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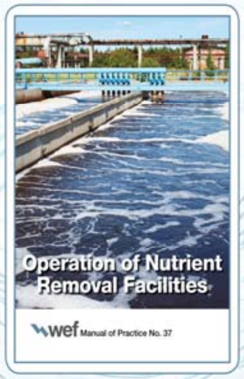

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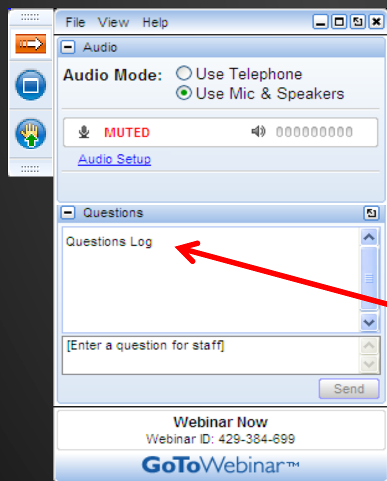

- **Audio Modes**
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  - Or, select "Use Telephone" and dial the conference (please remember long distance phone charges apply).
- **Submit your questions using the Questions pane.**
- **A recording will be available for replay shortly after this webcast.**

Death by Nutrients: Toxicity of Ammonia and Harmful Algal Bloom Events

Wednesday, March 8th, 2017

1:00 – 2:30pm Eastern

Today's Moderator

- Tad Slawecki, LimnoTech

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Today's Agenda

- Tom Dupuis, P.E., HDR
- Hans W. Paerl, Ph.D., University of North Carolina, Chapel Hill
- Erin Houghton, M.S., NEW Water: the brand of Green Bay Metropolitan Sewerage District

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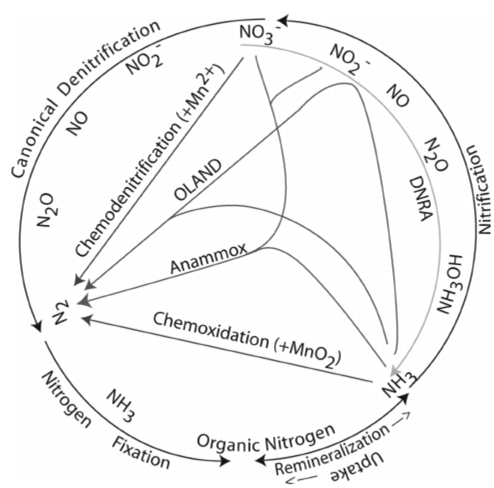
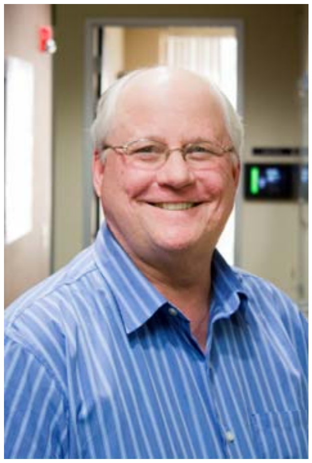
The Nitrogen Cycle



Brandes et al.
Chem. Reviews Vol 107:577-589 (2007)



Tom Dupuis,
HDR, Boise, ID

tom.dupuis@hdrinc.com

Understanding Revised Federal Ammonia Criteria

Impacts on Treatment Requirements, and Strategies for Implementation in State Rulemaking

Acknowledgement

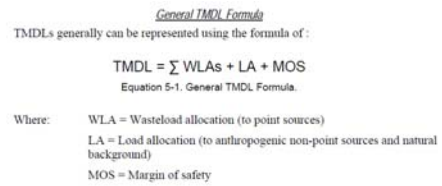
- Previous co-presenters at PNCWA:
  - Dave Clark, HDR Boise
  - Andy McCaskill, HDR Portland

Overview

- History of Federal Ammonia Criteria
- Revised 2013 Federal Ammonia Criteria
- Example of Northwest Ammonia Rulemaking
  - Oregon
- Site Specific Ammonia Criteria and Water Quality Based Effluent Limits
- Example Scenarios
  - Criteria and Effluent Limits
    - Mussels Present
    - Mussels Absent, Early Life Stage Fish Present
    - Mussels Absent, Early Life Stage Fish Absent

Water Quality Based Effluent Limits (WQBELs) for Ammonia

- Can be based on several effects of ammonia in receiving waters:
  - Dissolved oxygen depletion (nitrification in the receiving water)
  - Nutrient effects (algal, plant growth stimulation)
  - Ammonia toxicity
- If more than one of these is applicable, the most restrictive will govern in the NPDES permit



General TMDL Formula

TMDLs generally can be represented using the formula of :

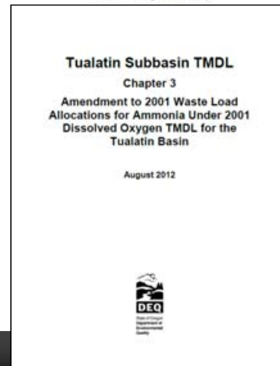
$$TMDL = \sum WLAs + LA + MOS$$

Equation 5-1. General TMDL Formula.

Where: WLA = Wasteload allocation (to point sources)

LA = Load allocation (to anthropogenic non-point sources and natural background)

MOS = Margin of safety



Tualatin Subbasin TMDL

Chapter 3

Amendment to 2001 Waste Load Allocations for Ammonia Under 2001 Dissolved Oxygen TMDL for the Tualatin Basin

August 2012

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Ammonia Toxicity Criteria / Early History

- Ammonia toxicity to aquatic life:
  - Unionized fraction of ammonia (NH_3) is toxic
  - % unionized increases with increasing pH
  - Increasing temperature also increases toxicity

- EPA recommended criteria history:
  - 1976 – Redbook (0.02 mg/L NH_3), simple pH and T matrix
  - 1984 – bifurcated (with or without salmonids), acute and chronic (1986 Goldbook)
  - 1992 – whitefish correction factor
  - 1999 – major revision for salmonids, considers early life stages

Note – Not all states adopted or received EPA approval for 1999 criteria (e.g., Oregon)

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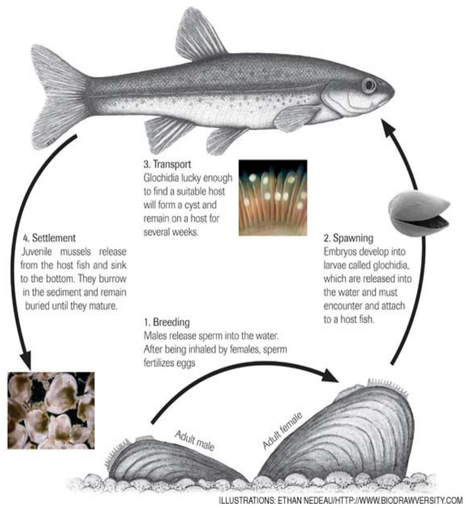
2004 – Changes are Coming



Life cycle of a typical freshwater mussel.

- EPA notice of intent to re-evaluate aquatic life criteria for ammonia
- Seeks submittal of data on freshwater mussels (Unionids)
- Early life stage that attaches to fish (glochidium)
- Short duration glochidium stage shown to be most sensitive to ammonia

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2009 Draft Criteria Reflect Mussel Sensitivity

TABLE 2.2 Comparison of U.S. Environmental Protection Agency recommended ammonia toxicity criteria.*

Temperature, °C	1984	1992	1999	Draft 2009 Freshwater mussels present	Draft 2009 Freshwater mussels absent
	Acute criteria, mg/L as N				
15	12.2	--	13.3	15.6	23.6
20	12.0	--	13.3	10.3	17.8
	Chronic criteria, mg/L as N				
15	1.7	2.1	4.2	0.88	6.3
20	1.2	1.5	3.1	0.63	4.6

*All values shown are at a pH of 7.5; 1999 values shown assume salmonids and early life stages present.

Source: WEF MOP #34, Nutrient Removal, 2011

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Distribution of Mussels and Snails

- They're Everywhere!
- Highest diversity of freshwater mussels in the world (300 species)
- Declining numbers, water quality is one reason
- 70% of mussels extinct or imperiled

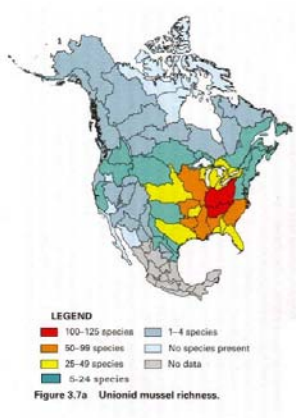

Figure 3.7a Unionid mussel richness.

