# Exploring the Role of Nutrients, Predator Stocking, and Climate Change on Fisheries Production in Lakes Michigan and Huron, North America


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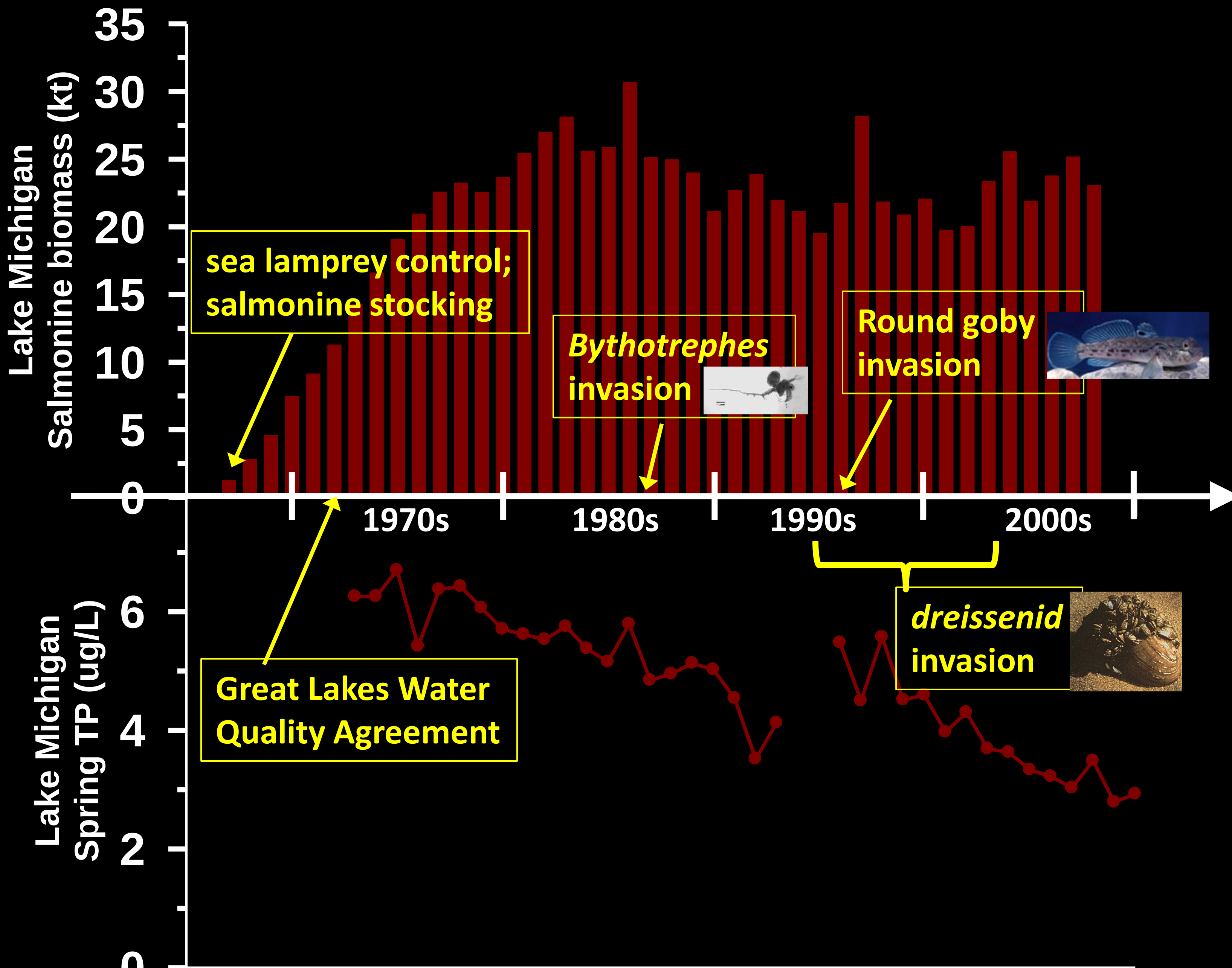
# Key Drivers in the Great Lakes

1. Nutrient inputs (Agricultural run-off, non-point sources near cities)

2. Invasive species (Transportation- ballast water)

3. Fisheries management (stocking)

4. Climate



Lake Michigan
Salmonine biomass (kt)
35
30
25
20
15
10
5
0
sea lamprey control;
salmonine stocking
Bythotrephes
invasion
Round goby
invasion
1970s
1980s
1990s
2000s
Lake Michigan
Spring TP (ug/L)
6
4
2
0
Great Lakes Water
Quality Agreement
dreissenid
invasion

