PHYTOPLANKTON, WATER QUALITY, AND JUVENILE SALMON DIET IN OFFCHANNEL MARSH HABITATS OF THE LOWER COLUMBIA RIVER

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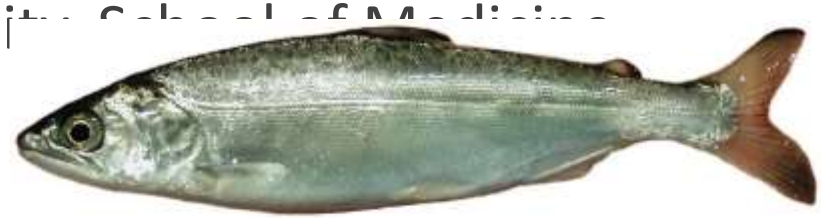
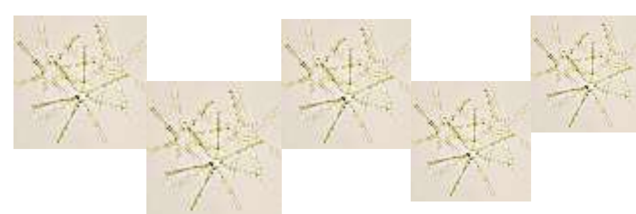


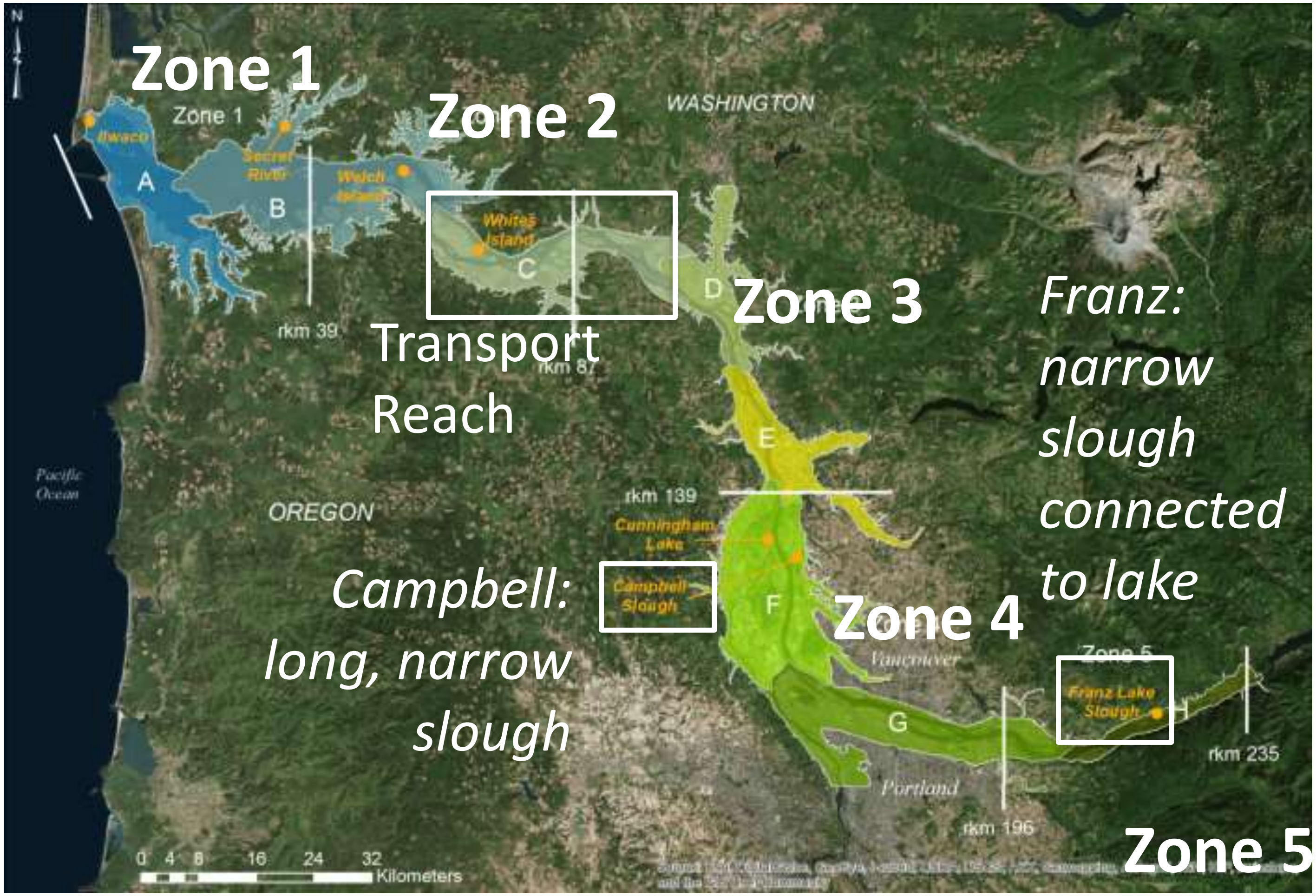


http://www.flycraftangling.com https://ameblo.jp

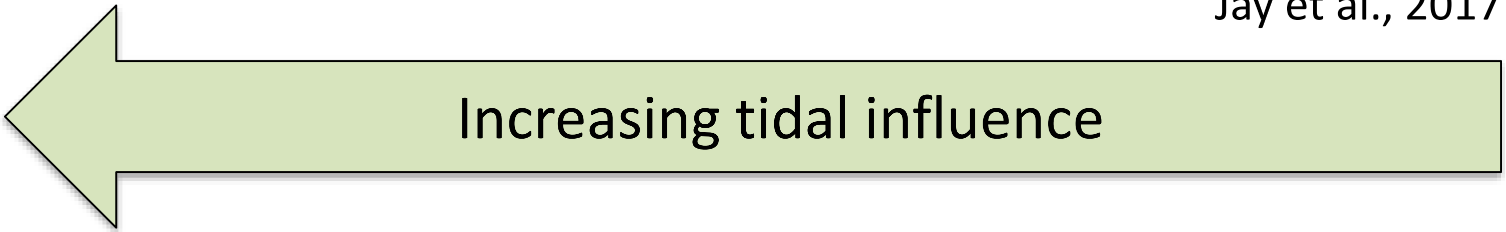
Goal: Characterize status and trends in rearing and migratory habitat for juvenile salmonids in the lower Columbia River

Focus

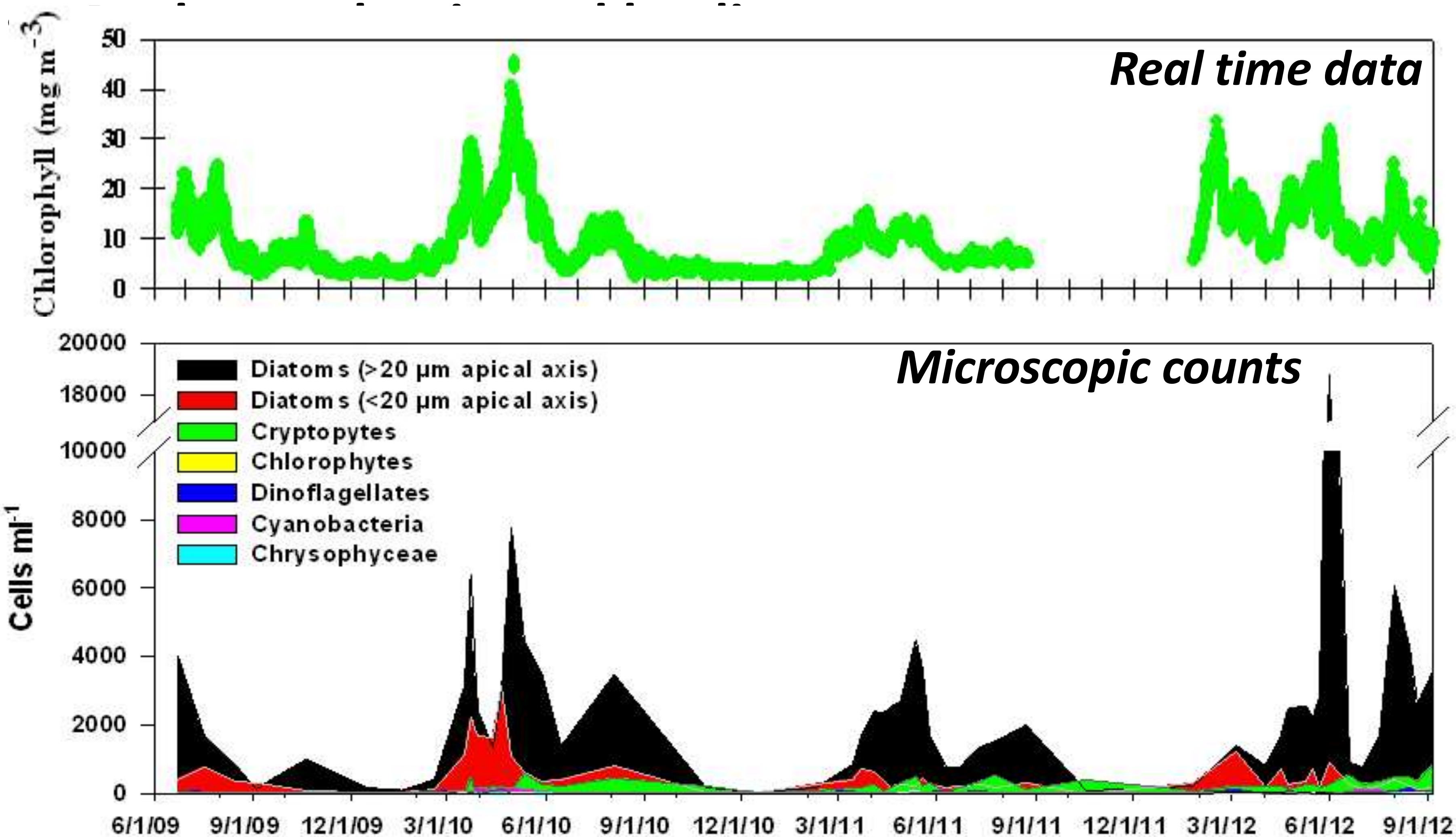
- What fish experience: Water quality
- What fish consume: Organic matter supporting juvenile salmon & prey



