Food web and landscape approaches to aquatic conservation

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Drivers of aquatic ecosystem change

Invasive species

Harvest

Agricultural pollution

Climate change

Outline

Food web

Addressing questions at broader spatial and temporal scale (landscape)

Conservation

Application of science to environmental management

-Prevention (invasive species, nutrient pollution)
-Restoration (Great Lakes)
-Preservation (Mongolia)

Stable isotope food web studies

Applications to basic research questions

-Importance of benthic production in lakes
-Land-lake linkages

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Food webs

- Food web represents predator-prey (trophic) relationships
- Value of a food web perspective in understanding species dynamics, ecosystem management, restoration, conservation

Food webs

Many different views of food webs!!

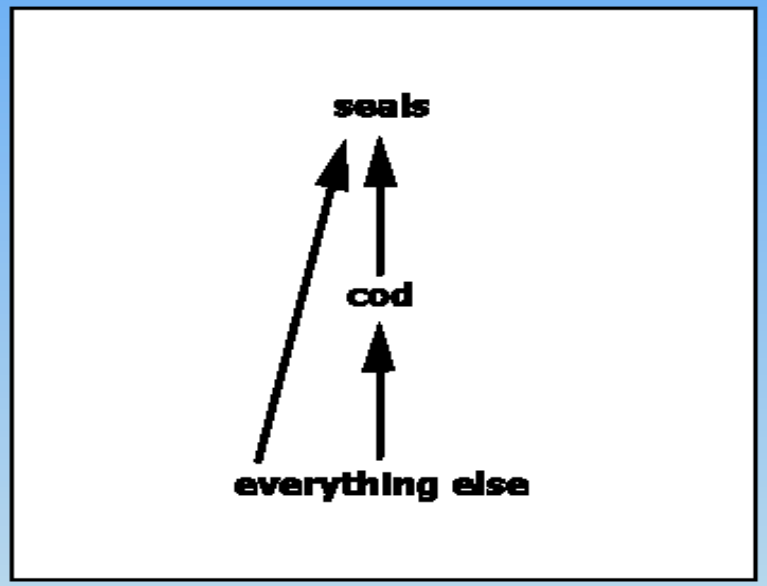


Figure 1. A food web of the North Atlantic
From Yodzis (1996)

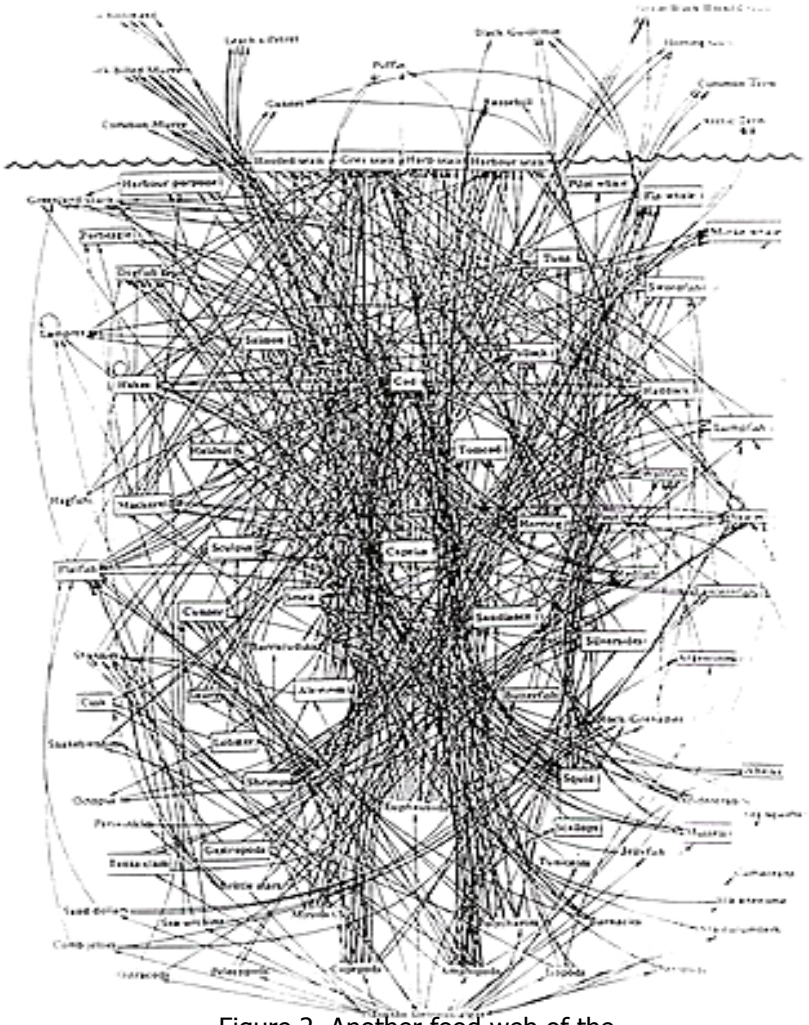


Figure 2. Another food web of the
North Atlantic From Yodzis (1996)

Approach to quantifying food webs: stable isotopes

Valuable ecological information from biological tissues

$\delta^{15}N$ ($^{15}N/^{14}N$) - 3.4‰ ± 0.4 enrichment per trophic level

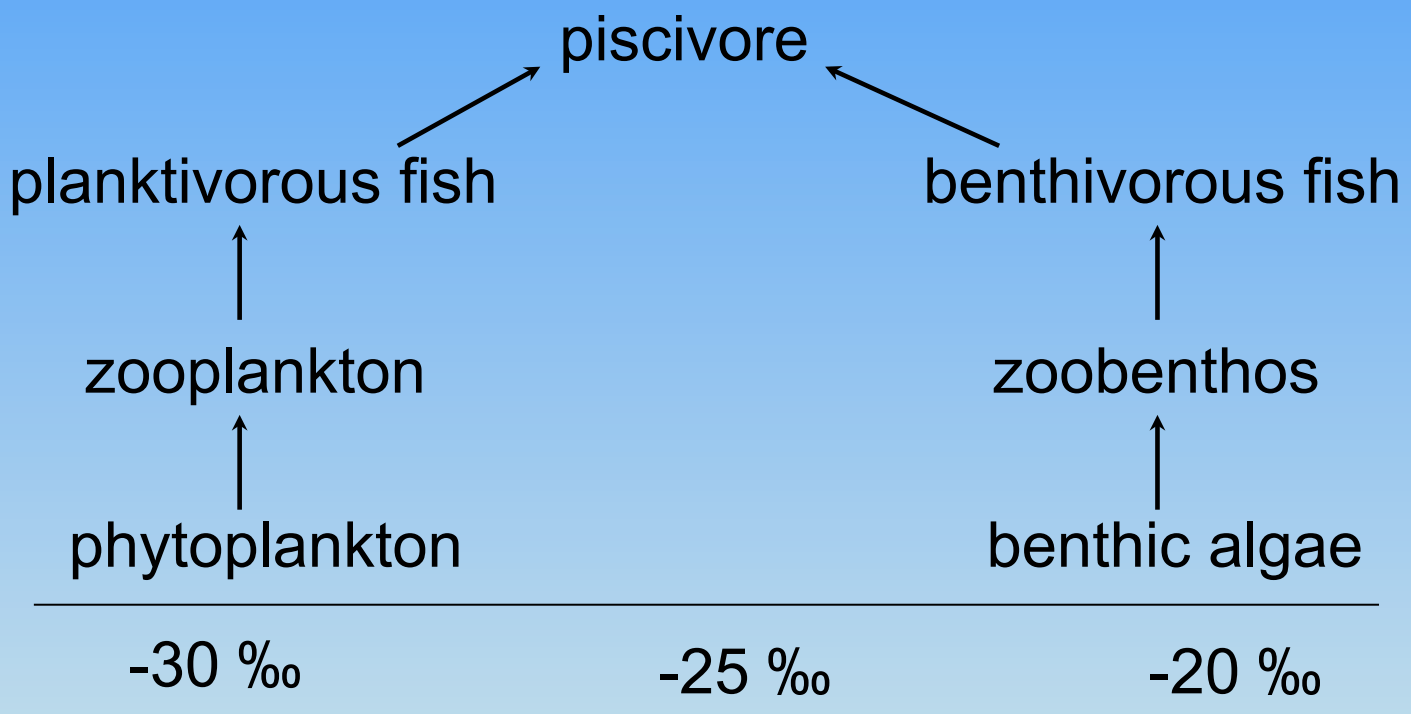
Indicator of consumer trophic position

ORGANISM	**$\delta^{15}N$**
Top predator	10.2 ‰
Planktivore	6.8 ‰
Zooplankton	3.4 ‰
Phytoplankton	0 ‰

Approach to quantifying food webs: stable isotopes

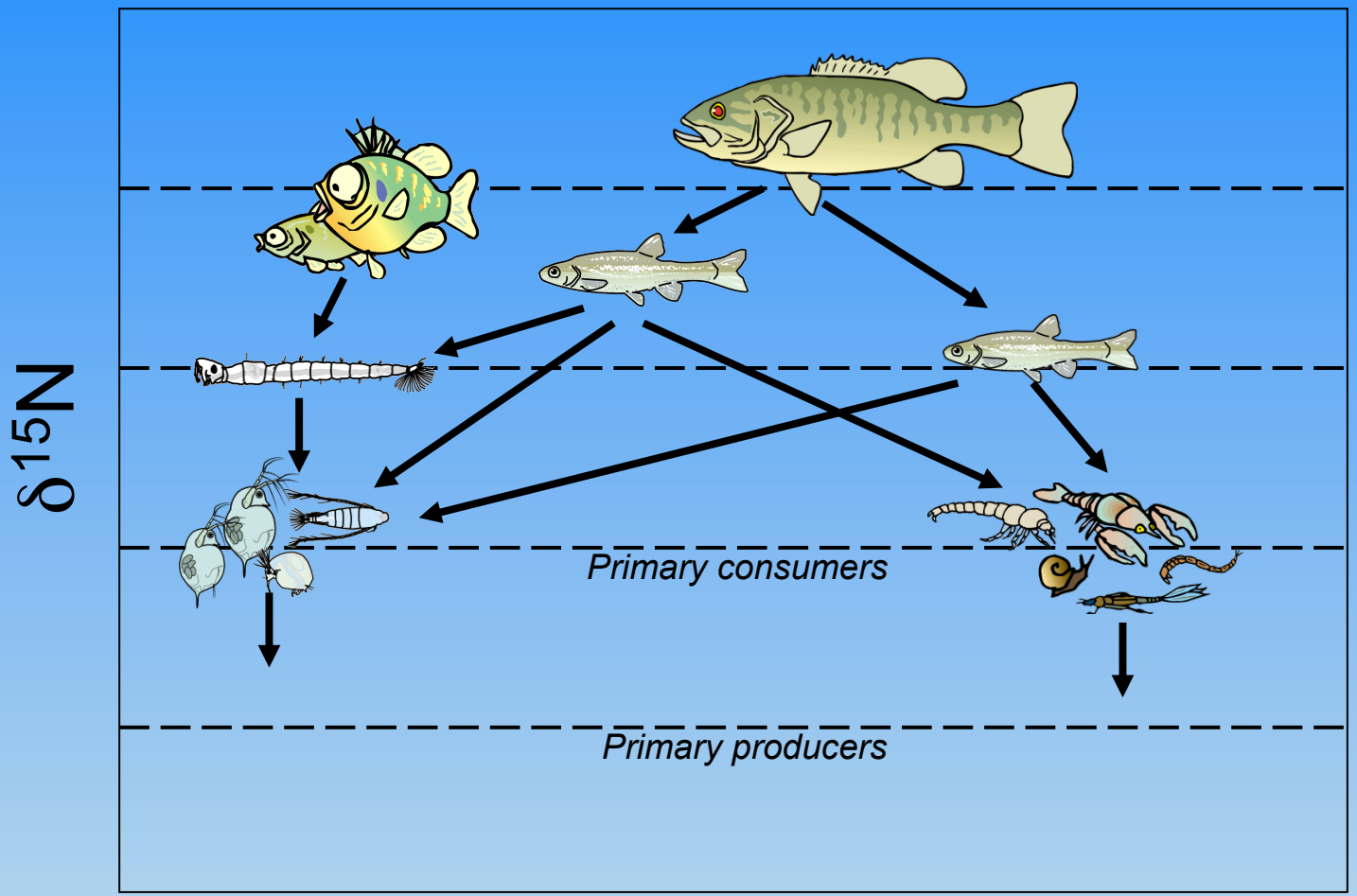
$\delta^{13}C$ ($^{13}C/^{12}C$) - little enrichment per trophic level

