Lake Erie Trophic Status

Lake Erie Millennium Network

Jan J.H. Ciborowski
University of Windsor
&
Gerald Matisoff
Case Western Reserve University

Environment Canada   Environnement Canada

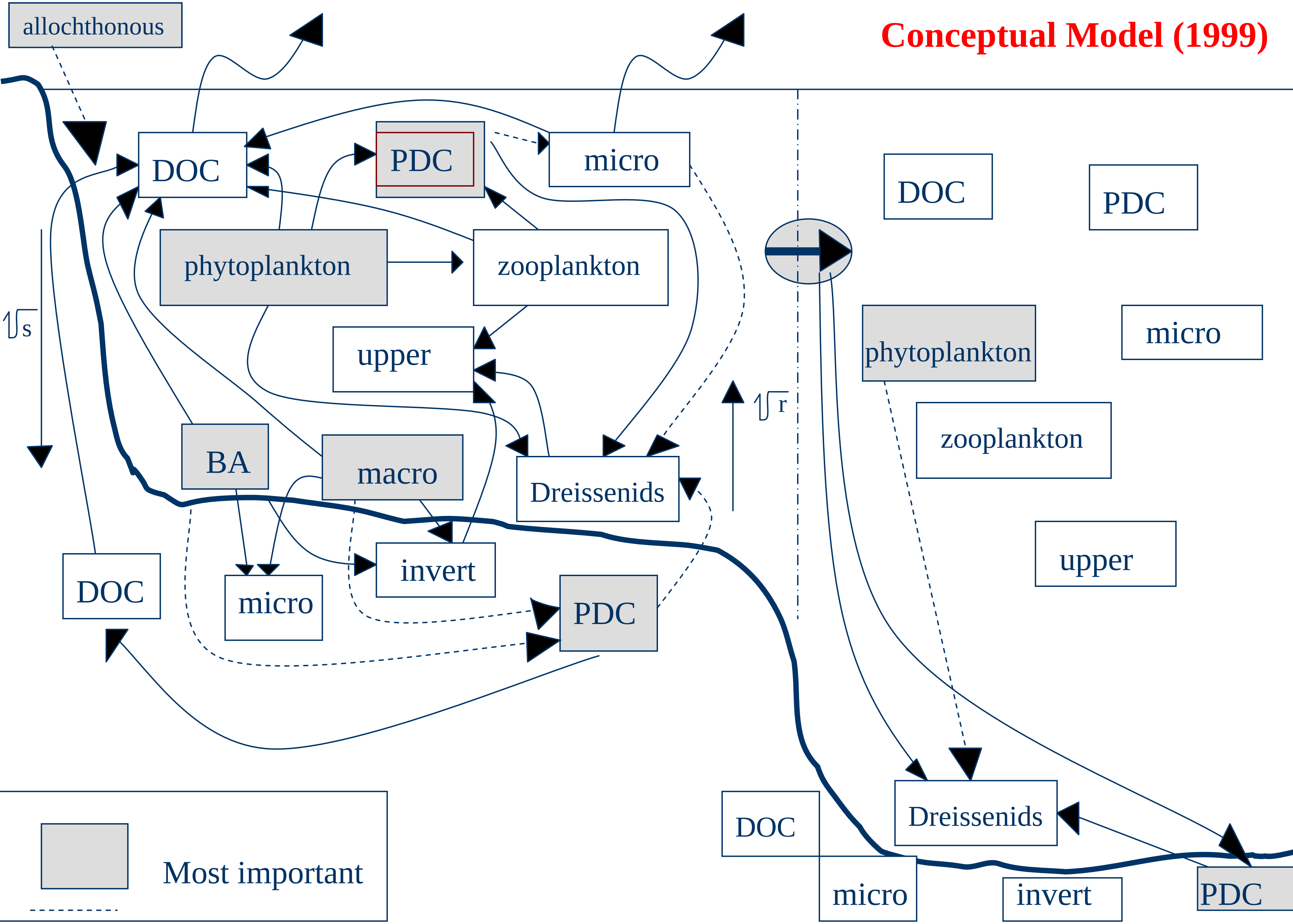
EPA

Coinvestigators

Murray Charlton	Environment Canada
Russell Kreis, Jr.	USEPA Grosse Ile
Jeffery Reutter, David Culver	Ohio State University
David Barton, Stephanie Guildford, Robert Hecky, Ralph Smith Michael Stone	University of Waterloo
Noel Burns	Lakes Consulting, NZ
Hunter Carrick	Penn State University
David Dolan	Univ. Wisconsin – Green Bay
Douglas Haffner	University of Windsor
Timothy Johnson	ON Ministry of Natural Resources
Michael Ketterer	Northern Arizona University
Cary Knight	Ohio Dept. of Natural Resources
Michael McKay	Bowling Green State Univ.
Nathaniel E. Ostrom	Michigan State University
Beverly Saylor	Case Western Reserve Univ.
Donald Schloesser	Great Lakes Center, USGS
Michael Twiss	Clarkson University
Glenn Warren, Paul Bertram, David Rockwell	EPA GLNPO

Significant Events

1950s-70s	Increasing Eutrophication
	(high TP & frequent anoxia)
1978	Great Lakes Water Quality Act
	(regulation of TP loadings)
1987	Dreissenids in Lake Erie
1995	Increasing water clarity – percid losses
1997	“too little phosphorus!- add sewage!” arguments
1998	Buffalo & Kent State dreissenid effects meetings
1999	LEMN trophic status workshop
2001	Rising TP - central basin hypoxia
	(“L. Erie’s dead zone!”)
	EPA Chicago meeting – “Possible causes”
2002	EPA GLNPO RFP
	LETS project
2004	L. Erie Binational Collaborative Year (ECCS)
2005	IFYLE project


Conceptual Model (1999)
allochthonous
DOC
PDC
micro
phytoplankton
zooplankton
upper
BA
macro
Dreissenids
invert
DOC
micro
PDC
√s
√r
DOC
PDC
phytoplankton
micro
zooplankton
upper
Dreissenids
DOC
micro
invert
PDC
Most important

Possible Explanations for Changes

A. Environmental influences
B. Increased phosphorus loadings
C. Possible limits on primary production
D. Increased rates or new pathways of internal cycling (dreissenids?)

