Protecting coldwater fish from climate change: Building resilience in deep lakes using a landscape approach

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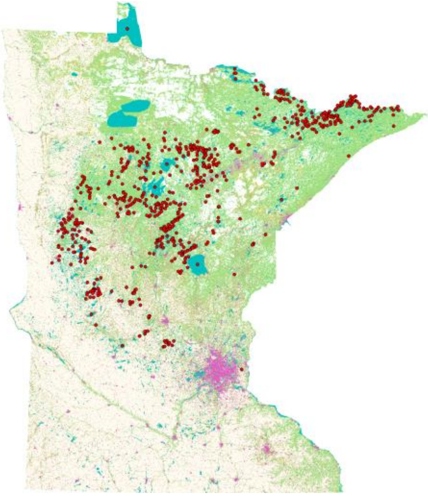
DEPARTMENT OF NATURAL RESOURCES

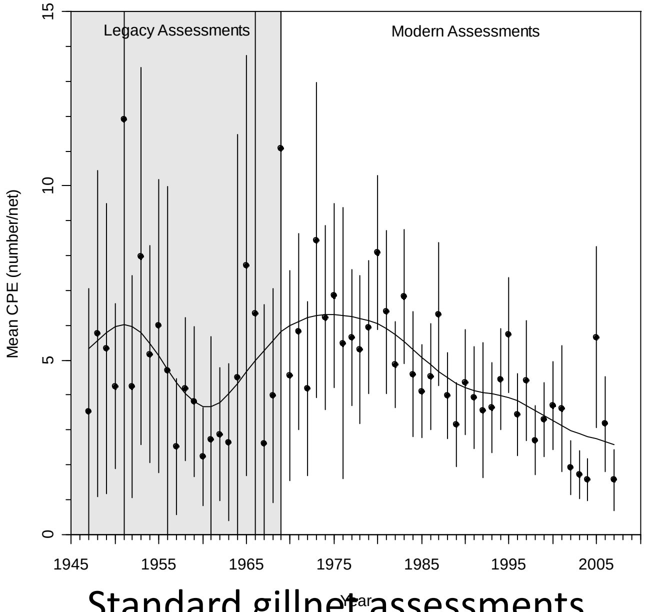
Cisco *Coregonus artedi* are important coldwater stenotherms and are declining in Minnesota

Important forage for walleye, northern pike, muskellunge, lake trout



Widespread – found in 650 lakes in Minnesota

Experience periodic summer mortality events



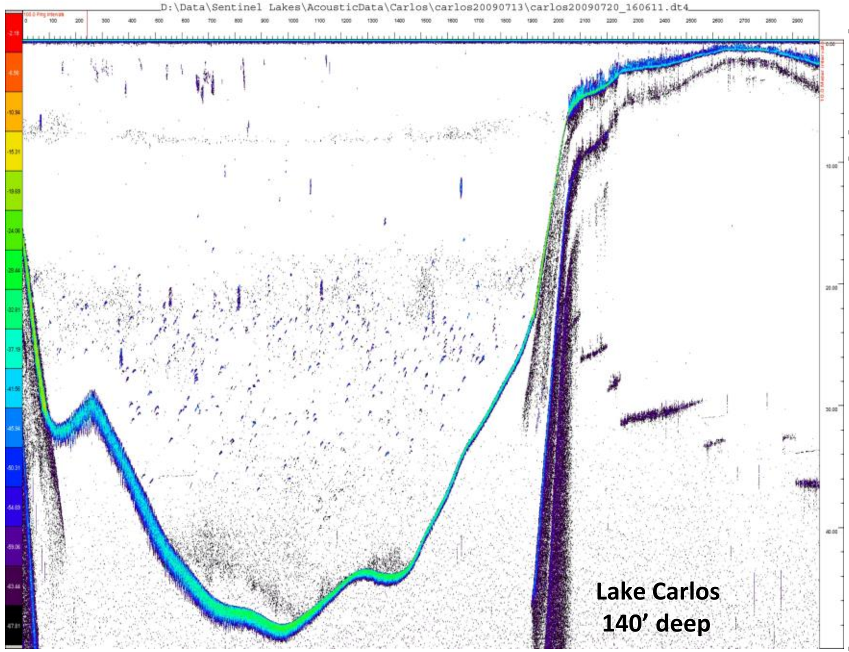
Standard gillnet assessments

Jacobson et al. 2008. Field estimation of a lethal oxythermal niche boundary for adult cisco in Minnesota lakes. Transactions of the American Fisheries Society 137:1464–1474.

Jacobson et al. 2012. The effects of climate change and eutrophication on cisco abundance in Minnesota lakes. Advances in Limnology 63:417-427.

Cisco habitat in lakes

- Primarily in the coldwater below the thermocline in Minnesota lakes
- Oxygen concentrations need to remain high
- Deep, clear lakes provide the best oxythermal habitat

