SPATIAL ECOLOGY OF COMMON LOON (*GAVIA IMMER*) AND FACTORS INFLUENCING PRESENCE/ABSENCE IN MICHIGAN'S LOWER PENINSULA

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A thesis submitted in partial fulfillment of
the requirements for the degree of
Master of Science

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Mount Pleasant, Michigan
March 2014

This is dedicated to my family and friends
who have supported me throughout
this journey.

ACKNOWLEDGEMENTS

I would like to thank my graduate advisory committee from Central Michigan University, which consists of my advisor Dr. Thomas Gehring and committee members Dr. Tracy Galarowicz and Dr. Brian Becker. I would also like to thank Dr. James Sikarskie from Michigan State University for his support during the beginning of this project. Miigwetch (Thank you) to the Little Traverse Bay Bands of Odawa Indians Natural Resource Department for providing Bureau of Indian Affairs – Circle of Flight funding for my summer 2007-2008 field seasons, equipment, and research support. I would also like to thank the Michigan Loon Preservation Association and Michigan Loonwatch members: Joanne Williams, Dale Doepker, Jeff Lange, and Peg Comfort for their continued support throughout the life of this project.

ABSTRACT

SPATIAL ECOLOGY OF COMMON LOON (*GAVIA IMMER*) AND FACTORS INFLUENCING PRESENCE/ABSENCE IN MICHIGAN'S LOWER PENINSULA

by Maxwell Field

The common loon has been a threatened species in Michigan since 1987. Loss of loon nesting habitat and increased disturbances on existing habitats are believed to have played a major role in the population decline throughout the 20th century. The Michigan Loon Recovery Plan was created in 1992, and detailed management objectives and population goals for Michigan's summer-resident loon population. Subsequent monitoring efforts undertaken by Michigan Loonwatch have created a state-wide loon productivity dataset from which estimates of abundance are calculated annually. The primary goal of this study was to examine different categories of inland lake attributes gathered with Geographic Information Systems and determine which are most significant in predicting loon presence and nesting presence through the creation of logistic regression models. The secondary goal of this study was to use the models as a management tool to identify potential loon nesting lakes to enhance loon monitoring and survey efforts in Michigan. Composite models for both loon presence and nesting presence show that loons in the primary study area preferred lakes with larger surface areas, natural or artificial nesting islands present, larger shoreline proportions of lowland forest, and smaller shoreline proportions of non-forested wetland. The composite models differed on the influence of the road density within 150m lake buffer, showing a small positive association with the loon presence model and a large negative association with the nest presence model. Importance values suggested that lake surface area and the presence of islands were the strongest predictors of both loon presence and nest presence. The influence of shoreline proportions of lowland forest, non-forested wetland, and road density within 150m lake buffer were of moderate importance when predicting only nest presence. Model validation suggested that a loon presence model can be a useful management tool for selecting lakes for survey effort and that coarse landscape-level lake attributes are likely not used by loons when selecting nesting lakes. Additional research should investigate whether biotic lake features (e.g., fish assemblage, water quality, substrates type) or intraspecific competition (e.g., territorial establishment of nesting pairs, minimum distance to a loon lake) are more important factors when determining the likelihood that a lake will used by loons for nesting.

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CHAPTER I

INTRODUCTION

Native American peoples of the Great Lakes region, the Anishinaabek, consider loon (or *Maang* in Ojibwe) to be one of the seven original clans that formed the Anishinaabe system of government. An animal emblem or doodem represented each clan and symbolized the clan's strength and duties. These clans were: Crane, Loon, Fish, Bear, Marten, Deer, and Bird. The crane and the loon clans were the two chief clans; members of these clans worked together to give the people a balanced government (Benton-Banai 1981). Outdoor enthusiasts consider common loons to be "the spirit of northern lakes" and a symbol of the wilderness (McIntyre 1988). Common loons were found throughout Michigan prior to the 1900's. By 1912, Michigan's loon population had noticeably decreased in the southern areas. The bird was considered a "serious annoyance" in the northern part of Michigan, where it "nests in undiminished numbers" (Barrows 1912). In 1962, the Michigan status of the common loon was listed as, "regular transient, summer resident in both peninsulas; now rare in the southern counties except during migration" (Cuthbert 1962). Common loons are now known to breed only in the Upper Peninsula and the northern half of the Lower Peninsula. Loons are most common in the Upper Peninsula and only a few isolated pairs remain in the southern half of the Lower Peninsula, one of which was believed to be the record of breeding loons occurring furthest south in the United States (McIntyre 1988). Between 1986 and 1994, Michigan Loonwatch survey data indicated that the common loon population was fluctuating (Williams 2007). Since 1997, although loon survey effort has decreased the loon population appears to be relatively stable (Figure 1).

