A Lake and Pond Classification System

for the Northeast and Mid-Atlantic States

November 2014

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U.S. FISH & WILDLIFE SERVICE

North Atlantic LCC
North Atlantic Landscape Conservation Cooperative

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Call Outline

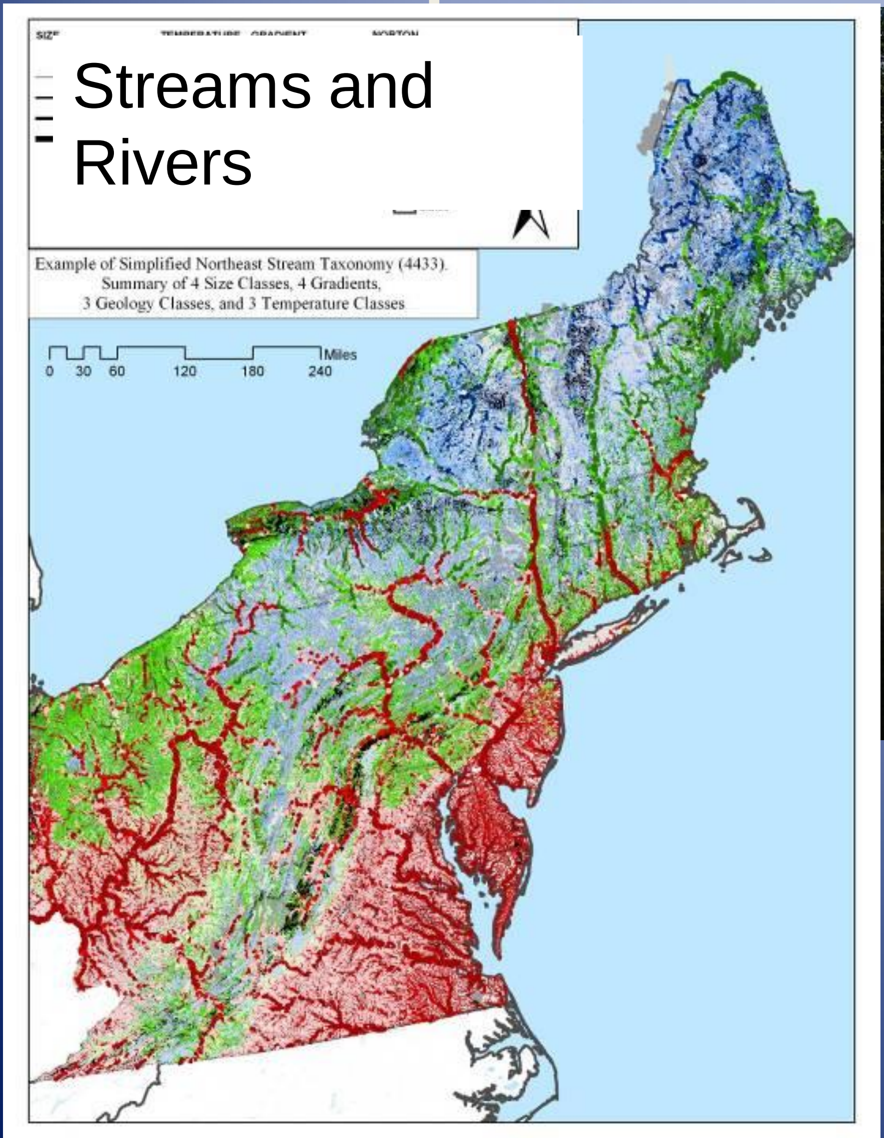
- Goal
- Process
- Key Variables
  - Trophic Level
  - Alkalinity
  - Temperature
  - Depth
- Integration of Variables into Types
- Distributable Information
- Web Mapping Service

Goal:

A classification and map of waterbodies in the Northeast

Product is not intended to override existing state or regional classifications, but is meant to complement and build upon existing classifications to create a seemless eastern U.S. aquatic classification that will provide a means for looking at patterns across the region.

Counterpart to the NE Aquatic Habitat Classification



Olivero, A, and M.G. Anderson. 2008. The Northeast Aquatic Habitat Classification. The Nature Conservancy, Eastern Conservation Science. 90 pp. http://www.rcngrants.org/spatialData

Steering Committee

State/Federal	Name	Agency
EPA	Jeff Hollister	Environmental Protection Agency
ME	Dave Halliwell	Department of Environmental Protection
	Douglas Suitor	Department of Environmental Protection
	Linda Bacon	Department of Environmental Protection
	Dave Coutemanch	The Nature Conservancy
NH	Matt Carpenter	Division of Fish and Game
VT	Kellie Merrell	Department of Environmental Conservation
MA	Richard Hartley	Department of Fish and Game
	Mark Mattson	Department of Environmental Protection
CT	Brian Eltz	DEEP Inland Fisheries Division
NY	Greg Edinger	Natural Heritage Program
	*David Newman	Department of Environmental Conservation
PA	Dave Arnold	Fish and Boat Commission
	Barbara Lathrop	Department of Environmental Protection
MD	*Sherm Garrison	Department of Natural Resources
NJ	Christopher Smith	Department of Environmental Protection
RI	*Elizabeth Herron	URI Watershed Watch
DE	*Kevin Kalasz	Department of Natural Resources and Conservation
WV	Brett Preston	Department of Natural Resources
VA	*Brad Fink	Department of Game and Inland Fisheries
	* unable to be on steering committee but advised and provided data as possible	

Develop frame-work

Share data

Review results

Reviewed Existing Classifications and Variables

	Sum Count	Sum Dominant	NAHCS	ME GIS	NH GIS/ Biotic	MA Living Waters	MA Heritage	VT Heritage	NY Heritage	CT Heritage	CT Fisheries	PA Heritage	VA Heritage	NJ Heritage	NJ Cold Water	MA Cold Water	NLA
•Water Chemistry	11	ph/ANC	ANC/pH	ANC/pH , shoreline wetlands	ANC	pH	pH	pH	pH/ANC, salinity	pH/ANC		pH/ANC	Sinkhole	pH/ANC			
•Physiography	6	Elevation (temperature proxy?)	Elevation	Elevation		Elevation		Elevation					Elevation				Ecoregion
•Stratification	5	Stratified in summer (temperature proxy?)	Depth	Depth	Depth	Depth			Stratification								
•Temperature	2	Cold Water Habitat/Trout Production									<19C >4mg/l DO				<21C > 4mg/l DO	<70F >5mg/l DO	
•Groundwater Linkage	5	Coastal Plain				Coastal Plain	Coastal Plain		Coastal Plain				Coastal Plain	Coastal Plain			
•Morphometry	5	Size	Size, Shoreline sinuosity	Size, Shoreline sinuosity	Size	Size			Size								
•Genesis	4	Man-made				Kettle			Oxbow, Impounded lake			Glacial					Man-mad
•Tropic State	3	Trophic						Trophic	Trophic		Trophic						
•Lake Hydrology	2	Stream Connected	Connection to streams	Connection to streams													
•Retention time																	
•Color and Clarity																	

The goal was to agree on a few key variables that apply to the whole region and could be mapped.

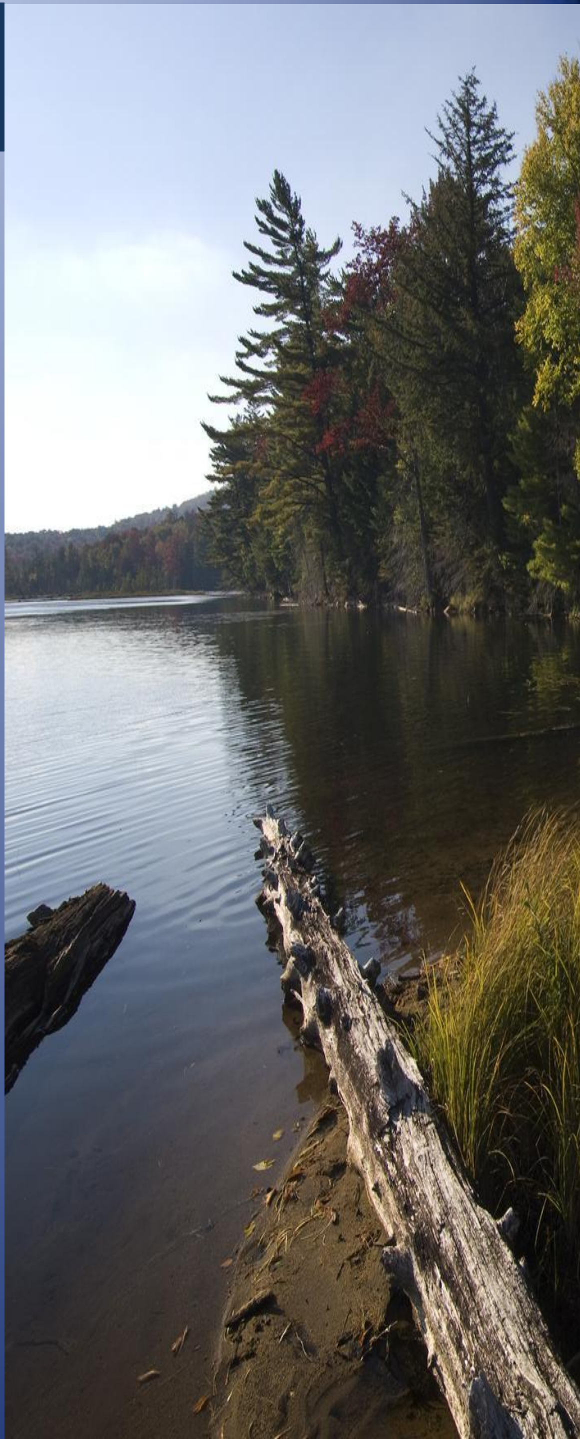
Final Variables

- **Temperature**
- **Trophic Level**
- **Alkalinity**
- **Depth**

These were unanimously agreed on by the steering committee

Approach for each Variable

- **Clarified ecological relevance**
- **Defined classes that correspond to observable biological changes**
- **Compiled known samples for Eastern waterbodies**
- **Developed predictive model based on waterbody and landscape attributes for unsampled waterbodies**



Accuracy and Confidence

- Required all models to have error rates less than .30 (the standard)
- Calculated a confidence score for each variable in each waterbody

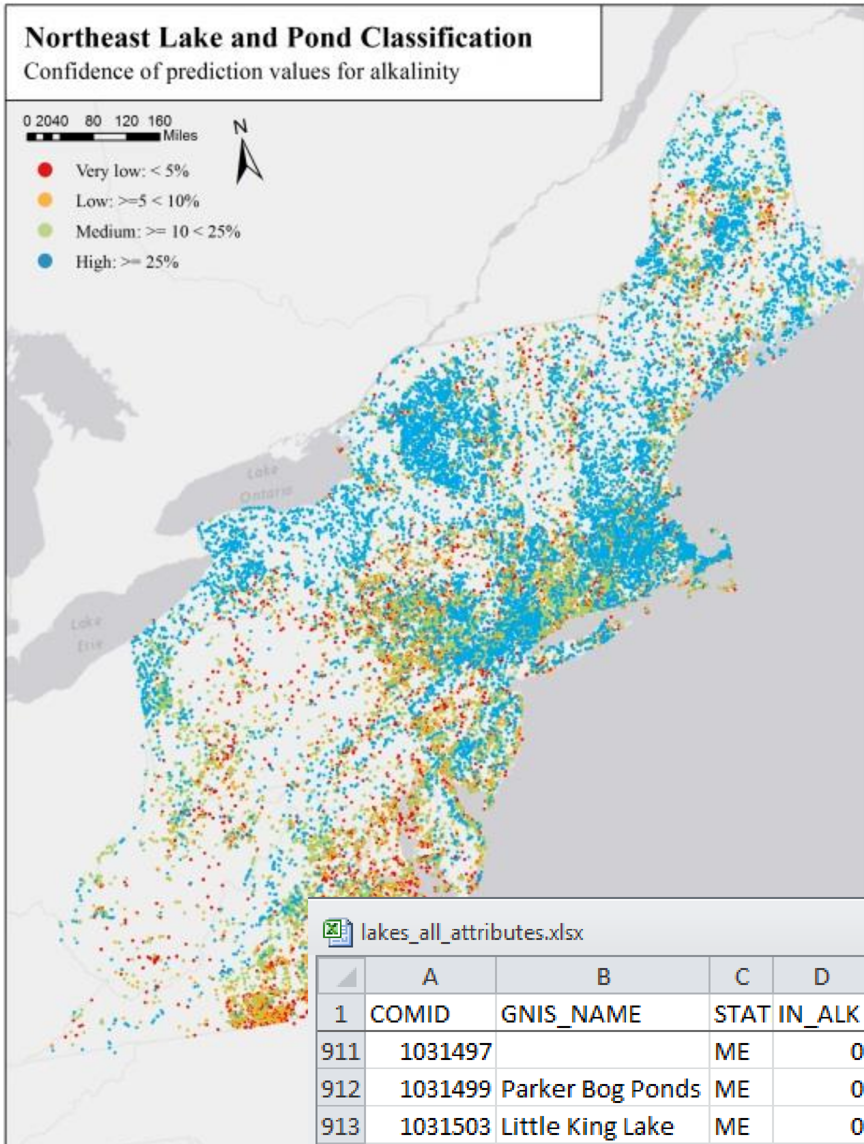
Waterbody X
Probability Very Cold = 60%
Probability Cold-Cool = 30%
Probability Warm = 10%

Difference = 30% = High

Waterbody Y
Probability Very Cold = 40%
Probability Cold-Cool = 38%
Probability Warm = 22%

Difference = 2% = Very Low

Confidence Classes



1. **Very Low <5%**
2. **Low >=5 <10%**
3. **Medium >=10 <25%**
4. **High >=25%**
5. **Known**

