Management of Biological Invasions (2025) Volume 16, Issue 3: 725–747

Special Issue: Proceedings of the 23rd International Conference on Aquatic Invasive Species
Guest editor: Mattias Johansson

Management in Practice

Benefits of standardized surveys and data centralization: a case study using New York's Watercraft Inspection Steward Program Application (WISPA)

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Editor's Note: This study was contributed in relation to the 23rd International Conference on Aquatic Invasive Species held in Halifax, Nova Scotia, Canada, May 12–16, 2024 (https://icais.org/past-conferences/). This conference has provided a venue for the exchange of information on various aspects of aquatic invasive species since its inception in 1990. The conference continues to provide an opportunity for dialog between academia, industry and environmental regulators.

Citation: Haws A, Marino J, O'Neill M, Dean J, Pearson S, McGlynn C (2025) Benefits of standardized surveys and data centralization: a case study using New York's Watercraft Inspection Steward Program Application (WISPA). *Management of Biological Invasions* 16(3): 725–747, https://doi.org/10.3391/mbi.2025.16.3.08

Received: 11 December 2024
Accepted: 17 May 2025
Published: 22 July 2025

Thematic editor: Mattias Johansson

Abstract

Minimizing overland transport of aquatic invasive species (AIS) via recreational watercraft is an essential component of invasive species spread prevention. Watercraft inspections at launch sites are a widely applied strategy to reduce human-mediated transport of AIS to protect priority waterbodies and offer public education and training of preventative cleaning procedures. Watercraft inspections also represent an opportunity to collect useful information for ecosystem managers on watercraft movement patterns and species occurrences that can be applied to risk assessments and early detection rapid response programs. New York State (NYS) in the Northeastern USA implemented use of a Watercraft Inspection Steward Program Application (WISPA) in 2018, which is a form-based survey that populates a centralized database with several data fields that include spatially explicit location, watercraft type, origin waterbody, and species observations. Coordinated and standardized collection of this data equips AIS managers with substantial information to make data-driven decisions. Here, we summarize the information collected in the WISPA database during the first six years of use and highlight two key management uses for this information using a set of eight popular destination lakes. Boater connectivity maps of origin-destination links are valuable to acknowledge the breadth of origins travelling to NYS destinations, and to identify the highest-magnitude connections that likely represent increased-risk pathways for species transport. "Hits" analysis is an applied mechanism to relate species interceptions to a confirmed presence database to identify previously undocumented species occurrences and direct early detection rapid response survey priorities. WISPA has been effective to establish the data infrastructure needed to support systematized data collection during watercraft inspection surveys and increase managers' ability to make informed decisions about AIS management.

Key words: spread prevention, boat stewards, Early Detection Rapid Response, network analysis

Introduction

Recreational boater movements represent a major vector of aquatic invasive species (AIS) secondary spread (i.e., continued spread of established invasive species to additional sites) by creating complex overland interconnections from invaded to uninvaded systems (Cole et al. 2019; Kao et al. 2021; Pradhananga et al. 2015; Rothlisberger et al. 2010; Vander Zanden and Olden 2008). Watercraft inspection programs have been widely adopted in response to this pathway, to reduce the likelihood of transfer and introduction of AIS biomass attached to the exterior (e.g., trailer, hull, motor), and interior (e.g., anchor, bilge, and live wells) structures of recreational vessels (Moore et al. 2024). Inspections typically consist of visually checking all boating and other recreational equipment (e.g., personal floatation devices, fishing tackle, bait buckets) before and/or after use of a waterbody, and removing all plants, animals, sediment, and water. Inspections additionally offer an opportunity for effective public education and outreach that can garner support for environmental stewardship programs and bolster the effectiveness of outreach campaigns (e.g., "Clean. Drain. Dry."; "Stop Aquatic Hitchhikers") employed at public access points (Cimino and Strecker 2018; Moore et al. 2024). Widespread adoption by recreationists to inspect and clean their watercraft is a critical hurdle for effective prevention and slowing of AIS secondary spread (Golebie et al. 2023; Moore et al. 2024; Pradhananga et al. 2015; Vander Zanden and Olden 2008).

New York State (NYS) is in the Northeastern USA with extensive opportunities for residents and visitors to access lakes, ponds, rivers, and coastal marine areas. Waterways in NYS are particularly vulnerable to the introduction and spread of AIS through shipping ports on two of the Laurentian Great Lakes and the Atlantic coast, and extensive canal systems connecting waterbodies and drainages (Hinchey et al. 2013). Numerous aquatic invasive species have established widespread distributions in NYS (e.g., zebra mussels, *Dreissena polymorpha* (Pallas, 1771); curly-leaved pondweed, *Potamogeton crispus* (Linnaeus, 1753); Eurasian watermilfoil, *Myriophyllun spicatum* (Linnaeus, 1753)), while other species are currently limited in extent but are at risk of further spread (e.g., hydrilla, *Hydrilla verticillata* (Royle, 1839); spiny waterflea, *Bythotrephes longimanus* (Leydig, 1860); starry stonewort, *Nitellopsis obtusa* (Groves, 1919); Asian freshwater clam, *Corbicula fluminea* (O.F. Müller, 1774)). Widespread boater movements across the landscape make AIS prevention a challenging endeavor, and NYS has implemented regulations and developed a network of local and regional organizations focused on spread prevention (Hinchey et al. 2013; NYSDEC 2018). New York State's Watercraft Inspection Steward Program (WISP) is intended to support 6 New York Codes, Rules and Regulations Part 576 (6 CRR-NY 576 2015; NYSDEC 2018), which requires that all watercraft be cleaned, drained, and dried (or treated) before launching into public waters.

The earliest Steward Program in NYS was established in the early 2000's and the statewide WISP has since expanded to host stewards at more than 200 boat launches. Launches are chosen based on frequency of use, accessibility, risk of introduction or spread, and capacity. In general, watercraft inspections are not required at most stations, but all watercraft users must take spread prevention measures. All stewards are tasked with talking with recreationists about their purpose for visiting a waterbody and determining if the recreationists have encountered stewards before and have taken preventive measures on their own. We note that in some cases the aforementioned data may not be a true representation of a boater's activity and experience. Once this initial conversation is complete, stewards assist watercraft users with voluntary inspections and cleaning of their equipment before (i.e., launching inspection) and/or after (i.e., retrieval inspection) use of a waterbody, thus ensuring compliance with Part 576 (NYSDEC 2022). At select locations, additional decontamination services (e.g., pressurized hot water washing station) are also made available depending on local program resources and priorities, especially at locations where boats frequently launch after overland transport from known AIS source waterbodies. NYSDEC and New York State Office of Parks, Recreation, and Historic Preservation collaborated with the New York Natural Heritage Program to develop a standardized survey titled "WISPA" (Watercraft Inspection Steward Program Application) and a centralized GIS database as a repository for data collected using the survey. Establishing this survey and centralized database enables consistency in data collection and reporting across inspection stations, which in turn facilitates better state-wide analyses of species detections and boater movements that can be used to improve AIS prevention and management (van Rees et al. 2022).

One of the benefits of WISPA is to improve understanding of boater connectivity patterns between waterbodies. Estimating the relative magnitude of watercraft movements between systems is useful to reconstruct routes of AIS dispersal and identify specific locations that are likely to serve as sources or recipients of AIS (Escobar et al. 2019; Kao et al. 2021; Vander Zanden and Olden 2008). The WISPA survey protocol involves asking the operator to indicate if and where the watercraft was launched in the previous two weeks prior to launching at the current location (NYSDEC 2022). Assessing the extent of boater connections is often limited due to lack of comprehensive data, but survey information collected via WISPA offers the opportunity to identify waterbodies across NYS with extensive connections via boat traffic. This information can then be used to direct outreach and infrastructure such as decontamination units, mobile systems that provide hot water at high pressure to rinse watercraft and trailer surfaces and compartments, to locations with high risks of spreading and/or receiving invasive species (Haight et al. 2021; Kao et al. 2021; Stewart-Koster et al. 2015).

In addition to estimating connectivity, WISPA data provides the opportunity to use AIS interceptions on watercraft leaving waterbodies to detect invasions in locations where the species was not previously documented. Spatiotemporally explicit information on species occurrences is fundamental to design field surveys, prioritize sites for active management interventions, and provide supporting information for regulatory decisions (van Rees et al. 2022). New York State uses novel species observations in a waterbody to trigger early detection rapid response (EDRR) efforts using "hits" analysis, where records of AIS encountered during retrieval are compared to existing observation records in a centralized invasive species occurrence database, iMapInvasives (NatureServe 2021). AIS detections by stewards can either be a "match" to iMapInvasives, meaning that the species has a previously confirmed presence in the waterbody, or represent a "hit" where there is no previously confirmed presence of the detected species in the waterbody. Upon a new species "hit", managers can verify and delineate the extent of species establishment in that previously unknown location. Integration of watercraft inspection data and iMapInvasives provides a more comprehensive depiction of species' spatial extents in the state, and "hits" analysis increases coordination for identification and assessment of newly detected species, with the goal of detecting new species populations at early stages of invasion when eradication is possible.

