Investigating Aquatic Invasive Species Propagation within the Adirondack Region of New York: A Lake and Landscape Approach

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Volume 36, 2013

Papers in Applied Geography

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PAPERS IN APPLIED GEOGRAPHY

VOLUME 36, 2013

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INVESTIGATING AQUATIC INVASIVE SPECIES PROPAGATION WITHIN THE ADIRONDACK REGION OF NEW YORK: A LAKE AND LANDSCAPE APPROACH

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1. INTRODUCTION

"Invasive species (IS)" are non-indigenous flora and fauna that adversely impact the integrity of native ecosystems. The impacts of IS on native species, communities, and ecosystems have been widely acknowledged since the late 1950s (Elton, 1958; Lodge, 1993; Simberloff, 1996), and they are now considered a significant component of global change (Vitousek *et al*., 1996). IS damage the lands and waters that native plants and animals need to survive, and it has been argued that IS are second only to habitat loss as the greatest threat to biological diversity (Wilcove *et al*., 1998). The severe economic impact of these species is evident; estimated costs of IS worldwide total more than $1.4 trillion – 5 percent of the global economy (Pimentel *et al*., 2001). In the United States alone, estimated economic damages and control costs associated with IS amount to roughly $120 billion annually (Pimentel *et al*., 2005). In response, Executive Order #13112 directed several federal agencies "to prevent the introduction of invasive species and provide for their control and to minimize the economic, ecological, and human health impacts that invasive species cause" (Fed. Regist. 1993:6183-86).

The means and routes by which IS are introduced into new environments are called "pathways" or "vectors." Focusing on aquatic invasive species (AIS), much of the ongoing propagation can be attributed to the overland movement of small-craft boats (Leung *et al*., 2006; Rothlisberger *et al*., 2010). Small-craft boats are vessels less than 40 feet (12.2 m) in length, including canoes and kayaks, personal watercraft, powerboats, small commercial and recreational fishing boats, sailboats, and pontoon boats, that can be towed overland on trailers (Rothlisberger *et al*., 2010). The spread of AIS by boaters can be intentional (*e.g.*, bait dumping) or unintentional (*e.g.*, bilge water), and are often attached on boat exteriors (e.g., entangled on propellers). AIS are known to have considerable negative effects on the aquatic ecosystems they invade with impacts including: damages to fisheries, interference with raw water usage, decreased property values, extirpation of native species, and threats to human health (Rothlisberger *et al*., 2010).

Efforts to stop the spread of AIS focus on pre-launch boat inspections at uninvaded waterways, and on campaigns to educate stakeholders on actions that they can take to reduce transporting AIS. Regional and national programs such as Protect Your Waters (www.protectyourwaters.net) recommend the following actions for boaters to reduce the likelihood of spreading AIS: "inspect and remove aquatic plants, animals, and mud from boat, trailer, and equipment before leaving the landing; drain all water from boat, motor, live wells, bilge, bait buckets and other containers before leaving the landing; ice your catch, and do not leave landing with any live fish, bait, or fish eggs; dispose of unused bait in trash, not in the water or on land; and rinse boat and equipment with hot and/or high pressure water or dry boat for at least five days." As most small-craft boat inspection sites occur at public ramps, more research is needed on the impacts of private verses public launch sites.

Invasion is a multi-step process comprised of the following three phases: (1) initial dispersal (where an organism moves from its native habitat, often over long distances, to a new habitat outside of its home range); (2) establishment of self-sustaining populations within the new habitat; and (3) spread of the organism to nearby habitats (Puth and Post, 2005). Due to the magnitude of issues associated with IS, studies of the invasion process and exotic species has increased considerably over the last decades. During a review of IS literature from 1995-2004, only 11 percent of studies examined the initial dispersal phase and only half of these were empirical (Puth and Post, 2005). The initial dispersal stage of invasion is the phase upon which the other two rest. Albeit, it is during the initial dispersal that efforts can prevent the establishment and subsequent impacts of IS (Simberloff *et al.*, 2005).

To address the lack of empirical research on the initial dispersal phase of invasion, we developed an empirical study between lake and landscape characteristics on two AIS in 26 lakes within the Adirondack region of northern New York. To elucidate progress of aquatic resource management, lake association affiliation was assessed against a measure of invasion (AIS richness), and lake and landscape characteristics. Using logistic regression (generalized linear model; GLM), the following three null hypotheses are tested: (1) no significant relationship exists between lake and landscape characteristics, and the presence of Eurasian Water-Milfoil (*Myriophyllum spicatum*); (2) no significant relationship exists between lake and landscape characteristics, and the presence of Curly-Leaf Pondweed (*Potamogeton crispus*); and (3) presence of a lake association is not significantly related to AIS richness nor lake and landscape characteristics.

