Aerations Effect on Algae: a review of success and failures

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Topic Overview

1. Mechanisms for which aeration can influence algal abundance and assemblage

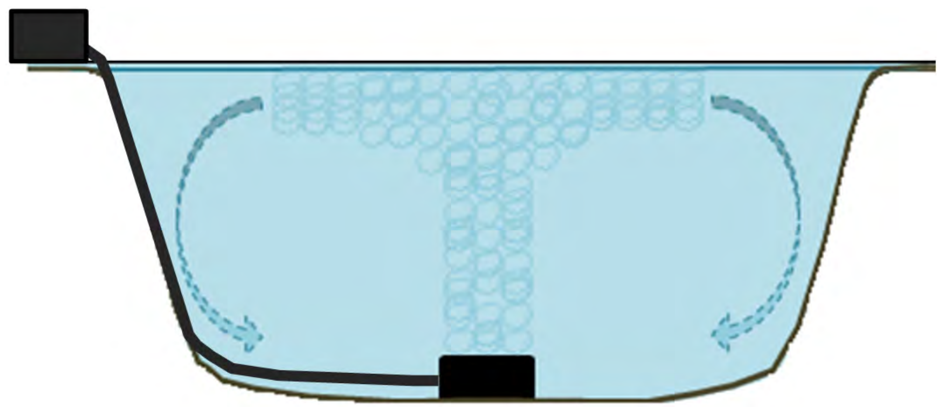
2. Aeration Projects: Success and Failures

3. Aeration Design Considerations

Artificial Aeration/Circulation

Aeration Type:

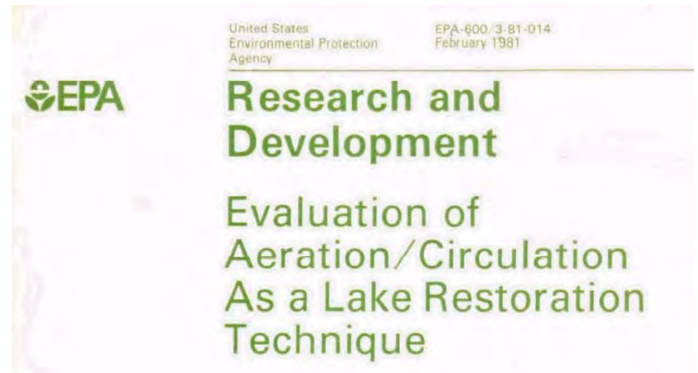
Bottom Aeration
Laminar Flow
Diffused Aeration
Destratifiers



Artificial Aeration/Circulation

Aerations Benefits:

- Water quality
- **Phytoplankton**
- Fisheries
- Sediment quality
- Benthic fauna



United States
Environmental Protection
Agency

EPA-600/3-81-014
February 1981

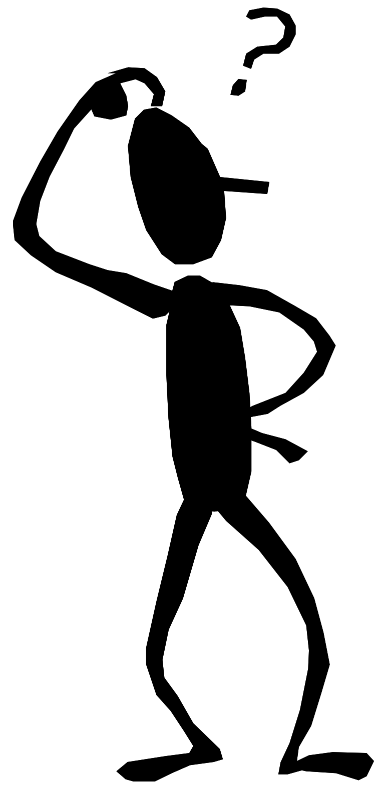
EPA

Research and Development

Evaluation of Aeration/Circulation As a Lake Restoration Technique

A REVIEW OF LAKE AERATION AS A TECHNIQUE FOR WATER QUALITY IMPROVEMENT

How does aeration effect algae?



Aeration and Lake Water Chemistry

Main Chemical Parameters:

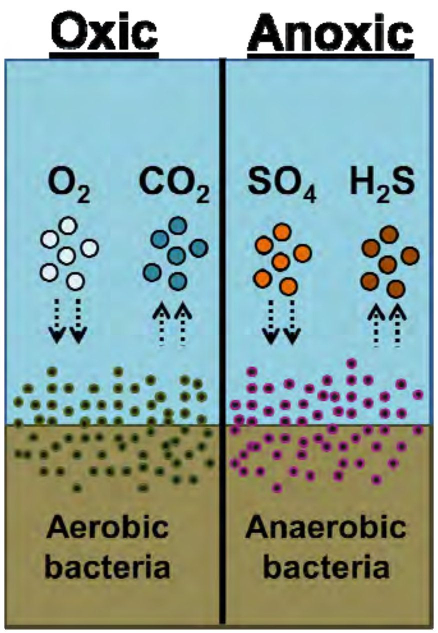
1. pH
2. Alkalinity
3. CO2
4. Phosphorous
5. Nitrogen

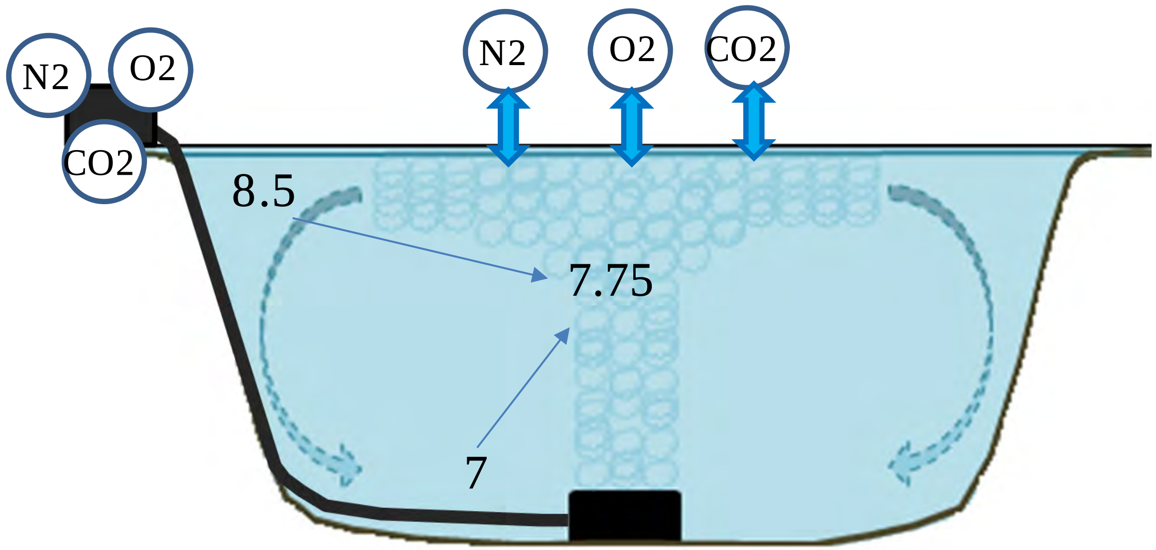
Influence Algal Abundance and Assemblage

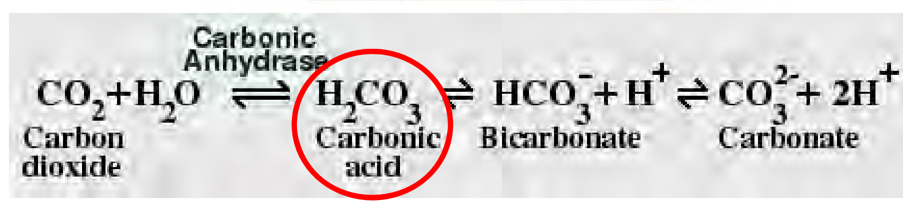
(Duarte et al. 1992; Maileht et. al 2012)