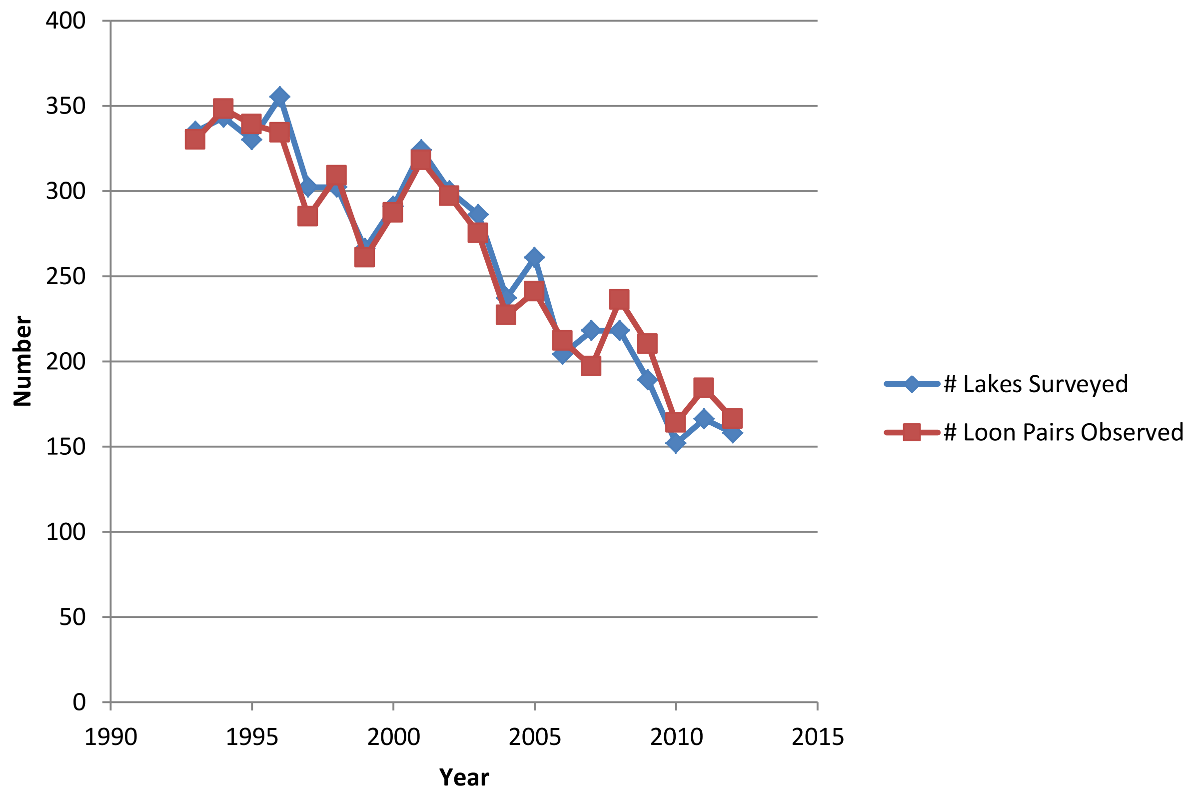

Figure 1. Number of Lakes Surveyed, and Number of Loon Pairs Observed, 1993-2012*
*Michigan Loonwatch survey data

Common loons were listed as a Michigan state threatened species in 1987 due to an observed reduction of the historical breeding range and estimated low population numbers. This led to the creation of the 1992 Michigan Loon Recovery Plan, which required that lakes be surveyed on an annual basis in order to estimate number of breeding loons present, estimate loon reproductive success, determine causes for low numbers of loons, and to recommend actions to increase their numbers (Robinson 1999). The goal of the Michigan Loon Recovery Plan is to maintain 575 breeding pairs and to sustain that number for at least five years in order to remove the loon from the State threatened species list (MI Loon Recovery Committee 1992). Loss of loon nesting habitat and increased frequency of human disturbance on inland lakes were commonly viewed as causes of this population decline (Williams 2007). Several factors collectively may be reducing the reproductive success of common loons in Michigan including: increased human shoreline development around inland lakes, increased frequencies of nest predation, increased mortalities from botulism outbreaks during fall migration and elevated levels of water pollutants such as mercury and lead (Evers et al. 2010).

Studies of common loons in eastern North America suggest that the species' dependence on fish for food limits its breeding habitat to large deep lakes with stocks of fish sufficient to support adults and chicks. Gingras and Paszkowski (1999) surveyed three categories of lakes: small shallow lakes that were fishless but had other small aquatic organisms, small shallow lakes that contained only minnows, and large deep "big fish" lakes. Results were similar to previous studies showing that territorial pairs occurred on all three lake types, but nesting loons and newly hatched loon chicks were more likely to be found on deep lakes, rather than fishless or minnow lakes. Fishless lakes offered good nesting habitat, but chicks rarely survived. Minnow lakes provided good chick-rearing habitat but loons did not often nest on these lakes (Gingras and Paszkowski 1999). These factors were investigated by surveying lakes of all sizes within the primary study area for loon activity.

The actual amount of shoreline development (cottages, houses, etc.) may not discourage loons from establishing nesting sites, but rather the amount of human activity associated with this particular development pattern (McIntyre 1988, Robinson 1999). Inland lakes with high recreational use and human activity often will result in the absence of loon nesting activity and territory establishment, but some lakes with high concentrations of human developments and low amounts of recreational activity are tolerated by nesting loon pairs (McIntyre 1988). Human shoreline developments and associated human disturbance were investigated in this study.

McIntyre (1988) suggested loons nest in a variety of lake depths, and under a variety of environmental conditions. Loons were observed nesting in waters only 1.5 m deep in some instances, and on lakes with a maximum depth of 10 m. The actual proportion of shoreline development may be irrelevant, once again supporting the idea that development isn't quite as important as the recreational activity level of that inland lake throughout the breeding season (McIntyre 1988, McCarthy and Destefano 2011, Kuhn et al. 2011).