# Today’s presentation

1. **Evidence of resource limitation (reduction of nutrient loading) or top-down control (predator stocking)?**

2. **How will future climate influence fish growth?**

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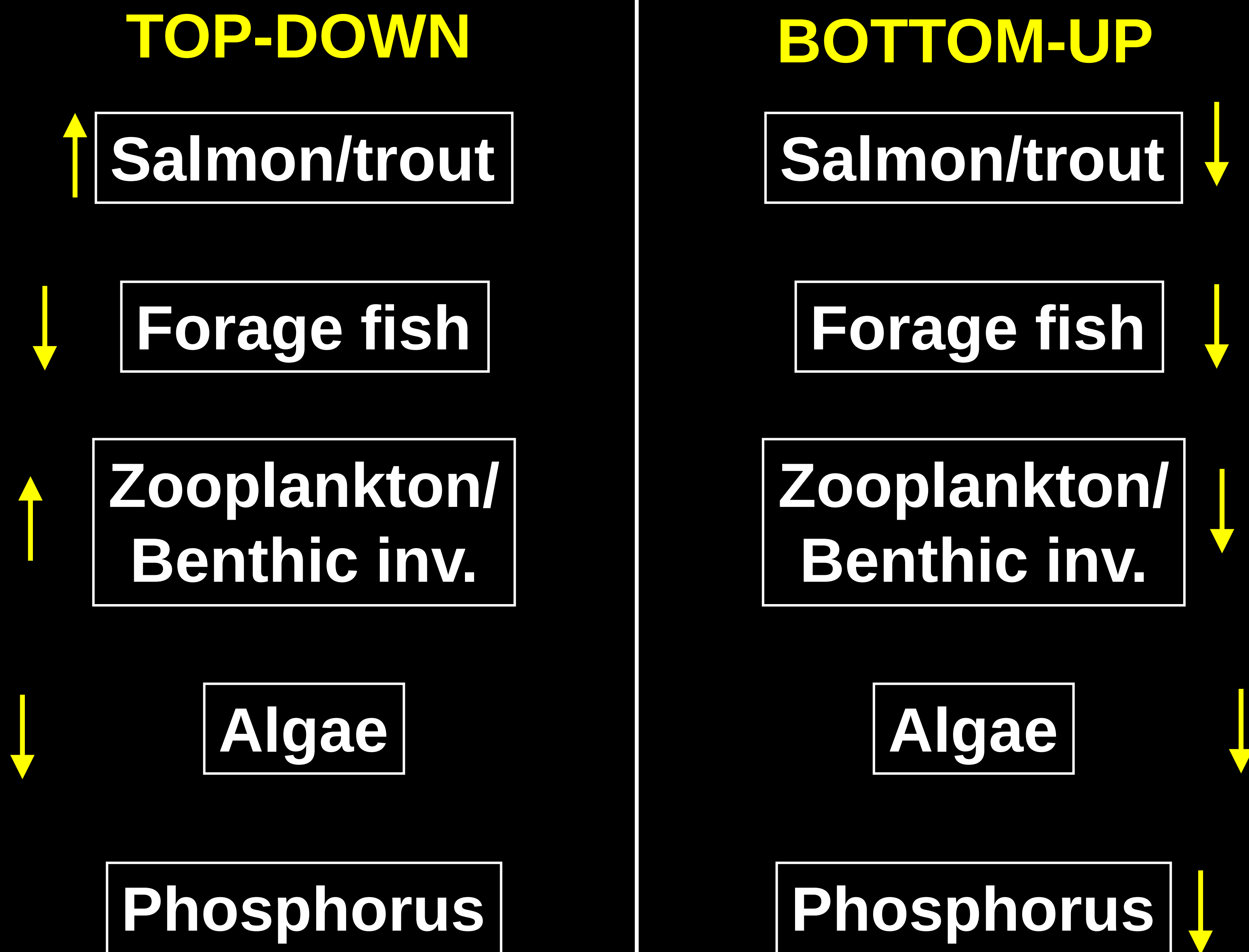
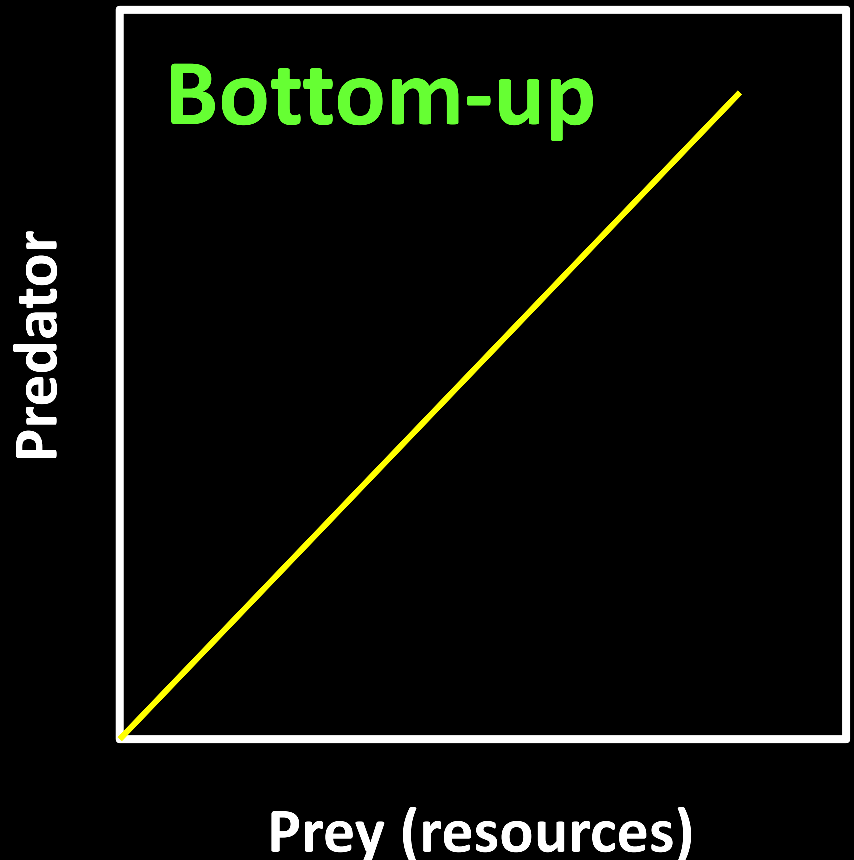
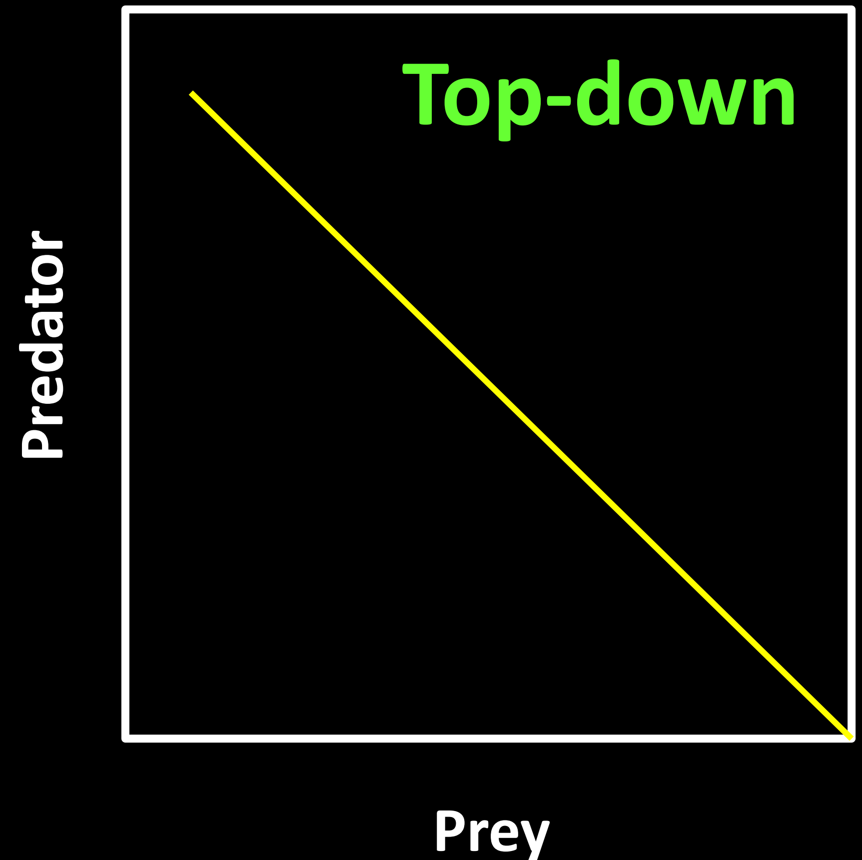

