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


Photo credit
Doug Killian

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1. USGS, Middleton, WI
2. USGS, LaCrosse, WI
3. WDNR, Rhinelander, WI
4. WDNR, Madison, WI
5. UW-Madison Limnology

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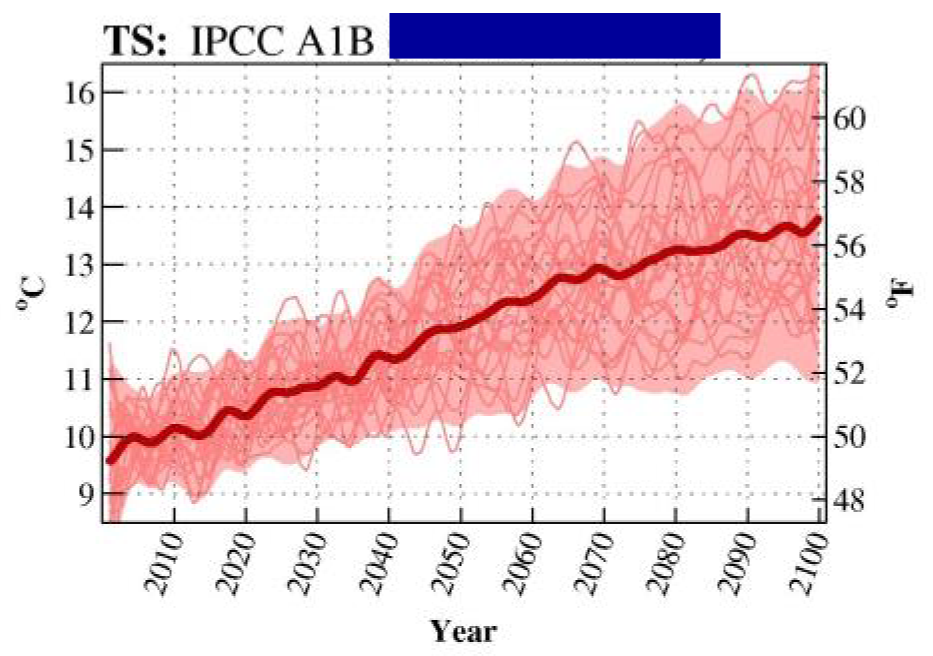
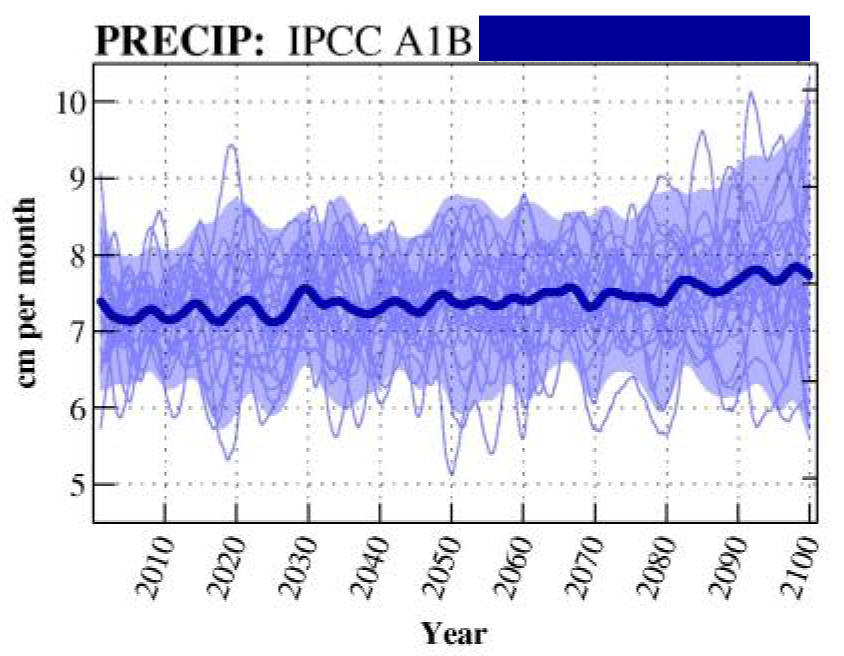
Climate Change in Wisconsin

What do the models tell us?





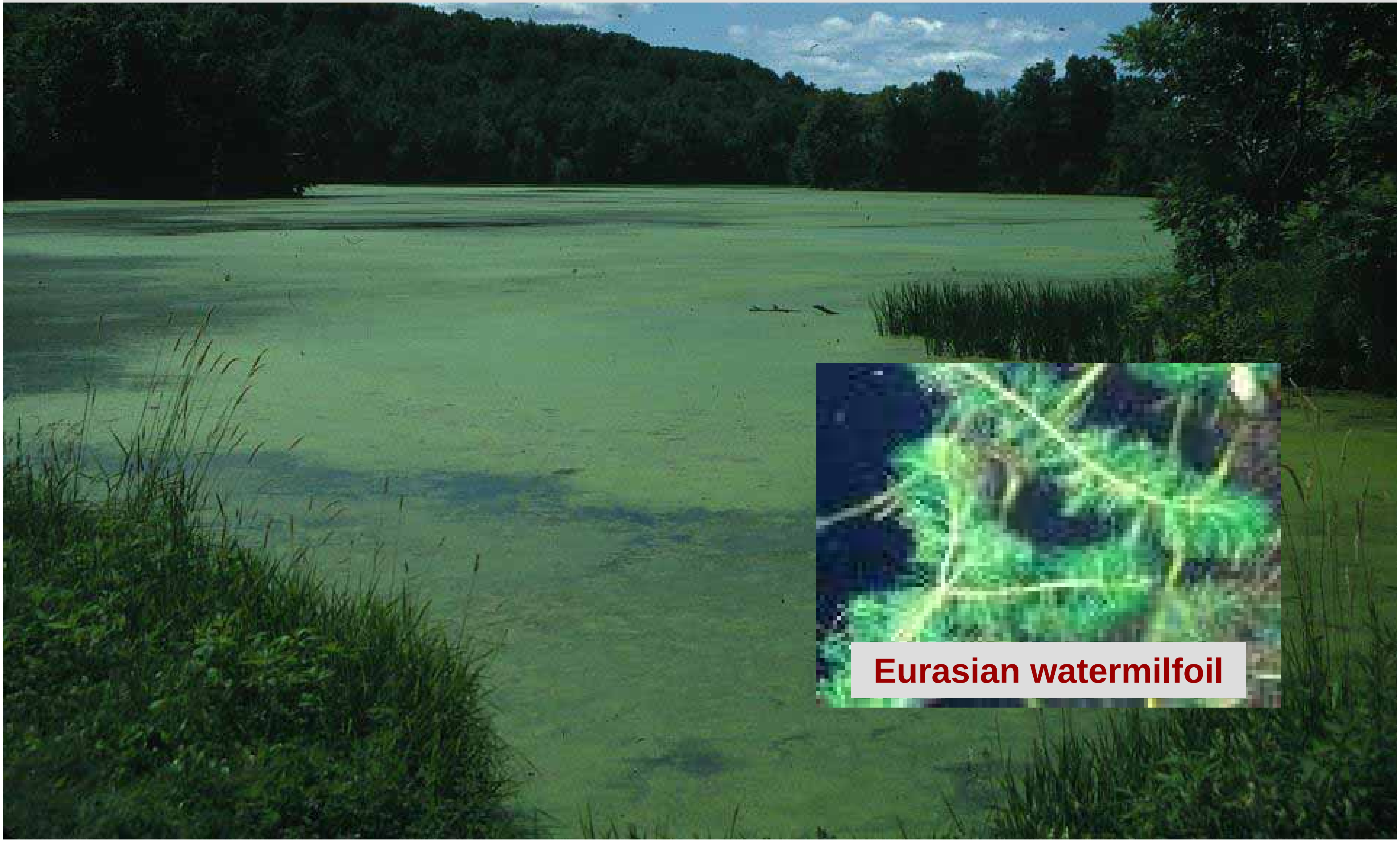
Temperature:
Warms by 2-6°C (3-10°F)
by end of century

Precipitation:
Less certain;
seasonally dependent


Water Sports In The Green Slime
Toxic Algae Blooms
Lake Erie | Now

Will changing temperatures and precipitation alter hydrology of northern Wisconsin lakes?