Distribution:

Unionid species richness by ecoregion

Abell et al., 2000
Freshwater ecoregions of North America: a conservation assessment.

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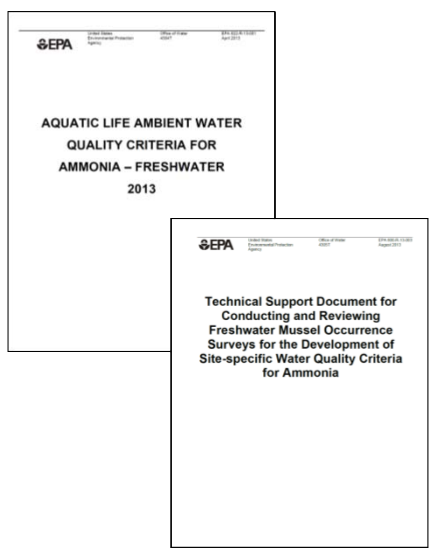
Final 2013 Ammonia Criteria Published by EPA

- "*Aquatic Life Ambient Water Quality Criteria For Ammonia – Freshwater, 2013*"
  - 225 pages with 14 appendices
- "*Flexibilities for States Applying EPA's Ammonia Criteria Recommendations*"
  - EPA presents a number of flexibilities available for state consideration including:



EPA

AQUATIC LIFE AMBIENT WATER QUALITY CRITERIA FOR AMMONIA – FRESHWATER 2013

EPA

Technical Support Document for Conducting and Reviewing Freshwater Mussel Occurrence Surveys for the Development of Site-specific Water Quality Criteria for Ammonia

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Final 2013 Revised Federal Ammonia Criteria

Criterion (Duration)	1999 Criteria Based on Juvenile Salmonids		2009 Draft Revised Criteria Mussels Present		Final 2013 Criteria Single Criteria Mussels Present	
	pH 8.0	pH 7.0, T=20°C	pH 8.0, T=25°C	pH 7.0, T=20°C	pH 8.0, T=25°C	pH 7.0, T=20°C
Acute, mg/L (1-hr average)	5.6	24	2.9	19	2.6	17
Chronic, mg/L (30 day average)	1.2	4.5	0.26	0.91	0.56	1.9

http://water.epa.gov/scitech/swguidance/standards/criteria/aqlife/ammonia/index.cfm

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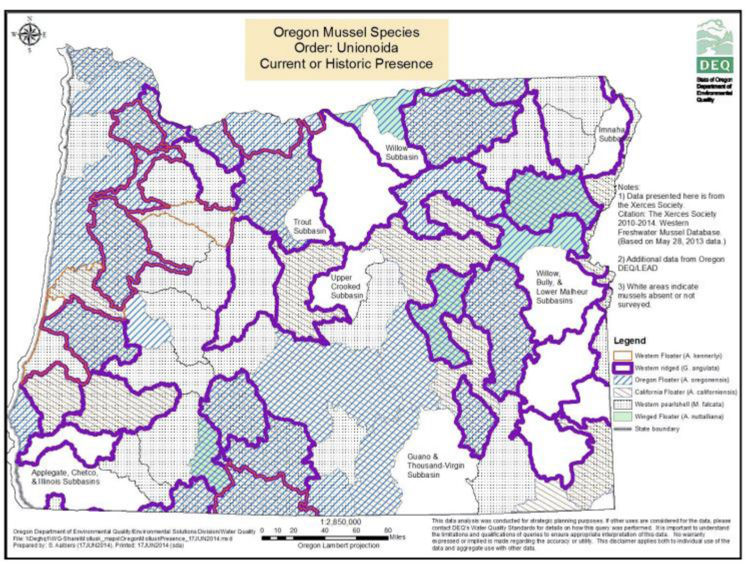
Mussels in Oregon



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Oregon Rulemaking - Ammonia

- Summary of What Was Adopted
  - Mussels and snails are the most sensitive species
  - DEQ did not adopt criteria for ammonia based on the absence of snails/mussels; current information indicates that they are (or historically were) present through most of Oregon
  - DEQ did not preclude the development of site specific criteria
  - Requires a scientifically robust survey that shows that these sensitive species are not present; requires EPA approval and consultation (NMFS and USFWS).

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Reasonable Potential To Exceed Analysis (RPTE, RPA)

- Mass Balance Equation
- Does predicted Receiving Water Concentration (RWC) have the reasonable potential to exceed water quality criteria after allowable mixing?
- If yes, WQBELs are established in the NPDES permit.

- Mass Balance Equation

$$RWC = \frac{(Qe * Ce) + (Qr * Cr)}{(Qe + Qr)}$$

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Wasteload Allocation for Single Discharger Situation

Mass Balance Equation

$$\text{WLA} = \frac{(WQC * (Q_e + (Q_r * M)) - (C_r * Q_r * M))}{Q_e}$$

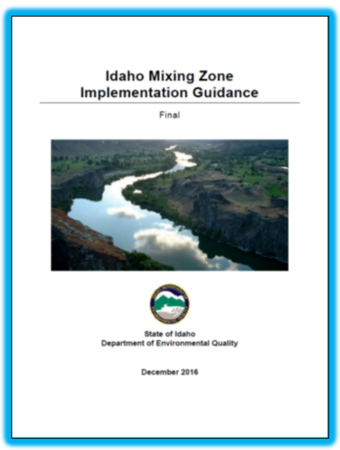
Where:

WLA	=	The wasteload allocation for a point source discharge; calculated separately for each type of WQC (i.e., acute, chronic, human health, etc.), concentration
WQC	=	Water quality criterion, concentration
Q_e	=	Effluent design flow
Q_r	=	Receiving water design flow
C_r	=	Background concentration in the receiving water
M	=	Fraction of receiving water flow allowed for mixing

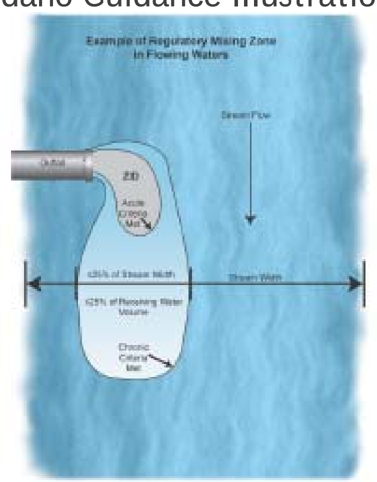
Types of WLAs include:

WLA_a	=	WLA for aquatic life acute WQC
WLA_c	=	WLA for aquatic life chronic WQC
WLA_h	=	WLA for human health WQC

States Have Mixing Zone Rules and Guidance



Idaho Guidance Illustration



EPA Technical Support Document WQBELs for Toxics

$$LTA_a = WLA_a \times EXP(0.5\sigma^2 - Z_{99}\sigma)$$

$$LTA_c = WLA_c \times EXP(0.5\sigma^2_n - Z_{99}\sigma_n)$$

Where:

EXP	=	Base e (or approximately 2.718) raised to the power shown between the parentheses
σ^2	=	$LN(CV^2 + 1)$
σ	=	Square root of σ^2
σ^2_n	=	$LN[(CV^2/n) + 1]$
σ_n	=	Square root of σ^2_n

Where:

LN	=	Natural logarithm (base e)
CV	=	Coefficient of variation = s/m

Where:

m	=	Mean of samples above the MDL in data set = $\Sigma Xi/k$
s	=	Standard deviation of the samples above the MDL in data set = $[\Sigma(X_i - m)^2/(k-1)]^{0.5}$
X_i	=	Each individual data point
k	=	Total number of samples in data set
n	=	4 for 4-day chronic criteria, and 30 for 30-day chronic criteria
Z_{99}	=	Z score for the 99th percentile probability basis

WLA to Long Term Average (LTA)

LTA to WQBELs,

Max. Day and Average Monthly Limits

(MDL and AML)

$$MDL = LTA_{low} \times EXP(Z_{99}\sigma - 0.5\sigma^2)$$

$$AML = LTA_{low} \times EXP(Z_{95}\sigma_n - 0.5\sigma^2_n)$$

Where:

EXP	=	Base e (or approximately 2.718) raised to the power shown between the parentheses
σ^2	=	$LN(CV^2 + 1)$
σ	=	Square root of σ^2
σ^2_n	=	$LN[(CV^2/n) + 1]$
σ_n	=	Square root of σ^2_n

Where:

CV	=	Coefficient of variation = s/m
m	=	Mean of samples above the MDL in data set = $\Sigma Xi/k$
s	=	Standard deviation of the samples above the MDL in data set = $[\Sigma(X_i - m)^2/(k-1)]^{0.5}$
X_i	=	Each individual data point
k	=	Total number of samples in data set
LN	=	Natural logarithm (base e)
n	=	number of samples per month
Z_{99}	=	Z score for the 99th percentile probability basis = 2.326
Z_{95}	=	Z score for the 95th percentile probability basis = 1.645

