High-Frequency Nutrient and Biogeochemical Monitoring: Connecting the Dots between Drivers and Effects of Constituent Concentrations

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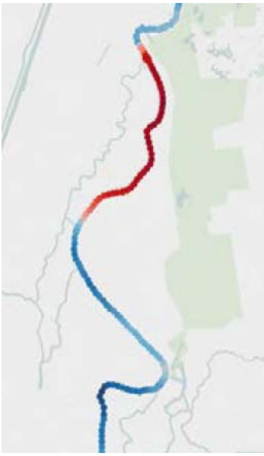
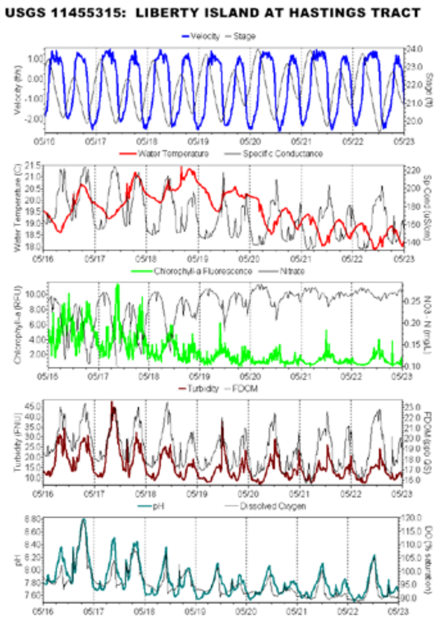
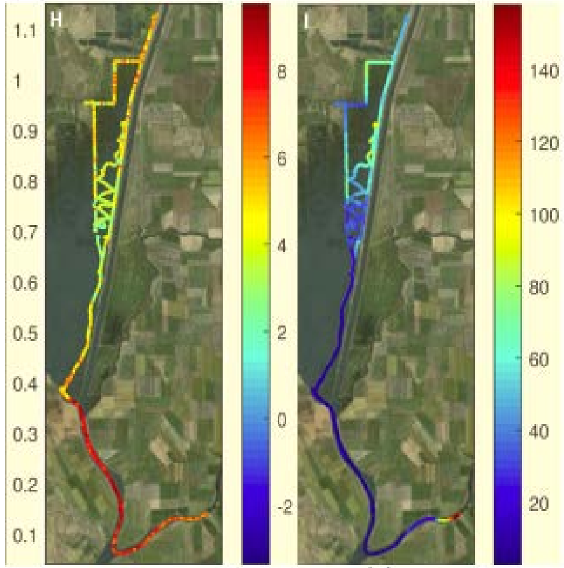
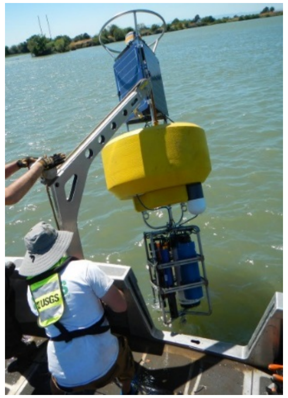
and many others!!



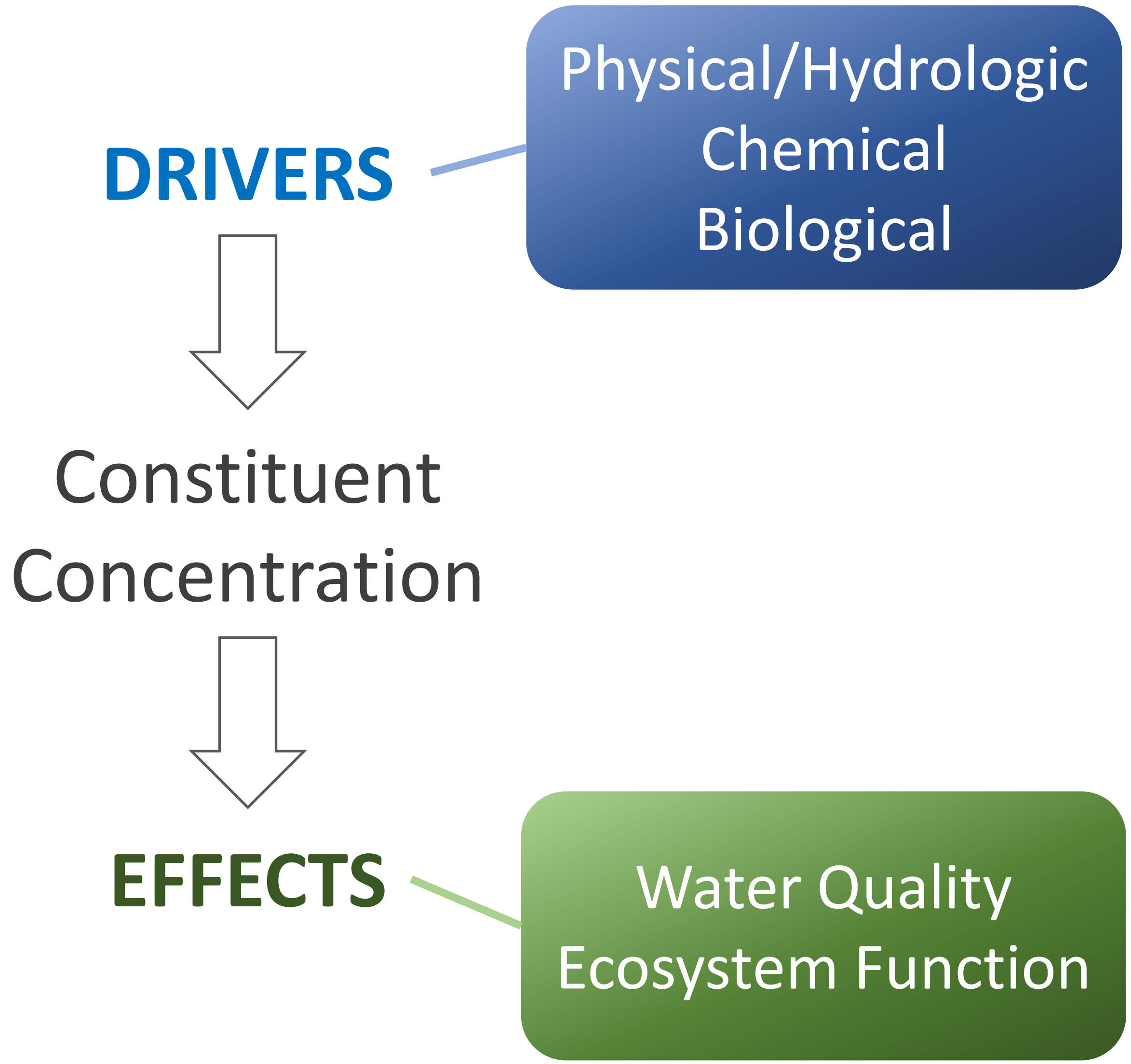






SWAMP
Annual Water Quality Health Indicator and Data Science Symposium
June 29-30, 2017

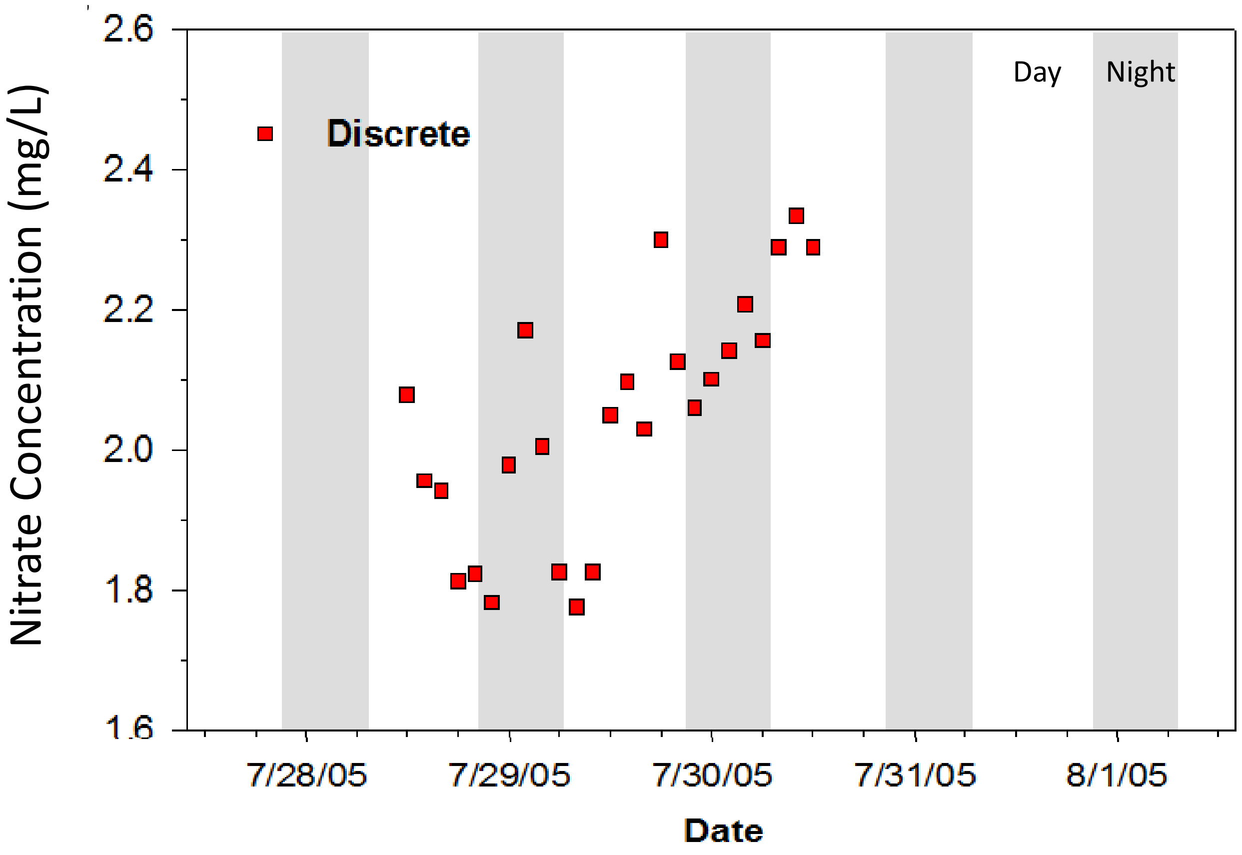
Identify Linkages



When needed & if possible…
Collect High Freq Data

- ✓in situ
- ✓High Frequency (15-min)
- ✓Continuous
- ✓Real Time (telemetry)
- ✓Flux-based (flow also)
- ✓Multi-parameter
- ✓Spatial network