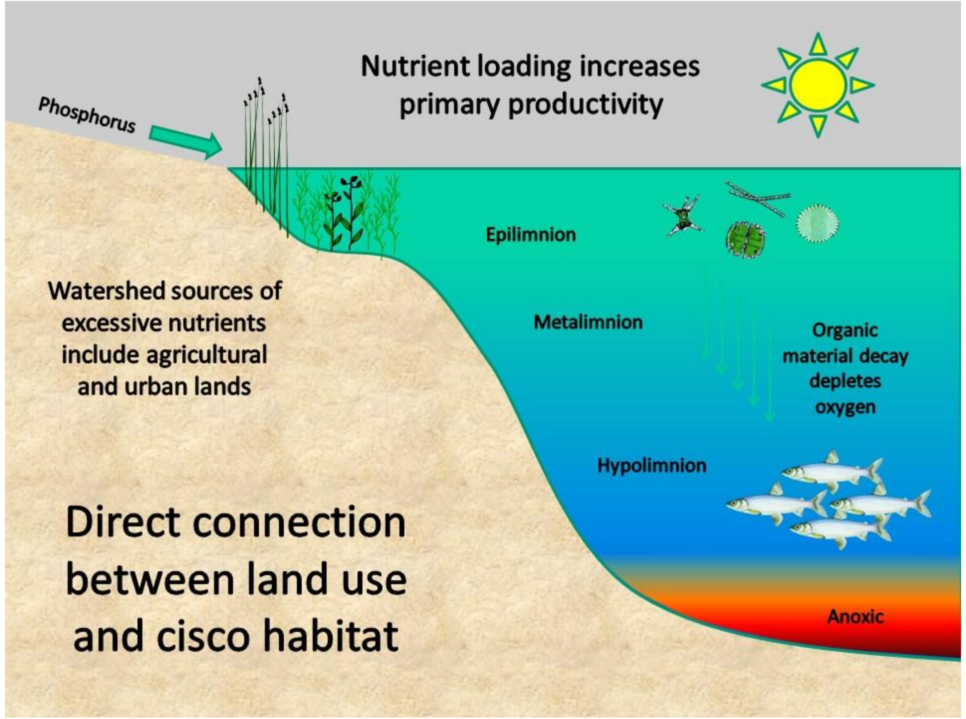


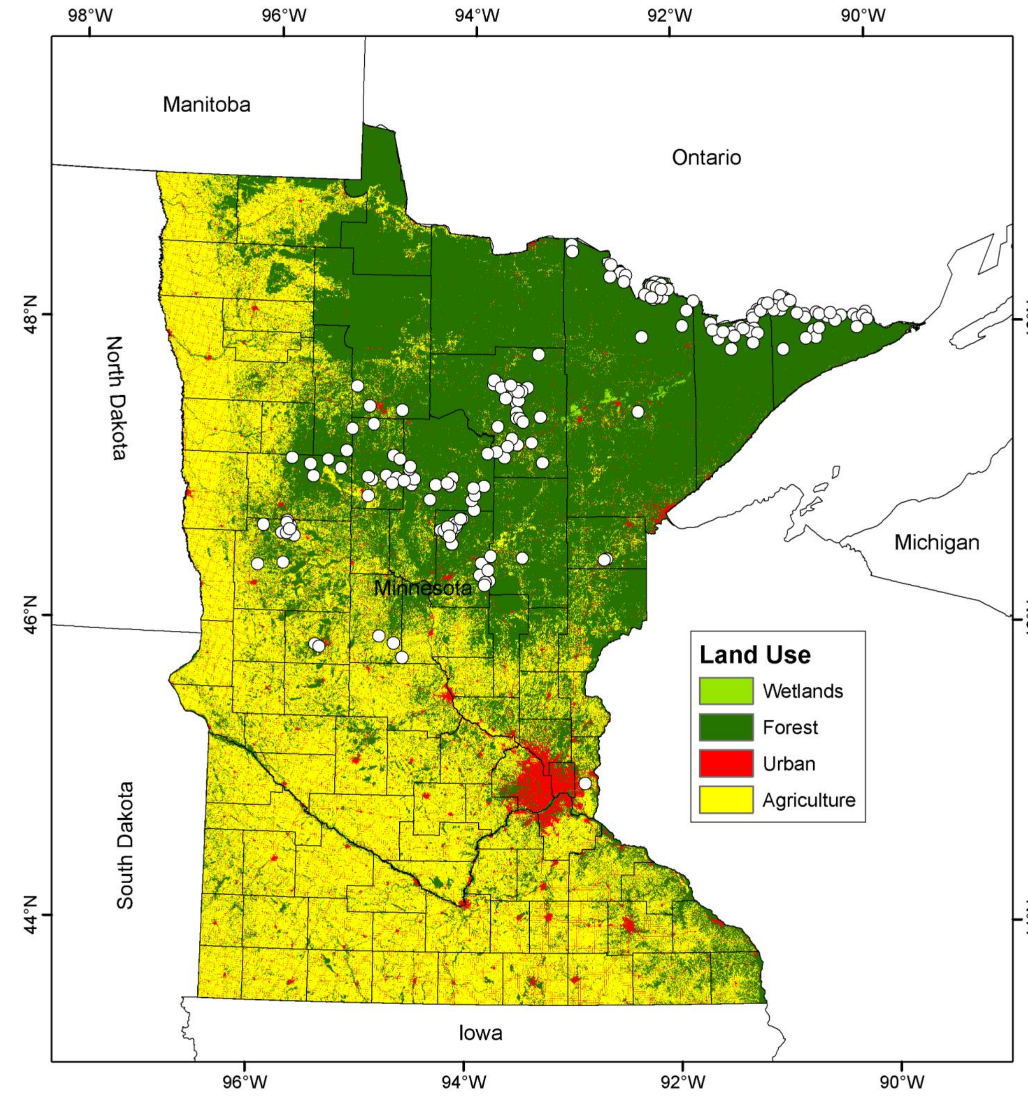
Epilimnion

Metalimnion and Hypolimnion

Climate and land use change significantly affect hypolimnetic oxygen concentrations

Jacobson et al. 2010. Coldwater fish oxythermal habitat in Minnesota lakes: influence of total phosphorus, July air temperature, and relative depth. CJFAS 67:2002-2013.



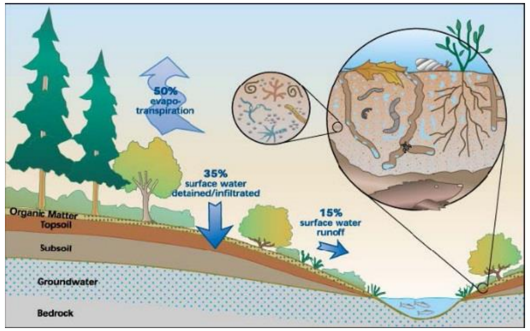


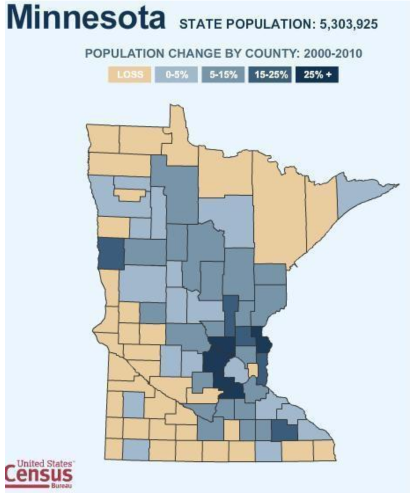
Fang et al. 2012. Identifying Cisco Refuge Lakes in Minnesota under Future Climate Scenarios. Transactions of the American Fisheries Society 141:1608-1621

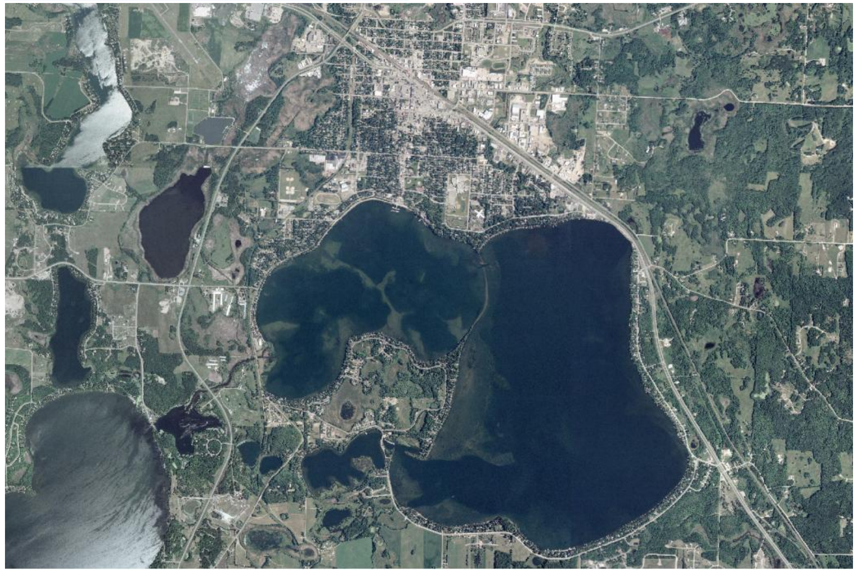
Fortunately, we have identified 176 deep, clear lakes that will provide refuge for coldwater fish from climate change

But only if we protect their forested watersheds!

Porous forest soils absorb precipitation and deliver clean water through groundwater connections to lakes







Large demographic projections of population growth in Minnesota Lakes Country

Watershed threats include urbanization and rural development

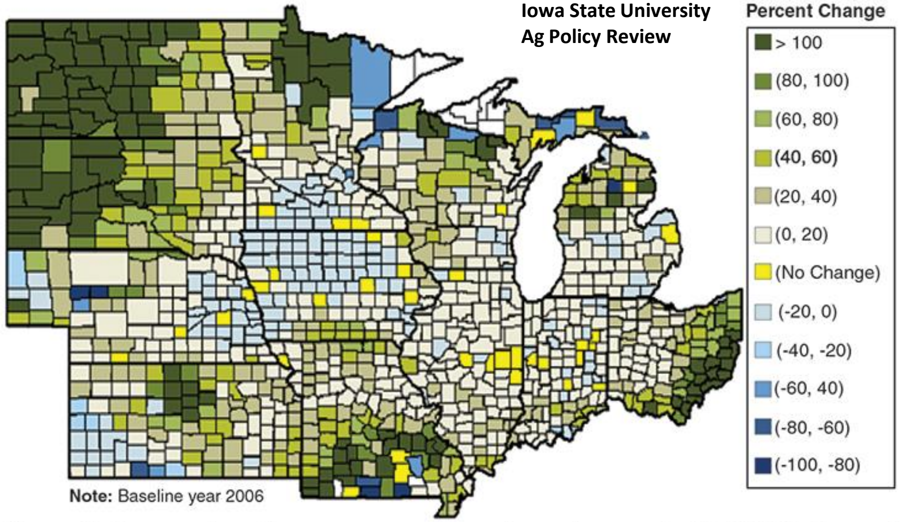


Figure 2. Corn and soybean acreage percentage changes in 2014 (CDL Survey)

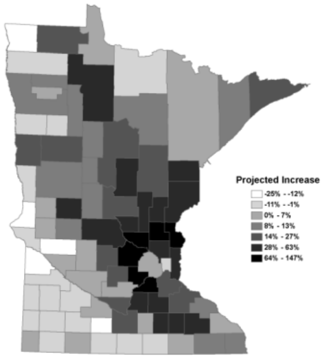
Increased demand and crop prices are driving an intensification of row crop agriculture across the region

