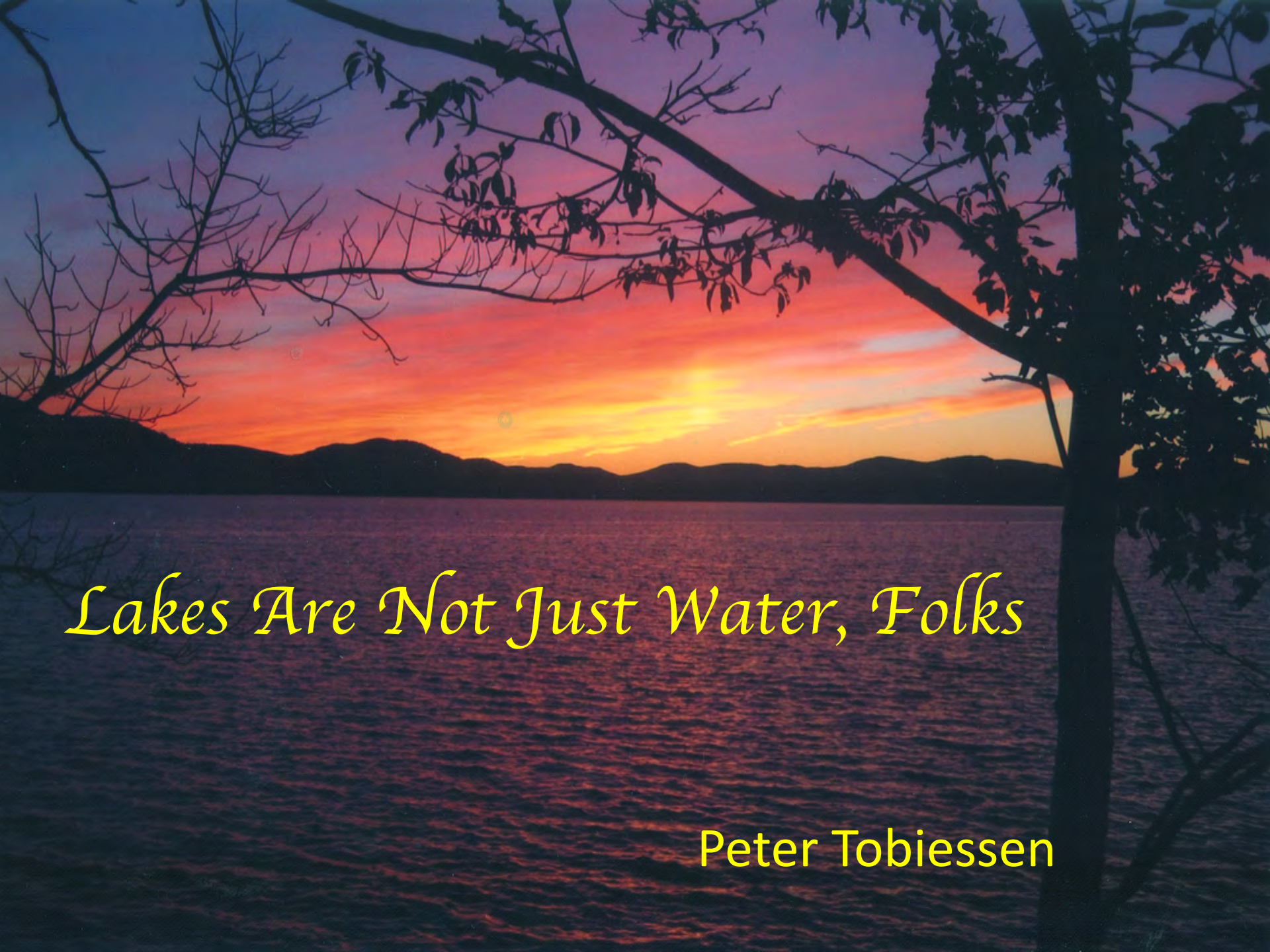
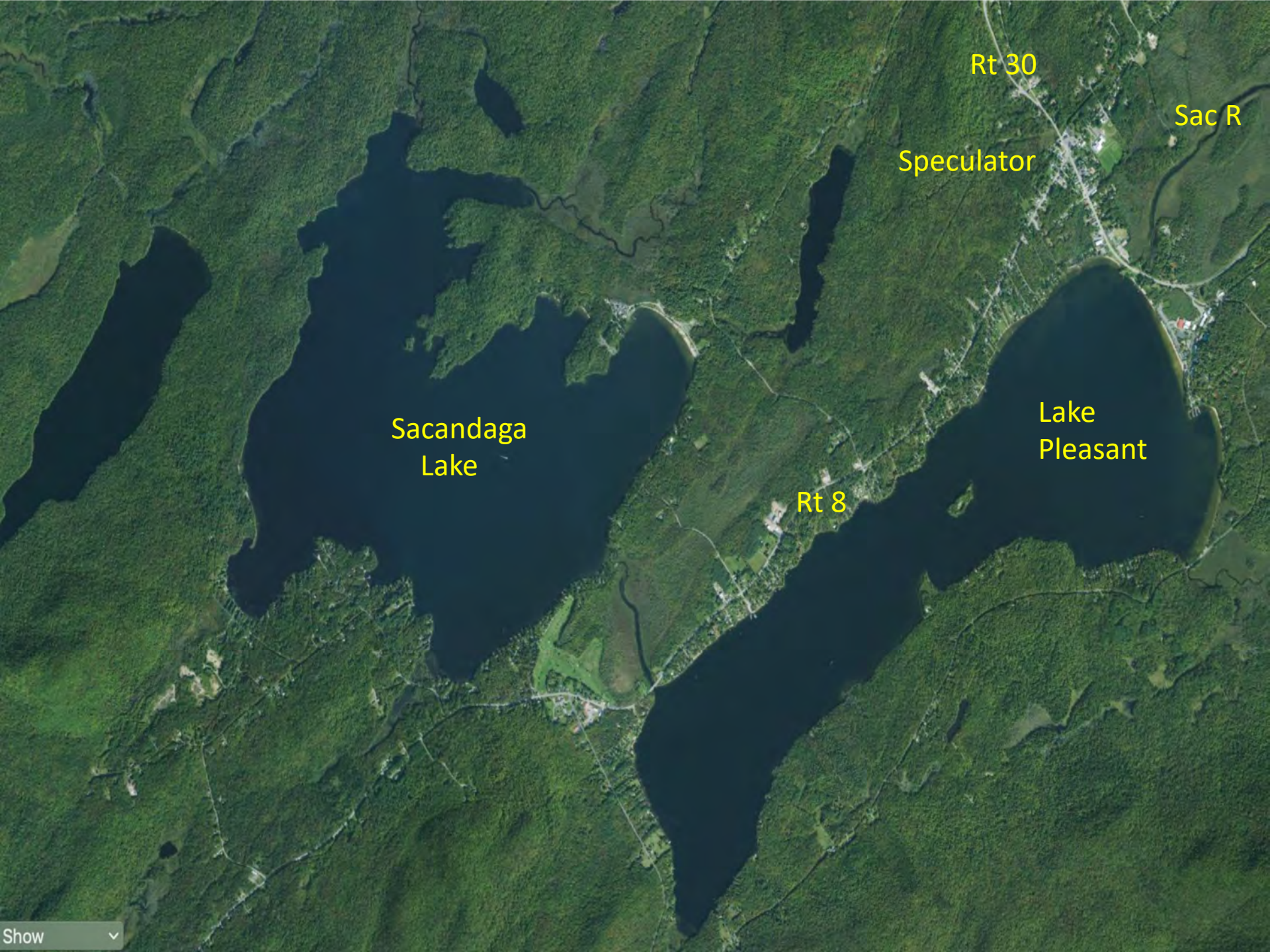


Lakes Are Not Just Water, Folks

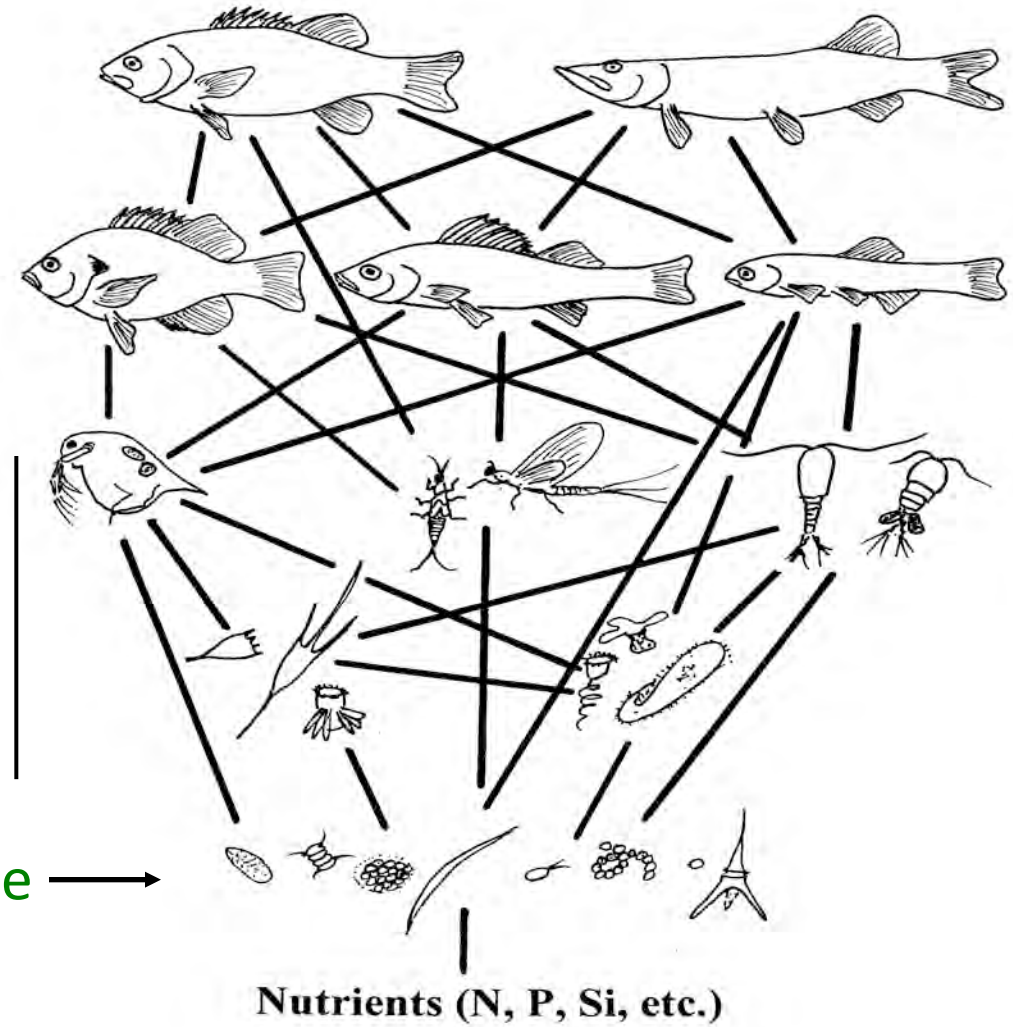
Peter Tobiessen


Rt 30
Sac R
Speculator
Sacandaga
Lake
Lake
Pleasant
Rt 8
Show

A food web

Those who eat those who eat algae

Those who eat the algae



Plants

Decomposers

Bacteria and Fungi
(All the organisms end up here to be recycled into the next generation)

Algae →

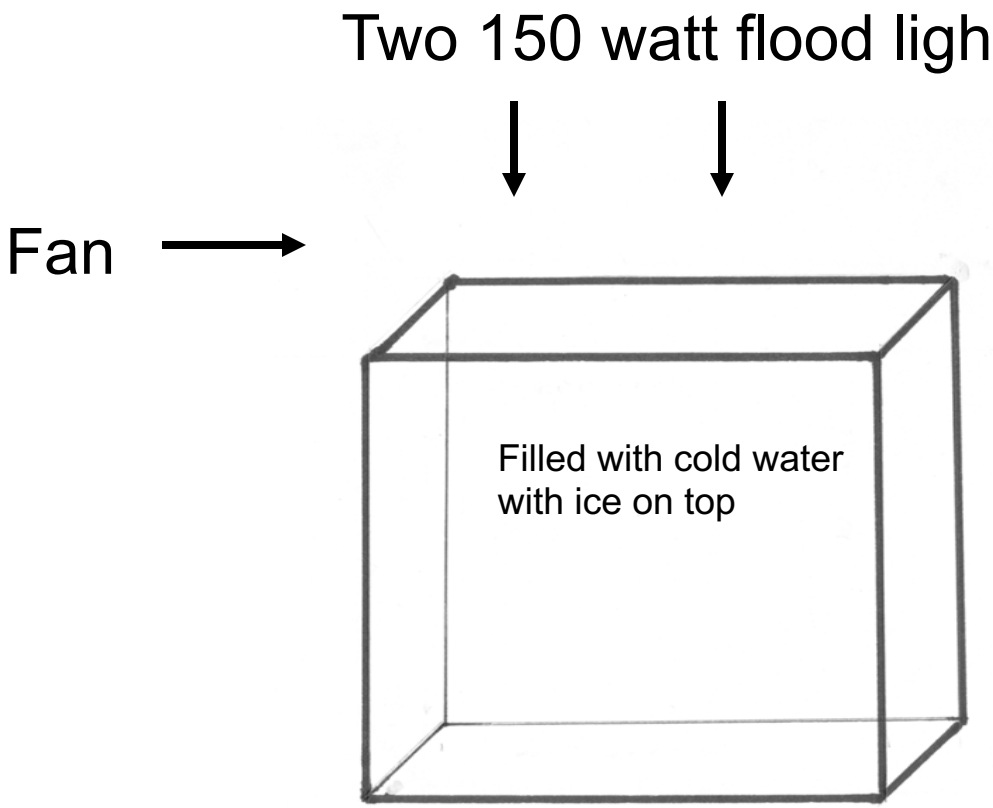
Water

Water is Weird

Water Density Vs Temperature

Temperature	Density (g/cm^3)
$30^oC = 86^oF$	0.99567
$20^oC = 68^oF$	0.99823
$10^oC = 50^oF$	0.99972
$4^oC = 39^oF$	1.00000
$0^oC = 32^oF$	0.99986
Ice	0.91680