2. METHOD

2.1 STUDY AREA

Twenty-six lakes were randomly selected from 88 lakes monitored and documented in the Adirondack Park Invasive Plant Program (APIPP) 2012 Annual Report (Figure 1). The Adirondack Park is a state-level protected area and National Historic Landmark in Upstate New York. The Adirondack region of New York covers 2.6 million hectares (6.4 million acres) and includes 10,000+ lakes and 48,200 km (30,000 miles) of rivers and streams (APA, 2011). The Adirondack Park is the largest park in the conterminous United States and its size is comparable to the state of Vermont. The Park, created in 1892 through an act of New York State legislation, is now home to 132,000 residences and has over 100 towns and villages (APA, 2011). Twelve counties overlap the Park limits, with only Essex and Hamilton counties wholly within its borders. With a wide variety of habitats including wetlands and old-growth forests, there are almost 200,000 seasonal residents and approximately six million people that are attracted to the Park annually (Sharp *et al.*, 2001). Situated within a day's drive of New York City, the Park is well positioned to offer its unique blend of wilderness solitude, outdoor recreation, and community life to millions of visitors who, in increasing numbers, see the Park as a unique travel destination (APA, 2011). The 26 lakes selected in this study represent various sub-regions of the Adirondack Park, and have largely different surface areas and elevations.

The mixture of public and private lands is a distinguishing feature of the Adirondack Park. As of 2011, state ownerships account for roughly 43% of the area within the Park, private ownerships account for 51%, and water accounts for 6% (APA, 2011). At the core of the Adirondack Park is the Forest Preserve that was created by New York Legislature in 1885; this area includes the 46 high peaks of the Adirondack Mountains. There has been a continued history of environmental stewardship in the Adirondacks since the "forever wild" amendment to the state constitution in 1894. Through Article 14 of the New York State Constitution, the Forest Preserve lands are constitutionally protected: "The lands now or hereafter constituting them shall be forever kept as wild forest lands. They shall not be sold, nor shall they be leased or taken by any person or corporation public or private." The water resources of the region are critical to the integrity of the Park. The water's designated use, established by the state, also has a direct impact on adjacent land holdings. Major causes to aquatic impairment of the Adirondack Park are linked to poor land use practices, acidification of waters through regional deposition, and the spread of AIS. Although the 1990 Clean Air Act Amendments have improved water pH, and the land-water interface receives environmental management attention, it can be presumed that increases in tourism will intensify the spread of AIS.