Jay et al., 2017

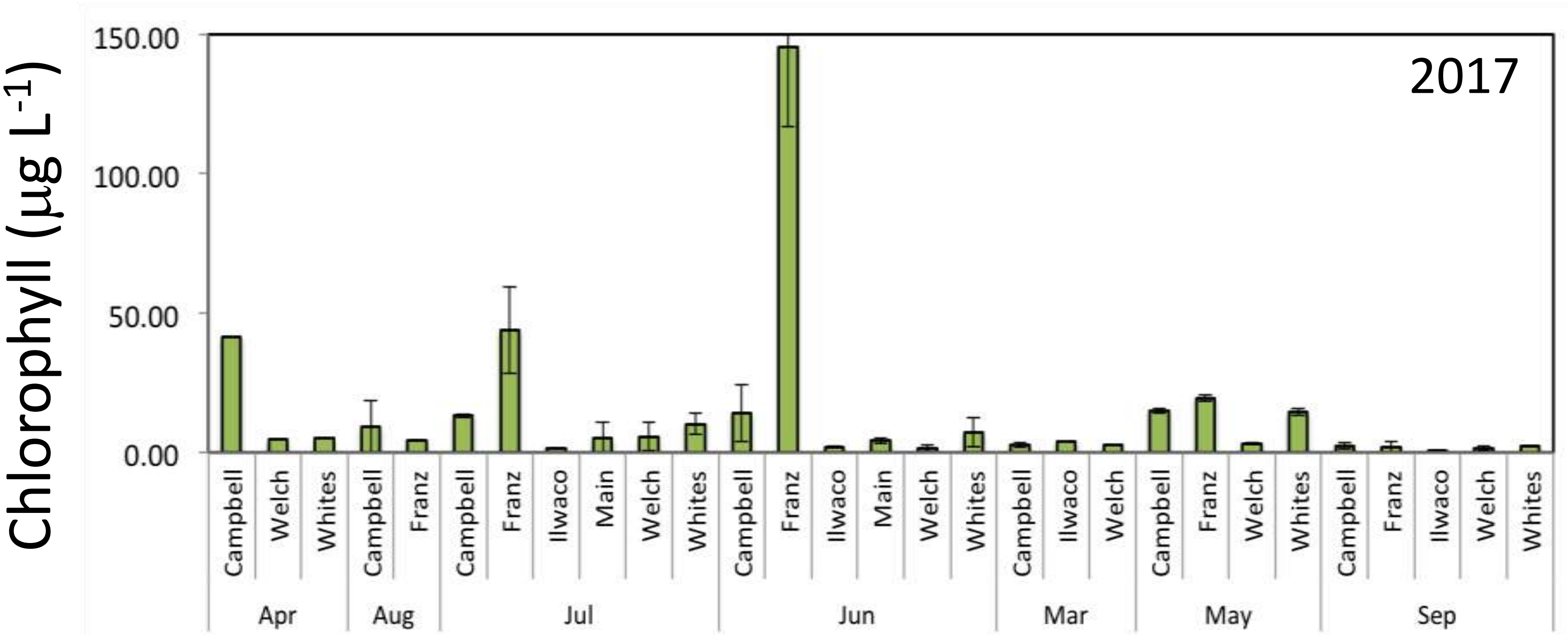


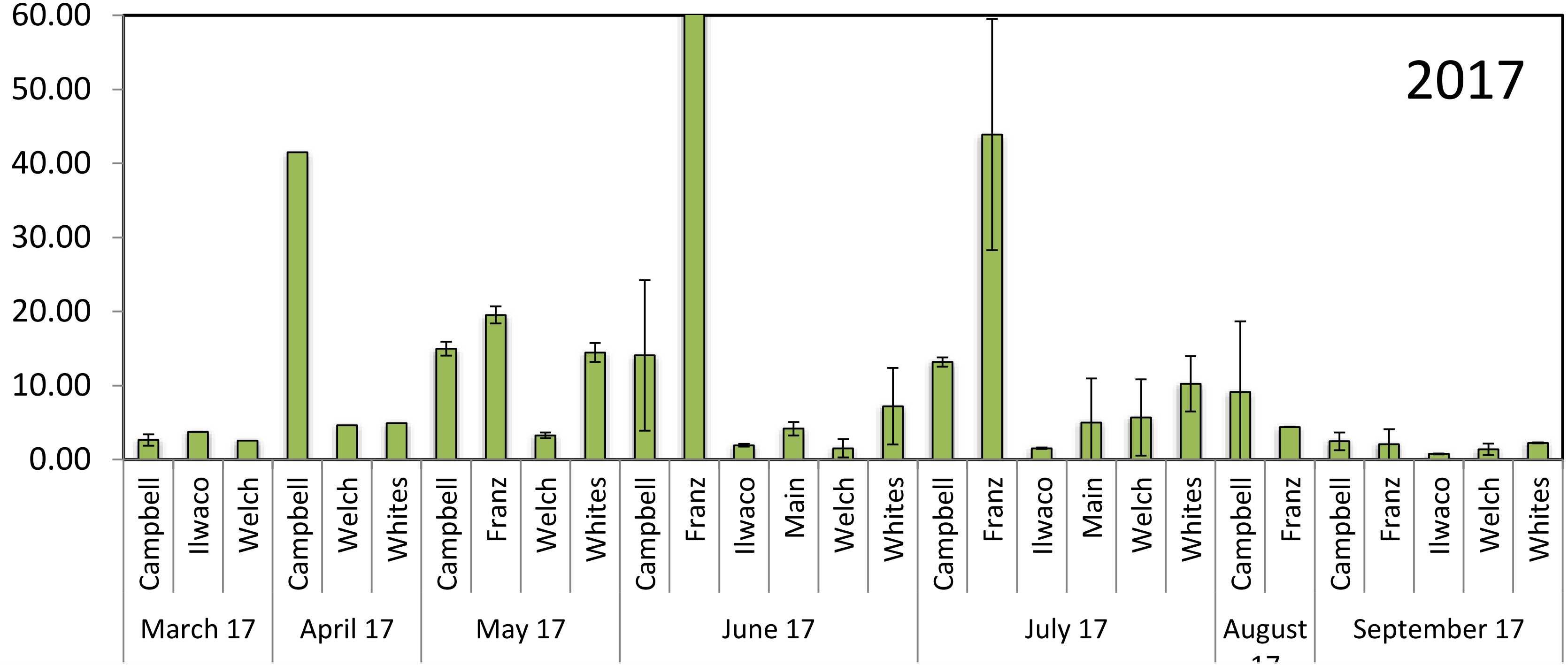
- **Chlorophyll peaks occur in spring in the mainstem Columbia**



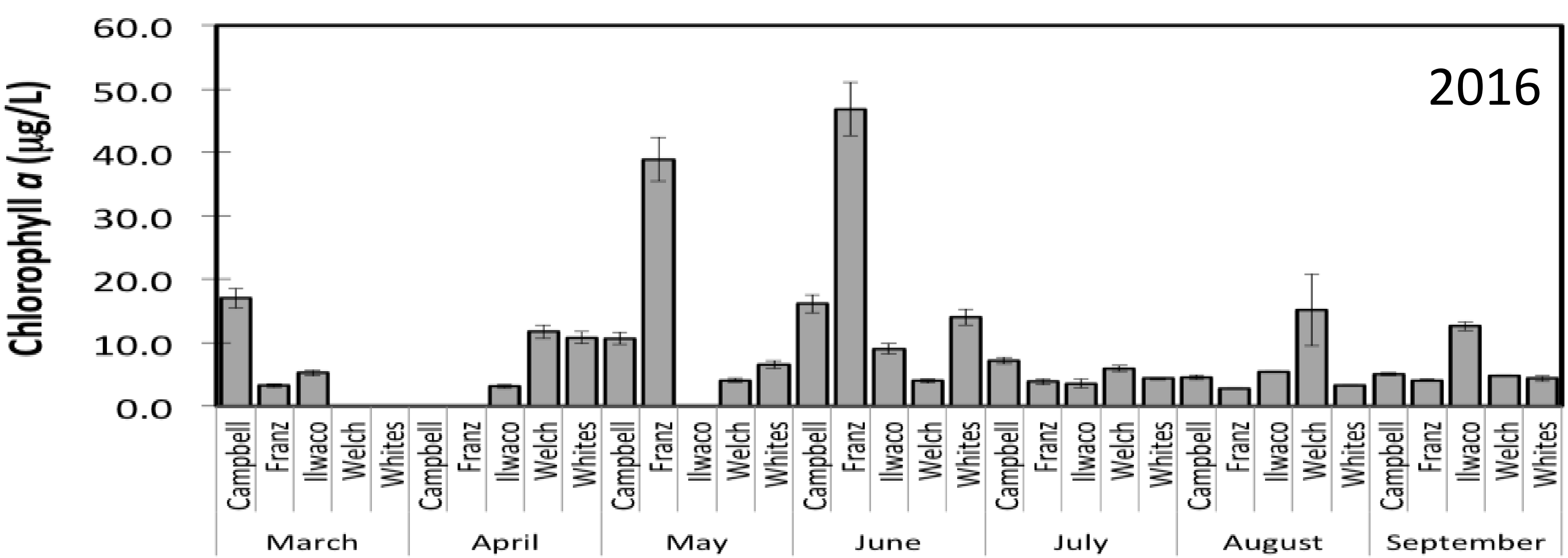
Maier, 2014

Peaks in total phytoplankton biomass tend to be highest at Campbell Slough and Franz Lake Slough