LEMP Steering Committee
Agency Managers, Scientists

EPA GLNPO
Blume, Rockwell, Warren

Lake Erie Millennium Plan
Codirectors (Charlton, Kreis, Reutter)

OVERALL PROJECT MANAGEMENT

Jan Ciborowski
University of Windsor

Gerald Matisoff
Case Western Reserve University

ater Column Processes
(Smith)

- Lakes Consulting (Burns)
- UWGB (Dolan)
- yerson Twiss)
- Bowling Green (McKay)
- 'aterloo uildford, th, Stone)
- Michigan State (Ostrom)
- 'indsor Haffner)
- Ohio State (Culver)
- Penn State (Carrick)
- NWRI harlton)

Zoobenthos
(Ciborowski)

- Waterloo (Barton)
- NOAA (Lozano)
- Windsor (Ciborowski)
- Ohio State (Culver)
- USGS (Schloesser)
- NWRI (Grapentine)

Sediment Mapping &
Characteristics (Biberhofer)

- OMNR (Johnson & Knight)
- NOAA (Lozano)
- Ohio State (Culver)
- NWRI (Biberhofer, Marvin)

Benthic & Sub-bent
Processes (Matiso

- Waterloo (Hecky, Stone)
- Case W (Matisoff,
- N. Ariz (Kette
- Ohio S (Culv
- Penn S (Carri
- USG (Schloe
- NWRI (Marvin)

. **Trophic Status of Lake Erie** project organization. Project managers Ciborowsk & Matisoff administer subcontracts to Canadian (pale blue) and US (darker blue ations respectively, and are responsible for overall project coordination. Sampling methdology and coordination of data acquisition and reporting are organized u ps, each with Canadian and US participants. Provisional subproject leads are listed in the header of each subtable. Subprojects have coPIs conducting theoretical a l of each subtable), coPIs collecting primary data on Lake Erie (middle portion of each subtable), and coPIs (bottome cells of each subtable) who are not subcontr tors are not listed.

Appendix II - Summary of water quality parameters to be measured and responsibility for taking measurements, as agreed at May 3 planning meeting.

	Basin			
Parameter	East (Limnos)	East (Guardian)	Central	Western
TP	WL		OSU, RY, ?EPA	HAFF
TSP	[talk to S.G.]			
SRP	WL	CWRU(1)	CWRU (1)	CWRU(1)
POC	WL		WL	WL
PON	WL		WL	WL
nitrate	OSU, CWRU	OSU, CWRU	OSU (Min)	OSU(Min)
Silica	WL,CWRU	CWRU	CWRU,WL	CWRU,WL
ammonia		OSU (Min)	OSU	OSU(Min)
Chl *a*	RY	RY,PSU,OSU	RY,PSU,OSU	HAFF
Fe	RY		RY(Min)	RY(Min)
oxygen	WL	MSU	MSU	?HAFF
pH	WL			?HAFF
conductivity	WL			?HAFF
TSS	WL		WL(Min)	WL(Min)
Part. P	WL		WL	WL
PAR		OSU	OSU	OSU

CWRU - Case Western Reserve Univ; HAFF - Univ. Windsor; MSU - Michigan State Univ.; PSU - Penn State Univ.; OSU - Ohio State Univ. RY - Ryerson Univ.; WL - Univ. Waterloo.

Min = minimal number of samples/sites; (1) = single site will be sampled; S.G. = Stephanie Guildford (Univ. Waterloo).

Chronology of LETS Program

Date	Event
Dec/01	EPA research needs meeting
Jan/02	RFP released
Mar/02	Proposal submitted
Apr/02	Logistics meeting
May/02	Proposal Approved
June/02	Sampling starts
Aug/02	First funds received
Aug/02	First field report
Nov/02	First progress meeting
May/03	Presentations at LEMN and IAGLR
Summer/03	Compiling metadata
Nov/03	Second progress meeting –> results to LAMP [feedback for ECCS]
May/04	Presentations at IAGLR
May/04	First manuscripts submitted to JGLR special issue
Sept/05	Final manuscripts reviewed
Dec/05	Special issue accepted and in press (2005)
March/06	Presentations of final results at LEMN and IAGLR
May/06	Final report submitted to EPA GLNPO

__________LAKE ERIE TROPHIC STATUS PROJECT - Strong Inference Summary

Possible Explanations:	**Results consistent with Explanation?** YES	NO	N/A
1. Observations may represent situations that have naturally occurred at regular or irregular intervals through time prior to that for which intensive monitoring data are available .	☐	☐	☐
2. Loading estimates are wrong/incomplete	☐	☐	☐
3. Climatic/physical/biogenic factors are increasing flux from sediments	☐	☐	☐
4. A) i) reduced size and/or	☐	☐	☐
ii) increased persistence of the central basin hypolimnion,	☐	☐	☐
possibly accompanied by			
B) increased rates of sediment oxygen demand or	☐	☐	☐
C) a change in autotrophic:heterotrophic C fixation	☐	☐	☐
5) reduced benthic and/or planktonic primary production caused by			
A) high grazing pressure	☐	☐	☐
B) nutrient limitation	☐	☐	☐
C) trace metal limitation and/or	☐	☐	☐
D) UV or contaminant-induced inhibition of photosynthesis	☐	☐	☐
6) increased net rates of organic C accumulation in hypolimnetic areas	☐	☐	☐