DATA COLLECTION – Discrete Sampling



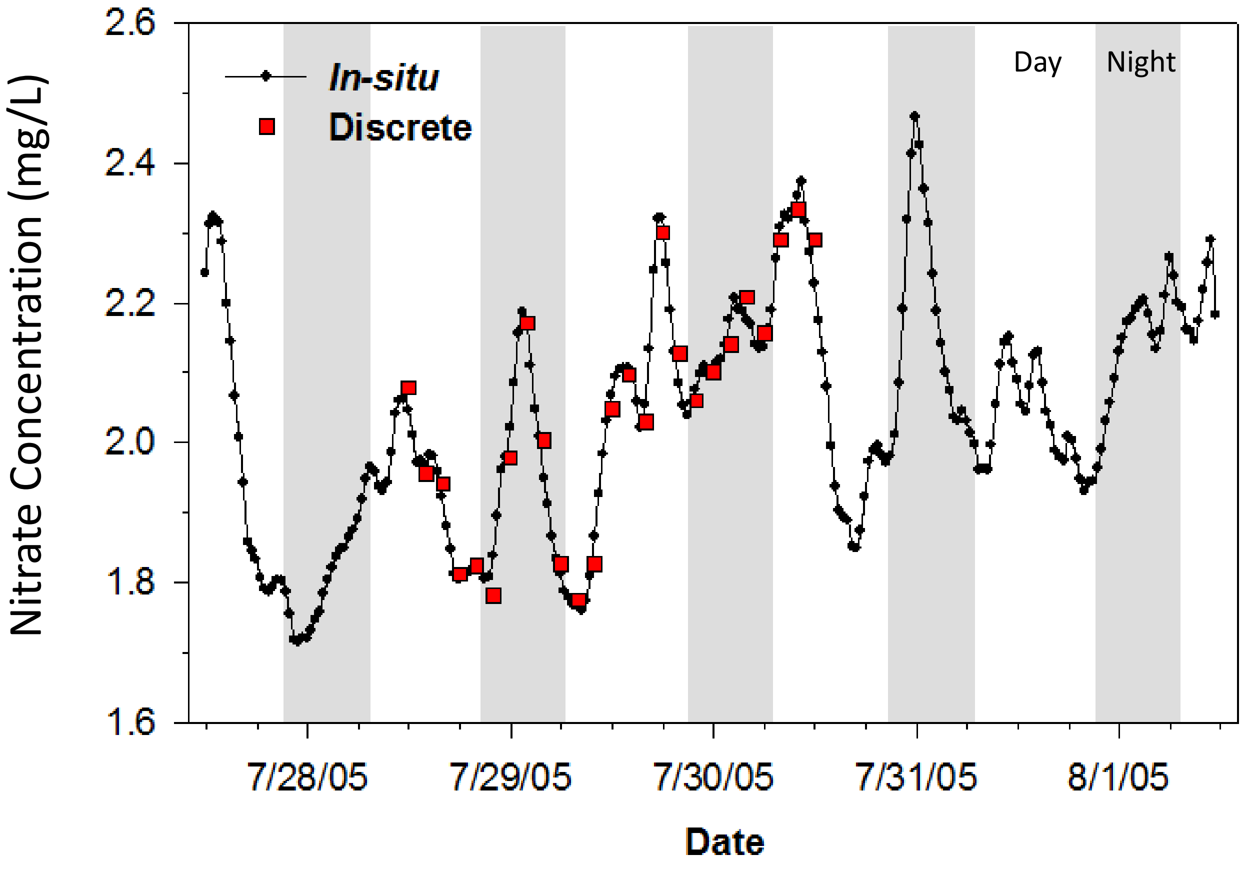
San Joaquin River
Nitrate Concentrations

Discrete/Grab (bottle→ lab)
2-hour sampling frequency

What controls on nitrate concentrations?

Pellerin et al. 2009 Freshwater Biology

DATA COLLECTION – in situ, High Frequency



San Joaquin River
Nitrate Concentrations

Discrete/Grab (bottle→ lab)
2-hour sampling frequency

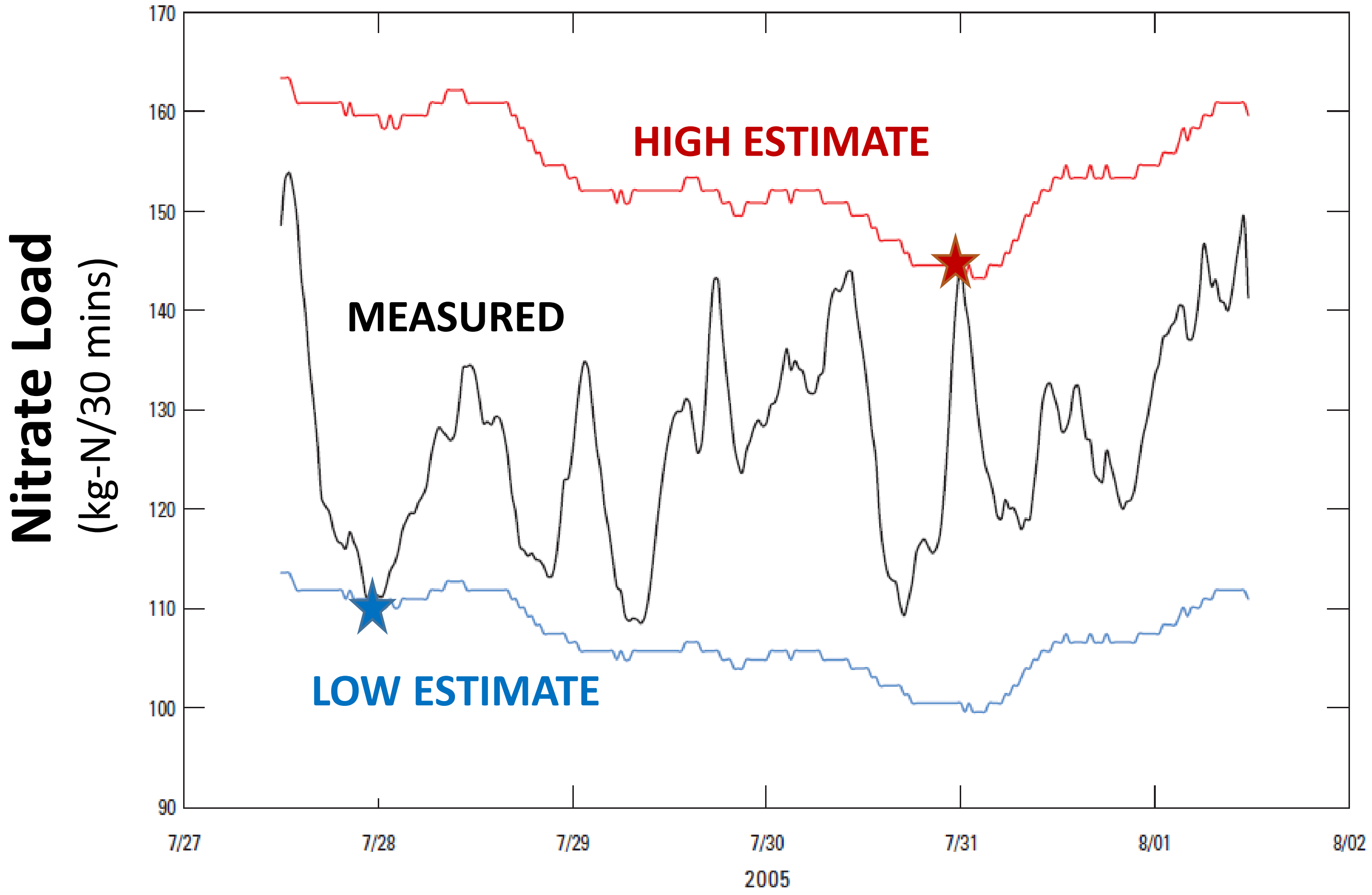
in situ sensor (SUNA)
15-minutesampling frequency

What controls on nitrate concentrations?

Pellerin et al. 2009 Freshwater Biology

LOAD Estimates

CONC x FLOW = LOAD



What controls nitrate Load?

