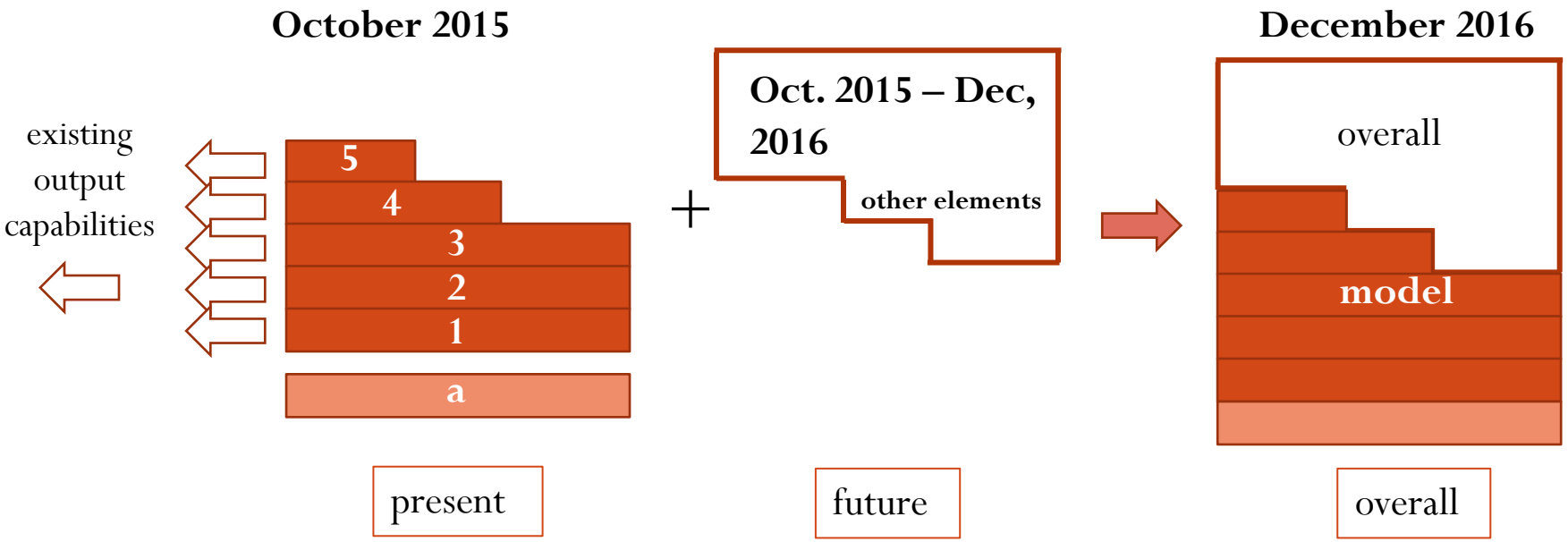
F. Scientific Status of Phosphorus Management for the Shelf

historic observations, process studies, model predictions, and other potentially related issues

There is presently a compelling scientific case against implementing further reductions in phosphorus (P) loading that targets trophic state conditions on the "shelf", rather than lake-wide for Cayuga Lake



- completed work
- scientifically accepted
- peer-reviewed publications

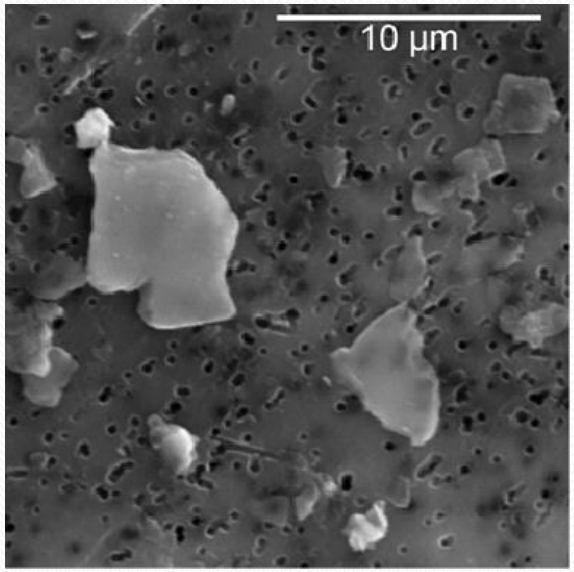
additional scientific information that is critical to the shelf P listing issue is not forthcoming over the Oct. 2015 – Dec. 2016 interval

Earlier dialogue and progress reporting documents an evolution to this position

- the 3 subsequent slides were reporting certain features of these finding to the group on Jan. 15, 2014
  - NYSDEC/TAC meeting with UFI, Cornell and others
- the following paper had been accepted by that date
  - Effler et al. (2014). Partitioning the contributions of minerogenic particles and bioseston to particulate phosphorus and turbidity. *Inland Waters*. 4:179-192.

Implications: Ecosystems-specific Shortcomings of TP as a Trophic State Metric Near-Shore (shelf)

- ✓ TP guidance value intended to protect against eutrophication-based degradations in water quality
- ✓ only forms of P that can support phytoplankton growth (bioavailable) should be included
- ✓ bioavailability of P forms:
  - soluble reactive P (SRP) - completely
  - dissolved organic P (DOP=TDP-SRP) - mostly
  - PP_o – completely (bioseston)
  - PP_m – limited (quantified by bioavailability assays)
- ✓ exceedances near-shore during summers of high PP_m
  - if low bioavailability, is this a trophic state issue?



Total P:
false-high metric of trophic state on shelf

Summary

- protocols to partition contributions of bioseston and minerogenic particles to Tn and PP, as 2-component summations were developed, tested, and applied
- basis: coincident observations of Tn, PP, Chl, and PAVm, 8 years, 2 sites (near-shore and pelagic) for Cayuga Lake – robust variations
- stoichiometric approach – 4 ratio values developed
  1. Tn_o:Chl
  2. Tn_m:PAV_m
  3. PP_o:Chl
  4. PP_m:PAV_m
- Tn, PP, PAV_m – higher near-shore than for pelagic

Summary

- reasonably good match of 2-component summations with observations for Tn and PP
  - good performance at an annual time step
- ✓ minerogenic particles
  - ✓ noteworthy to substantial contributions to PP
  - ✓ exceedances of TP guidance values near-shore in certain years due to high PP_m (allochthonous inputs);
    TP likely a "false-high" representation of trophic state for shelf
  - dominant component of Tn, supported by optical theory

There is presently a compelling scientific case against implementing further reductions in phosphorus (P) loading that targets trophic state conditions on the "shelf", rather than lake-wide for Cayuga Lake

- three critical scientific elements
  A. the demonstrated unresponsiveness of the shelf, and shelf vs. pelagic conditions, to substantial reductions in local BAP_L
  B. the demonstrated rapid flushing of the shelf relative to rates of phytoplankton growth in natural waters
  C. the demonstrated fundamental flaws of the concentration of TP as a measure of trophic state on the shelf, and its comparison with pelagic waters of the lake
- these scientific elements are based on extensive scientific data, analyses, and related publications in the peer-reviewed literature

