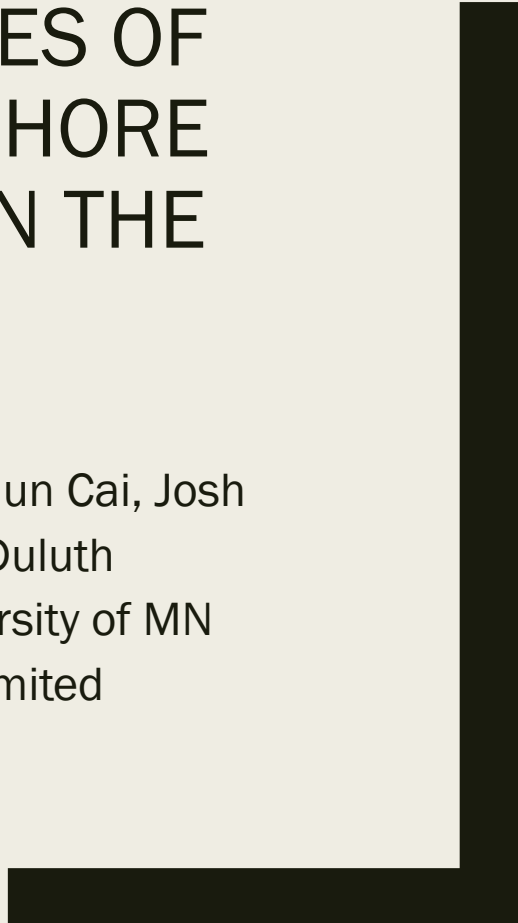


# HOW COLD IS COLD ENOUGH? STREAM TEMPERATURES OF MINNESOTA'S NORTH SHORE STREAMS TODAY AND IN THE FUTURE

Lucinda B. Johnson, Valerie Brady, Meijun Cai, Josh  
Dumke, NRRI, University of MN Duluth  
William Herb, St. Anthony Falls, University of MN  
John Lenczewski, MN Trout Unlimited



JANUARY 2014:

IMPACTS OF CLIMATE CHANGE ON LAKE  
SUPERIOR'S NORTH SHORE BROOK TROUT  
HABITAT

Lucinda Johnson William Herb Meijun Cai  
NRRI-UMD ; SAFL- UM

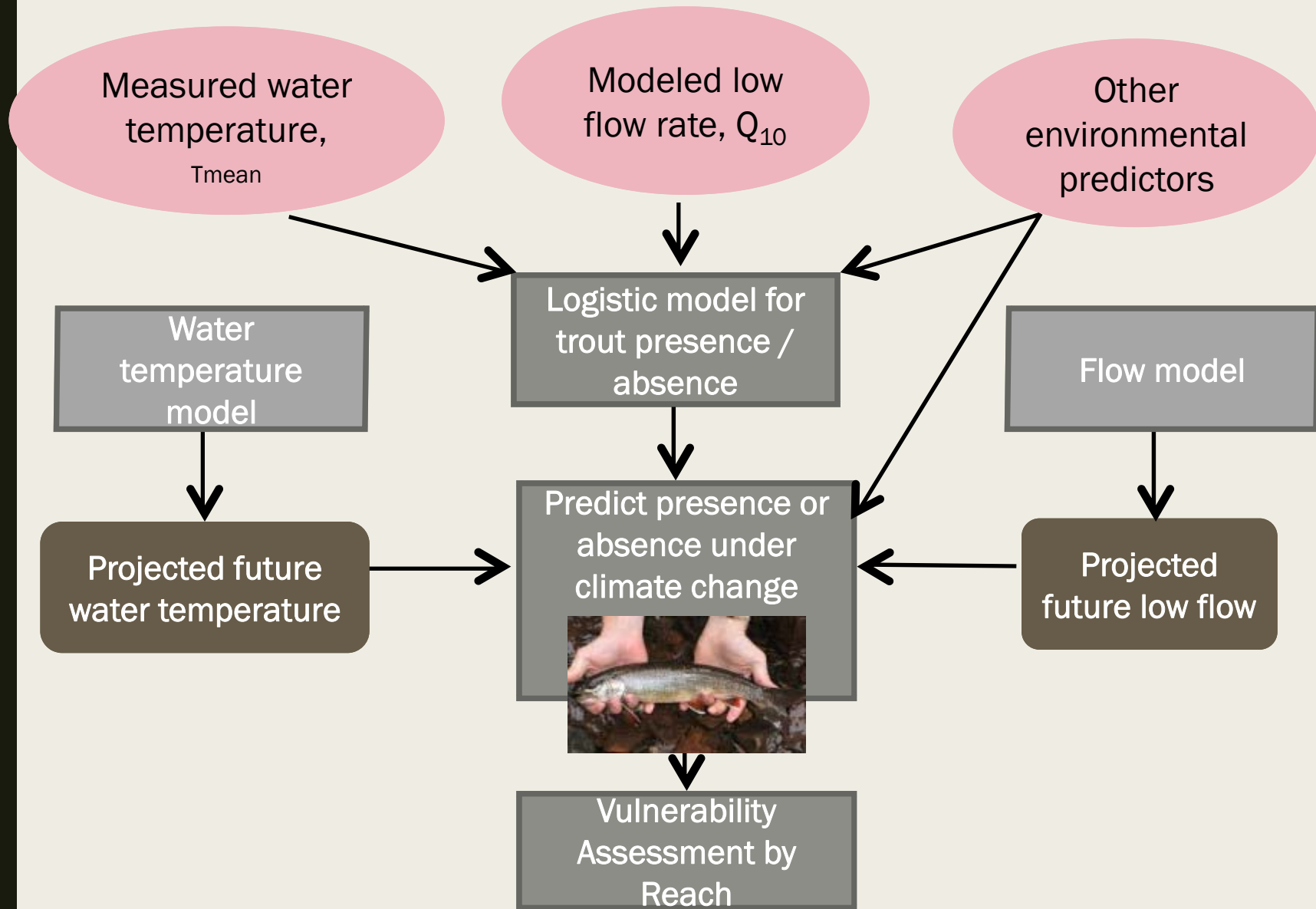
Collaborators: D. Pereira, P. Jacobson, D. Hendrickson, M. Negus, D. Schreiner  
Funding: MN Clean Water Legacy Program



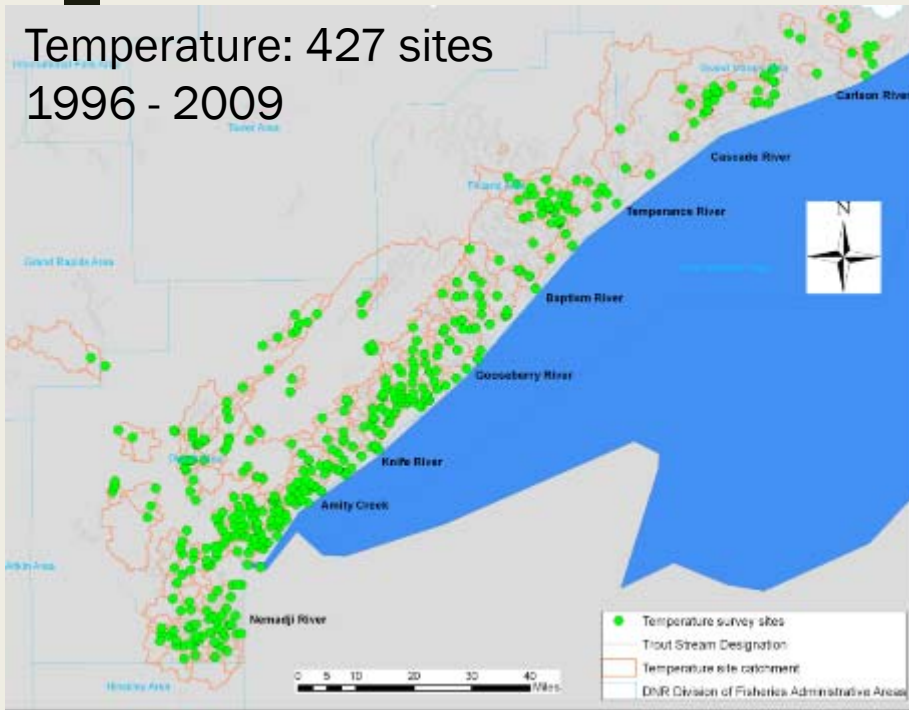
**Goal: Predict the effects of climate and land use / cover change on cold water fish habitat (brook trout).**

With emphasis on the North Shore, Lake Superior

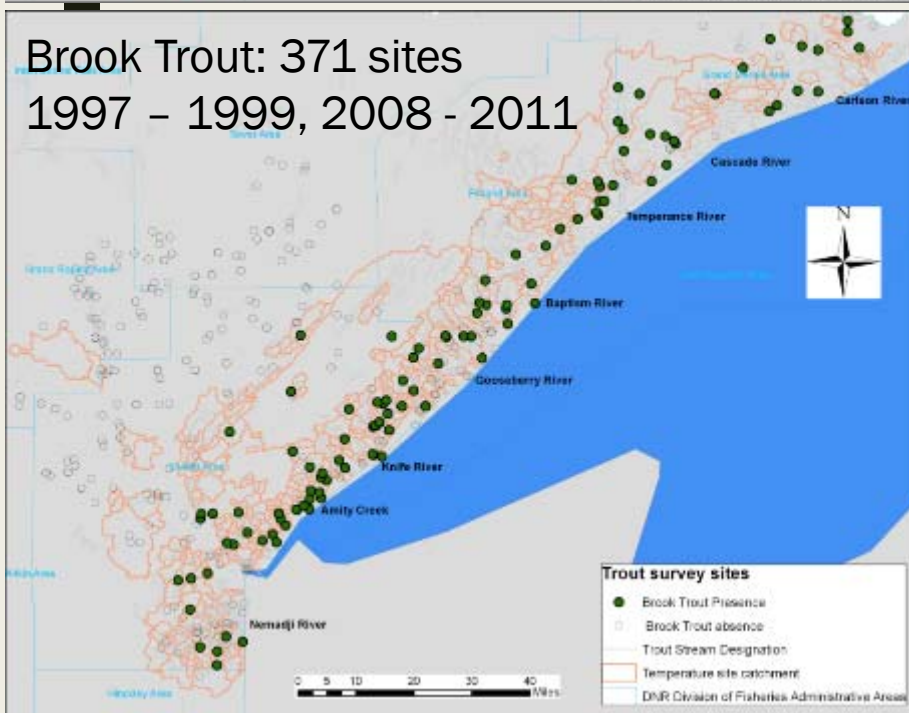
# Vulnerability Assessment



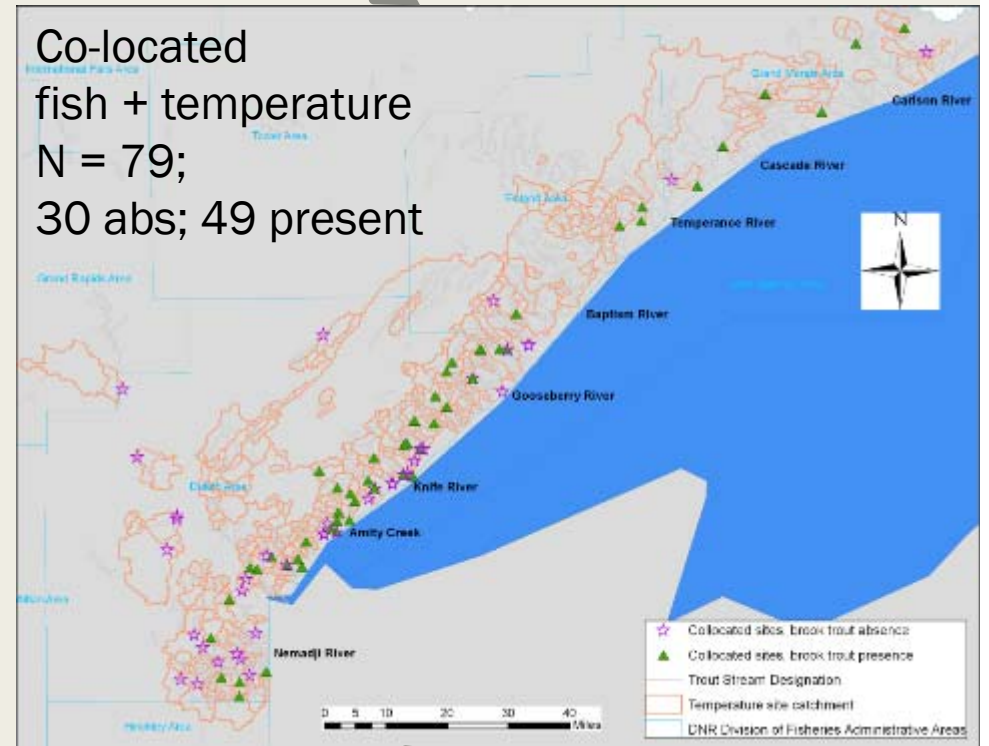
Temperature: 427 sites  
1996 - 2009



Brook Trout: 371 sites  
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Co-located  
fish + temperature  
N = 79;  
30 abs; 49 present

