction vector = physical mode of organism transport (e.g., ballast water)

Examples of introduction pathways can be found here:

<https://www.invasivespeciesinfo.gov/subject/pathways>

15. Considering only pathways through which nonnative aquatic species are introduced UNINTENTIONALLY, what introduction pathway into the Northeast is the most concerning to you?
16. What groups of species are you concerned will arrive via the above pathway?
Please do not name individual species.

17. Considering only pathways through which nonnative aquatic species are introduced UNINTENTIONALLY, is there another introduction pathway into the Northeast is highly concerning to you?
18. What groups of species are you concerned will arrive via the above pathway?
Please do not name individual species.
19. Considering only pathways through which nonnative aquatic species are introduced UNINTENTIONALLY, is there another introduction pathway into the Northeast is highly concerning to you?
20. What groups of species are you concerned will arrive via the above pathway?
Please do not name individual species.
21. Considering the groups of species named above, why are they of concern to you?

Introduction Pathways, continued

22. Are you aware of any existing datasets (relevant to the Northeast) that quantify the movement of either species or vectors within the pathways you mentioned on in the previous questions?
23. Please provide any additional comments on introduction pathways or pathway prioritization here:

Priorities for Risk Screening

We will likely be limited to completing species-specific risk screening (i.e., <https://www.fws.gov/story/ecological-risk-screenign-summaries>) for a subset of species that show up in the horizon scan. The following questions ask about your priorities for risk screening.

24. Please rank the importance of the following factors in prioritizing a species for risk screening. (Drag to reorder.)
 - Larger native range
 - Present in a specific country or continent outside North America
 - Past history of introduction outside its native range
 - Present in one or more trade pathways, in addition to unintentional movement pathways
 - Present in North America
25. If “Present in a specific country or continent outside North America” is important to you, which country or continent would you want to prioritize? If you gave a low rank to this factor, feel free to leave this question blank.
26. Are there other factors that you think should be considered in prioritizing species for risk screening? What are they and where would they rank?
27. Please provide any other comments on risk screening priorities here:

Appendix B: Full Species List

The following list of species represents all species from focal families reported from top climate-matched donor regions (see tables 1, 2) but not yet reported from the Northeast region as well as species that were identified through the hydrologic connections pathway. Species occurrence data were obtained from GBIF Secretariat (2023). Accepted species names were verified with World Flora Online (2021), Catalog of Fishes (Fricke et al. 2021), and WoRMS (WoRMS Editorial Board 2021).

