Using Stable Isotopes to Evaluate the Effects of Seasonal and Spatial Changes in Flow and Nutrients on Biogeochemical Processes and Habitat Quality in the SFE, 2006-2016

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Goals of this talk:

- Briefly explain what we are doing -- and why.
- Try to interest potential collaborators with modeling, statistical, and ecological expertise -- to help us make better use of our data and biogeochemical expertise to develop and/or test fish habitat or other hydro-biogeochemical models.

USGS

Our ongoing POD-oriented projects since 2009 are investigating:

- **spatial and temporal changes in the relative contributions of NO3 vs NH4 to phytoplankton blooms in the Delta.**
- **whether NO3 or NH4 is the dominant N source supporting *Microcystis* growth in the Delta, and the geographic sources of the nutrients.**
- **geographic sources of nutrients and organic matter to the Sacramento River, Delta, and Bay.**

USGS

Our ongoing <u>habitat-oriented</u> projects since 2009 are investigating:

- **the relative impact of different Delta biogeochemical processes (nitrification, uptake, organic degradation, etc) on water chemistry and ecological issues.**
- **the effects of small differences in flow on ecosystem biogeochemistry and (ultimately!) fish abundance.**

All these **POD** and **Habitat** studies involve piggybacking a multi-isotope approach onto chemical and hydrological monitoring programs.

USGS

Approach: We use a comprehensive multi-isotope and multi-tool approach for quantifying nutrient and organic matter sources and biogeochemical processes.

Since 2009, all new samples are analyzed for:

- Water $\delta^{18}O$ and $\delta^{2}H$
- Nitrate $\delta^{15}N$ and $\delta^{18}O$
- Ammonium $\delta^{15}N$
- POM $\delta^{13}C$, $\delta^{15}N$, $\delta^{34}S$, C:N, and C:S
- DOC $\delta^{13}C$ and %C
- Chemistry (extensive data from our partners)

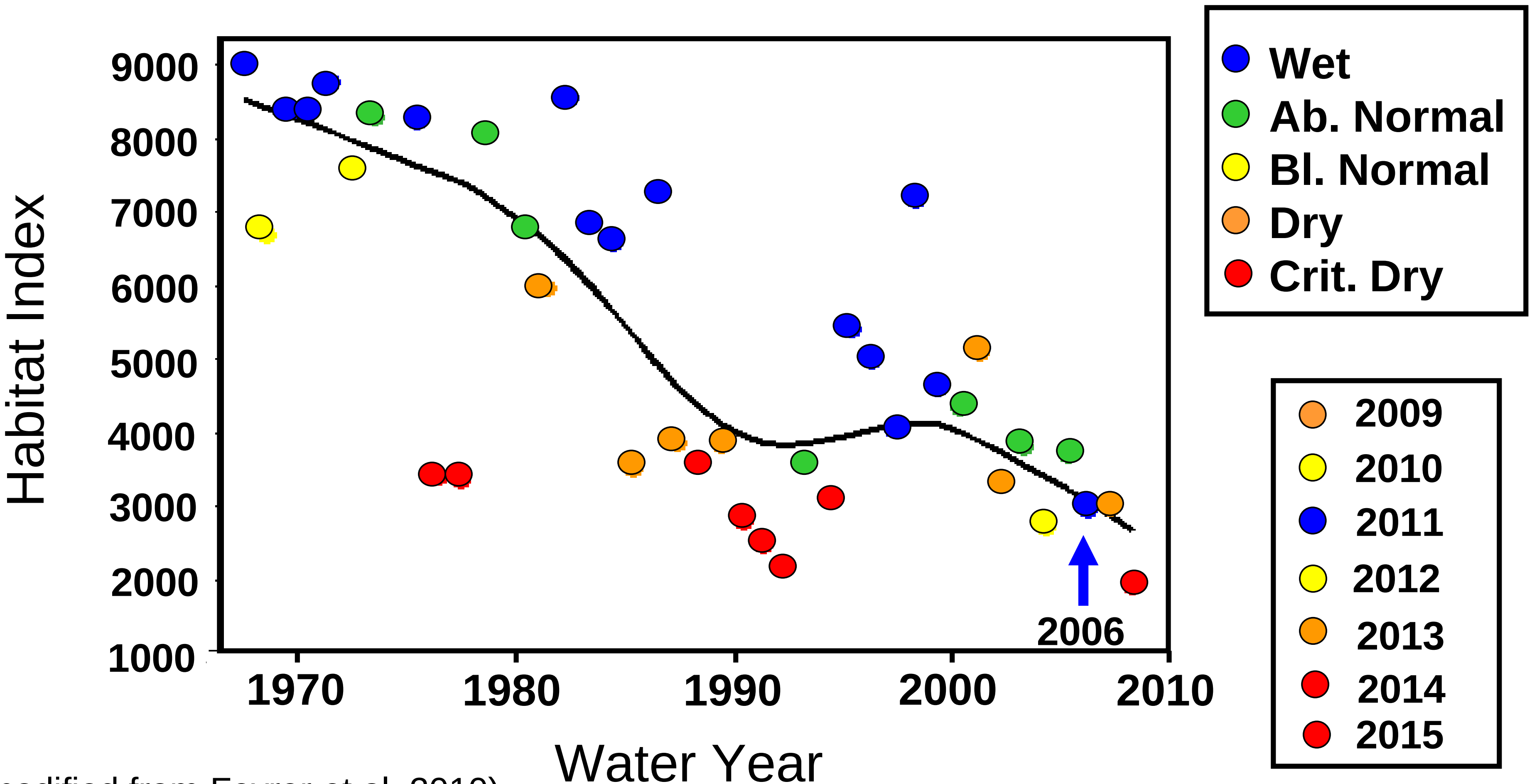
Subsets of samples also analyzed for:

- DIC $\delta^{13}C$
- DOM $\delta^{13}C$, $\delta^{15}N$, $\delta^{34}S$, and C:N, C:S
- Sulfate $\delta^{34}S$ and $\delta^{18}O$
- Other chemical and isotopic analyses.

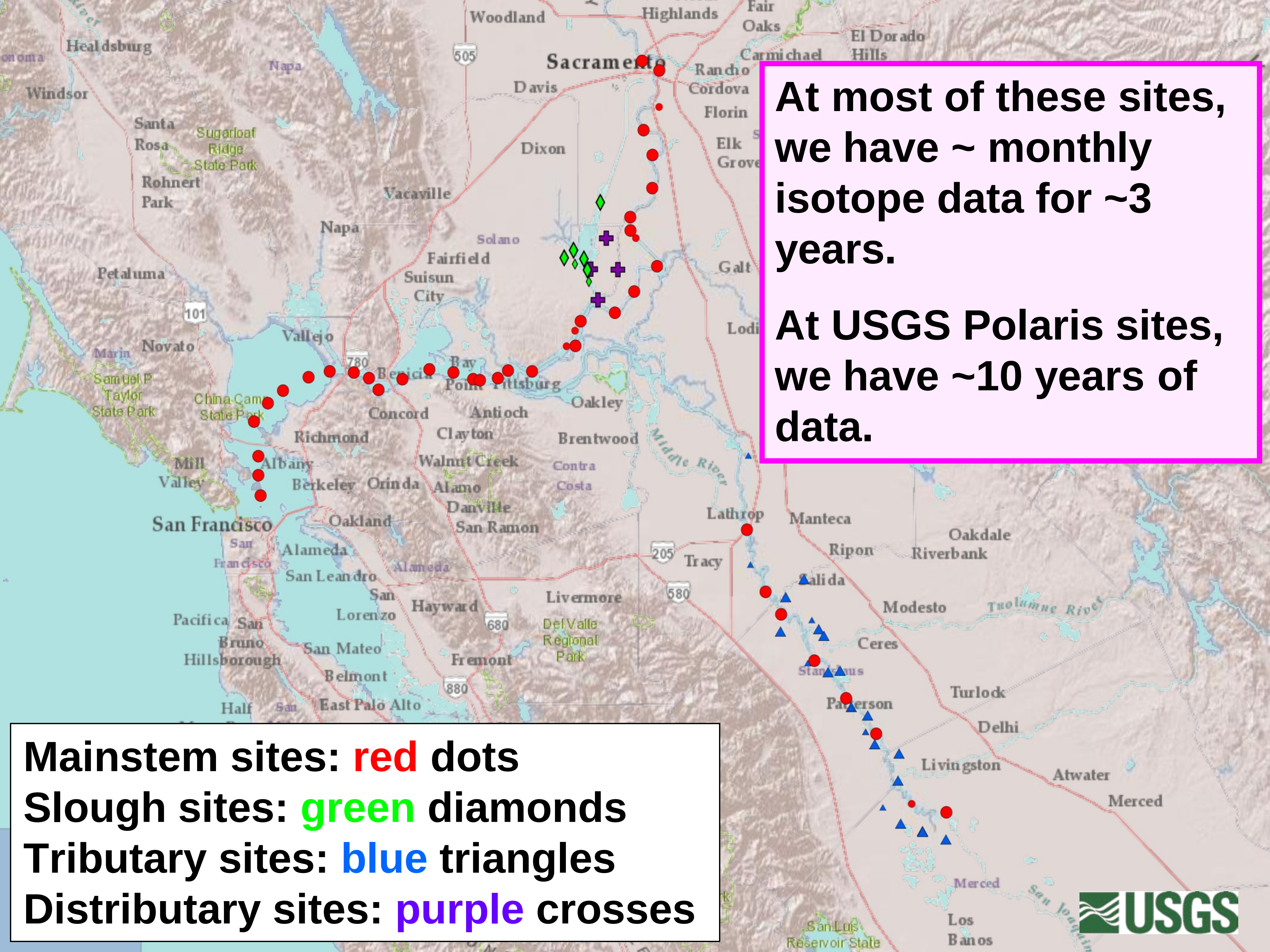
USGS

The USGS Water Quality of San Francisco Bay program has been measuring nutrients, chlorophyll, and other parameters since 1969.