Information on predictions and confidence are in the attribute table

lakes_all_attributes.xlsx

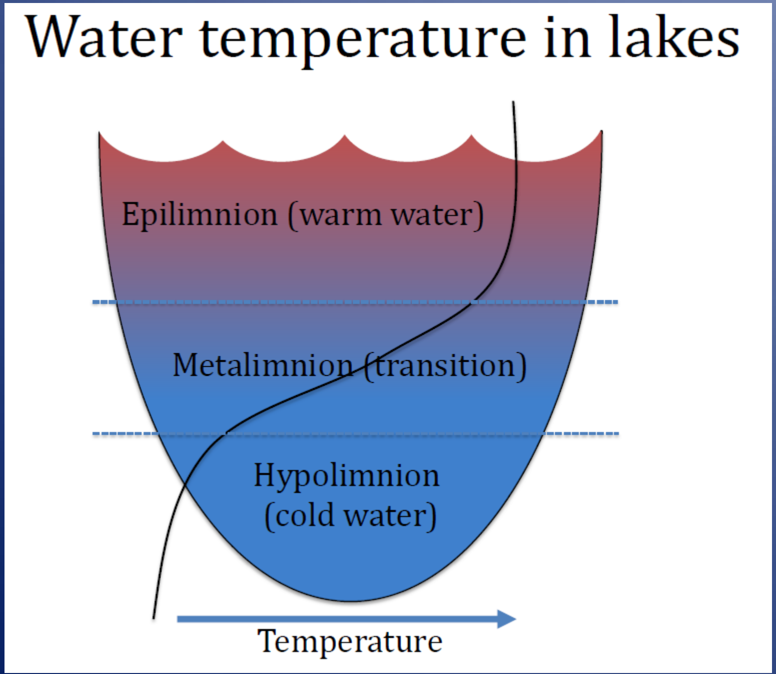
	A	B	C	D	E	F	G	H	I	J
1	COMID	GNIS_NAME	STAT	IN_ALK	PROB_HALK	PROB_MALK	PROB_LALK	CLASS_ALK	ALK_DIFP	ALK_CONF
911	1031497		ME	0	0.193750	0.536250	0.270000	Medium Alk	0.266250	4. High >=25%
912	1031499	Parker Bog Ponds	ME	0	0.176250	0.516250	0.307500	Medium Alk	0.208750	3. Medium >=10 <25%
913	1031503	Little King Lake	ME	0	0.011250	0.420000	0.568750	Low Alk	0.148750	3. Medium >=10 <25%
914	1031505	Call Pond	ME	0	0.018750	0.498750	0.482500	Medium Alk	0.016250	1. Very Low <5%
915	1031511	Felker Pond	ME	0	0.012500	0.402500	0.585000	Low Alk	0.182500	3. Medium >=10 <25%
916	1031513		ME	0	0.018750	0.537500	0.443750	Medium Alk	0.093750	2. Low >=5 <10%

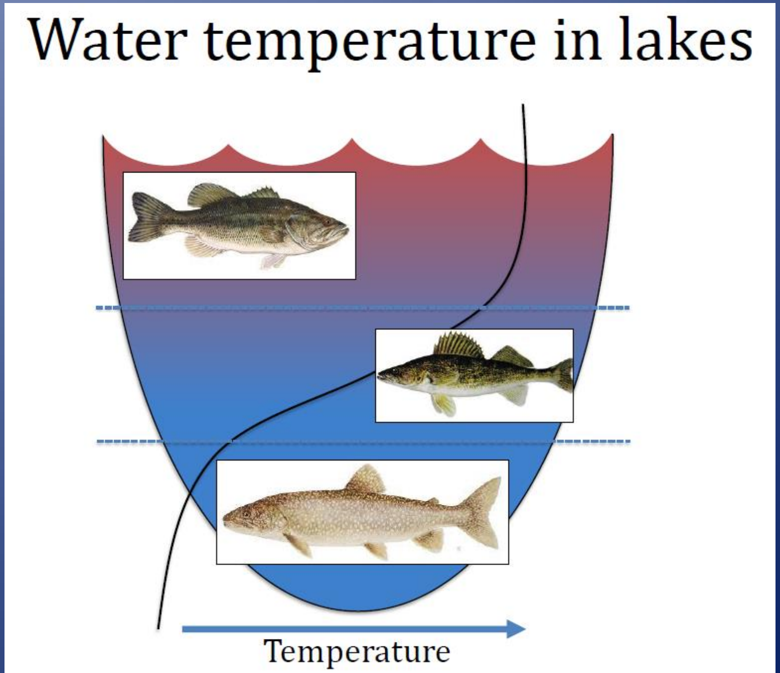
For Each Variable….

- Ecological Importance
- Classes Used
- Starting Data Map
- Final Results Map
- Driving Variables
- Model Error and Confidence

Temperature Class

Water temperature is critical in the life of aquatic organisms (fishes, amphibians, reptiles, invertebrates). It sets the physiological limits where these lake organisms can persist. Seasonal changes in water temperature often also cue reproduction, migration, influence growth rates of eggs and juveniles, and can affect the body size and therefore the fecundity of adults.





Temperature Class

Coldest water present in the summer

Presence of greater than 1 meter of following habitat throughout the summer (use July/August profile if available).

1. VERY COLD: <12.8C and >=5 mg/l DO or indicator fish = lake trout reproduction

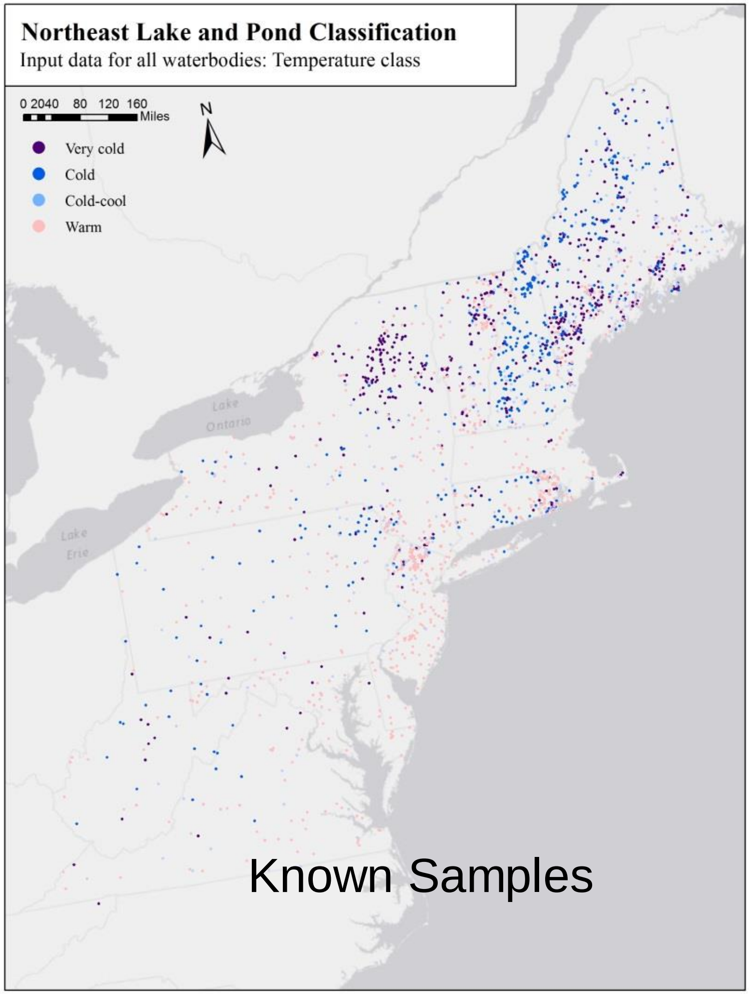
2a. COLD: 12.8C<=18C >=5 mg/l DO or indicator fish = wild brook trout reproduction

2b. COLD-COOL: >18<=21C, >=4 mg/l DO or indicator fish = non-reproducing brook trout, holdover or reproduction of brown trout, kokanee, smelt

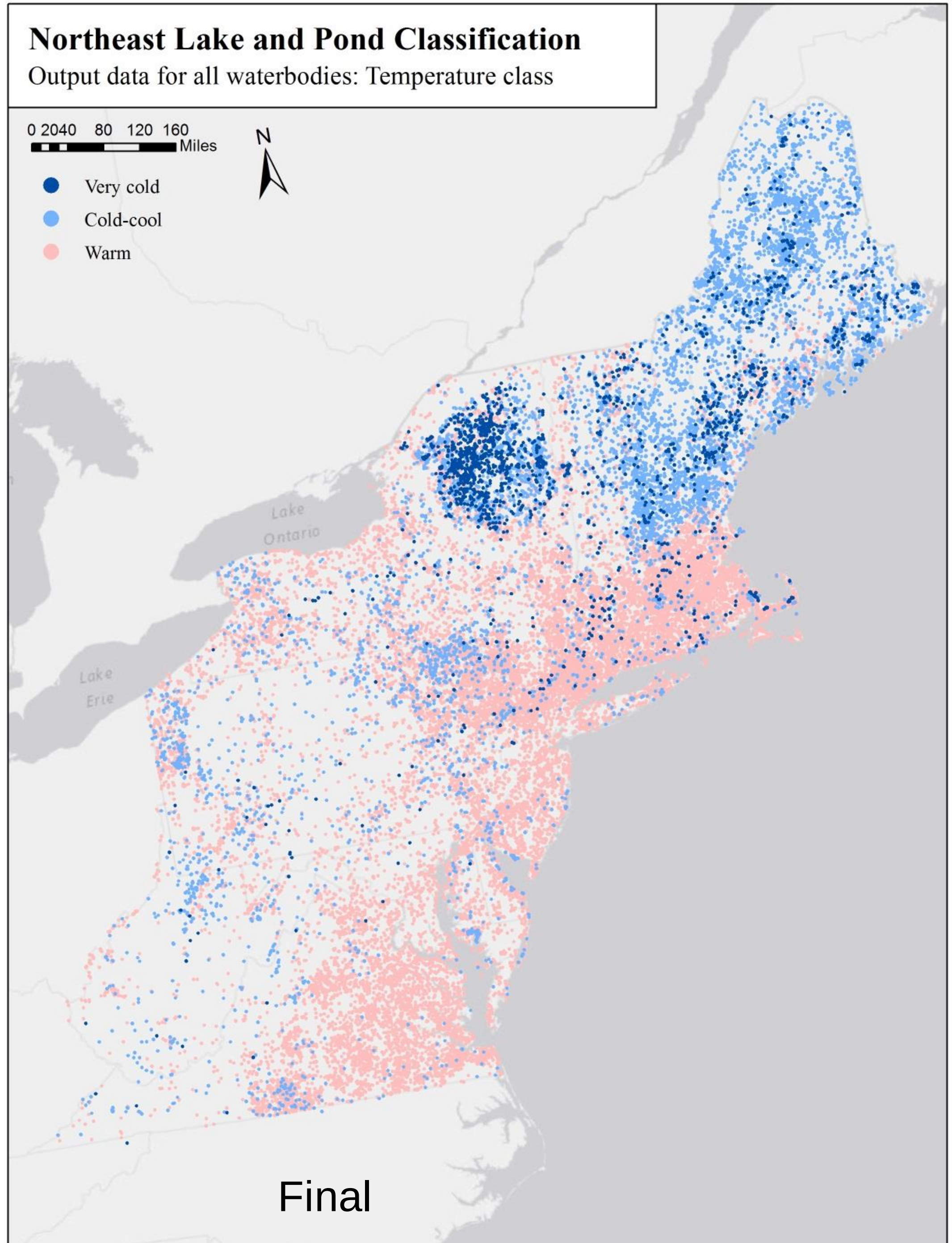
Combined into Cold-Cool

3. WARM >21C

Results



Class	# output	# input	Total	Percent
Very cold	1,262	529	1,791	6
Cool to cold	7,502	811	8,313	26
Warm	21,643	790	22,433	69
Grand Total	30,407	2,130	32,537	100



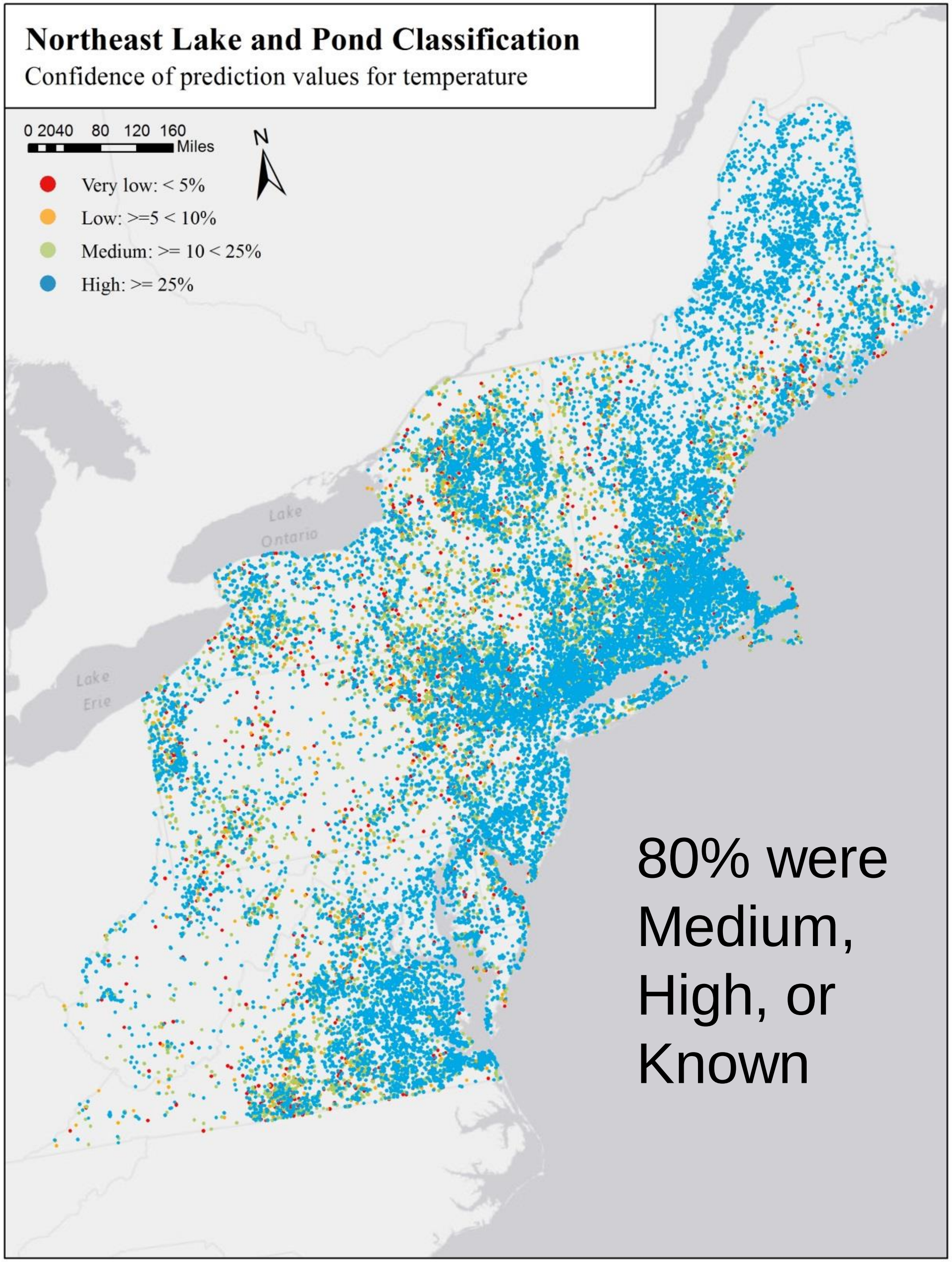
Temperature: Best Predictors

- Latitude
- Maximum and mean depth
- Longitude
- Elevation
- Fetch
- Emergent wetlands in the 100m buffer

These variables make ecological sense given the strong influence of depth and fetch on lake stratification. Cooler climates in the more northern and higher elevation parts of the region also have cooler seasonal air temperatures.