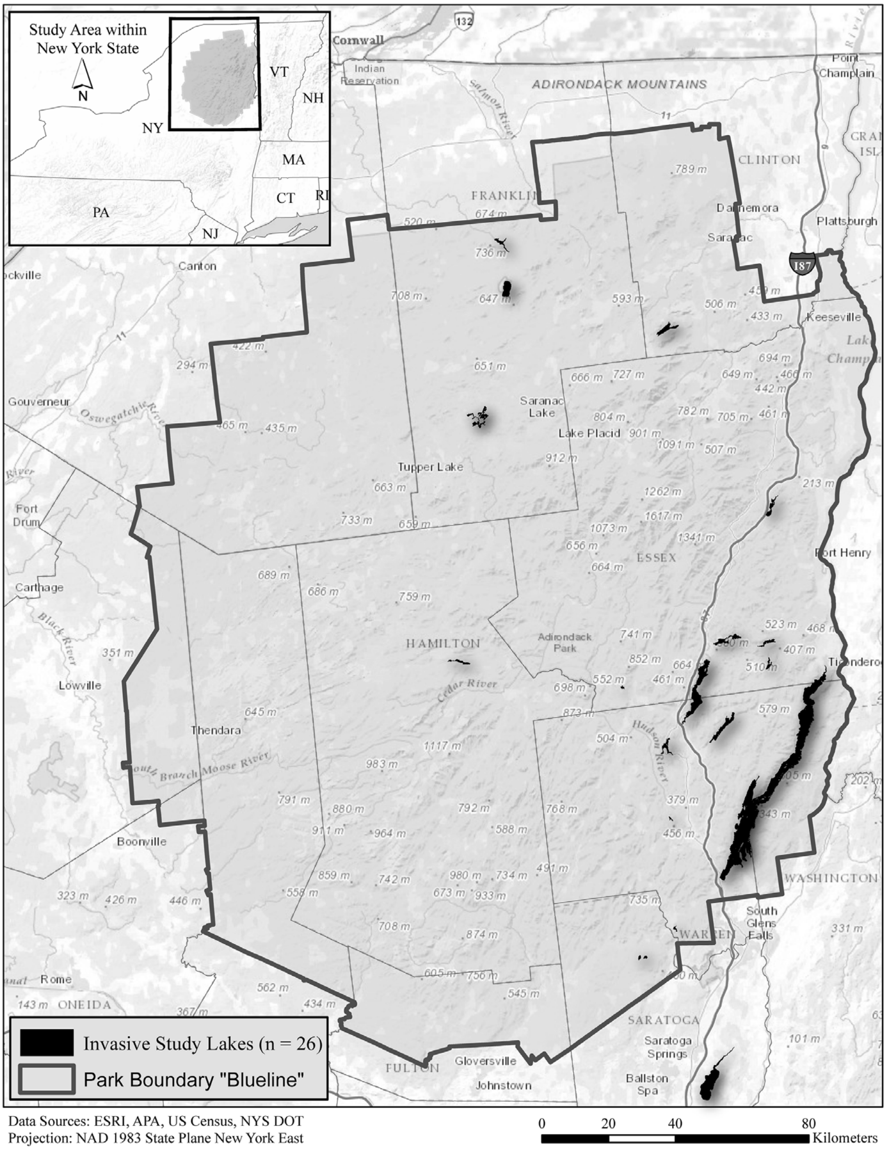

FIGURE 1
STUDY AREA LOCATION OF 26 LAKES WITHIN THE ADIRONDACK REGION OF NORTHERN NEW YORK (43°56'N, 74°23'W)

2.2 APIPP LAKE MONITORING AND *IN SITU* DATA COLLECTION

The New York State Legislature created the Adirondack Park Agency (APA) in 1971 with the mission to protect private and public resources within park limits (commonly known as the "Blue Line") through the exercise of the powers and duties of the Agency as provided by law (APA, 2011). The thesis of the APA Act is "to insure optimum overall conservation, development and use of the unique scenic, aesthetic, wildlife, recreational, open space, historic, ecological and natural resources of the Adirondack Park." In response to protecting the

Adirondack region from the negative impacts of invading species, the Adirondack Partnership for Regional Invasive Species Management (PRISM) initiated APIPP in 1998. The Adirondack Chapter of The Nature Conservancy houses APIPP. APIPP coordinates two regional projects: the Aquatic Invasive Species Project and the Terrestrial Invasive Species Project. The forthcoming research uses data collected in 2012 by the Aquatic Invasive Species Project.

Over the past eleven seasons more than 597 APIPP volunteers surveyed 300 distinct waterways; albeit 88 waterways are now recognized to have a least one non-native aquatic plant or animal present (APIPP, 2012). Currently, the number of "invasive-free" lakes surveyed by APIPP volunteers is more than 2.5 times that of infested lakes. Of the 88 invaded waterways, approximately 64 are considered public and 24 are private (APIPP, 2012). Since APIPP's inception, its volunteers have registered the following eleven aquatic flora and fauna throughout the region: Asian Clam, Brittle Naiad, Curly-leaf Pondweed, Eurasian Watermilfoil, European Frog-bit, Fanwort, Spiny Waterflea, Variable-leaf Milfoil, Water Chestnut, Yellow Floating Heart, and Zebra Mussel (Table 1). Of those eleven invasive species, nine were found present throughout the 26 lakes of this study. AIS richness, an additive index of only those AIS present in each lake, and Eurasian Water-milfoil and Curly-Leaf Pondweed were focused on in the ensuing analyses.