We have piggybacked on USGS and other sampling programs to generate multi-isotope data for 2006-2016 -- with a range of flows and habitat indices



(modified from Feyrer et al. 2010)



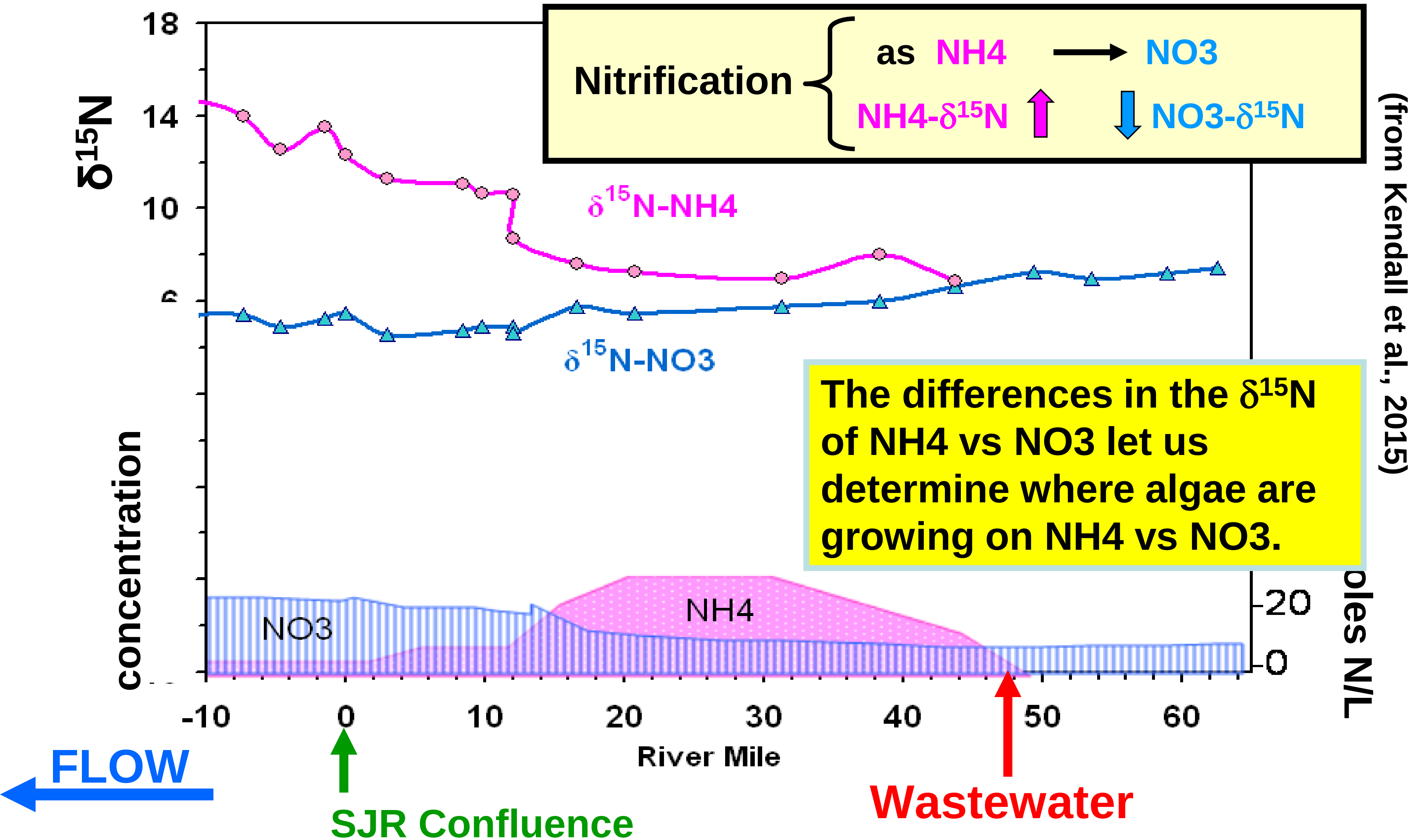
At most of these sites, we have ~ monthly isotope data for ~3 years.

At USGS Polaris sites, we have ~10 years of data.

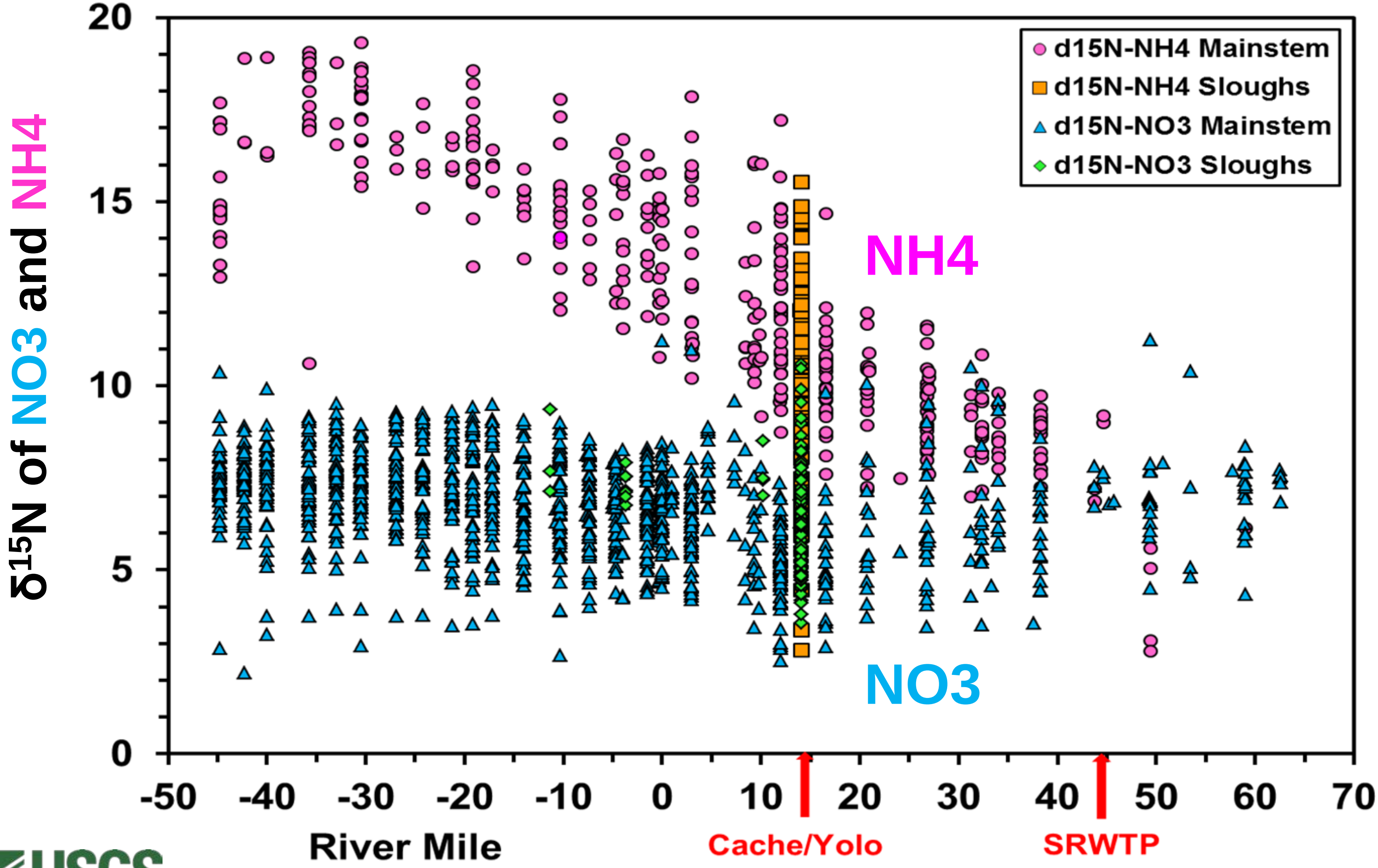
Mainstem sites: red dots
Slough sites: green diamonds
Tributary sites: blue triangles
Distributary sites: purple crosses

USGS

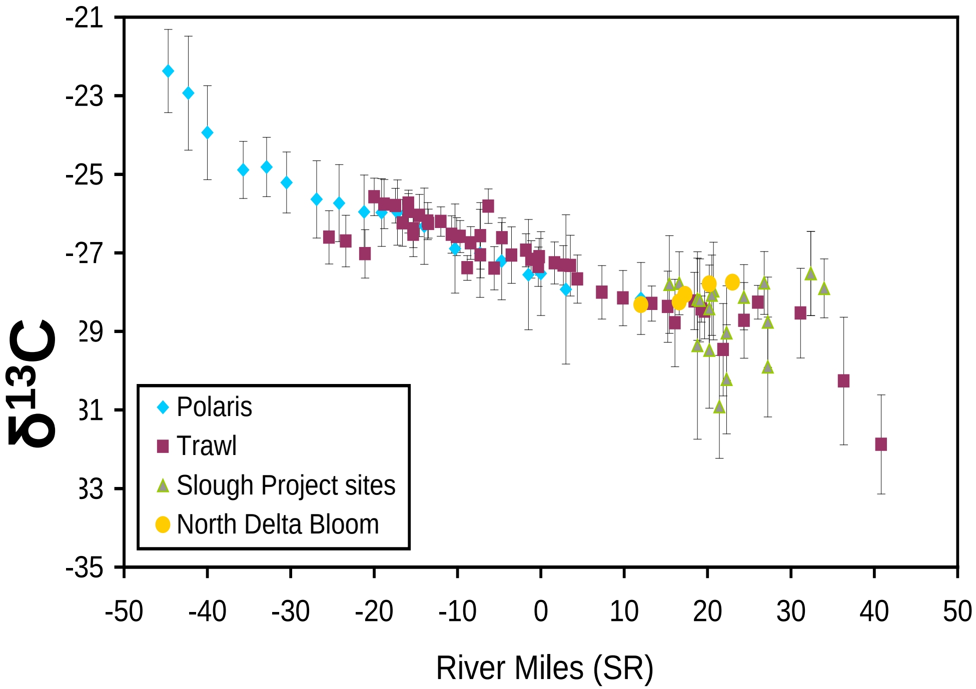
Nitrification of NH_4 provides a distinctive isotopic signature for wastewater-derived NH_4 through the Delta.



