USING GIS TO MODEL COMMON LOON (*Gavia immer*) HABITAT

Alexis M. Rudko, MS Student
Russell G. Congalton, Professor
Department of Natural Resources and the Environment
University of New Hampshire
Durham, NH 03824
arudko@cisunix.unh.edu
russ.congalton@unh.edu

ABSTRACT

The common loon (*Gavia immer*) is a water bird that lives throughout northern North America. In New Hampshire, the Loon Preservation Committee (LPC) has monitored loons for over thirty years. This long-term monitoring program has allowed for the analysis of patterns in the loons' distribution. A GIS model to evaluate loon habitat was created in 2002 using all the loon data collected up until that time. This model was used to predict where loon occupancy occurs based on parameters that were determined to be statistically significant. It was then applied to lakes throughout New Hampshire to give an indication as to where to monitor for loon activity on lakes that were not yet occupied. In our project, we used updated occupancy data from 2002 – 2008 to evaluate if this existing model continued to work beyond 2002. In addition, a new model was created using additional parameters that have been collected since 2002. An evaluation was performed to test if this new model improved the prediction of loon habitat. This new model will further aid the Loon Preservation Committee in determining which lakes to increase their monitoring efforts and which to monitor less in order to make the most efficient use of the field biologists' time.

INTRODUCTION

Common Loons (*Gavia immer*)

There are 5 species of loons, but this paper is focused on the North American common loon (*Gavia immer*). In New England, males typically weigh 5.89 kg (13 lbs) and females weigh about 4.63 kg (10.2lbs) (Brennan, 2005). Loons in New England tend to be larger in body mass than other loons because New England loons do not have to travel as far to reach their ocean wintering grounds and therefore can be heavier. Loons have identical plumage for both males and females but this plumage changes from summer to winter. The winter plumage is a brown with white belly, while summer plumage (or breeding plumage) has a black head, with white and black checkered back and white belly. There is also a distinctive white "necklace" on the back of the bird's neck in summertime. The eyes are always red (once they reach sexual maturity) and the beak and feet are always black (Loon Preservation Committee, 2010). See Figure 1 for a picture of a common loon in breeding plumage.

Figure 1. Common Loon & Chick (taken from **http://www.acrosstheborders.com/atb/usa.html**).

In New Hampshire, the common loon was listed as "threatened" by the New Hampshire Fish and Game Department in 2000 under the New Hampshire RSA 212-A, the Endangered Species Conservation Act (Vogel and Taylor, 2006). The status of "threatened" means that if the habitat around the animal declines further from its current status, then the animal may be moved to "endangered" status. The "endangered" status is described as a native species of animal's prospects for survival is in danger because of loss, damaged, or declining habitat, overexploitation, predation, competition, disease, disturbance or contamination and that assistance is needed to ensure their continued survival (NH Fish & Game Department, 2008a). The New Hampshire list of endangered and threatened species is supposed to be reviewed every eight years to maintain its up-to-date status after its creation in

1980 (NH Fish & Game Department, 2008b). However it has been revised in 1987, 2000 and 2008 only (NH Fish & Game Department, 2008a).

Common loons are important to study for a variety of reasons but the most prevalent one, which directly concerns human health, is the loons' role as a bio-indicator species. We use loons to measure water quality in freshwater lakes. When toxins get into sediment in a lake, the toxin can bio-accumulate up the food chain to higher predators. We measure this through blood and feather samples taken directly from a living loon, unhatched egg analysis, and necropsies performed on loons carcasses. The samples are usually tested for levels of methylmercury as well as other toxins, which can cause neurological problems in developing human fetuses. Pregnant women should not eat high levels of mercury laden fish because of the risks associated with their child's development.

Loons are top predators on fresh and salt water. They are considered piscivorous, and feed mostly on a diet of fish, such as yellow perch, as well as aquatic invertebrates, amphibians, crustaceans, mollusks, and occasionally vegetable matter (Barr, 1996). Loons use their vision to locate fish underwater. They will float on top of the water and "peer" below them to watch for fish, and then they dive after them. Water clarity is an important factor for loons to locate their prey.

Common loons are renowned for their different calls and are a distinct characteristic of the genus. The four calls a loon can make are the wail, tremolo, yodel and hoot. Only males can yodel, and it is used for territorial purposes. Loons will call to other loons on different lakes and sometimes on the same lake if the lake is large enough for multiple territories (Henry, 2007).

Nesting is a vulnerable period for loons. They are out of the water and are especially susceptible to predation. Raccoons, minks, and foxes have been known to take a loon when it is on land (Henry, 2007). Loons usually have only one nesting attempt per season, so if something happens to their nest or eggs midseason, they are most likely not going to reproduce for the year. For these reasons, nests locations are chosen very carefully. Loons prefer to nest on an island if possible, but when no islands are available suitable shoreline are used. Careful selection reduces the risk of land predators disturbing the nest (DeSorbo et al, 2007).