Impact on Permit Limits

- *"Flexibilities for States Applying EPA's Ammonia Criteria Recommendations"*
  - EPA presents a number of flexibilities available for state consideration including:
    1. Recalculation Procedure for Site-specific Criteria Derivation

Example Scenarios

- 2013 Revised Federal Ammonia Criteria
  - 2013 v. 1999 Ammonia Criteria
  - Mussels Present
- Site Specific Criteria
  - Mussels Absent, Early Life Stage Fish Present
  - Mussels Absent, Early Life Stage Fish Absent

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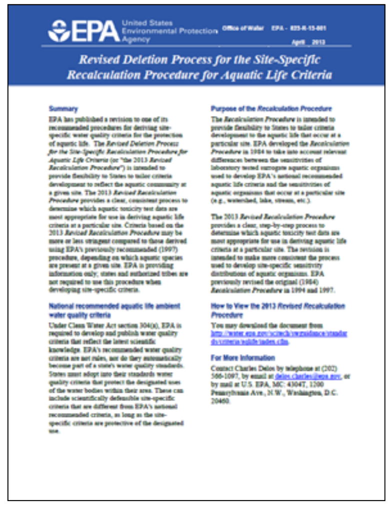
Site Specific Criteria

EPA Approved Methods

- The Recalculation Procedure, a taxonomic composition adjustment (revised in 2013).
- 2. The Indicator Species Procedure, a bioavailability adjustment now called the Water-Effect Ratio Procedure. [Biotic Ligand Model alternative]
- 3. The Resident Species Procedure, a little-used approach effectively superseded by combined application of the Recalculation and Water-Effect Ratio Procedures.

2013 Ammonia Recalculation Guidance


EPA United States Environmental Protection Agency — Office of Water — EPA - 823-R-13-001 — April 2013

Revised Deletion Process for the Site-Specific Recalculation Procedure for Aquatic Life Criteria

Summary

EPA has published a revision to one of its recommended procedures for deriving site-specific water quality criteria for the protection of aquatic life. The *Revised Deletion Process for the Site-Specific Recalculation Procedure for Aquatic Life Criteria* (or "the 2013 *Revised Recalculation Procedure*") is intended to provide flexibility to States to tailor criteria development to reflect the aquatic community at a given site. The 2013 *Revised Recalculation Procedure* provides a clear, consistent process to determine which aquatic toxicity test data are most appropriate for use in deriving aquatic life criteria at a particular site. Criteria based on the 2013 *Revised Recalculation Procedure* may be more or less stringent compared to those derived using EPA's previously recommended (1997) procedure, depending on which aquatic species are present at a given site. EPA is providing information only; states and authorized tribes are not required to use this procedure when developing site-specific criteria.

National recommended aquatic life ambient water quality criteria

Under Clean Water Act section 304(a), EPA is required to develop and publish water quality criteria that reflect the latest scientific knowledge. EPA's recommended water quality criteria are not rules, nor do they automatically become part of a state's water quality standards. States must adopt into their standards water quality criteria that protect the designated uses of the water bodies within their area. These can include scientifically defensible site-specific criteria that are different from EPA's national recommended criteria, as long as the site-specific criteria are protective of the designated use.

Purpose of the *Recalculation Procedure*

The *Recalculation Procedure* is intended to provide flexibility to States to tailor criteria development to the aquatic life that occur at a particular site. EPA developed the *Recalculation Procedure* in 1984 to take into account relevant differences between the sensitivities of laboratory tested surrogate aquatic organisms used to develop EPA's national recommended aquatic life criteria and the sensitivities of aquatic organisms that occur at a particular site (e.g., watershed, lake, stream, etc.).

The 2013 *Revised Recalculation Procedure* provides a clear, step-by-step process to determine which aquatic toxicity test data are most appropriate for use in deriving aquatic life criteria at a particular site. The revision is intended to make more consistent the process used to develop site-specific sensitivity distributions of aquatic organisms. EPA previously revised the original (1984) *Recalculation Procedure* in 1994 and 1997.

How to View the 2013 *Revised Recalculation Procedure*

You may download the document from

For More Information

Contact Charles Delos by telephone at (202) 566-1097, by email at delos.charles@epa.gov, or by mail at U.S. EPA, MC: 4304T, 1200 Pennsylvania Ave., N.W., Washington, D.C. 20460.

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Example Scenarios Analysis Assumptions for RPA and Effluent Limits Calculations

- Scenarios
  - A Medium Discharge, Small Stream
  - B Medium Discharge, Medium River
- Reasonable Potential Analysis
  - All Example Scenarios Have Reasonable Potential for Exceedance
  - Regulatory Agency Spreadsheet Calculators Used for Analysis
- Effluent Limits Calculations
  - All Example Scenarios Result in Low Limits
  - 95th Percentile: Average Monthly Limit (AML)
  - 99th Percentile – Max Daily Limit (MDL)

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Scenario A: Medium Discharger to Small Stream

- Treatment Plant
  - Max Day 10.2 mgd
- Receiving Water
  - 7Q10: 24 cfs
  - Temperature: 22^0C
  - pH: 8.8

Scenario A: Medium Discharger to Small Stream
Ammonia Criteria

Criteria	Chronic	% Change	Acute	% Change	Remarks
Current	0.41	--	1.23	--	Baseline
2013 EPA Revised Federal Ammonia Criteria					
Mussels Present, ELS Fish Present	0.19	-54%	0.73	-41%	More Stringent
Mussels Absent, ELS Fish Present	0.70	+70%	1.23	0%	Fish Control
Mussels Absent and Fish Absent	0.70	+70%	1.92	+56%	More Lenient

Scenario A: Medium Discharger to Small Stream

Effluent Ammonia Limits

Criteria	Monthly, mg/L	% Change	Daily, mg/L	% Change	Remarks
Current	0.31	--	1.26	--	Baseline
2013 EPA Revised Federal Ammonia Criteria					
Mussels Present, Fish Present	0.17	-45%	0.69	-45%	Lower Limits
Mussels Absent, Fish Present	0.31	0%	1.27	0%	Reverts to Current
Mussels Absent and Fish Absent	0.49	+58%	1.99	+58%	Relaxed Limits

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Scenario B: Medium Discharger to Medium River

- Treatment Plant
  - Max Day 8.5 mgd
- Receiving Water
  - 7Q10: 573 cfs
  - Temperature: 18.1^{0}C
  - pH: 8.1

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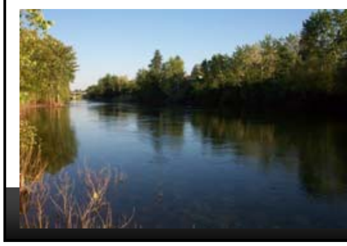
Scenario B: Medium Discharger to Medium River
Ammonia Criteria

Criteria	Chronic	% Change	Acute	% Change	Remarks
Current	1.77		5.00		Baseline
2013 EPA Revised Federal Ammonia Criteria					
Mussels Present, Fish Present	0.80	-55%	4.08	-18%	More Stringent
Mussels Absent, Fish Present	2.44	+38%	5.01	0%	Similar to Current
Mussels Absent and Fish Absent	3.02	+71%	7.82	+56%	More Lenient



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Scenario B: Medium Discharger to Medium River
Effluent Ammonia Limits

Criteria	Monthly, mg/L	% Change	Daily, mg/L	% Change	Remarks
Current	2.52		10.25		Baseline
2013 EPA Revised Federal Ammonia Criteria					
Mussels Present, Fish Present	2.05	-19%	8.31	-19%	Lower Limits
Mussels Absent, Fish Present	2.53	0%	10.28	0%	Reverts to Current
Mussels Absent and Fish Absent	3.99	+58%	16.2	+58%	Relaxed Limits