Benthic vs. pelagic energy sources



Use of carbon and nitrogen stable isotopes

Trophic niche space



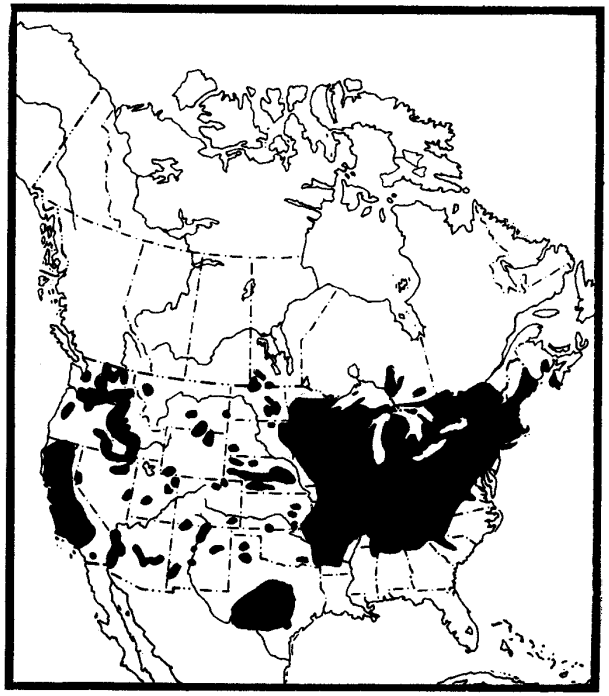
Food web consequences of biological invasions

Predatory fishes spreading rapidly into new lakes

Smallmouth bass
(***Micropterus dolomieu***)

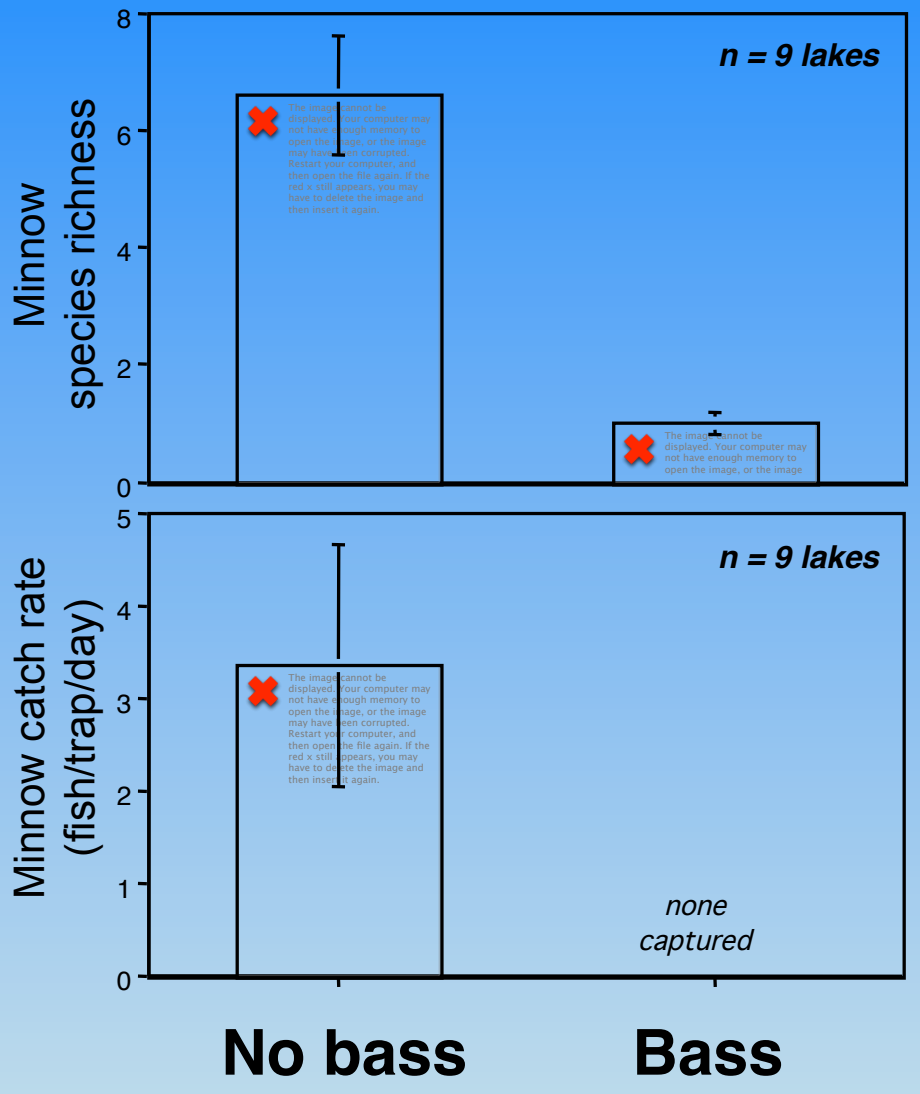
Rock bass
(***Ambloplites rupestris***)

Former Distribution



Present Distribution

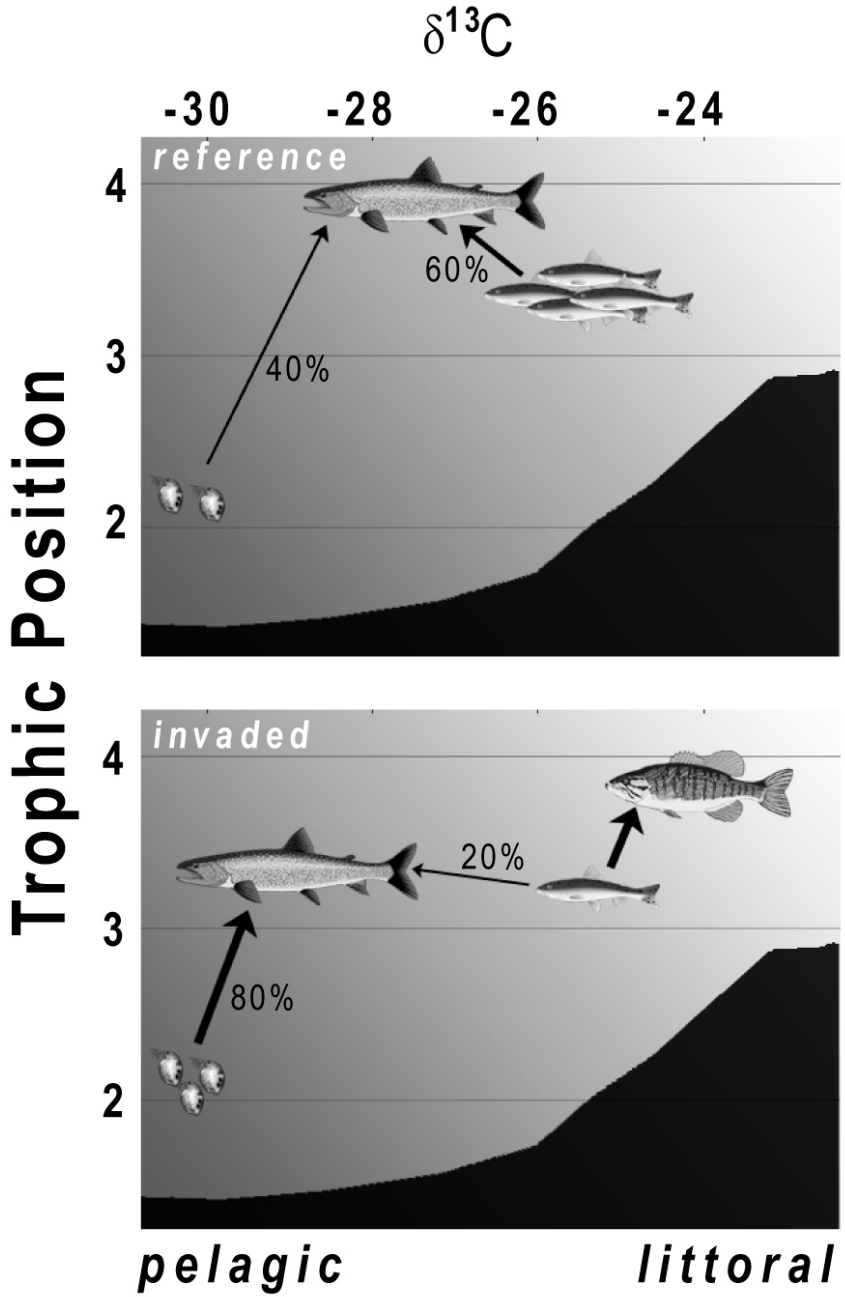
Minnow populations in Canadian lakes - bass versus no bass



From Vander Zanden et al. 1999 Nature

Quantify food web shift following bass introduction

Negative impacts on native lake trout populations



From Vander Zanden et al. 1999 Nature

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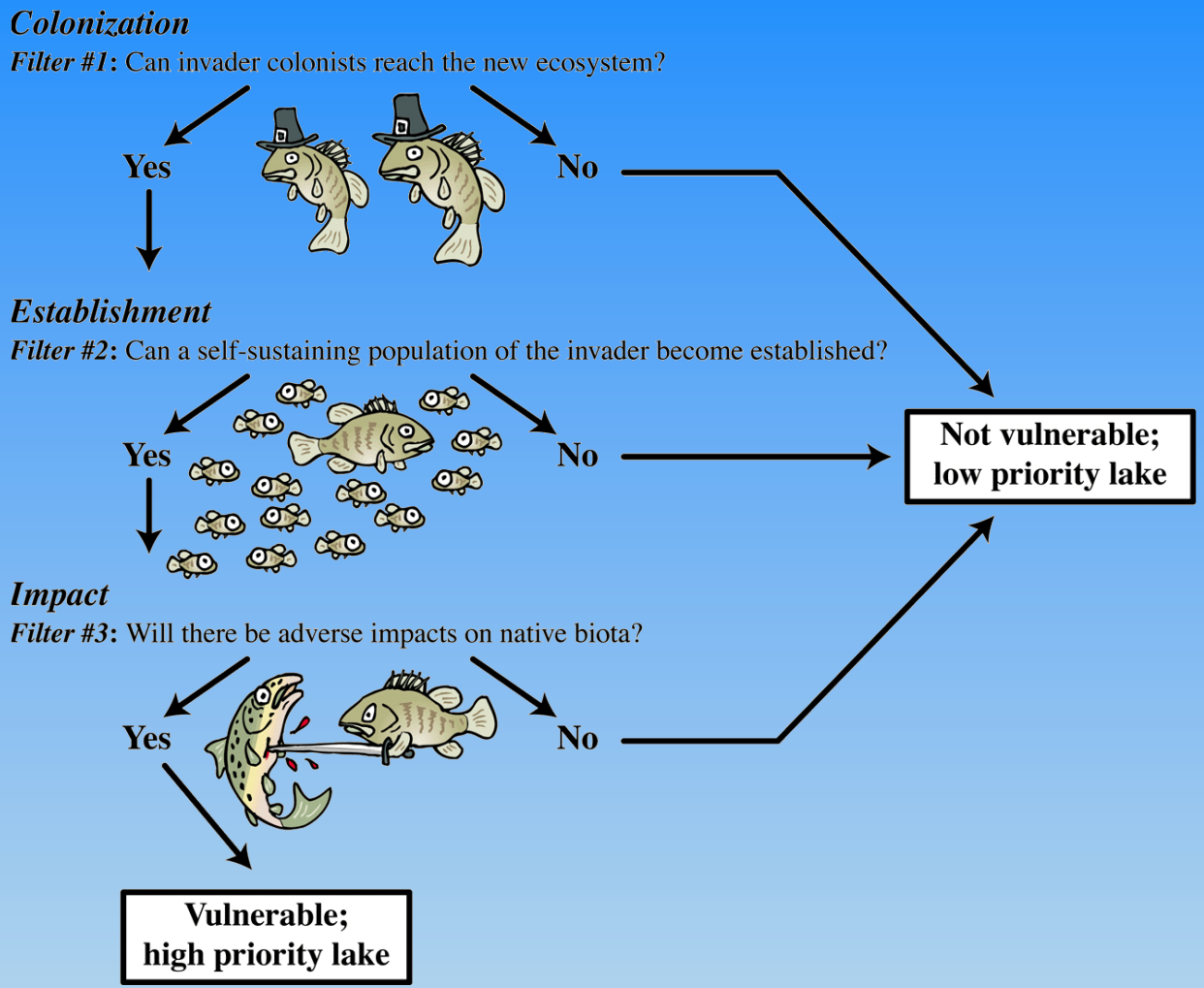
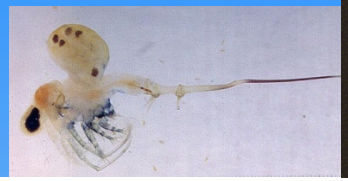
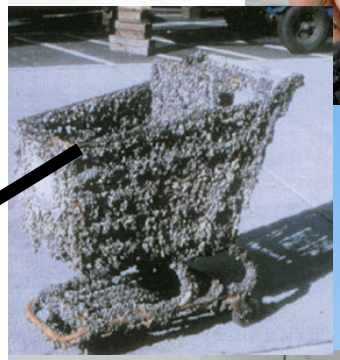
Smart Prevention: conceptual model to identify 'vulnerable' lakes