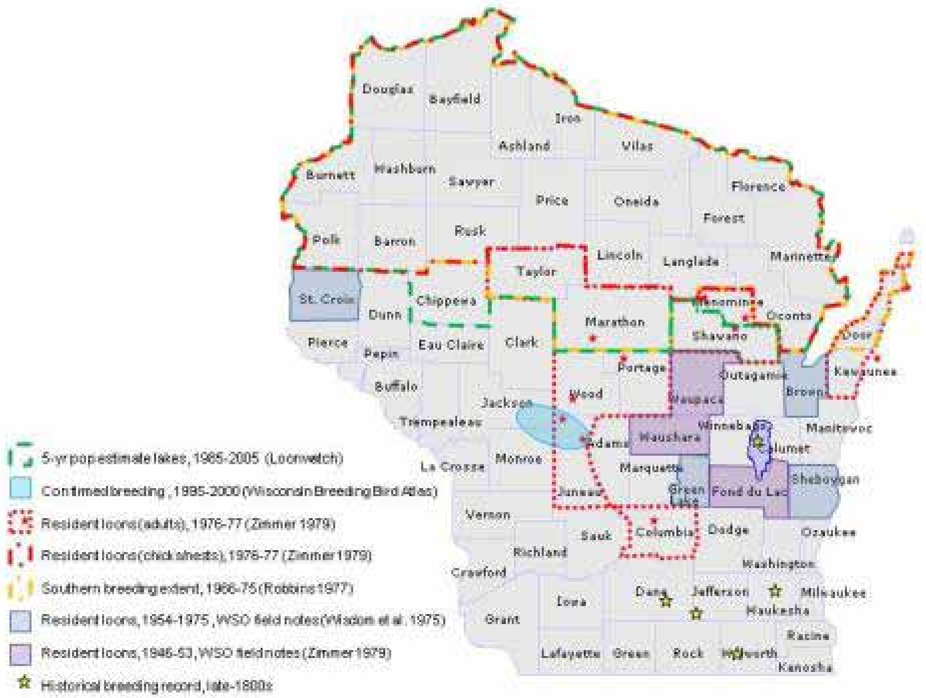
Negatives: Poorer water quality, more nuisance exotics



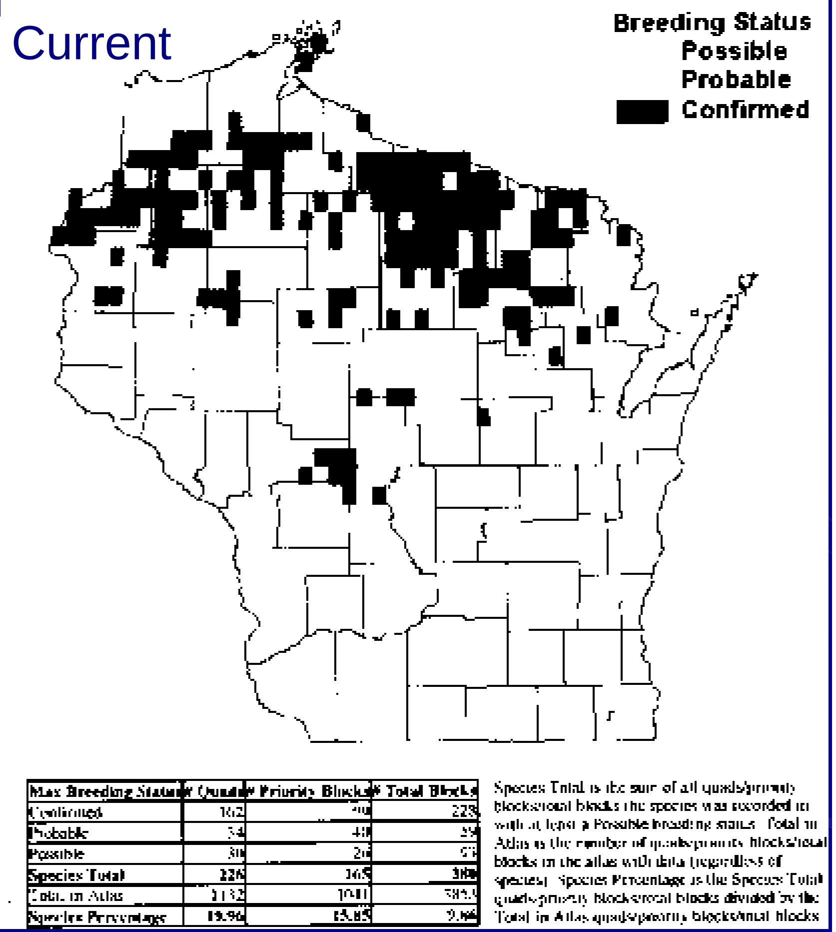
Eurasian watermilfoil

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

Historic



Current



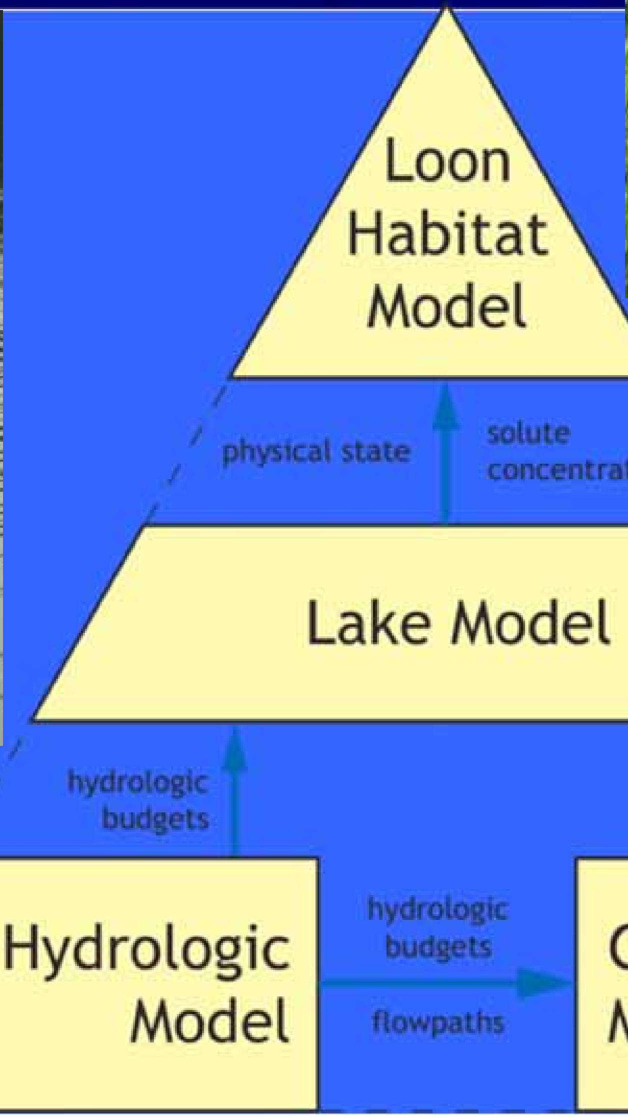
Max Breeding Status	# Quads	# Priority Blocks	# Total Blocks
Confirmed	162	[illegible]	228
Probable	34	40	39
Possible	30	26	[illegible]
Species Total	226	165	[illegible]
Total in Atlas	1132	1041	[illegible]
Species Percentage	19.96	15.85	[illegible]

Species Total is the sum of all quads/priority blocks/total blocks the species was recorded in with at least a Possible breeding status. Total in Atlas is the number of quads/priority blocks/total blocks in the atlas with data (regardless of species). Species Percentage is the Species Total quads/priority blocks/total blocks divided by the Total in Atlas quads/priority blocks/total blocks.

