

Lake Michigan Food Web Woes

Top Down or Bottom Up?

Dan O'Keefe, Ph.D.

Ottawa County Water Quality Forum
November 19, 2018



Sea Grant Communication Products

YouTube Channel

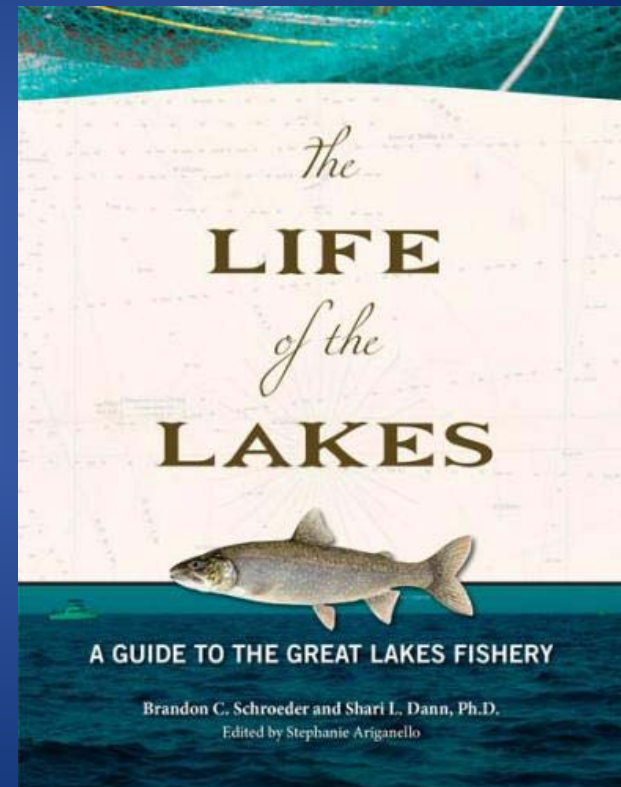
Fish Notes eNewsletter

MSU Extension News

Fact sheets and brochures

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Peer reviewed literature



