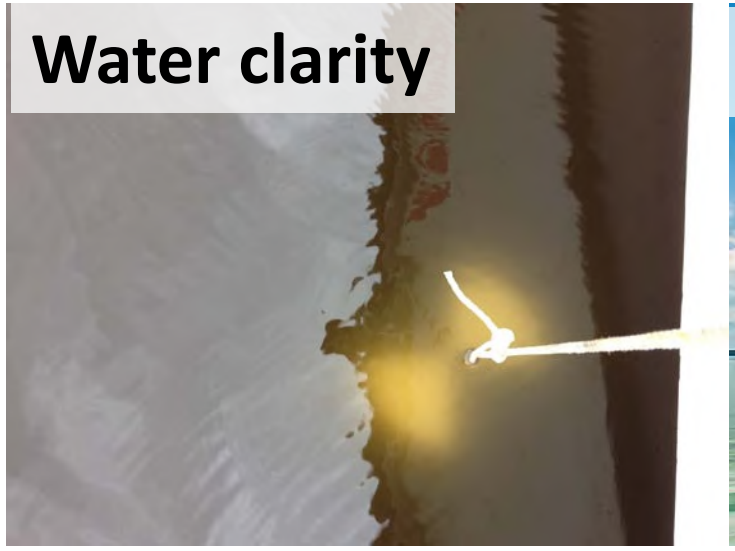
Spiny water flea uncouples indicators of water quality in eutrophic Lake Mendota

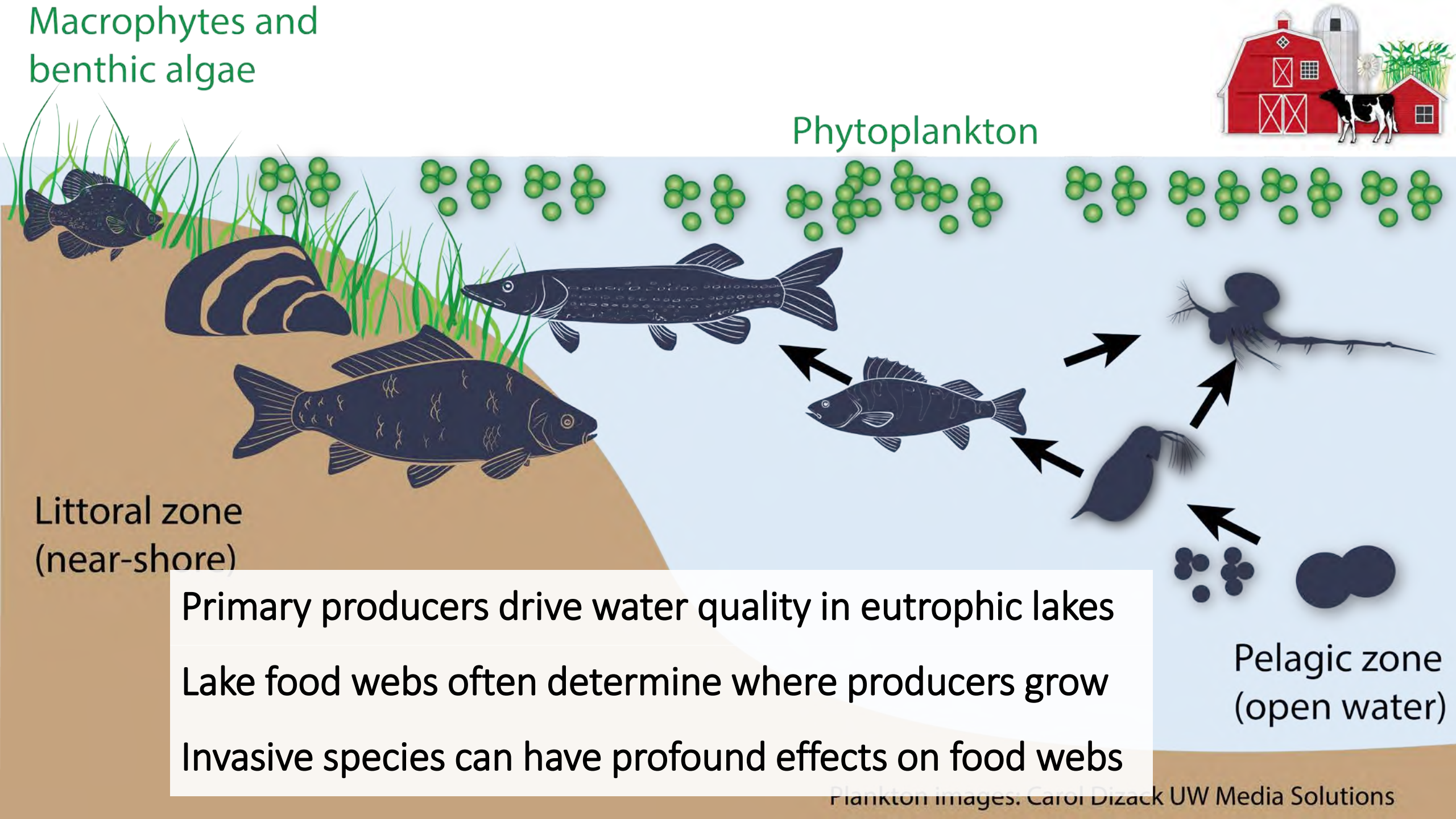
Jake Walsh, Richard Lathrop, Jake Vander Zanden

ICAIS 2019 | G1 | Impacts on Biodiversity and Ecosystems

Center for Limnology
University of Wisconsin–Madison

Water quality in eutrophic lakes is multi-faceted





Primary producers drive water quality in eutrophic lakes

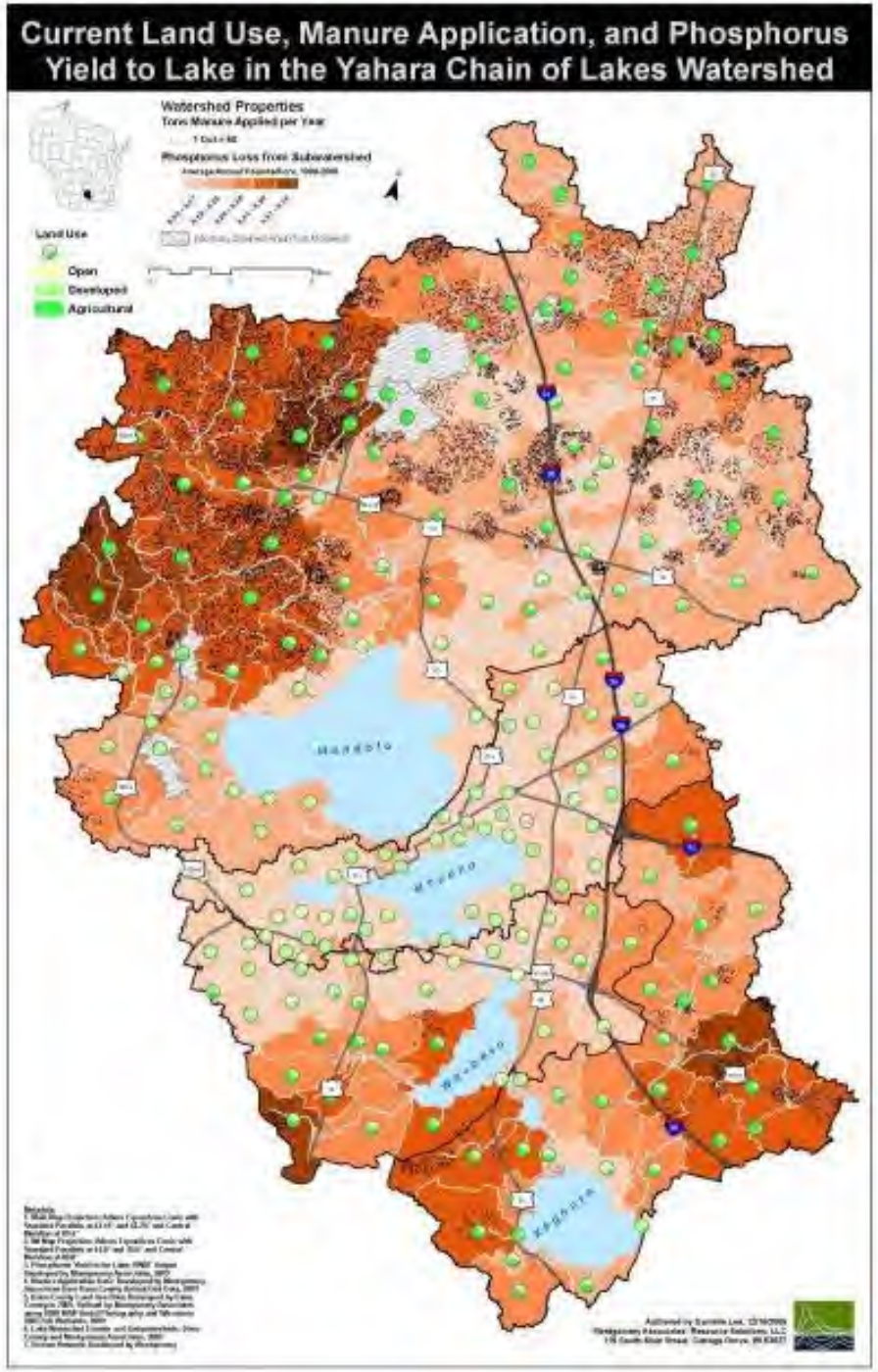
Lake food webs often determine where producers grow

