G. Other potentially related topics

Outline

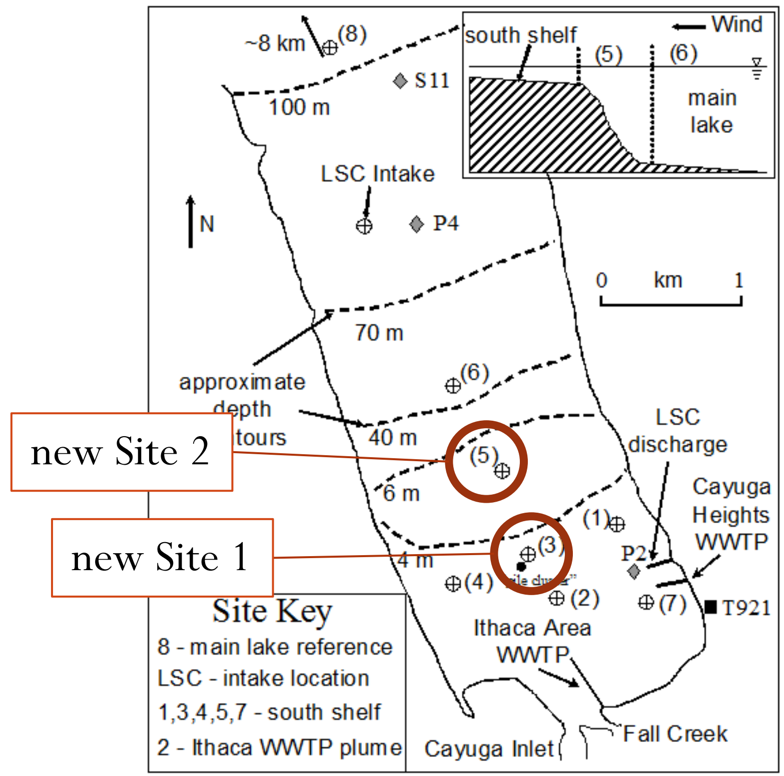
1. Near-field phosphorus monitoring issues
2. problems with potential application of the phosphorus Narrative Standard for the shelf
3. improved scientific status of the representation of minerogenic particles: Opportunities for advancement and management
4. chlorophyll *a* as an alternative trophic state metric to guide management
5. expectations for increased sediment delivery in NY from anticipated effects of climate change

1. Near-field phosphorus monitoring issues

Spatial issues on the shelf: Avoiding the complexities of changes in the "near-field"

- "near-field" the area adjoining the point of entry of inflows, with concentrations approaching those of the inflows – extent depending on turbulence of the inflow and ambient lake waters
- original sampling sites for LSC monitoring vs 2013 study
- original site 2 recognized to irregularly reflect the higher concentration of the IAWWTP near-field conditions
  - – not historically included in representation of average shelf concentration (an accepted protocol)

Fig. 1 2006 LSC Annual Report

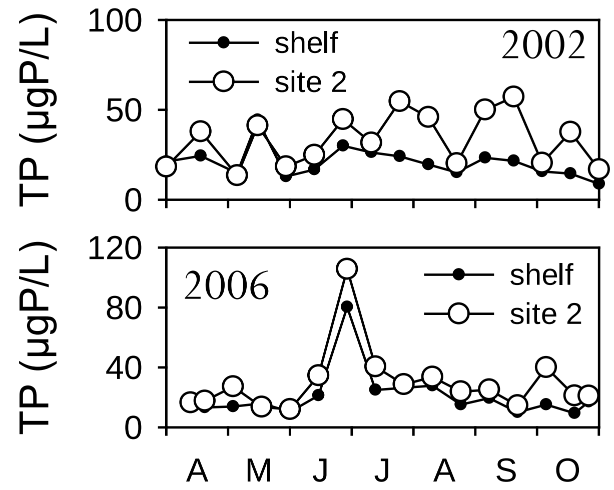


- lake sampling sites adopted in 2013 study were guided by NYSDEC

Findings of study of IAWWTP outfall TP implications from Actiflo upgrade

"IAWWTP tertiary treatment upgrades before/after impact study: effects and lake phosphorus results"
Jose Lozano and Lynn Smith (2011)

- sampling (multiple local lake) and measurements by IAWWTP in 2005 (before) and 2006 (after)
  - ~ 60% decrease in effluent TP
  - ~ 40% decrease in local (including near-field) TP
- lake response with respect to TP was not targeted specifically by the coincident LSC monitoring program
  - however, reductions in TP at site 2 observed in 2006 were quantitatively consistent with the charge observed in that year



this local (e.g., near-field) improvement was not manifested in the long-term trend for the shelf consistent with mixing effects at larger scales

2. Problems with potential application of the phosphorus Narrative Standard for the shelf

Narrative phosphorus standard: Scientific context

2 1

"none in amounts that will result in growths of algae weeds, and slimes that will impair the waters for their best usages"

