Eutrophication:
Nutrients, Algae, Toxins and Geosmin……..The Basics

Edward Carney

Kansas Department of Health and Environment

Lake and Wetland Program

Presented to The Kansas Aquaculture Association

Annual Meeting January 27-28, 2007

McPherson, Kansas

Definition of Eutrophication

The process of enrichment of a waterbody due to increases in nutrient loading.

Phosphorus is often the most important nutrient, but other factors may also be influential in the process.

Eutrophication increases the trophic status of a lake over time, leading many to refer to the enrichment process (inaccurately) as "lake aging."

Limiting Factors

Concept goes back to Liebig's "Law of The Minimum."

Many factors influence algal production, but the one(s) least available in the environment, compared to the biological "need" in the organisms, will "limit" biomass production.

Measuring Eutrophication

Eutrophication is a process over time, but we measure it at discrete points in time. These are individual estimates of lake "trophic state."

What we measure tends to be algal standing crop or nutrient levels, which are then used to infer a "eutrophication rate."

Chlorophyll-a (photosynthetic pigment in all algae), and total phosphorus, are most often used as parameters for measuring trophic state.

Trophic State

Assigning lakes to discrete classes along the spectrum of algal production has valid uses.

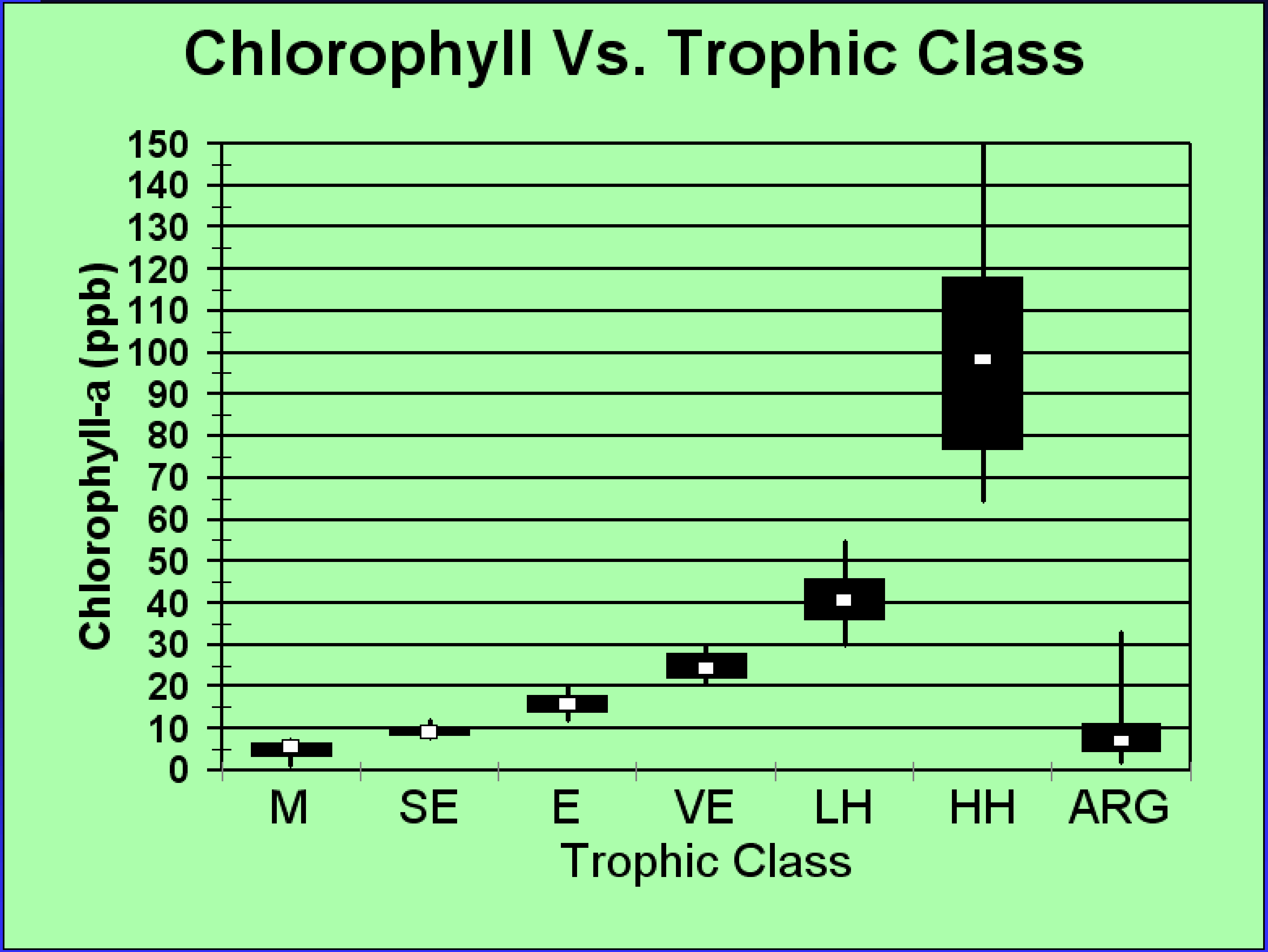
Oligotrophic or Meso-Oligotrophic

Mesotrophic

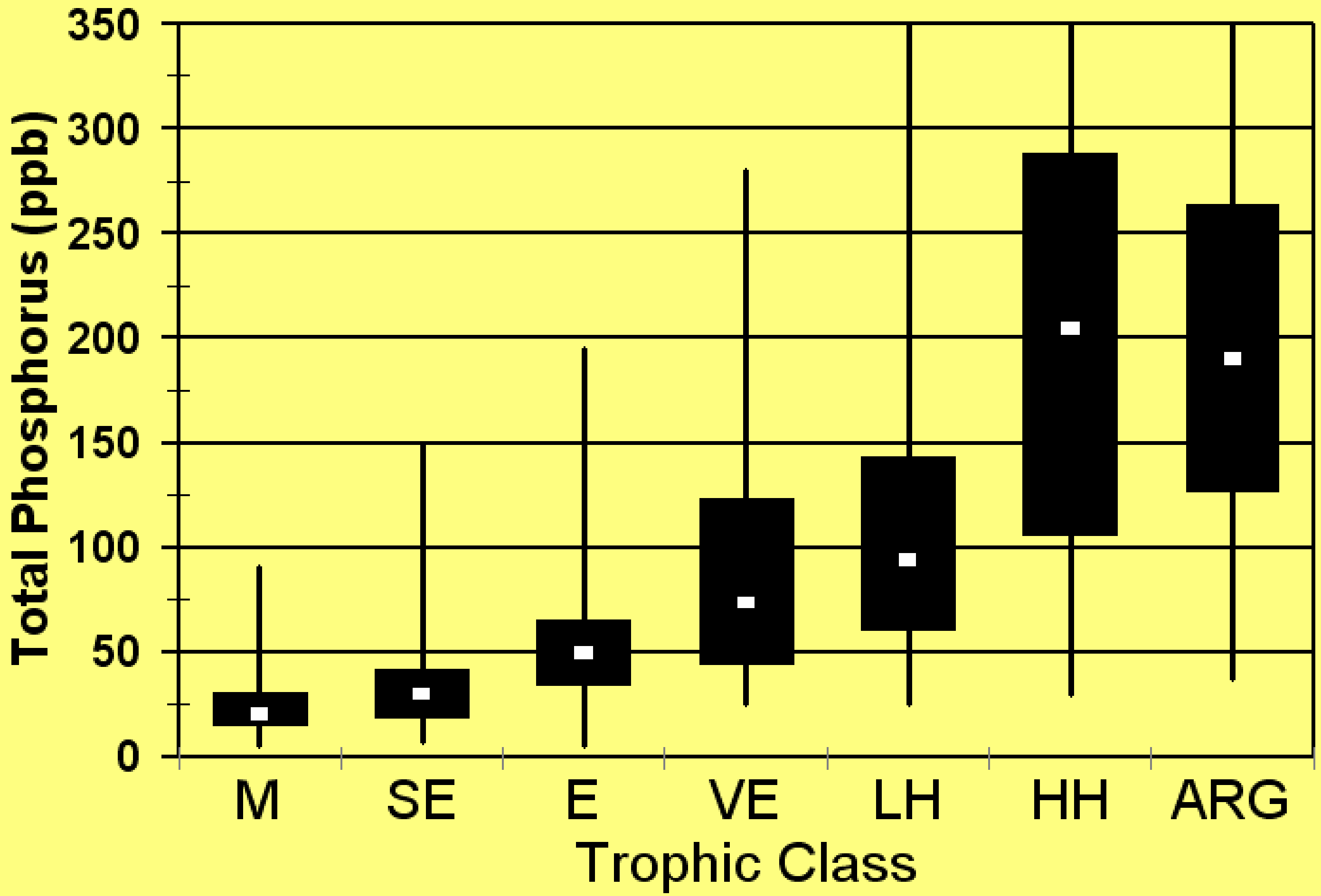
Eutrophic

Hypereutrophic

Argillotrophic


Chlorophyll Vs. Trophic Class
Chlorophyll-a (ppb)
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
M
SE
E
VE
LH
HH
ARG
Trophic Class

Total Phosphorus Vs. Trophic Class



Sources of Nutrients

- ✓ Major Sources
  - ✓ Agriculture
  - ✓ Urban Drainage
  - ✓ Point Sources
  - ✓ Manure (CAFOS, Etc.)
- ✓ Minor Sources
  - ✓ Atmospheric Deposition
  - ✓ Groundwater/Springs
  - ✓ Grasslands/Wooded Drainages
  - ✓ Internal Loading

The Process

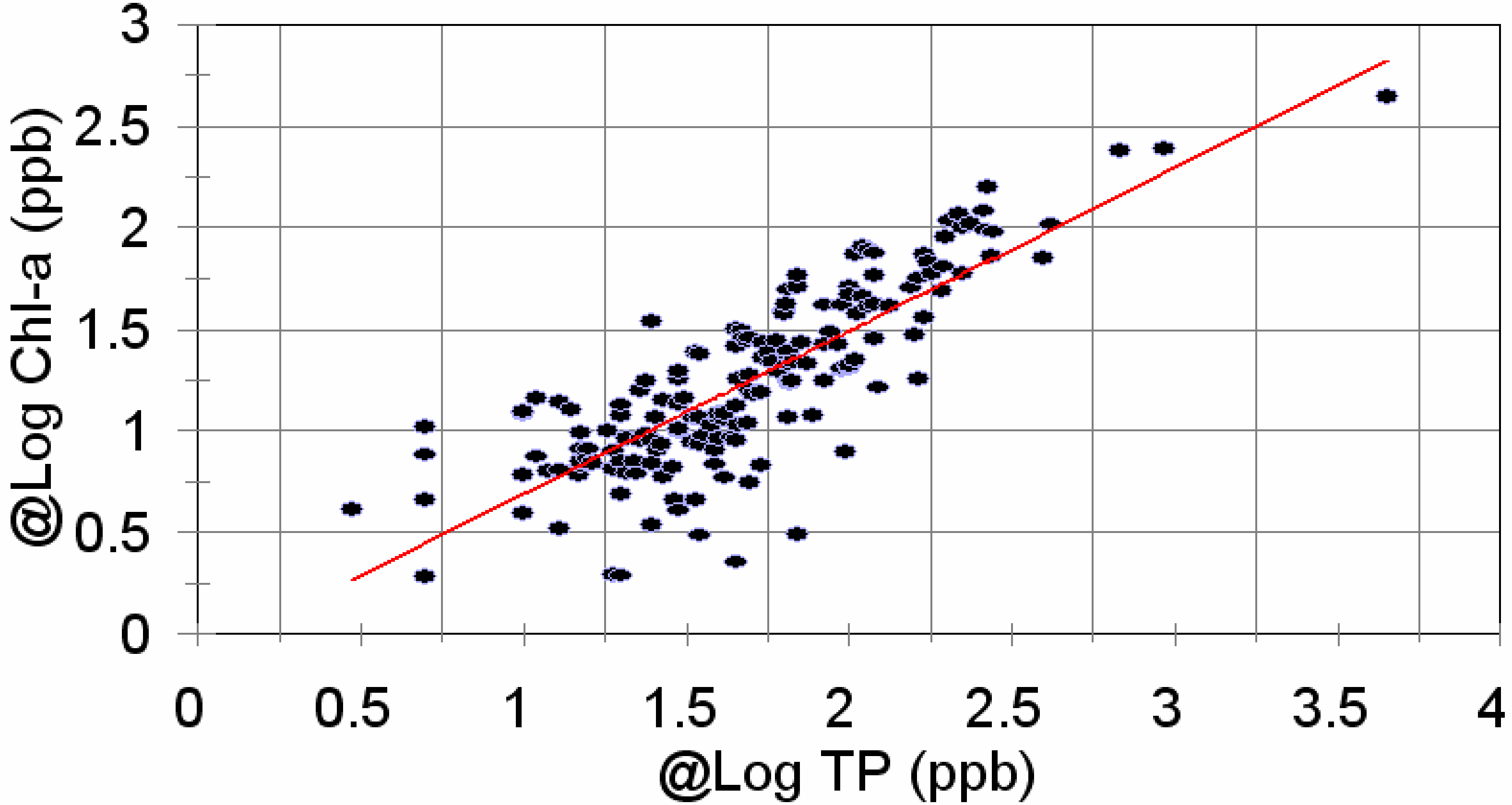
Watershed generates nutrients that travel to lake.