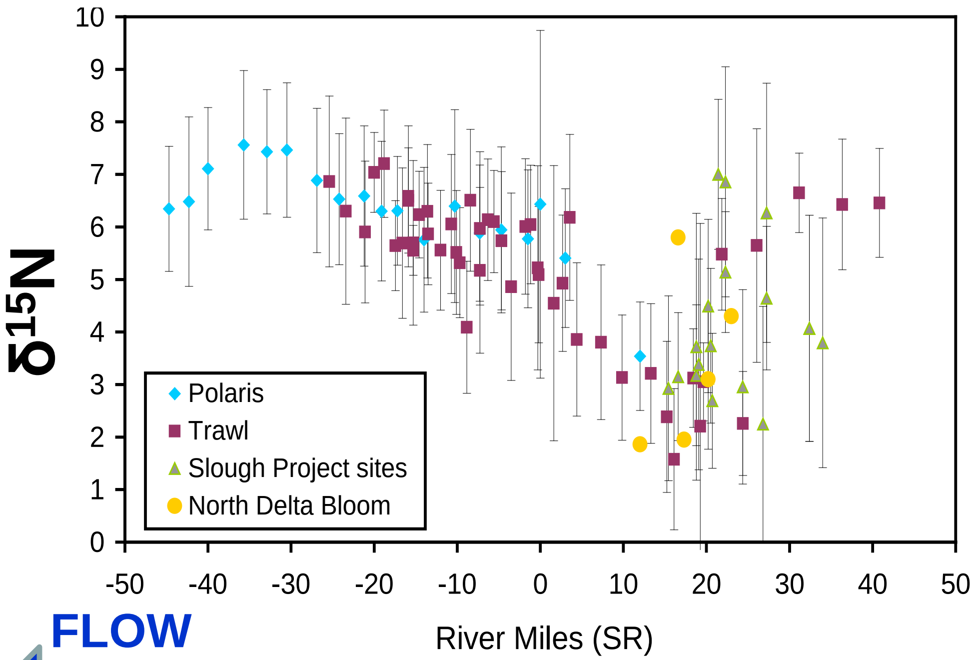
Nitrification causes progressive NH4-δ^{15}N increases downstream

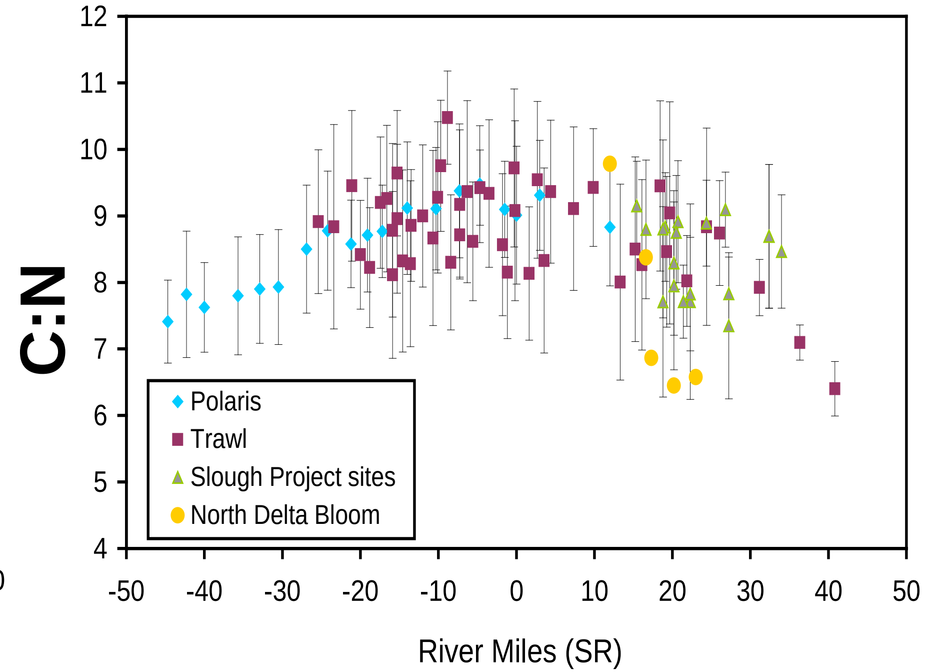


USGS

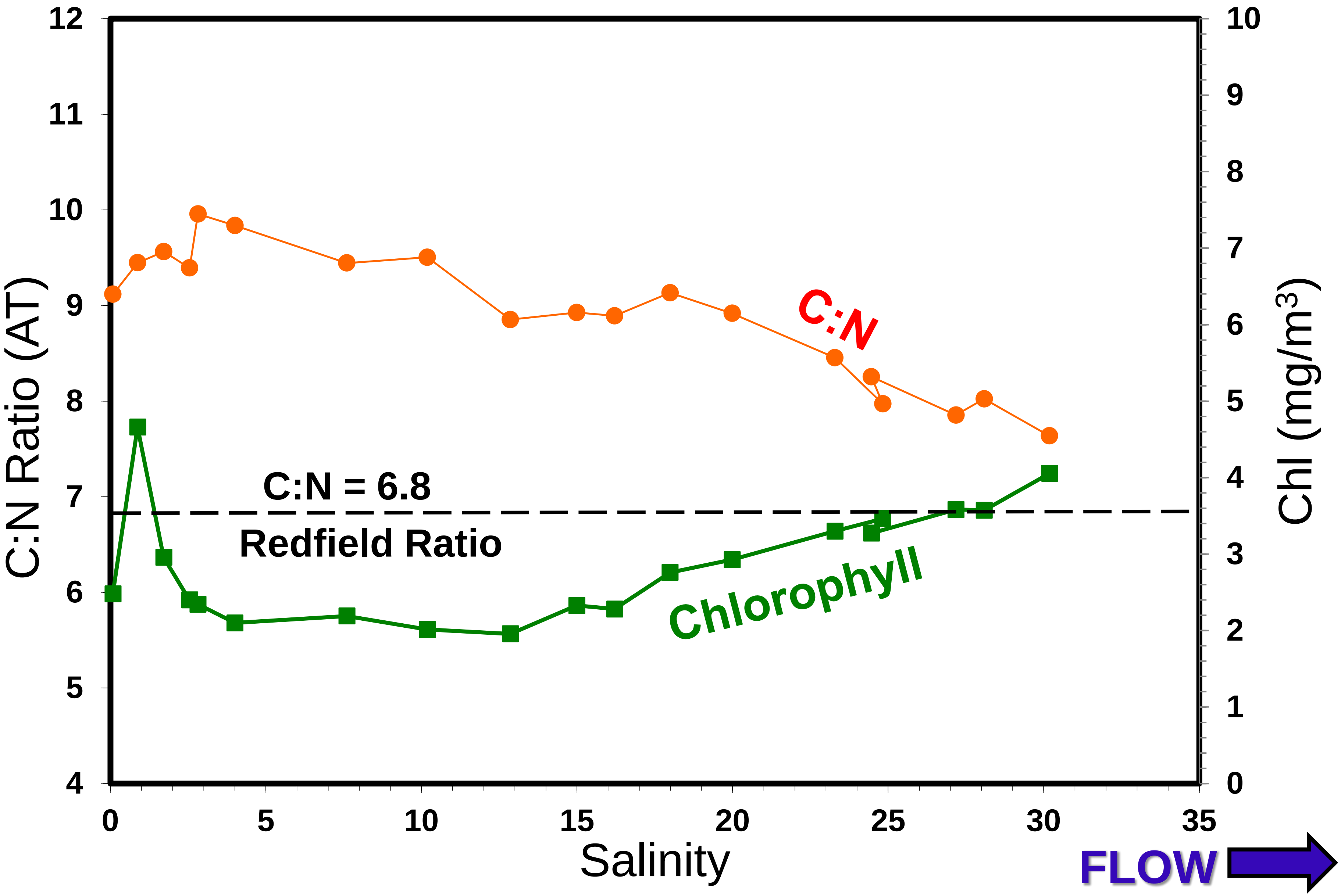


POM also shows downstream changes in composition -- for samples from different sites in the Sacramento River (SR) and Bay collected 2010-2013, plotted relative to River Mile.





Long-term average values at Bay-Delta sites are usually linearly correlated with salinity