Vander Zanden et al. 2004. Ecol. Appl. 14: 132-148

Smart prevention of invasive species in Wisconsin





Suite of invaders:

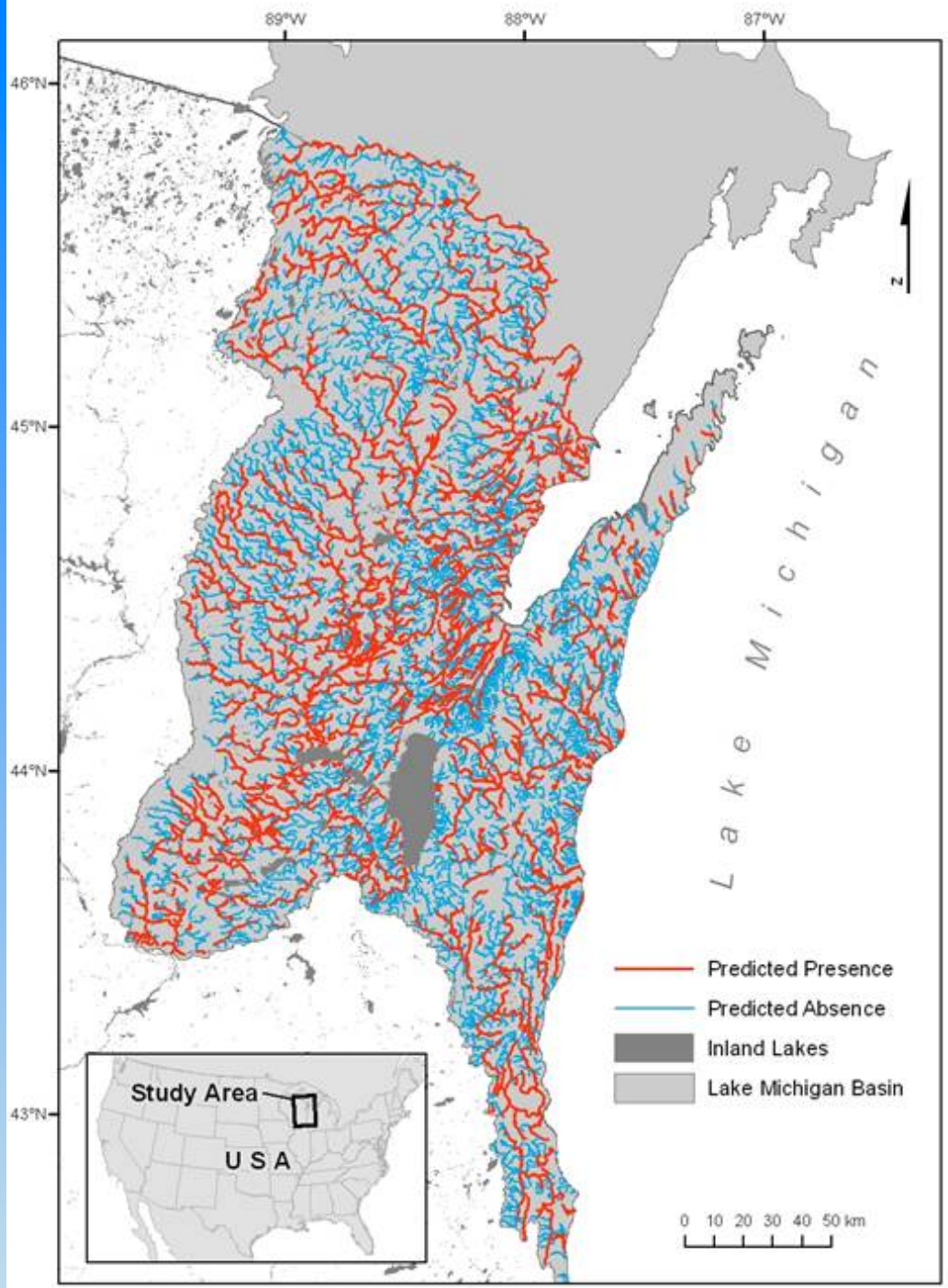
rainbow smelt
rusty crayfish
zebra mussel
spiny water flea
round goby
Chinese mystery snail
Eurasian watermilfoil

Where will round goby invade next?

42% (1,369 km) identified as suitable

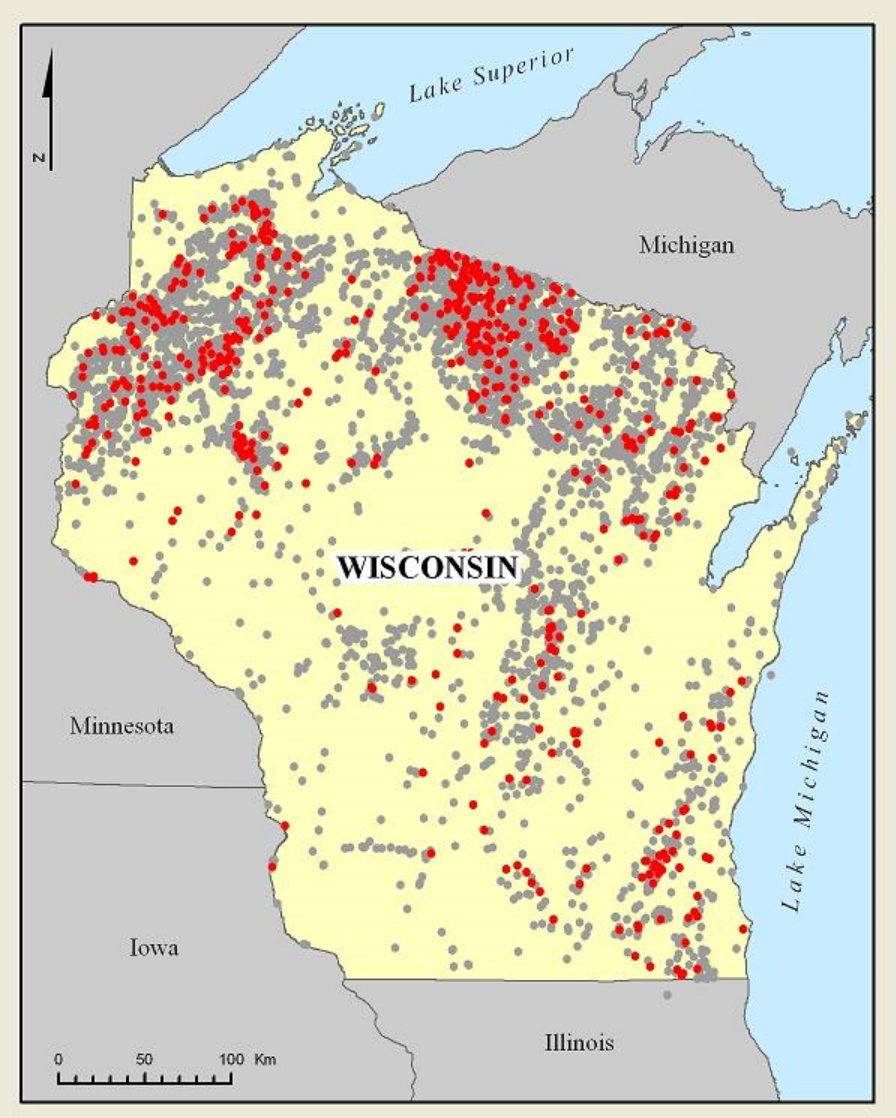
44% (8,878 km) identified as suitable

Kornis and Vander Zanden in press CJFAS



Rainbow smelt model application to Wisconsin

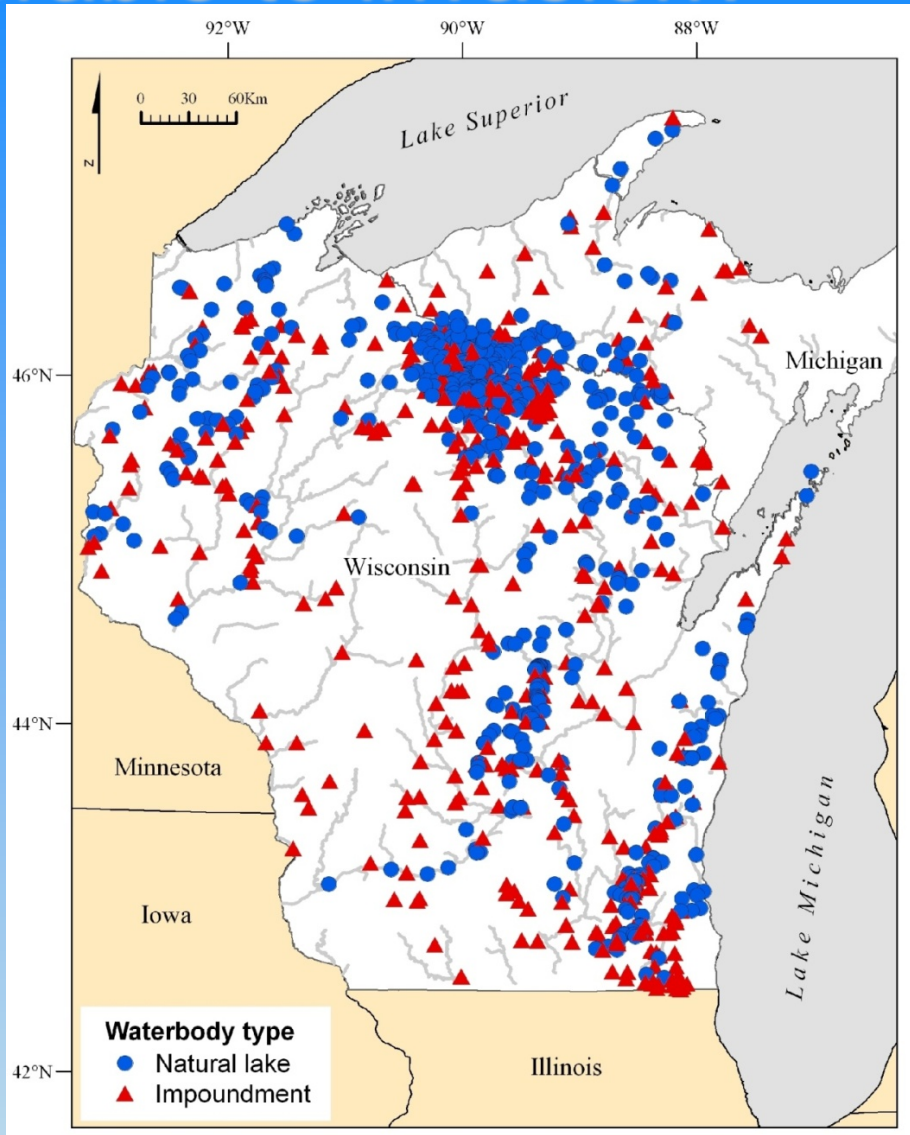
- > 5,000 Wisconsin lakes
- 26 support smelt
- 553 can support smelt (10% of Wisconsin lakes)
- Wisconsin is ~5% saturated with smelt



Mercado-Silva et al. 2006 Cons. Biol. 20: 1740-1749

Red = vulnerable lakes

Dam invaders: Are impoundments more vulnerable to invasion?