Nutrients interact with lake hydrology, morphology, light availability and…

Generate algal biomass.

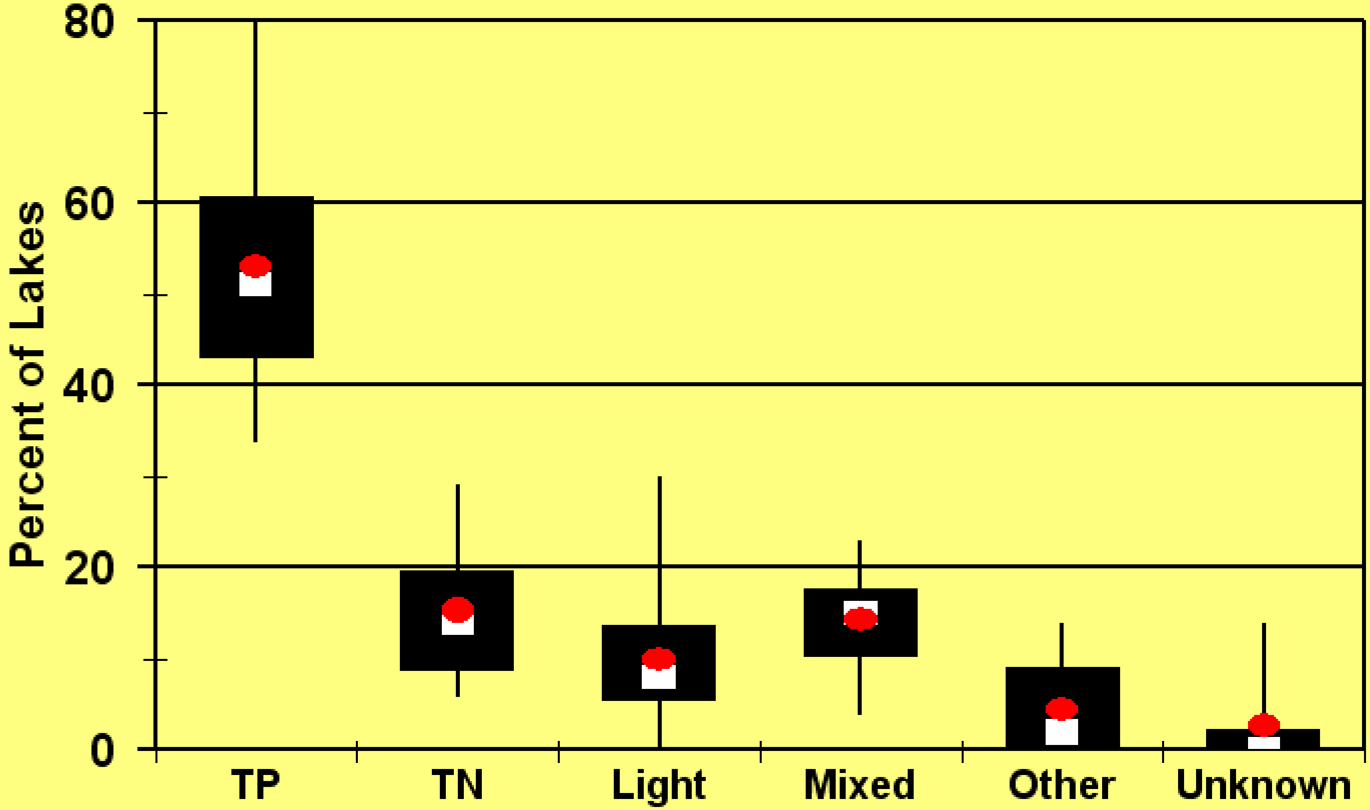
The higher the algal biomass (chlorophyll-a) is, on average, the higher the trophic status of the lake.