Aeration and Lake Water Chemistry

Aeration→ Epilimnetic CO2 (↑), pH (↓), alkalinity (↓)







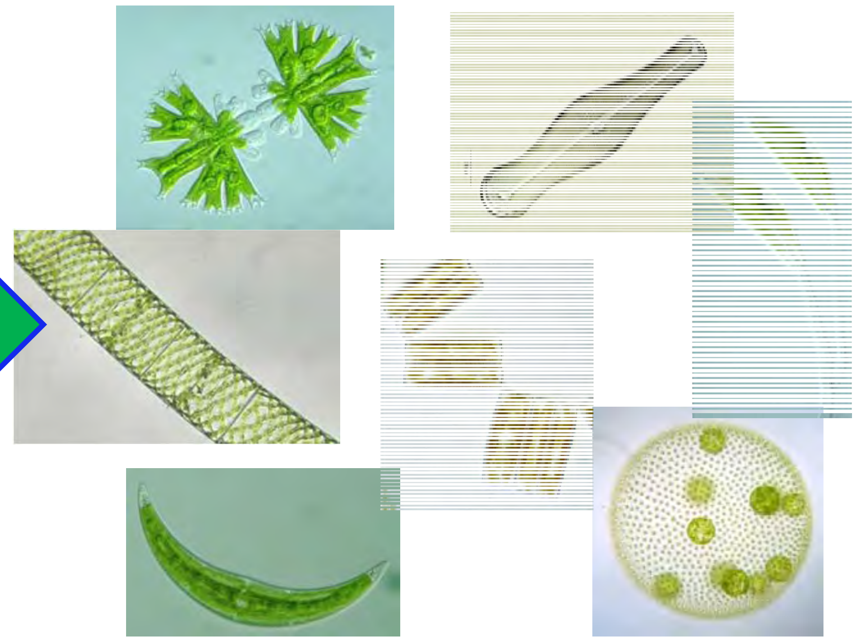
Pastorok, 1981

Aeration and Lake Water Chemistry

Cyanobacteria have a competitive edge
in higher pH and Alkaline waters

Cyanobacteria

Green Algae/Diatoms



pH <8.5 Shift Possible   pH 8.5-7.5 Variable   pH <7.5 Shift Absolute

(Shapiro et al., 1975, 1977)

Aeration and Phosphorous

Aeration→ Can Reduce Phosphorus

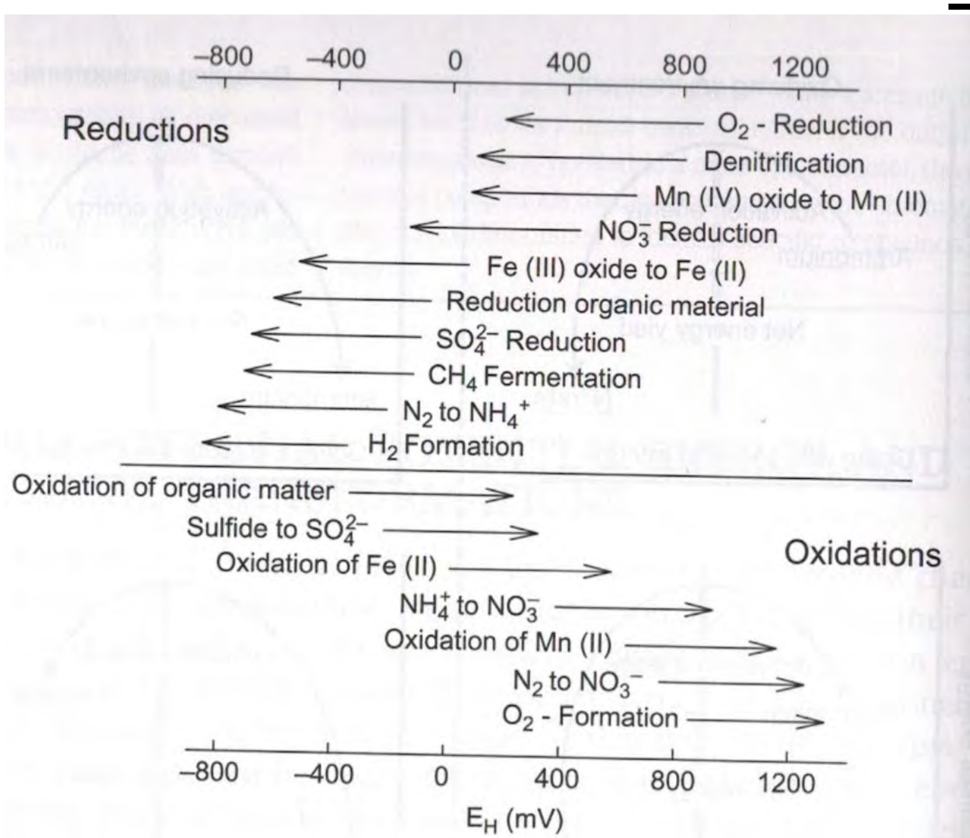
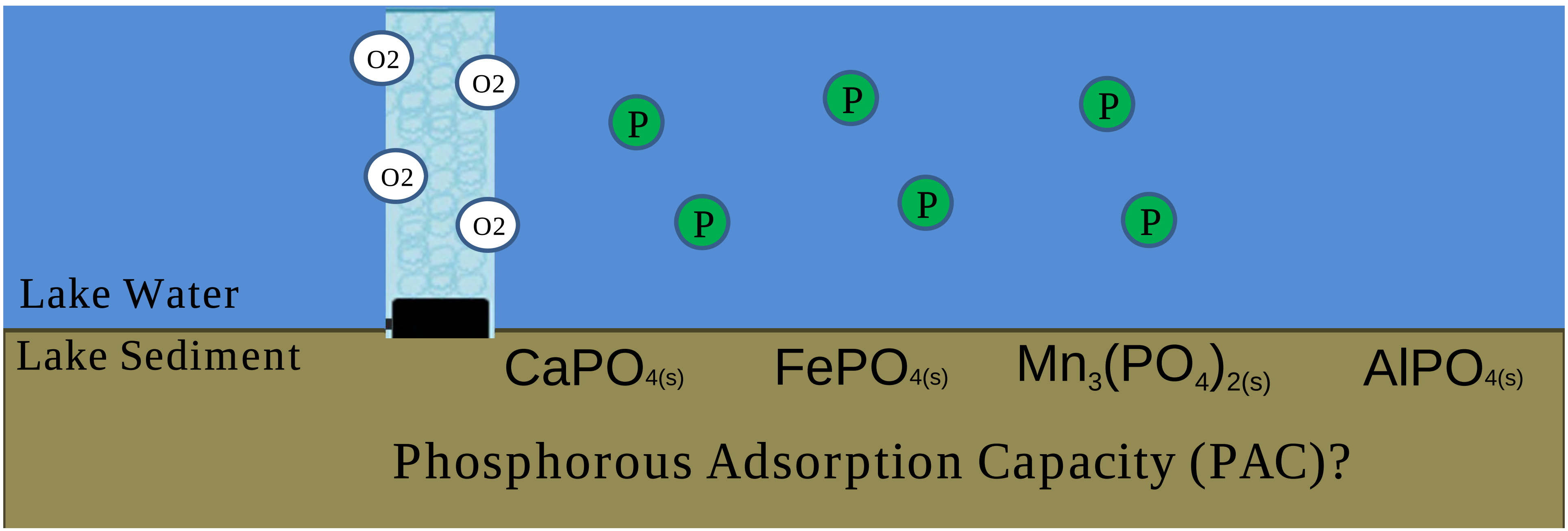


Figure taken from Dodds, 2002

Microbe-mediated chemical transformations using Redox (mV)

Aeration and Phosphorous

- Aeration maximizes a lakes ability to adsorb Phosphorous (Stumm and Morgan, 1970; Syers et al., 1973; Boyd, 1995; Shrestha and Lin, 1996).
- The Lakes soil determines the Phosphorus Adsorption Capacity (PAC). Organic matter reduces PAC (Borggaard et al., 2003 & 2004).