TOP-DOWN
Salmon/trout
Forage fish
Zooplankton/
Benthic inv.
Algae
Phosphorus
BOTTOM-UP
Salmon/trout
Forage fish
Zooplankton/
Benthic inv.
Algae
Phosphorus

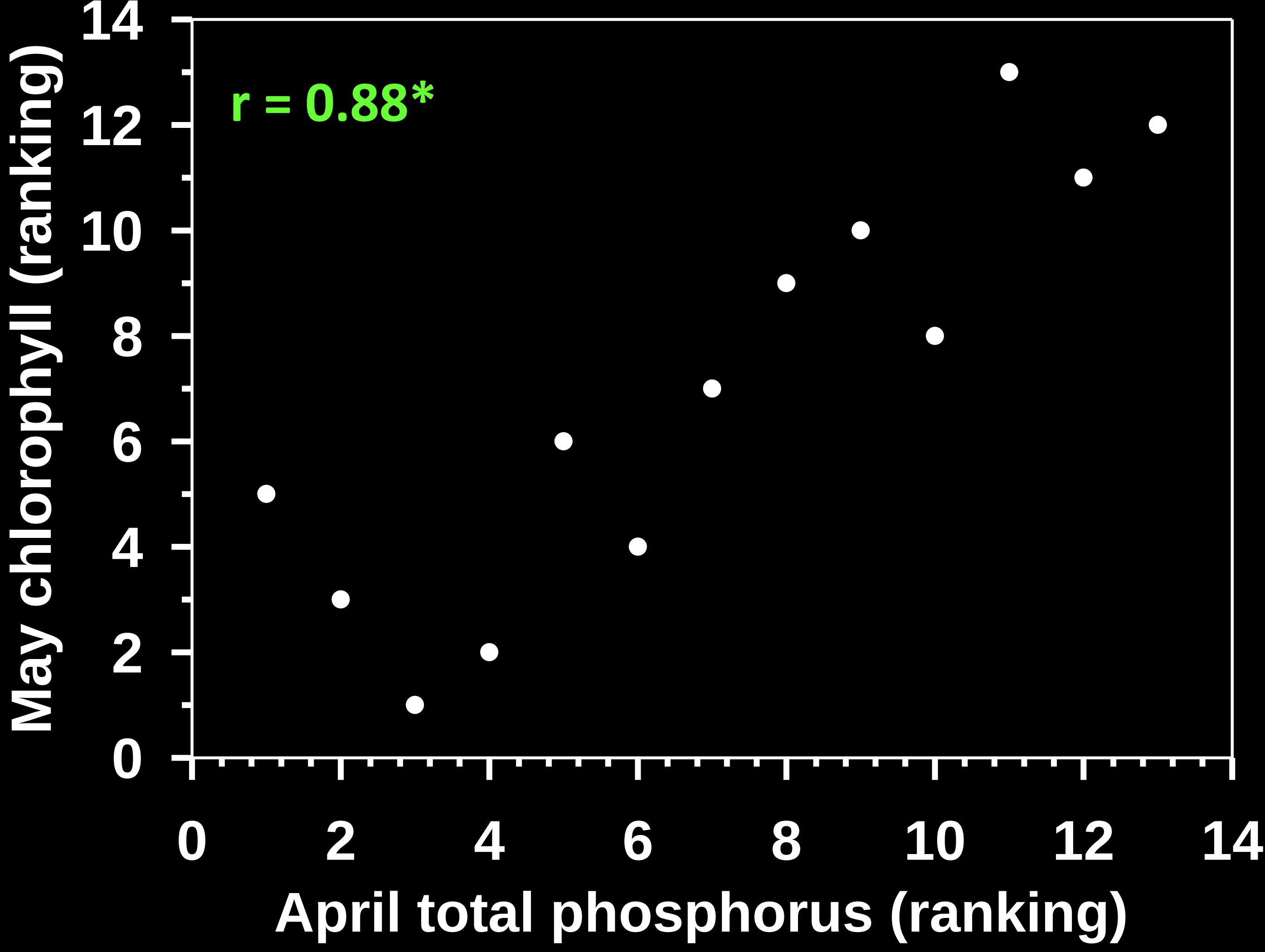
# Methods

- Compiled data on nutrients, and all trophic levels (plankton to fish) back to earliest common date (1998).
- Ran correlations on ranked data (data = non-normal).

