
Source: C. Benton

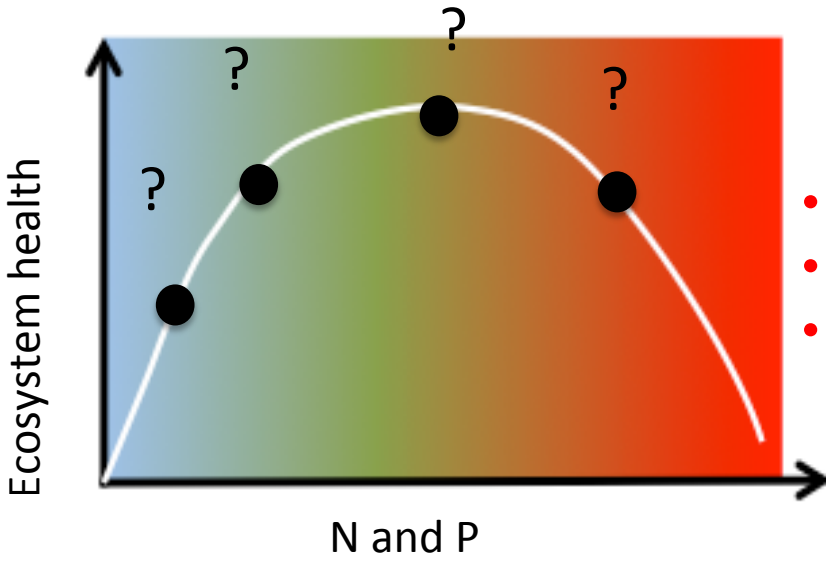
Do restored salt ponds influence water quality in Lower South Bay?

D Senn[1], E Novick[1], M Downing-Kunz[2], P Bresnahan[1], and R Holleman[1]

[1]San Francisco Estuary Institute
[2]USGS

sfbaynutrients.sfei.org

SF Bay
Nutrient Management Strategy



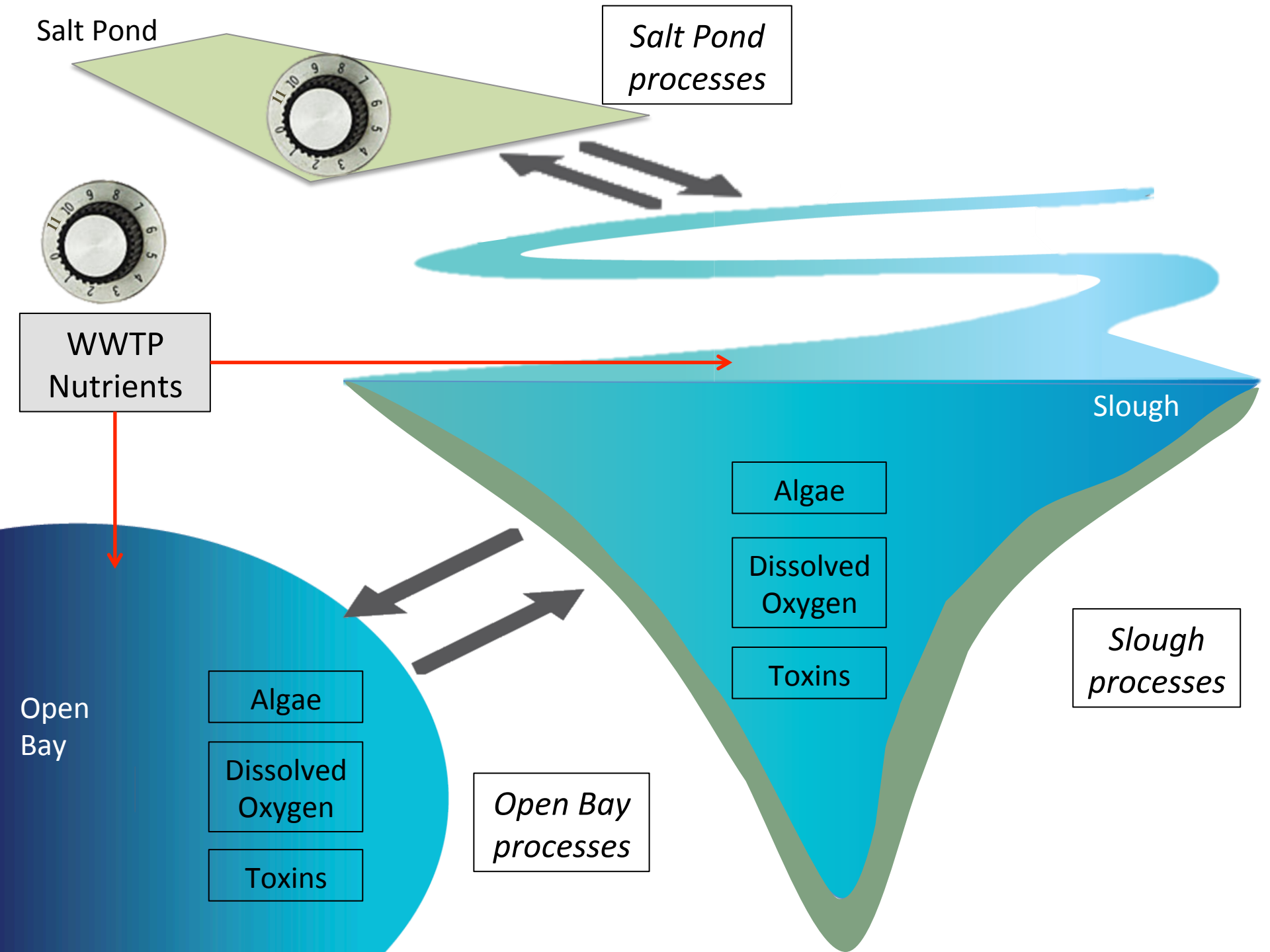
- Large algae blooms
- Low DO
- Harmful algae, toxins

November 2012

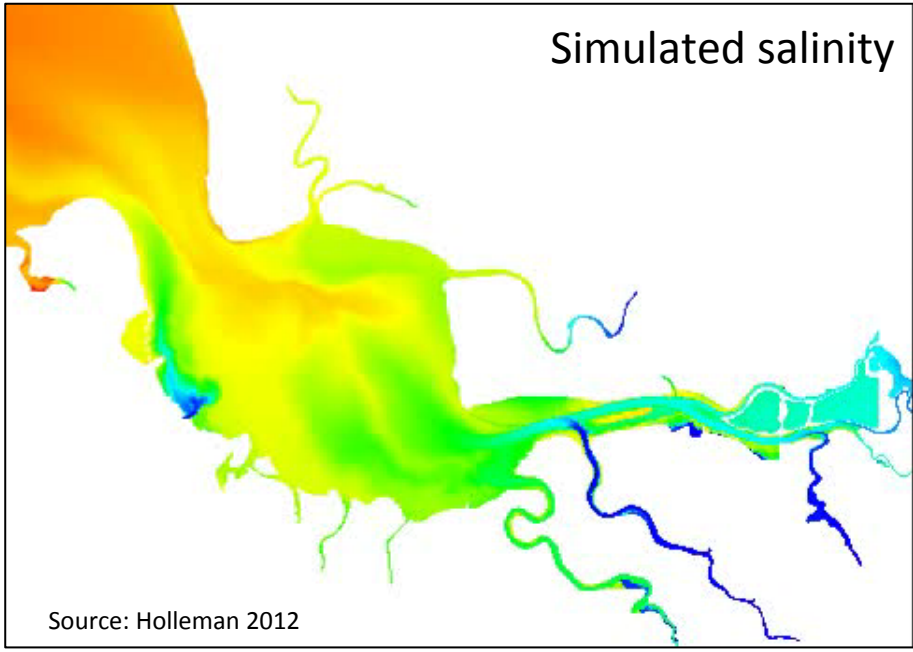
San Francisco Bay Nutrient Management Strategy

San Francisco Bay Regional Water Quality Control Board

- Motivated by observed changes in ecosystem response to N and P
- Collaborative effort: multi-stakeholder/regulator steering committee
- Science Program: 10 year science plan

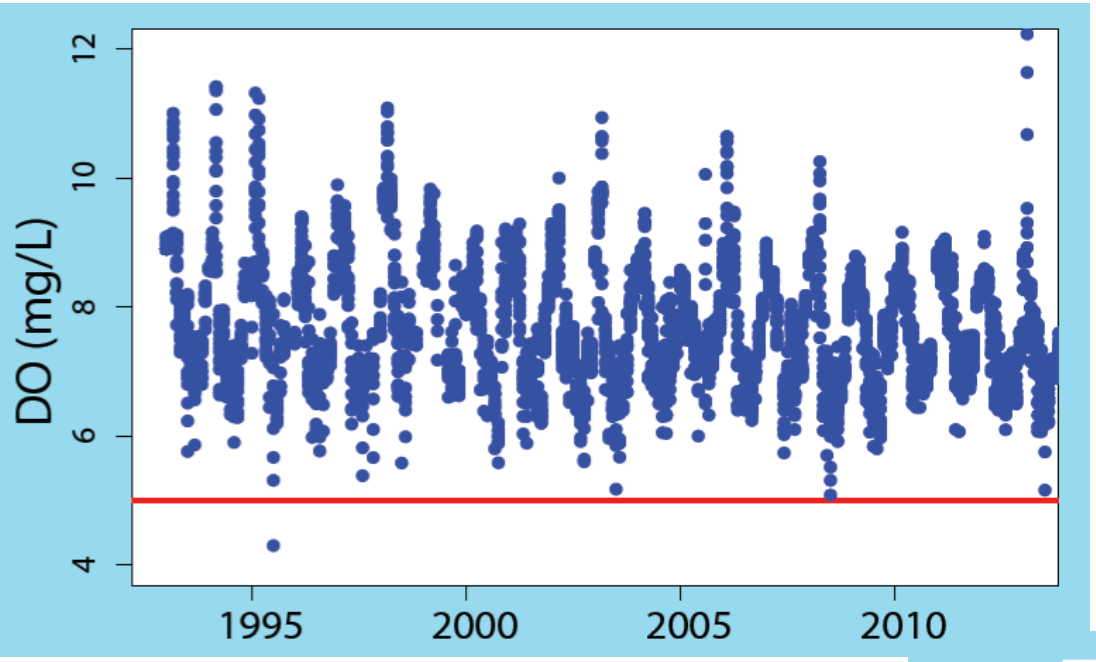

Salt Pond
Salt Pond processes
WWTP Nutrients
Slough
Algae
Dissolved Oxygen
Toxins
Slough processes
Open Bay
Algae
Dissolved Oxygen
Toxins
Open Bay processes