Crustaceans

Family Ameiridae

Nitokra hibernica hibernica

Family Cambaridae

Bouchardina robisoni

Cambarellus ninae

Cambarellus puer

Cambarellus texanus

Cambarus aculabrum

Cambarus acuminatus

Cambarus aldermanorum

Cambarus angularis

Cambarus appalachiensis

Cambarus asperimanus

Cambarus brimleyorum

Cambarus legiomo

Cambarus callainus

Cambarus carinirostris

Cambarus carolinus

Cambarus catagius

Cambarus causeyi

Cambarus chasmodactylus

Cambarus chaugaensis

Cambarus davidi

Cambarus distans

Cambarus dubius

Cambarus eeseehensis

Cambarus extraneus

Cambarus fetzneri

Cambarus franklini

Cambarus georgiae

Cambarus girardianus

Cambarus hatfieldi

Cambarus hiwasseeensis

Cambarus hobbsorum

Cambarus howardi

Cambarus hubbsi

Cambarus hystricosus

Cambarus jezerinaci

Cambarus johni

Cambarus latimanus

Cambarus lenati

Cambarus longirostris

Cambarus longulus

Cambarus magerae

Cambarus monongalensis

Cambarus nodosus

Cambarus ortmanni

Cambarus parrishi

Cambarus parvoculus

Cambarus pristinus

Cambarus reburus

Cambarus reduncus

Cambarus sciotensis

Cambarus spicatus

Cambarus striatus

Cambarus theepiensis

Cambarus tuckasegee

Cambarus veteranus

Cambarus zophonastes

Creaserinus caesius

Creaserinus clausus

Creaserinus fodiens

Creaserinus gilpini

Creaserinus hedgpethi

Fallicambarus devastator

Fallicambarus dissitus

Fallicambarus harpi

Fallicambarus houstonensis

Fallicambarus jeanae

Fallicambarus kountzeae

Fallicambarus macneesei

Fallicambarus petilicarpus

Fallicambarus strawni

Fallicambarus tenuis

Fallicambarus wallsi
Faxonella beyeri
Faxonella blairi
Faxonella clypeata
Faxonella creaseri
Faxonius acares
Faxonius carolinensis
Faxonius castaneus
Faxonius causeyi
Faxonius compressus
Faxonius cristavarius
Faxonius cyanodigitus
Faxonius deanae
Faxonius difficilis
Faxonius erichsonianus
Faxonius eupunctus
Faxonius forceps
Faxonius juvenilis
Faxonius lancifer
Faxonius leptogonopodus
Faxonius longidigitus
Faxonius luteus
Faxonius macrus
Faxonius maletae
Faxonius marchandi
Faxonius meeki
Faxonius menae
Faxonius nais
Faxonius nana
Faxonius occidentalis
Faxonius ozarkae
Faxonius palmeri
Faxonius placidus
Faxonius punctimanus
Faxonius raymondi
Faxonius sanbornii
Faxonius sloanii
Faxonius spinosus
Faxonius texanus
Faxonius virginienis
Faxonius wagneri
Faxonius williamsi
Hobbseus prominens
Lacunicambarus acanthura
Lacunicambarus ludovicianus
Lacunicambarus nebrascensis

Lacunicambarus polychromatus
Lacunicambarus thomai
Orconectes pellucidus
Procambarus ablusus
Procambarus albaughi
Procambarus ancylus
Procambarus braswelli
Procambarus brazoriensis
Procambarus ceruleus
Procambarus curdi
Procambarus dupratzii
Procambarus elegans
Procambarus enoplosternum
Procambarus fayettei
Procambarus geminus
Procambarus gracilis
Procambarus hinei
Procambarus incilis
Procambarus kensleyi
Procambarus lepidodactylus
Procambarus liberorum
Procambarus luxus
Procambarus medialis
Procambarus natchitochae
Procambarus nechesae
Procambarus nigrocinctus
Procambarus nueces
Procambarus ouachitae
Procambarus parasimulans
Procambarus parvus
Procambarus pearsei
Procambarus plumimanus
Procambarus regalis
Procambarus 2egiomontanus
Procambarus reimeri
Procambarus simulans
Procambarus spiculifer
Procambarus steigmani
Procambarus texanus
Procambarus tulaneii
Procambarus versutus
Procambarus viaeviridis
Procambarus vioscai
Procambarus zonangulus

Family Cercopagididae

Bythotrephes cederstroemi

Family Cyclopidae

Acanthocyclops brevispinosus
Acanthocyclops capillatus
Acanthocyclops columbiensis
Acanthocyclops exilis
Acanthocyclops parasensitivus
Cyclops divergens
Cyclops sibiricus
Diacyclops albus
Diacyclops chrisae
Diacyclops jeanneli
Diacyclops nearcticus
Diacyclops palustris
Diacyclops sororum
Megacyclops latipes
Mesocyclops americanus
Mesocyclops pehpeiensis
Mesocyclops ruttneri
Metacyclops dengizicus
Microcyclops diaphanus
Microcyclops rubellus
Paracyclops canadensis
Paracyclops chiltoni
Rheocyclops virginianus
Thermocyclops decipiens

Family Daphniidae

Ceriodaphnia lacustris
Daphnia hyalina
Daphnia lumholtzi
Scapholeberis kingii
Simocephalus exspinosus
Simocephalus punctatus

Family Ergasilidae

Neoergasilus japonicus

Family Gammaridae

Chaetogammarus ischnus

Family Miraciidae

Schizopera borutzkyi

Family Palaemonidae

Calathaemon holthuisi
Macrobrachium acanthurus
Macrobrachium carcinus
Macrobrachium nipponense
Macrobrachium ohione
Macrobrachium olfersii
Palaemon antrorum
Palaemon ritteri
Palaemon texanus
Troglocubanus eigenmanni
Urocaris longicaudata