Confidence

Temperature Model	% Waterbodies
1. Very Low <5%	10%
2. Low >=5 <10%	10%
3. Medium >=10 <25%	24%
4. High >=25%	50%
5. Known	7%
Grand Total	100%



80% were Medium, High, or Known

Trophic Level

Trophic level: **Meaning "nourishment." Used to describe the level of productivity of a lake.**

<u>*Oligotrophic: (<=2 ug/L Chlorophyll-a)*</u> A nutrient poor lake. Low biological productivity, High transparency

Oligotrophic Dimictic Lake David M. Hunt

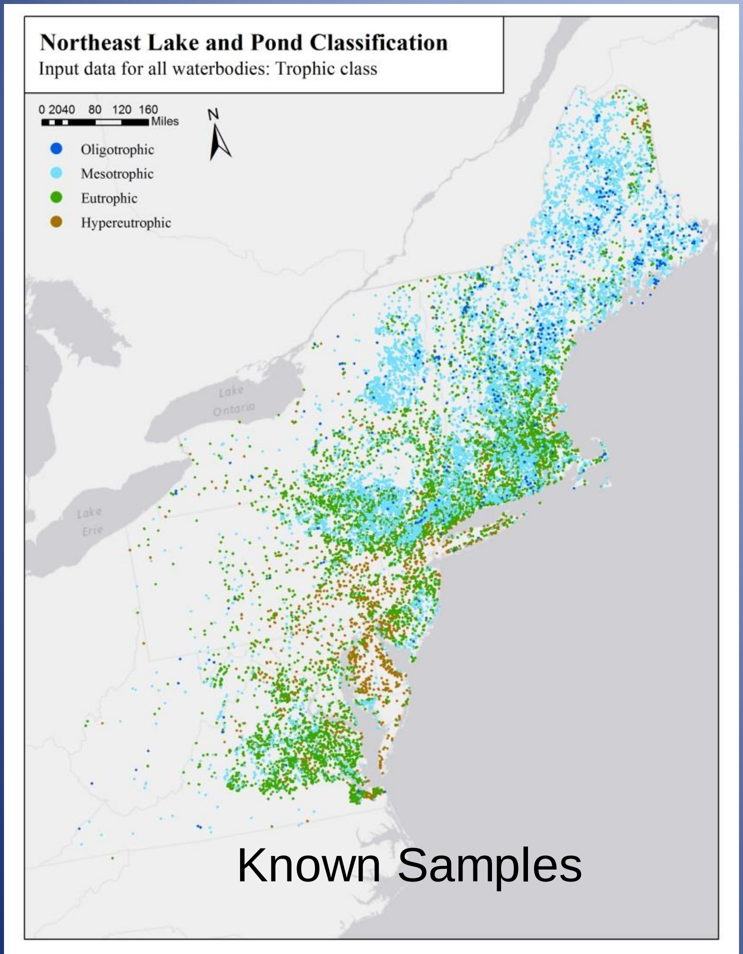
<u>*Mesotrophic (>2 -7ug/L Chlorophyll-a) :*</u> A lake that is moderately productive.

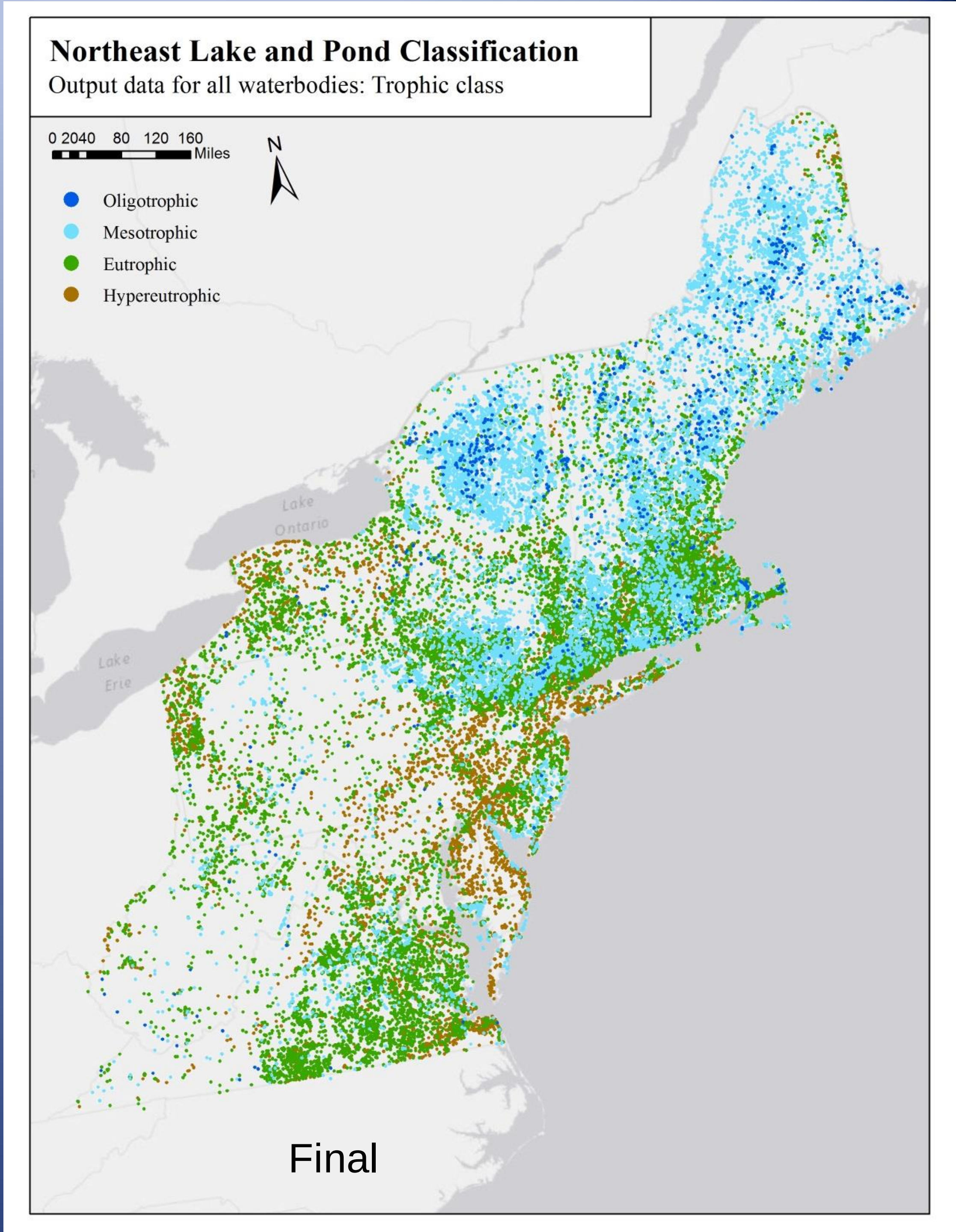
<u>*Eutrophic (>7-30 Chlorophyll-a) :*</u> A well-nourished lake, very productive, A balanced and diverse array of organisms. Low transparency due to high algae and chlorophyll-*a* content.

A eutrophic lake, characterized by algal blooms

<u>*Hypereutrophic: (>30 ug/L Chlorophyll-a)*</u> Characterized by an excess of nutrients. Algal blooms, vegetative overgrowth, low biodiversity.

Results





Class	# output	# input	Total	Percent
Hypereutrophic	3,464	1,996	5,460	17
Eutrophic	7,167	7,534	14,701	45
mesotrophic	3,958	7,575	11,533	35
Oligotrophic	368	511	879	3
Grand Total	14,957	17,616	32,573	100

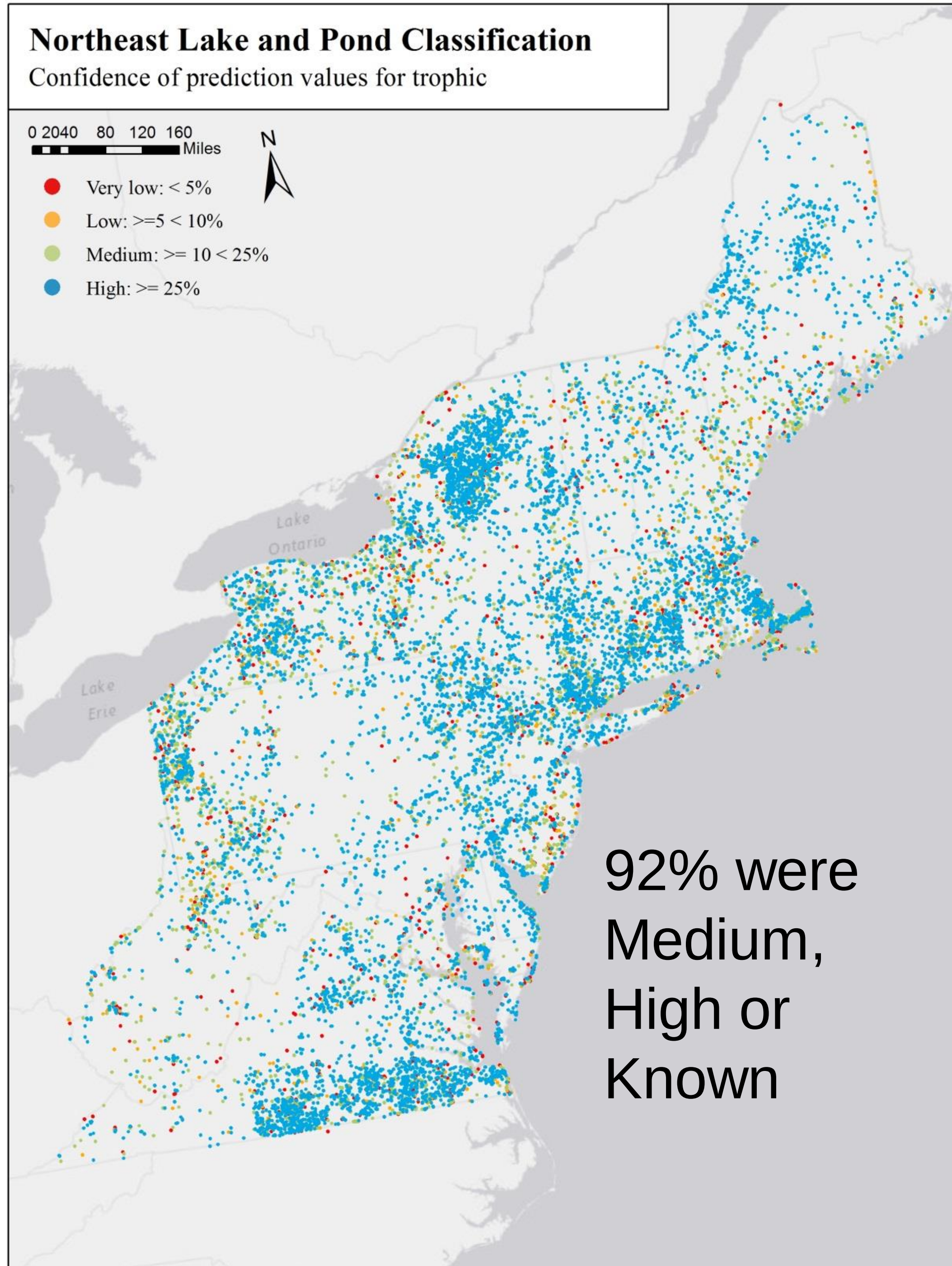
Trophic Level: Best Predictors

- % Natural cover
- Longitude
- Maximum depth
- Latitude
- Elevation
- % Deciduous forest
- % Agriculture

These variables make ecological sense given the geographic patterns, the strong influence of depth, and the strong influence of nutrient inputs from local development and agriculture.

Confidence

Trophic Model: Confidence Class	% Waterbodies
1. Very Low <5%	4%
2. Low >=5 <10%	4%
3. Medium >=10 <25%	10%
4. High >=25%	29%
Known	54%
Grand Total	100%



Alkalinity

Acid Neutralizing Capacity

ANC indicates sensitivity to changes in pH. ANC is primarily determined by the soil and underlying geology of the surrounding watershed. Waterbodies in limestone watersheds have higher pH and higher ANC