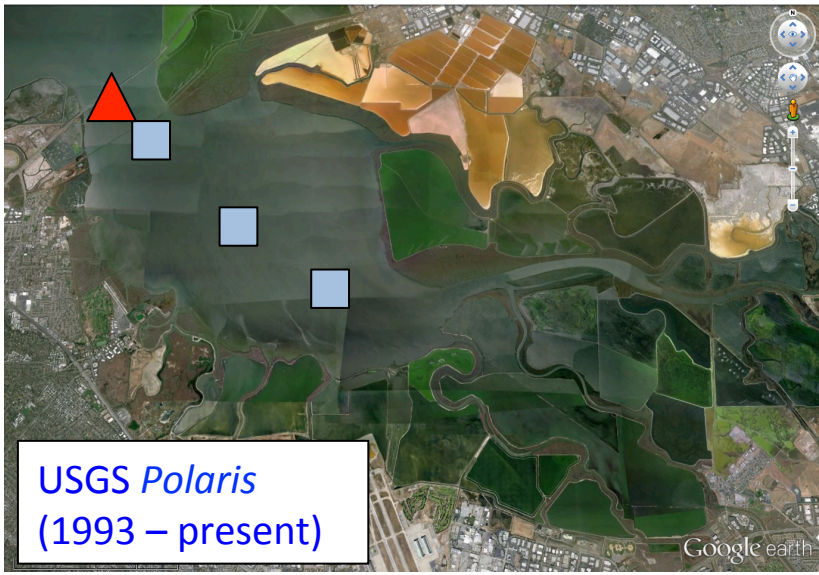
Lower South Bay



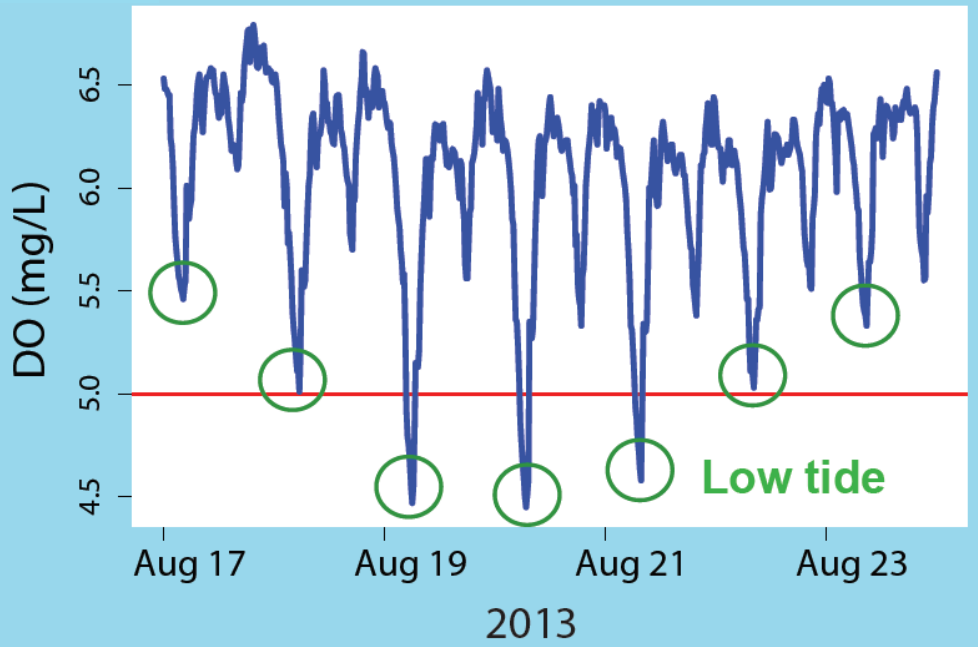
- Complex system, slow flushing
- Highest **N**itrogen and **P**hosphorous concentrations in the Bay
- 3 WWTPs
- Parameters of interest: algal biomass (chl-a), dissolved oxygen (DO) , algal community, toxins, **N** and **P**

Dissolved Oxygen – Deep subtidal





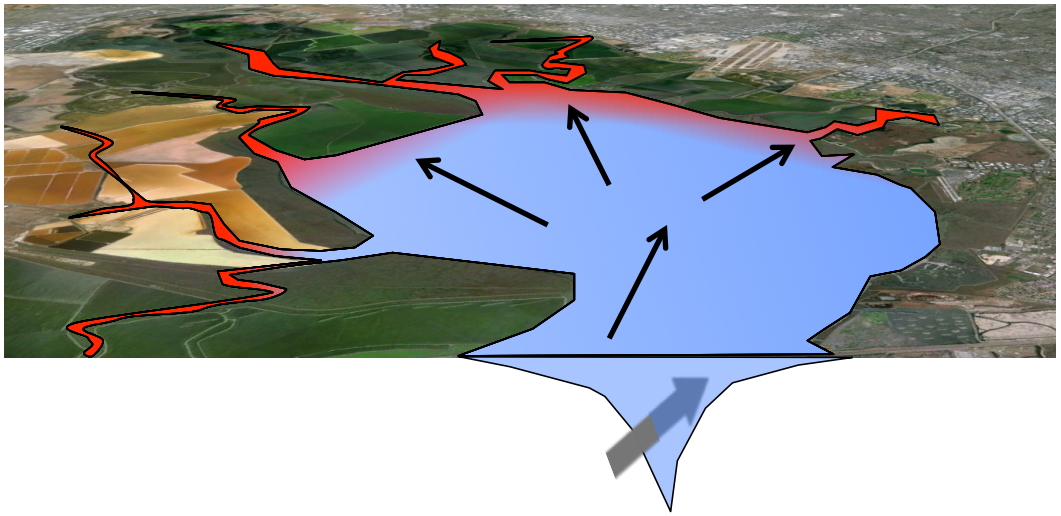
Dumbarton near-surface continuous sensor



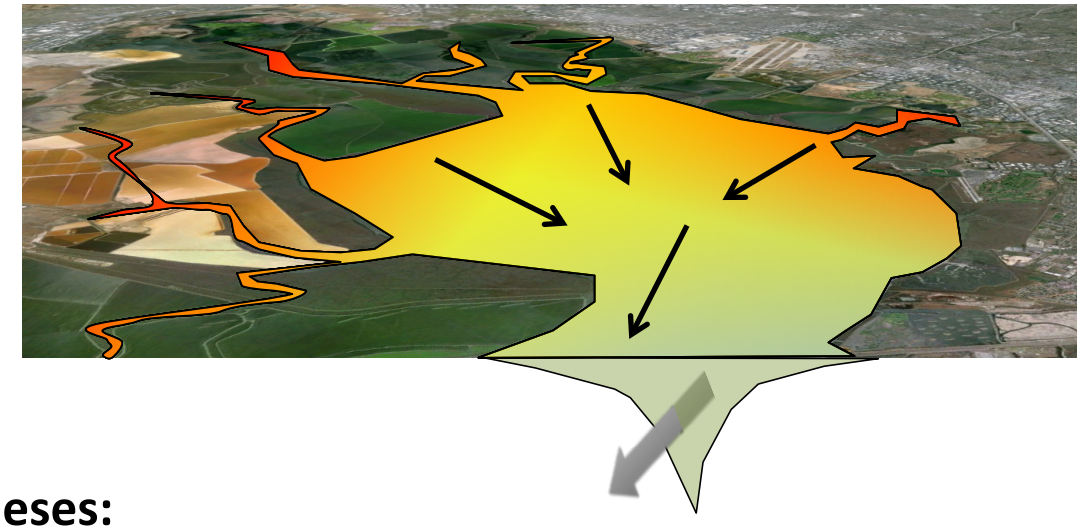
SFEI 2015

Conceptualization of water quality/source in LSB as a function of tide

Flood tide



Ebb tide



Margin Water:
Sloughs/Creeks/Marshes

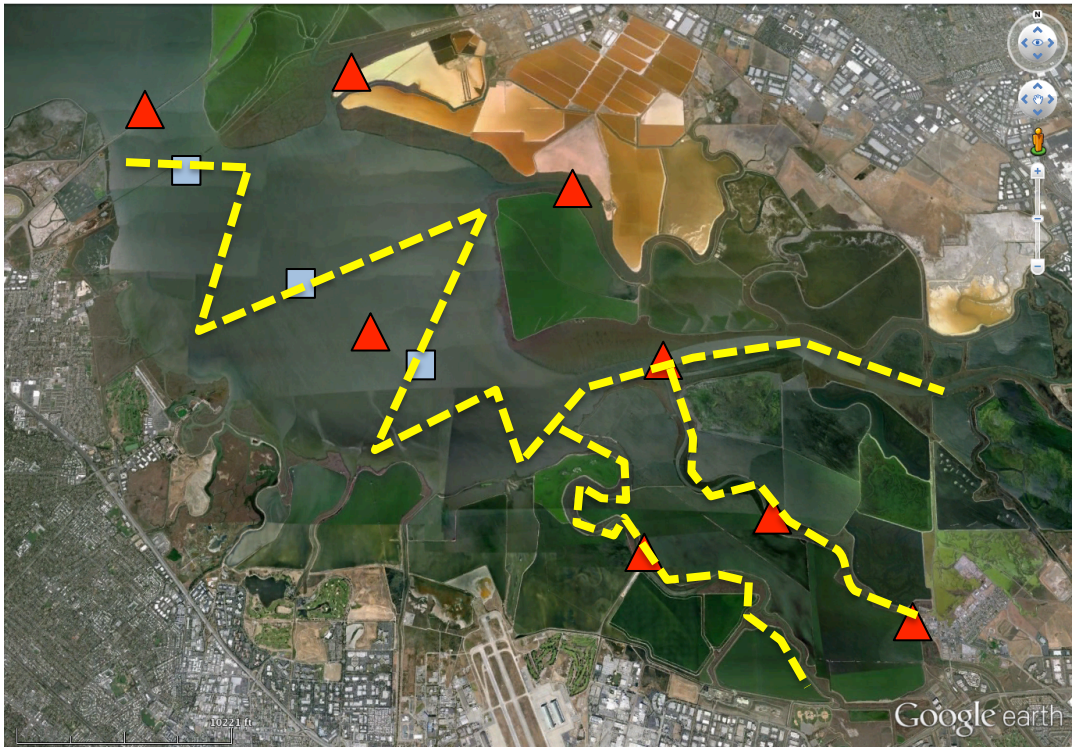
Open Bay Water:
Originating north
of Dumbarton