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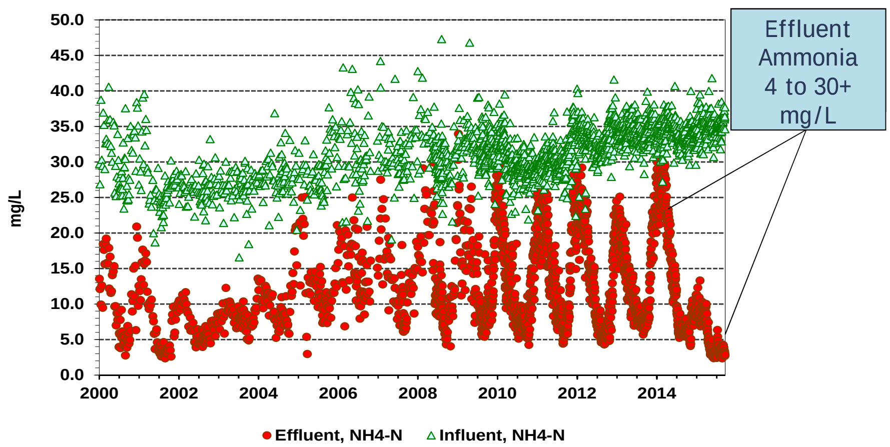
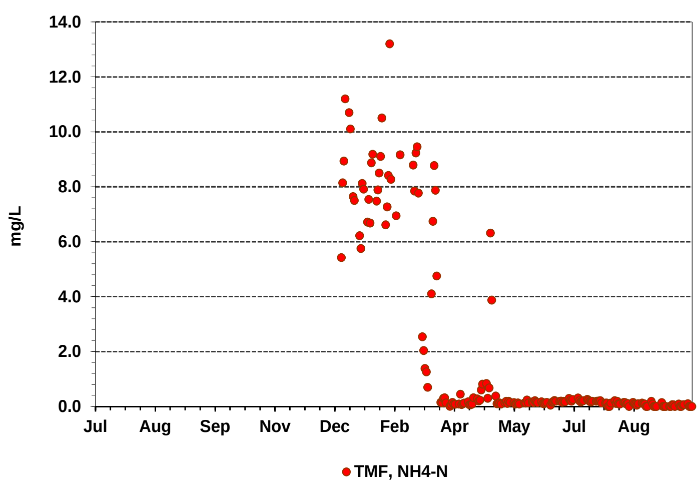
Effluent Ammonia Treatment Performance

Seasonal Nitrification with Lenient Limits
(Summer < 10 mg/L)



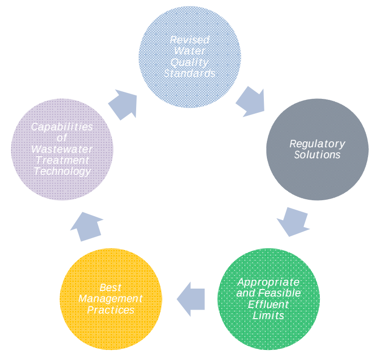
Effluent Ammonia Treatment Performance

Nitrifying Tertiary Membrane

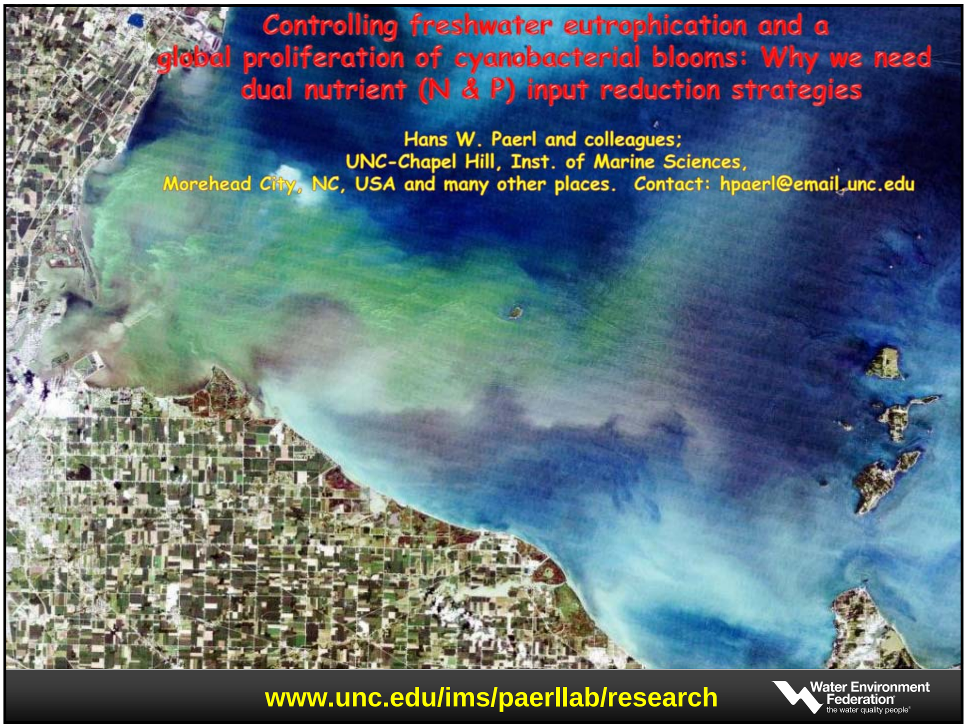


Addressing Potential Ammonia Effluent Limits

- Treatment Technology
  - Evaluate Current Plant Performance
  - Evaluate How Permit Limits will Change
- Site Specific Criteria
  - Consider Mixing Zone and Dilution Analyses
  - Revised Federal Criteria Provide Flexibility



Questions?



Cyanobacterial Harmful Blooms (CyanoHABs): Symptomatic of human and climatic alteration of aquatic environments

Urban, agricultural and industrial expansion

↓

Increasing nutrient (Nitrogen & Phosphorus) inputs

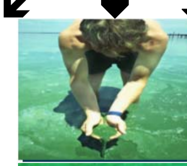
↓

Water use and hydrologic modification play roles

↓

Climate (change) plays a key interactive role

Blooms are intensifying and spreading



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It' s a global problem

- Freshwater Ecosystems (lakes, reservoirs, rivers)
- Estuaries
- Coastal waters & seas

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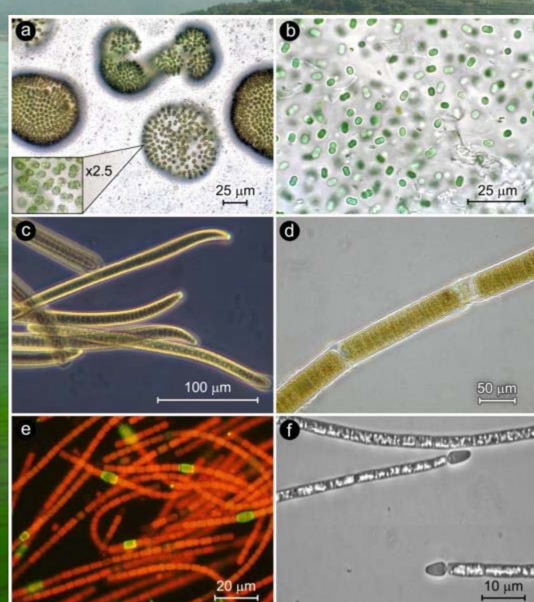
The CyanoHAB "Players"

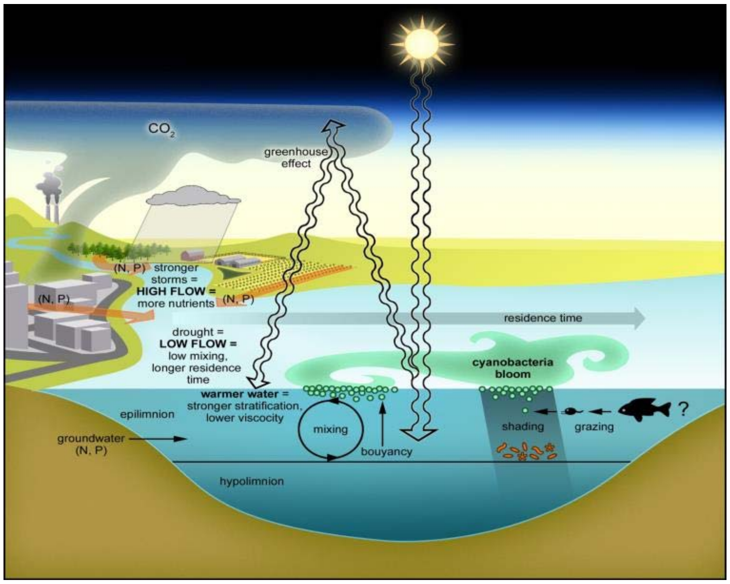
Coccoid, solitary/colonial (e.g. *Microcystis* & picocyanos). Most do not fix N_2

Filamentous, non-heterocystous (e.g. *Lyngbya*, *Oscillatoria*). Some species fix N_2

Filamentous, heterocystous (e.g. *Anabaena*, *Nodularia*, *Cylindrospermopsis*). All fix N_2