Fish

Family Atherinopsidae

Labidesthes vanhyningi
Menidia clarkhubbsi
Menidia extensa
Menidia peninsulae

Family Catostomidae

Carpiodes carpio
Cycleptus elongatus
Cycleptus meridionalis
Hypentelium roanokense
Ictiobus bubalus
Ictiobus cyprinellus
Ictiobus niger
Moxostoma albidum
Moxostoma ariommum
Moxostoma austrinum
Moxostoma cervinum
Moxostoma collapsum
Moxostoma congestum
Moxostoma hubbsi
Moxostoma pappillosum
Moxostoma poecilurum
Moxostoma robustum
Moxostoma rupiscartes
Thoburnia hamiltoni
Thoburnia rhothoeca
Xyrauchen texanus

Family Centrarchidae

Ambloplites ariommus
Ambloplites cavifrons
Ambloplites constellatus

Archoplites interruptus
Lepomis humilis
Lepomis miniatus
Lepomis symmetricus
Micropterus coosae
Micropterus henshalli
Micropterus punctulatus
Micropterus treculii

Family Cichlidae

Coptodon zillii
Geophagus steindachneri
Gymnogeophagus balzanii
Herichthys cyanoguttatus
Herichthys labridens
Herichthys minckleyi
Herichthys steindachneri
Maylandia zebra
Oreochromis aureus
Rubricatochromis guttatus

Family Clupeidae

Alosa alabamae
Brevoortia gunteri
Brevoortia smithi

Family Cottidae

Cottus baileyi
Cottus caeruleomentum
Cottus carolinae
Cottus girardi
Cottus gobio
Cottus hypselurus
Cottus kanawhae
Cottus leiopomus
Myoxocephalus scorpioides

Family Cyprinidae

Agosia chrysogaster
Campostoma ornatum
Campostoma spadiceum
Chrosomus cumberlandensis
Chrosomus oreas
Chrosomus saylori
Chrosomus tennesseensis
Codoma ornata

Cyprinella camura
Cyprinella chloristia
Cyprinella galactura
Cyprinella labrosa
Cyprinella lepida
Cyprinella monacha
Cyprinella nivea
Cyprinella panarcys
Cyprinella proserpina
Cyprinella pyrrhomelas
Cyprinella venusta
Cyprinella zanema
Dionda argentosa
Dionda diaboli
Dionda episcopa
Dionda flavipinnis
Dionda melanops
Dionda nigrotaeniata
Dionda serena
Dionda texensis
Erimystax cahni
Erimystax harryi
Erimystax insignis
Gila nigrescens
Gila pandora
Hybognathus amarus
Hybognathus argyritis
Hybognathus hayi
Hybognathus placitus
Hybopsis amnis
Hybopsis hypsinotus
Hybopsis rubrifrons
Hypophthalmichthys molitrix
Hypophthalmichthys nobilis
Luxilus albeolus
Luxilus cardinalis
Luxilus cerasinus
Luxilus pilsbryi
Luxilus zonatus
Luxilus zonistius
Lythrurus fasciolaris
Lythrurus fumeus
Lythrurus lirus
Lythrurus matutinus
Lythrurus roseipinnis
Lythrurus snelsoni

Macrhybopsis aestivalis
Macrhybopsis australis
Macrhybopsis hyostoma
Macrhybopsis marconis
Macrhybopsis meeki
Macrhybopsis tetranema
Mylopharyngodon piceus
Nocomis asper
Nocomis leptocephalus
Nocomis platyrhynchus
Nocomis raneyi
Notropis alborus
Notropis altipinnis
Notropis amabilis
Notropis ariommmus
Notropis atrocaudalis
Notropis bairdi
Notropis braytoni
Notropis buccula
Notropis buchanani
Notropis chihuahua
Notropis chiliticus
Notropis chlorocephalus
Notropis cummingsae
Notropis girardi
Notropis greenei
Notropis jemezianus
Notropis leuciodus
Notropis lutipinnis
Notropis maculatus
Notropis mekistocholas
Notropis micropteryx
Notropis nubilus
Notropis ortenburgeri
Notropis oxyrhynchus
Notropis ozarcanus
Notropis percobromus
Notropis perpallidus
Notropis potteri
Notropis rubricroceus
Notropis sabinae
Notropis scabriceps
Notropis scepticus
Notropis semperasper
Notropis shumardi
Notropis simus