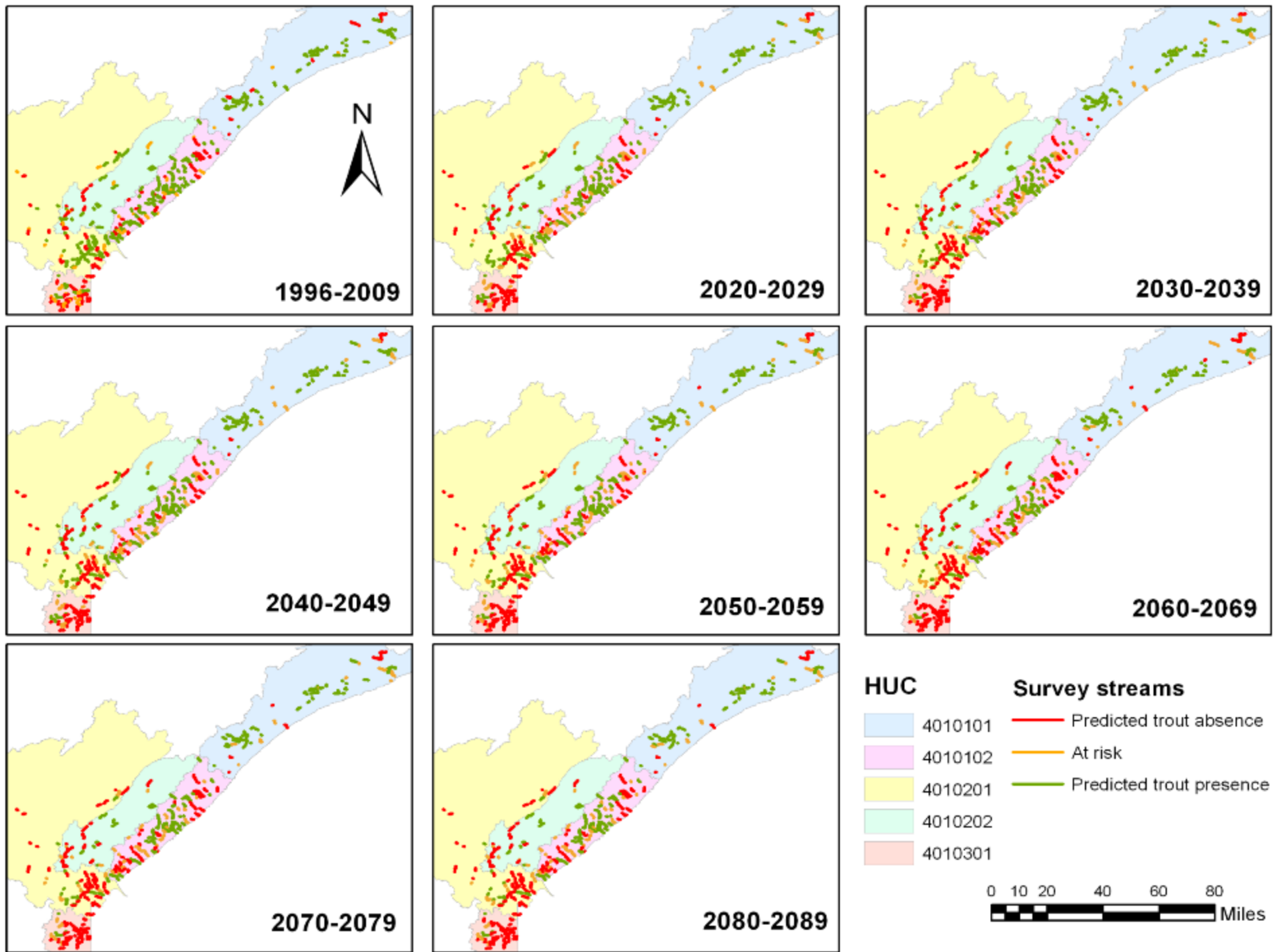


# Final Logistic Model: Brook Trout Presence / Absence

$$\text{Log } p / 1-p = 15.19 - .63 T_{\text{mean}} + 0.37 Q_{10} - 5.28 \% \text{ Decid. For}_{150\text{m}}$$

$p$	- brook trout presence probability
$T_{\text{mean}}$	- July mean water temperature
$Q_{10}$	- Base Flow: the 10th percentile August flow
$\% \text{ Decid}_{\text{For}_{150\text{m}}}$	- % deciduous forest land cover in riparian zone

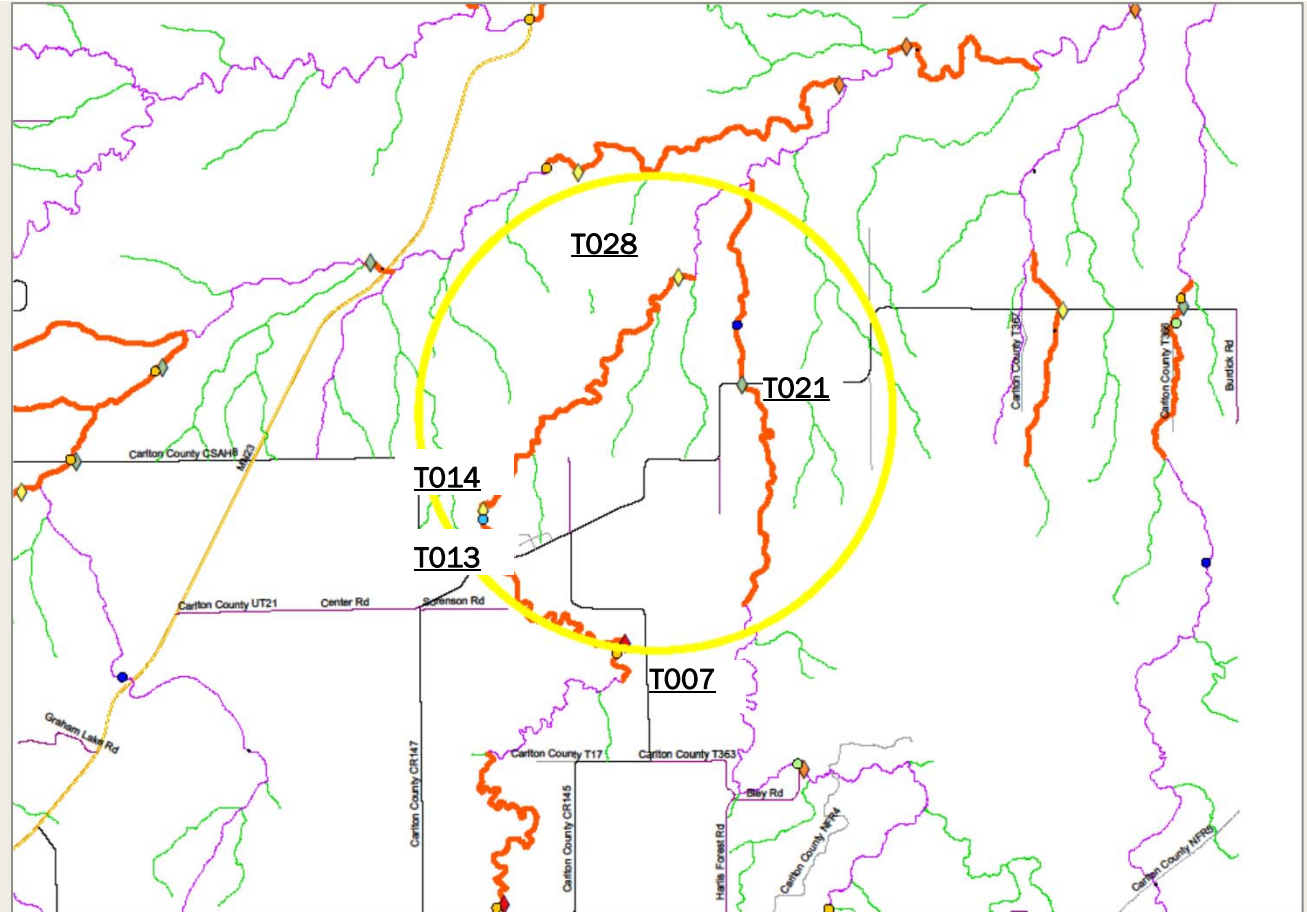
- Predictors in future scenarios
  - $T_{\text{mean}}$ : *predicted by temperature model*
  - $Q_{10}$ : *use average flow change rate from three hydrology stations (Baptism, Knife and Amity) to estimate site  $Q_{10}$*
  - $\% \text{ Decid}_{\text{For}_{150\text{m}}}$ : *remains constant due to lack of future land cover estimates\**



# Net and Little Net

Equation to predict trout presence probability:

$$\log \frac{p}{1-p} = 15.19 - 0.63T_{\text{mean}} + 0.37Q_{10} - 5.28 \% \text{Deciduous\_Forest\_150m}$$

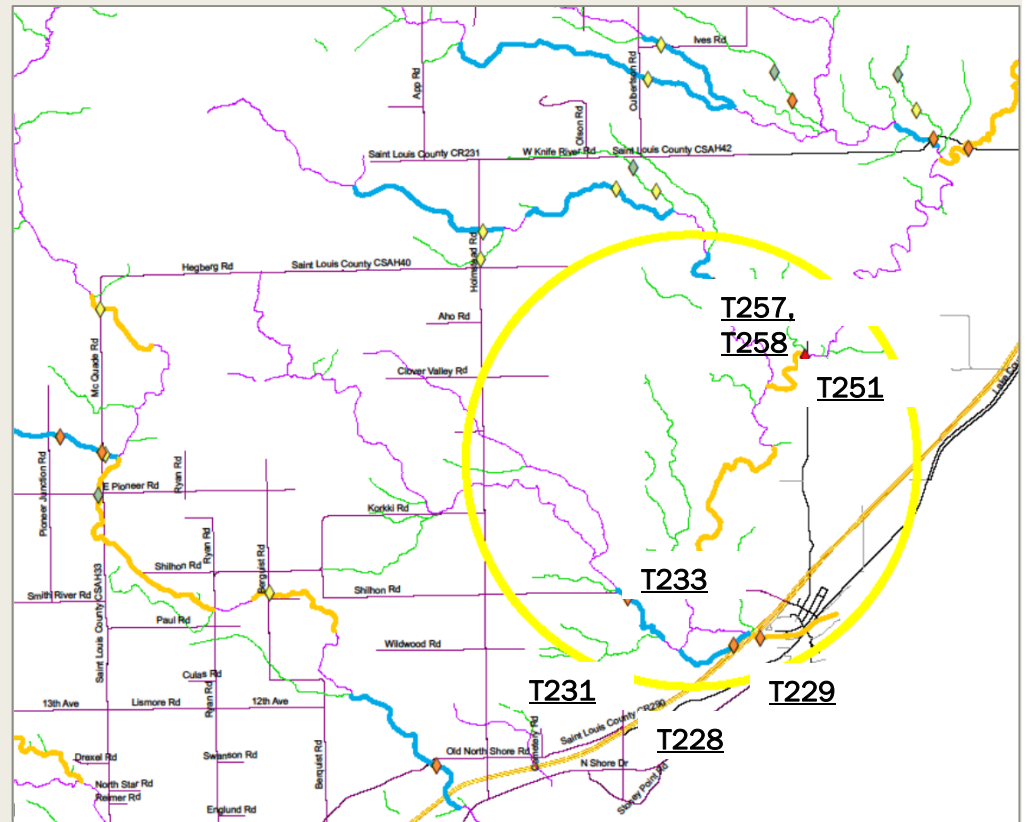


ID	Survey years	July mean temp	Q10 (m <sup>3</sup> /s)	%Deciduous Forest_150m	Probability of trout presence
T007	2009	12.68	0.00031	0.51	0.96
T013	2000-2002	19.20	0.00032	0.51	0.29
T014	2006-2009	17.90	0.00032	0.51	0.49
T028	2009	17.46	0.00035	0.51	0.55
T021	2002-2004	17.30	0.00146	0.68	0.41