Hypotheses:

- Waters in sloughs/creeks have low(er) DO and higher algal biomass
- Exchange with restored salt ponds is one of several contributing factors

Need to measure…

- The right things
- In the right places
- At the right times



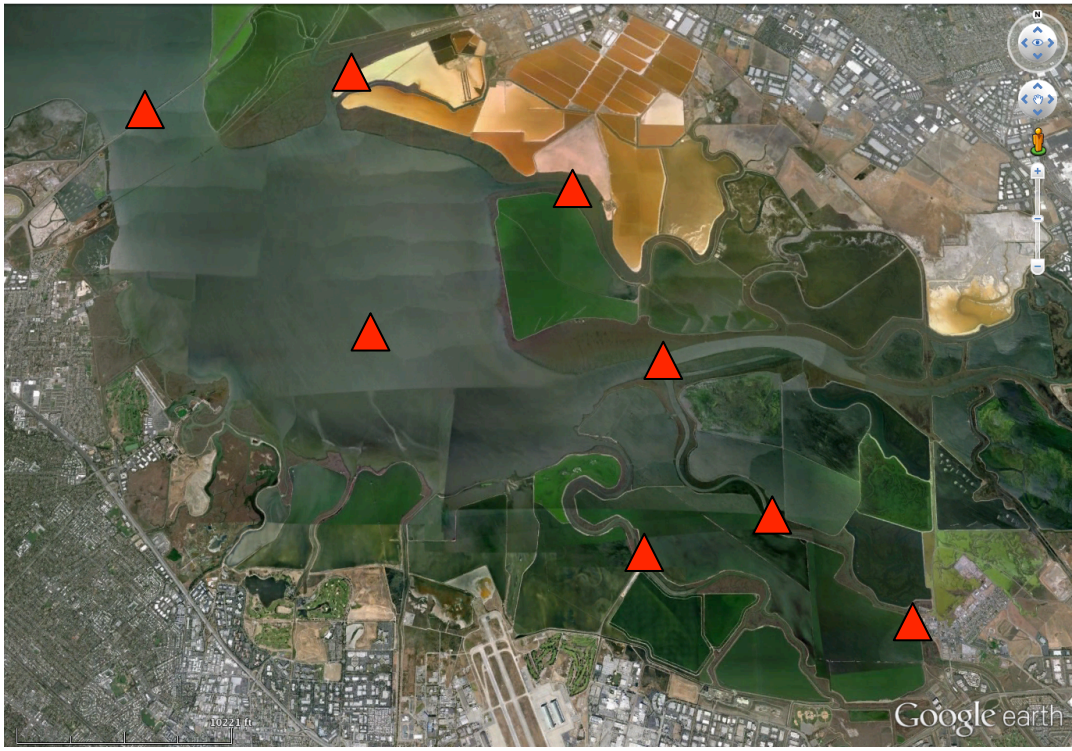
Long-term USGS *Polaris* (1970s – present)

Moored sensors: SFEI / USGS-Sac / UC Berkeley (2013 – present)

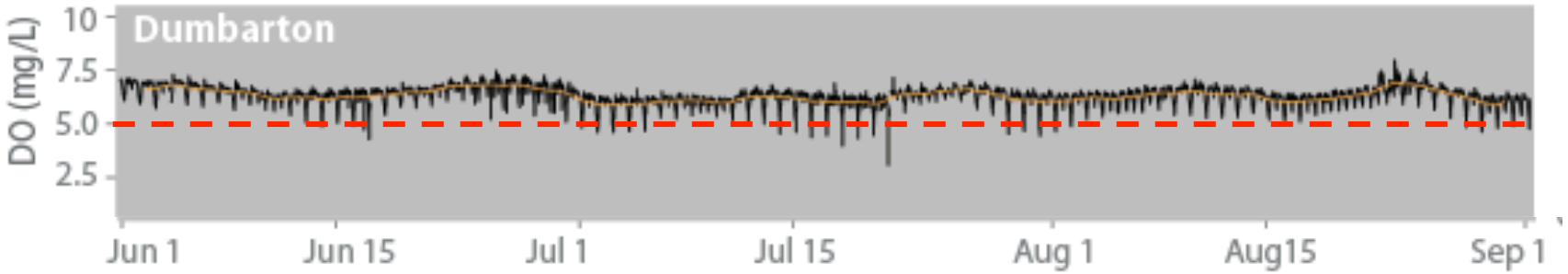
High-resolution biogeochemical mapping – USGS-Sac / SFEI / UCSC (2015)

Need to measure…

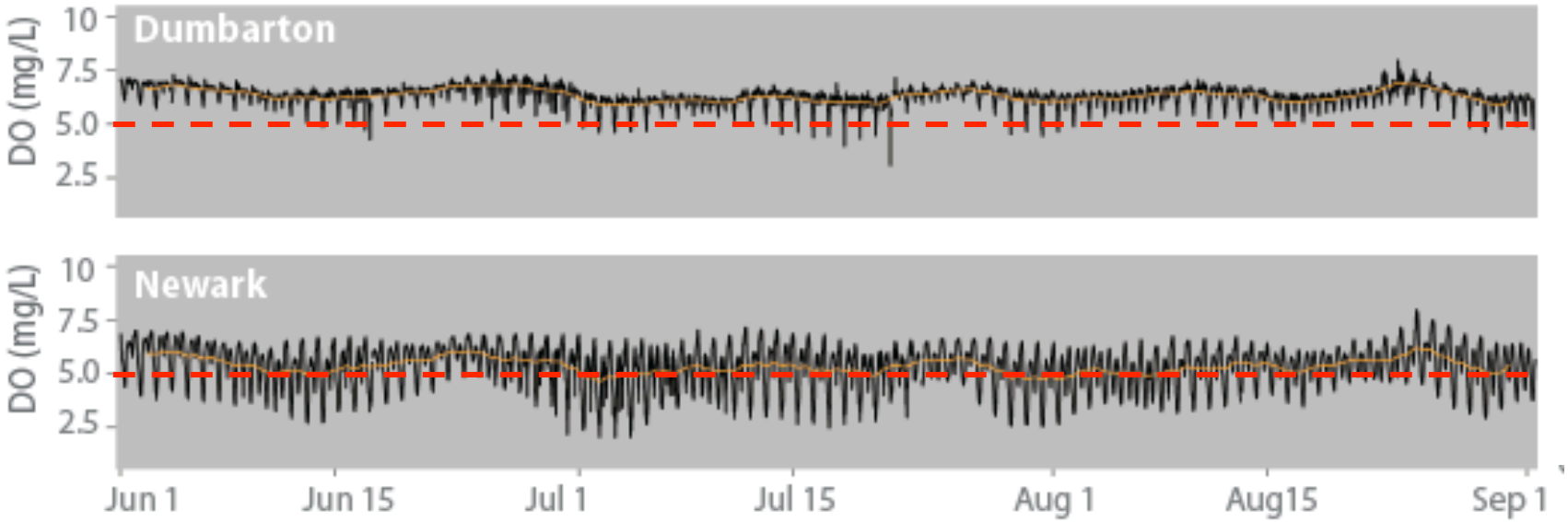
- The right things
- In the right places
- At the right times



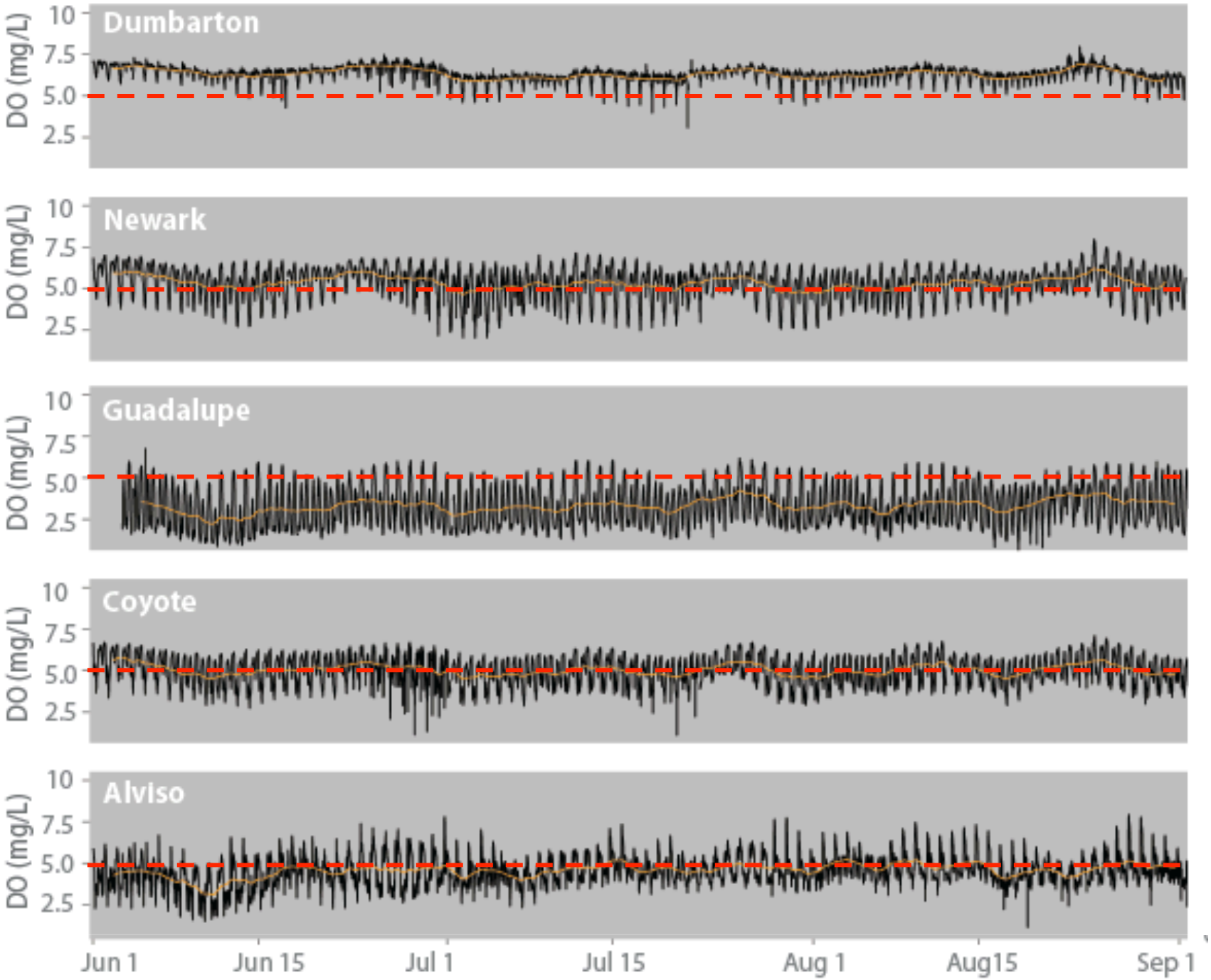
Moored sensors: SFEI / USGS-Sac / UC Berkeley