Kenow KP, Garrison P, Fox TJ, Meyer MW. 2013. Historic distribution of common loons in Wisconsin in relation to changes in lake characteristics and surrounding land use. The Passenger Pigeon 75(4):375-389

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

Photo: Doug Killian



Loon Habitat Model

physical state

solute concentrations

Lake Model

hydrologic budgets

solute fluxes

Hydrologic Model

hydrologic budgets

flowpaths

Geochemical Model

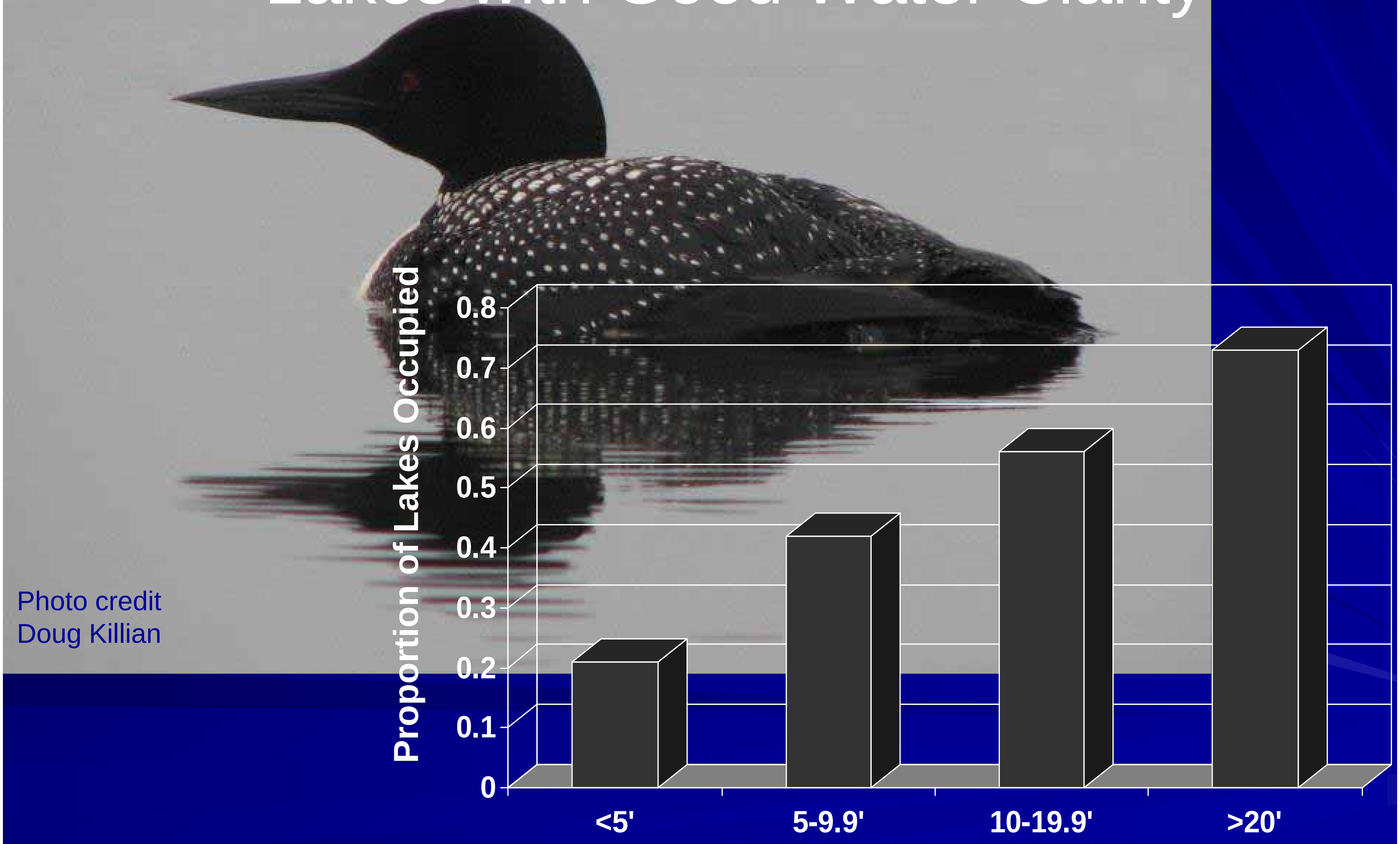
Photo: Doug Killian

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


Photo: Doug Killian

Wisconsin Loons More Likely Found on Lakes with Good Water Clarity



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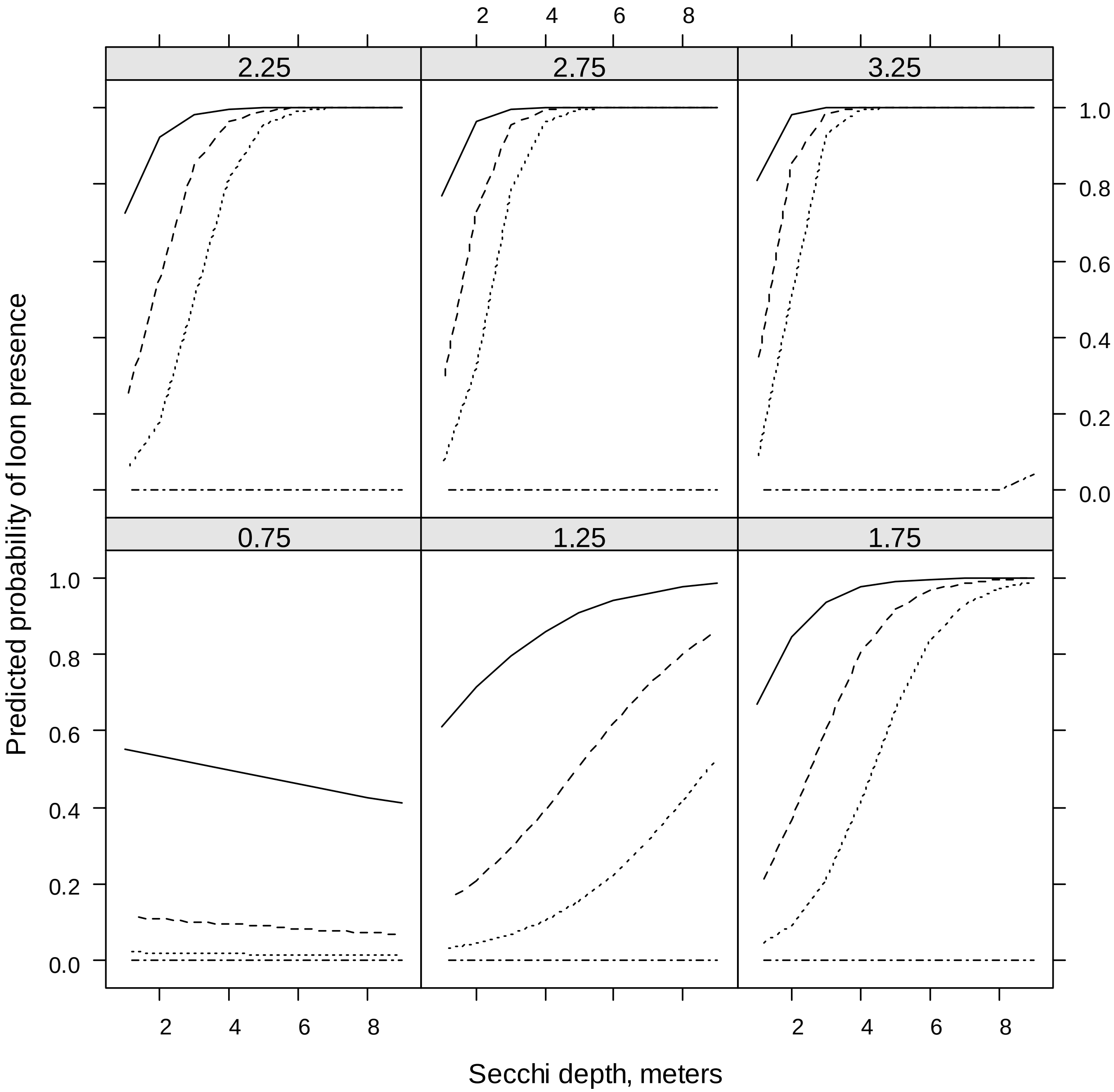
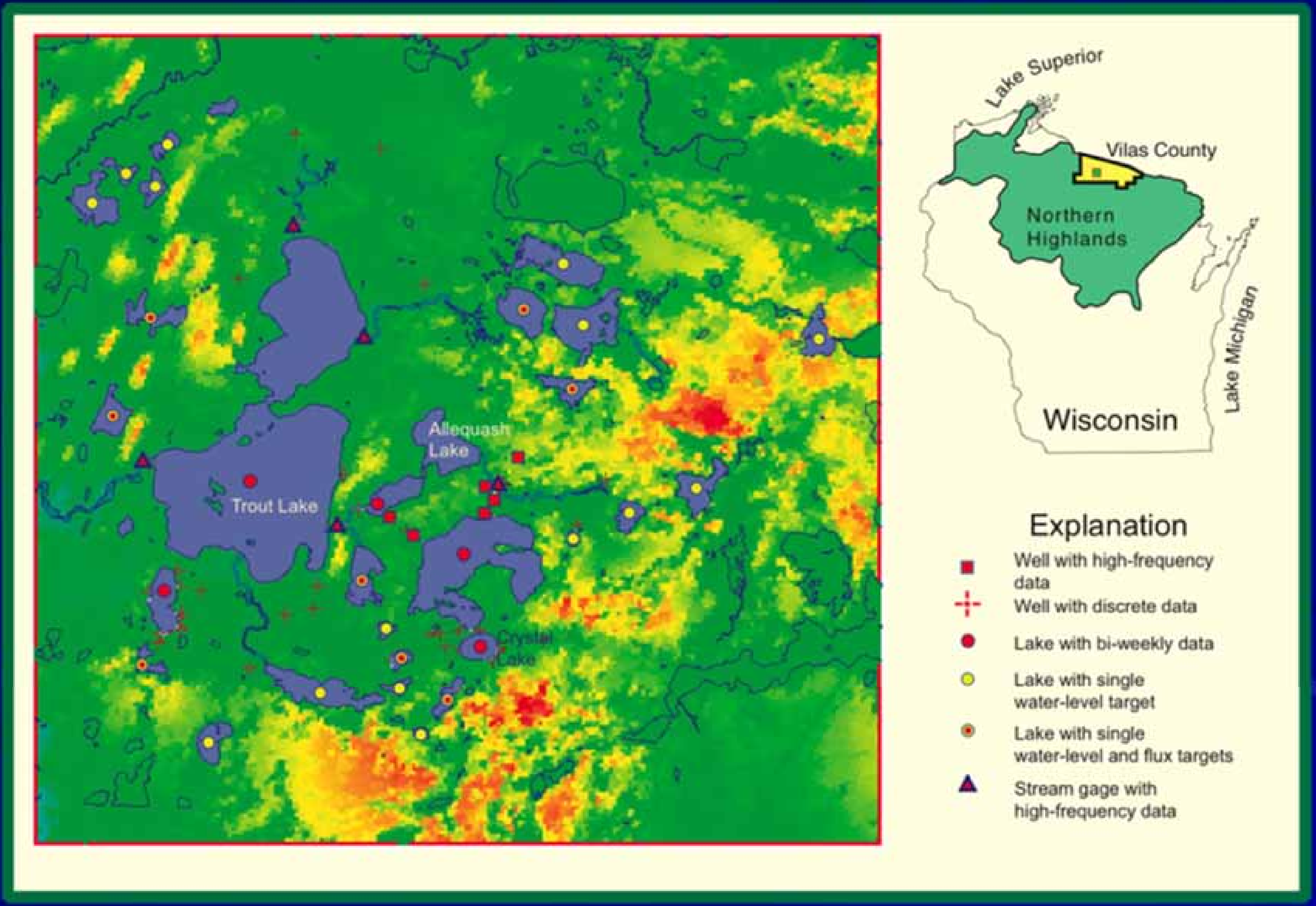
…of large size (>25 acres), in close proximity to other nesting loons….