Invasive species research and policy actions often require collating data across sources, and it is imperative that standards and formats be established to improve the quality and relevance of established data infrastructure, and avoid data loss or incompatibility (Groom et al. 2017; Rice 2007). Empirical information on spread patterns of AIS is needed by policy and management decisionmakers to support risk analyses, horizon scanning, and rapid response planning, create decision support tools, and intercept non-native organisms along spread corridors (Reaser et al. 2020). Platforms that can enable the exchange of information about invasive species occurrence and spread between entities at international, national, and subnational scales is increasingly encouraged to improve coordination and identify pathways of dispersal (Büyüktahtakın and Haight 2018; Groom et al. 2017; Reaser et al. 2020; Wallace et al. 2020). WISPA makes progress towards establishing protocols, standards, and formats to create an aggregate database of watercraft inspections with consistent interoperability between data collection origins that could be expanded to assemble information at larger geographical scales (Groom et al. 2017; Wallace et al. 2020).

Synthesis of the data collected during watercraft inspections and making the information publicly available is vital in fostering confidence among recreational boaters that the behaviors they take to prevent the spread of AIS are effective and beneficial (Rothlisberger et al. 2010). We analyzed the information collected through the first six years of using WISPA (2018–2023) to summarize the core data collected by the application, create boater movement networks that identify high-magnitude links for a selection of eight popular destination lakes, and highlight the mechanism of "hits" analysis to couple the outcomes of boat inspections with EDRR programs.

Materials and methods

Watercraft Inspection Steward Program Application (WISPA)

WISPA is a survey form within Esri's Survey123 mobile application. All stewards from participating organizations use WISPA to document every boater survey, including visual observations by the steward and verbal responses from the boater to questions asked by the steward. During each inspection, stewards are prompted with the series of standardized questions and discrete response options on tablet computer devices to complete the survey, enabling them to enter the data immediately and minimize transcription errors. The data collection application automatically populates some metadata fields (e.g., date, time, location) thereby increasing speed of the inspection process and supporting data quality. Each record represents one survey for watercraft being launched or retrieved, with several core fields required in every record that represent the standard questions asked and observations made by stewards for every watercraft inspection (Table 1). Some programs opt for custom questions and data fields in addition to the core survey to facilitate local data needs while maintaining the consistency and standardization of the core survey data across all programs. Completed surveys are uploaded to populate a cloud-based spatial database in Esri's ArcGIS Online platform, where the information collected by stewards is reviewed and quality-checked by the program managers of each participating host organization. This results in a centralized database of boater surveys and inspections conducted each year, providing opportunities for analyzing overland boat traffic and the movement of invasive species between waterbodies, and changes in boater involvement in spread prevention measures. Analyses are conducted with the understanding that not all boaters may be forthright in their responses.

WISPA summary

Data from the core survey fields recorded during the first six years of WISPA implementation (2018–2023) were summarized. Total sums of survey records were calculated according to program year and each of the nine NYSDEC regions (each region is a distinct area with unique geography and management goals) to describe spatiotemporal coverage of NYS's WISP. The waterbody with the most completed inspections in each NYSDEC region was identified. The relative proportion of launching versus retrieved watercraft were evaluated, and the composition of boaters accessing NYS's recreational waterways were characterized by registration locations and types of inspected vessels (e.g., motorboat, kayak, personal watercraft, etc.). Species observations were summarized separately for launching and retrieval directions, and the proportion of inspections where any material or at least one invasive species detected was determined for each direction. Retrieval records where at least one invasive species was detected were further used for the "hits" analysis (see below).

Table 1. Summary of core fields in the WISPA data collection form, required for all surveys.

Field Name	Description
Launch name	Boat launch site where the survey was conducted.
Organization	Name of WISP host organization
Location	Geographic coordinates for the launch where the survey was conducted.
Date	Date that the survey was conducted.
Launch direction	Launching (boat entering the waterbody) or retrieving (boat exiting the waterbody)
Watercraft type	Select from: motorboat, personal watercraft (jet ski), kayak, canoe, sailboat, rowboat, stand-up paddleboard, windsurfer, barge (construction), or dock.
Boater Registration	State/province code at the beginning of the boater registration.
Was the watercraft in water in the past two weeks?	Whether the watercraft was in the same or different waterbody within the past two weeks, if known, as a potential indicator of aquatic invasive hitchhikers.
Last waterbody used by this watercraft	Select from list of waterbodies by state, with a free-text field available if not listed.
Did the watercraft user agree to an inspection?	Yes or no; for most programs the inspection is voluntary.
Organisms or debris detected on the watercraft or trailer	Multiselect from organism list, with free-text field available if the taxon is not listed.

The extent of boater movement between waterbodies was examined using responses to the "Was the watercraft in water in the past two weeks?" field. The different response options were tallied and represented as the percentage of total observations in the WISPA database. Additionally, the proportion of records where the response was "Yes, different waterbody" were computed by destination lake, and the waterbodies with the highest percentage of surveys specifying boater movement between waterbodies were identified. Records where the operator indicated "Yes, different waterbody" were further used for connectivity analyses (see below).

We selected eight case study destinations to showcase the variability of waterbody and connectivity information that can be derived from the database. Waterbodies with the most survey records in NYSDEC regions 5–9 were used, because regions 1–4 remain data limited. We also selected the inter-jurisdictional waterbody with the most survey records (i.e., waterbody that shares shoreline with another US state or Canadian province), and two waterbodies with the highest percentages of boaters reporting inter-waterbody movement. The five most popular waterbodies were indicative of highest spread and/or introduction risk while the interjurisdictional waterbody demonstrates the potential risk of introduction from neighboring states. The remaining two waterbodies illustrated the risk of a waterbody receiving high amounts of boaters with movement between systems. We selected these eight destination waterbodies to further demonstrate the management utility of connectivity analyses and "hits" analysis derived from WISPA information.

All summary and statistical analysis was conducted in R version 4.3.2 (R Core Team 2023).

Connectivity analysis

Connectivity networks are produced using responses that indicate the watercraft was used in a different body of water (origin waterbody) prior to launching at the new location (destination waterbody) following overland transport. Survey records from separate launches on a single waterbody are aggregated to the waterbody level, and origin-destination links are mapped to show overland watercraft pathways from the origin waterbody stated by the watercraft user to the destination body where the survey occurred. Each pathway is summarized to determine the number of survey records that specify each origin-destination link, which can indicate the relative risk of AIS spread via different pathways (Escobar et al. 2019; Rothlisberger et al. 2010). The waterbody mapping layer was originally derived from the National Hydrography Dataset (USGS 2018), with subsequent updates. For some unknown or unrecorded origin waterbodies outside NYS, particularly those with few records, the centroid of state/province was used as the origin. The results are published on an annual basis to an interactive data viewer developed using the ArcGIS Web AppBuilder (Esri Inc. 2024), and shared with WISP coordinators and regional AIS managers, allowing users to filter by origin or destination waterbody.

We produced a set of maps using the full aggregated database of reported pathways for the set of eight case study waterbodies: Chautauqua Lake, Keuka Lake, Cayuga Lake, Skaneateles Lake, Black Lake, Lower Saranac Lake, Lake George, and Lake Champlain. We measured the distance between each origin waterbody (when known, otherwise state/province) centroid to the destination waterbody centroid. Mean distance of all reported origins to a given destination waterbody were compared to the mean distance of the 10 most frequently reported origins using a t-test.

"Hits" analysis

The goal of "hits" analysis is to identify instances where an invasive species detection during a watercraft retrieval survey suggests the presence of a species not otherwise documented in the waterbody (referred to as a "hit"). The analysis focused on a suite of fourteen species including the most frequently reported non-native species, several prohibited and regulated AIS, and priority AIS selected by NYSDEC and WISP managers ("focal species"). Observations of the focal species upon retrieval for each waterbody in WISPA are compared spatially (using ArcGIS software by Esri) to the known occurrences of that species within the centralized NYS Invasive Species Database hosted through iMapInvasives (NatureServe 2021), which stores aggregated species occurrence data from natural resource managers, community science contributors, and other databases such as the USGS Nonindigenous Aquatic Species Database (USGS 2024).