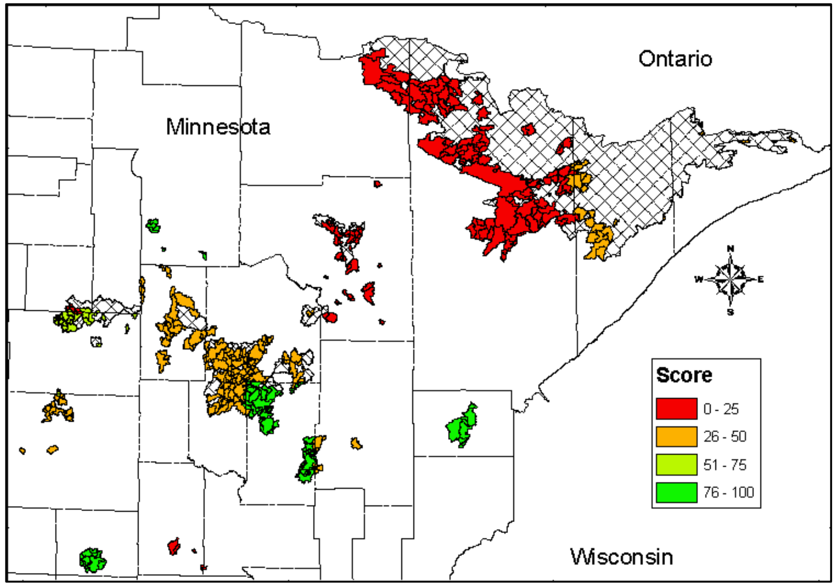
Conversion of forest land to industrial agriculture has emerged as a major threat to water quality

Cisco refuge lake watersheds were prioritized based on threat and investment efficiency