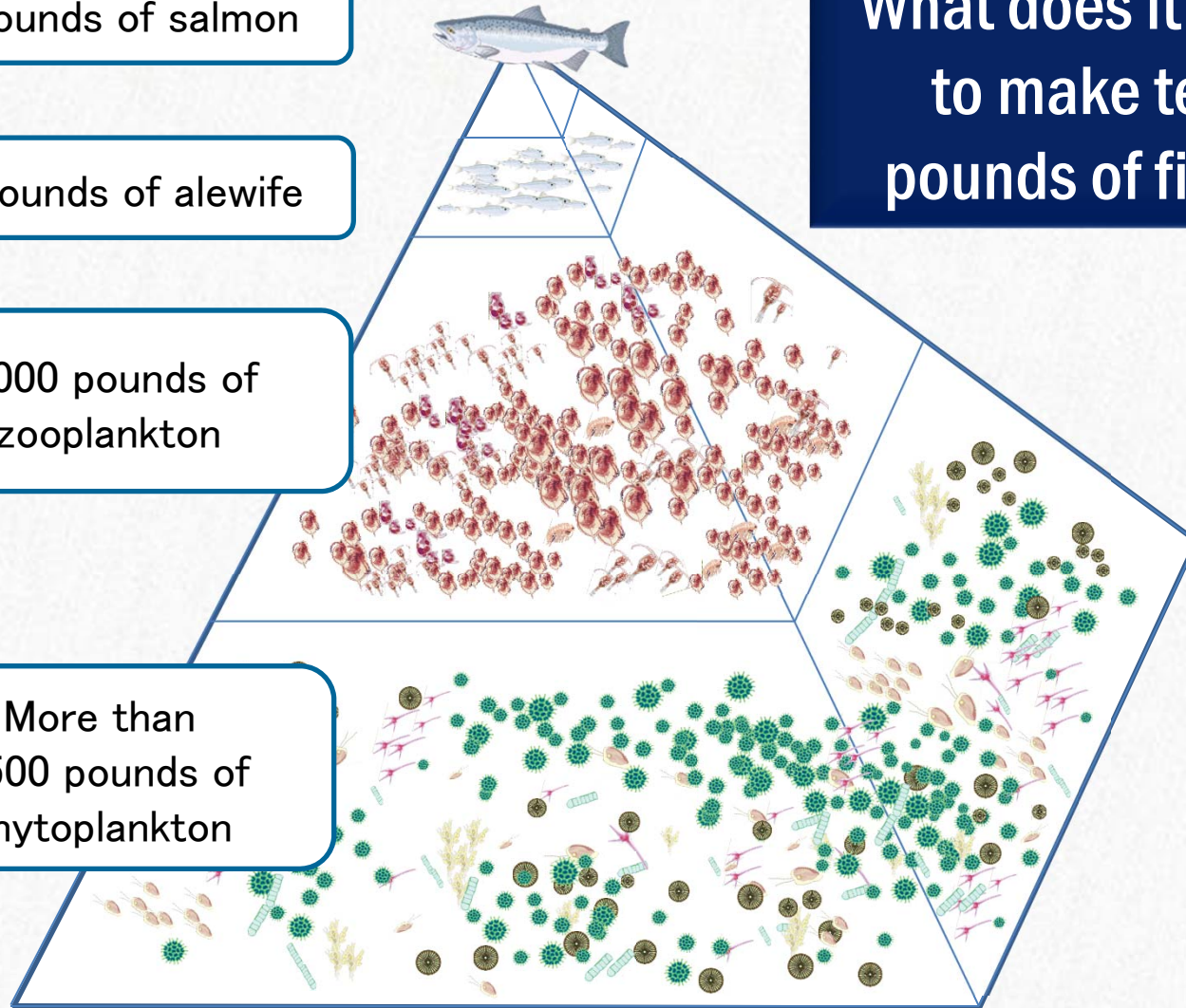
10 pounds of salmon

75 pounds of alewife

2,000 pounds of zooplankton

More than 7,500 pounds of phytoplankton

What does it take
to make ten
pounds of fish?



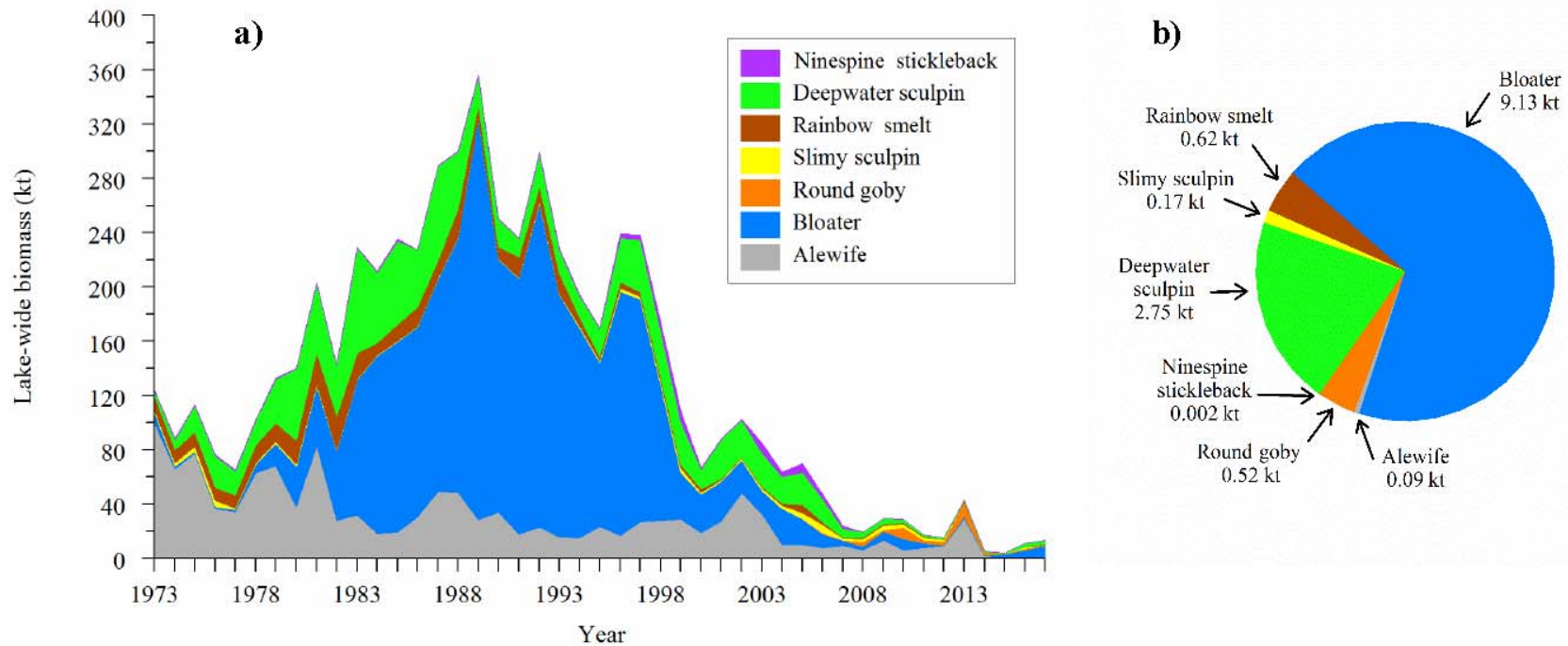


Figure 12. Estimated lake-wide (i.e., 5-114 m depth region) biomass of prey fishes in Lake Michigan, 1973-2017 (a) and species composition in 2017 (b).