Chlorophyll-a Vs. TP



Limiting Factors

1992 through 2006



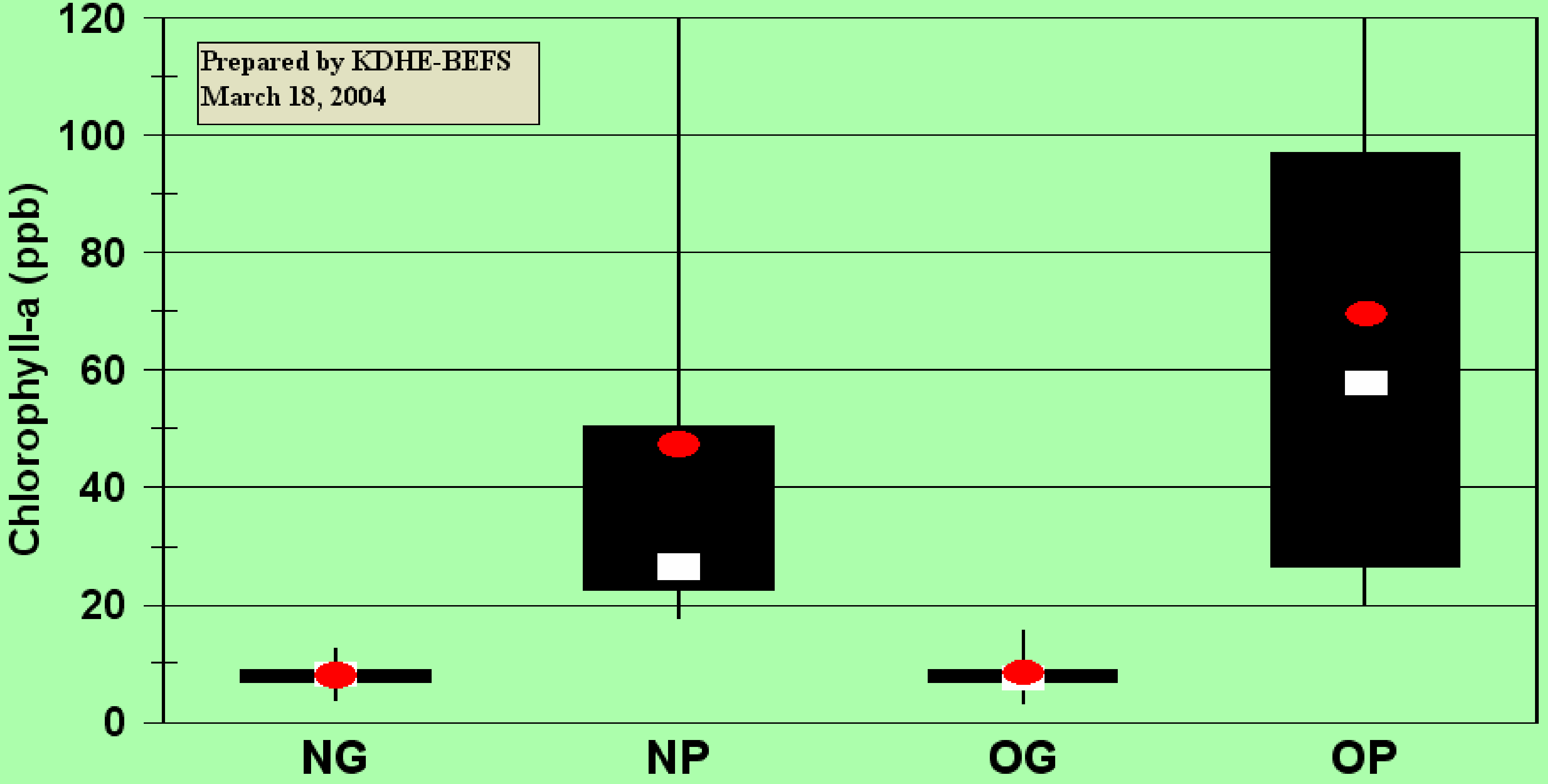
Fallacy of Eutrophication As Lake Aging

Although found in many books, and sometimes useful in trying to explain eutrophication, the “lake aging” analogy fails in two respects….

Because lakes can begin their lives at points other than “zero,” and….

The eutrophication process can reverse.

Mean Chlorophyll-a by Group



Ecological Impacts Of Eutrophication

More than any specific impact, eutrophication

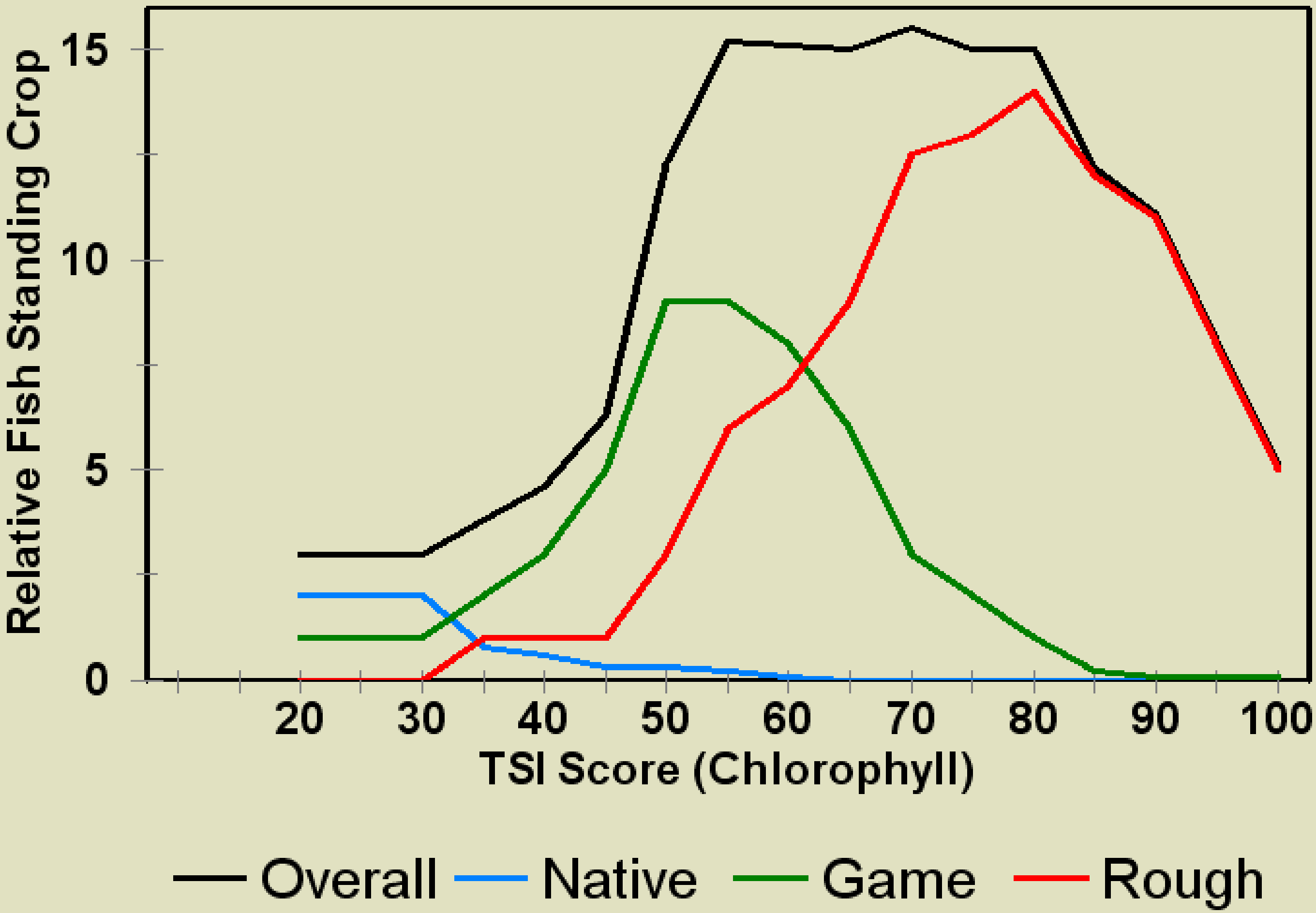
1. Reduces diversity, richness, and complexity of the biological community …and
2. Simplifies food webs and energy pathways …and
3. Reduces the systems ability to tolerate and recover from perturbations.