Threat

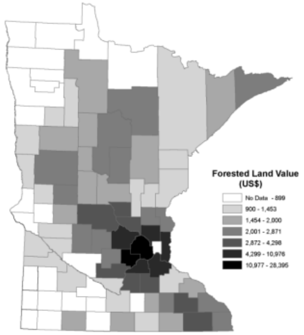
Projected Population Growth 2005-2035

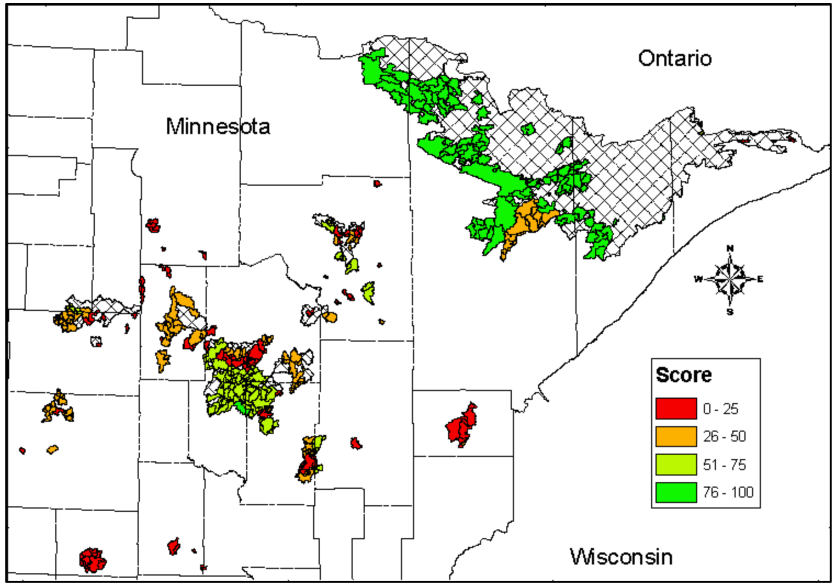


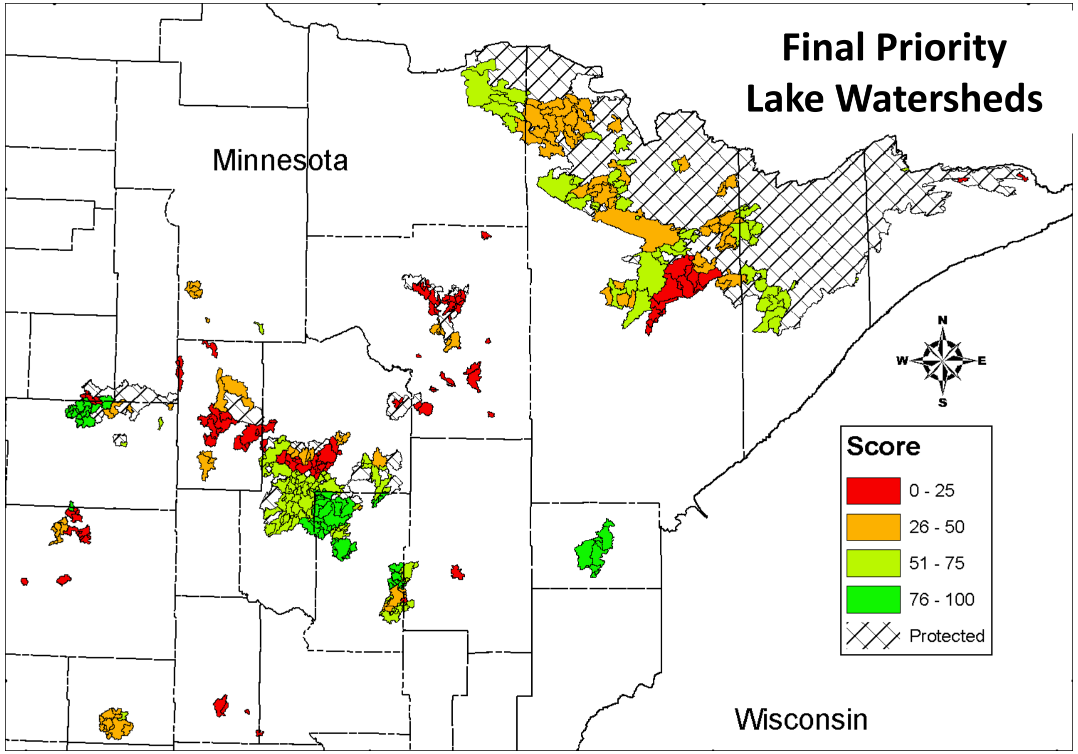


Investment Efficiency

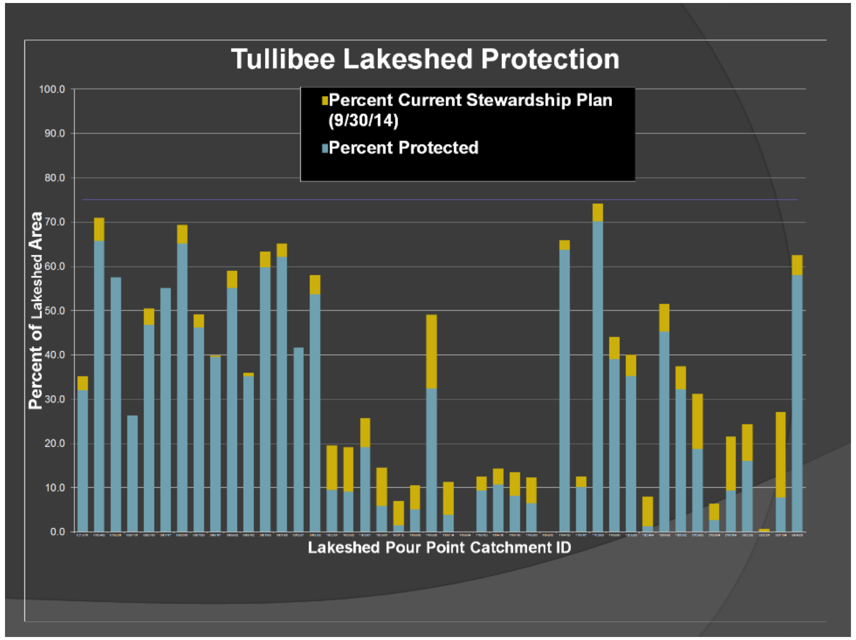
Forest Land Value

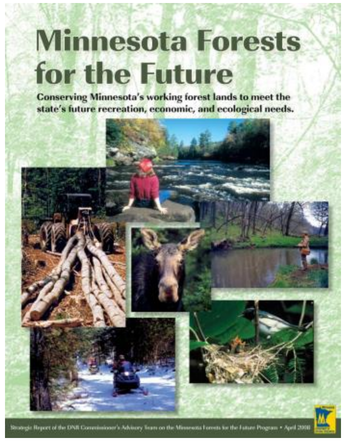




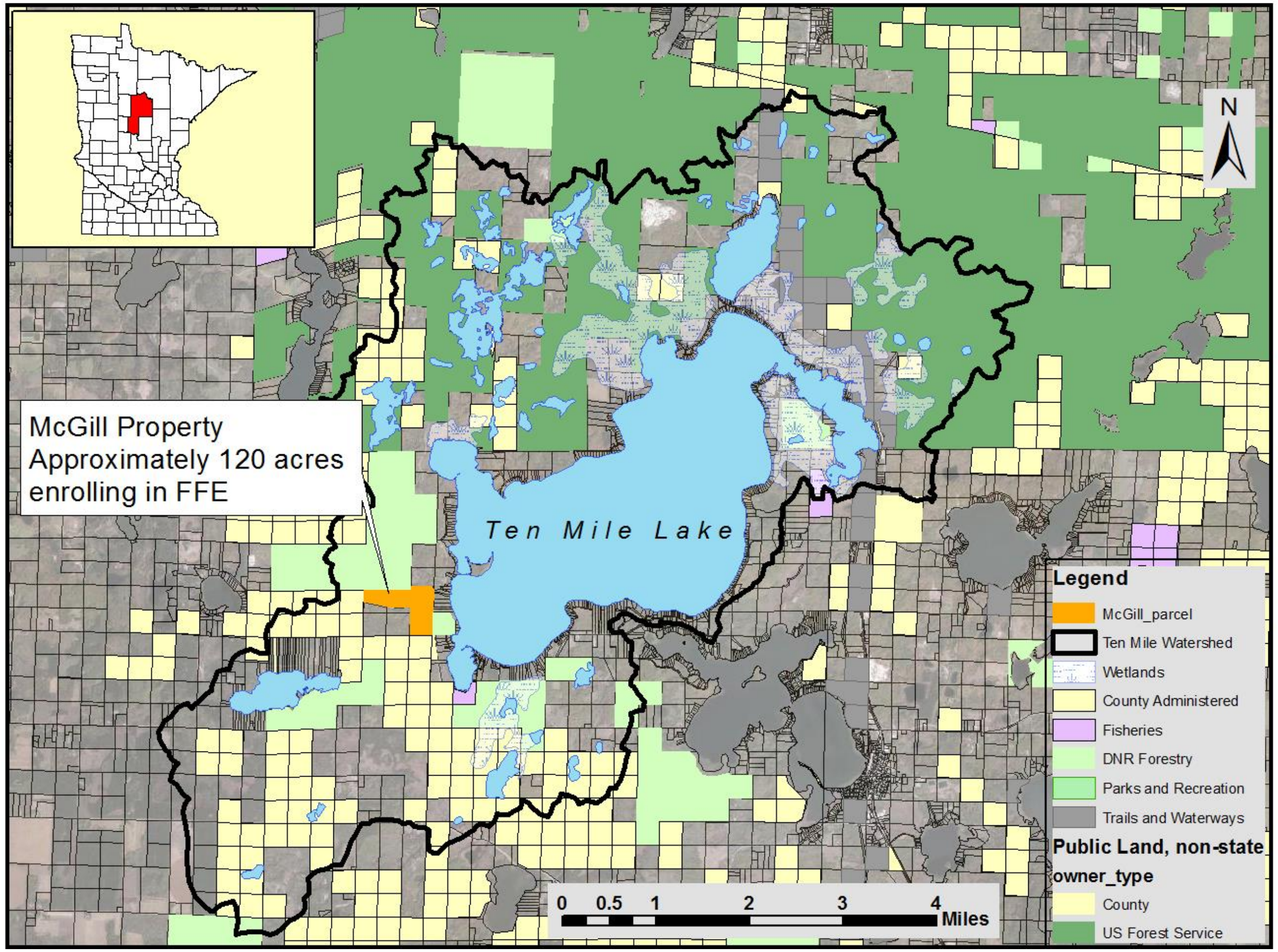


Jacobson et al. 2013. Protecting cisco oxythermal habitat from climate change: building resilience in deep lakes using a landscape approach. Advances in Limnology 64:323-332

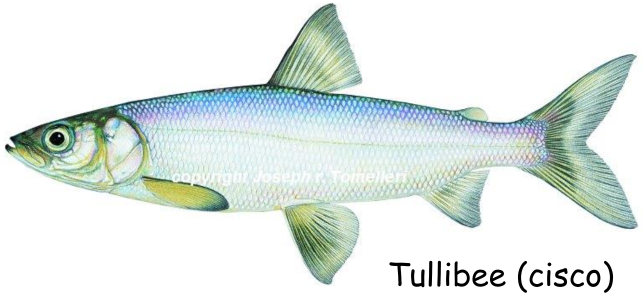




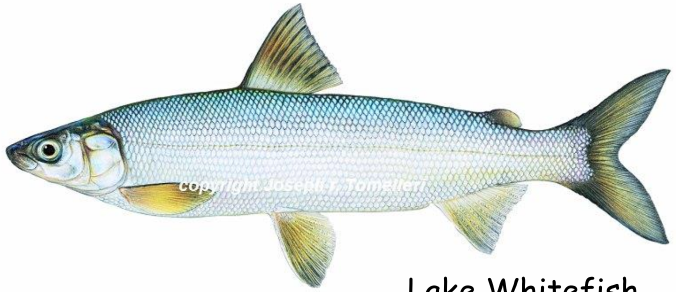
Conservation activities are ongoing in the watersheds of 44 cisco refuge lakes



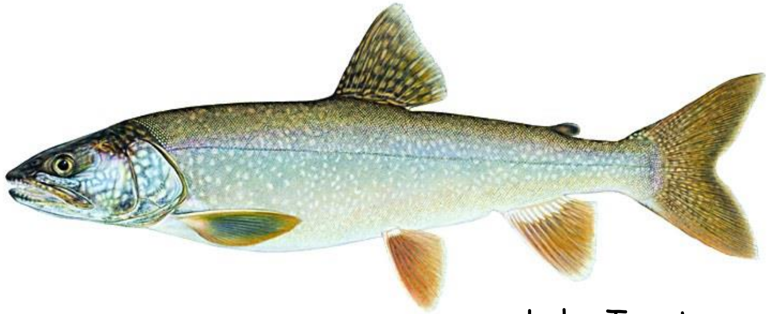
Private forest conservation easements and forest stewardship planning with many partners!



Tullibee (cisco)



