Reinvesting in the Delta's Food Web Portfolio

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wetland ECOSYSTEM TEAM

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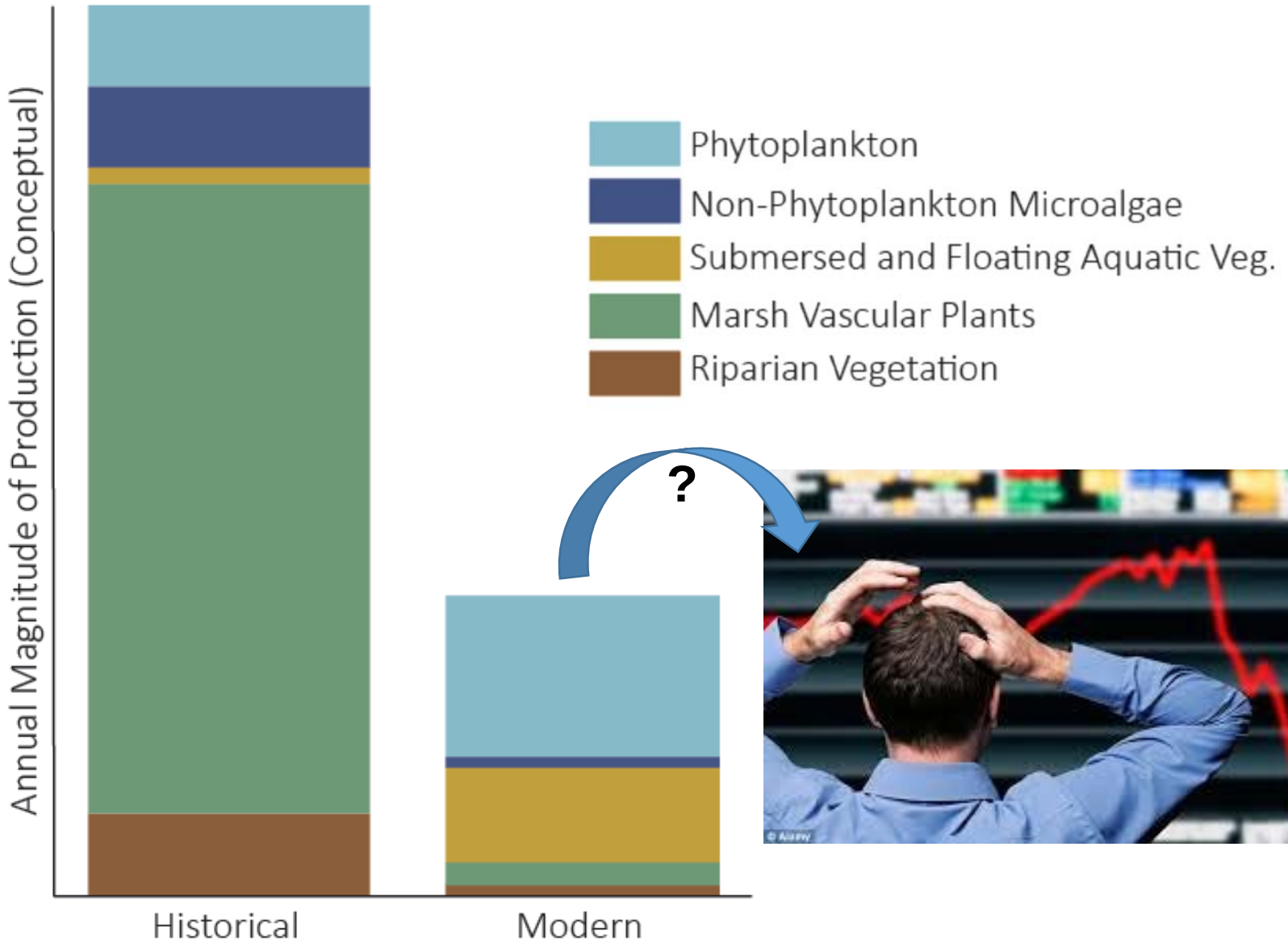
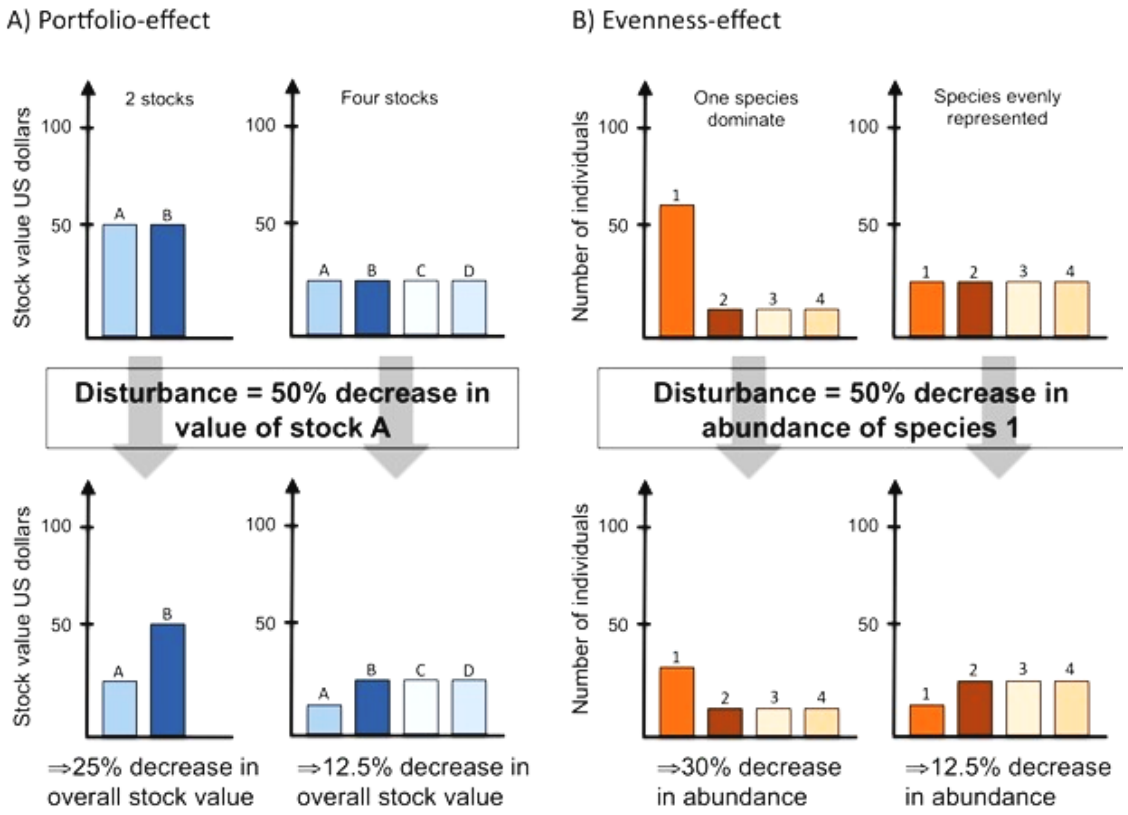
A Delta Renewed; SFEI Aquatic Science Center 2016