Inland Calcareous Lake Shore Timothy Howard

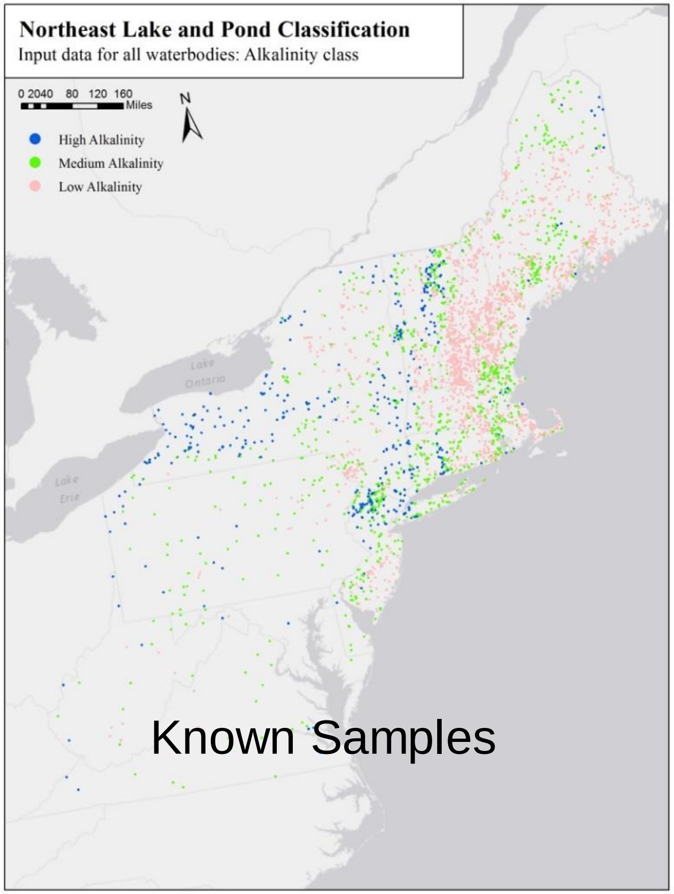
Alkalinity Classes

High Alkalinity >=50 mg/L

Medium Alkalinity >=12.5 & < 50 mg/L

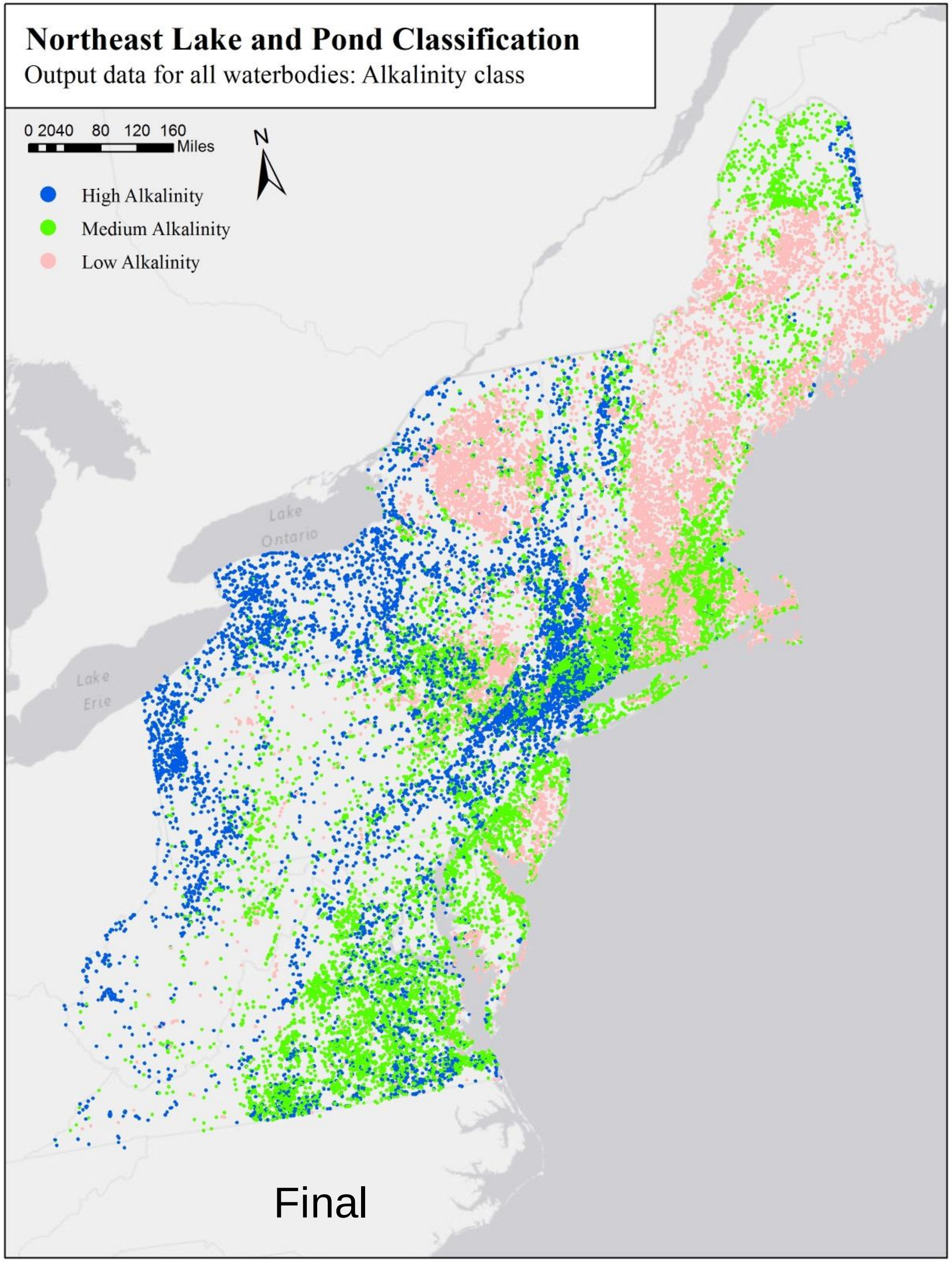
Low Alkalinity <12.5 mg/L

Results



Known Samples

Class	# output	# input	Total	Percent
Low Alk	9,504	1,903	11,407	35
Medium Alk	11,824	973	12,797	39
High Alk	7,902	431	8,333	26
Grand Total	29,230	3,307	32,537	100



Final

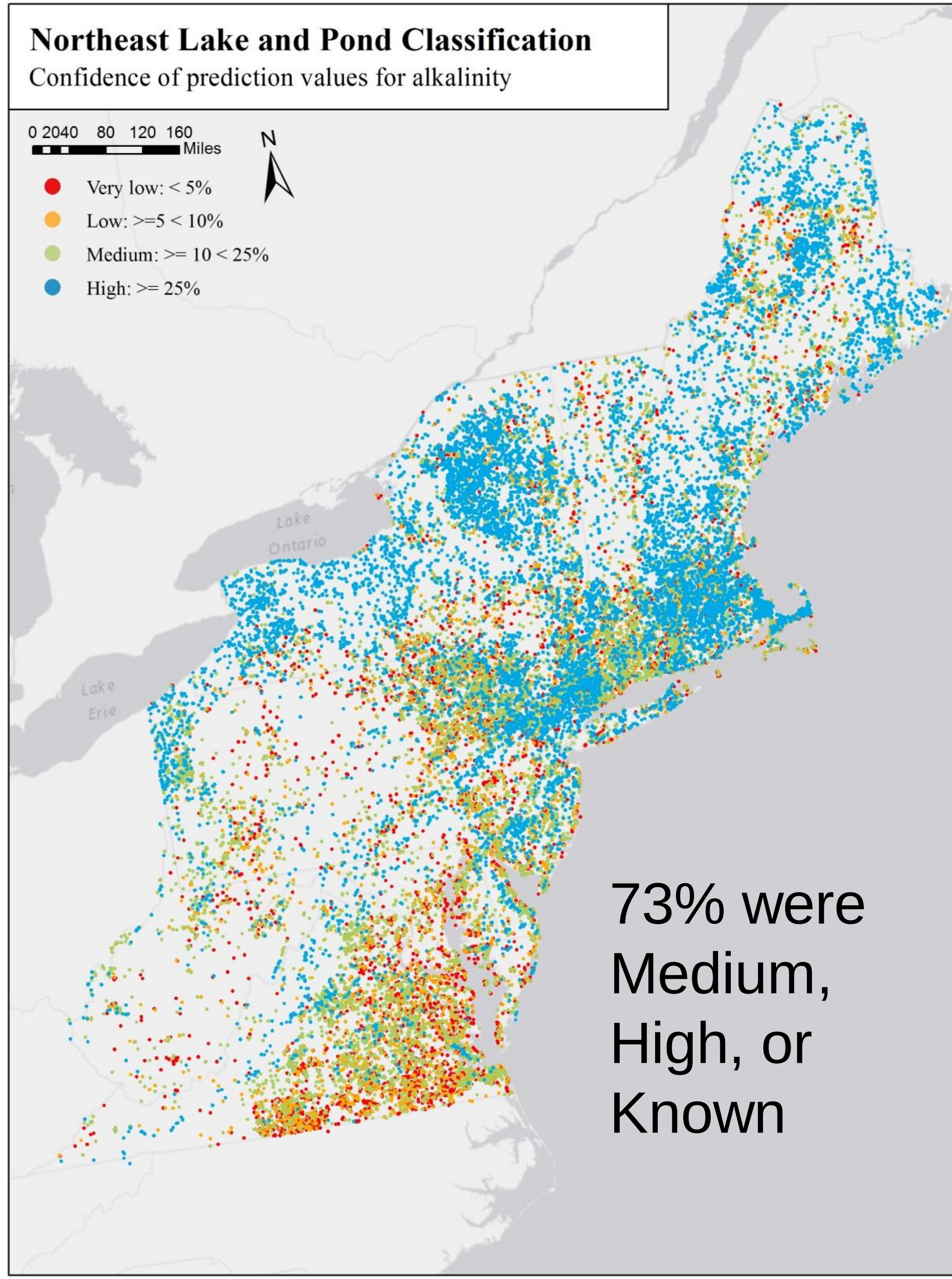
Alkalinity: Best Predictors

- Latitude
- Longitude
- % calcareous bedrock
- % natural cover
- Elevation
- % evergreen forest
- % acidic granitic bedrock
- % agriculture

These variables make ecological sense given the geographic patterns and the particularly strong influence of calcareous bedrock (limestone, dolomite, dolostone, marble) on buffering capacity.

Confidence

Alkalinity Model: Confidence Class	% Waterbodies
1. Very Low <5%	14%
2. Low >=5 <10%	13%
3. Medium >=10 <25%	27%
4. High >=25%	36%
Known	10%
Grand Total	100%



Depth: Lake vs Pond

Ponds = light penetration to the bottom, photosynthesis throughout.

Lakes = areas where light does not penetrate, profundal zone with no photosynthesis.

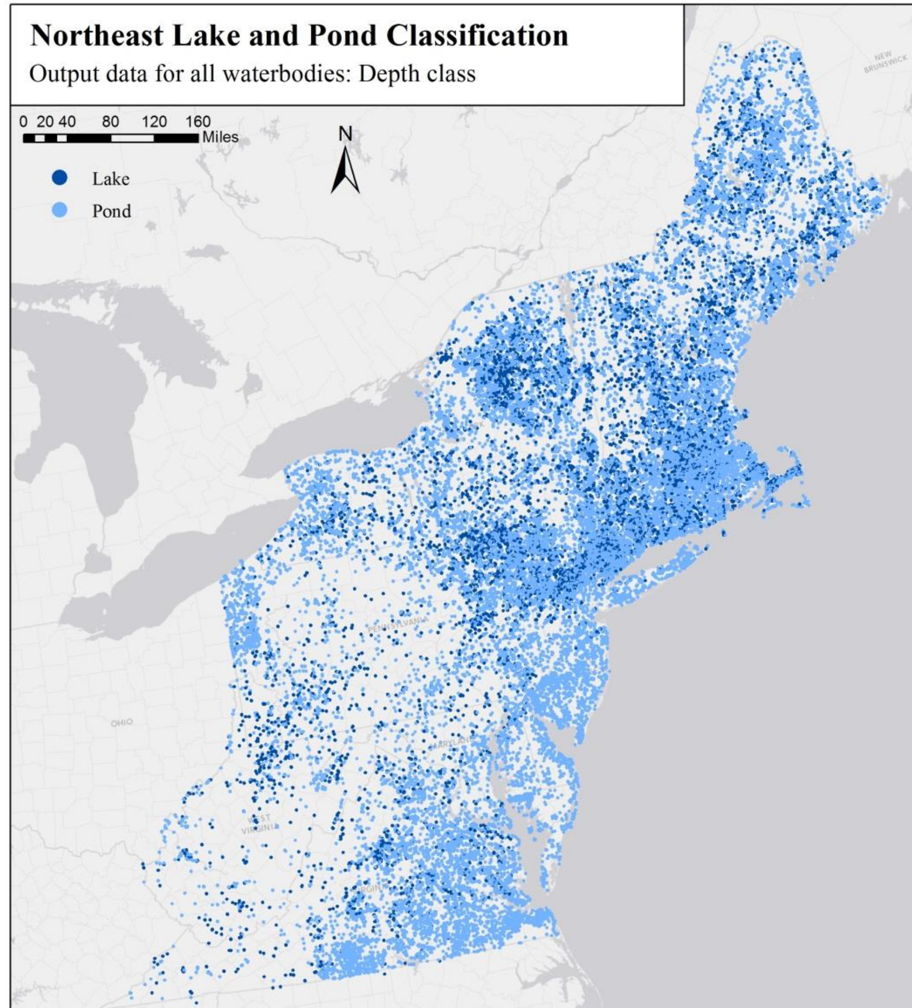
Depth Threshold

- depends on water clarity:

Oligotrophic <30ft

Mesotrophic <20ft

Eutrophic <10ft



	# Waterbodies	Percent
Lake	7023	22
Pond	25,628	78
Grand Total	32,651	

Waterbody Types: 3 Variables

First: Split by depth into lakes and ponds.