Economic Impacts Of Eutrophication

Many ecological impacts readily translate into economic impacts, such as…

1. Loss of recreation revenues
2. Increased costs for water supply
3. Fishkills, Taste and Odor events, Algae Blooms
4. Loss of opportunity revenues, and
5. Potential health impacts and costs.

Fisheries Vs. Trophic State

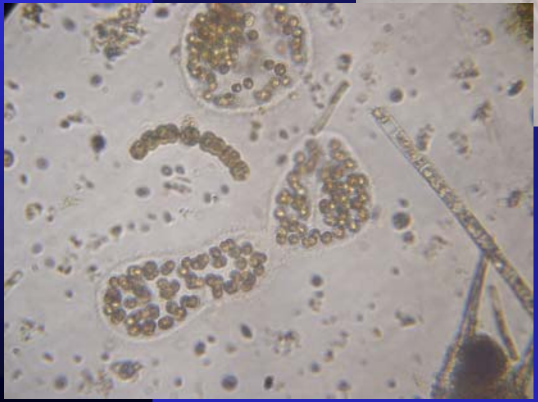


Blue-Green Algae

There are a number of algal “groups” with similar features and traits.

These include green algae, diatoms, golden algae, dinoflagellates, cryptophytes, euglenoids, and blue-green algae.

In the Midwest, the blue-greens are the primary cause of most eutrophication related impacts.

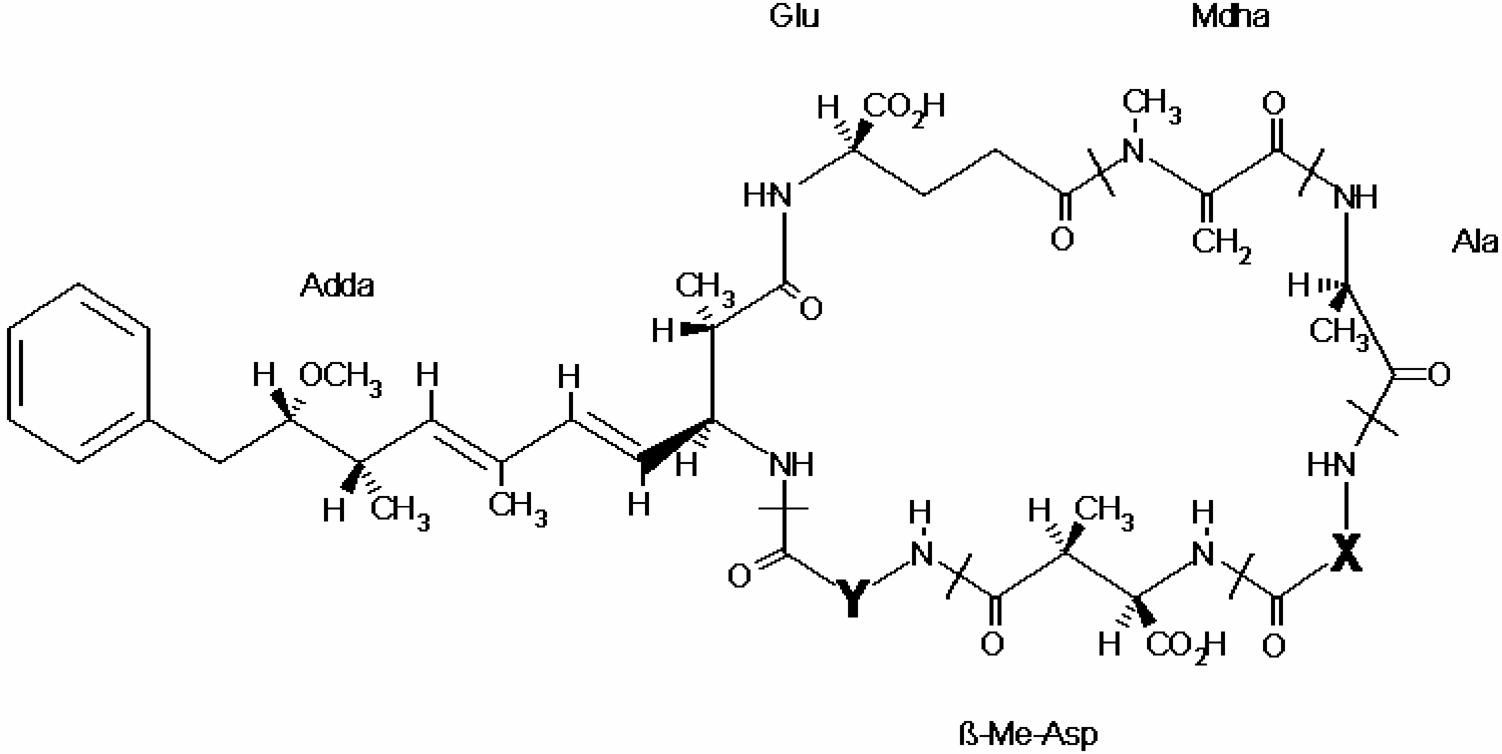

Blue-Green Algae And Special Concerns

Although other types of algae produce toxins and taste/odor compounds, blue-greens hold special concern because they are often the dominant algae in our lakes.

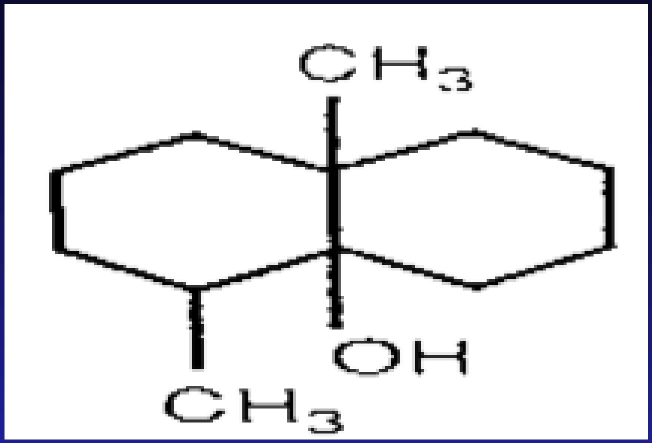
Toxins of concern are primarily the microcystins.

Geosmin and MIB are common T&O compounds.