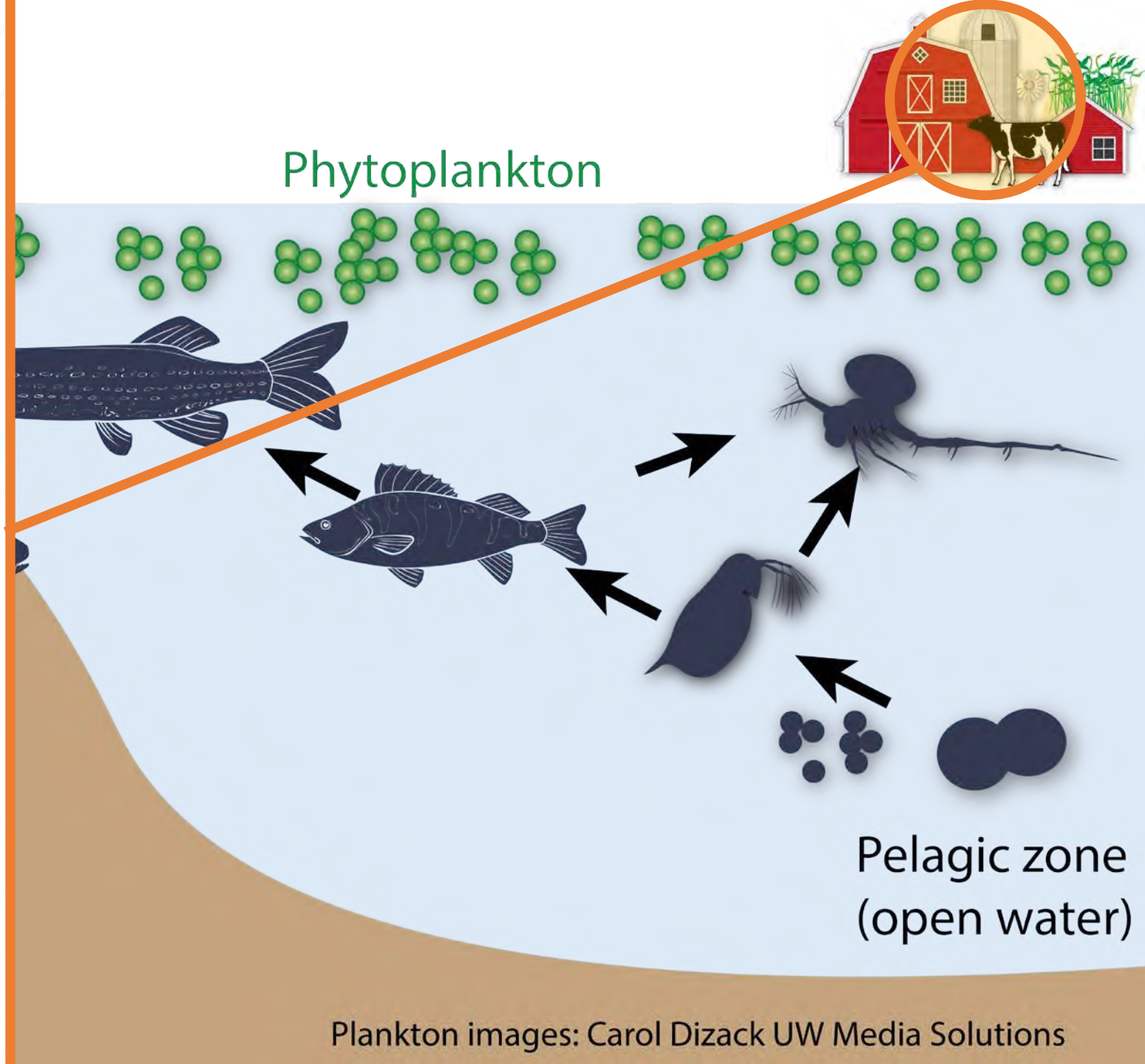
Invasive species can have profound effects on food webs

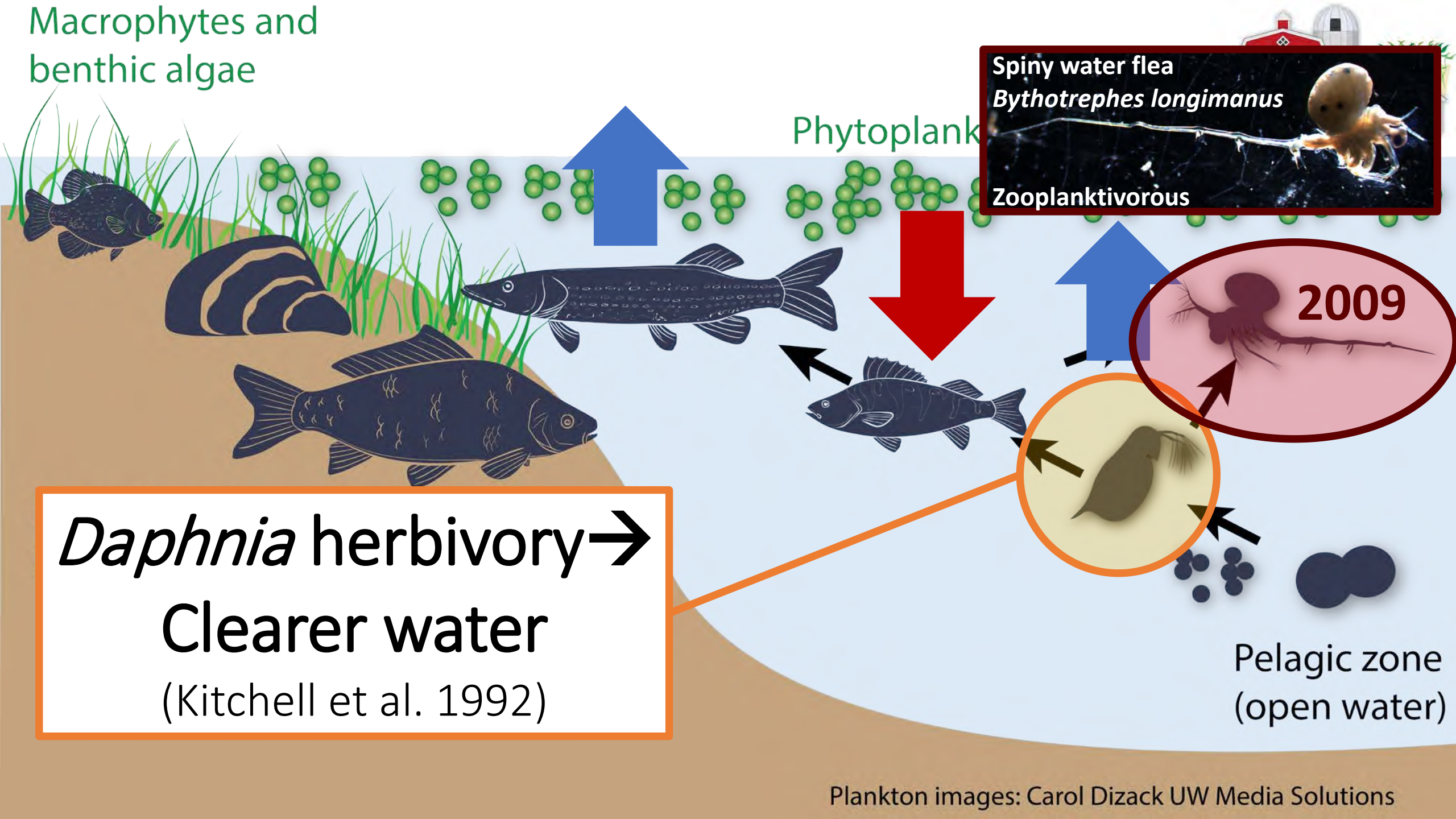
Plankton images: Carol Dizack UW Media Solutions