A. Analysis of long-term data for trophic state metrics in Cayuga Lake: Background

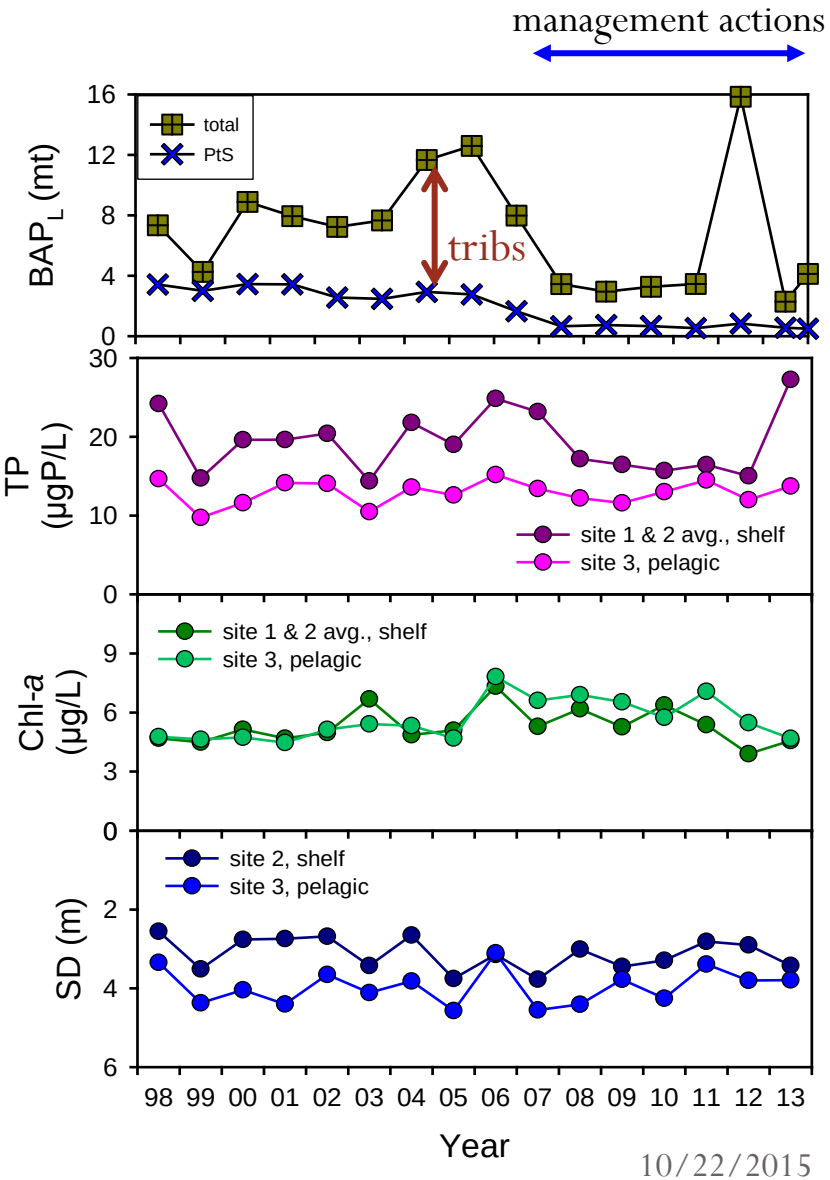
Analysis of the responses to earlier reductions in phosphorus loading

- based on LSC monitoring program
  - 1998-2012, most comprehensive for the period (plus 2013)
  - bi-weekly, upper waters, pelagic (site 3) and shelf (sites 1 and 2) locations
    - site 3 demonstrated to be representative of lake-wide pelagic waters in 2013 program
  - Jun.-Sept. primary (regulatory) focus
- ID signatures for modeling
  - responsiveness to the "experiment" – decreases in point source loading (local) to the shelf
    - time signatures?
    - space signatures?
- differences in the trophic state metrics
  - TP – concentration of total P
  - SD – Secchi disk depth (Site 1 not considered – too shallow)
  - Chl-*a* – concentration of chlorophyll *a*
- results of the analyses previously presented in Phase I report (Dec. 2014); i.e., accepted

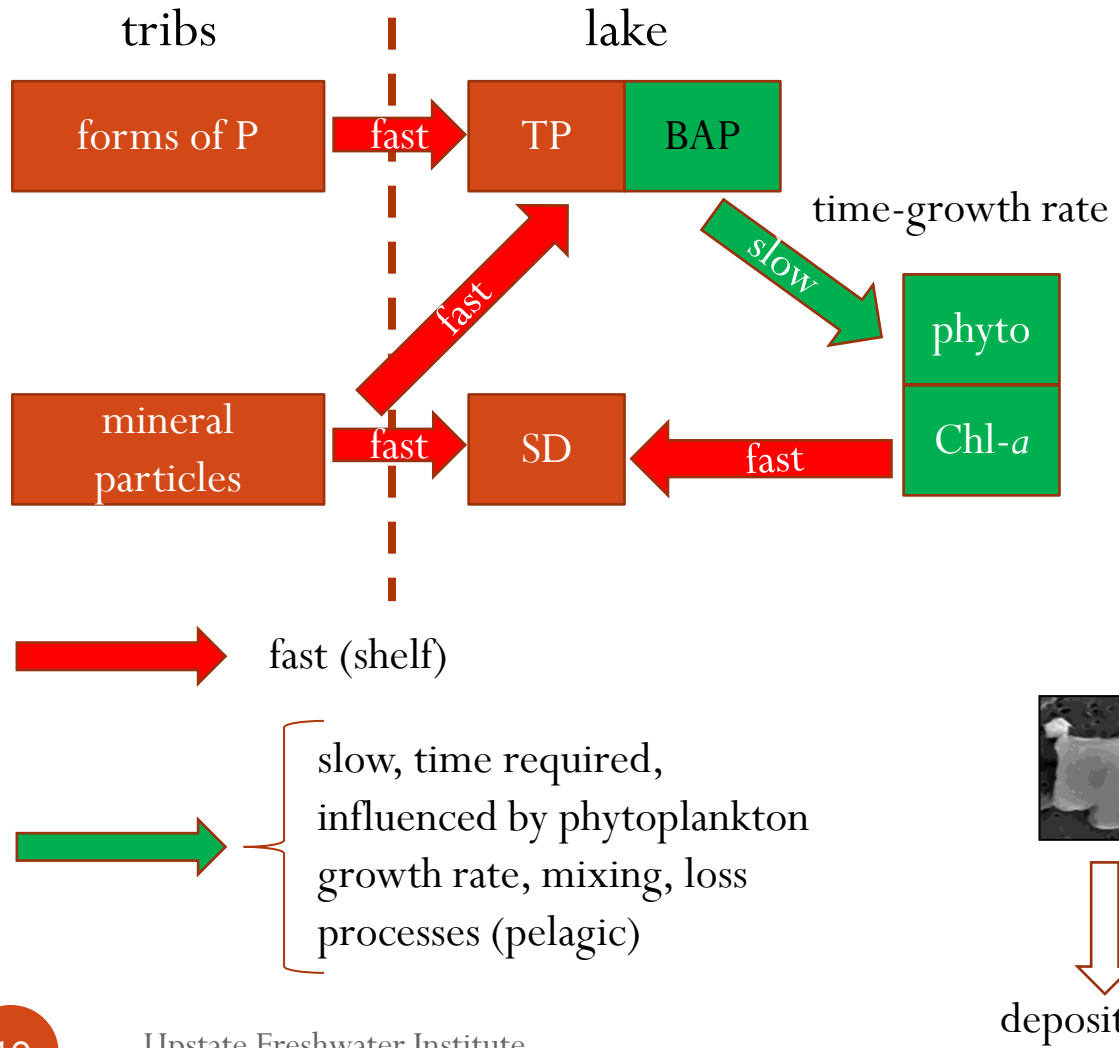
A. Analysis of long-term data for trophic state metrics in Cayuga Lake

summer (Jun.-Sept.) average values noteworthy features

- the 5.5-fold reduction in point source BAP_L, 23% decrease in lake-wide BAP_L, and 43% decrease in overall local BAP_L from upgrades in WWTPs
- pelagic vs shelf (summer avg.)
  - TP lower and SD higher at pelagic site, Chl-*a* approximately equivalent for shelf vs. pelagic
- distinct changes in trophic metrics to reductions in BAP_L *were not observed*
- flow-driven variations in trib BAP_L, as a complicating feature