Cloern: Output = Annual Primary Production by Five Groups Then and Now



Delta Food Web Portfolio

Portfolio Concept as Applied to Population Resilience



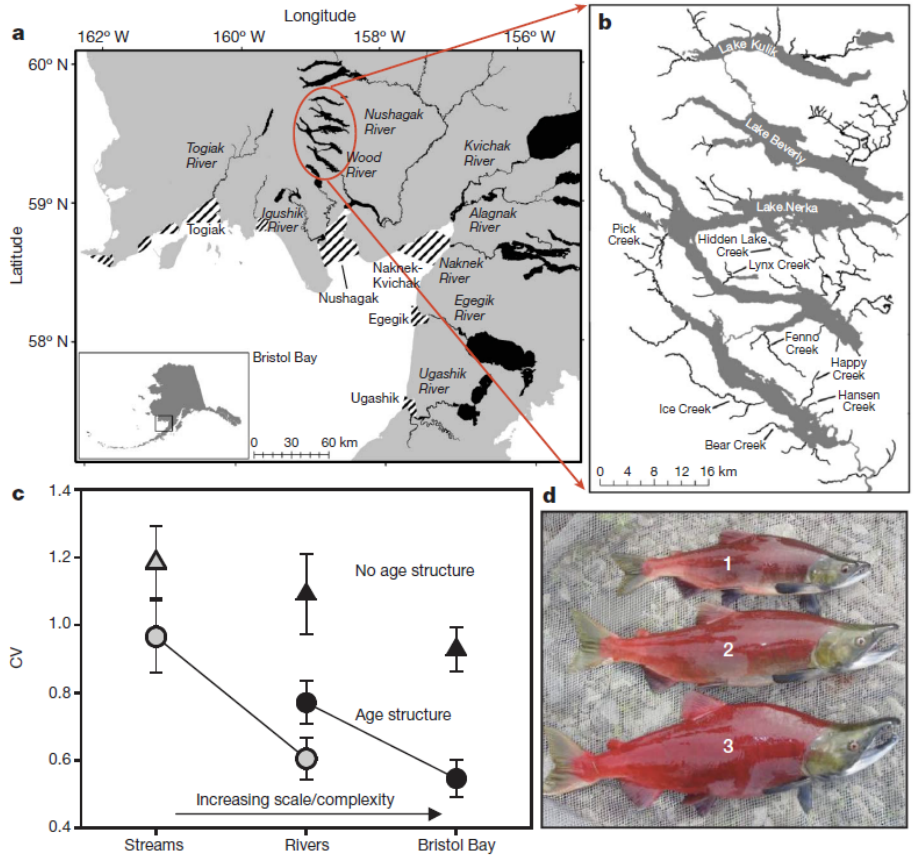
Wall and Nielsen. 2012. Biodiversity and Ecosystem Services: Is It the Same Below Ground? Nature Education Knowledge 3:8

"…even the absence of ecological interactions, statistical effects can cause greater species diversity to lead to lower oscillations in community biomass" …analygous to "effects of the diversity of a portfolio of investments on the stability of its valuation…"

Tilman et al. 1998. Diversity-stability relationships: Statistical inevitability or ecological consequence? Am. Nat. 151: 277-282.
Doak et al.1998. The statistical inevitability of stability-diversity relationships in community ecology. Am. Nat. 151:264-276.

"…ecological resilience is generated by diverse, but overlapping, function within a scale and by apparently redundant species that operate at different scales, thereby reinforcing function across scales." Peterson et al. 1998; Ecosystems 1:6-18

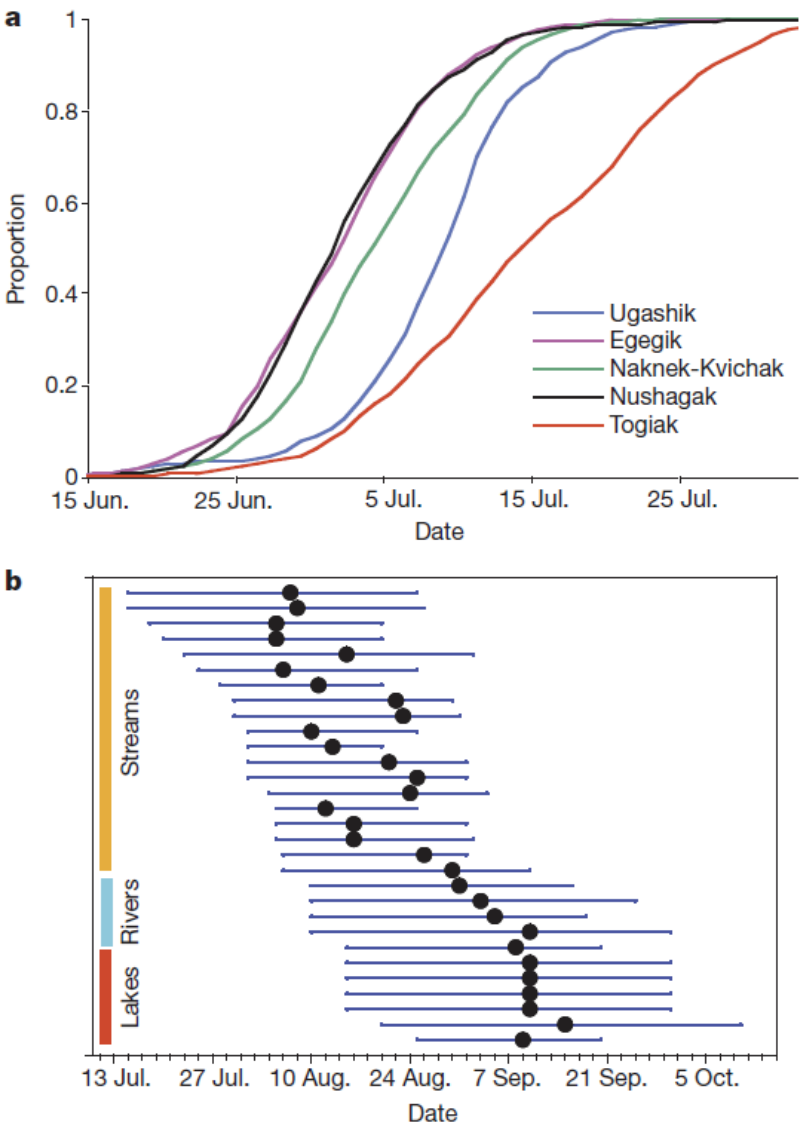
Delta Food Web Portfolio



"Variability in annual Bristol Bay salmon returns is 2.2 times lower than it would be if the system consisted of a single homogenous population rather than the several hundred discrete populations it currently consists of."

"Portfolio effects are also evident in watershed food webs, where they stabilize and extend predator access to salmon resources."

Portfolio Concept as Applied to Population Resilience



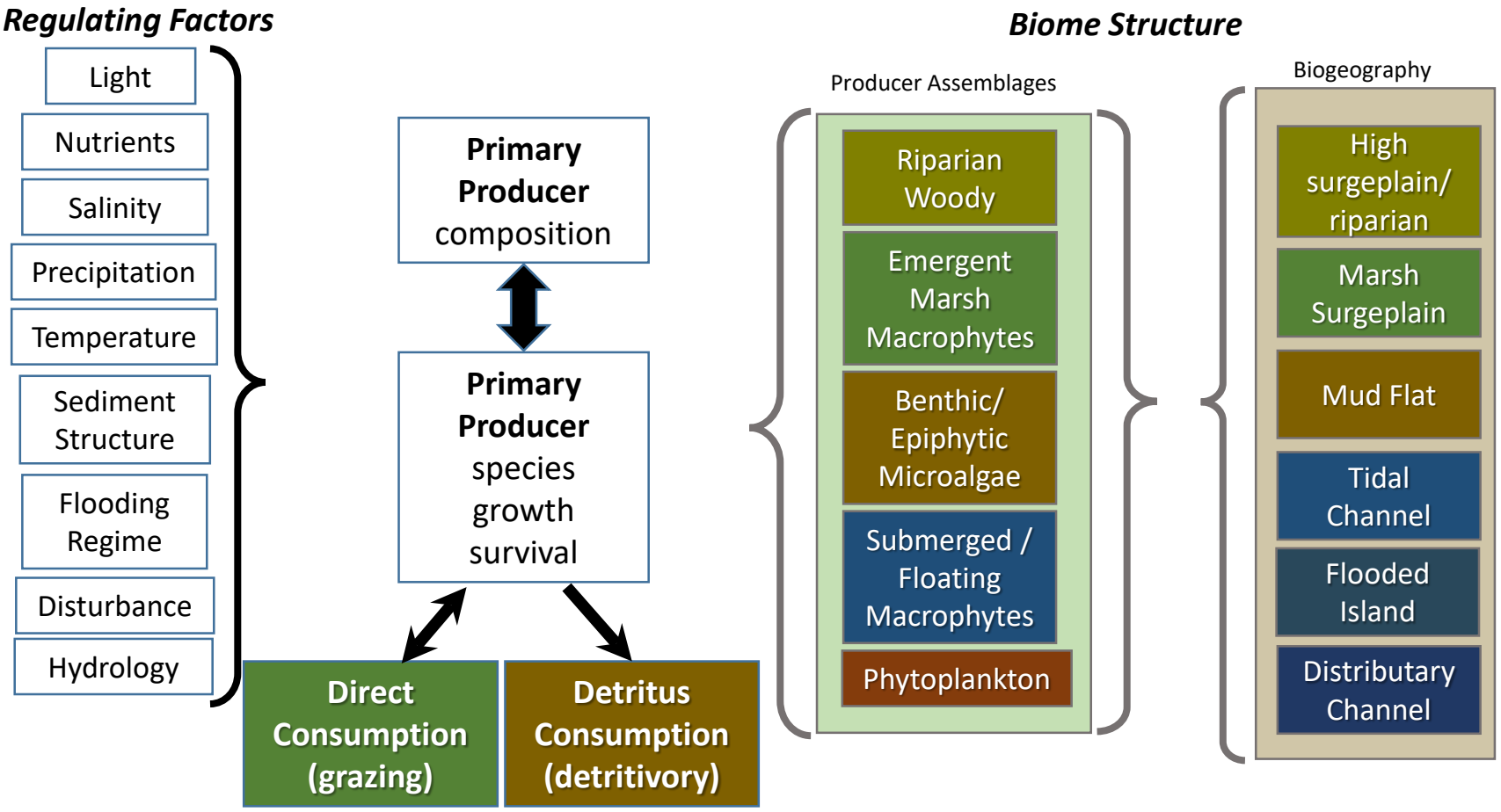
Source: Schindler et al. 2010. Population diversity and the portfolio effect in an exploited species. Nature Letters 465: 609-613.