Aeration and Phosphorous

Ex: (3) 10 Year Lake Aeration Studies

Grochowska (2004)	Sinke (1992)	Gachter and Wehrli (1998)
Significant reduction in Total Phosphorous	Release rates went from 1 mg P/m^2·day to 0.3 mg P/m^2·day) in Lake Loosdrecht	No Significant effect on the internal phosphorus loading of two eutrophic lakes

Phosphorous Adsorption Capacity (PAC)

Aeration and Nitrogen

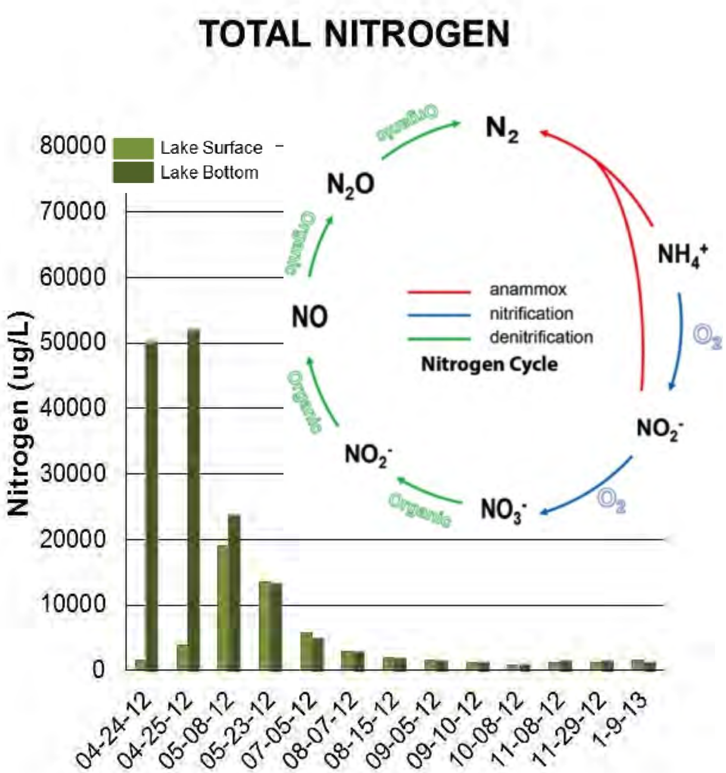
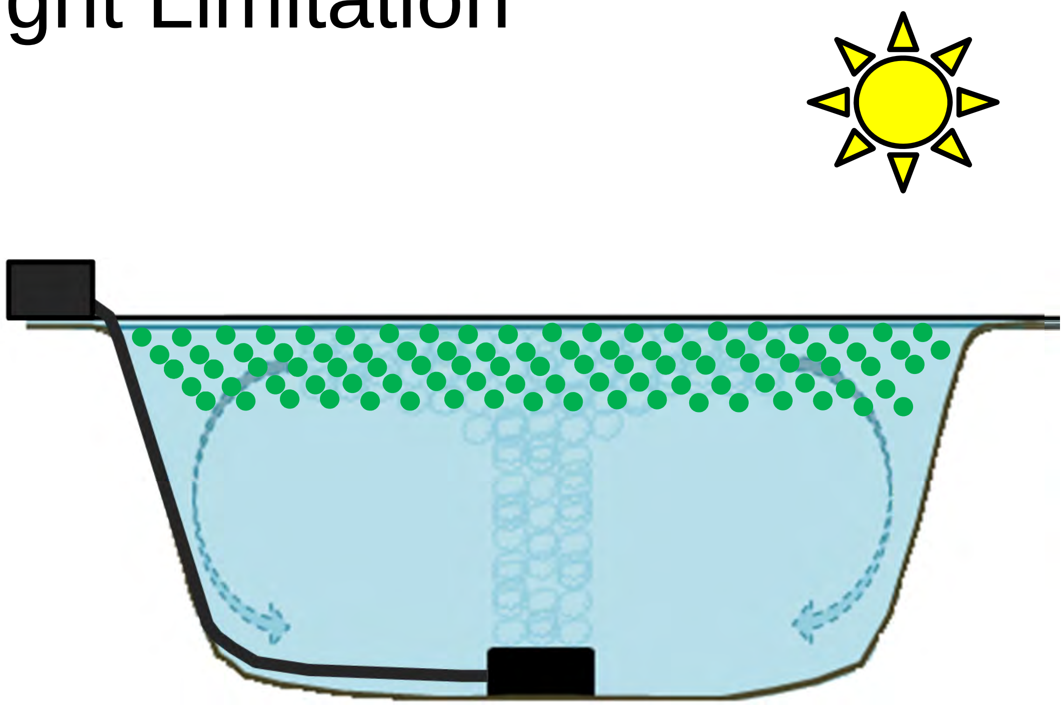


Figure taken from Bahia Del Mar case Study, un-published

- Denitrification can also occur under fully aerobic conditions (Robertson and Kuenen, 1984; Chen et al., 2003).
- "Aeration increased the abundance of nitrifying and denitrifying bacteria, resulting in higher mortality rates of cyanobacteria in aerated aquariums" (Yang et al., 2013)