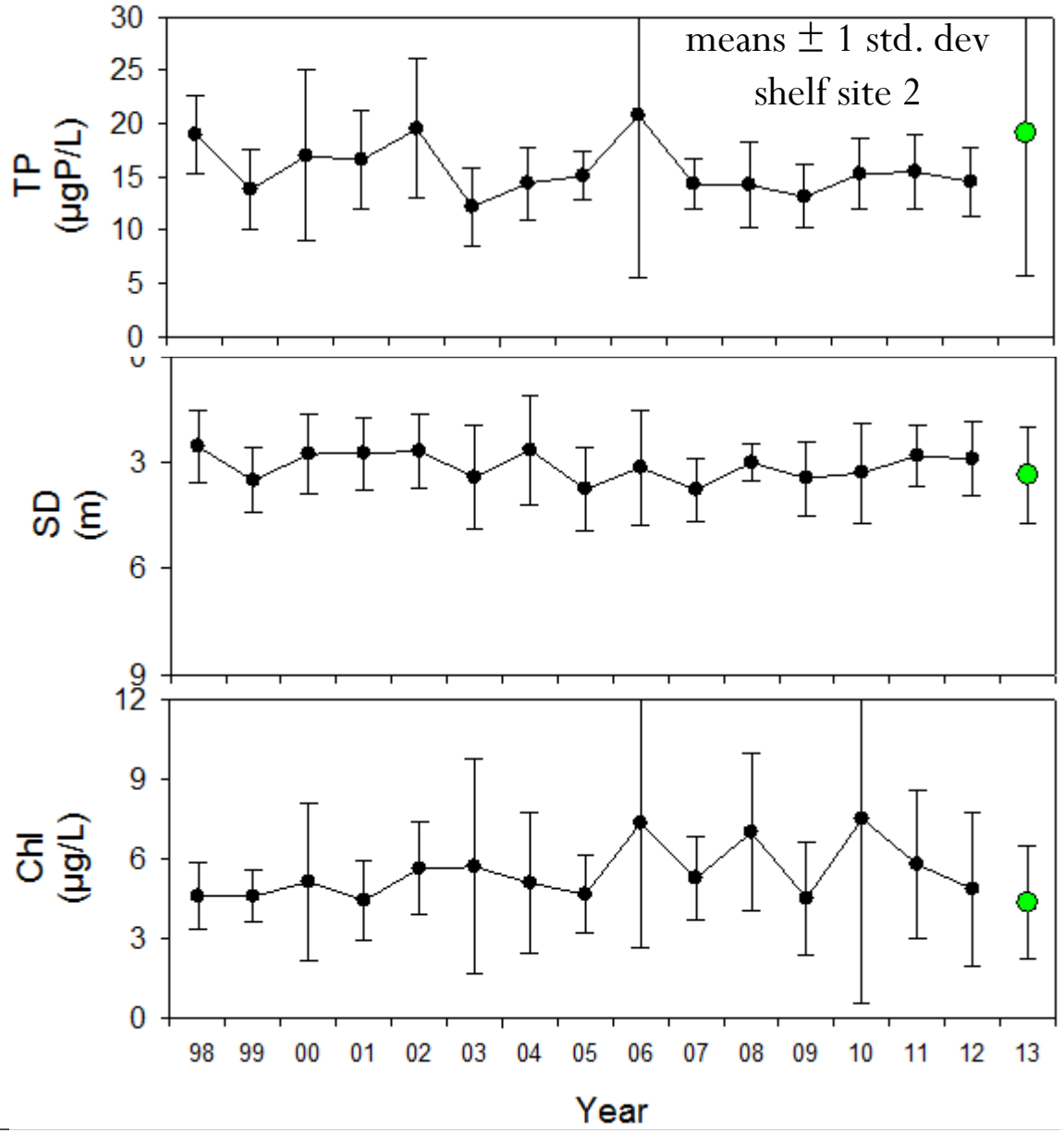
A. Considering trophic state metric response differences: Origins



- basic factors responsible for differences shelf vs pelagic of the 3 trophic state metrics
  - shelf – immediacy from minerogenic particle inputs
  - pelagic – longer time scale; clay deposition phytoplankton growth involved

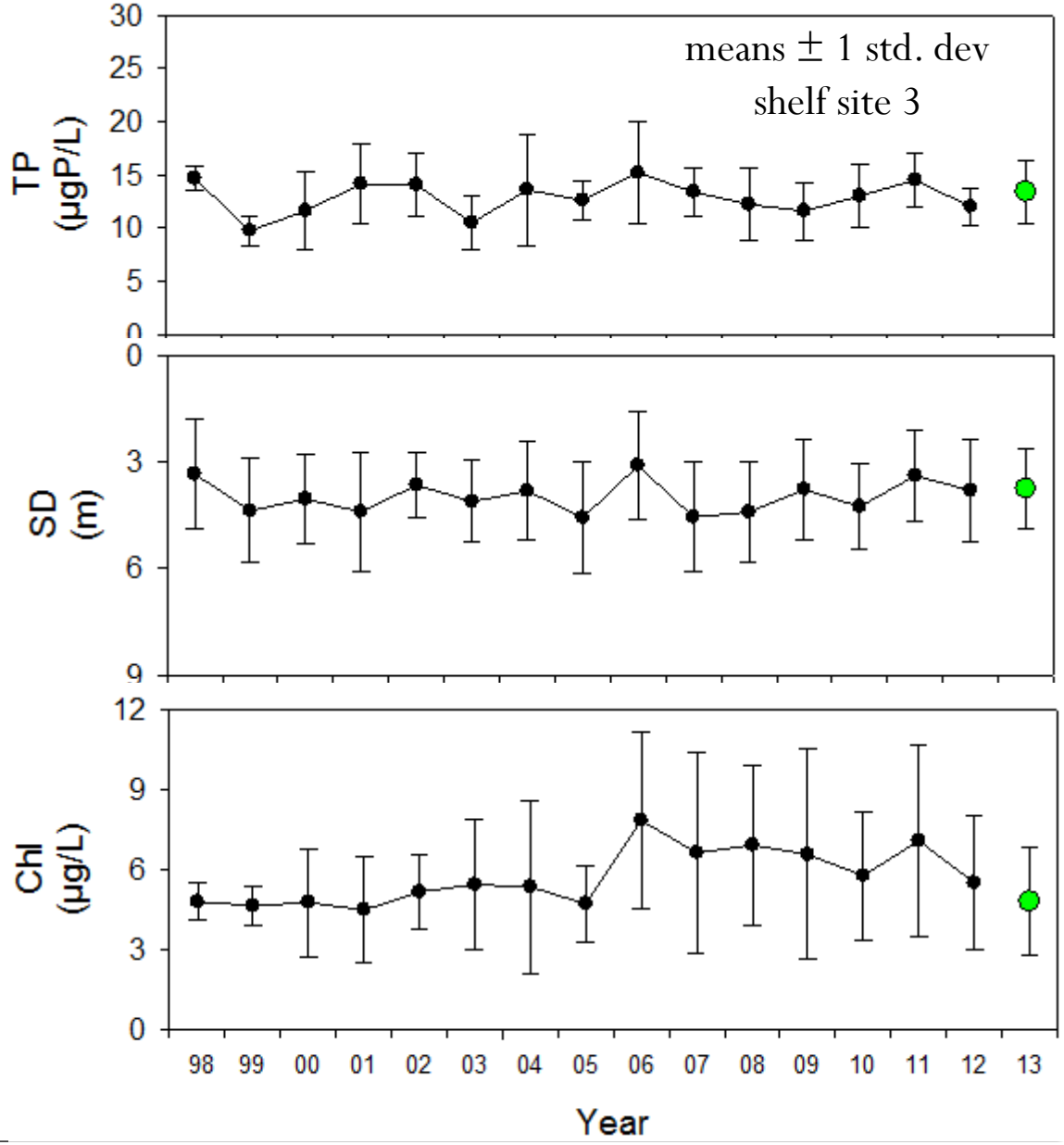
A. Analysis of long-term changes or trends in trophic state metrics in Cayuga Lake: Summer average values, shelf and pelagic

