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Assessing the Success of Outreach at Preventing the Movement of Aquatic Invasive Species in Illinois

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ASSESSING THE SUCCESS OF OUTREACH AT PREVENTING THE MOVEMENT OF AQUATIC INVASIVE SPECIES IN ILLINOIS

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CHAPTER I

INTRODUCTION

With the increase in globalization, introductions of non-native species have risen resulting in harmful ecological and economic impacts for ecosystems across the globe (Hulme 2009; Pimentel et al. 2005). These non-native animals, plants, and their diseases, have been responsible for altering habitats, initiating the extinction of native species, and causing large financial costs (Mack et al. 2000). Globally, these non-native species are a major cause of environmental change (Sala et al. 2000) and the extent of negative impacts caused by these non-native species will continue to grow if rates of introduction and spread remain high (Keller et al. 2009).

Freshwater systems, which traditionally have been isolated by geographical barriers, are particularly at risk for non-native species introduction (Rahel 2007). The isolation of these systems have given rise to unique faunas (Rahel 2007) which support 6% of all described species and over 40% of the world's fish species (Lundberg et al. 2000). Thus, freshwater systems can be severely impacted by the introduction of non-native species as these species can alter habitats by outcompeting native species for resources (Mills et al. 1993) thereby causing the extinction of native species (Ricciardi et al. 1998) and reducing biodiversity.

Geographical barriers isolating freshwater systems have been removed through human mediated actions such as the dumping of ballast water, biofouling, the pet and aquarium trades, unintentional transport on recreational boats (Mills et al. 1993), as well as the building of canals, and water conveyance systems (Rahel 2007). For example, the construction of the Chicago Area Waterways System currently connects the Great Lakes basin and the Mississippi River and serves as a year round conduit for the movement of non-native species between these two water systems (Horner et al. 1999). As human actions provide a variety of ways which non-native species can be introduced and spread (Rahel 2007) since these actions have removed natural boundaries (Vander Zanden and Olden 2008), modifying human behavior to reduce non-native species introduction is an important strategy to prevent the loss of biodiversity.

Once introduced, non-native species can establish and spread, and are considered to be invasive if they cause environmental harm, economic harm, or both, to the waterbodies in which they establish (Kolar and Lodge 2001; Keller and Lodge 2007). There are many examples worldwide of the devastating effects of these aquatic invasive species (AIS) on freshwater systems. AIS include the Nile perch (*Lates nilotica*) introduced to Africa's Lake Victoria which has caused the extinction of numerous native fish species (Reinthal et al. 1994). Hydrilla (*Hydrilla verticillata*), an aquatic invasive weed from Asia introduced to the United States in 1960, has damaged aquatic habitats in Florida by displacing native plant species, and management costs for controlling this invader exceed 10 million dollars per year (Langeland 1996). These two examples illustrate the devastating effects that invasive species can have on the biodiversity of global ecosystems and the management costs these invaders can incur.

Many invasions have also occurred and continue to occur in the Mississippi River and Great Lakes basins. Bighead (*Hypophthalmichthys nobilis*) and silver (*H. molitrix)* carps (these species are often collectively referred to as Asian carp) are well-known invaders that escaped from aquaculture facilities in the 1980s into the Mississippi River and have been moving up the river, outcompeting native fish species for food ever since (Sampson et al. 2009). Another notorious invader is the zebra mussel (*Dreissena polymorpha*), which was accidentally transported to North America in the ballast tanks of ships from Eurasia and discovered in Lake St. Clair in 1988 (Mills et al. 1993). Since then, zebra mussels have spread throughout the United States decreasing the richness and abundance of native mussels and causing tens of millions of dollars in damages (Drake and Brossenbrook 2004; Mills et al. 1993).

The Mississippi River and Great Lakes Basins are characterized by each having a few large waterbodies (rivers, large lakes) and many isolated lakes. AIS can generally spread through natural means throughout the large waterbodies, but require human intervention if they are to become established in isolated lakes. For this type of spread, the behaviors of recreational boaters have proven to be the most important way through which these AIS are moved (Johnson et al. 2001). Boaters can transport AIS among waterbodies through four main vectors: on the boat exterior, in the boat interior (e.g., live wells or free water in the bottom of the boat), on fishing equipment, and through intentional transport and release. Through these vectors, recreational boaters have dispersed a range of AIS including crustaceans (Havel and Stelzleni-Schwent 2001), fishes (Hrabik and Magnuson 1999), mollusks (Padilla et al. 1996), plants (Rothlisberger and Lodge 2011), and others (Johnson et al. 2001).

Preventing the introduction and spread of AIS into freshwater systems is crucial to protect biodiversity (Gurevitch and Padilla 2004), and reduce economic losses (Keller et al. 2008). The nature of recreational boating involves many people traveling across the landscape following different routes, making possible AIS spread extremely difficult to monitor and control. For this reason, public education and outreach has been seen as a method to encourage boaters to make conservation efforts that can prevent further introductions and spread of AIS to freshwater systems (Strayer 2010; Vander Zanden and Olden 2008). These conservation efforts are behaviors related to boater hygiene habits such as cleaning the boat exterior, interior, and fishing tackle, as well as not transporting or releasing any organisms. Public outreach and education has specifically targeted recreational boaters (Strayer 2010), and represents a large investment in the limited available funding for conservation work.

Although public outreach and education efforts are a major investment for multiple management organizations, a large knowledge gap exists because very little is known about how these efforts impact boaters' perceptions, or influence boaters' adoption of behaviors that reduce AIS risk. In turn, this has limited the understanding of the relationship between boater behavior and patterns of AIS invasion on the landscape. Using the U.S. state of Illinois, which straddles the ecologically and economically important Laurentian Great Lakes and Mississippi River Basins, I investigate this knowledge gap using interview data from management organizations in Illinois and self-reported survey data from Illinois boaters.

Fourteen organizations that promote public education and outreach efforts concerning AIS prevention were interviewed and asked about their (1) use of public education and outreach materials which promote AIS messages; (2) investment in public outreach and education; (3) priorities for promoting AIS information in each of the five administrative regions of Illinois; and (4) interactions with each other in regard to AIS prevention. I then distributed a mail survey to Illinois boaters that evaluated (1) the usefulness of public outreach and education campaigns; (2) knowledge of AIS; (3) frequency of performance for behaviors that can prevent AIS spread via the boat exterior, boat interior, fishing tackle, and transport and release vectors, and (4) what waterbodies had been visited during the summer of 2013. By combining the manager interviews with the responses from boater surveys, I was able to examine how outreach is conducted, how it is received, how it impacts perceptions and knowledge of AIS, and most importantly, if and how it affects the behaviors of boaters to reduce AIS spread.

In Chapter II, I use network analysis to identify travel patterns of boaters among waterbodies and how these waterbodies were connected based on the behaviors of boaters. Network analysis has previously been used to describe the interactions and relationships among individuals or groups of people (Wasserman and Faust 1994). In my study, it offered a quantitative approach to describe how waterbodies are linked by the movement of recreational boaters. I use ecological data from a previous study that looked at the number of non-native species established in Illinois (Jacobs 2014), and this allowed me to understand possible movement of AIS based on the waterbodies that boaters were visiting and the AIS prevention behaviors they were performing as they moved among these waterbodies. I use data from my boater survey to evaluate what waterbodies had been visited and what behaviors boaters were likely performing at these waterbodies. As boaters who do not *Always* perform AIS prevention behaviors have a higher probability of moving AIS, the networks presented in Chapter II consider which waterbodies were visited by boaters that do not *Always* perform AIS prevention behaviors.

The network analyses presented in Chapter II integrate social and ecological data with the aim of advancing existing modeling and analysis approaches. Existing models attempt to anticipate what waterbodies will be invaded based on parameters such as boater travel habits, what waterbodies boaters find attractive, and frequency of visits (Leung et al. 2006; Buchan and Padilla 1999; Muirhead and MacIssac 2011; Schneider et al. 1998). Network analysis adds to this by integrating actual travel patterns of recreational boaters, including the waterbodies visited by boaters that do not *Always* perform AIS prevention behaviors. This approach can thus identify actual links among invaded and non-invaded waterbodies.

Although network analysis is a useful tool for conservation goals (Prell et al. 2009), such as identifying waterbodies at risk, completely preventing AIS introduction is seen as the best management approach (Mack et al. 2000) since complete eradication of AIS has rarely been achieved (Keller and Lodge 2007). Thus, public outreach and education efforts are crucial in influencing boater perceptions concerning AIS and increasing adoption and performance of behaviors which *Always* reduce introduction and spread.

Chapter III of my thesis investigates public outreach and education investments in Illinois as well as the influence of these efforts on boater perceptions and performance of behaviors that prevent AIS spread. This chapter evaluates the disconnect between the efforts of conservation organizations and outcomes among recreational boaters. I use my boater survey results to evaluate boaters' access to outreach, knowledge of AIS, and consistency of prevention behavior. Chapter III thus comprises an empirically-based approach to better understand how conservation outreach and education may support (or fail to support) widespread adoption and use of conservation behavior on the part of primary resource users (i.e., recreational boaters) to prevent invasion. As human behaviors and actions are a critical driver of introduction and spread, understanding how to best support behavioral change is important to reduce biodiversity loss to freshwater systems.

CHAPTER II

EXAMINING THE SPREAD OF AQUATIC INVASIVE SPECIES WITH RESPECT TO THE MOVEMENT OF RECREATIONAL BOATERS IN ILLINOIS

Introduction

The removal of barriers separating isolated waterbodies has increased the introductions of non-native species which in turn has critically damaged freshwater systems (Strayer 2010). These non-native species can be introduced through a variety of vectors including ballast water, biofouling, and the movement of recreational boats (Rothlisberger et al. 2010; Johnson et al. 2001; Schneider et al. 1998). Once established, non-native species can reduce biodiversity of freshwater ecosystems (Gurevich and Padilla 2004), cause large economic losses (Pimentel et al. 2005), and negatively affect human health (Pejchar and Mooney 2009).

The Laurentian Great Lakes is a highly invaded freshwater ecosystem that contains non-native species at almost every level of the food web (Pimentel et al. 2005; Mills et al. 1993). Many vectors, including intercontinental shipping and intentional stocking, have delivered non-native species to the Great Lakes. At least 180 of these species are now established, and many have subsequently spread to inland waterbodies throughout North America (Ricciardi 2006). This secondary spread has been mostly attributed to the movement of recreational boaters (Johnson et al. 2001; Leung et al. 2006). As boats are moved from one body of water to another, they can vector non-native species on the exterior of the boat, the boat interior (e.g., live wells, bilge, and free water at the bottom of the hull), on fishing tackle, and through boaters intentionally transporting and releasing organisms. These non-native species can then become introduced and establish in new waterbodies, with many causing severe impacts.

The spread of non-native species is widely considered to be major problem and much effort has been put towards monitoring and modeling patterns of spread. To determine dispersal patterns of non-native species and thus predict areas at risk, the use of models (e.g. gravity and diffusion) has been widespread (Muirhead and MacIssac 2011). These models use multiple variables such as; boater information (e.g. number of registered boats, travel distance among waterbodies, frequency of visits to waterbodies), waterbody attractiveness (i.e. waterbodies boaters prefer to frequent), as well as habitat suitability for non-native species (Leung et al. 2006; Buchan and Padilla 1999; Muirhead and MacIssac 2011; Schneider et al. 1998). Based on these data, an assortment of model types have been used to predict areas at greatest risk for non-native species introduction. An example of the insights that this work has produced is the knowledge that waterbodies at risk for the introduction of non-native species are often close to each other as boaters prefer to visit waterbodies within shorter driving distances (Buchan and Padilla 1999; Schneider et al. 1998). However, these models make the critical assumption that all boaters are behaving the same way. In particular, they assume that all boaters perform behaviors that reduce invasion risk at the same rate.

Public education and outreach has become a major management tool targeting recreational boaters with the ultimate goal of decreasing the spread of non-native species (Rothlisberger et al. 2010). State and federal agencies, as well as non-profit organizations use multiple types of media, events, and personal communication designed to inform boaters about aquatic invasive species (AIS) and how their personal behaviors can help prevent undesirable introduction and spread. For example, the *Protect Your Waters* campaign has operated across much of the United States for over a decade (U.S. Fish and Wildlife Service 2015). It has been presented to boaters through signs at boat ramps, stickers for cars and fishing gear, booths at boat shows, and other engagements. The main messages of this program are that boaters should remove all plants and animals before transporting equipment, clean and dry their equipment, eliminate water from their equipment, and never release any plants, fish or animals into the waterbodies they visit (U.S. Fish and Wildlife Service 2015). Through this outreach program and many others, boaters are informed of these conservation behaviors so they can appropriately clean the exterior and interior of their boat, their fishing tackle, and not transport and release any organisms. This form of education and outreach is seen as a useful strategy to prevent spread because in most cases, waterbodies are shared public resources; it is difficult or impossible to monitor all users to enforce consistent use of behaviors to prevent AIS introduction and spread. Public education that encourages adoption of these conservation behaviors is thus seen as an approach that matches the problem.

Illinois lies on the border of the Great Lakes and Mississippi River Basins. This border is easily traversed by movement of recreational boats overland from waterbody to waterbody. These Basins are also connected by the Chicago Area Water Way System, which serves as a year round conduit for the movement of non-native species (Horner et al. 1999). For these reasons, movement of non-native species into and around Illinois can have serious implications for ecosystems throughout much of North America (Jacobs 2014).

Examining patterns of boater movement and behaviors can shed light on broader patterns of invasion at the state, regional, and broader scales. Specifically, networks, such as connections among waterbodies realized by recreational boaters that visit more than one lake or river during the boating season, can be measured and analyzed using social network analysis (Scott 2000). In this paper, I focus on social networks that contain different stakeholders within a fairly well-defined management area, the U.S. state of Illinois, which can be used to inform management of common-pool resources such as public waterbodies (Bodin et al. 2006).

Using survey data from Illinois boaters, I assessed the travel patterns of boaters to determine the waterbodies they visit most often and the frequency with which they perform behaviors related to reducing spread of non-native species. I used network analysis and metrics to evaluate the network of waterbodies (nodes), connected by visits from recreational boaters (links) and considered density, the proportion of possible ties in a network that are actually present (Wasserman and Faust 1994); density is commonly used to measure the extent to which all nodes in a network are connected to one another (Wasserman and Faust 1994; Prell et al. 2009). Characteristic path length is another key metric I use to evaluate the networks among waterbodies; it describes the "median of the average shortest distances (number of links)" connecting any waterbody to all other waterbodies (Carley et al. 2013). I interpret characteristic path length, which gives an insight into how AIS may spread via travel of recreational boaters. A small average path length results in fewer trips or "hops" between waterbodies; if the network is found to be well connected (e.g., high density, low characteristic path length), the risk for spread of AIS may be significant if recreational boaters are not always performing behaviors related to AIS prevention. Network analysis enhances efforts at invasion modeling by integrating actual travel patterns of recreational boaters, including the waterbodies visited by boaters who not *Always* perform AIS prevention behaviors. This approach can thus identify actual links among invaded and non-invaded waterbodies.