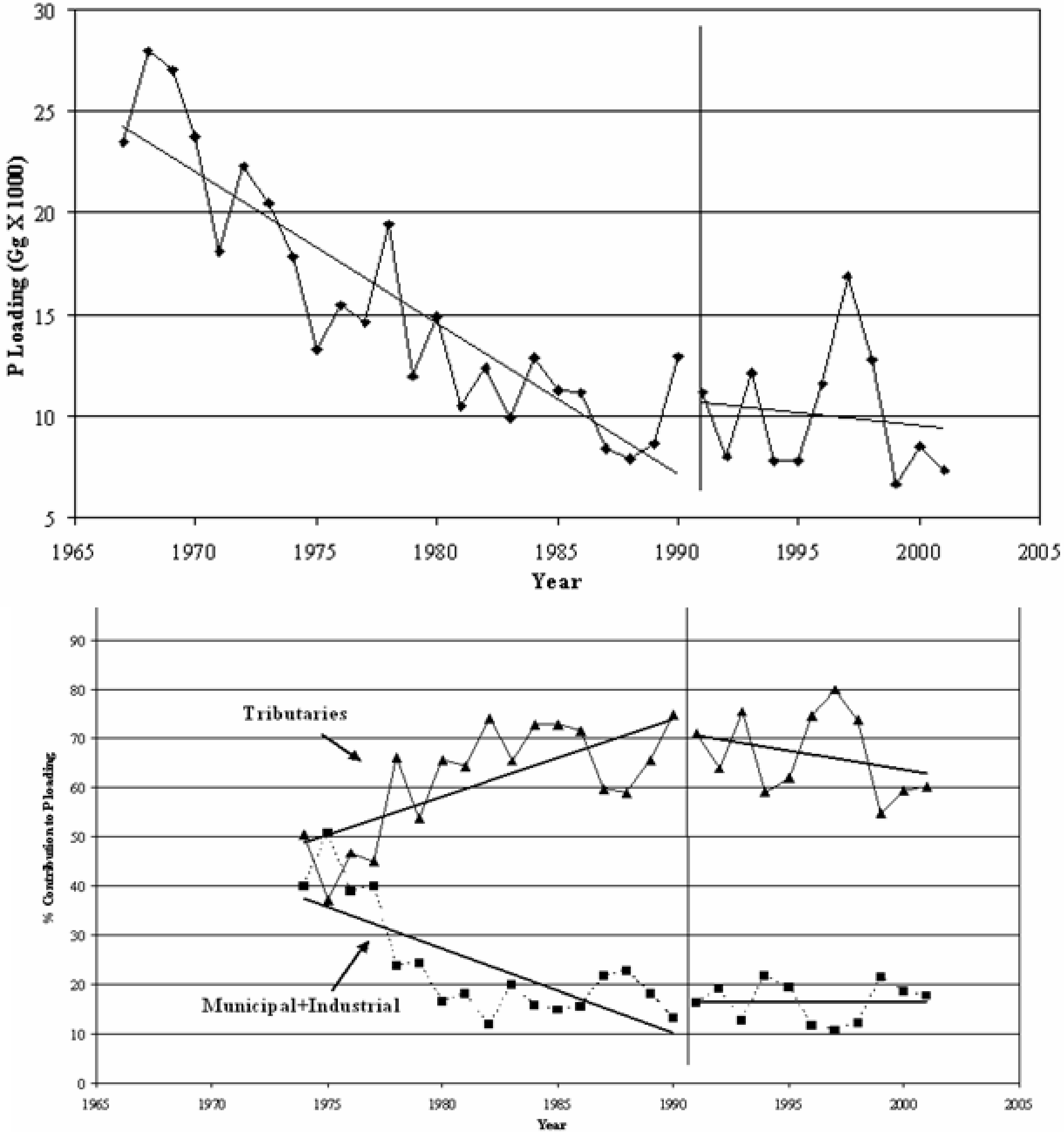
Which of these linkages are controlling factors and which are cofactors?

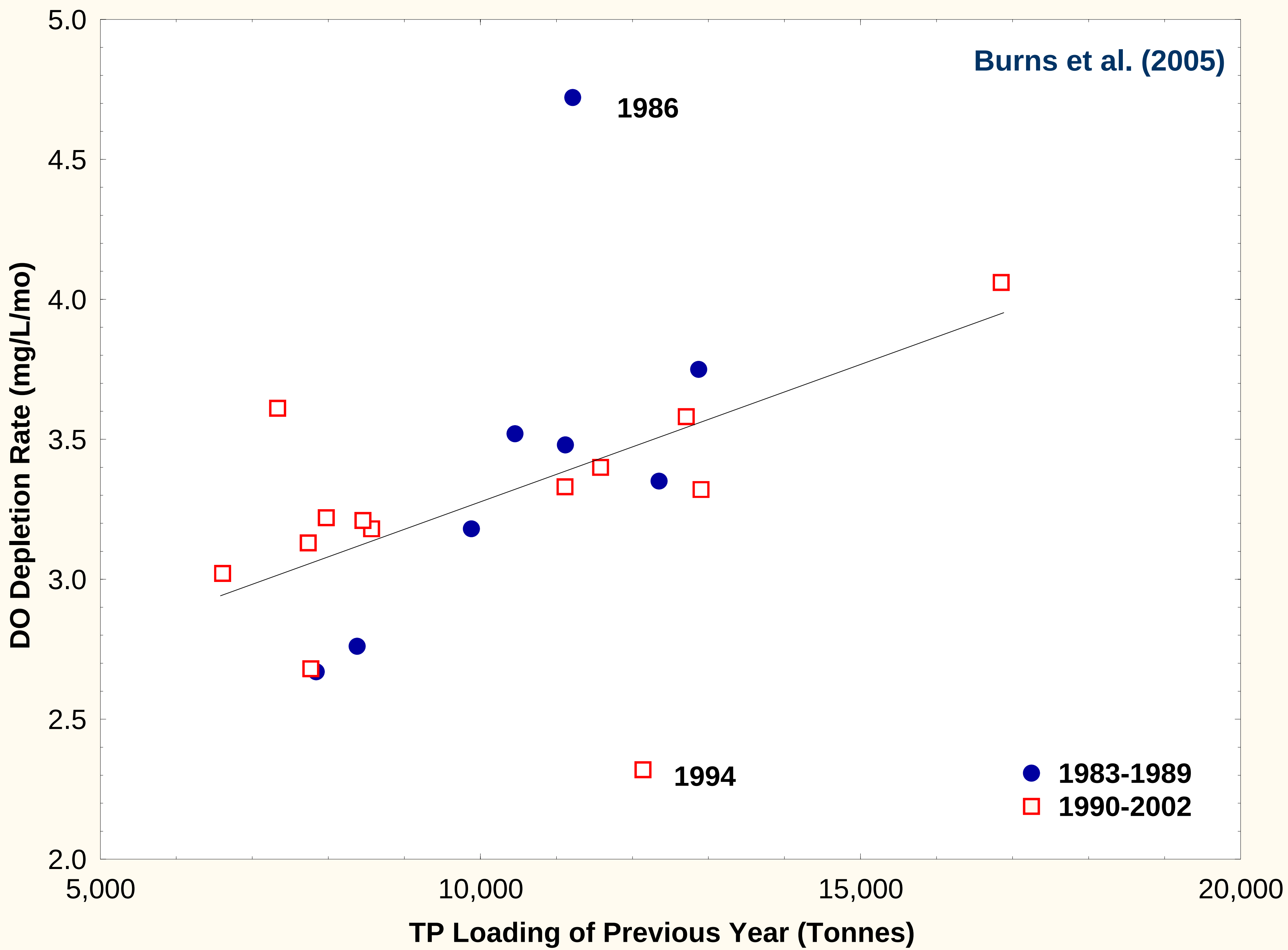
________LAKE ERIE TROPHIC STATUS PROJECT - Strong Inference Summary