USGS Figure

Top Down vs. Bottom Up

Regulation of Productivity

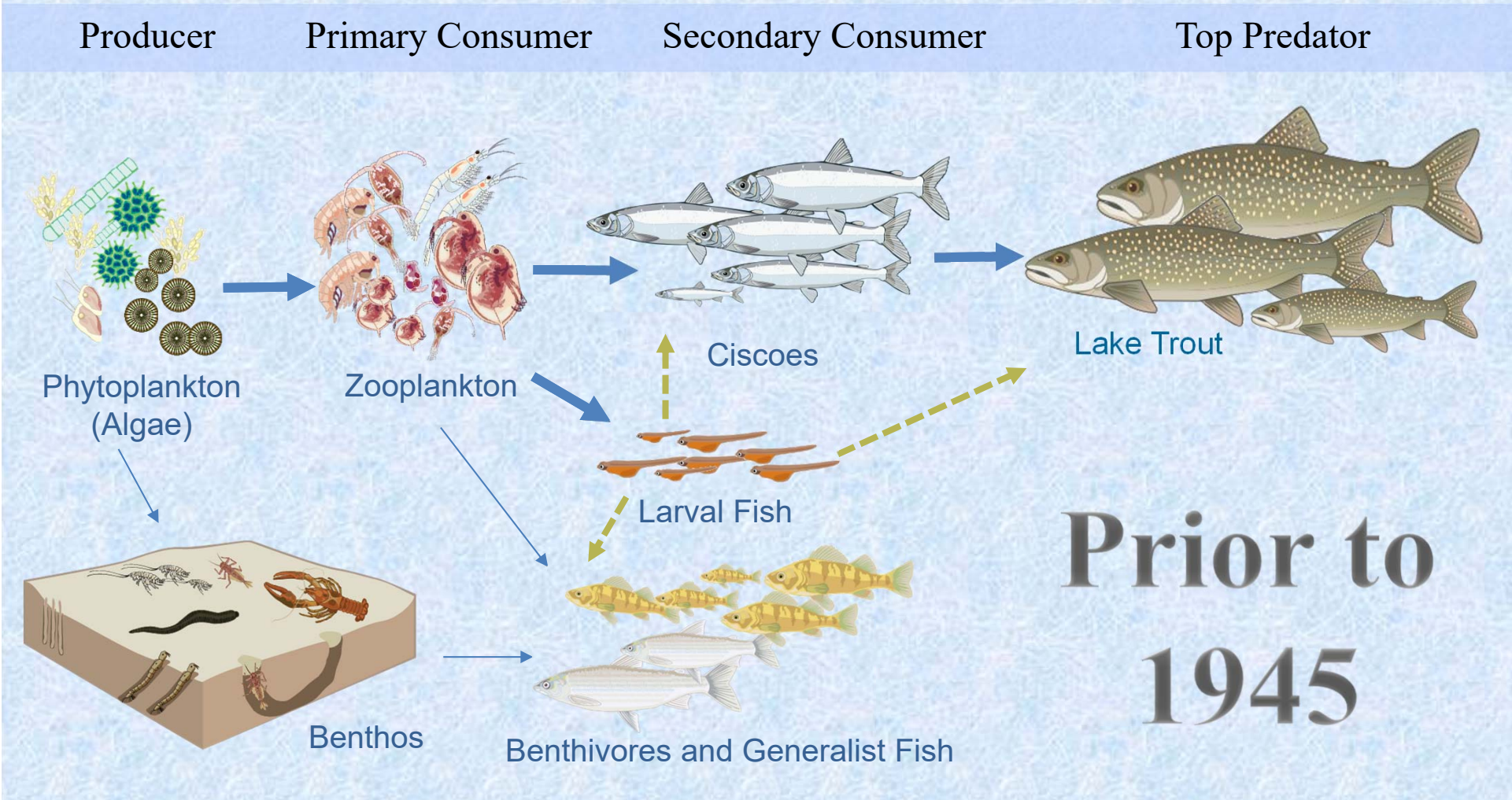


DFO Canada Image

- Strong link between phosphorus and primary production
Schindler (1974)
- Trophic cascade paper demonstrated impact of predation on lower trophic levels
(Carpenter et al. 1985)
- Complementary concepts