3

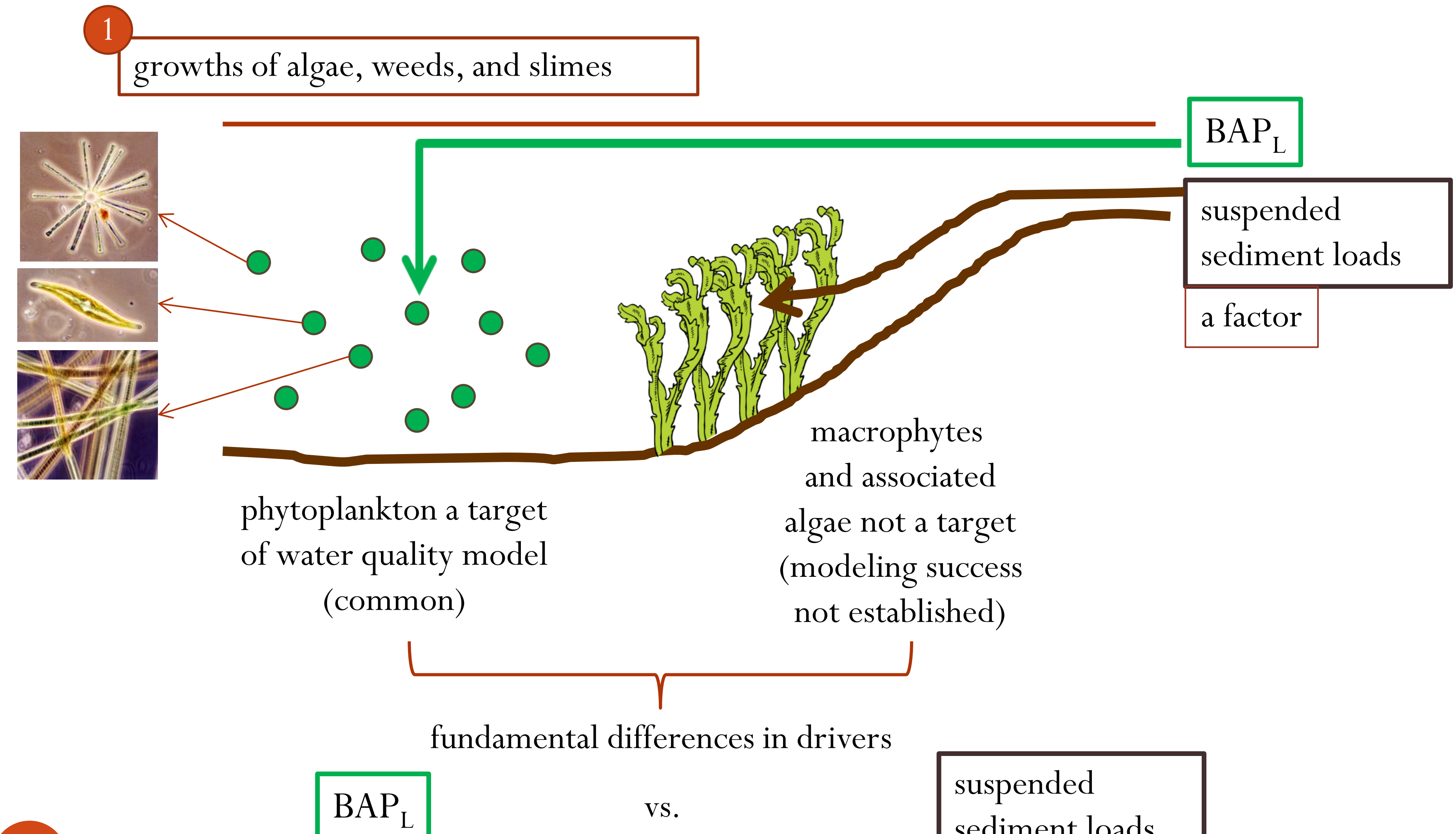
multiple scientific short-comings/issues would compromise the use of this language in an effort to protect the shelf, and potentially elsewhere in New York

1

growths of algae, weeds, and slimes

- "slimes" – not contemporary language – could include various biological communities
- algae – varied types
  - phytoplankton – open waters; targeted in this study
  - epiphytic – attached to macrophytes
  - attached macroalgae – e.g., *Cladophora*
- weeds – submerged macrophytes often the primary concern
  - epiphytic and attached macroalgae associated with the submerged macrophytes
    - water column P sources for the non-macrophytes, but
    - generally overall biomass dominated by the macrophytes

Narrative phosphorus standard: Scientific context



Narrative phosphorus standard: Scientific context

1 growths of algae, weeds, and slimes

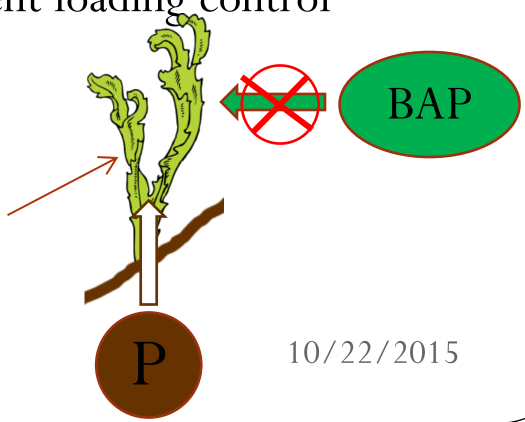
- the dominance of sediments vs the water column as the source of phosphorus for most submerged macrophytes is well established science
  - scientific position presented earlier (July 24, 2013; NYSDEC meeting, Albany)
  - supported by scientific literature – with limited exceptions
  - leading citations:
  - Carignan and Kalff. 1980. Phosphorus Sources for Aquatic Weeds: Water or Sediments? *Science* 202:987-989.
  - Wetzel. 2001. Limnology: Lake and River Ecosystems