- 3 statistical tests (phase 1 report)
  - t-test, selection of boundaries
    - (e.g., 03-04, 05-06)
  - seasonal Kendall analysis
  - regression analysis over period
- no significant trends for Chl-*a*, TP and SD



A. Analysis of long-term changes or trends in trophic state metrics in Cayuga Lake: Summer average values, shelf and pelagic

- 3 statistical tests (phase 1 report)
  - t-test, selection of boundaries
    - (e.g., 03-04, 05-06)
  - seasonal Kendall analysis
  - regression analysis over period
- generally only weak support for *increase* in pelagic Chl-*a*, not supported for shelf
- no significant trends for TP and SD



A. Analysis of long-term data for trophic state metrics in Cayuga Lake: Unresponsiveness to reductions in P loading

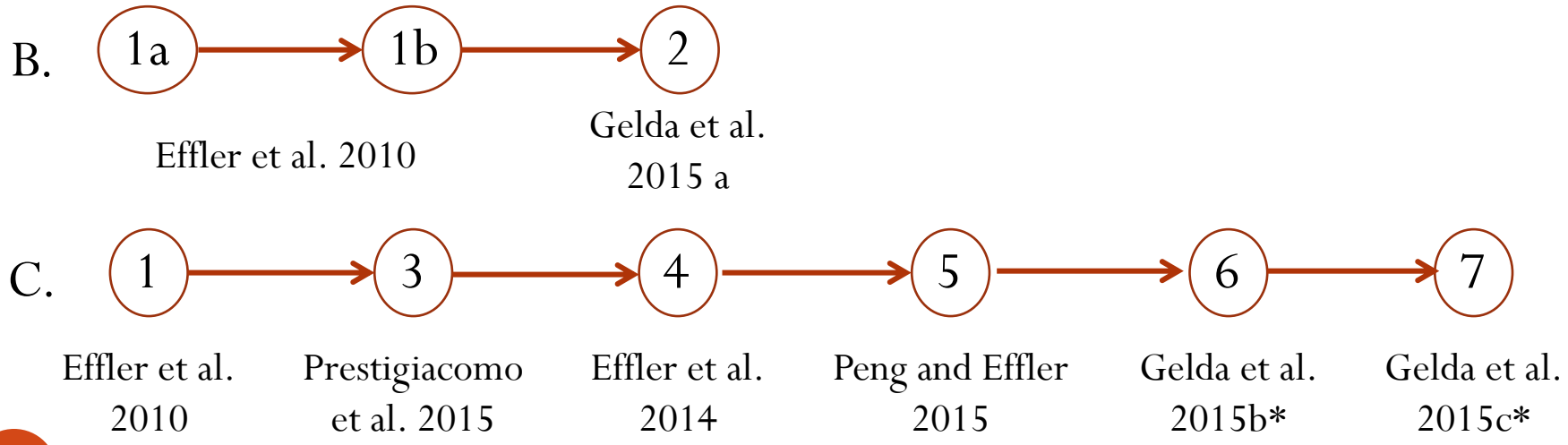
- monitoring data not supportive of measurable improvements in trophic state metrics from reductions in local P loading, including
  - shelf vs. pelagic waters
  - lake-wide
- recall
  - lack of documented response to noteworthy decrease in (85%) BAP_L from local WWTP upgrades
  - the small additional decrease in BAP_L (6% local or 1.5% lake-wide) that would accompany moving the LSC discharge
- *the observed unresponsiveness should be important to related management deliberations for future potential actions*

B. and C. Scientific literature specific to Cayuga Lake is unsupportive of present phosphorus (P) – based initiative for shelf

B. rapid flushing of the shelf prevents locally higher phytoplankton biomass, prevents local manifestations from reductions in P loading

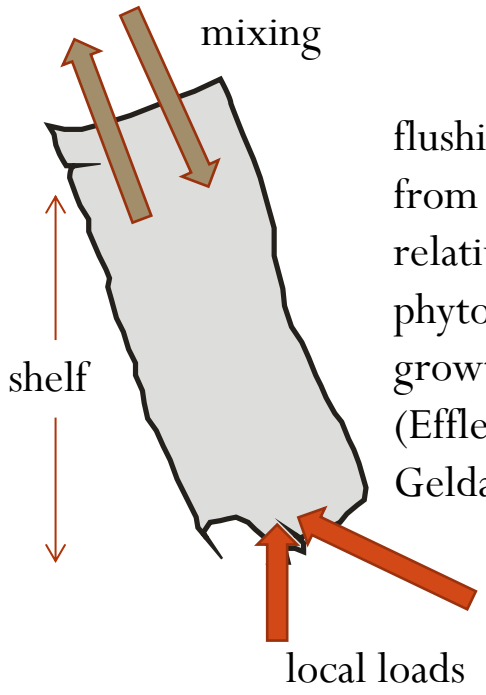
C. TP on the shelf is fundamentally flawed as a measure of trophic state, compromises shelf and pelagic comparisons

progression in peer-reviewed literature according to topics:

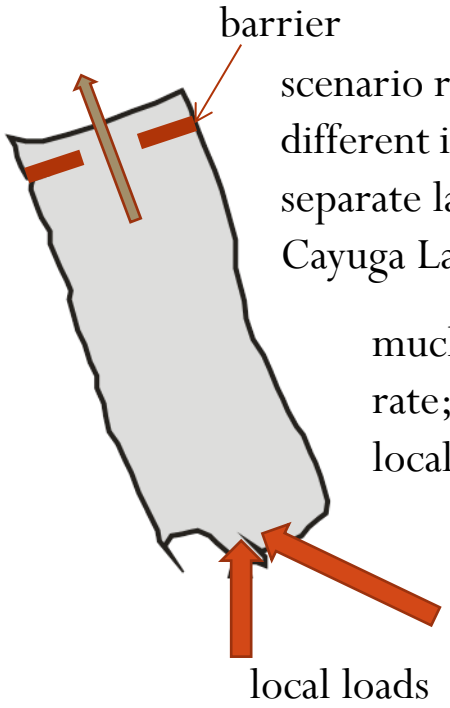


* in review

B. Natural mixing processes prevent development of greater phytoplankton biomass concentration on the shelf relative to pelagic waters



flushing rate of shelf from mixing is rapid relative to phytoplankton growth rates (Effler et al. 2010, Gelda et al. 2015a)



scenario response would be different if the shelf was a separate lake in series with Cayuga Lake

much slower flushing rate; could increase local phytoplankton

the lack of shelf-wide improvements in trophic state from previous reductions in local point source loading of P are understood to be a result of the rapid flushing of the shelf from natural mixing processes

B. Rapid flushing of shelf

1a and 1b. Effler et al. 2010; Tripton, trophic state metrics, and near-shore versus pelagic zone responses to external loads in Cayuga Lake, New York, U.S.A., *Fundam. Appl. Limnol.* 178:1-15.

1a. review of monitoring data

- trophic state metrics – lack of local positive response to the experiment/ management action
- active mixing extends onto the shelf

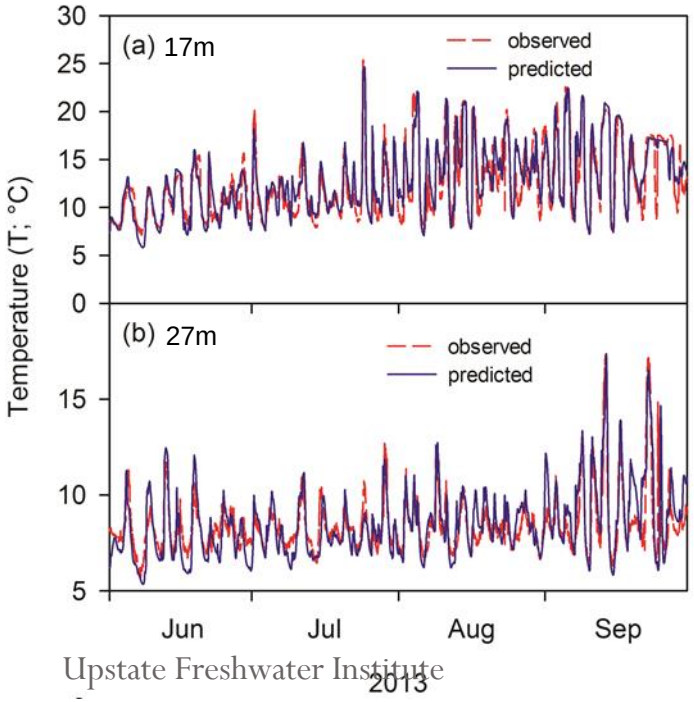
1b. engineering analysis of flushing rates

"A hydrodynamic/transport analysis demonstrated that the rate of flushing of the shelf, including the effects of mixing exchange with pelagic waters, was high enough (e.g., greater than reasonable rates of phytoplankton growth) to prevent this potential from being substantially realized in this near-shore zone."