The primary goal of this study was to examine different categories of inland lake attributes gathered with Geographic Information Systems (GIS) and determine which are most significant in predicting general loon presence and loon nesting presence through the creation of logistic regression models from presence/absence data. The secondary goal of this study was to use the model as a management tool to identify potential high-quality loon nesting lakes and to guide loon survey efforts to increase our understanding of Michigan's summer-resident loon population.

Study Area

The primary study area included Charlevoix, Cheboygan, and Emmet Counties located in the northern tip of Michigan's Lower Peninsula and included 43 surveyed lakes. The secondary study area included Mecosta County located near the center of Michigan's Lower Peninsula and included 27 surveyed lakes (Figure 2).

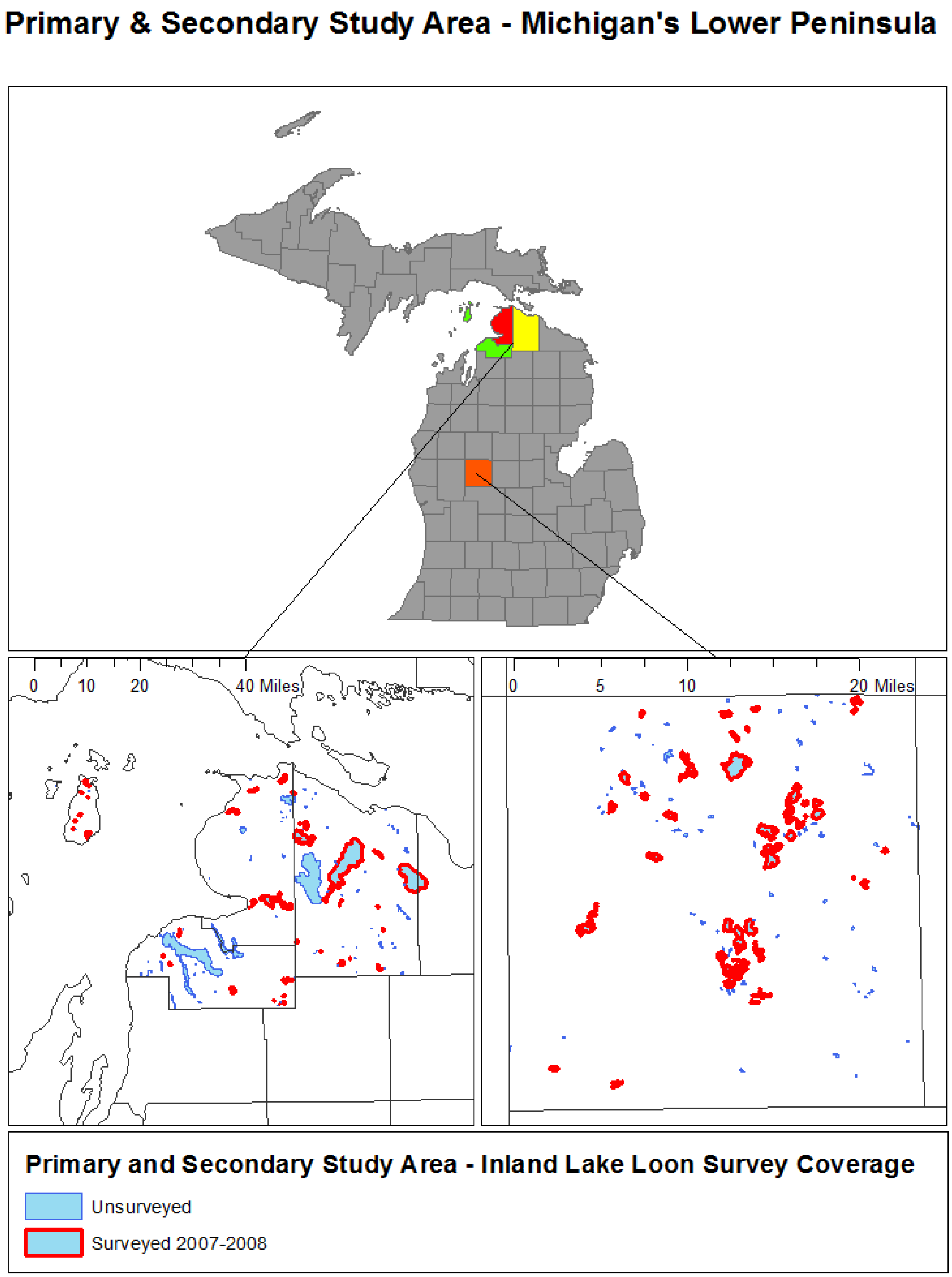

Figure 2. Primary and secondary study areas located in Michigan's Lower Peninsula*
*Green: Charlevoix County, Red: Emmet County, Yellow: Cheboygan County, Orange: Mecosta County

Charlevoix, Cheboygan, and Emmet Counties have a total area of 8,179 km^2, of which 4,035 km^2 (49%) is water (Census 2010 Gazetteer Files). The landscape of this region is shaped by rolling hills, large inland lakes, numerous rivers, large forests, and Great Lakes shorelines including coastal dunes on the west coast. Mecosta County has a total area of 1,479 km^2, of which 40 km^2 is water (Census 2010 Gazetteer Files). Compared to the primary study area, Mecosta County is landlocked with no Great Lakes shoreline. The landscape contains over 100 lakes and rivers including the Muskegon River which is a tributary to Lake Michigan. Both study areas are representative of high quality loon habitat with the large amount of lake systems available for both feeding and nesting.