Possible Explanations:	Results consistent with Explanation? **YES**	**NO**	**N/A**	Work in **Progress**
1. Observations may represent situations that have naturally occurred at regular or irregular intervals through time prior to that for which intensive monitoring data are available .	☐	☐	☐	■
2. Loading estimates are wrong/incomplete	☐	■	☐	
3. Climatic/physical/biogenic factors are increasing flux from sediments	■	☐	☐	
4. A) i) reduced size and/or	■	☐	☐	
ii) increased persistence of the central basin hypolimnion,	■	☐	☐	
possibly accompanied by				
B) increased rates of sediment oxygen demand or	■	☐	☐	
C) a change in autotrophic:heterotrophic C fixation	■	☐	☐	
5) reduced benthic and/or planktonic primary production caused by				
A) high grazing pressure [shallow, dreissenid-rich areas]	■	☐	☐	
B) nutrient limitation	☐	■	☐	
C) trace metal limitation and/or	■	■	☐	(differed between years)
D) UV or contaminant-induced inhibition of photosynthesis	☐	☐	■	
6) increased net rates of organic C accumulation in hypolimnetic areas	☐	☐	☐	
	■	■		

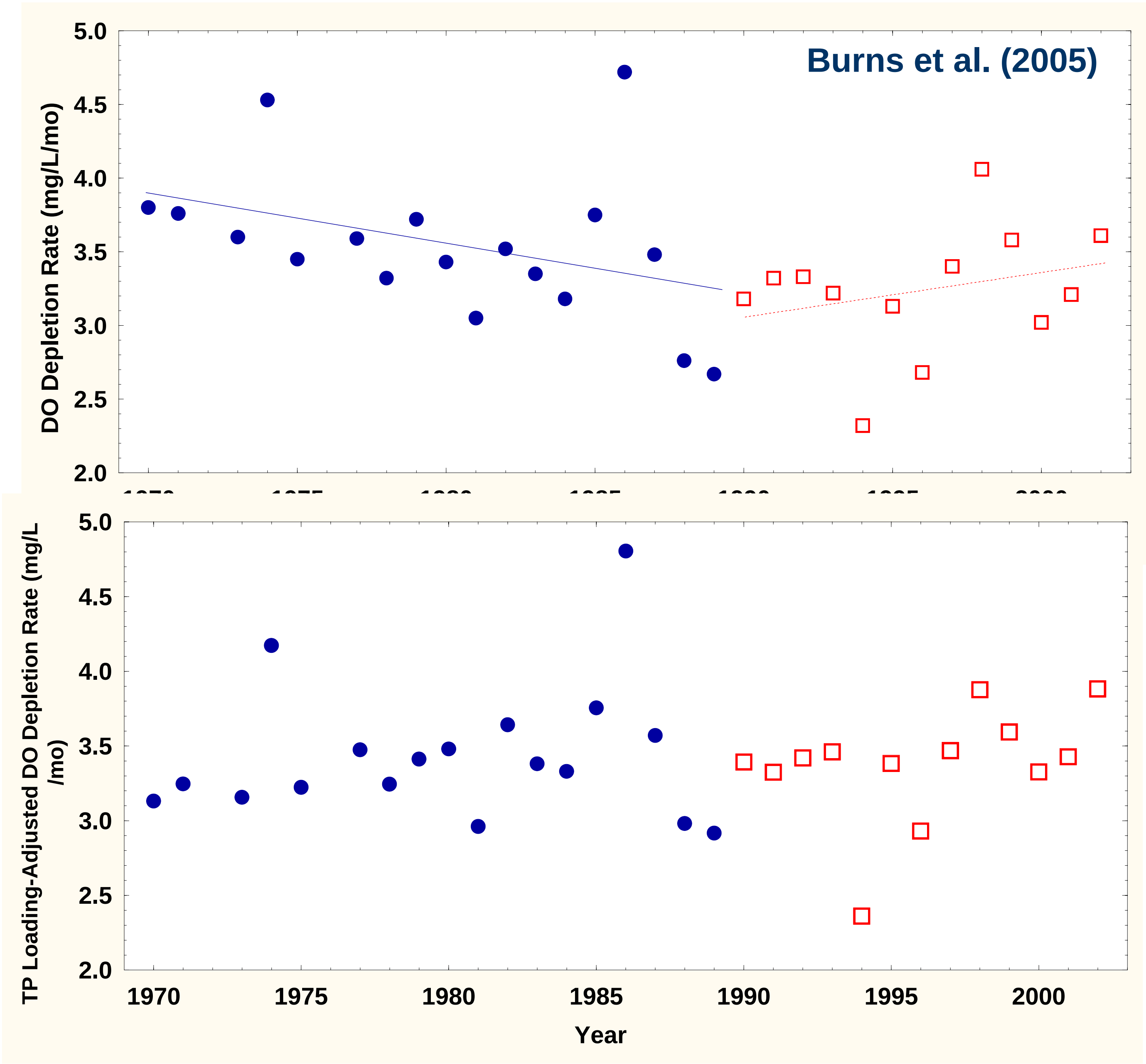
Which of these linkages are controlling factors and which are cofactors?