TABLE 1
ELEVEN AQUATIC INVASIVE SPECIES FOUND IN ADIRONDACK WATERWAYS; NINE SPECIES PRESENT IN STUDY AREA LAKES HIGHLIGHTED IN BOLD

Common Name	Scientific Name
Asian Clam	***Corbicula fluminea***
Brittle Naiad	***Najas minor***
Curly-leaf Pondweed	***Potamogeton crispus***
European Frog-bit	*Hydrocharis morsus-ranae*
Eurasian Watermilfoil	***Myriophyllum spicatum***
Fanwort	***Cabomba caroliniana***
Spiny Waterflea	***Bythotrephes longimanus***
Variable-leaf Milfoil	***Myriophyllum heterophyllum***
Water Chestnut	***Trapa natans***
Yellow Floating Heart	*Nymphoides peltata*
Zebra Mussel	***Dreissena polymorpha***

The question of whether AIS are transmitted more through private or public boat ramps has rarely been asked. Although it can be assumed that the majority of small-craft boats are launched at public access points, AIS continue to be introduced into previously invasive free waterways. Examples of private launch sites seldom monitored include: private campgrounds, private marinas, waterfront residences, hotels and resorts. These seldom monitored launch sites create unregulated entry points that AIS can pass through. Further, to complicate aquatic management in the Adirondacks, most waterways have both private and public entry locations. To study the independent impact of access type, field data were collected for the 26 lakes. The following variables were collected for each lake in this study: elevation, depth, total boat access locations, percent private boat ramps, and percent public boat ramps. To collect field data, we used a 24' transient cruiser with 200 HP inboard/outboard (I/O) motor, 16' transient aluminum hull with 35 HP outboard motor, 6' inflatable zodiac with 4 HP outboard, and a 12' self-powered canoe. Geospatial field data were collected with Trimble Juno^{TM} ST and Garmin E-trex^{TM} GPS units for use during subsequent statistical analyses.

2.3 LAKE AND LANDSCAPE DATA

Power metrics consist of additive lake and landscape features. During *in situ* data collection, and cross-referencing a 30 m-resolution digital elevation model (DEM) provided by the USGS, lake elevation was recorded. Also during *in situ* data collection, mean lake depth was estimated using a Lowrance^{TM} sonar for each of the 26 water-bodies. Using a 2004 hydrology dataset from the New York State Department of Environmental Conservation (NYSDEC), area and perimeter were calculated utilizing Geospatial Modelling Environment (www.spatialecology.com). Euclidian distance between nearest I-87 ramp and lake access point was measured for each of the 26 lakes using ESRI's ArcMap 10.

Landscape (composition) and *(diversity)* were quantified using landscape ecology metrics developed for quantifying the spatial arrangement of land cover and land use (Turner *et al*., 2001; McGarigal *et al*., 2012). To establish a landscape-water interface, a 200 m buffer "lake landscape" was created for calculating landscape ecology metrics; albeit, this distance was chosen based on the inclusion of at least one entire adjacent property parcel. Land cover data were acquired through the National Land Cover Database (NLCD) (USGS, 2011). The 2006 NLCD land cover dataset was used for calculating land cover percent and diversity of each lake landscape. FRAGSTATS version 4.1 (McGarigal *et al*., 2012), free and publicly accessible software, was used for computing land cover compositions and landscape diversity for each lake landscape. NLCD land cover data were preserved at 30 m resolution. Sixteen land cover composition and six landscape diversity metrics were initially computed for each of the 26 lake landscapes. Landscape ecology metrics were calculated and then statistically reduced into a highly relevant subset. Please see McGarigal *et al*. (2012) for landscape composition and diversity metric details.

Robust Pearson correlation test was used to remove lake and landscape variables that exhibited a high degree of multicollinearity ($r > 0.75$). Six power, seven composition, and three landscape diversity metrics exhibited independence and were used in the forthcoming GLM analyses (Table 2). In some cases, data distributions of predictor variables can be nonlinear (skewed). The results of a GLM can be significantly improved by transforming a skewed variable to linear distributions (Menard, 2002), thus two types of transformation, negative arcsine (proportion data) and log10 (length/score data), were applied when needed.

TABLE 2
LAKE AND LANDSCAPE PREDICTOR VARIABLES AND THEIR ASSOCIATED GLOBAL LEVEL OF SPATIAL AUTOCORRELATION

Power metrics	Lake & landscape composition metrics	Landscape diversity metrics
Boat ramp total***	% boat ramps - private***	RPR***
Lake elevation**	% boat ramps - public	SIDI
Lake area**	% Developed open space**	SIEI
Lake mean depth**	% Deciduous forest	
Distance I-87 to ramp***	% Evergreen forest	
AIS Richness	% Mixed forest*	
	% Woody wetland	

*Denotes < 10 %, **Denotes < 5%, ***Denotes < 1% chance spatial pattern is random.