What Controls CyanoHABs? <u>Interacting</u> Physical, Chemical & Biotic Factors



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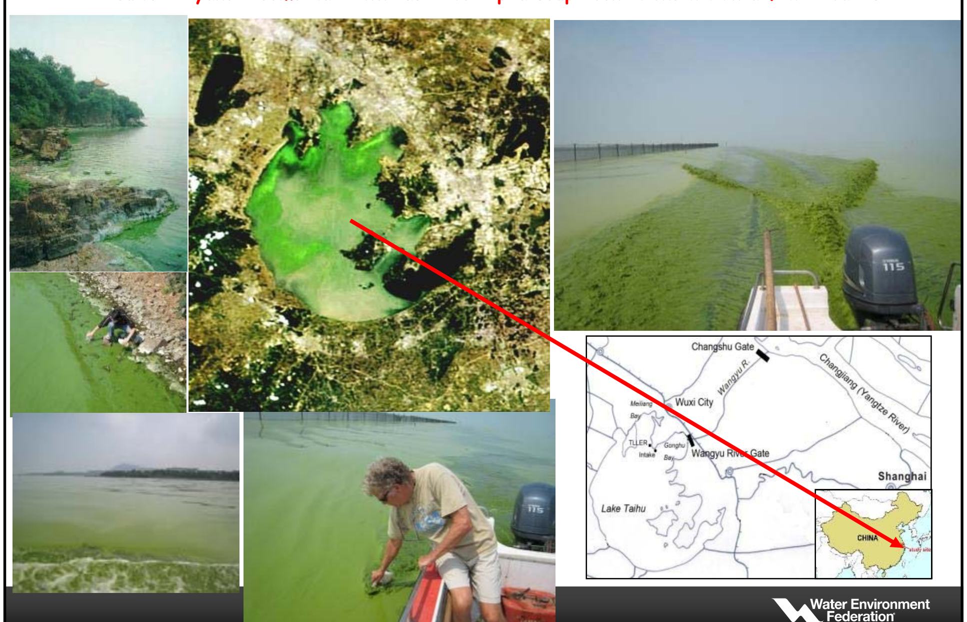
The "poster child": Lake Taihu 3rd largest lake in China. Nutrients (Lots!) associated with unprecedented human development in the Taihu Basin (Jiangsu Province). Results: Cyano blooms have increased to "pea soup" conditions within a few decades



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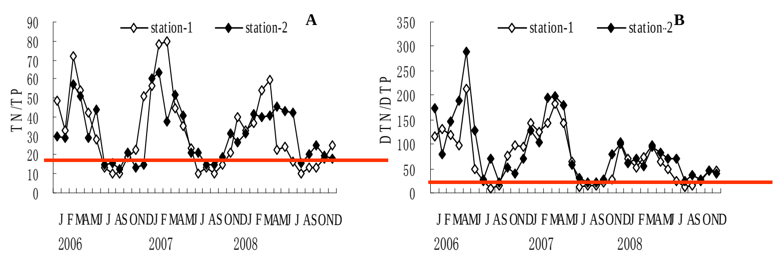
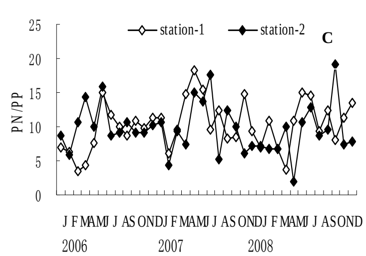
The water crises (2007- ?) in the Taihu Basin:

- Cessation drinking water use for >20 million (hepato- and neuro-toxins)
- Curtailed recreational use (contact dermatitis)
- ↓ Fisheries (commercial and recreational)
- ↓ Tourism

The "nutrient problem" in Taihu

N & P inputs exceed what's needed for balanced algal growth.
Result: "Runaway" eutrophication & toxic CyanoHABs





Nutrient (N&P) ratios in Taihu

Redfield (balanced growth)
~15:1 (N:P)

HYPOTHESIS
Dual (N & P) reductions will be needed to stem eutrophication and CyanoHABs

Xu et al., 2010

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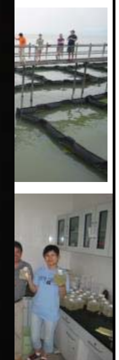
Effects of nutrient (N & P) additions on phytoplankton production (Chl *a*) in Lake Taihu, China: **Both N & P inputs matter!!**



Xu et al. 2010
Paerl et al. 2011

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Using nutrient dilution bioassays to determine N&P reductions needed to control blooms

Sampling

Distribution

Nutrient addition

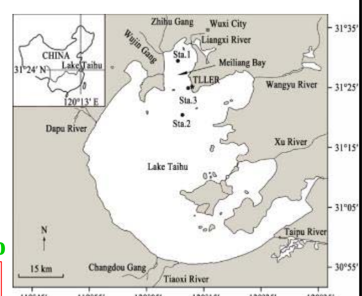
Incubation

Nutrient dilution bioassays:

1. 0% (lake water, no dilution)
2. 30% dilution
3. 50% dilution
4. 70% dilution

N was added as KNO_3, and P was added as $K_2HPO_4 \cdot 3H_2O$.

Containers were incubated in the surface water to maintain ambient conditions.



Xu et al., 2015

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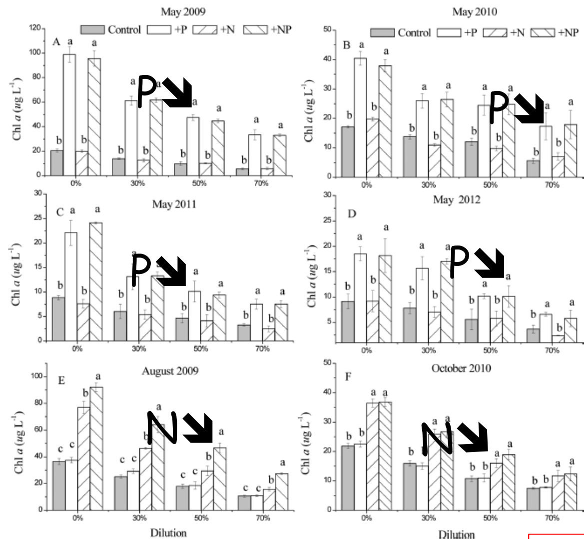
Nutrient Dilution Bioassays: How much N & P reduction is needed to control blooms?





30-50% for P
50% or greater for N

Xu et al., 2015

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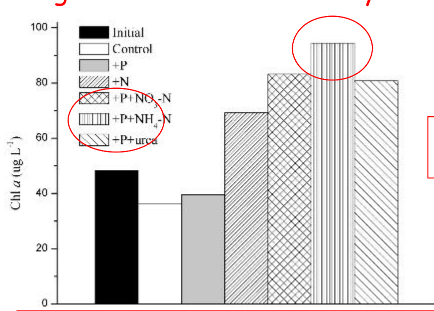
Effects of different nitrogen sources on Taihu's CyanoHAB potential

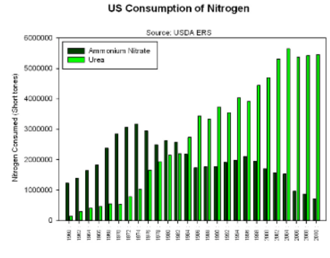




Paerl et al., 2015
Xu et al., in Prep.

Why the concern about **organic N**, specifically urea?

US Consumption of Nitrogen



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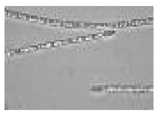
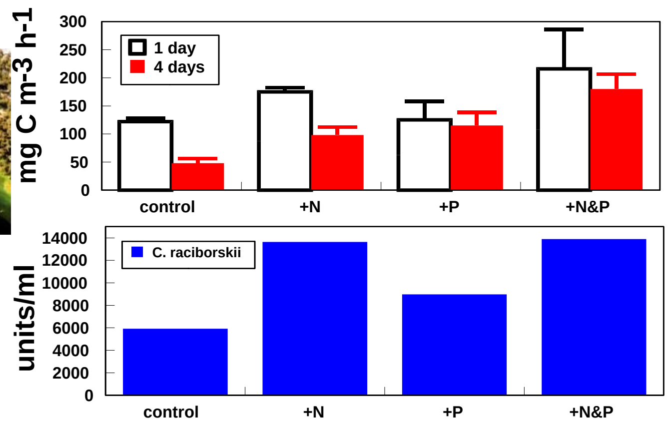
Is Taihu a "looking glass" for eutrophying large lake and coastal ecosystems worldwide?