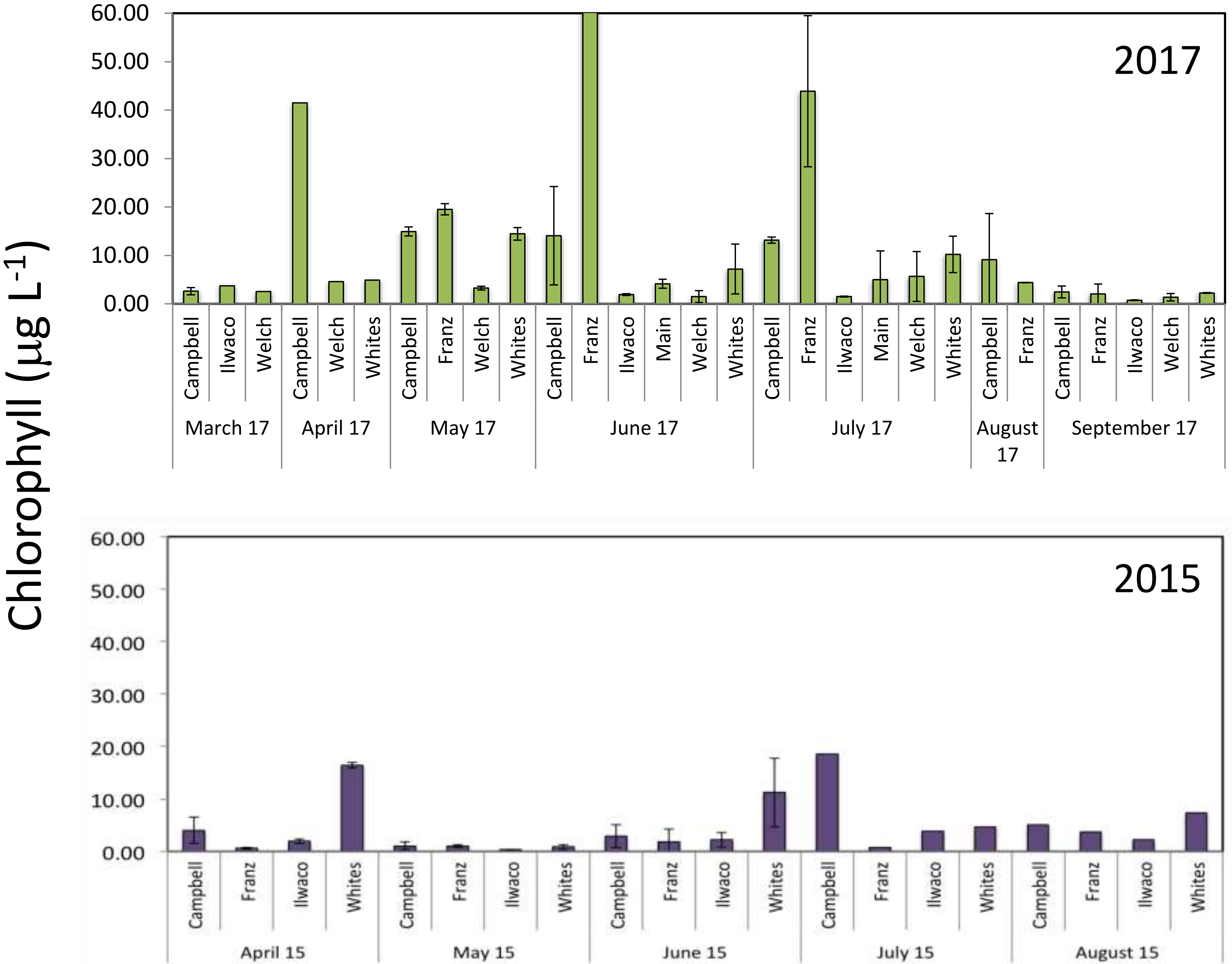




2017
60.00
50.00
40.00
30.00
20.00
10.00
0.00
Campbell
Ilwaco
Welch
Campbell
Welch
Whites
Campbell
Franz
Welch
Whites
Campbell
Franz
Ilwaco
Main
Welch
Whites
Campbell
Franz
Ilwaco
Main
Welch
Whites
Campbell
Franz
Campbell
Franz
Ilwaco
Welch
Whites
March 17
April 17
May 17
June 17
July 17
August 17
September 17



2016
Chlorophyll *a* (µg/L)
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Campbell
Franz
Ilwaco
Welch
Whites
March
April
May
June
July
August
September



Chlorophyll (μg L-1)
2017
60.00
50.00
40.00
30.00
20.00
10.00
0.00
Campbell
Ilwaco
Welch
Campbell
Welch
Whites
Campbell
Franz
Welch
Whites
Campbell
Franz
Ilwaco
Main
Welch
Whites
Campbell
Franz
Ilwaco
Main
Welch
Whites
Campbell
Franz
Campbell
Franz
Ilwaco
Welch
Whites
March 17
April 17
May 17
June 17
July 17
August 17
September 17
2015
60.00
50.00
40.00
30.00
20.00
10.00
0.00
Campbell
Franz
Ilwaco
Whites
Campbell
Franz
Ilwaco
Whites
Campbell
Franz
Ilwaco
Whites
Campbell
Franz
Ilwaco
Whites
Campbell
Franz
Ilwaco
Whites
April 15
May 15
June 15
July 15
August 15

Chlorophyll: an indictor of water quality

- <0.015 mg/L = the level at which phytoplankton may impair the recognized beneficial uses of rivers and estuaries; must not exceed in at least 3 samples over 3 consecutive months (1)
- West of the Willamette Valley, 2.53 μg/L (2)
- East of the Willamette Valley, 1.01 μg/L (2)
- Willamette Valley, 1.83 μg/L (2)