Second: Further classified by 2 variable combinations

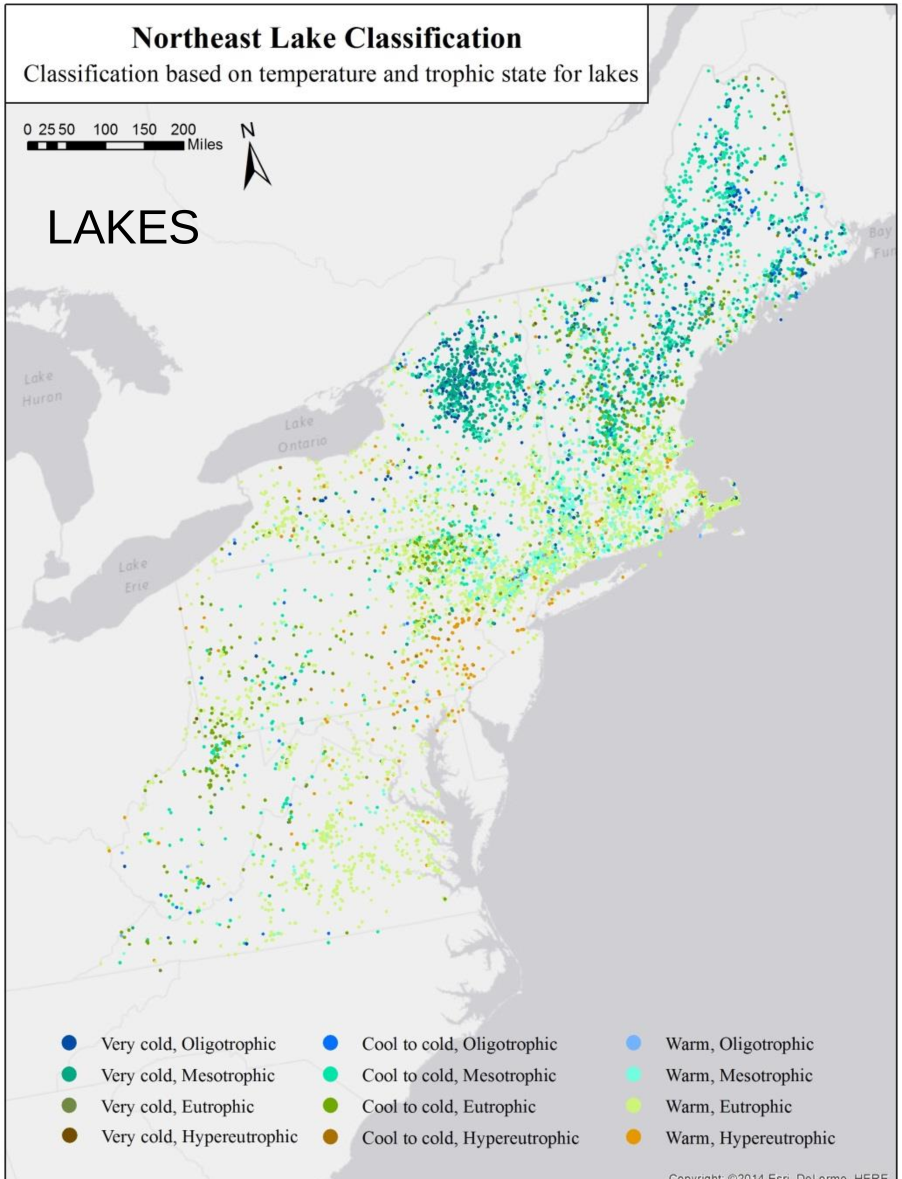
- Temperature + Trophic:
  12 types

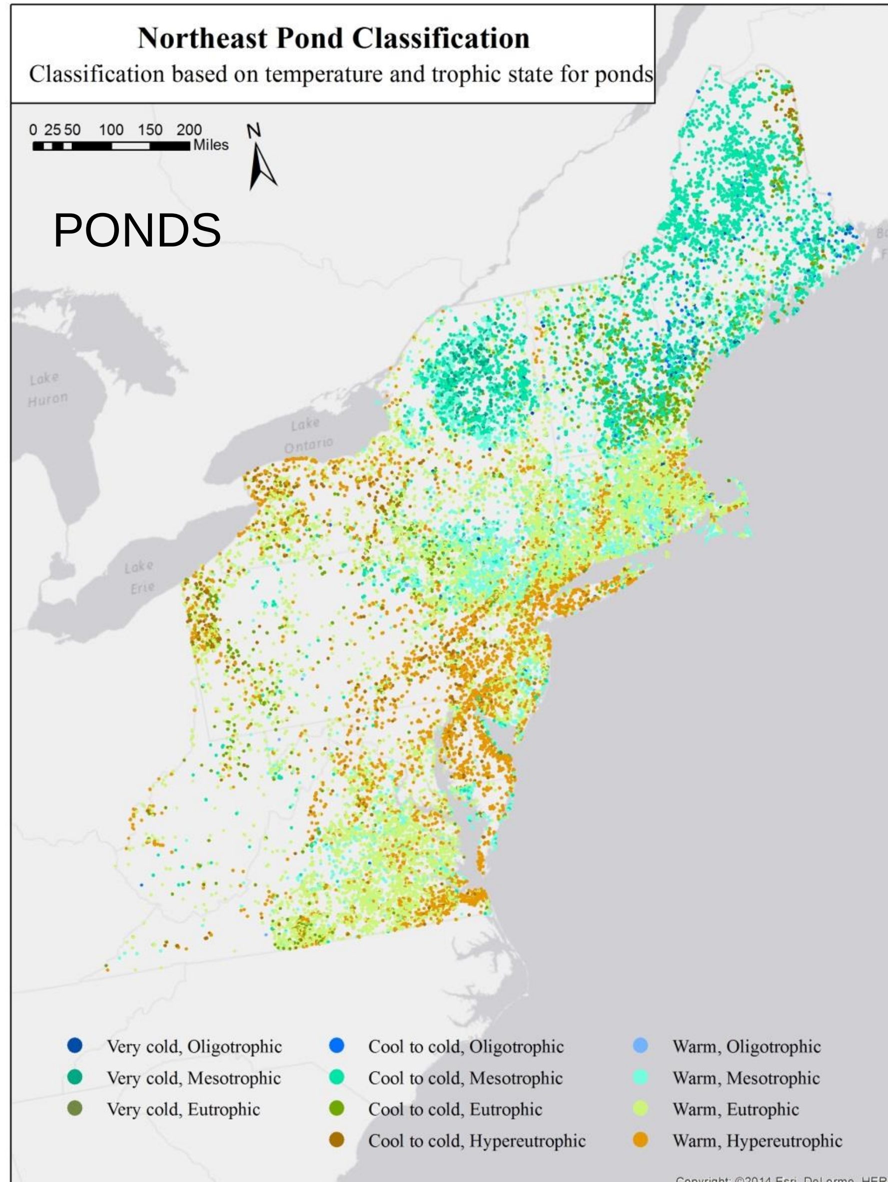
- Temperature + Alkalinity:
  9 types

- Trophic + Alkalinity:
  12 types

Temperature plus Trophic

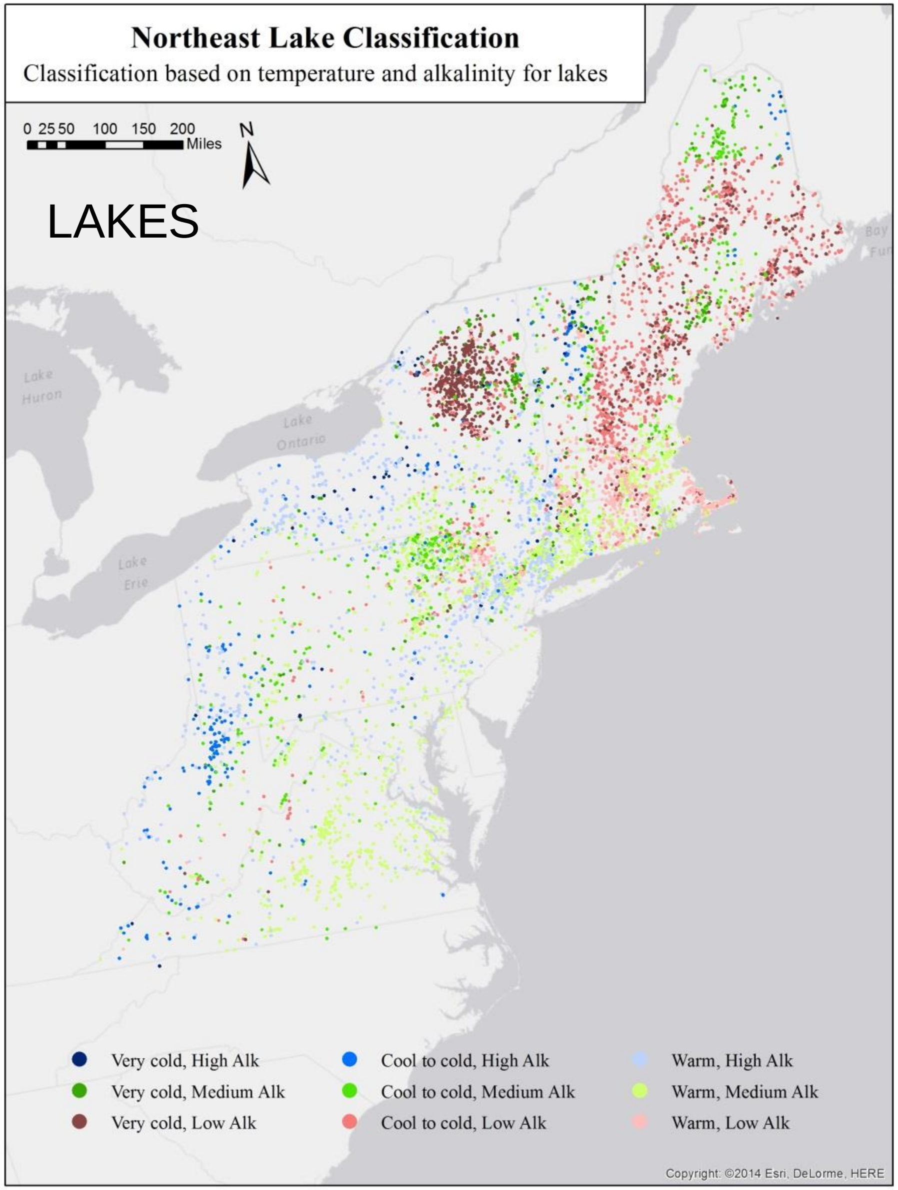
Example: Very Cold Oligitrophic Lake

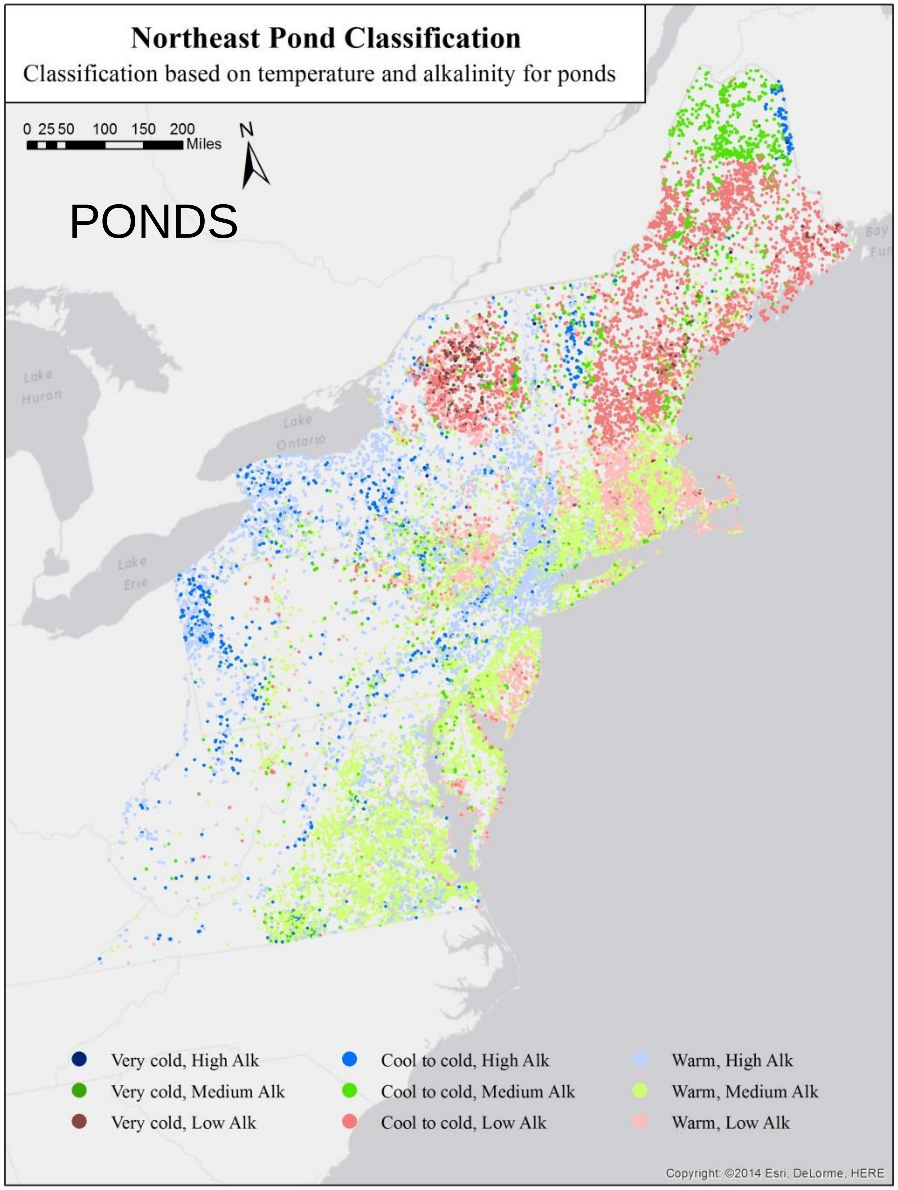




Temperature and Alkalinity

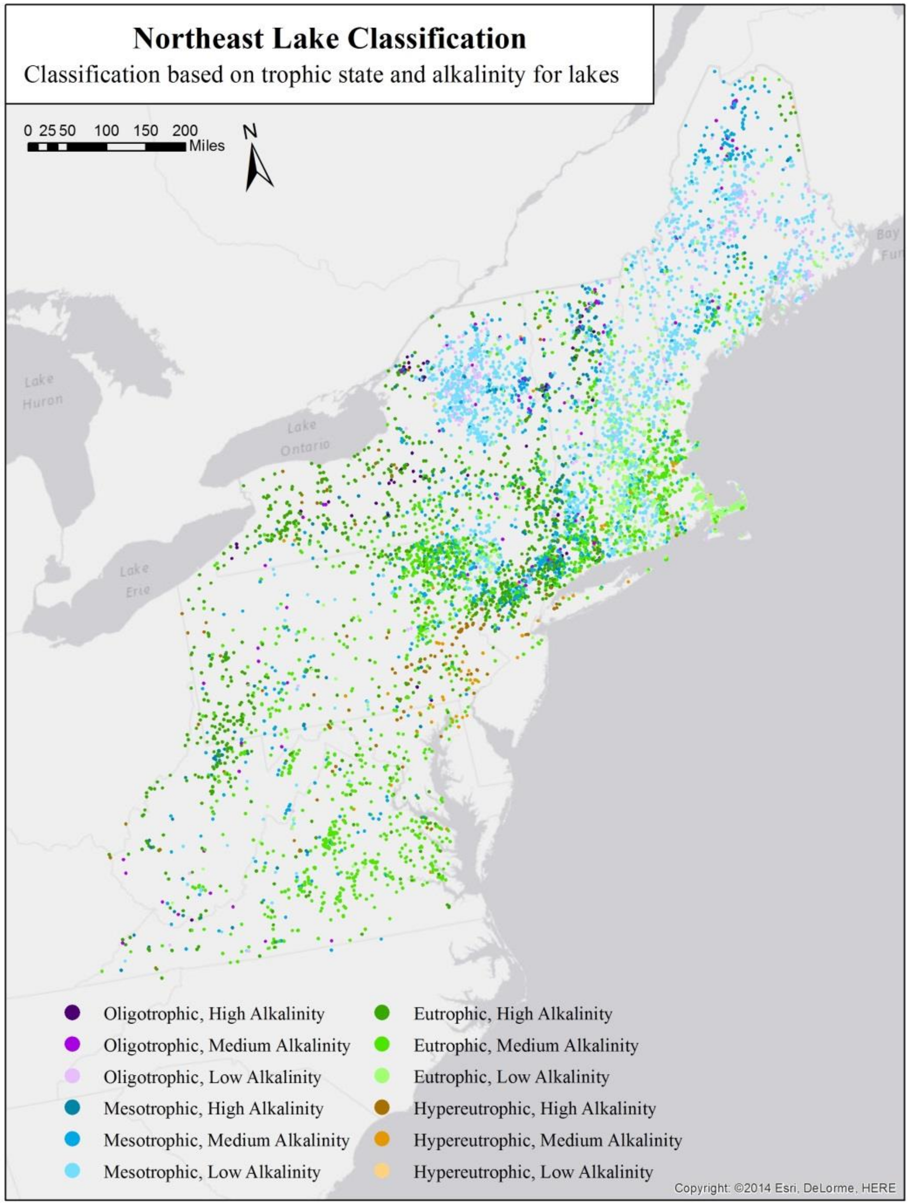
Example: Very cold, acidic pond

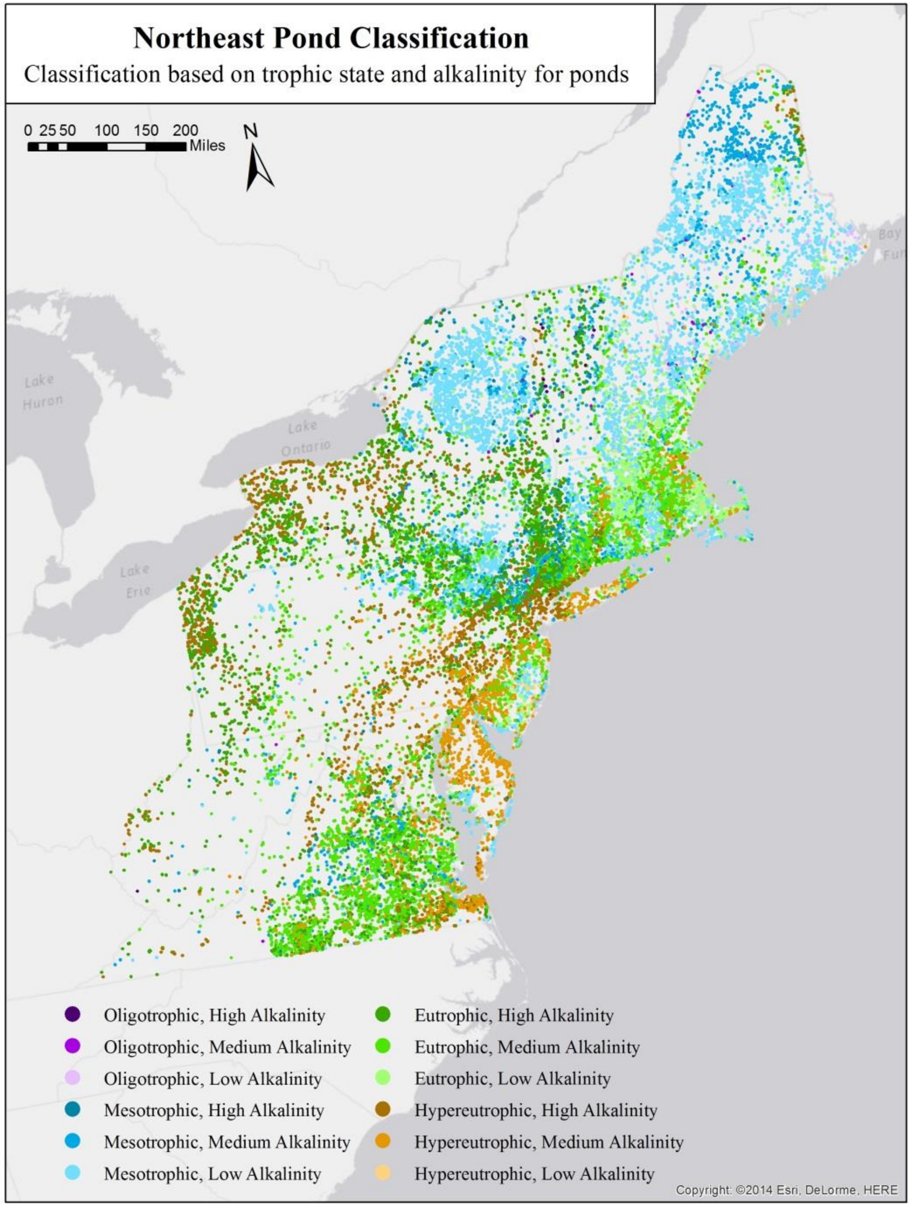




Trophic and Alkalinity

Example: Eutrophic, Highly Alkaline Lake





Four Variable Classification

Example: Warm, hypereutrophic, highly alkaline, pond

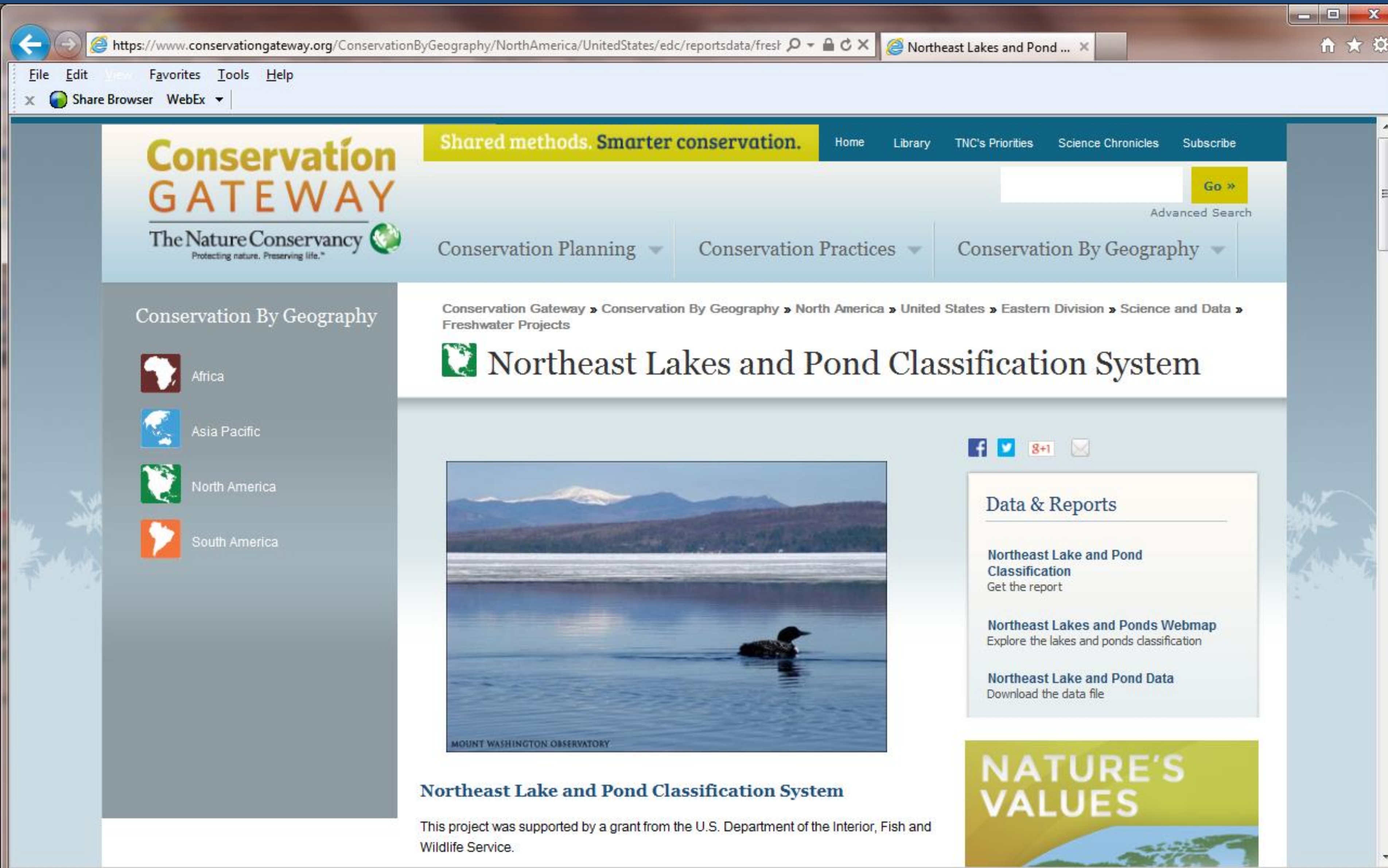
- Waterbodies were assigned a four-variable code that combined their class for temperature, trophic state, alkalinity, and depth.
- Four variable integration results in 68 waterbody types: 35 lake types and 33 pond types.
- Waterbodies were called "unclassifiable" if three or more of their variables had very low confidence scores (2% of all waterbodies)

Most Common Lake and Pond Types

LAKES | PONDS

Warm, Eutrophic, Medium Alk	1305	Warm, Eutrophic, Medium Alk	4950
Warm, Eutrophic, High Alk	880	Warm, Eutrophic, High Alk	3424
Cool to cold, Mesotrophic, Low Alk	748	Cool to cold, Mesotrophic, Low Alk	3360
Very cold, Mesotrophic, Low Alk	670	Warm, Hypereutrophic, Medium Alk	2334
Warm, Eutrophic, Low Alk	446	Warm, Mesotrophic, Low Alk	2334
Warm, Mesotrophic, Low Alk	383	Warm, Hypereutrophic, High Alk	1999