2.4 DATA ANALYSIS

The first law of geography states that things that are near are more similar (autocorrelated) than things that are farther apart (Tobler, 1970; Fortin and Dale, 2005). In spatial environmental studies it is imperative to take into account spatial autocorrelation. Spatial autocorrelation is the lack of independence between pairs of observation at given distances in time and space and is commonly found in environmental data (Legendre, 1993).

For this study, a common exploratory spatial data analysis (ESDA), spatial autocorrelation index global Moran's *I*-test, was applied. Spatial autocorrelation index scores vary from each other; however, positive scores indicate similar values are spatially clustered and negative scores indicate unlike values are spatially clustered (Wong and Lee, 2005). ESDA is frequently used in studies of geographical ecology and macroecology (Wagner and Fortin, 2005; Dormann *et al*., 2007; Rangel *et al*., 2010), and can be particularly useful when testing spatial autocorrelation in environmental systems. ESRI's ArcMap 10 Spatial Statistics toolbox was employed to assess the level of spatial autocorrelation of variables used in this study.

Ecologists and environmental managers increasingly rely on predictive models as a means for estimating patterns of species distribution. In our case, logistic regression (generalized linear model; GLM) was used to model the presence or absence of Eurasian Water-Milfoil, Curly-Leaf Pondweed, and lake association across 26 study area lakes. All possible combinations from the sixteen predictor variables (Table 2) were used to identify the most effective models for testing the aforementioned hypotheses. Logistic regression (Kleinbaum, 1994) is a statistical method that predicts the probability of an event occurring, in this case, the probability of Eurasian Water-Milfoil, Curly-Leaf Pondweed or lake association occurring from various lake and landscape characteristics. Logistic regression is conceptually similar to ordinary least squares (OLS) regression, because relations between one dependent variable and several independent variables can be tested. Whereas OLS returns a continuous value for the dependent variable, logistic regression returns the probability of a positive binomial outcome.

Logistic regression calculates several statistical parameters that determine the predictive success of the model (Kleinbaum, 1994). Identical to OLS, the p-values calculated can represent individual covariate statistical significance and overall significance of the logistic regression model. However, directional relationships, and the p-values of logistics regression often accompany a Chi-square score. We evaluated each GLM using McFadden's rho-squared (ρ^2), which is an attempt to approximate an OLS standard coefficient of determination (R^2). ρ^2 has the desirable property of ranging between 0 and 1, which makes it analogous to R^2; however estimates of ρ^2 and R^2 are not entirely equivalent, and it is commonly accepted that ρ^2 values greater than 0.2 indicate good fits (Terribile *et al*. 2009). All models were generated using the logistic regression module included in the free and publically available software Spatial Analysis in Macroecology (SAM) version 4 (Rangel *et al*., 2010).

3. RESULTS AND DISCUSSION

3.1 EXPLORATORY SPATIAL DATA ANALYSIS

Taking all 26 sample lake locations into account, Global Moran's *I* analysis revealed varying levels of spatial autocorrelation across effect variables (Table 2). Nine of the sixteen predictor variables had some degree of spatial clustering. The power metric, AIS richness was found to be spatially random. The land cover composition metrics: percent public boat ramps, percent deciduous forest, percent evergreen forest, and percent woody wetland were also found spatially independent. The landscape diversity metrics: *Simpson Diversity Index* (SIDI) and *Simpson Evenness Index* (SIEI) were both found to be spatially random. Although traditional logistic regression models assume observations are independent of each other (Kleinbaum, 1994), we include both spatially random and non-random predictors in the ensuing geographical distribution analyses. To improve future AIS studies, autoregressive techniques should be utilized where needed.

3.2 LOGISTIC REGRESSION ANALYSES

Fifteen lake and landscape GLMs were established for predicting the occurrence of Eurasian Water-Milfoil (Table 3). Values of McFadden's ρ^2 ranged from 0.002 to 0.154 for predicting Eurasian Water-Milfoil. Despite no predictor variable above the established McFadden's ρ^2 threshold of 0.2, lake area and lake elevation were found statically significant at the 95 percent confidence level. Lake area was positively related to the presence of Eurasian

Water-Milfoil, and lake elevation was negatively related. Eurasian Water-Milfoil is highly dispersed throughout the Adirondacks, which can help to explain low GLM statistical findings because it lacks absence.