For this study, the field data were collected by summer field biologists employed by the Loon Preservation Committee. This dataset began in the 1970s with Squam Lake in New Hampshire and continues to grow today as more loons are discovered on different lakes.

Loon Preservation Committee (LPC)

The Loon Preservation Committee (LPC) was established in 1975 as a self-funded branch of the New Hampshire Audubon Society when residents on Squam Lake in New Hampshire noticed a decline in the lake's population of common loons (Loon Preservation Committee, 2010). The Loon Preservation Committee's headquarters is located in Moultonborough, NH, which is on the shore of Lake Winnipesauke. LPC works with an extensive volunteer network to manage the loon population within the state of New Hampshire. LPC also works with many organizations within the region to help manage the common loon including Biodiversity Research Institute in Maine, Tufts University in Massachusetts, New Hampshire Fish & Game, U.S. Fish and Wildlife and The New Hampshire Wetlands Bureau under the New Hampshire Department of Environmental Services (Loon Preservation Committee, 2010).

Previous Habitat Model

Our project is a continuation of a previous habitat model created by Dr. Mark Brennan (2005). He used thirty years worth of field data from the LPC to create a habitat model that predicted loon occupancy on lakes around New Hampshire. This model resulted in three GIS layers each with a different level of predictable occupancy called high level of occupancy, medium level of occupancy and low level of occupancy. Four parameters were used to predict occupancy and they were: perimeter of lake, depth of lake, elevation of lake & distance to nearest lake with loon occupying it (Brennan, 2005). The original analysis began with a possible twenty parameters but only four were found to be statistically significant. The data used to make this model ended in 2002.

OBJECTIVES

There were two objectives for our project. The first objective was to evaluate the original habitat model created by Brennan (2005) using field data collected after he completed his project. The second objective was to combine data from Brennan's habitat model with new factors acquired from different sources to create a new model to improve the process of predicting loon habitat. Future work on our project is to create new GIS layers that show how levels of prediction for lakes have changed since 2002.

METHODS

To accomplish the first objective for our project, we performed an error analysis on the original model. The predicted probabilities from Brennan's model were used as predicted data and the field data from the years 2002 - 2008 were used as observational data. A series of error matrices (Congalton and Green 2009) were created to test each year against the results from Brennan's model to perform an accuracy assessment of Brennan's model.

To accomplish the second objective of our project, there was a substantial amount of initial prep work to perform before the analysis could begin. Several databases of information needed to be reviewed prior to analysis. A list of lakes that are monitored on a yearly basis was provided by LPC. This lake list was used as a baseline for lakes to use in creating a new model that was tested against the original model to see if it was better at predicting loon habitat. Half of the LPC lake list was used to build the new model and then the second half of the lake list was used to test the new model's accuracy. Not all of the lakes were complete in their attributes and some lakes were discarded because there was not enough information to enter into the statistical analysis. In addition, a number of new potential model parameters came from Dr. Anne Kuhn-Hines (2009). In her dissertation, she created a model of comparing the effects of human disturbance on loon nesting ability. This model has some similar parameters as the original loon habitat model created by Brennan, but also some new ones that we investigated for potential use in the new model presented here. Finally, some parameters investigated in the new model came from Ms. Deb Soule from the New Hampshire Department of Environmental Services (NHDES). Soule queried the NHDES's database for lake attributes that were not publically accessible on their website and provided us with this valuable information.

Compilation of the complete list of parameters to be evaluated for use in the new model was accomplished using Microsoft Excel. The geographic information systems (GIS) analysis part of this project was performed using Environmental Systems Research Institute's (ESRI) ArcGis® 9.3 software. R, an open source software package, was used to perform the logistic regression part of this project. R is written in the S language, has good graphics and is considered one of the better statistical packages for doing spatial statistical analysis (Burns, 2006).

Creation of the new model was performed using a logistic regression approach in R. Prior to the statistical analysis; the dataset in Excel was split in half. The first half was used to create the model; the second half was set aside to be used to test the model's ability to make predictions. The eleven proposed variables for the new model were:

- pH
- Shecci disk depth (measure of water clarity)
- Number of islands
- Surface area (hectares)
- Lake elevation (m)
- Maximum depth (m)
- Mean depth (m)
- Lake area (acres)
- Lake perimeter (m)
- Distance to loon lake (m)
- Distance to no loon lake (m)

These eleven variables were also tested using different variations of these variables, such as taking the square or log of these individual variables. The new model was evaluated for significant variables and condensed into the final model. The final model was then tested by predicting the probability of a loon's presence on a lake with the other half of the dataset. An error matrix was then generated for the new model to see how it compared to the original habitat model created by Brennan.