- therefore, management of P external loading (BAP_L) cannot be quantitatively linked to control of weed growth

2 "none in amounts"

- however, a qualitative positive linkage between external sediment loading and weed growth is reasonable
  - advancement in sediment modeling (PAV_m) could contribute to a long-term sediment loading control strategy

PAV_m loading may promote through local deposition



Quotes from Wetzel (2001), not supportive of the application of New York's narrative phosphorus standard for the shelf phosphorus issue

1 and 2

- a leading limnology book, featuring review of critical scientific findings on multiple topics
- selected quotes from book presented, Chapter 18*

<u>page 545</u>
"An overwhelming accumulation of evidence now demonstrates that rooting tissues are essential for primary acquisition of nutrients for aquatic plants, including those that are submersed."

* see Wetzel's book for cited references

Quotes from Wetzel (2001), not supportive of the application of New York's narrative phosphorus standard for the shelf-phosphorus issue

1 and 2

- a leading limnology book, featuring review of critical scientific findings on multiple topics
- selected quotes from book presented, Chapter 18

page 547

"Where experiments are designed to specifically examine these pathways (e.g., Moeller et a!., 1988), clearly most of the phosphorus acquisition by the macrophyte was from roots, and uptake from the water was largely into epiphytic microorganisms and predominantly independently cycled in the epiphytic periphyton (cf. Chap. 19)."

Quotes from Wetzel (2001), not supportive of the application of New York's narrative phosphorus standard for the shelf-phosphorus issue

1 and 2

- a leading limnology book, featuring review of critical scientific findings on multiple topics
- selected quotes from book presented, Chapter 18

page 548

"Experimental analyses have demonstrated that most rooted submersed angiosperms obtain most of their phosphorus from the interstitial water of the sediments (Bristow and Whitcombe, 1971; Schults and Malueg, 1971; DeMarte and Hartman, 1974; Bole and Allan, 1978; Welsh and Denny, 1979; Barko and Smart, 1980; Carignan and Kalff, 1980; Gabrielson et at., 1984; Moeller et at., 1988; Chambers et at., 1989). Although some evidence is contradictory (e.g., Seadler and Alldridge, 1977; Swanepoel and Vermaak, 1977), most studies show an active absorption by the roots and translocation to the leaves."

Quotes from Wetzel (2001), not supportive of the application of New York's narrative phosphorus standard for the shelf-phosphorus issue

1 and 2

- a leading limnology book, featuring review of critical scientific findings on multiple topics
- selected quotes from book presented, Chapter 18

page 548

"Detailed studies of the transport of phosphorus through the epiphytic algae and bacteria (Moeller et at., 1988) have demonstrated that most of the phosphorus is actively recycled within the periphyton and that most of the phosphorus utilized by the submersed macrophytes is absorbed by the roots and translocated to the foliage. These studies indicate that many earlier studies that attributed high phosphorus uptake by the macrophytes from the water are in part simply a reflection of the inability to separate the uptake by epiphytic microbiota from the true assimilation from the water by the submersed angiosperm. High phosphorus concentrations in water frequently encourage the prolific development of epiphytic algae to the detriment of submersed macrophytes light attenuation (see Chap. 19)."

Narrative phosphorus standard: Variations/changes in the macrophyte community

- personal communication from Robert L. Johnson; macrophyte expert, with Cayuga Lake experience
- his monitoring of the shelf has been as extensive effort, resulting in more information than in most New York lakes
- recent densities (g/m^2) are no greater than in the 1980s and 1990s; generally diminished
- observed changes
  - Eurasian water milfoil replaced by native plants
  - locations of maximum density have shifted
  - multiple potential drivers – other biota, local deposition rates and clarity (light penetration) related to runoff events
- generally similar to many other NYS lakes

Narrative phosphorus standard: Uniqueness of Cayuga Lake weed situation?

3 impair the waters for their best usages

- generally most dense weed growths are in shallow depths, observed in many New York lakes




- useage interfered with – recreational activities? other?
- but broadly occurring
  - how many sites are implementing the narrative standard for these conditions in New York?
- user control methods available and implemented

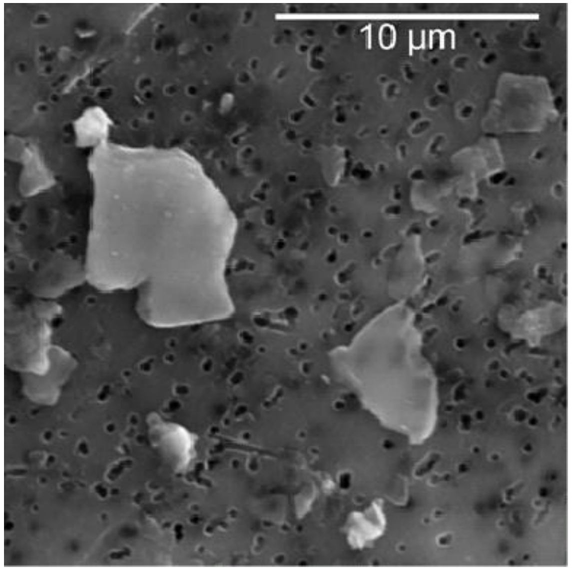
Narrative phosphorus standard: Considerations relative to its incorporation in the Cayuga Lake initiatives