We extracted all waterbodies that were associated with watercraft inspection records (for data between 2018 and 2023) from the National Hydrography Dataset (USGS 2018) into a discrete layer to serve as the foundation for the analysis. The dataset comprising observations of existing populations and occurrences was dynamically accessed via a web feature service (WFS) from iMapInvasives. For each species, the WFS was filtered to only return occurrence records for that species. An intersection with the waterbodies was then performed with the filtered occurrences. All waterbodies with any intersecting species occurrence records were assigned a value of "1" in a data field representing presence of that species. Next, each retrieving watercraft inspection record where at least one species was detected by the steward was spatially joined to the waterbody to which it is physically connected. All retrieval records were then aggregated by waterbody and by sum of the detection count for each species. For each waterbody feature, each retrieving species detection sum is then compared to the waterbody species "Presence" value. Each instance of retrieving species detection count greater than zero and waterbody "Presence" value for that species equal to zero constituted a "hit", or potential data gap species for the specific combination of species and waterbody.

The results of the "hits" analysis are published in an Esri online map viewer (Esri Inc. 2024) for WISP managers and regional AIS coordinators to review. In some cases, a "hit" may indicate a data gap or an opportunity for early detection. AIS professionals are encouraged to conduct surveys for the "hit" species within the waterbody and then submit an observation or not detected survey record to iMapInvasives to determine if an established population exists for the species. Species flagged as a "hit" do not guarantee an actual infestation in need of documenting, but rather an actionable trigger to direct on-the-ground surveillance. We summarized the potential gap species identified via hits analysis for the eight case study lakes.

Results

Watercraft Inspection Steward Program Application (WISPA) summary

New York State's centralized WISPA database contains inspections from 19 host organizations, 166 waterbodies, and 333 launches. A total of 1.352.849 watercraft inspections were entered from 2018–2023, with an average of 225,475 ± 91,589 (mean ± SD) entries annually (Supplementary material Table S1). Currently, WISPA coverage is unequal across NYS, with downstate regions (NYSDEC regions 1–3, Figure 1) having fewer surveyed launches and total records than the rest of the state (Table 2). Destination waterbodies with the most inspection records in each NYSDEC region are outlined in Table S2.

Launching inspections (n = 834,189) exceeded retrieving inspections (n = 518,660), making up a majority (62%) of the database. Motorboats comprise the bulk (68%) of inspected vessels, with non-motorized watercraft (i.e., kayaks, canoes, stand-up paddleboards, rowboats, windsurfers) making up a smaller portion (22%) of inspection records (Table S3). The majority (63.8%) of inspected boats were registered within NYS, and much of the representation from other states or provinces came from those contiguous with New York (i.e., Vermont, Pennsylvania, New Jersey, Quebec, Massachusetts, Connecticut) (Table 3).

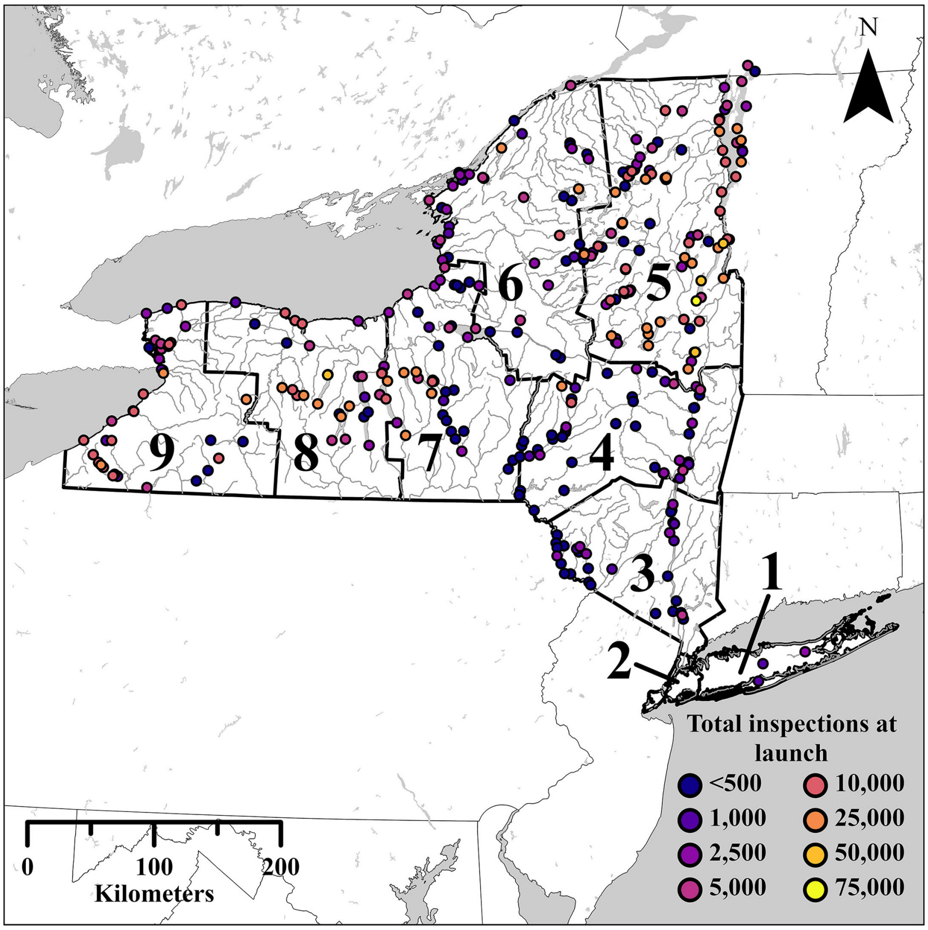

Figure 1. Map of boat launches surveyed as part of New York State WISP, where inspection data has been collected using WISPA. Boundaries within New York represent Department of Environmental Conservation regions.

Table 2. Summary of watercraft survey records from different NYSDEC regions. NYSDEC Region 2 is the five boroughs of New York City and there are no public boat launches into freshwater lakes or ponds.

NYSDEC Region	n (%)
1	1,880 (0.1%)
3	18,483 (1.4%)
4	55,076 (4.1%)
5	510,968 (37.8%)
6	90,154 (6.7%)
7	123,505 (9.1%)
8	193,563 (14.3%)
9	120,976 (8.9%)
Border	238,244 (17.6%)
Total	1,352,849
Average	150,317

Organisms or other debris were identified and removed during 141,383 inspections (10.5%), and 66,623 (5.0%) of records included detection of invasive species. Fourteen AIS, including 9 macrophyte species and 5 invertebrate species, have been intercepted during WISP inspections (Table 4). Invasive species interceptions were over seven times more common in retrieval inspections (n = 54,910, 10.6%) than launching inspections (n = 11,713;

Table 3. The ten most frequent registration states or provinces represented among watercraft inspected in New York State.

Registration State	n (%)
New York	863,343 (63.8%)
Vermont	59,066 (4.4%)
Pennsylvania	46,613 (3.4%)
New Jersey	15,470 (1.1%)
Ohio	11,612 (0.9%)
Québec	8,251 (0.6%)
Massachusetts	7,336 (0.5%)
Connecticut	6,281 (0.5%)
New Hampshire	5,208 (0.4%)
Florida	4,017 (0.3%)

Table 4. Observed aquatic taxa and the number of records where they were detected during launching and retrieving inspections. **M. heterophyllum* is considered native to some waterbodies in Western and Southern New York, but is introduced in much of the state, and both *M. heterophyllum* and its nearly indistinguishable hybrid with *M. laxum* are prohibited invasive species in New York State (Howard 2024; Part 575 Prohibited and Regulated Invasive Species 2015; Werier et al. 2024).

	Species	Common Name	Native to New York	n [launching]	n [retrieving]
Macrophytes	*Vallisneria americana*	Water celery	Yes	6,736	45,252
	Myriophyllum spicatum	Eurasian watermilfoil	No	7,192	33,098
	Potamogeton spp.	Native pondweed species	Yes	5,909	30,832
	Potamogeton crispus	Curly pondweed	No	3,137	21,275
	Elodea spp.	Elodea species	Yes	3,078	17,761
	Ceratophyllum demersum	Coontail; Hornwort	Yes	2,787	14,372
	Nitellopsis obtusa	Starry stonewort	No	246	1,610
	Myriophyllum heterophyllum	Variable-leaf watermilfoil	Yes*	245	1,553
	Nymphaeaceae	Native lily species	Yes	80	1,261
	Trapa natans	Water chestnut	No	461	1,084
	Najas minor	Brittle naiad	No	66	760
	Utricularia spp.	Bladderwort species	Yes	71	645
	Hydrocharis morsus-ranae	European frogbit	No	17	167
	Egeria densa	Brazilian waterweed	No	13	59
	Hydrilla verticillata	Hydrilla	No	12	3
Invertebrates	*Dreissena polymorpha*	Zebra mussel	No	1,981	7,642
	Bythotrephes	Waterflea species	No	54	673
	Dreissena bugensis	Quagga mussel	No	83	279
	Corbicula fluminea	Asian clam	No	6	12
	Faxonius rusticus	Rusty crayfish	No	1	9
N/A	Miscellaneous Debris	N/A	N/A	10,313	11,721
	Unknown	N/A	N/A	1,521	1,624
	Total			44,009	191,692

1.4%). We recognize that certain AIS may persist following a launch and may not accurately indicate presence in a waterbody upon retrieval. The most frequently intercepted AIS include Eurasian watermilfoil (*Myriophyllum spicatum*), curly pondweed (*Potamogeton crispus*), and zebra mussel (*Dreissena polymorpha*).

