Modeling Salmon Habitats in Penobscot River, Maine

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Introduction to GIS and Remote Sensing

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Introduction

The Penobscot River is an important path for Atlantic salmon, Rainbow smelt, alewives and a total of 11 species of anadromous fish for spawning migration (PRRT n.d.). Historically, Atlantic salmon ran upstream numbering more than 50,000 for 100 miles upstream before dams were built on the river (Americanrivers 2011). With several dams blocking the way of these anadromous fish from migrating into upstream, the habitats of salmon are very scattered and number of salmon run back with only 531 Multi-sea-winter (MSW) salmon and 309 grilse Atlantic salmon counted over a half year period in 2017 (Maine.gov 201). The Penobscot River Restoration Project set to assist with the fish run through removal of the Veazie Dam and Great Works Dam and the fish lift projects. Other than the impact of dams, the shift in land use and natural barriers will also affect the fish run. I used GIS to analyze the impact of dam numbers, slope of streams, different land usages including forest and urban on the possible salmon habitat choices in the Penobscot River. From there I would come up with a model predicting the habitats of salmon.

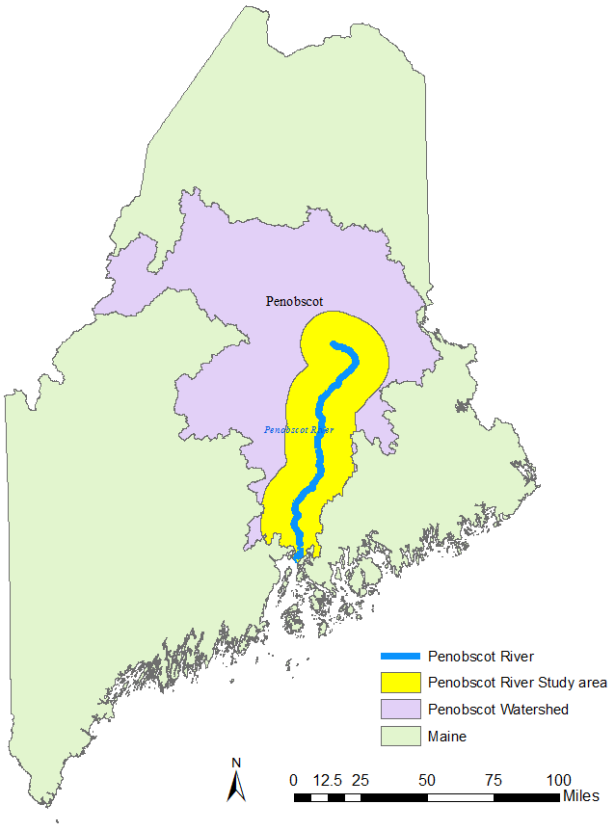

Figure 1. Penobscot River and Watershed’s position in Maine.

Figure 2. Picture of Atlantic salmon.

Figure 3. Removal of the Veazie Dam (2013).

Methods

To predict the potential habitats, I used ArcGIS 10.4 (ESRI) to come up with a map of Penobscot River and generated random 80 points for habitats and non-habitats individually within 20 km of the Penobscot River. For variables, I reclassified the land use data of 16 categories into urban land use, agricultural land, wetland, forest, open water, grassland and barren land. Other variables I used are slope, dam numbers, natural barrier (beaver dam and natural falls) numbers as well as distance to estuary. I developed the logistic model to predict habitats using the variables that are significant.

I collect data from multiple sources: National Land Cover Database is from U.S. Department of the Interior, National Hydrography Dataset is obtained from USGS, 2016 Salmon habitats data and dam data are from Maine Office of GIS. The data for natural barriers are from Mr. Alex Abbott from U.S. Fish and Wildlife Service.

Results

Human land use (include open land, low/ medium/ high intensity urban land) $(\mathrm{p} = 3.37 * 10^{-7})$and number of dams $(\mathrm{p} = 1.66 * 10^{-4})$ along the path are adopted in a logistic model to predict the potential habitats of salmon. The equation generated by R is

$$P(habitat) = \frac{1}{1+e^{-(0.1103*\log(Human\ Land\ Use)-0.6706*Number\ of\ Dams+1.4041)}}$$

The distance to Estuary (p<0.001) shows significant relationship but can be confounded with number of dams and other variables so I did not adopt it in my model.

Other variables I tested in R does not show a significant relationship or the general shape of the logistic model does not fit into the “S” shape logistic model has. The shape length from the 2016 Salmon Habitat data in this region adds up to be 32,642.6 m. In my model, the potential habitat with probability over 60% adds up to 143,783.4 m in total.

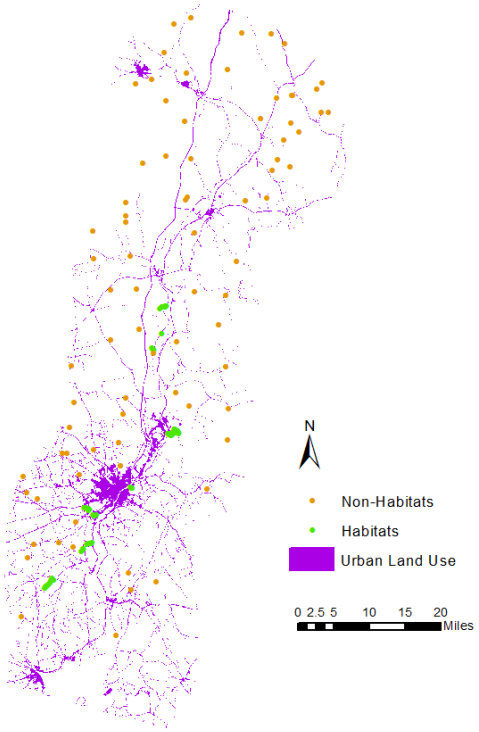

Figure 4. Urban land use and the 160 points for habitats and non-habitats.