Methods

Study area

In July of 2014, I mailed 6,000 surveys to Illinois residents holding boat registrations in 12 counties throughout Illinois (see Table 6 in appendix). Boater registration information was from 2013 and obtained with permission from the Illinois Department of Natural Resources (IDNR). Counties were chosen to provide a sampling frame that represents the observed range of (1) number of established non-native fish species in the county (Jacobs 2014), (2) surface water area (U.S. Geological Survey 2013), and (3) median household income (U.S. Census 2015). Four counties were chosen from the Northeast region of the state, four in the Northwest, and four in the Southern. These regions represent three out of the five state regions defined by the IDNR (Illinois Dept. of Natural Resources 2015).

Boater Surveys

The survey asked boaters to give their zip code of residence and the five most recent waterbodies in which they had launched their boats during the summer of 2013. For the latter, respondents were asked to give the name of the waterbody, the nearest town, the state, and an estimate of the distance traveled from their home. These details were necessary because many waterbodies have the same or similar names. It is important to note that I asked boaters to list the five most recent independent waterbodies visited and not their five most recent trips. Thus, if a boater's last three trips were all to the same waterbody, this waterbody would only have been listed once in the response.

Boaters were also asked several questions about the frequency with which they performed behaviors that reduce the risk that their boats would introduce and spread non-native species among waterbodies. These questions were related to the four main vectors of species movement that have been targeted by outreach programs; the boat exterior, the boat interior (including live-wells and water in the bilge), fishing gear, and the intentional movement of species. Specifically, I asked respondents how often they performed behaviors that have been recommended to prevent non-native species movement via each of these vectors. Respondents selected the best answer of options on a five-point Likert scale: 0=Never; 1=Rarely; 2=Sometimes; 3=Often; and 4=Always, with an option of N/A for not applicable.

For the boat exterior, I asked how often after leaving a waterbody respondents visually inspected the outside of their boat and removed organisms, rinsed their boat with high-pressure and/or hot water, or dried their boat with a towel or allowed their boat to dry for at least five days. Concerning the boat interior vector, I asked respondents how often they drained water from live wells, bilge, and bait buckets between their visits to waterbodies. For the fishing tackle vector, I asked how often boaters inspected all angling equipment and removed organisms. Finally, for intentional transport and release, I asked respondents how often they transported and released animals or plants from one body of water to another. For each vector, I grouped respondents according to whether they *Always* perform AIS prevention behaviors or do not *Always* (i.e., Never, Rarely, Sometimes or Often) perform the recommended behaviors which reduce the risk of non-native species spread. I assumed that members of the former category (boaters who *Always* perform behaviors that decrease the possibility of non-native species movement) pose low risk for spreading invasive species while members of the latter category (boaters that perform behaviors *less than Always*) pose a greater risk.

Respondents returned 515 surveys with number of returned surveys roughly equal across counties and regions. From these surveys, I classified respondents as being either travelers (n=343) or non-travelers (n=172), with the latter being boaters who only reported launching their boat at a single waterbody during 2013. As these non-traveling boaters (33% of respondents) may have repeatedly launched their boat at the same site, left their boat in the water at one site for the season, or may have only launched their boat a single time, they pose a negligible risk for spreading non-native species. Thus, they were not considered further and I concentrated on only the respondents who were travelers. I then determined which surveys contained complete and usable data for analyzing the distance traveled from boater residence to the waterbodies boaters visited. Thirty-three respondents were removed as they did not provide their zip code and 18 were removed because waterbody locations could not be identified (e.g. illegible handwriting, incomplete information), leaving 292 surveys (57% of respondents).

Distance between Boaters Residences and Waterbodies

I used the National Hydrology Dataset (U.S. Geological Survey 2013) and ArcGIS 10.1 ESRI software (ESRI 2014) to determine the Euclidean distance between the centroid of boater residence zip codes (i.e. source) and the centroid of each waterbody that they visited (i.e., destination). For all rivers and waterbodies larger than $25km^2$ (see Table 7 in appendix for names and sizes of waterbodies), I calculated the distance from source to the town that the respondent reported was nearest to their destination.

Based on the self-reported behaviors, I categorized respondents as *Always* or *less than Always* boaters for each of the four vectors of non-native species transport. Analysis of distances between source and destination for *Always* and *less than Always* boaters was performed in R (R Core Development Team 2013) with the distances traveled for *Always* and *less than Always* boaters compared using Welch's t-test. Results are reported as mean ± standard error.

Network Analysis

My principal goal was to investigate movement of boaters among waterbodies and how their behaviors may influence the spread of invasive species. To ensure that I had sufficient data, I restricted my analyses to waterbodies that had been visited by respondents at least five times, resulting in survey data from 226 boaters. For each of these waterbodies, I determined from Jacobs (2014) the number and type of established non-native species that are reported to be established. The total number of non-native species is an important component of the risk posed by boaters who visit a waterbody and subsequently move their boat to another waterbody as it can indicate how many species they may vector.

I created a network of boater travel among these highly visited waterbodies to investigate how these waterbodies were connected by boater travel. Within this network, each node represents an independent waterbody and each edge is a link from that waterbody to the next waterbody that an individual boater visited. Next, I removed all edges corresponding to boaters who reported *Always* performing the recommended behaviors as these boaters are considered to have a low risk of spreading non-native species. All other edges remained. This was performed four times–once for each vector of spread (i.e. boat exterior, boat interior, fishing tackle, intentional transport)–yielding four additional networks. These reduced networks give an indication how boaters might be spreading non-native species to the waterbodies they are visiting with respect to their behaviors. Representing the number of non-native species established in each waterbody (see Results) adds an additional layer of information about the risk of non-native species spread throughout the network.

Two metrics were used to parameterize the networks. First, I calculated network density as it represents the proportion of all possible links among nodes (i.e., waterbodies) that are actually present (Wasserman and Faust 1994). For my analysis, lower network density should be associated with reduced invasion risk as it indicates fewer trips and lower propagule pressure. Second, average shortest path length was calculated to determine the average number of edges or links to get from any given node (i.e., waterbody) in the network to any other (Carley et al. 2013). In this study, higher average path length should be associated with lower invasion risk as it represents a longer distance that non-native species would have to travel to get from one waterbody to another. All network analyses were performed in ORA (Carley et al. 2013).

I also used Pearson's correlation coefficient to examine the correlation between number of non-native species and visits by boaters for waterbodies in each of the five networks. This allowed me to critically examine if number of non-native species was correlated to visits of *less than Always* boaters for each vector.

Results

Illinois Boater Travel Patterns

On average, each boater reported visiting 2.8±0.1 (mean ± standard error) waterbodies yielding 823 unique visits spread across 264 waterbodies. These waterbodies are located in Illinois (n=111), Wisconsin (n=84), Minnesota (n=17), Michigan (n=13), Florida (n=6), Missouri (n=4), Arkansas (n=3), Tennessee (n=3), Alabama (n=2), Kentucky (n=2), Mississippi (n=2), Texas (n=2), Maine (n=1), North Dakota (n=1), and Ohio (n=1). Thirteen boaters reported visits to a total of 12 waterbodies in Canada. Sixty-one percent of these unique waterbody visits were in Illinois while 39% occurred in other states or Canada.

Forty-seven percent of waterbodies visited were within 50km, and 73% within 100km, of boater residences (Figure 1). The modal distance of waterbodies from residences was 13.7km and the average was 175.9km. The distribution of waterbody distances from residences is positively skewed, with most waterbodies being relatively close to residences but with many boaters visiting waterbodies several hundred kilometers from their home.

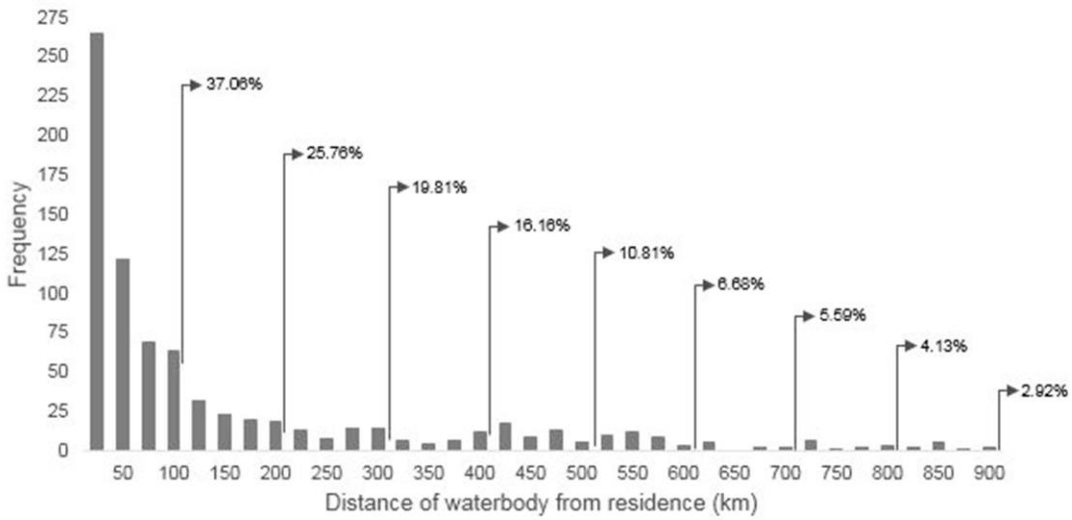

Figure 1. Number of boaters and Euclidean distances (km) of waterbodies visited from boaters' residence (centroid of zip code) to centroid of waterbody. Numbers to the right of arrowheads are the percentage of distances between boater residence and waterbodies that are greater than the specified 100km interval.

Of the 292 respondents, 72% percent reported *Always* performing a behavior to clean their boat's exterior, 78% reported *Always* cleaning their boat's interior, 55% reported *Always* cleaning their fishing tackle, and 96% reported that they never transported or released organisms. Boaters who *Always* performed behaviors to clean the boat exterior, boat interior, fishing tackle, and transport, traveled longer distances (183.6±10.6km, 184.7±10.9km, 195.8±12.5km, and 176.6±9.8km, respectively) than boaters who performed behaviors *less than Always* (153.5±21.3km, 141.2±19.7km, 148.9±14.7km and 160.9±42.3km, respectively). With the exception of the fishing tackle vector (t-test(821)=2.42, p=0.02), these differences in distances traveled were not statistically significant for the other 3 vectors.

Highly Visited Waterbodies and Boater Behavior

There were 226 respondents who visited waterbodies five or more times during 2013. The network of these waterbodies contained 28 nodes (waterbodies; Figure 2). Eighty-two unique links among these nodes were recorded from boaters traveling from one to the next (density=0.217; average path length=2.280) (Figure 2; Table 1) regardless of whether they performed behavior *Always* or *less than Always*. The number of non-native species recorded from each waterbody is indicated by node shading.

When this network was reduced to remove the seventy percent of boaters who reported that they *Always* perform behaviors to clean the exterior of their boats, the network shrunk from 28 to 25 waterbodies with 46 links and a density of 0.153 (Figure 3). Average path length increased to 2.612. Seventy-seven percent of boaters reported that they *Always* performed behaviors to ensure that the interior of their boat was clean. This left a network containing 21 of the original 28 waterbodies with 33 connections among them, a density of 0.157, and an average path length of 4.086 (Figure 4). Removal of the fifty-three percent of boaters who *Always* cleaned their fishing tackle reduced the original network of 28 waterbodies to 27 waterbodies with 65 links among them, a density of 0.185, and average path length of 2.293 (Figure 5). For the transport and release vector (Figure 6), 95% of boaters were removed because they *Always* reported never transporting and releasing organisms. This resulted in a network containing 14 of the original 28 waterbodies with 20 links among them, a density of 0.220, and an average path length of 1.744. Note that average path lengths for each network are not directly comparable as there are different numbers of waterbodies. This is particularly true for the final network which contains substantially fewer waterbodies.

For each network, I used Pearson's r correlation to test for association between the number of visits to each waterbody and the number of non-native species that have been recorded as established there. Results showed a significant positive correlation between number of non-native species and number of visits for boaters who performed *less than Always* behaviors for the boat interior ($r=0.66$, $n=28$, $p<0.001$) and fishing tackle vectors ($r=0.59$, $n=28$, $p<0.001$[3]). There was no significant correlation among waterbodies visited by both *Always* and *less than Always* boaters for the boat exterior ($r=0.26$, $n=28$, $p=0.20$) and the transport and release vector ($r=0.14$, $n=28$, $p=0.48$). Thus, for the boat interior and the fishing tackle vectors, this result suggests that the number of non-native species at these twenty-eight waterbodies is positively correlated with the number of visits by boaters.

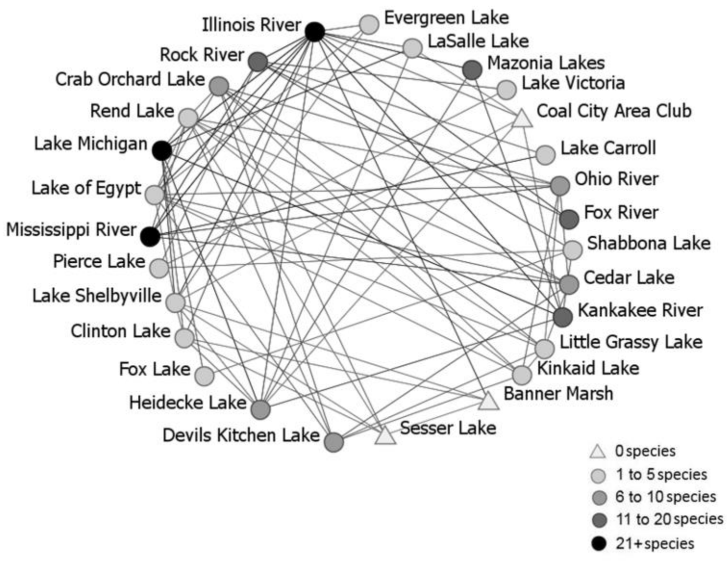

Figure 2. Network of waterbodies (n=28) visited by boaters five or more times during the summer of 2013. Shading of nodes indicates the number of established non-native species (from Jacobs 2014). Density=0.217. Average path length=2.28.

Table 1. Waterbodies visited five or more times during 2013 (Total Visits). Subsequent columns are the number of visits by boaters that did not *Always* address the vector listed.