Most boaters reported past activity in the same waterbody (33.1%) or that the watercraft had not been launched in the last two weeks (18.6%) (Table 5). However, 9.7% of boaters reported recent activity in different waterbodies, providing data for movement and connectivity analyses (n = 131,776). Two to nineteen percent of boaters in all surveyed waterbodies

Table 5. Summary of responses to "Was the watercraft in water in the past two weeks?" data field.

Boater Response	n (%)
Yes, different waterbody	131,776 (9.7%)
Yes, same waterbody	447.958 (33.1%)
Not launched	251,557 (18.6%)
Rented or borrowed	4,933 (0.4%)
Refused to answer	1,181 (0.1%)
Unknown / blank	515,444 (38.1%)

reported arriving from a different waterbody. The top lakes where the highest percentage of surveyed boaters reported movement between waterbodies are outlined in Table S4.

Waterbodies with the most survey records in NYSDEC regions 5–9 were Lake George, Black Lake, Cayuga Lake, Keuka Lake, and Chautauqua Lake, respectively (Table S2). Lake Champlain was the interjurisdictional waterbody with the most inspection records (Table S2). Skaneateles Lake and Lower Saranac Lake exhibited the highest recorded proportions of inter-waterbody traffic (Table S4). This set of waterbodies were selected as case studies to present connectivity and "hits" analysis results.

Connectivity analysis

Connectivity maps produced for the eight case study lakes are contained in Figures 2–3. These case study lakes were connected to an average of 309 ± 103 (mean ± SD) different origins (Figure 2, 3). The mean (± SD) distance of the ten most frequently reported origin lakes (104.96 km ± 68.25 km) was significantly shorter than the mean (± SD) distance for all connected waterbodies (320.78 km ± 59.61 km) ($t_{(13)} = 6.43$, $P < 0.05$) (Figure 4).

"Hits" analysis

In the eight case study lakes from the connectivity analysis, there were 143 reported detections of focal species on watercraft exiting waterbodies where the species was not documented in iMapInvasives ("hits", Table 6). Macrophyte species comprised more ($n_{(observations)} = 115$, $n_{(species)} = 5$) of the hits than animals ($n_{(observations)} = 28$, $n_{(species)} = 3$), which is consistent with macrophytes being generally more frequently reported (see Table 4). There was at least one hit for each of the eight case study lakes, with Skaneateles Lake having the most species not matched – out of the nine species reported on watercraft exiting the waterbody, five were not documented in iMapInvasives. The most frequent hit among the case study lakes was *Najas minor* in Lake Champlain (n = 56). There were no hits in the case study lakes for six of the fourteen focal species, meaning these species were only detected on retrieving watercraft at case study lakes where the species were already documented in iMapInvasives: *Corbicula fluminea, Dreissena polymorpha, Hydrilla verticillata, Myriophyllum spicatum, Nitellopsis obtusa,* and *Potamogeton crispus.*

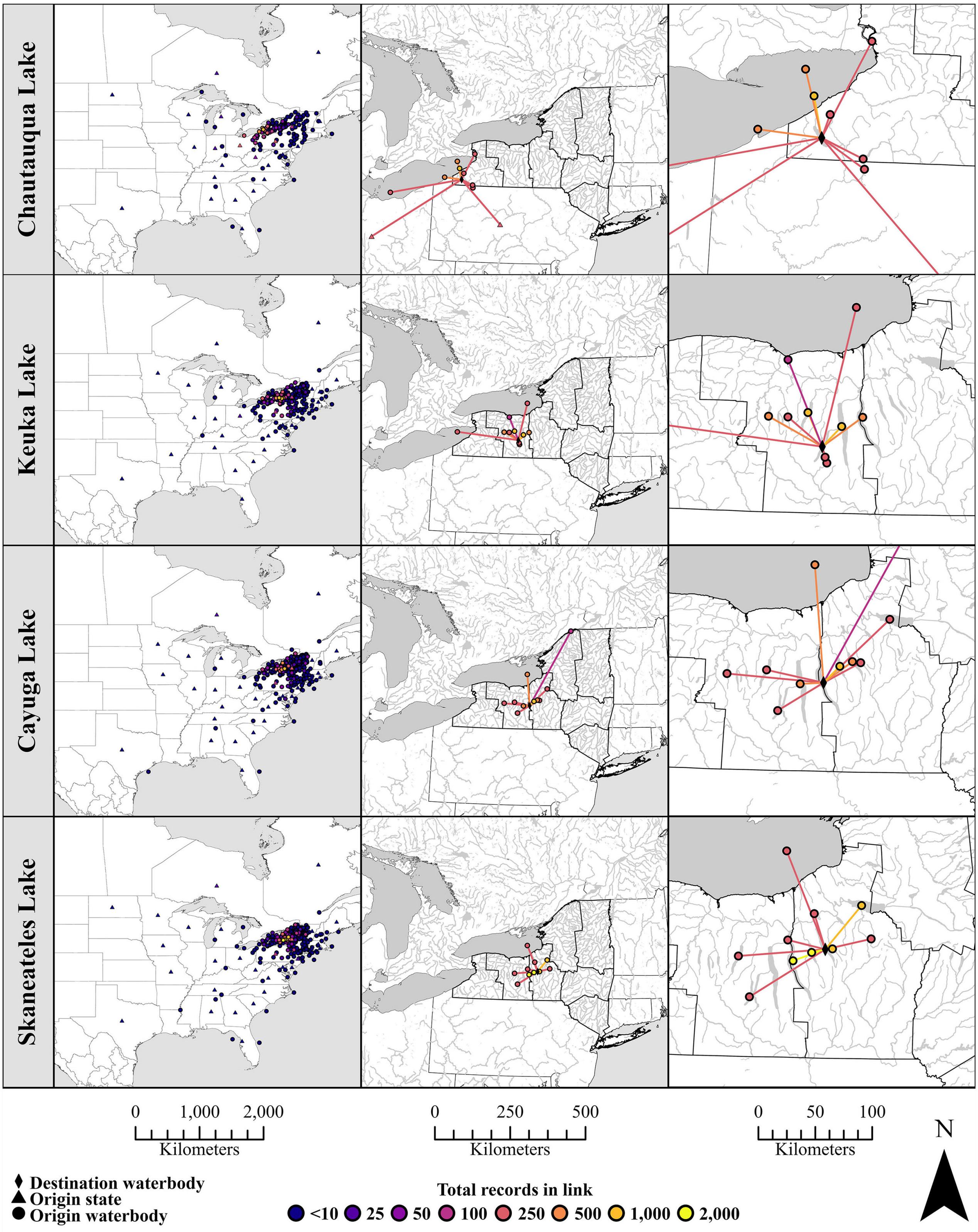

Figure 2. Watercraft origins for four selected destination lakes: Chautauqua Lake, Keuka Lake, Cayuga Lake, and Skaneateles Lake. The first column of panels displays a zoomed-out view of all origin waterbodies recorded for each destination, only showing points east of the continental divide. The middle column shows the ten most frequently reported origin waterbodies for each destination, with zoomed-in views in the rightmost column.