A “Portfolio Context” to the Delta’s Food Web

1. Diverse sources of organic matter
2. Spatial/temporal scales of variability
3. Quantity vs. quality
4. Evidence of organic matter sources to pelagic food web from Delta and specifically Cache Slough complex
   - Organic matter budget
   - Biogeochemical biomarkers
     - Stable isotopes
     - Fatty acids
5. Implications for Delta ecosystem restoration

Delta Food Web Portfolio

Portfolio Composition of Primary Producer Assemblages and Source Biomes in Delta, with Factors Regulating Productivity and Availability



Delta Food Web Portfolio

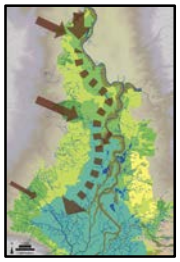
Conceptual Model Framework for Delta Scale Food Web Processes

Allochthonous Input
(import from watershed)

phytoplankton

organic matter

consumers



Autochthonous
(internal)

Delta

Abiotic Regulation

Biotic Regulation

NET PRIMARY PRODUCTION

DETRITUS
POC ⟷ DOC

"Microbial Loop"

Direct Consumption
(herbivory/omnivory)

Direct Consumption
(detritivory)

burial

respiration

Export to Suisun Marsh/Bay
(passive particle and active organism transport at different spatial/temporal scales)

phytoplankton

organic matter

consumers

Scales of Variability in Types and Quantities of Organic Matter Sources and Consumer Access to Food Web

Temporal

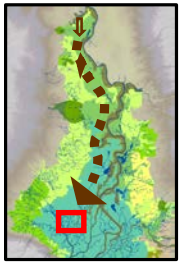
- Fine-scale
  - Tidal (pumping)—neap/spring
- Broad-scale
  - Seasonal flooding
  - Dry-wet years

Spatial

- Fine-scale
  - Tidal ecosystem
  - Channel hierarchy
  - Connectivity
  - Consumer life history
- Broad-scale
  - Estuarine gradient
  - Consumer distribution