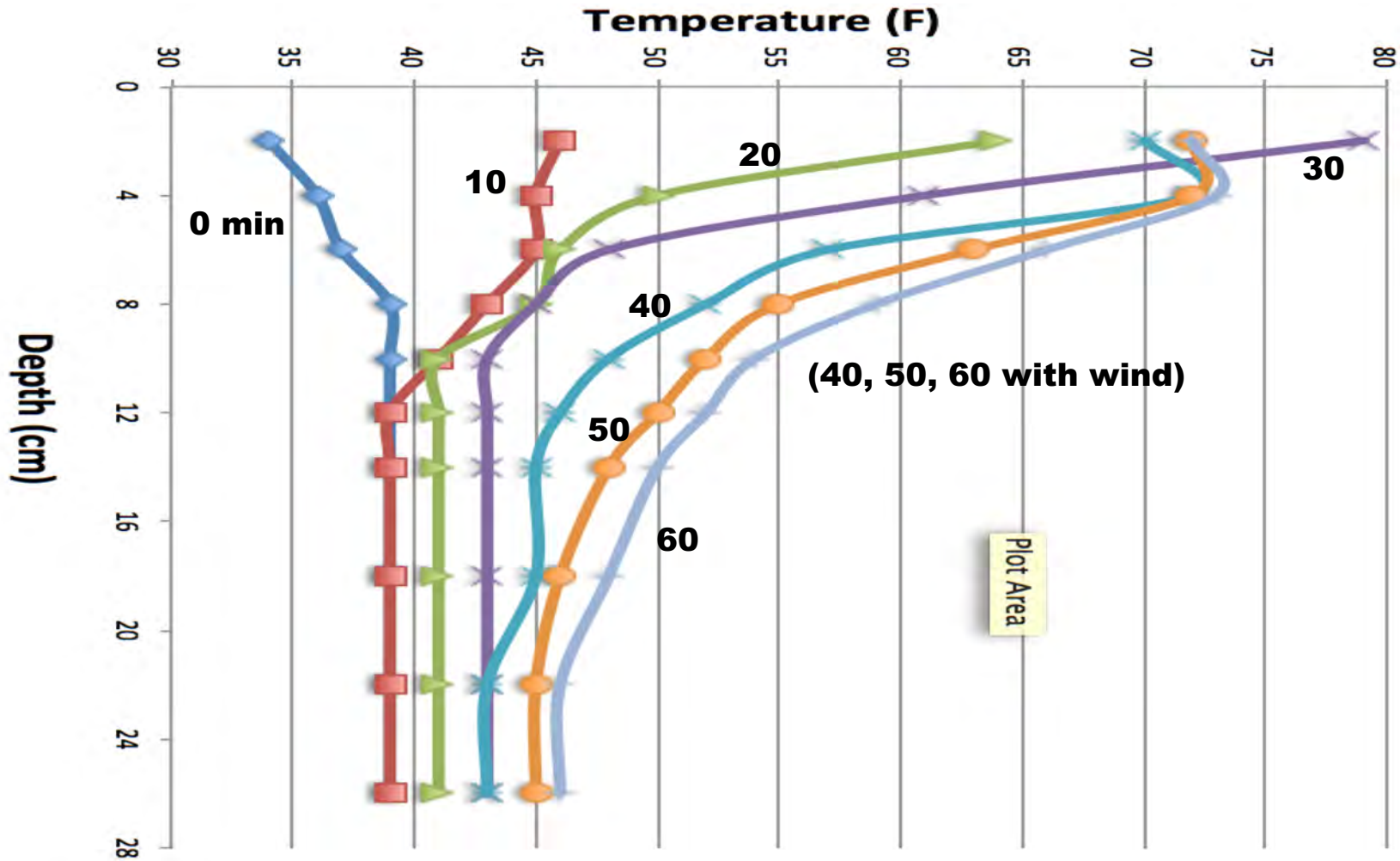
An in-class micro lake demonstration

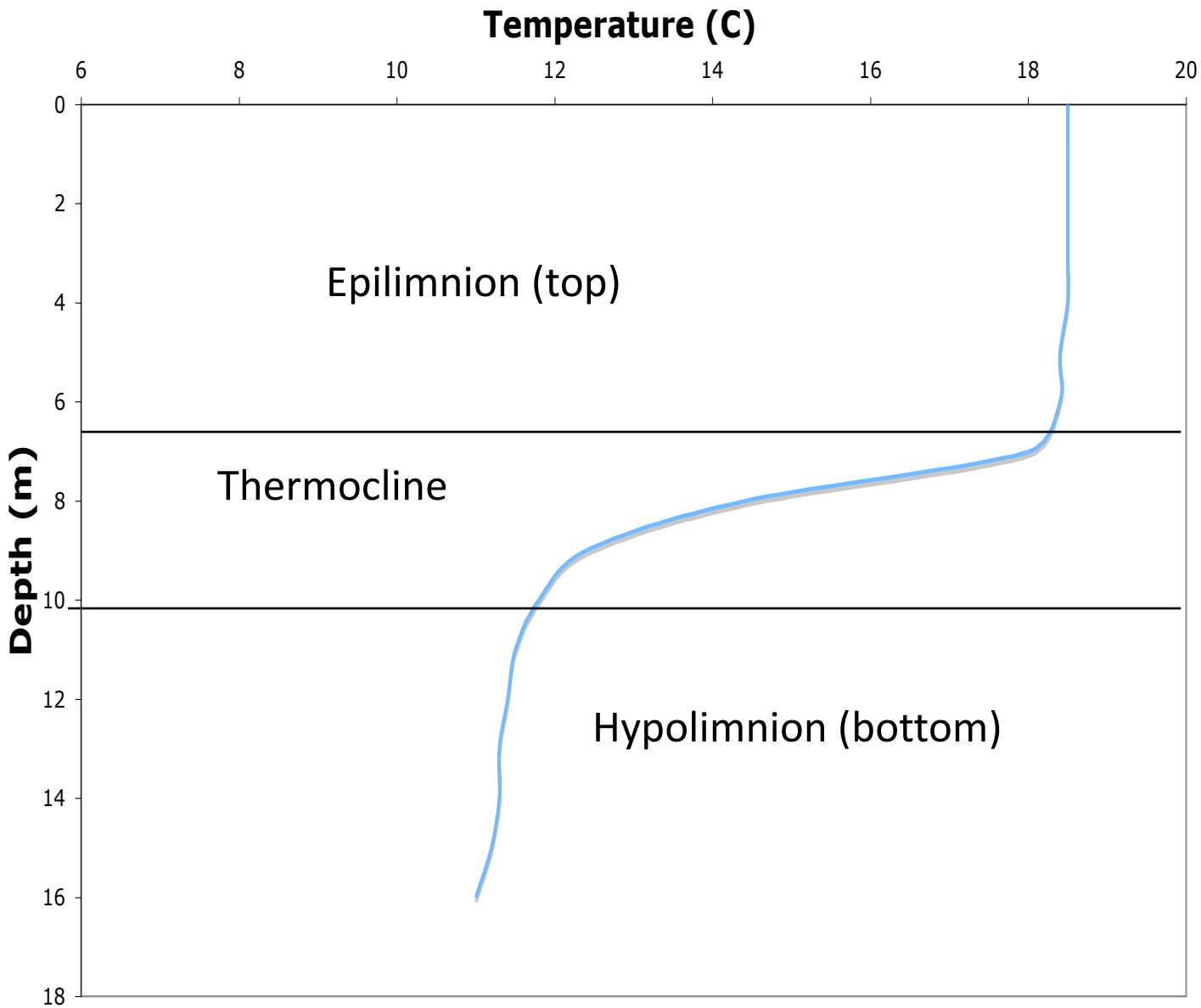


Data from micro lake experiment

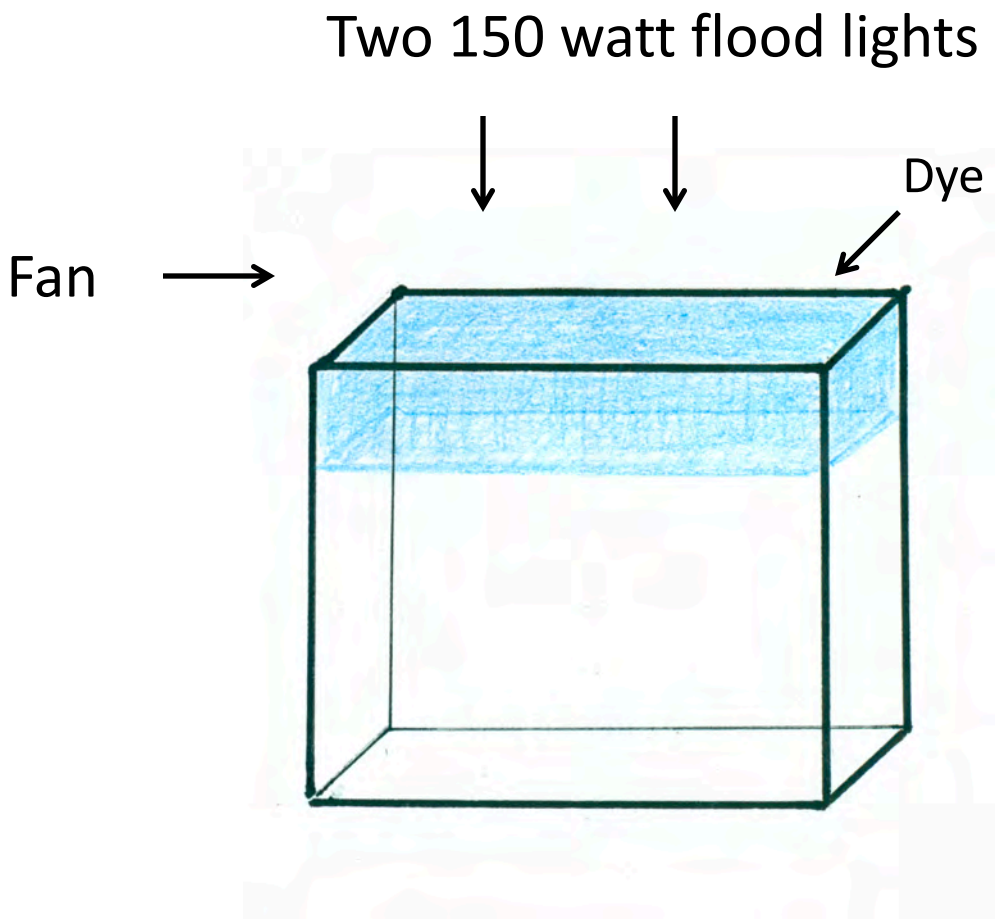
			Micro-lake Temperature Profile (°F)					
Depth		Ice	Light on-->			Wind and Light -->		
(cm)	2	34	46	64	79	70	72	72
	4	36	45	50	61	72	72	73
	6	37	45	46	48	57	63	66
	8	39	43	45	45	52	55	59
	10	39	41	41	45	48	52	54
	12	39	39	41	43	46	50	52
	14	39	39	41	43	45	48	50
	18	39	39	41	43	45	46	48
	22	39	39	41	43	43	45	46
	26	39	39	41	43	43	45	46
		0	10	20	30	40	50	60
				Time (minutes)				

Mini Lake Temperature Profiles




Temperature (C)
6
8
10
12
14
16
18
20
Depth (m)
0
2
4
6
8
10
12
14
16
18
Epilimnion (top)
Thermocline
Hypolimnion (bottom)

If you add a few drops of blue dye into the top layer--



The dye will stay in the top layer!

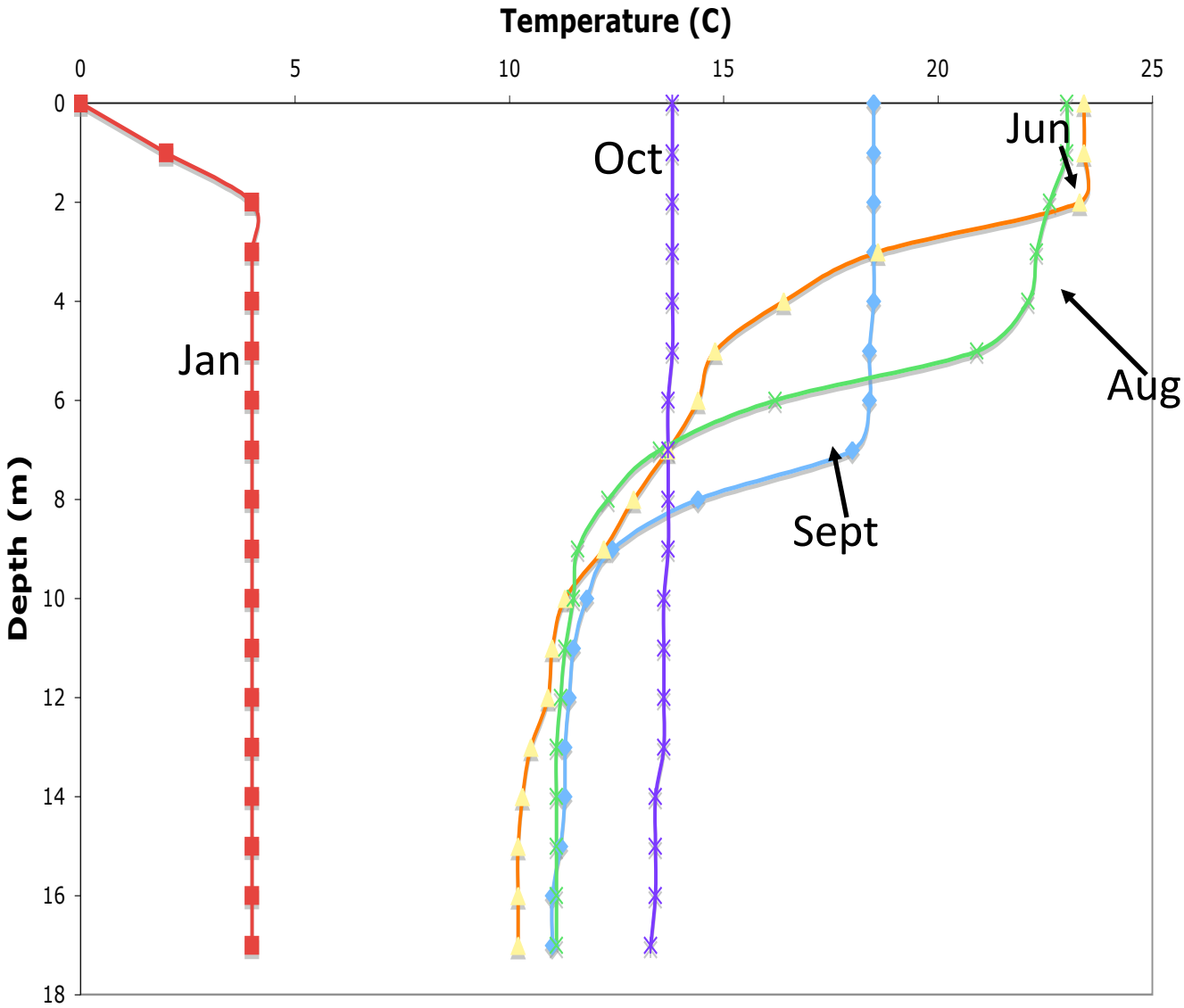
Water density vs temperature
(again)

Temperature	Density (g/cm^3)
30°C (86°F)	0.99567
20°C (68°F)	0.99823
10°C (50°F)	0.99972 (diff. 10 vs. 20 = 0.15%)
4°C (39°F)	1.00000
0°C (32°F)	0.99986
Ice	0.91680

This tiny difference in density (10 vs 20°C) will isolate the two layers for the entire summer

Seasonal Temperatures

In Sacangada Lake

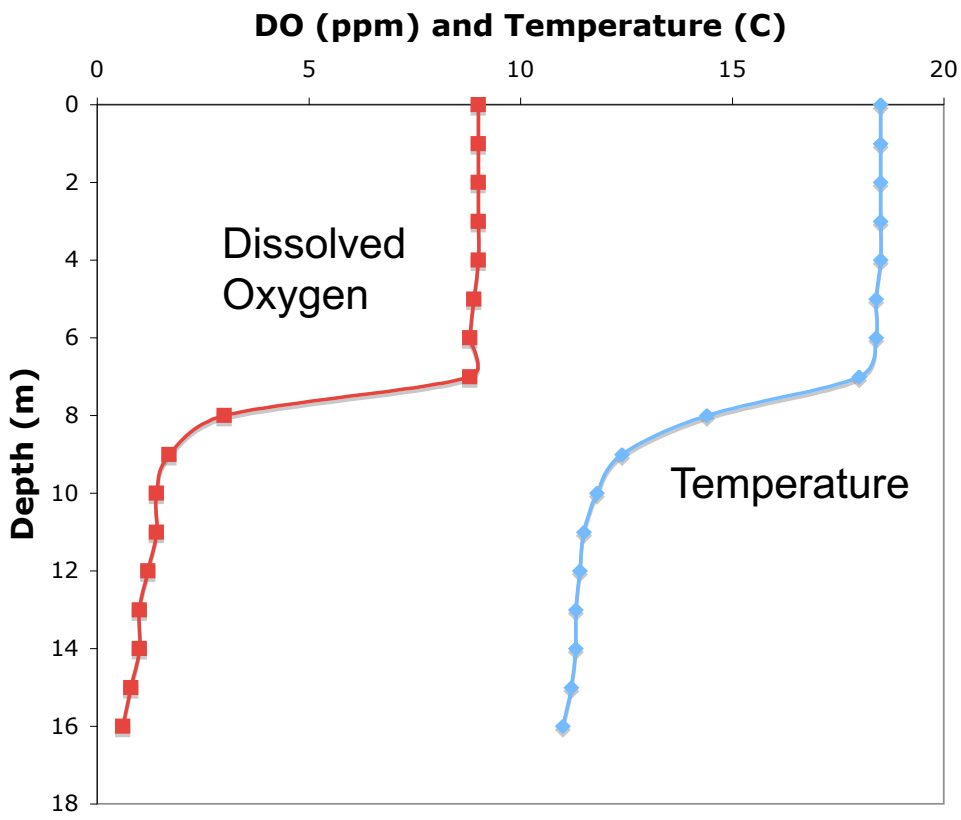


As the season progresses:

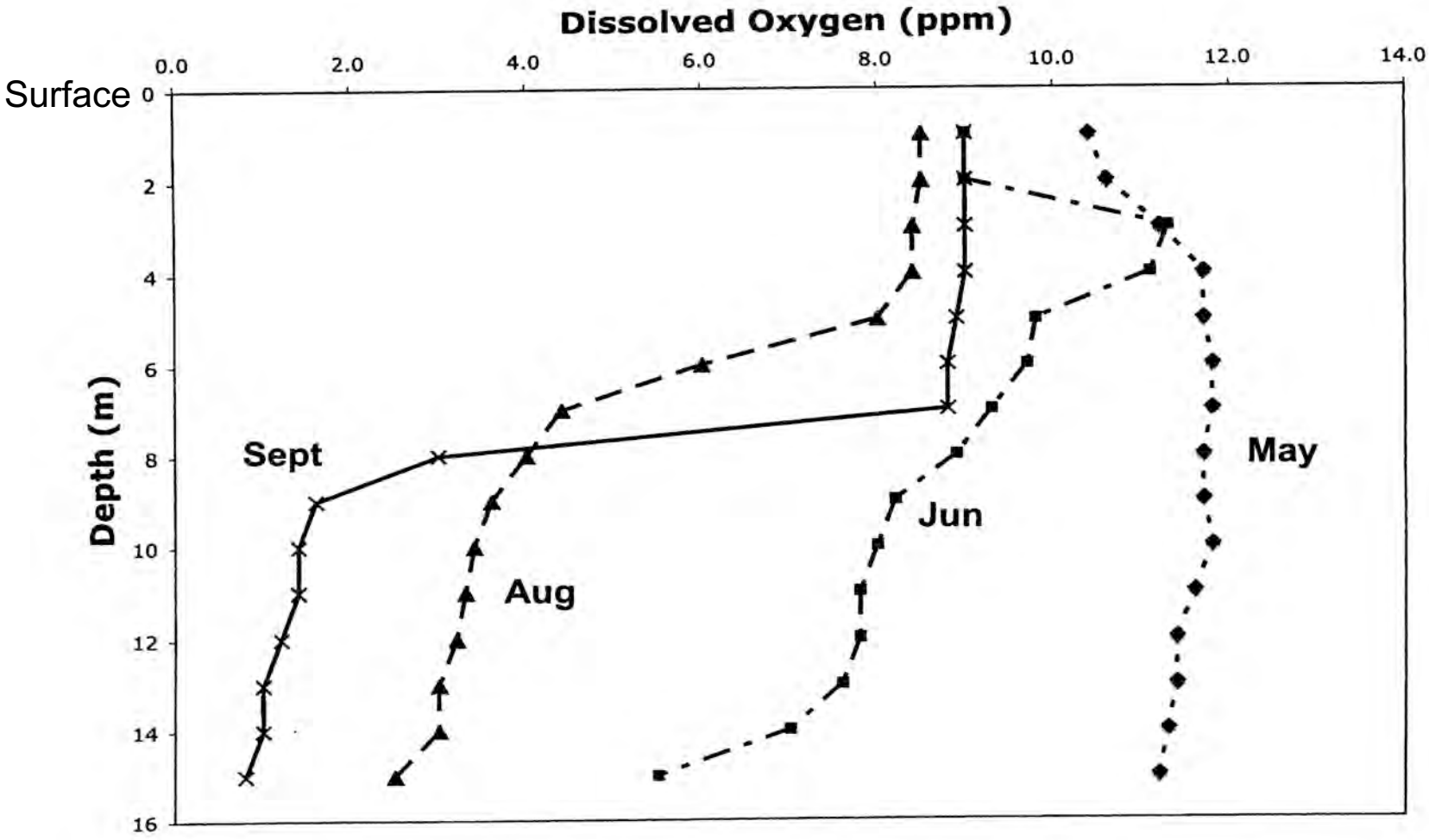
- In the upper, high light layer, atmospheric oxygen diffuses in and algae produce oxygen through photosynthesis, ($CO_2 + H_2O \rightarrow CH_2O + O_2$) therefore **dissolved oxygen remains high**

- In the lower layer, low light reduces photosynthesis, the thermocline prevents atmospheric gasses from entering, and sediment and organism respiration ($CH_2O + O_2 \rightarrow CO_2 + H_2O$) all tend to **reduce dissolved oxygen levels as the season progresses**

The thermocline forms a resistance to the mixing of the upper lake layer with the lower layer (Sacandaga lake data from late August)



Seasonal DO levels (Sacandaga Lake)



Consider the effects of global warming

Nutrients

A shoutout here to the **C**itizen's **S**tatewide **L**ake **A**ssessment **P**rogram (CSLAP), administered by FOLA and developed and funded by DEC. This is where most NY lakes learn about their nutrient status. Volunteers sample water temperature, water clarity with a Secchi disc, and collect a water sample that is sent to a lab for analysis (pH, Chl, P, N, Cl, Ca, etc.) and DEC summarizes the data into a report sent back to the lake association. CSLAP data will be quoted frequently in this presentation.