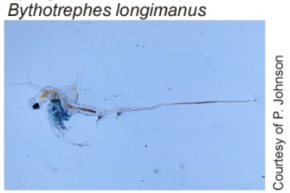
Eurasian watermilfoil
Myriophyllum spicatum

Courtesy of Alison Fox

zebra mussel
Dreissena polymorpha

Courtesy of Environmental Protection Agency

spiny water flea
Bythotrephes longimanus



Courtesy of P. Johnson

rainbow smelt
Osmerus mordax

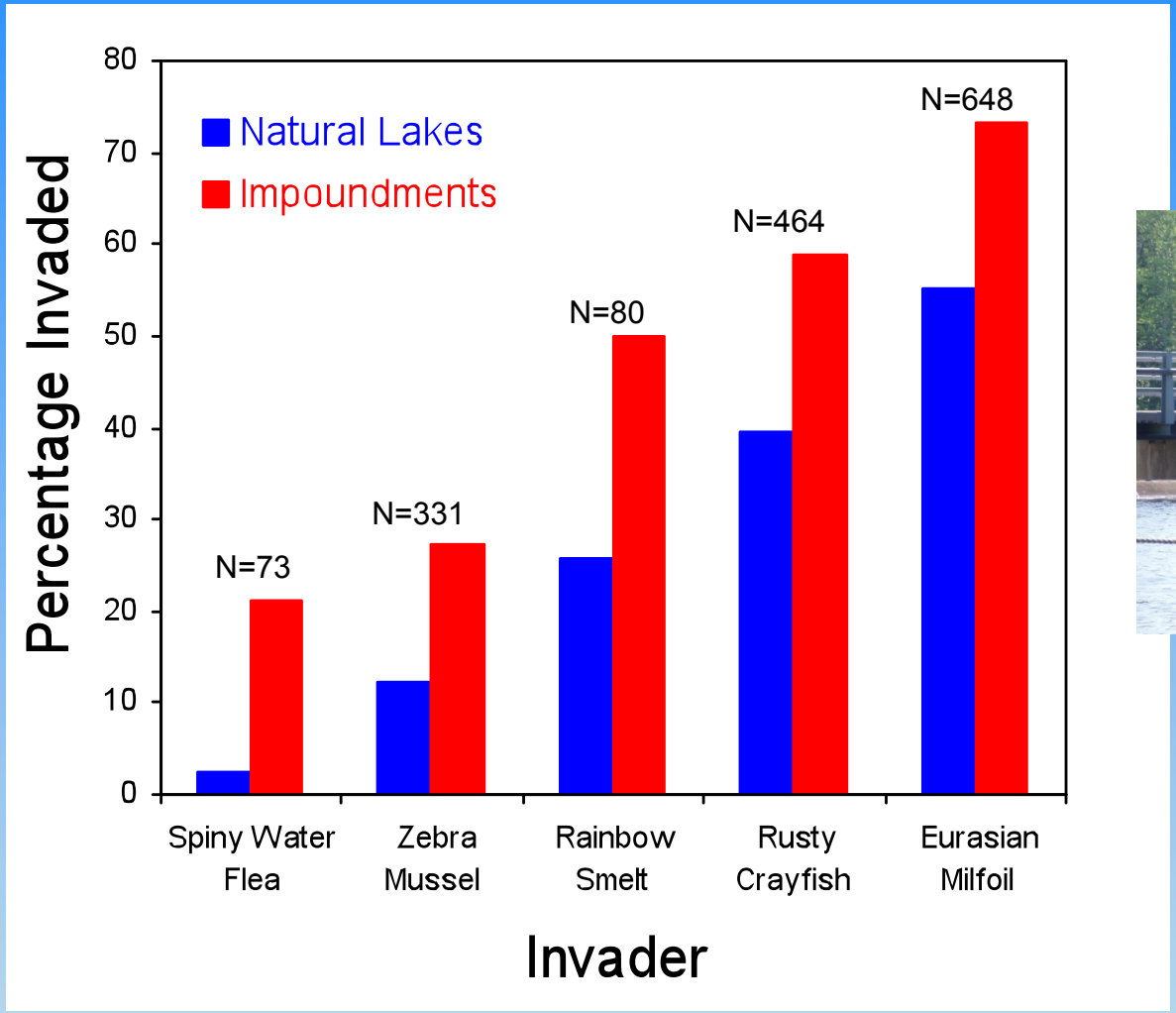
Courtesy of J. Lyons

rusty crayfish
Orconectes rusticus

Courtesy of E. Engbretson

Johnson, P.T, J.D. Olden & M.J. Vander Zanden 2008. Front. Ecol. Environ.

Impoundments are over-invaded



Johnson, P.T, J.D. Olden & M.J. Vander Zanden 2008. Front. Ecol. Environ.

Smart prevention of invasive species

Ongoing research on the spread and impacts of seven invasive species

Tools for managers to assess lake suitability

A broader management approach for guiding the allocation of prevention efforts on a complex landscape with a suite of invaders

Integrating the ecology and economics of aquatic invasives

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Prevention of diffuse agricultural pollution

- Agricultural runoff is leading source of nitrogen, phosphorus, sediment pollution to rivers and streams
- Improved land use practices – riparian buffers


before
Photo by Dick Schultz


after
Photo by Dick Schultz

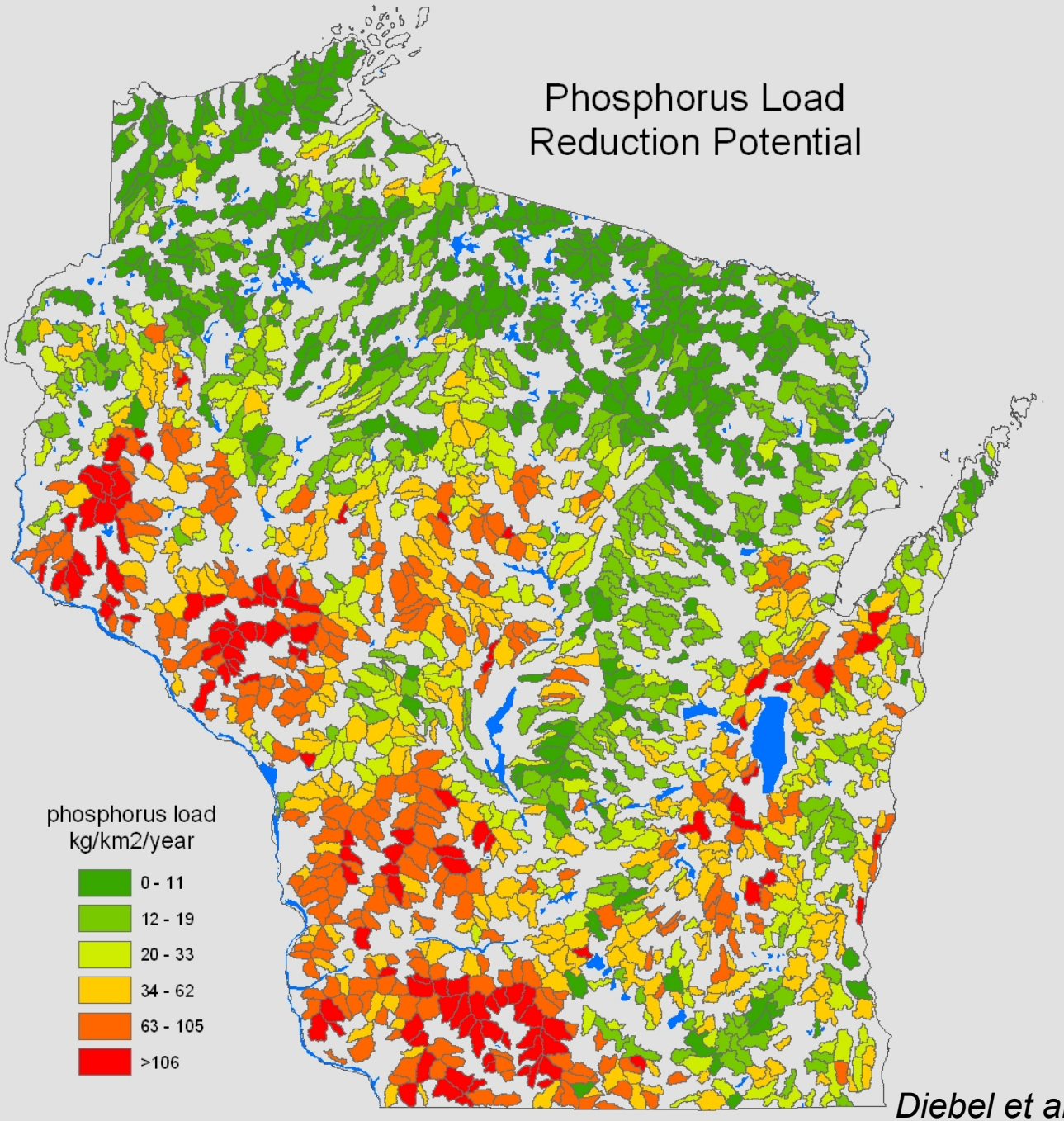
Prevention of diffuse agricultural pollution

Voluntary programs have poor track record

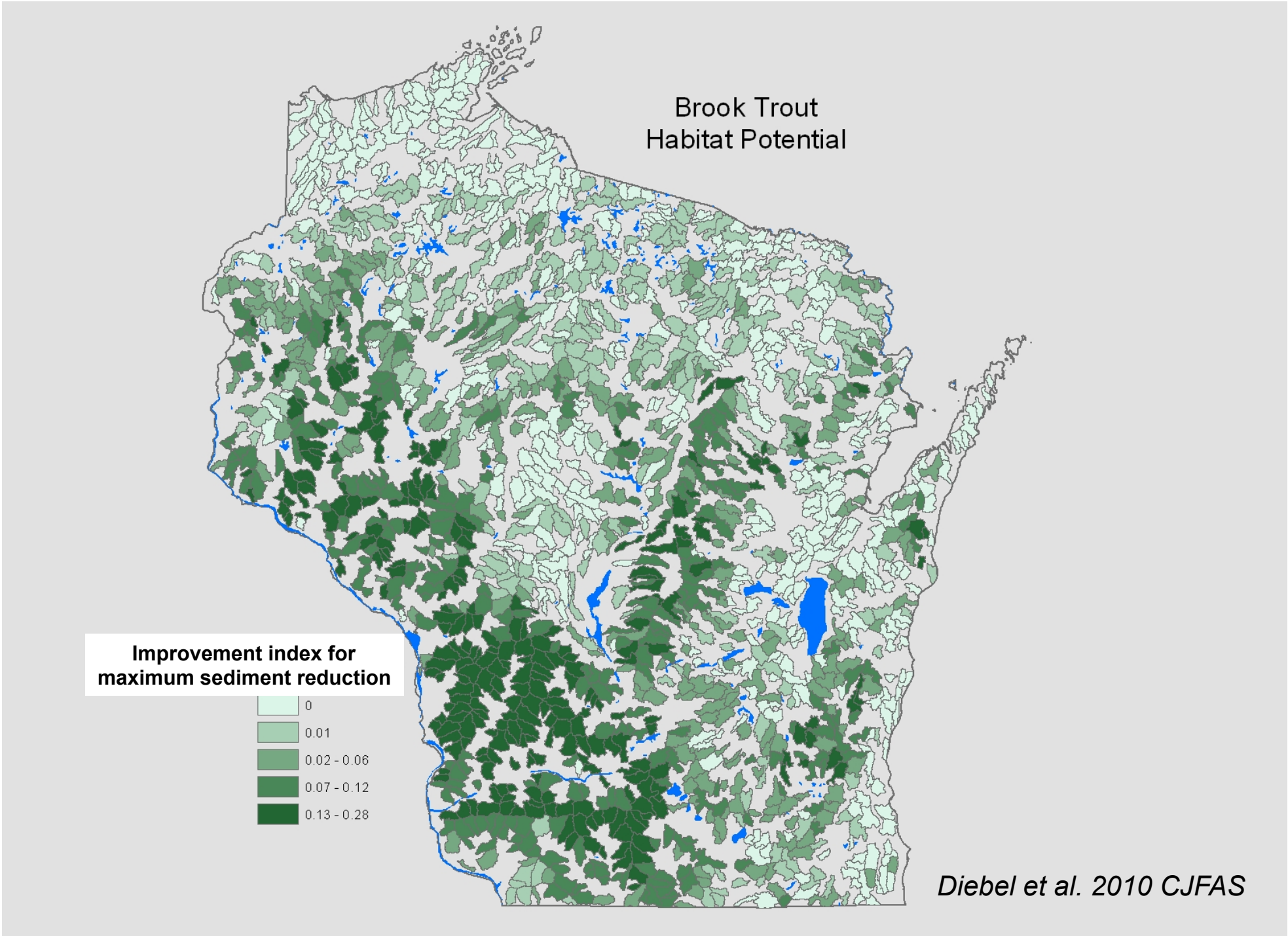
WI revising non-point regulations –> creation of Wisconsin Buffer Initiative (WBI)