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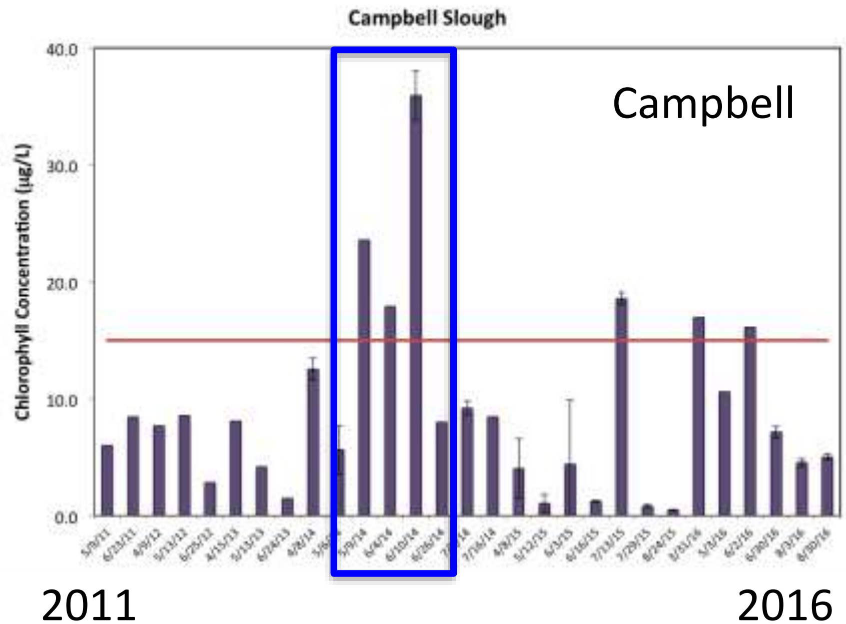
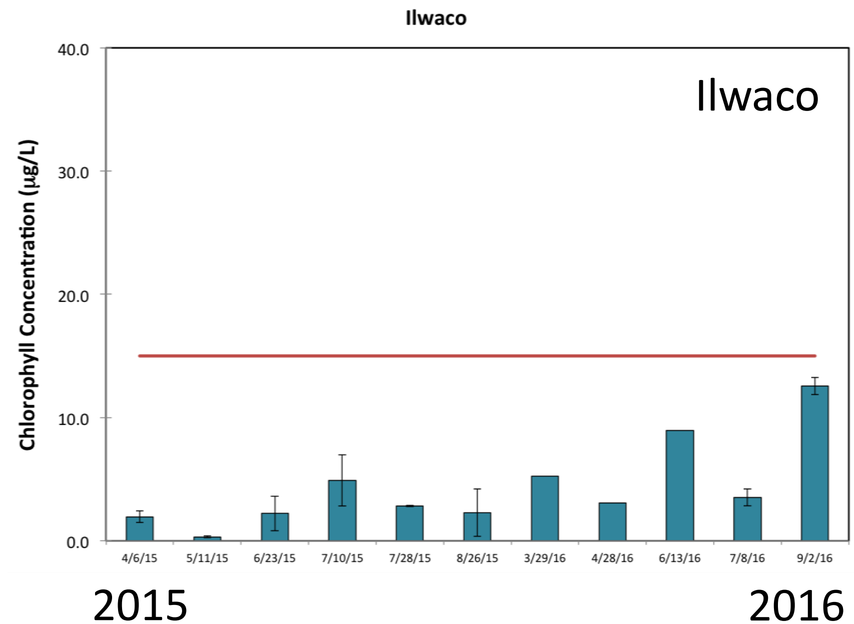
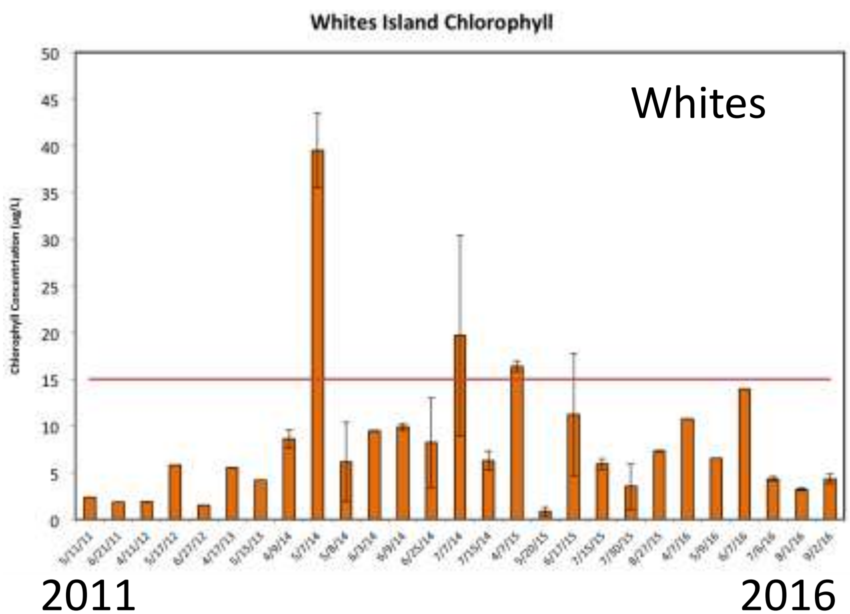
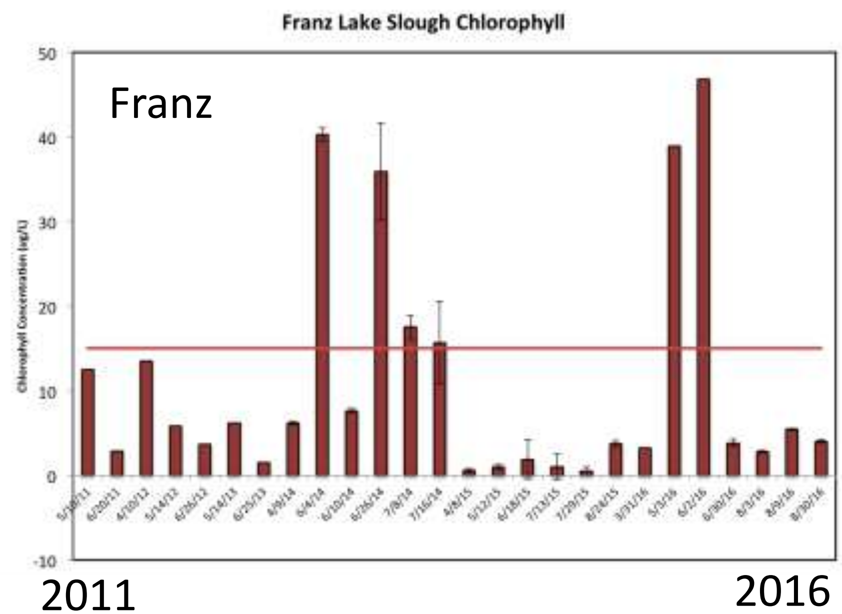
(1) Oregon State Water Quality Standards

(2) EPA proposed reference conditions for Aggregate Nutrient Ecoregions


Campbell Slough
Campbell
Chlorophyll Concentration (µg/L)
40.0
30.0
20.0
10.0
0.0
2011
2016


Ilwaco
Ilwaco
Chlorophyll Concentration (µg/L)
40.0
30.0
20.0
10.0
0.0
4/6/15
5/11/15
6/23/15
7/10/15
7/28/15
8/26/15
3/29/16
4/28/16
6/13/16
7/8/16
9/2/16
2015
2016


Whites Island Chlorophyll
Whites
50
45
40
35
30
25
20
15
10
5
0
2011
2016


Franz Lake Slough Chlorophyll
Franz
50
40
30
20
10
0
-10
2011
2016

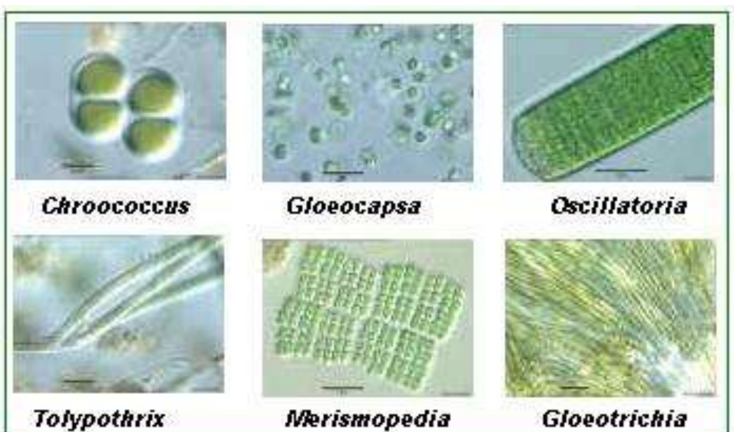
DIATOMS

http://www.daviddarling.info

Diatoms

- High polyunsaturated fatty acids
- High nutritional quality
- Dominate spring blooms
- Thrive under moderate to high turbulence