Water clarity is a major factor when we evaluate lake water quality, and we measure it with a Secchi disc

It is affected by many things, but most importantly by the amount of algal growth in the lake

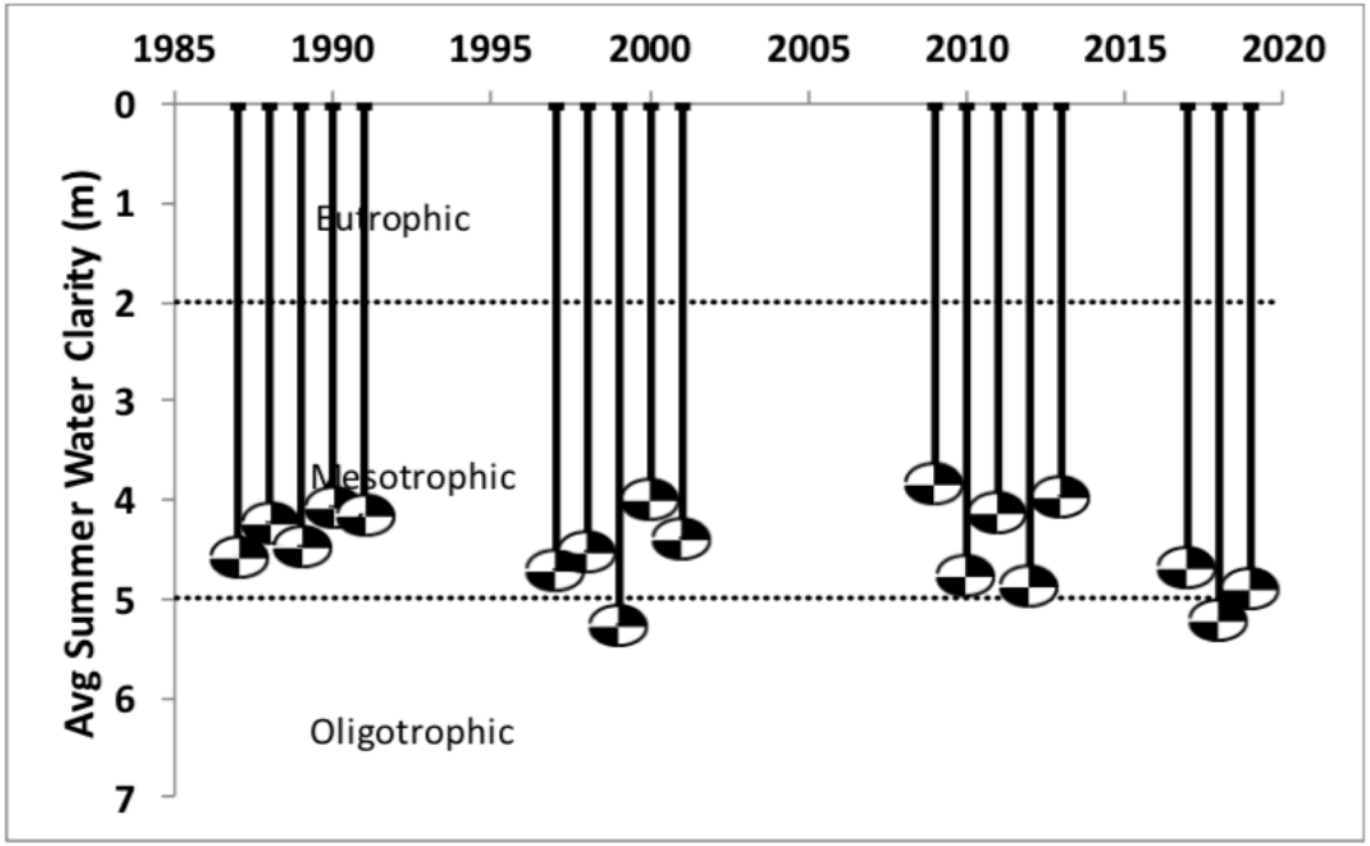
Water clarity of various lakes

As measured with a Secchi disc:

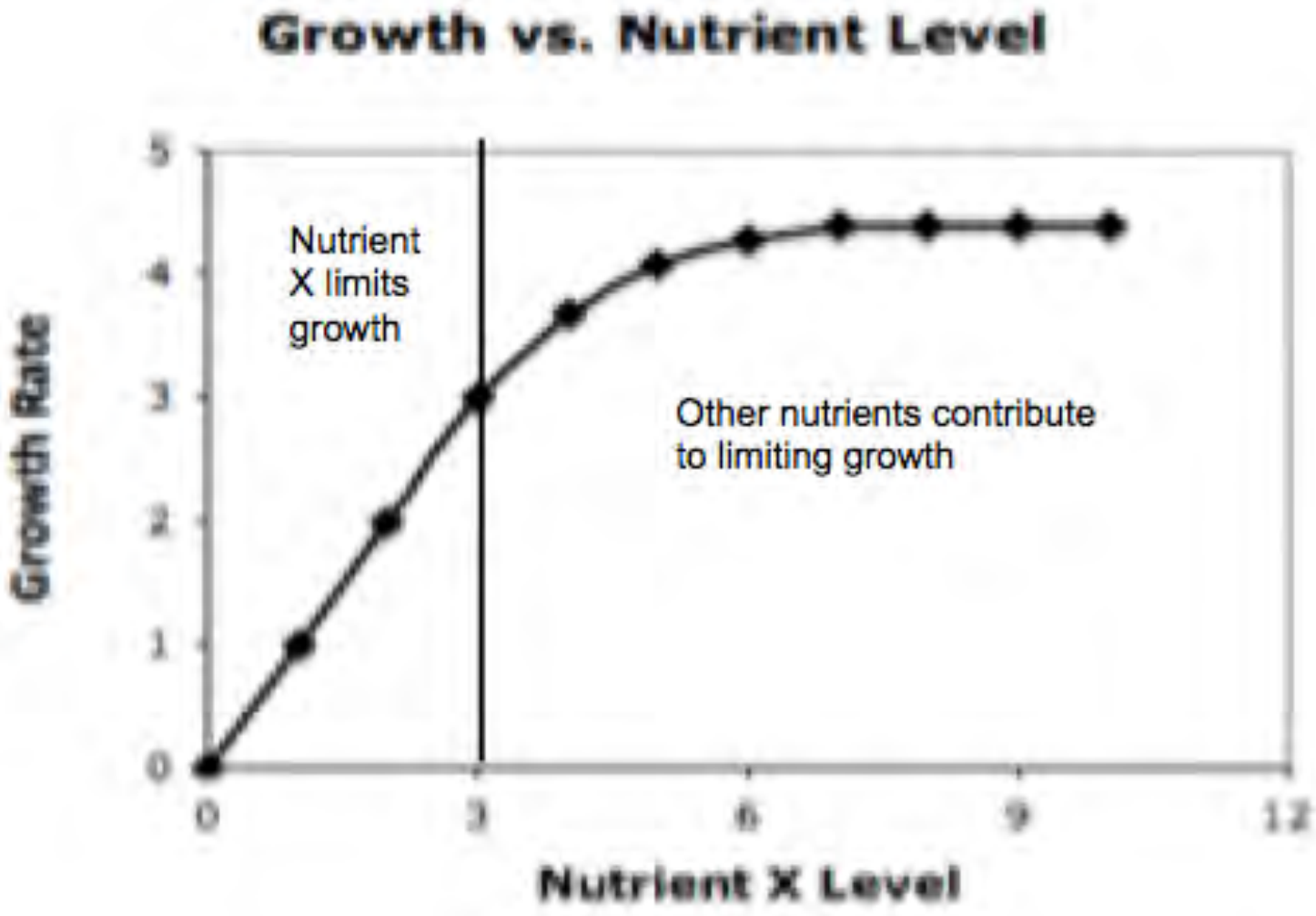
Crater Lake OR	132 ft
Lake Tahoe CA	100 ft
Lake George	27 ft
Lake Champlain	13 ft
Sacandaga Lake	17 ft
Collins Lake, Scotia	3 ft
One EIS lake	4 inches!

CSLAP data from Sacandaga Lake 1987-2019

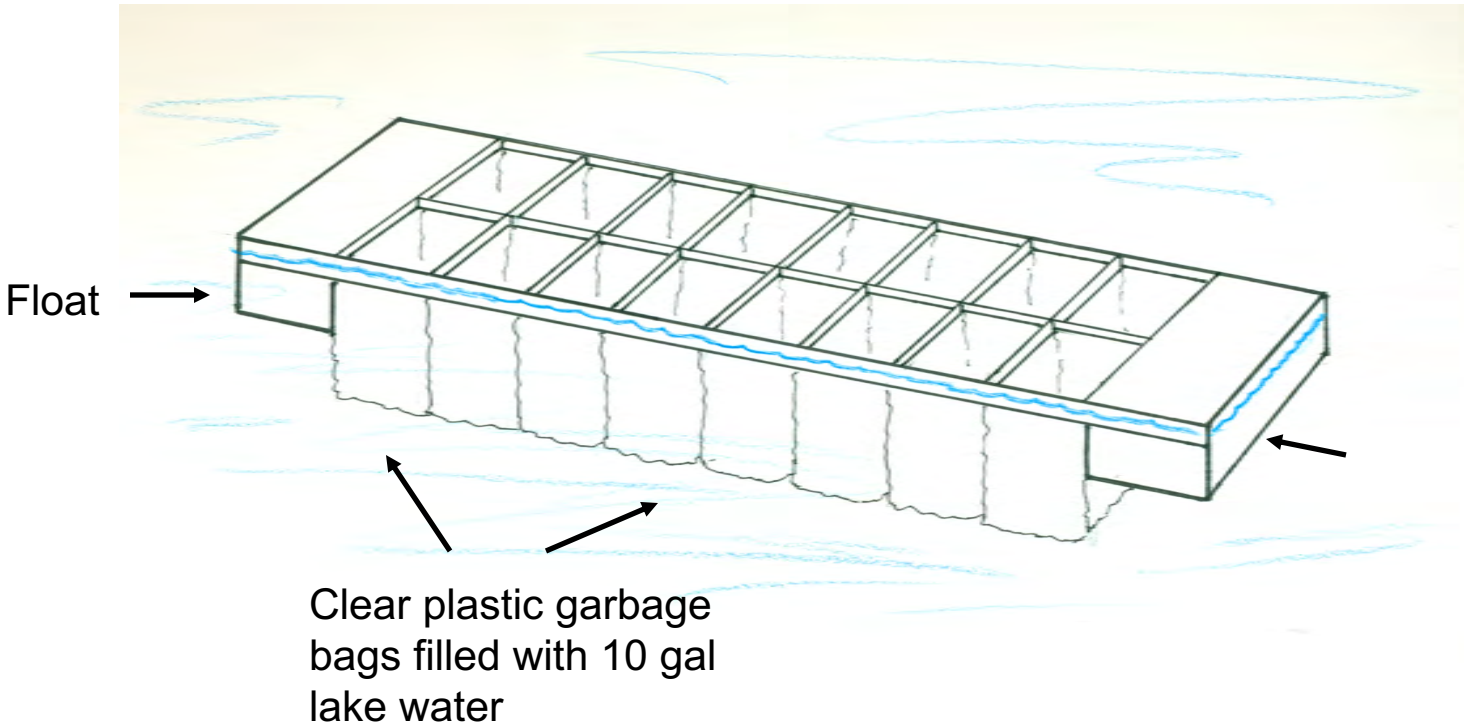
Clarity



What is a limiting factor and why all the fuss about P?

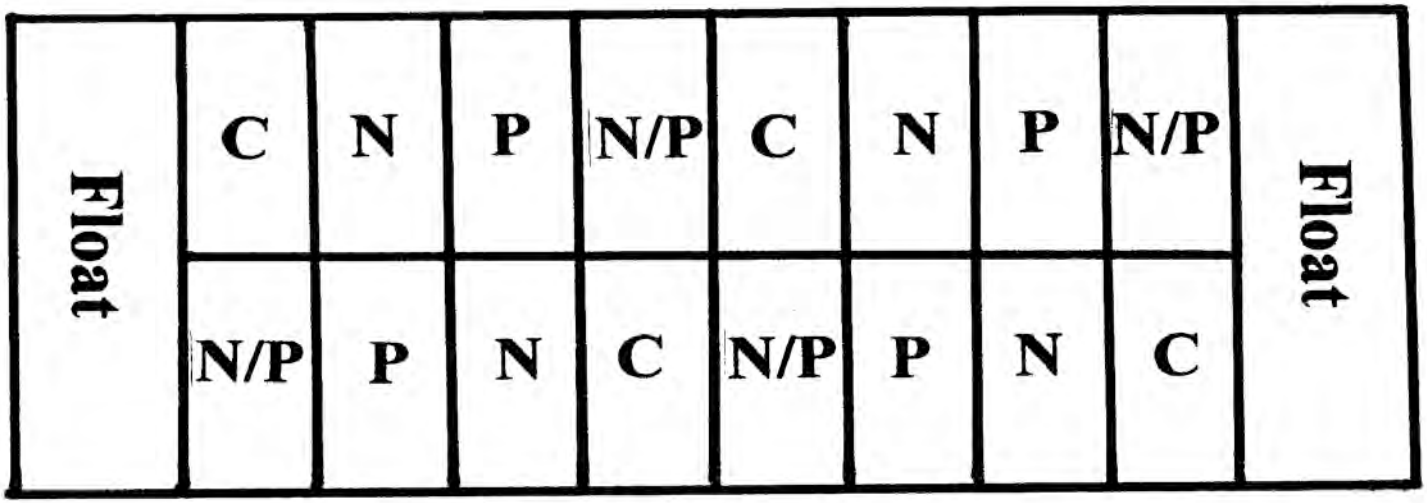


An in-lake experiment to determine the limiting nutrient to algal growth



Possible limiting nutrients:

Phosphorus? Nitrogen?



Limiting nutrient experiment results

(Chlorophyll levels after 1 week)

Nutrient Added	Chlorophyll (ppb)
None added (control)	6.4
Nitrogen	6.7
Phosphorus	13.5
N & P	15.3

Therefore phosphorus limits algal growth in Sacandaga Lake (and Lake George and all other Adk lakes tested)

Phosphorus is relatively rare in most lakes—down in the parts per billion range (ppb) So how much is a ppb?

Consider an Olympic sized swimming pool:

It's 50 m long, 25 m wide and 2 m deep (165 x 83 x 6 ft), or 2,500 m^3

A cubic meter has 1000 Liters in it, and a Liter is 1000 g or one kg. Therefore the pool has 2,500 x 1000 kg of water in it, or 2.5 million kg

So add 2.5 kg of sugar to the pool and that will equal one ppm. (A kg is 2.2 lbs, so that's about 5.5 lbs)

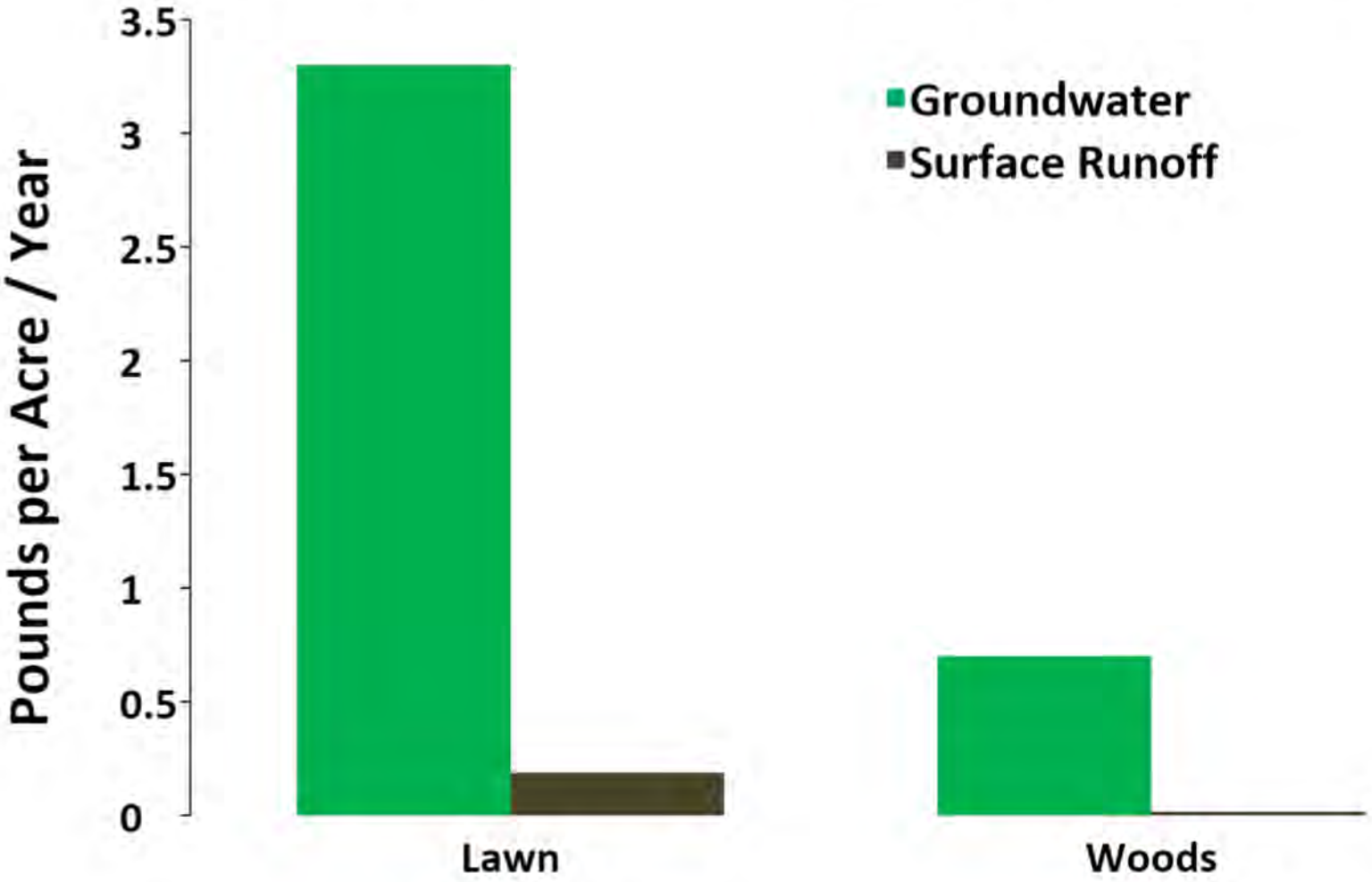
A ppb would be 1000 x less, or 2.5 g, or the weight of half a nickel.

So adding just a little more P through human activity can have a major effect on a lake

Sources of phosphorus to a lake

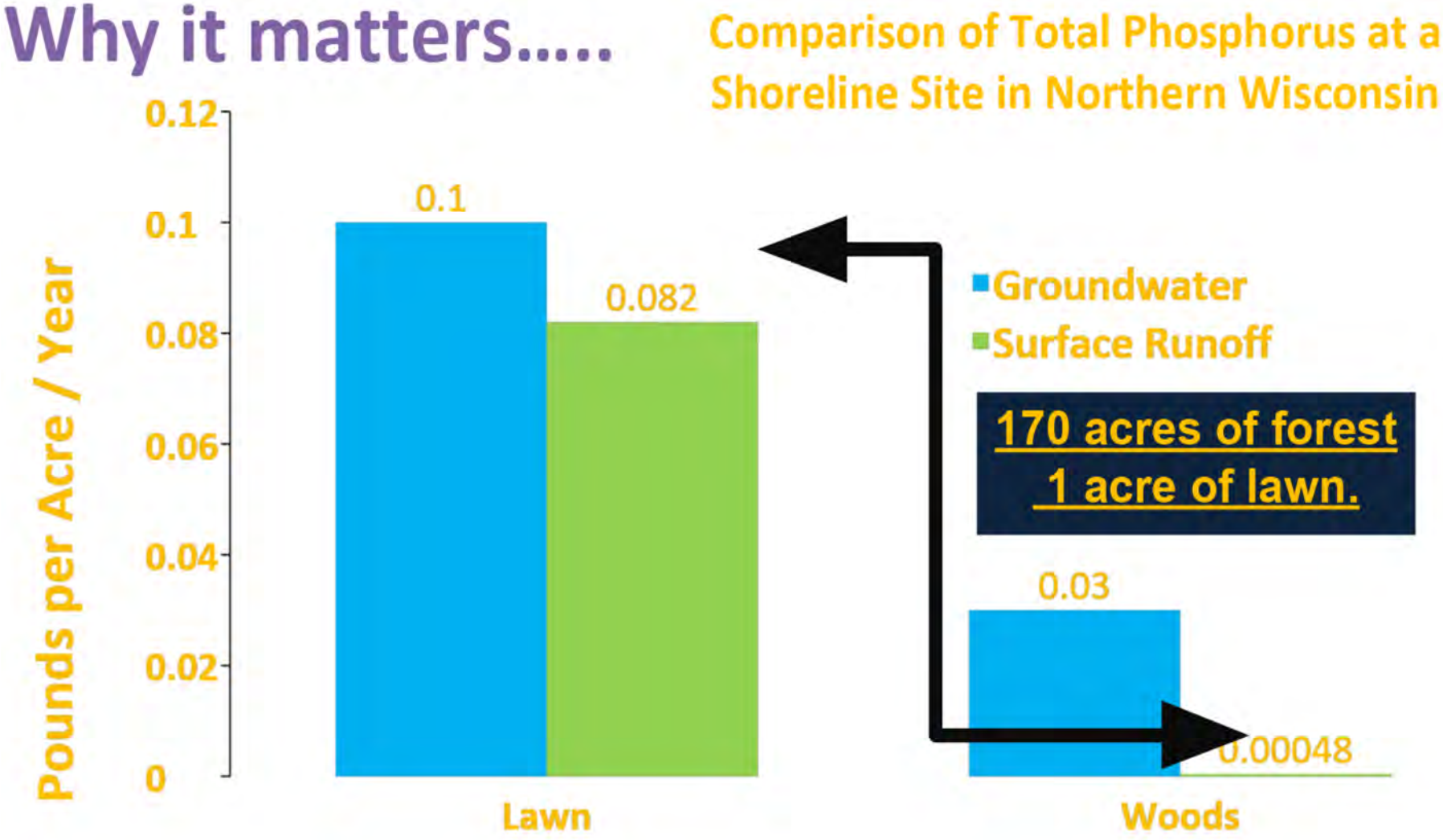
- Wastewater outfalls in large lakes
- Septic leakage in smaller lakes. Adk soils are typically sandy so don't bind P as it flows in groundwater toward a lake
- Runoff from impermeable surfaces (parking lots, etc.)
- Decomposition of organic material, but in terrestrial areas P is taken up quickly by deep rooted plants
- Internal loading from lake sediment.
- **LAWNS** that come to the shoreline leach 100+X more nutrients into a lake than a forest. Consider a native (deep-rooted) vegetative buffer ("Lakescape" book)

Comparison of Nitrite and Nitrate Yields at a Shoreline Site in Northern Wisconsin



Graczyk and others, 2003

Why it matters.....