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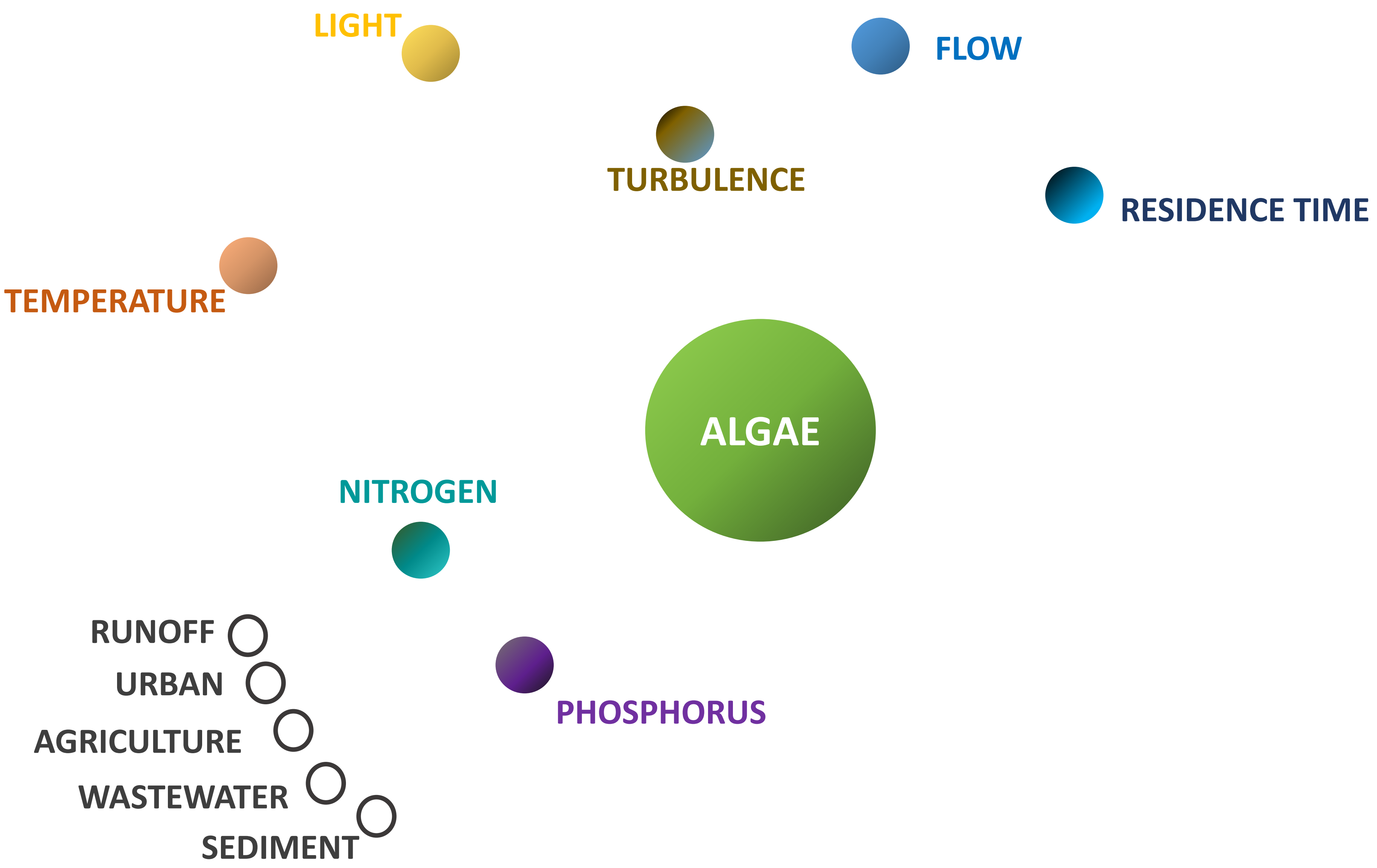
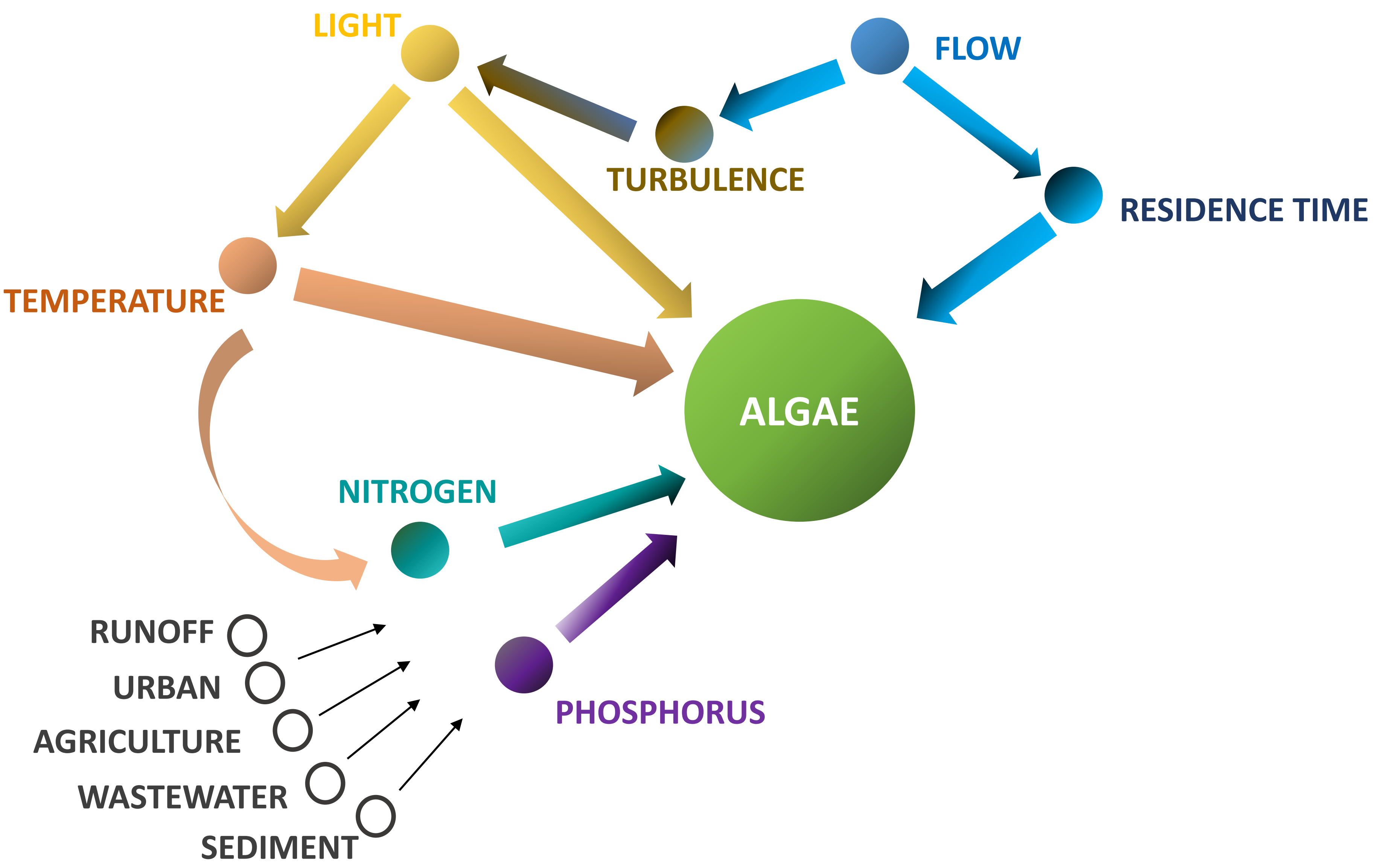
ALGAE
(Chl-*a*)

Connecting the Dots…



Connecting the Dots…



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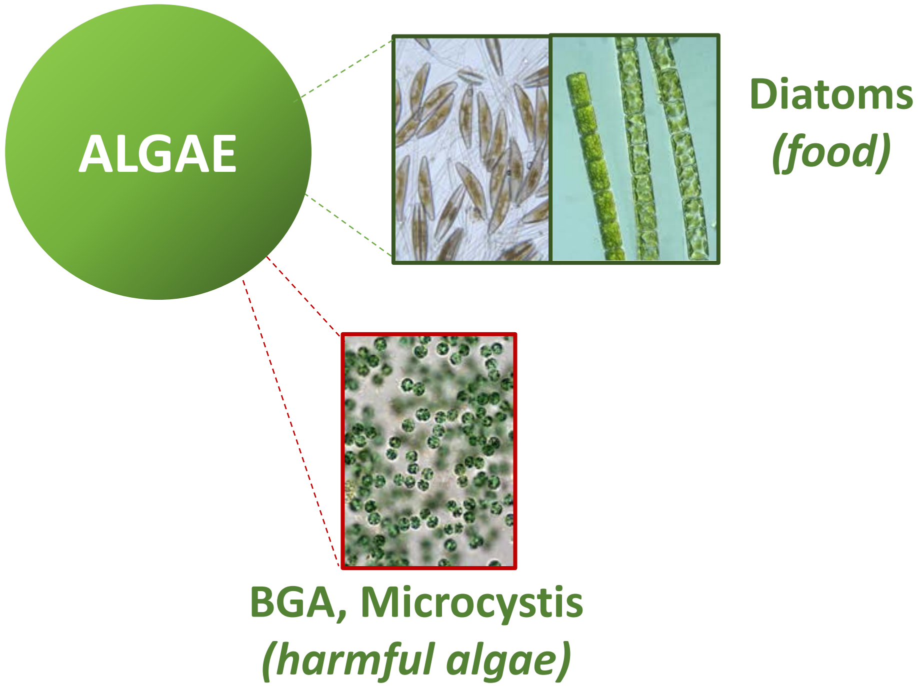

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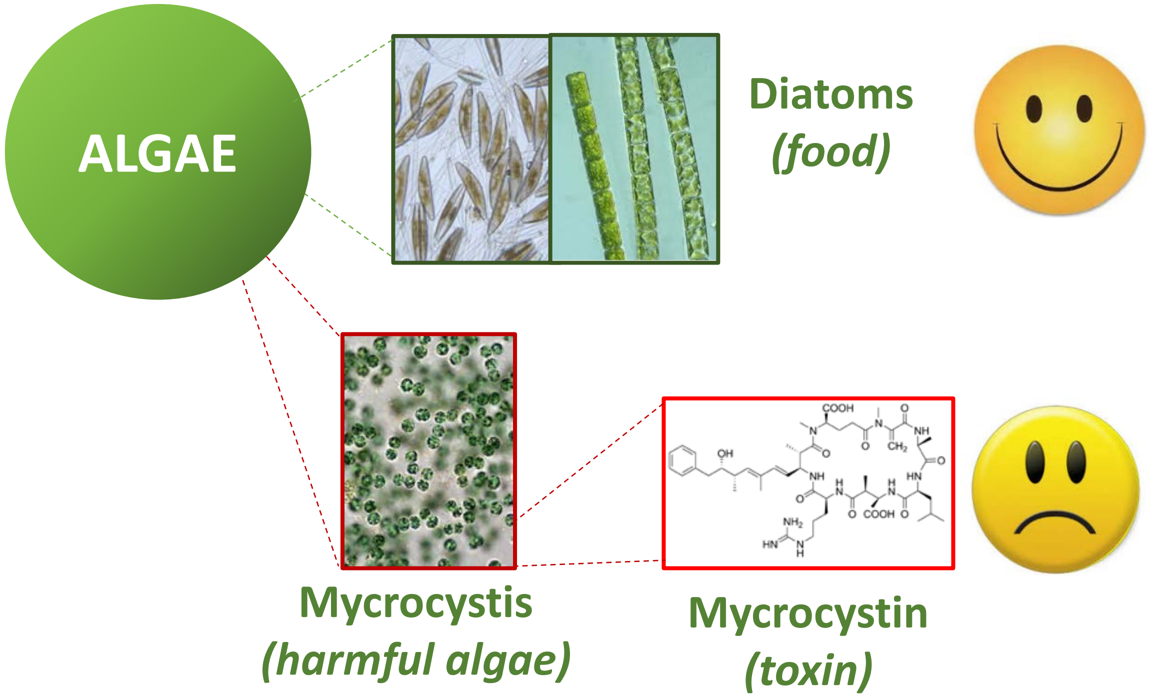