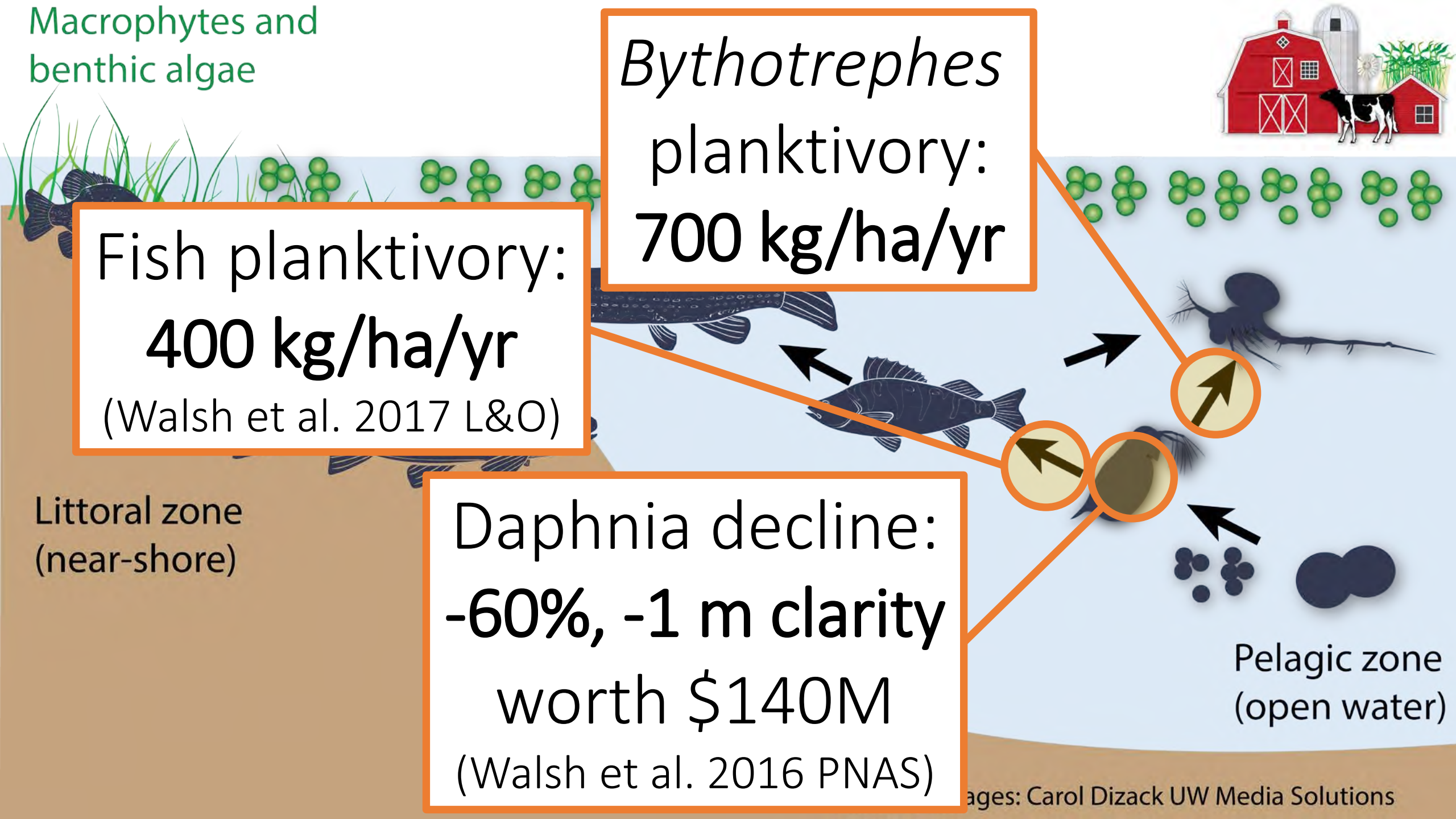
Lake Mendota, WI (USA)

Lake Mendota is a culturally eutrophic lake.

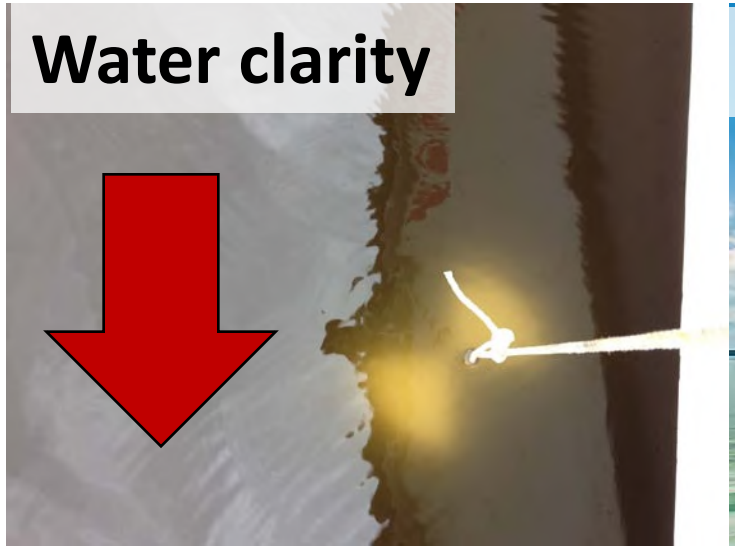

Current Land Use, Manure Application, and Phosphorus Yield to Lake in the Yahara Chain of Lakes Watershed
Watershed Properties
Tons Manure Applied per Year
Phosphorus Loss from Subwatershed
Land Use
Open
Developed
Agricultural


Phytoplankton
Pelagic zone
(open water)
Plankton images: Carol Dizack UW Media Solutions

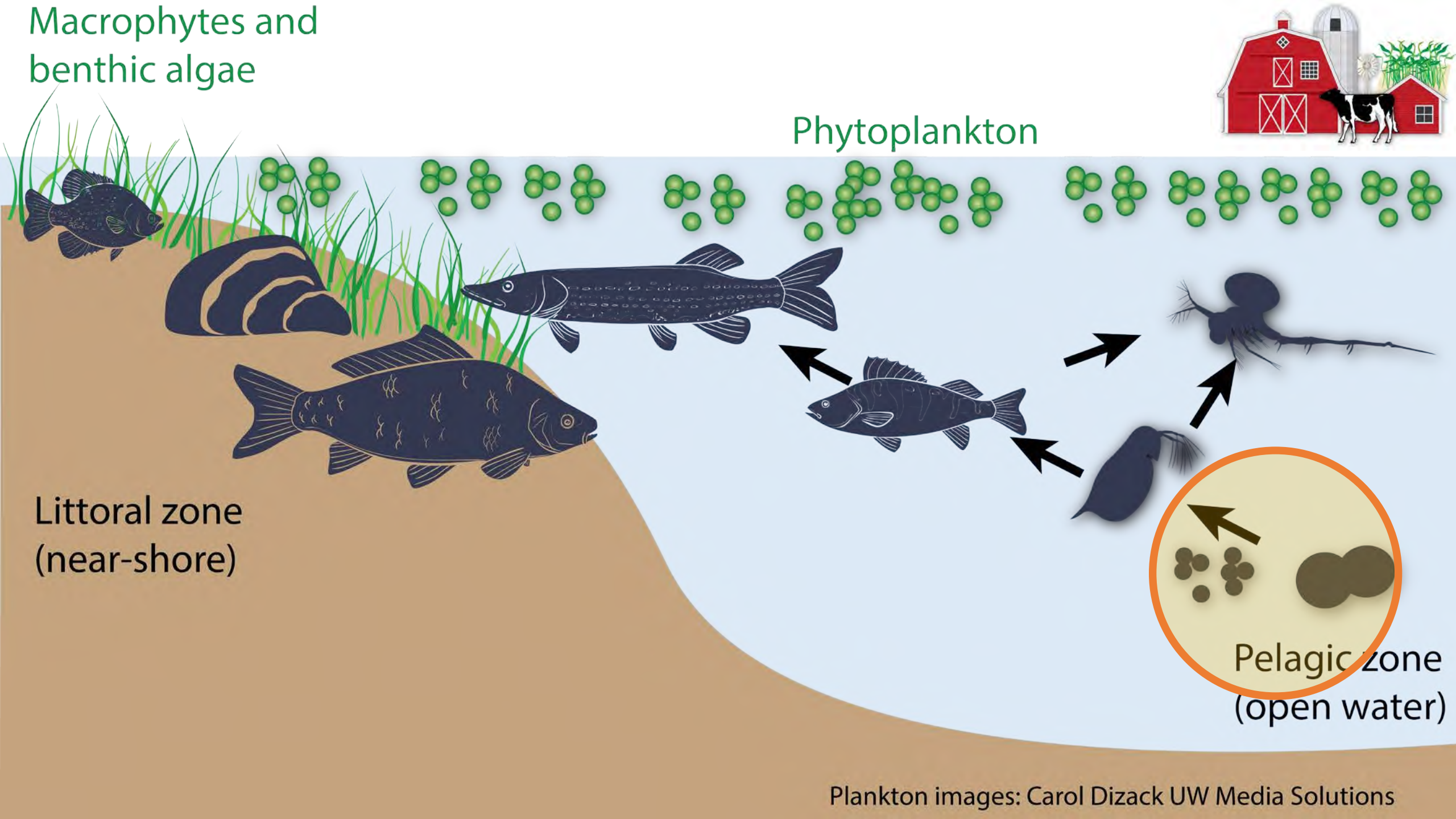

Macrophytes and benthic algae
Phytoplank
Spiny water flea
Bythotrephes longimanus
Zooplanktivorous
2009
Daphnia herbivory→
Clearer water
(Kitchell et al. 1992)
Pelagic zone
(open water)
Plankton images: Carol Dizack UW Media Solutions