Delta Food Web Portfolio

Variability in Temporal Production, Processing and Delivery of Food Web Sources



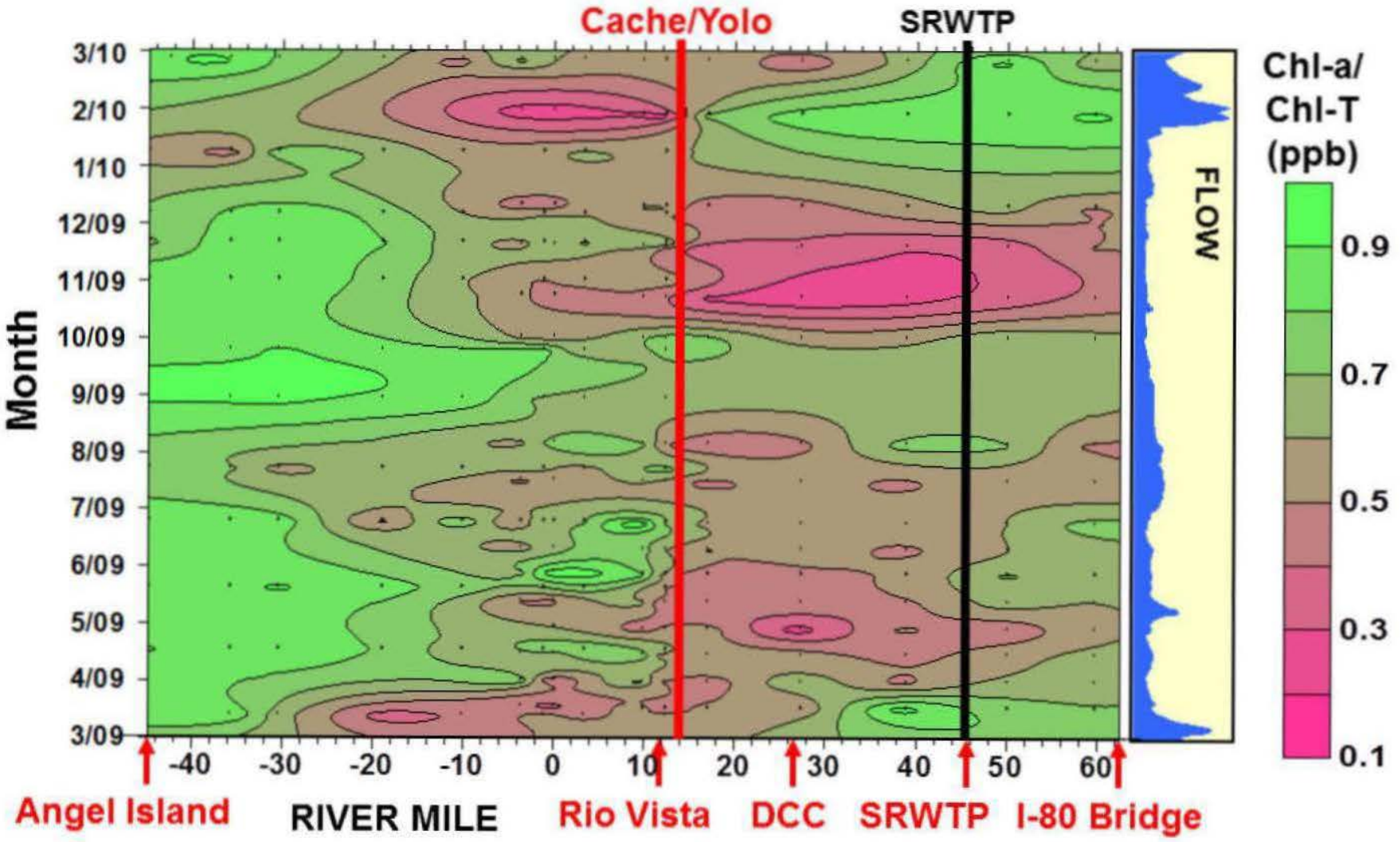
DRY year

Delta Food Web Portfolio

Variability in Temporal Production, Processing and Delivery of Food Web Sources

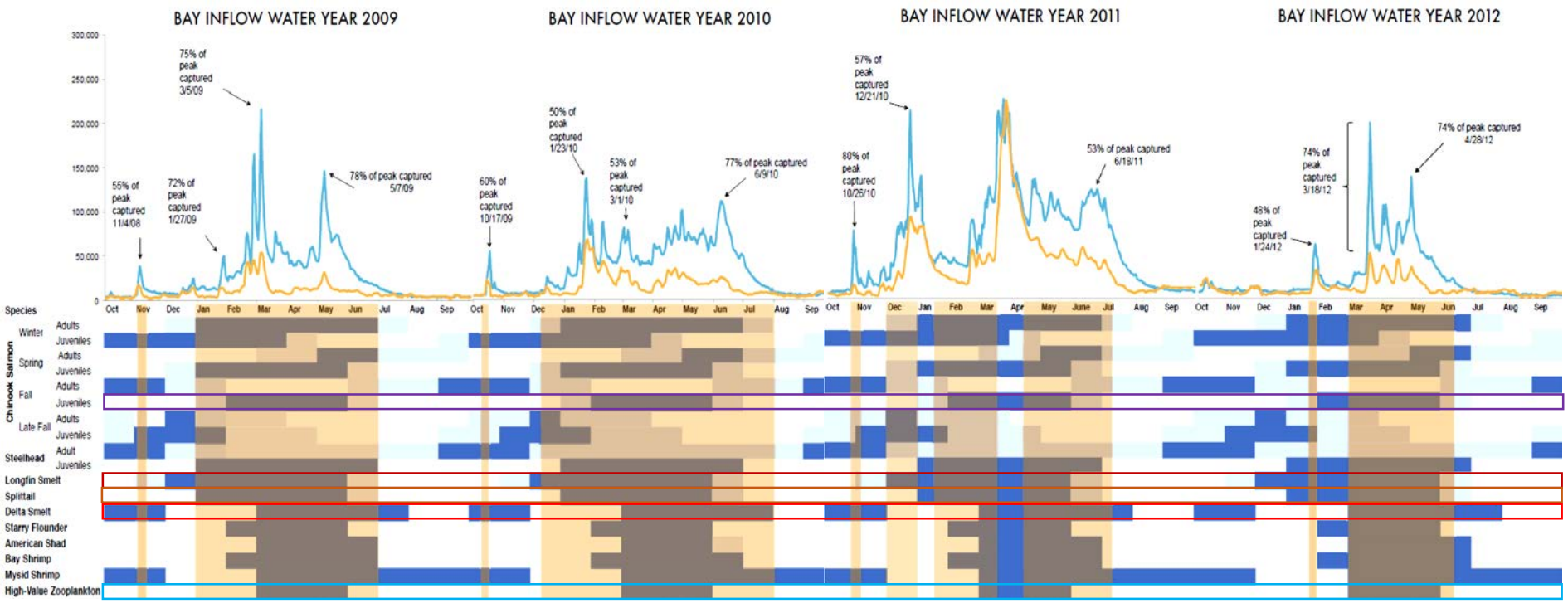
WET year

Temporal and Spatial Variability in the Ratio of Chlorophyll-*a* to Total Chlorophyll Concentration



Source: Kendall, C., Young, M.B., Silva, S.R., Kraus, T.E.C., Peek, S., and Guerin, M., 2015. Tracing nutrient and organic matter sources and biogeochemical processes in the Sacramento River and Northern Delta: proof of concept using stable isotope data. U.S. Geological Survey, Data Release, http://dx.doi.org/10.5066/F7QJ7FCM

Temporal Variability in Life Cycle Occurrence of Fishes in San Francisco Bay and the Delta, 2009-2012

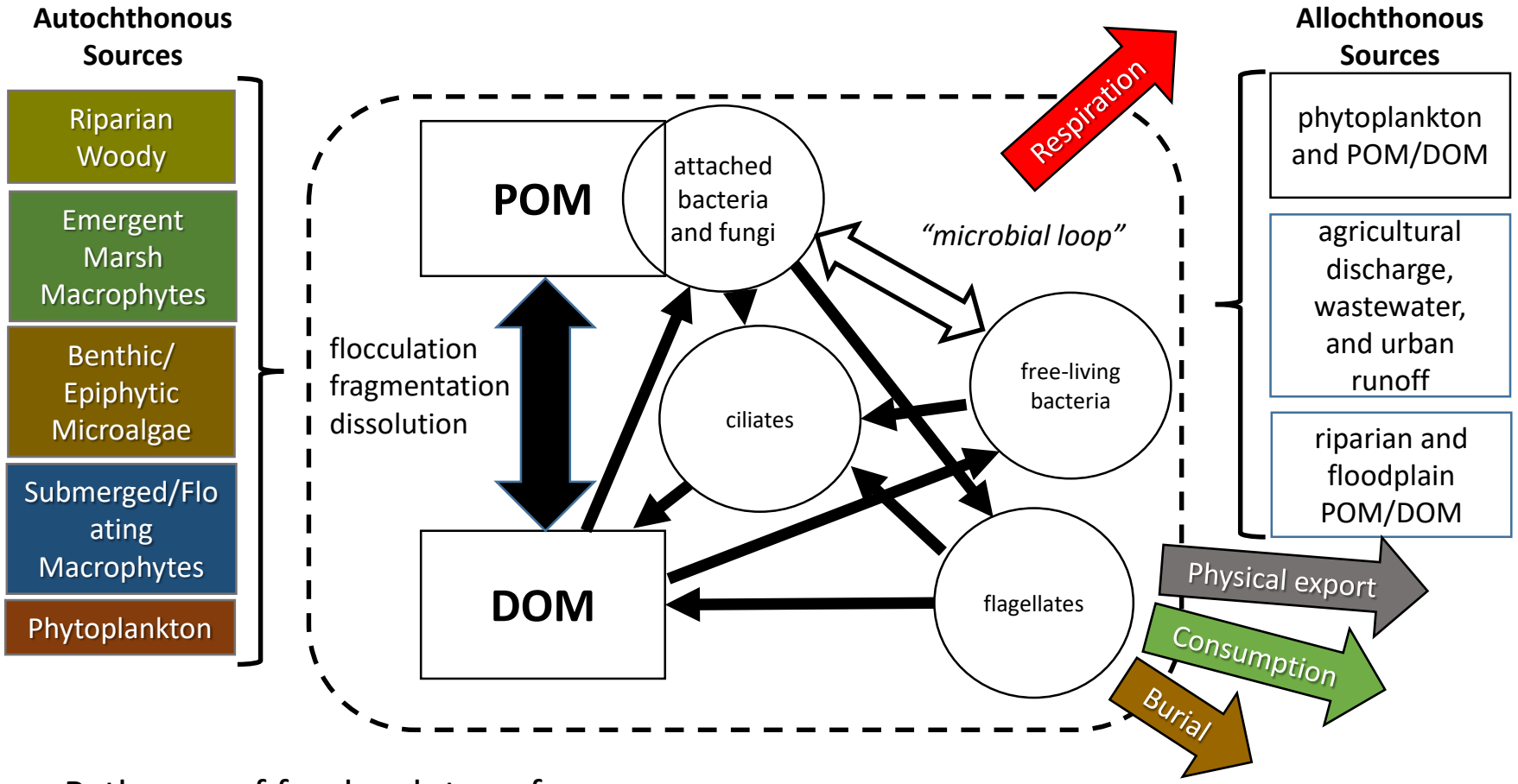


Light blue bars indicate when a life stage may be present; dark blue bar indicated the life stage is definitely present at that time; amber shading indicates when flow volume was significantly reduced by water diversions and exports

Data for figure from: California Department of Water Resources Dayflow and California Department of Fish and Game Report, 2010 (Quantifiable Biological Objectives and Flow Criteria for Aquatic and Terrestrial Species of Concern Dependent on the Delta).

Source: The Bay Institute. 2016. San Francisco Bay: The Freshwater-Starved Estuary; How Water Flowing to the Ocean Sustains California's Greatest Aquatic Ecosystem.