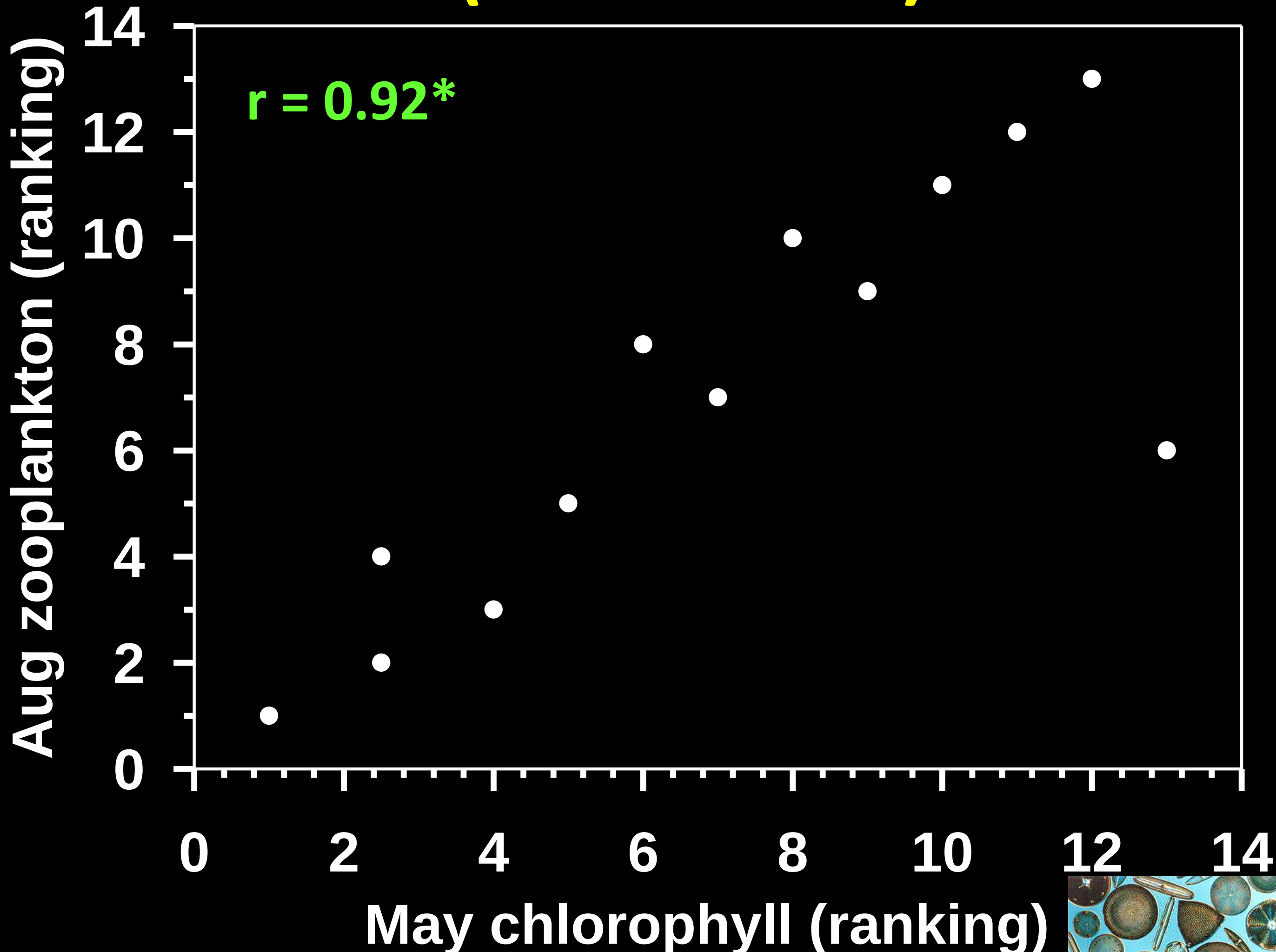


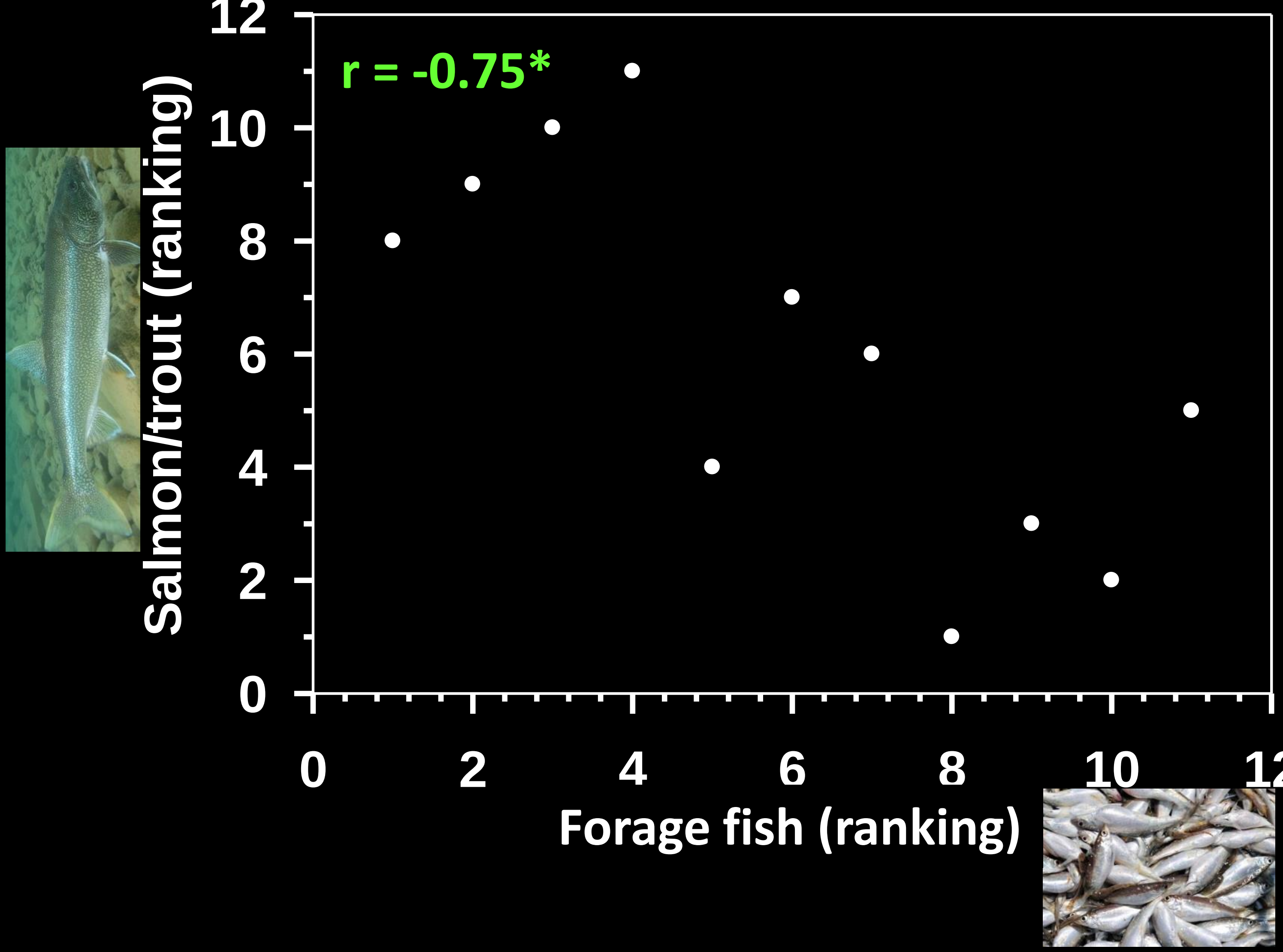
# Bottom-up control of phytoplankton (Lake Michigan)



# Bottom-up control of zooplankton (Lake Huron)




# Top-down effect of salmon/trout on forage fish (Lake Michigan)



# Common trophic interactions across lakes

| | Huron | Michigan |
|---|---|---|
| Phytoplankton | Bottom-up,Top-down | Bottom-up,Top-down |
| Zooplankton | Bottom-up | Bottom-up |
| Forage fish | Bottom-up | Bottom-up,Top-down |
| Piscivores | Bottom-up | |

Bunnell et al. (2014) *BioScience*

# Today's presentation

1. Evidence of resource limitation (reduction of nutrient loading) or top-down control (predator stocking)?

2. How will future climate influence fish growth?

# Methods

- Developed down-scaled climate model for the Great Lakes. Forecasted vertical water temperature from 2043-2070.