Notropis spectrunculus
Notropis telescopus
Notropis topeka
Notropis wickliffi
Notropis xaenocephalus
Phenacobius crassilabrum
Phenacobius teretulus
Phenacobius uranops
Pimephales tenellus
Platygobio gracilis
Pteronotropis hubbsi
Rhinichthys osculus
Semotilus lumbee
Semotilus thoreauianus

Family Dorosomatidae

Harengula clupeola
Harengula jaguana

Family Ehiravidae

Clupeoides borneensis

Family Fundulidae

Fundulus blairae
Fundulus chrysotus
Fundulus dispar
Fundulus grandis
Fundulus jenkinsi
Fundulus kansae
Fundulus lineolatus
Fundulus notatus
Fundulus nottii
Fundulus pulvereus
Fundulus rathbuni
Fundulus sciadicus
Fundulus seminolis
Fundulus stellifer
Fundulus waccamensis
Fundulus xenicus
Fundulus zebrinus
Lucania goodei

Family Gobiidae

Awaous banana
Awaous tajasica
Bathygobius soporator

Callogobius depressus
Ctenogobius boleosoma
Ctenogobius claytonii
Ctenogobius smaragdus
Evorthodus lyricus
Gobioides broussonnetii
Gobionellus hastatus
Lophogobius cyprinoides
Microgobius gulosus
Proterorhinus marmoratus
Proterorhinus semilunaris

Family Ictaluridae

Ameiurus platycephalus
Ameiurus serracanthus
Ictalurus lupus
Ictalurus pricei
Noturus albater
Noturus elegans
Noturus eleutherus
Noturus flavater
Noturus flavipinnis
Noturus furiosus
Noturus gilberti
Noturus lachneri
Noturus leptacanthus
Noturus maydeni
Noturus phaeus
Noturus stigmosus
Noturus taylora
Prietella phreatophila
Satan eurystomus
Trogloglanis pattersoni

Family Percidae

Ammocrypta clara
Ammocrypta vivax
Crystallaria asprella
Crystallaria cincotta
Etheostoma acuticeps
Etheostoma artesia
Etheostoma asprigene
Etheostoma autumnale
Etheostoma brevispinum
Etheostoma chlorobranchium
Etheostoma chlorosoma

Etheostoma clinton
Etheostoma collettei
Etheostoma collis
Etheostoma cragini
Etheostoma denoncourti
Etheostoma duryi
Etheostoma euzonum
Etheostoma fonticola
Etheostoma fragi
Etheostoma fricksium
Etheostoma gracile
Etheostoma grahami
Etheostoma gutselli
Etheostoma histrio
Etheostoma inscriptum
Etheostoma jessiae
Etheostoma juliae
Etheostoma kanawhae
Etheostoma kennicotti
Etheostoma lepidum
Etheostoma longimanum
Etheostoma maria
Etheostoma meadia
Etheostoma microperca
Etheostoma mihileze
Etheostoma moorei
Etheostoma obama
Etheostoma oophylax
Etheostoma osburni
Etheostoma pallididorsum
Etheostoma parvipinne
Etheostoma perlongum
Etheostoma podostemone
Etheostoma pottsii
Etheostoma proeliare
Etheostoma punctulatum
Etheostoma radiosum
Etheostoma rubrum
Etheostoma rufilineatum
Etheostoma sanguifluum
Etheostoma serrifer
Etheostoma simoterum
Etheostoma spectabile
Etheostoma stigmaeum
Etheostoma swannanoa
Etheostoma teddyroosevelt

Etheostoma thalassinum
Etheostoma thompsoni
Etheostoma tippecanoe
Etheostoma uniporum
Etheostoma virgatum
Etheostoma vitreum
Etheostoma vulneratum
Etheostoma whipplei
Etheostoma zonale
Gymnocephalus cernua
Percina apristis
Percina aurantiaca
Percina bimaculata
Percina brucehompsoni
Percina carbonaria
Percina crassa
Percina cymatotaenia
Percina fulvitaenia
Percina gymnocephala
Percina macrolepida
Percina nasuta
Percina nevisensis
Percina notogramma
Percina oxyrhynchus
Percina pantherina
Percina rex
Percina roanoka
Percina sciera
Percina shumardi
Percina squamata
Percina uranidea
Percina westfalli
Percina williamsi

Family Poeciliidae

Belonesox belizanus
Gambusia clarkhubbsi
Gambusia gaigei
Gambusia geiseri
Gambusia heterochir
Gambusia hurtadoi
Gambusia krumholzi
Gambusia marshi
Gambusia nobilis
Gambusia puncticulata
Gambusia speciosa