Aeration: Mixing/Circulation

- Dilution
- Light Limitation

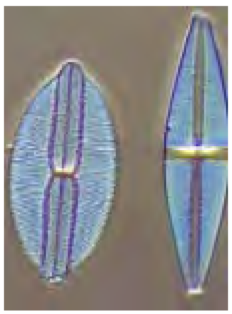


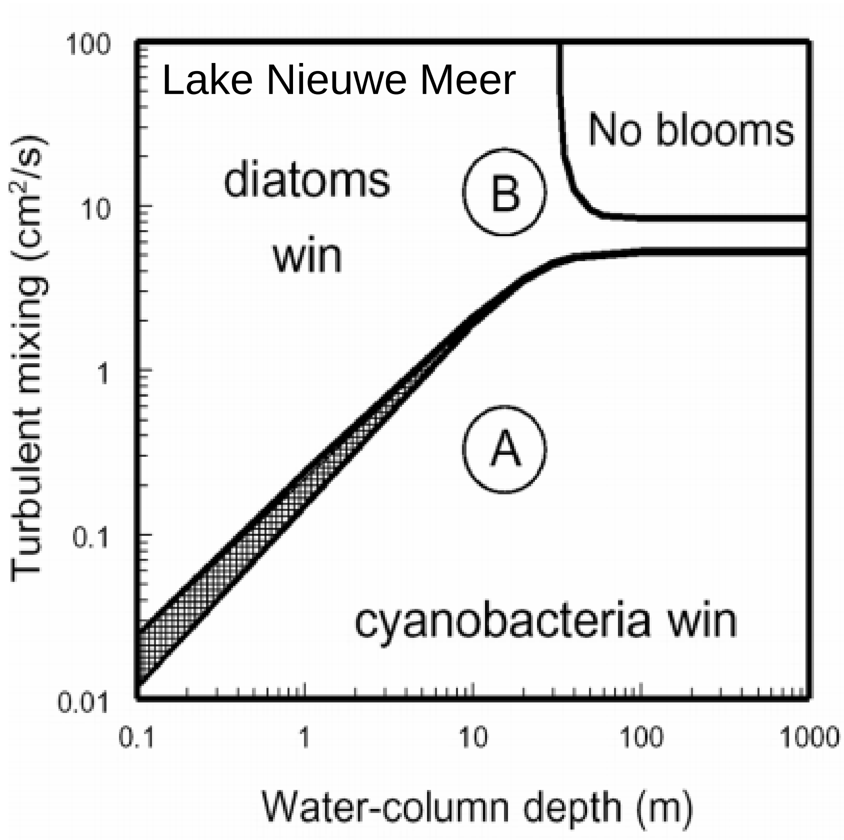
Lorenzen & Mitchell, 1975

Aeration: Mixing/Circulation

A = mixing off B = mixing on

Sinking Diatoms

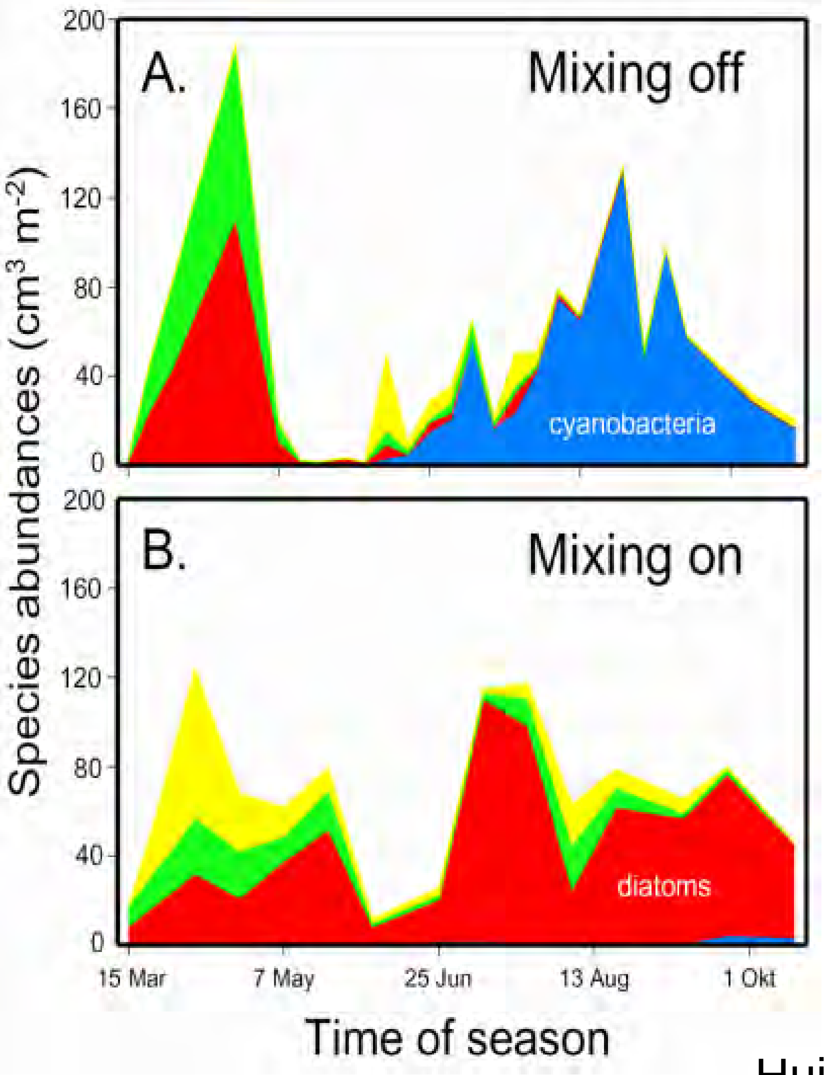




Buoyant Cyanobacteria

Huisman et al. 2004

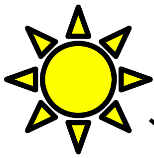
Aeration: Mixing/Circulation



Huisman et al. 2004

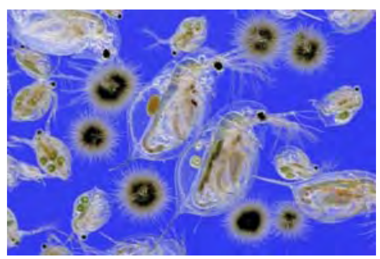
Aeration: Mixing/Circulation

Increased Zooplankton Grazing



Nutrients → Primary Producers → Primary Consumers → Secondary Consumers → Tertiary Consumer

Trophic level:	1	2	3	4
	Algae/Plants	zooplankton	Planktivorous Fish	Piscivorous Fish



Pastorok, 1981

Aeration Design: Success or Failure?

1) Lake Factors:

- Physical (Stratification, Depth?)
- Chemical (PAC, NH3, Color, pH?)
- Biological (TSI, BOD, HAB?)

2) Aeration Design Factors:

- Turnover
- #Diffusers
- Air Flow
- Placement
- Lifting Rates

Aeration Design: Success or Failure?

Lake Factors:

Physical:	Chemical:	Biological:
Bathymetry Stratification Secchi	Surface and Bottom TP,TN,NH3, Profiles DO/Redox Conductivity	Chl-a Algae Zooplankton TSI

Aeration Design: Success or Failure?

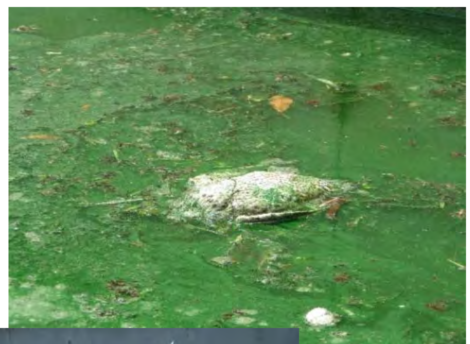
Lake Factors:

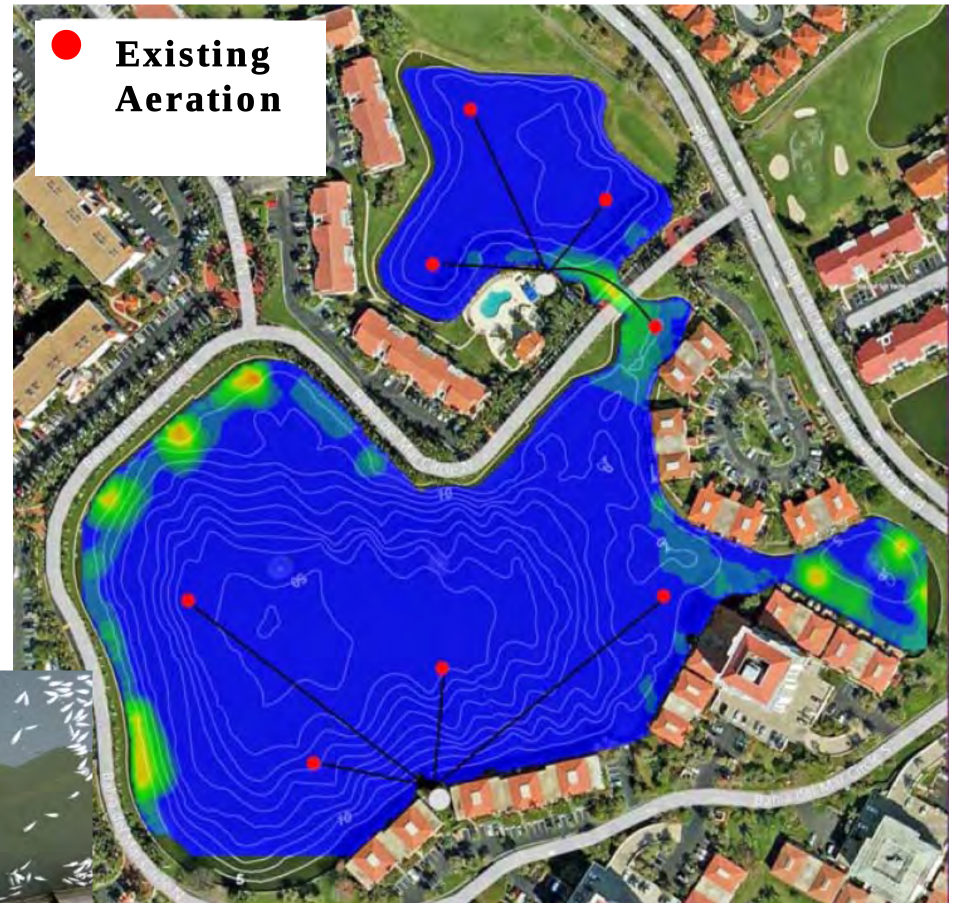
Bahia del Mar– St. Petersburg, FL

Area: 14 Acres

Depth 18 - 51ft

Aeration Design:
Turnovers: **.60 per/day**





Aeration Design: Success or Failure?