TABLE 3
LAKE AND LANDSCAPE PREDICTORS EXPLAINING PRESENCE OF EURASIAN WATER-MILFOIL

Logistic regression for Eurasian Water-Milfoil (*Myriophyllum spicatum*)

Effect variable	McFadden's rho-square	Chi-square	Std. Coeff.	*P*-value	True Skill Statistic (TSS)
Boat ramp total	0.101	2.56	2.75	0.1098	0.21
Lake area	**0.149**	**3.79**	**4.90**	**0.0517**	**0.22**
Lake mean depth	0.105	2.68	2.33	0.1019	0.22
Elevation	**0.154**	**3.91**	**-4.97**	**0.0479**	**0.22**
Distance I87 to ramp	0.093	2.37	-2.69	0.1238	0.22
% Developed open space	0.019	0.49	0.93	0.4833	0.06
% Deciduous forest	0.016	0.40	-0.77	0.5258	0.06
% Evergreen forest	0.063	1.61	-2.03	0.2042	0.16
% Mixed forest	0.002	0.04	0.26	0.8440	0.00
% Woody wetland	0.106	2.71	-2.59	0.0998	0.21
RPR	0.116	2.95	3.53	0.0857	0.27
SIDI	0.033	0.84	-1.34	0.3590	0.01
SIEI	0.142	3.62	-3.90	0.0572	0.36
% of boat ramps- public	0.057	1.45	1.75	0.2279	0.51
% of boat ramps- private	0.012	0.29	0.69	0.5877	0.00

Fifteen lake and landscape GLMs were established for predicting the occurrence of Curly-Leaf Pondweed (Table 4). Values of McFadden's ρ^2 ranged from <0.001 to 1 for predicting Curly-Leaf Pondweed. Eight variables had McFadden's ρ^2 values above the established threshold of 0.2. Total number of boat ramps, lake area, mean lake depth, percent developed open space, and *Relative Patch Richness* (RPR) were positively related to the presence of Curly-Leaf Pondweed; albeit, elevation, distance from I-87 to ramp, and SIEI were found negatively related. Fitting with the literature, as the total number of boat ramps increase on a waterbody more small-craft vectors transmit AIS. Further, as lake area and lake depth increase, the likelihood of small-craft using that waterbody also increases. Our results reveal that as the percent of developed open space increases around a lake, so the does the likelihood of Curly-Leaf Pondweed being present. A positive relationship between RPR and presence of Curly-Leaf Pondweed suggests an increase in land cover diversity, and their associated uses, around a lake intensifies the propagation of AIS. The negative relationships between lake elevation and distance from I-87 to ramp with the presence of Curly-Leaf Pondweed suggests people do not want to pull their small-craft boats up mountains or far distances. A negative relationship with lake elevation could imply an impact of downslope flow patterns and natural hydrology, but more research is needed in this area. The negative relationship between SIEI and presence of Curly-Leaf Pondweed suggests as land cover types become evenly distributed around a lake AIS propagate.

TABLE 4
LAKE AND LANDSCAPE PREDICTORS EXPLAINING PRESENCE OF CURLY-LEAF PONDWEED

Logistic regression for Curly-Leaf Pondweed (*Potamogeton crispus*)

Effect variable	McFadden's rho-square	Chi-square	Std. Coeff.	*P*-value	True Skill Statistic (TSS)
Boat ramp total	**0.478**	**13.44**	**5.41**	**0.0002**	**0.50**
Lake area	**0.449**	**12.62**	**5.85**	**0.0004**	**0.50**
Lake mean depth	**0.440**	**12.37**	**6.07**	**0.0004**	**0.28**
Elevation	**1.000**	**28.09**	**-613.32**	**<0.0001**	**1.00**
Distance I87 to ramp	**0.403**	**11.31**	**-4.53**	**0.0008**	**0.28**
% Developed open space	**0.324**	**9.11**	**4.77**	**0.0025**	**0.12**
% Deciduous forest	**0.164**	**4.60**	**-3.45**	**0.0320**	**0.00**
% Evergreen forest	**0.140**	**3.92**	**-2.20**	**0.0477**	**0.17**
% Mixed forest	0.066	1.87	-2.00	0.1720	0.00
% Woody wetland	0.003	0.07	-0.29	0.7886	0.00
RPR	**0.648**	**18.20**	**8.93**	**<0.0001**	**0.62**
SIDI	0.030	0.83	-0.97	0.3614	0.00
SIEI	**0.248**	**6.98**	**-3.82**	**0.0083**	**0.17**
% of boat ramps- public	<0.001	<0.001	0.01	0.9908	0.00
% of boat ramps- private	0.125	3.51	2.37	0.0610	0.00