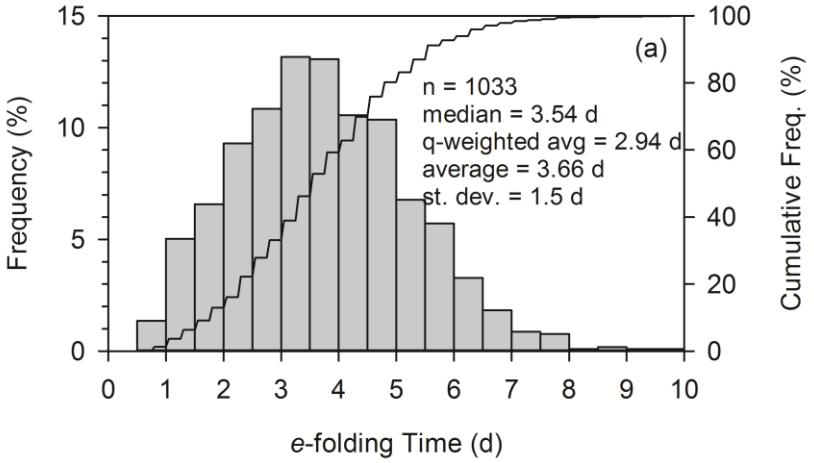
B. Rapid flushing of shelf

2. Gelda et al. 2015a; Testing and application of a two-dimensional hydrothermal/ transport model for a long, deep, and narrow lake with moderate Burger number, *Inland Waters* (in press).

- peer-reviewed manuscript Gelda et al. 2015a
- example testing against thermistor string observations



- example application
  - residence time of tributary input within shelf



- e-folding time (37% of tracer remains; 1/wk release from stream, 1994-2013)

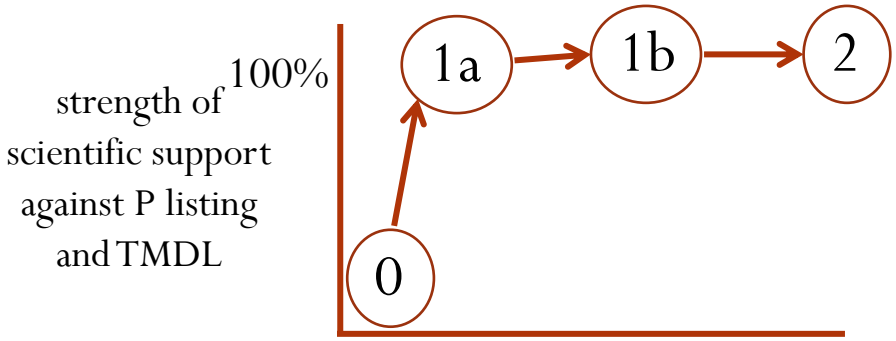
B. Rapid flushing of shelf

2. Gelda et al. 2015a; Testing and application of a two-dimensional hydrothermal/ transport model for a long, deep, and narrow lake with moderate Burger number, *Inland Waters* (in press).

- independently validated for robust array of measurements; upwelling events, T stratification, seiche activity,
- applications, including residence time/flushing

"The relatively low residence time (e.g., high flushing rate; d^{-1}) is an important factor in the lack of localized high phytoplankton biomass concentrations on the shelf, despite higher nutrient concentrations (Effler et al. 2010). The flushing rate is substantial (Effler et al. 2010) relative to net phytoplankton growth rates (Chapra 1997, Reynolds 2006)."

B. Rapid flushing of shelf not supportive of P loading reductions to achieve *local* improvements in trophic state

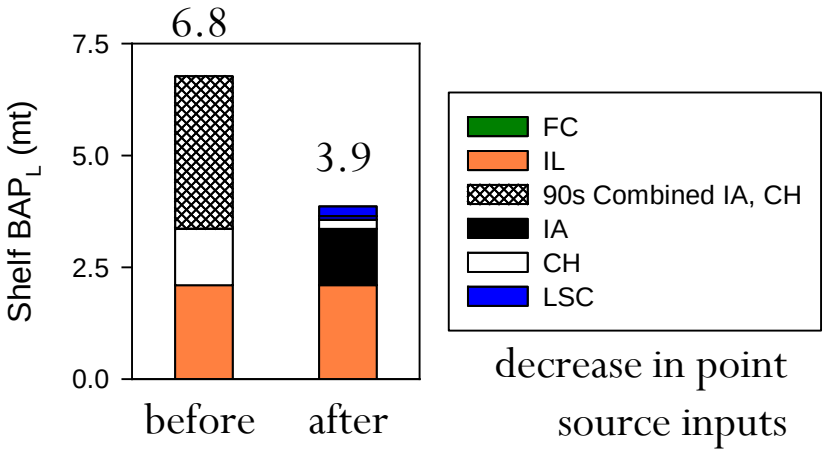


scaling reflects UFIs professional opinion

not a scientifically legitimate open question

1a. limnological analysis, lack of local positive response to the experiment

"experiment" driver (local)



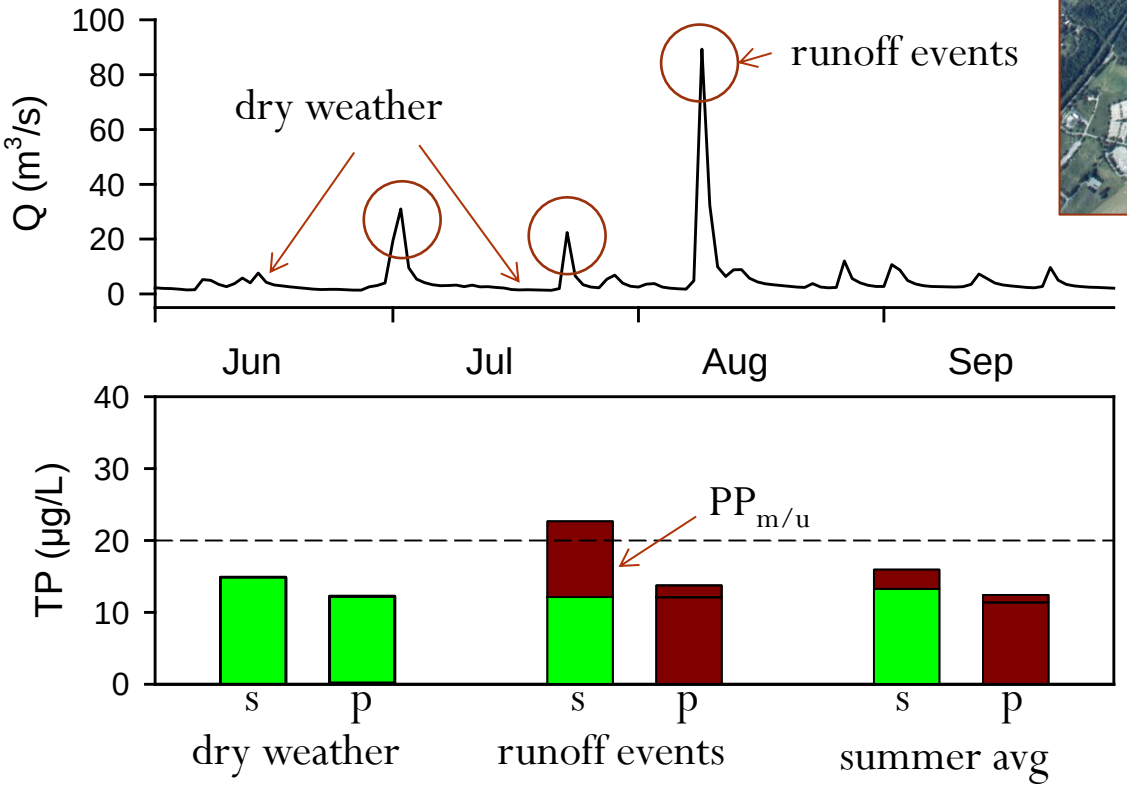
decrease in point source inputs

1b. flushing rate analysis (Effler et al. 2010)