Microcystins



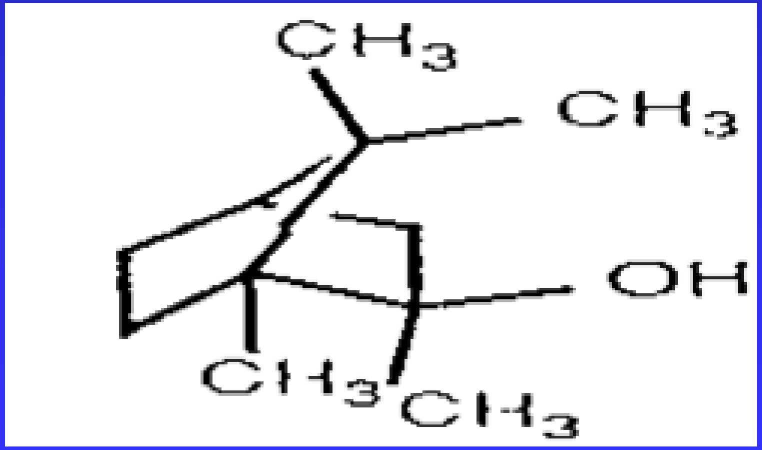
	X	Y
MC-RR	Arginin	Arginin
MC-YR	Tryptophan	Arginin
MC-LR	Leucin	Arginin
MC-LA	Leucin	Alanin



Geosmin

MIB

2-methylisoborneol



When Thinking of Eutrophication……….