Florida lakes : *Cylindrospermopsis raciborskii*, rapidly-proliferating, toxic N_2 fixing cyanoHAB

- High P uptake and storage capacity
- High NH_4^+ uptake affinity (competes well for N)
  - N additions (NO_3^- + NH_4^+) often significantly increase growth (chl *a* and cell counts) and productivity
- N_2 fixer (can supply its own N needs)
- Tolerates low light intensities
  - Eutrophication/decreased transparency favors *Cylindro*
  - …n water column with other cyano

St. Johns R. System, Florida, USA: N-NO_3 and P-PO_4 effects on CyanoHAB growth and bloom potential (*Cylindrospermopsis raciborskii*)





Take home message: *Cylindrospermopsis raciborskii* is highly opportunistic
<u>Dual N & P input constraints will likely be needed to control it</u>

Piehler et al, 2009

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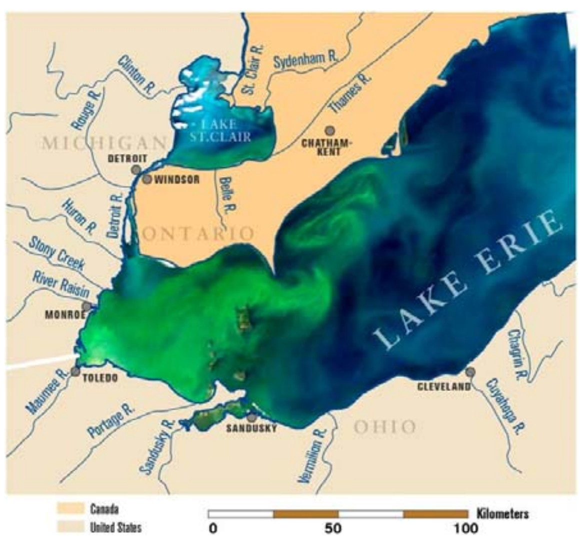
What about Lake Erie?



J. Chaffin et al., (2013) "Nitrogen Constrains the Growth of Late Summer Cyanobacterial Blooms in Lake Erie" *Advances in Microbiology* 3, 16-26.

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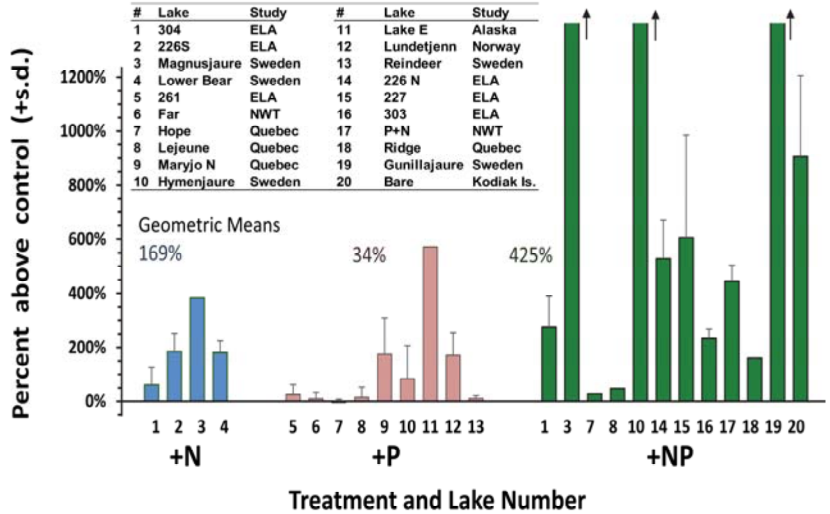
Lets ask the lakes? Whole-Lake Fertilization Experiments (ELA, Quebec, NWT, Sweden)



Co-Limitation Dominant

Wurtsbaugh et al., 2012; Paerl et al., 2016

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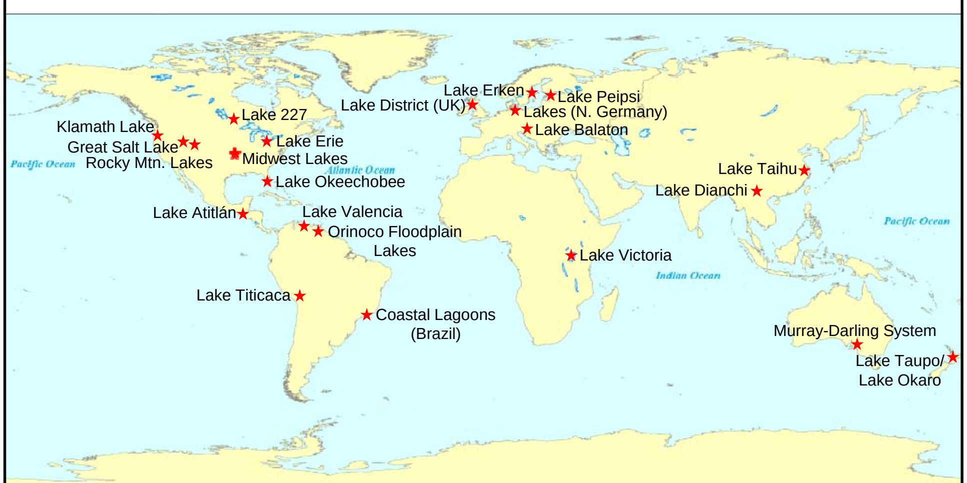
Large lakes and reservoirs in which algal blooms (mostly cyanobacteria) have been shown to be N & P stimulated



Sources: Havens et al., 2003; Elser et al. 2007; North et al., 2007; Lewis & Wurtsbaugh 2008; Conley et al., 2009; Moisander et al., 2009; Lewis et al. 2011; Abell et al., 2011; Özkundakci et al., 2011; Paerl et al., 2014; and many others

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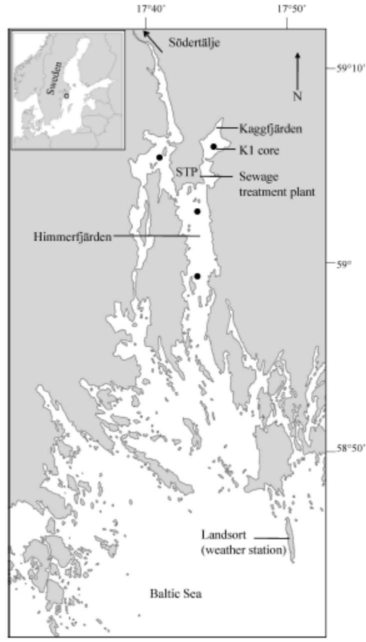
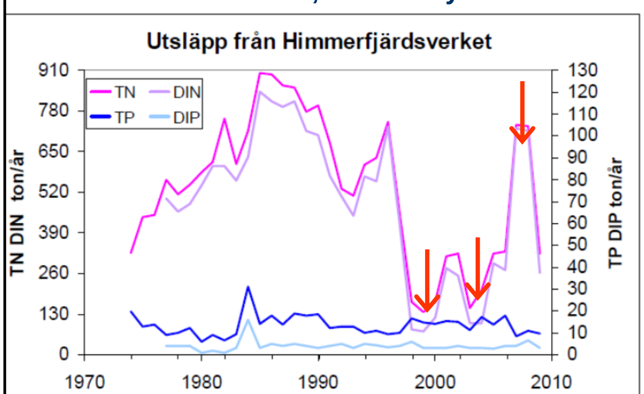
Nutrient load and phytoplankton (dominated by cyanobacteria) growth response in Himmerfjärden, Sweden

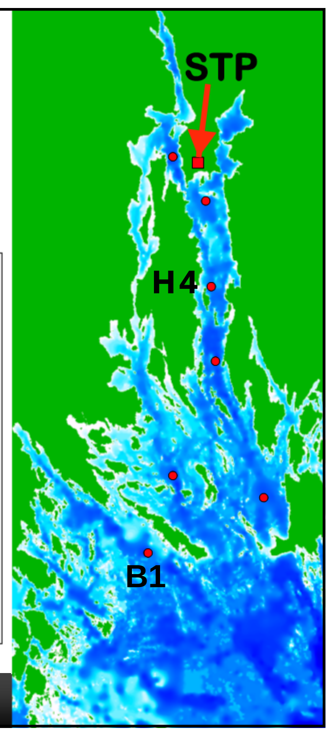
Courtesy: Ulf Larsson & Ragnar Elmgren
Stockholm University



The Himmerfjärden case: Baltic ooastal area with large Sewage treatment plant,
P removal since 1976
N removal started in 1993 (50%) & 2000 (80%).
No N removal 2004-2008
EFFECTS ON PHYTOPLANKTON (Chl a)?