- existing language is flawed relative to the scientific understanding of the contrasting sources of P for different aquatic plants
  - phytoplankton – water column; i.e., linked to BAP_L
  - weeds – underlying sediment; i.e., not well linked to BAP_L, more dependent on external sediment loading
- the relationship between external loads (BAP_L) and weed growth, and thereby the application of the Narrative Standard for the shelf P listing, is not supported for Cayuga Lake
- weeds, and related management pathways, are not being addressed in this water quality modeling initiative (agreement with NYSDEC), for related cause – *disconnect with* BAP_L
- the dense weed growths in shallow portions of the shelf occur widely in lakes in New York, and beyond (Wetzel 2001)
- the Cayuga Lake study initiative is making multiple contributions, outside of BAP_L that may be valuable in pursuing weed growth on the shelf
  - sediment loading, transport and local deposition – the minerogenic particle submodel
  - optics submodel – supports prediction of light available to support weed growth and relationship to external loads

3. Improved scientific status of the representation of minerogenic particles: Opportunities for advancement and management

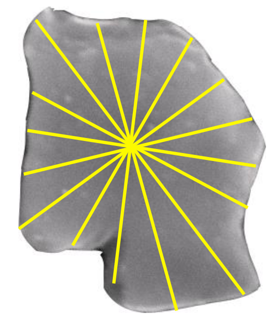
Improved scientific status of the representation of minerogenic particles: Opportunities for advancement and management

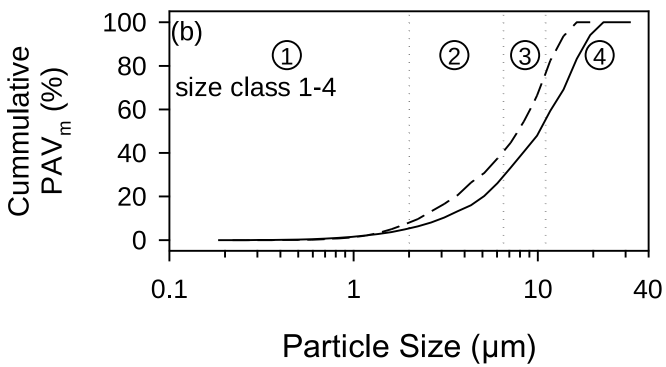
- minerogenic particles dominate the sediment loading to many lakes and reservoirs (i.e., ISPM>>OSPM); e.g., Cayuga Lake
- this sediment loading has any array of potential impacts that support the value of a lacustrine model to simulate its effects
  - net sediment accumulation
  - metabolic activity and composition of biological communities
  - apportionment, transport, cycling of nutrients and contaminants
  - optical attributes of water quality



Improved scientific status of the representation of minerogenic particles: Opportunities for advancement and management

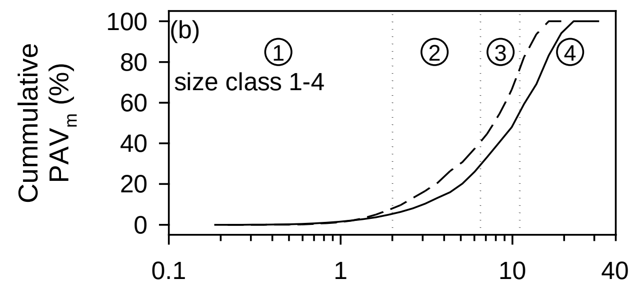
- the advancement relies on embracing the new measurement technology (SAX) and the metrics of minerogenic particle morphology (PA_m, PAV_m) and chemical type (e.g., clay minerals)
- the advancements to date, including at Cayuga Lake, have been based on SAX monitoring of both tributaries and lakes, according to particles size (PSD) and type
- the historic gravimetric approaches (e.g., ISPM) fail, particularly when extended from tributaries into the more dilute lacustrine receiving systems



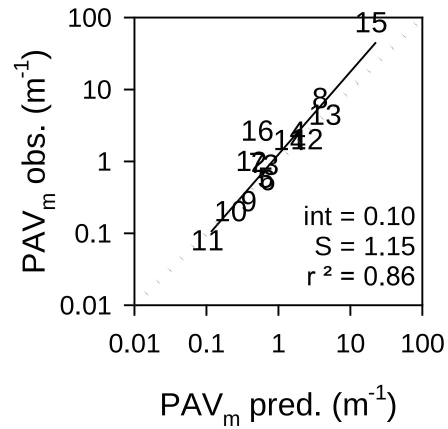


Improved scientific status of the representation of minerogenic particles: Opportunities for advancement and management