# Lower Knife

Equation to predict trout presence probability:

$$\log \frac{p}{1-p} = 15.19 - 0.63T_{mean} + 0.37Q_{10} - 5.28\%Deciduous\_Forest\_150m$$



Site ID	survey year	July mean temperature	Q10 (m <sup>3</sup> /s)	% Deciduous Forest_150m	Probability of trout presence	Trout risk predicted by NRRI	DNR result
T228	1997-2003	20.60	0.07	0.24	0.63	presence	stressful
T229	1996-2009	20.70	0.46	0.37	0.52	at risk	stressful
T231	2005-2009	19.20	0.08	0.25	0.79	presence	stressful
T233	2005-2009	21.59	0.41	0.37	0.38	absence	stressful
T251	2007, 2009	20.86	0.35	0.37	0.48	absence	stressful
T257	2006-2008	19.79	0.12	0.31	0.68	at risk	stressful
T258	2006-2008	18.57	0.12	0.31	0.82	presence	stressful

# Summary / Recommendations

- Very generally: southern streams are most “at risk” to change in air temperature and flow;
- Risk decreases in mid to northern-most streams.
- Models are highly significant, but with clear issues that preclude use for site-specific planning.
- Lack of groundwater data is a clear gap and accounts for misclassification in Net, Little Net Rivers.
- Lack of future land cover a gap.
- Lack of high-resolution riparian cover is a gap.
- A stream classification system might help provide path for generalization across region.



# Prioritizing Future Management of North Shore Trout Streams

**LUCINDA JOHNSON, VALERIE BRADY, MEIJUN CAI,  
JOSH DUMKE: UMD NRRI**

**WILLIAM HERB: UM, ST. ANTHONY FALLS LABORATORY**

**JOHN LENCZEWSKI: MINNESOTA TROUT UNLIMITED**



Funded by: Environmental Trust Fund of Minnesota

# The Setting: Minnesota's North Shore of Lake Superior



Stewart River



Sucker River

# Problems

1. Changing climate and pressures from development are already decreasing the amount of suitable coldwater fish habitat.
2. North Shore streams have low levels of groundwater inputs; therefore, coldwater fish are “at risk” due to high water temperatures and low base flows.
3. While the most productive trout and steelhead streams are known, specific areas with cold groundwater seeps (“coldwater refuges”) are not known.

# Background

- North Shore streams are especially vulnerable to climate change due to the shallow soils and general lack of groundwater inflows.
  - higher water temperature during summer
  - lower base flows during low precipitation periods
  - flashy flows with storms
- Groundwater seeps within streams maintain localized conditions that serve as coldwater refugia.
- Coldwater fish move substantial distances during low summer flows to seek coldwater habitat.

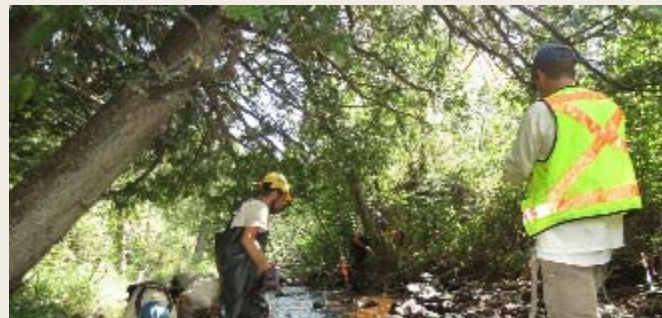
## Background, cont.

- Knowing locations of coldwater refugia can help prioritize planning and implementation of both in-stream habitat restoration projects, as well as other infrastructure projects.



Bridge replacement

e.g., culvert replacement, bridge maintenance, road diversion, road salting.



Blocked Culvert

# Goals & Objectives

**NEED:** Scientific data to identify environmental conditions associated with coldwater refugia, allowing prediction in unknown areas.

## **OBJECTIVES:**

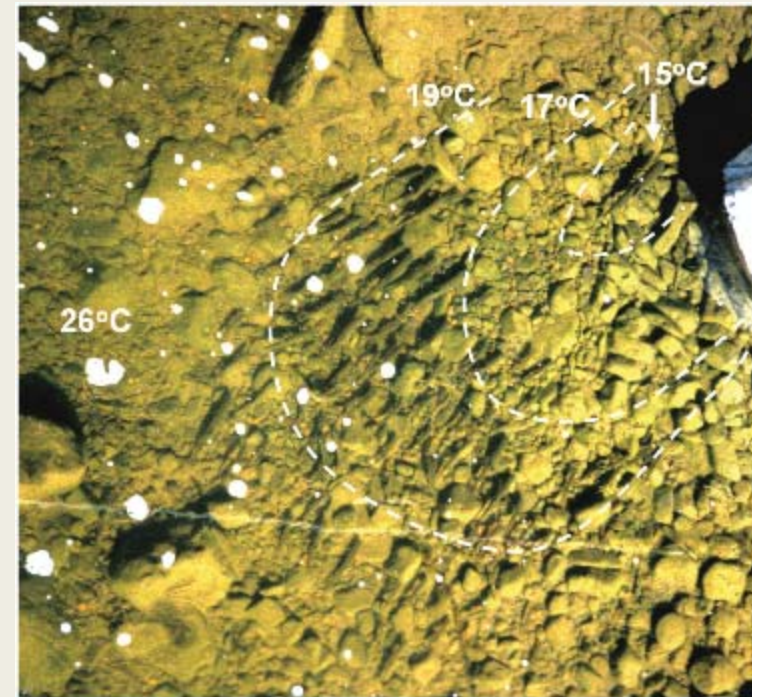
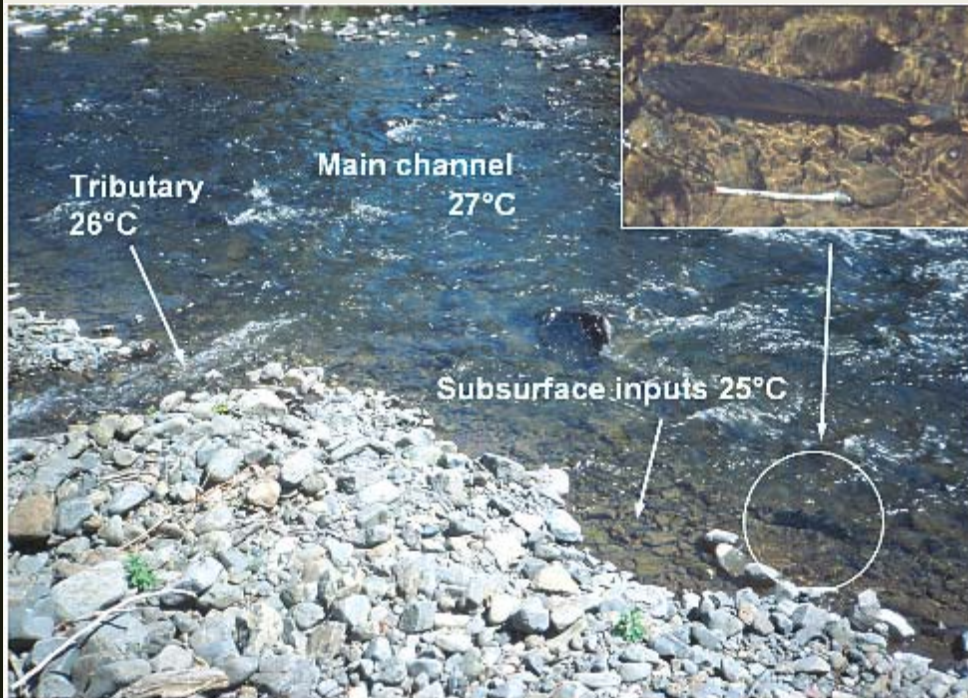
1. Locate and map coldwater refugia in ~15-20 North Shore watersheds;
2. Determine environmental characteristics associated with coldwater refugia, and model relationships with fish habitat;
3. Predict areas that would be resilient to climate change;
4. Recommend targeted actions to increase long-term resilience for coldwater fish.

# Gaps from 2013 study

1. Lack of groundwater data
  - *ID through direct observations and modeling*
2. Lack of future land cover
  - *LANDIS model output available*
3. Lack of high resolution riparian cover
  - *ongoing efforts, see Hollenhorst & Jereczek's talk 3:20*
4. Stream classification
  - *now available from ELOHA project*

# Cold Water Refuges

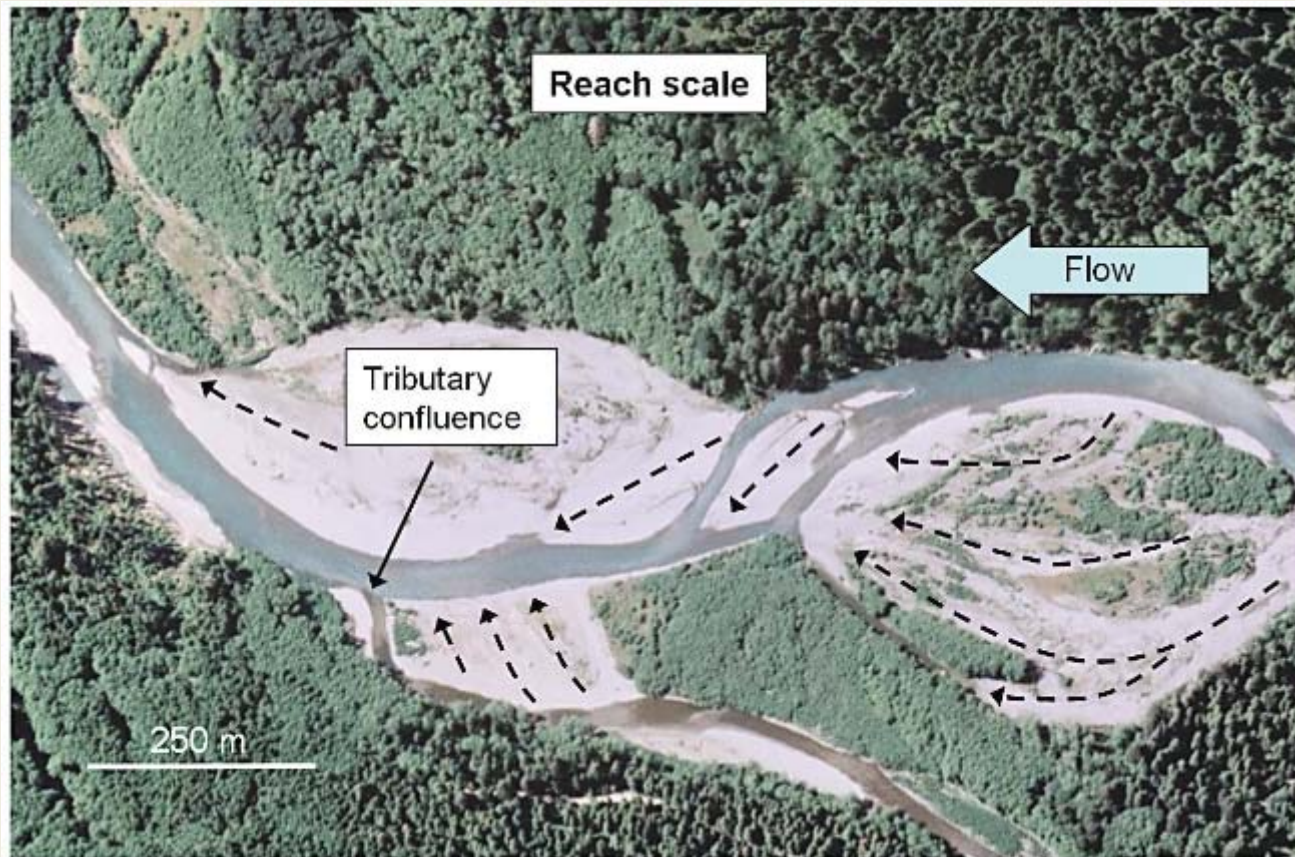
- Defined as area with temperatures  $< \sim 2.0^{\circ}\text{C}$  from surrounding (point source)