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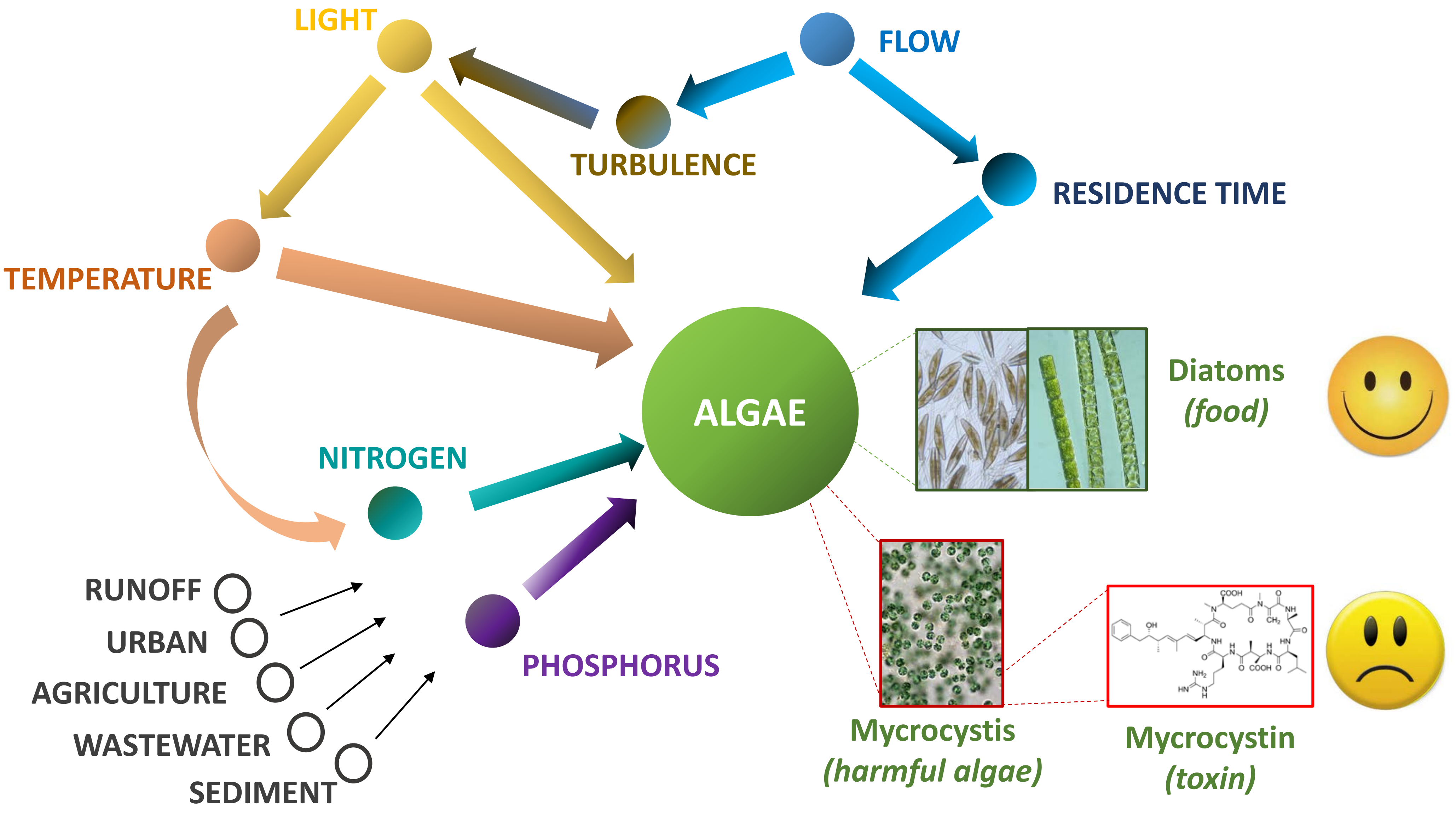

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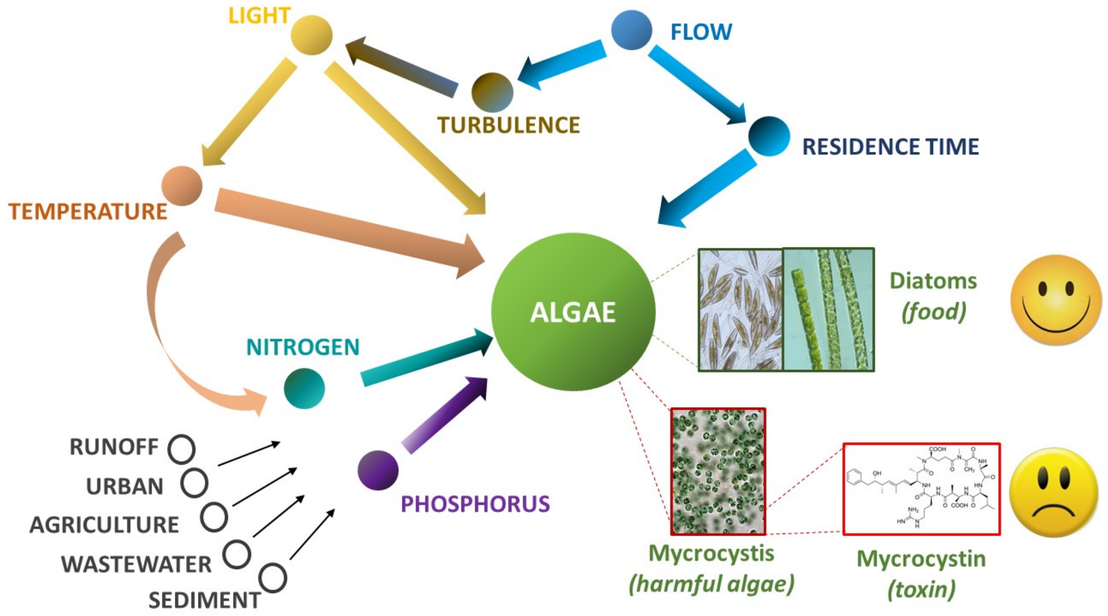


<u>What do HABs Like?</u>

Longer residence time?

Higher Temperatures?

Higher Nutrients (NH_4?)

Low N:P ratio?

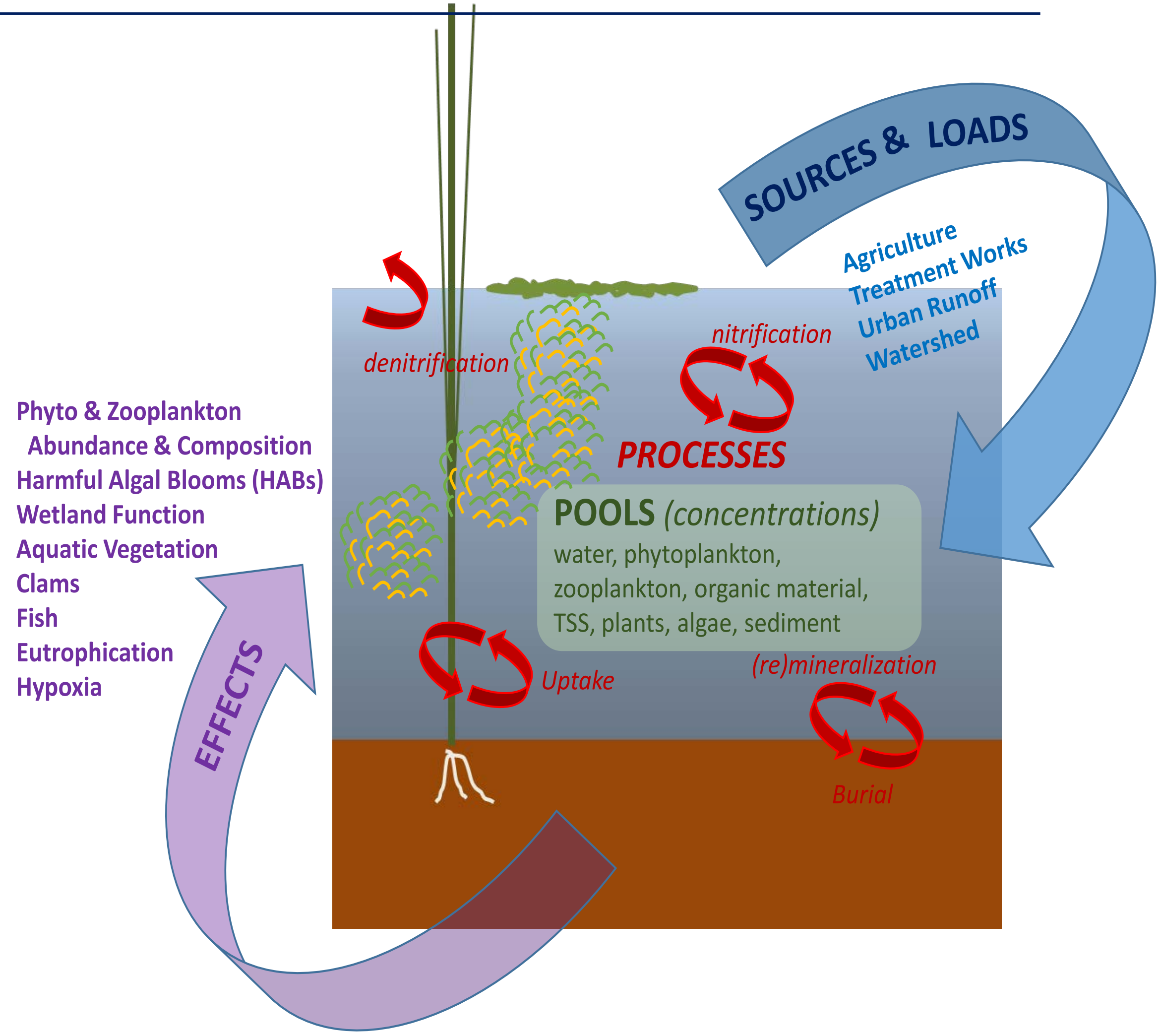
Stratified (buoyant) or

Turbulence (redistribution)?