- polydispersed minerogenic particle populations have been found to be important in Cayuga Lake and elsewhere
  - optical metrics of water quality
  - P measurements ($PP_{m/u}$)
  - additional features not yet addressed here
    - e.g., biological communities (macrophytes), contaminants fate and transport, sediment accumulation (shelf



- the first multiple size class PAV_m model was developed and successfully totaled for Cayuga Lake, to support modeling of $PP_{m/u}$ (i.e., serving as a submodel)
  - however, this PAVm (sediment) model has great potential to support other issues for this lake, including issues identified to be related to the existing "sediment listing"
  - *the PAV_m basis provides unique scientific and functional credibility for the particle/sediment model*



model performance

Improved scientific status of the representation of minerogenic particles: Opportunities for advancement and management

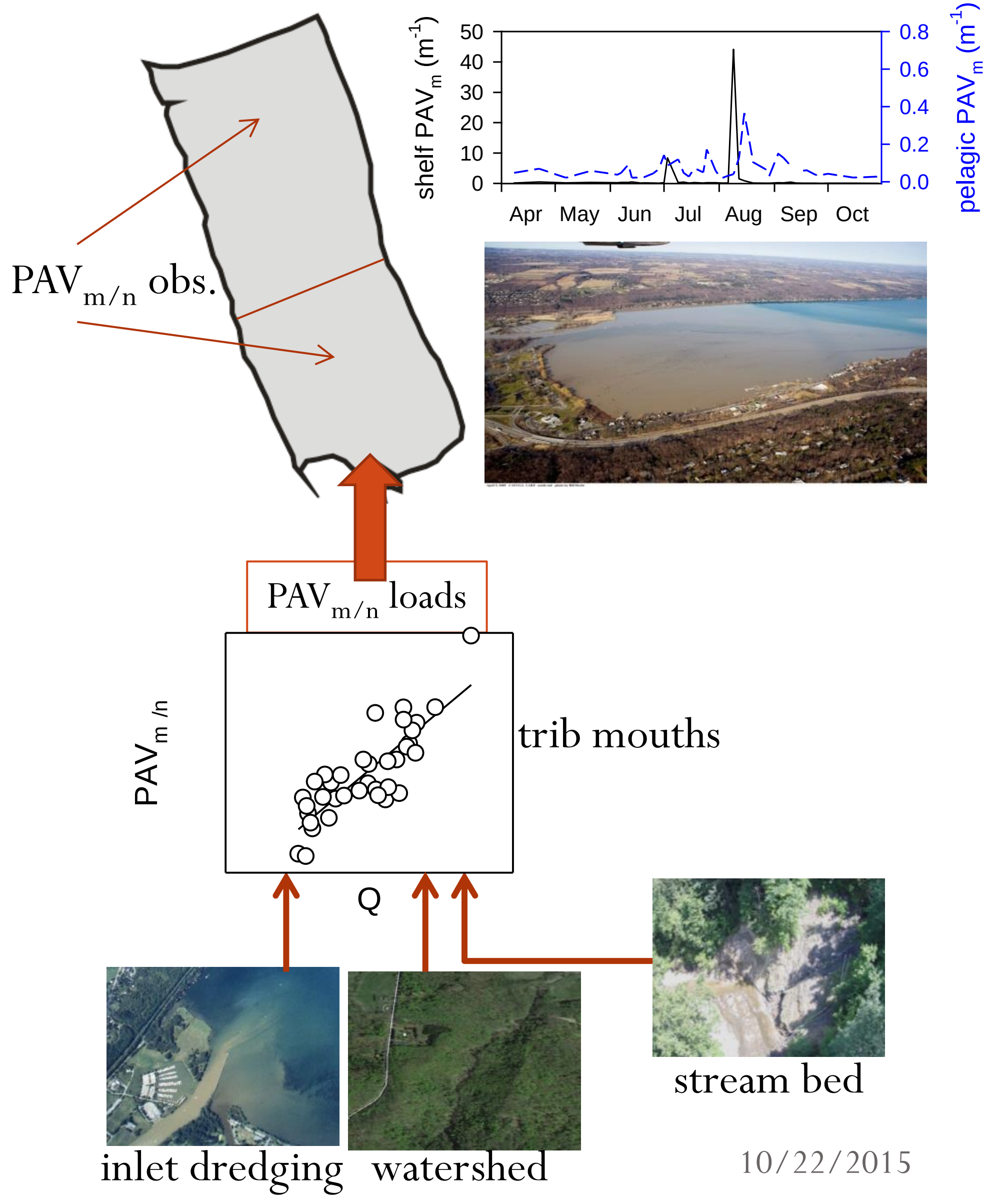
- this system, particularly at its southern end, has substantial sediment/minerogenic particle impacts following runoff events



- predicted effects of climate change would exacerbate such effects, because of increased occurrences and severity of such events (NOAA 2013)

Improved scientific status of the representation of minerogenic particles: Opportunities for advancement and management

- potential further (future) application of the Cayuga Lake PAV_m model
  - sediment listing issues of the shelf
    - manageability – stream banks, watersheds, Inlet dredging
    - runoff event dependencies
    - climate change implications
    - target metrics
- other similar cases in New York
- advancing the model
- evaluate potential management targets
- questions/studies – throughout the components