CYANOBACTERIA

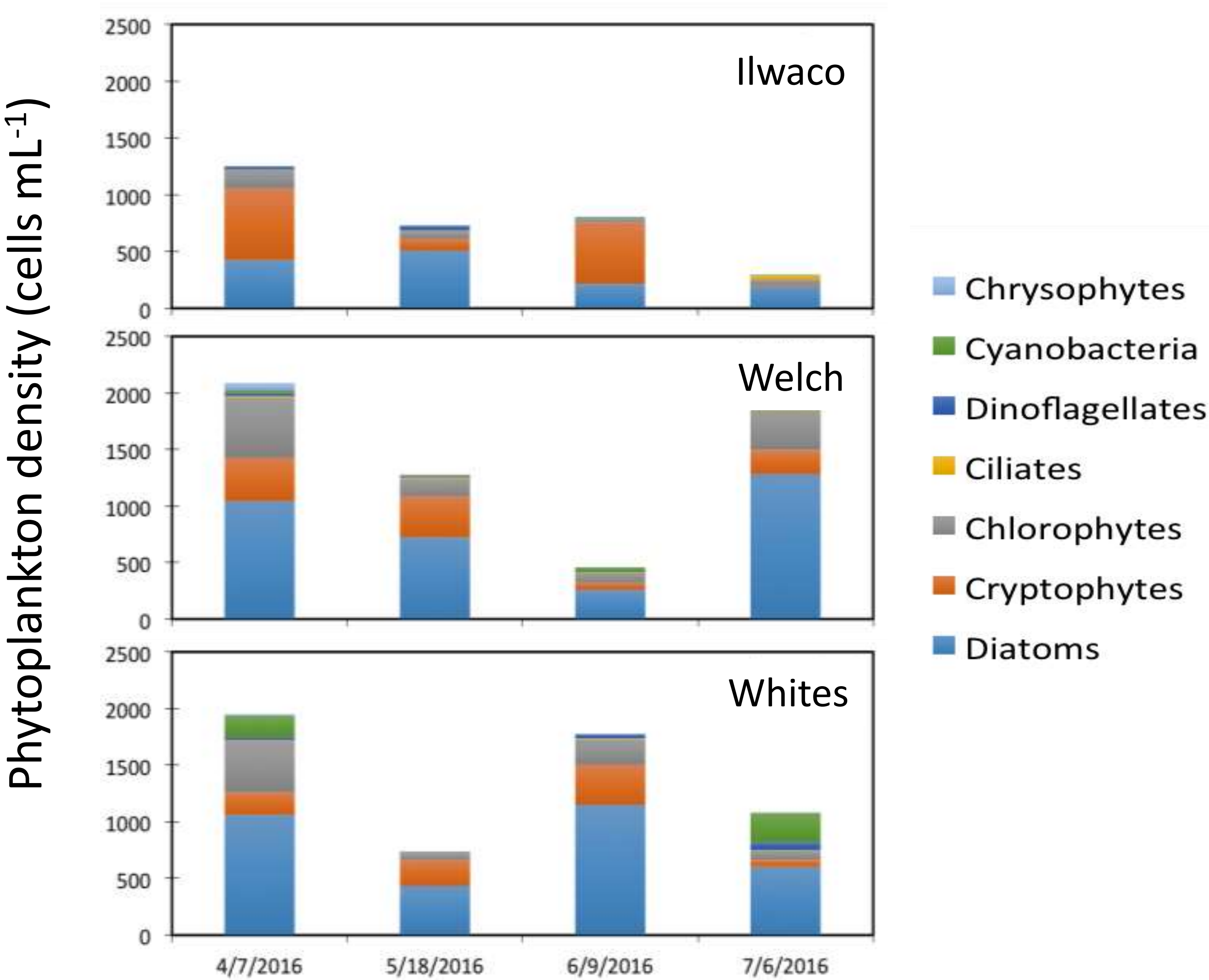


http://www.tutorvista.com

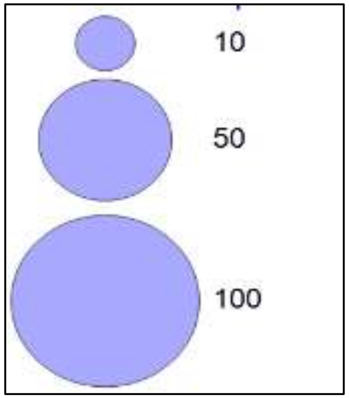
CHLOROPHYTES

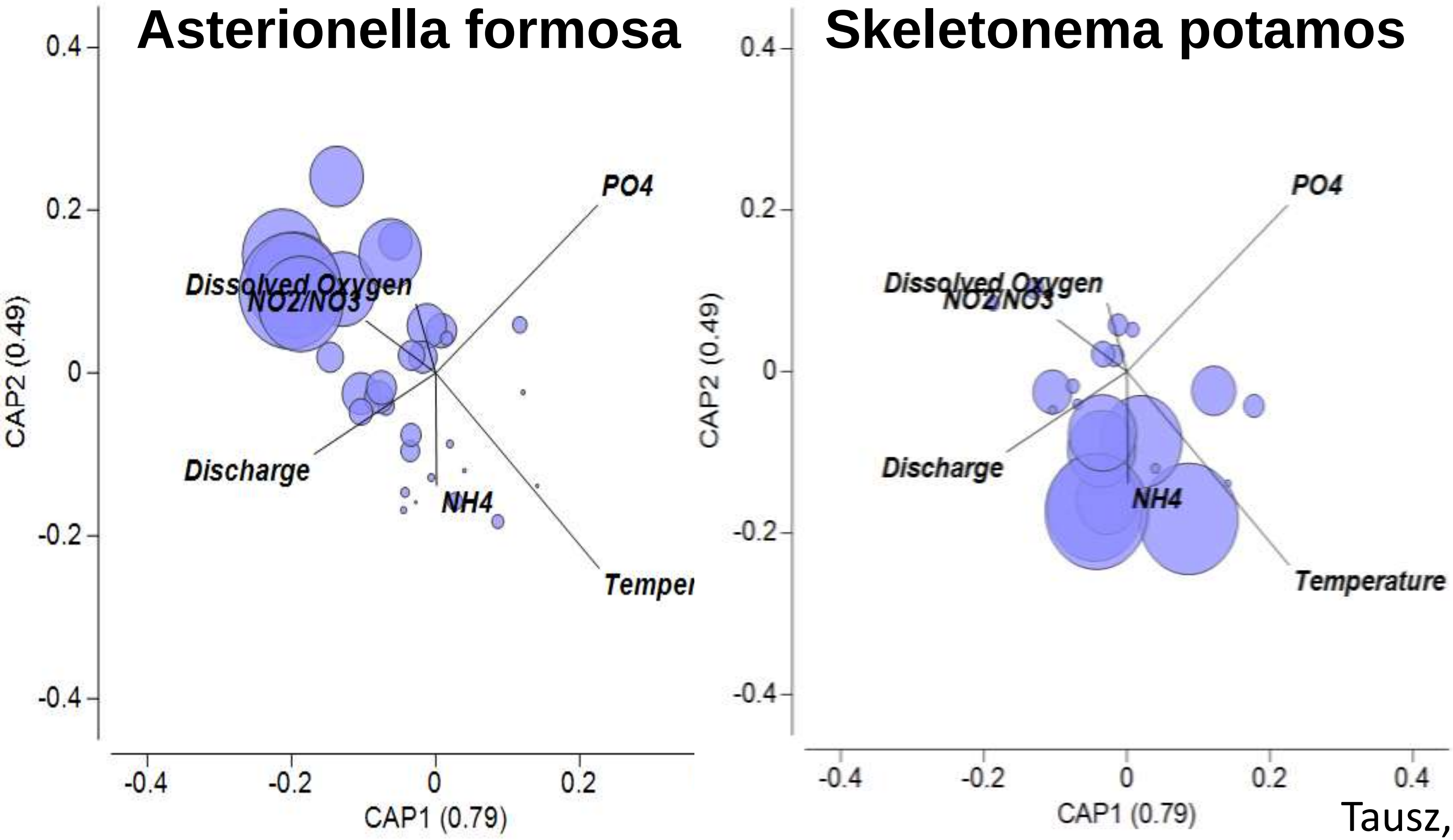
Mark Lane, slideplayer.com

Diatoms dominate at Welch and Whites



Different taxa are associated with different environmental conditions

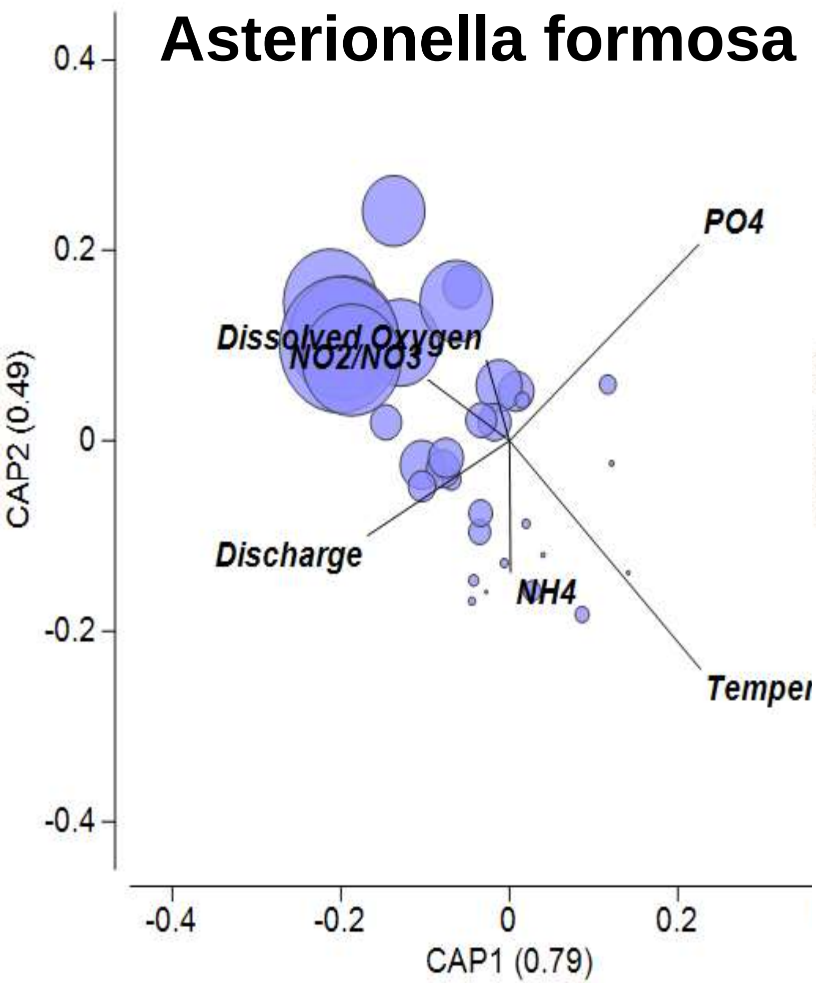