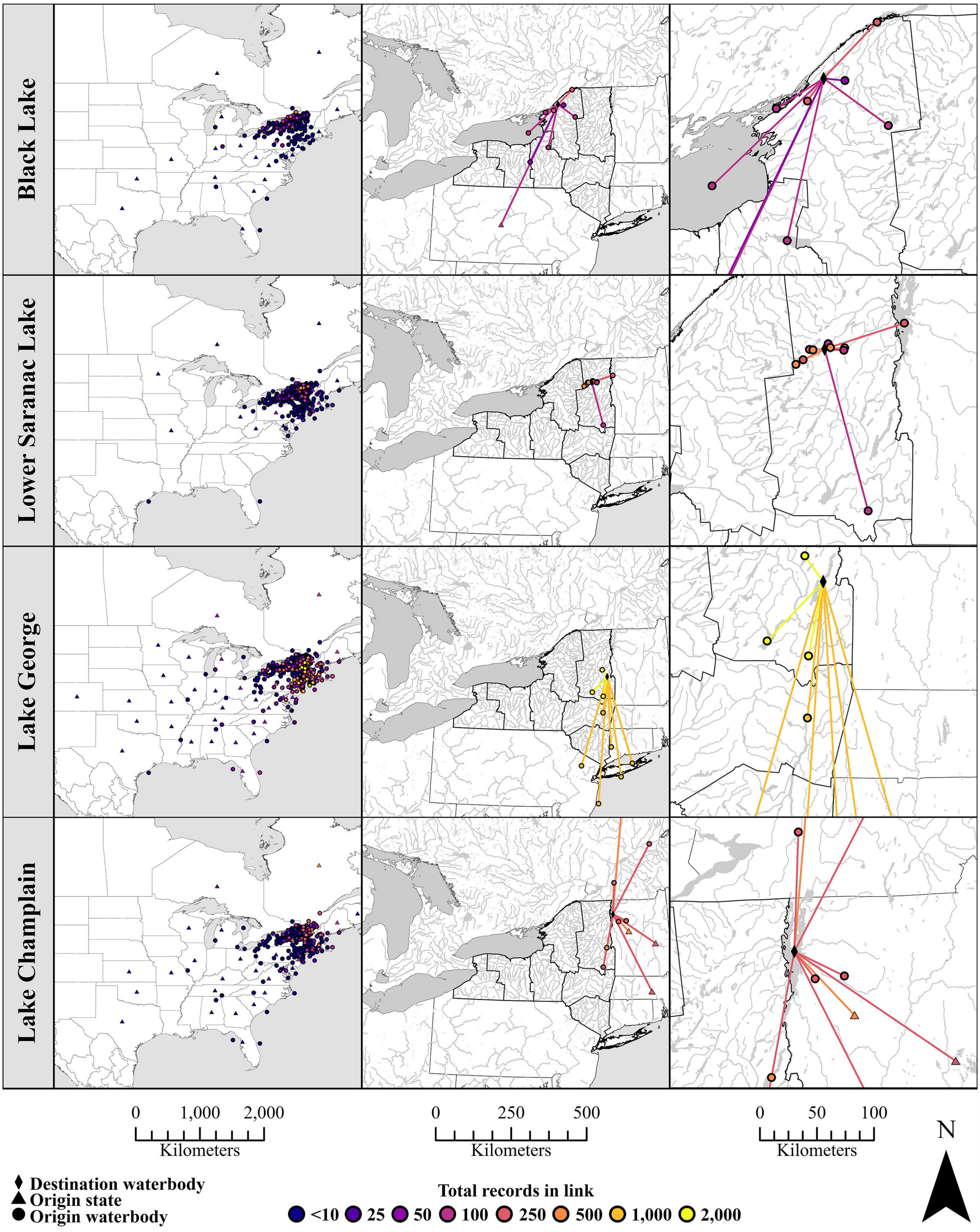

Figure 3. Watercraft origins for four selected destination lakes: Black Lake, Lower Saranac Lake, Lake George, and Lake Champlain. The first column of panels displays a zoomed-out view of all origin waterbodies recorded for each destination, only showing points east of the continental divide. The middle column shows the ten most frequently reported origin waterbodies for each destination, with zoomed-in views in the rightmost column.

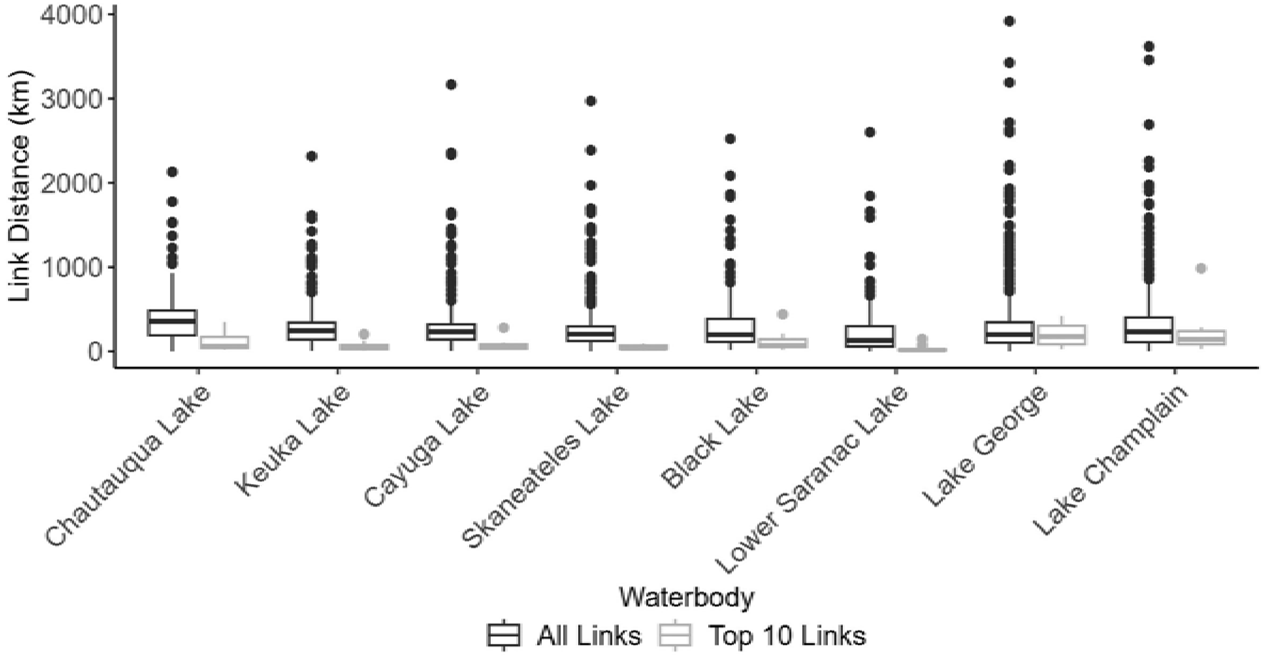

Figure 4. Boxplot of link distances for all origin lakes and the ten most frequently reported origins for eight selected destination lakes in New York State.

Table 6. Summary of potential gap species and number of flagged inspection records through "hits" analysis for the eight case study lakes from 2018-2023. A * symbol denotes agreement between WISPA retrieving data and iMapInvasives Confirmed Presence for that particular species/waterbody combination.

	Species	Chautauqua Lake	Keuka Lake	Cayuga Lake	Skaneateles Lake	Black Lake	Lower Saranac Lake	Lake George	Lake Champlain
Macrophytes	*Cabomba caroliniana*			6	9				
	Egeria densa	1	9	16					
	Hydrilla verticillata			*					
	Hydrocharis morsus-ranae	2		*	3	*			
	Myriophyllum spicatum	*	*	*	*	*	*	*	*
	Najas minor	*	*	*	1	6			56
	Nitellopsis obtusa	*	*	*	*				
	Potamogeton crisups	*	*	*	*	*	*	*	*
	Trapa natans	*	*	*	1	*	1	4	*
Invertebrates	*Bythotrephes*	1	*	*	6				*
	Corbicula fluminea			*					
	Dreissena bugensis	18	*	*					
	Dreissena polymorpha	*	*	*	*	*		*	*
	Faxonius rusticus			3					

Discussion

WISPA summary

New York State has implemented substantial infrastructure to slow the human-mediated spread of AIS via recreational boating through expansion of the state's WISP. The centralized WISPA database for watercraft inspection survey records establishes a systematized process for curation and assessment of information collected at a state-wide level. Data management and analysis are inherent precursors to science-based decision making, and implementation of a data repository platform is an important step toward coordinated and spatially prioritized AIS research, management, and outreach (Reaser et al. 2020; Rice 2007; van Rees et al. 2022). The core survey fields are used to better understand waterbody connectivity and species geographic distributions, and to identify previously unknown introductions. It is important to collect data from watercraft travelling in both directions from a waterbody, as different aspects of spread prevention are detailed in launching versus retrieval data. Interceptions of AIS on watercraft prior to launching illustrate prevention of new introductions, while retrieval inspections can demonstrate species containment and reductions in overland transport from infested waterbodies. The repository of watercraft inspections further offers the opportunity to meet data needs to investigate trends over time, guide surveillance programs, predict the spread of AIS, and recognize social and ecological patterns of AIS among recreational waterways (van Rees et al. 2022). Each waterbody where surveys are prioritized in NYS has a unique inventory of boater use, existing AIS, and potential AIS, and managers can use the extensive WISPA dataset to support informed management choices. The information contained in WISPA is rapidly growing, by an average of a quarter of a million records annually, and our capacity to employ this dataset to refine AIS programming is continually increasing. However, for this data collection platform to have the most impact, the information needs to be shared across state and international lines to recognize the potential for spread out of NYS, and implementation of WISPA should be expanded beyond NYS to more consistently document boater movements and AIS interceptions at a larger geographic scale.