RESULTS

Accuracy Assessment of the Original Model

An accuracy assessment was performed on the original model using the data from 2002 - 2008. The overall average accuracy for all three levels of occupancy (high, medium, and low) for the years 2002 - 2008 was 67%. The overall accuracy for the high level of occupancy for years 2002 - 2008 was 79%. The overall accuracy for the medium level of occupancy for years 2002 - 2008 was 53%. The overall accuracy for the low level of occupancy for year 2002 -2008 was 73%. Figure 2 graphically presents the results of the accuracy assessment of the original model applied for years 2002-2008.

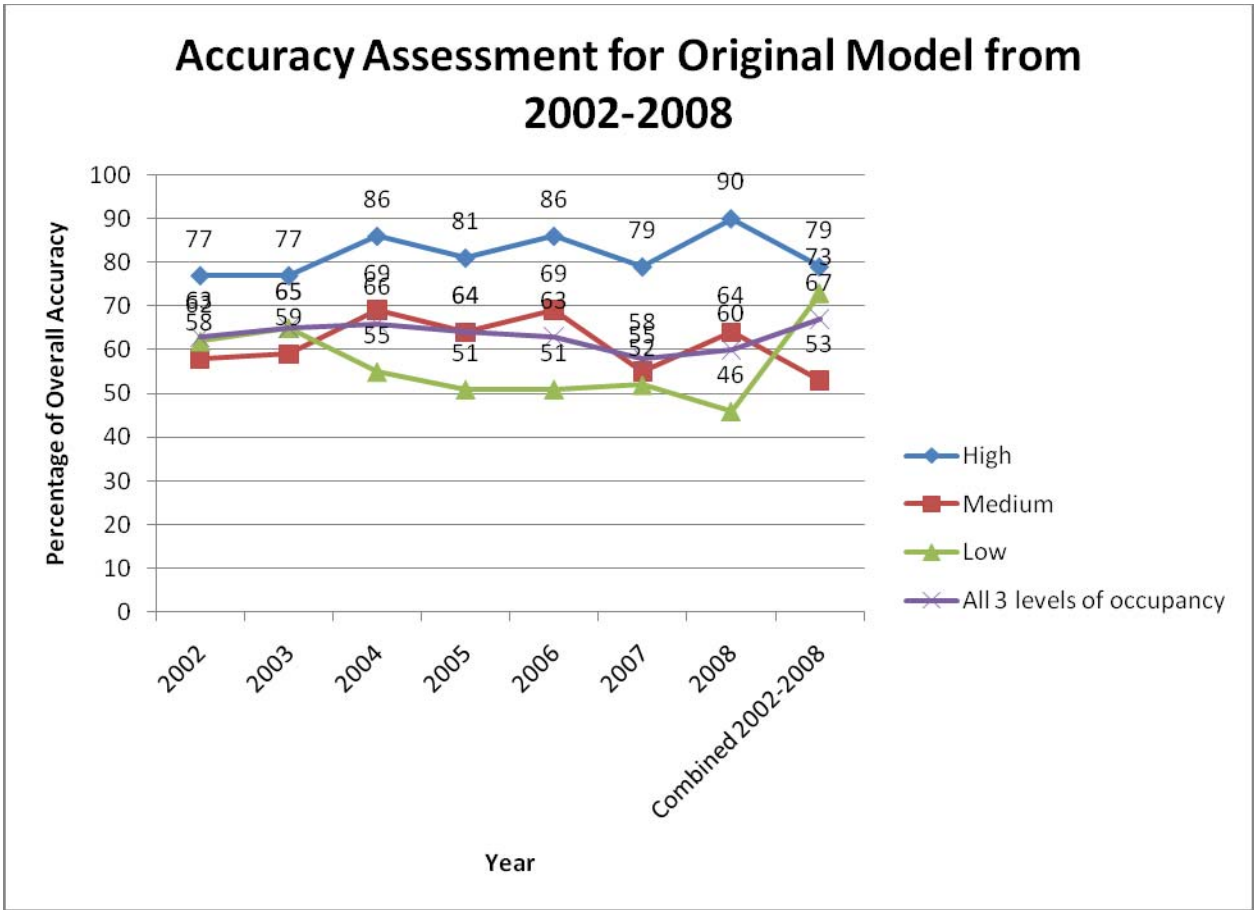

Figure 2. Accuracy Assessment over time of original habitat model.