Analysis of these data allows us to better understand bloom formation and thus – maybe maybe – manage systems to get the ones we want, and avoid the ones we don't.

Parameters

- **Flow (velocity, discharge, depth)**
- **Temperature**
- **Specific conductivity**
- **Turbidity/TSS**
- **pH**
- **Dissolved oxygen**
- **Chlorophyll-*a***
- **BGA**
- **fDOM** (Dissolved Organic C)
- **Nitrate**
- *Phosphate*
- *Ammonium. . .*



Nutrients

Sources – Processes – Effects

Nutrient Sensors

Nitrate
UV absorbance

Phosphate
wet chemistry

Ammonium…
wet chemistry

Prototype -
in development
…also for high frequency mapping

In situ Tools to Measure Phytoplankton/HABs

Chlorophyll Fluorescence

YSI “Total Algae Sensor”

ABUNDANCE chlorophyll-*a*
phycocyanin (blue-green algae, BGA)

Chlorophyll-a @ Ex470, Em685
BGA @ Ex590, Em685

FluoroProbe

SPECIES - cyanobacteria, green algae, diatoms/dinoflagellates/chrysophytae, cryptophytae

Ancillary Measurements

ACTIVITY
Turbidity
Dissolved Oxygen
pH
Nutrients

EXO2 Multiparameter Sonde

<u>Discrete samples</u>
Visual ID
Enumeration
Pigments
Toxins
DNA/RNA

CHALLENGES

Chlorophyll Fluorescence and other tools

- "**Proxy Measurement**" – requires conversion to biomass units (µg/L)
  - *f*(species, growth phase, health, "packaging")
  - calibration with standards (algae, rhadomine dye)
  - calibration with grab samples

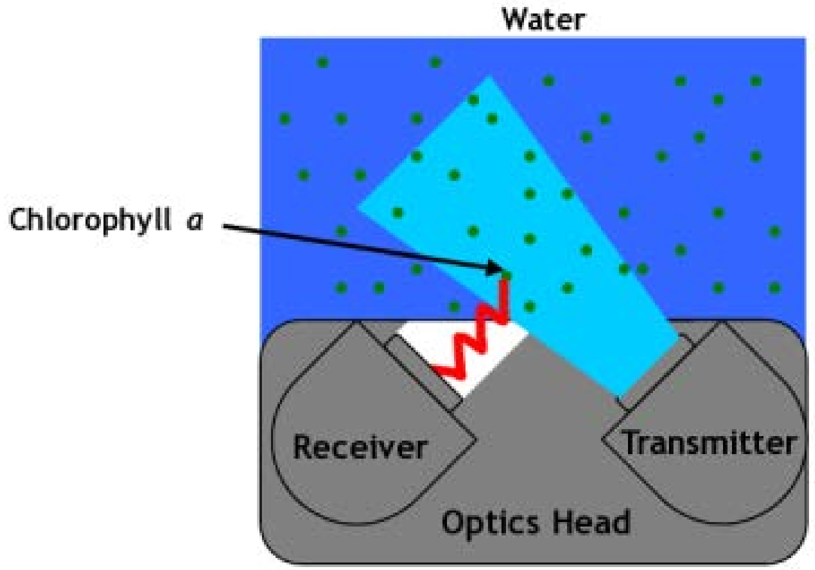
- **Interferences** – particles, dissolved organic matter (FDOM)

- **Temperature** effects
  - 1% per ˚C

CHALLENGES

Chlorophyll Fluorescence and other tools

- **<u>Where</u> in the water column?**
  surface, 0.5 m, 1 m, at depth (profiles…)
  what about benthic/epibenthic populations?
- **What is the <u>sample volume</u> being measured?**
- **What is the <u>rate</u> of measurement?**
  What is the variability?
- **How does this relate to "<u>patchy</u>" populations?**
- **What is the <u>detection level</u>?**
  can it measure 'seed populations'?



Look for
USGS Techniques and Methods
Report on
Chlorophyll Fluorescence
Pellerin et al.

CHALLENGES

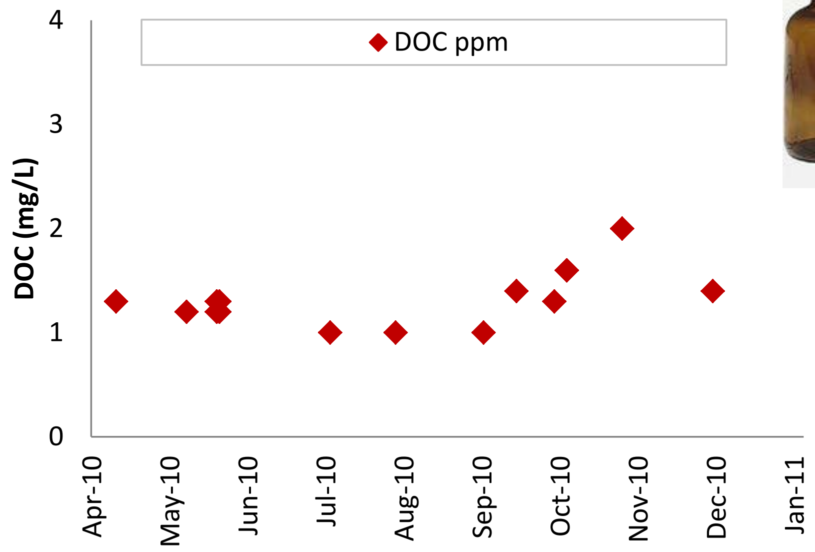
How do these measurements relate to

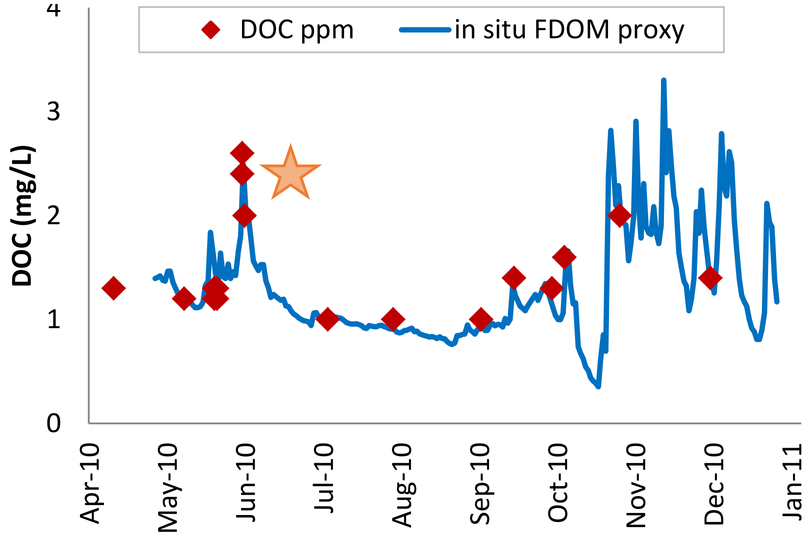
- o Specific Species
- o Toxins
- o Taste/Odor Compounds
- o When do they become ‘nuisances’, ‘harmful’

- Ecologic Concerns
- Economic Concerns
- Public Health Concerns

Why Use In Situ Tools?

- Potential for 24/7 data
- Capture rapid changes (events)
- Real time monitoring - immediate action possible
- **Trigger sampling** ☆
- Potential cost savings (reduction in labor/lab costs)
- Remote Locations
- Proxies for other constituents ($$, difficult to measure)





When do you need more frequent data?