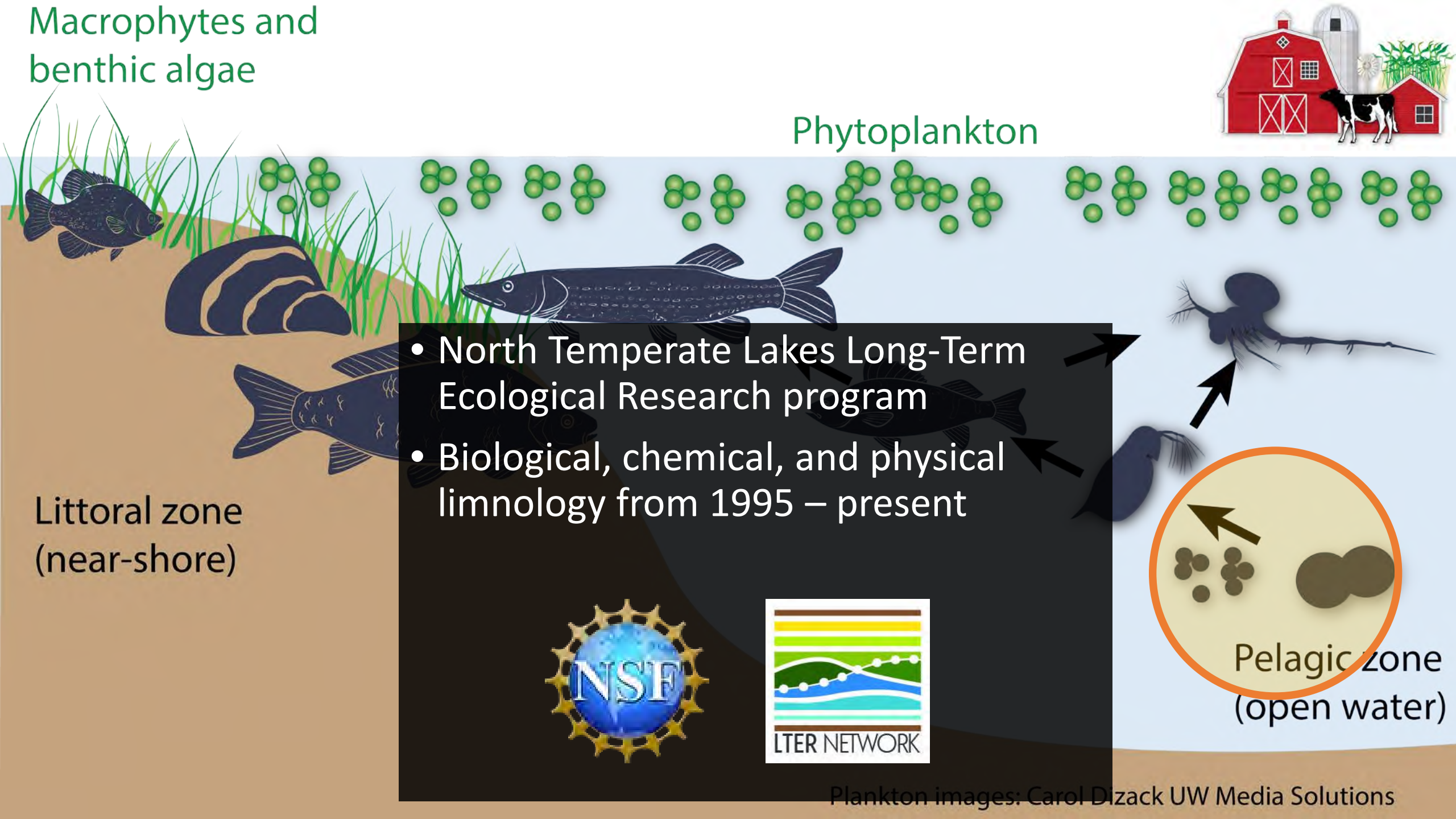

Macrophytes and benthic algae
Bythotrephes planktivory: **700 kg/ha/yr**
Fish planktivory: **400 kg/ha/yr** (Walsh et al. 2017 L&O)
Littoral zone (near-shore)
Daphnia decline: **-60%, -1 m clarity** worth $140M (Walsh et al. 2016 PNAS)
Pelagic zone (open water)
ages: Carol Dizack UW Media Solutions

What do we mean by “water quality”?



Benthic algae and macrophytes

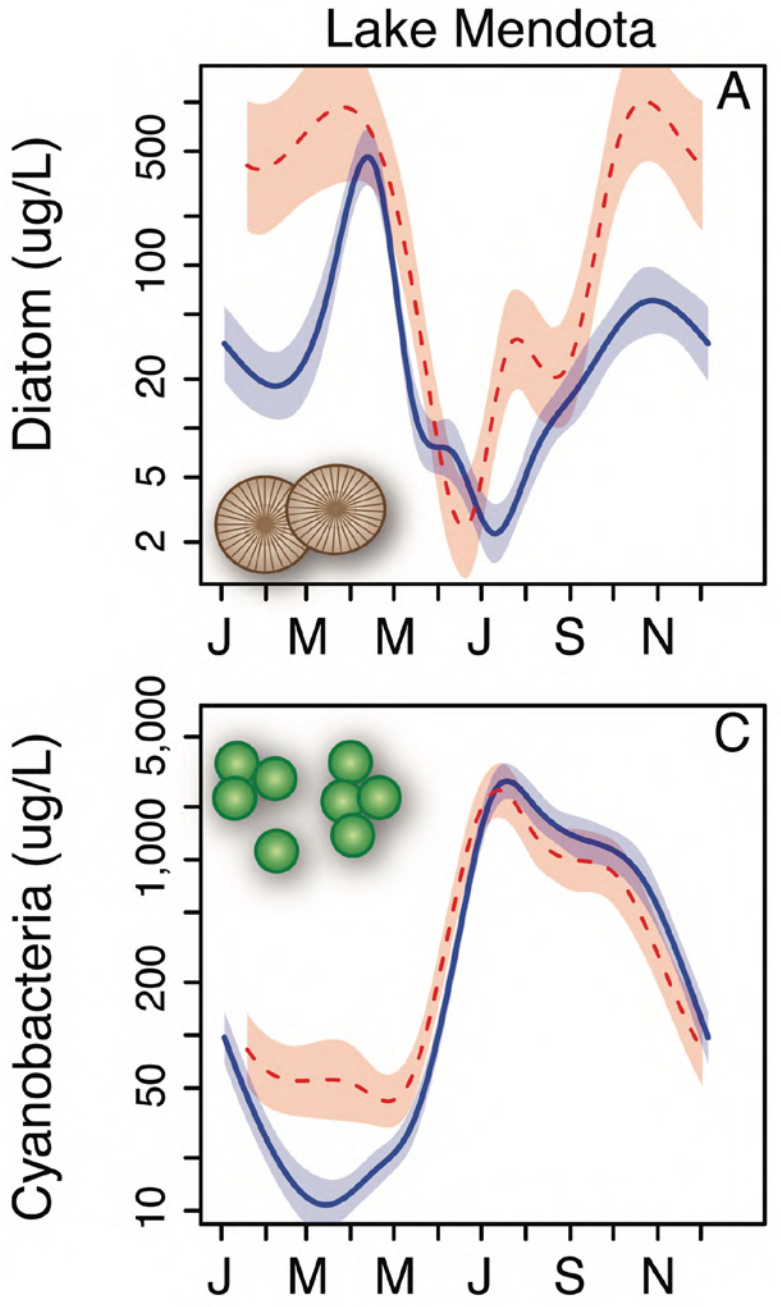

Macrophytes and
benthic algae
Phytoplankton
Littoral zone
(near-shore)
Pelagic zone
(open water)
Plankton images: Carol Dizack UW Media Solutions


Macrophytes and benthic algae
Phytoplankton
Littoral zone (near-shore)
Pelagic zone (open water)
• North Temperate Lakes Long-Term Ecological Research program
• Biological, chemical, and physical limnology from 1995 – present
NSF
LTER NETWORK
Plankton images: Carol Dizack UW Media Solutions