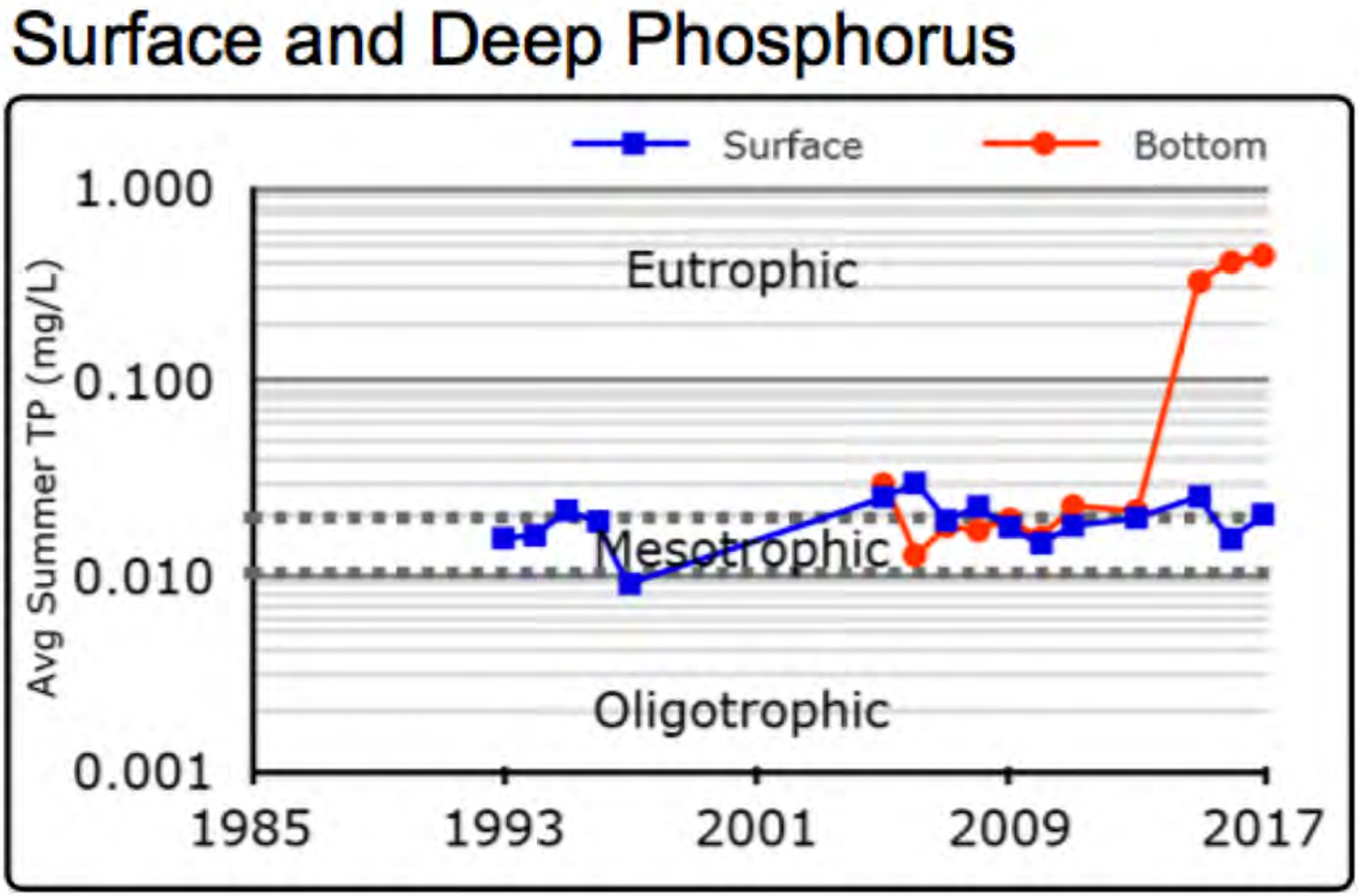
What is “Internal Loading”

- There is a large store of phosphorus locked up in organic lake sediments
- When oxygen is present phosphorus is held tightly in a ferric phosphate molecule that is insoluble in water
- Under low oxygen conditions, the ferric phosphate is changed into ferrous phosphate, a water soluble molecule that is released from the sediments into the water column
- High oxygen Low oxygen

  $FePO_4$ ←--→ $Fe_3(PO_4)_2$

  Water insoluble Water soluble

CSLAP data from a mystery lake
(NOT Sacandaga)



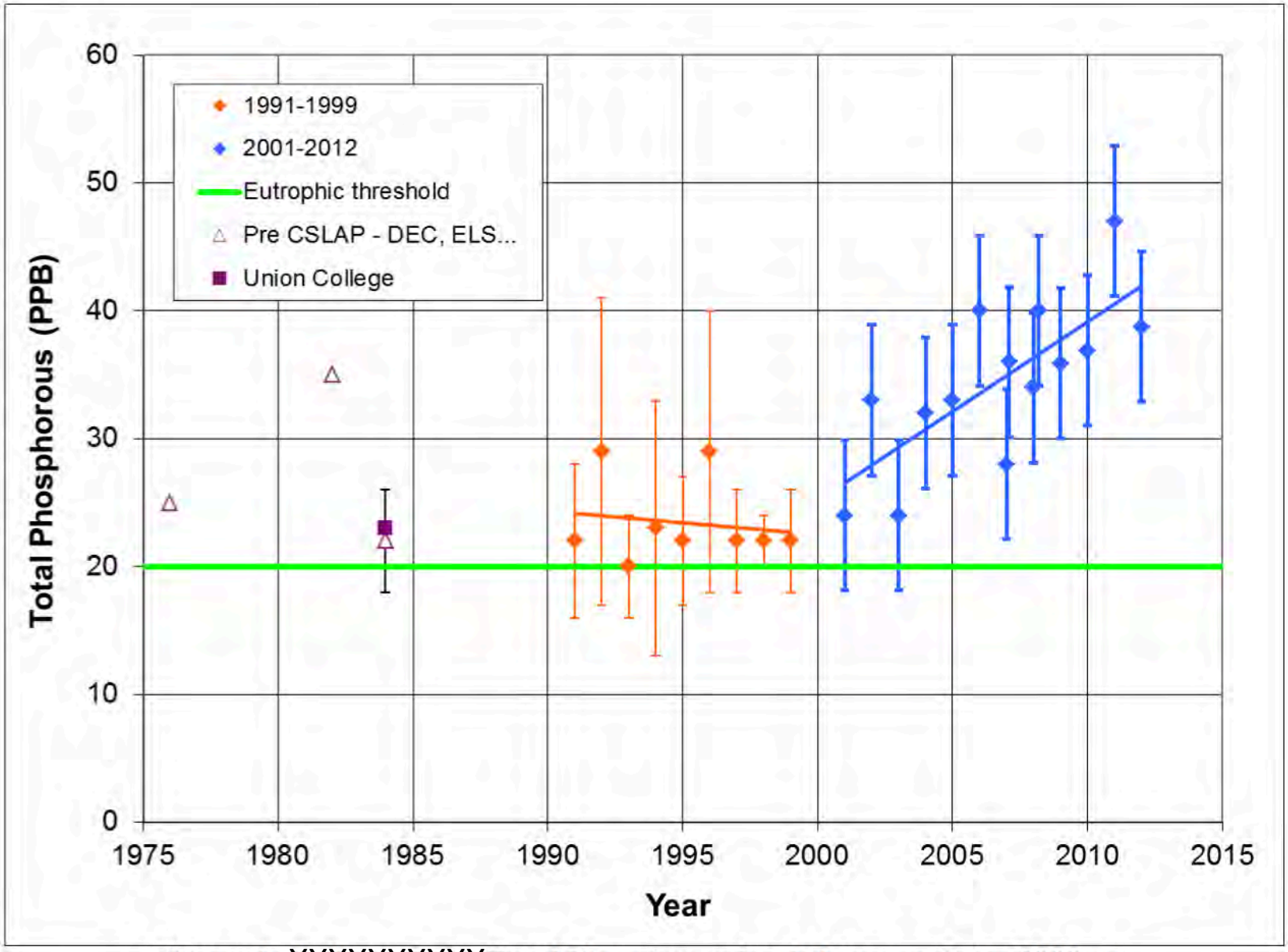


Figure 1- Ballston Lake Total Phosphorus levels increase from 2000 on.

EPA data from a study of 99 lakes

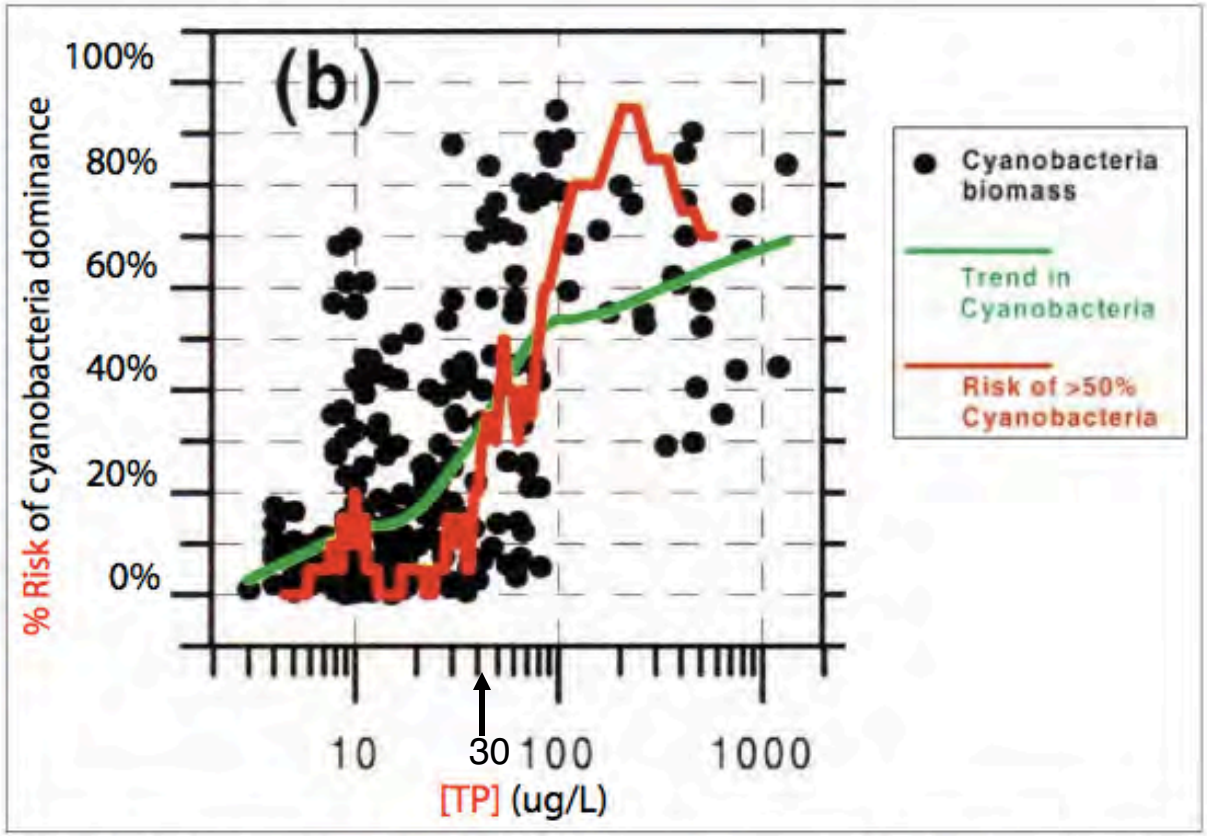


Figure 2. The probability of cyanobacteria dominance is controlled by phosphorus, but there is much variation. (from Downing et al. 2001)

All lakes contain blue green algae

Even lakes with P levels <10 ppb can have small, transient shoreline “blooms”

Consider Lake Erie

Average Total P levels (ppb)

Basin	In spring	In summer
East	17	6
Central	12	10
West	29	24

Daily Gazette 20 Oct 2013

Algae blooms on Lake Erie add toxins to Ohio's drinking water

BY JOHN SEEWER
The Associated Press

TOLEDO, Ohio — Toxins from blobs of algae on western Lake Erie are infiltrating water treatment plants along the shoreline, forcing cities to spend a lot more money to make sure their drinking water is safe.

It got so bad last month that one township told its 2,000 residents not to drink or use the water coming from their taps.

The cost of testing and treating the water is adding up quickly. The city of Toledo will spend an extra $1 million this year to combat the toxins while a neighboring county is considering a fee increase next year to cover the added expenses.

Algae blooms during the summer and early fall have turned the water into a pea soup color in recent years. The unsightly surface has scared away tourists, and toxins produced by the algae have contributed to oxygen-deprived dead zones where fish can't survive.

The toxins also are a threat to the drinking water that the lake provides for 11 million people.

The annual algae blooms have been concentrated around the western end of Lake Erie — though a few have spread to the Cleveland area — and have affected water treatment plants in Toledo and other cities that dot the water's edge in northern Ohio.

The algae growth is fed by phosphorous from farm fertilizer runoff and other sources, leaving behind toxins that can kill animals and sicken humans.

Tests on drinking water in Carroll Township, which is just west of Toledo, showed the amount of toxins had increased so much in early September that officials decided to order residents to stop using the water for two days until they could hook up to another water supply.

It was believed to be the first time a city has banned residents from using the water because of toxins from algae in the lake.

"I wasn't sure how dangerous it was, but we wanted to be cautious," said Henry Biggert, the township's water plant superintendent.

The township's treatment plant is now back online, but the water is being filtered and treated over a longer period to remove the toxins, he said.

What makes combating these toxins a challenge for operators of water treatment plants is that there are no standards on how to handle the problem or federal guidelines on what is a safe amount in drinking water. Plus, each water treatment facility is unique.

SCRAMBLING AROUND

Plant operators along the lake in Ohio have been teaming up to figure out what works best.

"We're out there scrambling around," said Kelly Frey, Ottawa County's sanitary engineer. "It's just been do the best you can."

The county, he said, tests the water three times a week while adding a chemical called activated carbon to absorb the algae before filtering it. The expense of treating the water may require an increase in water rates next year of a couple of dollars a month for the average family, Frey said.

Toledo officials anticipated spending $3 million this year to treat its water, but the cost increased to $4 million because it has needed more chemicals to treat the toxins from the algae. That's about double what the city spent just a few years ago.

"We can throw a little more money and defeat it for a while," said David Leffler, the city's commissioner of plant operations.

But the larger issue, he said, is how to cut down on the amount of phosphorus from farm fertilizer and other sources that run off into the lake and feed the algae blooms.

His biggest fear is that the toxins could overwhelm Toledo's treatment plant and force officials to shut down its water supply to the state's fourth largest city and its suburbs.

"It keeps me up at night," he said.

D'ARCY EGAN/THE PLAIN DEALER

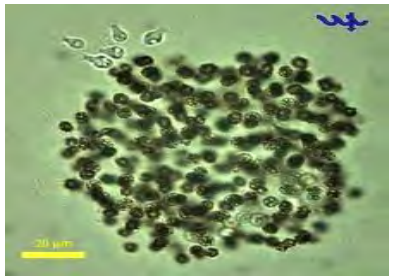
A dredge barge works along the edge of a large algae bloom in the Toledo, Ohio, shipping channel in this photograph from August. Toxins from the algae blooms on western Lake Erie are infiltrating water treatment plants along the shoreline.

Lake Erie in 2013

Why worry about blooms of blue-green algae? (HAB's)

Anabaena

Aphanizomenon



Microcystis

Blooms of some B/G algae can produce toxins:

Microcystin--a liver toxin, can produce nausea

Anatoxin--the "Very fast death factor," a neurotoxin that can cause respiratory paralysis

Cylindrospermopsin--toxic to liver and kidney

BMAA—has been related to neurodegenerative disease, but the jury still out on this

In the summer of 2013 at least 5 dogs were killed by the Lake Erie B/G bloom, and 50 people made ill.

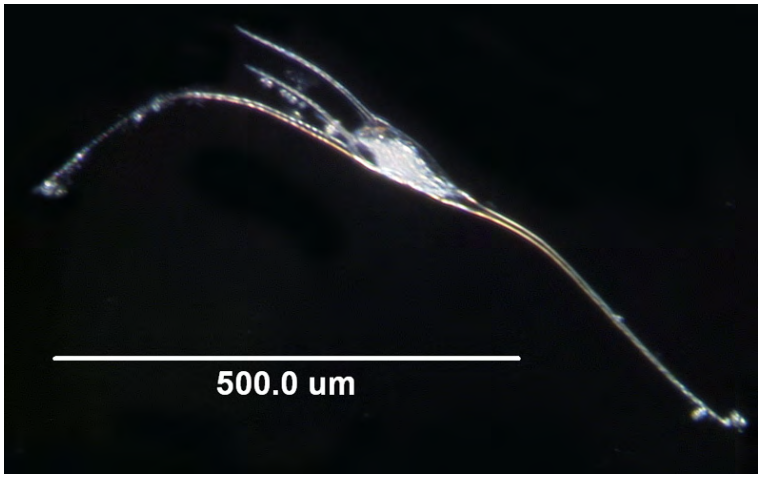
Botswana 2020

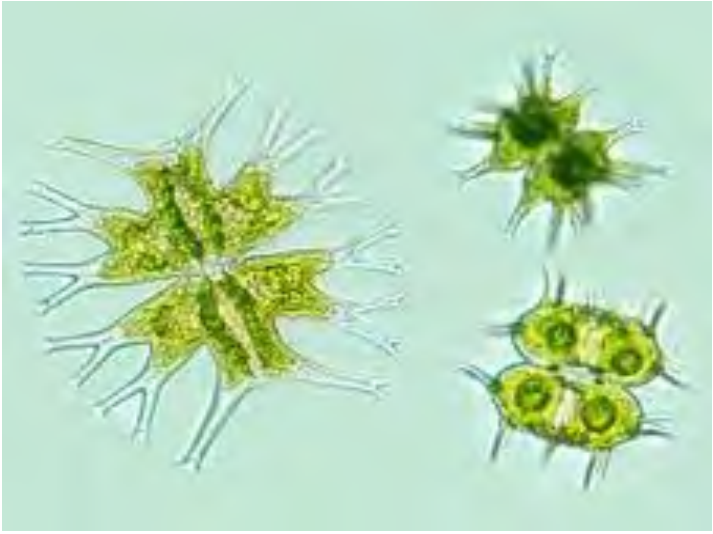
300+ elephants die of a mysterious cause

Found to be toxins from HABs

<u>This</u> is why we worry and about high levels of P in our lakes. We won't be killing elephants in the Adks, but things can get nasty if we're not careful

And Now for Some Really Cool Little Lake Creatures that Help the Lake Function:





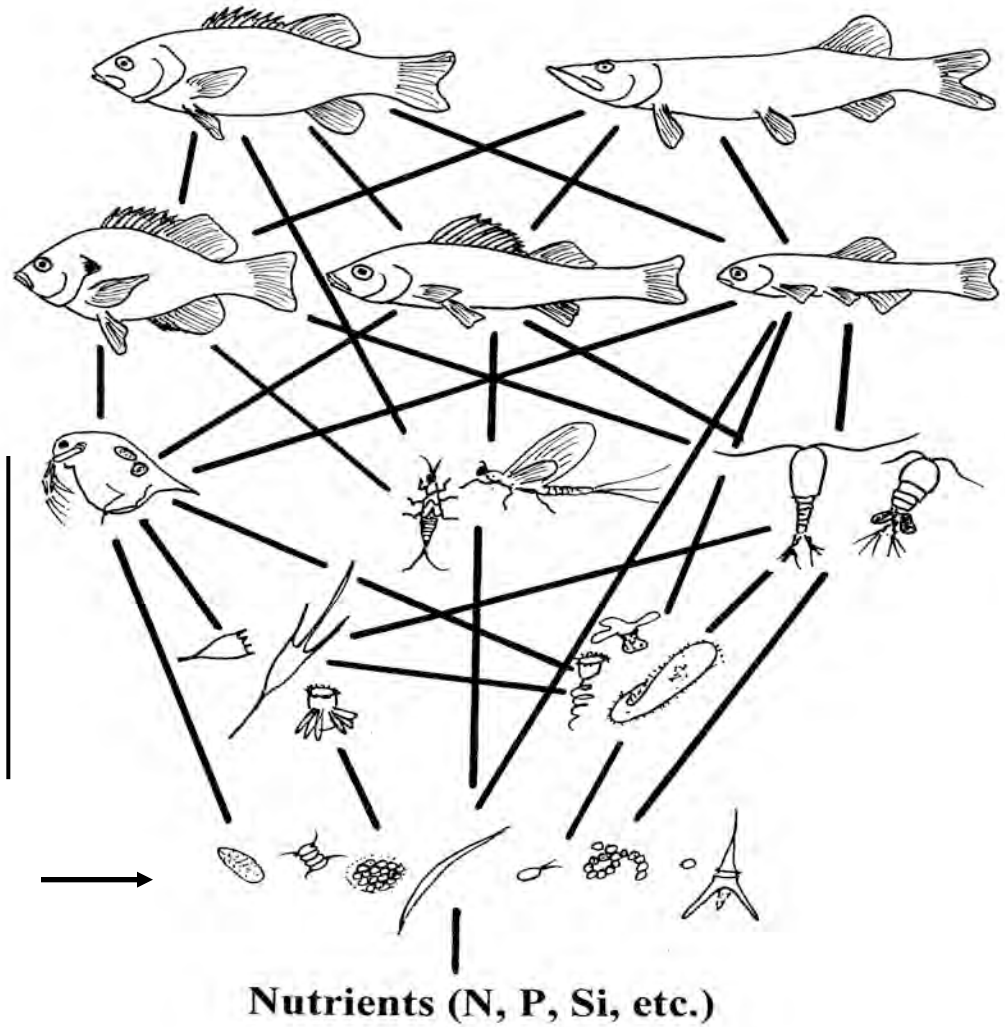
A food web

Those who eat those who eat algae

Those who eat the algae

Plants

Algae



Water

What about the creatures?