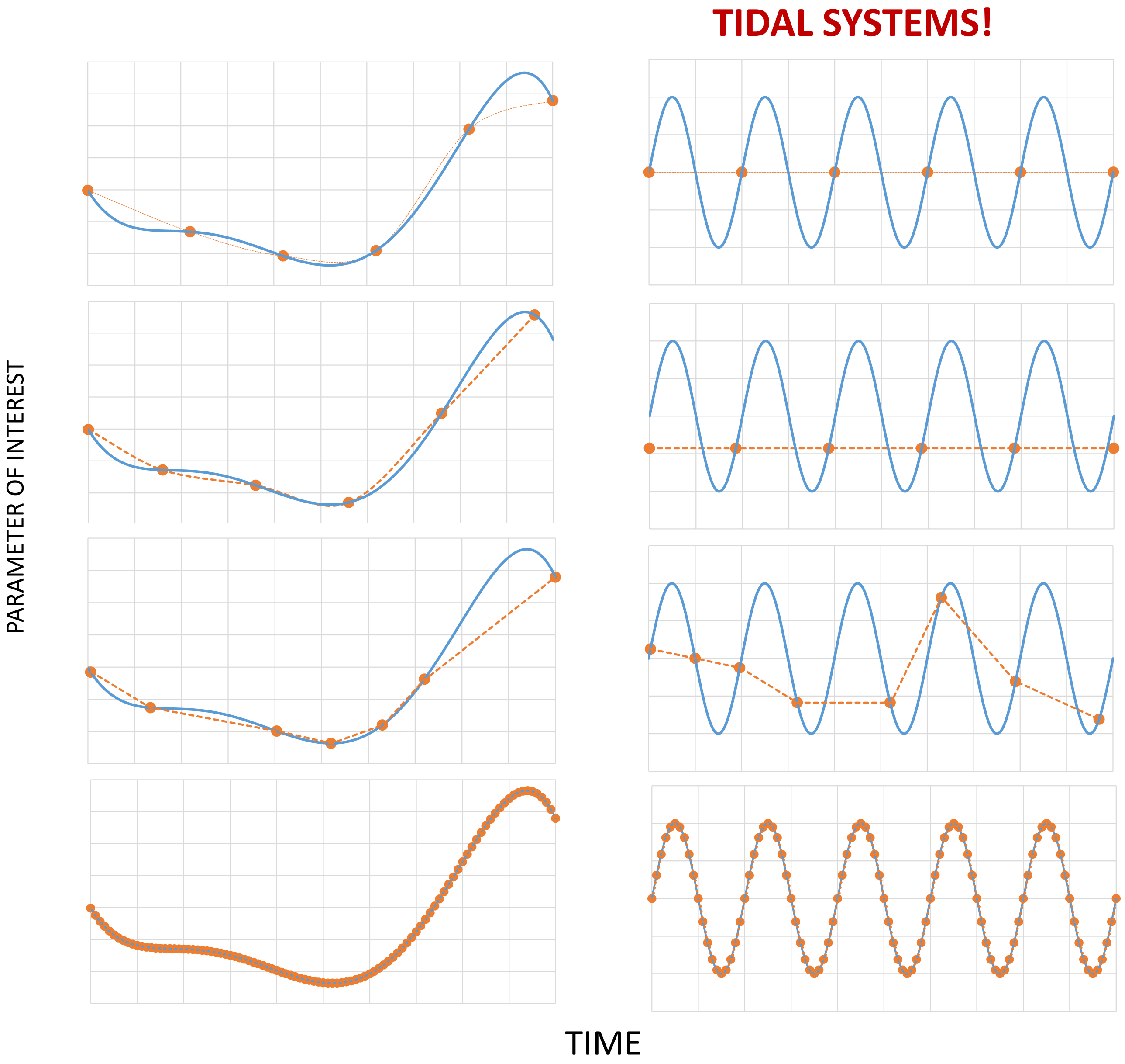
- Water Quality, Continuous
- Discrete Sample Collection

Monthly, first week of month

Monthly, second week of month

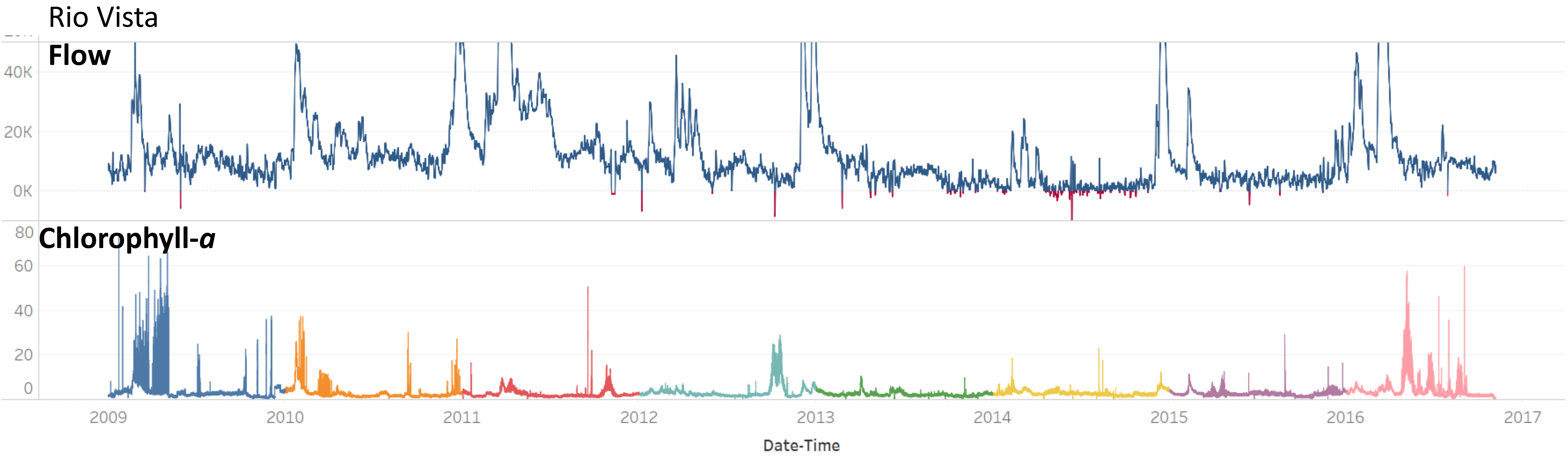
Random

High Frequency



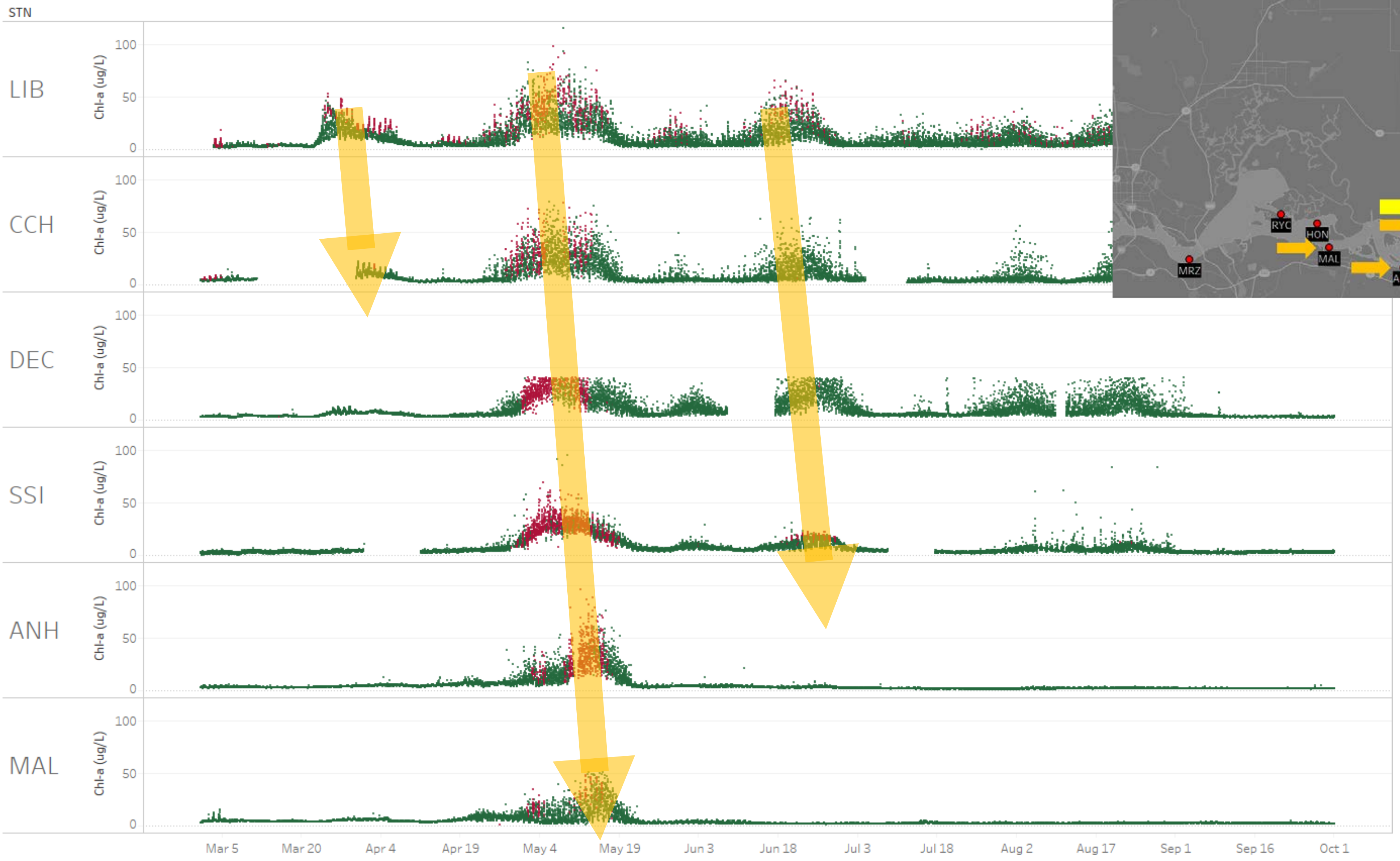
When do you need more frequent data? . . .TIDAL SYSTEMS!