Phytoplankton community change

- Diatoms: “brown algae”, harmless BUT decrease clarity

- Cyanobacteria: “blue-green algae”, harmful AND decrease clarity

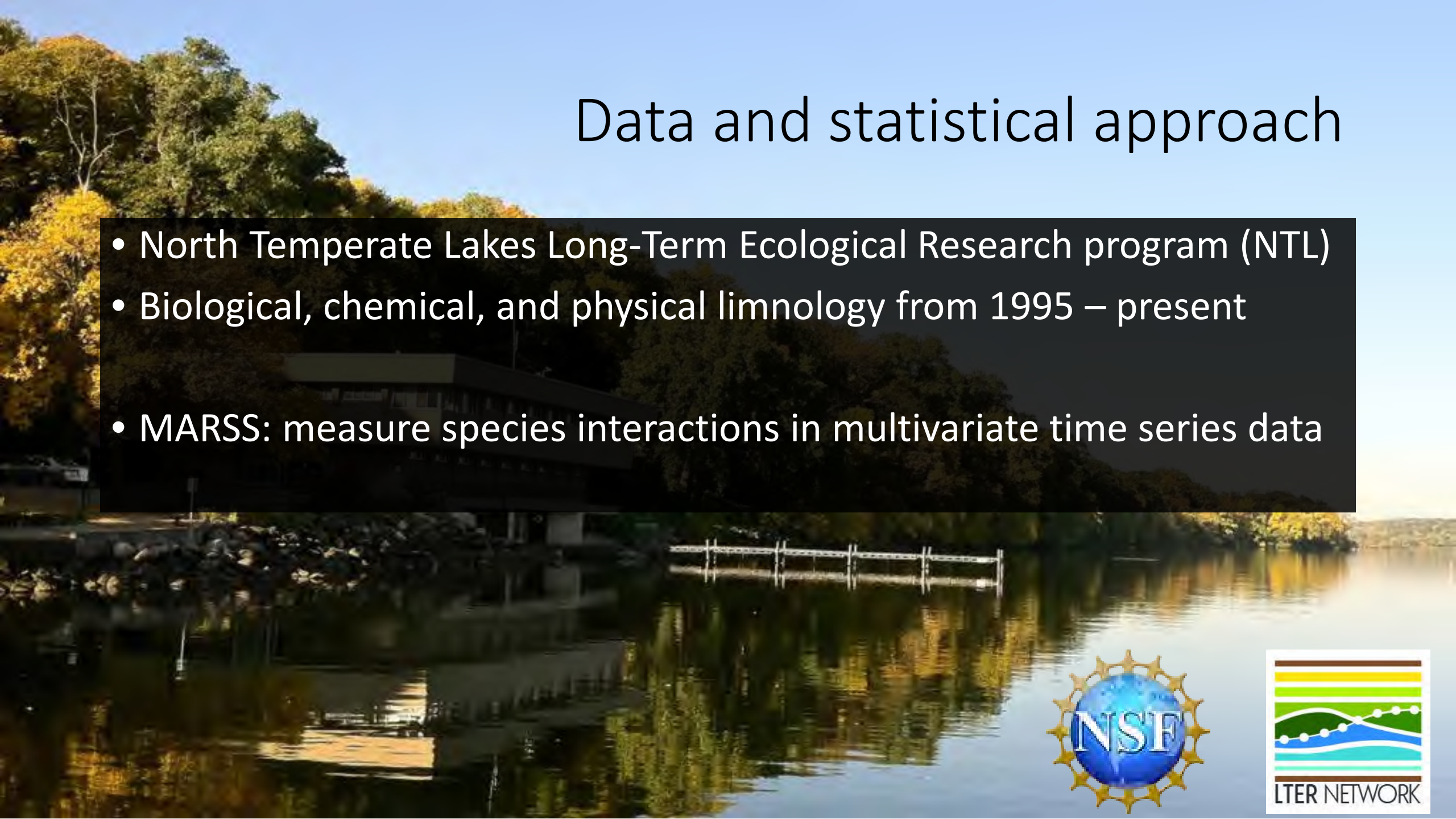


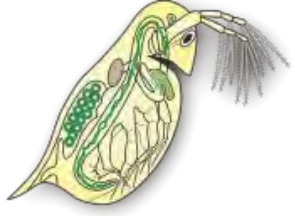
Walsh et al. 2018 L&O

Data and statistical approach

- North Temperate Lakes Long-Term Ecological Research program (NTL)
- Biological, chemical, and physical limnology from 1995 – present