2. application of validated 2-D model, demonstration of high shelf flushing rates

C. Minerogenic unavailable particulate phosphorus ($PP_{m/u}$) interferes with the application of the TP guidance value on the shelf

hydrology cases of interest

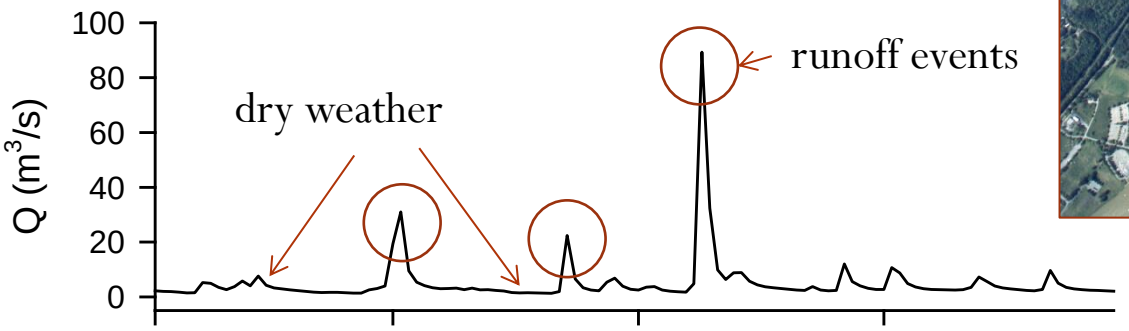


s – shelf
p – pelagic

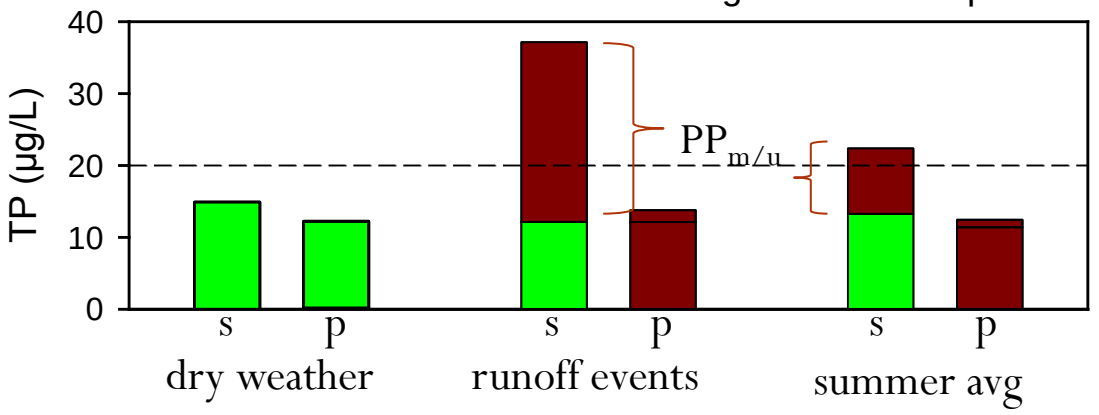
TP guidance value of 20 µg/L (summer average) can be exceeded on shelf, dependency on runoff events and timing of monitoring, but trophic state is not an issue because of the unavailability of the responsible $PP_{m/u}$

C. Minerogenic unavailable particulate phosphorus ($PP_{m/u}$) interferes with the application of the TP guidance value on the shelf

hydrology cases of interest



s – shelf
p – pelagic



wet summer case

TP guidance value of 20 µg/L (summer average) can be exceeded on shelf, dependency on runoff events and timing of monitoring, but trophic state is not an issue because of the unavailability of the responsible $PP_{m/u}$

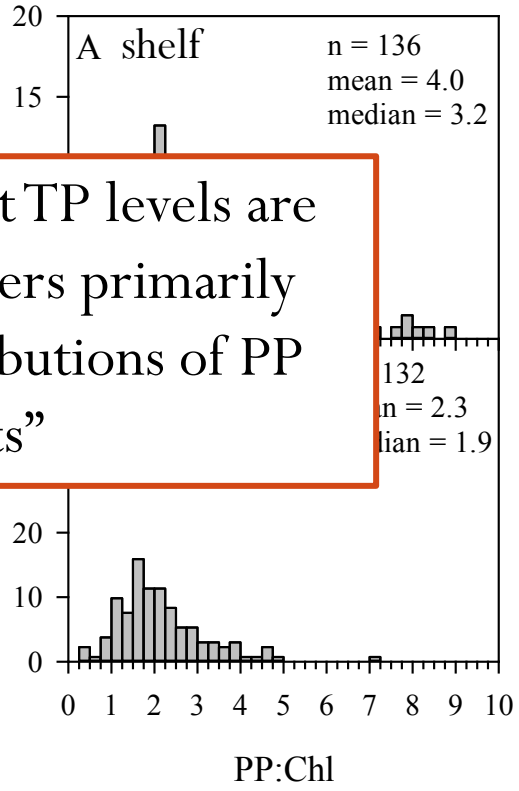
C. Flaws in TP as trophic state metric on shelf

1. Effler et al. 2010; Tripton, trophic state metrics, and near-shore versus pelagic zone responses to external loads in Cayuga Lake, New York, U.S.A., *Fundam. Appl. Limnol.* 178:1-15.

- a review of tributary and limnological data through 2007
- recognition of minerogenic particle interference with trophic state metrics of TP and SD; aggravated by runoff events
- systematic decrease in local P loading (late 2000s) described
- lack of pc

"Multiple lines of evidence indicate that TP levels are higher on the shelf than in pelagic waters primarily because of higher tripton-based contributions of PP received from stream inputs"

2. PP:Chl-*a*; stoichiometry
   - indicates more tripton (minerogenic particle) contribution on shelf



C. Flaws in TP as trophic state metric on shelf

3. Prestigiacomo et al. 2015; Apportionment of Bioavailable Phosphorus Loads Entering Cayuga Lake, New York, *JAWRA* (accepted).

"The limited bioavailability (Figure 5a) of the PP_L delivered to the near-shore shelf area of Cayuga Lake (Figure 1) during periods of high flow (Figure 3a and b) has important implications with respect to exceedances of the state's TP guidance value in that area. The intent of the guidance value, acknowledging the wide use of the concentration of TP as a metric of trophic state (Chapra, 1997; Cooke et al., 2005), is to protect against the effects of excessive eutrophication. The exceedances on the shelf are attributable to the inclusion of observations of particularly high TP concentrations soon after runoff events for which PP associated with terrigenous minerogenic particles (mostly clay minerals) dominates (Effler and Peng, 2014; Effler et al., 2014). The low f_{BAP} for the PP fraction for the three local tributaries (Figures 1 and 5a), together with the even lower f_{BAP} value (1.7%) observed for a shelf sample soon after a runoff event, establishes the elevated TP concentrations on the shelf following such events are essentially uncoupled from trophic state. Accordingly, such observations should not be integrated into assessments of the status of this area relative to the guidance value. Summer average concentrations of TP in pelagic portions of the lake, beyond the local effects of lotic inputs, where minerogenic particle concentrations remain lower (Effler and Peng, 2014), do not approach the guidance value (Effler et al., 2010; 2014)."