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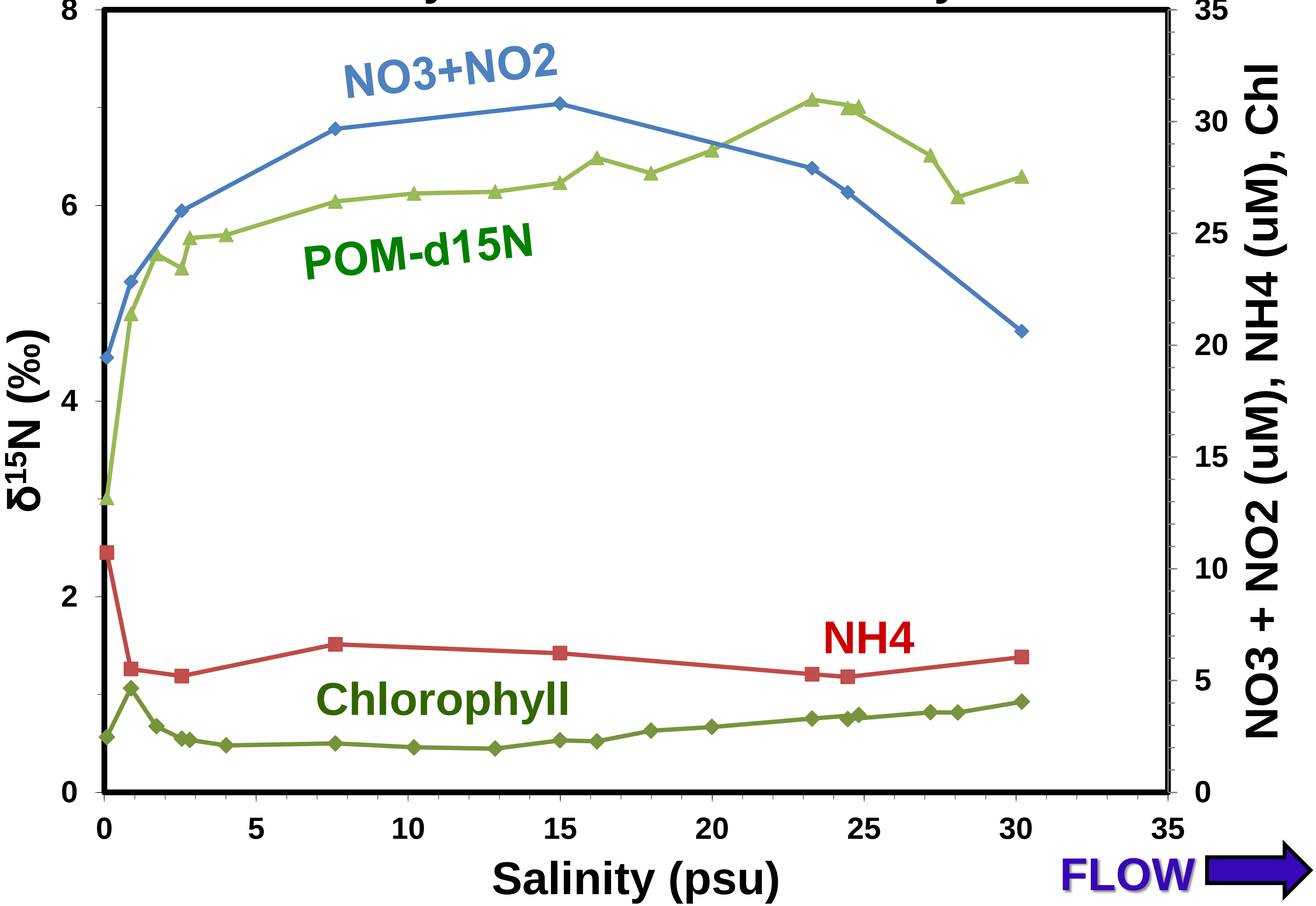
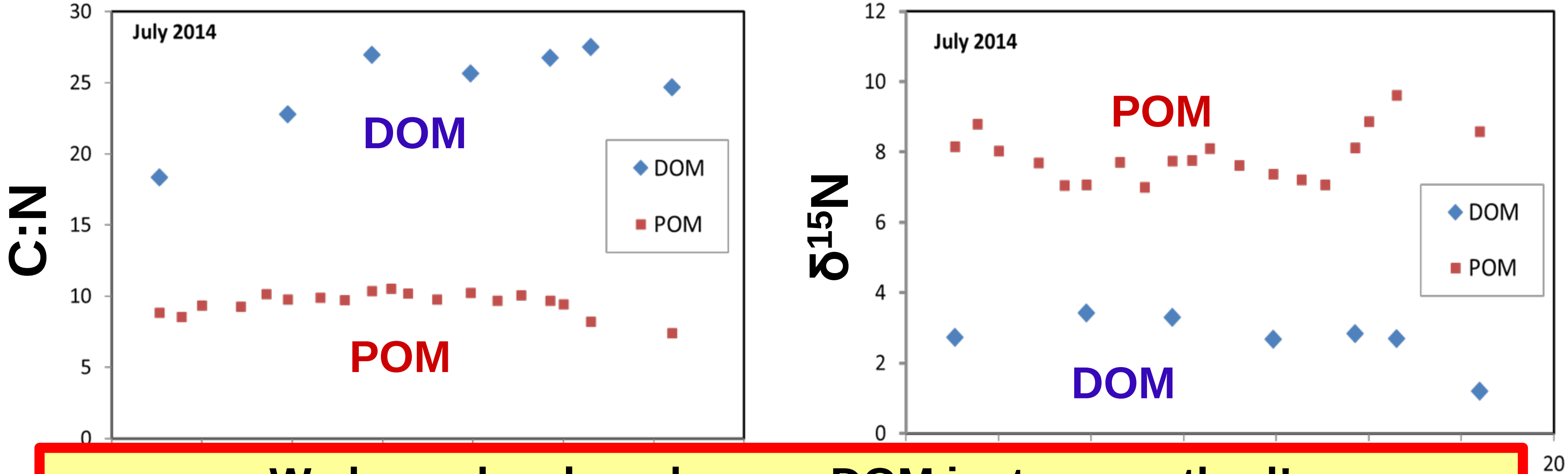
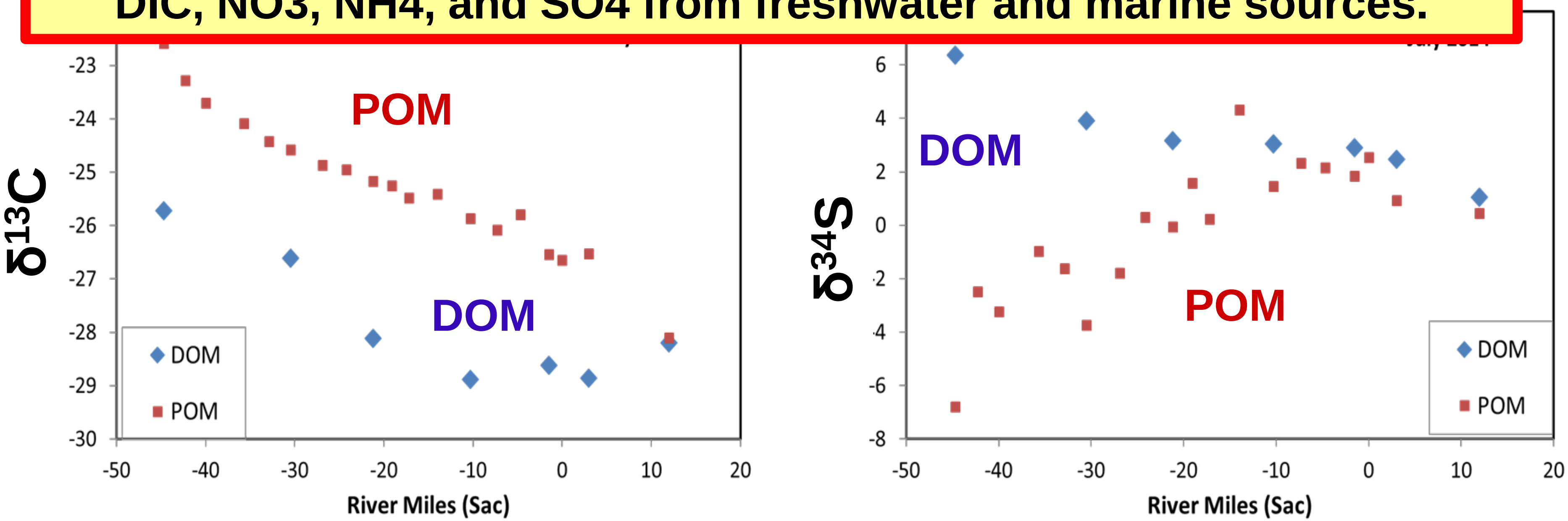
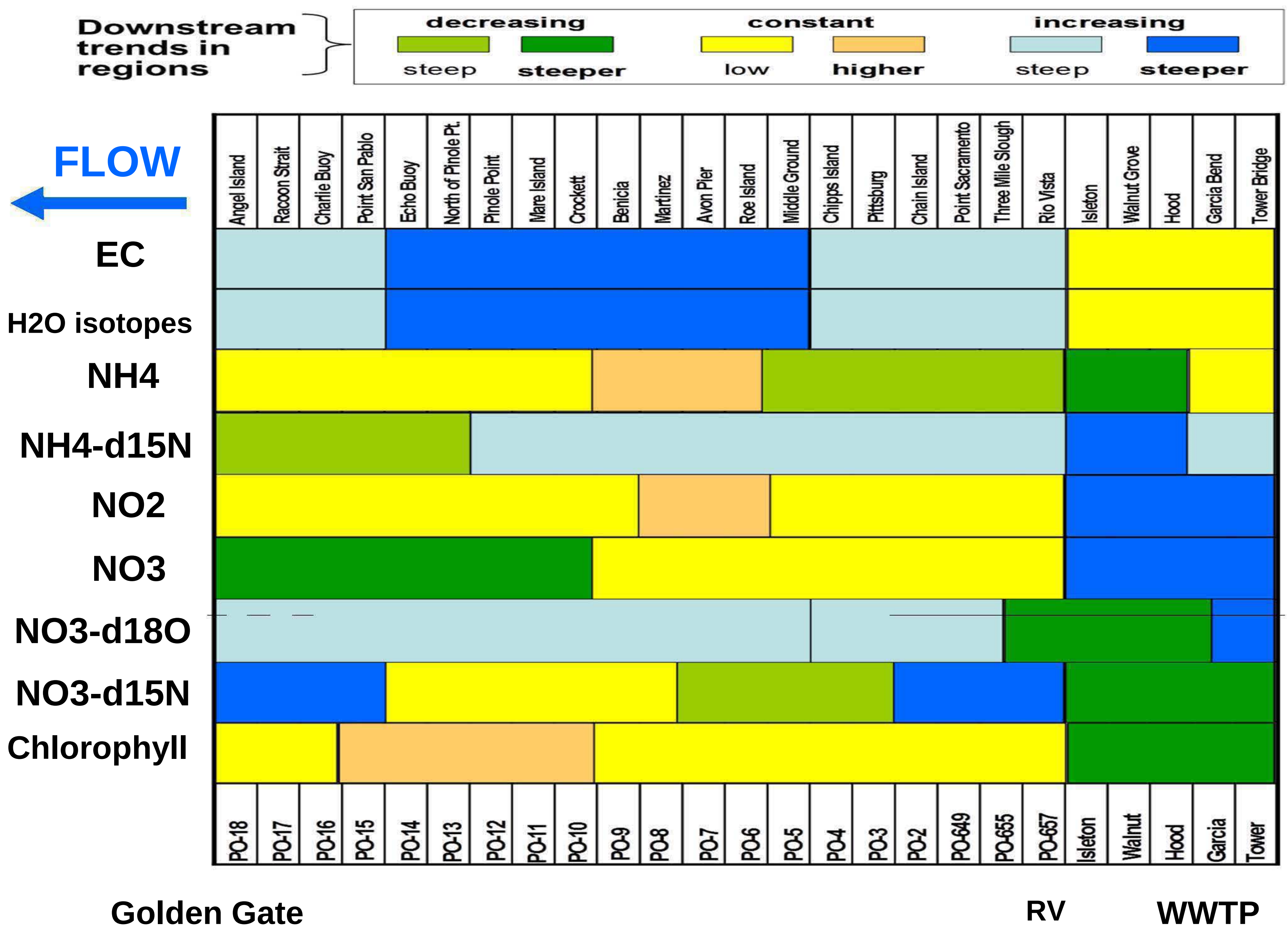