Waterbody	Number of AIS recorded*	Total Visits	Boat Exterior: Visits by <Always Boaters	Boat Interior: Visits by <Always Boaters	Fishing tackle: Visits by <Always Boaters	Transport & Release: Visits by <Always Boaters:
Lake Michigan	182*	30	9	0	16	0
Illinois River	27	42	12	11	29	2
Mississippi River	23	26	9	6	16	3
Fox River	19	7	2	6	4	0
Kankakee River	18	9	0	3	6	0
Mazonia Lakes	18	5	3	3	4	0
Rock River	13	40	7	8	21	2
Cedar Lake	8	9	6	3	6	1
Devils Kitchen Lake	8	13	7	3	6	1
Ohio River	8	6	1	0	3	1
Crab Orchard Lake	6	38	18	9	18	3
Heidecke Lake	6	13	4	3	7	0
Fox Lake	4	14	0	4	0	0
Lake of Egypt	4	27	9	4	10	3
Little Grassy Lake	4	12	7	4	7	0
Rend Lake	4	35	13	3	16	4
Clinton Lake	3	14	2	2	6	2
Lake Shelbyville	3	15	5	0	7	0
Pierce Lake	3	19	4	5	5	4
Evergreen Lake	2	5	3	0	3	0
Kinkaid Lake	2	10	5	2	4	1
Shabbona Lake	2	7	1	3	1	0
Lake Carroll	1	6	1	0	2	0
LaSalle Lake	1	5	2	2	3	0
Lake Victoria	1	5	1	0	1	0
Banner Marsh	0	12	5	2	4	1
Coal City Area Club	0	6	0	1	3	0
Sesser Lake	0	12	3	0	3	1

*Number of established AIS taken from Jacobs (2014) except for Lake Michigan, for which the total number of established AIS recorded is according to Ricciardi (2006).

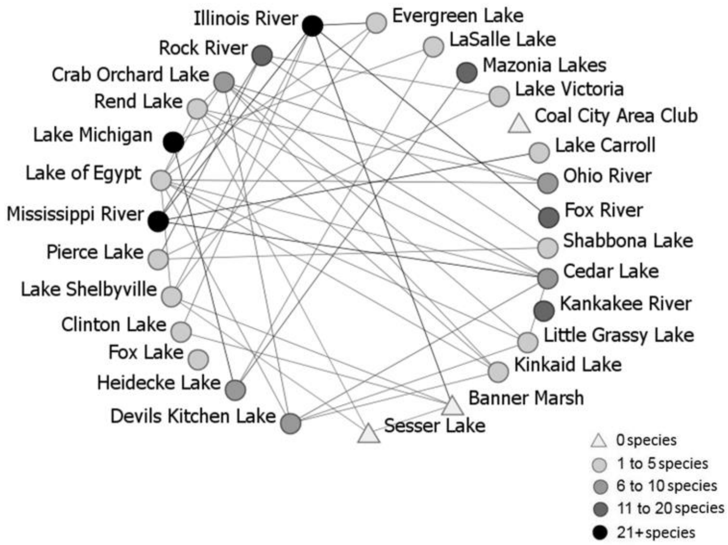

Figure 3. Network of waterbodies (n=28) visited by *less than Always* boaters for the boat exterior vector during the summer of 2013. Shading of nodes indicates the number of established non-native species (from Jacobs 2014). Density=0.2153. Average path length=2.612.

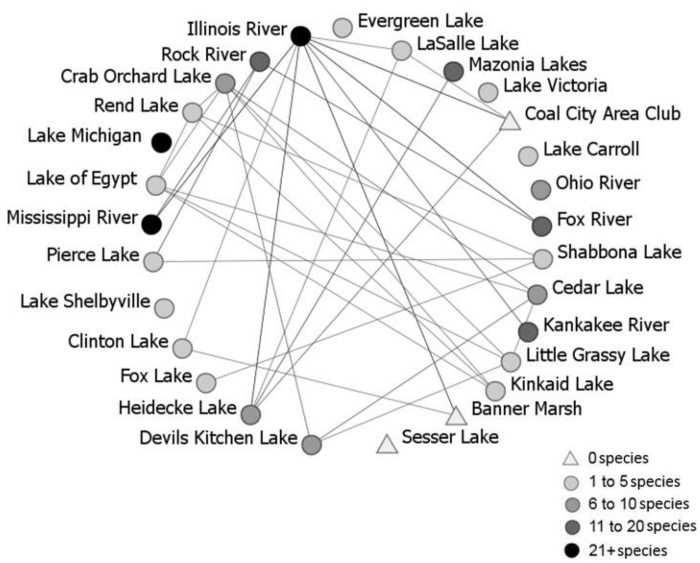

Figure 4. Network of waterbodies (n=28) visited by *less than Always* boaters for the boat interior vector during the summer of 2013. Shading of nodes indicates the number of established non-native species (from Jacobs 2014). Density=0.157. Average path length=4.086.

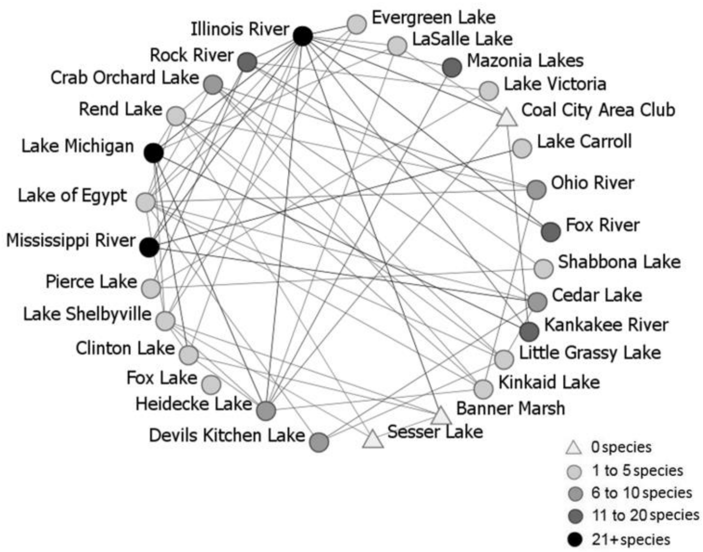

Figure 5. Network of waterbodies (n=28) visited by *less than Always* boaters for the fishing tackle vector during the summer of 2013. Shading of nodes indicates the number of established non-native species (from Jacobs 2014). Density=0.185. Average path length=2.293.

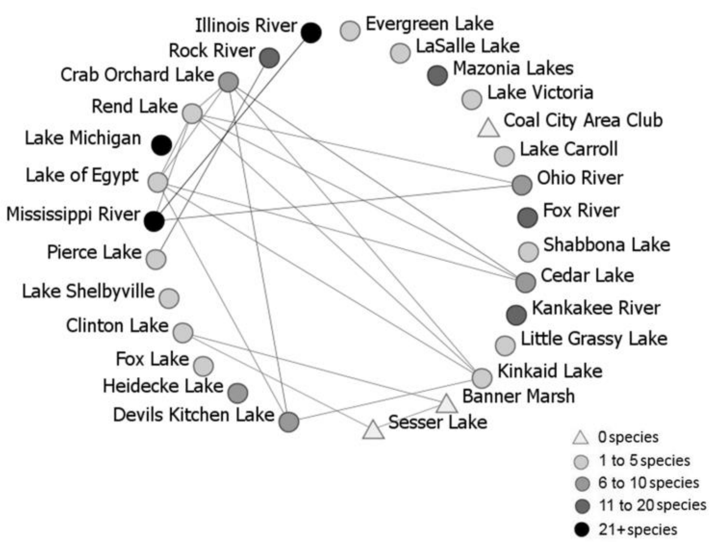

Figure 6. Network of waterbodies (n=28) visited by *less than Always* boaters for the intentional transport and release vector during the summer of 2013. Shading of nodes indicates the number of established non-native species (from Jacobs 2014). Density=0.220. Average path length=1.744.

Discussion

Using self-reported data from boaters, I identified twenty-eight waterbodies that were visited 5 or more times and examined how these waterbodies were connected based on boater behaviors. Network analysis was used to show that waterbodies which are only visited by *less than Always* boaters are still relatively connected. This indicates that although *less than Always* boaters comprise less than half of my respondents who visited these 28 waterbodies (30%, 23%, 47%, and 5% for the boat exterior, boat interior, fishing tackle and transport and release vectors, respectively), waterbodies are still at risk for invasion because boaters are not performing recommended behaviors to prevent non-native species spread.

In examining average path length for the network analysis, boaters who might be potentially spreading non-native species via the boat exterior, fishing tackle and transport and release vectors are visiting at least two waterbodies (nodes) to get to any other waterbody (node) in the network (see Figures 2-6). Thus, for these three vectors, it suggests that non-native species in these waterbodies have a higher chance of being transported to other waterbodies in the network as they are traveling, on average, to only two waterbodies to get to any other waterbody in the network. For the boat interior vector, *less than Always* boaters were shown to be visiting an average of four waterbodies (nodes) between their visits to other waterbodies (nodes) in the network. This indicates that non-native species which could be spread from this vector might have a lower chance of being transported to other waterbodies in the network.

Results of the network analysis were based solely on the twenty-eight waterbodies that were visited by boaters 5 or more times during the summer of 2013. I did not include any links to or from other waterbodies. Thus, these waterbodies are visualized as an isolated sub-network in this analysis, although they are clearly part of the much larger network of waterbodies across Illinois and outside the state. However, visualizing these twenty-eight waterbodies as an isolated sub-network allowed me to investigate how boater behaviors affect the potential for species spread based on the numbers of non-native species present in these waterbodies. I caution that, except for fishes, there has been limited systematic sampling of Illinois waterbodies for many of these non-native taxa. Despite this, the range of non-native species recorded (0–27 for inland waterbodies, and 182 for Lake Michigan), and the fact that many non-native species are readily identifiable in the field, gives me confidence that these data produced by Jacobs 2014 are a reasonable estimate of the total number of non-native species present in each waterbody.

Average distance traveled for all respondents was 175km with 58% of waterbodies being located in other states and Canada. Previous studies examining average boater travel distance among counties reported that Wisconsin and Michigan residents traveled an average of 34km and 74km, respectively (Buchan and Padilla 1999; Leung et al. 2006) and most boaters (90%) did not travel over 50km (Buchan and Padilla 1999). As boaters prefer to visit waterbodies close to each other, models have predicted that areas at risk will also be close together (Schneider et al. 1998; Buchan and Padilla 1999). My data show that 37% of visits from boater residence to waterbodies were more than 100km from their residence. This suggests that Illinois boaters are traveling longer distances than others, potentially putting waterbodies at risk farther from each than previously predicted.

Although Illinois boaters who *Always* perform behaviors necessary to prevent spread traveled longer distances than *less than Always* boaters, there was no statistical difference among these distances traveled except for the fishing tackle vector where *less than Always* boaters traveled significantly shorter distances. However, *less than Always* boaters are traveling far distances which might increase the probability of a long-distance dispersal event of multiple non-native species to waterbodies outside the state and to Illinois waterbodies. As Wisconsin was visited the second most frequently, Wisconsin waterbodies might be at a greater risk for non-native species introduction from Illinois and Illinois might be at a greater risk from non-native species introductions from Wisconsin. Particularly for Illinois, increasing sampling efforts here to more actively look for non-native species such as *Hydrilla verticillata* (which has not been found in Illinois but has been found in Wisconsin (Wisconsin Dept. of Natural Resources 2012) could be a strategy to prevent the introductions of non-native species from Wisconsin to Illinois.

I also found that there was a significant, positive correlation between waterbodies that were visited and number of established non-native species in those waterbodies for the boat interior and fishing tackle vectors. This indicates that waterbodies which are visited more often by *less than Always* boaters for the boat interior and fishing tackle vectors have higher numbers of non-native species. Potentially, the interior of the boat can harbor multiple species, particularly small bodied organisms as well as serious pathogens such as viral hemorrhagic septicemia (Rothlisberger et al. 2010) and species with planktonic life stages, such as spiny waterflea (*Bythotrephes cederstroemi*) (Johnson, Ricciardi, and Carlton 2001). Thus, boaters who do not clean their boat interior could be moving multiple non-native species to the waterbodies they visit. Forty-five percent of boaters reported performing behaviors *less than Always* for the fishing tackle vector and this was the highest percentage of *less than Always* boaters for any vector. Thus, this suggests that there are more *less than Always* boaters visiting these waterbodies and these boaters could be potentially introducing more non-native species into these areas. Increased sampling in these waterbodies for non-native species, which can be spread through the boat interior and fishing tackle vectors, might prove to be beneficial to management organizations as the number of these non-native species might actually be higher than previously reported.

Public education and outreach efforts have been used across the Great Lakes and Mississippi River Basins as a main method to prevent non-native species introduction and spread. The belief is that if individuals are made knowledgeable of a conservation problem, they are more likely to adopt and perform behaviors that will solve that problem (Hungerford and Volk 1990). For this reason, educational and outreach efforts target recreational boaters (Bossenbroek et al. 2007; Strayer 2010) to inform them about non-native species and the behaviors to take to prevent introduction and spread. Illinois management was shown to have spent $600,475 on educational and outreach efforts to influence boater knowledge and behaviors (Cole et al. *In review*), but my results show that adoption of behaviors that reduce non-native species introduction and spread is not consistently performed by boaters. Therefore, areas inside and outside of Illinois remain at risk.

In a study examining the effectiveness of public education and outreach efforts in Illinois, Cole and colleagues showed that boaters who *Always* performed behaviors reducing spread for the boat exterior, boat interior and fishing tackle also had higher knowledge of non-native species (boaters recognized on average 6 out of 14 species), but this knowledge was not very high when compared with *less than Always* boaters recognition (boaters recognized on average 5 out of 14 species) (Cole et al. *In review*; see Chapter III). This indicates that knowledge is influencing boater behavior, but perhaps not enough to eradicate *less than Always* behaviors which can have a disproportionate effect on the introduction and spread of non-native species. This emphasizes the need for incorporating impact metrics into public education and outreach so management can better understand how to target *less than Always* boaters and successfully change their behaviors.

It is important to note that this study may overestimate the rate at which boaters are performing *Always* behaviors. The boaters who responded to this survey were probably interested in non-native species spread and so might already perform many of the behaviors that reduce spread. I caution that these data might be a highly conservative estimate for the numbers of boaters performing *less than Always* behaviors as these boaters might have been less inclined to answer a survey about non-native species introduction and spread.

In this study, I used network analysis to evaluate the connections among Illinois waterbodies based on boater visits. Although we have a high performance of behaviors, these waterbodies remain connected to each other by boaters who do not *Always* perform behaviors reccommended by management organizations in their public education and outreach initiatives to reduce the risk of spread. Public education and outreach does seem to influence behaviors of boaters, and the connections to waterbodies are reduced, but it does not completely eliminate connections among waterbodies by *less than Always* boaters. Thus, it is important for public education and outreach to target boaters who are performing behaviors *less than Always* as these boaters have a higher probablity of introducing and spreading non-native species to waterbodies inside and outside Illinois.

The data and analyses presented here comprise an empirically-based approach to identify how boater behavior and travel patterns can be used to identify clusters of waterbodies that may be at risk, through links created by recreational boaters, with other invaded waterbodies. There is a strong need to link data of non-native species patterns on the landscape, such as those presented here, with quantitative data of boater recognition of invasive species and the consistency with which they perform behaviors to prevent them. Taken together, building understanding in these two areas can inform conservation organizations how to strategically use public education and outreach to enhance use of conservation behaviors where they are most needed on the landscape.