Fourteen GLMs predicting the occurrence of a lake association by AIS richness, or lake and landscape characteristics were established (Table 5). Values of McFadden's ρ^2 ranged from <0.001 to 0.553 for predicting lake association presence. Eight variables had McFadden's ρ^2 values at or above the established threshold of 0.2. AIS richness, lake area, mean lake depth, percent developed open space, RPR, and total number of boat ramps were positively related to the presence of a lake association; albeit, elevation, distance from I-87 to ramp, and percent deciduous forest were found negatively related. Lake area, mean lake depth, percent of developed open space, RPR, and total number of boat ramps are all likely to increase the number of waterway stakeholders. Thus, explaining an increased presence of lake associations when these human attracting lake and landscape predictors strengthen. Intuitively, as land cover diversity (RPR) increases around a lake, there is likely more people present and an increased chance for a lake association being present. Further, as the percent of developed open space (*e.g.*, city park) increases next to a lake, so does the likelihood of a lake association existing. The positive relationship between AIS richness and presence of a lake association denotes that aquatic resources management groups are self-organizing to problem waterbodies. The negative relationships between lake elevation and distance from I-87 to ramp imply a lack of stakeholders organizing themselves into self-governing groups at distant waterbodies. However, it is more likely that waterways in high elevations and distances far from I-87 have less small-craft usership. The negative relationship between percent deciduous forest and occurrence of a lake association is likely related to land ownership. A large percentage of forest around a waterbody in the Adirondacks is likely to be managed by the State. Thus, these lands around the lake are likely to have fewer private property owners and fewer stakeholders to develop a lake association. Some of these interpretations are speculative, and could be erroneous, but more research could further develop our understanding of how lake and landscape characteristics influence the creation of self-governing groups.

TABLE 5
LAKE AND LANDSCAPE PREDICTORS EXPLAINING PRESENCE OF A LAKE ASSOCIATION

Logistic regression for lake association affiliation

Effect variable	McFadden's rho-square	Chi-square	Std. Coeff.	*P*-value	True Skill Statistic (TSS)
Invasive species richness	**0.319**	**11.46**	**29.15**	**0.0007**	**0.50**
Lake area	**0.199**	**7.14**	**3.12**	**0.0075**	**0.33**
Lake mean depth	**0.200**	**7.19**	**2.43**	**0.0073**	**0.02**
Elevation	**0.489**	**17.56**	**-7.41**	**<0.0001**	**0.60**
Distance I87 to ramp	**0.466**	**16.72**	**-5.88**	**<0.0001**	**0.51**
% Developed open space	**0.253**	**9.09**	**3.22**	**0.0026**	**0.25**
% Deciduous forest	**0.241**	**8.65**	**-3.23**	**0.0033**	**0.33**
% Evergreen forest	0.003	0.10	-0.25	0.7532	0.00
% Mixed forest	0.029	1.04	0.83	0.3077	0.00
% Woody wetland	<0.0001	<0.001	0.01	0.9893	0.00
RPR	**0.261**	**9.37**	**3.63**	**0.0022**	**0.42**
SIDI	0.001	0.01	-0.09	0.9104	0.00
SIEI	0.054	1.95	-1.25	0.1622	0.08
Boat ramp total	**0.553**	**19.85**	**7.25**	**<0.0001**	**0.59**

4. CONCLUSION

Our analysis revealed that the propagation of AIS is affected by a complexity of lake and landscape variables across waterbodies in the Adirondack region of northern New York. Further, our results revealed that aquatic resource management groups are self-organizing to problem waterbodies. In the case of both Eurasian Water-Milfoil and Curly-Leaf Pondweed, occurrence was statistically correlated to lake and landscape variables used in this study. Thus, the first null hypothesis of no significant relationship exists between lake and landscape characteristics, and the presence of Eurasian Water-Milfoil can be rejected. The second null hypothesis of no significant relationship exists between lake and landscape characteristics, and the presence of Curly-Leaf Pondweed can also be rejected. The third null hypothesis stated that presence of a lake association is not significantly related to AIS richness nor lake and landscape characteristics. The third and final null hypothesis is also rejected because both AIS richness and lake and landscape characteristics were statistically relevant to the presence of a lake association. Although this study serves as a pilot, a larger analysis could be used to create propagation probability maps of regionally non-invaded waterways. Much work remains for applied geographers to improve the understanding of how IS spread, and how stakeholder groups organize themselves to combat their advance.