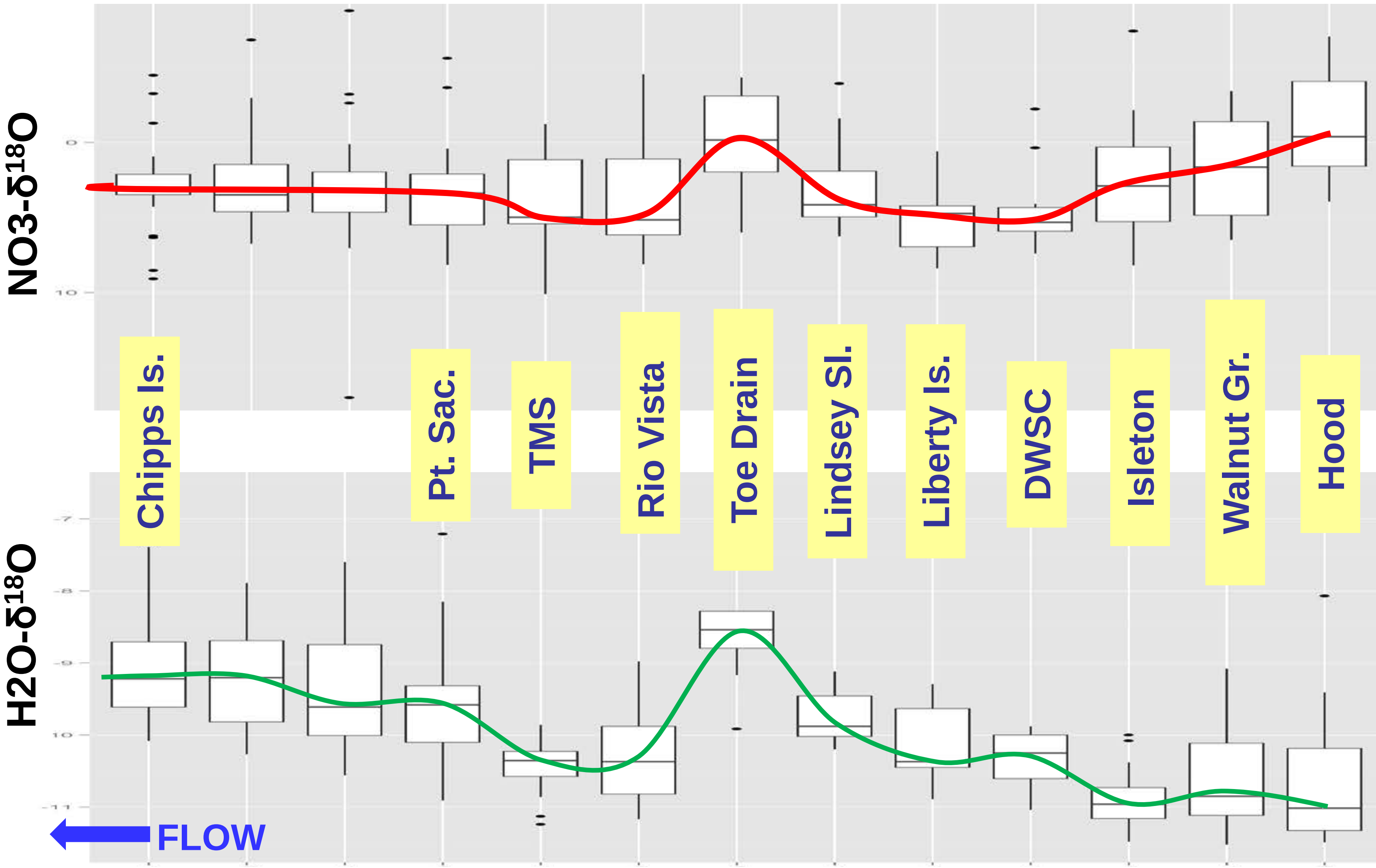


We have developed a new DOM isotope method!
Using it, we find that DOM, like POM, is largely aquatic in origin (in situ) – with C-N-S isotopic compositions influenced by the mixing of DIC, NO3, NH4, and SO4 from freshwater and marine sources.

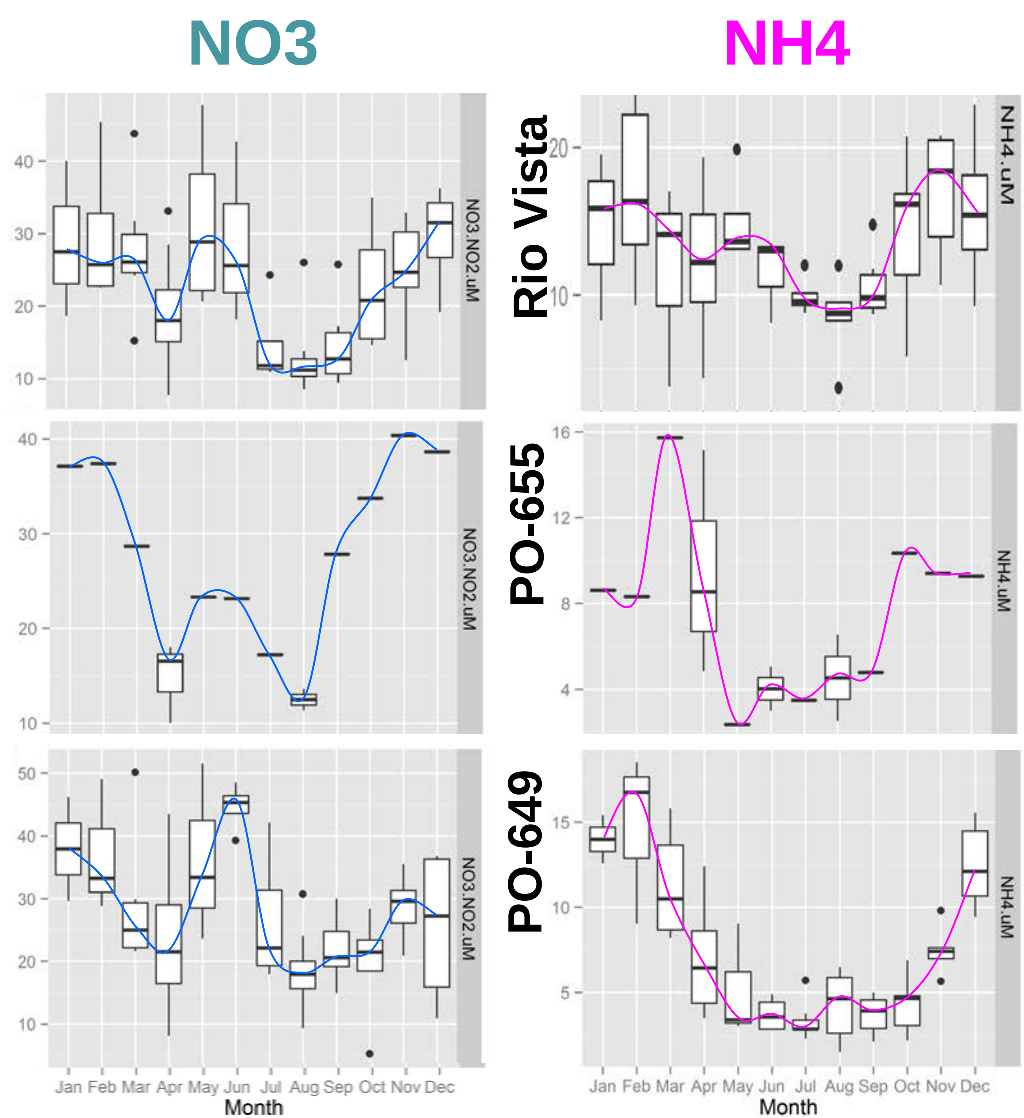



Downstream trends in regions
decreasing
steep
steeper
constant
low
higher
increasing
steep
steeper
FLOW
EC
H2O isotopes
NH4
NH4-d15N
NO2
NO3
NO3-d18O
NO3-d15N
Chlorophyll
Angel Island
Racoon Strait
Charlie Buoy
Point San Pablo
Echo Buoy
North of Pinole Pt.
Pinole Point
Mare Island
Crockett
Benicia
Martinez
Avon Pier
Roe Island
Middle Ground
Chipps Island
Pittsburg
Chain Island
Point Sacramento
Three Mile Slough
Rio Vista
Isleton
Walnut Grove
Hood
Garcia Bend
Tower Bridge
PO-18
PO-17
PO-16
PO-15
PO-14
PO-13
PO-12
PO-11
PO-10
PO-9
PO-8
PO-7
PO-6
PO-5
PO-4
PO-3
PO-2
PO-649
PO-655
PO-657
Isleton
Walnut
Hood
Garcia
Tower
Golden Gate
RV
WWTP

The downstream trends of the $\delta^{18}O$ of NO3 and H2O are similar because of progressive nitrification – where the new NO3 is formed in contact with the ambient H2O.