Transformation and Loss of Organic Matter Sources in Delta Food Web

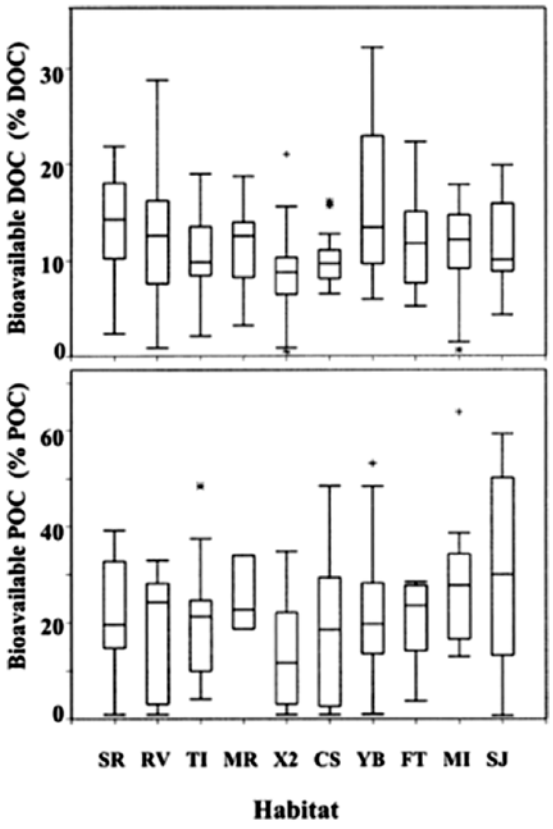


Pathways of food web transfer:

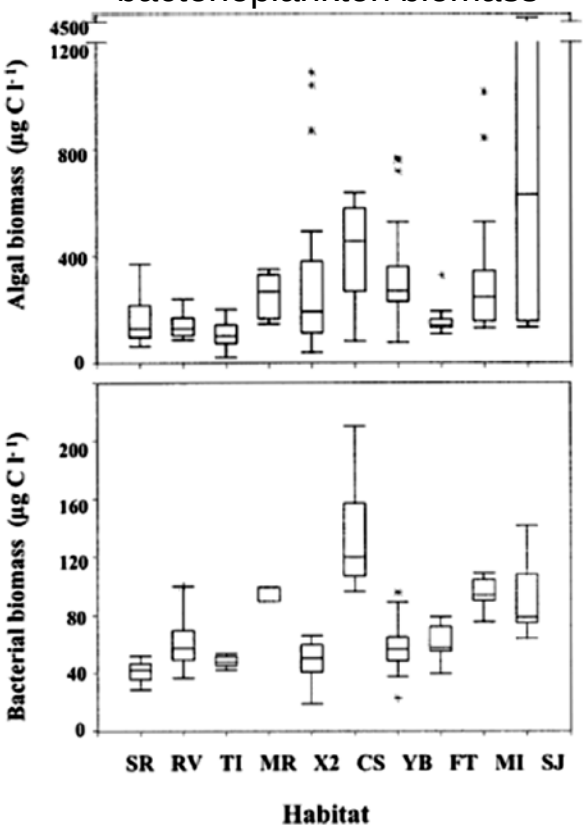
1. Direct grazing on phytoplankton (herbivory)
2. Direct feeding on particulate detritus (detritivory)
3. Predation on bacteria that consume POC or DOC (bacterivory), including feeding bactiverious microzooplankton

Bioavailability Budgeting of Organic Matter

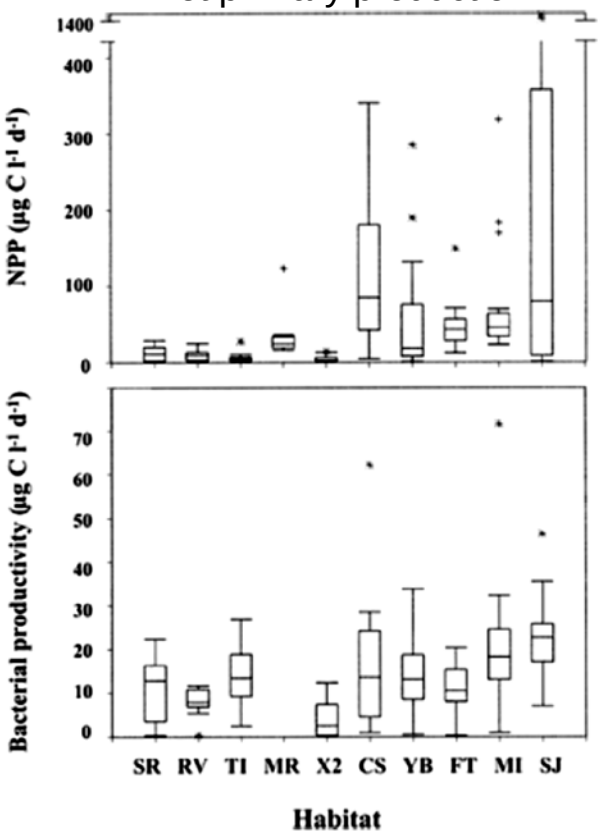
DOC and POC bioavailability



phytoplankton and bacterioplankton biomass



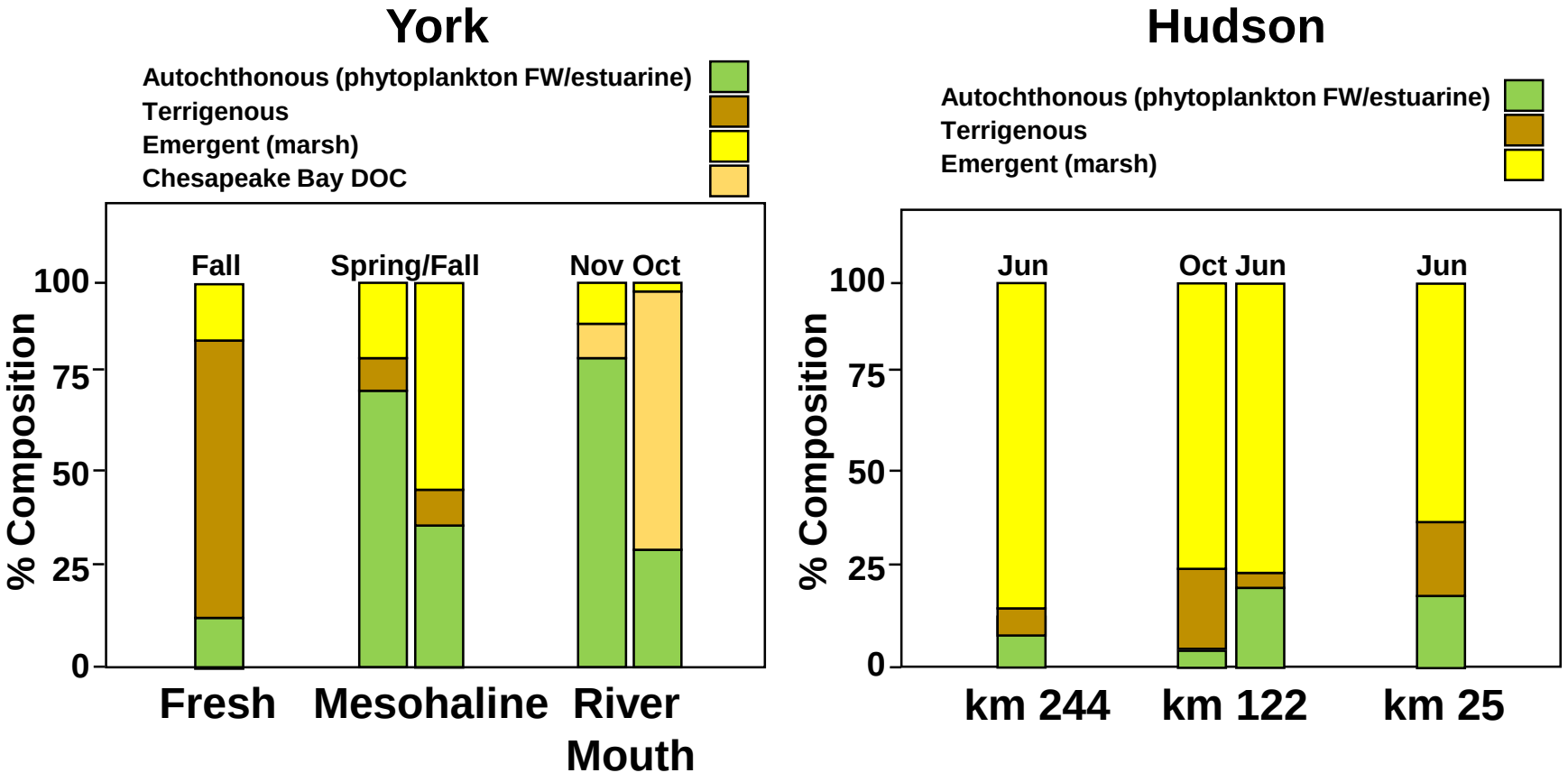
phytoplankton and bacterioplankton net primary production



Delta habitats: SR = Sacramento River at Hood; RV = Sacramento River at Rio Vista; TI = San Joaquin River at Twitchell Island; MR = Middle River at Clifton Court Forebay; X2 = export to SF Bay at salinity = 2 psu; YB = Yolo Bypass drainage; FT = Franks Tract; MI = Mildred Island; SJ = San Joaquin River at Mossdale

Source: Sobczak *et al.* 2005. Detritus fuels ecosystem metabolism but not metazoan food webs in San Francisco estuary's freshwater delta. Estuaries 28:124-137.