Historic Lake Michigan Food Chain



Prior to
1945

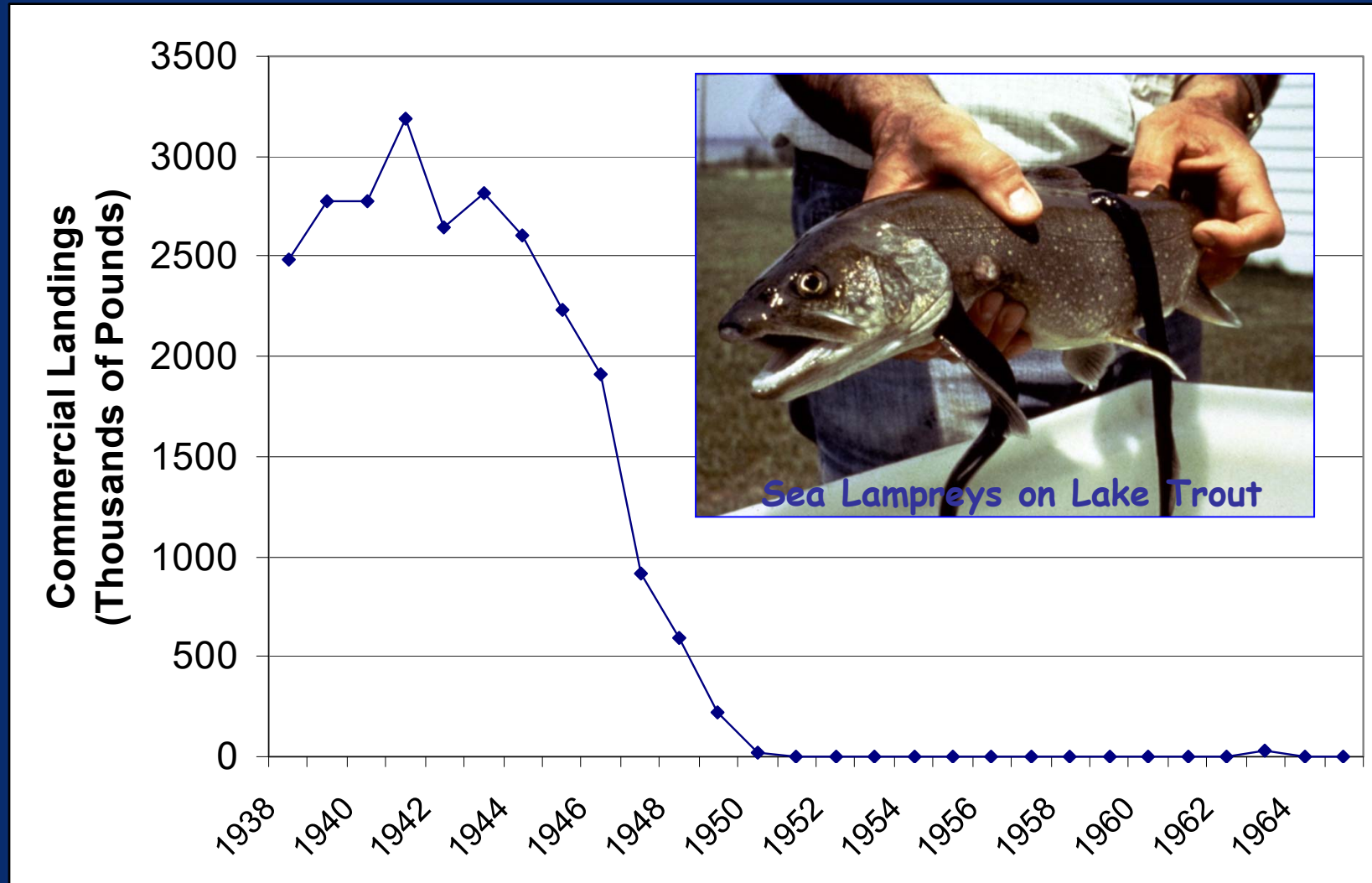
Sea Lamprey





Photo: Great Lakes Fishery Commission

Collapse of Lake Trout in Lk. Michigan



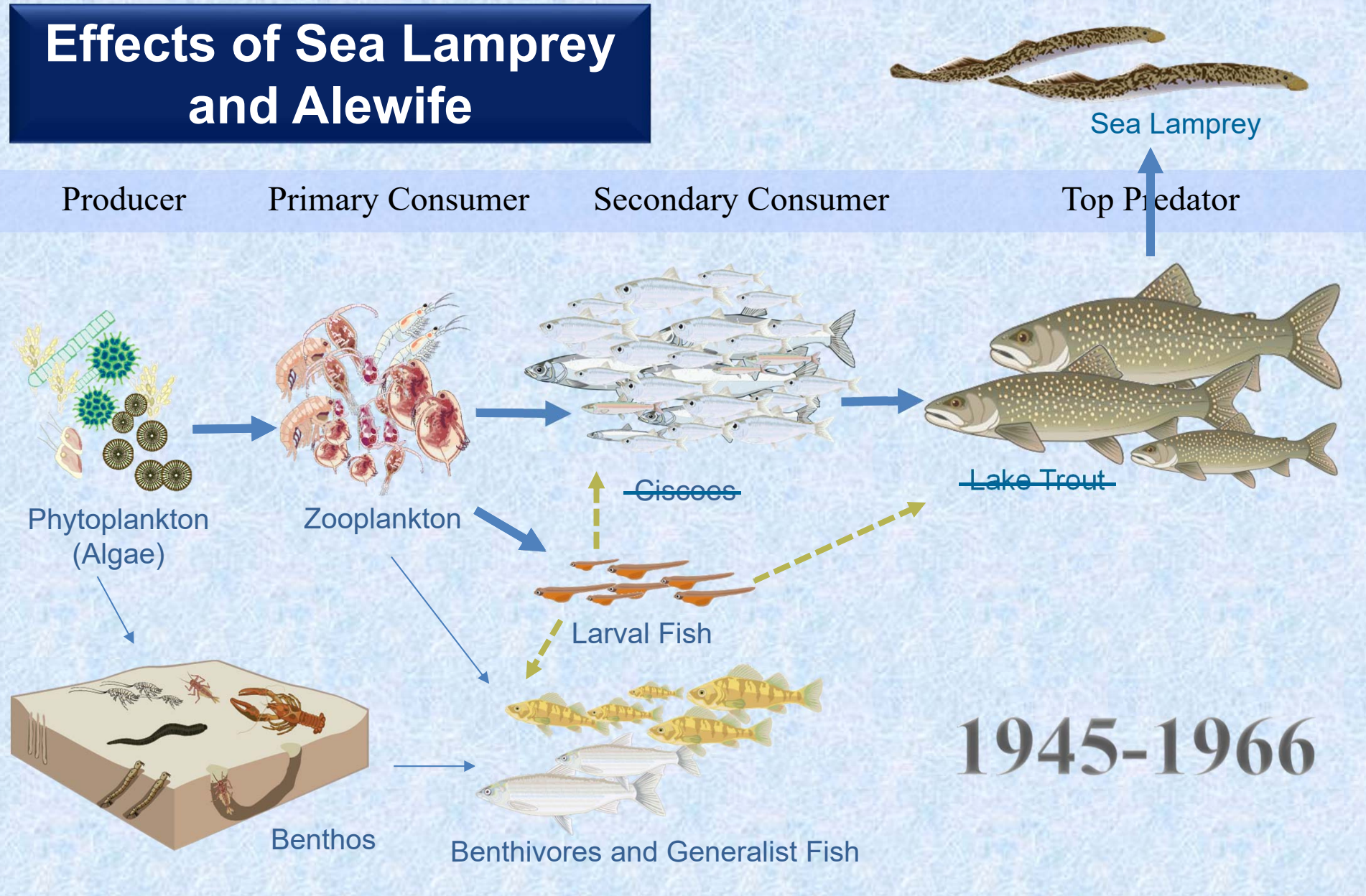
Alewife



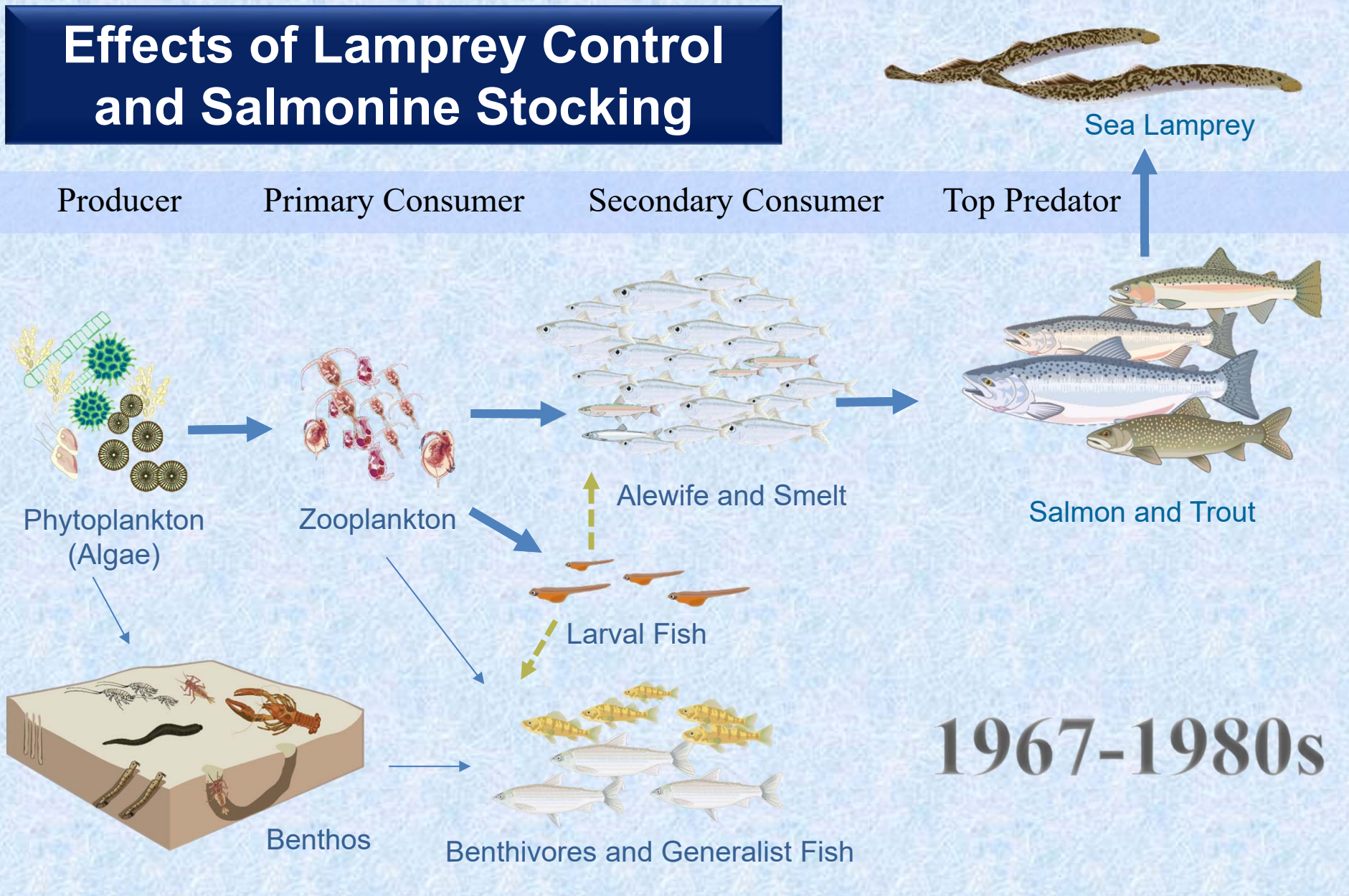


GLFC Photo

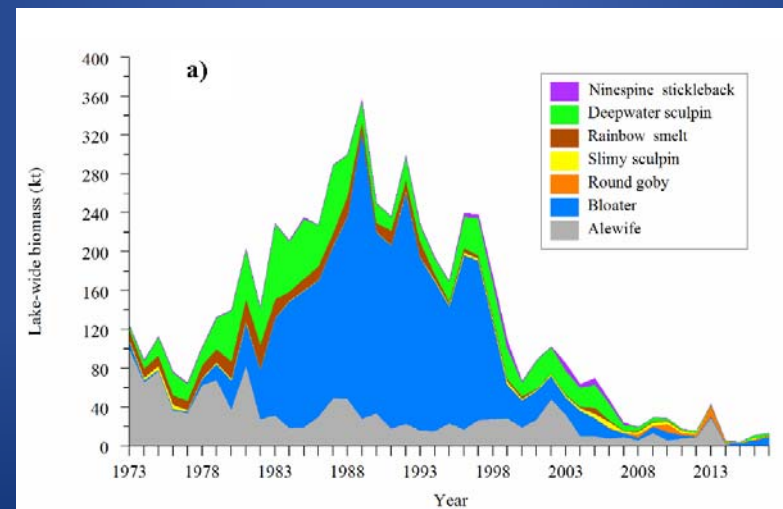
Effects of Sea Lamprey and Alewife



Effects of Lamprey Control and Salmonine Stocking



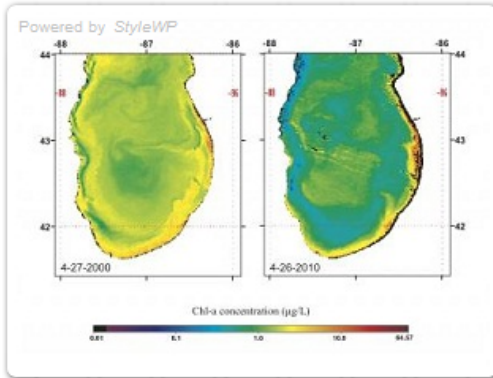
Why have forage fish been declining in Lake Michigan?





In Great Lakes, 'the sky really IS falling'

Published Tuesday, 7th September 2010



How should we react to news that the world's fourth largest lake is rapidly dying before our eyes and that practically nothing is being done to stop it?

Horror and outrage seem appropriate. However, the lead researcher tracking this particular slow-motion death says the response he's gotten is more of a shrug because "people are getting tired of hearing that the sky is falling."

The lake in question is Lake Michigan, the second-largest (by volume) of the US-Canadian Great Lakes. (It's actually the second-largest lake in the world, after the Caspian Sea, if you consider that it and Lake Huron are physically a single body of water.)

be in its biological death throes, just 12 short years after scientists first discovered the unique large-scale "river of phytoplankton" that forms the foundation of

Siphon of quagga mussel



Mar 16, 2009 11:00 AM in [Basic Science](#) | [1 comments](#)

Quagga terror: Alien mussels in U.S. waters cause problems for other species

By [John Platt](#)



Individually, the quagga mussel (*Dreissena rostriformis bugensis*) doesn't look like much.