CHAPTER III

ASSESSING THE SUCCESS OF INVASIVE SPECIES PREVENTION PUBLIC OUTREACH AND EDUCATION EFFORTS AT CHANGING THE BEHAVIORS OF RECREATIONAL BOATERS

Introduction

As global trade and other human actions continue to dismantle the natural barriers that separate aquatic ecosystems, the introduction of non-native species has risen causing severe negative impacts to freshwater ecosystems (Ricciardi 2006; Strayer 2010). Non-native species have been introduced via deliberate and unintentional release, including through shipping (e.g., dumping ballast water, biofouling), trade for the aquarium industry, and transport by recreational boaters and anglers (Mills et al. 1993). Protecting freshwater ecosystems from further introduction and spread of aquatic invasive species (AIS) is critical for many reasons, including maintaining biodiversity (Gurevitch and Padilla 2004), preventing economic losses (Keller et al. 2008), and avoiding adverse human health impacts (Pejchar and Mooney 2009). Accordingly, there is a growing emphasis on the importance of public outreach and education designed to encourage conservation efforts that could halt introduction and spread of AIS. In particular, these efforts have targeted recreational boaters (U.S. Fish and Wildlife Service 2009a), with outreach and education representing a major investment in conservation funding.

However, remarkably little is known about whether public outreach and education catalyzes significant changes in boaters' perceptions, or whether it translates into changes in behavior that reduce AIS risk. As a result, the ability to strategically target public outreach and education to have maximum conservation benefit has been limited. This study builds understanding needed to bridge this critical knowledge and action gap in two ways. First, it investigates the context of AIS prevention through public outreach and education in the U.S. state of Illinois, which straddles the ecologically and economically important Laurentian Great Lakes and Mississippi River Basins where AIS comprise serious threats in both. Second, this study evaluates relationships between the extent and source of education received by boaters and a) their knowledge of invasive species and b) their behavior (or absence of behavior) to prevent the spread of AIS.

Conservation considerations related to AIS prevention are critical for lakes, rivers, streams, and other public waterways. A key vector by which these species are spread between bodies of freshwater is on recreational boats that are transported overland (Bossenbroek et al. 2007; Johnson et al. 2001; Leung et al. 2006). As boaters travel, there are several ways that they can transport: on the outside of boat hulls; on boat interiors (e.g., live wells, bilge and free water at the bottom of the hull), on fishing equipment, and through intentional transport and release. If these organisms survive transit, they can be introduced into the next body of water where the boat is launched, potentially causing negative impacts. Despite the use of several technologies, including physical removal and pesticide application (U.S. Fish and Wildlife Service 2009b), complete eradication of AIS has rarely been achieved, and the costs of managing invaders should be seen as perpetual (Zavaleta et al. 2001).

Rather than relying on laws and regulations, many efforts to prevent AIS introduction and spread have been through public outreach and education; educational efforts have become common (Vander Zanden and Olden 2008), increasingly targeting recreational boaters (Bossenbroek et al. 2007; Strayer 2010). These programs operate on the premise that educating boaters about the risks of invasive species, and about behaviors that can prevent AIS introduction and spread, will result in boaters' adoption of behaviors needed to reduce AIS risk. U.S. programs include the *100th Meridian Initiative* (U.S. Fish and Wildlife Service 2009a) and *Protect Your Waters* (U.S. Fish and Wildlife Service 2015). These programs are demonstrative examples of public outreach and education for AIS prevention; the first emphasizes the risk posed by invaders in one genus, zebra (*Dreissena polymorpha*) and quagga (*D. bugensis*) mussels, and the importance of preventing their introduction west of the 100^{th} meridian. The second emphasizes general AIS prevention. While there are many AIS prevention programs, they often share slogans that link to recommended behaviors to prevent AIS. Examples include "Clean Boat, Clean Waters" (Wisconsin Dept. of Natural Resources 2014) and "Be a Hero, Transport Zero" (Illinois-Indiana Sea Grant Program 2015), each of which is accompanied by specific recommendations for boater behavior, such as conducting visual inspections of boat and fishing equipment and removing all plants and animals. In turn, the slogans and their associated AIS prevention behaviors are promoted through a range of media channels (e.g., television, internet, written materials), events (e.g., booths at fishing shows), and through personal communication between conservation managers (e.g., program managers at state and federal agencies) or conservation volunteers and the public. These public outreach and education efforts aim to reach boaters directly to transmit information about AIS identification and behaviors needed to prevent their introduction and spread.

Despite these well-developed campaigns, current program evaluation typically focuses on implementation metrics, such as the number of boaters contacted (Davenport and Shults 2009; Illinois-Indiana Sea Grant Program 2015), rather than impact metrics, such as reported behavior change. Using Illinois as an illustrative example, this study aims to advance previous program evaluation by investigating the complete chain of communication of public education on AIS prevention, from slogans distributed by conservation organizations, to investigating where boaters receive information, boater recognition of prevention slogans and knowledge of AIS, and boaters' self-reported behavior to prevent the spread of AIS.

This study draws on diffusion of innovation theory to understand the uptake and consistency of AIS prevention behaviors. Diffusion theory describes how information about innovations is communicated through a group of individuals over time, with the innovation ultimately adopted or rejected at the individual level (Rogers 2003). This type of conservation behavior can be considered a preventive innovation that individuals adopt in order to lower the probability of an unwanted future event (Rogers 2003, p. 234). Diffusion theory has been used to describe patterns of adoption of conservation behaviors (Lubell and Fulton 2008; Pannell 2008) including those supporting public goods (Garbach et al. 2012). This study builds on previous research by applying diffusion theory to adoption of AIS prevention behaviors that are conducted in public waterways. Addressing AIS prevention in public resources management is salient, given that introduction of an AIS to public waterways reduces resource quality and, in many cases, resource quantity (e.g., of desirable freshwater species).

My first goal was to investigate the context of AIS prevention outreach and education in Illinois. To do this, I used network analysis—which describes who interacts with whom (Wasserman and Faust 1994)—to quantify relationships among the conservation organizations that promote AIS prevention behavior to a critical group of primary resource users: recreational boaters. Specifically, I interviewed managers at the organizations involved with AIS prevention education in Illinois, measuring their investment of person power and financial resources, and the extent of coordination among organizations as these can each be important drivers of the outcomes. Often, Illinois conservation organizations interact with each other to coordinate messages, and these interactions form a network which can be analyzed for density, which measures proportion of existing relationships out of the total possible, and centrality, which measures the number of connections to each organization, as well as which organizations have unique connections (Wasserman and Faust 1994). High network density facilitates communication and trust among actors (Bodin et al. 2006); a practical application of this theory is measuring which organizations are collaborating to share public education slogans for AIS prevention, as common slogans presented through multiple organizations to boaters can reinforce the conservation message, which is hypothesized to result in greater adoption of associated AIS prevention behavior. Organizations that are highly central in the network are often important distributors of information (Prell et al. 2009). This can be measured as in-degree centrality, or how frequently an organization is named by others as a key interaction partner, and out-degree centrality which measures the amount of interactions which an organization seeks with others (Wasserman and Faust 1994).

Second, this study tests a hypothesis that is foundational to public outreach and education for conservation, such as AIS prevention: education will increase knowledge of the conservation challenge, and resource users with more knowledge of the challenge will take appropriate action. For my study, this hypothesis would hold that boaters who have greater knowledge about AIS are more likely to adopt and consistently use personal behaviors, such as cleaning their boats, which reduce the risk of AIS being spread.

Methods

Manager Interviews

This study focused on public education and outreach efforts related to AIS in the U.S. state of Illinois. Illinois contains many lakes and rivers and at least 60 established non-native freshwater species (Jacobs and Keller *In Review*). Additionally, the state straddles the border between the Laurentian Great Lakes and Mississippi River Basins and as such, is an important pathway for AIS spread across North America.

I began with a focus on Illinois organizations engaged in public outreach and education related to AIS prevention during 2013, and on registered boaters in the state. I identified the 14 conservation organizations that conducted public outreach and education for AIS prevention, locating organizations using a snowball sampling method (Dillman 2000). I asked managers at state conservation organizations to list other organizations involved in AIS prevention, continuing this sampling method until all leads were exhausted. My final list included organizations at the state (n=7), federal (n=1) and county (n=3) levels, as well as non-governmental (NGOs, n=2), and private organizations (n=1). Managers from all 14 organizations were interviewed by phone and respondents were asked about the following themes: (1) their organization's use of communication channels and slogans; (2) investment in public outreach and education to prevent AIS during 2013 (i.e., monetary investment, including personnel); (3) the importance of each of the state's five conservation administration regions for education on AIS prevention, measured as percent of the organization's education effort that was targeted to each region; and (4) interactions with other conservation organizations on AIS prevention. Manager interviews included both free response and multiple-choice questions; responses for the latter were presented using a five-point Likert scale (see Survey A in appendix).

Boater Surveys

I distributed 6,000 surveys to Illinois boaters registered in 2013 (state registry data obtained with permission through Illinois Department of Natural Resources) using a modification of the tailored design method (Dillman 2000), sending an introduction letter with the survey, and then two followup reminders (see Survey B in appendix). This stratified sample of boaters in the state's Northeastern, Southern, and Northwestern regions, represents a spectrum of investment in public education on AIS prevention based on ratings assigned by conservation managers, with higher investment in the Northeastern region. I surveyed boaters in four counties in each region, for a total of 12 counties (Figure 7). The surveyed counties reflect the range of biophysical conditions relevant to AIS prevention, including: number of established non-native fish species per county (Jacobs 2014); surface water area per county (U.S. Geological Survey 2013); and range of boater demographics, including median household income and education (U.S. Census Bureau 2015) (Table 2).

The samping frame initially divided survey effort evenly across the 12 counties, randomly allocating 500 surveys to boaters in each. If counties had fewer than 500 registered boats, I distributed the surplus surveys evenly among the remaining counties in that region. For the Southern region, there were fewer than 2,000 registered boats in the four surveyed counties; surplus surveys were evenly distributed among all counties in the Northeastern and Northwestern regions (see Table 1 in appendix).

The boater survey evaluated experience with the following key themes: use of public outreach and education related to AIS prevention including slogans, media, events, and personal contact resources used to promote key prevention messages;

knowledge of AIS; and adoption of AIS prevention behaviors on four main vectors for introduction (1) boat exterior, (2) boat interior, (3) fishing tackle, (4) intentional transport and release of organisms. The survey provided a list of resources related to AIS prevention education, common names of AIS, and prevention behaviors which were compiled from previous boater surveys (Davenport, Trushenski, and Whiteledge 2010) and updated during manager interviews. Respondents were asked to rate how useful they found each type of media, event, and personal contact through which they had received AIS education. This survey also solicited information about boaters' travel during the 2013 boating season. Prior to analysis, I grouped boaters into two categories: travelers and non-travelers. A boater was considered a 'traveler' if they launched their boat in more than one waterbody. Taken together with AIS prevention behaviors, traveler data allowed me to assess each boaters' potential risk of AIS introduction; non-travelers and boaters with complete and consistent adoption of AIS prevention pose low risk. I also solicited basic demographic data (e.g., age, gender, and education level).

The survey incorporated a mix of question types including multiple choice (e.g., frequency of use of AIS prevention behaviors); binary outcomes (e.g., familiarity with an AIS), and questions soliciting free responses (e.g., most useful source of information on AIS prevention). For multiple choice questions, I used a five-point Likert scale to represent the range of possible responses (e.g., 0=Never; 1=Rarely; 2=Sometimes; 3= Often; and 4=Always), with an option for Don't Know.

Respondents returned 515 completed, usable surveys (total survey return rate, 9.3%; completed usable return rate, 8.6% (calculations per AAPOR 2000).

Figure 7. Illinois conservation administration regions identified by the Illinois Department of Natural Resources. Surveyed counties by region were as follows: Northeastern region: Lake (LK), DuPage (DP), Cook (CO) and Grundy (GU); Southern region: Franklin (FA), Gallatin (GA), Williamson (WL) and Alexander (AE); and Northwestern region: Carroll (CR), Winnebago (WN), Putman (PT) and Tazewell (TZ).

Table 2. AIS, measured as number of established non-native fish species[1], surface water area per county[2], and demographics of surveyed counties[3], and mean values of AIS Boater Survey respondents. [1] Jacobs 2014; [2] U.S. Geological Survey 2013; [3] U.S. Census Bureau 2015.

County	Number of established non-native fish species	Surface water area (km2)	Median household income (USD)	Males (%)	Median Age (years)	College degree (%)
Cook	16	63.58	$54,648.00	48.4	35.3	40.5
DuPage	4	18.7	$78,538.00	49	38.2	52.7
Grundy	13	38.07	$63,840.00	50	36.4	26.8
Lake	13	132.62	$79,085.00	49.9	36.7	47.9
Franklin	6	66.06	$37,158.00	49.3	41.8	24.2
Gallatin	3	19.85	$38,934.00	48.6	45	18.5
Williamson	5	64.46	$41,596.00	49.5	40.4	31.5
Alexander	8	52.48	$27,248.00	51.2	41.0	15.1
Carroll	2	68.86	$48,456.00	49.8	46.5	23.8
Putnam	4	36.73	$54,467.00	50.6	44.6	25.9
Tazewell	12	36.93	$55,580.00	49.3	39.9	33.5
Winnebago	7	21.41	$47,573.00	48.8	38.4	28.5
AIS Boater Survey Mean				***91***	***Median = 59***	***27***

Data analysis

Survey response data were analyzed in R (R Core Development Team 2013), and evaluated using Analysis of Variance (ANOVA), Tukey's mean separation test for multiple choice responses, and Welch's t-test for binary responses. Using manager interview data, I visualized relationships among conservation organizations using the ORA software for network analysis (Carley et al. 2013). This facilitated evaluation of network level metrics, including network density (the number of connections realized out of the total possible), and individual-level metrics for conservation organizations including in-degree centrality, which measures the number of connections to an organization identified by others, and out-degree centrality, a measure of the connections an organization identified, and capability, a measure of unique connections. Taken together, data from manager interviews provides an overview of the investment, regional emphasis, and network of conservation organizations supporting AIS prevention in Illinois during the study period.

Using logistic regression models, selected to included relevant variables, minimize multiple collinearity, and minimize Akaike Information Criteria score (AIC; considering a reduction of two or more significant per (Burnham and Anderson 1998), I analyzed boater survey data to test relationships between boater behavior, use of AIS education resources, traveling habits, knowledge, and demographic information. Results are summarized by arithmetic means ± standard error (se), unless otherwise noted.