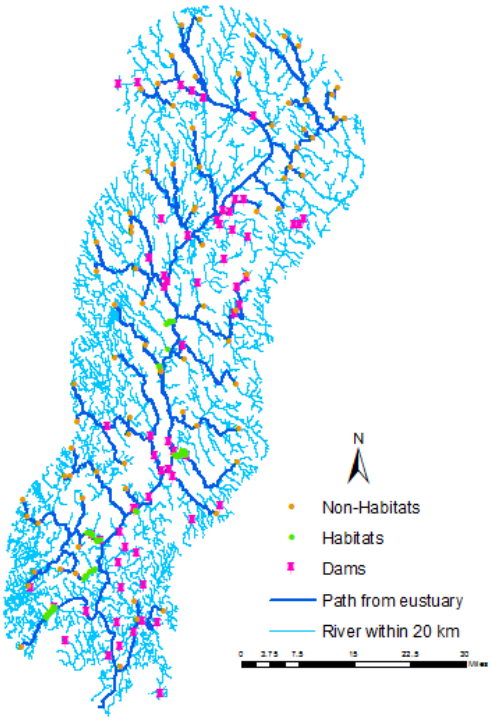

Figure 5. River system within 20km of Penobscot River.

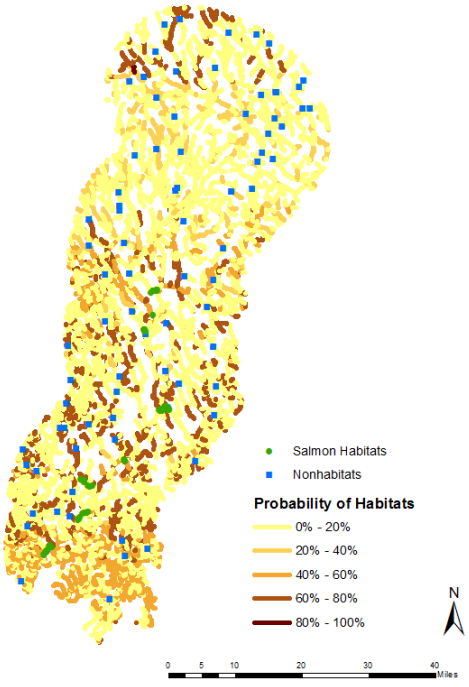

Figure 6. Probability of habitats and the 160 points for habitats and non-habitats.

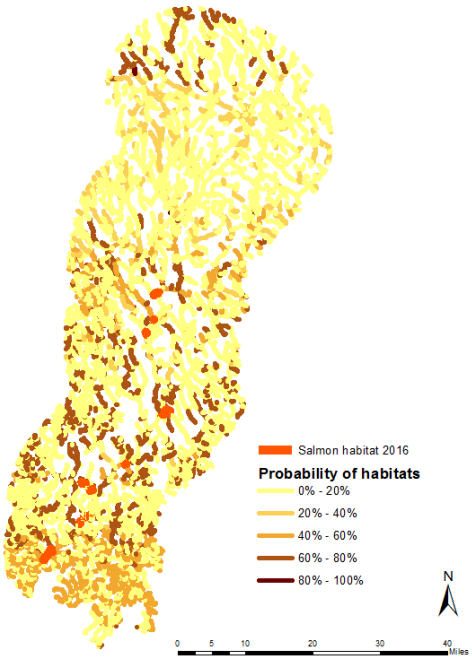

Figure 7. Probability of habitats and the salmon habitats in 2016.

Discussion

I found that the human urban land use and the number of dams are the most important predictors in finding salmon habitat. Based on the potential habitats I come up with, the potential habitats clustered more at the southern part of the watershed which is closer to more populated areas like Bangor and the fish will encounter less dams on their way. As I took the logarithm of urban land so I set the undefined entries to zeroes which does not has huge impact on my model.

Some factors, like forests, could show factors for the habitat choice potentially. As it drives temperature and other possible habitat choosing drivers (Jorgensen et al. 2009). But in my case nothing significant is found. Natural barriers is another factor that could have an impact but was not significant in my case.

Some data that should be adopted were stream segment slope, drainage area, reach width which were used in a model to predict salmon habitats (NOAA 2008). Other data like turbidity and precipitation could also be potential indicators of habitats. For this project either data were lacking online or it was hard for me to run in ArcGIS. But they could be important variables to analyze in future studies.

Ideally, data for each point along the river feature should be acquired to get more precise data. But as it would generate too many points, I used river segment as a basic unit which also functions in my case.

Though my data shows that the returning salmon tend to inhabitat areas exhibiting human land use, researches had showed that human wastewater had negative effect on juvenile salmons. The level of Polycyclic Aromatic Hydrocarbons (PAHs), polychlorinated biphenyl (PCBs) concentration in stomach and PCBs in liver in salmons from urban area was significantly higher compared with others (Stein, Hom, Collier, Brown, & Varanasi 1995).

Acknowledgement

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