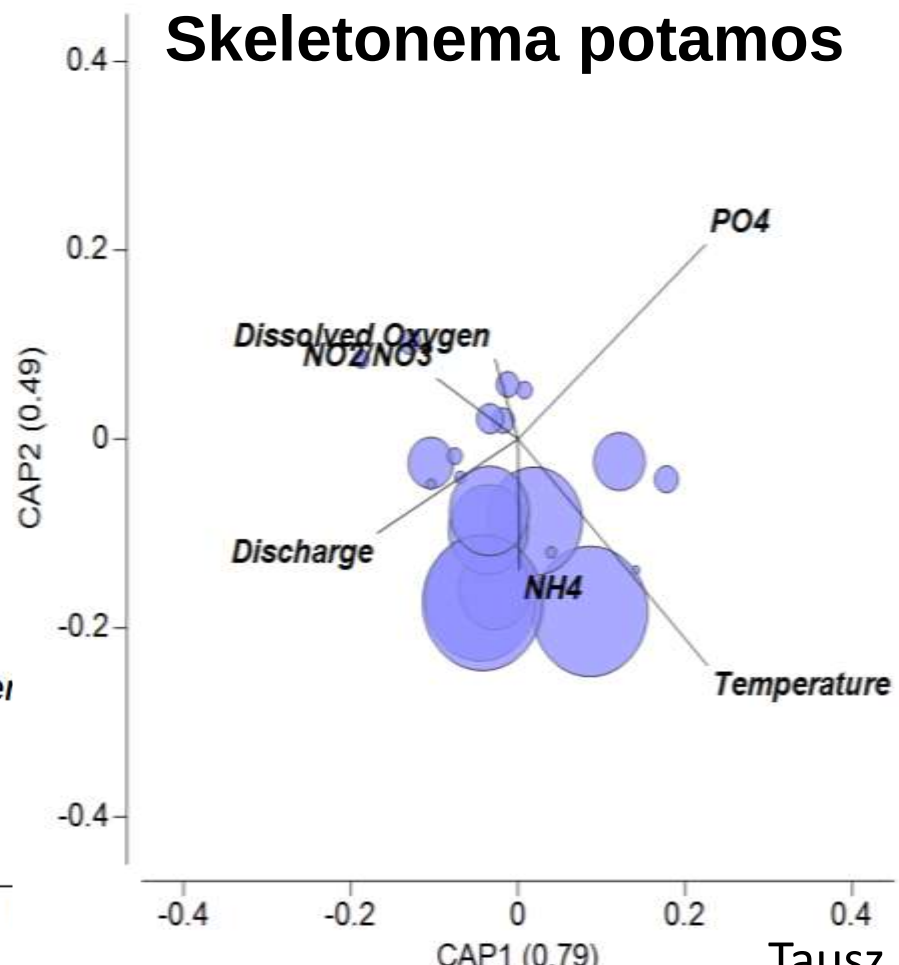


Tausz, 2015

Spring-type

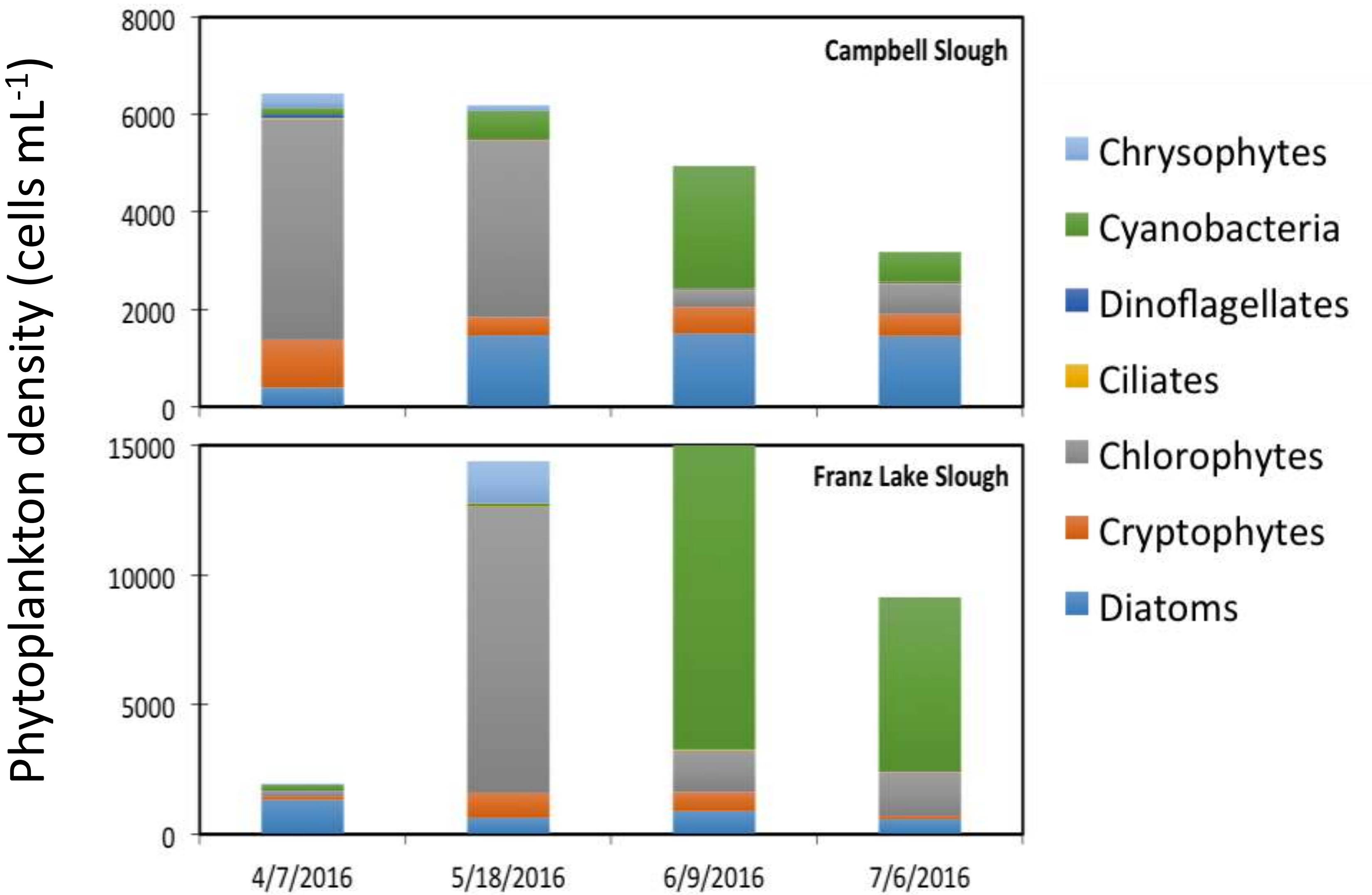
Summer-type





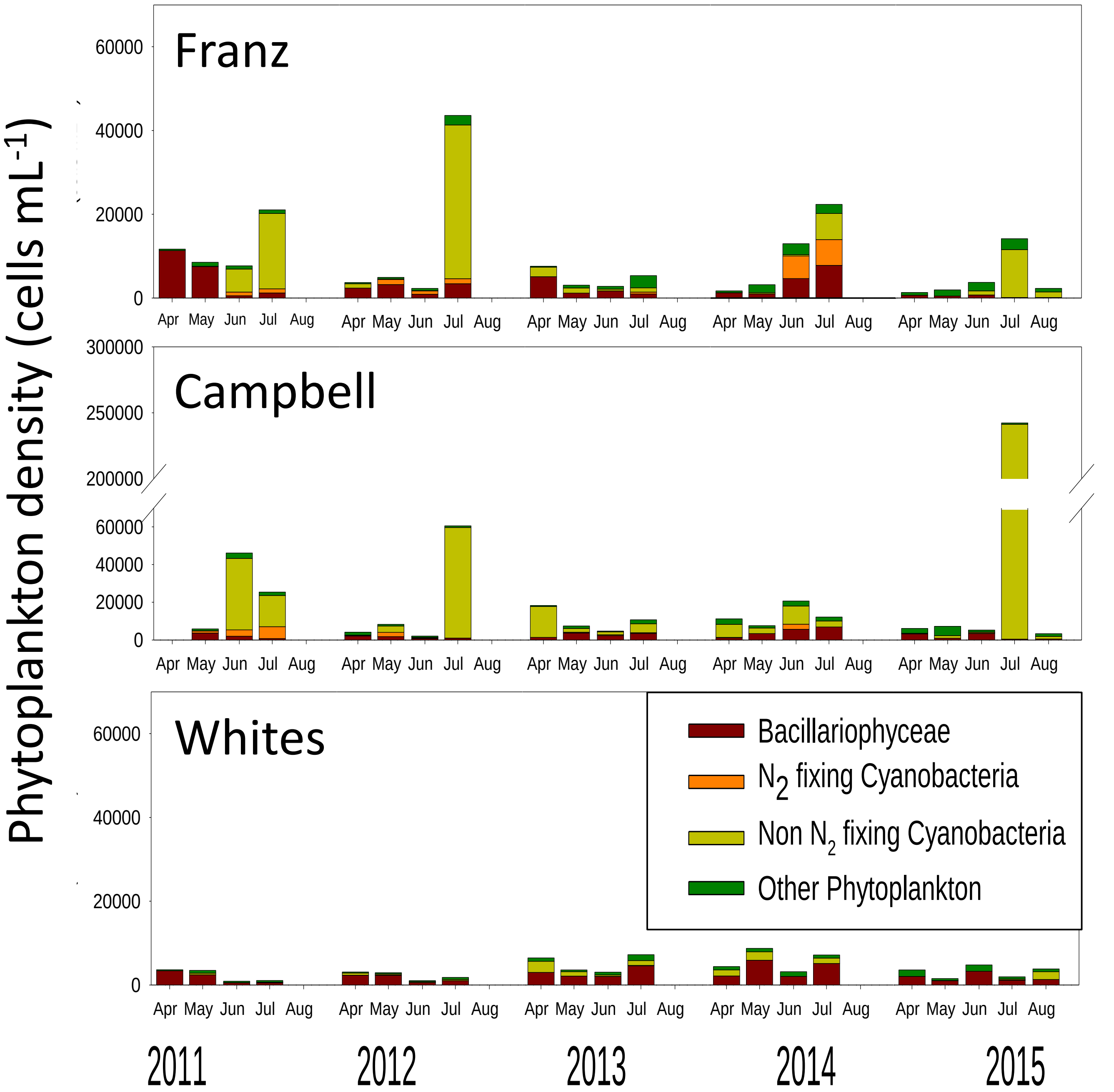
Tausz, 2015

Chlorophytes and cyanobacteria dominate at Campbell and Franz



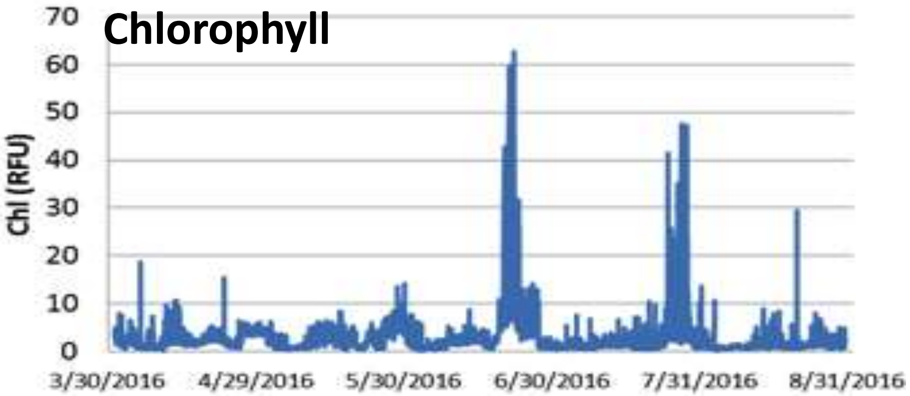
2011-2015:
More flagellate and cyanobacteria at Campbell and Franz