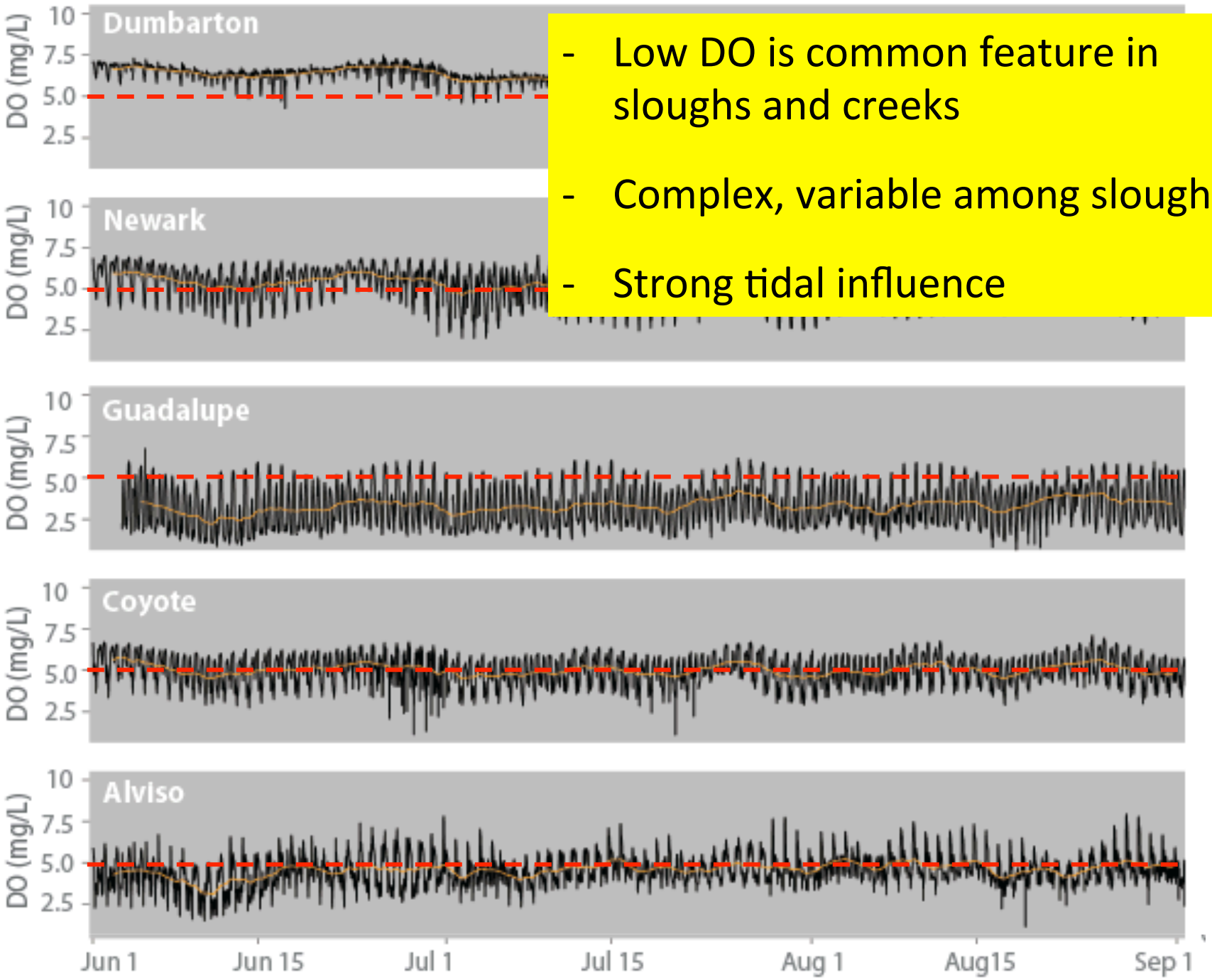

Dumbarton
DO (mg/L)
10
7.5
5.0
2.5
Jun 1
Jun 15
Jul 1
Jul 15
Aug 1
Aug15
Sep 1


Newark slough
Dumbarton Bridge
Mowry slough
Coyote Creek
Alviso Slough
Guadalupe slough
Pond A8

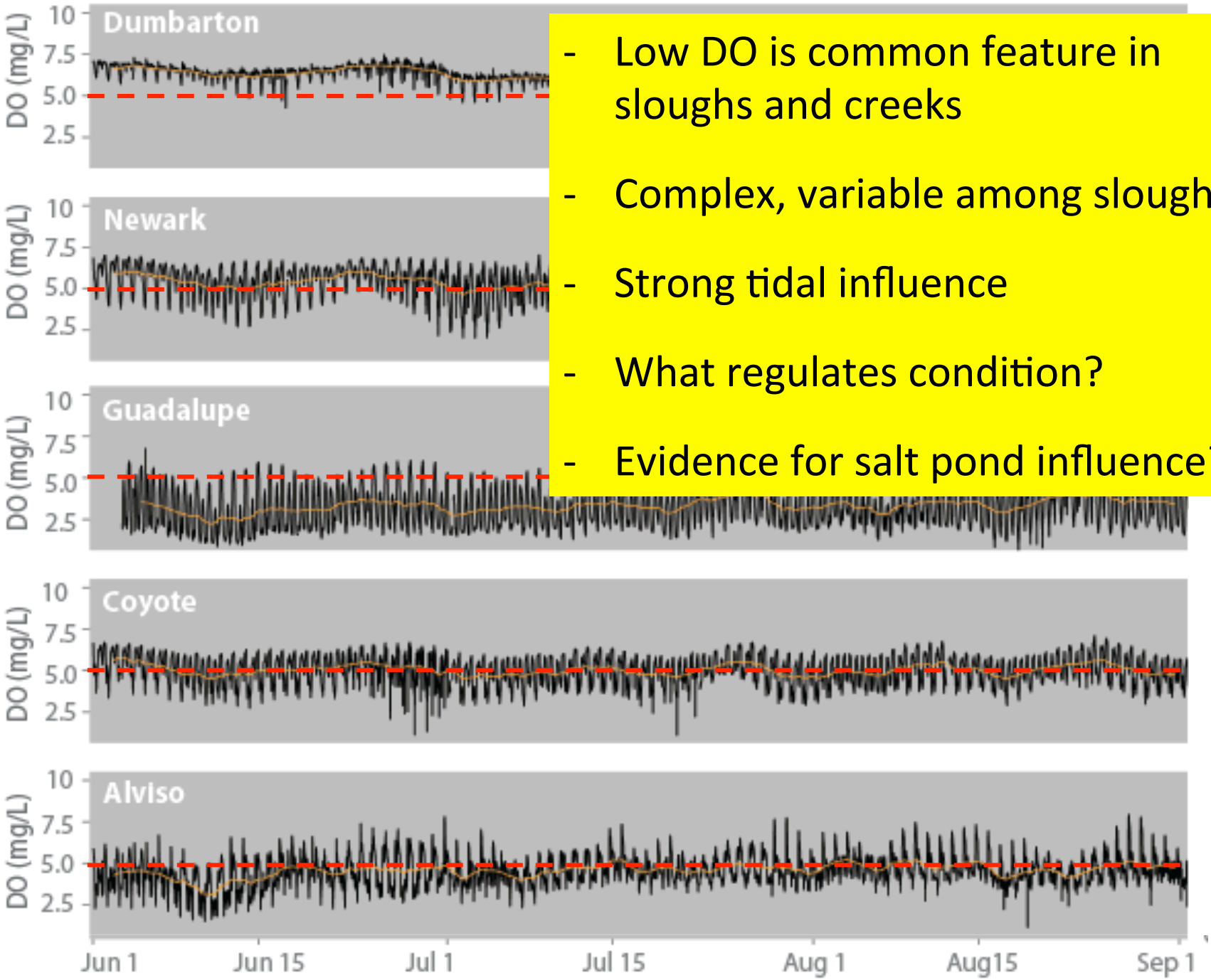

Dumbarton
Newark
DO (mg/L)
10
7.5
5.0
2.5
Jun 1
Jun 15
Jul 1
Jul 15
Aug 1
Aug15
Sep 1


Newark slough
Dumbarton Bridge
Mowry slough
Coyote Creek
Alviso Slough
Guadalupe slough
Pond A8