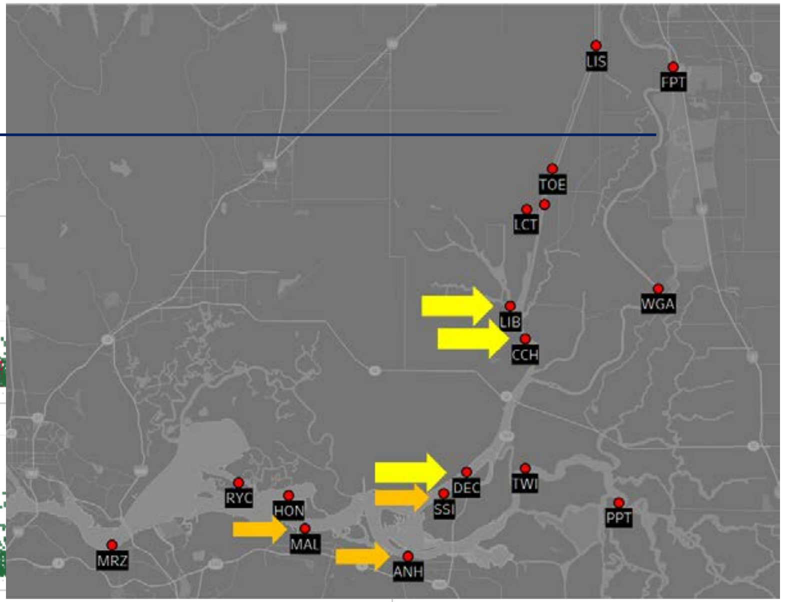
High temporal variability



Benefits of a spatially arrayed network

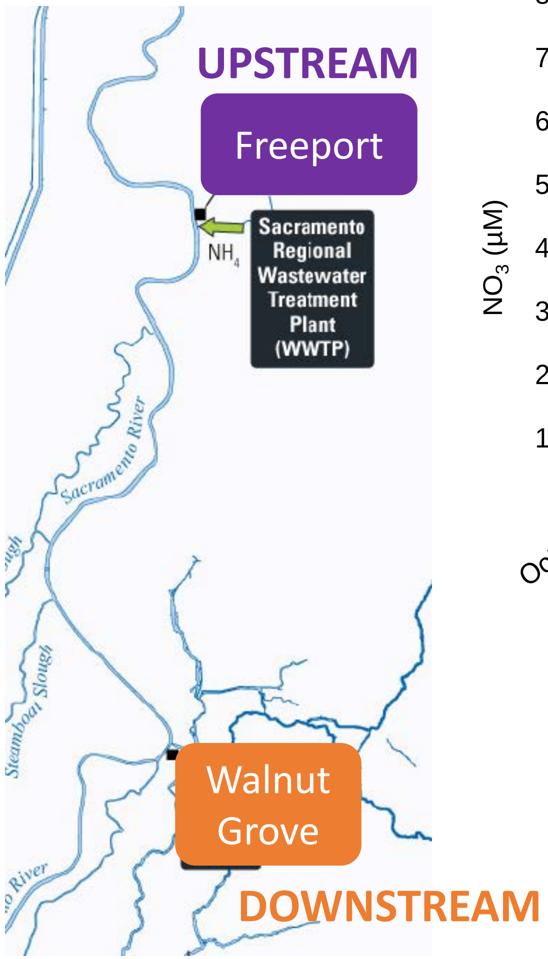
Progress of Blooms – Space and Time

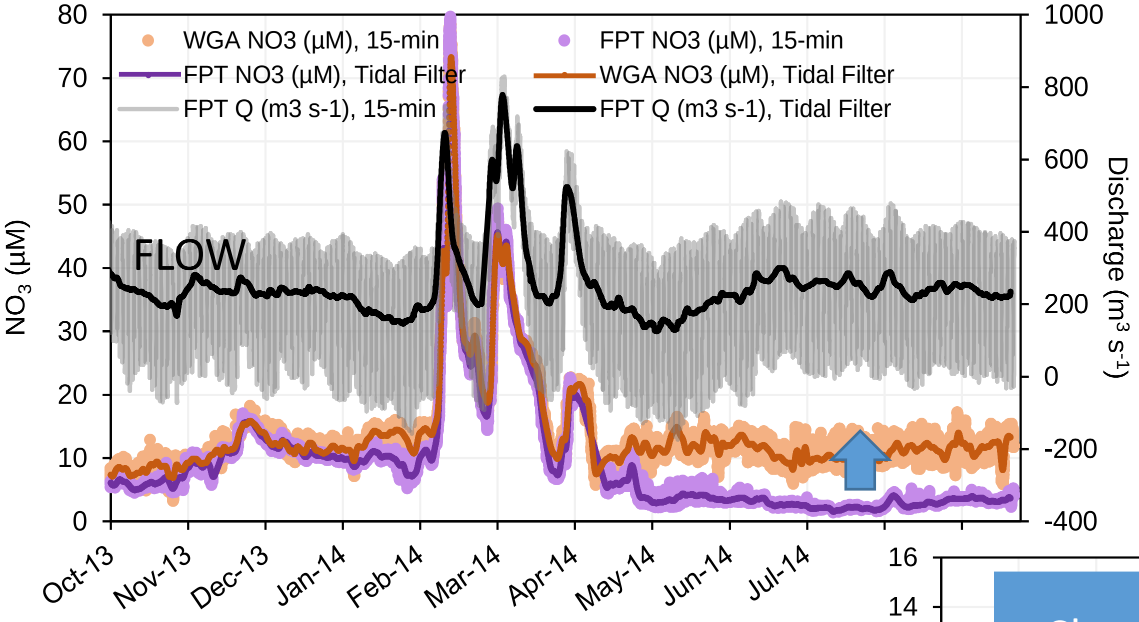


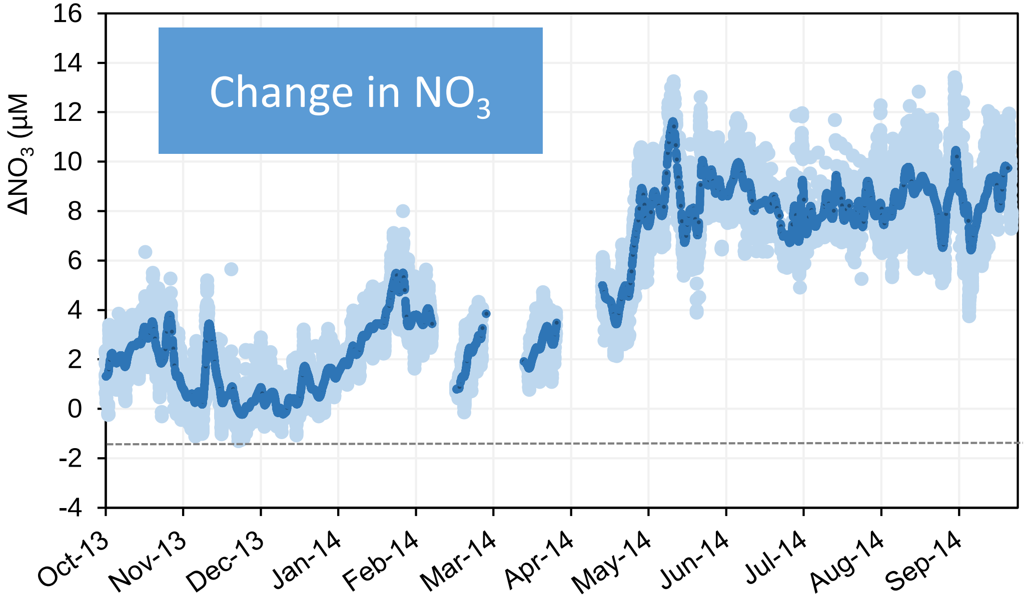


Benefits of a spatially arrayed network

PAIRED NITRATE SENSORS

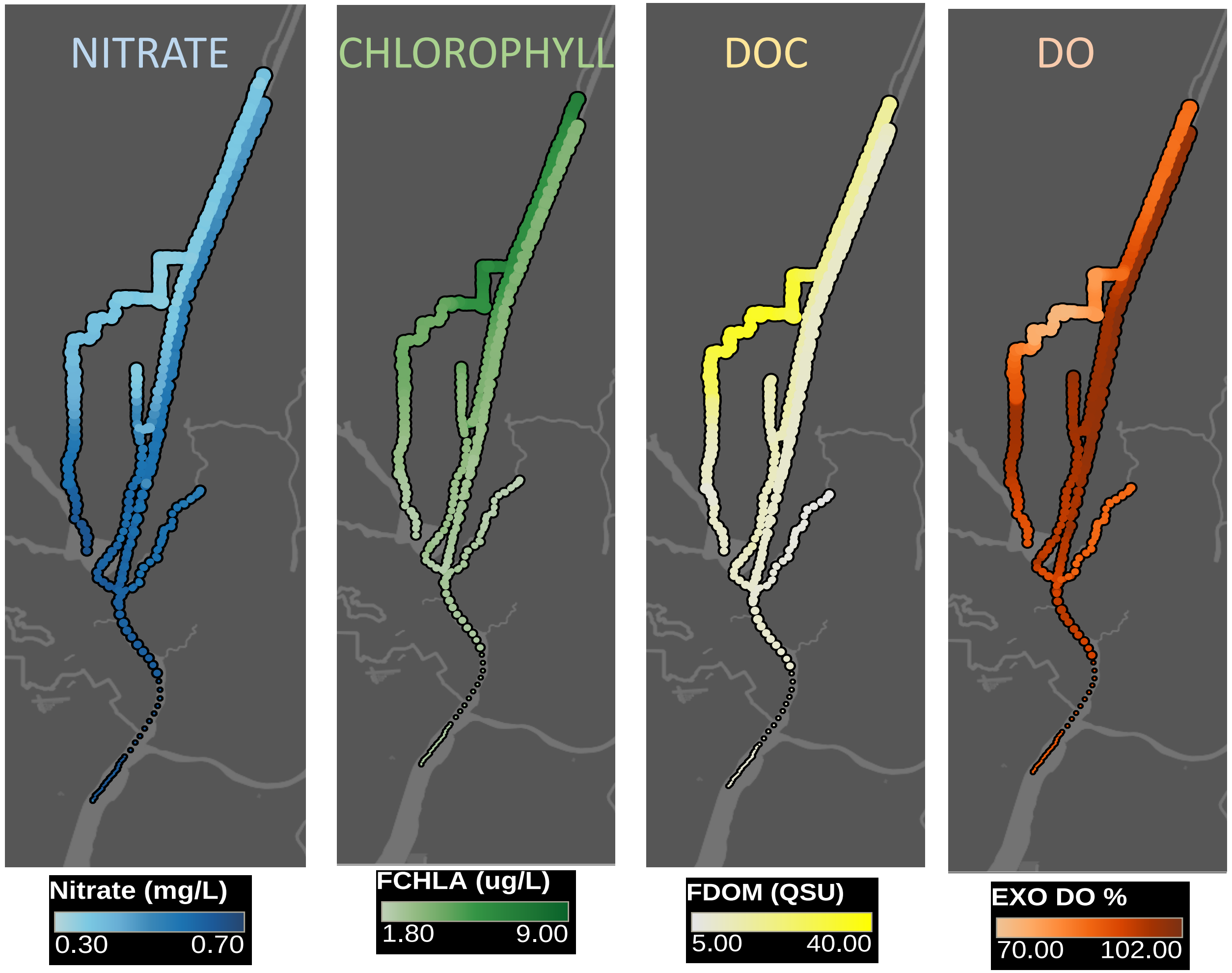






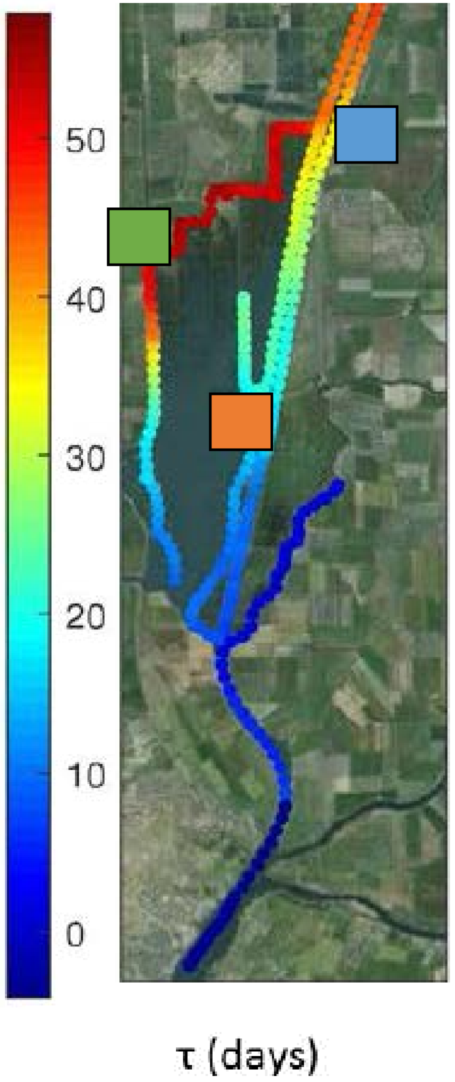
Kraus et al. WRR (in review)

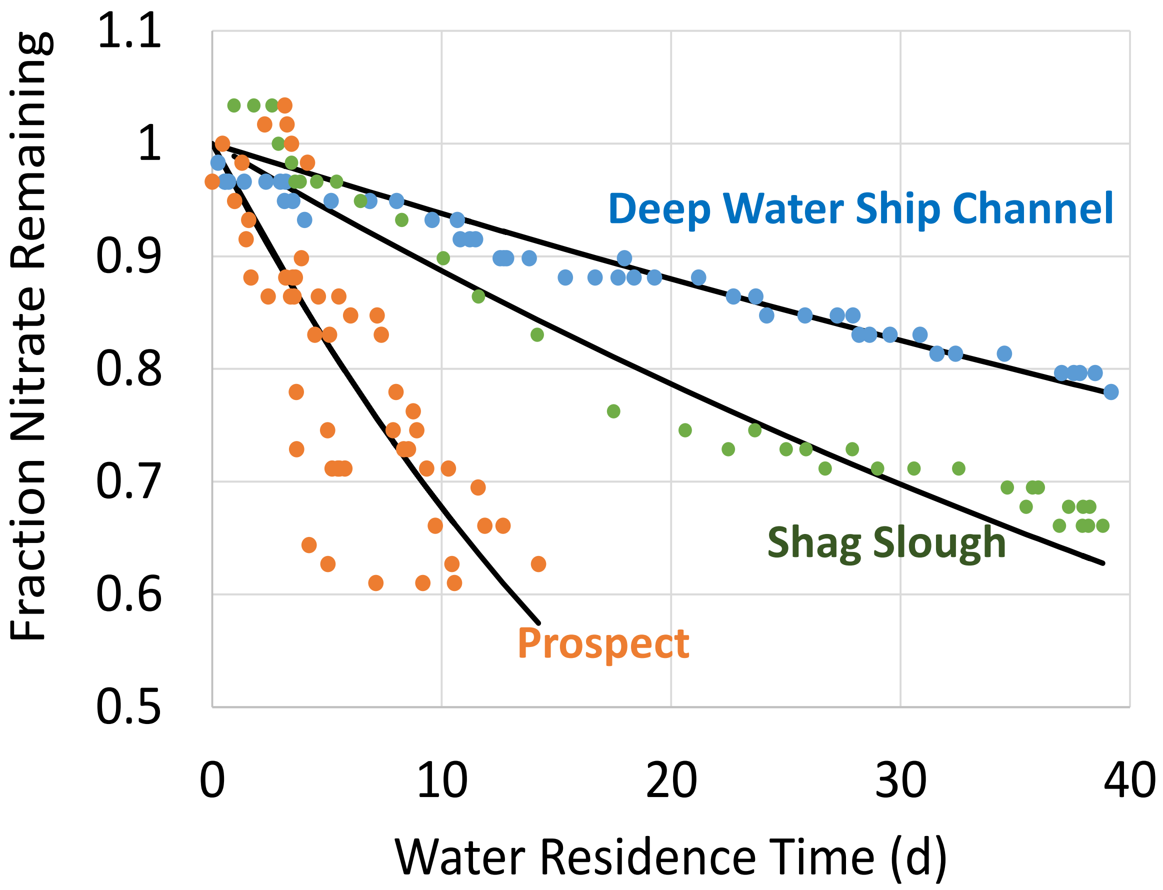
Hi Frequency (HF) Mapping



HF Mapping of Water Residence Time

Net Ecosystem Nitrate Uptake





Why are rates different?

tidal wetlands
aquatic vegetation
hydrology
benthos

Downing et al. ES&T (2017)

HF Data - TAKE AWAY POINTS

Analysis of these data allows us to better understand linkages between drivers – constituents - effects

- Temporally and spatially rich information at reasonable cost
- Enable real-time decisions
- Trigger rapid-response sampling
- New approaches! Fixed Stations, Mapping
- New Tools! (ammonium, phyto. taxonomy)

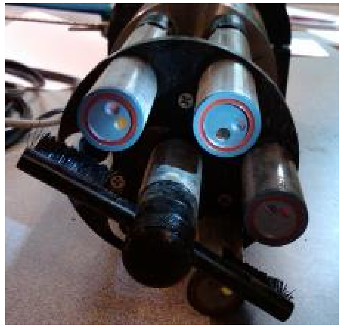
DRIVERS

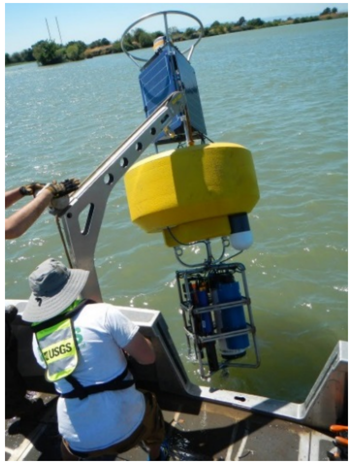
↓

Constituent Concentration

↓

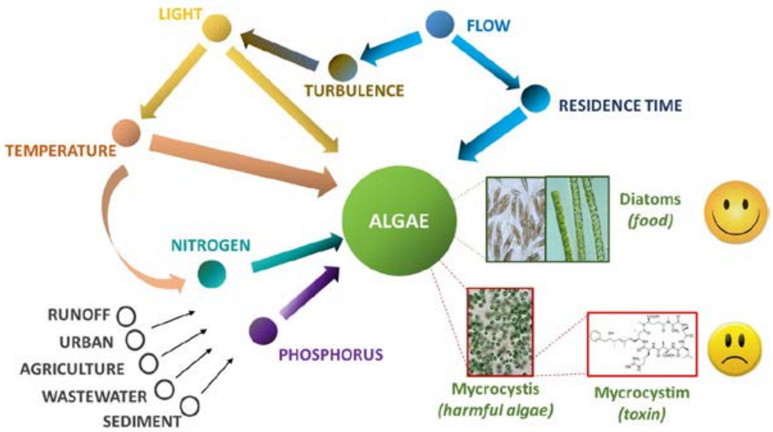
EFFECTS





CAVEATS

- Instruments must be calibrated, maintained, and QA/QC'ed appropriately.
- Need to understand the limitations of the sensors
- Not all parameters can be measured this way.



High-Frequency Nutrient and Biogeochemical Monitoring:
Connecting the Dots between Drivers and Effects of Constituent Concentrations

Abstract.

Advances in sensor technology are allowing us to collect high resolution water quality data across both time and space. These sensors (e.g., chlorophyll-a, blue green algae, nitrate, dissolved oxygen) are becoming increasingly important tools for long-term water quality monitoring, for rapid detection of water quality impairment, and for understanding links between drivers, constituent concentrations, and ecosystem effects. These rich data sets provide scientists, managers and policy-makers information to make sound water resource management decisions. The use of in situ nutrient sensors (nitrate, ammonium, phosphate) capable of collecting high frequency data are of particular interest because of the well-known adverse effects of nutrient enrichment on harmful algal blooms, hypoxia, and human health. In the Sacramento-San Joaquin Delta, the USGS has developed a network of high frequency water quality stations that include sensors for chlorophyll, blue green algae, and nitrate. We have also been testing sensors for phosphate and ammonium. Deployment of these sensors in tandem with a suite of other tools on boats allows us to rapidly map water quality across diverse habitats. This presentation will relate several examples of how these tools can provide information not previously achievable with discrete sampling approaches, and discuss some of the advantages, opportunities and challenges associated with high-frequency data collection programs.