C. Flaws in TP as trophic state metric on shelf

3. Prestigiacomo et al. 2015; Apportionment of Bioavailable Phosphorus Loads Entering Cayuga Lake, New York, *JAWRA* (accepted).

- additionally consider the magnitudes of individual contributions relative to likely flow-based interannual variations
- Figure 8 from paper, lake-wide estimates

"Moreover, it is appropriate to consider the potential benefits of a systematic reduction in this, or other sources, in the context of interannual variations in BAP_L that may be attributable to natural variations in Q. The magnitudes of BAP_L from the individual sources presently are small relative to reasonable estimates of interannual variations in summed tributary BAP_L (Figure 8). This variability will act to mask the effects of reductions in individual inputs."

- pertinent quote:

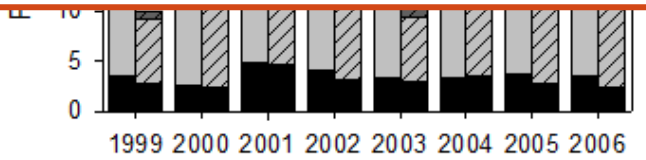
C. Flaws in TP as trophic state metric on shelf

4. Effler et al. 2014; Partitioning the contributions of minerogenic particles and bioseston to particulate phosphorus and turbidity, *Inland Waters* 4: 179-192.

noteworthy quote(s), pgs 188-189:

"The findings that PP_m makes a noteworthy to substantial contribution to PP (Fig. 6b) and TP, and that the exceedances at the near-shore site were primarily associated with summers of higher PP_m (Fig. 7), raises interesting questions related to a TP limit and its implementation for this system." . . . "Given these considerations, the observed interannual and spatial variations in TP, driven by year-to-year and spatial differences in PP_m, are not a reliable indicator of changes or differences in trophic state in Cayuga Lake."

- bioavailability concept, limited for minerogenic particles
- supporting literature references presented



C. Flaws in TP as trophic state metric on shelf

5. Peng and Effler 2015; Quantifications and water quality implications of minerogenic particles in Cayuga Lake, New York, and its tributaries, *Inland Waters* (in press).

"The large contributions of PP_m to TP on the shelf (Figure 9) raises questions concerning the appropriateness of TP as a regulated metric for this particular area, because this form of P generally has limited bioavailability (DePinto et al., 1981; Young et al., 1985; Auer et al., 1998; Effler et al., 2002; Prestigiacomo et al., 2015). PP on the shelf was found to have low (3%) bioavailability in a sample collected soon after a major runoff event (Prestigiacomo et al., 2015), as determined with a bioassay protocol (Auer et al., 1998; Effler et al., 2012). Accordingly, TP values collected on the shelf after runoff events should not be integrated into assessments of the status of this area relative to the guidance value (i.e., trophic state). Exceedances identified for previous years were also the result of the inclusion of high PP_m (i.e., PAV_m) levels caused by runoff events (Effler et al., 2014). Moreover, such assessments are highly dependent on the timing of monitoring relative to the occurrences of runoff events. For example, a limited number of very high values that occur soon after major runoff event can cause high summer average TP concentrations."

C. Flaws in TP as trophic state metric on shelf

6. Gelda et al. 2015b; Simulation of minerogenic particle populations in time and space in Cayuga Lake, New York, in response to runoff events, *Inland Waters* (in review).

Brief background/preliminary findings – see Abstract

- a mass balance type mechanistic model for PAV_m, partitioned according to multiple size classes, is developed and tested for Cayuga Lake, supported by PAV_m monitoring
- central roles of major runoff events and localized external loads of minerogenic (clay) particles at southern in driving PAV_m patterns in time and space (shelf PAV_m > pelagic PAV_m)
- protocols to use PAV_m predictions to estimate $PP_{m/u}$ and optics effects are described

- noteworthy southern end quotes:

C. Flaws in TP as trophic state metric on shelf

6. Gelda et al. 2015b; Simulation of minerogenic particle populations in time and space in Cayuga Lake, New York, in response to runoff events, *Inland Waters* (in review).

"The complications of unavailable (i.e., will not support algae growth) P associated with minerogenic particles ($PP_{m/u}$) relative to the use of the concentration of total P (TP) as a trophic state metric (Carlson 1977, Chapra and Auer 1999), and the stoichiometry of P relative to other cellular constituents of phytoplankton (Hecky et al. 1993), have long been qualitatively recognized, but only recently (Effler et al. 2014) quantified."

C. Flaws in TP as trophic state metric on shelf

6. Gelda et al. 2015b; Simulation of minerogenic particle populations in time and space in Cayuga Lake, New York, in response to runoff events, *Inland Waters* (in review).

> "The contributions of minerogenic particles to PP remained minor in pelagic waters (Fig. 10d; Effler et al. 2014), but important on the shelf following runoff events. "

C. Flaws in TP as trophic state metric on shelf

6. Gelda et al. 2015b; Simulation of minerogenic particle populations in time and space in Cayuga Lake, New York, in response to runoff events, *Inland Waters* (in review).

"The large contributions of $PP_{m/u}$ to the very high TP levels on the shelf following runoff events indicate such TP observations are false high in the context of eutrophication concerns, because $PP_{m/u}$ is not bioavailable (Young et al. 1985, Auer et al. 1998, Prestigiacomo et al. 2015). Irregular exceedances of the summer average TP limit of 20 $\mu g \cdot L^{-1}$ on the shelf are caused primarily by high sediment loads received from its watershed during runoff events, and are not valid representations of a problem related to cultural eutrophication. Either the TP observations on the shelf following runoff events should not be included in the calculation of the summer average statistic, or such values should be reduced according to estimates of the contribution of the $PP_{m/u}$ concentration (e.g., Effler et al. 2014)."

C. Flaws in TP as trophic state metric on shelf

7. Gelda et al. 2015c; Simulation of the contribution of minerogenic particles to particulate phosphorus concentration in Cayuga Lake, New York, *Ecological Modeling* (in review).

Brief background/preliminary findings – see Abstract

- P associated with minerogenic particles delivered from the watershed interferes with the use of TP as a trophic state metric in lakes because of its limited availability
- mass balance mechanistic model for $PP_{m/u}$ has been developed and successfully tested
- central roles of major runoff events and localized tributary loading at the southern end drive patterns of $PP_{m/u}$ in time (high after events) and space (shelf > pelagic)

- noteworthy quotes:

C. Flaws in TP as trophic state metric on shelf

7. Gelda et al. 2015c; Simulation of the contribution of minerogenic particles to particulate phosphorus concentration in Cayuga Lake, New York, *Ecological Modeling* (in review).

- noteworthy quotes:

"The presence of high concentrations of minerogenic particles (Fig. 4c) and the associated $PP_{m/u}$ (Fig. 8c) compromises the TP measurement as a metric of trophic state. Such a problem for certain systems has been qualitatively recognized for decades (Carlson, 1977; Hecky et al., 1993; Carlson and Havens, 2005). Predictions of $PP_{m/u}$ represent a distinct and quantitative advancement, as the TP minus $PP_{m/u}$ residual more closely approaches a nearly completely available P pool, that drives trophic state in most lacustrine waters (Reynolds and Davies, 2001). "

C. Flaws in TP as trophic state metric on shelf

7. Gelda et al. 2015c; Simulation of the contribution of minerogenic particles to particulate phosphorus concentration in Cayuga Lake, New York, *Ecological Modeling* (in review).