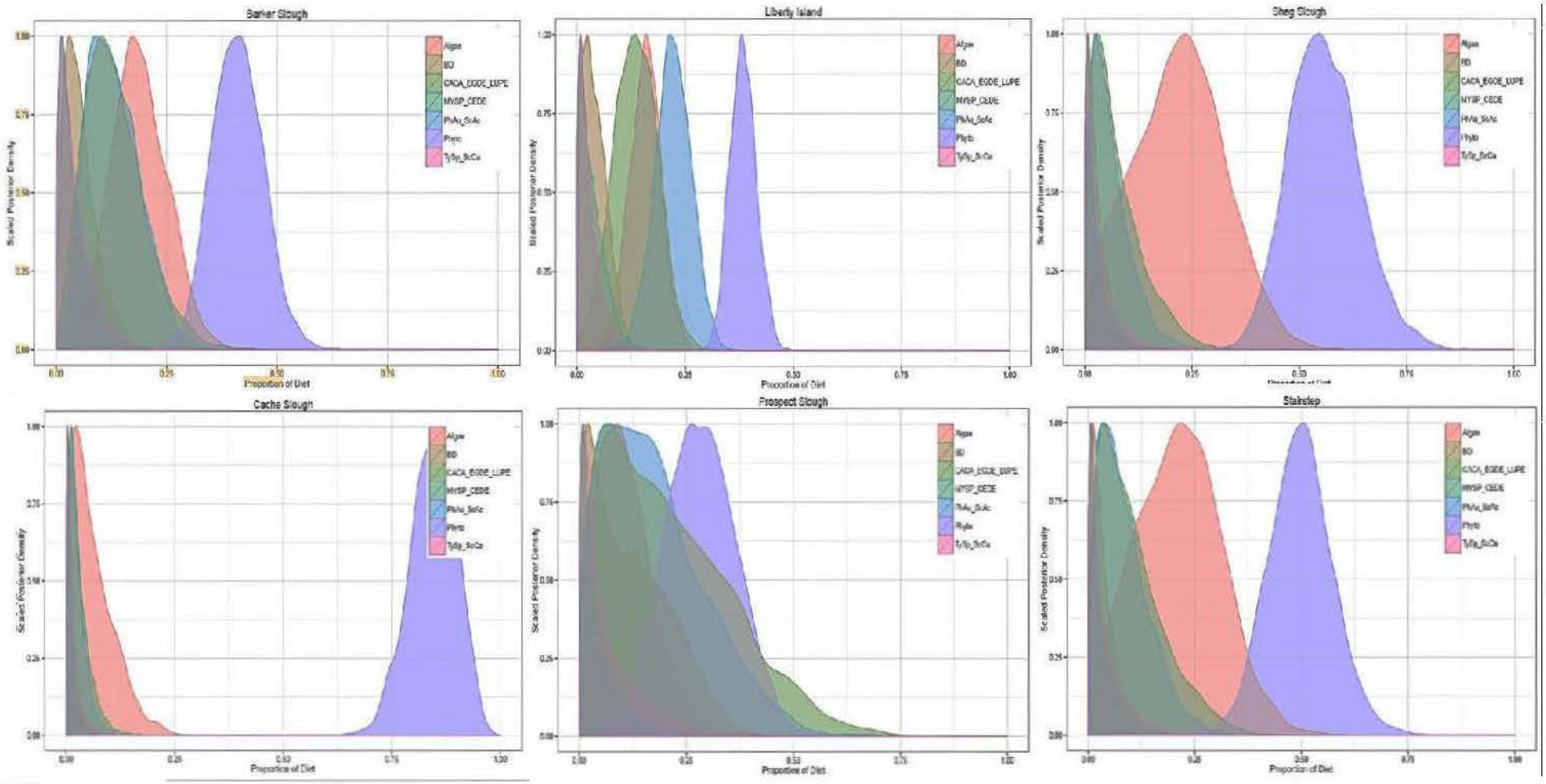
Proportions of Allochthonous (subsidized) and Autochthonous (internal) Sources of Organic Matter Assimilated by Bacteria in York and Hudson Rivers Estuaries Estimated from Average Dual Isotope, Three-Source Mixing Models of Nucleic Acid $\delta^{13}C$ and $\Delta^{14}C$



Source: McCalliuster et al. 2004; L&O 49: 1687-1702

Delta Food Web Portfolio

Bayesian Mixing Model (MixSIAR) Estimation of Primary Organic Matter Sources to Zooplankton in Cache Slough Complex



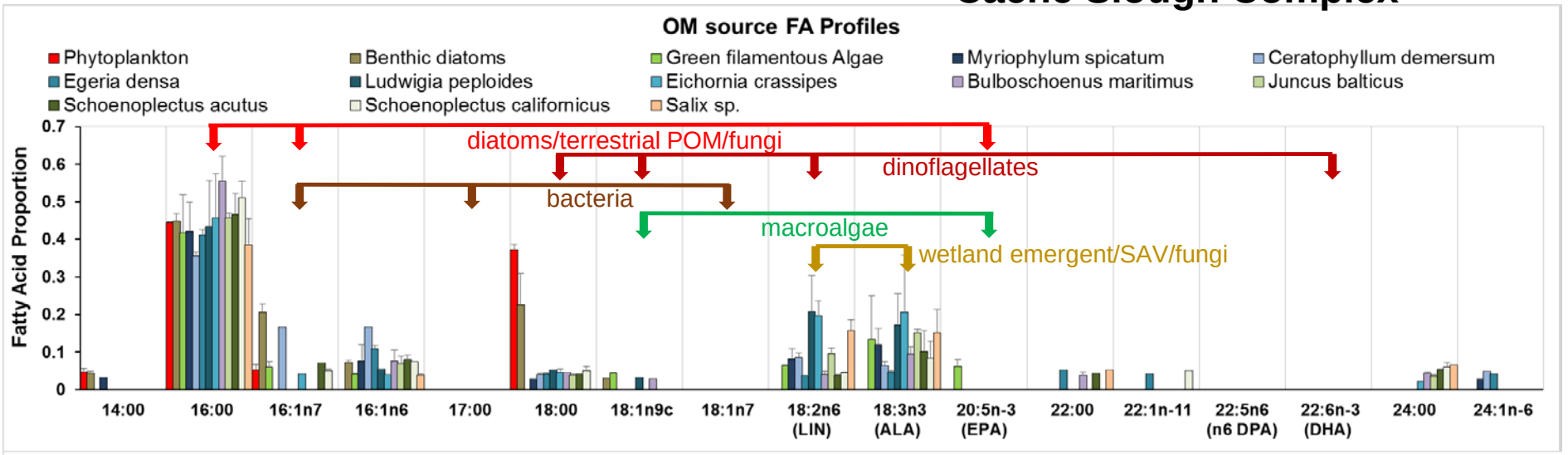
Algae	filamentous green algae
BD	Benthic diatoms
CACA_EGDE_LUPE	SAV species*: Egeria densa, Ludwigia peploides, Cabomba canadensis*
MYSP_CEDE	SAV species: *Myriophyllum spicatum, Ceratophyllum demersum*
PhAu_ScAc	*Phragmites australis, Schoenoplectus acutus*
Phyto	phytoplankton
TySp_ScCa	*Typha* spp., *Schoenoplectus californica*