Lake Whitefish



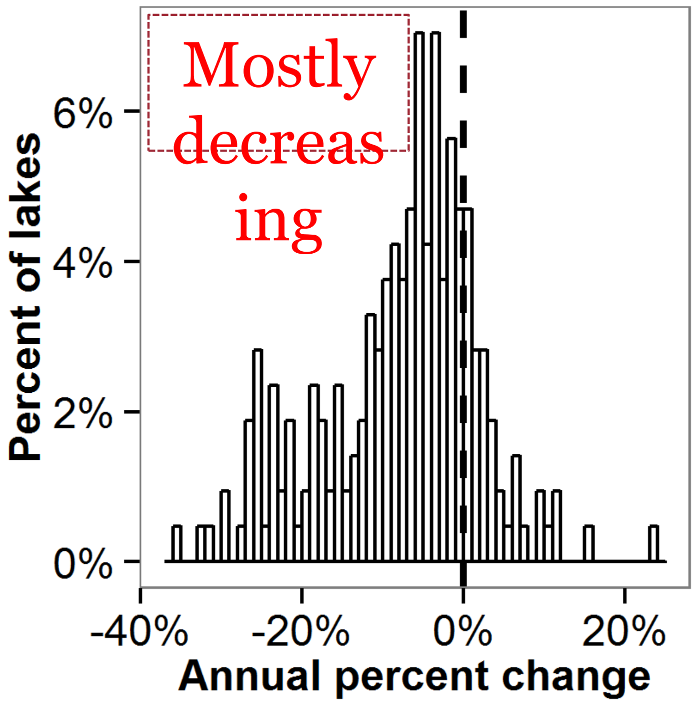
Lake Trout

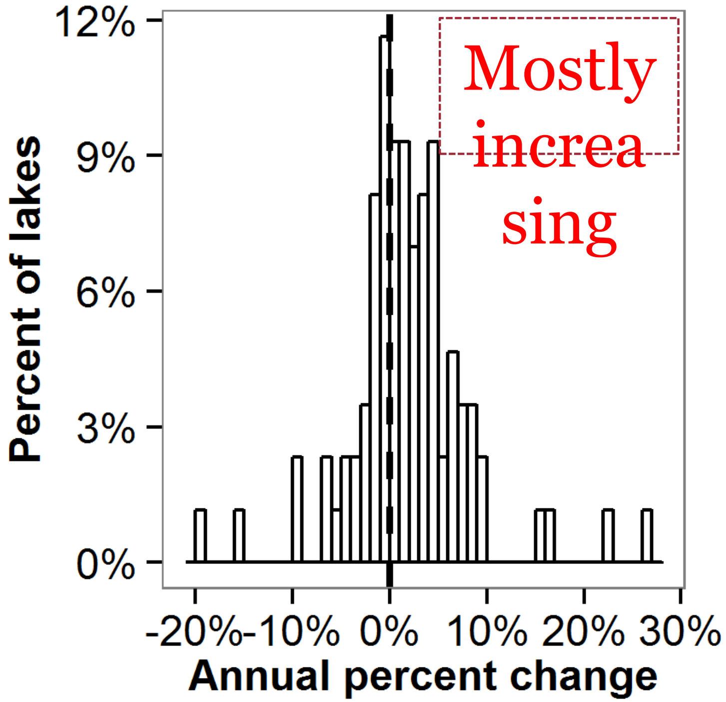
Artwork - Joseph Tomelleri

Treasures of the Deep: protecting hypolimnetic oxygen in Minnesota lakes

- Hypolimnetic oxygen will be an increasingly valuable ecological resource in a climate-warmed Minnesota
- Deep lakes with good water quality need extra protection
- Many of these lakes have statewide significance
- High priority for shoreland and watershed protection
- Invest $180 million to protect 300,000 acres ($600/acre) of forest to protect watersheds of all 176 coldwater refuge lakes.