Warm, Mesotrophic, Medium Alk	366	Warm, Eutrophic, Low Alk	1517
Cool to cold, Mesotrophic, Medium Alk	288	Warm, Mesotrophic, Medium Alk	1201
Very cold, Oligotrophic, Low Alk	281	Cool to cold, Mesotrophic, Medium Alk	843
Cool to cold, Eutrophic, Medium Alk	220	Cool to cold, Eutrophic, Low Alk	468

CONSERVATION GATEWAY



Download: Report and Data

- Report

- Spatial Data:

  waterbodies with simple attribute table, .lyr files for ArcGIS display

- Tabular Excel Data:

  waterbodies with 140+ attributes used the modeling

Database of Attributes

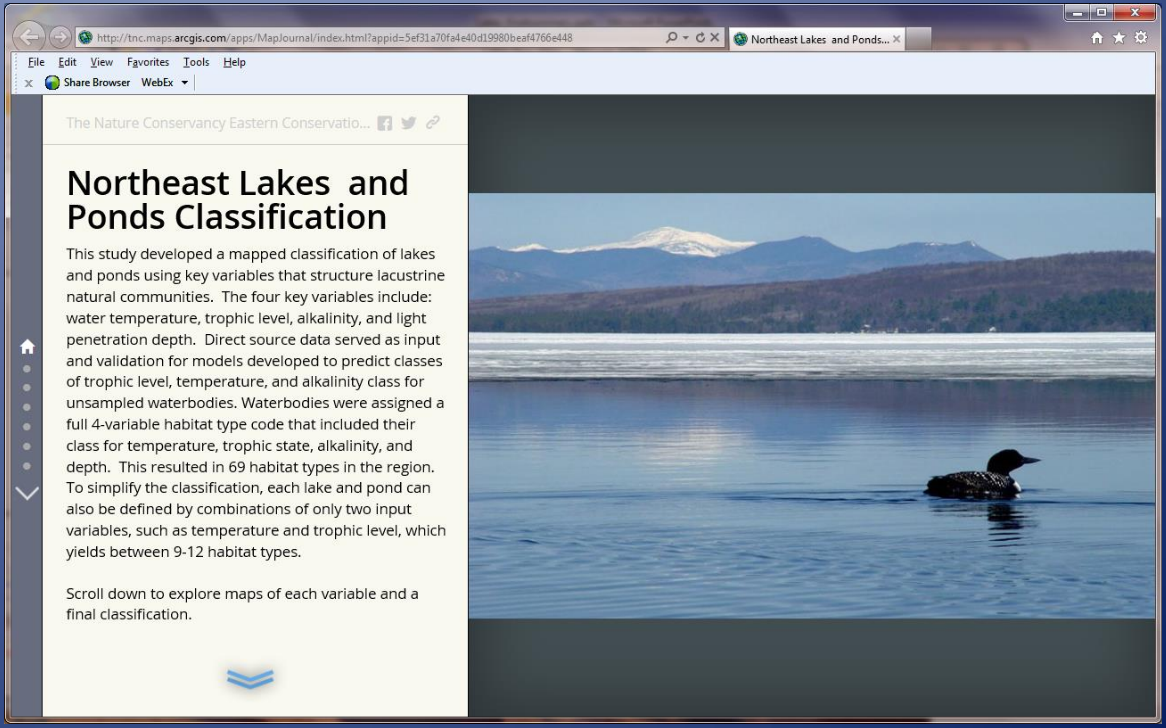
Waterbodies codes with 140+ attributes

- **Lake Morphometry:** surface area, max depth, mean depth, fetch, shoreline complexity…
- **Buffer Characteristics**: 100m, 500m and 1000m buffer land cover, geology, impervious surface, baseflow index
- **Presence and type of dam**
-
- **Chlorophyll a, Alkalinity, Temperature** : State/federal sample data and values averaged for each waterbody
- **Confidence and probabilities** for every waterbody

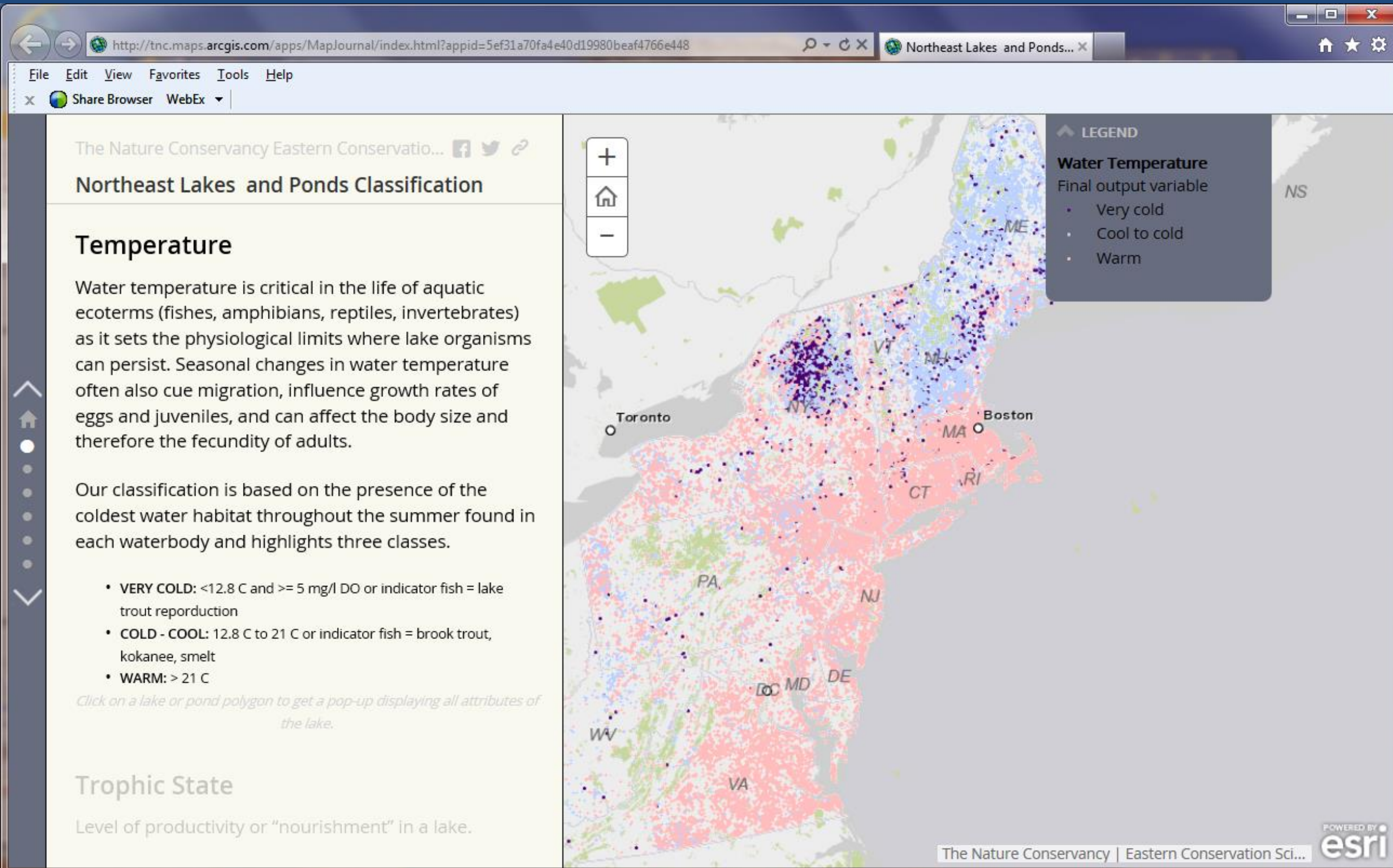
Web Map

http://bit.ly/1sVYyOQ

- Short text about each classification variable
- View and zoom in on a map of each attribute
- Click on polygon to get simple attribute table displayed
- View one simplified 2 Variable classification: Temperature and Trophic



Web Map: Temperature



Web Map: Trophic

http://tnc.maps.arcgis.com/apps/MapJournal/index.html?appid=5ef31a70fa4e40d19980beaf4766e448

Northeast Lakes and Ponds...