Some are small, but how small?

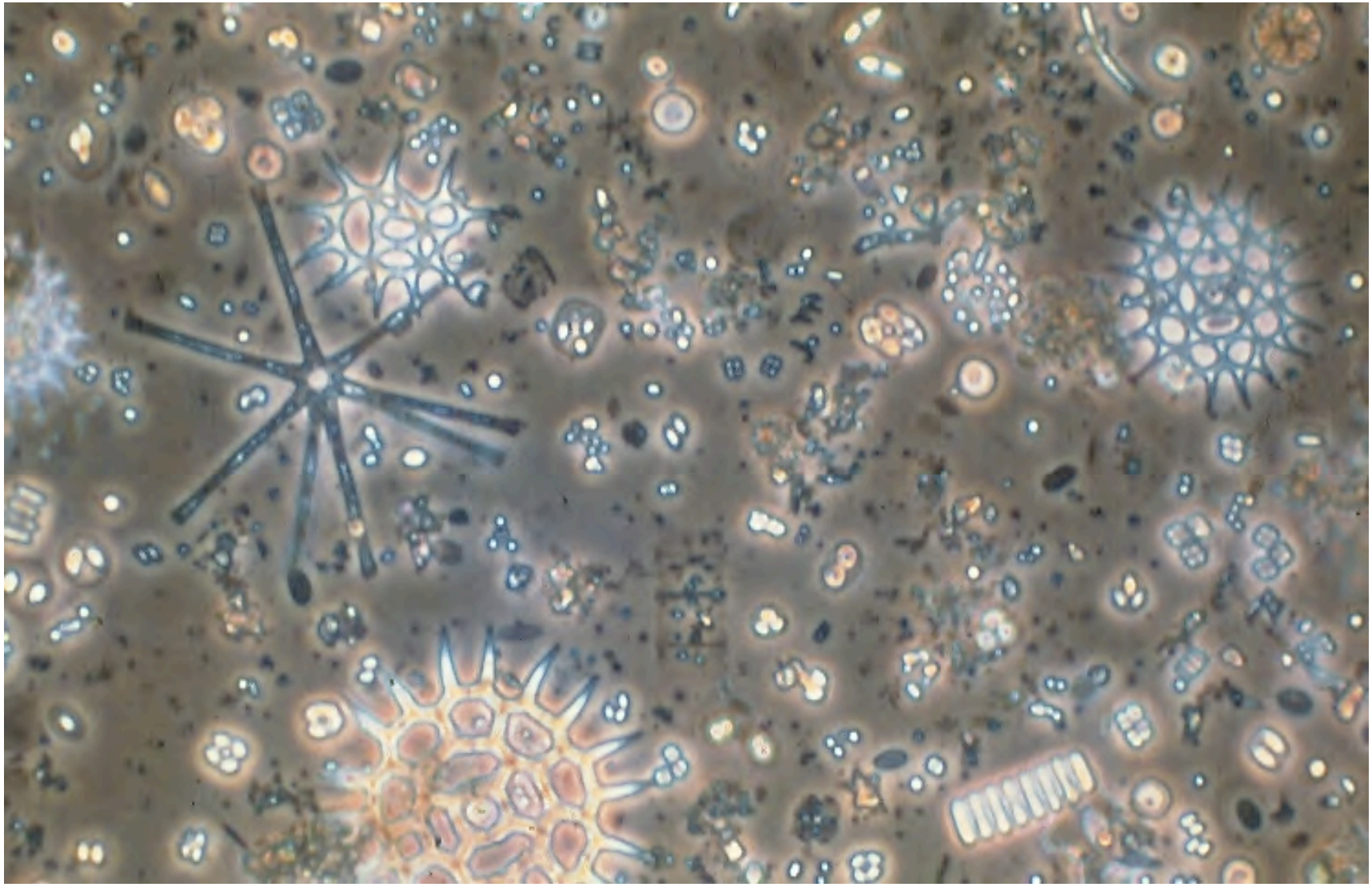
(We have to think metrically)

- A **centimeter** (cm) is 0.4 of an inch--the radius of a nickel is 1 cm; its diameter 2 cm.
- A **millimeter** (mm) is one tenth of a cm--a dime is about one mm thick. (0.04 or 4 one hundredths of an inch)
- A **micometer** (µm) is one, one thousandth of a mm. (0.00004 inch or 4 one hundred thousandths of an inch) Usually called a "micron"
- Many small algae are 2-5 µm in diameter, so you could have 500 to 200 cells side by side within the thickness of one dime.
- Bacteria can be 0.2 µm +/-, so 5,000 would take one dime width

Phytoplankton
or Algae

- Mostly microscopic
- Photosynthetic (ADD OXYGEN to water), but need sufficient light intensity to do it
- Basis of food chain in open water
- Important to water clarity
- Very diverse in shape and function

Algae: Note the diversity in size and shape

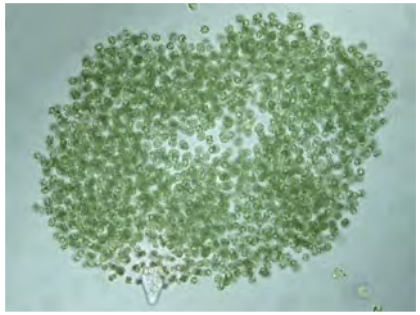


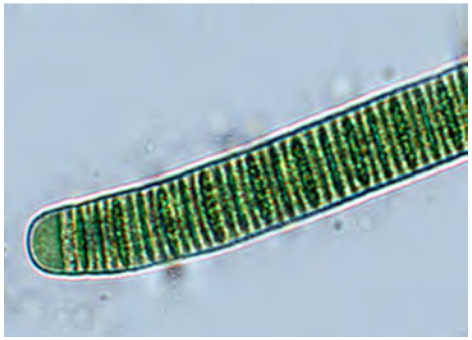
Blue green algae
(Cyanobacteria)

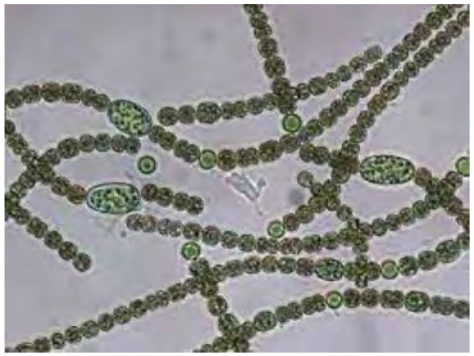
Extremely old—indirect evidence 3.5 billion years ago direct evidence 2.4 bya.

The first to evolve photosynthesis that produces O_2.

Produced our present atmospheric O_2 that has allowed life as we know it to exist on earth.

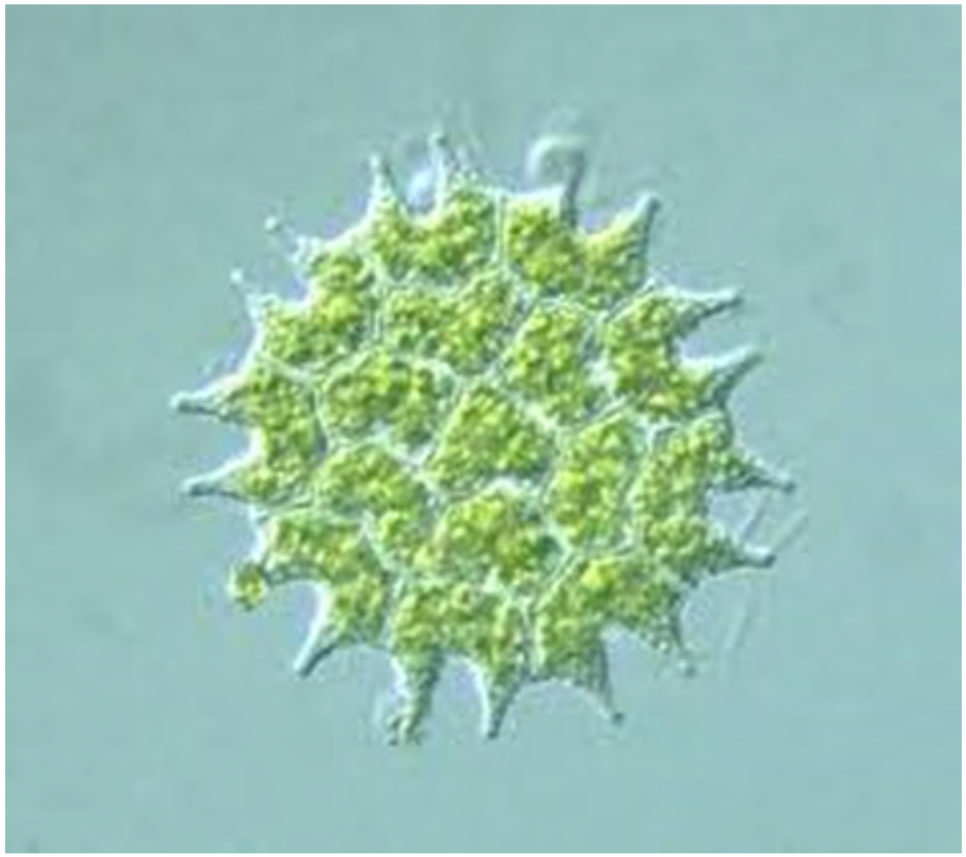




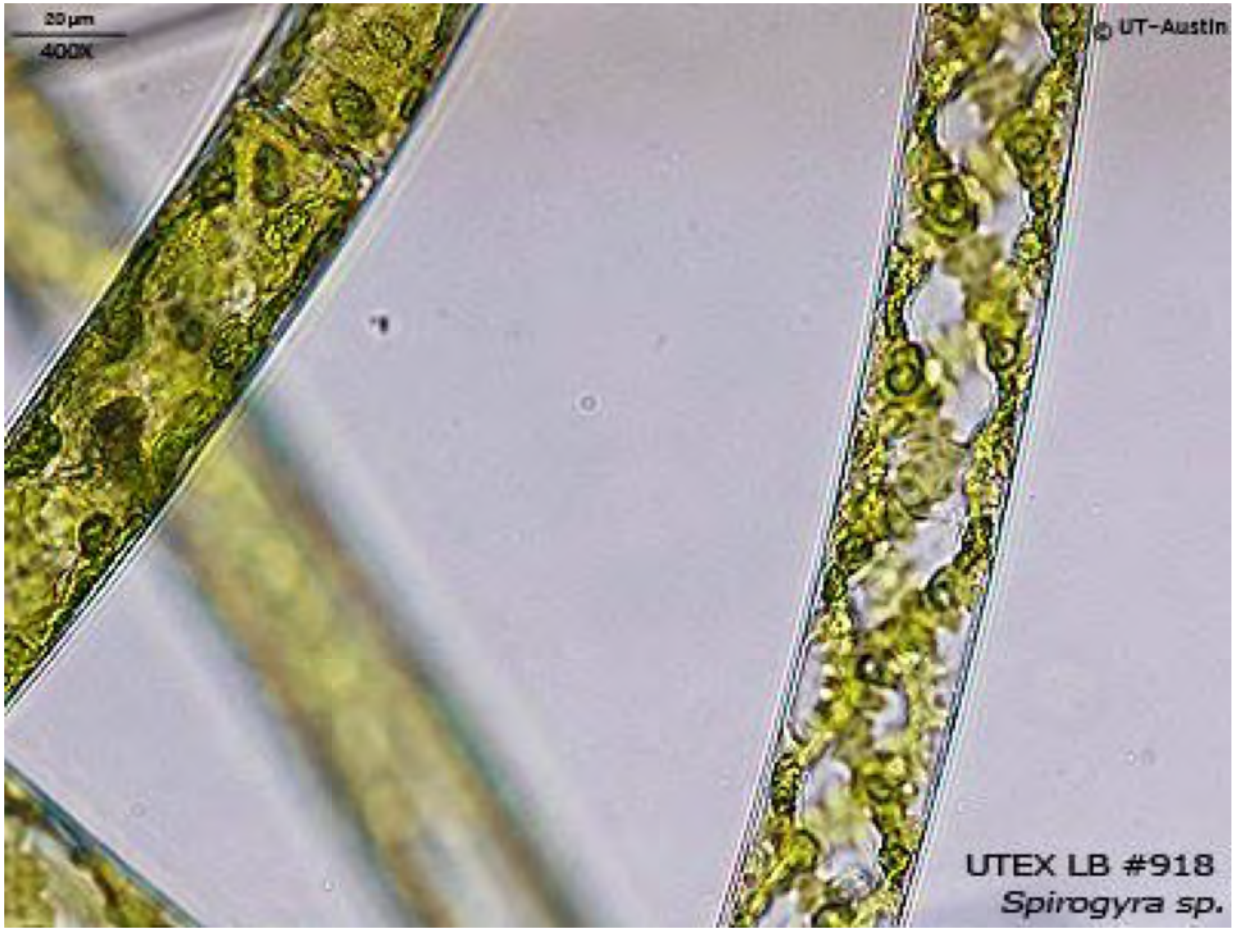


Visible in our lakes
(Little translucent dots about a mm in diameter)

Other algae



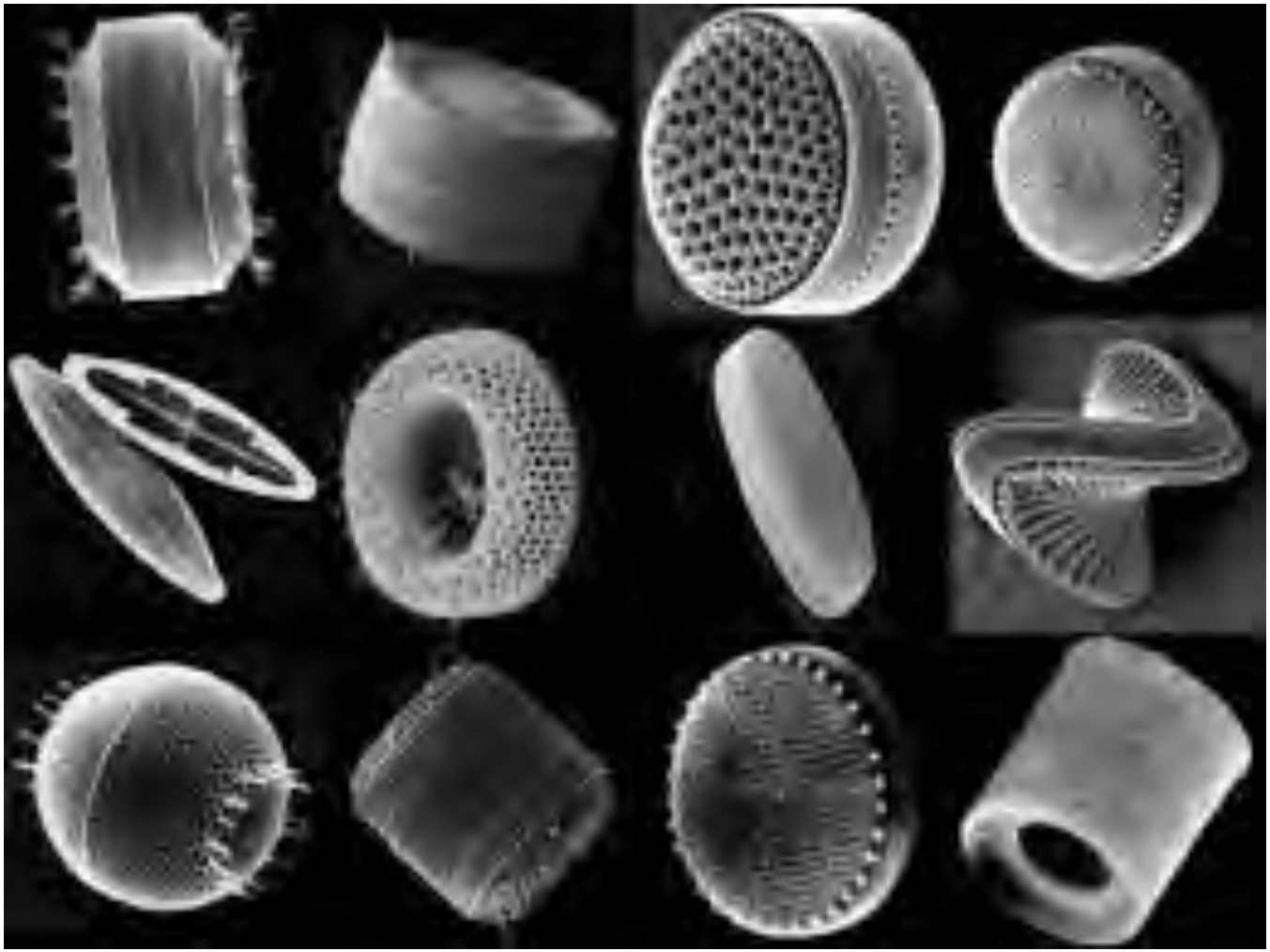
Spirogyra



(Also the name of a British rock band????)