From Torgerson, et al. 2012 EPA 910-C-12-001

# Refuges, cont.

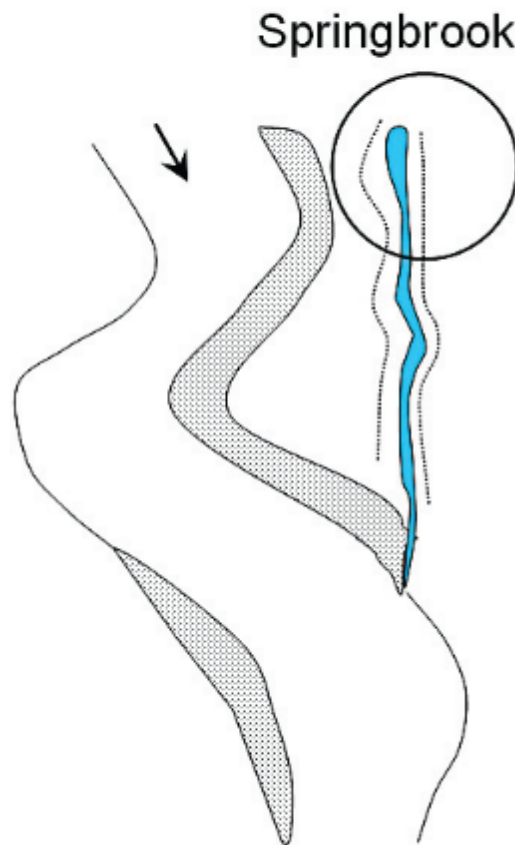
- Can also occur as coldwater tributary to warm water stream



From Torgerson, et al. 2012 EPA 910-C-12-001

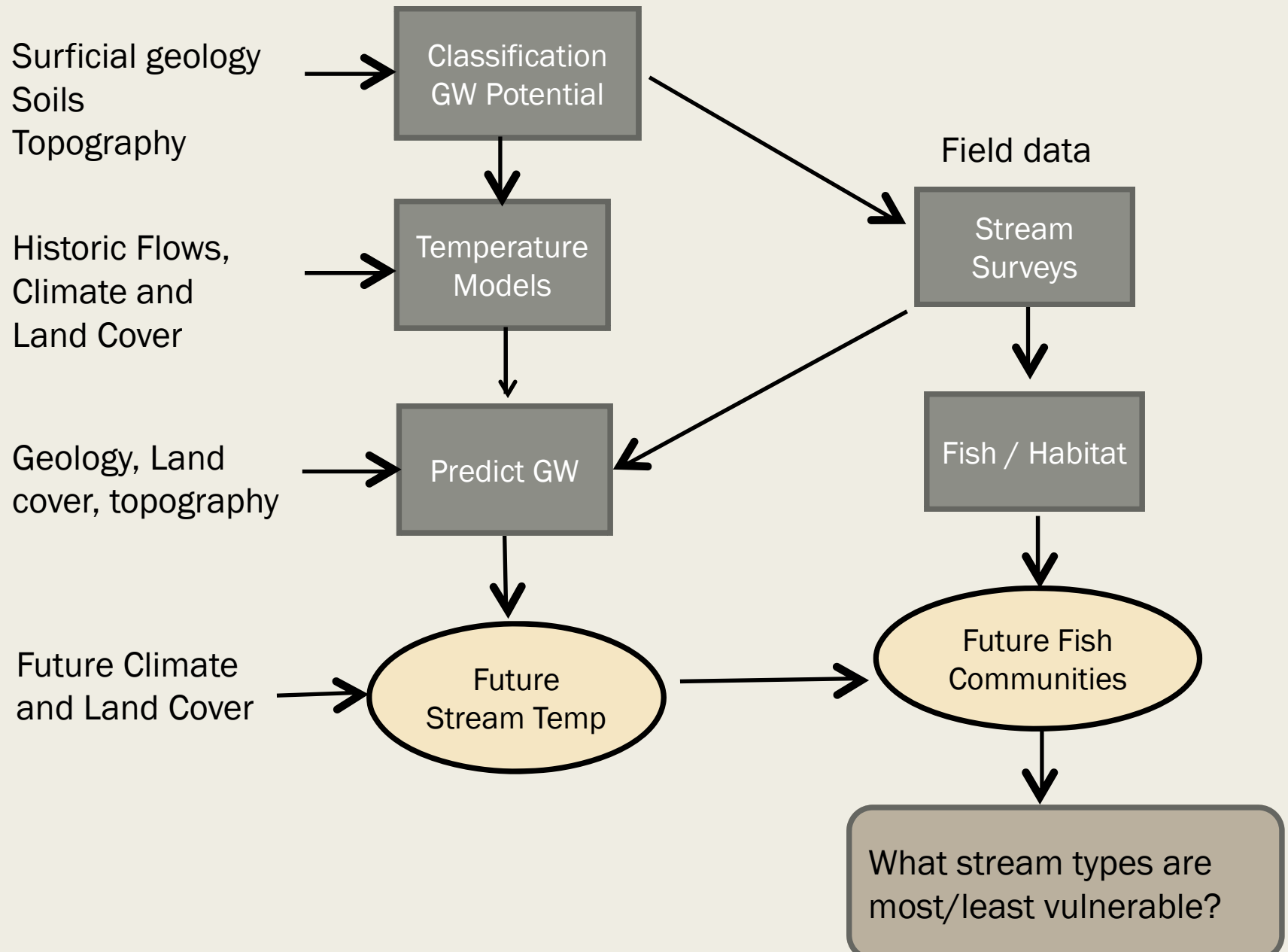
# Springs: MN DNR Spring Survey

Channel unit scale



From Torgerson, et al. 2012 EPA 910-C-12-001

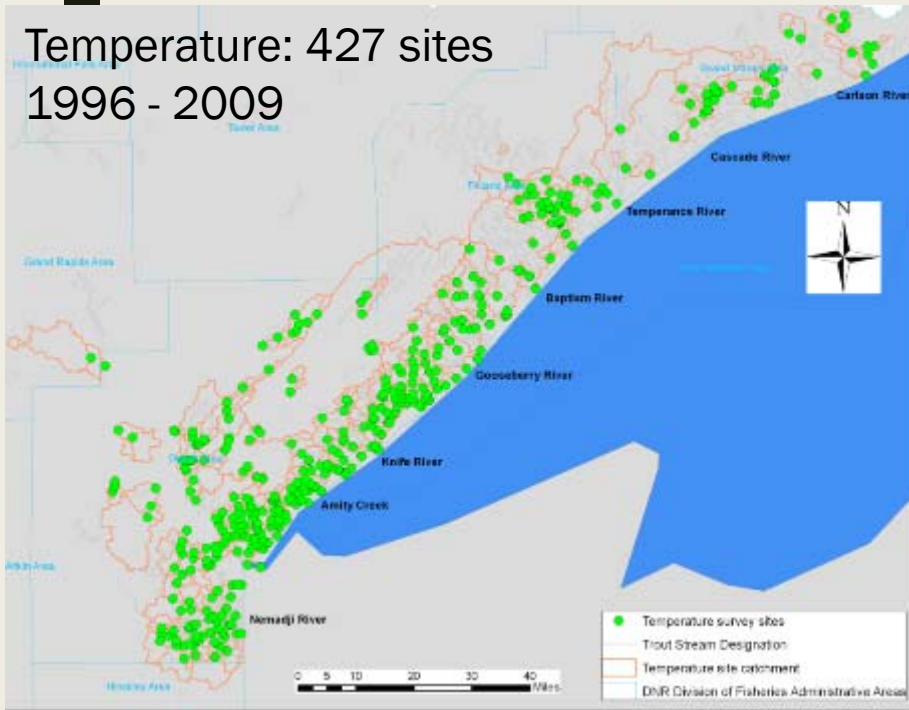
# Methods Summary



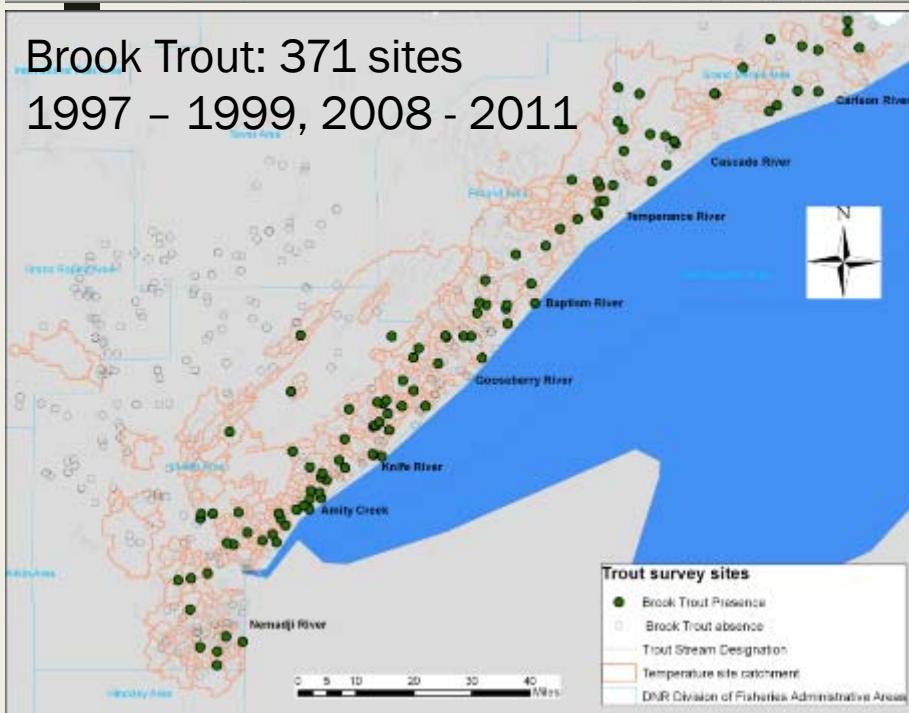
# Methods

1. Map coldwater refuges
2. Conduct field studies to sample fish and locate coldwater refugia in ~ 200 sites across 15-20 watersheds;  
document temperature, local habitat, terrain, soils, vegetation, land use.
3. Quantify relationships between fish / temperature and environmental factors (riparian vegetation, geology, landform, soils, hydrology).
4. Validate predictions in the field.
5. Project temperature and flow conditions under future climate scenarios.
6. Identify future viability of coldwater fish habitat.
7. Develop management recommendations to promote sustainable coldwater habitat.