- MARSS: measure species interactions in multivariate time series data



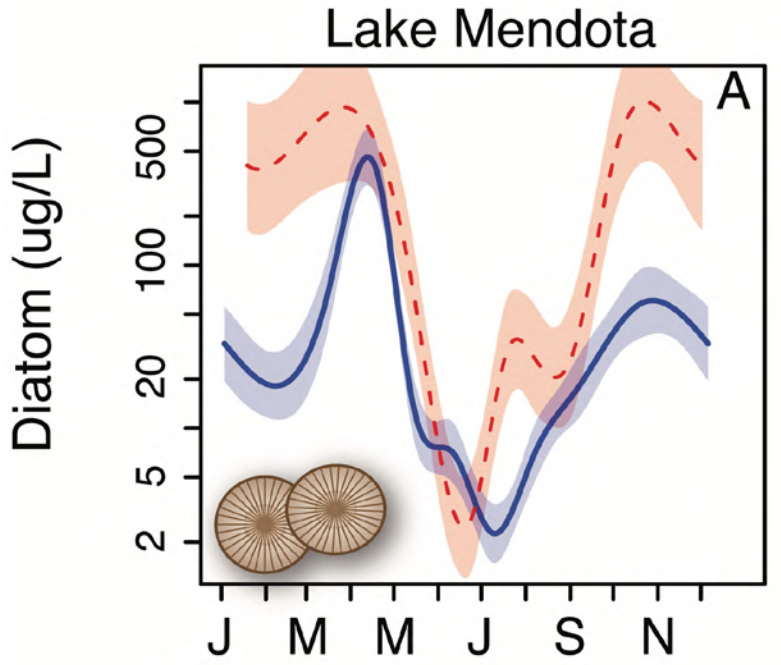


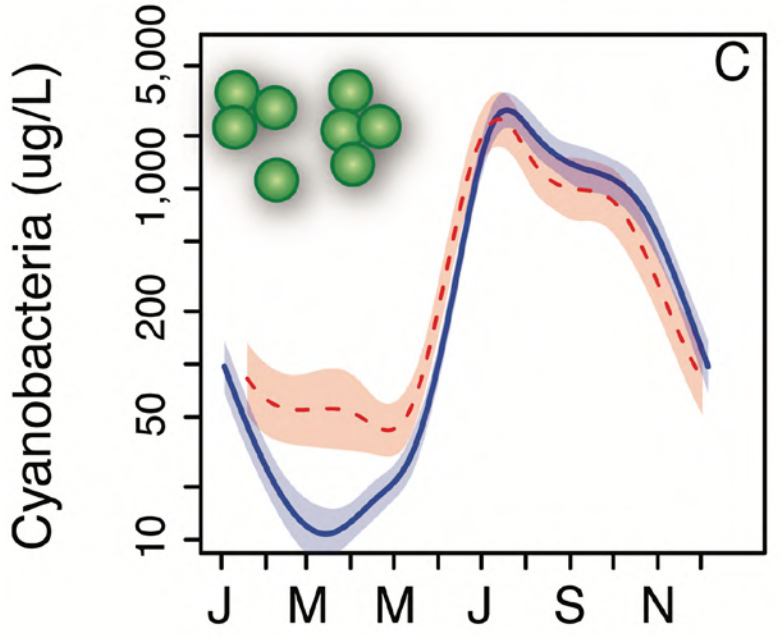
D. pulicaria

Cyanobacteria

Diatoms

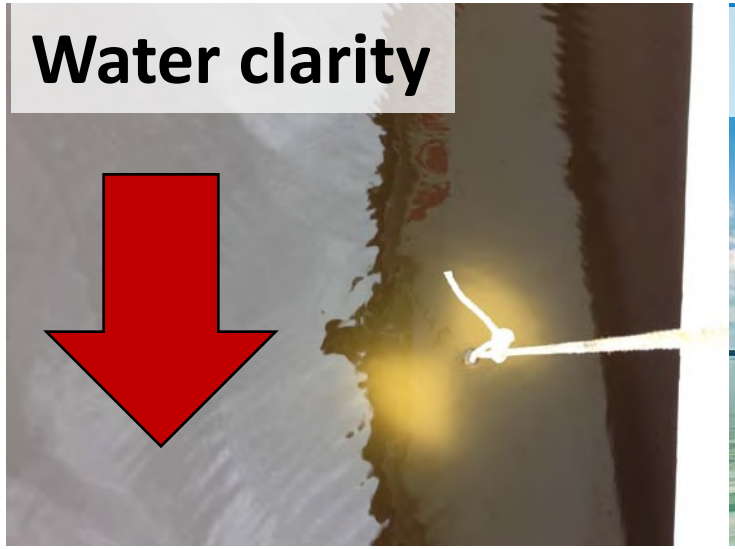
[TP]
Nutrients

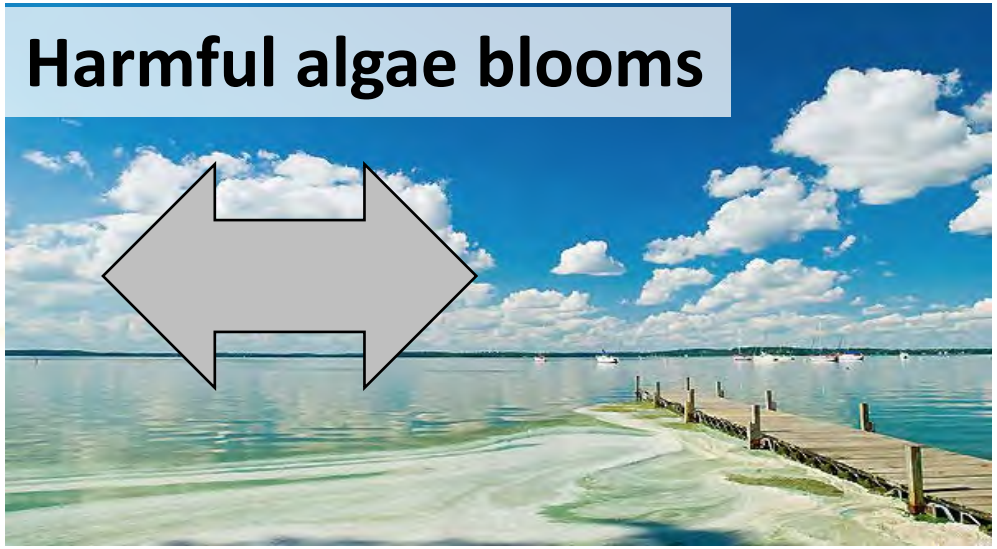




Walsh et al. 2018 L&O

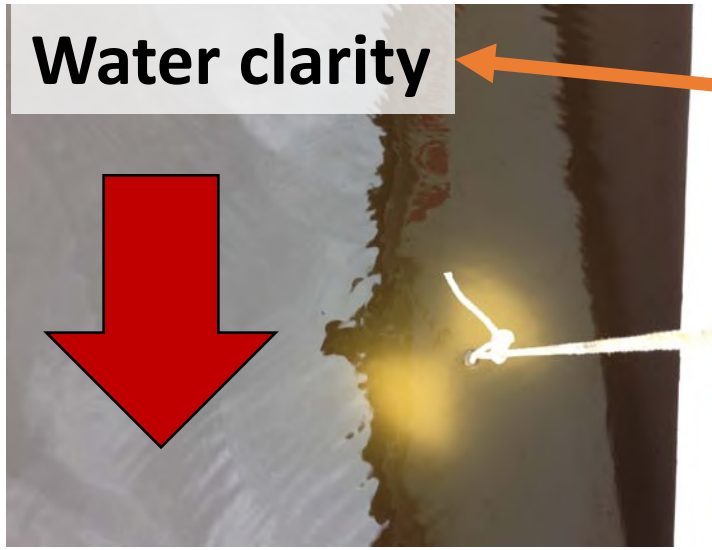
Uncoupling indicators of water quality

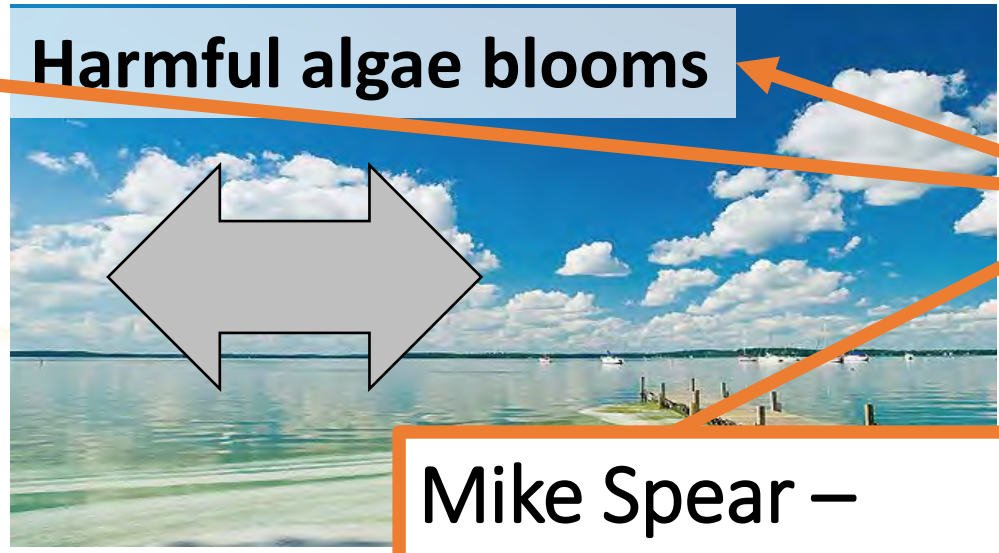


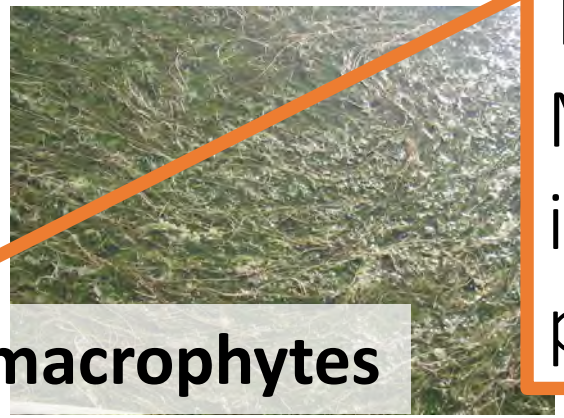


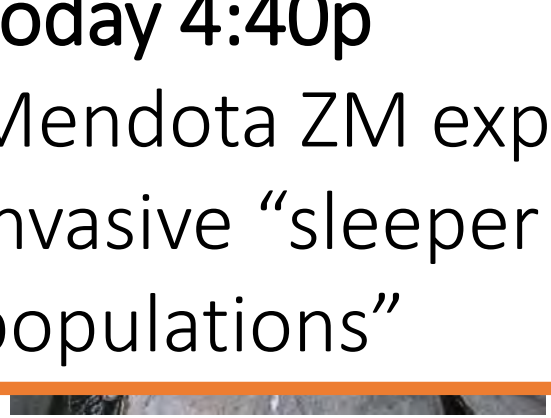
Benthic algae and macrophytes

Zebra mussels: Detected in 2015





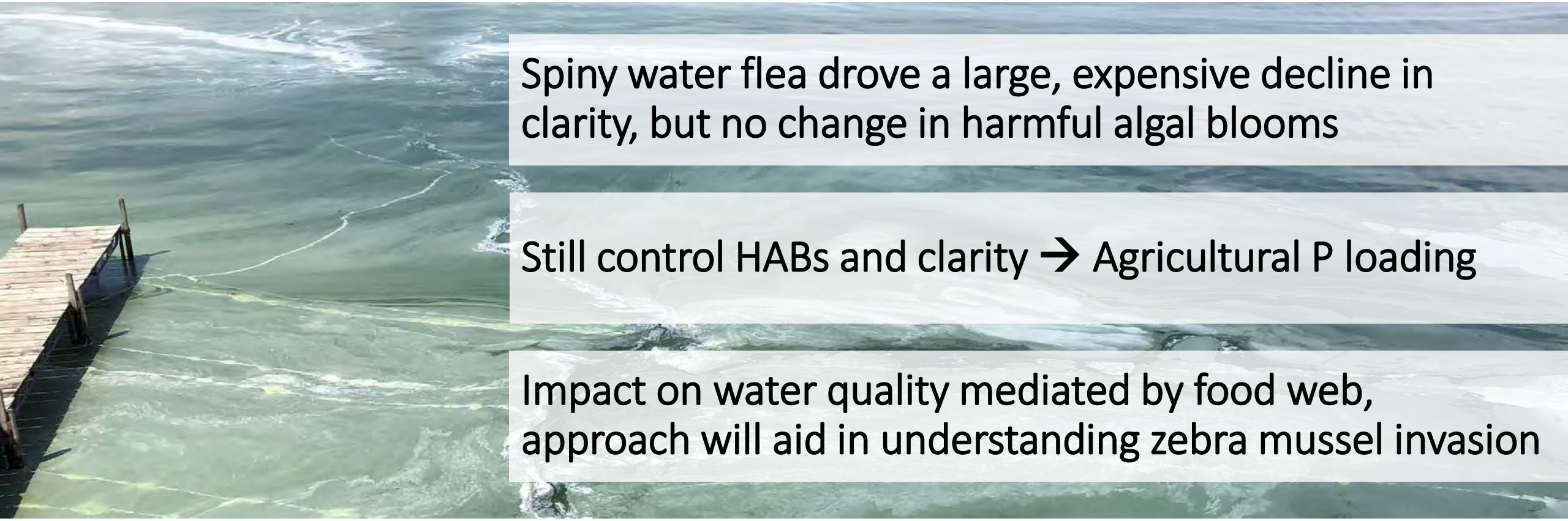




Benthic algae and macrophytes

Mike Spear –
Today 4:40p
Mendota ZM expert: invasive “sleeper populations”

Summary:



Spiny water flea drove a large, expensive decline in clarity, but no change in harmful algal blooms

Still control HABs and clarity → Agricultural P loading

Impact on water quality mediated by food web, approach will aid in understanding zebra mussel invasion

Thanks!