Results

Management Organizations

Illinois conservation organizations interact across organization types (government, non-profit, private) through project collaboration (Figure 8). Connections realized through project collaborations represent 22.5% out of the total possible (network density=0.225). This level of connectivity, and an absence of isolated organizations that lack connections to others, indicates strong capacity for information sharing to support education related to AIS prevention. Two state agencies emerged as central organizations; Organization 7 was named most frequently as a project partner by other organizations (in-degree centrality=0.692), likely reflecting its visibility in building a coalition for the identification of invasive plants; and Organization 1 had the highest number of unique connections to support project partnership (capability metric=0.993) and initiated the highest number of connections to other organizations (out-degree centrality=0.462), reflecting the key role of Organization 1 in distributing funding and providing program materials, serving as an information distribution hub for other conservation organizations. In contrast, Organization 2, a private NGO, identified relatively fewer connections with other organizations (out-degree centrality=0.077), reflecting the organizations' primary role in research and distributing research findings. Organization 12, a state agency, acts as a secondary information hub by connecting more perepheral NGOs and the private organization to the central hubs of Organization 7 and Organization 1; these bridging ties facilitate sharing information and materials across different organization types.

There were six main AIS prevention slogans used in Illinois; all were promoted by five or more organizations. Conservation organizations rated the importance of slogans on a 5-point scale (4=promoted in >75% of materials; 3=75-50%; 2=49-25%; 1=24-5%; 0=not included). These slogans were promoted as follows: "Hydrilla Hunt" (promoted by 93% of organizations; mean rating 2.57±0.37); "Protect Your Waters, Stop Aquatic Hitchhikers" (86% of organizations; rating 2.54±0.43); "Clean, Drain and Dry" (79% of organizations; rating 1.54±0.35); "Be A Hero, Transport Zero" (64% of organizations; rating 1.62±0.46); "Clean Boats Crew" (64% of organizations; rating 1.31±0.44); and

“Get a Habitattitude” (43% of organizations; rating 0.62±0.31). In general, organizations would emphasize two or three slogans heavily, including them in >75% of outreach materials and the remainder of slogans would be included less frequently (included in <50% of outreach materials). As a group, the organizations reinforced the same slogans and the AIS prevention behaviors they intend to promote.

Taken together, the conservation organizations report a significant investment in public outreach and education for AIS prevention during 2013, totaling $600,475 USD. The conservation organizations targeted >75% of effort in the Northeastern region (3.64±0.23, range 0-4), and much less in the Southern and Northwestern Regions, (respectively, 2.21±0.40 and 2.07±0.45), which were targeted for 50-25% of organizations’ effort (Table 3).

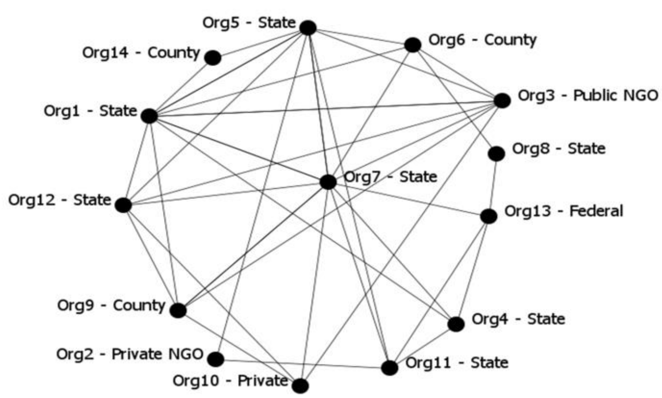

Figure 8. Network of interactions among conservation organizations; connections reflect a formal project interaction. Network density=0.225, reflecting 22.5% of connections of total possible are present. Organization types (federal, state, county agencies, NGOs and private) are listed after each organization number.

Table 3. Importance of AIS prevention outreach and education in conservation administration regions (via Illinois Dept. of Natural Resources). Ratings on a 5-point scale reflecting the amount of outreach and education dedicated to each region: 4= >75% effort; 3=75-50%; 2=49-25%; 1=24-5%; 0=not included. Investment in AIS Education, $USD, reflects the 2013 estimates of personnel and materials in outreach and education activities. Centrality reflect the number of interactions an organization had with others; in-degree centrality reflects interactions organizations had with others.

Organization - Type	Northeastern Region Rating	Northwestern Region Rating	Southern Region Rating	Investment in AIS Education	Out-Degree Centrality	In-Degree Centrality
Org1 - State	4	1	2	$332,600	0.462	0.385
Org3 - NGO	4	3	3	$66,000	0.077	0.077
Org4 - State	3	2	4	$60,500	0.231	0.385
Org5 - State	4	4	4	$45,275	0.308	0
Org2 - NGO	4	4	1	$41,250	0.154	0.615
Org6 - County	4	0	0	$22,700	0.231	0.154
Org7 - State	4	3	3	$15,000	0.308	0.692
Org8 - State	4	4	4	$6,650	0	0.154
Org9 - County	4	0	0	$5,000	0.308	0.154
Org10 - Private	3	3	3	$1,700	0.154	0.154
Org11 - State	1	1	4	$1,500	0.308	0.077
Org12 - State	4	2	3	$1,000	0.385	0.077
Org13 - Federal	4	2	0	$800	0.154	0.154
Org14 - County	4	0	0	$500	0.077	0.077

Boater Response and Knowledge of AIS

Survey respondents were predominantly male (91%), with median age 59, and 27% college degree holders (32% with some college, no degree). The population of survey respondents represented older males and relatively fewer college degree holders than the broader state population (Table 2).These biases are similar to those reported in a previous boater questionnaire (Davenport et al. 2010) which surveyed the Northeastern, the Southern, and Northwestern regions.

Boater knowledge of AIS, measured as the number of AIS species recognized (range 0-14), was similar across the three survey regions (Northeastern, 6.19±0.23; Northwestern, 5.54±0.22; Southern, 5.49±0.31, $F_{2,512}=2.7$, $p=0.07$) and varied across species (Table 4). Knowledge of AIS had a significant, positive relationship with the number of information sources boaters accessed for all three types: media, events, and personal contact ($p<0.001$) and average usefulness rankings across information sources (p<0.01). Boaters' average ratings of the usefulness of information sources (range 0–4) revealed a preference for media (2.61±0.04), rating it more useful than both events (2.13±0.06) and resources in the personal contact category (2.09±0.06, p<0.001). The most useful media sources included print, television, and internet sources and most useful events included booths and educational displays at fishing and boating shows (Figure 9).

Table 4. AIS knowledge, measured as number of AIS recognized, by Illinois boaters. [N] are species not established in Illinois; all other species are established. *Species usually include the following: *Hypophthalmichthys nobilis, Hypophthalmichthys molitrix, Ctenopharyngodon idella, Cyprinus carpio.*

Group	Common name (*Species name*)	Boaters reporting AIS recognition (%)
Plants	Hydrilla, *(Hydrilla verticillata)* [N]	53%
	Water Hyacinth, *(Eichhornia crassipes)* [N]	41%
	Eurasion Watermilfoil, *(Myriophyllum spicatum)*	40%
	Curly Pondweed, *(Potamogeton crispus)*	24%
	Purple Loostrife, *(Lythrum salicaria)*	23%
	Brazilean Elodea, *(Egeria densa)*	5%
Mollusks	Zebra mussels, *(Dreissena polymorpha)*	89%
	Quagga mussels, *(Dreissena bugensis/rostriformis)*	25%
Fishes	Asian carp, *Multiple species	97%
	Northern Snakehead, *(Channa argus)* [N]	52%
	Round Goby, *(Neogobius melanostomus)*	48%
Crayfish	Rusty crayfish, *(Orconectes rusticus)*	37%
Fish disease	VHS, *(Viral hemorrhagic septicemia)*	23%
Zooplankton	Spiny waterflea, *(Bythotrephes longimanus)*	22%

Similarly, the number of slogans boaters recognized (range 0–6) had a significant relationship with knowledge of AIS (p<0.001). Boater recognition of AIS prevention slogans was highest for "Protect Your Waters, Stop Aquatic Hitchikers" (recognized by 59% of boaters), which represents the oldest slogan (approximately 11 years old), promoted by one of the state's most well-funded campaigns. "Clean, Drain and Dry" was recognized by 41% of boaters. I note that "Be A Hero, Transport Zero" (recognized by 25% of boaters) was released just prior to the 2013 boating season, and given the short time frame, has considerable recognition. “Clean Boats Crew” was recognized by 9% of boaters, which may reflect that this effort primarily engages boaters on boat ramps and is thus expected to reach fewer boaters than more widely promoted slogans that use a variety of media and communication channels. In contrast, “Hydrilla Hunt” had modest recognition, 5% of boaters, despite being reported as the most broadly promoted by conservation organizations. “Get a Habitatitude” also had modest recognition, comprising 2% of boaters. I note that this slogan is primarily targeted at aquarium and pet owners rather than boaters.

Travelers, boaters that launch their boat in more than one waterbody, comprised 67% of survey respondents. Travelers had detectably higher AIS knowledge (6.31±0.18) than non-travelers (4.78±0.21, Welch’s t(408.6)=5.53, p<0.001), although this difference was modest, representing recognition of, on average, 1.4 additional species.

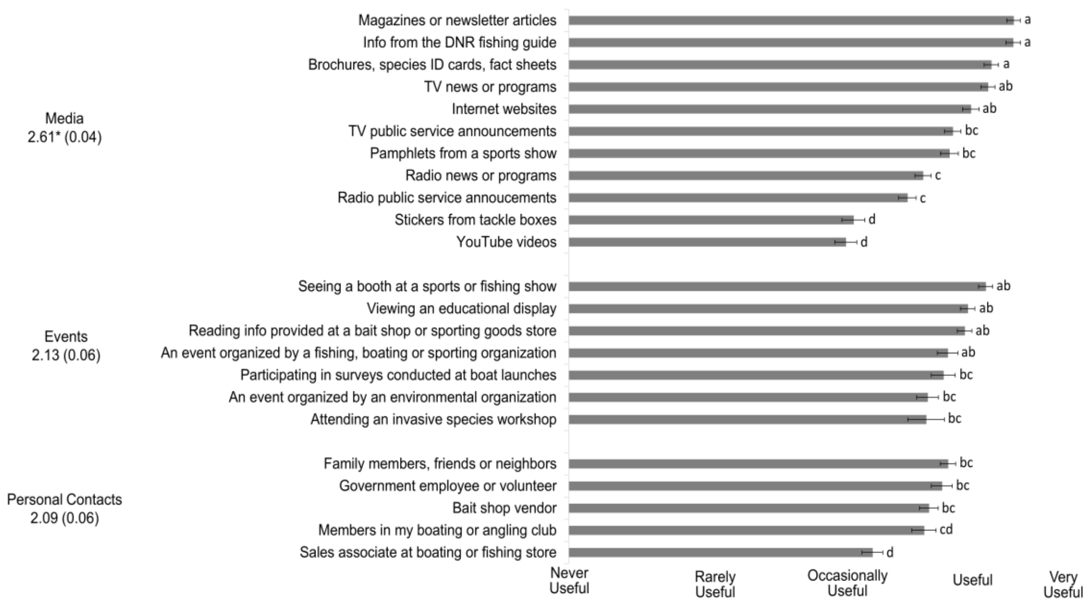

Figure 9. Boater ratings of information sources on AIS prevention. Ratings were on 5-point scale ranging from “Never Useful” to “Very Useful.” Average ratings that are significantly different (p≤0.05) are noted with different letters reflecting Tukey mean separation tests.

Boater Adoption of AIS Prevention Behavior

Boaters reported the frequency with which they performed AIS prevention-behaviors (Never, Rarely, Sometimes, Often, and Always) on four main vectors for AIS spread (1) boat exterior, (2) boat interior, (3) fishing tackle, (4) intentional transport and release of organisms. There was no significant difference in frequency across regions for any vector ($F_{6,2048}$=1.7, p=0.12) so responses for each vector were pooled across regions for further analysis. To help assess potential risk in AIS introduction, I divided responses for each vector into boaters that *Always* perform AIS prevention behaviors (low potential risk) and those that performed AIS prevention behaviors less frequently (higher potential risk). Only 6% of boaters reported that that they intentionally move organisms (i.e., reporting Rarely, Sometimes, or Often). The vectors of boat interior and boat exterior had performance that was not significantly different, with 68% and 63% of boaters, respectively, reporting they *Always* performed AIS prevention behaviors targeted at these vectors. The vector of fishing tackle had the least consistent performance with 47% of boaters reporting that they *Always* cleaned their tackle after use (ANOVA for vector performance, $F_{3,2056}$=74.7, p<0.001).

To evaluate the relationship between AIS knowledge and prevention behavior, I compared knowledge for boaters that *Always* perform AIS prevention behaviors versus other boaters. I considered each vector separately and found that knowledge had a significant, positive relationship with behavior for boat exterior (boaters *Always* performing prevention behavior, 6.04±0.18; other boaters, 5.39±0.23, t(513)=2.21, p=0.03) boat interior (boaters *Always* performing prevention behavior, 6.07±0.18; other boaters, 5.23±0.22, Welch's t(374.1)=2.94, p<0.001), and tackle (boaters *Always* performing prevention behavior, 6.36±0.21; other boaters 5.29±0.19, Welch's t=3.78, p<0.001). Although statistically significant, the average number of AIS which boaters that

Always perform behaviors recognized was not overwhelmingly high, approximately six out of 14 species, compared to boaters who perform behaviors less frequently, who reported recognizing five species on average. This suggests that AIS knowledge can positively influence boater behavior. However, given that the difference in knowledge is modest, and that there is significant overlap in knowledge among boaters who do and do not *Always* perform recommended behaviors, increasing knowledge may not affect the widespread behavorial change that conservation organizations seek.

Next, I developed a model with factors that helped predict characteristics of boaters that are likely to *Always* perform AIS prevention practices versus those who are not. This information is critical to conservation managers that want to understand how to target education where it is most needed, which is to boaters otherwise unlikely to perform AIS prevention behaviors (and thus pose higher potential risk). Specifically, I tested the influence of the variables that conservation agencies seek to increase: the proportion of resources that boaters access, and slogans recognized. I included two additional aspects in our analysis: travel behavior, which is an important dimension of potential risk for AIS introduction, and I controlled for demographic characteristics of age and formal education level, as previous diffusion studies have emphasized their potential influence on adoption of conservation behavior (Prokopy et al. 2008).

For the boat exterior vector, two variables had a positive influence on *Always* performing AIS prevention practices: the proportion of slogans recognized, and being a traveler. These model estimates represent the log odds; exponentiating the coefficients allows me to interpret them as odds-ratios. For each unit increase in the proportion of slogans recognized (e.g., the difference between recognizing zero slogans and all slogans) the odds of *Always* performing AIS prevention practices increased by a factor of 6.4; and the odds of travelers *Always* performing practices increased by a factor of 2.6

relative to non-travelers. For this vector, the proportion of education resources accessed did not have a detectable influence (Table 5).