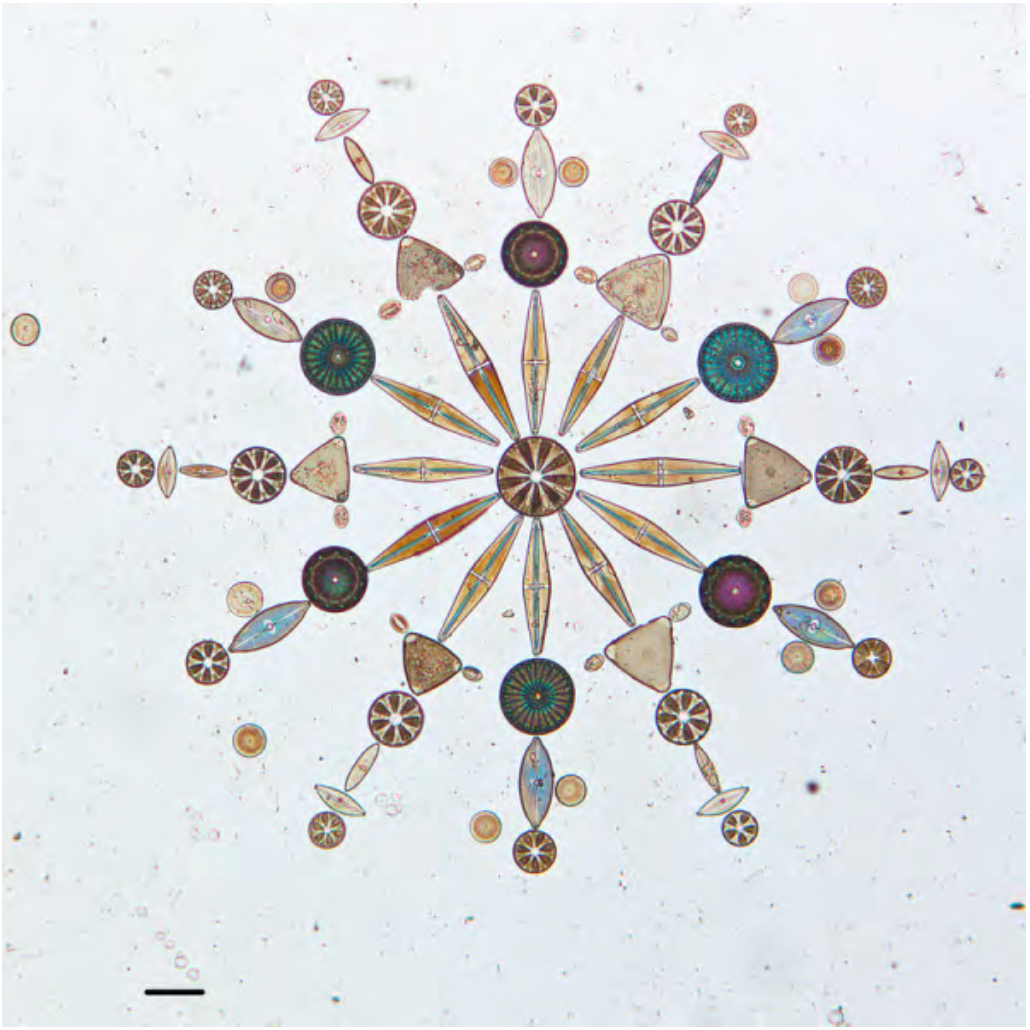

12.08.02, 640x
50 µm

Diatom shapes (SEM images)
Diatoms are about 10 microns in diameter



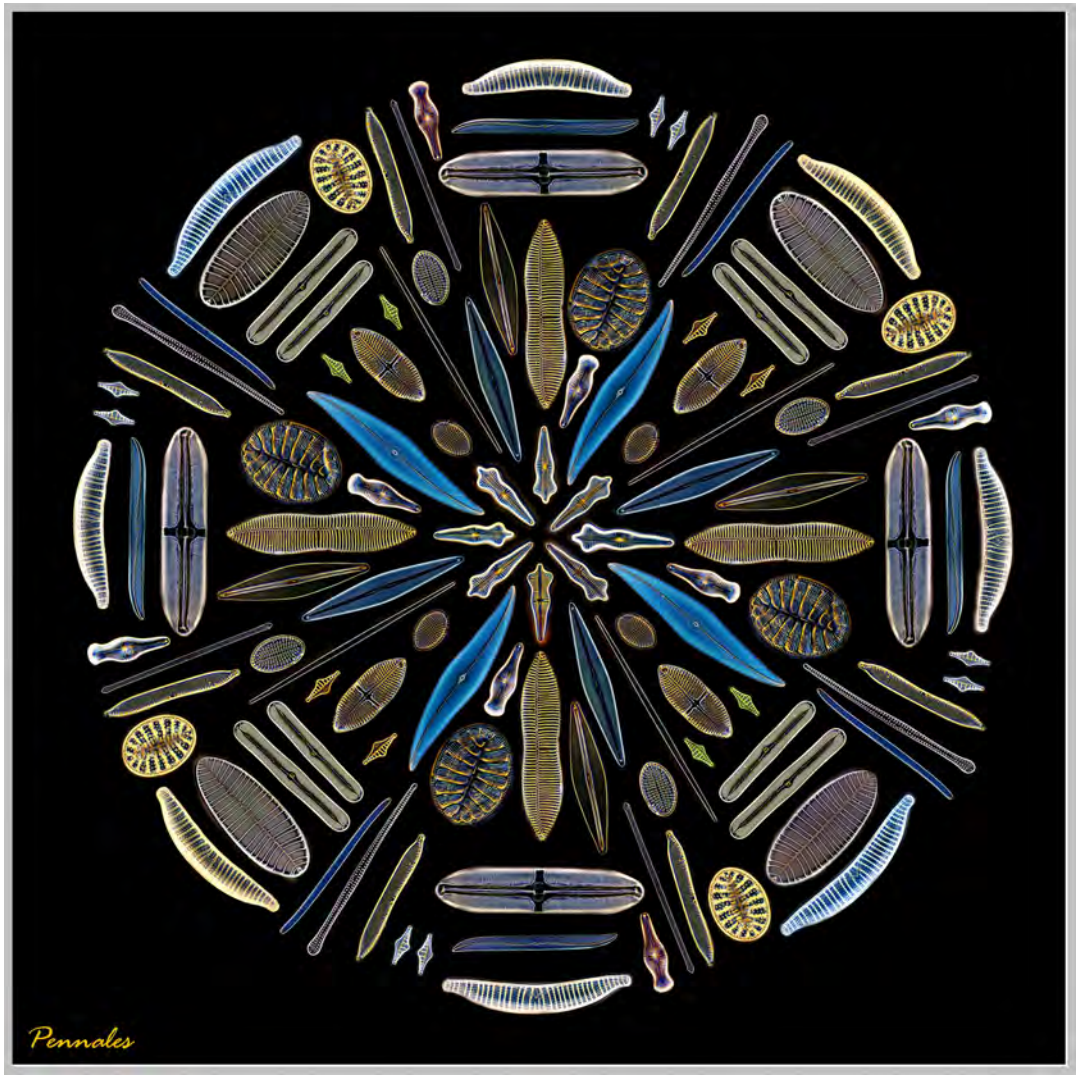
A space ship???

Artistic microscopic diatom arrays
(diameter of array typically smaller than a printed “.”)



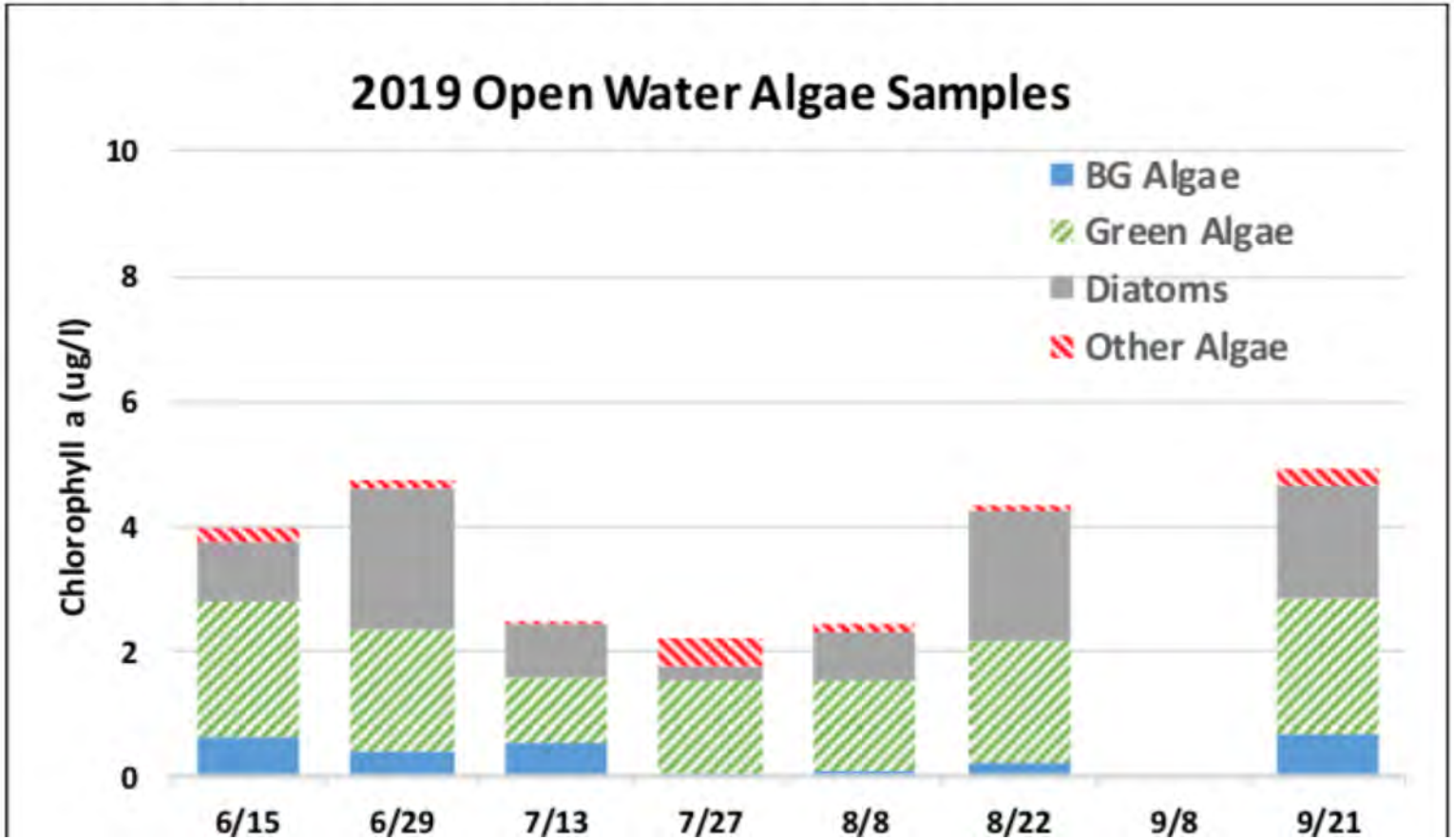
Some people have way too much time on their hands!

(in the late 1800”s and early 1900’s)



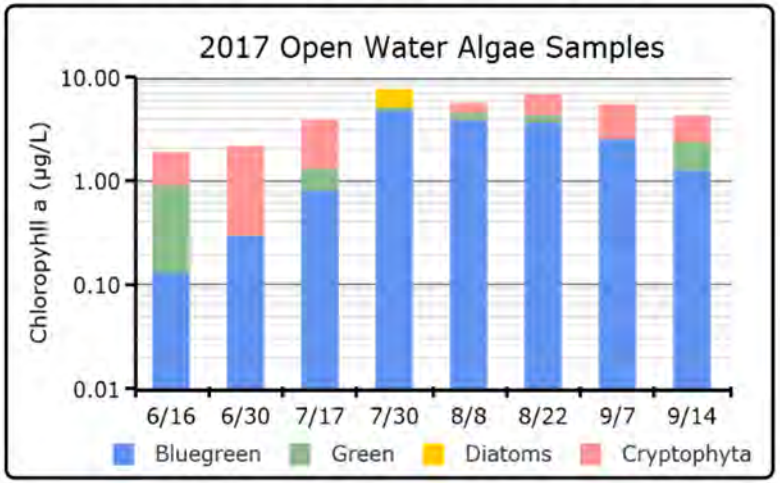
Sacandaga Lake algal population composition CSLAP report

HABs Status Open water Algae

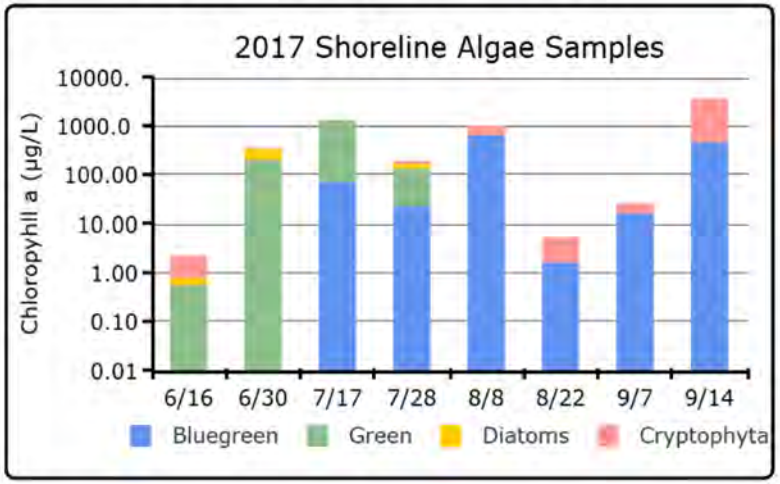


The algal composition in 2017 in mystery lake is now dominated by B/G algae

2017 Open Water Algae Samples



2017 Shoreline Algae Samples



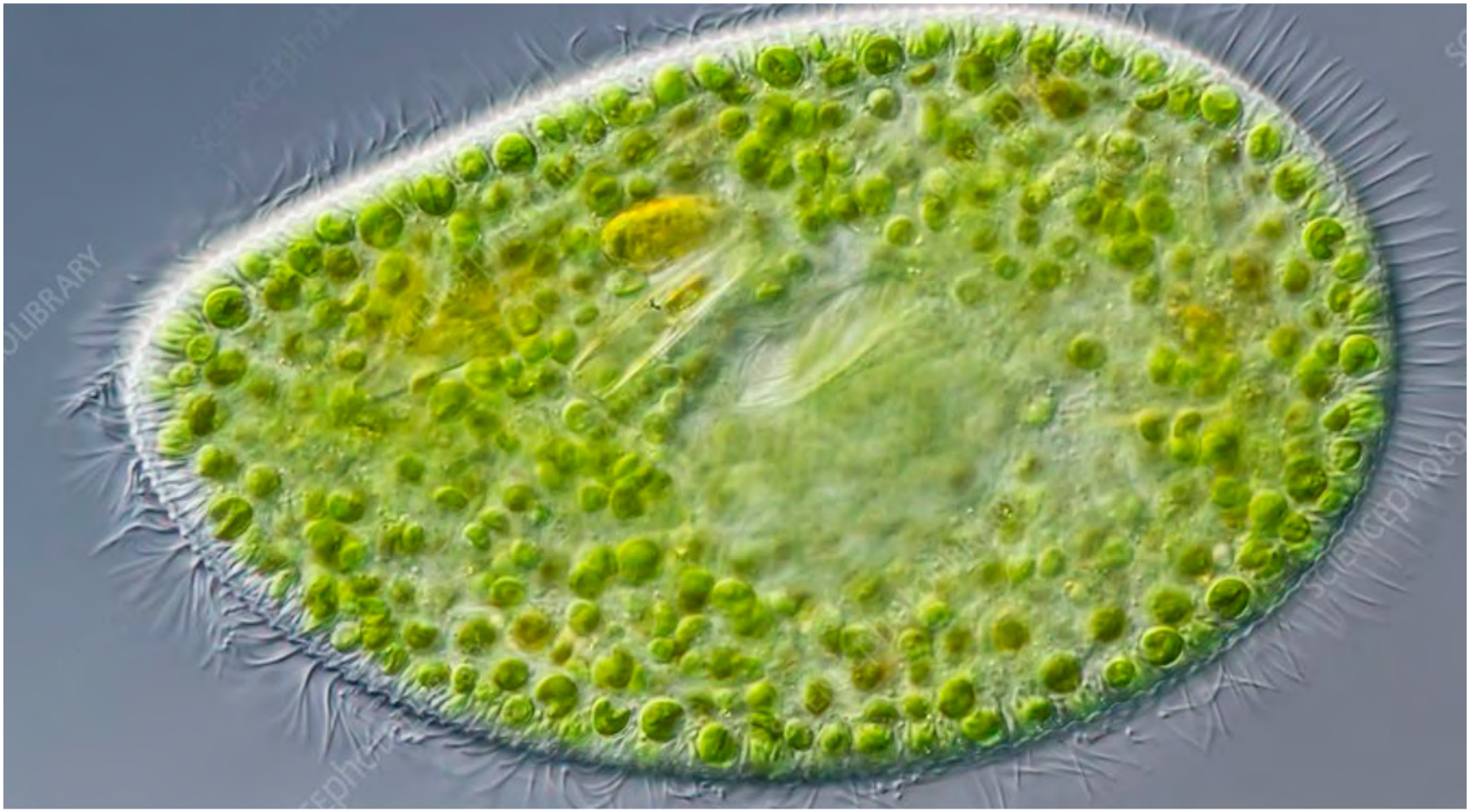
And some toxins are appearing

Shoreline HAB Sample Dates 2017											
HAB Indicators	HAB Criteria	6/16	6/30	7/17	7/28	8/8	8/22	9/7	9/14		
BGA	25 µg/L	0	0.0	70.5	22.3	633.0	1.6	16.0	451.5		
Microcystin	20 µg/L	ND	ND	ND	ND	58	ND	2.51	4.05		
Anatoxin-a		ND	ND	.16	ND	ND	ND	ND	ND		

Zooplankton

Protozoa (single celled animals)

Paramecium bursaria ingests single-celled green algae, does not digest them but uses them to provide nourishment like a plant



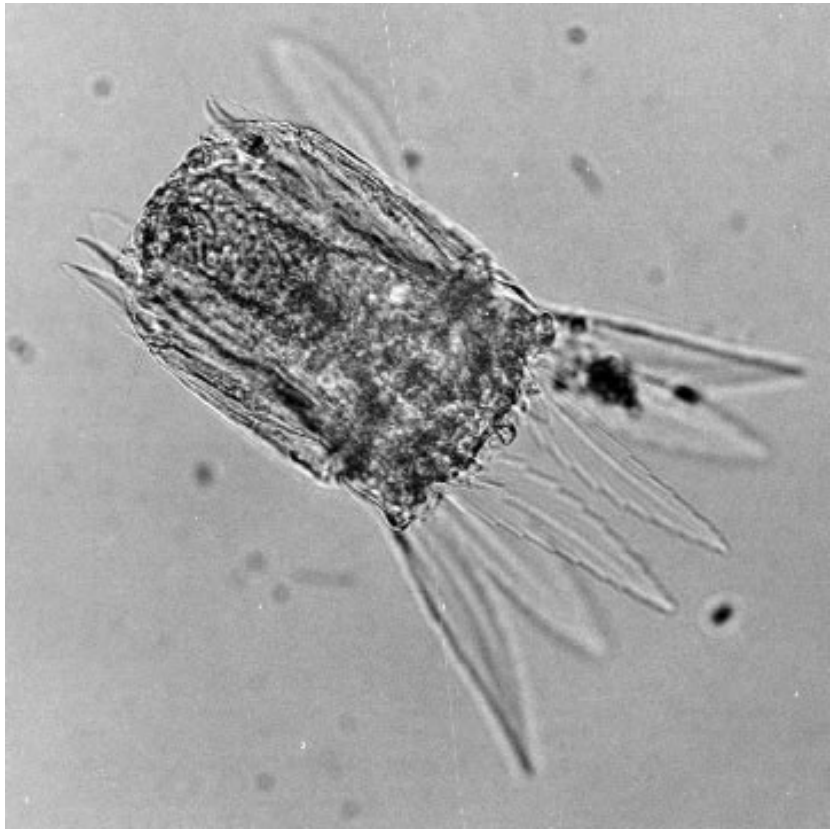
Rotifers (small multicelled animals)

- 100 to 1,000 µm long (10 to 1 per dime thickness)
- Some with bodies less than 900 cells, a brain of 15 cells
- Filter feeders, can filter 1,000 x body volume/hr--eat bacteria and small algae. A few are predatory on other rotifers.
- Very common – 500+/Liter typical