Dumbarton
Newark
Guadalupe
Coyote
Alviso
DO (mg/L)
10
7.5
5.0
2.5
Jun 1
Jun 15
Jul 1
Jul 15
Aug 1
Aug15
Sep 1



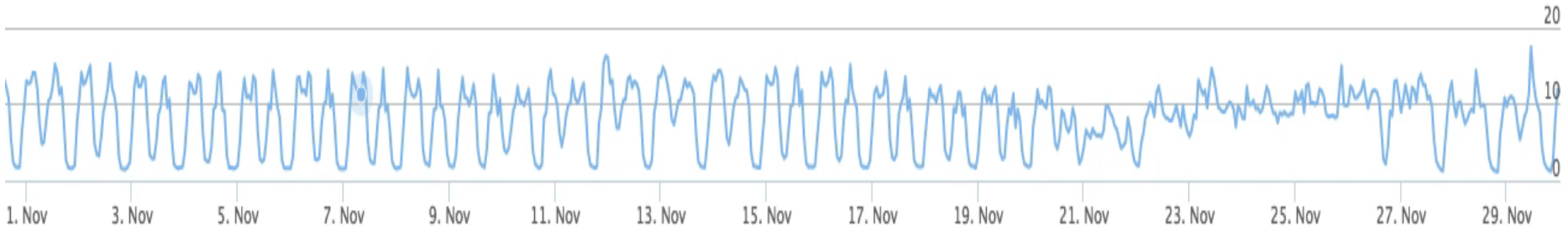
- Low DO is common feature in sloughs and creeks
- Complex, variable among sloughs
- Strong tidal influence



- Low DO is common feature in sloughs and creeks
- Complex, variable among sloughs
- Strong tidal influence
- What regulates condition?
- Evidence for salt pond influence?

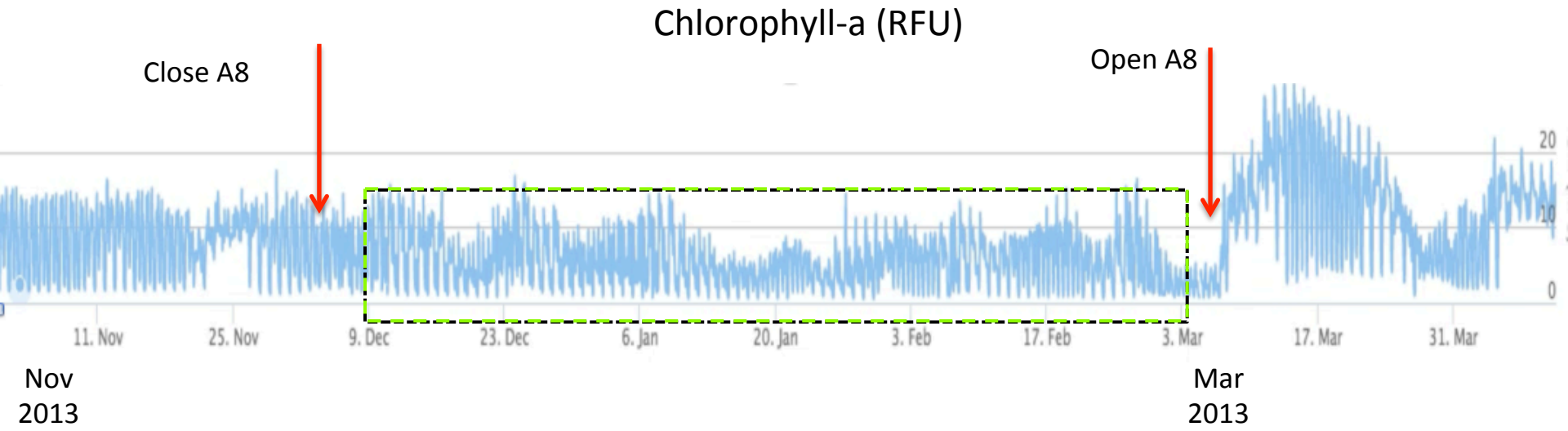
Alviso : Evidence of salt pond influence on water quality?

Chlorophyll-a (RFU)

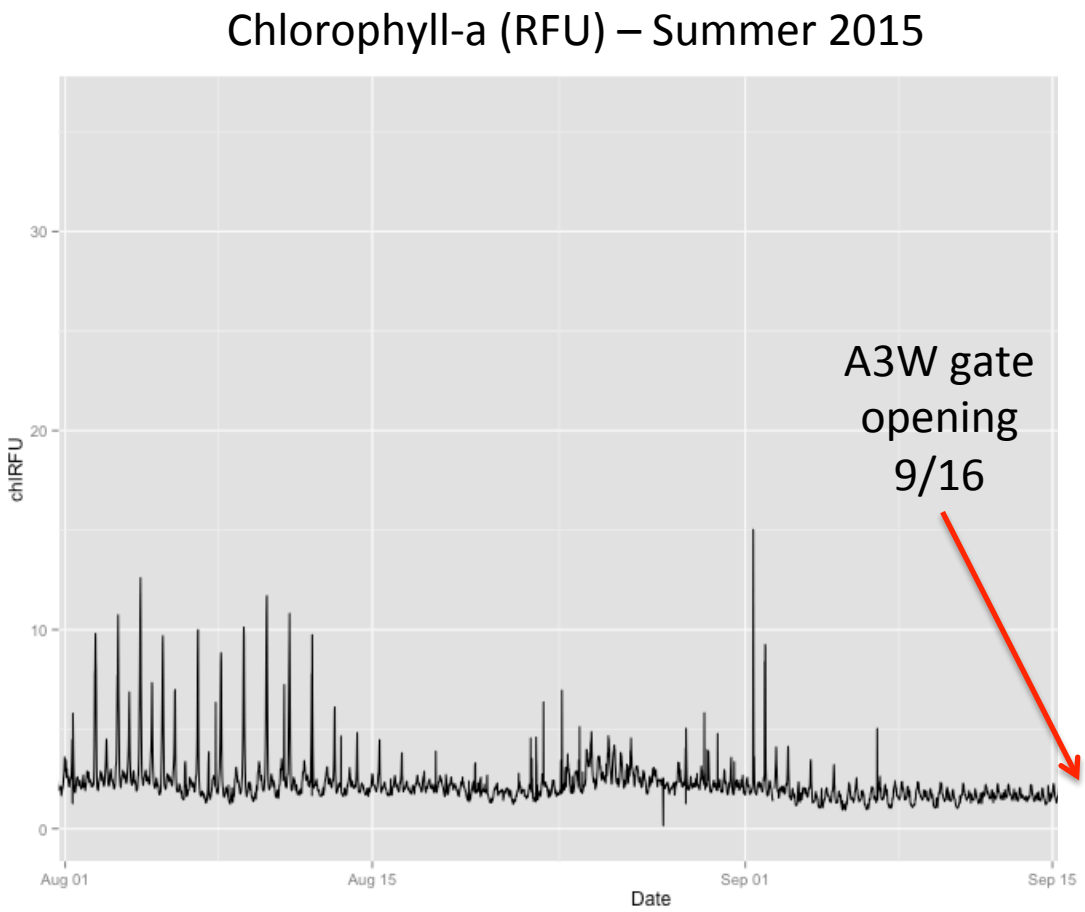


Nov 2013

Alviso : Evidence of salt pond influence on water quality?



Guadalupe: Evidence of salt pond influence on water quality?



Need to measure…

- The right things
- In the right places
- At the right times

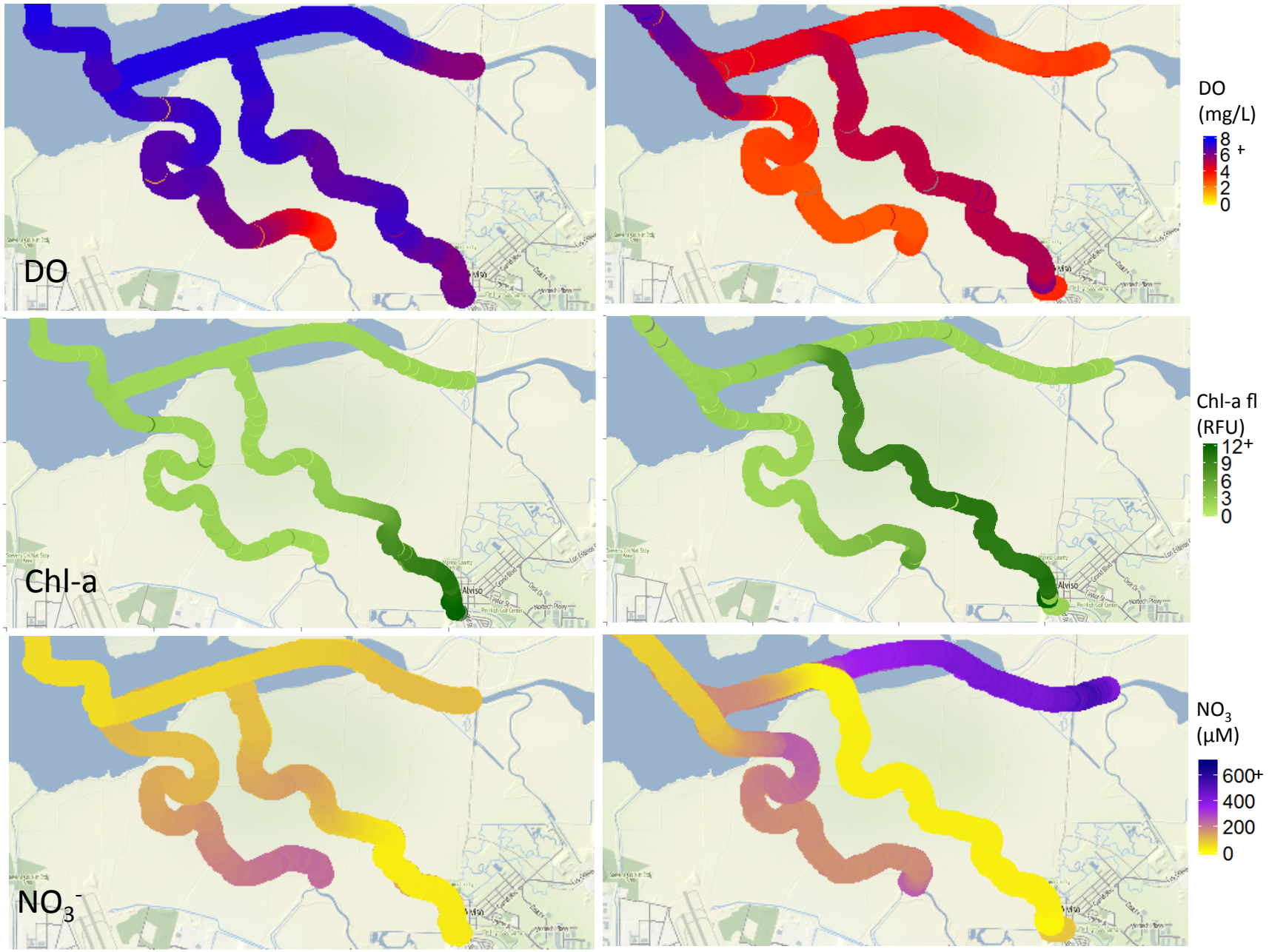
High-resolution biogeochemical mapping – USGS-Sac / SFEI / UCSC