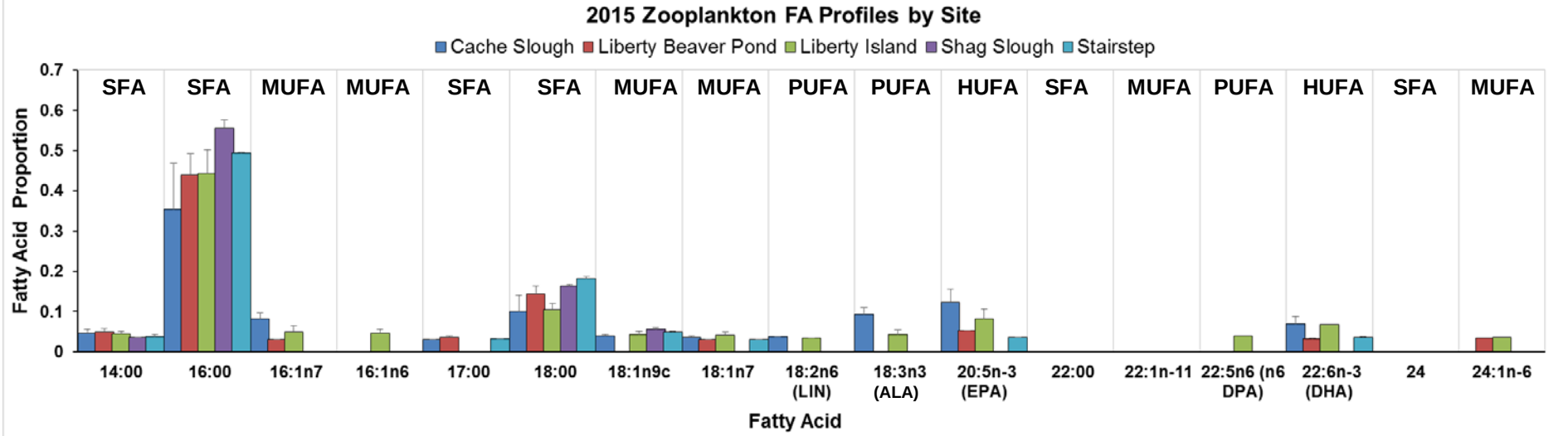
(Important caveat: sampling dates differ)

See: Lori Smith, Tue., 4:35pm; Room 306

Source: SFCWA Cache Slough Complex unpubl.

Fatty Acid Composition of Primary Organic Matter Sources (top) and Zooplankton (bottom) from Five Sites in Cache Slough Complex





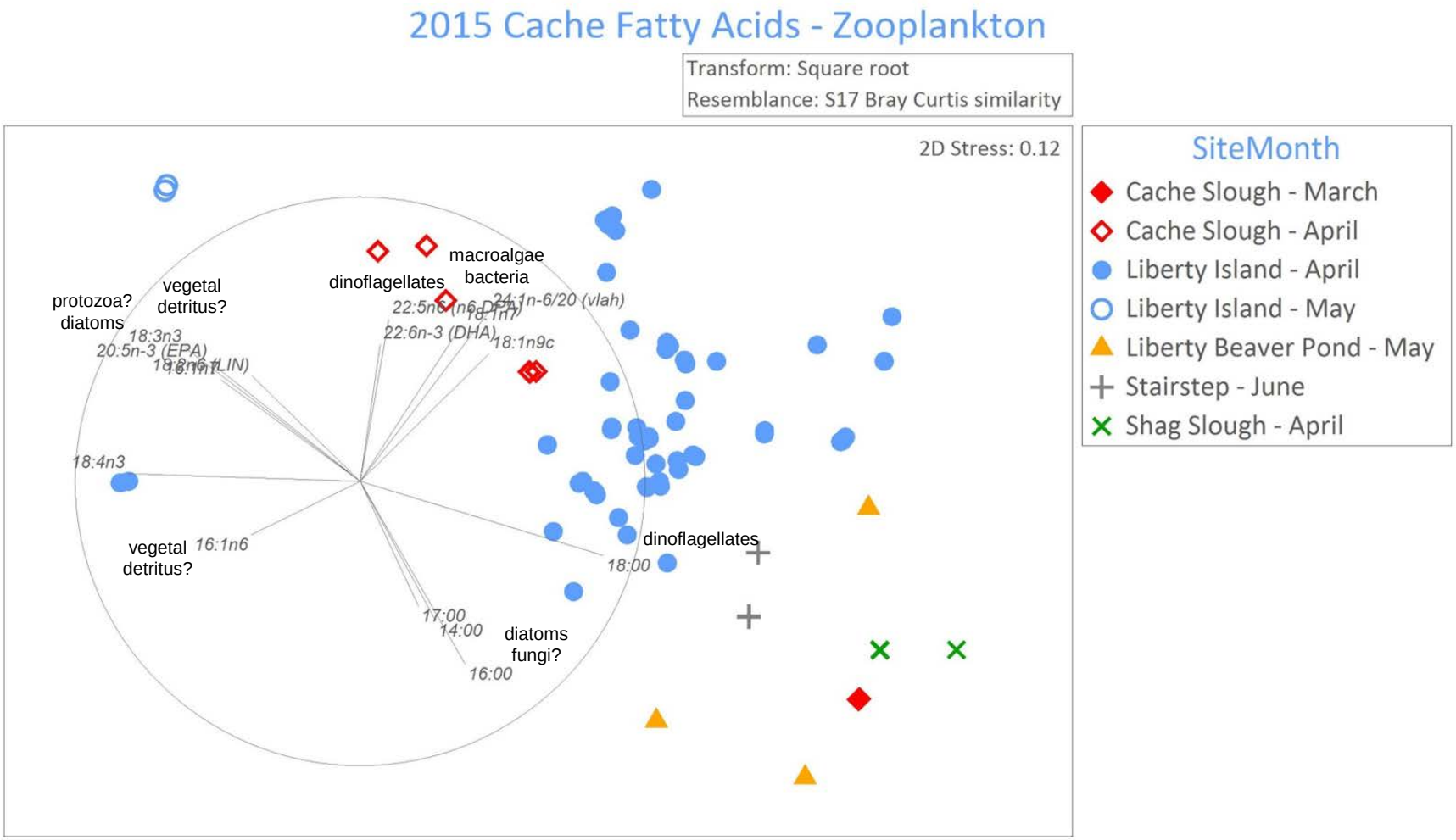
Dominant zooplankton: *Pseudodiaptomus forbesi* (nauplii, copepodids, adults) and *Sinocalanus doerrii* (see Cordell *et al.* poster, "Trophic Ecology of Zooplankton and Larval Fish the Cache Slough Complex")

FA (fatty acid): SFA = saturated; MFA = monounsaturated; PUFA = polyunsaturated; HUFA = highly unsaturated

Source: SFCWA Cache Slough Complex unpubl.