Fish community changes in Wisconsin Lakes

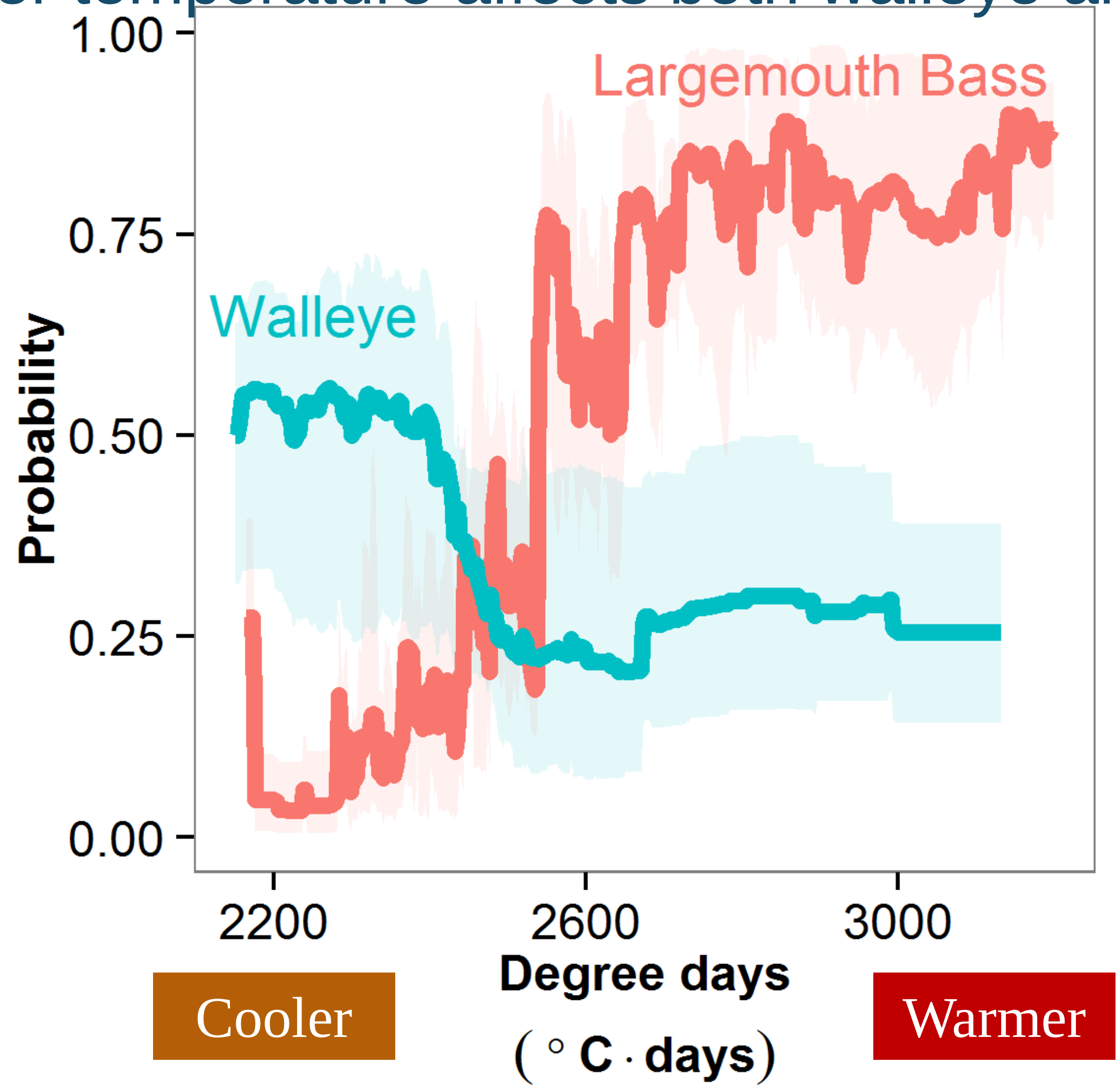




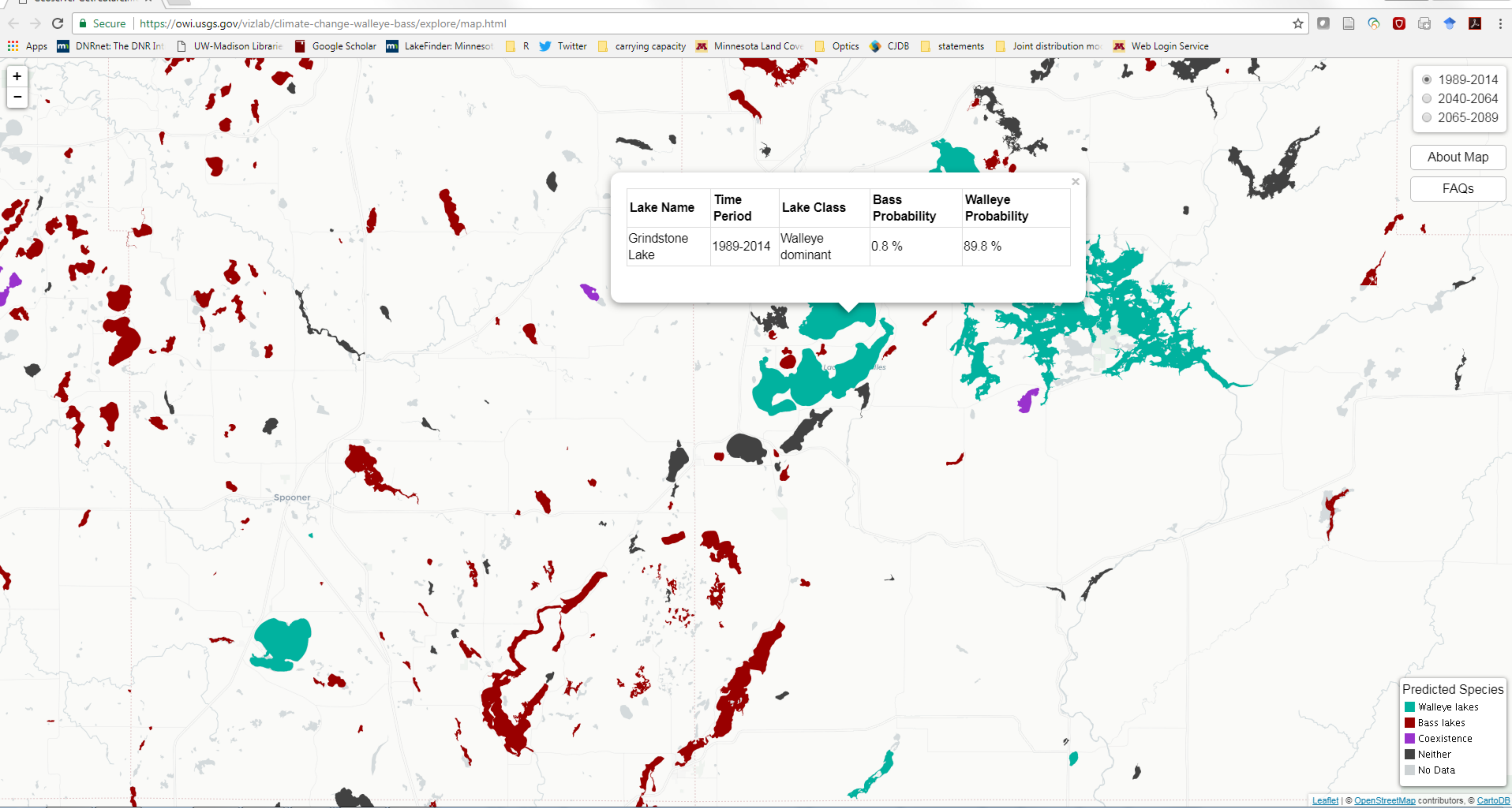
Walleye recruitment

Largemouth bass relative abundance

Water temperature affects both walleye and bass



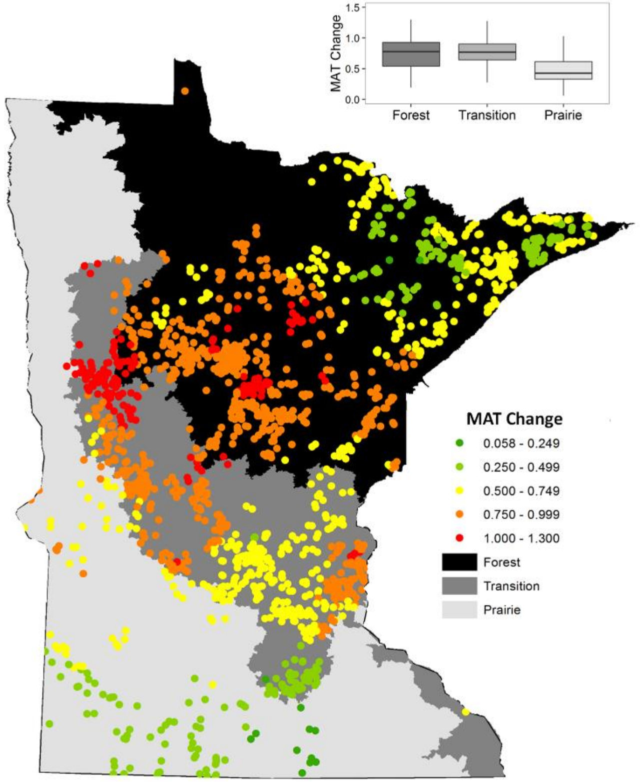
Hansen et al. 2017 Global Change Biology



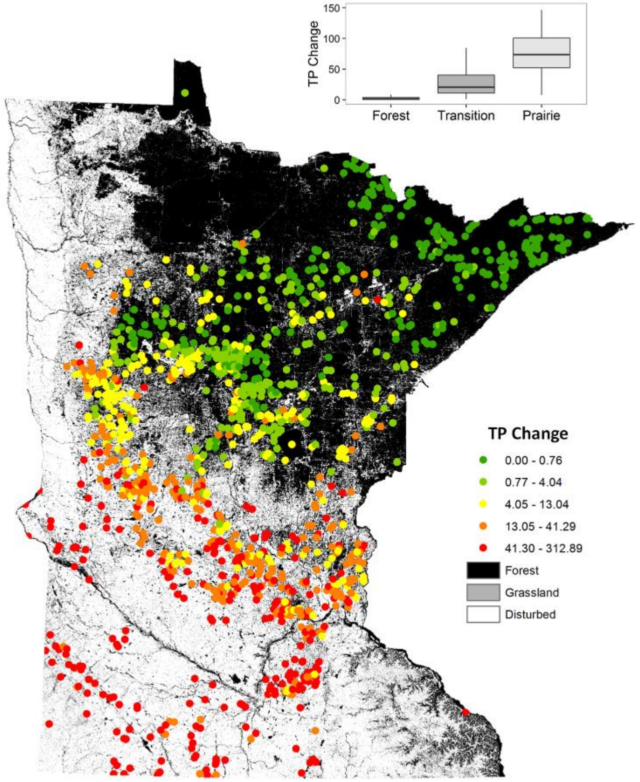
https://owi.usgs.gov/vizlab/climate-change-walleye-

Climate and land use change have profoundly changed many Minnesota lakes

Climate Change



Eutrophication



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RESEARCH ARTICLE

Disentangling the effects of a century of eutrophication and climate warming on freshwater lake fish assemblages

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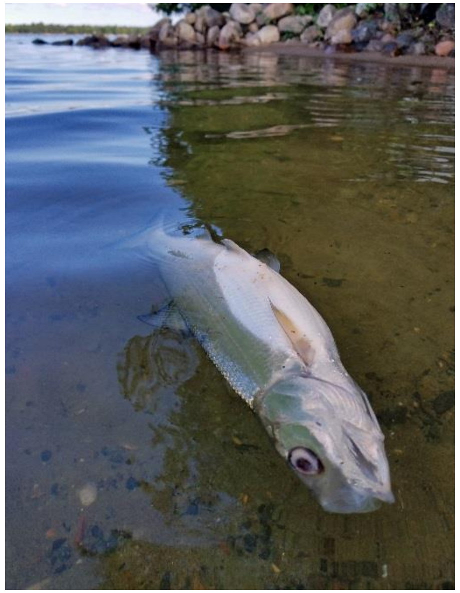
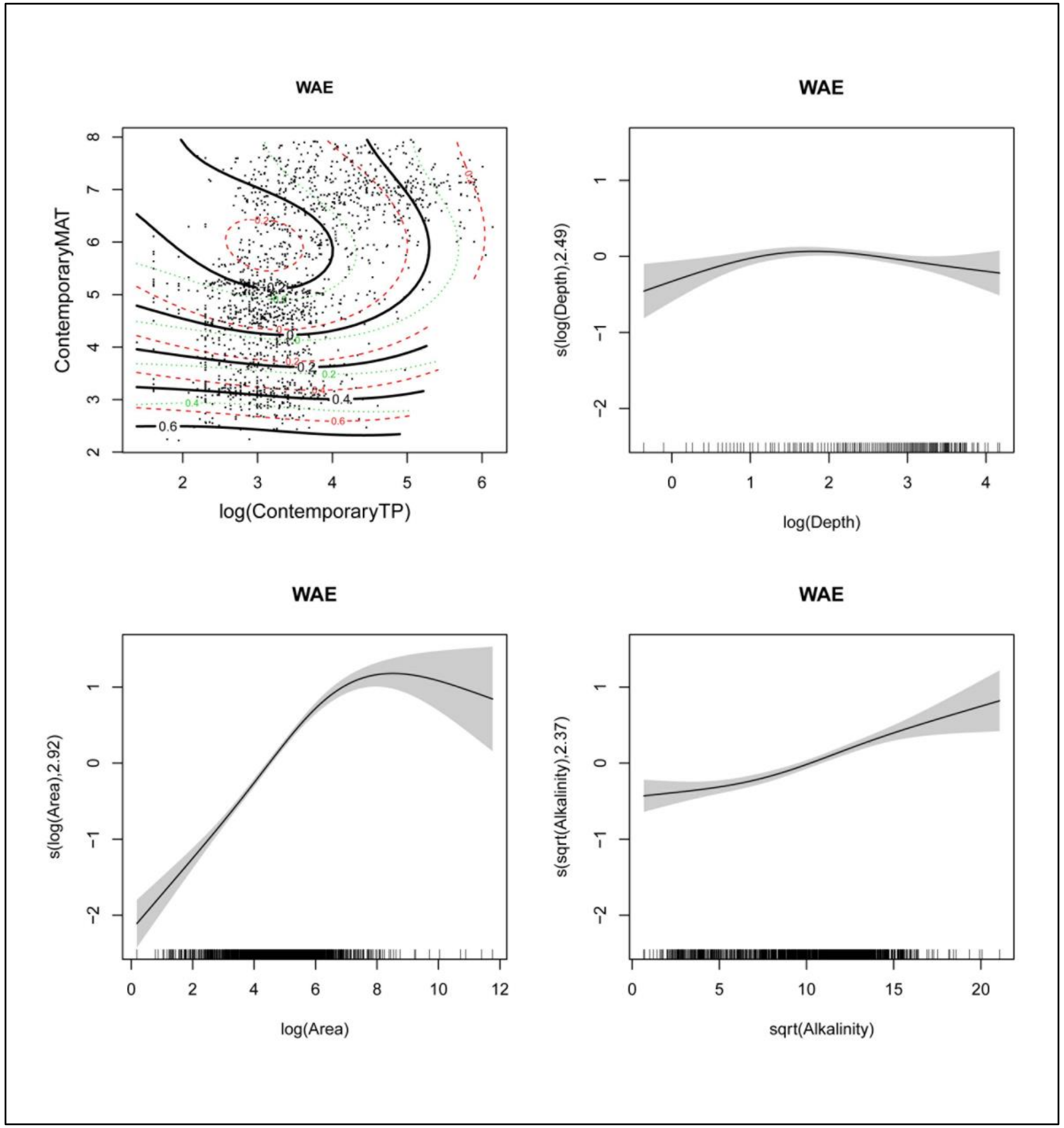
Abstract