Stream bank erosion and sediment loading impacts on lake sedimentation

- from Nagle 2007 (stream bank erosion)

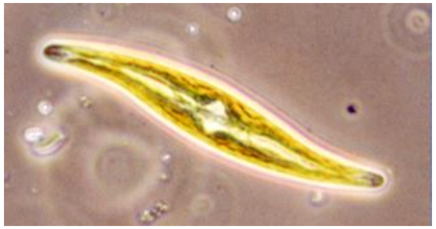
Stream Name	Sediment Loading from Bank Erosion (%)
Six Mile	76
Fall Creek	52
Cayuga Inlet	76
Salmon Creek	57

- from Yager 2001 (sediment core analyses)

Period	Sediment Accumulation Rates
pre-settlement	<1 mm/yr
since 1900	2.4-6 mm/yr
since 1950	2.4-8.1 mm/yr

4. Chlorophyll *a* as an alternative trophic state metric to guide management

Chlorophyll-*a* (Chl-a) as a trophic state and phytoplankton biomass metric



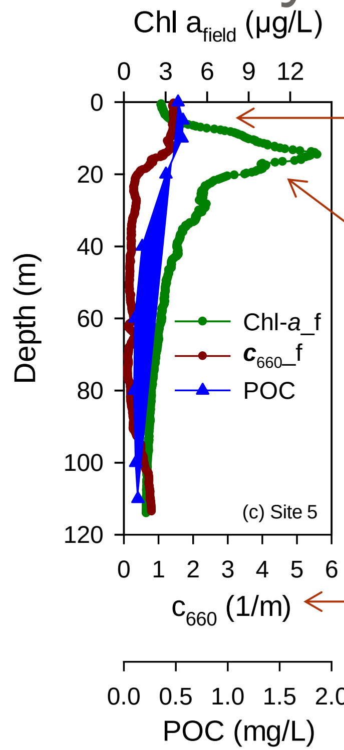
1. One of the three most widely used metrics of trophic state –total P (TP) concentration and Secchi depth (SD) are the other two
2. Chl-a advantage – does not suffer from interference from non-phytoplankton particles, as both TP and SD do
3. Chl-a disadvantage – individual observations are weak measurements of phytoplankton biomass – cellular content is dependent on community composition and ambient conditions (see Reynolds 2006)
   - more valuable as temporal average over extended intervals; number of observations a limiting issue

Chlorophyll-*a* (Chl-*a*) as an alternate target metric: Measurement and water quality issue concerns

- fundamental limitations as a metric of phytoplankton biomass
  - amount per unit biomass varies as a function of ambient conditions and community composition
  - summary (e.g., average) values depend on timing and location of measurement
  - values depend on measurement protocols; laboratory and/or field
- Chl-*a* levels of concern
  - trophic state (e.g., mesotrophy earlier) – similar to the Vollenweider TP = 20 µg/L; corresponding Chl-*a* level(s) of ~ 8 to 10 µg/L for upper bound of mesotrophy
  - more recent, relative to public health concerns (e.g., disinfection by-products (DBPs)) Chl-*a* threshold of 4-6 µg/L was identified as protective of potable water supply lakes and reservoirs (e.g., Callinan et al. 2013)

Chlorophyll *a* measurement issues; Cayuga Lake – specific guidance on sources of variability

1. field fluorometric measurements now commonly made but have limitations



near surface photo-inhibition

deep chlorophyll maximum (DCM)

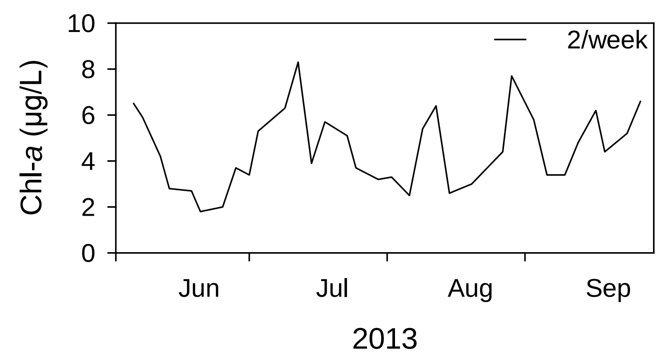
<u>vertical complexities from field fluorometric measurements</u>

light scattering

2. divergence with POC pattern (alternate biomass measure a concern)

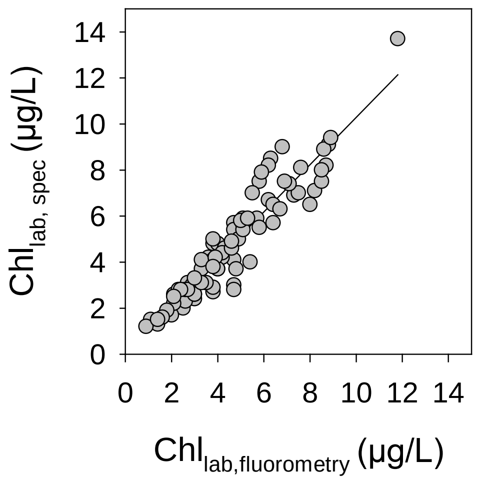
3. frequency – high better than low as an indicator of biomass