5. REFERENCES

ADA – Adirondack Park Agency. 2011. *New York State Adirondack Park Agency annual report.* Downloadable at: www.apa.ny.gov.

APIPP – Adirondack Park Invasive Plant Program. 2012. *Adirondack Park Invasive Plant Program annual report*. Downloadable at: www.adkinvasives.com.

Dormann, C.F., *et al*. 2007. Methods to account for spatial autocorrelation in the analysis of species distributional data: a review. *Ecography* 30:609-628.

Elton, C.S. 1958. *The ecology of invasions by animals and plants*. London: Methuen.

ESRI ArcGIS 10. Copyright 1999-2012. Computer Software, Redlands, CA.

Fortin, M.J., and M.R.T. Dale. 2005. *Spatial analysis: a guide for ecologists*. Cambridge University Press, Cambridge, United Kingdom.

Kleinbaum, D.G. 1994. *Logistic regression, a self-learning text*. New York: Springer-Verlag.

Legendre, P. 1993. Spatial autocorrelation: trouble or new paradigm? *Ecology* 74:1659-1673.

Leung, B., J.M. Bossenbroek, and D.M. Lodge. 2006. Boats, pathways, and aquatic biological invasion: estimating dispersal potential with gravity models. *Biological Invasions* 8:241-354.

Lodge, D.M. 1993. Biological invasions: lessons for ecology. *Trends in Ecology & Evolution* 8:133-137.

McGarigal, K., S.A. Cushman, and E. Ene. 2012. *FRAGSTATS: spatial pattern analysis program for categorical maps*. Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at the following web site: http://www.umass.edu/landeco/research/fragstats/fragstats.

Menard, S. 2002. *Applied logistic regression analysis*. Thousand Oaks, Calif., Sage Publications.

Pimentel, D., *et al*. 2001. Economic and environmental threats of alien plant, animal and microbe invasions. *Agriculture, Ecosystems & Environment* 84(1):1-20.

Pimentel, D., R. Zuniga, and D. Morrison. 2005. Update on the environmental and economic costs associated with alien-invasive species in the United States. *Ecological Economics* 52(3):273-288.

Puth, L.M., and D.M. Post. 2005. Studying invasion: have we missed the boat? *Ecological Letters* 8:715-721.

Rangel T.F., J.A.F. Diniz-Filho, L.M. Bini. 2010. SAM: a comprehensive application for spatial analysis in macroecology. *Ecography* 33:46-50.

Rothlisberger, J.D., W.L. Chadderton, J. McNulty, and D.M. Lodge. 2010. Aquatic invasive species transport via trailered boats: what is being moved, who is moving it, and what can be done. *Fisheries* 35(3):121-132.

Simberloff, D. 1996. Impacts of introduced species in the United States. *Consequences* 2(2):13-22.

Simberloff, D., I.M. Parker, and P.N. Windle. 2005. Introduced species policy, management, and future research needs. *Frontiers in Ecology and the Environment* 3:12-20.

Sharpe, V.A., Norton, B., Donnelly, S. 2001. *Wolves and human communities: biology, politics, and ethics*. Washington: Island Press.

Tobler, W.R. 1970. A computer movie simulating urban growth in the Detroit region. *Economic Geography* 46:230-240.

Terribile, L.C., J.A.F. Diniz-Filho, M.A. Rodriguez, and T.F. Rangel. 2009. Richness patterns, species distributions and the principle of extreme deconstruction. *Global Ecology & Biogeography* 18:123-136.

Turner, M.G., R. Gardner, and R. O'Neill. 2001. *Landscape ecology in theory and practice: pattern and process*. Springer-Verlag, New York.

Vitousek, P.M., C.M. D' Antonio, L.L. Loope, and R. Westbrooks. 1996. Biological invasions as global environmental change. *American Scientist* 84(5):468-478.

Wagner, H.H., and M.J. Fortin. 2005. Spatial analysis of landscapes: concepts and statistics. *Ecology* 86:1975-1987.

Wilcove, D.S., D. Rothstein, J. Dubow, A. Phillips, E. Losos. 1998. Quantifying threats to imperiled species in the United States. *Bioscience* 48(8):607-615.

Wong, D., and J. Lee. 2005. *Spatial analysis of geographic information with ArcView GIS and ArcGIS*. New Jersey: Wiley & Sons Inc.

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