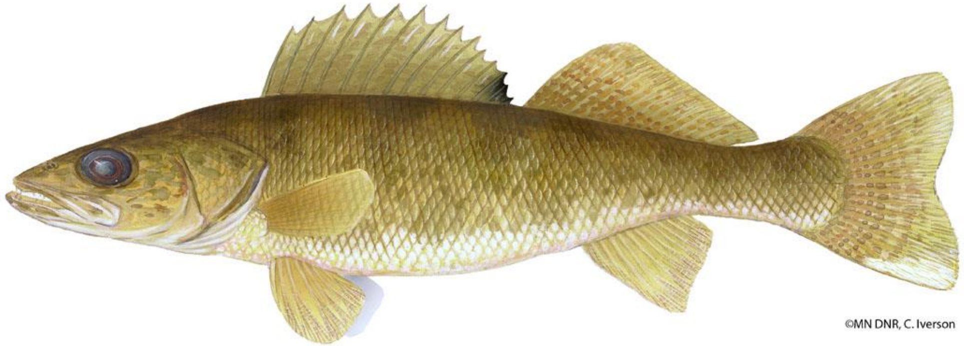
Eutrophication and climate warming are profoundly affecting fish in many freshwater lakes. Understanding the specific effects of these stressors is critical for development of effective adaptation and remediation strategies for conserving fish populations in a changing environment. Ecological niche models that incorporated the individual effects of nutrient concentration and climate were developed for 25 species of fish sampled in standard gillnet surveys