…with presence of nesting habitat (wetlands or small islands).

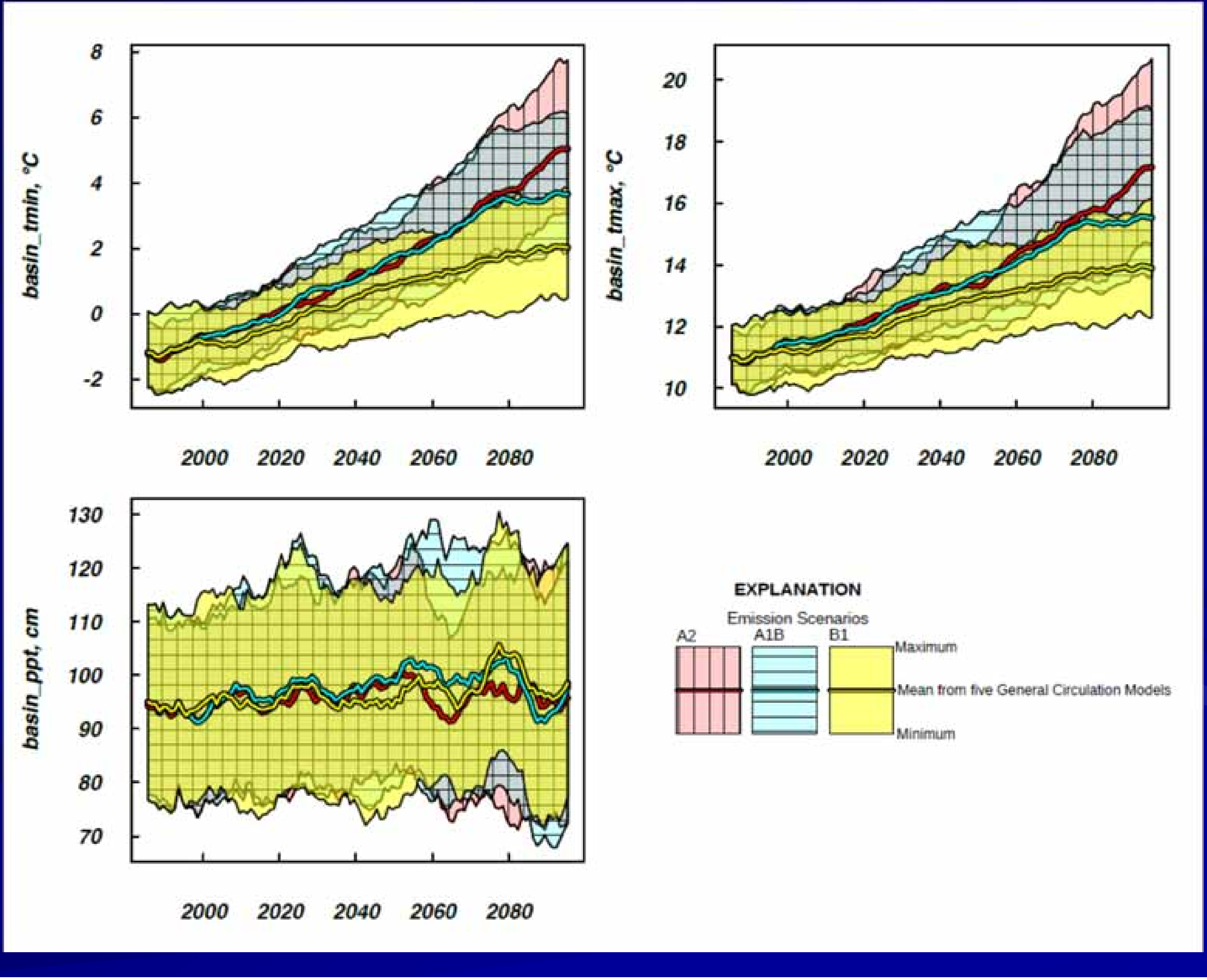


Predicted probability of territorial loon presence based on the best fitting model for data from all three ecoregions. Each line is for one nest habitat category (excellent – solid line; good – dashed line; fair – dotted line; poor – dotted/dashed line). Numbers in the strips above each panel are the log of lake area that the predictions in the panel assume.