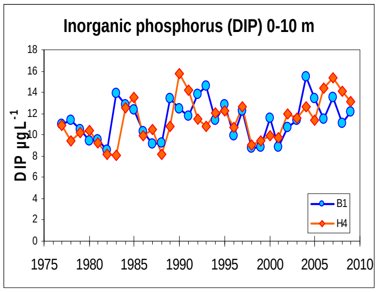
Plant loads , tonnes/ year

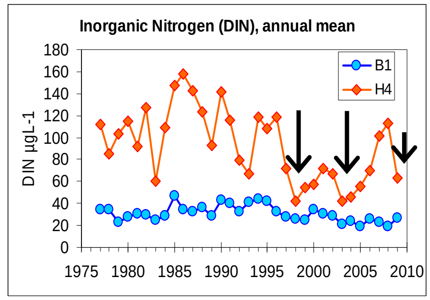


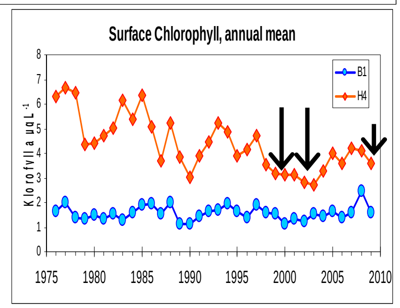


H4 =Eutrophicated station
B1= Reference station

The results: Reducing DIN inputs reduced Chl a







Larsson and Elmgren, 2012

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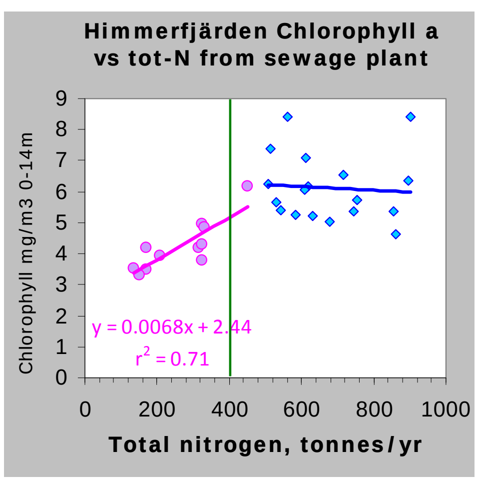
Developing a N loading-bloom threshold

Stockholm University



Lowering nitrogen discharge below 400 tonnes/yr clearly reduced local phytoplankton biomass.

Source:
Ulf Larsson, pers.comm.

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Why does N limitation persist in eutrophic systems? N_2 losses from shallow eutrophic systems exceed "new" N inputs via N_2 fixation

Annual estimates of ecosystem N_2 fixation, denitrification, and net ecosystem N_2 flux in lakes.

Location	N_2 Fixation ($g\ N\ m^{-2}\ yr^{-1}$)	Denitrification ($g\ N\ m^{-2}\ yr^{-1}$)	Net N_2 Flux ($g\ N\ m^{-2}\ yr^{-1}$)[1]
Lake 227 (ELA)[2]	0.5	5-7	-6.5 – -4.5
Lake Mendota[2]	1.0	1.2	-0.2
Lake Okeechobee[2]	0.8 – 3.5	0.3 – 3.0	-2.2 – 0.5
Lake Erken[2]	0.5	1.2	-0.7
Lake Elmdale	10.4[3]	18[4]	-7.6
Lake Fayetteville	10.6[3]	23[4]	-12.4
Lake Wedington	7.0[3]	12[4]	-5.0

[1]Net negative N_2 flux represents reactive N loss, positive represents gain; [2]Paerl and Scott (2010); [3]J.T. Scott (unpublished data); [4]Grantz et al. (2012)

Conclusions: 1. N_2 fixation does NOT meet ecosystem N demands
2. More N inputs will accelerate eutrophication
3. We Gotta get serious about controlling N (as well as P) !!

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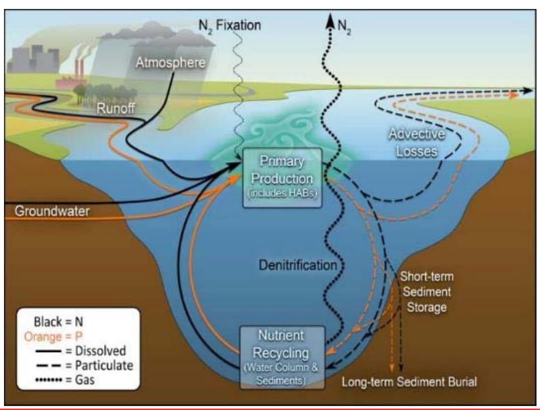
Conclusion: N limitation is pervasive in aquatic ecosystems, even ones receiving anthropogenic N enrichment



Bottom line: Need to reduce N along with P to control eutrophication and bloom formation

EPA United States Environmental Protection Agency | Office of Water MC 4304T | EPA - 820-S-15-001 February 2015

Preventing Eutrophication: Scientific Support for Dual Nutrient Criteria

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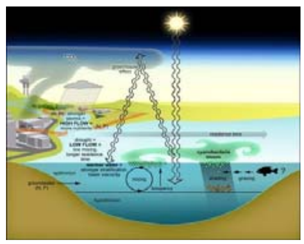
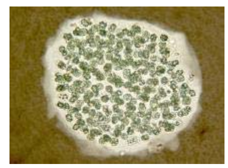
Conclusions/Recommendations

- Reduce both N & P inputs (often by >30%)
  - Nutrient-bloom threshold are system-specific
  - May need to reduce N and P inputs even more in a warmer world
- Impose nutrient input restrictions year-round
  - Residence time is long in many lakes (usually > 6 months)
  - Warmer, longer growing seasons

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Thanks!!

www.unc.edu/ims/paerllab/research/cyanohabs/

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M. Piehler
K. Rossignol
S. Wilhelm
H. Xu
G. Zhu
TLLER "crew"

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Grant # 82667701



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NEW Water
The brand of the Green Bay Metropolitan Sewerage District

Erin Houghton, M.S.
Watershed Specialist
NEW Water: the brand of Green Bay Metropolitan Sewerage District

Take-a-ways

- Nitrogen in our effluent has direct ecological effects
- Wastewater treatment plants can go beyond the end of their pipe
- Phosphorus may not be the only nutrient of concern

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Nitrogen Toxicity: from Effluent to Ecology

March 8, 2017

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NEW Water:
the brand of Green Bay Metropolitan Sewerage District

- Serving customers since 1931
  - First plant built in 1935
  - Added De Pere facility in 2008
- Wholesaler of wastewater services for 18 municipalities
- Currently treat 38 million gallons of wastewater a day
  - Two facilities:
  - Green Bay Facility (30 mgd, 113,600 m^3)
  - De Pere Facility (8 mgd, 30,280 m^3)
- Nationally recognized, multiple award-winning effluent
  - 14 Years straight of compliance
- 5-member Board of Commissioners

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Ammonia Toxicity and Treatment

- Revised 2013 Federal Ammonia Criteria
  - Protect sensitive freshwater mussels and snails
  - WI has not yet adopted
- Lake Michigan/Green Bay
  - Invasive dreissenid mussels have outcompeted native unionids
  - Fox River and lower Green Bay are heavily impaired waterways
- Nitrogen in our WPDES permit
  - Ammonia is the only Nitrogen component limited
  - Follow weekly and monthly limits that change with the time of year
  - WQBEL not necessary at this time
  - Optimize removal of ammonia within the capabilities of wastewater treatment plant

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Ammonia Toxicity and Treatment

- Green Bay Facility Upgrades
  - Goal: improve **P** & **N** biological breakdown
  - Increased the size of our hypoxic or anaerobic zone
  - Decreased aeration size and installed new diffusers
  - Increased anaerobic interaction time from 20 min -> 1hr
- Treatment Process and effluent are monitored as part of our state permit
  - Some nutrient speciation work has been done on Phosphorus
  - Future speciation work on Nitrogen is being discussed

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Regional Water Quality Issues

• **TOTAL MAXIMUM DAILY LOAD(TMDL)**:
- Lower Fox River & Lower Green Bay
- For Total Phosphorus & Total Suspended Solids
- By WI Department of Natural Resources & US Environmental Protection Agency

• **AREA OF CONCERN (AOC)**:
- Lower Green Bay & Fox River
- By International Joint Commission & US Environmental Protection Agency

Photo credit: Steve Seilo

• **EXCESS NUTRIENTS & SEDIMENT RUNOFF**:
- Push to address non-point source inputs

• **Harmful Algal Blooms (HABs):**
- Seeing large cyanobacteria blooms dominate over desired algal species
- Can produce toxins

• **DEAD ZONE**:
- Green Bay: Mid to lower bay
- Hypoxic and anoxic bottom water
-Highly eutrophic water brings large amount of organic material consumed by benthic organisms that breathe O2 and respire CO2