- noteworthy quotes:

"This short-coming in TP as a trophic state metric should not be considered fatal relative to the alternate use of one or both of the other two common metrics of SD and Chl-*a*. These parameters have their own limitations. The short-comings in SD are generally concurrent and conceptually consistent with those for TP as the same minerogenic particle populations act to diminish this clarity measurement, mediated through coupled increases in the regulating light scattering process (Davies-Colley et al., 2003; Peng and Effler, 2015). This coincidence of short-comings of TP and SD to differentiate trophic state conditions between the shelf and pelagic waters was identified in an earlier empirical analysis of long-term monitoring data for the lake (Effler et al., 2010). While Chl-a is the most widely used proxy of phytoplankton biomass, the relationship is often weak because of the dependency of cellular pigment content on species composition and ambient conditions (Reynolds, 2006)."

C. Flaws in TP as trophic state metric on shelf

7. Gelda et al. 2015c; Simulation of the contribution of minerogenic particles to particulate phosphorus concentration in Cayuga Lake, New York, *Ecological Modeling* (in review).

"Disproportionately large fractions of these inputs are received during runoff events (Fig. 7h, Table 1; Longabucco and Rafferty, 1998; Prestigiacomo et al., 2007;2015), that in this region can be expected to be manifested as substantial year-to-year differences in timing and magnitude (Fig. 12) because of the generally stochastic character of the meteorological drivers (Effler, 1996). Interannual variations in both the long-term predictions of $PP_{m/u}$ (Fig. 12) and observations of TP and PP for Cayuga Lake (Fig. 11) are supportive of this position. However, longer time scale increasing trends in $PP_{m/u}$, and degradation of other water quality metrics driven by PAV_m (Peng and Effler, 2015), are reasonable expectations for this lake and others in the northeastern portion of the United States, given the predicted increases in occurrences and severity of runoff events from climate change (National Oceanic and Atmospheric Administration, 2013)."

C. Flaws in TP as trophic state metric on shelf

7. Gelda et al. 2015c; Simulation of the contribution of minerogenic particles to particulate phosphorus concentration in Cayuga Lake, New York, *Ecological Modeling* (in review).

- noteworthy quotes:

"The spatial differences predicted for $PP_{m/u}$ (Figs. 5c and 11) and observed in measured forms of P (Figs. 5a and 11) are a result of the localization of external tributary loading (e.g., 40% of the hydrologic and $PP_{m/u}$ loads), delivered mostly during runoff events (Fig 7h), that directly enters the shelf. Such spatial structure in $PP_{m/u}$ doubtless occurs widely in other lacustrine waters after runoff events, as localization of loading at one end of a basin is a common case, particularly for reservoirs (Wetzel, 2001)."

C. Flaws in TP as trophic state metric on shelf

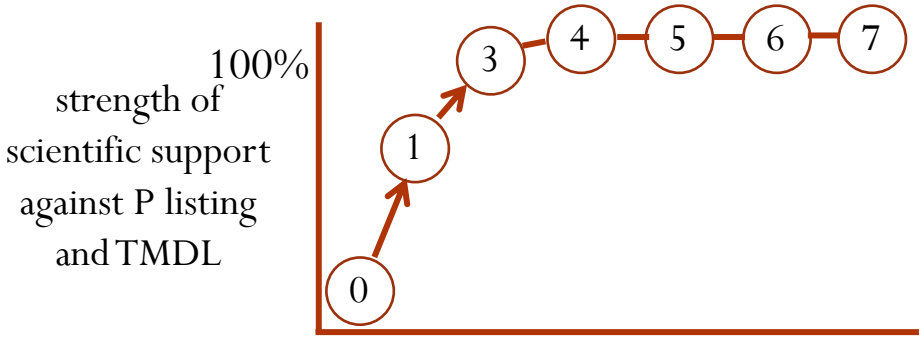
7. Gelda et al. 2015c; Simulation of the contribution of minerogenic particles to particulate phosphorus concentration in Cayuga Lake, New York, *Ecological Modeling* (in review).

- noteworthy quotes:

"Analyses of the model predictions indicate the higher shelf $PP_{m/u}$ concentrations and their interannual variations are primarily responsible (Fig. 11) for the: (1) higher TP (e.g., summer average) concentrations on the shelf versus pelagic waters, (2) interannual variations in the differences between the sites, and (3) the irregular exceedances of the regulatory TP limit of 20 µg/L on the shelf. Accordingly, TP should not be applied as an equivalent metric of trophic state spatially in this lake, and many others with similar lake-tributary configurations. In particular, it is problematic for the application of a single TP guidance value throughout Cayuga Lake (Effler et al., 2010; 2014; Peng and Effler, 2015; Prestigiacomo et al., 2015). The predicted $PP_{m/u}$ should be subtracted from TP observations made on the shelf following runoff events, if regulatory use of the guidance value were to continue."

C. Flaws in TP as a trophic state metric on shelf, now widely supported by scientific experts through the peer-reviewed literature

TP on shelf fundamentally flawed as a measure of trophic state; i.e., a single TP guidance value cannot be applied equivalently lake-wide



scaling reflects UFIs professional opinion

the magnitude of system-specific information against the P listing and TMDL is likely unique

<u>supporting peer-reviewed literature</u>

1. Effler et al. 2010
   – limnological analysis
3. Prestigiacomo et al. 2015
   – bioassays and loading analysis
4. Effler et al. 2014
   – empirical $PP_{m/u}$ model
5. Peng and Effler 2015
   – PAV_m-$PP_{m/u}$ connection
6. Gelda et al. 2015b
   – PAV_m lake model, $PP_{m/u}$ implications
7. Gelda et al. 2015c
   – mechanistic $PP_{m/u}$ lake model, management implications

Considering the multiple published analyses related to the appropriateness of the phosphorus listing for the shelf

The compelling case against the phosphorus (P) listing of the shelf, and the focus of management actions to reduce local P inputs to the shelf rather than lake-wide:

1. the lack of clear shelf-wide positive response of trophic state metrics (e.g., Chl-*a*) from reductions in the BAP_L from two local WWTPs, that were 5.5-fold greater than the contemporary LSC BAP_L and represented a 43% decrease in local total BAP_L and 23% decrease in lake-wide BAP_L

Considering the multiple published analyses related to the appropriateness of the phosphorus listing for the shelf

The compelling case against the phosphorus (P) listing of the shelf, and the focus of management actions to reduce local P inputs to the shelf rather than lake-wide:

2. two fundamental scientific features of the shelf explain the unresponsiveness and the flawed character of TP concentration as a trophic state metric in that area
    a. its rapid flushing relative to rates of phytoplankton growth
    b. contributions of unavailable forms of P to TP, particularly following runoff events, associated with sediment (minerogenic particles)

Considering the multiple published analyses related to the appropriateness of the phosphorus listing for the shelf

The compelling case against the phosphorus (P) listing of the shelf, and the focus of management actions to reduce local P inputs to the shelf rather than lake-wide:

3. a substantial and growing treatment of the scientific problems associated with this P listing has emerged in the form of multiple related papers in the peer-reviewed literature (i.e., non-advocacy positions). Five papers have been published, or accepted for publication; others are in the review process. Accordingly, at least 10 (more in the future) independent, anonymous peer-reviewers, along with an Associate Editor for each of the five papers, have supported the criticisms relative to the P listing

Considering the multiple published analyses related to the appropriateness of the phosphorus listing for the shelf

The compelling case against the phosphorus (P) listing of the shelf, and the focus of management actions to reduce local P inputs to the shelf rather than lake-wide:

4. specific recommendations made by NYSDEC expert technical staff for the 2013 study, particularly related to bioavailability analyses, runoff event monitoring, and appropriateness of the tested implemented 2D transport model, provided critical support for multiple of the above peer-reviewed papers

Considering the multiple published analyses related to the appropriateness of the phosphorus listing for the shelf

The compelling case against the phosphorus (P) listing of the shelf, and the focus of management actions to reduce local P inputs to the shelf rather than lake-wide:

5. the setting for the shelf of Cayuga Lake is a common case for lakes in New York that should be considered for related management deliberations elsewhere