Barely the size of a human thumbnail, with a non-descript shell, most people probably wouldn't give a quagga mussel a second glance if they saw one in a lake or river.

Unfortunately, quagga mussels don't appear individually, or in pairs, or in tens, but in tens of thousands. This invasive species, native to the Ukraine, has found a home in the United States, causing ecological damage wherever it spreads, and according to experts, it isn't going away any time soon.

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Like it? Thumbs-

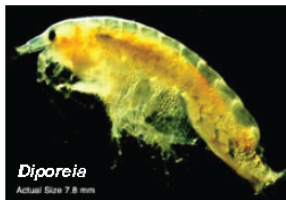
up 5/5 Stumble!

DECLINING FISH HEALTH

While many species of fish will readily eat *Diporeia* (see right), few species can use zebra and quagga mussels efficiently for food. Moreover, even if a fish species does eat these mussels, the loss of *Diporeia* has left many of them with food choices much lower in nutrition than *Diporeia*. In Lake Erie, a severe decrease in smelt stocks was seen in the 1990s. Estimates of the slimy sculpin and lake trout populations in Lake Ontario showed a 95% decline between the late 1980s and 1996. In Lake Michigan, many fish populations are now sacrificing health to feed off zebra mussels. Whitefish, for example, shifted from a diet of 25-75% *Diporeia* to a diet of zebra mussels. During their first 2 weeks of life, larval bluegill reared in the presence of mussels grew 24% slower than fish reared alone. Alewife energy density was 23% lower during 2002-2004 (post zebra mussel invasion) compared to 1979-1981 (pre zebra mussel invasion). As a result, a Chinook salmon now needs to eat 22% more alewives to attain an ideal body weight by age 4.

DIPOREIA DECLINES

Diporeia, a tiny shrimp-like organism, was the dominant benthic invertebrate in most offshore areas of the Great Lakes since the glaciers receded ~10,000 years ago. *Diporeia* have a high lipid (fat) content, with lipids often exceeding 30% of its total weight. As a result, it is rich in calories and a good source of energy for fish. Since the early 1990s population densities of *Diporeia* in all the lower Great Lakes have dropped dramatically. "Exact mechanisms are unclear, but the decline of *Diporeia* is related to the introduction and expansion of the zebra and quagga mussels," says Tom Nalepa, a GLERL biologist who has been sampling Lake Michigan sediments since the early 1980s.



Diporeia

Actual Size 7.8 mm



Possible Explanations

- Dreissenid mussels filter out phytoplankton
- Disappearance of *Diporeia*
- Water Quality Act of 1972 reduced phosphorus inputs
- Other ballast-borne invaders
- Increase in gamefish biomass

Overview Articles











Changing Ecosystem Dynamics in the Laurentian Great Lakes: Bottom-Up and Top-Down Regulation

DAVID B. BUNNELL, RICHARD P. BARBIERO, STUART A. LUDSIN, CHARLES P. MADENJIAN, GLENN J. WARREN, DAVID M. DOLAN, TRAVIS O. BRENDEN, RUTH BRILAND, OWEN T. GORMAN, JI X. HE, THOMAS H. JOHNGEN, BRIAN F. LANTRY, BARRY M. LESHT, THOMAS F. NALEPA, STEPHEN C. RILEY, CATHERINE M. RISENG, TED J. TRESKA, IYOB TSEHAYE, MAUREEN G. WALSH, DAVID M. WARNER, AND BRIAN C. WEIDEL









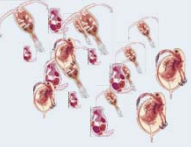
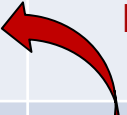






Bunnell et al. 2014; BioScience: 64(1):26-39













Lake Michigan

	April Total Phosphorus (ppb)	Zooplankton (lbs/acre)	Gamefish (lbs/acre)	Water Clarity (feet)	Dreissenids (no/ft ²)
1985-1990	 5	 27	 4.6	 32.8	
2005-2010	 3	 16	 4.3	 41.7	 1,175.08






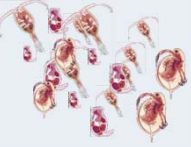





Lake Michigan

		Trend From 1998-2010	Top Down or Bottom Up?
Trout and Salmon			
Forage Fish			 TOP DOWN
Native Benthos			 BOTTOM UP
Zooplankton		NO TREND	 BOTTOM UP
May Chlorophyll a			 BOTTOM UP
April Total Phosphorus			 BOTTOM UP












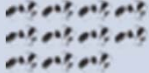



Lake Huron

	April Total Phosphorus (ppb)	Zooplankton (lbs/acre)	Gamefish (lbs/acre)	Water Clarity (feet)	Dreissenids (no/ft ²)
1985-1990	 4	 12	 1.0	 28.9	
2005-2010	 2	 8	 0.6	 45.4	 116