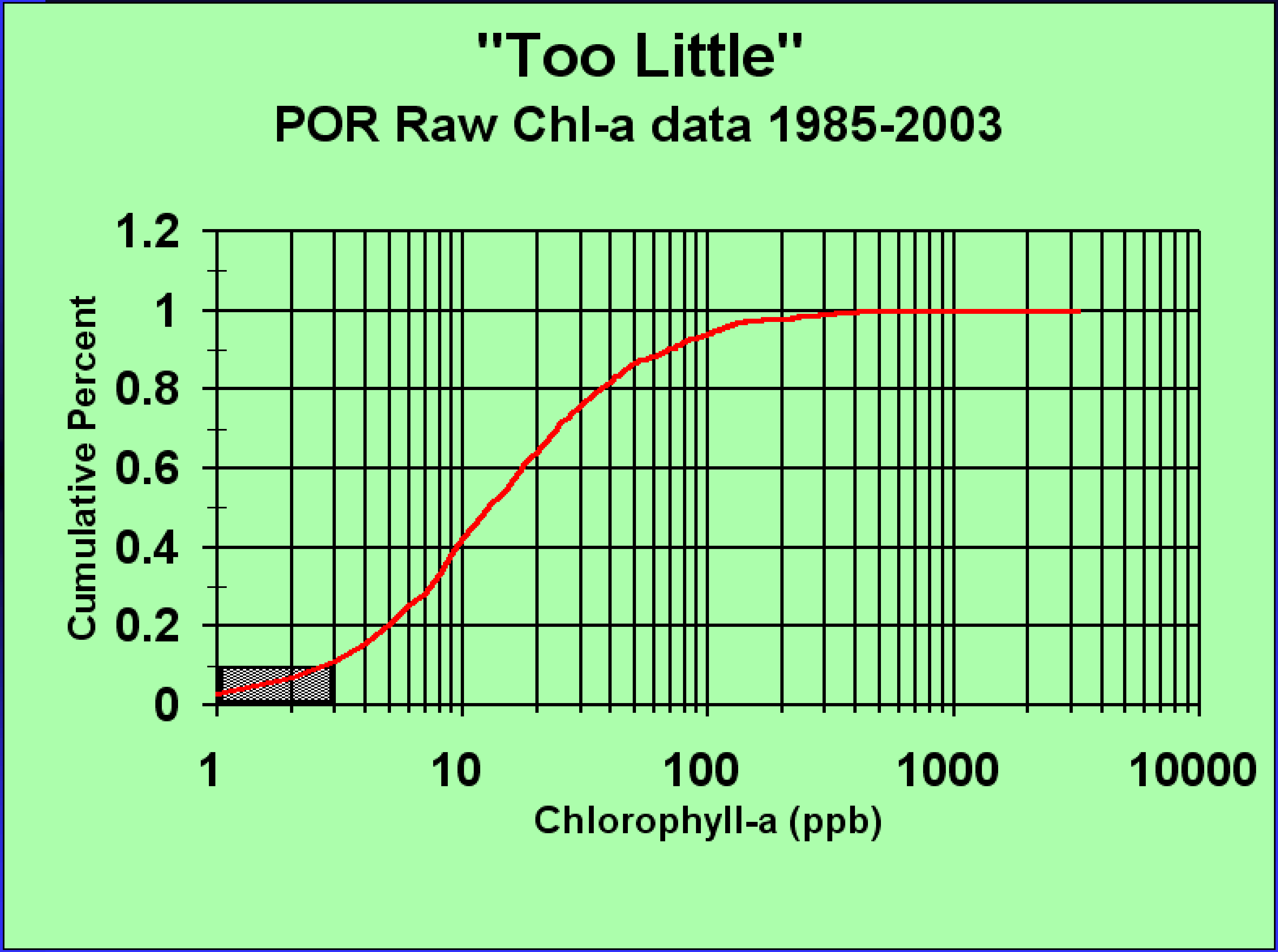
It works well to think of

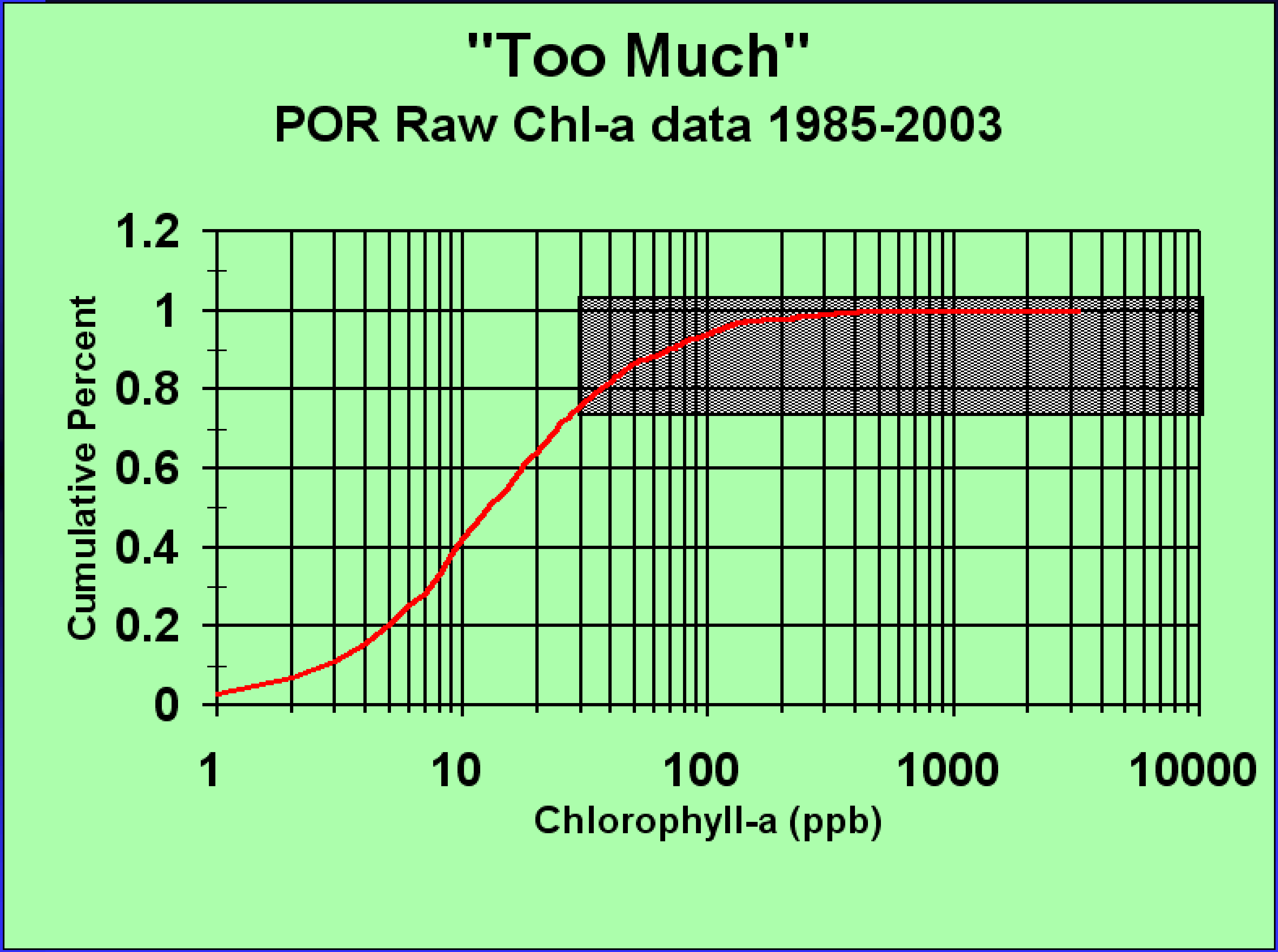
"Goldilocks and the Three Bears."

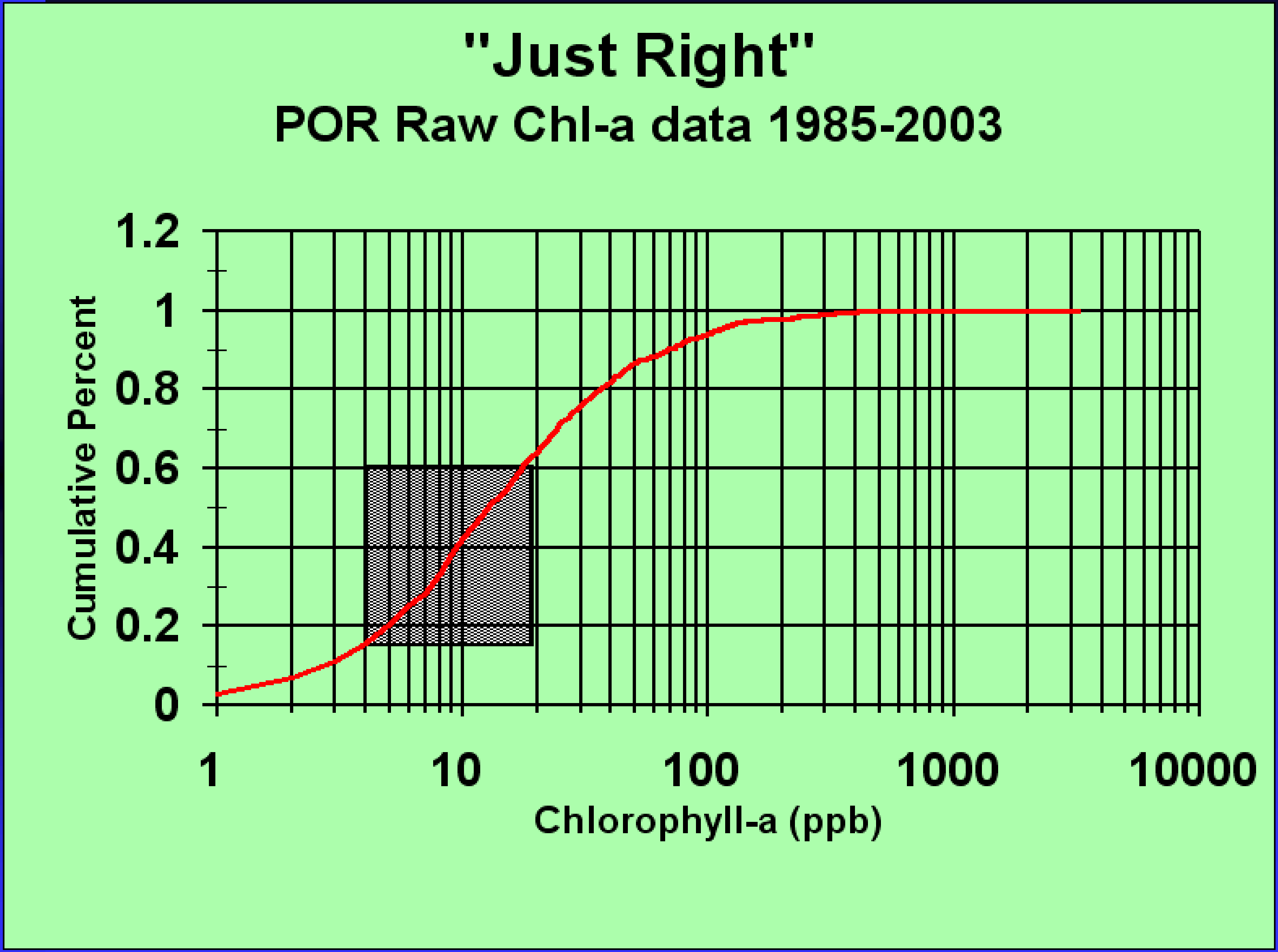
Or…..In this case…..