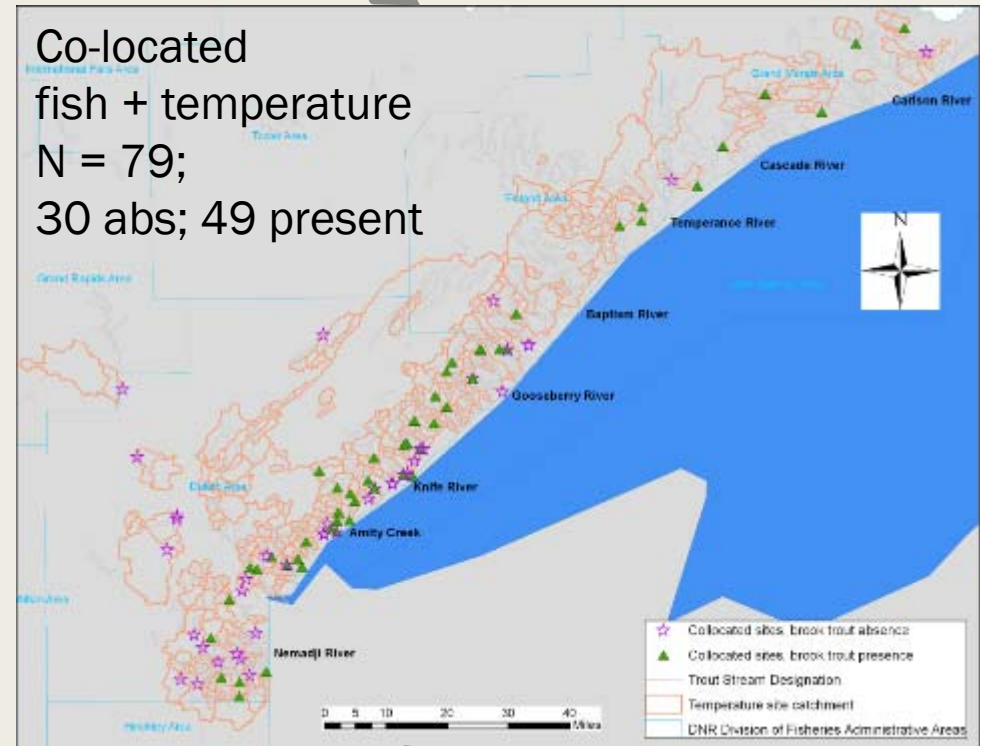
Temperature: 427 sites  
1996 - 2009



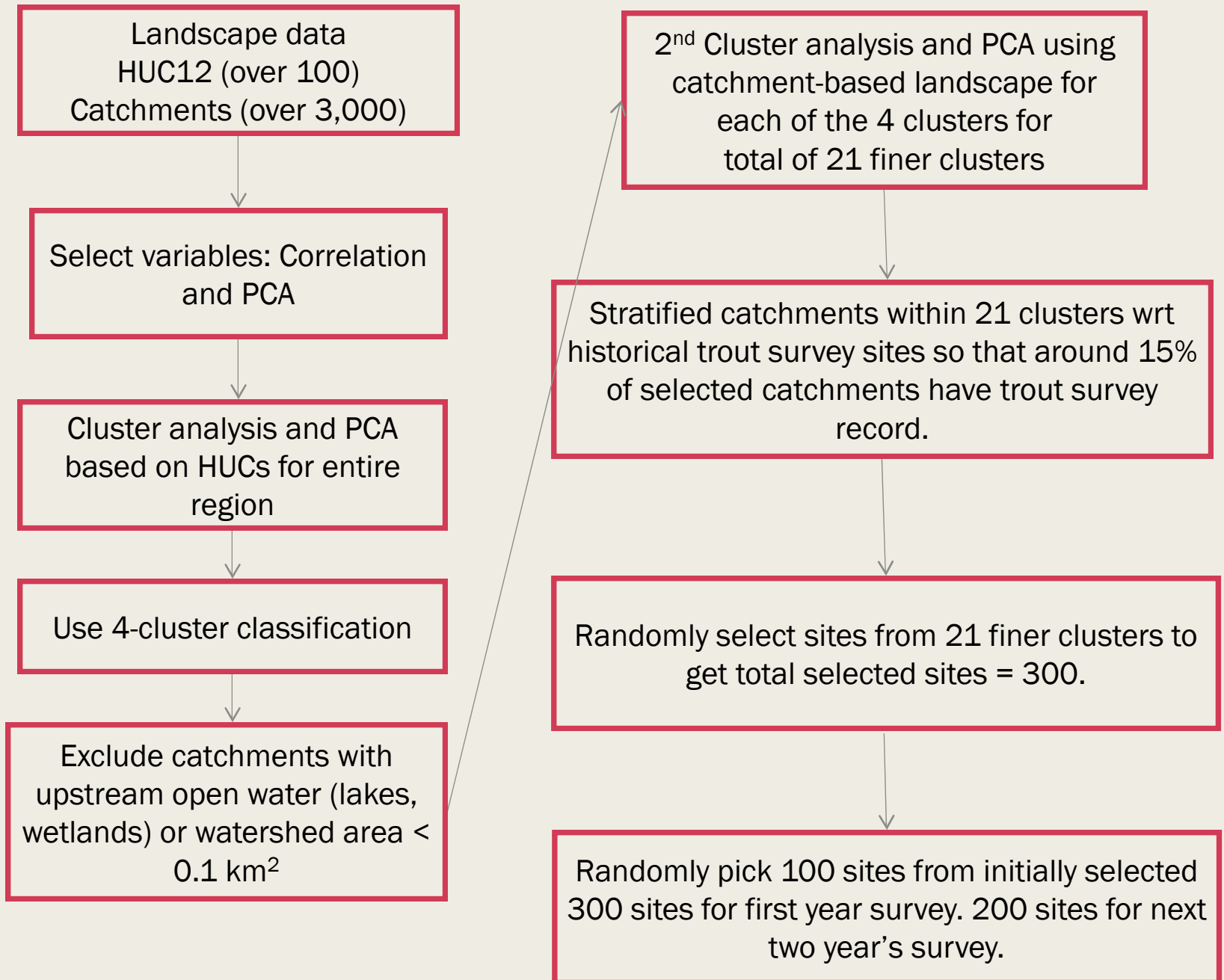
Brook Trout: 371 sites  
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Co-located  
fish + temperature  
N = 79;  
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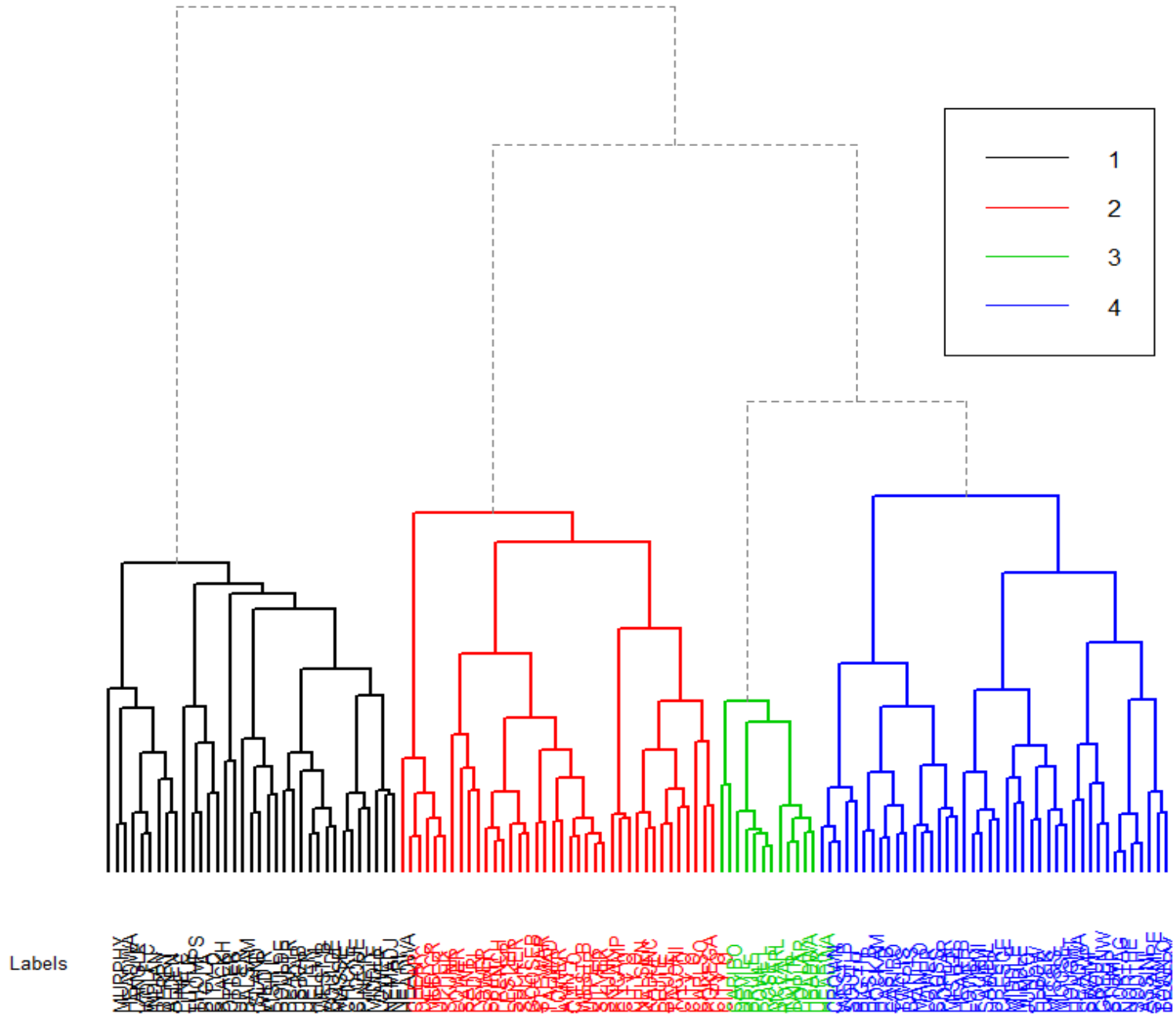
# Site Selection Process