For the boat interior vector, travelers were significantly more likely to *Always* perform AIS prevention practices, with odds of *Always* performing practices increasing by a factor of 2.9 relative to non-travelers. In this model, formal education level had a negative influence on *Always* performing the practices (Table 4). One potential explanation is that boaters with higher education may perceive themselves as well-informed, and thus pay less attention to recommended behaviors and ultimately underperform relative to counterparts that recognize their knowledge gaps (see McCracken et al. 2015 for how experiential learning can be more successful when learners are aware of their own knowledge gaps).

For the fishing tackle pathway, our preliminary analysis showed that including AIS knowledge better explained the variation in the people that *Always* cleaned fishing tackle than models without this variable (AIC reduced by 2.9), therefore it was integrated in this regression model but not the others. For each unit increase in the proportion of AIS knowledge, the odds of *Always* performing AIS prevention practices increases by a factor of 1.8. The odds of *Always* performing practices increased by a factor of 2.7 for travelers relative to non-travelers. Similar to other vectors, the proportion of education resources on AIS prevention accessed did not have a detectable influence, and formal education level had a negative relationship with *Always* cleaning fishing tackle.

For the final vector, intentional transport and release of organisms, 94% of boaters *Always* avoid transport and release; the proportion of education resources accessed had a negative relationship with consistently performing this action. One potential reason for this is that avoiding intentional spread is simple and well-known, the recommendation has not changed over time, and it may already be widely practiced.

Thus referencing multiple sources of information to become, and remain, informed about this behavior may be viewed as unnecessary by boaters.

Table 5. Regression models for the four vectors through which AIS are spread, boat exterior, boat interior, fishing tackle, and transport and release of organism. The binary outcome variable reflected whether boaters *Always* used prevention behaviors (1) or reported inconsistent use of prevention behaviors (0, reported as Never, Rarely Sometimes, Often). Significance indicated with *0.00 ≤ p ≤ 0.05.

	Boat Exterior			**Boat Interior**			**Fishing Tackle**			**Transport and Release**		
	Est.	(SE)	p-value	Est.	(SE)	p-value	Est.	(SE)	p-value	Est.	(SE)	p-value
Intercept	0.52	0.64	0.41	0.48	0.66	0.47	-0.29	0.61	0.63	4.29	1.31	0.00*
Prop. All Resources	-0.72	0.40	0.07	0.36	0.41	0.39	0.58	0.38	0.13	-1.95	0.82	0.02*
Prop. of Slogans	1.87	0.55	0.00*	0.81	0.56	0.15	0.94	0.51	0.06	1.70	1.05	0.11
Traveling Habits	0.97	0.22	0.00*	1.08	0.22	0.00*	0.60	0.21	0.01*	0.38	0.41	0.36
Prop. AIS Knowledge	-	-	-	-	-	-	1.00	0.45	0.03*	-	-	-
Age	-0.00	0.01	0.61	-0.01	0.01	0.53	-0.00	0.01	0.86	-0.01	0.02	0.51
Education Level	-0.12	0.08	0.12	-0.17	0.08	0.04*	-0.25	0.08	0.00*	-0.11	0.15	0.45
AIC Value	*572.6*			*540.3*			*606.3*			*219.9*		
Residual Deviance	*560.6*			*528.3*			*592.2*			*207.9*		
McKelvey and Zavonia R^2	*0.10*			*0.11*			*0.10*			*0.09*		

Discussion

The traditional thinking in public outreach and education to support conservation goals has been that behavior will change by making people more knowledgeable about environmental challenges (Hungerford and Volk 1990). However, my results do not support a key assumption of this traditional model: that as conservation organizations direct more information to boaters, boater knowledge will increase, and boaters will overwhelmingly adopt the behaviors needed to prevent AIS introduction. In contrast, I found that boater knowledge and AIS prevention behavior was similar in the three surveyed regions in Illinois, despite far greater investment in public outreach and education in the Northeastern region by multiple conservation organizations. This result emphasizes both the need for a more nuanced understanding of how education strategies influence behavior, and a need to incorporate outcome metrics in program evaluation.

Results of my manager interviews suggest that outreach and education efforts for AIS prevention in Illinois provide strong support for reinforcing conservation messages. These interview data described how conservation organizations are connected through a network of shared projects, program materials, and mutual promotion of six main AIS prevention slogans to stimulate prevention behaviors. AIS prevention messages were delivered through media, events, and contact with conservation professionals. This approach of information transfer from organizations to resource users mirrors the approach traditionally used by cooperative extension to stimulate technical learning (Lubell, Niles, and Hoffman 2014) with the aim of helping people to understand a challenge, and the behavior needed to address it (De Young 1993). Boaters identified media as the most useful source of information on AIS, with top ratings for: the Ilinois Department of Natural Resources fishing guide; magazines, newsletters, and brochures; ID cards; television; and Internet. Placing information on AIS prevention slogans and articles in varied media can reinforce key messages through repetition, provide complementary details, and allow users to either triangulate or select a preferred source of information (Jacobson 2009).

However, current evaluation of AIS prevention is not designed to evaluate knowledge and action gaps. Previous efforts evaluating boater education for conservation behavior highlight the importance of identifying and targeting specific gaps (Morris, Jacobson, and Flamm 2007). Across organization types—including state, federal, and county agencies, NGOs, and private organizations) and their roles in AIS prevention (information distribution hub, coalition builder), managers reported that implementation metrics such as the number of outreach and education events conducted and estimates of boaters contacted were the primary measures of program success. Yet, implementation metrics have been shown to be relatively poor predictors of success of conservation results. Measuring key outcomes (e.g., specific knowledge, behaviors) provides a more reliable proxy for whether an initiative is delivering conservation benefits (Kapos et al. 2009). Results from my boater survey suggest that while boaters recognize six AIS on average (out of 14), recognition varied widely across species, ranging from 5% (Brazilian Elodea) to 95%, (Asian Carp). This variation suggests a critical and outstanding need for continued measures of both knowledge and action gaps. These data are needed to tailor education toward the AIS that pose highest risk, those for which boater recognition is lower, and toward prevention behaviors that have inconsistent performance.

It is interesting that several of the most highly recognized AIS are not yet established in Illinois (Table 4). These include hydrilla, which has been the subject of a public education campaign designed to increase awareness so that if it does arrive it will be quickly reported, and the northern snakehead, which was prominent in the national news for several months after it was found in a Maryland pond (Dolin 2003). In contrast, several of the most damaging AIS in Illinois are less well recognized. Eurasian watermilfoil, curly pondweed, and rusty crayfish are all damaging invaders across Illinois, and all continue to spread (Jacobs 2014). Despite this, they are poorly recognized (Table 4) which is likley to reduce the chance that boaters will be aware of them as they remove their boat from one waterbody and transport it to another. In turn, this reduces the chance that boaters will implement behaviors to prevent spread of these species.

Inconsistent performance of AIS prevention behaviors is a primary concern as many AIS can be introduced with only one instance of transport. Thus even a small number of “bad actors” can have a disproportionate, negative influence on the landscape, particularly in public waterways where it may be difficult or impossible to exclude them. In particular, travelers and boaters with incomplete or inconsistent adoption of AIS prevention behavior pose potential higher risk for introduction and spread of invasive species. My boater survey demonstrated that travelers were significantly more likely to *Always* perform AIS prevention behavior on the boat exterior, boat interior, and by cleaning fishing tackle. Travelers also have slightly higher AIS-knowledge, recognizing one additional species on average than non-travelers. These data emphasize the preliminary success and continued importance of targeting public education to travelers. In a practical sense, continued investment in engaging travelers (e.g., direct outreach at boat launches) could be further supported by tailoring messages to describe AIS risk and illustrating the potential negative impacts associated with AIS introduction and spread. The latter may be particularly important because preventive innovations, such as AIS prevention behaviors, are new ideas designed to lower the probability of an unwanted future event (Rogers 2003). Resource users may need specific illustration of the outcomes to fully recognize the advantage of current behavior, since the future consequences of action and inaction are unobservable.

Taken together, these data also highlight the importance of using outcomes-based metrics specifically targeted to travelers. Although travelers are more likely to consistently perform AIS prevention practices, there is still a significant action gap (e.g., 53% of boaters do not *Always* clean fishing tackle). This gap indicates a need to further investigate patterns of AIS prevention behavior and boater movement on the landscape, including which waterbodies are most visited and whether boater visits connect waterbodies with known invaders to uninvaded areas.

Results from my boater survey suggest that increasing knowledge may be a necessary condition, but alone this may not be sufficient to catalyze consistent adoption of AIS prevention behaviors. Recognition of prevention slogans and the number of AIS recognized were significantly, positively associated with *Always* performing AIS prevention behavior on the vectors of the boat exterior (63% of boaters) and cleaning fishing tackle (47% of boaters), respectively: these two vectors had the lowest consistency of adoption of prevention behaviors. One possible explanation is that the influence of knowledge increase is most detectable among prevention behaviors that are not yet widely performed, during the period of consideration and uptake of innovative actions (Rogers 2003). I did not detect a significant, positive association between slogans recognized and *Always* performing AIS prevention behavior on the boat interior (performed by 68% of boaters) and non-transport and release of organisms (94% of boaters). This suggests that when behaviors are already performed at intermediate to high levels, alternatives to stimulate further behavior change may need to be explored. These can include consequences (e.g., incentives, disincentives) and social influences, such as modeling behavior (De Young 1993; Katzev and Johnson 1987). Formally engaging boaters to model AIS prevention behaviors, for example recruiting and training volunteer ambassadors for AIS prevention, could be considered as part of an active-engagement public education strategy.

The modest reponse rate to the boater survey means that some of my results should be interpreted with caution. My main analyses (relationships between knowledge and actions) were performed at the individual level and are thus expected to be robust to response rate. My overall results for boater adoption of conservation behaviors, however, may overestimate the adoption of AIS prevention behaviors at the population level. In particular, I consider that boaters likely to take time to respond to a survey about AIS are also the boaters who are most likely to engage with outreach programs and AIS education, and perhaps also to have been influenced by it to the extent that they adopt conservation behaviors. For this reason, I regard my results about boater knowledge and adoption of conservation actions to be high estimates of the population level knowledge and adoption rates.

Given limited conservation budgets and the significant resources invested in preventing invasive species, it is critical that efforts be as effective as possible. The Great Lakes Restoration Initiative reported that for 2014, $57 million USD were spent on invasive species including managment and eradication strategies, and public education and the materials distributed (GLRI 2014). For public education and outreach in Illinois alone, more than $600,000 was spent. Together with my study results, this investment highlights the need for systematic evaluation of AIS public education programs, with a focus on outcome metrics key to identifying knowledge and action gaps. Doing so is essential to identify program strengths and weaknesses in support of evidence-based approaches to conservation.

CHAPTER IV

CONCLUSIONS

Preventing the introduction and spread of aquatic invasive species (AIS) is a conservation challenge that requires integrated understanding and management across ecological and social systems. As humans have eliminated the natural barriers among once isolated freshwater systems (Rahel 2007), the continued increase in introduction and spread of AIS into these systems is imminent unless human behaviors are modified to decrease risk. In particular, the behaviors of recreational boaters are considered to be the most important way that many AIS are spread to waterbodies. Thus, positively influencing boater behaviors through public outreach and education can decrease the extent of waterbodies at risk.

Using Illinois as an illustrative example, this thesis demonstrates how waterbodies are linked by the travel patterns of recreational boaters and thus, what species might be spreading among these waterbodies. The network analysis in Chapter II evaluates the visits made to waterbodies by boaters. My results show that most waterbodies are visited annually by at least one boater that performs AIS prevention behaviors inconsistently. When boaters who *Always* perform recommended behaviors were removed, the resulting networks retained high density and low average path length. Waterbodies within the networks were connected, on average, by approximately two steps. This highlights the importance of improving consistency of proper prevention behaviors in respect to AIS spread among recreational boaters, because, under the right conditions, AIS can survive up to five days when they are transported by boats (Ricciardi et al. 1995), and can become established from a single introduction event (Lockwood et al. 2005). More generally, the analyses target boater travel patterns and demonstrate the applications of using network analysis to identify waterbodies at risk for AIS introduction and spread.

Chapter III discussed public education efforts and assessed how these efforts impact boater knowledge of invasive species and boater behavior that can prevent spread. Again, as boaters can be responsible for the spread of multiple species, modifying boater behavior through public outreach and education is seen as an important way to reduce introduction and spread. I found that boater knowledge and AIS prevention behavior was similar across three Illinois regions despite far greater investment in public outreach and education in the Northeastern region. Boaters who *Always* perform recommended behaviors did have statistically more knowledge of AIS than boaters who perform behaviors *less than Always*, but this difference was small (*Always* boaters recognized six species on average while *less than Always* boaters recognized five species on average out of 14 species total). Thus, AIS knowledge can influence boater behavior, but as the knowledge difference between *Always* and *less than Always* boaters is not large, AIS species knowledge might not have the extensive effect on boater behavior that conservation organizations would like to achieve. These results challenge the traditional thinking in public outreach that more knowledge about conservation issues will lead to changes in behavior (Hungerford and Volk 1990). Therefore, my results stress the importance of better understanding how public outreach and education programs impact behavior that can reduce introduction and spread, and a need for the incorporation of outcome metrics into evaluating the success of these programs as their success is crucial to protecting waterbodies from invasions.

Current evaluation of AIS public education and outreach is based on implementation metrics (e.g., numbers of individuals contacted and number of materials distributed) and does not emphasize outcome metrics. Indeed, managers in Illinois reported that primary measures of program success were estimates of boaters contacted and the number of education and outreach materials distributed or events that were conducted. These types of implementation metrics have been shown to be weak predictors of successful conservation efforts. My approach of measuring key outcomes such as boater knowledge and behavior provides a more reliable measurement of whether a public education program is delivering conservation benefits (Kapos et al. 2009). Results from my boater survey indicate that boaters recognized five to six AIS on average (out of 14 species total), and that boater recognition varied widely across species. This variation indicates a need for measuring knowledge and behaviors of boaters and to adapt public education and outreach towards AIS that boaters do not recognize, AIS that pose the highest risk, and towards consistent performance of behaviors that prevent AIS spread. By doing this, introduction and spread could be drastically reduced thereby protecting the biodiversity of freshwater systems.

Boaters indicated that media resources such as the Illinois Department of Natural Resources fishing guide, magazines, newsletters, and brochures as well as ID cards, television, and internet resources were highly useful for informing them about AIS. Thus, management organizations might want to consider incorporating more AIS prevention messages into these types of resources as these could enhance boater performance of behaviors. As the benefits of preventing spread might not be obviously noticeable to boaters, augmenting current education materials by advertising these benefits could increase adoption and performance of behaviors. This, along with providing more demonstrations at boat ramps of how to properly clean boats, could increase performance of behaviors thereby decreasing the potential for AIS spread.