Polyarthra

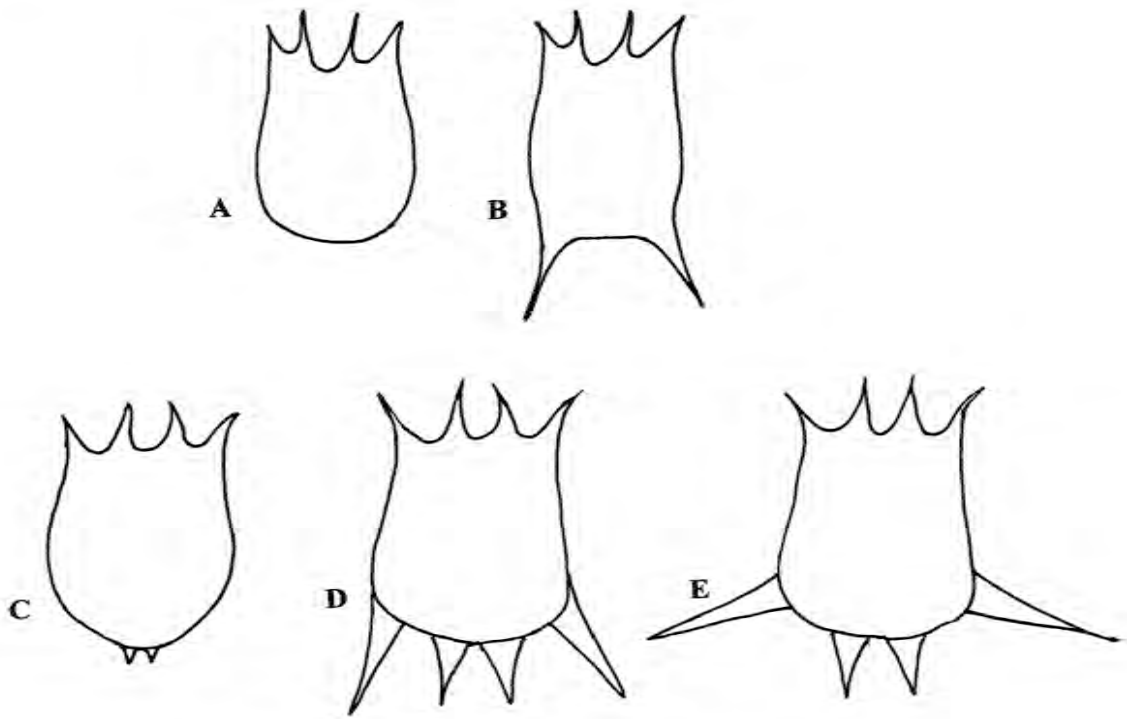
Relaxed

Flipped out

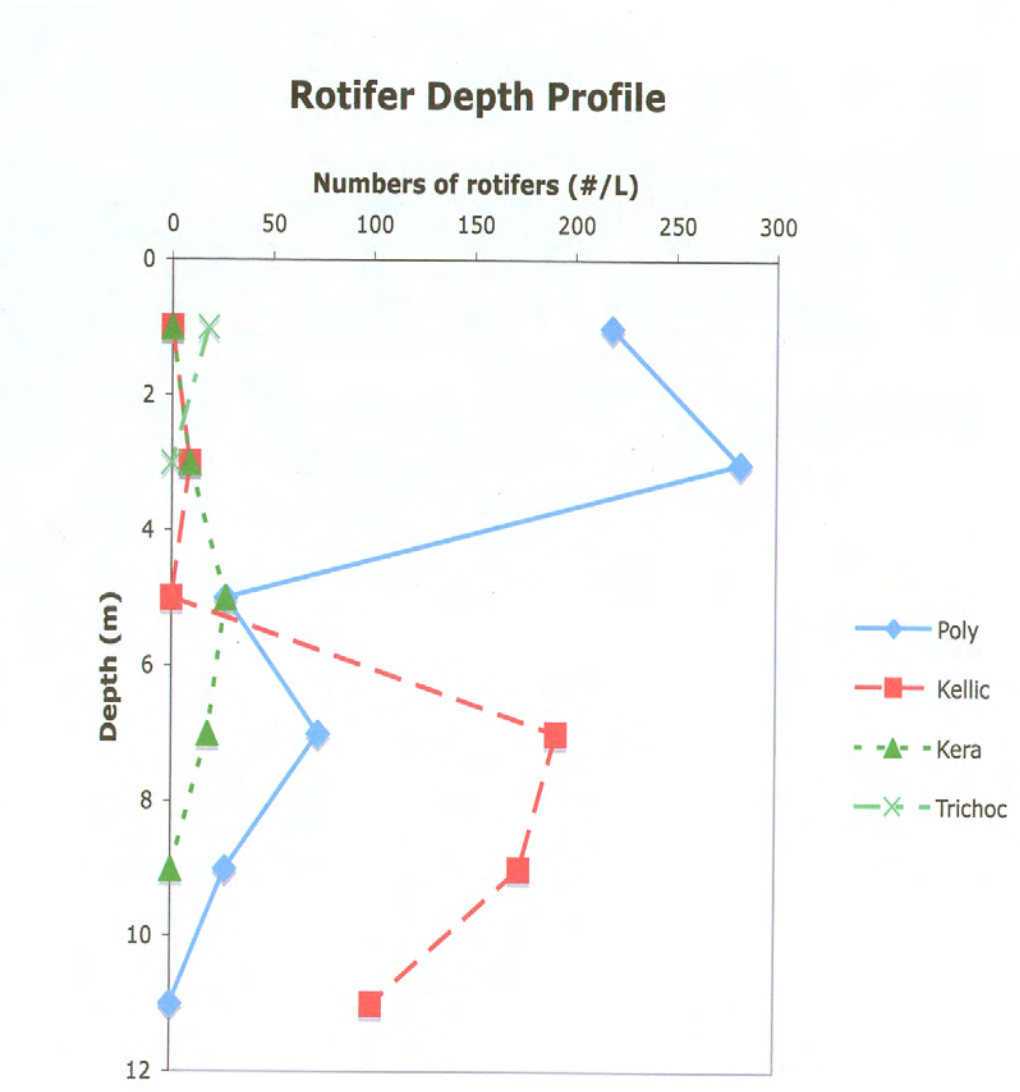


Escape response: 15 body lengths in 0.05 seconds using 12 paddles

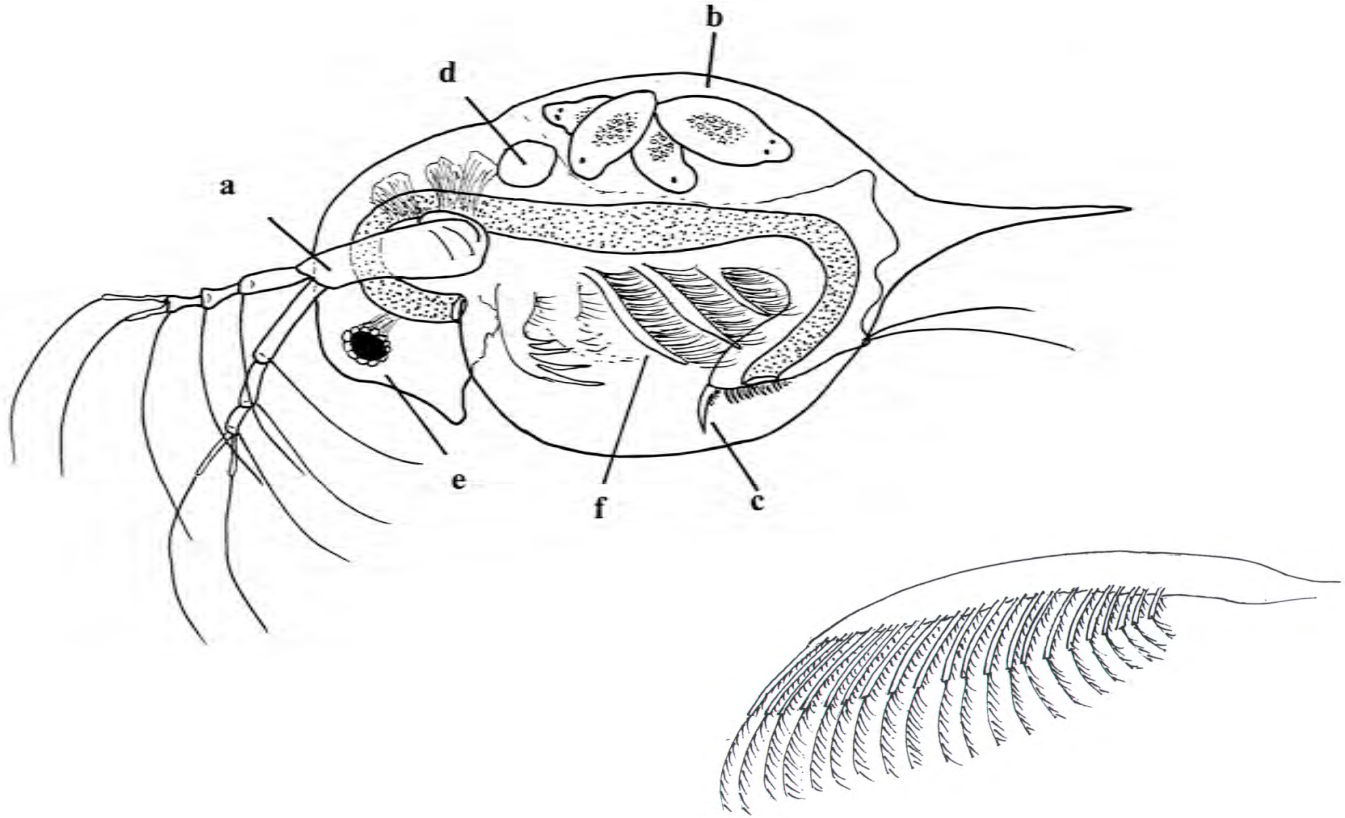
Rotifer defense



Rotifer segregation in lake

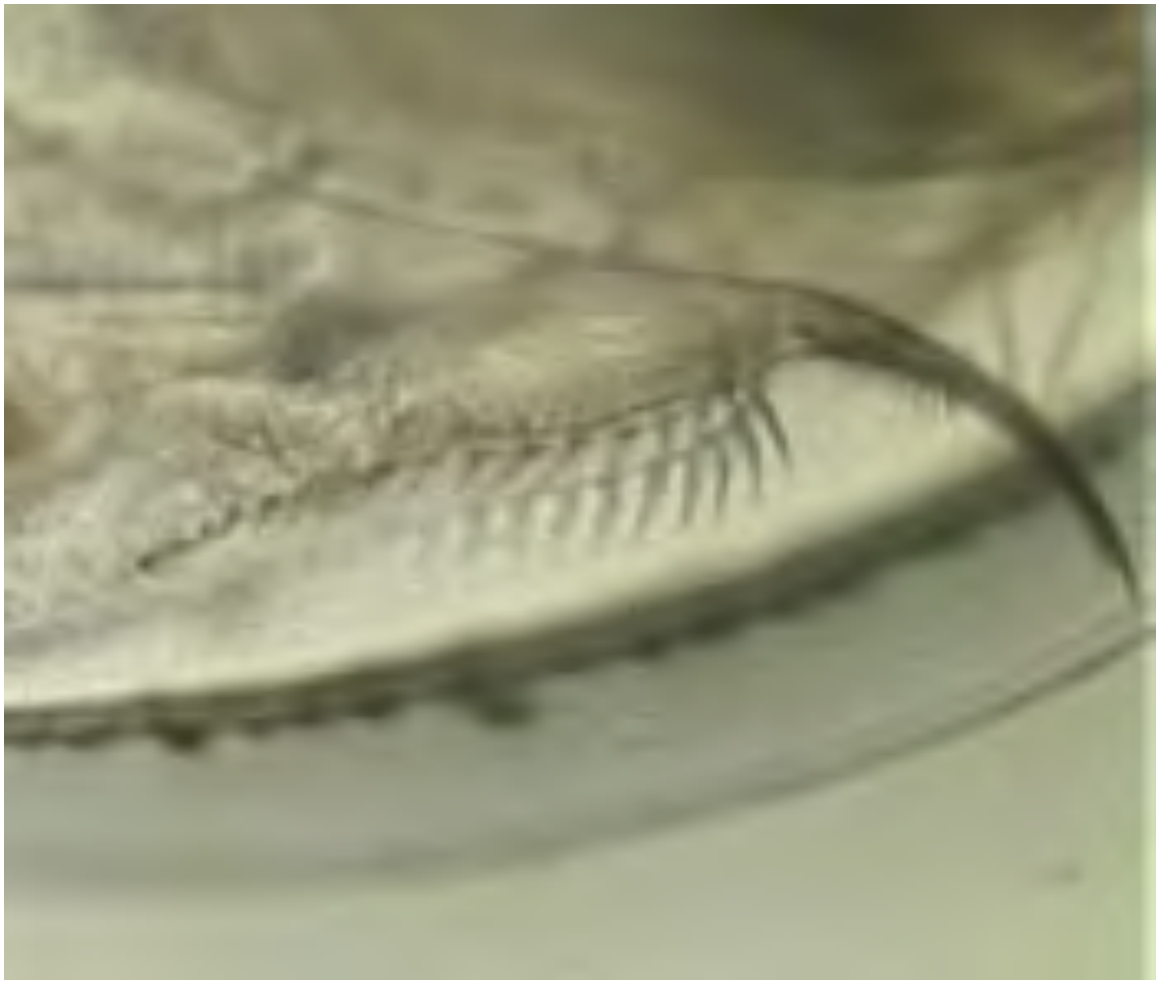


“Water fleas”



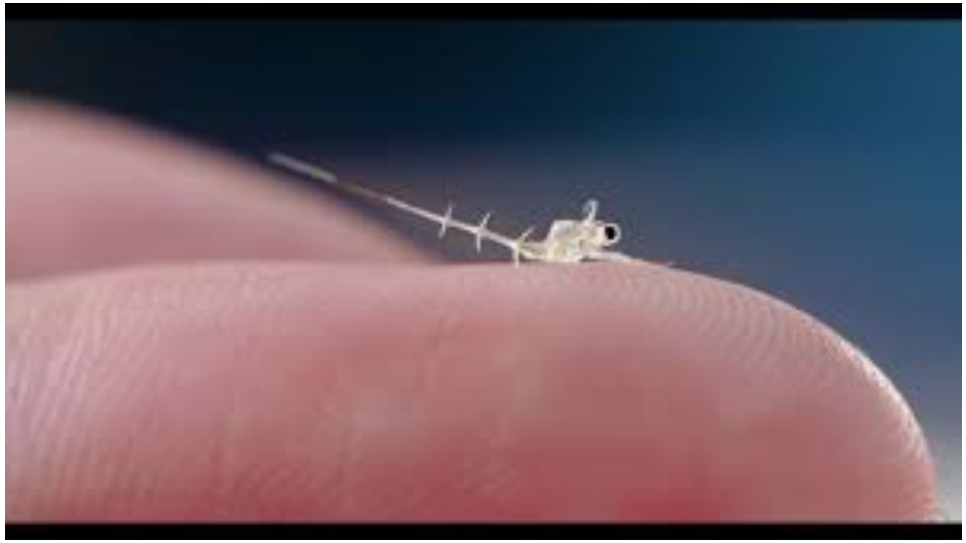
Food filtering appendage (f)

Daphnia Claw



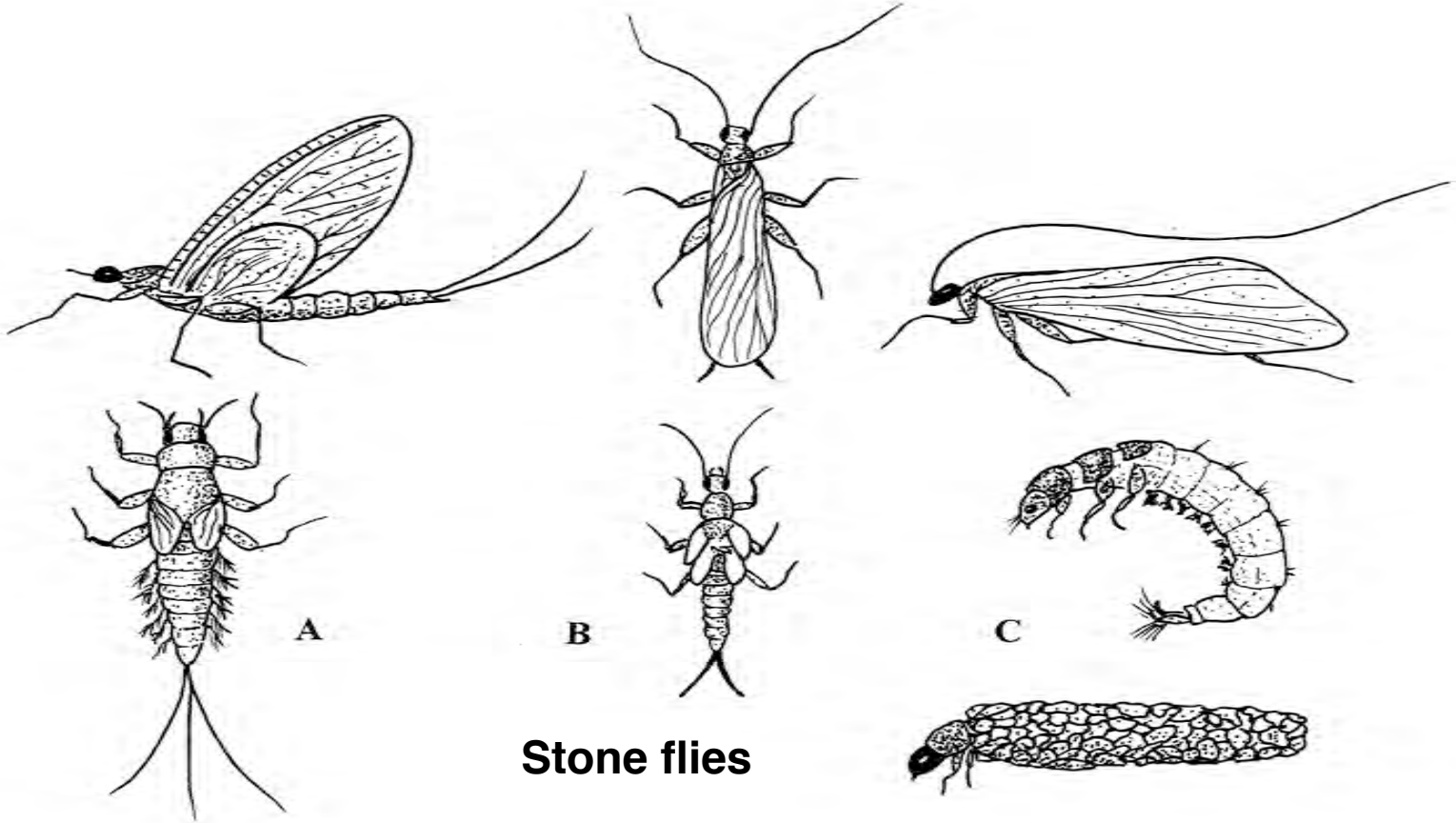
Typical “water fleas” (0.5 to 2 mm)

The Invasive spiny water flea



INSECTS

Macroinvertebrates (adults and nymphs or larvae)