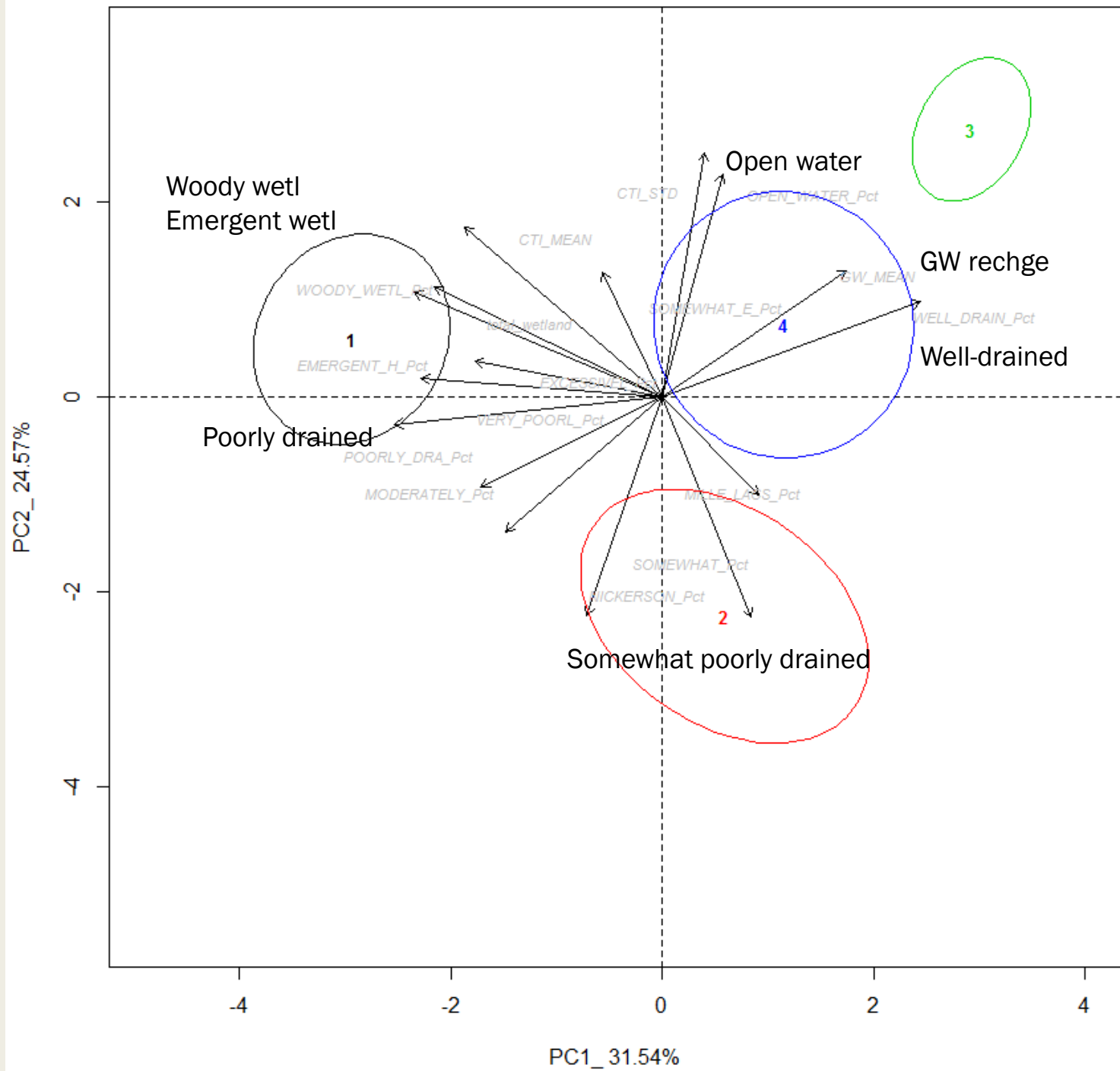


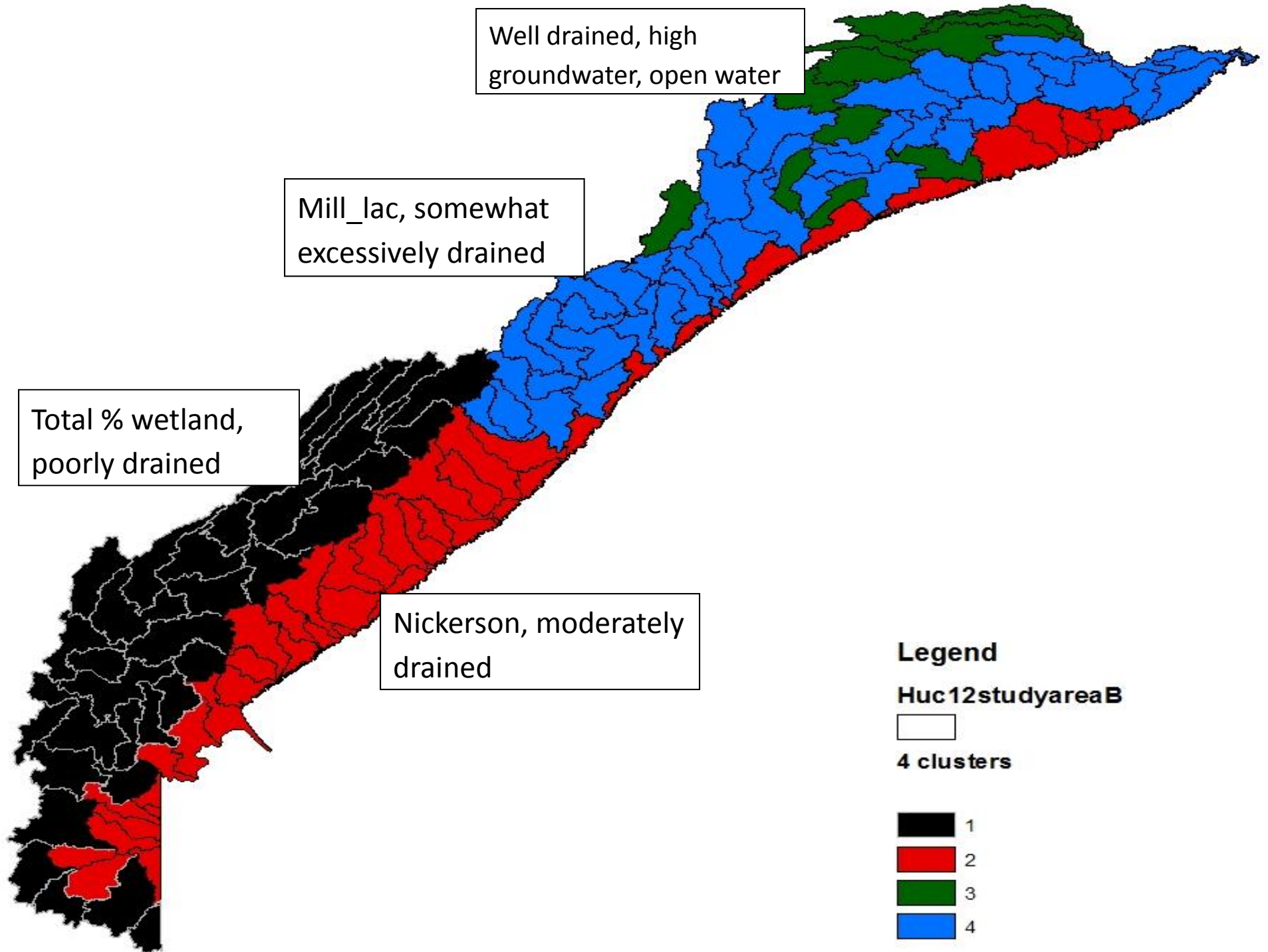
# Landscape Variables Predictive of Groundwater

Variable group	Variables
CTI (Compound Topographic Index)	CTI MEAN
	CTI STD DEV
Groundwater recharge	GROUNDWATER RECHARGE_MEAN
Surficial geology (2 variables)	%MILLE_LACS
	%NICKERSON
Drainage type (7 variables)	%VERY_POORLY DRAINED
	%POORLY_DRAINED
	%SOMEWHAT_POORLY DRAINED
	%WELL_DRAINED
	%SOMEWHAT_EXCESSIVELY
	%MODERATELY DRAINED
	%EXCESSIVELY DRAINED
NLCD wetland type (4 variables)	%Wetland
	% EMERGENT
	% WOODY_WETL
	%OPEN_WATER