Majority of pollution derived from a small portion of the landscape

Target hotspots

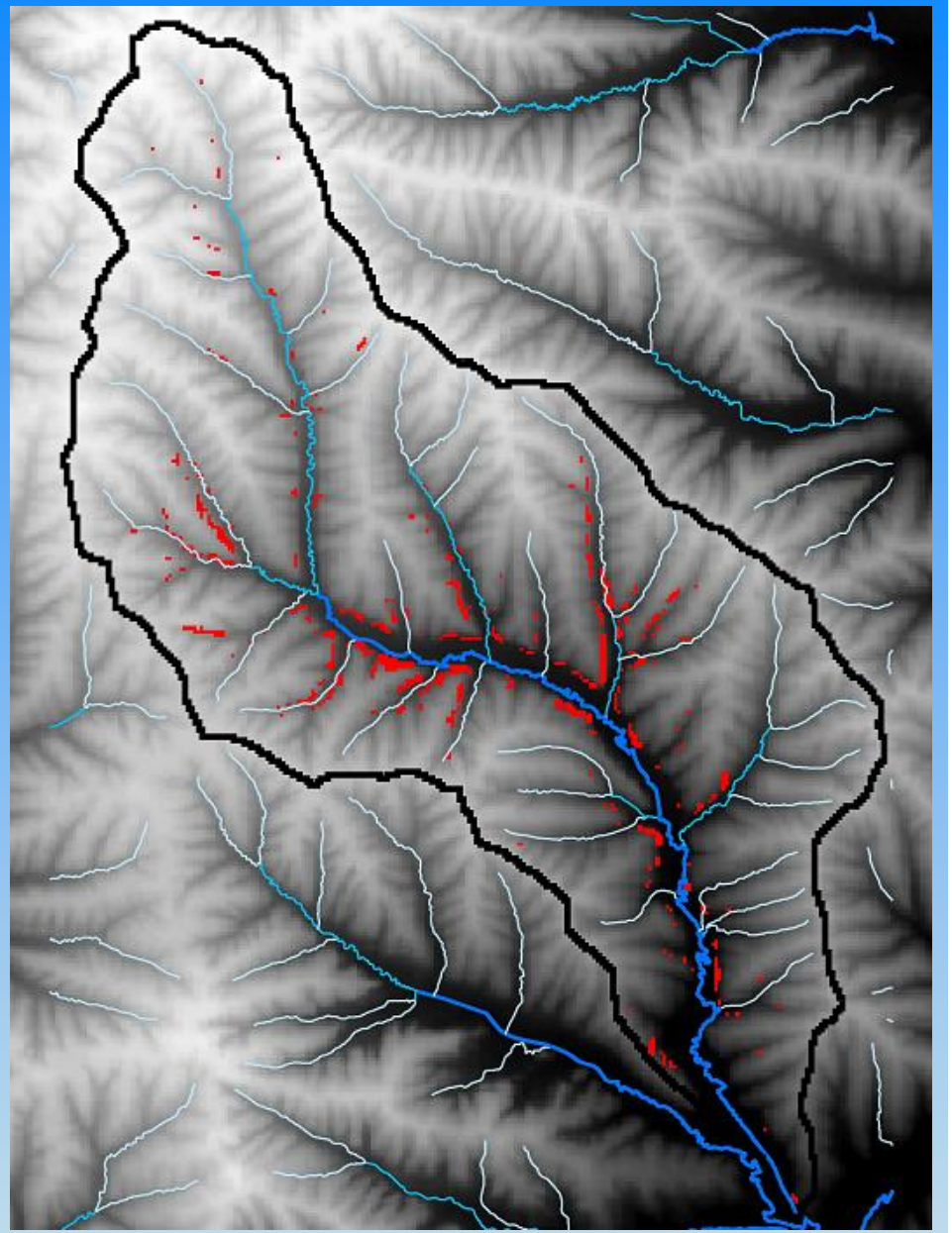


Diebel et al. 2009 Env. Man.


Brook Trout
Habitat Potential
Improvement index for
maximum sediment reduction
0
0.01
0.02 - 0.06
0.07 - 0.12
0.13 - 0.28
Diebel et al. 2010 CJFAS

Prioritization *within* WBI watersheds

GIS-based analysis to identify local hotspots with high potential for nutrient inputs to streams



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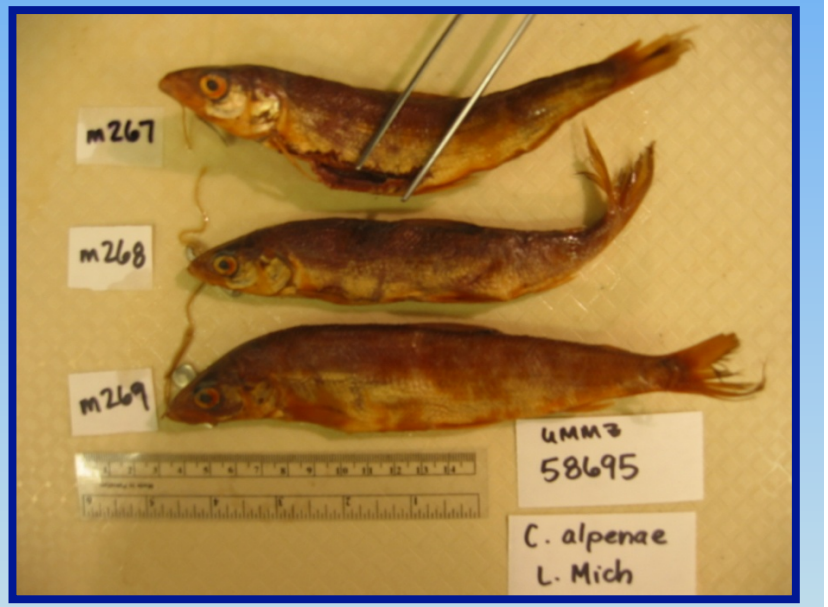
Laurentian Great Lakes – evaluating food web change and restoration potential

- Extirpation of deepwater cisco community
- What have been the long-term food web change resulting from species introductions?
- Implications for restoration and reintroduction

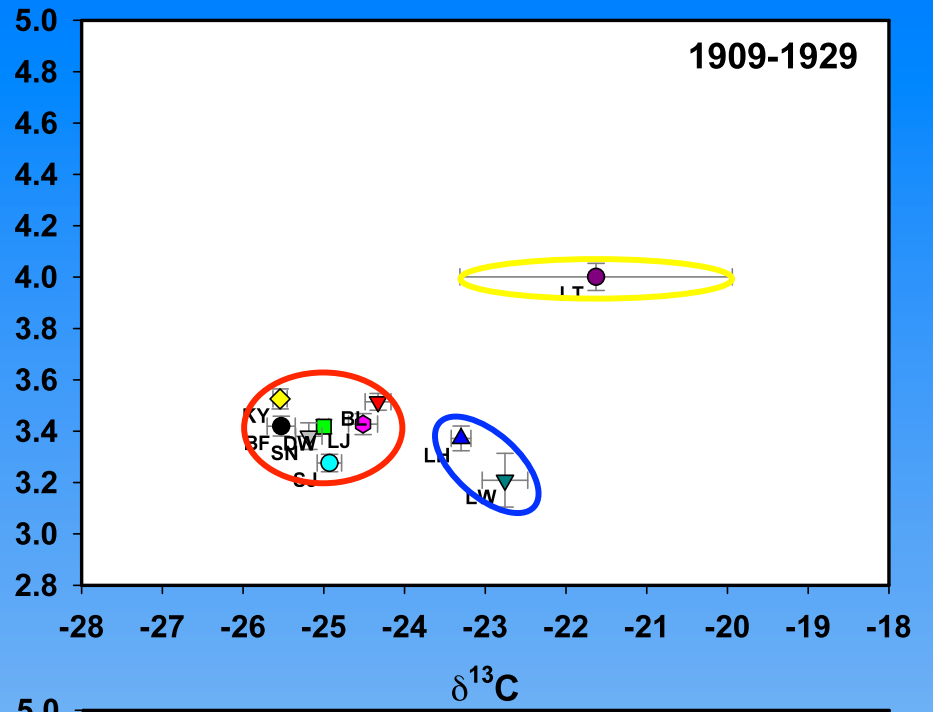
Stable isotope analysis of museum-archived specimens

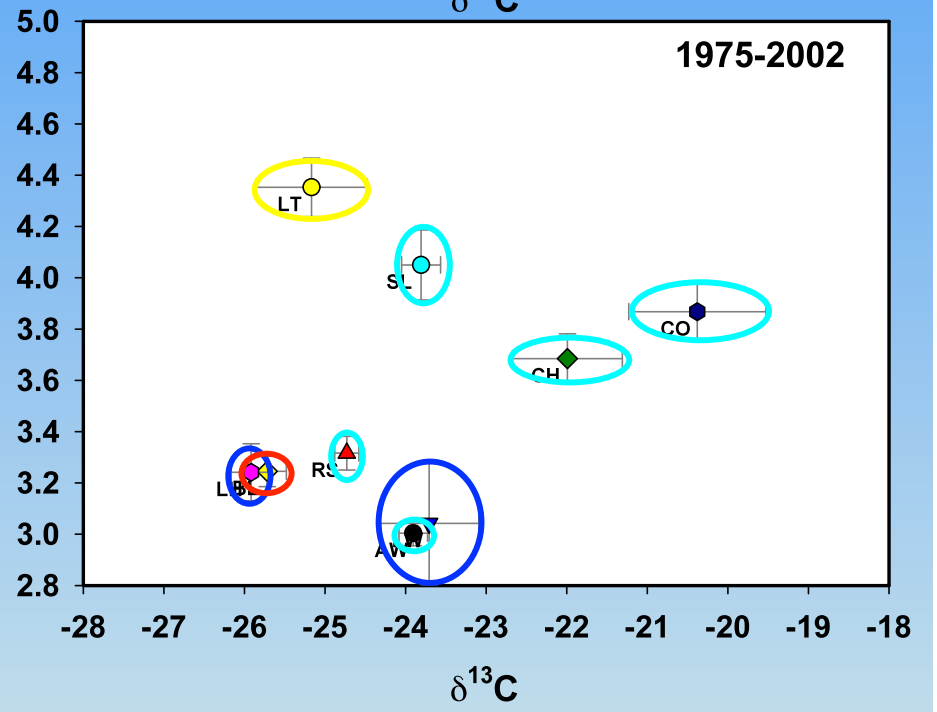


Schmidt et al. 2008 Ecology

Red = deepwater ciscoes
Blue = shallow-water ciscoes
Yellow = Lake trout
Light blue = non-natives

Take-home messages:





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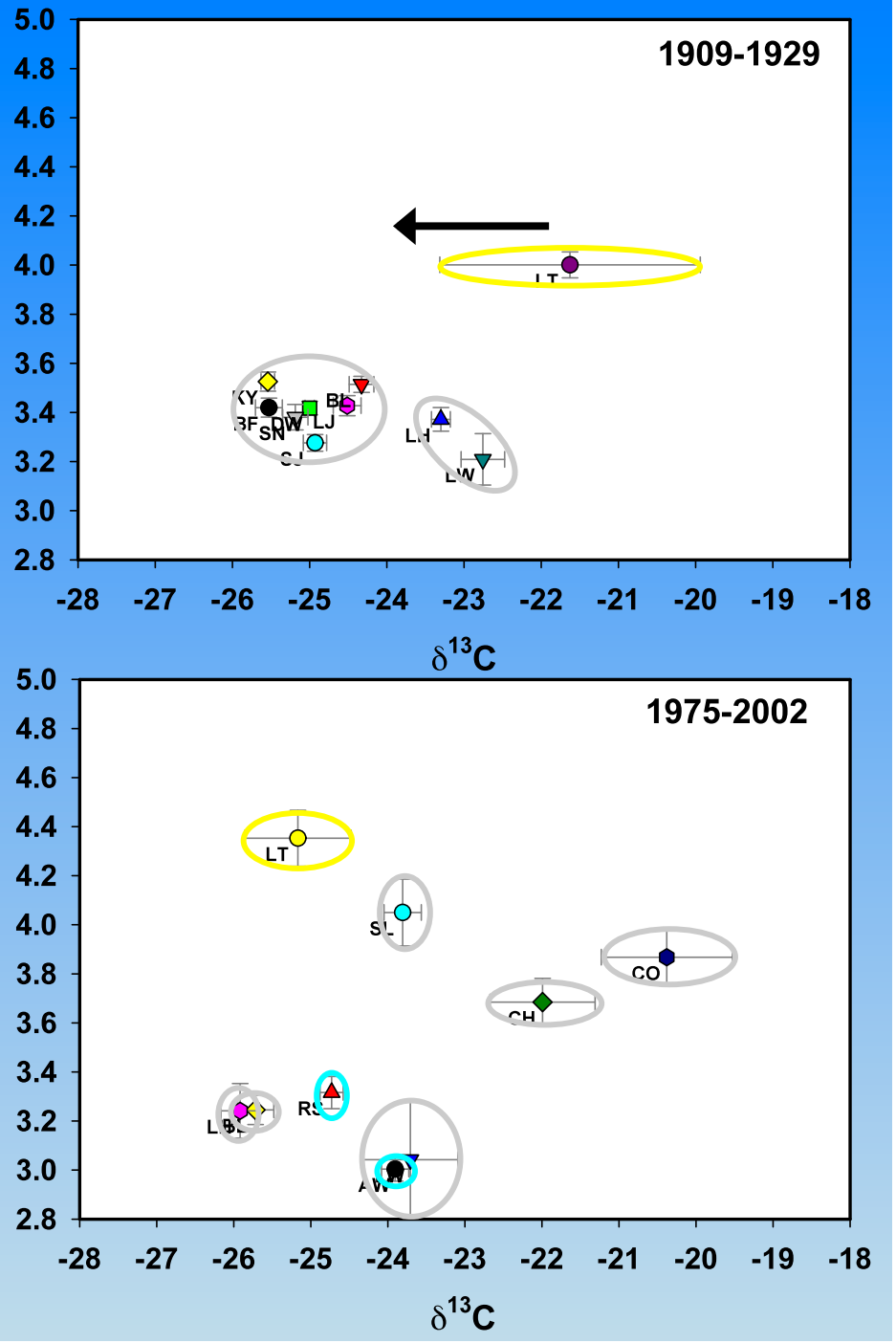
Take-home messages:

1) Lake trout shifted to pelagic, feed more on non-native rainbow smelt and alewives



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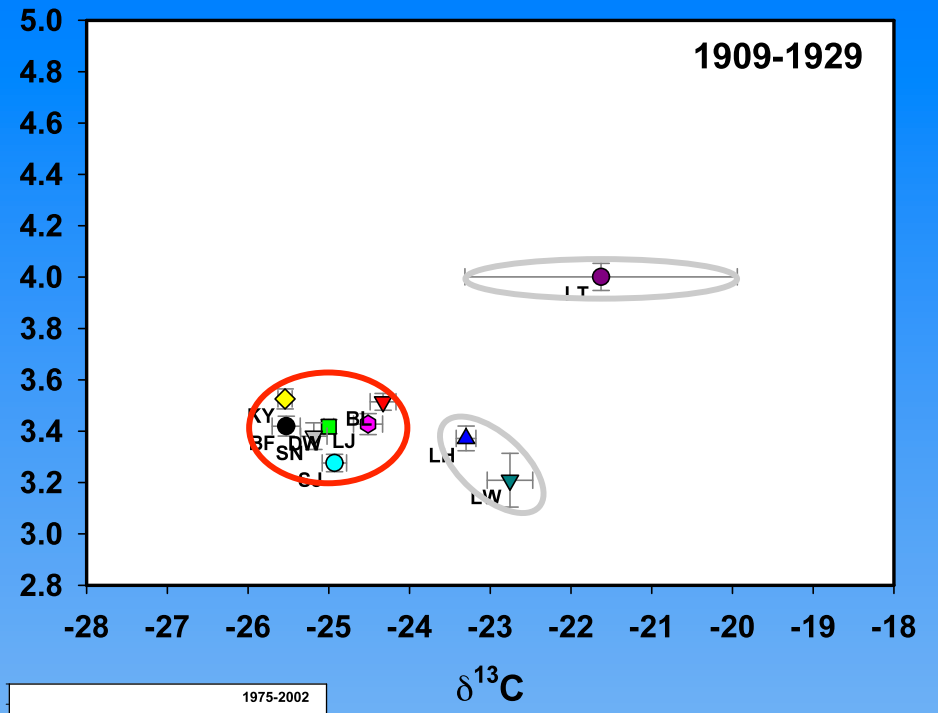
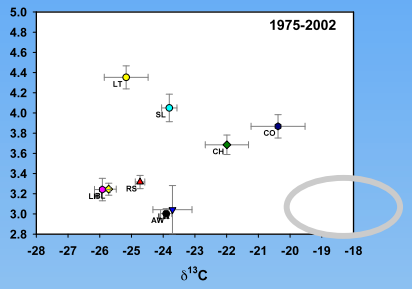
2) Deepwater cisco niche space shrinks due to extirpations





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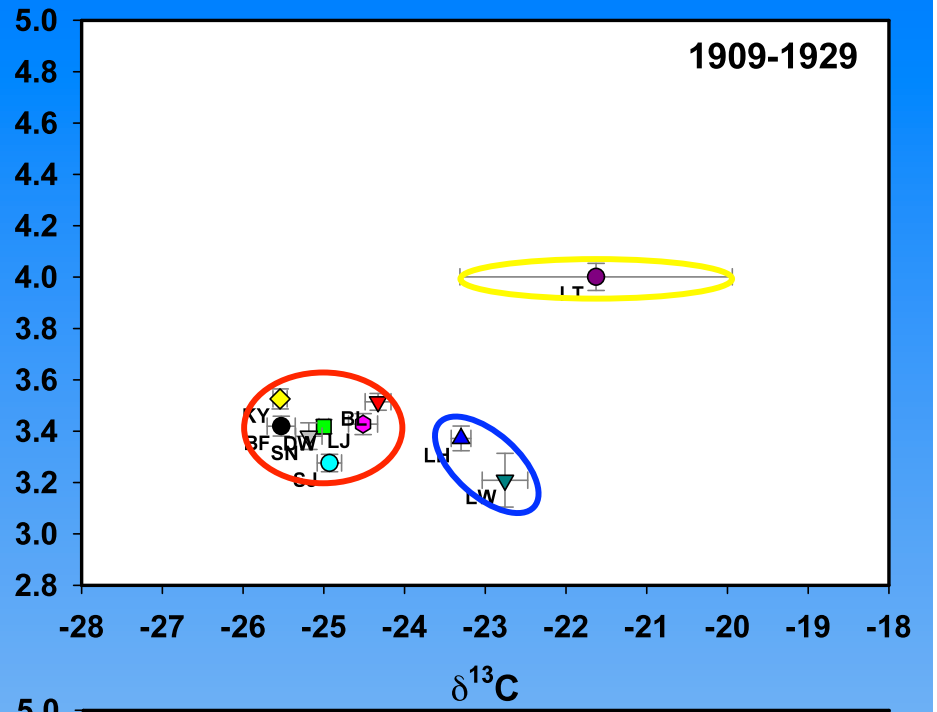
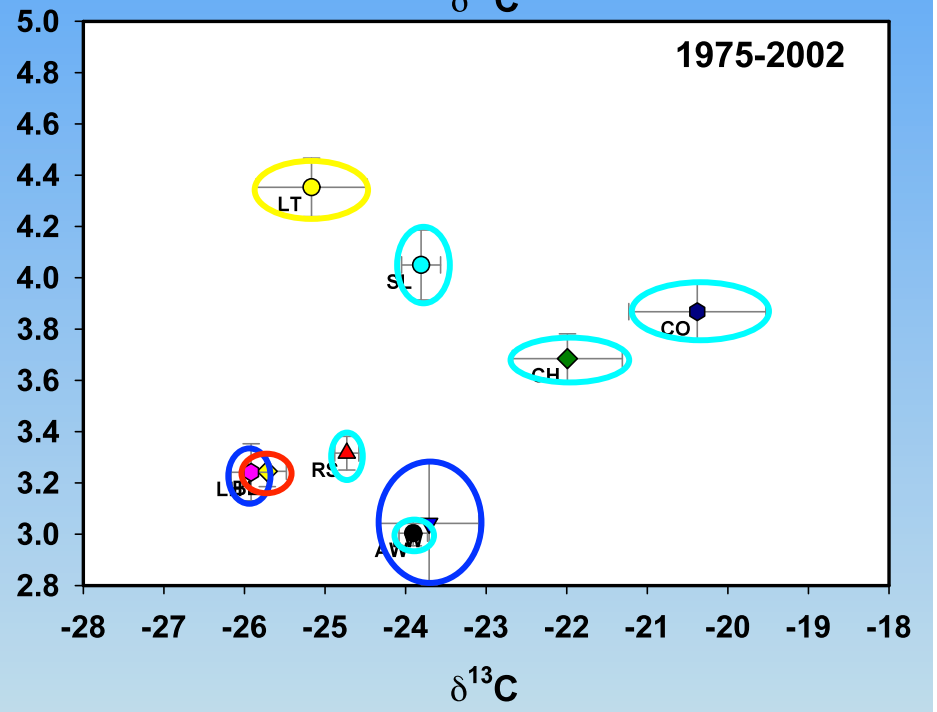
3) Exotics distinct from natives, but now occupy niche space similar to historical natives





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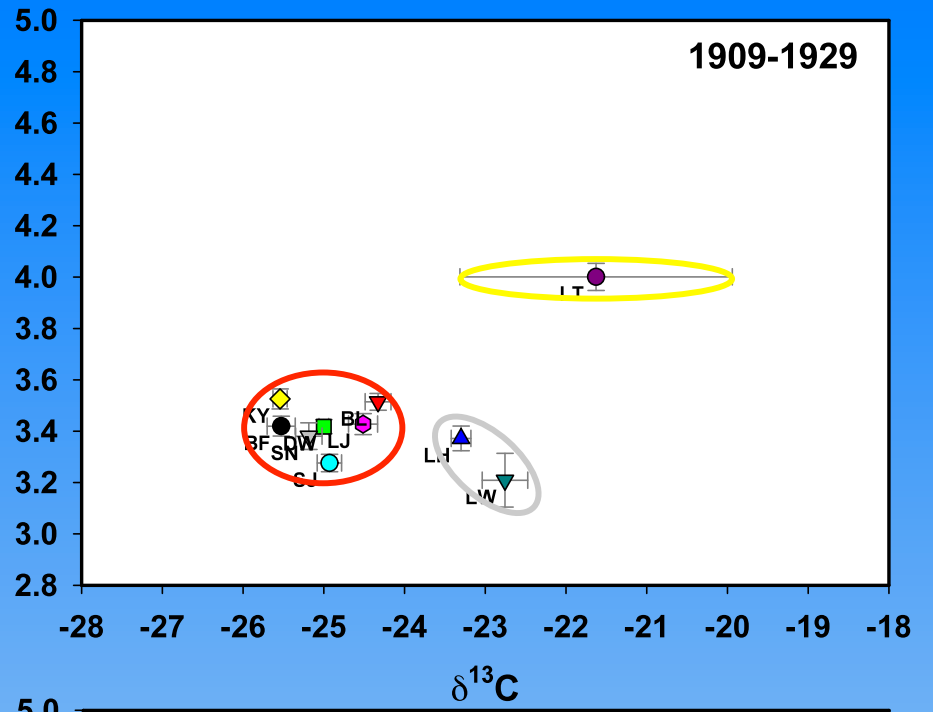