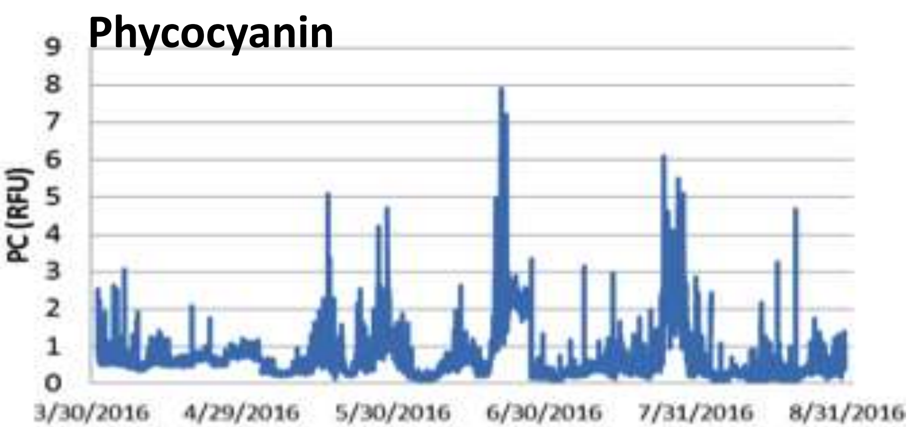
Concentrations are more variable



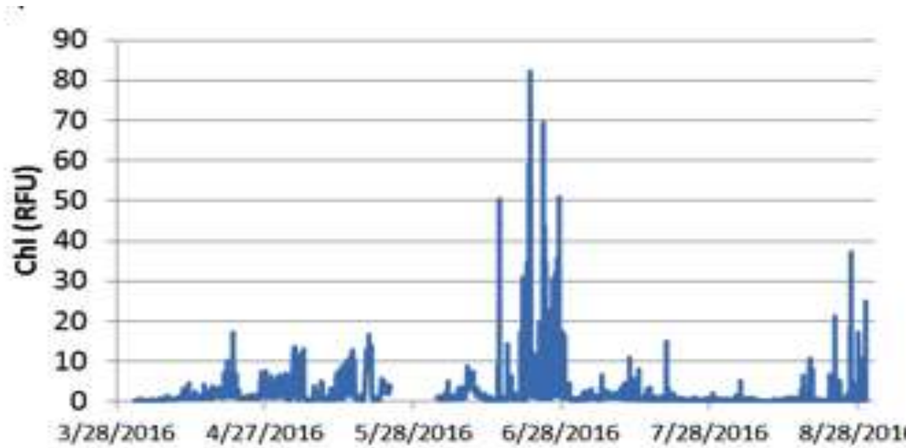
High resolution data show peaks in cyanobacteria pigments at Campbell and Franz

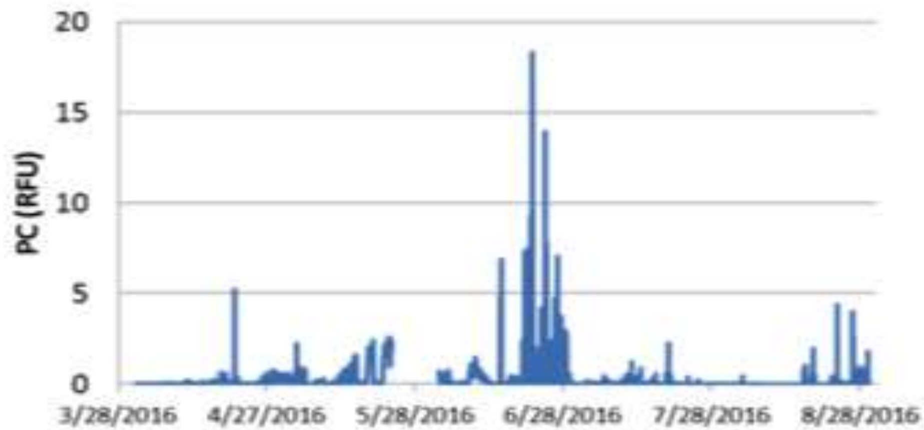
Campbell Slough (2016)



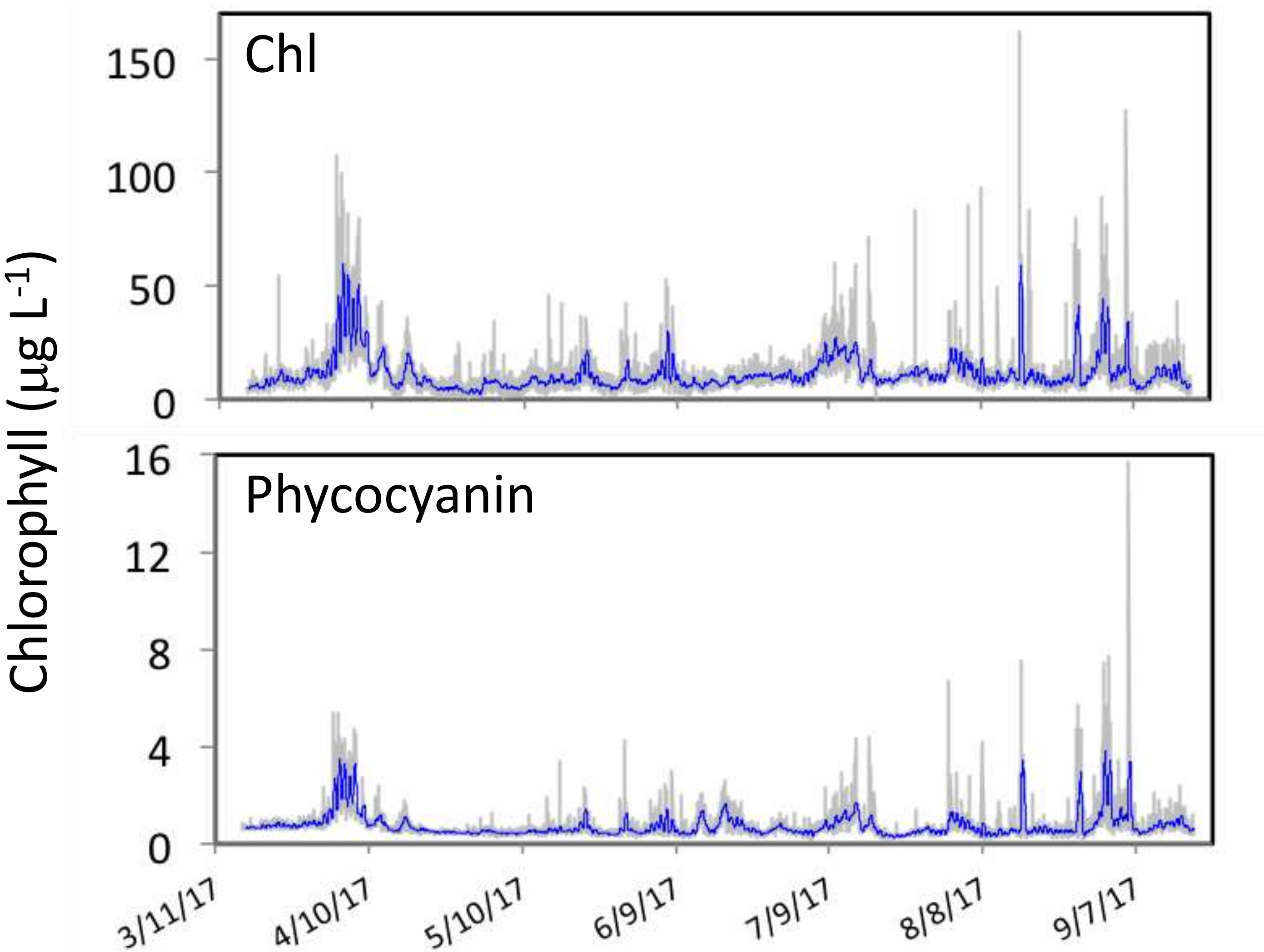


Franz Lake Slough (2016)