### HUC12\_optionB dendrogram ( 4 groups)



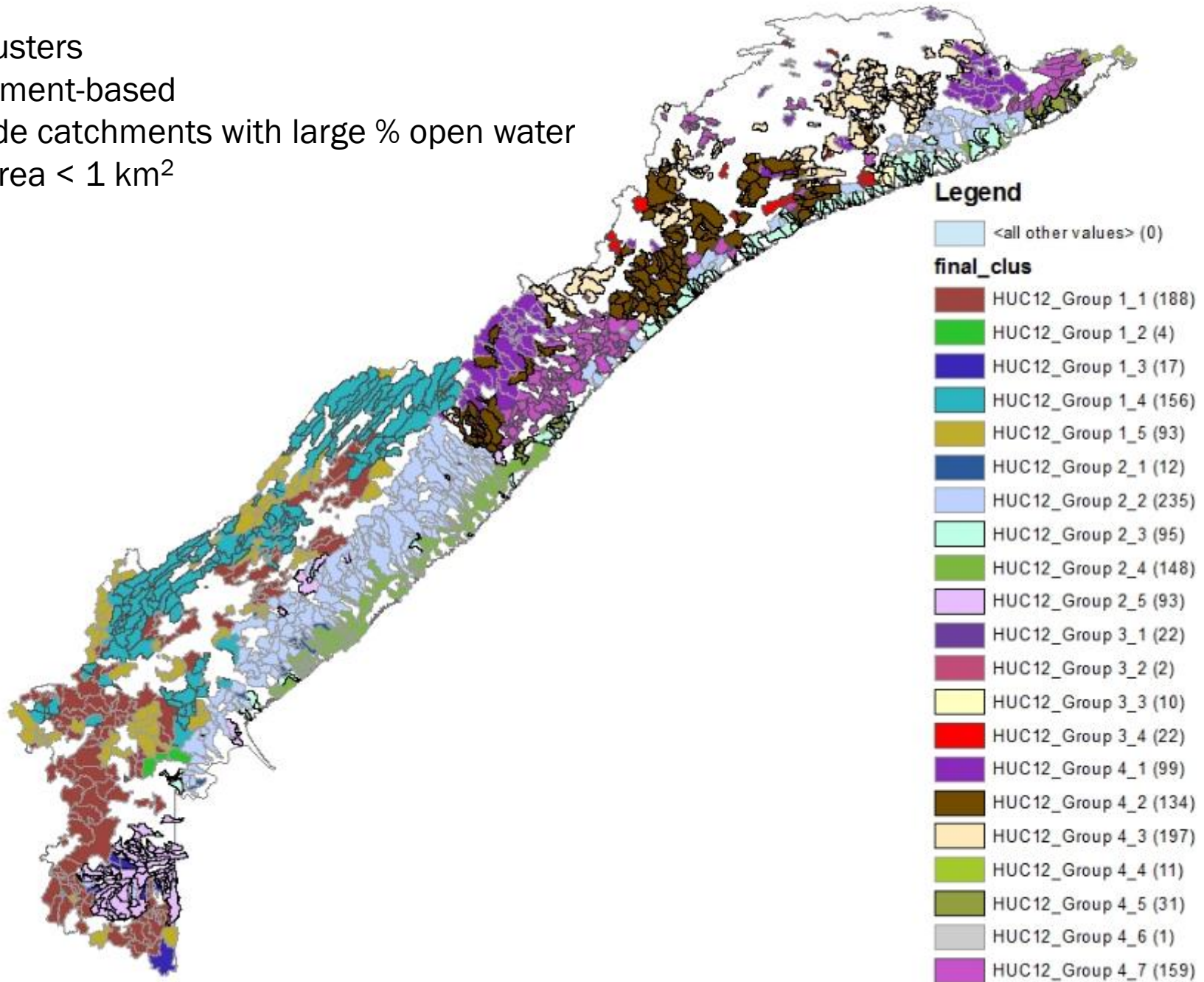




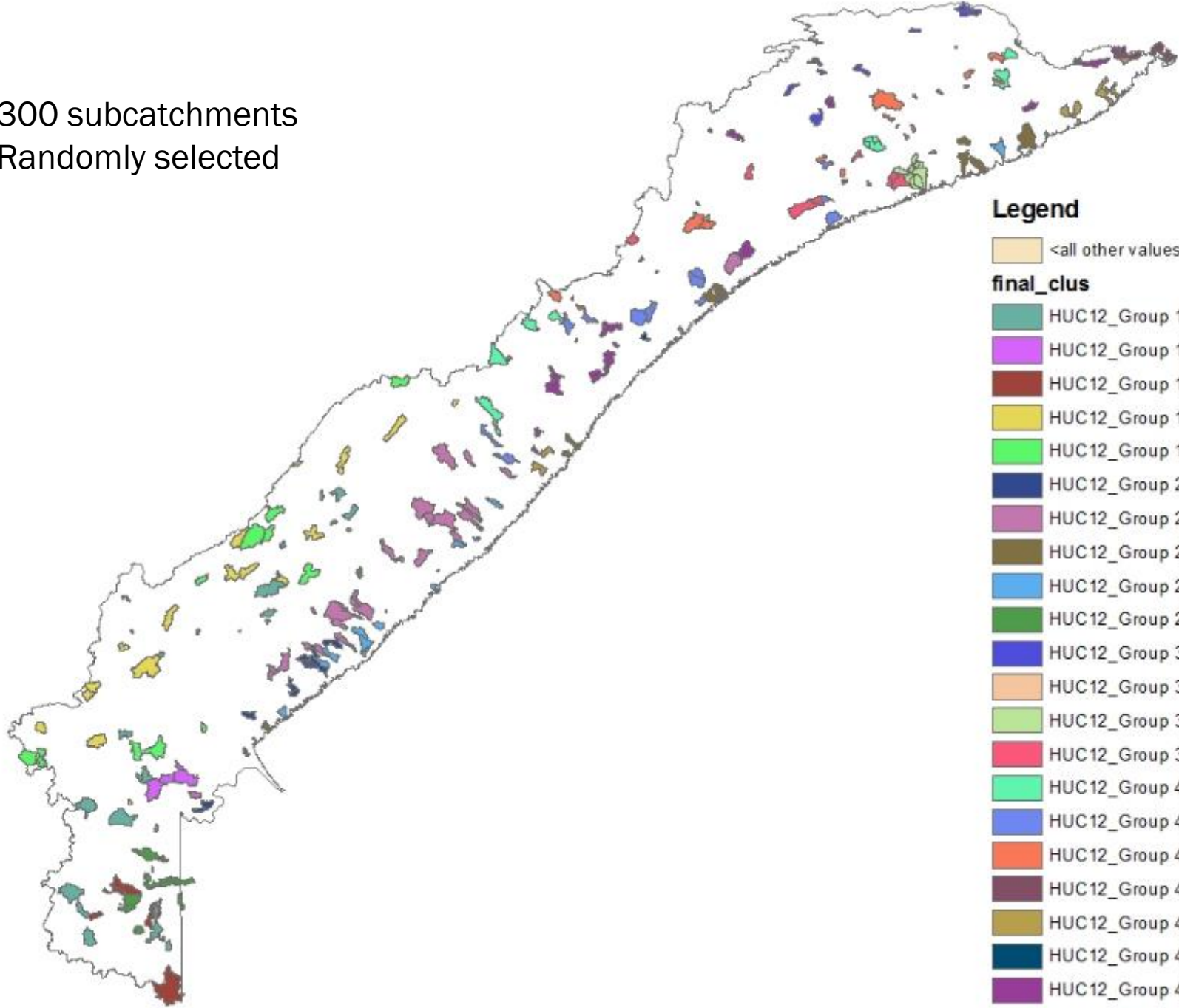
## 21 Clusters

Catchment-based

Exclude catchments with large % open water  
and area < 1 km<sup>2</sup>



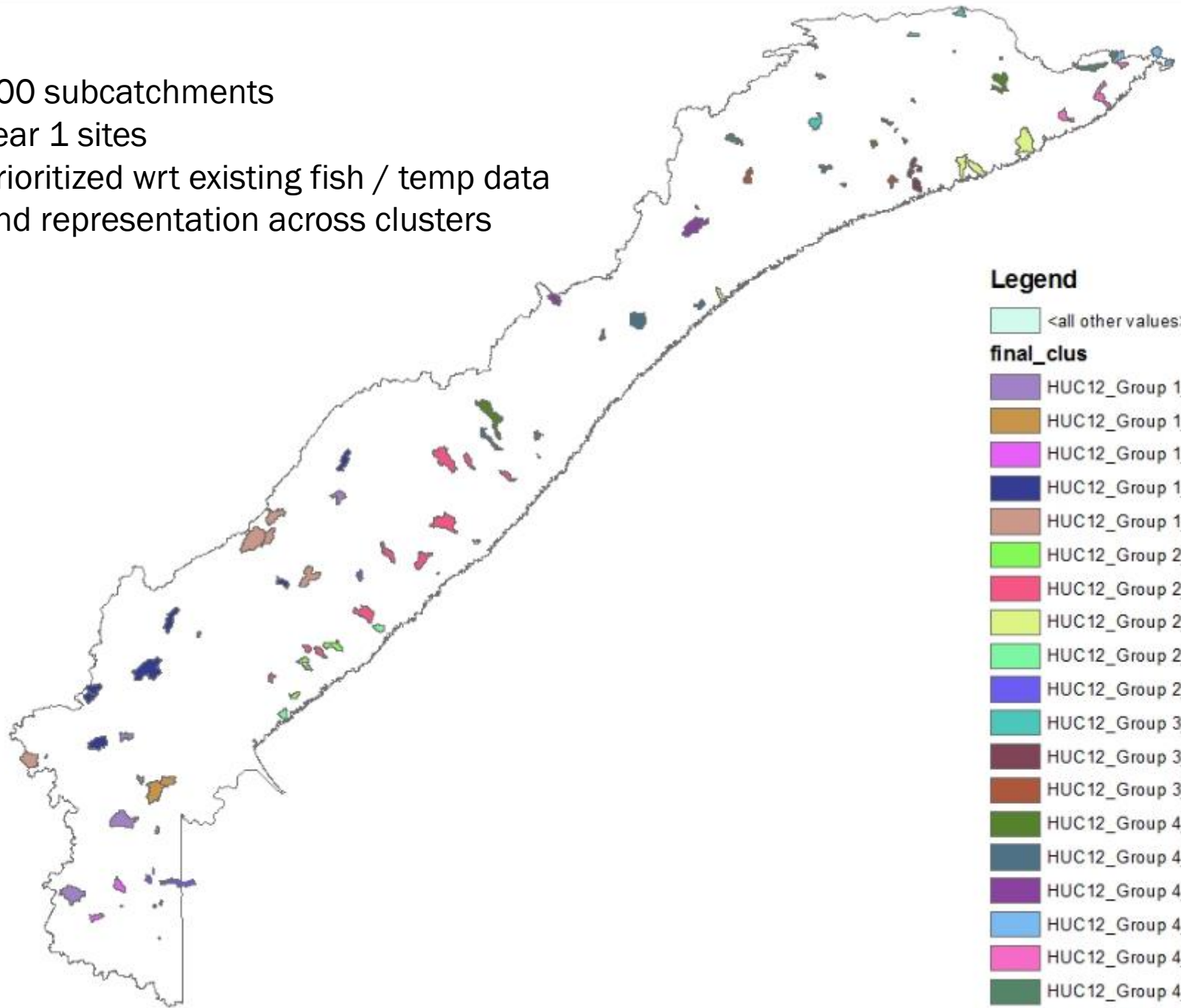
300 subcatchments  
Randomly selected



100 subcatchments

Year 1 sites

Prioritized wrt existing fish / temp data  
and representation across clusters



### Legend

<all other values> (0)

### final\_clus

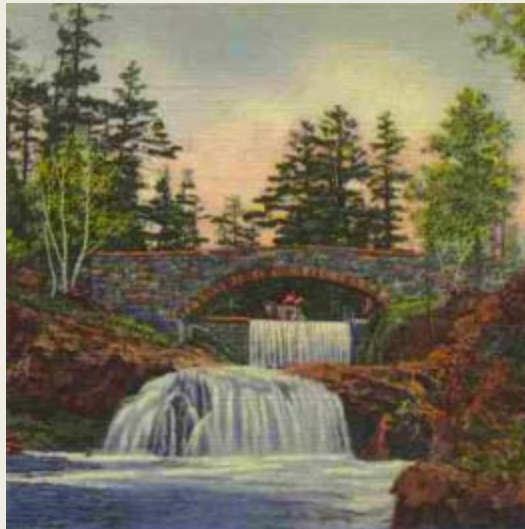
- HUC12\_Group 1\_1 (8)
- HUC12\_Group 1\_2 (2)
- HUC12\_Group 1\_3 (4)
- HUC12\_Group 1\_4 (7)
- HUC12\_Group 1\_5 (6)
- HUC12\_Group 2\_1 (4)
- HUC12\_Group 2\_2 (10)
- HUC12\_Group 2\_3 (4)
- HUC12\_Group 2\_4 (6)
- HUC12\_Group 2\_5 (5)
- HUC12\_Group 3\_1 (5)
- HUC12\_Group 3\_3 (4)
- HUC12\_Group 3\_4 (4)
- HUC12\_Group 4\_1 (5)
- HUC12\_Group 4\_2 (5)
- HUC12\_Group 4\_3 (7)
- HUC12\_Group 4\_4 (4)
- HUC12\_Group 4\_5 (5)
- HUC12\_Group 4\_7 (5)

# Field Protocols

## Volunteer sampling

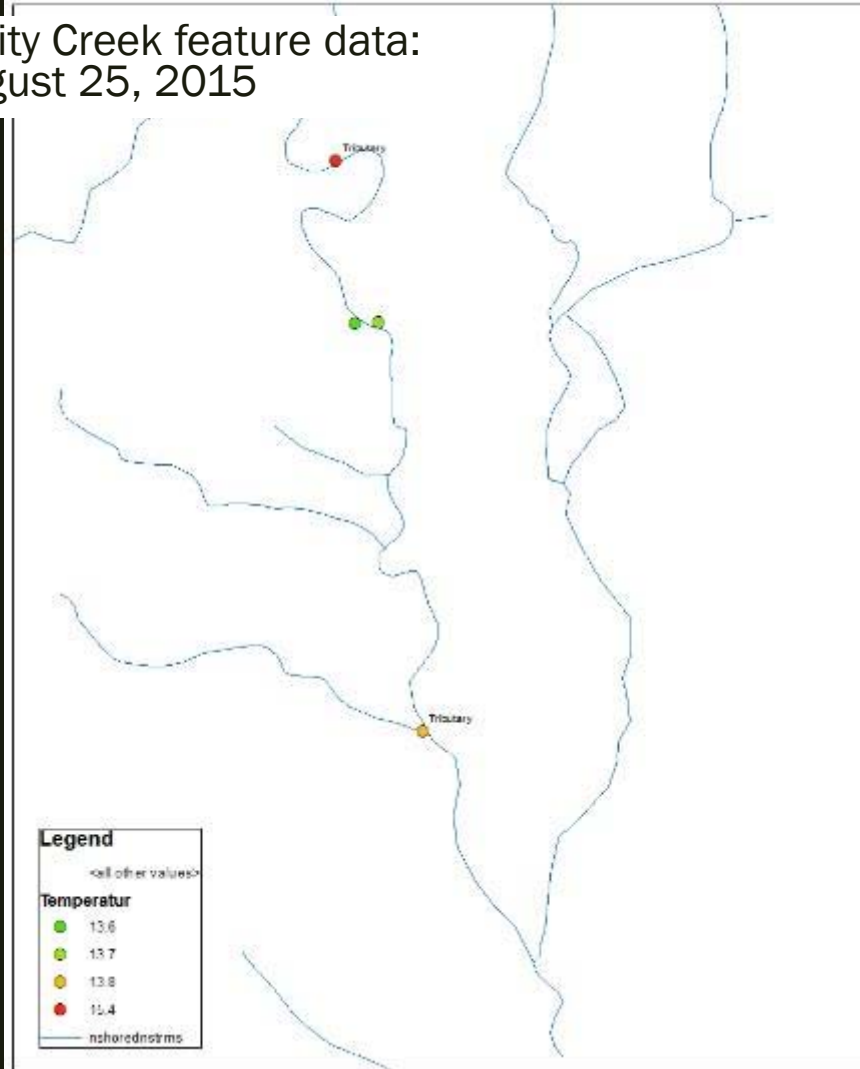
- *Rapid response thermister*
- *Note*
  - temperature
  - features associated with cold water input
  - barriers

- Temperature Monitoring
- Channel habitat survey
- Fish survey
- GIS characterization