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Northeast Lakes and Ponds Classification

Trophic State

Level of productivity or “nourishment” in a lake.

This classification recognizes 4 levels:

Oligotrophic: (<=2 ug/L Chlorophyll-a) A nutrient poor lake. Describes a lake of low biological productivity and high transparency or clarity.

Mesotrophic (>2 -7ug/L Chlorophyll-a) : A lake that is moderately productive.

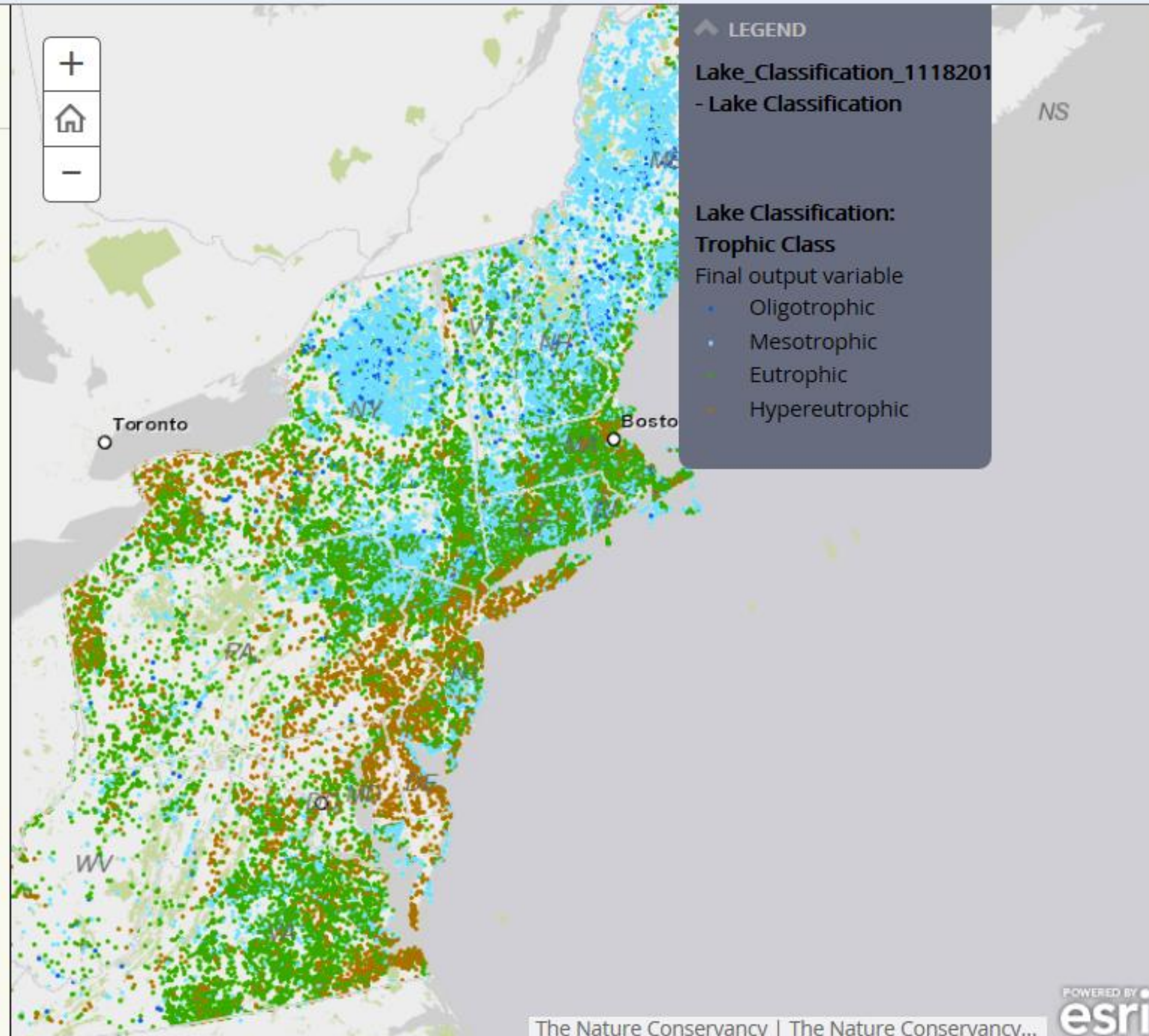
Eutrophic (>7-30 Chlorophyll-a) : A well-nourished lake, very productive and supports a balanced and diverse array of organisms. Usually low transparency due to high algae and chlorophyll-a content.

Hypereutrophic: (>30 ug/L Chlorophyll-a) Characterized by an excess of nutrients. These lakes usually support algal blooms, vegetative overgrowth, and low biodiversity.

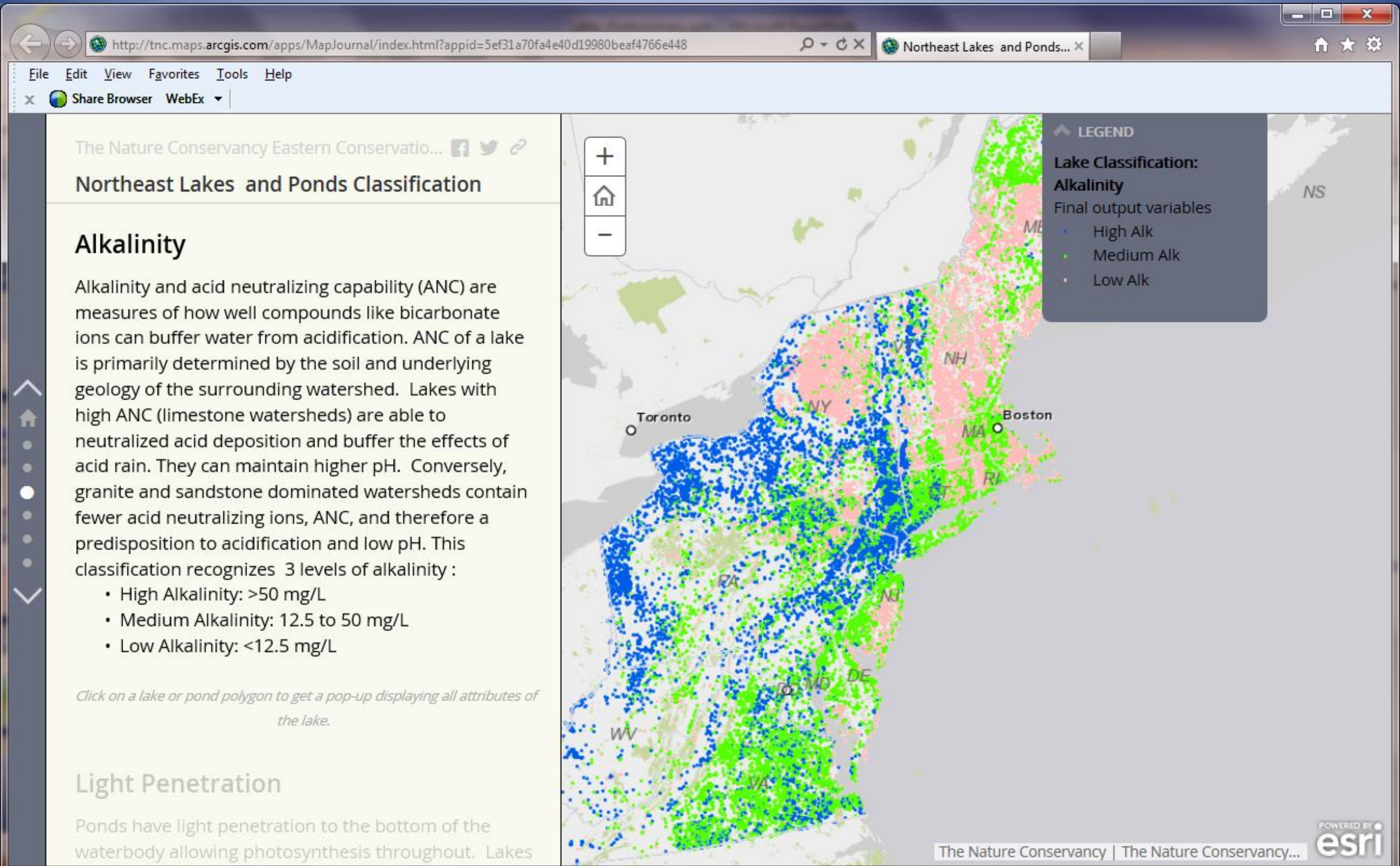
Click on a lake or pond polygon to get a pop-up displaying all attributes of the lake.

Alkalinity

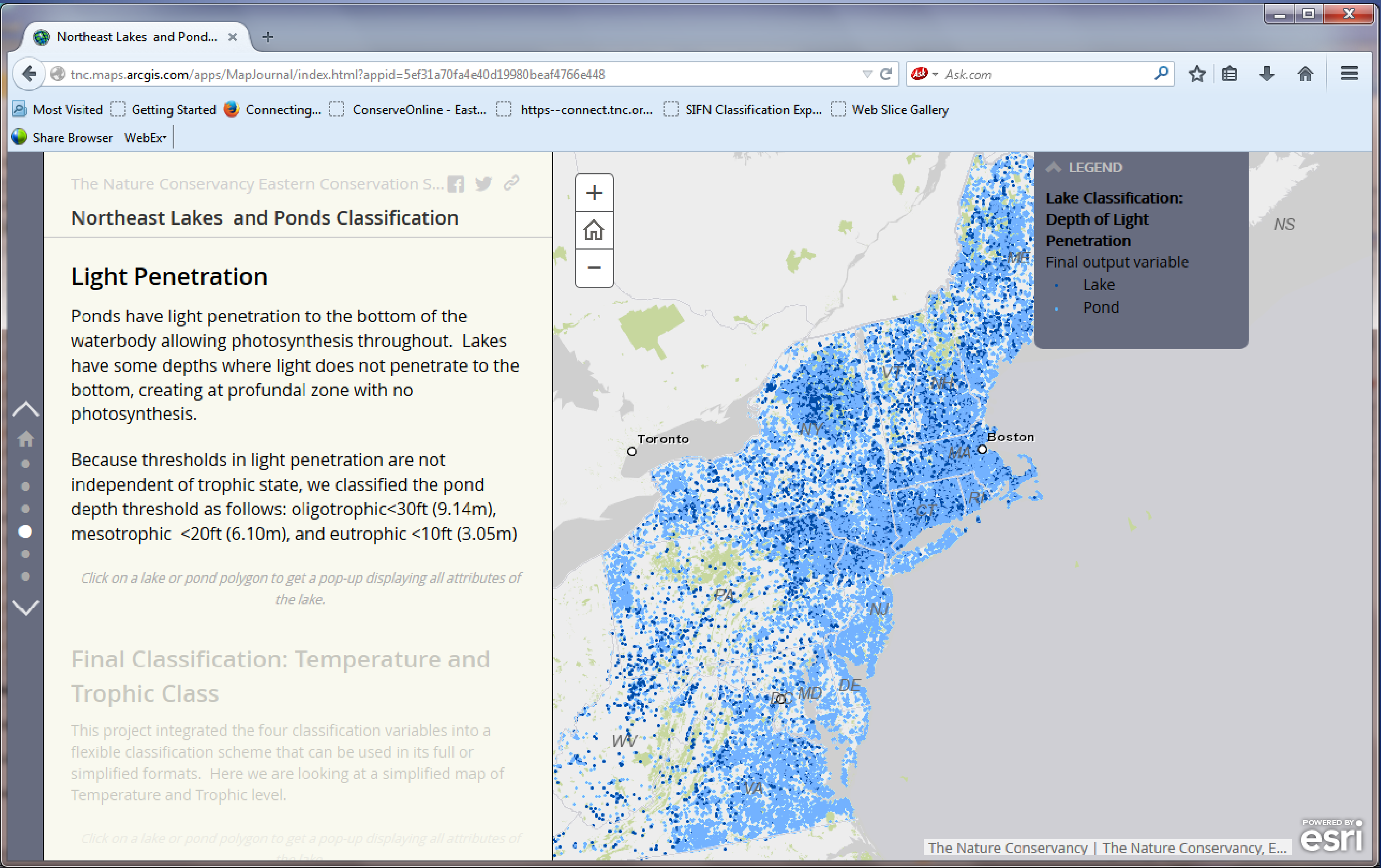
Alkalinity and acid neutralizing capability (ANC) are



Web Map: Alkalinity



Web Map: Lakes vs. Ponds



Light Penetration

Ponds have light penetration to the bottom of the waterbody allowing photosynthesis throughout. Lakes have some depths where light does not penetrate to the bottom, creating at profundal zone with no photosynthesis.