CHAPTER II

INFLUENCES OF LAKE-LEVEL HABITAT FEATURES AND HUMAN DISTURBANCE ON PRESENCE/ABSENCE OF COMMON LOONS IN MICHIGAN'S LOWER PENINSULA

Methods

I conducted loon presence/absence surveys on inland lakes in the primary study area between April and September in 2007-2008 to observe and record numbers of loon individuals and confirm loon nesting activity. Inland lakes greater than 2.5 hectares were selected for loon surveys because lakes of this size and greater contain a flight runway of approximately 50 meters which loons require for take-off (MI Loon Recovery Plan 1992). Once all lakes greater than 2.5 hectares were identified, lake selection for loon surveys was based on accessibility by roads or trails that were not on private land. Inland lakes were surveyed during daylight hours in order to confirm individual loon presence through visual observation using binoculars (12x50 magnification for smaller lakes, 20x60 magnification for larger lakes). Each inland lake was visited at least three times to be considered surveyed for loon absences. Most surveys occurred in the morning and early afternoon and were approximately 2-3 hours long depending on lake size. Lakes surveyed by boat covered the entire shoreline of the lake (including islands) to confirm loon nesting activity. General loon presence observations were investigated further with additional survey effort (up to five surveys) to determine if loon nesting activity was occurring. Loon nesting activity was confirmed through observations of adult loons incubating on nests, hatched loon chicks, and observations of loon juveniles prior to fledging. Small inland lakes where loon individuals were observed from one point-count survey site were conducted on foot. Larger inland lakes required the use of a kayak, canoe, or motorboat. The number of islands, natural or artificial loon nesting islands (ANI's), were counted and recorded as loon habitat data.

The number of boats on the water and number of boat launches around the lake were recorded as loon disturbance data.

Inland lake predictor variables used in ArcGIS (ESRI 2014. ArcGIS Desktop: Release 10.1. Redlands, CA: Environmental Systems Research Institute) were gathered online from the Michigan Geographic Spatial Data Library (http://www.mcgi.state.mi.us/mgdl/). I defined predictor variables that were relevant to loon ecology including: lake surface area (ha), maximum lake depth (m), lake perimeter (m), presence/absence of islands (artificial or natural), shoreline complexity, hydrological connectivity, proportion of human shoreline development, and proportion of land use/land cover types and road density within buffers around lake polygons. Baseline lake attributes (surface area, maximum depth, and lake perimeter) were gathered from lake polygon attribute tables in GIS. Presence/absence of naturally occurring islands was determined from lake polygon boundaries, satellite imagery (e.g., Google Earth), and loon survey data. Presence/absence of artificial nesting islands was determined from Michigan Loonwatch lake reports provided by area coordinators and loon survey data. Presence/absence of islands was incorporated into the analysis as an indicator variable (Neter et al. 1996). Shoreline complexity (Sc) was calculated as: $Sc = \text{Perimeter} \div \sqrt{(\text{Area})}$. Hydrological connectivity of inland lakes was calculated from GIS hydrology layers as: # Inflows + # Outflows. I estimated shoreline proportion of human developments (Sd) by counting numbers of houses on lake perimeter using satellite imagery and creating a ratio: # Houses ÷ Lake Perimeter (m). Potential shoreline loon nesting habitat was estimated by creating a 15 m buffer around each inland lake polygon using GIS and calculating the proportions from each of the eight categories as: $Lx \div \text{Total Buffer Area}$ (Table 1).

Table 1. Land Use/Land Cover Categories & Descriptions from 2001 IFMAP Michigan Dataset

Category	Description
Urban	Land areas > 10% man-made structures including paved and gravel roads and parking lots
Agricultural	Lands intensely managed for vegetation production excluding forestry
Upland Openland	< 25% land area covered by tree canopy, > 25% land area vegetated
Upland Forest	Proportion of trees > 25% of land area
Water	Proportion of open water > 75% of land area
Lowland forest	Proportion of trees > 25% of land area
Non-Forest Wetland	Proportion of trees ≤ 25% of land area
Bare/Sparsely Vegetated	Land < 25% vegetated

Source: Michigan Geographic Spatial Data Library

Roads density (Rd) was calculated as: Rd = Length of Roads (m) ÷ Area of 150 m Lake Polygon Buffer. This variable was used to represent relative road density immediately surrounding inland lakes as an indicator of human disturbance (Kuhn et al. 2011).

I used Pearson correlation analysis in Program R (R Core Team 2013) to determine multicollinearity among potential model input predictor variables. Predictor variables that were correlated (i.e., $r \geq 0.40$) were removed from the modeling process in order to evaluate the importance and weights associated with the remaining independent predictor variables.