Taken together, the data and analyses presented in this thesis comprise an empirically-based approach to better understand how conservation public education and outreach may support (or fail to support) widespread adoption and performance of conservation behaviors on the part of primary resource users. Successfully engaging primary resource users in widespread adoption and consistent performance of behaviors needed to support desirable conservation outcomes (e.g., *Always* cleaning boats, *Always* cleaning fishing tackle to prevent AIS introduction and spread) is a challenge common to all ecosystems open to the public for recreation and other shared uses. The freshwater ecosystems of Illinois illustrate the key elements of this challenge as many waterbodies in Illinois are public and their use is not restricted.

The contributions of this thesis advance modeling techniques used to understand patterns of AIS on the landscape and inform management about the effectiveness of current approaches to AIS prevention. Using Illinois as an illustrative example, this thesis maps boater behavior and travel patterns with biophyscial records of AIS to understand risk of AIS in Illinois waterbodies. It then investigates the complete chain of communication of AIS prevention outreach to boaters (e.g., slogans distributed by conservation organizations, where boaters receive their AIS information) and how this impacts boater perceptions and behaviors (e.g., boater recognition of prevention slogans and knowledge of AIS, as well as boaters' self-reported behaviors that prevent AIS spread). If introduction and spread are to be minimized, understanding boater travel patterns and behaviors as well as the effectiveness of boater public education and outreach is critical to reduce the risk of AIS to waterbodies.

The Great Lakes Restoration Initiative reported that for 2014, $57 million USD was spent in the Great Lakes Basin on invasive species including management and eradication strategies, as well as public education and the materials distributed (GLRI 2014). In Illinois alone, my results show that more than $600,000 USD was spent on public education and outreach. Thus, it is critical that public outreach and education efforts be as effective as possible. This significant investment in public education and outreach highlights the need for systematic evaluation of AIS education programs, with a focus on outcome metrics to identify strengths and weakness of programs so that program effectiveness can be improved. Using network analysis of boater travel patterns and records of AIS presence on the landscape facilitates integration of social and ecological data. This is important to conservation science and practice to prevent AIS and has potential applications to a variety of conservation challenges.

APPENDIX A

SUPPLEMENTAL SURVEYS AND TABLES

Survey A. Manager Interviews

As we begin this interview process, I will ask you to open the word document that I sent to you this morning. This word document will guide you through the interview process and I thought it might be easier for you to have a visual representation of my questions to increase accuracy and efficiency. If you have any questions during this interview process or a question is unclear, please feel free to ask. I'm happy to clarify.

To begin, I would like to ask you some questions about your organization and your AIS activities from 2013.

1) What is the mission statement of your organization?

2a) Could you briefly describe your outreach and how you address AIS concerns in the Great Lakes?

2b) What were your AIS outreach activities for 2013?

3a) What was the estimated budget for all your AIS outreach programs and activities for 2013?

3b) For the AIS outreach activities you mentioned, about how much was spent on each activity in 2013?

3c) What was your approximate full time equivalency (FTE) and volunteer hours devoted to each AIS activity in 2013? Did these people work year round?

AIS Activities	**Estimated Budget**	**Amount Spent**	**FTE**	**YrRound?**	**Vol. Hrs**

Survey A. *Continued*

Now, I would like to ask you about the preventative messages that your organization highlights. If you have that word document open, on page 1, you can see the table under the header Preventative Messages. This table represents the preventative messages which are common from online sources and I would like to know how important these messages are for your organization to highlight. "Importance" is based on "how much you promote these messages in your outreach materials."

4a) How important has it been for your organization to highlight the following AIS preventative messages?
Very important = included in >75% of outreach materials, Important = included in 75-50% of outreach materials, Somewhat Important = included in 50-25% of outreach materials, Not Very Important = included in 25-5% of outreach materials, Not At All Important = included in 0% of outreach materials

Table 4a: PREVENTATIVE MESSAGES	**Very Important**	**Important**	**Somewhat Important**	**Not Very Important**	**Not At All Important**
Conduct visual inspections of boat and remove all aquatic plants, animals and gelatinous globs	□	□	□	□	□
Visually inspect all angling equipment (including tackle) and remove all aquatic plants, animals and gelatinous globs	□	□	□	□	□
Drain water from boats, including live wells, bilge, and bait buckets	□	□	□	□	□
Flush motor's cooling system with tap water	□	□	□	□	□
Rinse boat with high pressure and/or hot water	□	□	□	□	□
Dry boat with a towel or allow boat to dry for at least five days	□	□	□	□	□
Identify and report invasive species to appropriate authorities	□	□	□	□	□
Dispose of live bait appropriately	□	□	□	□	□
Did not transport or release any animal or plant from one body of water to another	□	□	□	□	□
Other:	□	□	□	□	□

4b) Are there other preventative practices that your organization promotes that were not on this list? If so, what are they and how important have they been for your organization to highlight?

Other Preventative Messages	**Very Important**	**Important**	**Somewhat Important**	**Rarely Important**	**Never Important**
	O	O	O	O	O
	O	O	O	O	O
	O	O	O	O	O
	O	O	O	O	O
	O	O	O	O	O
	O	O	O	O	O
	O	O	O	O	O
	O	O	O	O	O

Survey A. *Continued*

4c) Are there slogan names that your organization associates with these AIS preventive messages?

	Slogan Name
Conduct visual inspections of boat and remove all aquatic plants, animals and gelatinous globs	
Visually inspect all angling equipment (including tackle) and remove all aquatic plants, animals and gelatinous globs	
Drain water from boats, including live wells, bilge, and bait buckets	
Flush motor's cooling system with tap water	
Rinse boat with high pressure and/or hot water	
Dry boat with a towel or allow boat to dry for at least five days	
Identify and report invasive species to appropriate authorities	
Dispose of live bait appropriately	
Do not transport or release any animal or plant from one body of water to another	

4d) Of these AIS preventative messages, approximately how much money (operational budget; other?), Full-time equivalent or FTE (did these people work year round?) and volunteer hours was invested by your organization for that message?

	Total $	*Oper $*	*Other $*	*FTE Hrs*	*YrRound ?*	*Vol. Hrs*
Conduct visual inspections of boat and remove all aquatic plants, animals and gelatinous globs						
Visually inspect all angling equipment (including tackle) and remove all aquatic plants, animals and gelatinous globs						
Drain water from boats, including live wells, bilge, and bait buckets						
Flush motor's cooling system with tap water						
Rinse boat with high pressure and/or hot water						
Dry boat with a towel or allow boat to dry for at least five days						
Identify and report invasive species to appropriate authorities						
Dispose of live bait appropriately						
Did not transport or release any animal or plant from one body of water to another						
Other:						

Survey A. *Continued*

The next table I would like to discuss is the "Slogans" table. This list represents those slogans which I have found online and I would like to know how important these listed slogans, and any others that your organization promotes that are unlisted, have been for your organization to promote. "Importance" is based on how much you promote these messages in your outreach materials.

5a) How important are the following slogans to your organization?
Very important =promoted in >75% of outreach materials, Important = promoted in 75-50% of outreach materials, Somewhat Important = promoted in 50-25% of outreach materials, Not Very Important = promoted in 25-5% of outreach materials, Not At All Important = promoted in 0% of outreach materials

Table 5a: SLOGANS	***Very Important***	***Important***	***Somewhat Important***	***Not Very Important***	***Not At All Important***
Be a Hero Transport Zero	□	□	□	□	□
Protect Your Waters: Stop Aquatic Hitchhikers	□	□	□	□	□
Hydrilla Hunt!	□	□	□	□	□
Get a Habitattitude!	□	□	□	□	□
Clean, Drain and Dry	□	□	□	□	□
Clean Boats, Clean Waters	□	□	□	□	□
Other:	□	□	□	□	□

5b) Are there other slogans that I did not mention that are promoted by your organization? If so, what are they and how important are these slogans for your organization to promote?

5c) Approximately, how much money (operational budget and other?), FTE (did these people work year round?) and volunteer hours were invested by your organization for the promotion of these slogans?

Table 5a: SLOGANS	*Total $*	*Oper $*	*Other $*	*FTE Hrs*	*YrRo?*	*Vol. Hrs*
Be a Hero Transport Zero						
Protect Your Waters: Stop Aquatic Hitchhikers						
Hydrilla Hunt!						
Get a Habitattitude!						
Clean, Drain and Dry						
Clean Boats, Clean Waters						

Survey A. *Continued*

In the next table found under the Methods of Outreach section on page 2, I would like to ask you about the different methods of outreach which your organization uses to inform your target audience about AIS and how important they are to your programs. This table lists those methods I found from online sources but please feel free to tell me about the methods of communication your organization uses that are not listed on the table.

6a) How important are these methods of communicating AIS information to your target audience?

Very important = used >75% of the time as a method of communication, Important = used 75-50% of the time as a method of communication, Somewhat Important = used 50-25% of the time as a method of communication, Not Very Important = used 25-5% of the time as a method of communication, Not At All Important =used 0% of the time as a method of communication

Table 6a: METHODS OF OUTREACH	***Very Important***	***Important***	***Somewhat Important***	***Not Very Important***	***Not At All Important***
Magazines or newsletter articles	□	□	□	□	□
Television news or programs	□	□	□	□	□
Radio news or programs	□	□	□	□	□
Television public service announcements	□	□	□	□	□
Radio public service announcements	□	□	□	□	□
Brochures, species ID cards, fact sheets	□	□	□	□	□
Internet websites	□	□	□	□	□
Pamphlets from a sports show	□	□	□	□	□
Stickers from tackle boxes	□	□	□	□	□
YouTube videos	□	□	□	□	□
Other:	□	□	□	□	□

Table 6a: METHODS OF OUTREACH	***Very Important***	***Important***	***Somewhat Important***	***Not Very Important***	***Not At All Important***
Workshops on aquatic invasive species prevention	□	□	□	□	□
Educational exhibits or displays	□	□	□	□	□
Booths at a sports or fishing show	□	□	□	□	□
Conducting surveys at boat launches	□	□	□	□	□
Providing information to a bait shop or sporting goods store	□	□	□	□	□
Volunteers distributing information on AIS	□	□	□	□	□
Actions of members of the Clean Boats, Clean Waters campaign	□	□	□	□	□
Other:	□	□	□	□	□

Survey A. *Continued*

6b) Are there other methods of outreach that I did not mention that are promoted by your organization? If so, what are they and how important are these methods for your organization to promote? ANY EVENTS?

6c) Of these outreach methods, approximately how much money (operational budget; other?), full time equivalency (FTE) did these people work year round?) and volunteer hours was invested by your organization for these outreach methods?

	Total $	*Oper $*	*Other $*	*FTE Hrs*	*YrRound?*	*Vol. Hrs*
Magazines or newsletter articles						
Television news or programs						
Radio news or programs						
Television public service announcements						
Radio public service announcements						
Brochures, species ID cards, fact sheets						
Internet websites						
Pamphlets from a sports show						
Stickers from tackle boxes						
YouTube videos						
Other:						

	Total $	*Oper $*	*Other $*	*FTE Hrs*	*YrRound?*	*Vol. Hrs*
Workshops on aquatic invasive species prevention						
Educational exhibits or displays						
Booths at a sports or fishing show						
Conducting surveys at boat launches						
Providing information to a bait shop or sporting goods store						
Volunteers distributing information on AIS						
Actions of members of the Clean Boats, Clean Waters campaign						
Other:						

6d) From the methods listed above and those which we talked about, in your opinion, what is the most effective method of communication that promotes a positive behavioral change in your target audience?

Survey A*. Continued*

The next table I would like to discuss is the “Specific AIS” table on page 3. This table lists those AIS which I found online which are highlighted by multiple organizations. Looking at the table, I would like to know how important to your organization the listed AIS, and any other AIS which your organization highlights, are to target in your outreach.

7a) How important are these AIS to target in your outreach activities?

Very important = mentioned in >75% of outreach materials, Important = mentioned in 75-50% of outreach materials, Somewhat Important = mentioned in 50-25% of outreach materials, Not Very Important = mentioned in 25-5% of outreach materials, Not At All Important = mentioned in 0% of outreach materials

Table 7a: SPECIFIC AIS	***Very Important***	***Important***	***Somewhat Important***	***Rarely Important***	***Never Important***
PLANTS					
Hydrilla	□	□	□	□	□
Curly Pondweed	□	□	□	□	□
Purple Loosestrife	□	□	□	□	□
Brazilean elodea	□	□	□	□	□
Water Hyacinth	□	□	□	□	□
Eurasian Watermilfoil	□	□	□	□	□
Reed canary grass	□	□	□	□	□
Flowering rush	□	□	□	□	□
Watercress	□	□	□	□	□
MUSSELS					
Zebra mussels	□	□	□	□	□
Quagga mussels	□	□	□	□	□
FISH					
Asian Carp	□	□	□	□	□
Northern Snakehead	□	□	□	□	□
Sea lamprey	□	□	□	□	□
Round Goby	□	□	□	□	□
OTHER SPECIES					
VHS (Fish disease)	□	□	□	□	□
Whirling Disease	□	□	□	□	□
Rusty crayfish	□	□	□	□	□
Spiny waterflea	□	□	□	□	□

7b) Are there other AIS included in outreach activities that I did not mention? If so, what are they and how important for your organization are they to target?

Now, I would like to ask some questions about the “AIS Vector” table. The AIS vectors listed are those which I found from several sources. I would like to know if your organization targets these AIS vectors, or others not mentioned, and how important these vectors are for your organization to target.

Survey A. *Continued*

8a) How important are these AIS vectors to target in your organization's outreach activities?

Very important = targeted in >75% of outreach materials, Important = targeted in 75-50% of outreach materials, Somewhat Important = targeted in 50-25% of outreach materials, Not Very Important = targeted in 25-5% of outreach materials, Not At All Important = targeted in 0% of outreach materials

Table 8a: AIS VECTORS	***Very Important***	***Important***	***Somewhat Important***	***Rarely Important***	***Never Important***
Boaters	□	□	□	□	□
Anglers	□	□	□	□	□
Bait Vendors	□	□	□	□	□
Water Gardeners	□	□	□	□	□
Aquarium Hobbyists	□	□	□	□	□

8b) Are there other vectors you target that are not on the above list? If so, who are they and how important for your organization are they to target? BALLAST WATER?

There is just one more graph I would like you to look at as this interview is almost finished. The "Regions" table on page 4 represents different regions of Illinois defined by the ILDNR. I would like to know how important it has been for your organization to target the different regions of the state for your outreach materials (can they give me specific counties and what they have done there?). To what extent do you target rural and urban areas? (give in percentage)

9a) How important have the following regions of Illinois been to target for your outreach activities? Very important =targeted >75% of the time, Important =targeted 75-50% of the time, Somewhat Important = targeted 50-25% of the time, Not Very Important = targeted 25-5% of the time, Not At All Important = targeted 0% of the time

Table 9a: REGIONS	***Very Important***	***Important***	***Somewhat Important***	***Not Very Important***	***Not At All Important***
Northwestern, IL	□	□	□	□	□
Northeastern, IL	□	□	□	□	□
East Central, IL	□	□	□	□	□
West Central, IL	□	□	□	□	□
Southern, IL	□	□	□	□	□

Survey A*. Continued*

9b) To what extent do you target rural and urban areas (percentage)? SPECIFIC LOCATIONS?