Because thresholds in light penetration are not independent of trophic state, we classified the pond depth threshold as follows: oligotrophic<30ft (9.14m), mesotrophic <20ft (6.10m), and eutrophic <10ft (3.05m)

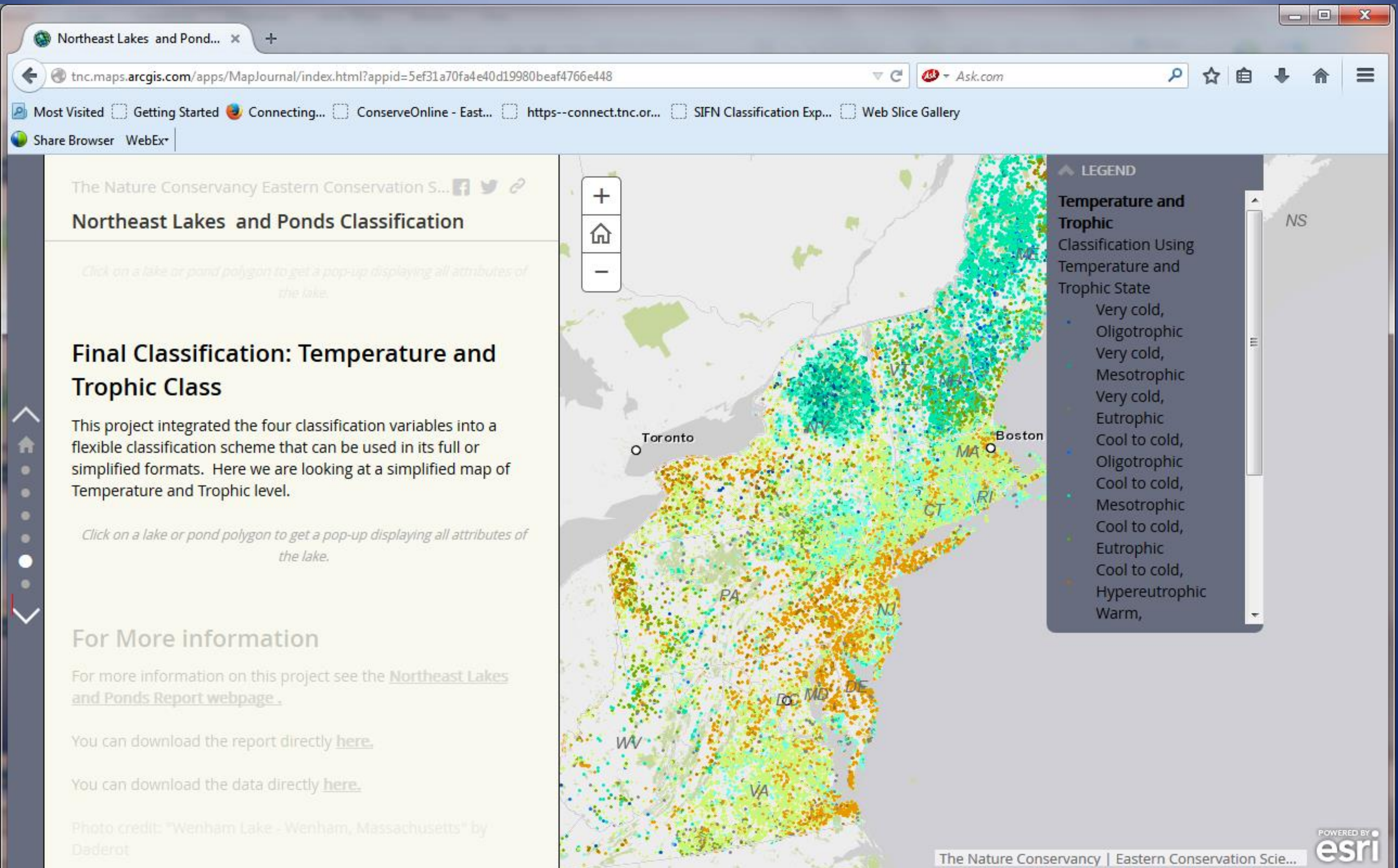
Click on a lake or pond polygon to get a pop-up displaying all attributes of the lake.

Final Classification: Temperature and Trophic Class

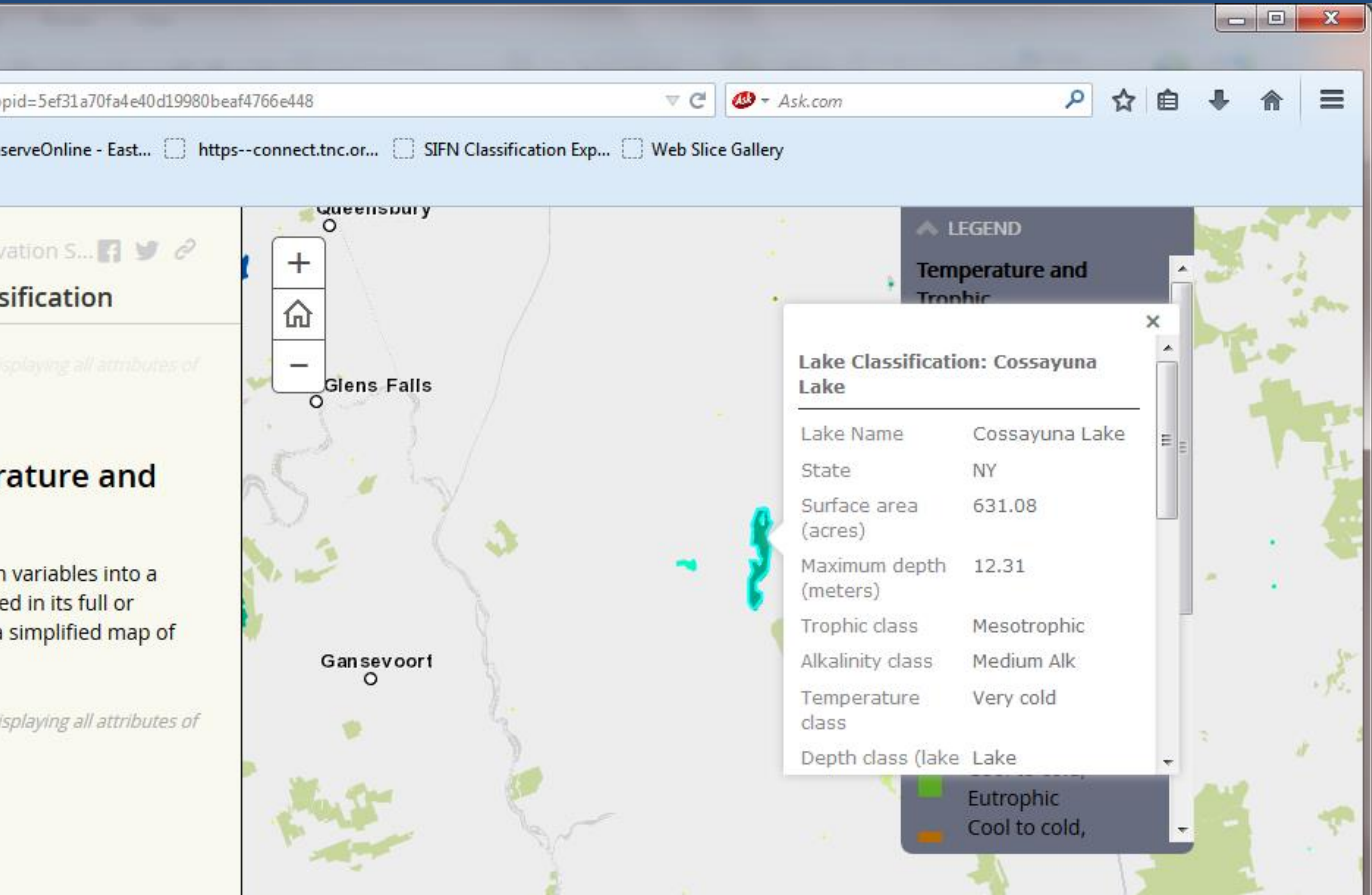
This project integrated the four classification variables into a flexible classification scheme that can be used in its full or simplified formats. Here we are looking at a simplified map of Temperature and Trophic level.

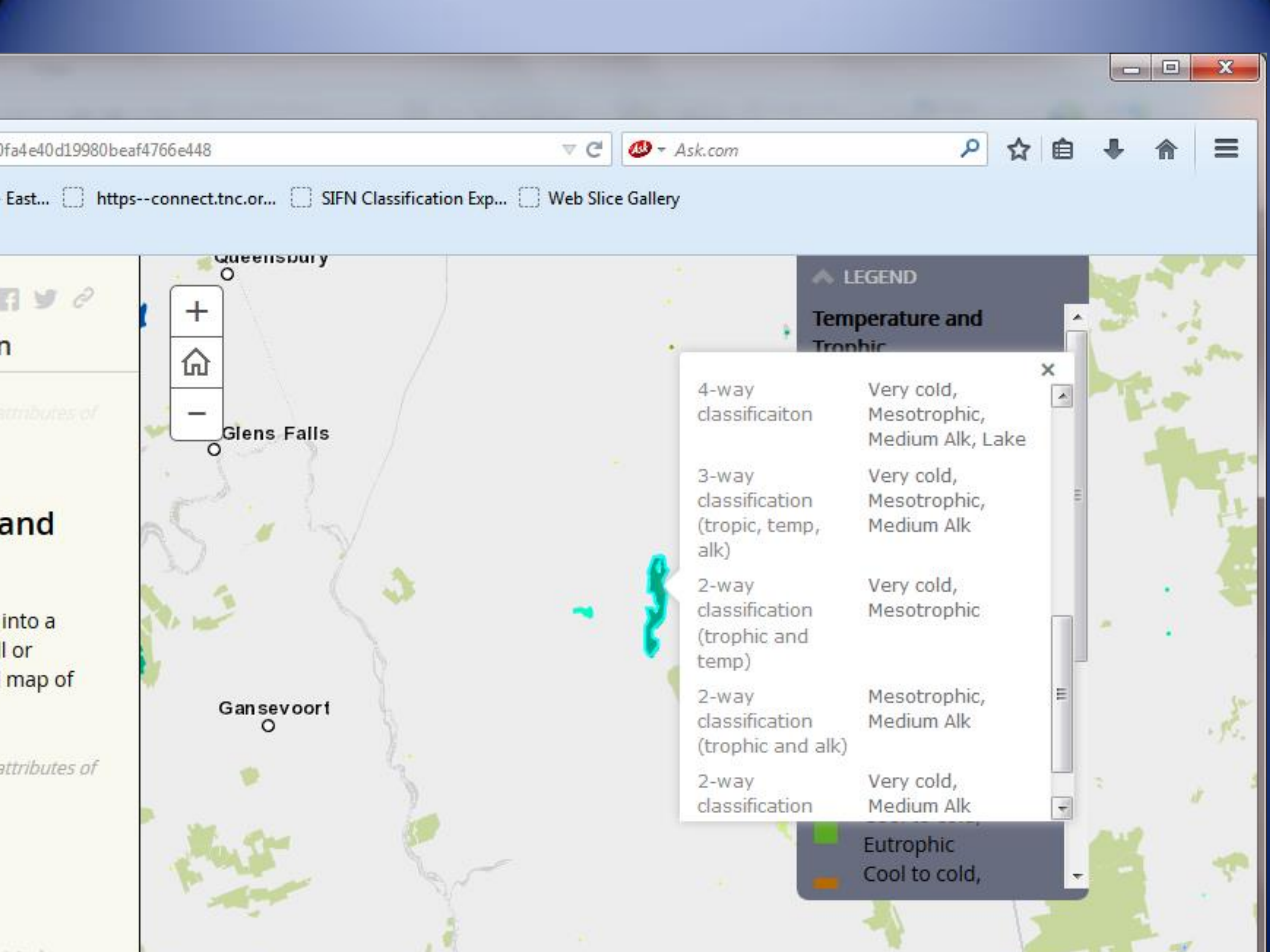
Click on a lake or pond polygon to get a pop-up displaying all attributes of the lake.

Web Map: Combining Variables



Web Map: Pop Up

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Web Slice Gallery
Glens Falls
Gansevoort
LEGEND
Temperature and Trophic
4-way classificaiton
Very cold, Mesotrophic, Medium Alk, Lake
3-way classification (tropic, temp, alk)
Very cold, Mesotrophic, Medium Alk
2-way classification (trophic and temp)
Very cold, Mesotrophic
2-way classification (trophic and alk)
Mesotrophic, Medium Alk
2-way classification
Very cold, Medium Alk
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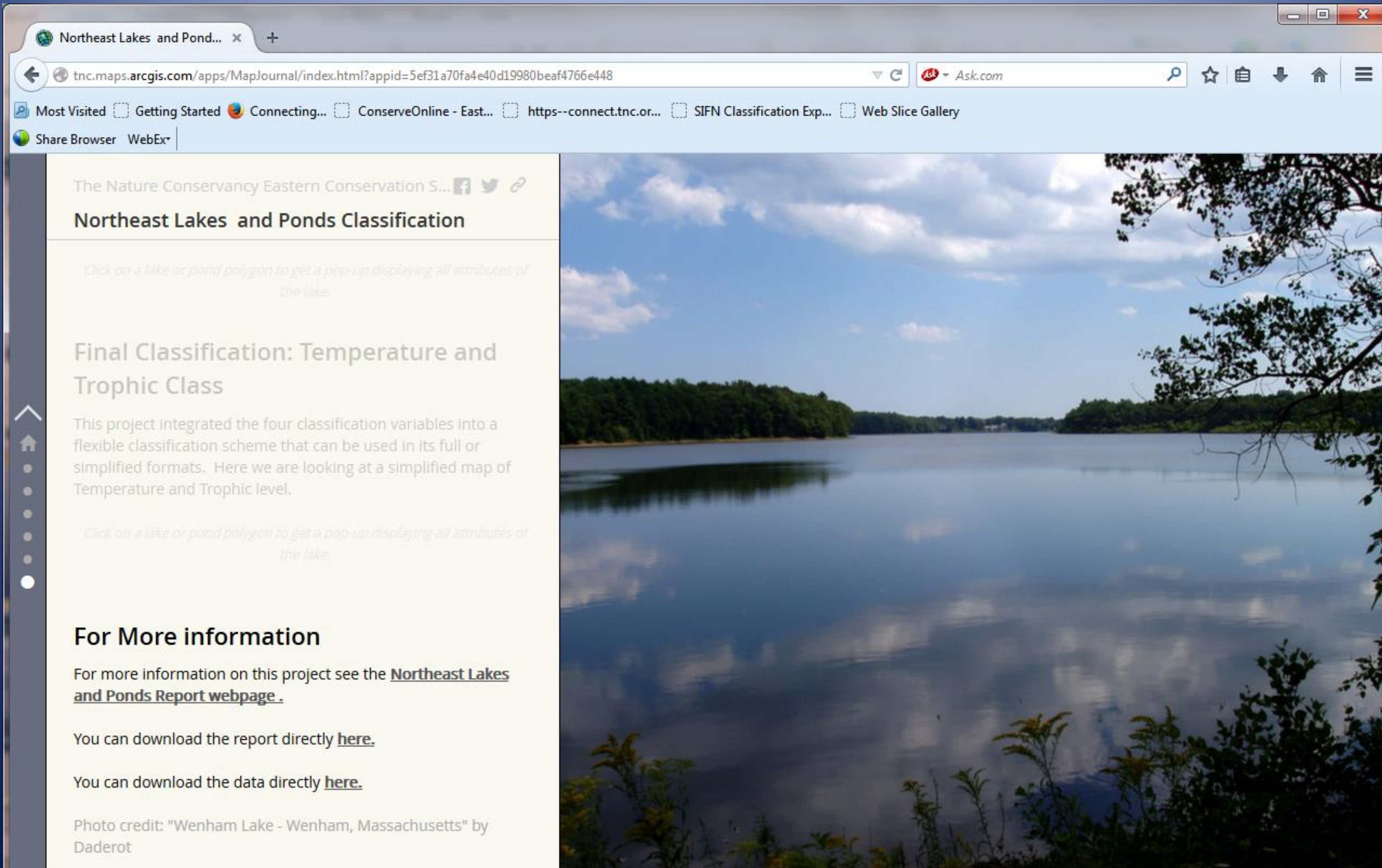
Webmap: Download Report and Data



Thank You!

Matt Carpenter and NEAFWA for envisioning and guiding this project

Andrew Milliken and Scott Schwenk of the North Atlantic LCC for support in making it a reality.

Jeff W. Hollister of EPA and all the individual State Departments of Fish and Wildlife, Environmental Management, and Natural Resources for sharing their data on the regions waterbodies Without their dedication and hard work to collect this data, our project would not have been possible.

The Lake Steering Committee for feedback, reports, coordinated data sharing, and review.