I used program PESENCE 6.2 (Hines 2003) to generate detection probabilities (p) from my input loon survey dataset to determine if imperfect detection was an issue before building predictive models (Mackenzie 2005). It is impossible to confirm with 100% certainty that observed loon absences were true unless a lake was surveyed constantly, however this assumption was tested. Probability of detecting loons and loon nesting was 0.89 (SE = 0.036) and 0.90 (SE = 0.050), respectively. Given a high detection probability in my surveys, I assumed my input dataset is unbiased with respect to my observed loon presence/absence data and used binary logistic regression in program R to create loon presence/absence and loon nest presence/absence models. I used an information-theoretic approach and Akaike Information Criteria (AIC_C) with AIC weights to select the best Kullback-Liebler model (Burnham and Anderson 2002). I used a $\Delta AIC \leq 4$ to identify top competing models and calculated importance values to identify important variables. Model averaging was used to develop one composite model for loon presence and loon nest presence (Burnham and Anderson 2002).

Predictive capabilities of loon presence and nest presence composite models were evaluated with an independent loon dataset from my secondary study area. This dataset included Michigan Loonwatch surveys of 47 inland lakes to determine loon presence and nest presence in Mecosta County, Michigan during the summer breeding season in 2007-2008. I calculated the number of correct classification rates for loon presence and nest presence detection to determine the predictive power of models developed from my loon survey data.

Results

I surveyed a total of 43 inland lakes between April and September in 2007-2008. I found lake surface area was positively correlated with lake perimeter ($r = 0.90$), maximum depth ($r = 0.51$), hydrological connectivity ($r = 0.50$), and proportion of human shoreline development ($r = 0.53$). Correlation analysis suggested that inland lakes with a larger surface area have larger perimeters, greater maximum depths, multiple inflows/outflows, and higher proportions of human shoreline development. Shoreline complexity and shoreline proportions of agriculture, upland openland, upland forest, water, and bare/sparsely vegetated were removed because of insignificance to predicting loon presence and nesting presence suggested by low AIC weights and not being represented in composite models. I retained lake surface area and presence/absence of islands as predictor variables because they were the easiest information to acquire from public databases (GIS, Satellite Imagery, etc.). Shoreline proportions of lowland forest and non-forested wetland were utilized as predictor variables representing desired lake-level loon habitat features, while road density was utilized as an indicator of human disturbance.

I identified five competing models through the modeling-averaging process for predicting loon presence (Table 2).

Table 2. Top Five Competing General Loon Presence Models Ranked with AICc ($\Delta \leq 4$)

Intercept	AREA	ISLA	LOWL	WETL	ROAD	df	logLik	AICc	Δ	weight
-9.236	0.722	1.603				3	-20.57	48	0	0.432
-9.578	0.709	1.671	2.58			4	-20.34	50	1.97	0.161
-8.204	0.701					2	-22.83	50	2.21	0.143
-8.73	0.708	1.663		-0.7436		4	-20.53	50	2.34	0.134
-9.303	0.725	1.613			1.956	4	-20.57	50	2.42	0.129

The loon presence composite model suggested that loon presence was positively associated with lake surface area, presence of islands, shoreline proportion of lowland forest, and road density, whereas it was negatively associated with proportion of mixed non-forest wetland. Importance values suggested that lake surface area and presence of islands were the dominant predictor variables, and shoreline proportions of lowland forest/wetland and road density were insignificant when predicting loon presence (Table 3).

Table 3. General Loon Presence Composite Model (with Importance Values)

Intercept	AREA	ISLA	LOWF	WETL	ROAD
-9.083	0.715 (1.0)	1.626 (0.86)	2.580 (0.16)	-0.743 (0.13)	1.956 (0.13)

The loon presence composite model successfully predicted 29 of 33 (88%) observed loon occurrences from 47 surveyed Mecosta County lakes (Figure 3).