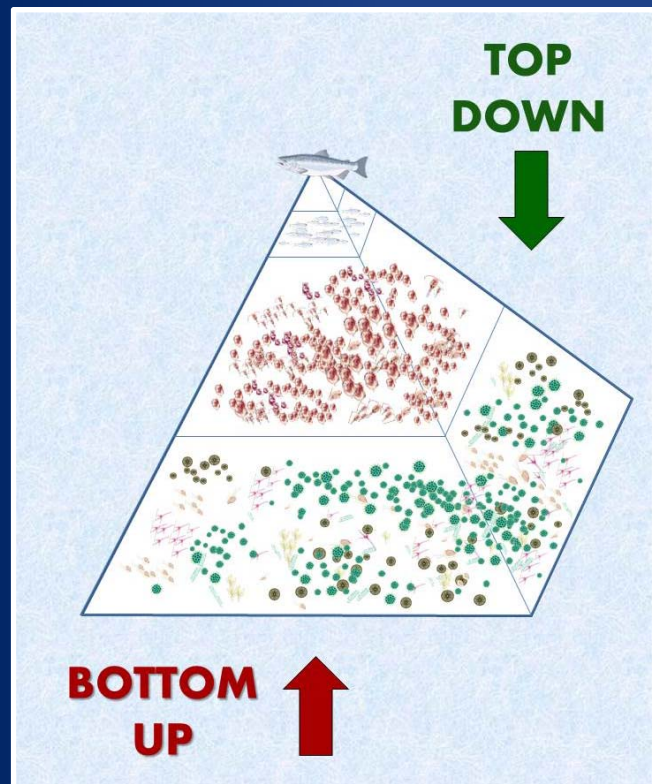
Lake Huron

		Trend From 1998-2010	Top Down or Bottom Up?
Trout and Salmon		NO TREND	BOTTOM UP
Forage Fish			BOTTOM UP
Native Benthos			BOTTOM UP
Zooplankton			BOTTOM UP
May Chlorophyll a			BOTTOM UP
April Total Phosphorus			BOTTOM UP

Lake Comparisons 2005-2010

	April Total Phosphorus (ppb)	Zooplankton (lbs/acre)	Gamefish (lbs/acre)	Water Clarity (feet)	Dreissenids (no/ft ²)
Lake Michigan	 3	 16	 4.3	 41.7	 1,175
Lake Huron	 2	 8	 0.6	 45.4	 116
Lake Superior	 2	 11		 50.9	

Conclusions



- Evidence for both top-down and bottom-up forcing in Lake Michigan
- Bottom-up regulation in Lake Huron
- Both processes are important
- Relative importance of each type of forcing varies by lake and time period



Acknowledgements

- Bo Bunnell (USGS)
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- Steve Pothoven (NOAA)
- Katelyn Brolick (MI Sea Grant)
- Todd Marsee (MI Sea Grant)



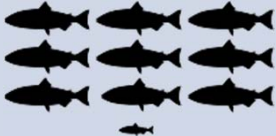







...and many, many more!

Any Questions?











Lake Superior

	April Total Phosphorus (ppb)	Zooplankton (lbs/acre)	Gamefish (lbs/acre)	Water Clarity (feet)	Dreissenids (no/ft ²)
1985-1990					
2005-2010	 2	 11		 50.9	











Lake Ontario

	April Total Phosphorus (ppb)	Zooplankton (lbs/acre)	Gamefish (lbs/acre)	Water Clarity (feet)	Dreissenids (no/ft ²)
1985-1990	 8	 25	 9.3	 29.1	
2005-2010	 6	 16	 2.6	 47.1	 573





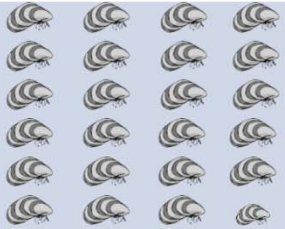





Lake Erie (*Western Basin*)

	April Total Phosphorus (ppb)	Zooplankton (lbs/acre)	Gamefish (lbs/acre)	Water Clarity (feet)	Dreissenids (no/ft ²)
1985-1990	 17	 5		 6.7	
2005-2010	 38	 18		 4.7	 96

Lake Comparisons 1985-1990

	April Total Phosphorus (ppb)	Zooplankton (lbs/acre)	Gamefish (lbs/acre)	Water Clarity (feet)	Dreissenids (no/ft ²)
Lake Michigan	 5	 27	 4.6	 32.8	
Lake Huron	 4	 12	 1.0	 28.9	

Lake Comparisons 2005-2010

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Fishhook and Spiny Water Fleas

Round Goby

Quagga and Zebra Mussels