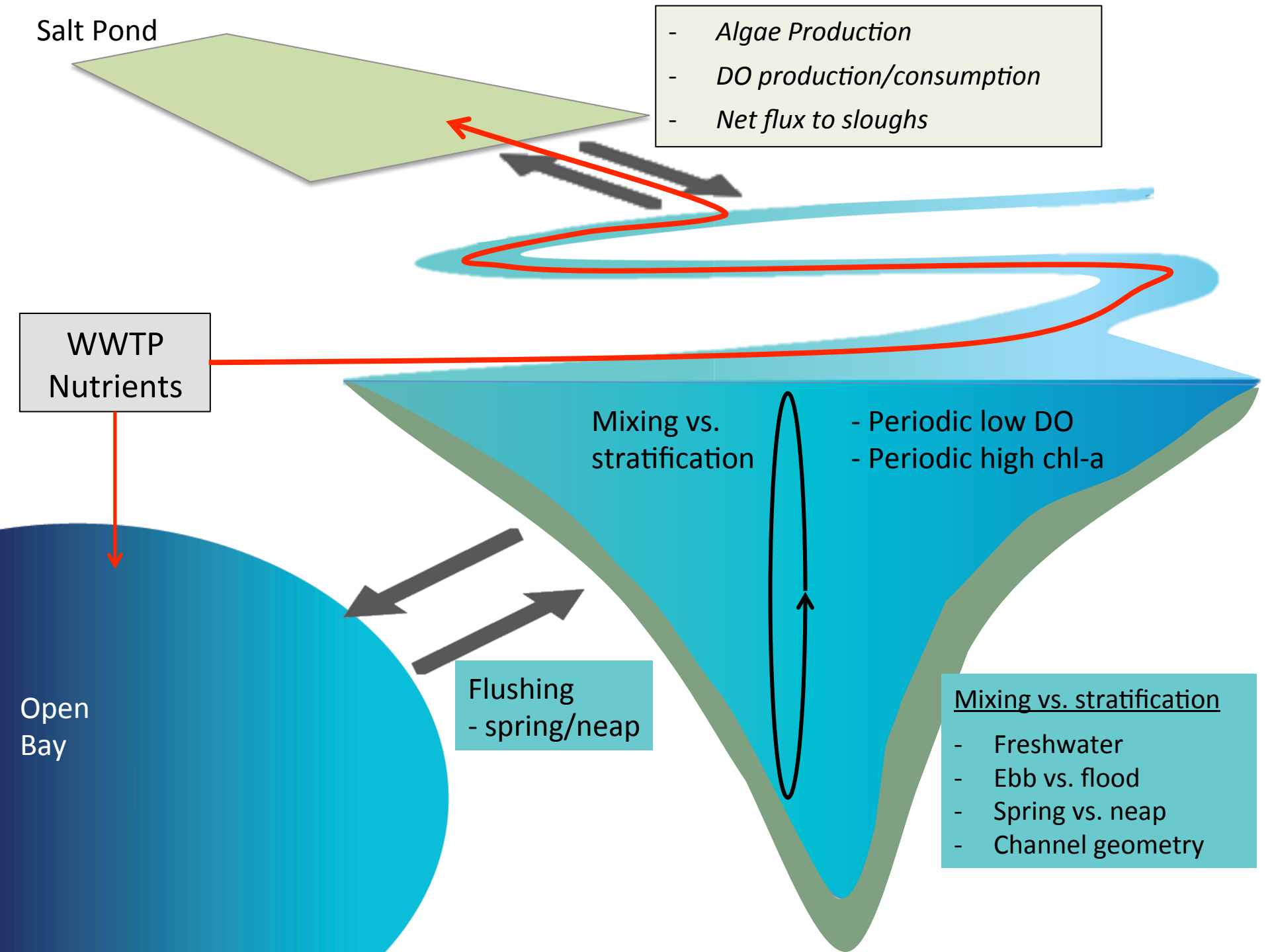
Bergamaschi, Downing et al.