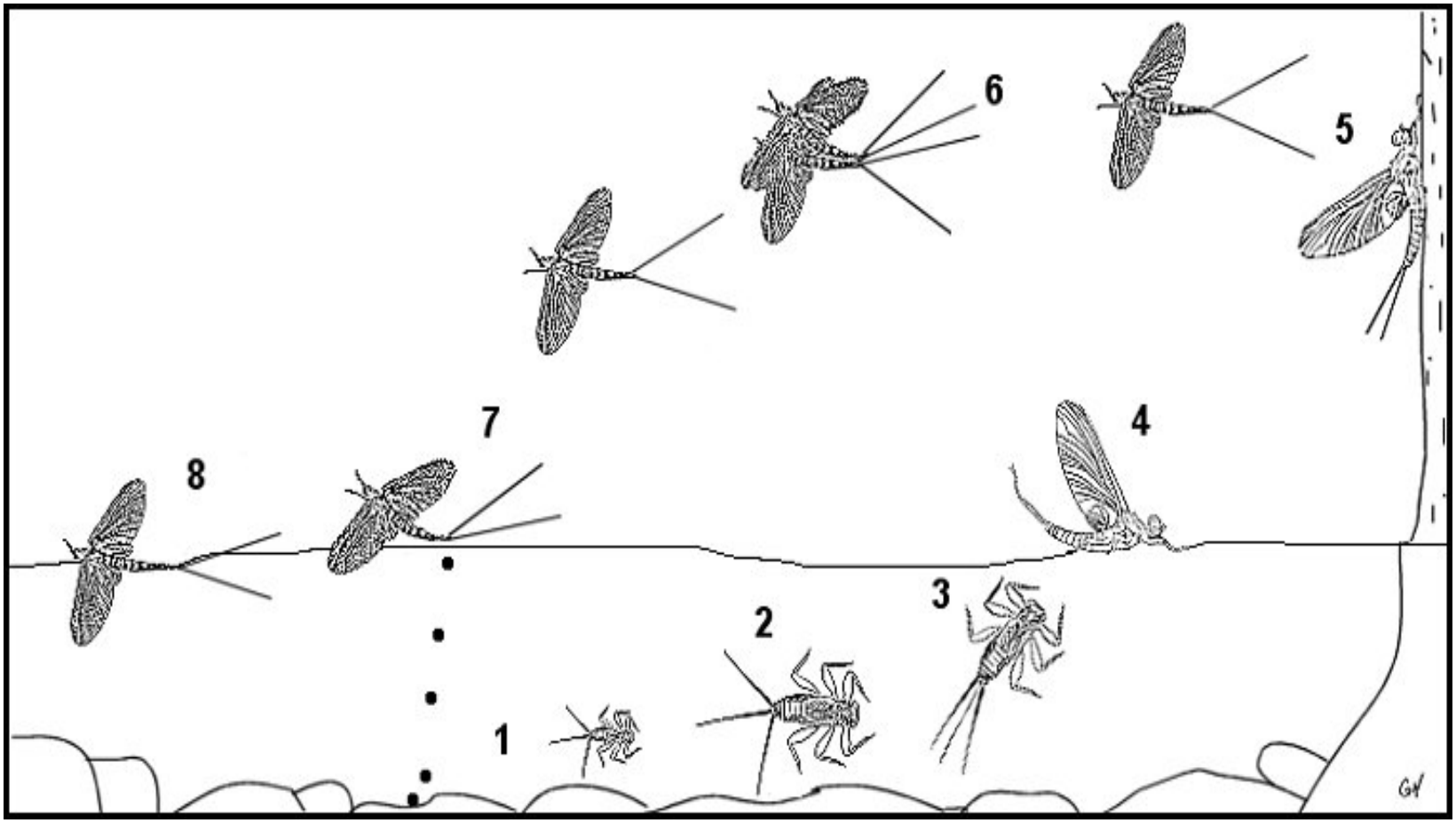
May flies

Stone flies

Caddis flies

Mayflies

May fly life cycle



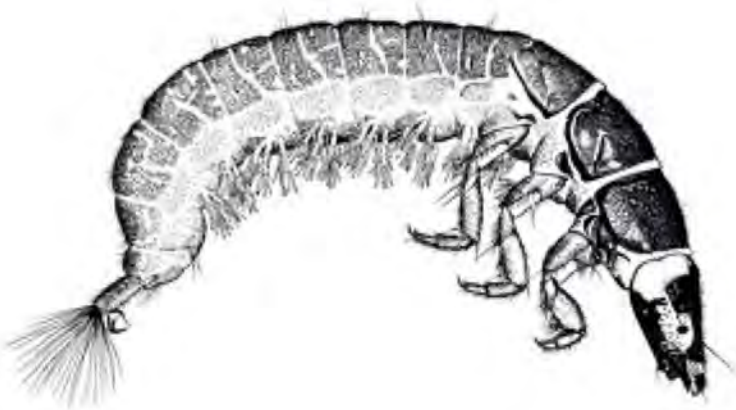
A Synchronous mayfly hatch

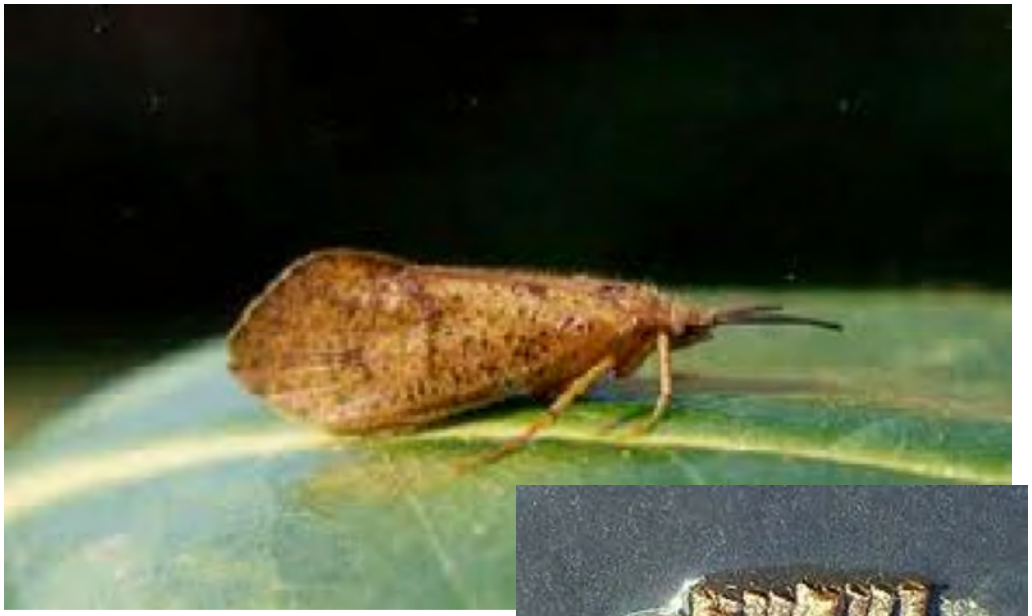
- A stream mayfly in Pennsylvania (*Dolania*)
- Hatch limited to 7-10 days in June
- Hatch only occurs in the half hour before sunrise
- In one half-hour period, 3,000 mayflies emerged from a 100 m (330 ft) stretch of the stream
- Adult males live max 30 min, females about an hour

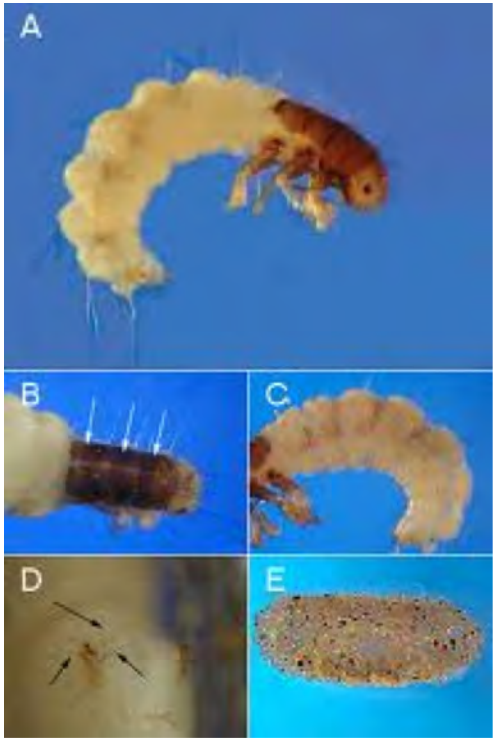
- **Advantage of synchrony**: predator satiation or mating ease? Streams with predatory fish have more synchrony, and asexually reproducing mayflies are synchronous. Therefore predator satiation wins.

Stoneflies

Caddisflies





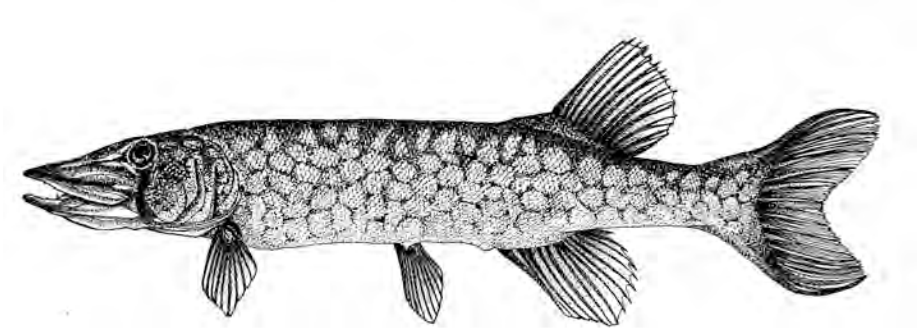


Caddisfly Jewelry

Fish

- Smaller fish—alewives, sunfish, minnows, etc—eat zooplankton.

- Larger fish—bass, walleyes, pickerels, trout, etc.-- eat smaller fish

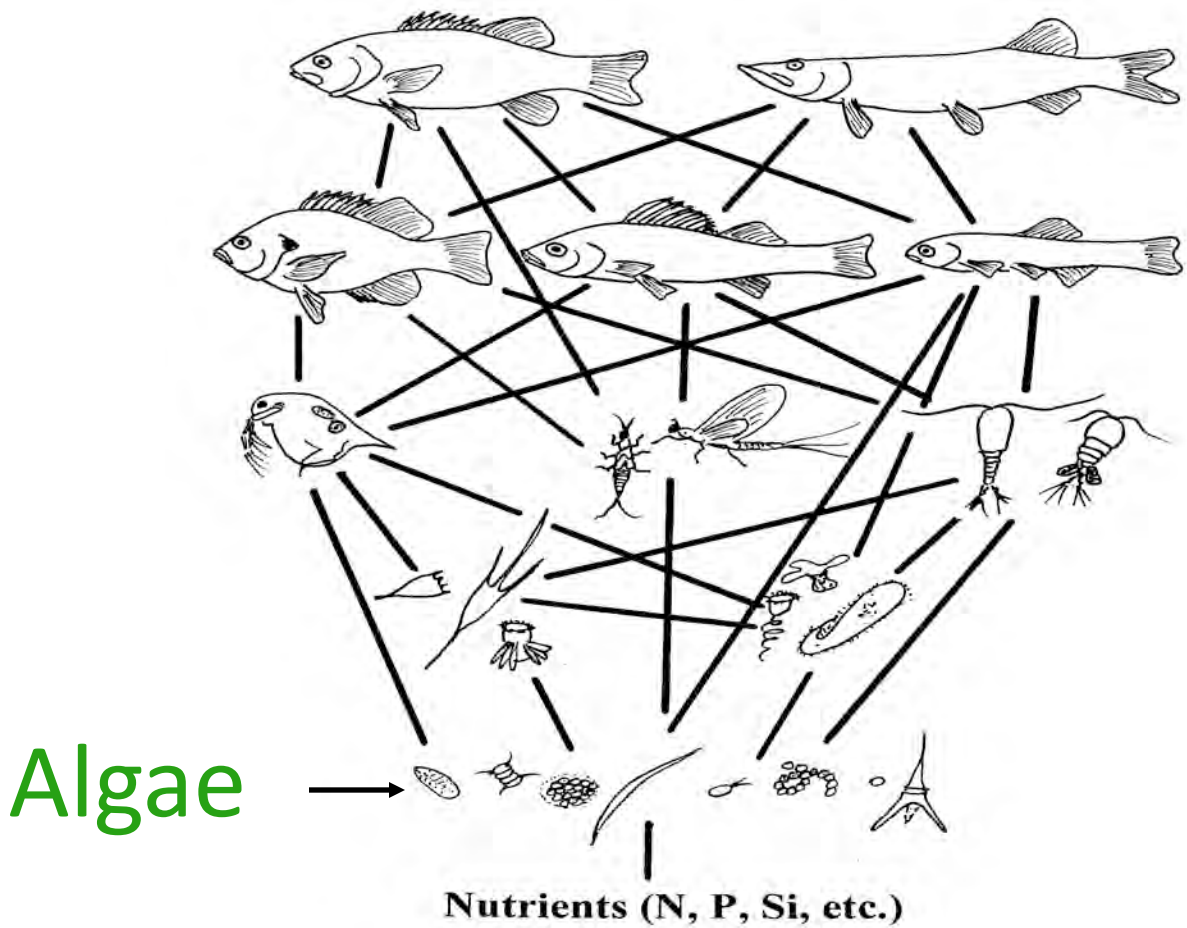


Plants

- Limited by light intensity—growth depth depends on water clarity
- Relationship between plants and algae
- Some fish eat plants directly (e.g. grass carp), but main benefit to fish is the habitat diversity they provide for the many smaller creatures that fish eat
- A habitat for sit-and-wait fish predators

Does limiting nutrients work in a lake?

A food web



A case study:
Lake Washington near Seattle

Developments around lake pumped waste water into the lake resulting in algal blooms:

	Lake Wash.
Secchi	3 ft
Chloro a	31 ppb
Total P	65 ppb
% B/G algae	90+/-

In 1963 they started a project to divert waste water outfalls into Puget Sound. The project was complete in 1968.

A success story!

	Before ‘62-66	After ‘75-79
Secchi	3 ft	23 ft
Chloro a	31 ppb	3 ppb
Total P	65 ppb	17 ppb
% B/G algae	90+/-	10+/-

Possible because P source was a “point source” and could therefore be controlled. This is a “bottom up” solution.

A success story!

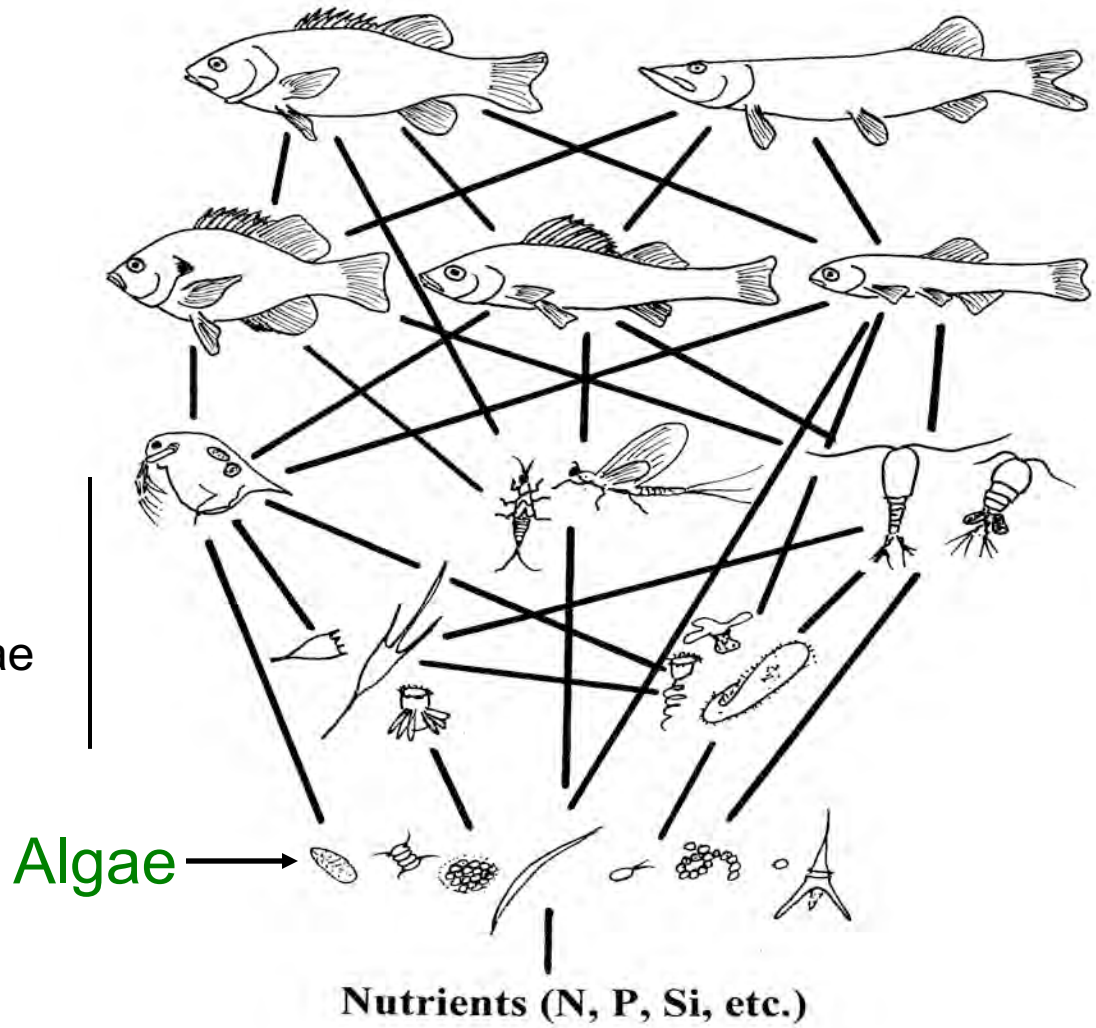
	Before ‘62-66	After ‘75-79	(2020)
Secchi	3 ft	23 ft	5-6 ft
Chloro a	31 ppb	3 ppb	5 ppb
Total P	65 ppb	17 ppb	10 ppb
% B/G algae	90+/-	10+/-	

Possible because P source was a “point source” and could therefore be controlled. This is a “bottom up” solution.

The quandary in Lake Mendota, Wisconsin

- In Madison, WI. Univ. Wisconsin is on its shore
- Roughly circular about 5 mile diameter
- There were frequent blooms of B/G algae
- Resulting in poor water clarity
- Phosphorus is limiting factor, but sources are <u>diffuse</u> with agricultural and urban/suburban land use in entire watershed
- Therefore, a "bottom up" control strategy would be difficult to impossible
- Is there another solution?

Food web



The proposed solution

The Rationale:

- Who eats the algae? Mainly zooplankton
- Who eats zooplankton? Planktivorous fish
- Who eats planktivorous fish? Piscivorous fish
- So they stocked <u>a lot</u> of walleyes and N. pike to eat the planktivores

BUT……Who eats piscivorous fish?

Just a joke, folks. I don't eat the fish I catch

- But the wily Wisconsin anglers do, and fishing pressure on Lake Mendota went from 180,000 person-hrs in 1987 to 460,000 person-hrs in two years

- Walleye harvest went from 22% to 57%, an unsustainable level for the state's hatcheries

- Conclusion: Top-down trophic manipulation won't work if you can't control the top predators (but it has worked on smaller lakes with controlled human access)

Lake Otsego, NY experience

- Had decreasing water clarity, similar to L. Mendota and L. Washington
- No point source of phosphorus, and no evidence of recent extensive development in watershed, either
- Research showed that the culprit was an invasive fish species--the alewife, a 6+/- inch fish that eats a lot of zooplankton.
- The reduced zooplankton community allowed the algae to flourish.

Solution:

- Bring a bigger fish to eat the alewives
- So they heavily stocked lake with walleyes, and the alewife population crashed
- Zooplankton populations increased, and algae populations and blooms decreased
- Water clarity increased
- For some reason, the NY anglers didn't increase fishing pressure very much (less public access?…didn't know about it?…not as good at fishing as their Wisconsin peers?…New Yorkers don't like walleyes?)
- At last report: no alewives to be seen, many water fleas and clearer water
- Pretty much a success story

Those were large lakes. What about smaller lakes?

Smaller lakes make more intensive management strategies affordable

- Phosphorus sequestration
  - Chemicals can strip P from the water column and lock it in the sediments
  - Aeration of the hypolimnion can prevent internal loading
- Weed treatments and harvesting
- Also other treatments (Come to next FOLA mtg and talk with vendors)

What are the take home messages?

- PREVENTION IS ALWAYS BETTER THAN MITIGATION
- Focus on phosphorus
- Lakeshore lawns are an important part of the equation, especially for lakes with good water quality
- Lake associations are on the front line for lake protection. They must keep up with nutrient levels and CSLAP warnings so they know soon when change is beginning


"In the end, we will conserve only what we love,
we will love only what we understand,
we will understand only what we are taught".
Baba Dioum, Senegalese environmentalist