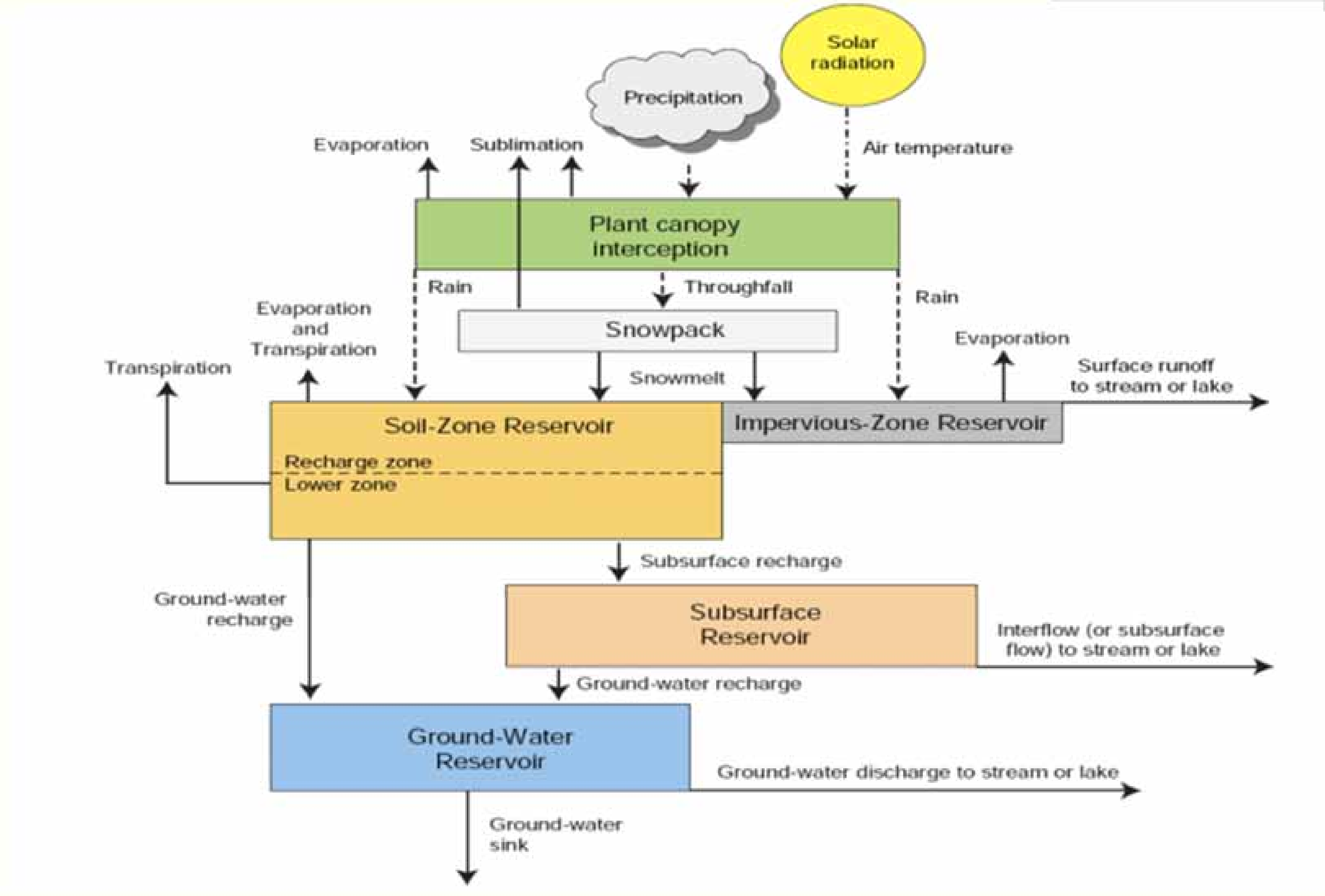
Objective 2 – Develop Lake Model that predicts future Secchi depth for 27 Trout Lake basin lakes as a function of climate related changes in hydrology and water column concentrations of dissolved organic carbon (DOC) and chlorophyll a.



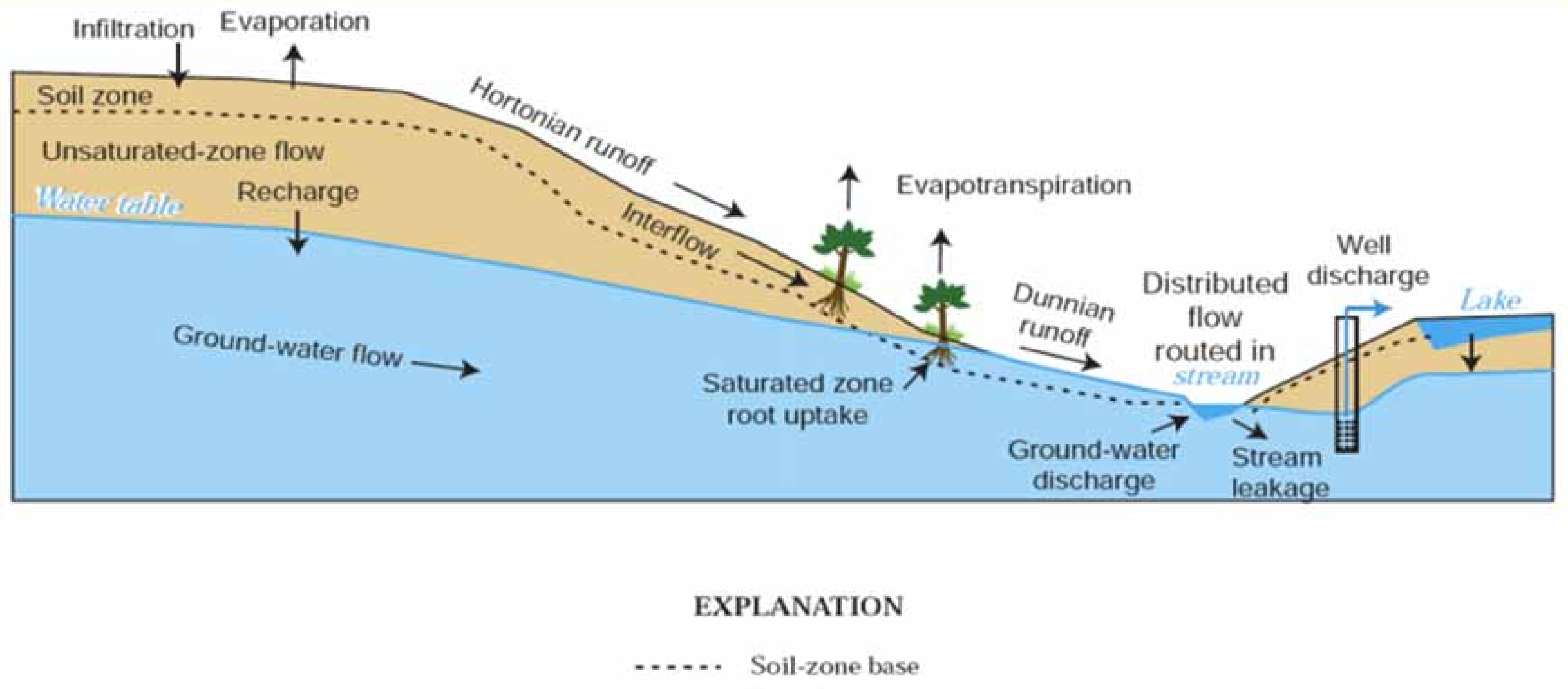
Future Annual Temperature (Min/Max) and Precipitation for Trout Basin under 3 CO_2 Emission Scenarios



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).