Dolan & McGunagle (2005)

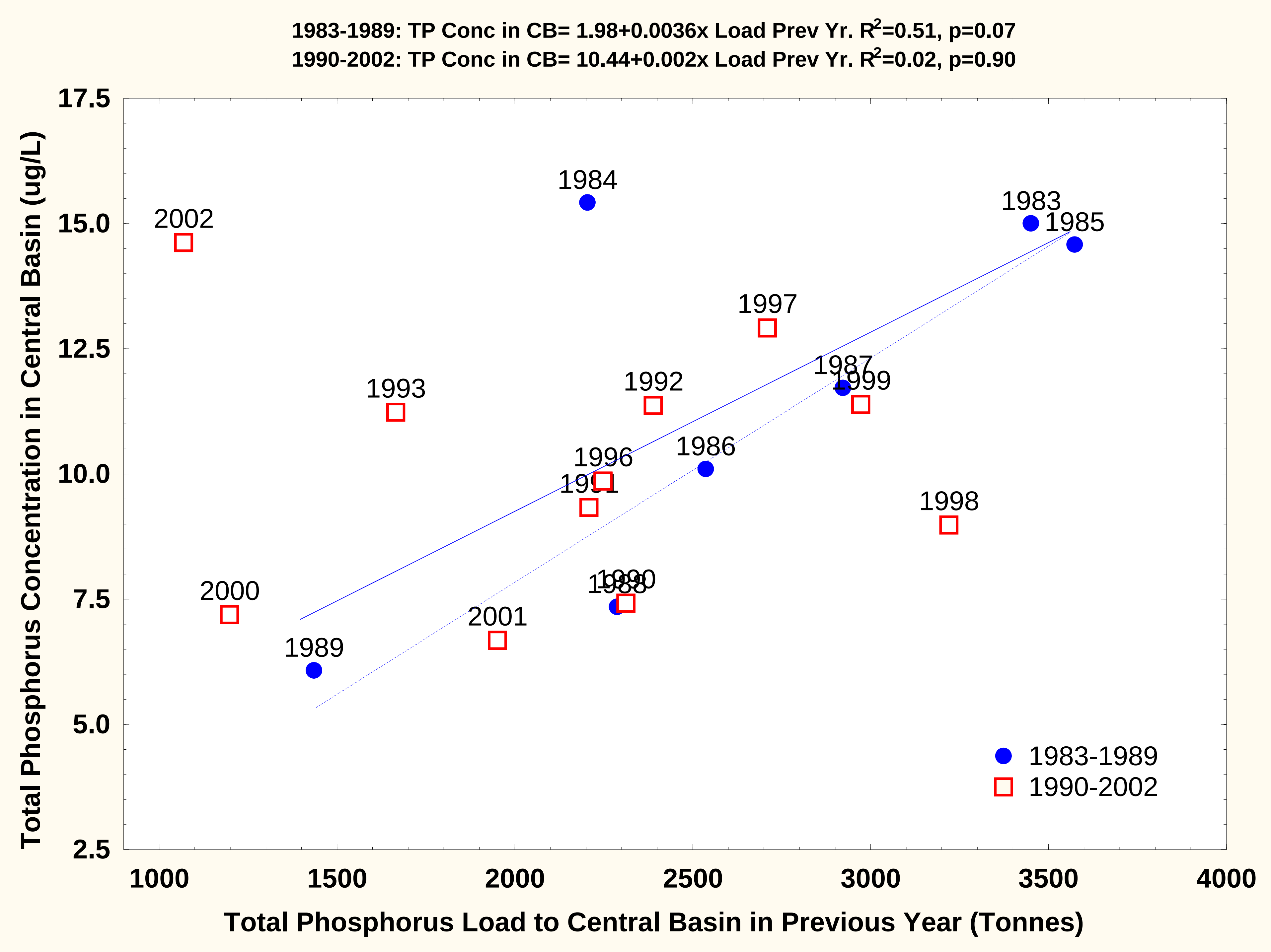




Burns et al. (2005)
1986
1994
1983-1989
1990-2002
DO Depletion Rate (mg/L/mo)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
5,000
10,000
15,000
20,000
TP Loading of Previous Year (Tonnes)



Burns et al. (2005)
DO Depletion Rate (mg/L/mo)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
TP Loading-Adjusted DO Depletion Rate (mg/L
/mo)
1970
1975
1980
1985
1990
1995
2000
Year



1983-1989: TP Conc in CB= 1.98+0.0036x Load Prev Yr. R2=0.51, p=0.07
1990-2002: TP Conc in CB= 10.44+0.002x Load Prev Yr. R2=0.02, p=0.90
Total Phosphorus Concentration in Central Basin (ug/L)
Total Phosphorus Load to Central Basin in Previous Year (Tonnes)
17.5
15.0
12.5
10.0
7.5
5.0
2.5
1000
1500
2000
2500
3000
3500
4000
1984
1983
1985
2002
1997
1987
1999
1993
1992
1986
1996
1991
1998
1990
1988
2000
2001
1989
1983-1989
1990-2002