Aeration Design Factors :

Sizing to the highest denominator

Aerations Benefits:

- Water quality
- Phytoplankton
- Fisheries
- Sediment quality
- Benthic fauna

Lorenzen & Fast (EPA), 1977

Lorenzen & Fast Aeration Sizing Model

Model Based off:

- Nutrient Limitation
- Light Limitation
- Mixing Depth
- Max Chl-a

Limitations:

- Grazing
- Parasitism
- Aeration design

Good Mixing = 1.33CFM/surface acre

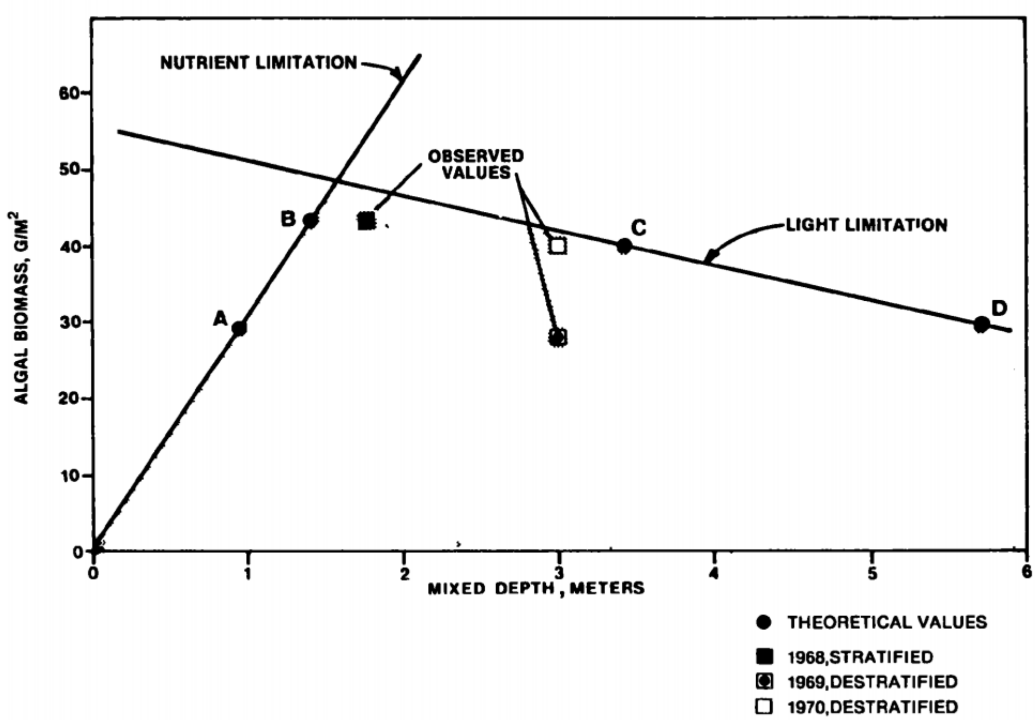
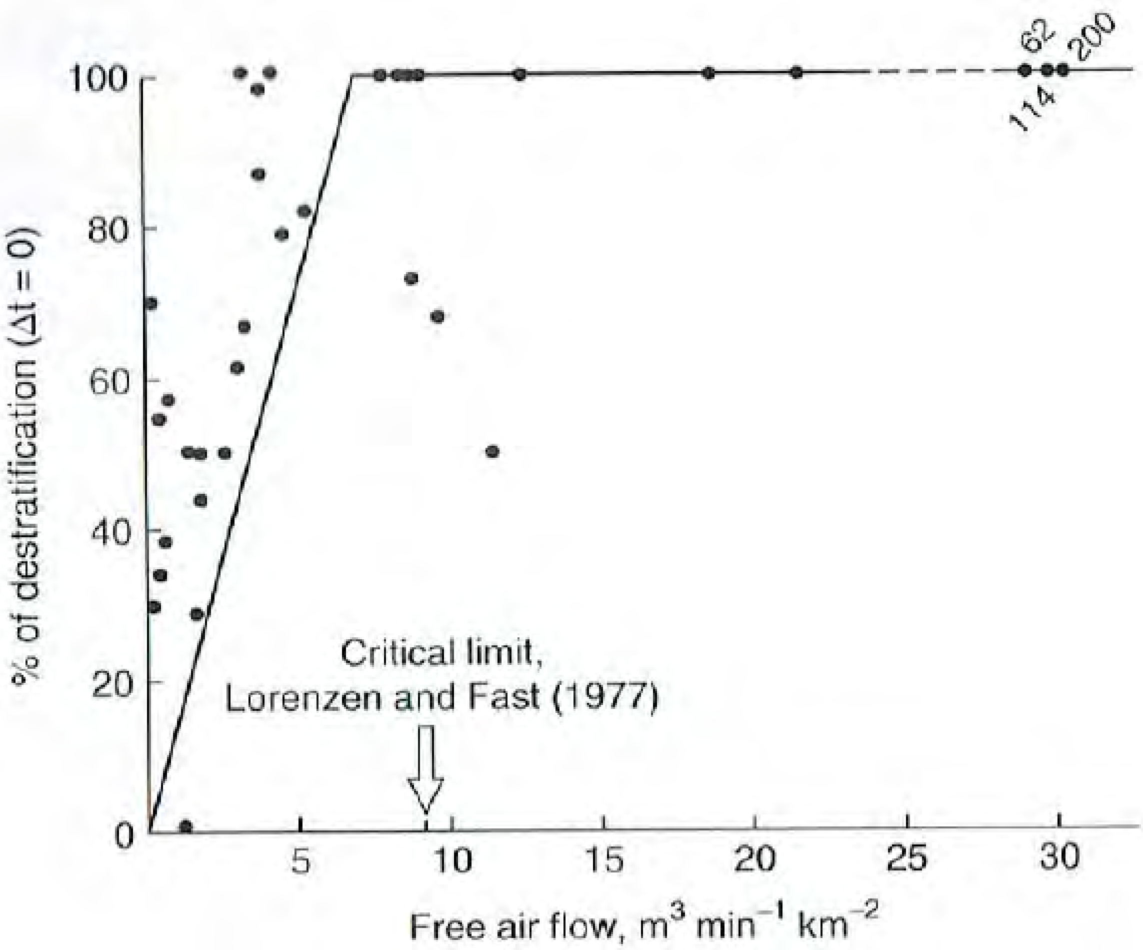


FIGURE 1 THEORETICAL AND OBSERVED PEAK BIOMASS OF ALGAE IN KEZAR LAKE (ADAPTED FROM LORENZEN AND MITCHELL 1975)

Lorenzen & Fast (EPA), 1977

Lorenzen & Fast Aeration Sizing Model



Pastorak, R.A. et al 1982

Post Lorenzen and Fast Aeration Projects

Successful	Unsuccessful
Lake Brooker, USA (Cowell et al. 1987)	Sheldon Lake, USA (Oberholster et al. 2006)
Fischkaltersee, Germany (intermittent , Steinberg & Zimmermann, 1988)	Fischkaltersee, Germany (continuous, Steinberg 1983)
Solomon Dam, Australia (Hawkins & Griffith (1993)	East Sidney Lake, USA (Barbiero et al. 1996)
Nieuwe Meer, The Netherlands (Visser et al. 1996b; Jöhnk et al. 2008)	North Pine Dam, Australia (Antenucci et al. 2005; Burford & O'Donohue. 2006)
Lake Dalbang, South Korea (Heo & Kim, 2004)	Lake Yogo, Japan (Tsukada et al. 2006)
Bleiloch reservoir, Germany (Becker et al. 2006)	
Ford Lake, USA (Lehman et al. 2013; Lehman 2014)	

Why Did Aeration Fail?

