Potential effects of climate change on inland glacial lakes and breeding common loons in Wisconsin

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FUNDING 2009-2012 - Wisconsin Focus on Energy, Research Grants: Environmental and Economic Research and Development Program Research Program

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Doug Killian
Climate Change in Wisconsin

What do the models tell us?

Temperature:
Warms by 2-6°C (3-10°F)
by end of century

Precipitation:
Less certain;
seasonally dependent
Will changing temperatures and precipitation alter hydrology of northern Wisconsin lakes?

Negatives: Poorer water quality, more nuisance exotics.

Eurasian watermilfoil
Historical accounts and current WBBA Atlas show WI Common Loon breeding distribution has shifted north associated with changes in landcover and lake trophic status in the south.

We will describe how predicted changes in Trout Lake watershed hydrology and lake trophic status will affect future loon habitat quality in the face of climate change.
Objective 1 – Develop a Wisconsin Loon Habitat Model that predicts the probability of loon lake occupancy within the breeding range by surveying 330 lakes, determining loon pair presence/absence and relating to measures of lake and habitat characteristics.

Photo: Doug Killian
Wisconsin Loons More Likely Found on Lakes with Good Water Clarity

Photo credit: Doug Killian
…of large size (>25 acres), in close proximity to other nesting loons....
…with presence of nesting habitat (wetlands or small islands).
Predicted probability of territorial loon presence based on the best fitting model for data from all three ecoregions. Each line is for one nest habitat category (excellent – solid line; good – dashed line; fair – dotted line; poor – dotted/dashed line). Numbers in the strips above each panel are the log of lake area that the predictions in the panel assume.
Objective 2 – Develop Lake Model that predicts future Secchi depth for 27 Trout Lake basin lakes as a function of climate related changes in hydrology and water column concentrations of dissolved organic carbon (DOC) and chlorophyll a.
Future Annual Temperature (Min/Max) and Precipitation for Trout Basin under 3 CO₂ Emission Scenarios
The GSFLOW model (Markstrom et al., 2008) is a coupling of the PRMS surface-water model (Fig 1a)........
and the MODFLOW ground-water flow model (Fig 1b).

Schematic diagram of the GSFLOW model showing ground-water modeling using MODFLOW. The surface- and ground-water processes are linked at the bottom of the soil-zone interface (after Markstrom et al., 2008).
Figure 2–5. Final climate-change simulations for Big Musky Lake showing precipitation minus evaporation (panel A), net groundwater inflow (panel B), net surface-water inflow (panel C) and resulting lake level (panel D).
The DOC concentration is thus calculated as

$$[DOC] = \frac{\text{Load}_{GW\&ppt} + \text{Load}_{SW} + \text{Load}_{shore}}{Z_{mean} \cdot (\text{Outflow}_{factor} + \text{Retention}_{factor})}$$

where

- $[DOC]$ is the concentration of DOC in the lake in g/m$^3$,
- $\text{Load}_{GW\&ppt}$ is the load from groundwater inflow and precipitation in g/m$^2$/y,
- $\text{Load}_{SW}$ is the load from surface-water inflow in g/m$^2$/y,
- $\text{Load}_{shore}$ is the load from the shoreline canopy in g/m$^2$/y,
- $\text{Outflow}_{factor}$ is the inverse of the outflow residence time in 1/y,
- $\text{Retention}_{factor}$ is the retention of DOC in the lake in 1/y, and
- $Z_{mean}$ is the mean depth of the lake in m.

The Chlorophyl-a concentration is calculated from total phosphorus concentration as

$$[Chl] = 10^{1.583 \log_{10}[TP] - 1.134}$$

where

- $[Chl]$ is the chlorophyll concentration in the lake in mg/m$^3$, and
- $[TP]$ is the total phosphorus concentration in the lake in mg/m$^3$.

Total secchi depth is thus calculated as

$$\text{Secchi} = \frac{1.45}{LEC_W + LEC_{DOC} \cdot [DOC] + LEC_{Chl} \cdot [Chl]}$$

where

- $\text{Secchi}$ is the secchi depth in the lake in m,
- $LEC_W$ is the light extinction coefficient of water in 1/m,
- $LEC_{DOC}$ is the light extinction coefficient of DOC in 1/m/gC/m$^3$,
- $[DOC]$ is the concentration of DOC in the lake in g/m$^3$,
- $LEC_{Chl}$ is the light extinction coefficient of chlorophyl in 1/m/mgChl/m$^3$, and
- $[Chl]$ is the concentration of chlorophyll in the lake in mgChl/m$^3$. 
Figure 2-15. Final climate-change simulations for Nichols Lake showing in-lake DOC concentrations (panel A) and resulting secchi depths for 0, 10 and 25 percent increases in average in-lake Total Phosphorus concentrations (panels B–D, respectively).
Objective 3 – Develop model that predicts the probability of loon lake occupancy in Northern Wisconsin following climate-related changes in Secchi depth and habitat quality.

Projected Trout Lake Secchi Depth
Figure A-3. Predicted probability of loon occurrence for Nebish, Nichols, Pallette, Rudolph, Sparkling and Street Lakes under 17 projected climate scenarios. For each lake listed along the x-axis, the figure gives predictions for 2010, 2050, and 2090. For each year, the open circle is the median of the 17 projections, and the vertical line extends from the minimum to the maximum of the 17 projections.
Figure A-2. Predicted probability of loon occurrence for Diamond, Edith, Fallison, Firefly, Jag and Little Rock Lakes under 17 projected climate scenarios. For each lake listed along the x-axis, the figure gives predictions for 2010, 2050, and 2090. For each year, the open circle is the median of the 17 projections, and the vertical line extends from the minimum to the maximum of the 17 projections.
Future Lake Stage - Sparkling
Figure A–8. Predicted probability of loon occurrence for Fallson, Firefly, Jag and Little Rock Lakes in the Trout Lake basin in 2050 and 2090 under 17 projected climate scenarios. Plotting symbols are median predictions for 0% change in total P (open circle), 10% increase (closed circle), and 25% increase (x). Vertical bars extend from the minimum to the maximum of the projections for the 17 climate scenarios. For each year (2050 and 2090), predictions are shown for a 1 step decrease in nesting habitat (leftmost), unchanged habitat (central), and a 1 step increase in nesting habitat (rightmost). The horizontal dotted line is the median of predictions for each lake in 2010.
Conclusions

Climate-related reductions in water clarity will not occur in the Trout Lake watershed. Mineralization of water column dissolved organic carbon is predicted to increase under warmer climatic conditions, resulting in increased water clarity, even with a simulated increase in total phosphorus of 25%.

This will result in a small increase in predicted loon occupancy probability at the 27 lakes within the Trout Lake basin – however this small increase is offset by simulated changes in nest habitat quality.

Protection of existing nesting habitat is critical to the conservation of common loons in northern Wisconsin.
Acknowledgements

Kathy Bibby, Pete Boma, Luke Fara, Tim Fox, Brian Gray, Jenny Hanson, Steve Houdek, Bob Kratt, Larry Robinson, Administrative staff, USGS, Upper Midwest Environmental Sciences Center

Darryl Heard, College of Veterinary Medicine, UW-Florida

Brian Lubinski, John Bidwell, US Fish and Wildlife Service

Mike Meyer, Brick Fevold, Doug Killian, Wisconsin Dept. of Natural Resources

Carrol Hendersen and staff, Minnesota Dept. of Natural Resources

Jeff Wilson, Terry Daulton, Mercer, WI

Faculty/staff, St. Johns University, Minnesota

USGS Great Lakes Science Center, National Wildlife Health Laboratory, Michigan Water Science Center