Key Trends of Concern - 1995- 2000

Confirmation of *a priori* statements:

1. Very low phytoplankton biomass in central & eastern basins

Carrick, Charlton,Culver, Guildford, Ostrom, Smith, Twiss

Yes Yes No Yes ? Yes Yes

2. Total phosphorus concentrations have been rising (last 5 yrs)

Burns Carrick, Charlton, Culver, Guildford, Haffner, McKay,

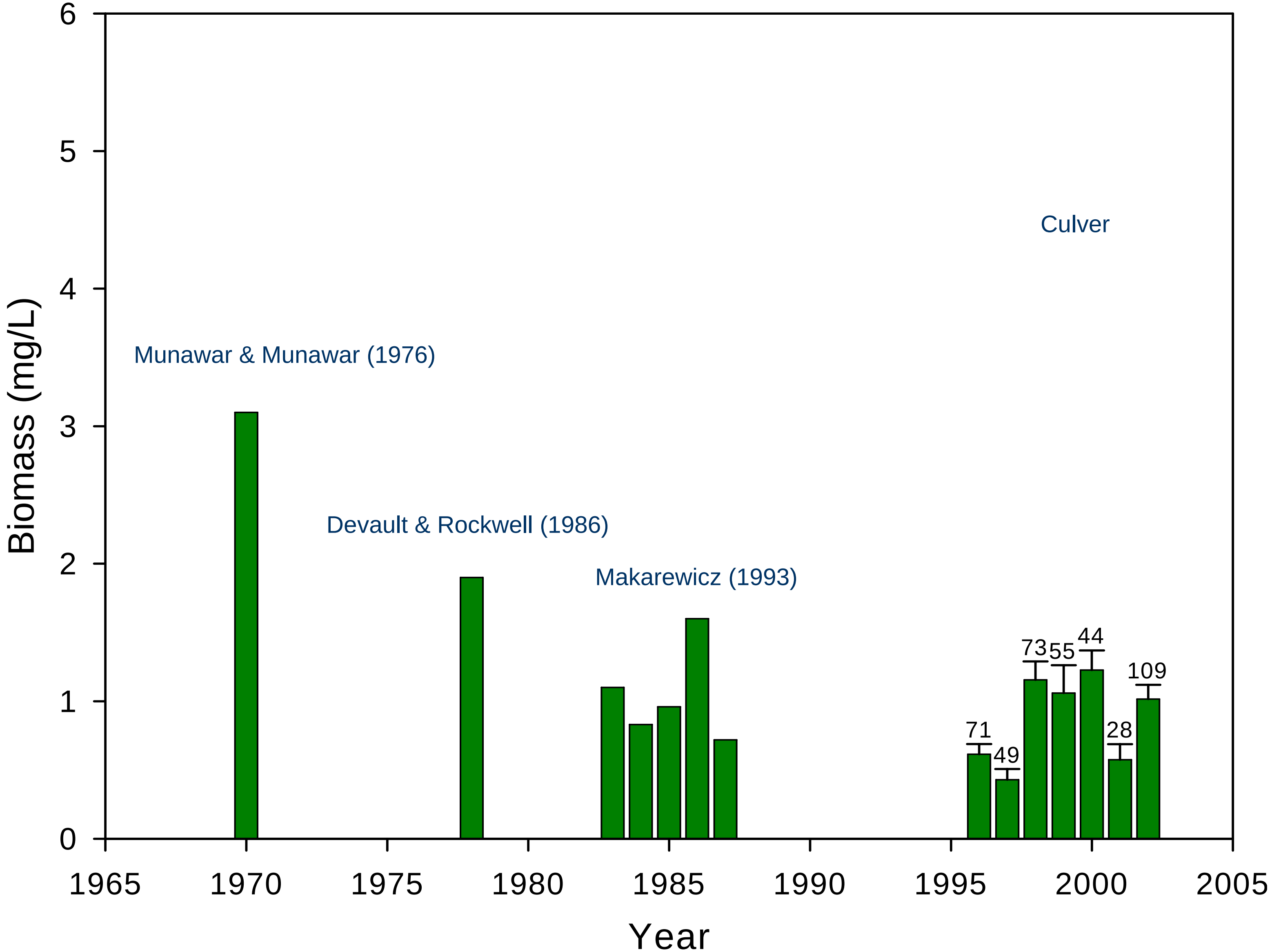
Yes ? Yes Yes No Yes Yes

Ostrom, Rockwell, Smith, Twiss

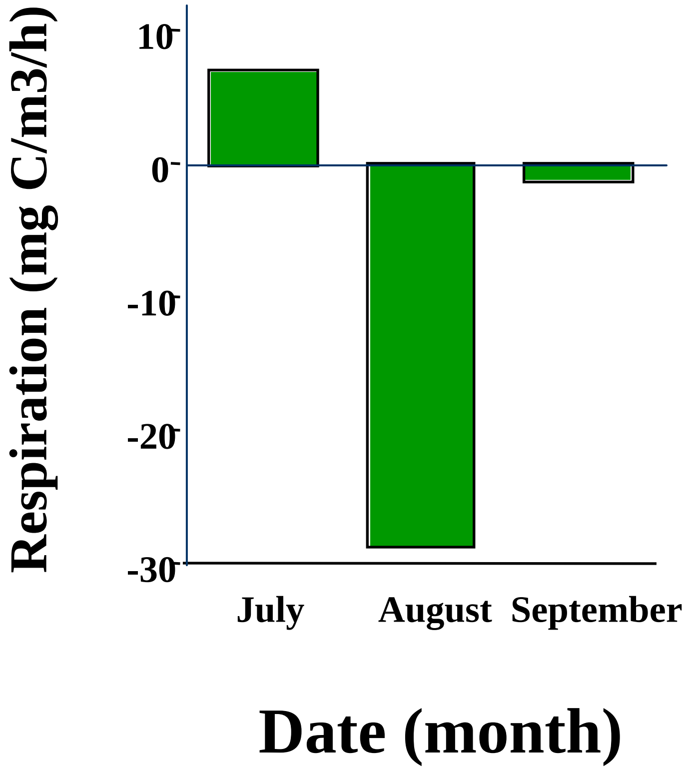
? Yes Yes Yes

Phytoplankton Biomass – Central Basin

D. Culver et al. – Ohio State Univ



Hypolimnetic Respiration: Seasonal Comparison



H. Carrick et al. – Penn State Univ.

Environmental/Loading Changes in CB?