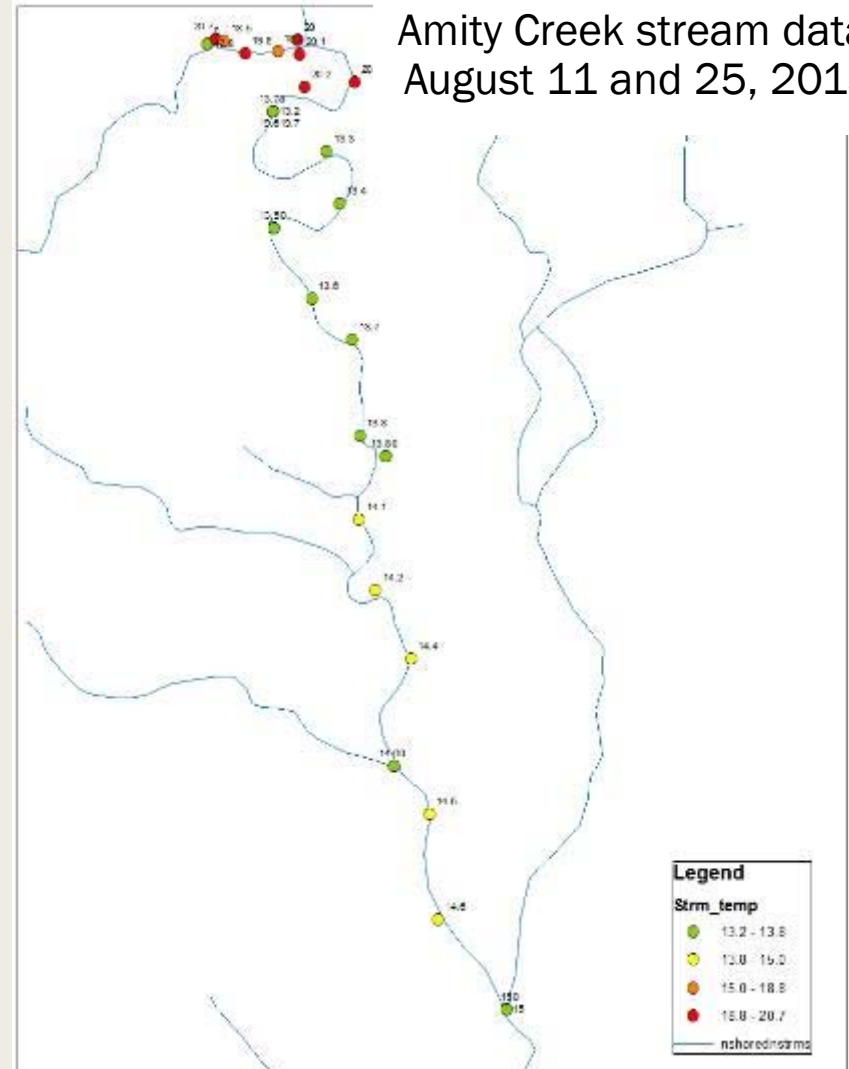


# 2015 Season: 17 segments

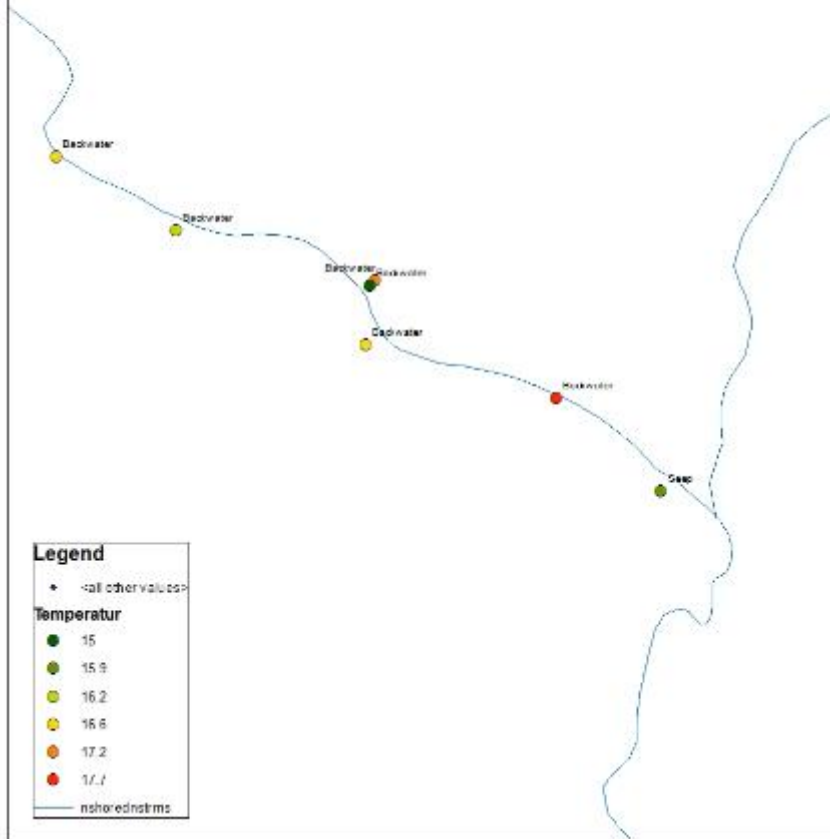
Amity Creek feature data:  
August 25, 2015



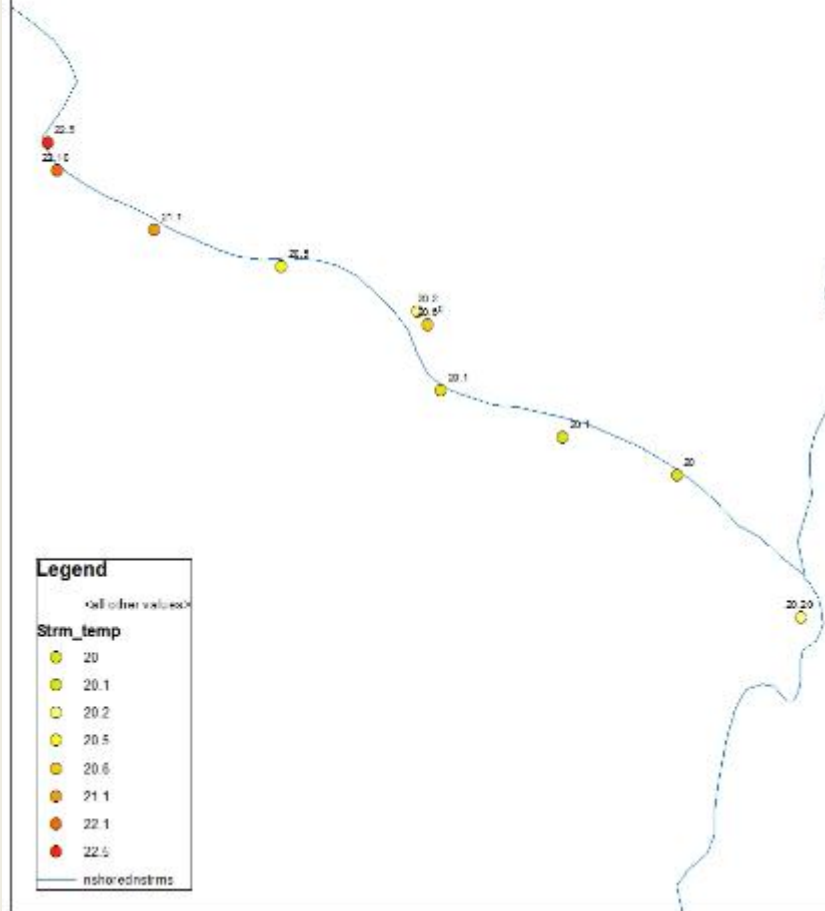
Amity Creek stream data:  
August 11 and 25, 2015



Drago Creek feature data:  
September 1, 2015

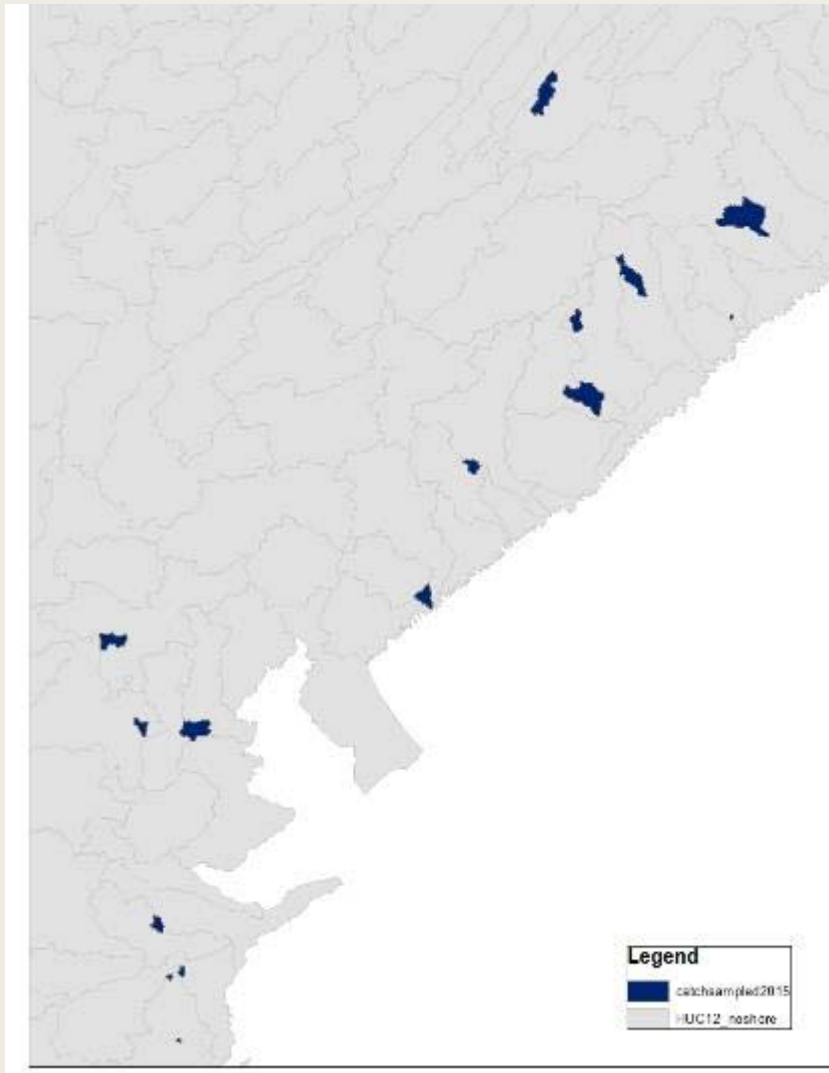


Drago Creek stream temperature  
data: September 1, 2015

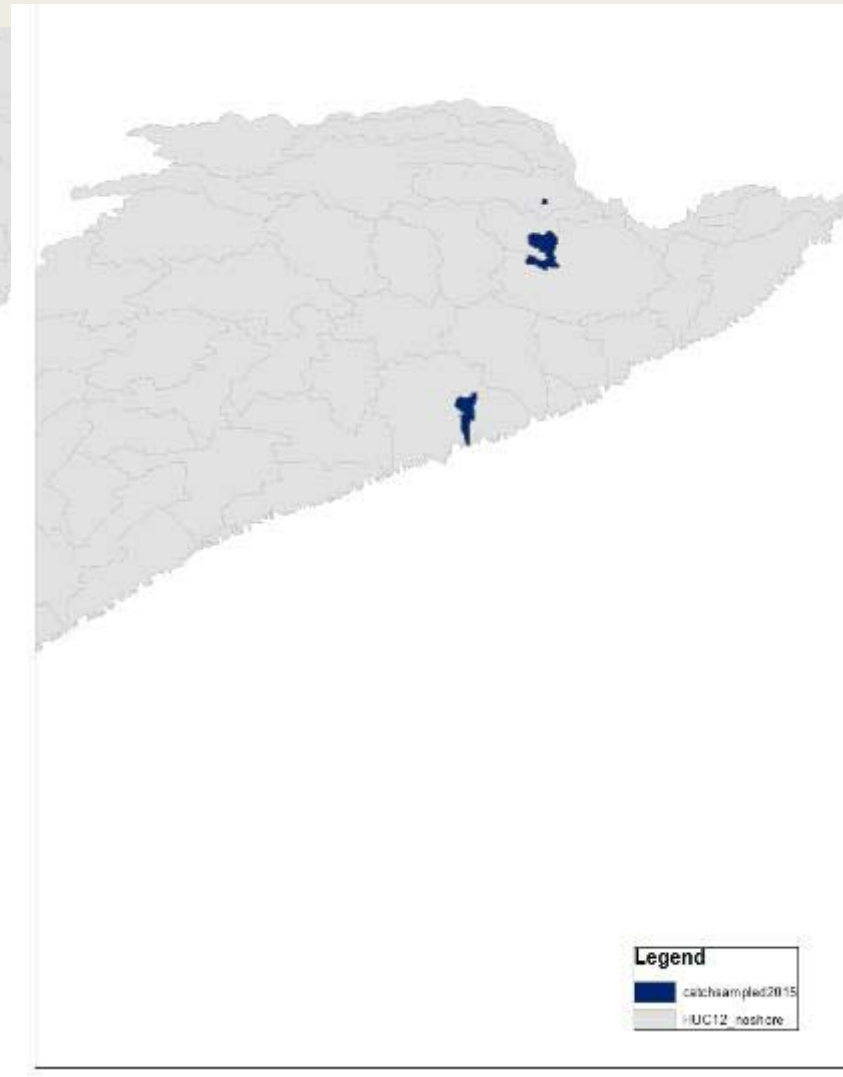


# 2015 Season: 17 Segments

Southern sampled catchments



Northern sampled catchments



# Projected Outcomes

- Scarce resources are targeted to the most critical areas within high-value streams... and factors promoting coldwater refugia are identified using scientific data.
- Targeted restoration reduces costs, and increases potential for success.
- Coldwater fishery is viable and sustainable under changing climate and development scenarios.

# Volunteer Opportunities Abound

MinnPost photo by Stephanie Hemphill



Lorri, left, and Don Mitchell learn how to use a GPS unit and quick-reaction thermometer.

Minnesota Trout Unlimited

[jlenczewski@comcast.net](mailto:jlenczewski@comcast.net)

612-670-1629

for more information.