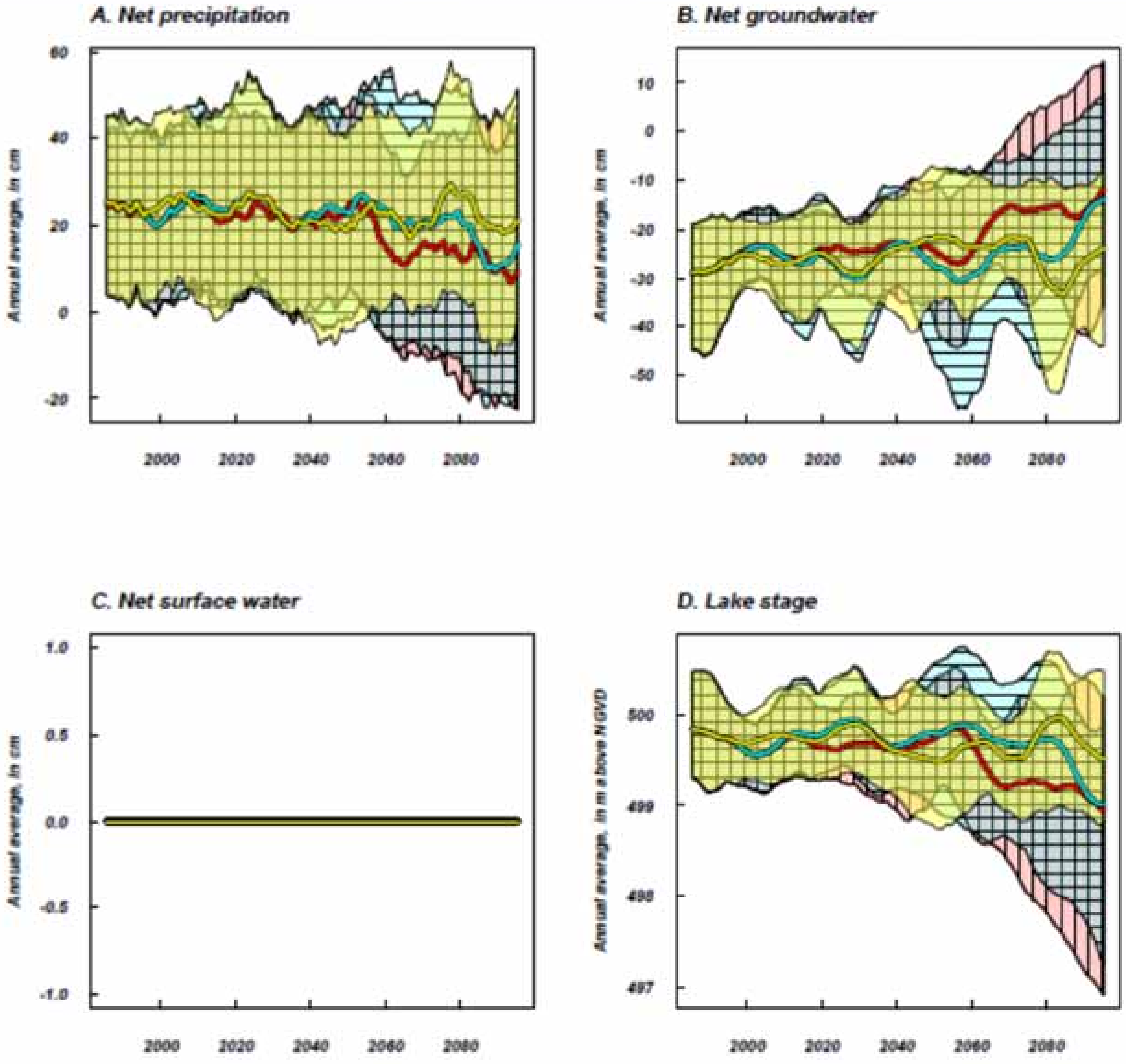


Figure 2–5. Final climate-change simulations for Big Musky Lake showing precipitation minus evaporation (panel A), net groundwater inflow (panel B), net surface-water inflow (panel C) and resulting lake level (panel D)

The DOC concentration is thus calculated as

$$[DOC] = \frac{Load_{GW\&ppt} + Load_{SW} + Load_{shore}}{Z_{mean} \bullet \left(Outflow_{factor} + Retention_{factor}\right)}$$

where

$[DOC]$ is the concentration of DOC in the lake in g/m^3,
$Load_{GW\&ppt}$ is the load from groundwater inflow and precipitation in g/m^2/y,
$Load_{SW}$ is the load from surface-water inflow in g/m^2/y,
$Load_{shore}$ is the load from the shoreline canopy in g/m^2/y,
$Outflow_{factor}$ is the inverse of the outflow residence time in 1/y,
$Retention_{factor}$ is the retention of DOC in the lake in 1/y, and
Z_{mean} is the mean depth of the lake in m.
T is the average annual temperature in °C.

The Chlorophyll-a concentrarion is calculated from total phosphorus concentration as

$$[Chl] = 10^{\left(1.583 \log_{10}[TP] - 1.134\right)}$$

where

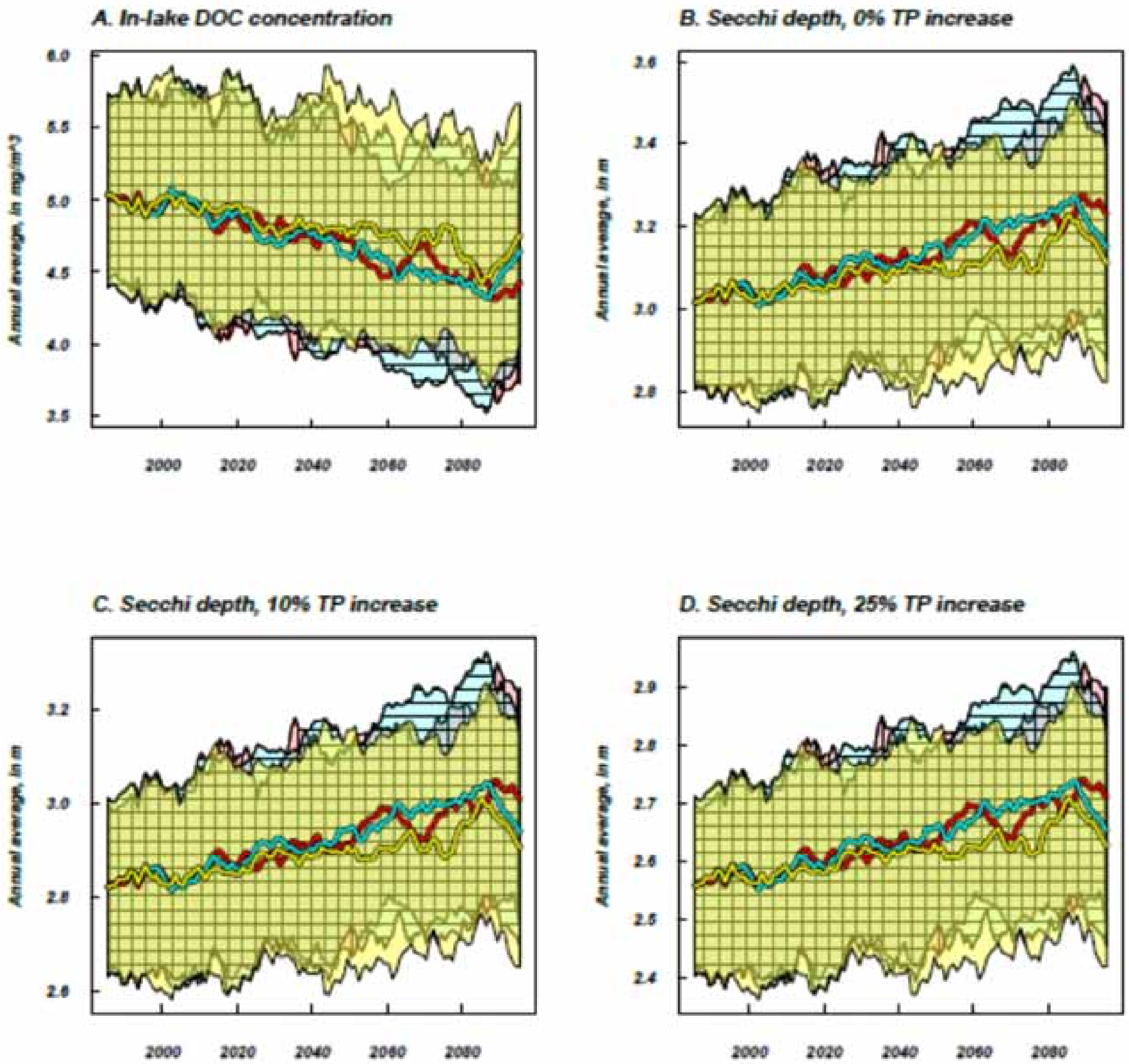
$[Chl]$ is the chlorophyl concentration in the lake in mg/m^3, and
$[TP]$ is the total phosphorus concentration in the lake in mg/m^3.

Total secchi depth is thus calculated as

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

where

$Secchi$ 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 chlorophyl in the lake in mgChl/m^3,



