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

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

Experience periodic summer mortality events

Standard gillnet assessments


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

Climate and land use change significantly affect hypolimnetic oxygen concentrations

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

Fang et al. 2012. Identifying Cisco Refuge Lakes in Minnesota under Future Climate Scenarios. Transactions of the American Fisheries Society 141:1608-1621
But only if we protect their forested watersheds!

Porous forest soils absorb precipitation and deliver clean water through groundwater connections to lakes.
Watershed threats include urbanization and rural development.

Large demographic projections of population growth in Minnesota Lakes Country.
Conversion of forest land to industrial agriculture has emerged as a major threat to water quality

Increased demand and crop prices are driving an intensification of row crop agriculture across the region
Cisco refuge lake watersheds were prioritized based on threat and investment efficiency.

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

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

Artwork - Joseph Tomelleri

Tullibee (cisco)
Lake Whitefish
Lake Trout
Fish community changes in Wisconsin Lakes

- Largemouth bass relative abundance: Mostly increasing
- Walleye recruitment: Mostly decreasing

Graphs showing percentage changes of lake populations.
Water temperature affects both walleye and bass

Hansen et al. 2017 Global Change Biology
Climate and land use change have profoundly changed many Minnesota lakes.
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:

\[ TP_{\text{predisturbance}} = e^{\ln(TP_{\text{contemporary}}) - 1.60 \times \text{disturbance}} \]

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