Heterandria formosa
Poecilia formosa
Poecilia latipinna
Poecilia sphenops
Xiphophorus hellerii
Xiphophorus variatus

Family Synbranchidae

Monopterus albus

Mollusks

Family Ampullariidae

Marisa cornuarietis
Pomacea canaliculata
Pomacea diffusa
Pomacea paludosa

Family Cyrenidae

Corbicula fluminalis

Family Hydrobiidae

Potamopyrgus antipodarum

Family Viviparidae

Callinina intertexta
Campeloma coarctatum
Campeloma geniculum
Heterogen longispira
Viviparus viviparus

Plants

Family Commelinaceae

Murdannia keisak

Family Cyperaceae

Carex adelostoma
Carex atrofusca
Carex austrodeflexa
Carex capillacea
Carex chapmanii
Carex cherokeensis
Carex crebriflora
Carex fissa
Carex fuliginosa
Carex fumosimontana
Carex hirtissima

Carex holostoma
Carex hyalina
Carex idahoensis
Carex lachenalii
Carex marina
Carex micropoda
Carex opaca
Carex pigra
Carex serratodens
Carex subspathacea
Carex ursina
Carex verrucosa
Cyperus albostriatus
Cyperus haspan
Cyperus ochraceus
Cyperus papyrus
Eleocharis albida
Eleocharis elongata
Eleocharis kamtschatica
Eleocharis mamillata
Eleocharis nigrescens
Eleocharis vivipara
Fimbristylis decipiens
Fimbristylis perpusilla
Fimbristylis quinquangularis
Fuirena breviseta
Isolepis cernua
Lipocarpha occidentalis
Rhynchospora baldwinii
Rhynchospora caduca
Rhynchospora chapmanii
Rhynchospora ciliaris
Rhynchospora colorata
Rhynchospora crinipes
Rhynchospora debilis
Rhynchospora elliottii
Rhynchospora galeana
Rhynchospora harperi
Rhynchospora latifolia
Rhynchospora microcarpa
Rhynchospora miliacea
Rhynchospora mixta
Rhynchospora pleiantha
Rhynchospora pusilla
Rhynchospora stenophylla
Schoenoplectiella saximontana

Schoenus rigens
Scirpus divaricatus
Scirpus flaccidifolius
Trichophorum pumilum

Family Haloragaceae
Myriophyllum ussuriense

Family Hydrocharitaceae
Najas marina
Stratiotes aloides

Family Lythraceae
Ammannia robusta

Family Onagraceae
Ludwigia alata
Ludwigia bonariensis
Ludwigia decurrens
Ludwigia erecta
Ludwigia glandulosa
Ludwigia grandiflora
Ludwigia hyssopifolia
Ludwigia lanceolata
Ludwigia linifolia
Ludwigia maritima
Ludwigia microcarpa
Ludwigia ravenii
Ludwigia uruguayensis
Ludwigia virgata

Family Plantaginaceae
Bacopa monnieri

Family Poaceae
Andropogon capillipes
Andropogon liebmannii
Antinoria agrostidea
Arctophila fulva
Aristida palustris
Arundinella leptochloa
Axonopus furcatus
Calamagrostis deschampsiioides
Calamagrostis nutkaensis
Chasmanthium nitidum
Ctenium aromaticum

Dichanthelium curtifolium
Echinochloa crus-pavonis
Eriophorum scheuchzeri
Glyceria nubigena
Glyceria pulchella
Hemarthria altissima
Leersia lenticularis
Leptochloa panicoides
Luziola fluitans
Muhlenbergia expansa
Muhlenbergia lindheimeri
Muhlenbergia sericea
Panicum gymnocarpum
Panicum obtusum
Paspalidium geminatum
Paspalum acuminatum
Paspalum bifidum
Paspalum urvillei
Phippsia algida
Puccinellia andersonii
Puccinellia phryganodes
Puccinellia stricta
Puccinellia vaginata
Saccharum baldwinii
Sacciolepis indica
Schizachyrium rhizomatum
Sphenopholis filiformis
Sporobolus pinetorum
Sporobolus teretifolius
Thinopyrum elongatum
Zizania latifolia