Connectivity analysis

Boaters in NYS are highly mobile, with nearly ten percent of inspected watercraft reporting recent activity in a different waterbody than where the survey occurred. Network analyses are useful to reconstruct the flow of watercraft between waterbodies and illustrate high-magnitude pathways with an elevated risk of invasive species transport (Escobar et al. 2019). We found that while some boaters will travel long distances between waterbodies, most boaters travel short distances to their destinations indicating that frequent boating networks occur most commonly at the local or regional scale (Figure 4). This pattern of boater movements may suggest that "stepping stone" invasions may be central to AIS spread across NYS, where recreational boaters visit waterbodies with high connectivity and popularity that are more likely to have established AIS, and subsequently travel to other local waterbodies and facilitate regional spread (Floerl et al. 2009). Targeted invasive species control and management in waterbodies with the highest traffic and connectivity is likely necessary to reduce overall spread from shorter-distance movement (Floerl et al. 2009; Havel et al. 2015). However, at certain lakes there are also extensive records of watercraft coming from outside of NYS. For example, destination lakes near or overlapping the state border (e.g., Chautauqua Lake, Lake George, Lake Champlain) experience substantial boater movement from other states or provinces that are adjacent to New York (e.g., Vermont, Pennsylvania, Massachusetts, Quebec) (Figures 2–4). We also note that since state/province centroids were used for some origins outside NYS, the lengths of distances from origins outside NYS may be generalized. These state/province centroids are a standardized way of representing origins from unknown waterbodies outside NYS. Even though boats that have longer travel distances may exhibit lower spread risk due to potential desiccation and mortality of organisms in transport, many AIS are known to remain viable after substantial drying (Barnes et al. 2013; Bickel 2015; Coughlan et al. 2018; Evans et al. 2011). Waterbody connectivity across northeastern North America demonstrated by WISPA data emphasizes that invasive species vectors do not observe political boundaries, and interstate and international coordination is necessary to achieve risk reduction goals (Büyüktahtakın and Haight 2018; Otts and Nanjappa 2016).

"Hits" analysis

Efficient AIS management relies on accurate knowledge of the spatial distribution of species' established populations and rapid identification and management of introductions while there is an opportunity for eradication (Finley et al. 2023). Traditional monitoring approaches using field surveys to achieve robust coverage over large geographical areas are time and personnel intensive (van Rees et al. 2022). Alternatively, these survey data sets can be supplemented using watercraft retrieval inspection data, where species observations can refine our knowledge of spatial extents, and flag previously unknown occurrence locations to reduce the time between introduction and first detection. "Hits" analysis is a mechanism that notifies regional AIS managers who are responsible for determining the need of response to previously unknown species occurrences, and this type of alert system is a core principle outlined in the US national invasive species information framework to support EDRR (Reaser et al. 2020). Each of the case study waterbodies we examined produced at least one "hit" across a range of macrophyte and invertebrate species, illustrating the waterbody-specific utility of this analysis to indicate potential presence of AIS. However, some species have been repeatedly reported during watercraft inspections but have not been confirmed in iMapInvasives (e.g., brittle naiad in Lake Champlain, Brazilian waterweed in Cayuga Lake, quagga mussels in Chautauqua Lake). These species may be confused by stewards with morphologically similar native or non-native species, suggesting that more targeted training of commonly misidentified species may be necessary. The summary of "hits" presented here can inform program managers for which species they need to provide better training with "look alike" species to improve confidence in the "hits" output. Nonetheless, community-generated data from watercraft retrieval inspections is particularly valuable to increase statewide species occurrence monitoring coverage and provide a useful action trigger for managers when a species "hit" is produced to inform EDRR surveys.

Limitations

There are limitations and biases to WISP data, including spatial biases in the regional and waterbody-specific distribution of staffed launches. Despite the substantial number of waterbodies and launches that are monitored as part of NYS's WISP, there are data gaps in the state's spatial coverage (i.e., NYSDEC regions 1–3) because launches are assigned based on ownership, user volume, program involvement, accessibility, risk of spread, and capacity. Furthermore, because participation in watercraft inspections is a voluntary action on the part of boaters in most locations, some individuals refuse to participate in the survey, or the accuracy of information solicited from the watercraft users (e.g., past activity, frequency of practicing preventative behaviors) may be dubious if offered reluctantly. We also found that proportional to launching inspections, retrievals were underrepresented in WISPA due to boaters staying on the water beyond the active hours of steward personnel, or a desire to clear the launch space as quickly as possible. Furthermore, there are numerous private launches throughout waterbodies in NYS, which generally do not have stewards conducting inspections. Even for waterbodies with inspection programs at local public launches, the dataset is not comprehensive for that waterbody unless private launches are also surveyed. Additionally, variation in staffing and inspection effort across sites poses challenges for comparing the magnitude of different origin-destination links. For example, the number of watercraft moving from Cayuga Lake to Skaneateles Lake may be higher than the number of watercraft moving from Cayuga Lake to Seneca Lake either because of a true difference in boater traffic, or simply because there are more stewards present at Skaneateles Lake to survey watercraft launching there. In the future, standardizing the frequency of each origin-destination link using an estimate of steward effort at each destination waterbody could mitigate potential biases.

Another potential limitation in the WISP dataset is reliance on species detections made visually by stewards at boat launches. Some aquatic plants can be difficult to visually distinguish from one another, especially when only plant fragments are available (e.g. the various native and non-native species of *Myriophyllum*). This issue is partially mitigated through standard AIS identification training for stewards across the state, providing stewards with species identification resources such as guidebooks, the option to report an "unknown" organism in the WISPA survey, and program managers verifying the species identity of key detections via photograph or specimen. Additionally, some aquatic invasive species are not visible to the native eye, particularly larval stages of aquatic invertebrates (e.g., veligers of zebra mussel, *Dreissena polymorpha*), which is why boaters are asked to drain water containing compartments during inspections. Furthermore, attached AIS (e.g., Dreissenid mussels) can persist following launches and retrievals, and observation of such species during watercraft retrievals may not accurately indicate presence from that particular waterbody if it were to generate a "hit". "Hits" analysis reveals potential data gaps or data quality issues that managers can address. For example, if data managers review photo attachments to verify "hits" for particular species and find them to be unverifiable, program managers can then provide additional training to stewards on identifying those species and how to collect specimens for verification. In addition, that waterbody may be added to the aquatic plant survey rotation for the next field season.

Future directions

Future applications of WISPA data will focus on risk assessments, surveillance priorities, and active management recommendations (van Rees et al. 2022). Species distribution and network models are two analytical tools that are useful to integrate the current spatial extent of AIS and potential source waterbodies, habitat suitability of vulnerable recipient waterbodies, and the probability of spread between origin-destination pairs via boater movement networks (Escobar et al. 2019; van Rees et al. 2022). These types of analyses would advance our ability to anticipate invasions at the waterbody level, further direct EDRR, and prioritize management interventions to best minimize spread (Clarke Murray et al. 2011; Escobar et al. 2019; Vander Zanden and Olden 2008). Development of these models would be particularly valuable for species that currently have a limited distribution in NYS and a containment management focus (e.g., hydrilla, starry stonewort), cryptic invaders that may go unobserved by community scientists in iMapInvasives (e.g., spiny water flea, rusty crayfish), or species that may arrive from neighboring states or provinces (e.g., Connecticut River Hydrilla, *Hydrilla verticillata* ssp. *lithuanica*).

While NYS has prioritized AIS prevention and WISP covers much of the state, decontamination stations at every recreational access point. Therefore, limitations still prevent establishment of inspection and managers need to optimize locations with higher risk of introductions or spread by considering both social and ecological factors of a launch (Moore et al. 2024). Accomplishing effective placement of preventative AIS infrastructure requires knowledge of spatial distributions of AIS and connectivity between invaded and at-risk habitats created by anthropogenic spread vectors (Cimino and Strecker 2018; Fischer et al. 2020; Moore et al. 2024). Hierarchical gravity and route choice models have previously been used to identify optimal locations for roadside decontamination stations and WISPA offers the spatially explicit data needed to fit models that can be used to identify the optimal placement of new preventative infrastructure (Fischer et al. 2020).