Delta Food Web Portfolio

Non-Metric Multidimensional Scaling (ordination) of Fatty Acids in Zooplankton from Five Sites in Cache Slough Complex, March-June 2015



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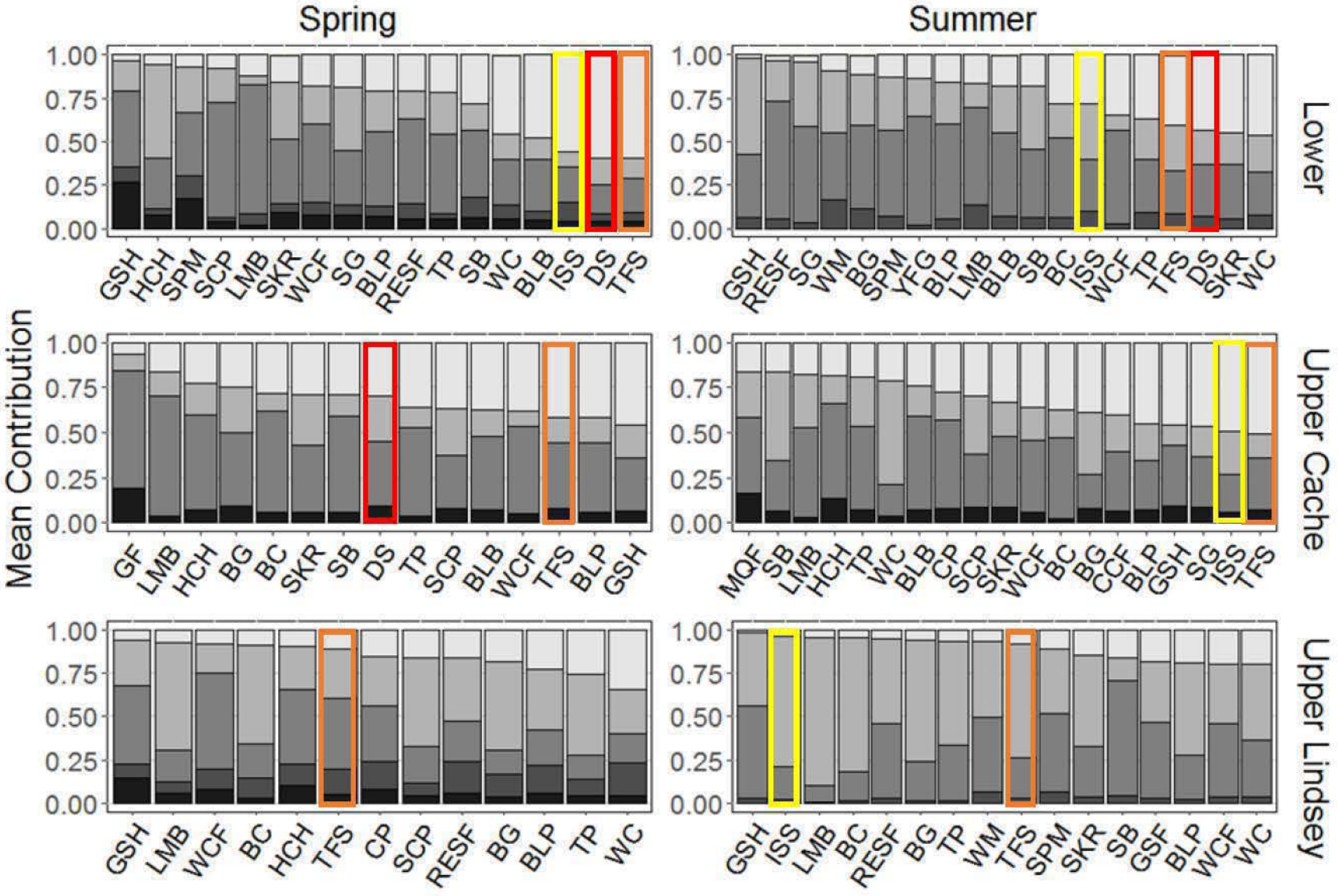
Source: SFCWA Cache Slough Complex unpubl.

Multiple Stable Isotope Estimates of the Contribution of Organic Matter Sources Supporting Cache Slough Complex Fishes



See: Matt Young, Wed., 1:35pm; Room 311-313

Source: Young, Howe, et al. manuscript in prep.

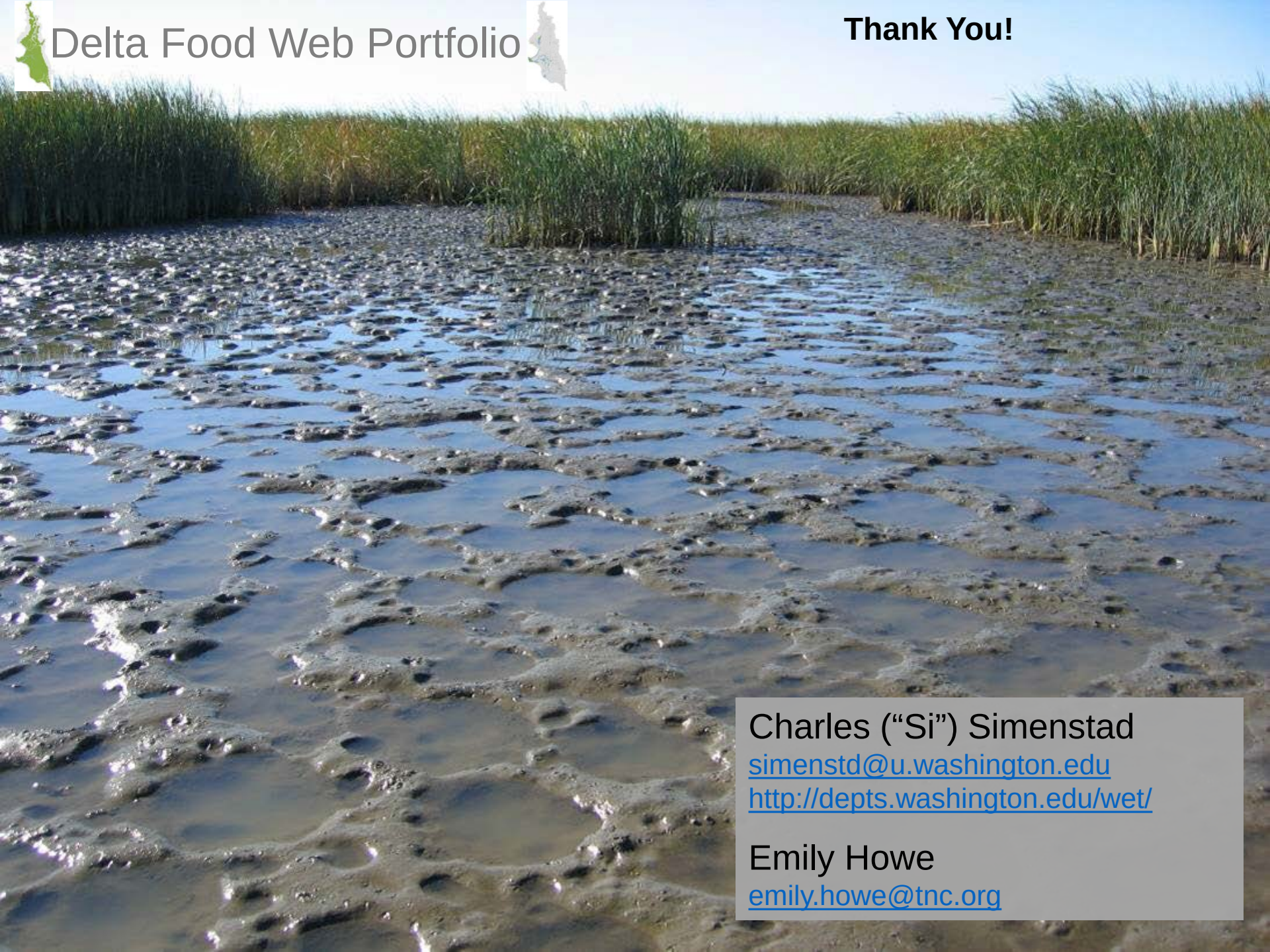
Delta Food Web Portfolio

Take-Home Message

- Despite historic reduction in tidal wetlands, surge- and floodplains, food web contributions from their non-algal sources is non-trivial, varying by time and location
- Although quality of organic matter sources differs between algal and detrital pathways to consumers, both contribute variably over different time and space scales
- Management and restoration of the Delta landscape needs to consider the contribution of ecosystem diversity, and resulting robust food web, to the resilience of species, populations, communities
- Resilience of consumer production would benefit from expansion of tidal wetland and surge/floodplain restoration, especially bridging periods of low algal contributions, from spatial and temporal diversification of organic matter sources
- Re-investment in diversifying the Delta's food web portfolio would benefit broad spectrum of higher trophic levels, even those based on pelagic food web pathways

Delta Food Web Portfolio

Thank You!



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