Unsuccessful
Sheldon Lake, USA (Oberholster et al. 2006)
Fischkaltersee, Germany (continuous, Steinberg 1983)
East Sidney Lake, USA (Barbiero et al. 1996)
North Pine Dam, Australia (Antenucci et al. 2005; Burford & O'Donohue. 2006)
Lake Yogo, Japan (Tsukada et al. 2006)

Undersized according to Lorenzen and Fast, 1977!?

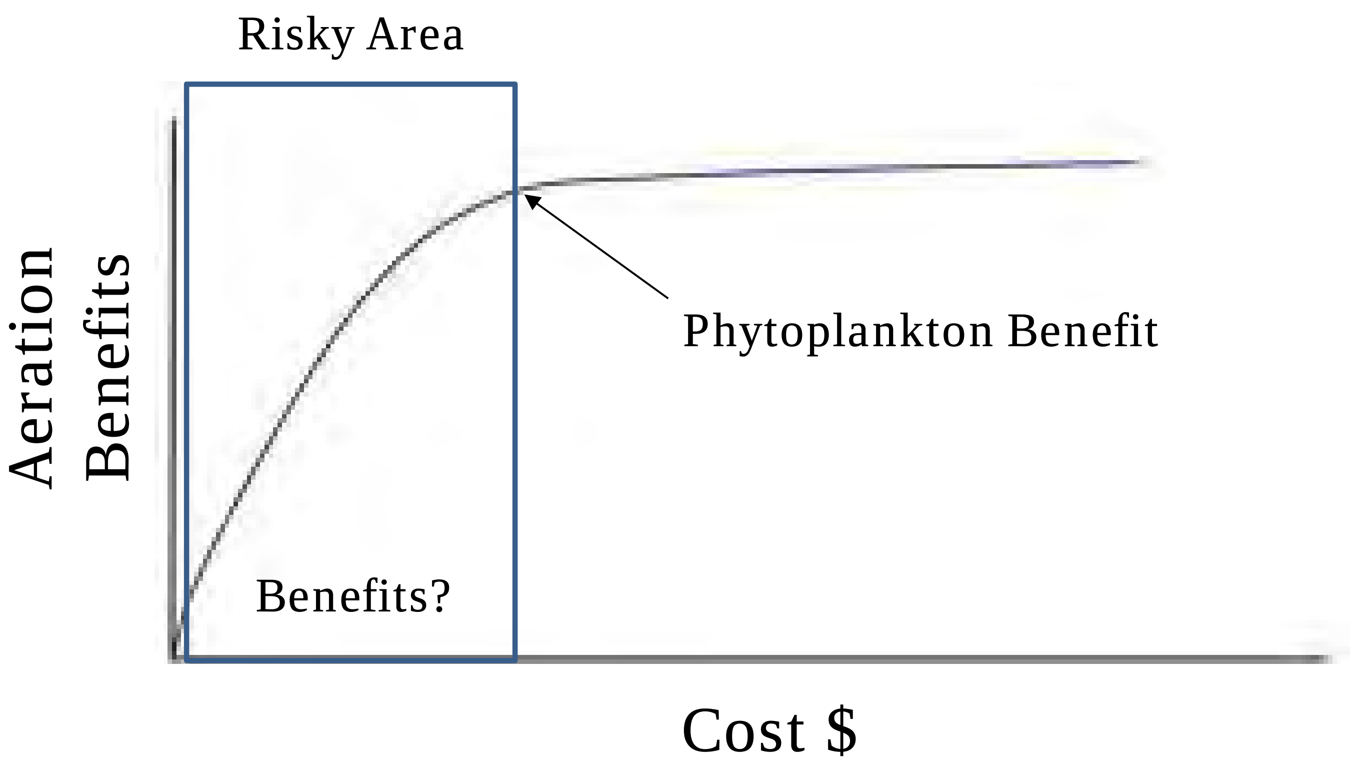
Sized to the Highest Denominator?

Ex: Sized to destratify. Used 63CFM but Needed 273CFM to improve algae

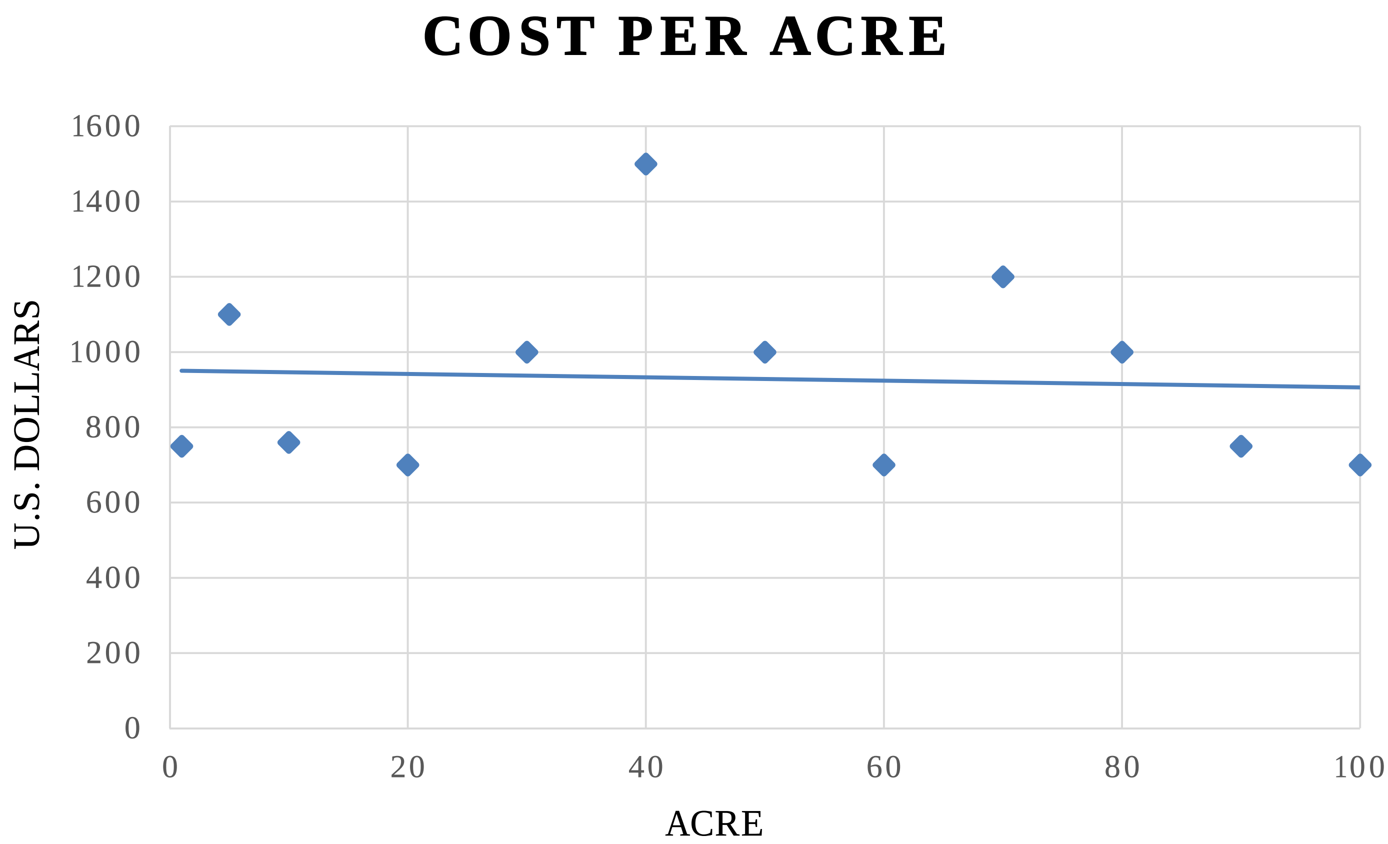
"The aeration destratification was not strong enough to prevent cyanobacterial blooms"