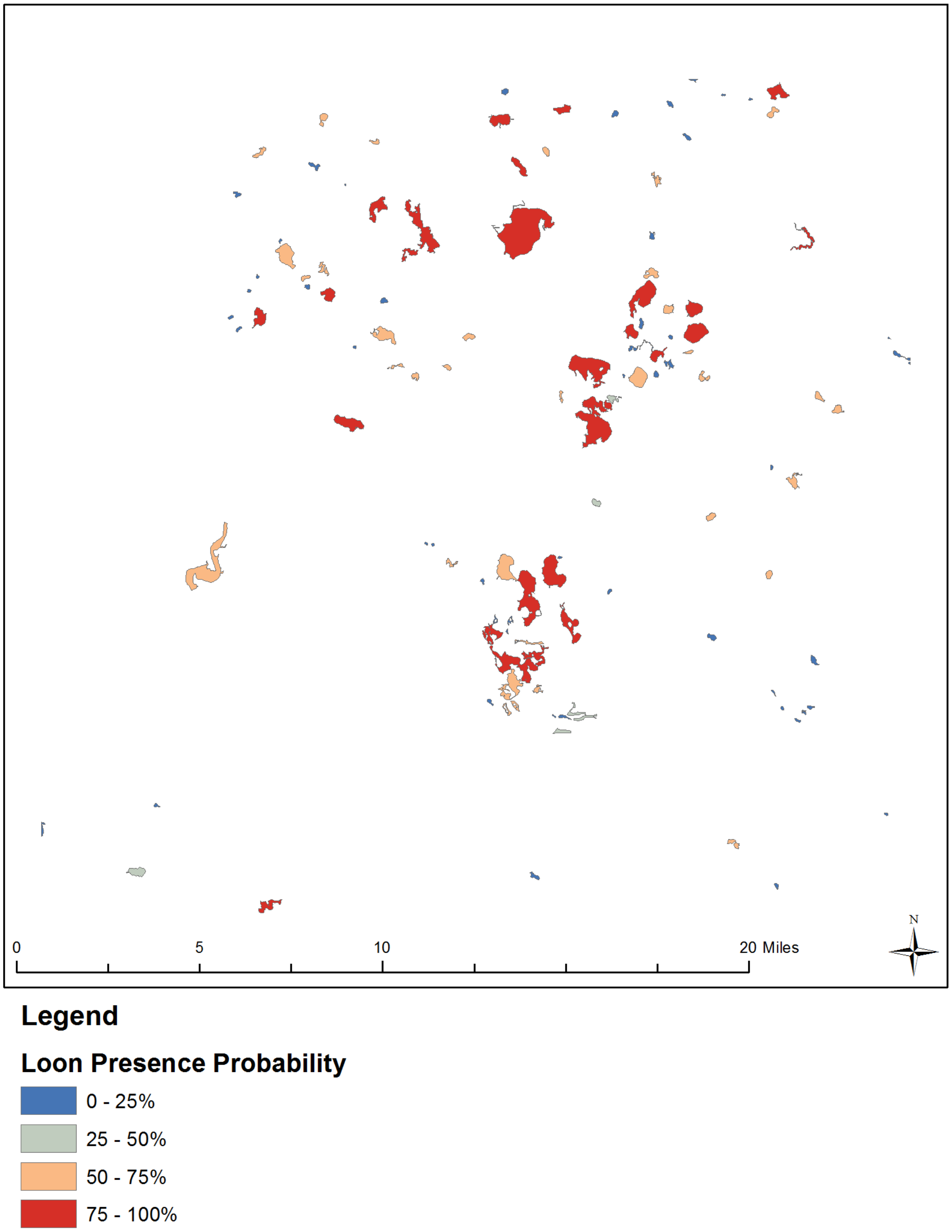

Figure 3. All inland lakes (>2.5 hectares) within secondary study area ranked by probability of general loon presence, *Blue: 0-25%, Light Blue: 25-50%, Orange: 50-75%, Red: 75-100%

I identified seven competing models through the modeling-averaging process for predicting loon nest presence (Table 4).

Table 4. Top Seven Competing Loon Nest Presence Models Ranked with AICc ($\Delta \leq 4$)

Intercept	AREA	ISLA	LOWL	WETL	ROAD	df	logLik	AICc	Δ	weight
-22.55	1.25	4.493	13.58			4	-13.54	36	0	0.306
-20.15	1.23	4.715	12.19	-4.428		5	-12.5	37	0.47	0.242
-21.15	1.23	4.151	13.5		-106.1	5	-13.12	38	1.71	0.13
-16.26	1.18	4.181		-5.322		4	-14.53	38	1.99	0.113
-18.83	1.21	4.324	12.04	-4.409	-107.4	6	-12.14	39	2.45	0.09
-18.1	1.16	3.65				3	-16.19	39	2.88	0.072
-14.96	1.15	3.834		-5.237	-96.69	5	-14.15	40	3.78	0.046

The loon nest composite model suggested that presence of loon nests was positively associated with lake surface area, presence of islands, and proportion of lowland forest, whereas it was negatively associated with proportion of mixed non-forested wetland and road density. Importance values suggested that lake surface area, presence of islands, and proportion of lowland forest were the dominant predictor variables, and proportion of mixed non-forest wetland and road density were slightly significant when predicting loon nest presence (Table 5).

Table 5. General Loon Nest Composite Model (with Importance Values)

Intercept	AREA	ISLA	LOWF	WETL	ROAD
-20.067	1.221 (1.0)	4.360 (1.0)	12.950 (0.77)	-4.706 (0.49)	-104.938 (0.27)

The loon nesting presence composite model successfully predicted 5 of 14 (36%) observed loon nest occurrences in Mecosta County lakes (Figure 4).