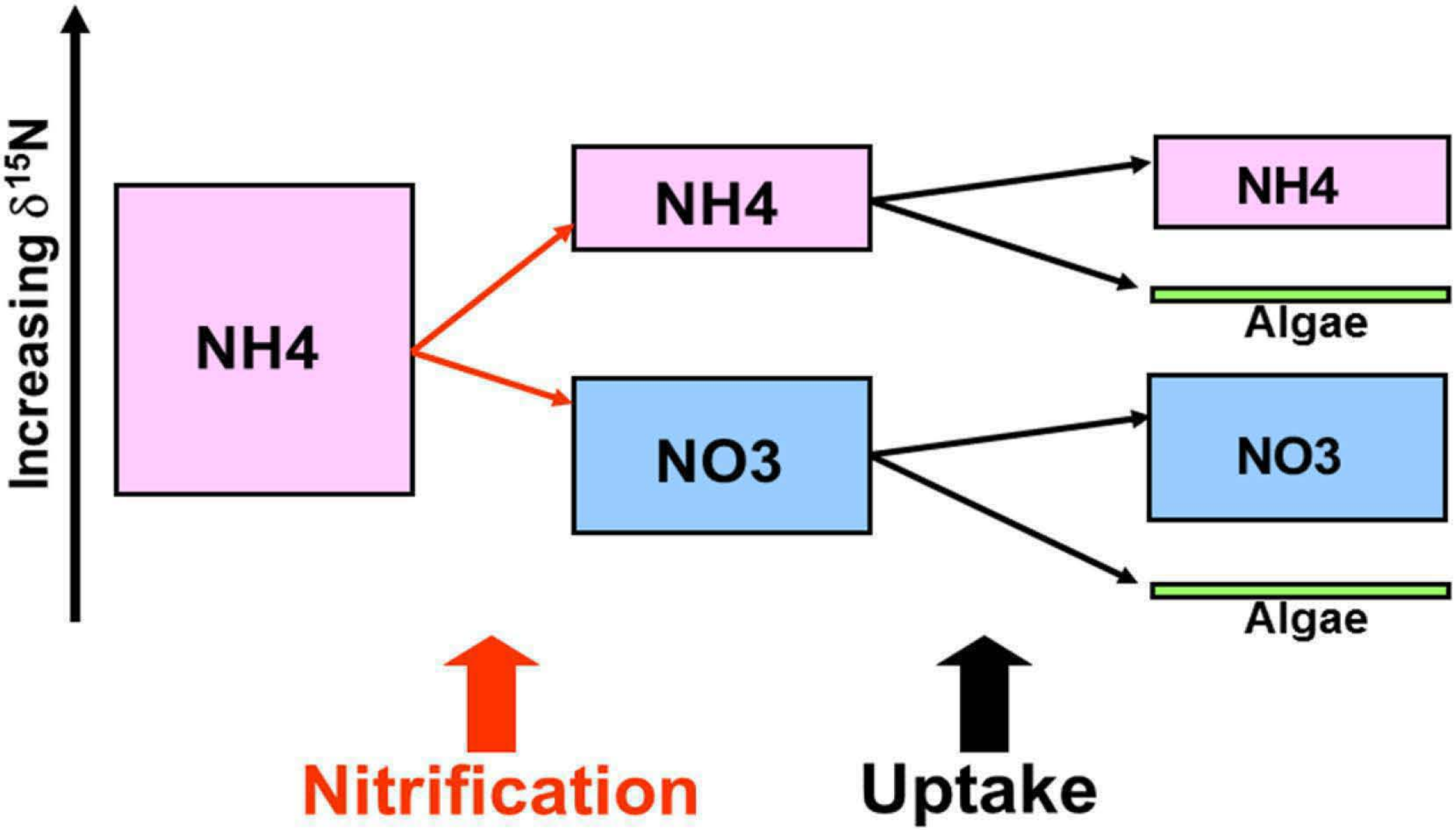
Strong seasonality in the NO3 and NH4 concentrations



NO3 seasonality initially defined by NO3 concentrations upstream of SRWTP.

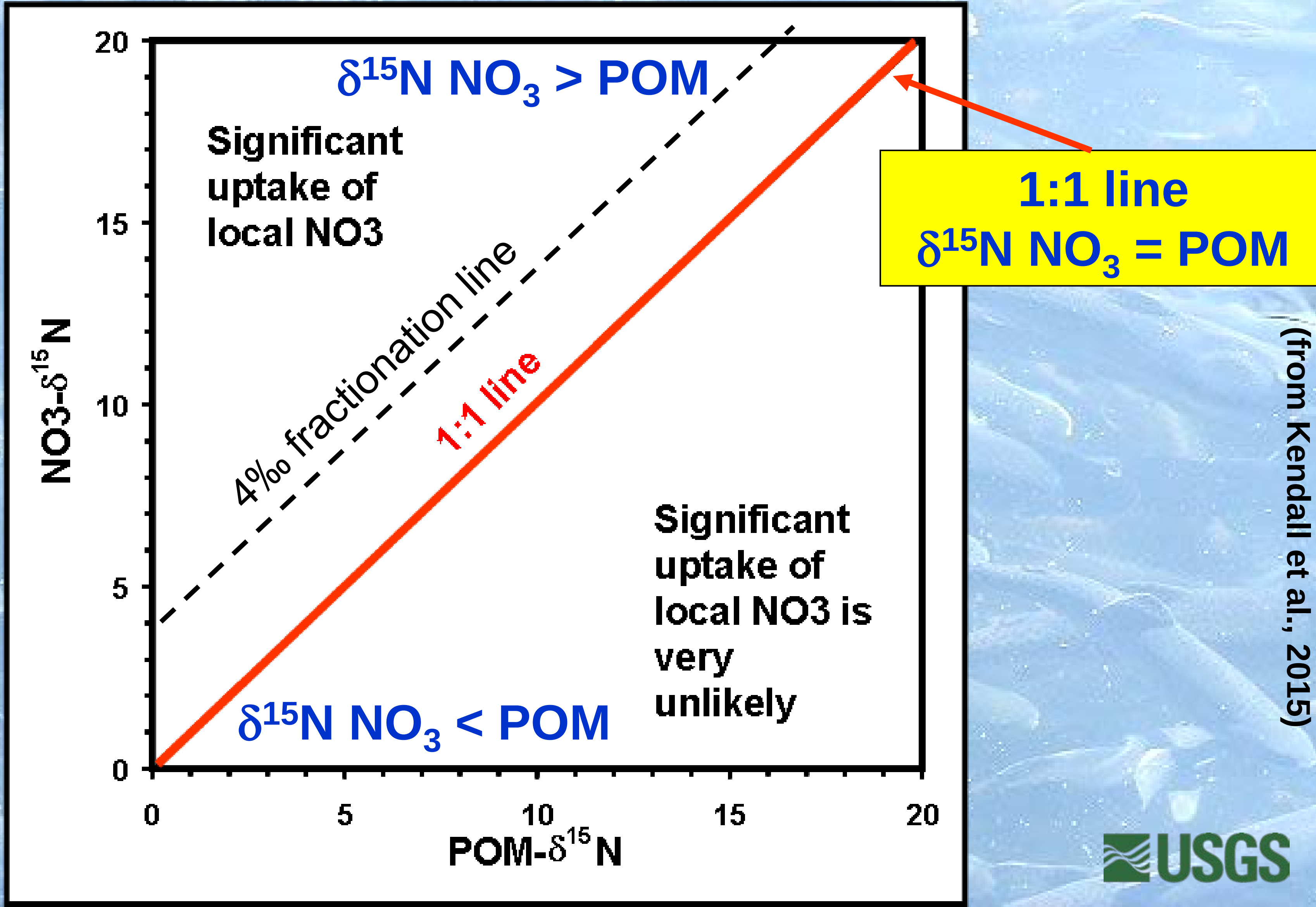
NH4 seasonality initially defined by NH4 concentrations from SRWTP effluent.

Conceptual model showing how uptake of N results in algae with a lower $\delta^{15}N$ than the N source.



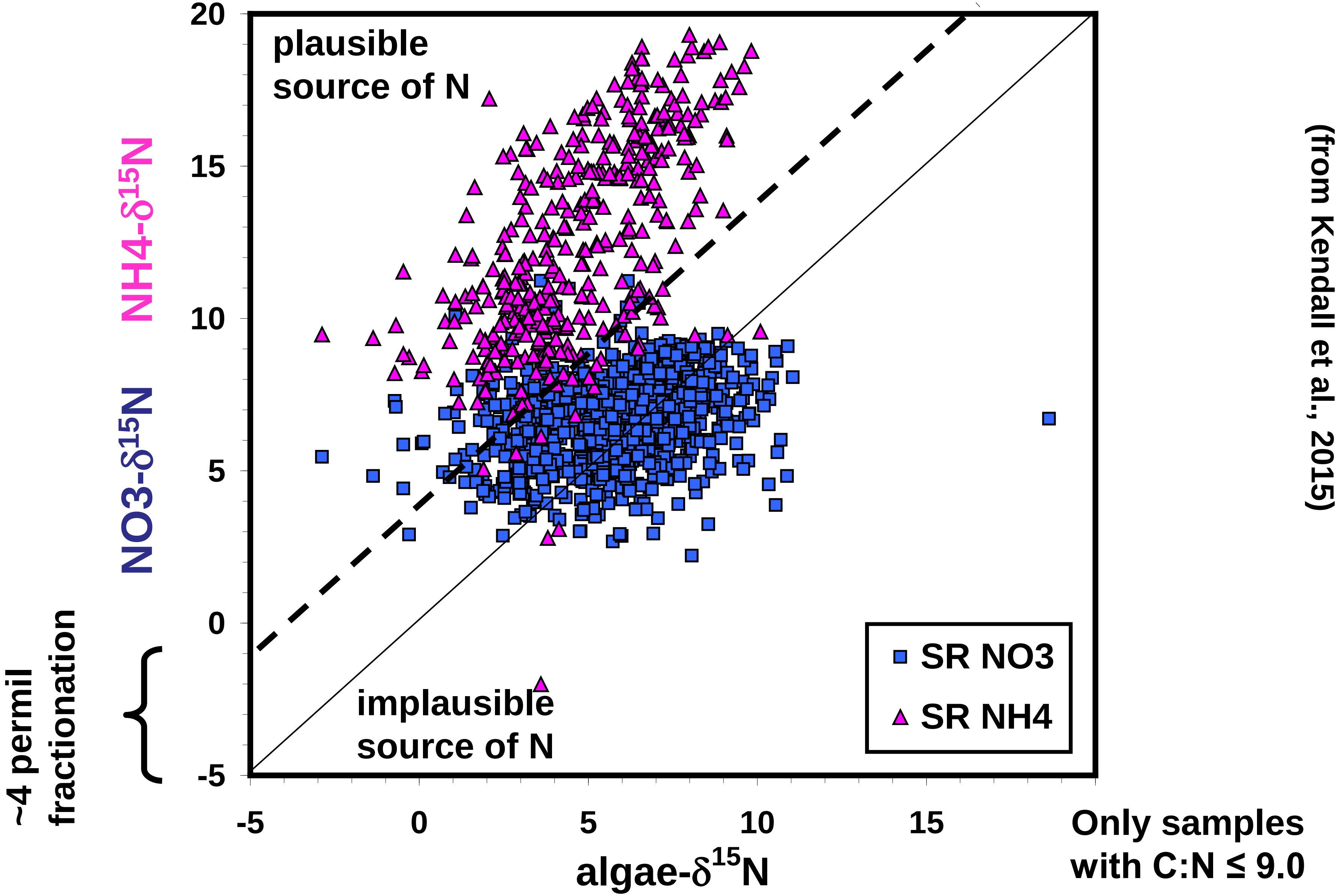
If the NH4 and NO3 have distinctively different $\delta^{15}N$ values, the $\delta^{15}N$ of algae can, in theory, be used to estimate the proportions of NH4 and NO3 assimilated by the algae.