Nutrient/ Oxygen demand Processes:

- Loadings of TP are dominated by interannual variation in trib. discharge (regional effect reflecting climate)
- TP conc. & hypolimnetic volume O_2 demand have risen through 90's
- TP conc. & HVOD depend on previous year's TP loading through 80's
- HVOD but not TP conc. depend on previous year's TP loading since 90's
- Winter discharge contributes higher TP load than summer discharge

Conclusions: no strong evidence of dreissenid effects on TP conc. or HVOD in central basin;

Dreissenid effects in central basin?

Pelagic processes:

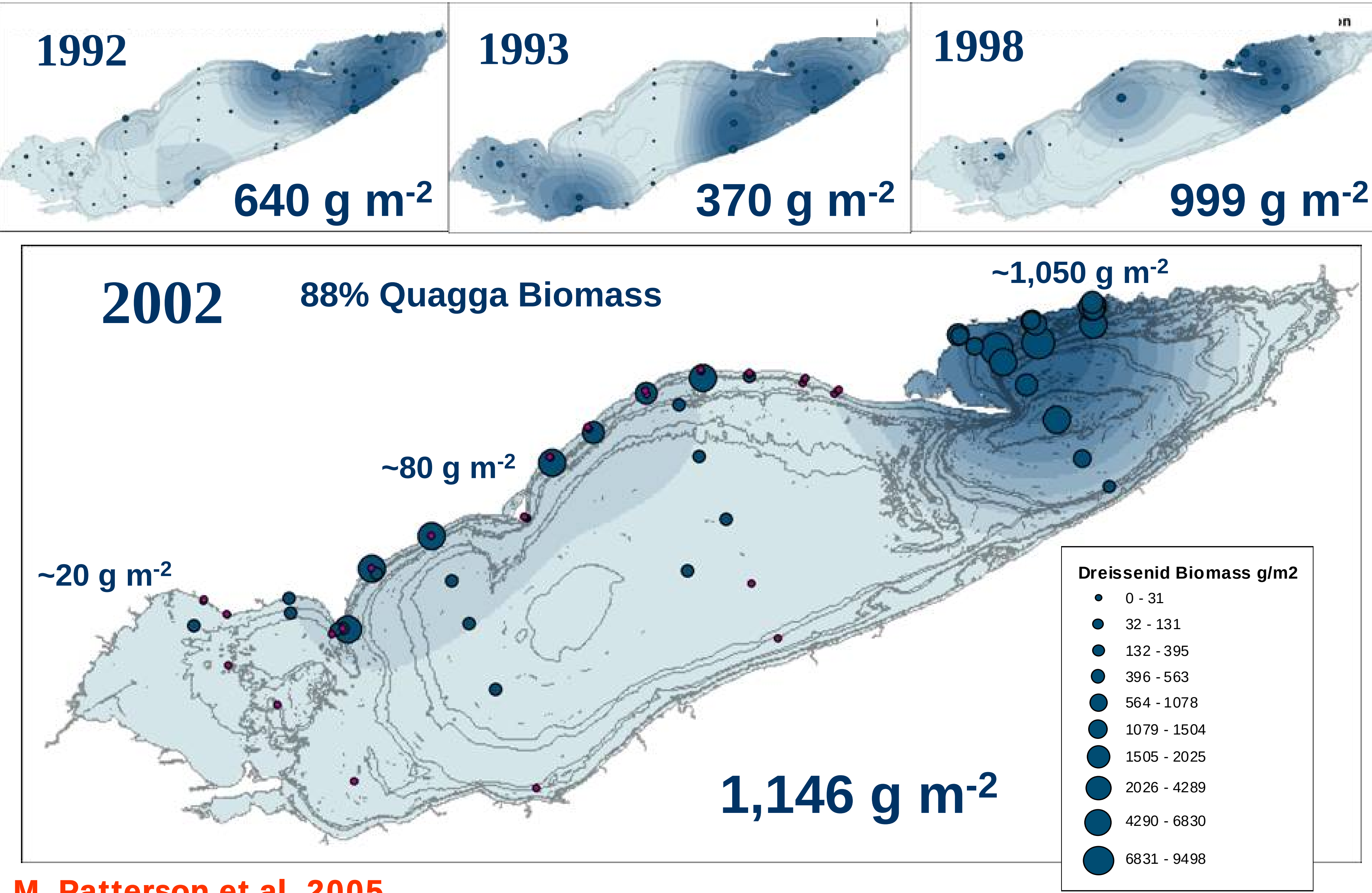
- no correlation between dreissenid distrib. & central basin hypoxia (Patterson et al. 2005; Conroy et al. 2005)
- no evidence of increased SOD (Schloesser 2005; Matisoff 2005)
- poor correlation between dreissenid abundance & turbidity (Rockwell et al. 2005)
- seasonal patterns of hypolimnetic production controlled by nutrients & clarity, independent of dreissenIds (Carrick et al. 2005; Ostrom 2005; Guildford et al. 2005)
- phytoplankton productivity regulation by nutrients (Guildford et al. 2005; Twiss et al. 2005; Smith et al. 2005; McKay et al.; Porta et al.)
- microbial productivity regulation by DOC (Heath et al. 2005)

Conclusions: no strong evidence of dreissenid effects on hypoxia in central basin; regional regulation over interannual scale

Are nearshore processes different?