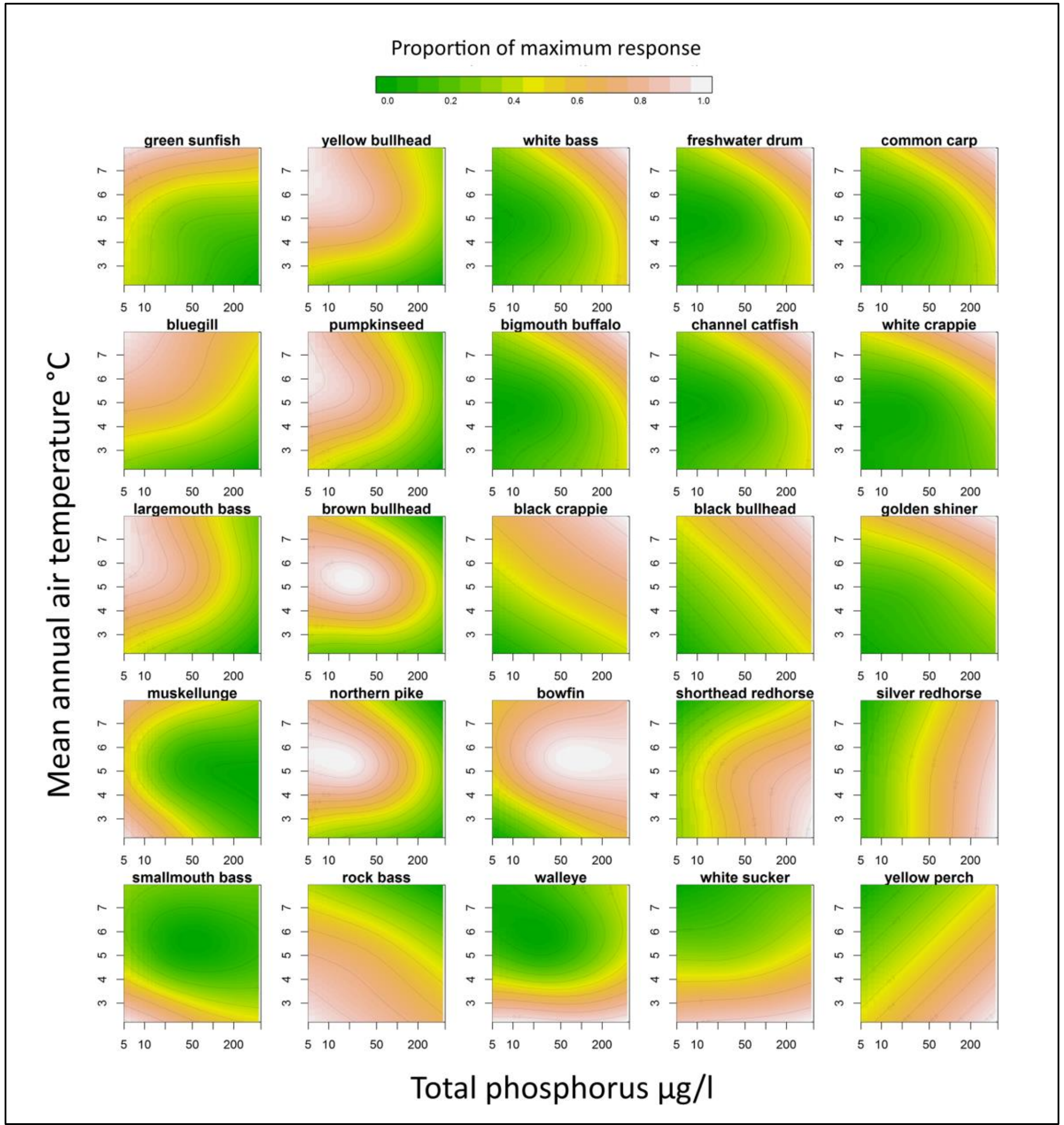




Species – specific ecological niche models

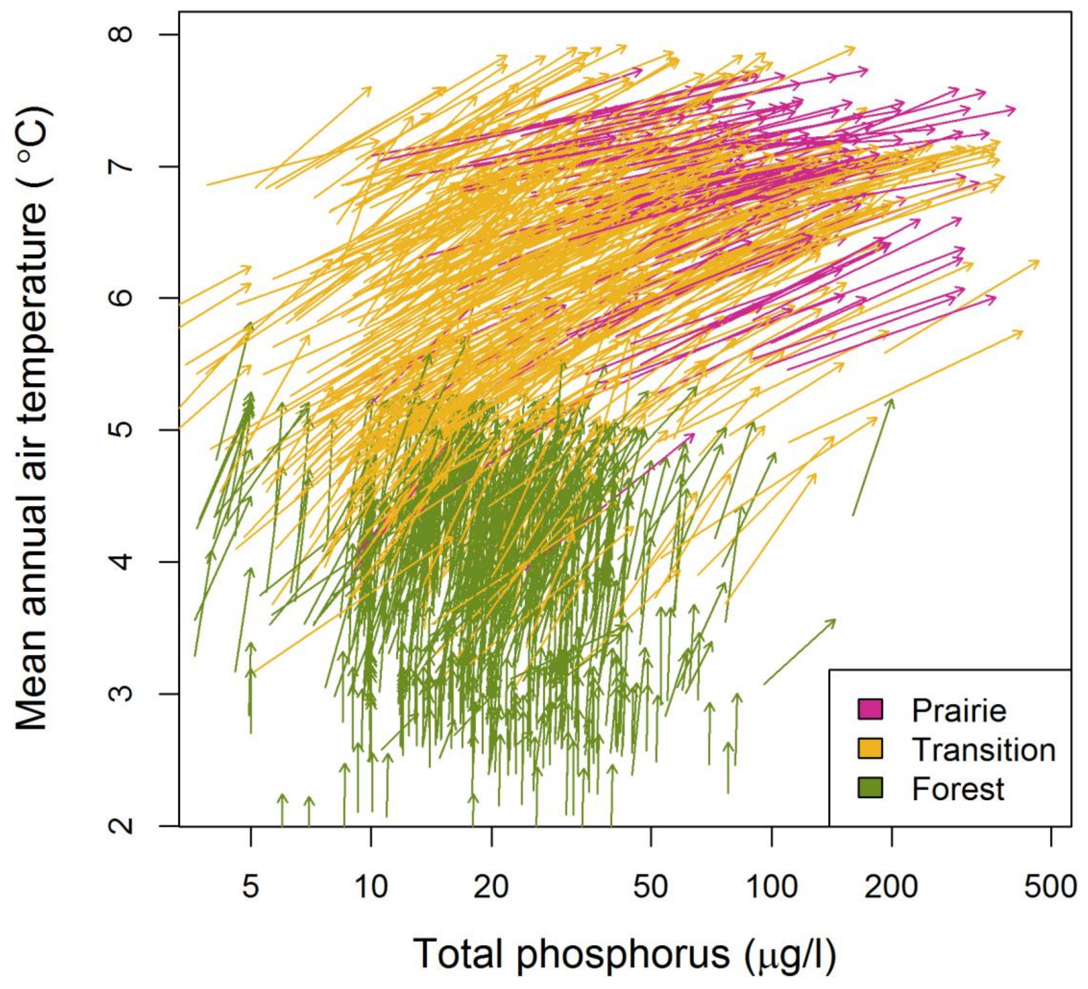
- Generalized Additive Models – commonly used for ecological niche modeling
- Works well for modeling non-linear relationships
- Mean Gillnet CPE was the response variable
- Climate and eutrophication variables modeled jointly
- Covariates also included maximum lake depth, lake area, total alkalinity
- Log CPE responses standardized by z-score to facilitate cross-species comparisons





Species – specific ecological niche models

- 25 species commonly sampled with standard Minnesota DNR gill nets
- Responses to climate and lake productivity allow for the identification of temperature preference and eutrophication tolerance
- Maximum responses:
  - >6°C MAT = warmwater
  - <6°C MAT = coolwater
  - >25µg/l TP = eutrophication-tolerant
  - <25µg/l TP = eutrophication-intolerant



Lake conditions hindcasted to pre-disturbance values

- Historical PRISM climate data available back to 1896
- Pre-disturbance total phosphorus concentrations estimated using the Cross/Jacobson landscape/lake P model:

$$TP_{predisturbance} = e^{ln(TP_{contemporary})-1.60disturbance}$$

where, disturbance = proportion of watershed in ag, urban, and mining land uses

Lake and Reservoir Management, 29:1–12, 2013

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Landscape factors influencing lake phosphorus concentrations across Minnesota

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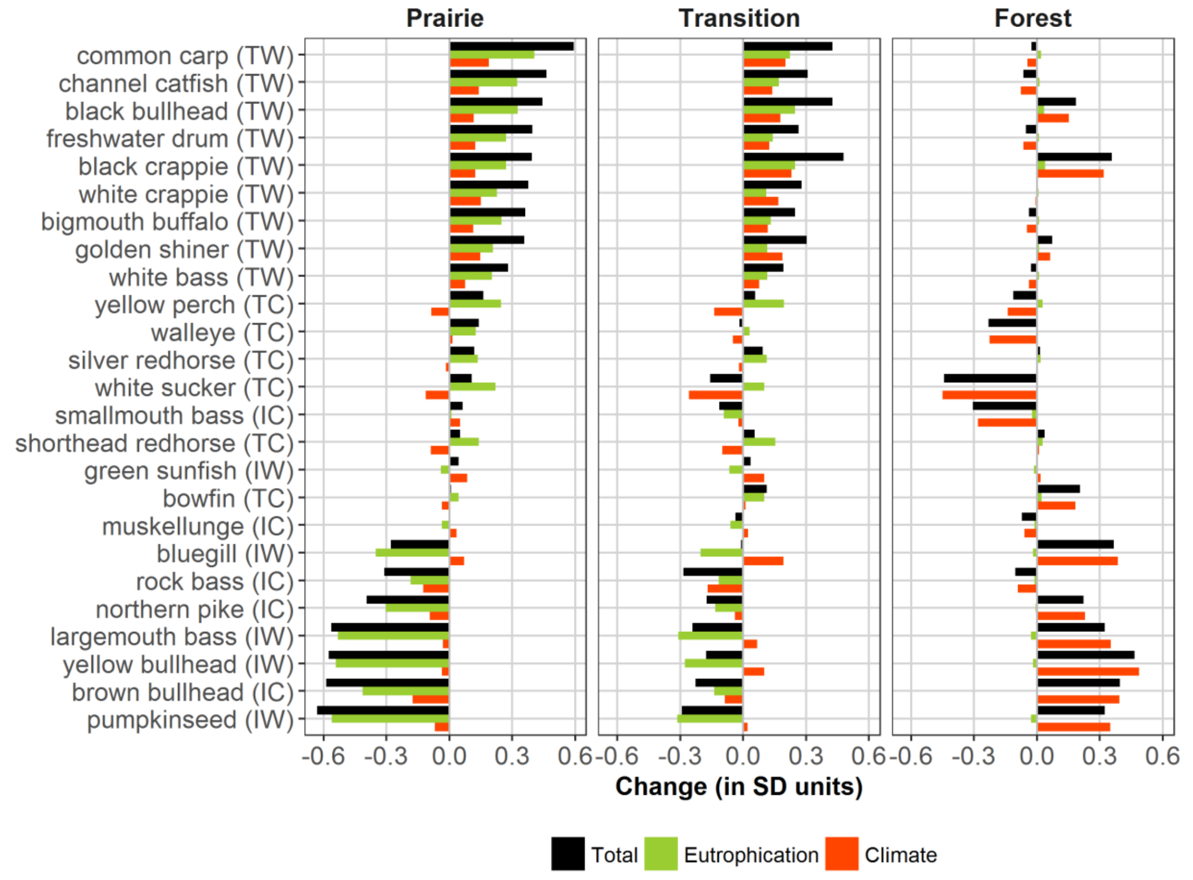
[2]Minnesota Department of Natural Resources, 27841 Forest Lane, Park Rapids, MN 56470

Stressor-specific responses varied by ecoregion

- Climate the primary driver of change in the forested ecoregion
- Both eutrophication and climate operating in the prairie and transition ecoregions
- Effects were in the same direction for some species/ecoregions, but opposite in other cases
- Large increases in tolerant warmwater taxa in the prairie and transition ecoregions
- Intolerant warmwater taxa such as centrarchids and ictalurids increased in the forested ecoregion




Thank you!