"Cyanolocks and the Eutrophication Bears."

(Nutrients, Light Environment, Hydrology)


"Too Little"
POR Raw Chl-a data 1985-2003
Cumulative Percent
1.2
1
0.8
0.6
0.4
0.2
0
1
10
100
1000
10000
Chlorophyll-a (ppb)


"Too Much"
POR Raw Chl-a data 1985-2003
1.2
1
0.8
0.6
0.4
0.2
0
Cumulative Percent
1
10
100
1000
10000
Chlorophyll-a (ppb)


"Just Right"
POR Raw Chl-a data 1985-2003
Cumulative Percent
1.2
1
0.8
0.6
0.4
0.2
0
1
10
100
1000
10000
Chlorophyll-a (ppb)

The Connection Between Blue-Greens and Nutrients

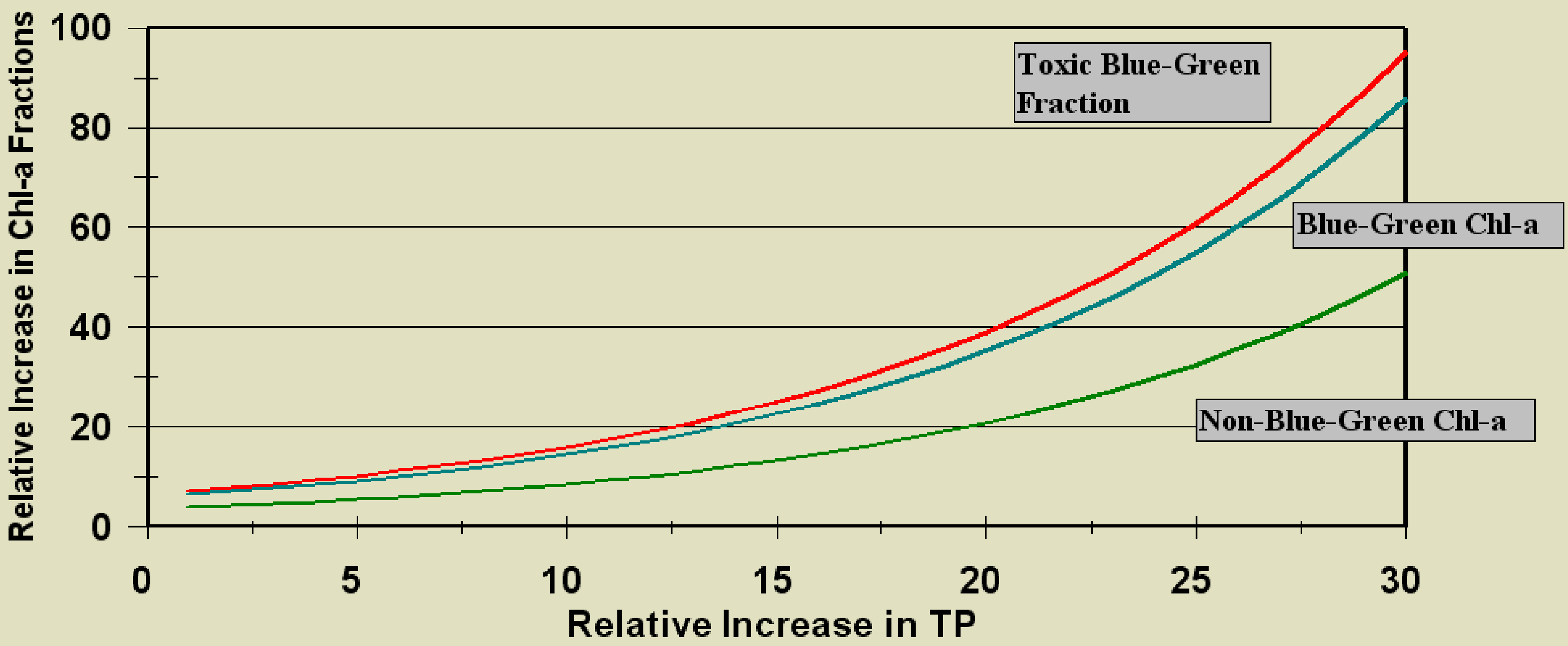
Increases in algal biomass are linked in mostly linear relationships with phosphorus (and nutrients in general).

However, for blue-green algae that relationship is exponential…….and increases even more for the toxin producing strains of blue-green algae.

More TP = more algae, but the probability of blue-greens and toxins increases dramatically with TP.

Relative Impacts

Based on Giani et al., 2005



So….How Does This Relate to Aquaculture?

Aquaculture is the recreation of an ambient aquatic system to a scaled down version that tries to maximize production of a specific aquatic feature.

The processes that cause impacts in ambient systems can also cause them in a simplified production-based system.

Eutrophication Concerns in Aquaculture

Aquaculture becomes a “balancing act” with nutrients. Enough to maximize the end product but not enough to create the negative impacts. The “just right” among the “bears.”

Avoiding high ammonia, low dissolved oxygen, toxins, and tainting compounds.

Dealing with downstream impacts from discharges.

The Case of Fish Feeding in Lakes

The use of fish feeders to augment fisheries in lakes (usually channel cat) may be the most obvious analogy to aquaculture in ambient systems in Kansas.

Most aquaculture in Kansas seems to be pond based, for channel cat, catfish, or bait fish? Most of these fish are grown by feeding them directly using commercial feeds?

Direct vs. Indirect

In the early 1990s, there was debate on whether fish feeders were preferable to lake fertilization for fishery augmentation (mainly channel cat production).

KDHE produced a modeling based comparison which clearly showed direct feeding was better (both for growing fish and to mitigate environmental problems), much like in aquaculture.

Feeders increased ambient TP and Chl-a by <2%, worst case, while fertilization would typically cause increases >30% and potentially as high as 200%.

Direct vs. Indirect

Indirect fish feeding by increasing nutrients and eutrophication rate was indicated to cause large “collateral” damage to other lake uses and potential future uses. There is also a high probability that increased nutrients would not channel themselves into useful food for a fishery.

The remaining issue with fish feed in commercial operations (based on recent literature) is with moving to feeds not derived from other fish caught in the wild, thus improving the ultimate global benefits of aquaculture.

The End: Unless Anyone Wants To Pose A Question?