Aeration Benefits Vs. Cost

Aeration Feasibility Assessment = Cost Effective Design



Aeration Benefits Vs. Cost



Average Cost per acre for <u>Correctly sized</u> systems **$1,000**

Modeling Air Flow and # AirStations

Same Air Flow: **25.4 CFM**

Different # of Air Station

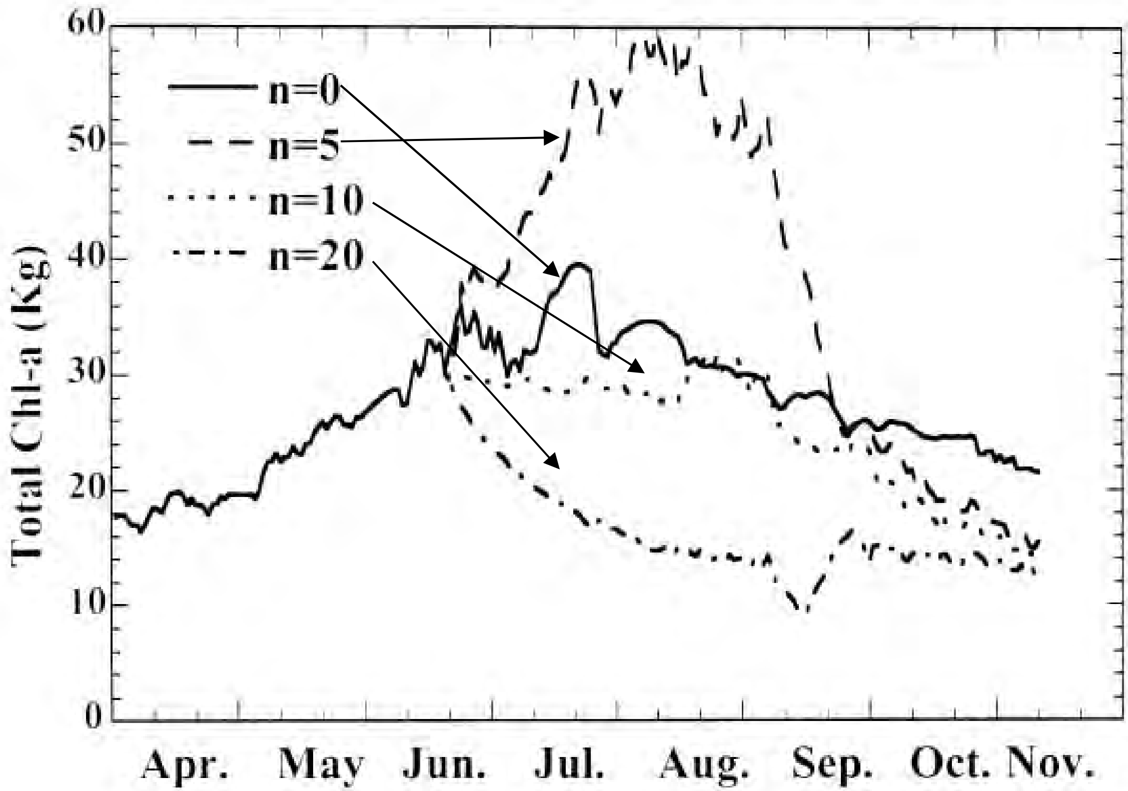


Fig. 3. Effect of number of ports on total Chl-a.

Monzur & Takashi, 2000

Modeling Air Flow Vs. # AirStations

Better to distribute the air more evenly

5 l/s = 10.6 CFM
10 l/s= 21.2 CFM
15 l/s= 31.8 CFM
20 l/s= 42.8 CFM

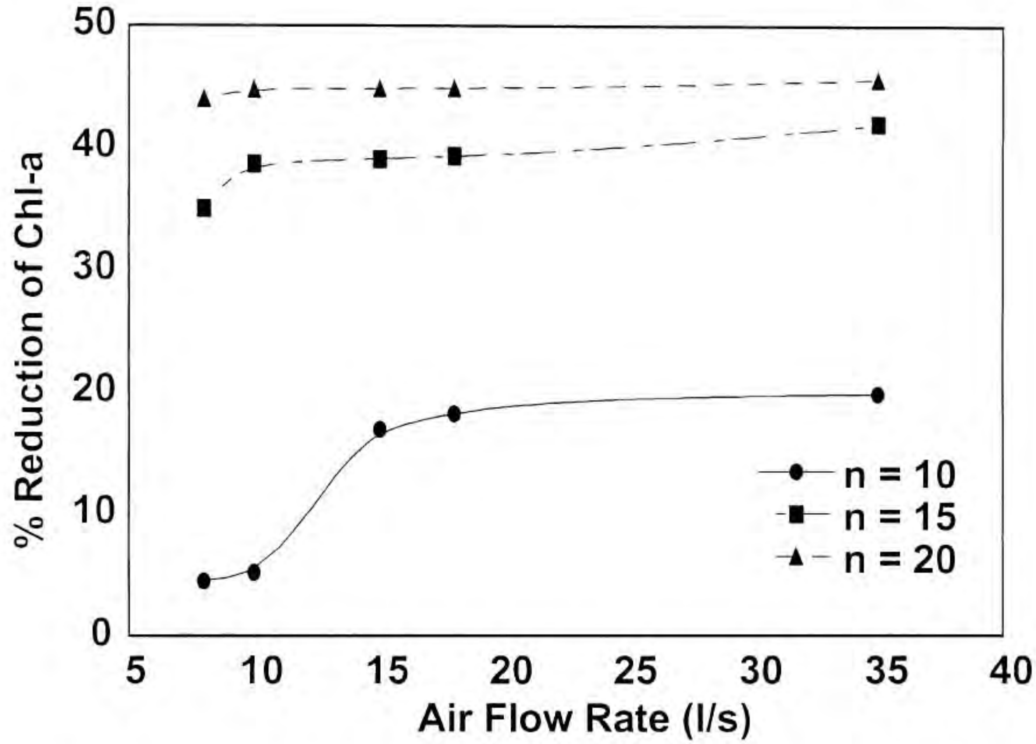


Fig. 5. Generalized effect of air flow rate and number of ports on Chl-a reduction.