We are almost done and I have learned a lot about your organization. I just have 2 questions concerning your outreach activities.

10a) How do you know if your outreach activities have been successful?

10b) Do you know how many people visit your AIS websites? Do these websites have counters? Names of these websites?

Finally, are there other organizations you work with? Who is your contact person for that organization? For those organizations you have mentioned, how often do you interact with these people? Of this list, who has been your most important financial contributor?

11a) What other organizations do you work with? Who is your contact person associated with these organizations? How much do you interact with these organizations and or their directors?

3 = Involved in a project together; 1 = Have met at professional meeting; 0 = Have had no interaction

Agency Name and Contact	***3***	***1***	***0***
	□	□	□
	□	□	□
	□	□	□
	□	□	□
	□	□	□
	□	□	□
	□	□	□

11b) Of the organizations you listed above, who has been your most important financial contributor?

12) Can you suggest who else I might contact who also works with AIS outreach in Illinois?

This concludes our interview and I really appreciate all your help in answering these questions. Thank you very much for your assistance.

Survey B. Boater Survey



We need your help to understand the outreach, education and extension efforts conducted around Aquatic Invasive Species (AIS) in our state. This is a survey of boaters and anglers in Illinois. This survey will allow you to express your opinions and experiences with Aquatic Invasive Species (AIS) in our state.

Voluntary Participation: Participation in this research survey is voluntary. If you do not want to be part of this research, you do not have to participate. Even if you decide to participate, you are free not to answer any question or to withdraw from participation at any time.

This survey takes 15-20 minutes to complete.

Confidentiality: All data and responses will remain strictly confidential. All survey answers will be coded so that no names will appear on the reports generated from this survey. All responses will be linked to numeric codes that are stored separately from participant response data to ensure confidentiality.

Risks/Benefits: There are no foreseeable risks involved in participating in this research beyond those experienced in everyday life. There are no direct benefits to you from participating in the interview, but this study evaluates the benefits of AIS-prevention programs, which is supported by Federal and State Agencies including the IL Department of Natural Resources and Illinois-Indiana Sea-Grant.

Statement of Consent: Continuing with this survey indicates that you have read the information provided above and agree to participate in this research study.

***Raffle Drawing:* If you'd like to be entered in a raffle for an iPad please let us know the best way to reach you by phone or e-mail:**

Name & contact for iPad raffle: ____

PLEASE RETURN THE SURVEY IN THE POSTAGE-PAID ENVELOPE

Contacts and Questions: If you have questions about this research study, please contact:

- ***Ellen Cole*** *(Graduate Researcher at Loyola University Chicago - Dept. of Biology) @ 517-262-8690, ecole3@luc.edu*
- ***Kelly Garbach*** *(Assistant Professor at Loyola University Chicago – Institute of Environmental Sustainability) @ 773-508-2948, kgarbach@luc.edu*
- ***Reuben Keller*** *(Assistant Professor at Loyola University Chicago - Institute of Environmental Sustainability) @ 773-508-2952, rkeller1@luc.edu*

If you have questions about your rights as a research participant, you may contact the Loyola University Office of Research Services at (773) 508-2689.

Survey B. *Continued*

Current Knowledge and Practices

1. What aquatic invasive species have you heard about and which species have you observed in or near the water bodies you went to during 2013? *Please select all appropriate boxes.*

Table 1:	**Have you heard of these species?**		**Did you see these species in or near the water bodies you visited over the summer?**	
PLANTS	**Yes**	**No**	**Yes**	**No**
Hydrilla	☐	☐	☐	☐
Curly Pondweed	☐	☐	☐	☐
Purple Loosestrife	☐	☐	☐	☐
Brazilean Elodea	☐	☐	☐	☐
Water Hyacinth	☐	☐	☐	☐
Eurasian Watermilfoil	☐	☐	☐	☐
MUSSELS				
Zebra mussels	☐	☐	☐	☐
Quagga mussels	☐	☐	☐	☐
FISH				
Asian Carp	☐	☐	☐	☐
Northern Snakehead	☐	☐	☐	☐
Round Goby	☐	☐	☐	☐
ADDITIONAL SPECIES				
Rusty crayfish	☐	☐	☐	☐
VHS (Fish disease)	☐	☐	☐	☐
Spiny waterflea	☐	☐	☐	☐

2. How important is it to prevent the spread of these groups of invasive species? *Please select all appropriate boxes.*

Table 2:	**Very Important**	**Important**	**Moderately Important**	**Of Little Importance**	**Not Important**
PLANTS	☐	☐	☐	☐	☐
MUSSELS	☐	☐	☐	☐	☐
FISH	☐	☐	☐	☐	☐
CRAYFISH	☐	☐	☐	☐	☐
FISH DISEASE	☐	☐	☐	☐	☐
SPINY WATERFLEA	☐	☐	☐	☐	☐
OTHER:____________________	☐	☐	☐	☐	☐

Survey B. *Continued*

3. How important do you think it is to prevent the spread of these specific invasive species in Illinois? *Please select all appropriate boxes.*

Table 3:	**Very Important**	**Important**	**Moderately Important**	**Of Little Importance**	**Not Important**
PLANTS					
Hydrilla	◻	◻	◻	◻	◻
Curly Pondweed	◻	◻	◻	◻	◻
Purple Loosestrife	◻	◻	◻	◻	◻
Brazilean Elodea	◻	◻	◻	◻	◻
Water Hyacinth	◻	◻	◻	◻	◻
Eurasian Watermilfoil	◻	◻	◻	◻	◻
MUSSELS					
Zebra mussels	◻	◻	◻	◻	◻
Quagga mussels	◻	◻	◻	◻	◻
FISH					
Asian Carp	◻	◻	◻	◻	◻
Northern Snakehead	◻	◻	◻	◻	◻
Round Goby	◻	◻	◻	◻	◻
ADDITIONAL SPECIES					
Rusty crayfish	◻	◻	◻	◻	◻
VHS (Fish disease)	◻	◻	◻	◻	◻
Spiny waterflea	◻	◻	◻	◻	◻
Other: ________________________	◻	◻	◻	◻	◻

4. Please tell us how often you performed the following actions during the summer of 2013 by selecting all appropriate boxes. (Note: Select N/A if you do not own a boat.)

Table 4:	**Always**	**Often**	**Sometimes**	**Rarely**	**Never**	**N/A**
Conducted visual inspections of boat and removed all aquatic plants, animals and gelatinous globs	◻	◻	◻	◻	◻	◻
Visually inspected all angling equipment (including tackle) and removed all aquatic plants, animals and gelatinous globs	◻	◻	◻	◻	◻	◻
Drained water from boats, including live wells, bilge, and bait buckets	◻	◻	◻	◻	◻	◻
Flushed motor's cooling system with tap water	◻	◻	◻	◻	◻	◻
Rinsed boat with high pressure and/or hot water	◻	◻	◻	◻	◻	◻
Dried boat with a towel or allowed boat to dry for at least five days	◻	◻	◻	◻	◻	◻
Disposed of or kept live bait for next fishing trip	◻	◻	◻	◻	◻	◻
Identified and reported invasive species to appropriate authorities	◻	◻	◻	◻	◻	◻
Transported and released any animal or plant from one body of water to another	◻	◻	◻	◻	◻	◻

Survey B. *Continued*

Sources of Information about Aquatic Invasive Species

5. Please tell us how useful you have found these resources for increasing your knowledge of aquatic invasive species by selecting the appropriate boxes.

Table 5:	**Very Useful**	**Useful**	**Occasionally Useful**	**Rarely Useful**	**Never Useful**	**Have Not Used**
Magazines or newsletter articles	□	□	□	□	□	□
Television news or programs	□	□	□	□	□	□
Radio news or programs	□	□	□	□	□	□
Television public service announcements	□	□	□	□	□	□
Radio public service announcements	□	□	□	□	□	□
Brochures, species ID cards, fact sheets	□	□	□	□	□	□
Internet websites	□	□	□	□	□	□
Pamphlets from a sports show	□	□	□	□	□	□
Stickers from tackle boxes	□	□	□	□	□	□
YouTube videos	□	□	□	□	□	□
Other: ______________________________	□	□	□	□	□	□

6. Please tell us how useful you have found these events for increasing your knowledge of aquatic invasive species by selecting the appropriate boxes.

Table 6:	**Very Useful**	**Useful**	**Occasionally Useful**	**Rarely Useful**	**Never Useful**	**Have Not Used**
Attending an aquatic invasive species workshop	□	□	□	□	□	□
Viewing an educational exhibit or display	□	□	□	□	□	□
Seeing a booth at a sports or fishing show	□	□	□	□	□	□
Participating in surveys conducted at boat launches	□	□	□	□	□	□
Reading information provided at a bait shop or sporting goods store	□	□	□	□	□	□
An event organized by a fishing, boating or sporting organization	□	□	□	□	□	□
An event organized by an environmental organization	□	□	□	□	□	□
Other: ______________________________	□	□	□	□	□	□

Survey B. *Continued*

7. Please tell us who has given you the most useful information about aquatic invasive species by selecting the appropriate boxes.

Table 7:	Very Useful	Useful	Occasionally Useful	Rarely Useful	Never Useful	Have Not Used
Members in my boating or angling club	□	□	□	□	□	□
Family members, friends or neighbors	□	□	□	□	□	□
Bait shop vendor	□	□	□	□	□	□
Sales associate at boating or fishing store	□	□	□	□	□	□
Governmental employee or volunteer	□	□	□	□	□	□
Other: ____________________________	□	□	□	□	□	□

8. The DNR distributes a fishing guide called Illinois Fishing Information. This guide provides information on fish that can be legally caught and how to identify invasive species. How useful did you find the information provided in this book for increasing your knowledge about aquatic invasive species? *Please select the most appropriate box.*

□ Very Useful
□ Useful
□ Occasionally Useful
□ Rarely Useful
□ Never Useful
□ I do not own a fishing license

9. Overall, what **RESOURCE** have you found to be the **MOST USEFUL** for increasing your knowledge about aquatic invasive species?

Please specify: ____

10. Please tell us what programs or slogans you have heard of and which have been the most useful in increasing your knowledge of how to prevent aquatic invasive species by selecting the appropriate boxes. (Note: Select N/A if you have not heard of these programs or slogans.)

Table 10:	Have you heard of this program or slogan?		How useful has this program or slogan been for you?					
	Yes	No	Very Useful	Useful	Occasionally Useful	Rarely Useful	Never Useful	N/A
Be a Hero Transport Zero	□	□	□	□	□	□	□	□
Protect Your Waters: Stop Aquatic Hitchhikers	□	□	□	□	□	□	□	□
Hydrilla Hunt!	□	□	□	□	□	□	□	□
Get a Habitattitude!	□	□	□	□	□	□	□	□
Clean, Drain and Dry	□	□	□	□	□	□	□	□
Clean Boats Crew	□	□	□	□	□	□	□	□

Survey B. *Continued*

Summer of 2013 Boating Practices

11. Do you have a boat? *Please select the appropriate box.*
    - □ Yes
    - □ No – please go to question 16 on the next page.

12. How many times did you launch your boat this past summer? *Please select the most appropriate box.*
    - □ 1-5 times
    - □ 6-10 times
    - □ 11-20 times
    - □ 21-40 times
    - □ 41 times or more
    - □ I did not launch my boat this past summer

13. Did you take you boat to any water bodies this summer either outside of Illinois or up to 100 miles from your home? *Please select the most appropriate box.*
    - □ Yes
    - □ No

14. Approximately, how many water bodies did you visit with your boat this past summer?
    Please specify: ___________

15. Please specify the names, the nearest towns, the states, and the distances traveled from your home of the five most recent water bodies you visited in 2013. *Please specify information in the appropriate box.*

Name of Water Body	Nearest Town	State	Approximate Distance traveled from your home
1)			
2)			
3)			
4)			
5)			

Survey B. *Continued*

Additional Information

16. What is your zip code? *Please enter a 5 digit code*.

17. What is your gender? *Please select the appropriate box.*
    - □ Male
    - □ Female

18. What is your age? *Please specify.*
    _____ years

19. What is the highest level of education you have completed? *Please select the appropriate box.*
    - □ High school coursework or GED
    - □ Some college, but no degree
    - □ College degree
    - □ Some graduate school, but no degree
    - □ Master's, doctoral or professional degree

Thank you very much for your help!

Please return this survey in the postage-paid return envelope.

Table 6. Survey distribution and response by county.

Region	County	Surveys Sent	Surveys Returned	% Returned
Northeastern	Cook	555	54	10%
Northeastern	DuPage	554	62	11%
Northeastern	Grundy	554	55	10%
Northeastern	Lake	555	48	9%
Northwestern	Carroll	285	40	14%
Northwestern	Putman	95	18	19%
Northwestern	Tazewell	919	62	7%
Northwestern	Winnebago	919	104	11%
Southern	Alexander	58	5	9%
Southern	Franklin	537	33	6%
Southern	Gallatin	70	0	0%
Southern	Williamson	899	68	8%
Unknown	-	-	7	-

Table 7. Waterbodies larger than 25km^2.

Waterbody Name	Area (km^2)
Bowstring Lake	37.2
Bull Shoals Lake	182.0
Carlyle Lake	92.2
Cass Lake	83.8
Castle Rock Lake	52.6
Cedar Lake	26.3
Crab Orchard Lake	29.5
Enid Lake	59.3
Green Lake	31.0
Guntersville Lake	265.5
H Neely Henry Lake	35.5
Indian Lake	35.0
J Percy Priest Reservoir	56.8
Kabetogama Lake	90.4
Kentucky Lake	476.8
Lac De Mille Lacs	245.1
Lake Chippewa	60.2
Lake Erie	25744.5
Lake Hamilton	27.0
Lake Istokpoga	107.3
Lake Koshkonong	42.9
Lake Lac Seul	1657.6

Table 7. Waterbodies larger than 25km *Continued*

Waterbody Name	Area (km^2)
Lake Mendota	39.6
Lake Michigan	57846.0
Lake Monroe	45.0
Lake O Pines	73.5
Lake of the Ozarks	185.3
Lake of the Woods	555.7
Lake Shelbyville	41.4
Lake St. Clair	419.1
Lake Truman	81.6
Lake Vermillion	157.4
Lake Wabaskang	60.7
Lake Winnebago	534.2
Lake Wisconsin	29.1
Leach lake	418.2
Mark Twain Lake	36.5
Millac's Lake	518.7
Mille Lacs Lake	518.7
Rainy Lake	185.2
Reed Lake	58.9
Rend Lake	69.0
Sam Rayburn Reservoir	452.3
Sardis Lake	162.3
Table Rock Lake	136.9

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