The success of WISP and other outreach programs in creating boater self-efficacy and consistent practice of preventative behaviors should also be examined. NYS has invested in an elaborate network of voluntary inspection stations and, in some cases, decontamination stations at public access sites to teach recreational water users the protocol for preventative cleaning and educate about the impacts of AIS. However, risk reduction is also reliant on boaters conducting those behaviors when staff are not present. Outreach messages are shared broadly via online and physical media, signage and personnel at boat ramps, bait and boating stores, event tables, and personal communications between conservation authorities and the public. However, examination of the impact and outcomes of different types of public engagement to bridge the gap between research, management, and outreach and promote actual behavior change and support for investment in AIS management is needed to fine-tune messaging and outreach approaches (Cole et al. 2016; Seekamp et al. 2016).

Conclusions

It is difficult and expensive to remediate an ecosystem that has been degraded by AIS, and much of the costs are incurred from managing the density and spread of widely established species and reducing their direct damages (Cimino and Strecker 2018; Pimentel et al. 2005). Unfortunately, reintroduction vectors like recreational watercraft can reduce the efficacy of implemented management programs (Golebie et al. 2023; Moore et al. 2024). Therefore, preventing initial introductions and secondary spread via human vectors are essential for sustainable AIS management (Golebie et al. 2023; Vander Zanden and Olden 2008). Protecting freshwater ecosystems from introduction of AIS relies heavily on increasing public willingness to adopt consistent watercraft cleaning when travelling between waterbodies (Cimino and Strecker 2018). Embracing preventative boat cleaning is dependent on general awareness of the impacts that AIS have on aquatic ecosystems, how water recreationists can prevent the spread of AIS, and how invasive species are managed by environmental authorities (Cimino and Strecker 2018; Moore et al. 2024). Creating accessible, public-facing analysis and products that demonstrate how WISP surveys are used by ecosystem managers may improve support for AIS spread prevention behaviors and voluntary interactions with WISP personnel. Boater decisions to engage with preventative watercraft inspections are increased when AIS are perceived as a significant threat, individuals feel confident in their ability to execute the actions to prevent AIS spread, and believe these actions are effective in reducing AIS spread (Golebie et al. 2023; Moore et al. 2024; Seekamp et al. 2016). Watercraft inspections are a significant opportunity to both increase public familiarity with AIS and strengthen the understanding that spread prevention measures significantly reduce AIS spread and benefit native ecosystems (e.g., better recreational experience, healthier ecosystem, improved boat maintenance) (Golebie et al. 2023; Moore et al. 2024).

Controlling invasive species over large spatial scales and extended temporal periods is challenging due to the variable nature of human spread vectors and environmental conditions (Büyüktahtakın and Haight 2018). Creating models to predict where species may arrive and be capable of establishing requires large-scale empirical data that details landscape patterns of transport vectors (Büyüktahtakın and Haight 2018; Havel et al. 2015). In NYS, the vast number of recreational boats moving across the state, combined with the large number of waterbodies that can serve as sources and recipients of invasive species, makes spread prevention a difficult goal. Data infrastructure to streamline the collection, curation, analysis, sharing and preservation of this information is key to efficient decision making and program implementation. New York State is striving to harness the community-generated information derived from WISP to refine AIS spread prevention and management programs. Collection and sharing of standardized watercraft data beyond NYS, such as described by Gruninger et al. (2024), has the potential to enable a more complete regional understanding of overland watercraft movement and potential AIS vectors. The demonstrated connectivity between waterbodies across state and national lines, as well as the record of AIS interceptions from out of state watercraft, emphasizes the need for dedicated watercraft inspection steward programs and associated data sharing across North America.

Authors’ contribution

AH conducted data analysis and interpretation, prepared the original draft, reviewed and revised the manuscript. JM and MO conceptualized the study, curated the dataset, analyzed data, and contributed to manuscript writing and review. JD and SP assisted with study design and review of the manuscript. CM obtained approval to prepare the manuscript and share the dataset, conceptualized the study, secured funding, and contributed to manuscript writing and review.

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Acknowledgements

This work is the result of the countless individuals who participate in the New York State Watercraft Inspection Steward Program as host organizations, program coordinators, boat stewards, and voluntary participants. Thanks to the NYSDEC Invasive Species Coordination Section Chief, Josh Thiel, for helpful feedback on this manuscript. Thanks to Fate Syewoangnuan, who assisted with preparing the WISPA dataset for use and sharing. Many thanks to the Water Resources Institute Director, Brian Rahm, and colleagues at WRI for their feedback during preparation of this manuscript. Additional thanks to Meg Wilkinson, retired NYNHP Invasive Species Database Program Coordinator, for WISPA programmatic support and hits analysis conceptualization, as well as past NYNHP graduate interns and seasonal staff who supported scripting of the WISPA derivative analyses. We would also like to thank the anonymous reviewer(s) who provided feedback on this manuscript.

Funding declaration

Funding for this research and WISPA were provided by the New York State Environmental Protection Fund as administered by the New York State Department of Environmental Conservation.

References

Barnes M, Jerde C, Keller D, Chadderton W, Howeth J, Lodge D (2013) Viability of Aquatic Plant Fragments following Desiccation. *Invasive Plant Science and Management* 6: 320–325, https://doi.org/10.1614/IPSM-D-12-00060.1

Bickel TO (2015) A boat hitchhiker's guide to survival: *Cabomba caroliniana* desiccation resistance and survival ability. *Hydrobiologia* 746: 123–134, https://doi.org/10.1007/s10750-014-1979-1

Büyüktahtakın İE, Haight RG (2018) A review of operations research models in invasive species management: State of the art, challenges, and future directions. *Annals of Operations Research* 271: 357–403, https://doi.org/10.1007/s10479-017-2670-5

Cimino SA, Strecker AL (2018) Boater Knowledge and Behavior Regarding Aquatic Invasive Species at a Boat Wash Station. *Northwest Science* 92: 224–233, https://doi.org/10.3955/046.092.0308

Clarke Murray C, Pakhomov EA, Therriault TW (2011) Recreational boating: A large unregulated vector transporting marine invasive species. *Diversity and Distributions* 17: 1161–1172, https://doi.org/10.1111/j.1472-4642.2011.00798.x

Cole E, Keller RP, Garbach K (2016) Assessing the success of invasive species prevention efforts at changing the behaviors of recreational boaters. *Journal of Environmental Management* 184: 210–218, https://doi.org/10.1016/j.jenvman.2016.09.083

Cole E, Keller RP, Garbach K (2019) Risk of invasive species spread by recreational boaters remains high despite widespread adoption of conservation behaviors. *Journal of Environmental Management* 229: 112–119, https://doi.org/10.1016/j.jenvman.2018.06.078

Coughlan NE, Cuthbert RN, Kelly TC, Jansen MAK (2018) Parched plants: Survival and viability of invasive aquatic macrophytes following exposure to various desiccation regimes. *Aquatic Botany* 150: 9–15, https://doi.org/10.1016/j.aquabot.2018.06.001

Escobar LE, Romero-Alvarez D, Larkin DJ, Phelps NBD (2019) Network analysis to inform invasive species spread among lakes. *Journal of Oceanology and Limnology* 37: 1037–1041, https://doi.org/10.1007/s00343-019-7208-z

Evans CA, Kelting DL, Forrest KM, Steblen LE (2011) Fragment viability and rootlet formation in Eurasian watermilfoil after desiccation. *Journal of Aquatic Plant Management* 49: 57–62

Finley D, Dovciak M, Dean J (2023) A data driven method for prioritizing invasive species to aid policy and management. *Biological Invasions* 25: 2293–2307, https://doi.org/10.1007/s10530-023-03041-3

Fischer SM, Beck M, Herborg LM, Lewis MA (2020) A hybrid gravity and route choice model to assess vector traffic in large-scale road networks. *Royal Society Open Science* 7: 1–20, https://doi.org/10.1098/rsos.191858-

Floerl O, Inglis GJ, Dey K, Smith A (2009) The importance of transport hubs in stepping-stone invasions. *Journal of Applied Ecology* 46: 37–45, https://doi.org/10.1111/j.1365-2664.2008.01540.x

Golebie E, van Riper CJ, Hitzroth G, Huegelmann A, Joffe-Nelson N (2023) Barriers to participation in aquatic invasive species prevention among Illinois, USA recreational water users. *Biological Invasions* 25: 2549–2565, https://doi.org/10.1007/s10530-023-03055-x