BASIC IDEA: Samples plotting below the 1:1 line are inconsistent with NO3 as a plausible dominant N source to the algae; samples above are consistent.

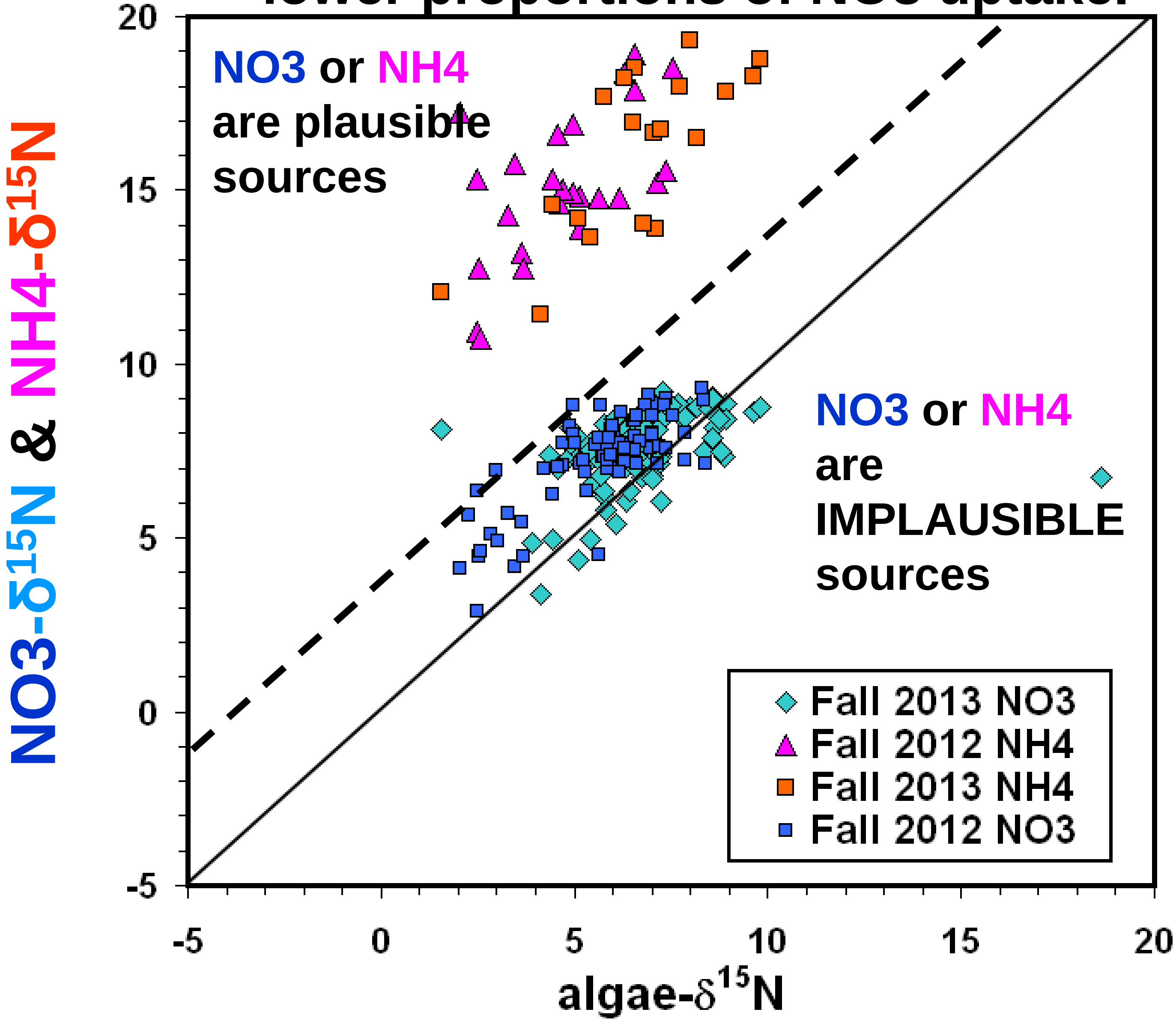


(from Kendall et al., 2015)

NH4 is the dominant source of N to algal uptake in the SR but many samples seem to have some portion of NO3-uptake

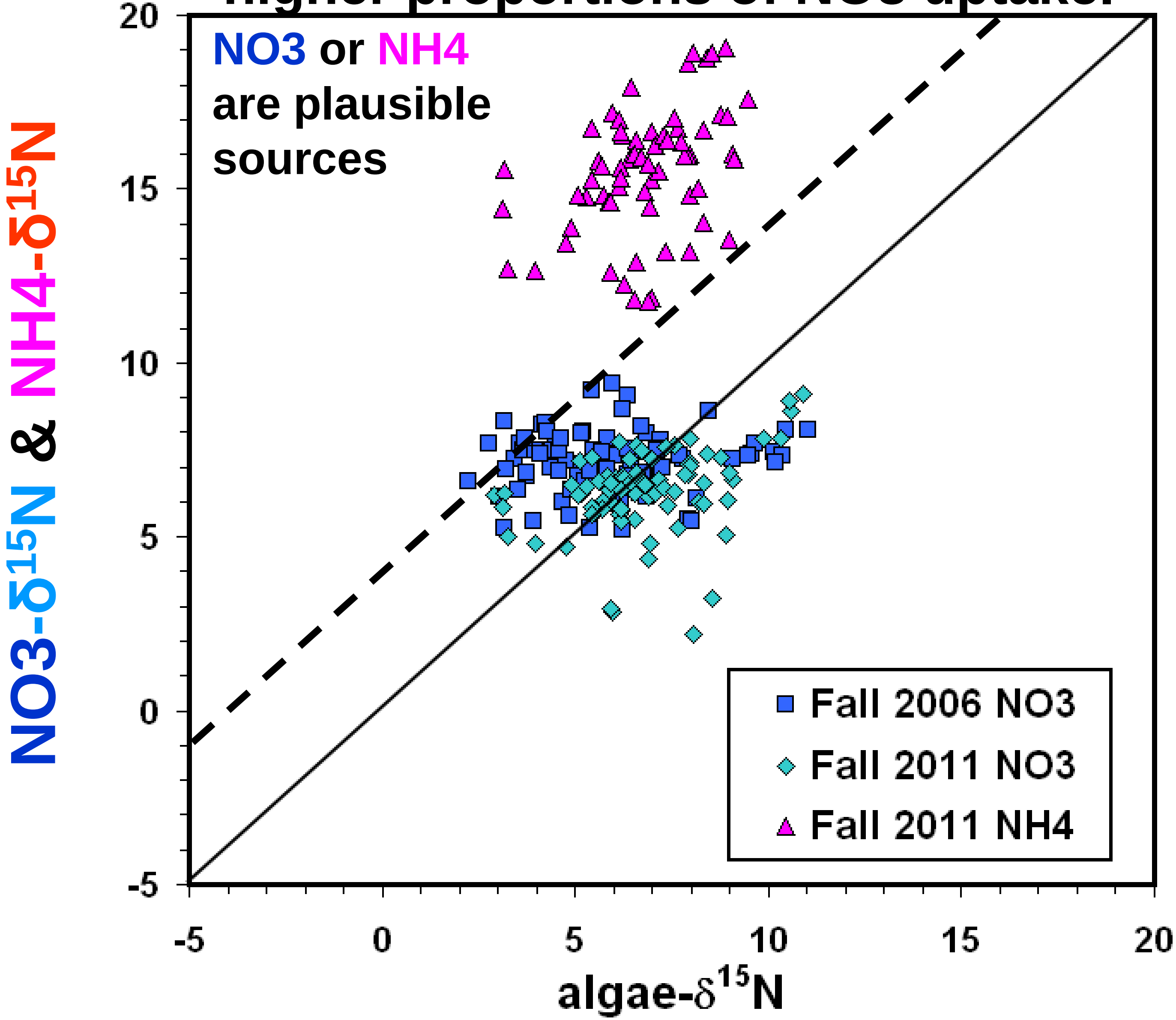


During falls of dry years (2012 & 2013), nitrification causes significant increases in NH4-δ¹⁵N and resulting algae, and lower proportions of NO3 uptake.