A. In-lake DOC concentration

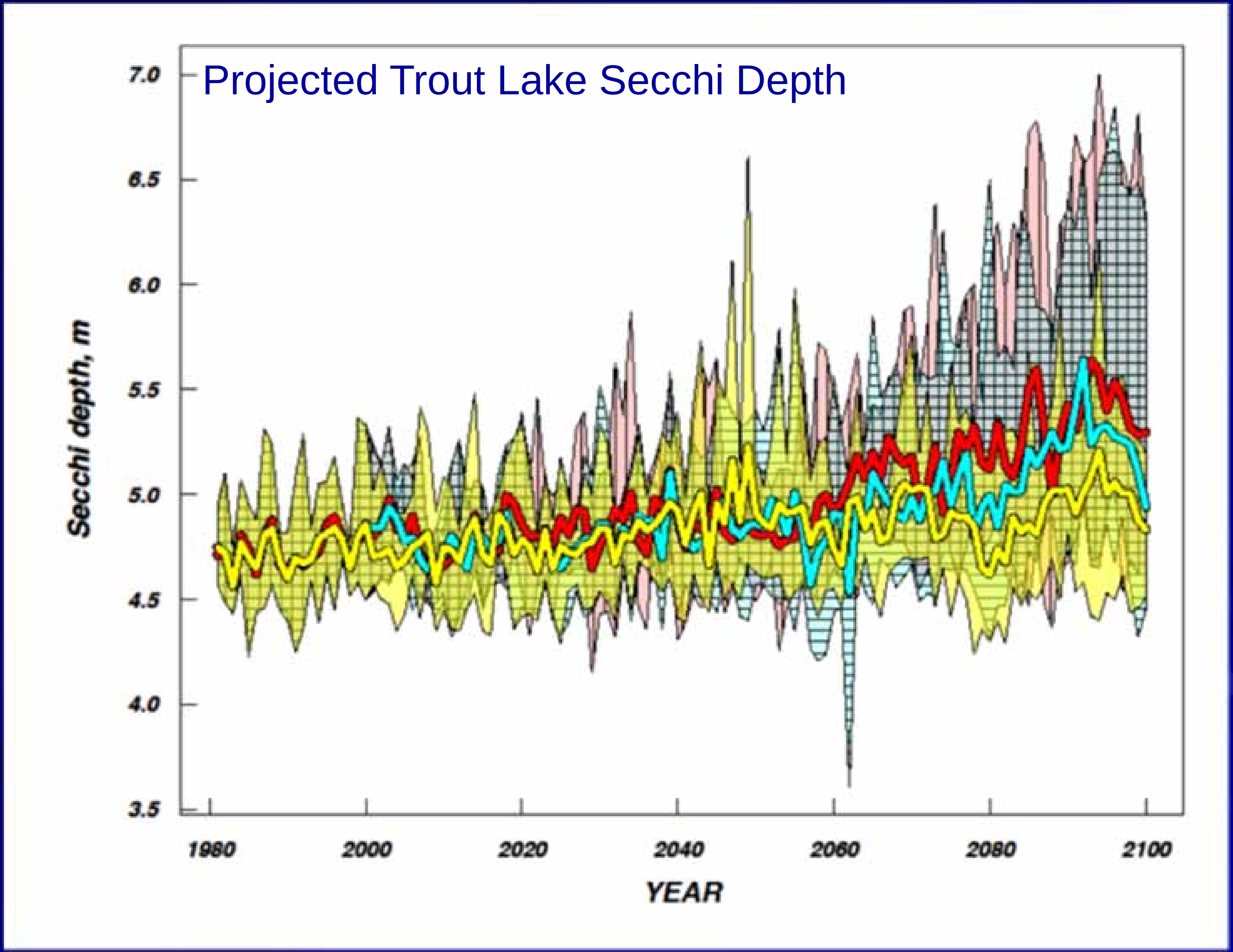
B. Secchi depth, 0% TP increase

C. Secchi depth, 10% TP increase

D. Secchi depth, 25% TP increase

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.



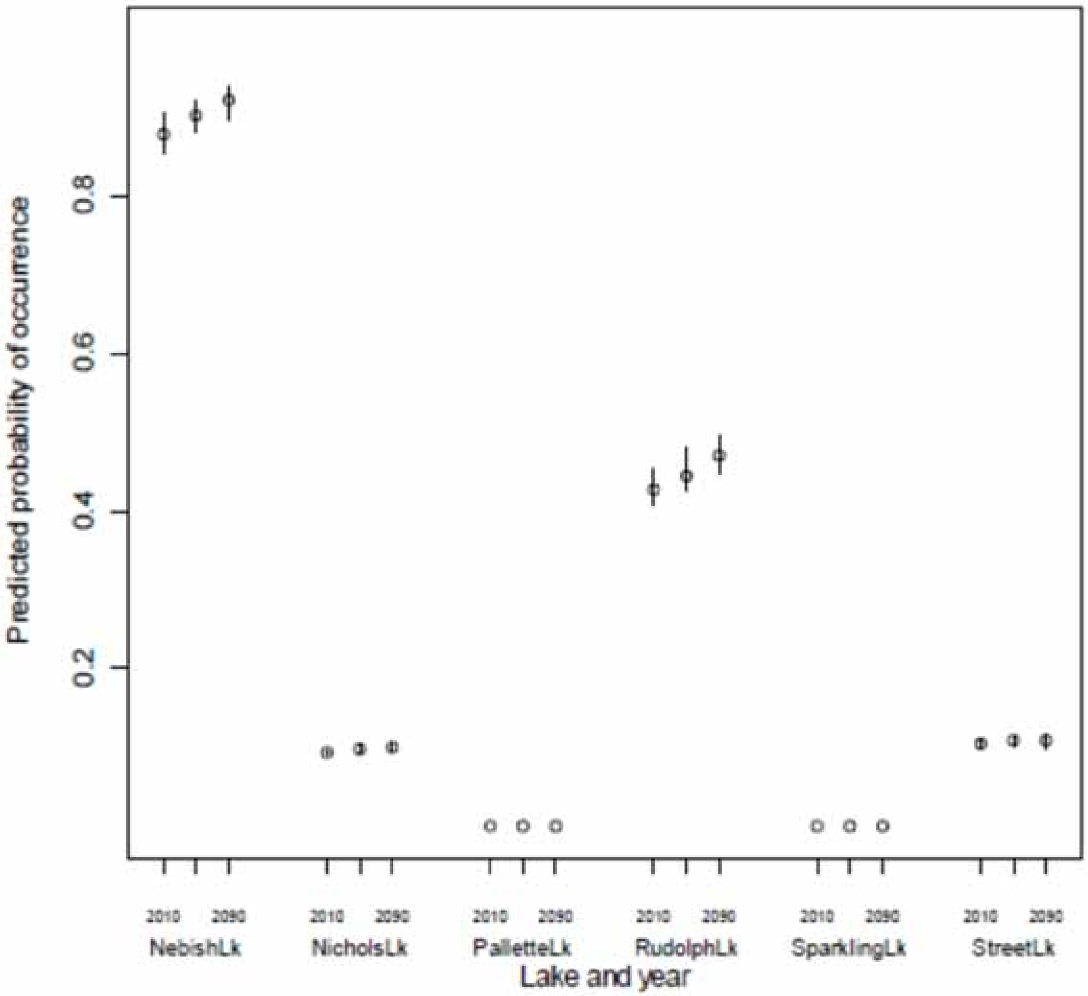


Figure A–3. Predicted probability of loon occurrence for Nebish, Nichols, Pallette, Rudolph, Sparkling and Street Lakes under 17 projected climate scenarios. For each lake listed along the x-axis, the figure gives predictions for 2010, 2050, and 2090. For each year, the open circle is the median of the 17 projections, and the vertical line extends from the minimum to the maximum of the 17 projections.