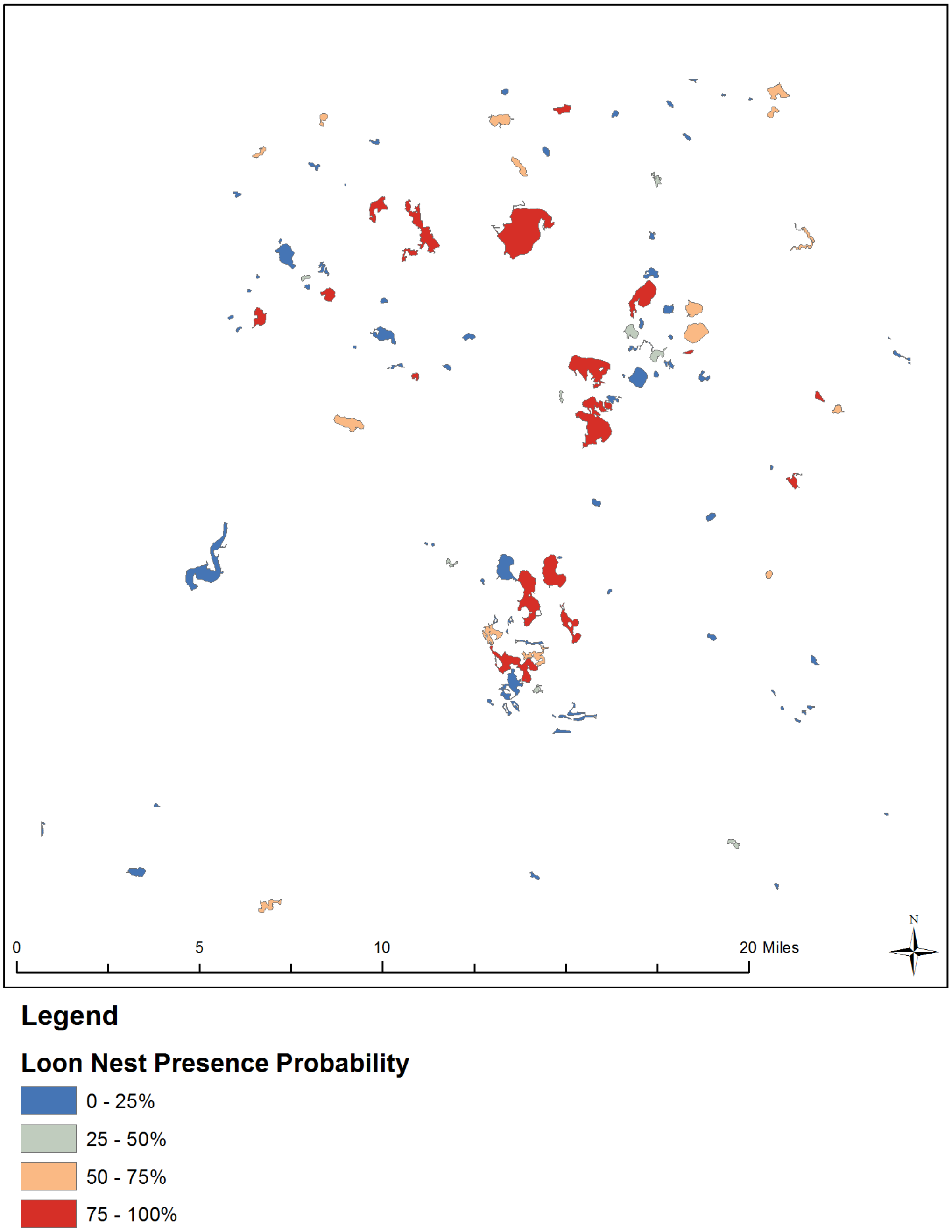

Figure 4. All inland lakes (>2.5 hectares) within secondary study area ranked by probability of loon nesting presence, *Blue: 0-25%, Light Blue: 25-50%, Orange: 50-75%, Red: 75-100%

Discussion

I found loon presence most strongly associated to lakes with higher surface areas and with either natural islands or ANI's. This model performed well (29 out of 33 correct classifications) when validated with an independent loon dataset. The composite loon presence model likely matches the scale of lake selection by loons for territory establishment. Loons likely assess larger scale features such as lake surface area and presence of islands when selecting a territorial lake for possible breeding. Thus, coarser, GIS-based landscape variables were likely adequate to build a useful loon presence predictive model. Although this specific model was created for the detection of general loon presence, it is supported by previous research on lake selection preferences of nesting loons. Dahmer (1986) found that the presence of an island and lake circumference were the two most important variables in selection of a lake by breeding loons in the northern Lower Peninsula of Michigan. Jung (1987) found similar results in the northern Lower and eastern Upper Peninsula of Michigan, with 91% of observed nesting loons found on lakes with islands. Larger lakes may offer loons more suitable and protected locations for nest sites and nurseries (McIntyre 1983, Evers 2001, Evers et al. 2010), and may reduce exposure to human disturbances (Evers 2007). The presence of islands may also influence occupancy because loons prefer islands for nesting rather than exposed shoreline where nest success is generally lower (Titus and VanDruff 1981, McIntyre 1988). The preference of loons for larger inland lakes and lakes with islands when selecting nesting sites shows that my general loon presence model may be the first step in the selection process used by loons when assessing lakes from a landscape-level for desirable features of a potential breeding territory.

I found loon nest presence most strongly associated to lakes with higher surface areas, either islands or ANI's, and higher shoreline proportions of lowland forest, and less strongly associated with lower shoreline proportions of mixed non-forest wetland habitat and road density. This composite model did not perform well (5 out 14 correct classifications) when validated with an independent loon dataset. The positive association of loon nest presence to increasing lake surface area and presence of islands is already explained through the general loon presence model. The negative association of loon nesting presence with shoreline proportions of non-forested wetland was opposite of what is believed to be optimal loon nesting habitat according to certain scientific literature. The mixed non-forested wetland predictor variable included marsh and bog shoreline habitat types which are believed to increase the probability of loon nesting activity (MI Loon Recovery Plan 1992). However, Kramar et al. (2005), suggested wetland habitat types within 150 m of loon territories were positively correlated with available mercury within the lake system and lakes with greater amounts of emergent wetland had lower loon productivity rates. Loon exposure to mercury reduces their productivity by decreasing reproductive success and adversely affecting behavior and health (Burgess and Meyer 2008, Evers et al. 2008). My loon nesting presence model may be identifying the same trend at a different spatial scale (i.e., wetland habitat types within 15 m lake polygon buffer rather than within 150 m of an observed loon nesting territory). Future modeling efforts should examine the association of wetland habitat types to loon nesting presence more closely by designating loon territories based on confirmed nest site locations with the use of GPS. The 2001 land use/land cover files used for this project were six years old at the time the loon surveying was conducted for this project. Updated satellite imagery that provides more detailed land use/land cover GIS data would improve the quality of inland lake attribute data used for biological modeling. The positive association of loon nesting presence to shoreline proportion of lowland forest and the strong negative association to road density within a 150 m lake polygon buffer supports the idea that loons prefer nesting lakes with higher amounts of forested shoreline that are exposed to minimal human disturbance (McIntyre 1988, McCarthy and Destefano 2011).