Groom QJ, Adriaens T, Desmet P, Simpson A, De Wever A, Bazos I, Cardoso AC, Charles L, Christopoulou A, Gazda A, Helmisaari H, Hobern D, Josefsson M, Lucy F, Marisavljevic D, Oszako T, Pergl J, Petrovic-Obradovic O, Prévot C, Vanderhoeven S (2017) Seven Recommendations to Make Your Invasive Alien Species Data More Useful. *Frontiers in Applied Mathematics and Statistics* 3: 1–8, https://doi.org/10.3389/fams.2017.00013

Havel JE, Kovalenko KE, Thomaz SM, Amalfitano S, Kats LB (2015) Aquatic invasive species: Challenges for the future. *Hydrobiologia* 750: 147–170, https://doi.org/10.1007/s10750-014-2166-0

Haight RG, Kinsley AC, Kao SY, Yemshanov D, Phelps NBD (2021) Optimizing the location of watercraft inspection stations to slow the spread of aquatic invasive species. *Biological Invasions* 23: 3907–3919, https://doi.org/10.1007/s10530-021-02620-6

Hinchey E, Vogler D, Stressler J (2013) Marsh thistle in New York: Early detection and rapid response to a recent invader. *Annals of the New York Academy of Sciences* 1298: 95–102, https://doi.org/10.1111/nyas.12176

Kao SYZ, Enns EA, Tomamichel M, Doll A, Escobar LE, Qiao H, Craft ME, Phelps NBD (2021) Network connectivity of Minnesota waterbodies and implications for aquatic invasive species prevention. *Biological Invasions* 23: 3231–3242, https://doi.org/10.1007/s10530-021-02563-y

Lee Ii H, Reusser DA, Olden JD, Smith SS, Graham J, Burkett V, Dukes JS, Piorkowski RJ, Mcphedran J (2008) Integrated monitoring and information systems for managing aquatic invasive species in a changing climate. *Conservation Biology* 22: 575–584, https://doi.org/10.1111/j.1523-1739.2008.00955.x

Moore A, Ford D, Golebie E, Joffe-Nelson N, Hitzroth G, Huegelmann A, King S, Stein JA, van Riper CJ (2024) Social and ecological drivers of behavior that prevents aquatic invasive species transport. *Biological Invasions* 26: 1845–1859, https://doi.org/10.1007/s10530-024-03287-5

Otts S, Nanjappa P (ed) (2016) Model regulation for state watercraft inspection and decontamination programs. National Sea Grant Law Center, Oxford, Mississippi, USA, 42 pp

Pimentel D, Zuniga R, Morrison D (2005) Update on the environmental and economic costs associated with alien-invasive species in the United States. *Ecological Economics* 52: 273–288, https://doi.org/10.1016/j.ecolecon.2004.10.002

Pradhananga A, Davenport MA, Seekamp E, Bundy D (2015) Preventing the spread of aquatic invasive species: boater concerns, habits, and future behaviors. *Human Dimensions of Wildlife* 20: 381–393, https://doi.org/10.1080/10871209.2015.1030479

Reaser JK, Simpson A, Guala GF, Morisette JT, Fuller P (2020) Envisioning a national invasive species information framework. *Biological Invasions* 22: 21–36, https://doi.org/10.1007/s10530-019-02141-3

Rice B (2007) Invasive species data applications and data sharing across the Americas. *Frontiers in Ecology and the Environment* 5: W15–W16, https://doi.org/10.1890/1540-9295(2007)5[W15:ISDAAD]2.0.CO;2

Rothlisberger JD, Chadderton WL, McNulty J, Lodge DM (2010) Aquatic invasive species transport via trailered boats: what is being moved, who is moving it, and what can be done. *Fisheries* 35: 121–132, https://doi.org/10.1577/1548-8446-35.3.121

Seekamp E, McCreary A, Mayer JE, Zack S, Charlebois PM, Pasternak L (2016) Exploring the efficacy of an aquatic invasive species prevention campaign among water recreationists. *Biological Invasions* 18: 1745–1758, https://doi.org/10.1007/s10530-016-1117-2

Stewart-Koster B, Olden JD, Johnson PTJ (2015) Integrating landscape connectivity and habitat suitability to guide offensive and defensive invasive species management. *Journal of Applied Ecology* 52: 366–378, https://doi.org/10.1111/1365-2664.12395

van Rees CB, Hand BK, Carter SC, Bargeron C, Cline TJ, Daniel W, Ferrante JA, Gaddis K, Hunter ME, Jarnevich CS, McGeoch MA, Morisette JT, Neilson ME, Roy HE, Rozance MA, Sepulveda A, Wallace RD, Whited D, Wilcox T, Luikart G (2022) A framework to integrate innovations in invasion science for proactive management. *Biological Reviews* 97: 1712–1735, https://doi.org/10.1111/brv.12859

Vander Zanden MJ, Olden JD (2008) A management framework for preventing the secondary spread of aquatic invasive species. *Canadian Journal of Fisheries and Aquatic Sciences* 65: 1512–1522, https://doi.org/10.1139/F08-099

Wallace RD, Bargeron CT, Reaser JK (2020) Enabling decisions that make a difference: Guidance for improving access to and analysis of invasive species information. *Biological Invasions* 22: 37–45, https://doi.org/10.1007/s10530-019-02142-2

Websites, online databases and software

Esri Inc. (2024) ArcGIS Web AppBuilder (Version 2.30). Redlands, California, USA. https://developers.arcgis.com/web-appbuilder/ (accessed 5 September 2024)

Gruninger TM, Tucker-Silva TR, Weibert C (2024) Best practices from the interjurisdictional "Evaluate data sharing options for watercraft pathway" project. Great Lakes Commission. https://www.glpanel.org/wp-content/uploads/2024/09/Best-practices_Evaluate-data-sharing-options-for-watercraft-pathway-project.pdf (accessed 26 November 2024)

Howard V (2024) *Myriophyllum heterophyllum* Michx (Version 9/28/2023). United States Geological Survey Nonindigenous Aquatic Species Database. https://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=236 (accessed 24 November 2024)

NatureServe (2021) iMapInvasives: NatureServe's online data system supporting strategic invasive species management. Arlington, Virginia, USA. http://www.imapinvasives.org (accessed 5 September 2024)

NYSDEC (2015) NYS Department of Environmental Conservation. *New York State Aquatic Invasive Species Management Plan*, 132 pp https://extapps.dec.ny.gov/docs/fish_marine_pdf/nysaisplan15.pdf (accessed 17 November 2024)

NYSDEC (2018) NYS Department of Environmental Conservation. New York State Invasive Species Comprehensive Management Plan, 81 pp. https://extapps.dec.ny.gov/docs/lands_forests_|pdf/iscmpfinal.pdf (accessed 17 November 2024)
NYSDEC (2022) NYS Department of Environmental Conservation. New York State Watercraft Inspection Steward Program Manual, 82 pp. https://extapps.dec.ny.gov/docs/lands_forests_pdf/WISP_Manual_4.22.22_(2).pdf (accessed 17 November 2024)
Part 575 Prohibited and Regulated Invasive Species, 6 CRR-NY 575 (2015). http://nyrules.elaws.us/nycrr/title6_chapterv_subchapterc_part575 (accessed 17 November 2024)
Part 576 Aquatic Invasive Species Spread Prevention, 6 CRR-NY 576 (2015). http://nyrules.elaws.us/nycrr/title6_chapterv_subchapterc_part576 (accessed 17 November 2024)
R Core Team (2023) R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/ (accessed 5 September 2024)
USGS (2018) United States Geological Survey. National Hydrography Dataset (Version USGS National Hydrography Dataset Best Resolution (NHD) for Hydrologic Unit (HU) 4 - 2018). https://www.usgs.gov/national-hydrography/access-national-hydrography-products (accessed 5 September 2024)
USGS (2024) United States Geological Survey. Nonindigenous Aquatic Species Database-NAS. https://nas.er.usgs.gov/ (accessed 24 November 2024)
Werier D, Webster K, Weldy T, Nelson A, Mitchell R, Ingalls R (2024). *Myriophyllum heterophyllum*—Species Page. NYFA: New York Flora Atlas. https://newyork.plantatlas.usf.edu/Plant.aspx?id=1579 (accessed 17 November 2024)

Supplementary material

The following supplementary material is available for this article:

Table S1. Summary of annual survey records to WISPA and participating host organizations during 2018-2023.
Table S2. Waterbodies with the most records in WISPA for each NYSDEC region.
Table S3. Composition of different watercraft types inspected by New York's Watercraft Inspection Steward Program.
Table S4. Waterbodies with the highest percentage of boaters reporting "Yes, different waterbody" to past activity question of survey.

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