2/week: 4.5 µg/L
weekly: 4.5 µg/L
bi-weekly: 5 µg/L
monthly: 5.5 µg/L

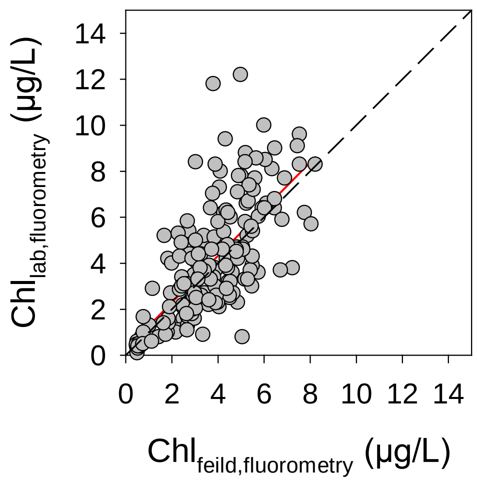


Chlorophyll *a* measurement issues; Cayuga Lake – specific guidance on sources of variability

3. laboratory methods – multiple, with some differences



4. field vs. laboratory measurements
   - field only for diagnostic value

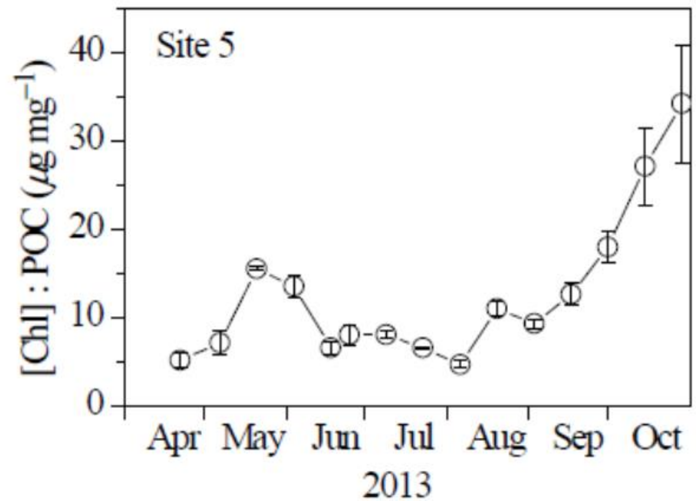


field measurements a rough indicator

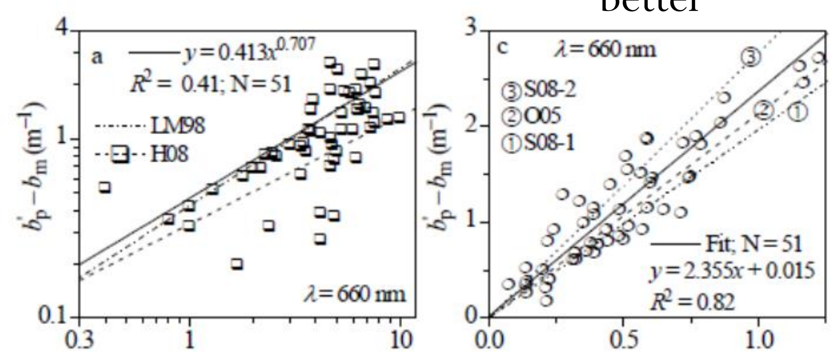
26% average deviation over 3-6 µg/L range

Particulate organic carbon (POC) as a preferred (vs. Chl-*a*) metric of phytoplankton biomass

1. Cellular content of POC more uniform than Chl-a (see scientific literature Peng and Effler 2015)
2. Dynamics of POC and Chl-a in upper waters of Cayuga L., not strongly correlated (r = 0.5)
3. Dynamics in Chl-a:POC ratio in upper waters. Cayuga L., 2013
   - highly variable
4. POC better predictor than Chl-a for particulate P (PP) and the organic particle component of light scattering (i.e., SD)
5. The better contemporary nutrient-phytoplankton model target POC, rather than Chl-a
   - Cayuga L. model – POC primary, Chl-a secondary (seasonally)



better



Chl-*a* POC

Peng and Effler (2015b)