The accuracy assessment results from Brennan's model for the years 1997 – 2002 was 78% (Brennan, 2005). The combined accuracy for the Brennan model extended to the years 2002 to 2008 is 67%.

New Model

Of the original eleven parameters entered into the logistic regression model, only four were found to be significant at the 0.05 level of significance. These were: distance to the nearest lake with a loon, sechhi disk depth (water clarity), perimeter of the lake, and perimeter of the lake squared. This model was chosen based on the significance of the factors and the Akaike Information Criterion (AIC) score, which is an estimator of predictive accuracy for a model. The final model was:

$$p(\text{loon presence}) = .2320349 + .05770603(\text{SECHHI}) - .00003767921(\text{DISTTOLOON}) + .00001862571(\text{PERIMETER}) - .00000000006771735(\text{PERIMETER}^2) + €$$

This model was then assessed for accuracy using the second half of the dataset that had been set aside to conduct this test. The model provided a predicted probability value for loon presence on a continuous scale from 0-1. This value was then converted to be a binary predicted value of 0 for absence and 1 for presence. Any lake with a predicted probability value above 0.5 was considered to be predicted to have presence and any lake with a predicted probability value below 0.5 was considered to be predicted to have absence. Each lake was then compared to the observed field data collected by LPC. The resulting error matrix shows an overall accuracy of 69%. The accuracy of this new model is not much different than the original (Brennan's) habitat model. Table 1 presents the error matrix including the overall accuracy of the new model and Table 2 shows the producer's and user's accuracies of the new model.

Table 1. Overall Accuracy Assessment for new model.

	Predicted Loon Presence (1)	Predicted Loon Absence (0)	Totals
Observed Loon Presence (1)	39	23	62
Observed Loon Presence (0)	25	66	91
Totals	64	89	153
		Overall Accuracy	**69%**

Table 2. Producer's & User's Accuracies for new model.

Producer's Accuracy			User's Accuracy		
Loon Presence	39/64	61%	Loon Presence	39/62	63%
Loon Absence	66/89	74%	Loon Absence	66/91	73%

DISCUSSION

The accuracy of the original model created by Brennan when extended to the years 2002-2008 is only 67%. This is a significant reduction from the 78% accuracy reported by Brennan (2005) for the model applied for 1997-2002. Monitoring practices change over time and certain lakes get prioritized differently based on what organization is monitoring them and what parameters need to be measured at the time. Not all lakes that were used to create the original model are still being monitored by LPC and therefore had to be deleted when calculating the accuracy assessment, therefore reducing the overall accuracy.

It is very interesting to note that only four parameters were significant in the new model. These parameters that were found to be significant are easy to explain by observing a loon's behavior in the wild. The distance to the nearest lake with a loon on it would be significant because loons are territorial. Loons signal their territory to other loons with vocal calls. Loons on nearby lakes would hear another loon in their territory and not want to be close to another loon which is why this variable was negatively correlated. The sechhi disk depth also makes sense because loons hunt using their vision with a behavior called "peering". If the sechhi disk is depth is very shallow, then loons will not be able to see prey, making this variable positively correlated. Finally, perimeter of the lake is also easily explained because loons need shoreline in order to nest on, which makes this variable also positively correlated. Loons tend to prefer lakes with islands on it in order to make their nests safer from terrestrial predators, but not all lakes in New Hampshire have islands so a substantial amount of shoreline is crucial for nesting habitat.

Some of the parameters that were expected to be significant, but were not, are more difficult to explain. For example, the number of islands would seem to be important because loons select islands for nesting. However, most of the lakes monitored in this dataset had no islands. Therefore, a large number of lakes in this data set had a value of zero and lowered the significance of this factor. Another example is the pH values for a lake, which were also found to not be significant. This can be explained by the fact that most of the lakes were in a very close range for pH and there wasn't much of difference between the lakes to be significant.

The error matrix of the new model showed an overall accuracy of 69%. The overall accuracy for the original model for combined years of 2002-2008 from the accuracy assessment in this project was 67%. This is a slightly better overall accuracy and ability to predict future loon habitat. Using the two models in combination would most likely be the best course of action for determining the predicted probability of loon presence for a specific lake.

Future work for this project includes creating new GIS layers in combination with previous layers created by Brennan (2005), which show where lakes in New Hampshire have the highest probability of future loon occupancy.

The layers will then be given to LPC to aid in their field data collection and make better use of their field biologists' time.

ACKNOWLEDMENTS

Partial funding for this project came from the New Hampshire View Project, which is a part of America View. We would like to thank many contributors to this project including; Dr. Mark W. Brennan, Dr. Anne Kuhn-Hines (US Environmental Protection Agency, Deb Soule (New Hampshire Department of Environmental Services), and Meghan Graham MacLean.

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