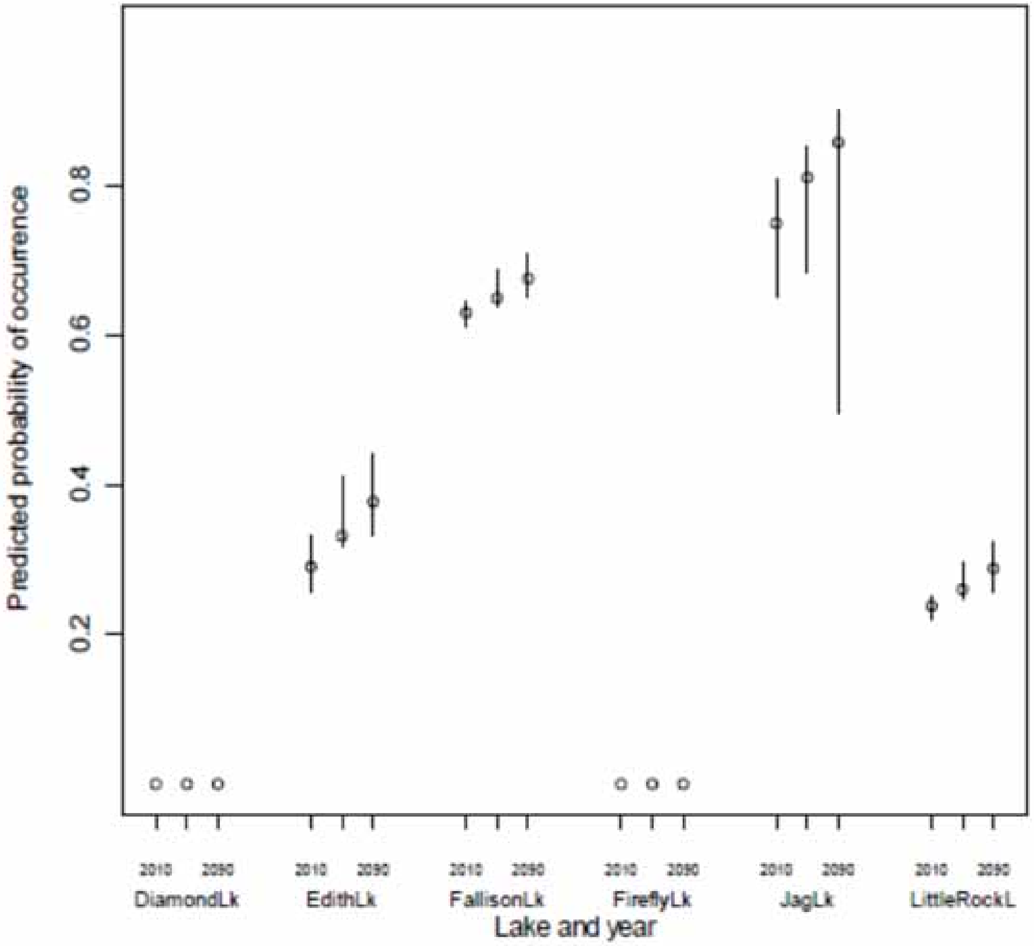
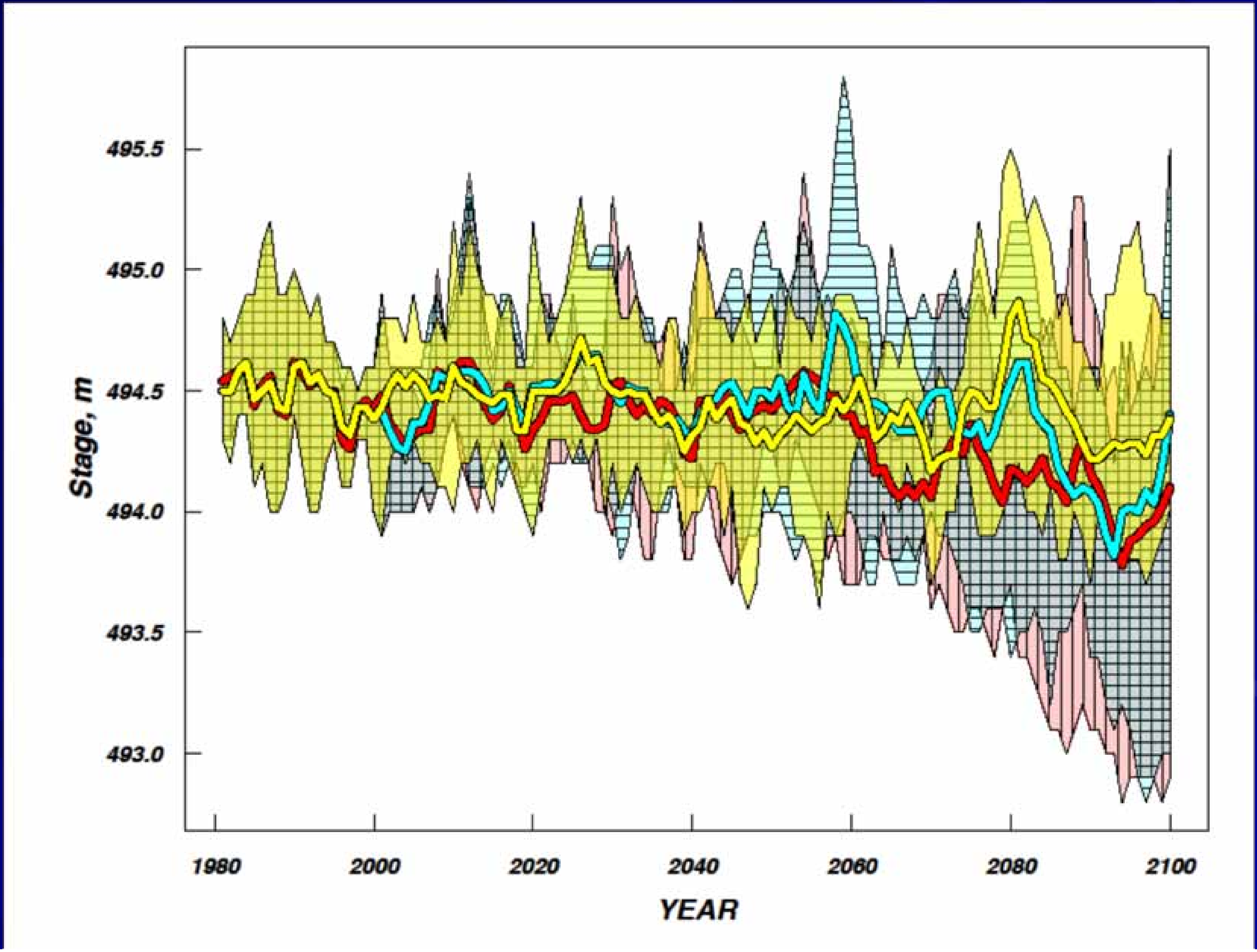


Figure A–2. Predicted probability of loon occurrence for Diamond, Edith, Fallison, Firefly, Jag and Little Rock Lakes under 17 projected climate scenarios. For each lake listed along the x-axis, the figure gives predictions for 2010, 2050, and 2090. For each year, the open circle is the median of the 17 projections, and the vertical line extends from the minimum to the maximum of the 17 projections.

Future Lake Stage - Sparkling



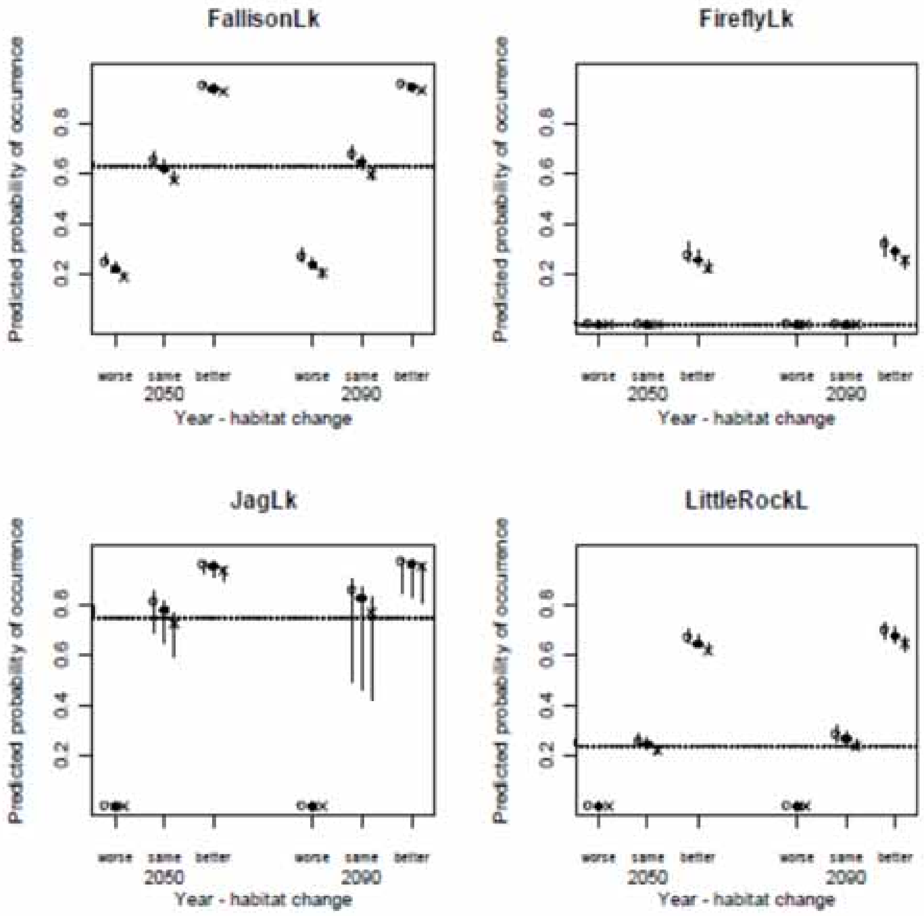


Figure A-8. Predicted probability of loon occurrence for Fallison, Firefly, Jag and Little Rock Lakes in the Trout Lake basin in 2050 and 2090 under 17 projected climate scenarios. Plotting symbols are median predictions for 0% change in total P (open circle), 10% increase (closed circle), and 25% increase (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

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