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Center for Limnology
University of Wisconsin

Data and statistical approach

Multivariate autoregressive state-space models

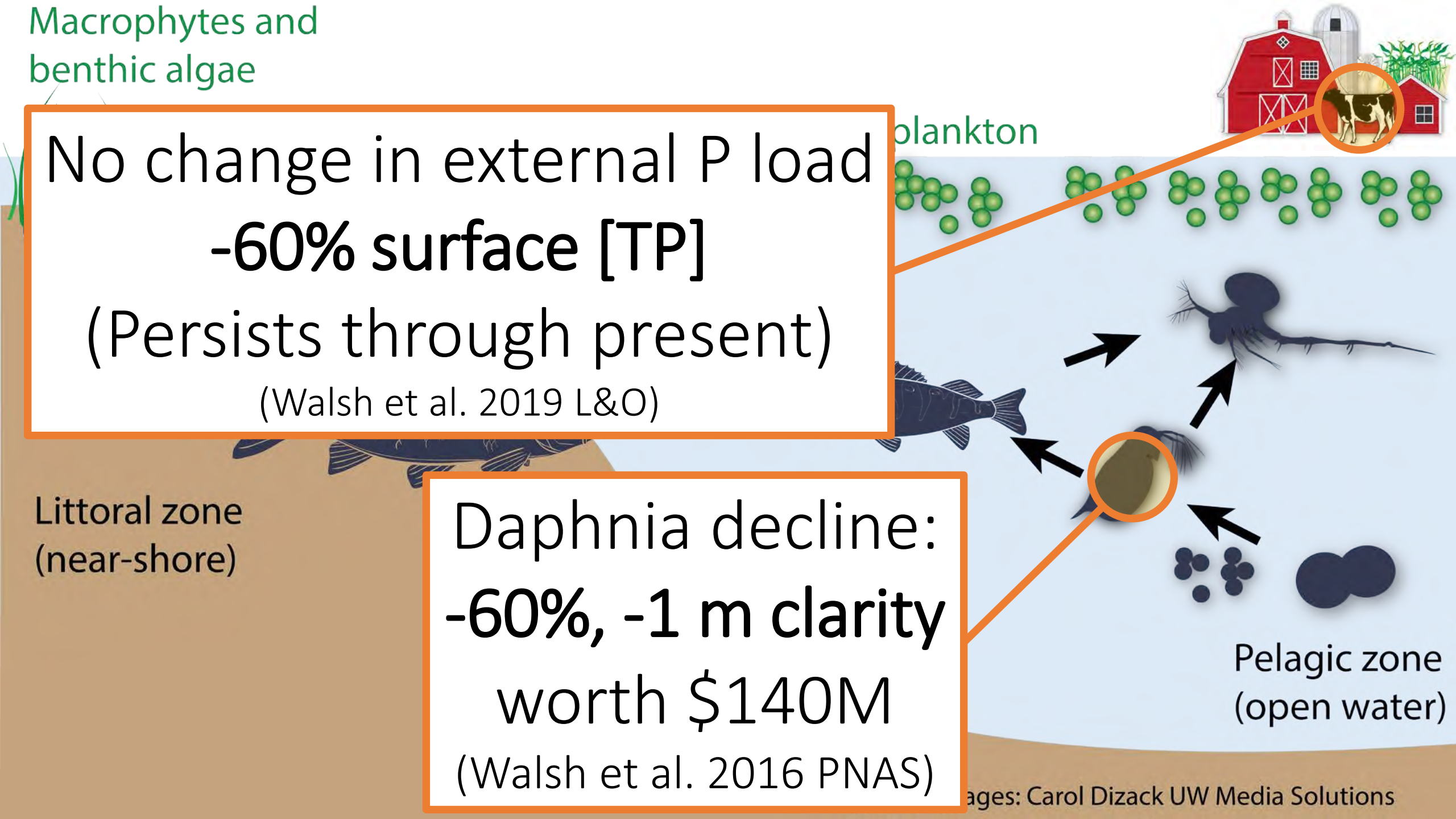
- **Primary purpose here:** Estimate ecological interactions in time series
- **Key advantage:** Separate observation and process error

Species interactions **Growth rates** **Process error**

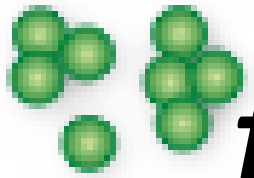
Process: $x_t = Bx_{t-1} + u + w_t, where\ w_t \sim MVN(0, Q)$

Maps observation time series (NTL data) onto hidden process variables

Observation: $y_t = Zx_t + a + v_t, where\ v_t \sim MVN(0, R)$

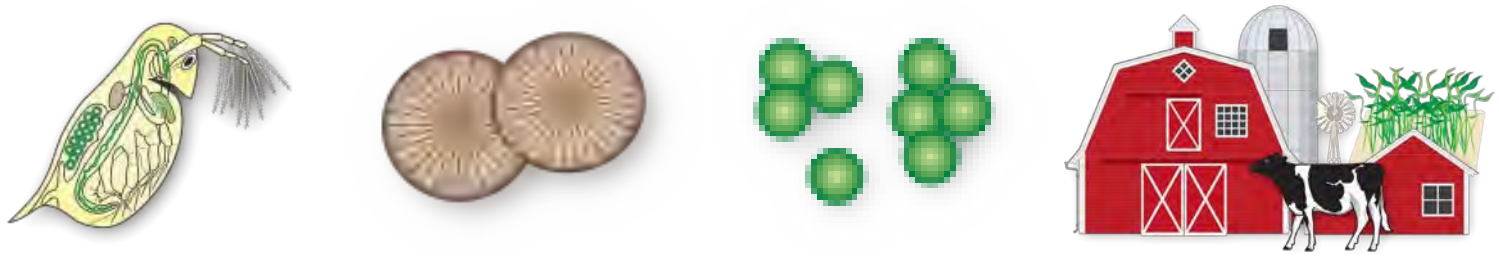

Macrophytes and
benthic algae
No change in external P load
-60% surface [TP]
(Persists through present)
(Walsh et al. 2019 L&O)
Littoral zone
(near-shore)
Daphnia decline:
-60%, -1 m clarity
worth $140M
(Walsh et al. 2016 PNAS)
Pelagic zone
(open water)
ages: Carol Dizack UW Media Solutions

Process: $x_t = Bx_{t-1} + u + w_t$

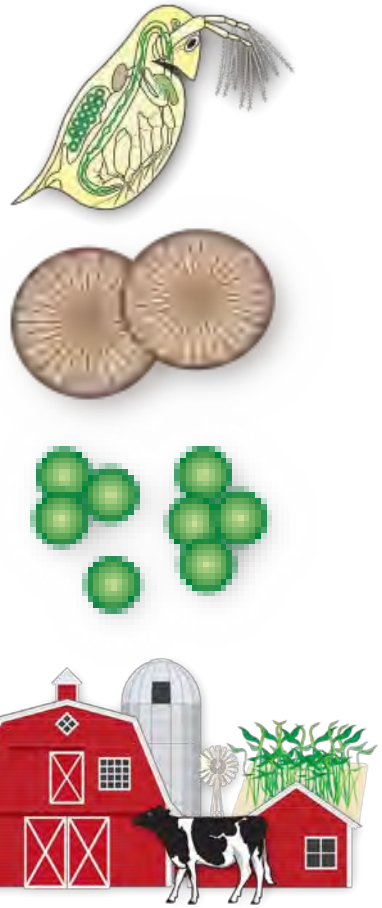
$$x_t = \begin{bmatrix} \text{  } \; t \\ \text{  } \; t \\ \text{  } \; t \\ \text{  } \; t \end{bmatrix}$$

Process: $x_t = Bx_{t-1} + u + w_t$

Matrix of column effects on rows



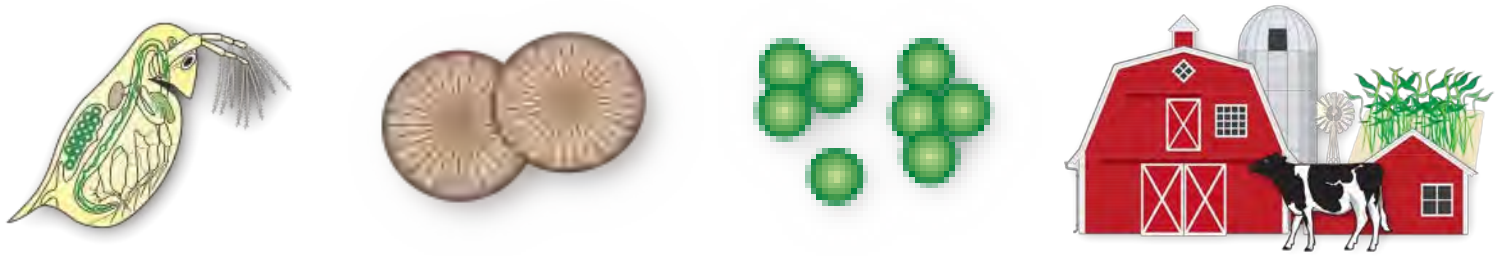
$B =$



~ Density dependence

Process: $x_t = Bx_{t-1} + u + w_t$

Matrix of column effects on rows



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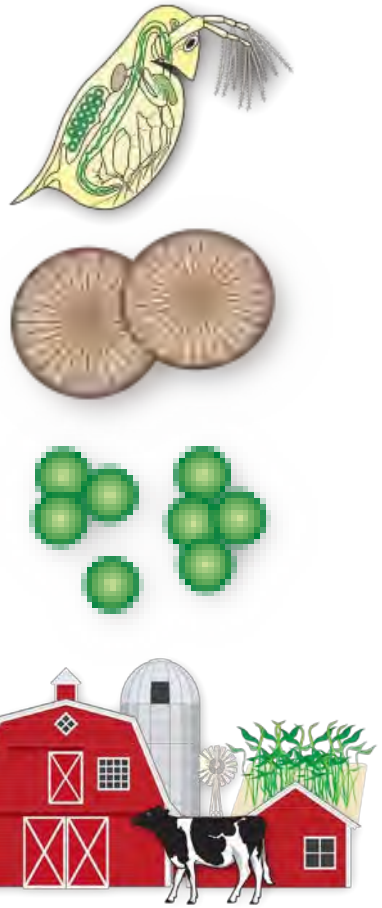