5. Expectations for increased sediment delivery in NY from anticipated effects of climate change

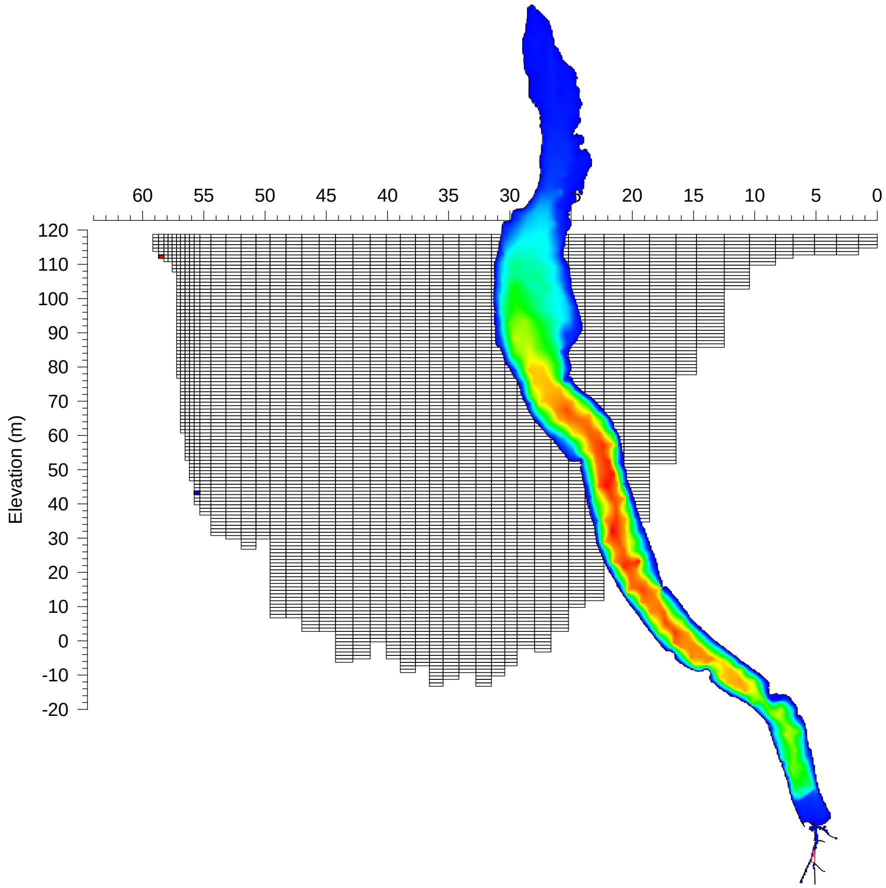
Linkages between climate change and water quality in New York

- manifested as changes in meteorological drivers
- climate model projections for the northeast
  - NOAA (2013) - higher air temperatures, and increased occurrences and severity of rainfall (i.e., runoff) events
- water quality model evaluations of potential impacts elsewhere
  - NYC watershed initiatives
  - USEPA informal review
  - big challenges in downsizing climate model outputs for a specific site
  - NYC use of models developed by UFI and approved by USEPA (publications by NYCDEP group)
    - hydrothermal/transport
    - turbidity
    - nutrient/phytoplankton

NOAA (National Oceanic and Atmospheric Administration). 2013. Regional climate trends and scenarios for the U.S. national climate assessment. Part 1. Climate of the Northeast U.S. NOAA Technical Report NESDIS 141-1. Washington, DC, U.S. Department of Commerce.

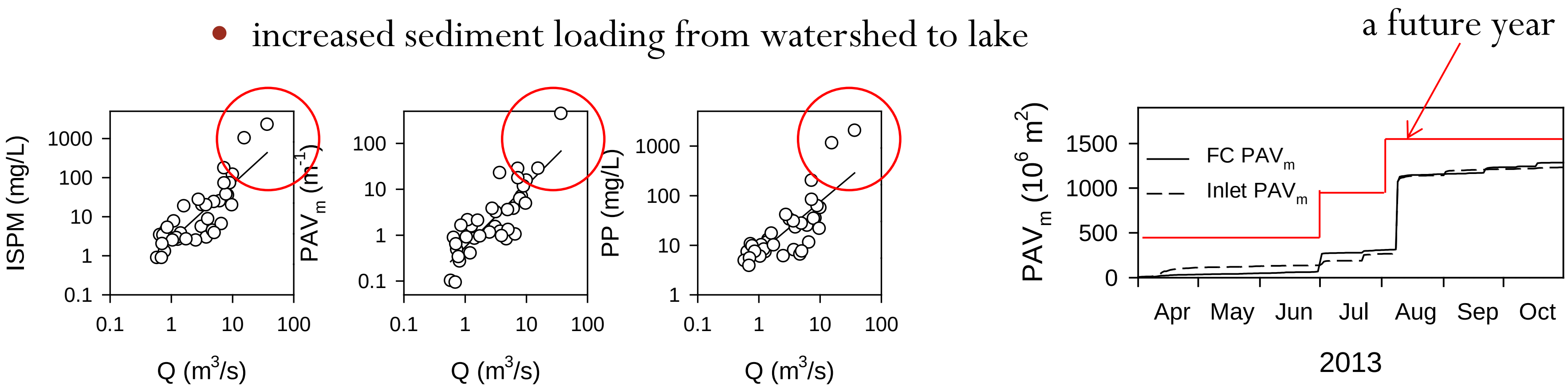
Linkages between climate change and water quality in New York

- higher air temperature effects
  - stratification/mixing regime could be pursued through application of the validated W2/T hydrothermal/transport model
  - biological communities
    - (e.g., production and composition of phytoplankton)



Linkages between climate change and water quality in New York: Preliminary thoughts for Cayuga Lake

- increased frequency and severity of runoff events
  - increased sediment loading from watershed to lake



  - increased lake concentrations of PAV$_m$, particularly on the shelf
    - degradations in optical features of water quality
    - increases in PP$_{m/u}$ and thereby TP
    - another reason to consider carefully the embedding of PP$_{m/u}$ in TP limits and management
  - important issues for sediment listing
    - magnitude of effect of climate change
    - manageability of tributary loads