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Water Quality Monitoring

- Aquatic Monitoring Program (AMP)
  - AMP *est.* 1986 on Green Bay and local rivers
  - Continuous monitoring sondes deployed at 2 locations
  - Water quality grab samples from 23 sites, weekly
  - Run suite of analytes in our state certified laboratory
- Watershed Nutrients & Sediments
  - Silver Creek Pilot Project (compliance option)
  - 5 sampling sites along creek
  - 1USGS gage station

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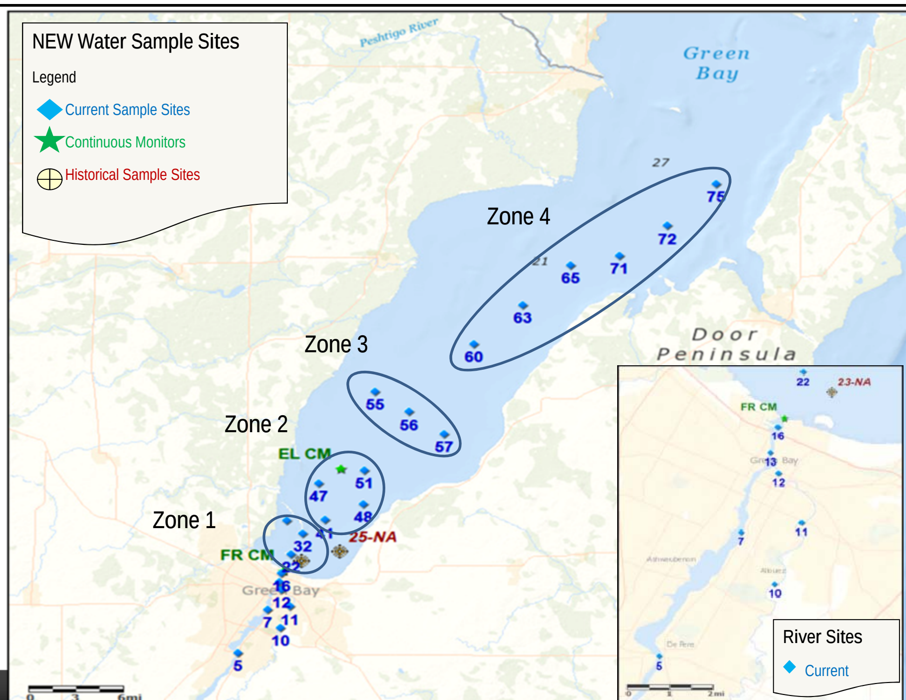

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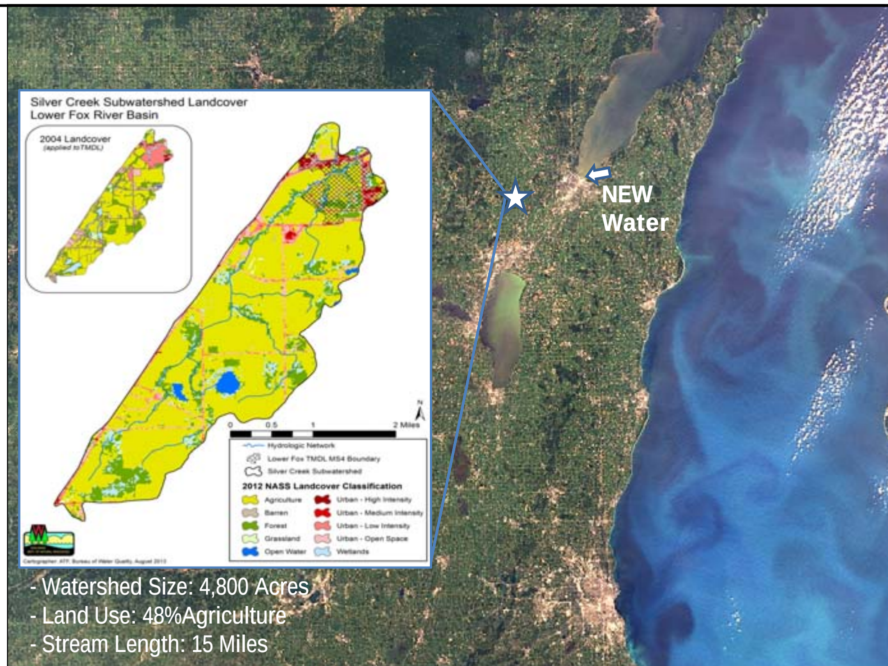
Adaptive Management

- NEW Water issued new combined WPDES permit July 1, 2014
  - 5-year-permit cycle
- New future Total Phosphorus and Total Suspended Solids reductions
- Several options for compliance:
  - Facility improvements: $223 - $394 million capital cost + $2 million annual O&M cost
  - Phosphorus Trading
  - Multi –Discharger Phosphorus Variance Program
- ***Adaptive Management** addresses new phosphorus and solids limits
  - Current: AM Pilot Silver Creek Watershed (Ag) + Plant Optimization



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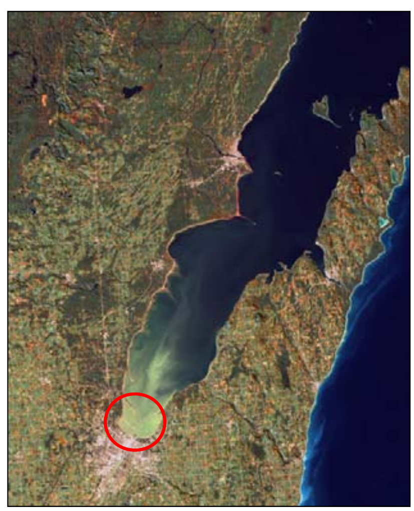
Harmful Algal Blooms

- HABs: Harmful Algal Blooms
  - Undesirable algae grows unchecked
  - Contribute large biomass to decomposition which can deplete local oxygen availability
  - Blooms are a nuisance to recreation
  - Can produce foul smells and toxins
- Unknowns about HABs
  - When and why do they produce toxins?
  - What drives/limits their formation?



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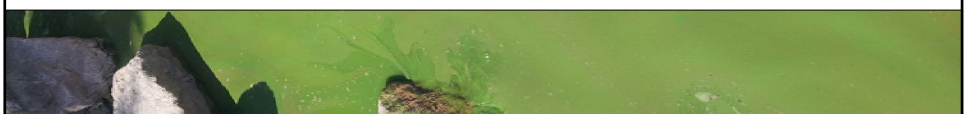
Harmful Algal Blooms & Nitrogen

- Green Bay is one of the largest freshwater estuaries
  - Excess nutrients from main rivers
  - Warm shallow environment
- Freshwater algae are thought to be phosphorus limited
  - Most regulations focus on phosphorus limits
  - Studies show blooms are largest with and increase in both available phosphorus and nitrogen
- Understanding the breakdown of nitrogen and its sources may lead to improved management



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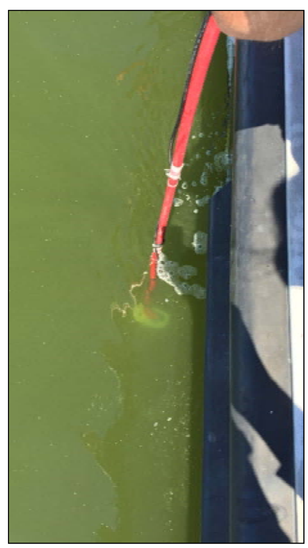
Harmful Algal Bloom Research

- Cyanobacterial Harmful Algal Bloom Grant
  - Collaboration with WDNR, University of Wisconsin – Milwaukee, & NEW Water
- Comprehensive sampling: 6 locations
  - Water quality grab samples
  - Instrument measurements
  - Algal counts and species ID
  - Toxin identification and concentrations
- Sampling Frequency
  - Weekly during the spring
  - Bi-weekly during the summer/fall
  - Bump grabs to 3x/wk during peak bloom conditions
- Timeline: 3yr grant
  - Year one – 2016 establish sampling sites and routine
  - Year two – 2017 continue monitoring, addition of monitoring buoys
  - Year three – 2018 continue monitoring, data work-up and final report summaries



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Future Life Support…
…to avoid *Death by Nutrients*!

- Better knowledge of nutrient breakdown along entire treatment process
  - To best address excess nutrient removal
  - Start preparing for future permit additions
- Improve collaboration between utilities and the community
  - New opportunities to work outside of treatment facility
  - New collaborations on water quality research
- Understanding main nutrient drivers in the environment
  - Include N and P as potential bloom drivers
  - Further understanding on HABs, toxin production, bloom management
  - Go beyond TP and TSS in TMDLs and AOCs

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Thank You!

"Protecting Our Most Valuable Resource, Water"
~NEW Water Vision Statement

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Questions?

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