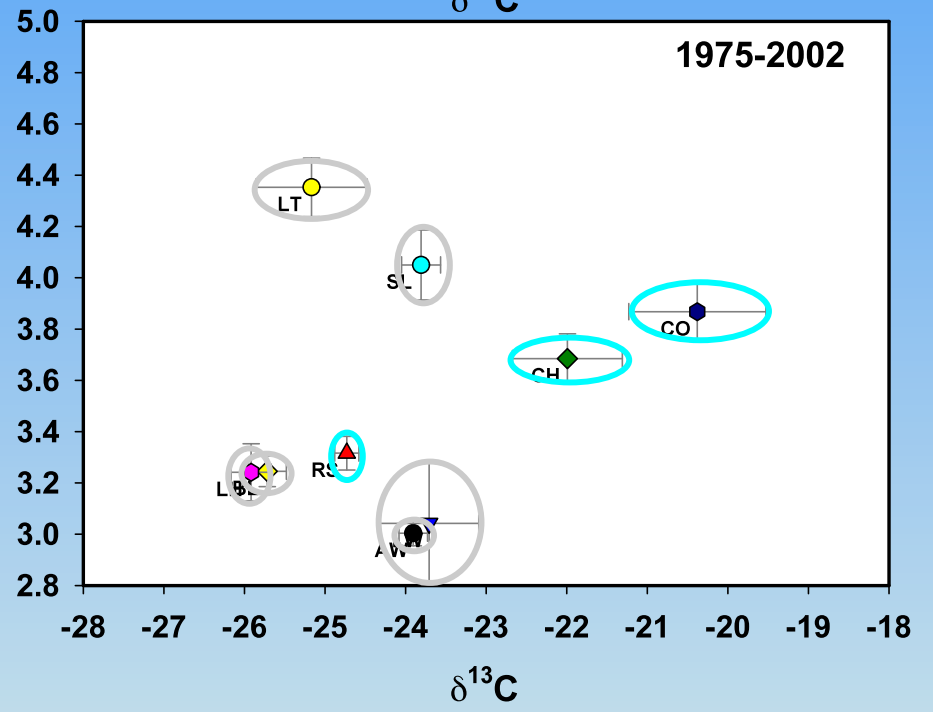

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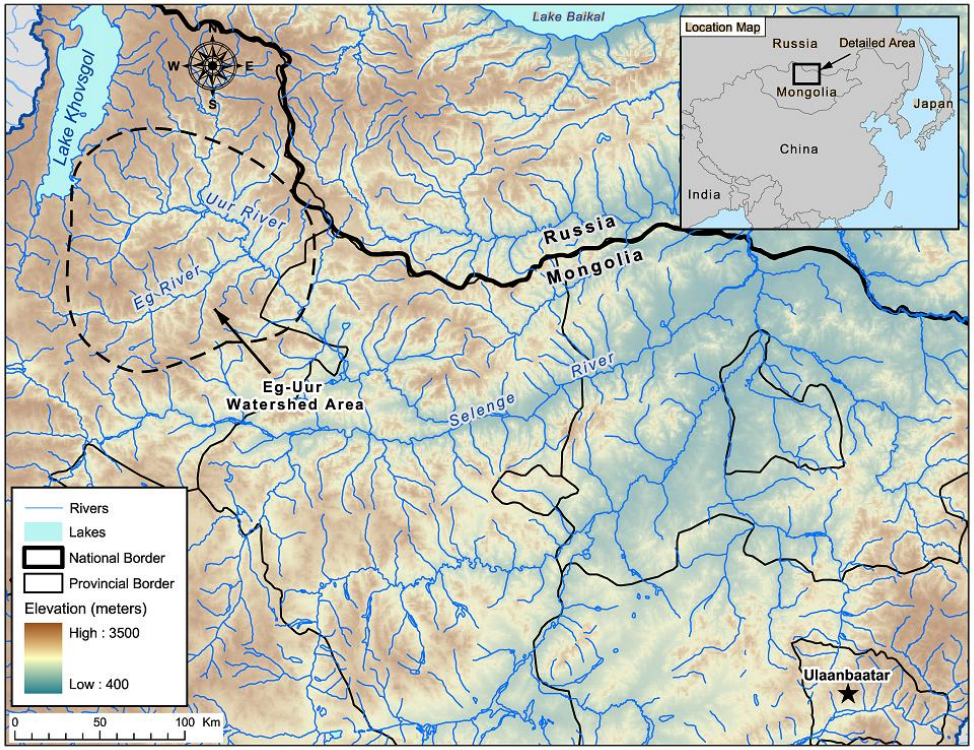
Management of *Hucho taimen* in Mongolia

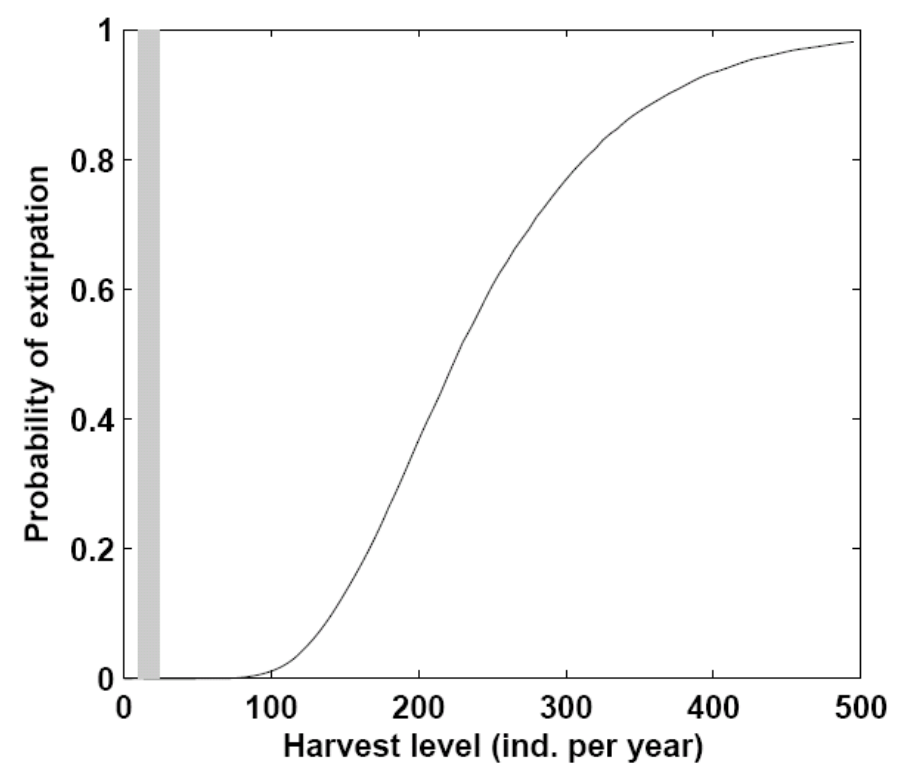
Catch-and-release flyfishing

Taimen as a conservation tool

Implement payment for ecosystem services-based resource management



Population model for simulating fishery impacts

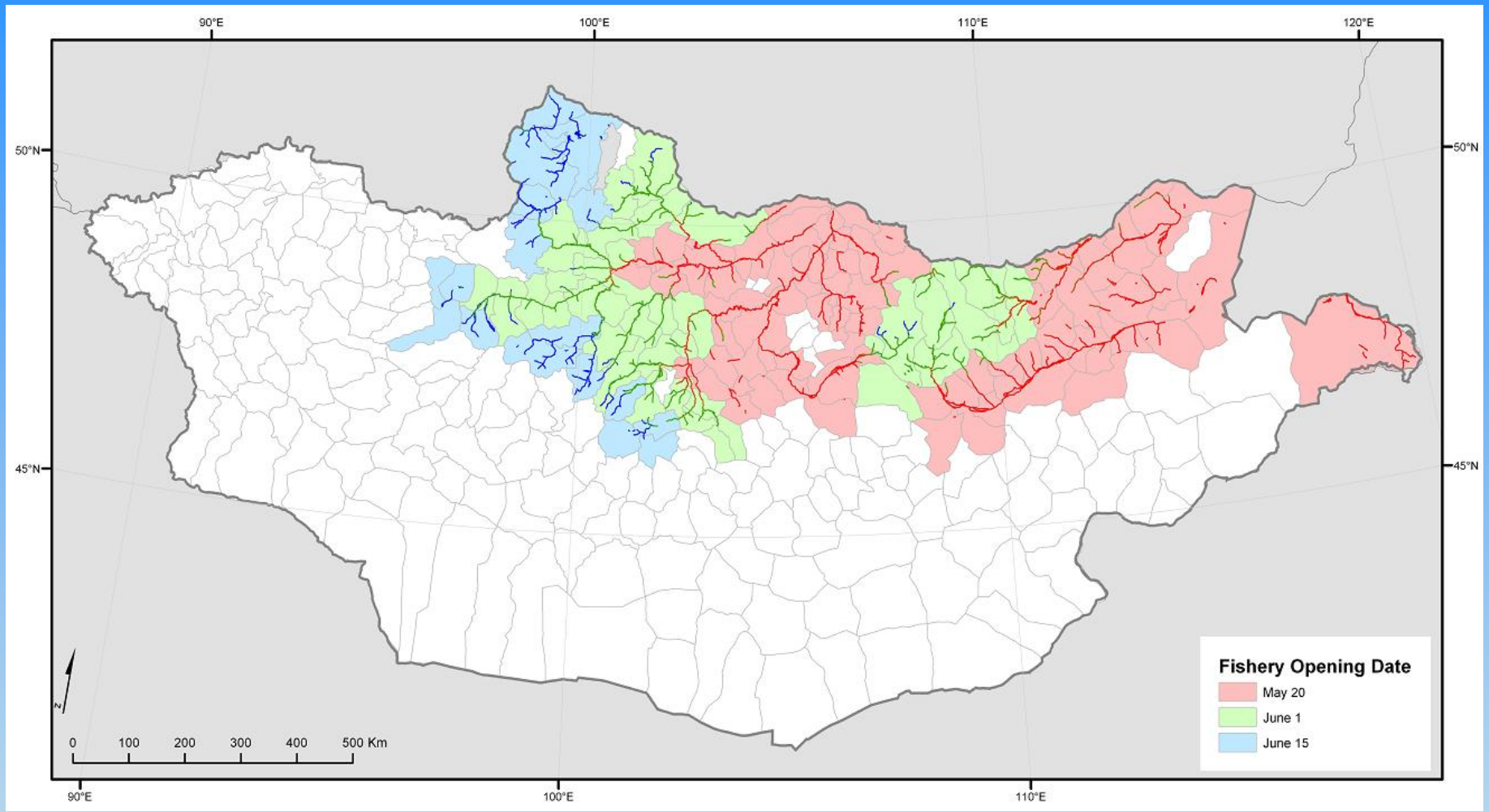


Jensen et al. 2009 CJFAS

Movement and migration

Gilroy et al. EFF in review

Map of proposed fisheries management zones for Mongolia



Vander Zanden et al. 2007. Ecol. Appl.