Landscape-scale GIS lake attribute data I used to create predictor variables may not be adequate to identify all high quality loon nesting lakes. Instead biotic lake features (e.g., fish assemblage, water quality, substrates type) or intraspecific competition (e.g., territorial establishment of nesting pairs, historic loon nesting presence, minimum distance to a loon lake) may be more important factors defining loon nesting success as demonstrated by Kuhn et al. 2011. Hammond et al. (2012) found that occupancy of loon territories was positively associated with the number of territorial loon pairs within 10 km of study lakes and negatively associated with the number of feeding lakes within 10 km. Supporting my results, they also found that human disturbance indices and measures of shoreline complexity were less important for predicting loon presence. Human disturbance on their study lakes may have been mitigated via successful conservation efforts such as education campaigns and floating buoys around loon nesting areas. This is the case for only one of my study lakes, which has the longest successful nesting history in the primary study area (over 20 years) attributed to the buoys deployed every summer to block off the loon nesting site and nursery area. Results from Piper et al. (2006) support the outcomes of my nest presence model with the idea that permanent lake attributes (physical and biotic) were inadequate for determining reproductive success in common loons. Rather, they found that territorial pairs that successfully produced chicks were targeted more by habitat copying solitary loons for territorial usurpation. Thus, variables not readily measured in available GIS layers may lack the resolution needed to successfully identify all factors influencing loon nesting success.

Annual Michigan Loonwatch survey data suggests that the loon population is stable despite rapidly decreasing survey effort. This diminishing survey effort demonstrates the critical need for systematic monitoring of Michigan lakes with limited resources. Common loon populations typically stay at or near carrying capacity (Evers 2007) and closely follow an ideal preemptive distribution (Pulliam and Danielson 1991) where dominant birds occupy and defend the best available territories and subordinate birds occupy marginal territories or do not attempt to breed. Territory fidelity among common loons is high, with approximately 75% of breeders occupying the same territory from year to year (Piper et al. 2000). Research has shown that when establishing new territories, adult loons typically move ≤7 km from previously occupied lakes, whereas returning juveniles typically establish territories ≤18 km from natal lakes (Evers 2001). This suggests that loons don't usually disperse far from known territories, thus both size and spatial distribution of lakes can have a strong influence on the establishment loon territories, potentially limiting population growth (Hammond et al. 2012). The success of the loon presence model over the nest presence model could be attributed to the models inability to recognize established loon territories, which would require unique identification of individual loons and an understanding of their local movements between nesting lakes and feeding lakes. I believe the loon presence model by itself is capable of recognizing potential loon territories because all 13 confirmed loon nest lakes within the secondary study area were included in the 29 out of 33 predicted loon presence occurrences.

Management Implications

The loon presence model I developed has direct application for identifying lakes used by loons as potential summer breeding territories in Michigan. Loon monitoring in Michigan is primarily conducted by volunteers and survey efforts have been decreasing since 1997. My model could assist by prioritizing lakes to survey by Michigan Loonwatch and other non-profit organizations and/or Tribal/State/Federal agencies. Aside from public outreach and education, current conservation efforts for loons in Michigan are limited to the creation and deployment of ANI's to create loon nesting habitat and protection of loon nesting areas with signs and/or buoys to prevent human disturbance during the breeding season. More potential habitat for nesting territorial loon pairs would likely be beneficial to long-term population stability given a degree of conspecific-attraction that loons exhibit when establishing territories (i.e., in addition to lake attributes) and the unique habitat copying behavior associated with greater loon productivity on lakes (Piper et al. 2006, Hammond et al. 2012). A recent development among a Michigan Loonwatch County Coordinator is a simple editable Google Maps database that shows which lakes have had ANI's and coordinates of the deployment site every summer. Using GIS, these occupied loon nest site coordinates could be used to analyze fine-scale lake and landscape features to better understand influences on loon nesting presence. My loon presence model supports the coordinated deployment of ANI's on inland lakes where no natural islands exist in order to increase the likelihood of loon presence and potential nesting territory establishment. The continued monitoring of loon lakes in Michigan is critical to understanding population dynamics, associated habitat preferences and territory establishment of summer-resident breeding loons. The model can be used as a management tool to guide Michigan Loonwatch survey efforts and other managers to lakes that are more likely to be used by loons in an effort to increase understanding and to enhance conservation efforts for the species.

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