Flood tide

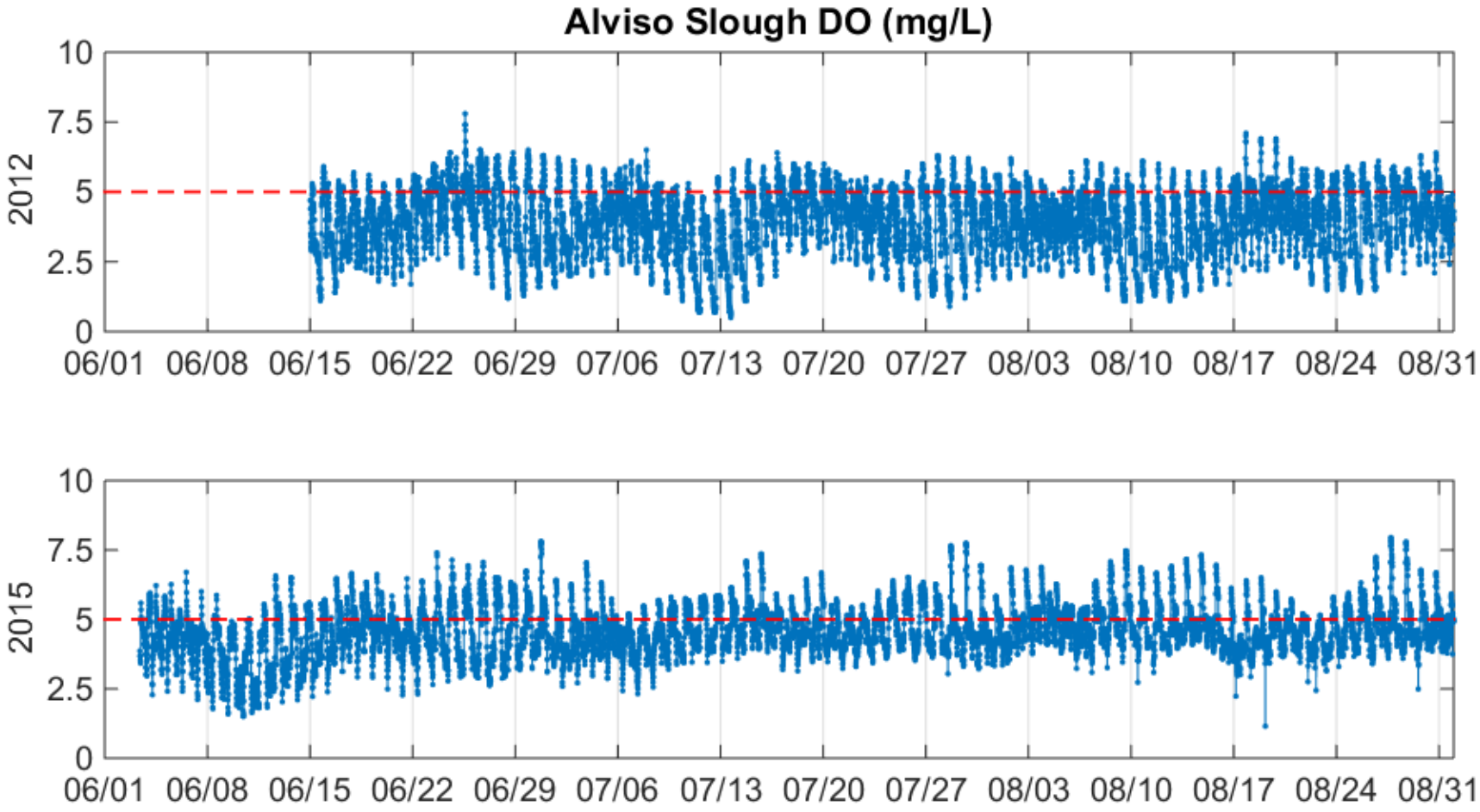
July 15-16 2015

Ebb tide

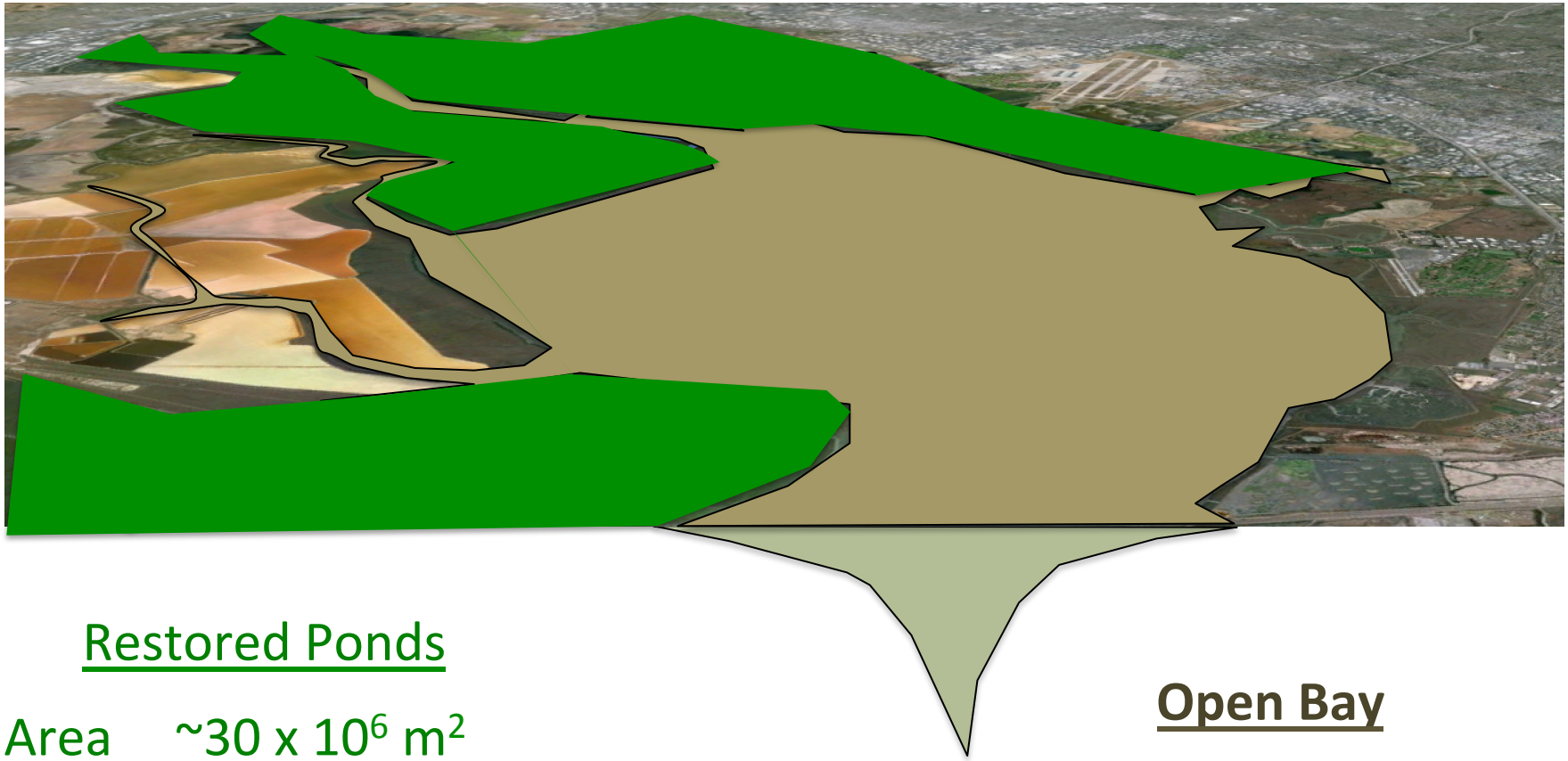



Salt Pond
- Algae Production
- DO production/consumption
- Net flux to sloughs
WWTP Nutrients
Mixing vs. stratification
- Periodic low DO
- Periodic high chl-a
Open Bay
Flushing
- spring/neap
Mixing vs. stratification
- Freshwater
- Ebb vs. flood
- Spring vs. neap
- Channel geometry

Interannual variability



Could biogeochemical processes in restored salt ponds influence open Bay water quality?



Restored Ponds

Area ~30 x 10^6 m^2

D_{avg} 1 m

D_{photic} 1.8 m

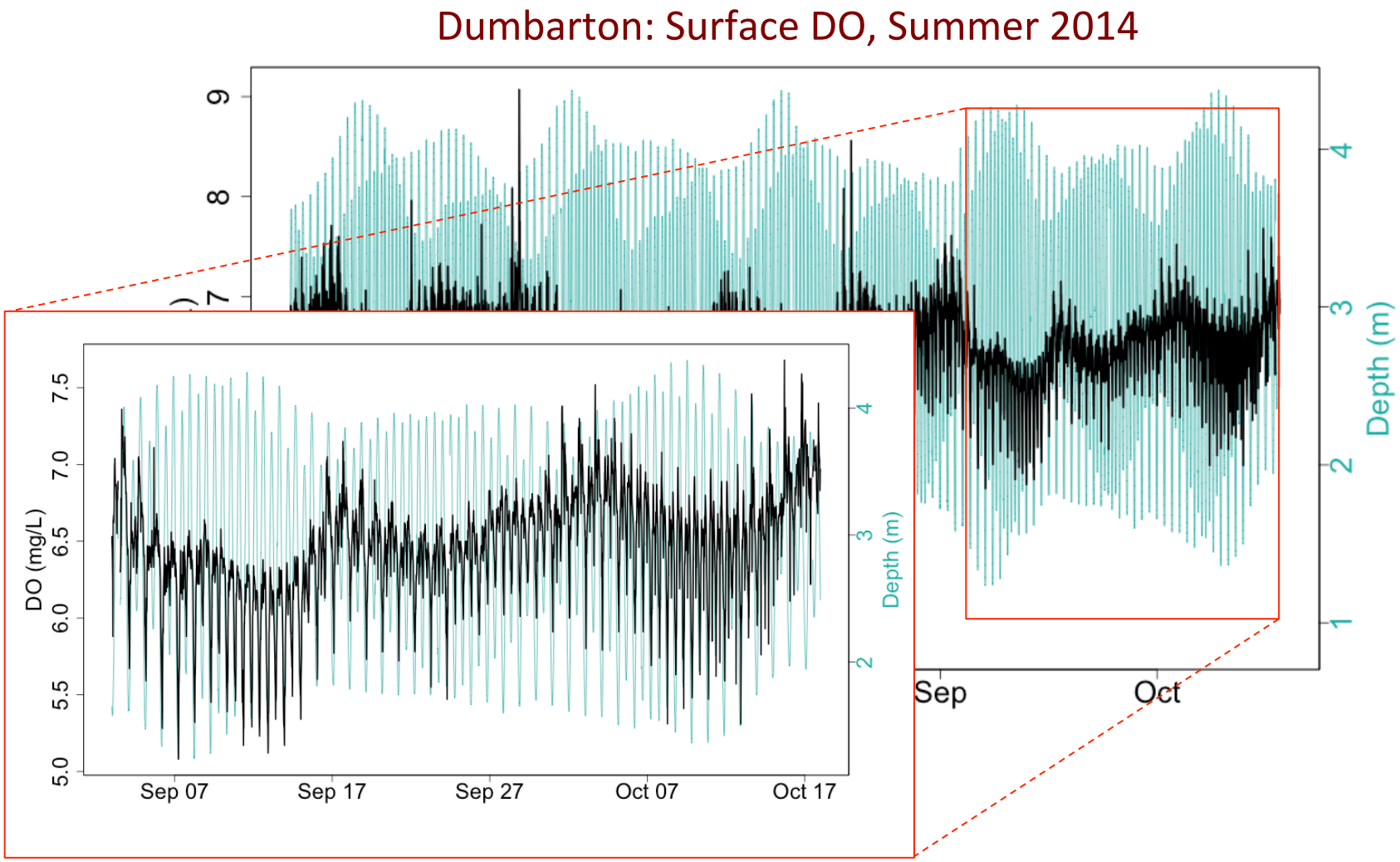
Open Bay

Area ~30 x 10^6 m^2

D_{avg} 3 m

D_{photic} 1.5 m

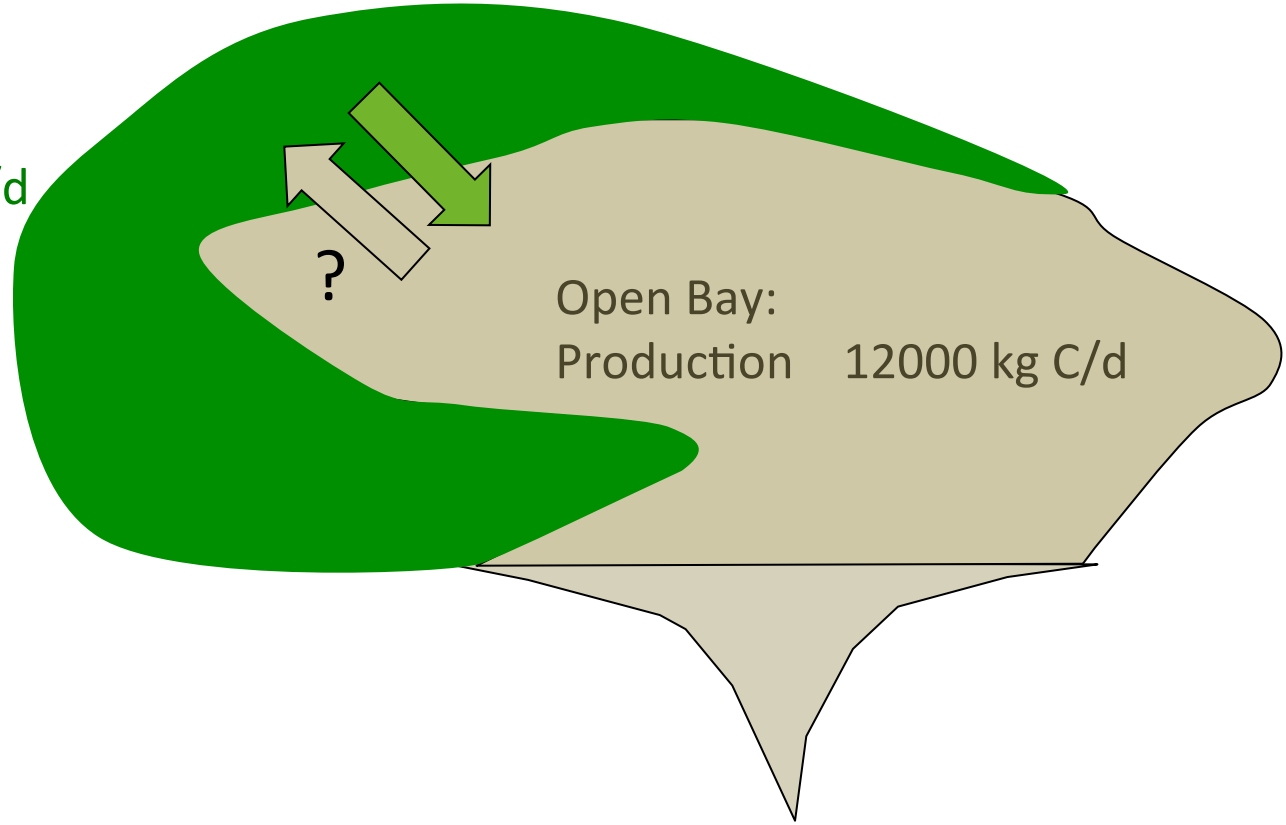
Could biogeochemical processes in restored salt ponds influence open Bay water quality?