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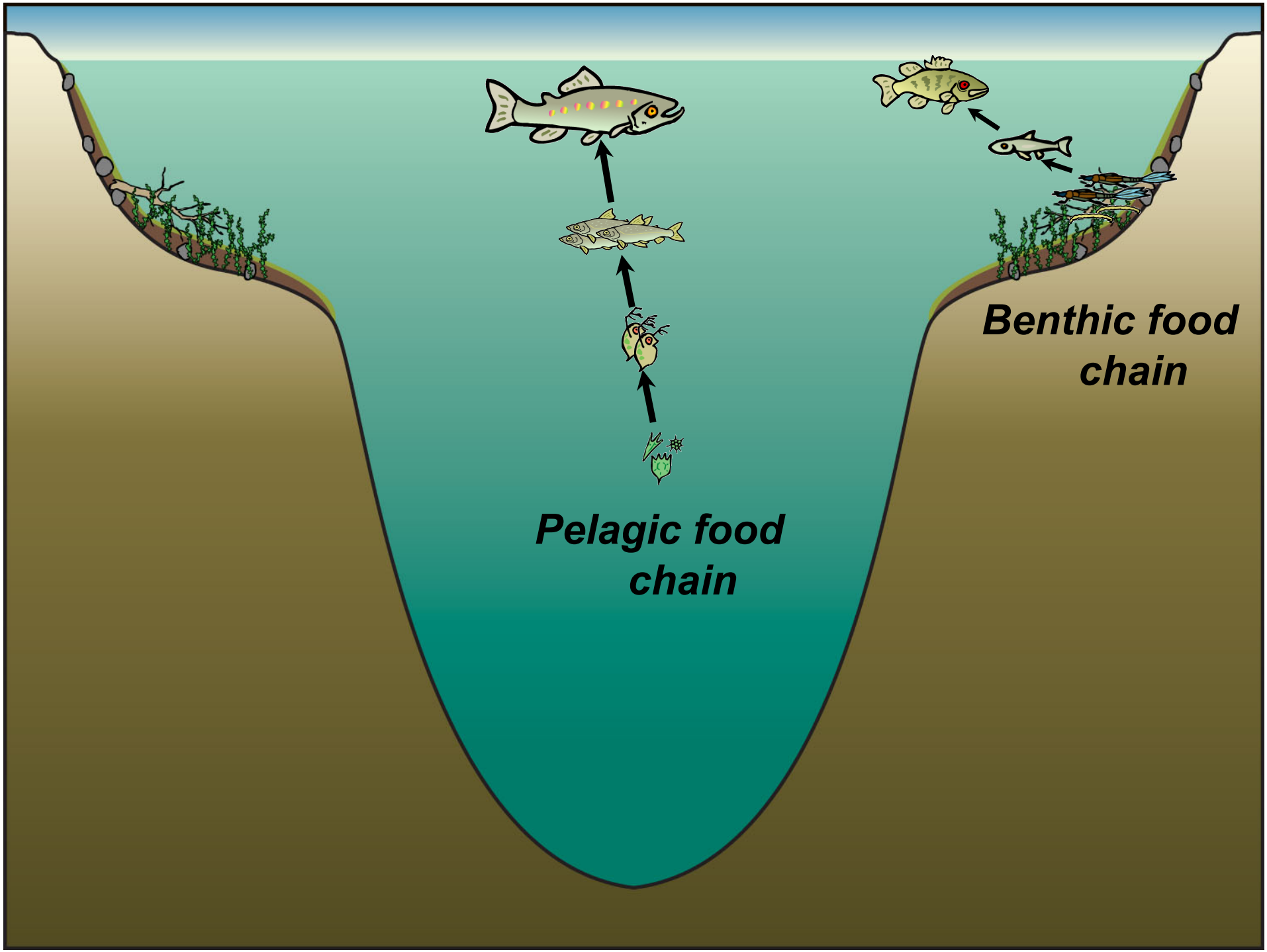
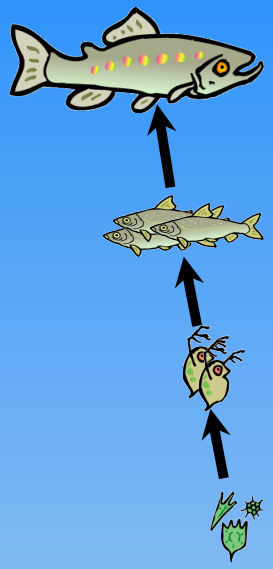
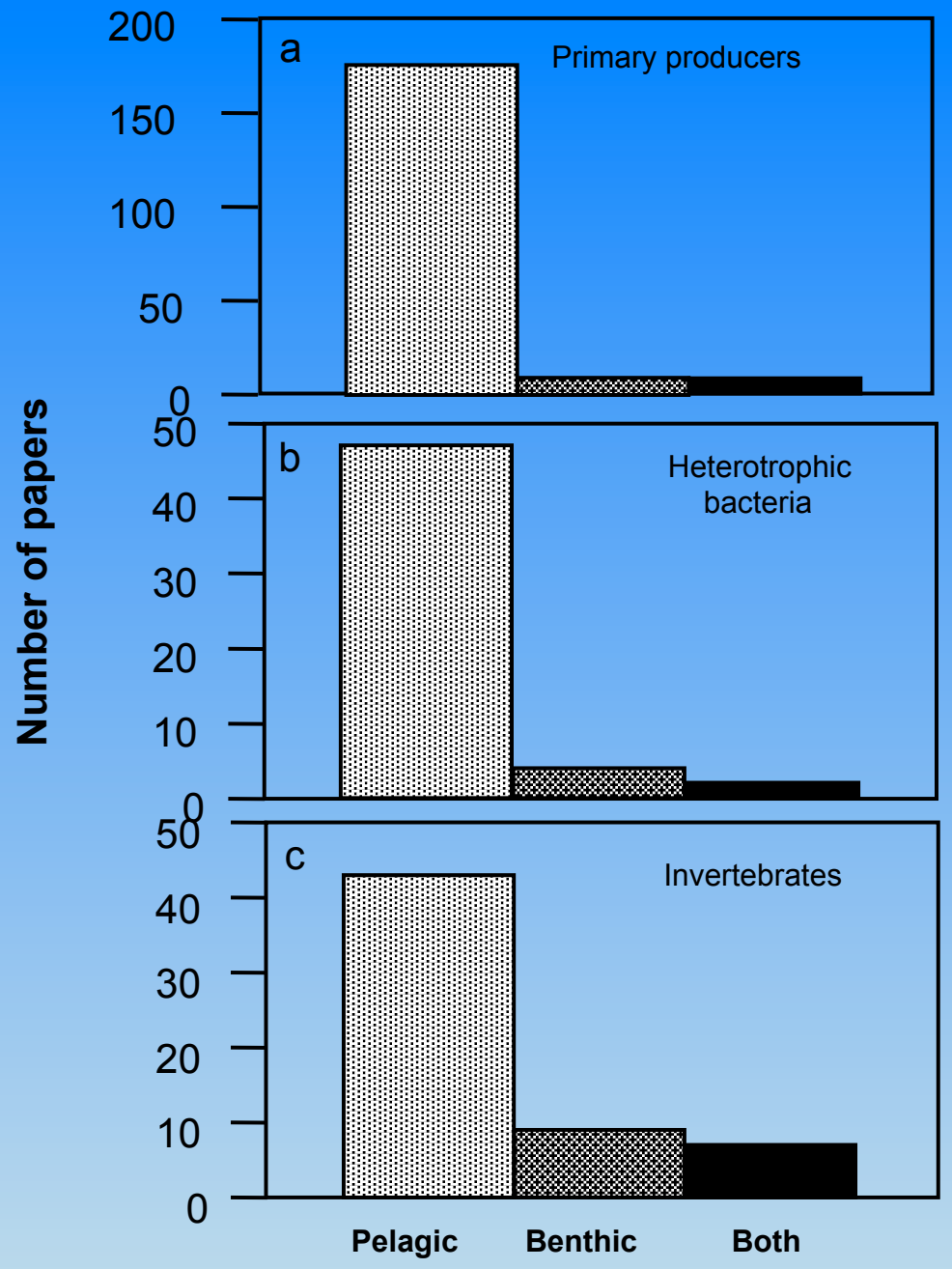

Benthic food chain
Pelagic food chain

Pelagio-centrism in limnology

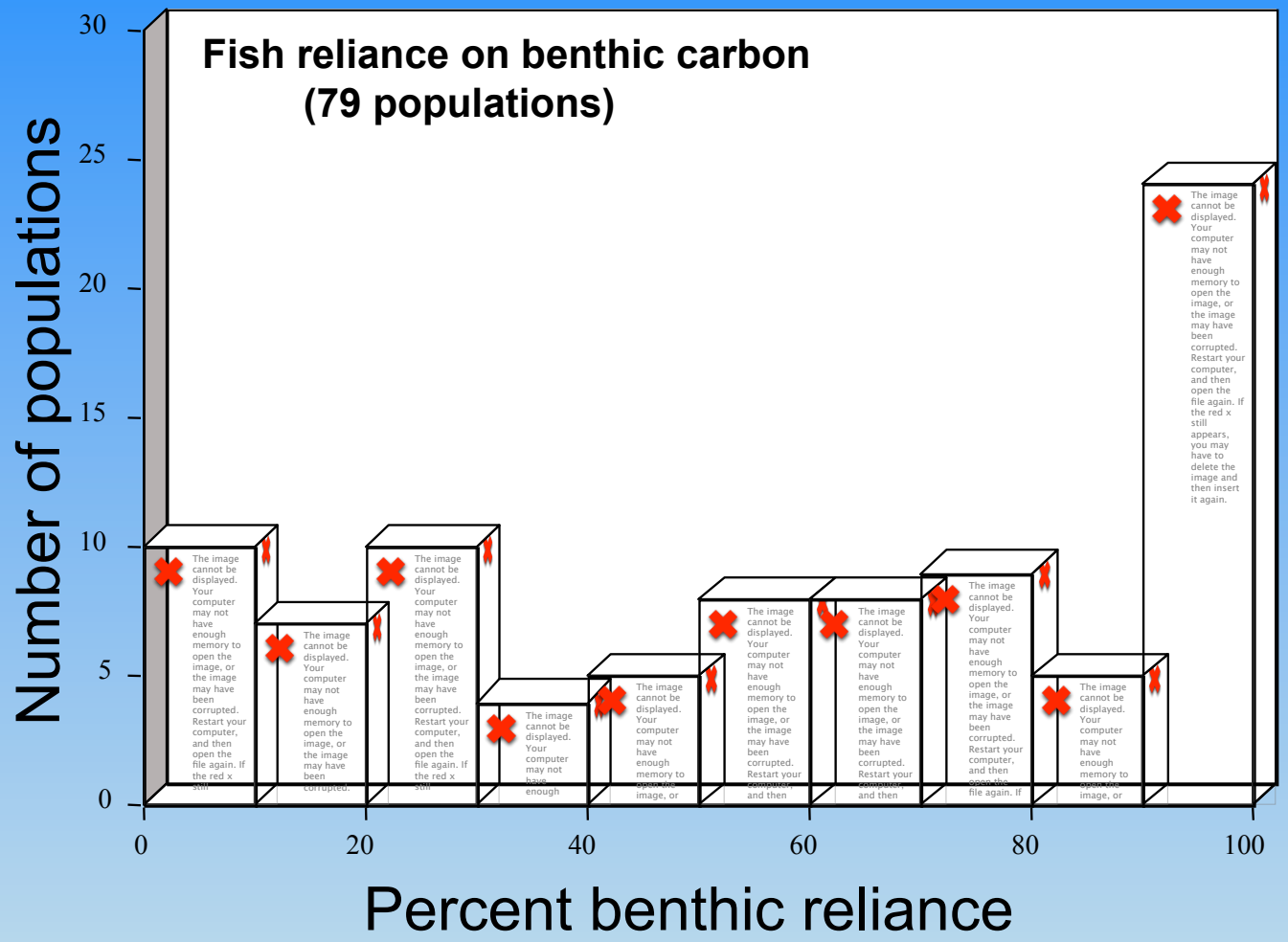


Data from papers published in 1990s



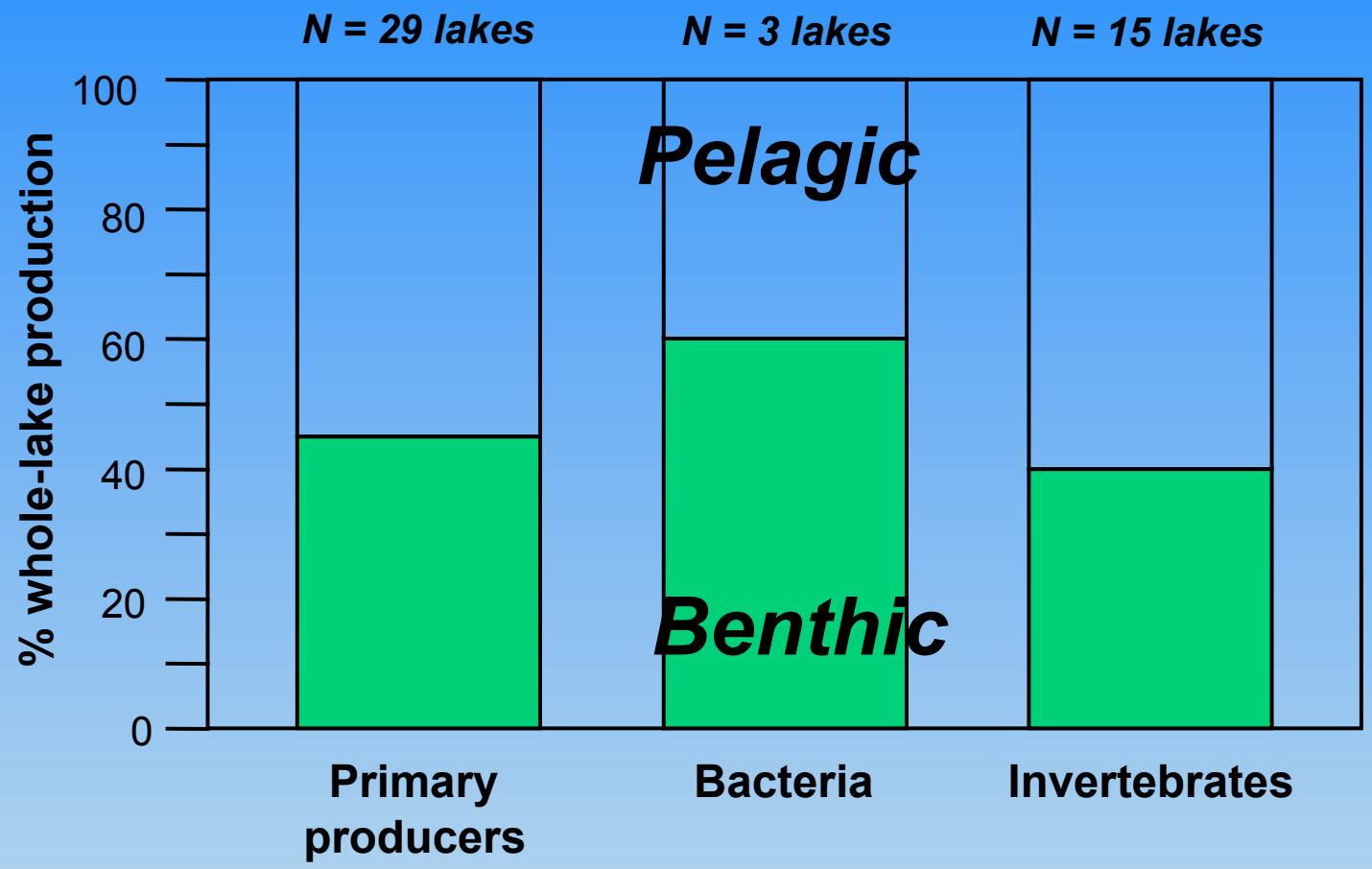
Vadeboncoeur et al. 2002. Bioscience 52: 44-54

Fishes heavily supported by benthic pathways
Fishes as *integrators* of benthic and pelagic



Vander Zanden & Vadeboncoeur, 2002. Ecology 83: 2152-2161

Benthic production – contribution to whole lake production



Vadeboncoeur et al. 2002. BioScience 52: 44-54

Importance of benthic production

Benthic production more efficiently channeled to higher trophic levels

Benthic production supports the majority of fish, even in large lakes

Benthic habitats support the majority of lake biodiversity

Fish benthivory drives top-down control in pelagic zone

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