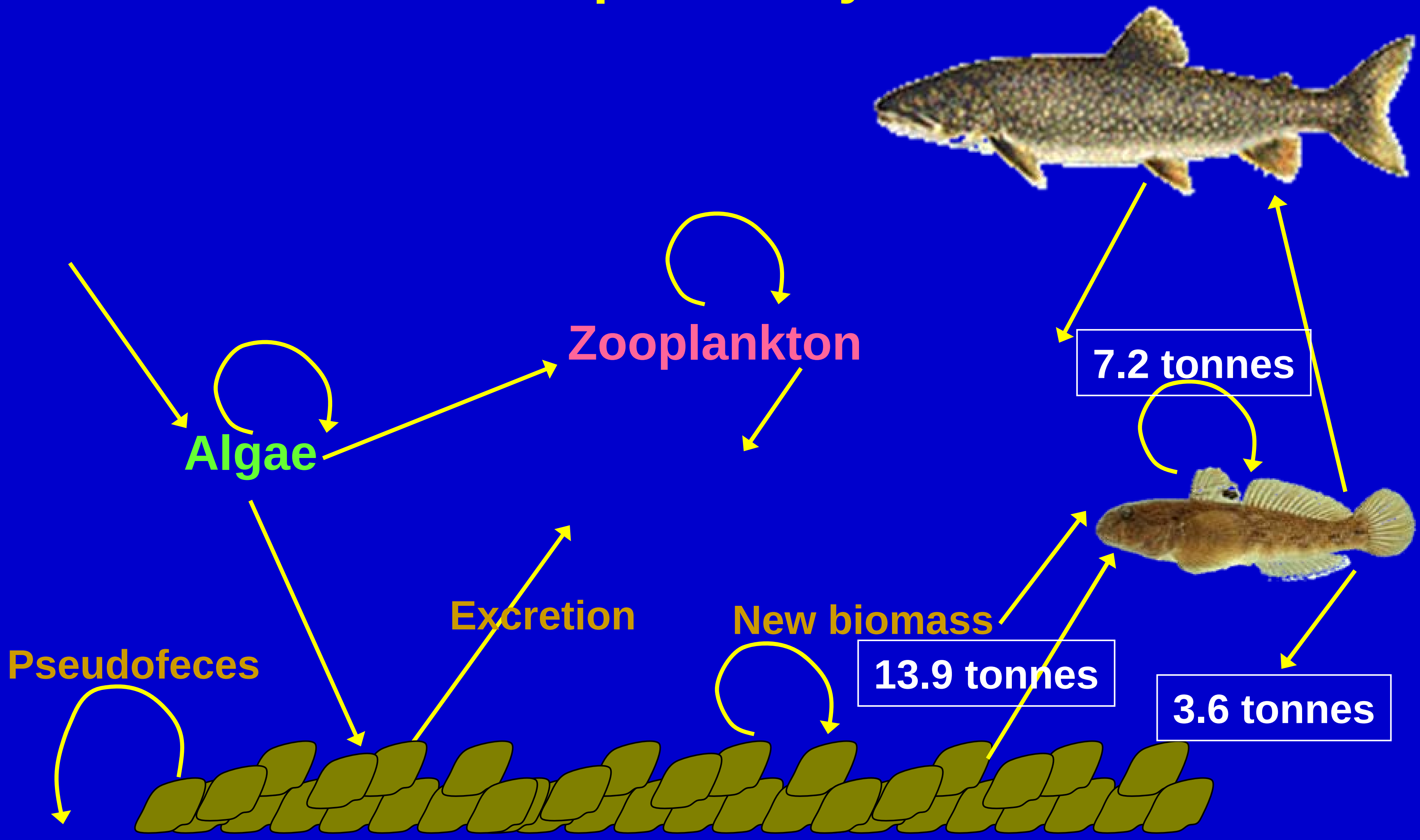
Western L. Erie
10 days after
power failure;
August 2003)

Combined Dreissenid Wet Biomass Distribution



M. Patterson et al. 2005

2002 Phosphorus dynamics



Bunnell, Johnson & Knight - OMNR & ODNR

Evidence of dreissenid effects in nearshore?

Pelagic processes:

- Correlation between local fluorometric measures of chla & local dreissenid abundance (Ghadouani & Smith 2005)
- Increased nearshore water clarity (various)

Benthic processes:

- *Cladophora* beds expanding (Higgins et al. 2005); anoxic beneath
- Dreissenids stimulate *Cladophora* production (Davis & Hecky 2005)
- Dreissenids & *Cladophora* influence LOI & SOD locally (various)
- Altered zoobenthic composition & distribution (Barton et al. 2005)
- Dreissenid - goby interactions & TP increases (Barton et al. (2005) Bunnell et al 2005))

Conclusions: Nearshore nutrient dynamics & trophic structure are regulated by local benthic-pelagic coupling & feedback loops over seasonal time scales

Summary of Findings

- Offshore nutrient dynamics & trophic structure are regulated by regional processes & annual time scales
- Weather conditions likely play a significant role (short and long-term)

- Nearshore nutrient dynamics & trophic structure are regulated by local benthic-pelagic coupling & feedback loops over seasonal or shorter time scales
- Dreissenids & local nutrient sources are likely important

Recommendations

- Assess open water processes at basin-scale & annual time steps (multibox model), with integrative sampling & observing systems

- Assess nearshore processes at contributing watershed scale & subseasonal time steps

- Integrate nearshore/basin-scale exchange processes & transfer rates with 3-D modeling

ACKNOWLEDGEMENTS

Lake Erie Millennium Network

EPA

Environment Canada
Environnement Canada

Ontario: MNR, Environment

Sea Grants: OH, MI, PA

State agencies: NY, PA

Personnel from many others