Could production in restored salt ponds influence openBay C and DO budgets?

Very rough numbers…

Restored ponds:
Production: >50000 kg C/d



10% of salt pond production would have a 40% impact on open Bay OC budget

Transport feasible? 2% of tidal prism, containing 50 mg/m3 chl-a

Open questions: Actual transport, better production estimates, linked N-C-O cycles

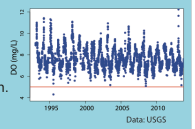
DISSOLVED OXYGEN IN SLOUGHS OF SAN FRANCISCO BAY

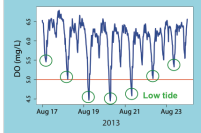
EMILY NOVICK San Francisco Estuary Institute, Richmond, CA
PHIL BRESNAHAN San Francisco Estuary Institute, Richmond, CA. @SUPScientist
MAUREEN DOWNING-KUNZ U.S. Geologic Survey, Sacramento, CA
DAVID SENN San Francisco Estuary Institute, Richmond, CA

Acknowledgements: P. Buchanan (USGS), K. Weldich (USGS), A. Powell (USGS), R.Castagna (USGS) for expertise with deployments; G. Shellenbarger (USGS), D. Schoellhamer (USGS), J. Cloern (USGS), N. Feger (SFBRWQCB), R. Schlpf (SFBRWQCB) for valuable advice on study design and interpretation
Funding Sources: RMP; Nutrient Management Strategy

WHY MONITOR THE SLOUGHS?

Dissolved oxygen (DO) monitoring in South San Francisco Bay has historically occured 1-2x monthly and average concentrations are typically 6-8 mg/L despite high nutrient loading to this region.





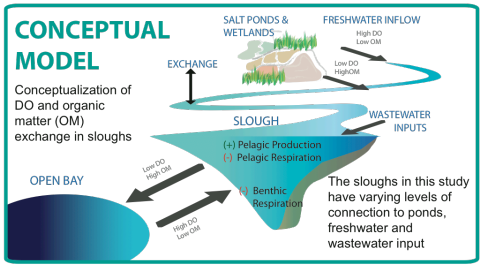
However, recent high frequency data at the Dumbarton Bridge has shown DO can dip below 5 mg/L in the deep channel on spring ebb tides.

We hypothesize that this is caused by exchange with low DO water in sloughs and wetlands, where intital observations at one moored slough site show DO frequently drops below 5 mg/L and is often 2-3 mg/L. In this project, we established a network of continuous sensors at slough and channel sites to answer the following questions:

1. **How do DO concentrations in sloughs vary in space and time?**
2. **What mechanisms control the frequency, duration and severity of low-DO events?**
3. **How does exchange with sloughs affect conditions in the open Bay?**

CONCEPTUAL MODEL

Conceptualization of DO and organic matter (OM) exchange in sloughs

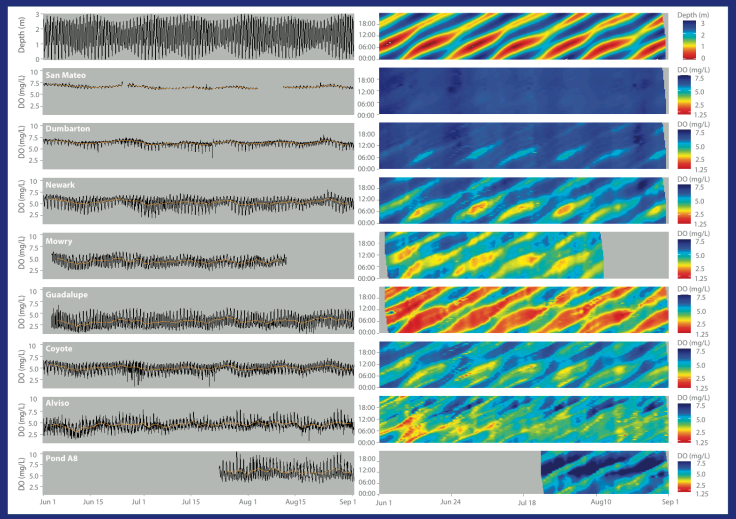


The sloughs in this study have varying levels of connection to ponds, freshwater and wastewater input

HOW DOES OXYGEN VARY IN SPACE AND TIME?

Throughout Spring 2015 we installed 5 additional sensors in sloughs and creeks of Lower South Bay, bringing our total network to 8 sites. The figures below show data from all sites for 3 months in summer 2015. The left panel shows time series, the right panel shows contour plots of date (x-axis) and time of day (y-axis). The top panel or each shows depth (m).

	Freshwater input?	Salt Pond connections?	Wastewater inputs?
Newark Slough			
Mowry Slough			
Coyote Creek	✓		✓
Alviso Slough	✓	✓	
Guadalupe Slough		✓	✓

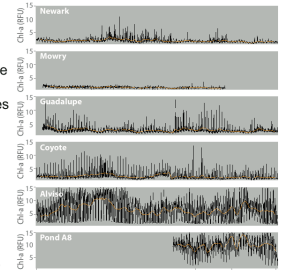


- All slough sites experienced DO concentrations < 5mg/L, and many frequently had DO < 3 mg/L
- DO concentrations were lowest in the sloughs with direct salt-pond connections: Alviso Slough and Guadalupe Slough, with Guadalupe being the lowest overall
- There is considerable tidal variability in DO concentrations at all slough sites, as much as +/- 5 mg/L at some sites
- On a qualititative basis, DO appears to be regulated not by a diurnal production cycle, but by the semidiurnal and semimonthly tides

WHAT MECHANISMS REGULATE OXYGEN CONCENTRATION?

Production/Respiration

- Chl-a concentrations in sloughs are higher than in the open Bay, as much as 5-10x higher at some sites
- Respiration of chl-a and other organic matter could draw DO down more in sloughs with low volume:area ratios

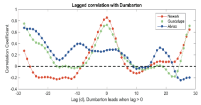


Physical Processes

- Stratification may contribute to low DO by restricting reaeration of bottom waters. Stratification has been observed previously in Alviso Slough
- DO is a minimum in Alviso and Guadalupe Sloughs on neap tides, when less flushing occurs with higher-DO waters of the open Bay

HOW MIGHT SLOUGHS AFFECT CONDITIONS IN THE OPEN BAY?

- DO at Dumbarton is lowest on ebb tides, particularly spring ebb tides, suggesting drainage of low-DO water from the sloughs. A lag correlation analysis shows that Guadalupe and Newark Sloughs are in phase with Dumbarton.



- We estimate total slough and salt pond volume to be about half of that in the open Bay. Even conservative estimates of exchange suggest the slough contribution to water conditions in the open-Bay is non-trivial.

NEXT STEPS

- Collect high-spatial resolution data (longitudinally and vertically) to complement the moored data to better characterize DO in sloughs
- Characterize the relative importance of biological and physical processes in controlling how sloughs respond to organic matter inputs
- Quantify how sloughs could affect conditions in the open Bay through a simple box-model (and ultimately complex 3D modeling)

Key Messages

- Lower South Bay is a complex and heterogeneous biogeochemical reactor: N transformations / Dissolved Oxygen / Blooms
- Low(er) DO in sloughs
  - Strong tidal variability
  - Variability: within sloughs, among sloughs, multiple time scales (tidal, seasonal, event
  - Influenced by multiple factors
- Continuing work…
  - Field investigations …physical/biogeochemical processes in sloughs, ponds
  - Modeling
  - Is the low DO adversely impacting biota?
  - Importance of Nutrient ←→ Salt Pond restoration
  - Algal toxins and HAB-forming organisms??
- Opportunities for co-management of Nutrients and Salt Ponds ?

Key Science Collaborators

SFEI

E Novick

P Bresnahan

R Holleman

D Senn

USGS-Menlo Park

J Cloern

L Lucas

T Schraga

UC Santa Cruz

R Kudela

M Peacock

SCCWRP

M Sutula

USGS-Sacramento

M Downing-Kunz

G Shellenbarger

D Schoellhamer

B Downing

B Bergamaschi

UC Berkeley

M Stacey


Source: C. Benton

Acknowledgements:

Funding: Regional Monitoring Program; Nutrient Watershed Permit (BACWA); State Water Resources Control Board; Interagency Ecological Program (IEP); In-kind funding from USGS (Cloern et al)

NMS Steering Committee and Planning Subcommittee

SFEI: J Davis, M Sedlak, J Wu, D Yee, A Malkasian, T Hale, T Featherston, S Bezalel, E Willis-Norton, P Frontieria, P Trowbridge

Technical Team and Collaborators: M Sutula (SCCWRP), J Cloern (USGS), R Dugdale (SFSU), T Hollibaugh (U-Georgia), W Kimmerer (SFSU), R Kudela (UCSC), L Lucas (USGS), A Mueller-Solger (IEP), M Stacey (UC Berkeley), E Gross (RMA), J Fitzpatrick (HDR-Hydroqual), O Fringer (Stanford), M Berg (AMS), A Parker (CSMA), J Hobbs (UC-Davis), T Schraga (USGS), J Thompson (USGS), D Schoellhamer (USGS), M Downing-Kunz (USGS), G Shellenbarger (USGS), K Weidich (USGS), P Buchanan (USGS), F Parcheso (USGS), J Crauder (USGS), M Peacock (UCSC), A Chastain (SFPUC)

Region 2: N Feger, T Mumley, K Taberski, B Baginska, R Looker

BACWA: D Williams, J Ervin, E Dunlavey, M Connor

USEPA: T Fleming

David Senn
San Francisco Estuary Institute
davids@sfei.org

sfbaynutrients.sfei.org