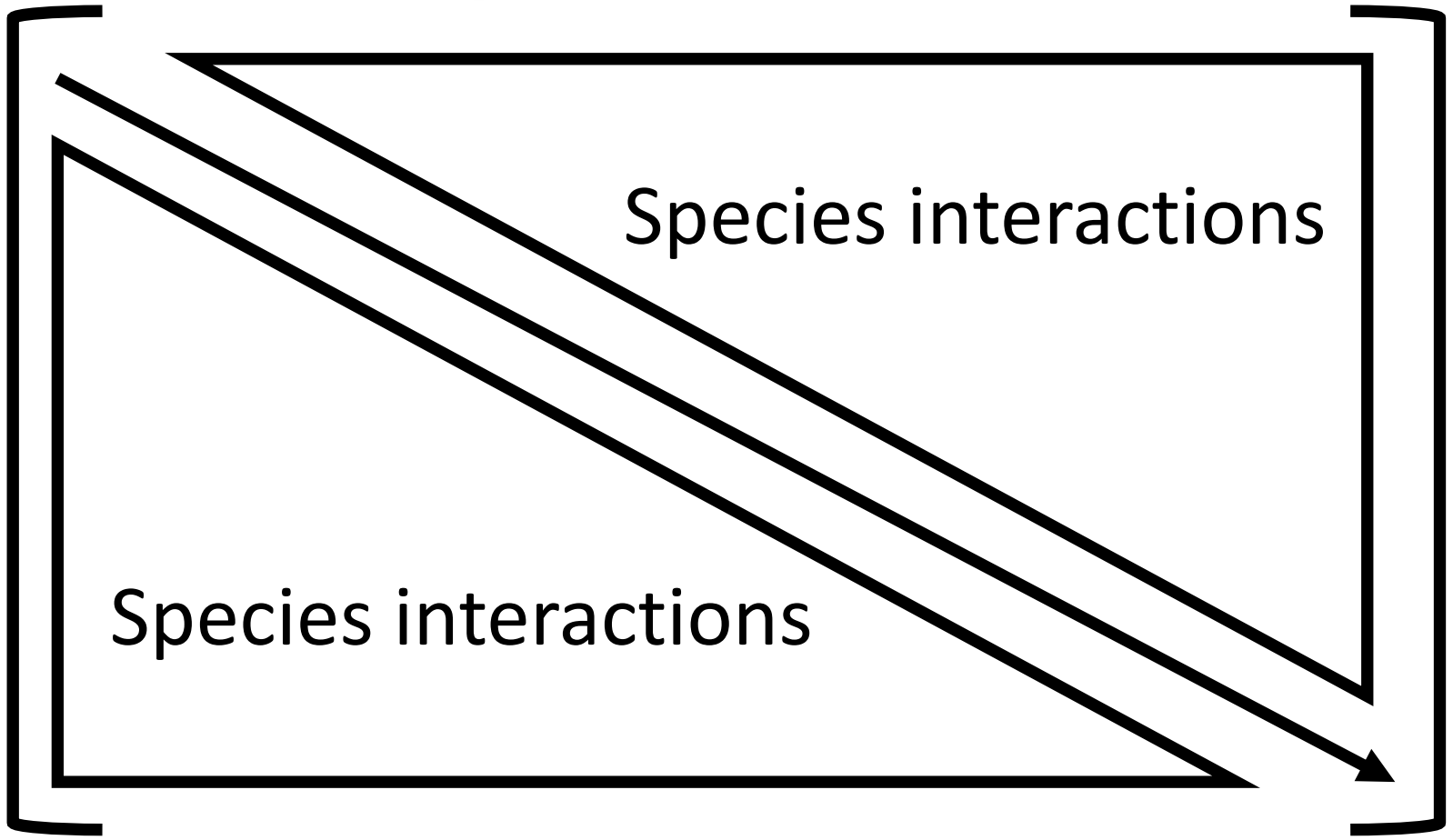

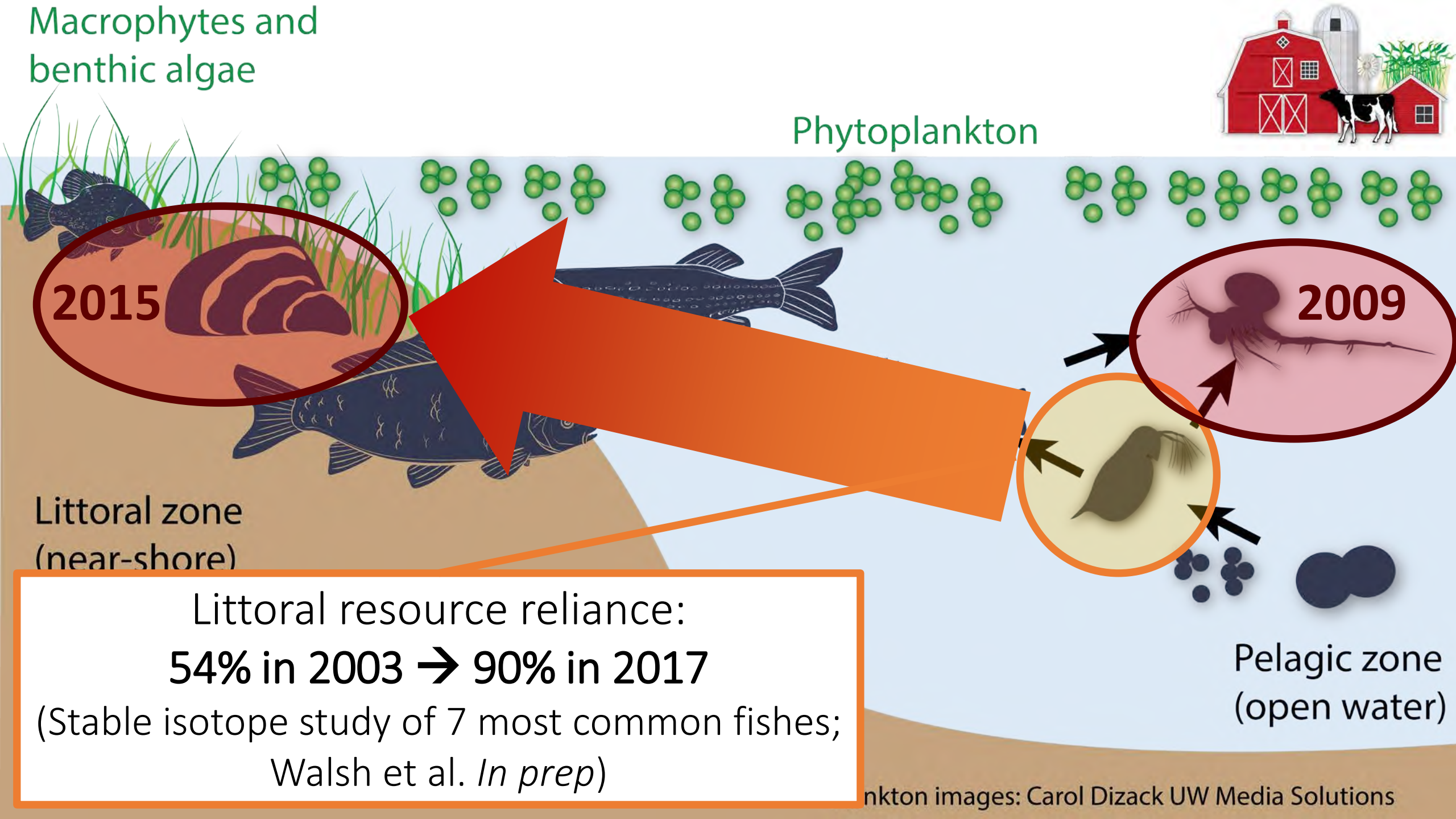

Littoral resource reliance:

54% in 2003 → 90% in 2017

(Stable isotope study of 7 most common fishes; Walsh et al. *In prep*)

nkton images: Carol Dizack UW Media Solutions