- Assumed that fish would occupy their physiological optimum temperature, if available.

- Bioenergetics models results for a coolwater (yellow perch) and coldwater (lake whitefish) fish.

- Had to assume different levels of prey fish densities: Low; Constant (1964-1993); Maximum.

# Results

- **Both species had > 30 additional days in 2043-2070 than in 1964-1993 when they occupied optimal temperature.**

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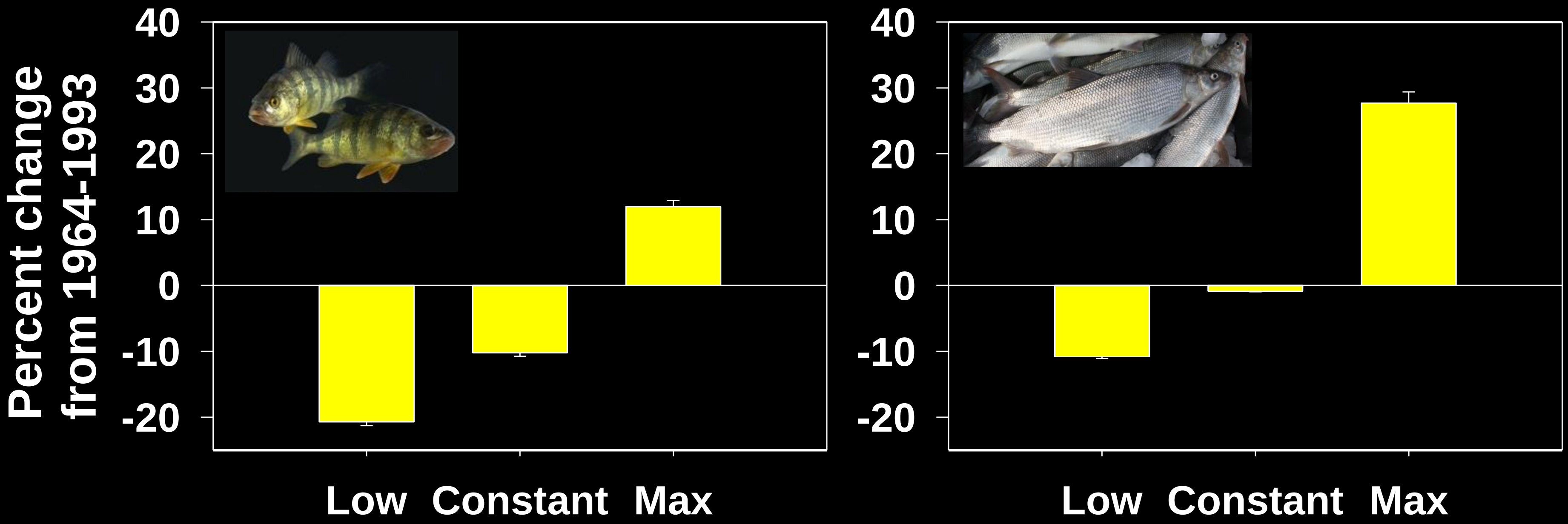
- **Both species had > 30 additional days in 2043-2070 than in 1964-1993 when they occupied optimal temperature.**
- **Because of higher metabolic costs, growth WAS NOT higher unless more food was available.**




Kao et al. (in press) *J. Great Lakes Res.*

# Conclusions: Interacting drivers

- **Reductions in nutrient inputs and invasive mussels are limiting plankton production.**
- **Forage fish squeezed by both top-down forces (stocking and naturalization of top predators) and bottom-up (less invertebrate prey).**
- **Future climate <u>not</u> likely to benefit cool- or cold-water fish unless prey densities increase.**

# Funding:

USGS
science for a changing world

National Climate Change Wildlife Science Center

Great Lakes RESTORATION