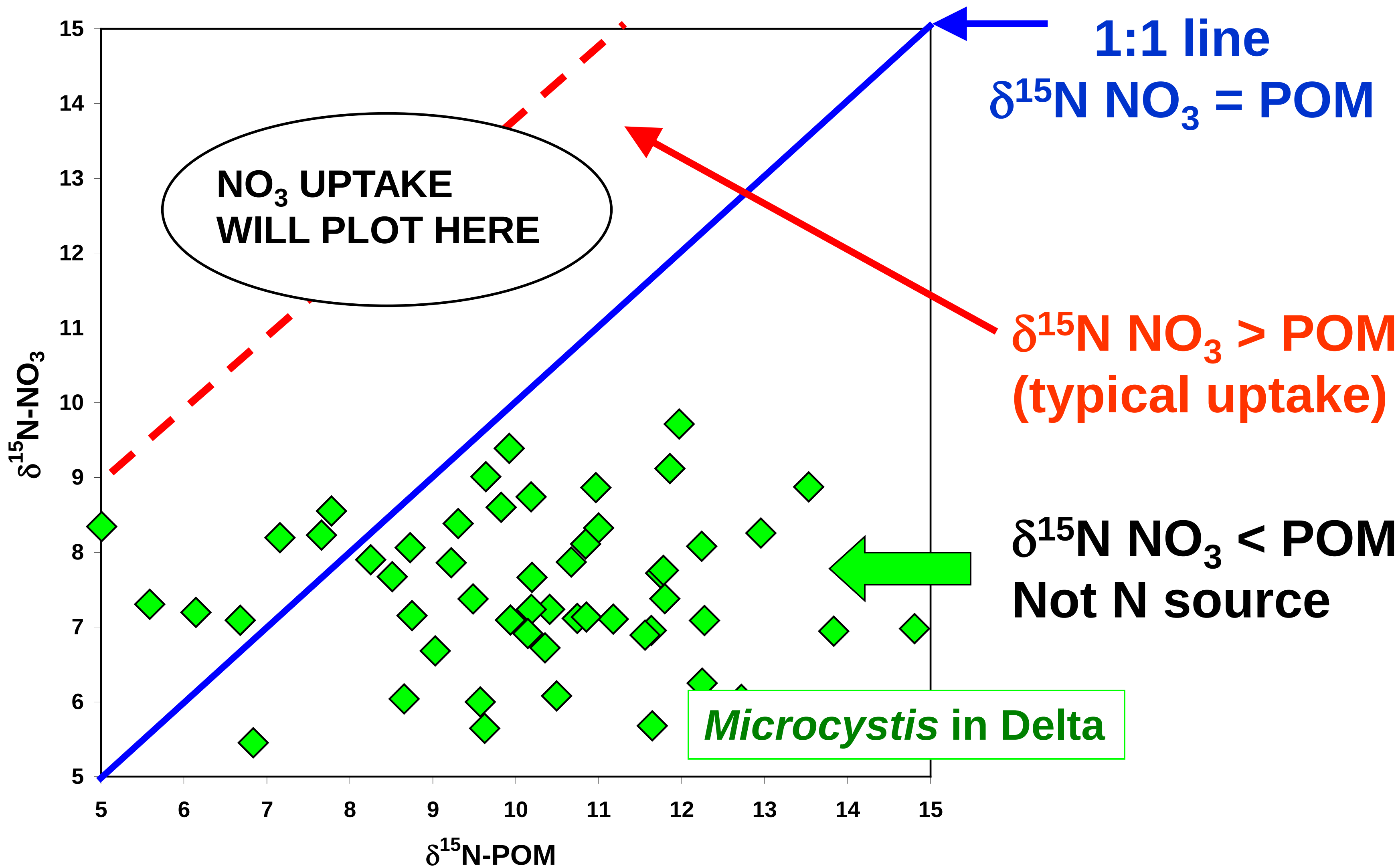
Dry years

During falls of wet years (2006 & 2011), nitrification causes smaller increases in NH4-δ15N and resulting algae, and higher proportions of NO3 uptake.



Wet years

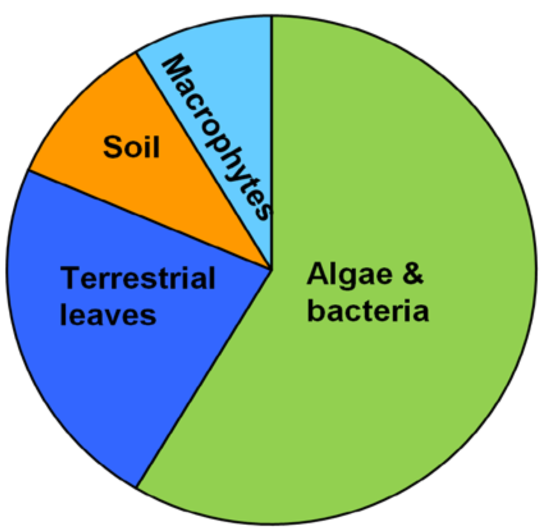
NO_3 and algae $\delta^{15}N$ analysis shows that *Microcystis* are not using NO_3



Modified from Lehman et al (2015)

Stable isotope mixing model to calculate how much of the algae derives its N from NH4 uptake (instead of NO3 uptake)

$$\% \, NH_4^+ \text{ uptake} = \frac{[(\delta^{15}N_{NO3} - \varepsilon_{NO3}) - \delta^{15}N_{algae}]}{[(\delta^{15}N_{NO3} - \varepsilon_{NO3}) - (\delta^{15}N_{NH4} - \varepsilon_{NH4})]} \times 100$$



Cartoon

But first we must calculate the isotopic composition of algae from POM isotope data..

Is a 2-component (algae/bacteria and terrestrial OM) model acceptable?

Conclusions:

- Flow is a major control on chemical and isotopic variations, with significant differences for wet/dry falls and wet/dry springs.

- The C-N-S isotopes of the POM are sensitive to changes in salinity, nutrient sources, extent and type of C-N-S cycling, geographic sources of the POM, quality of the organic matter, etc. – making them useful tracers of habitat environmental quality conditions.

- Nutrient isotopes are allowing us to estimate NO3 vs NH4 uptake proportions.

- The temporal and spatial variations in chemical and isotopic data should allow calculation of relative proportions from sources and extent of several biogeochemical reactions.

- **We are looking collaborators with modeling, statistical, and ecological expertise -- to help us make better use of our data and biogeochemical expertise to develop and/or test fish habitat or other hydro-biogeochemical models.**

Thanks to:

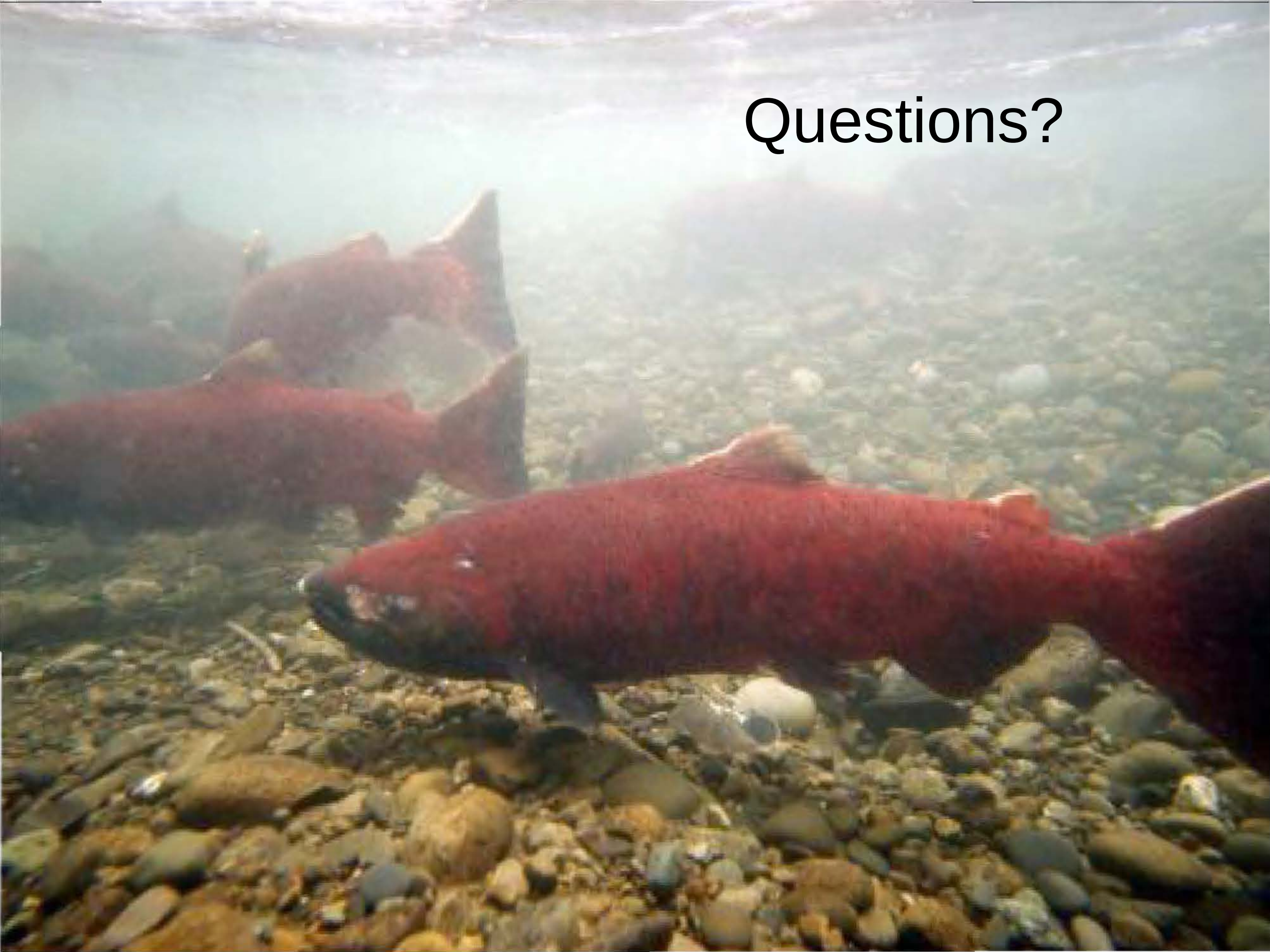
(1) the USGS ***RV Polaris*** team for letting us piggyback our isotope sampling on their monitoring program 2006-2016, and for providing the chemistry for the samples (http://sfbay.wr.usgs.gov/);

(2) Brian Bergamaschi (USGS) and his team for providing boats and skippers for our “Slough project” and FLaSH project sampling trips, 2011-12.

(3) Randy Dahlgren (UCD) for the chemistry data for “Slough project” samples.

(4) Our funding sources for this study:

USGS National Research Program
Bay-Delta (CALFED) Program
Interagency Ecological Program
Bureau of Reclamation


Questions?