Monzur & Takashi, 2000

Modeling Air Flow Vs. # AirStations

Larson Lake

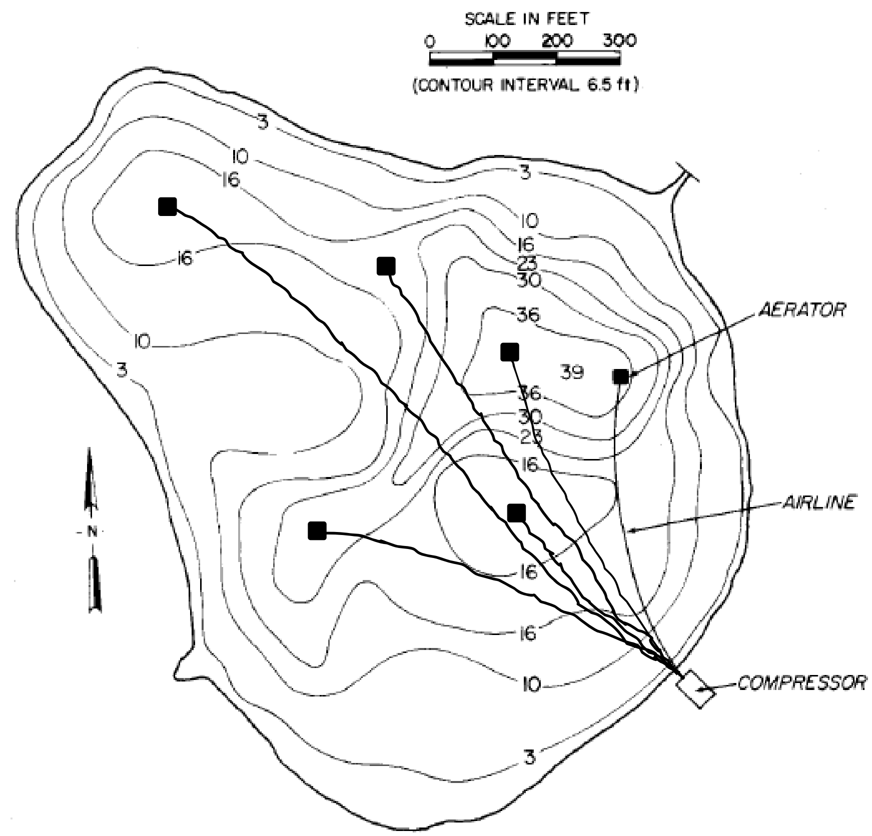
Area: 12 acres

Volume: 152 acre-feet

Mean depth (volume/area): 13ft

Maximum depth: 39ft

Failed to Improve Algae



Wisconsin Department of Natural Resources, 1975

Modeling Aeration Start Time

Start aeration well before peak Chl-a

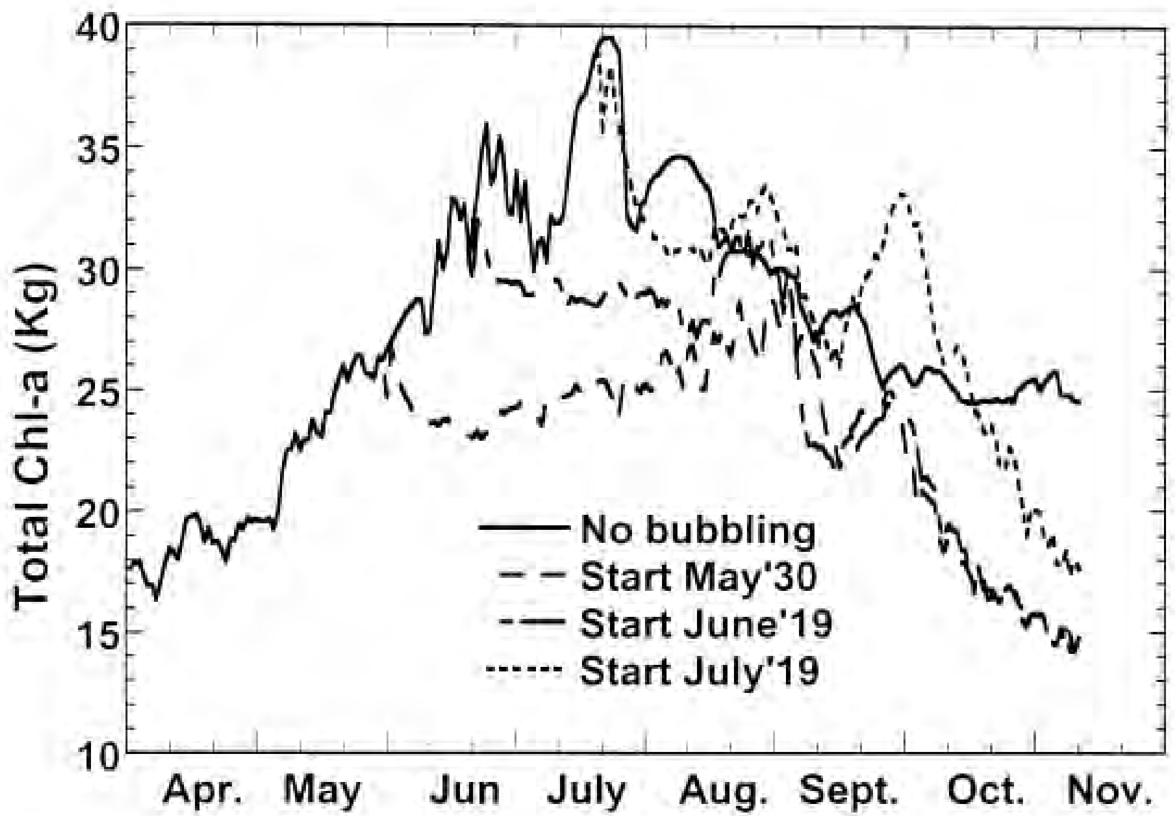


Fig. 6. Effect of starting time of bubbler on total Chl-a.

Monzur & Takashi, 2000

Modeling Aeration Start Time

Start time doesn't matter if Undersized

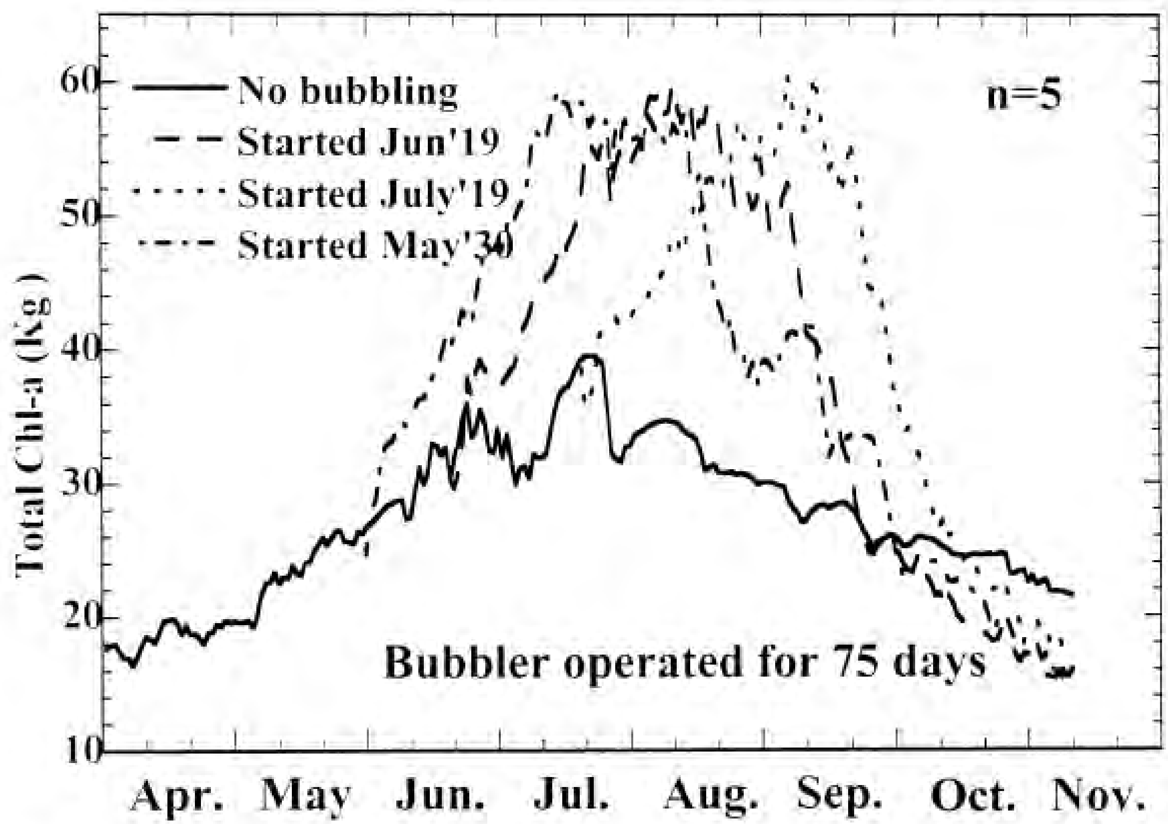


Fig. 9. Effect of starting time of bubbler for five ports.

Monzur & Takashi, 2000

Summary

- Aeration designs should be site-specific and account for a lakes physical, chemical, and biological characteristics.
- Aeration systems should be sized to the highest denominator (phytoplankton).
- Consult with a professional.

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Questions?

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