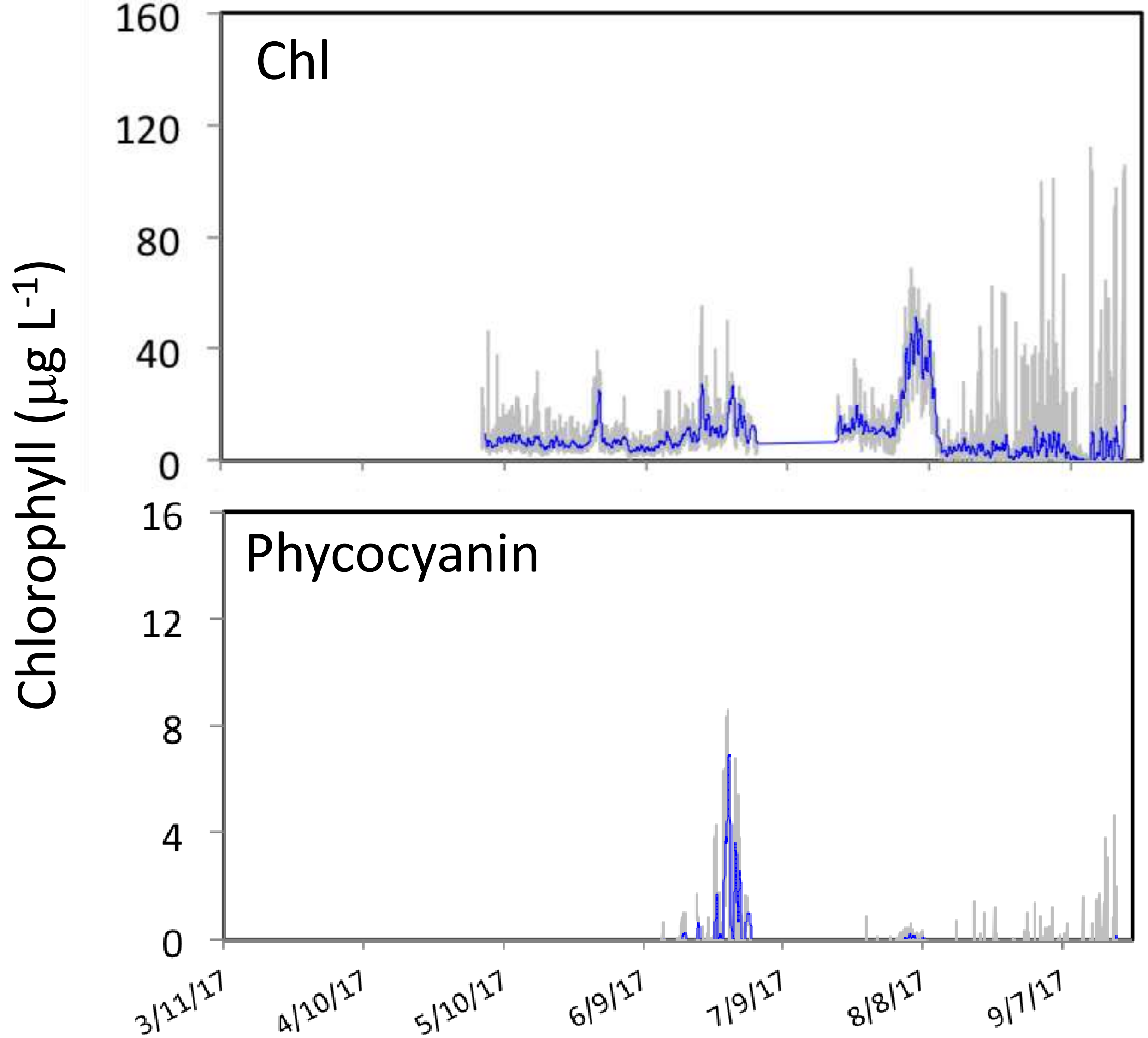


Campbell Slough, 2017



Grey: hourly data ● *Blue*: 25 h moving average

Franz Lake Slough, 2017



Grey: hourly data ● *Blue*: 25 h moving average

Observations

- Site differences
  - **Whites Island**: similar to mainstem
  - **Campbell and Franz**: different from mainstem when connectivity is low (summer, drought)
- *Asterionella* (spring) → *Skeletonema* (summer)
  - Similar to mainstem
  - Lower connectivity = differences in diatoms emerge among sites (e.g., small *Nitzschia* sp. seen in high abundance at Franz in 2015)
- Cyanobacteria (*Microcystis* sp.) dominant in summer at Campbell Slough and Franz Lake Slough

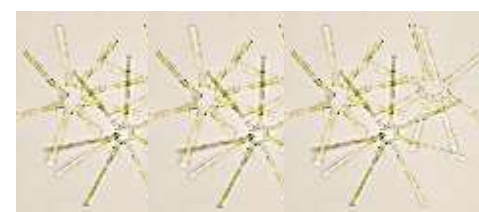
Significance

- Phytoplankton groups differ in their food quality (e.g., diatoms > chlorophytes > cyanobacteria)
  - $\Sigma_{flagellates}:\Sigma_{total}$ phytoplankton nutritional quality/water quality index
- Phytoplankton influence water quality: dissolved oxygen, pH
- Some species produce toxins

Identifying sources of organic matter supporting salmon using stable isotopes

Invertebrates

Lyn Topinka, 2007



Vascular plants

Aquatic, terrestrial

Freshwater & marine

Phytoplankton & macroalgae

Fluvial, benthic

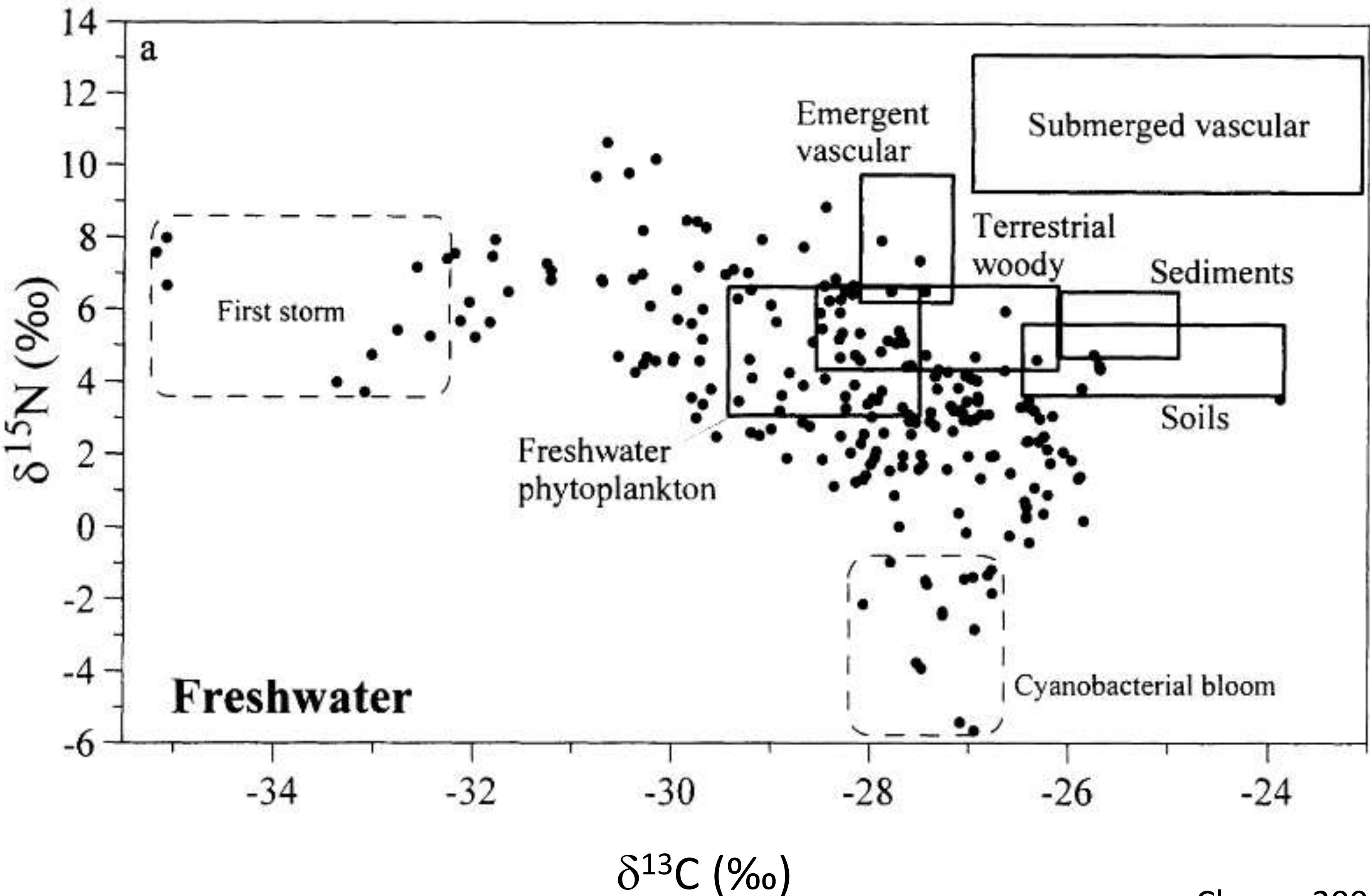
Freshwater & marine

Salmon diet: sampling methods

Samples: Juvenile Chinook salmon muscle and liver

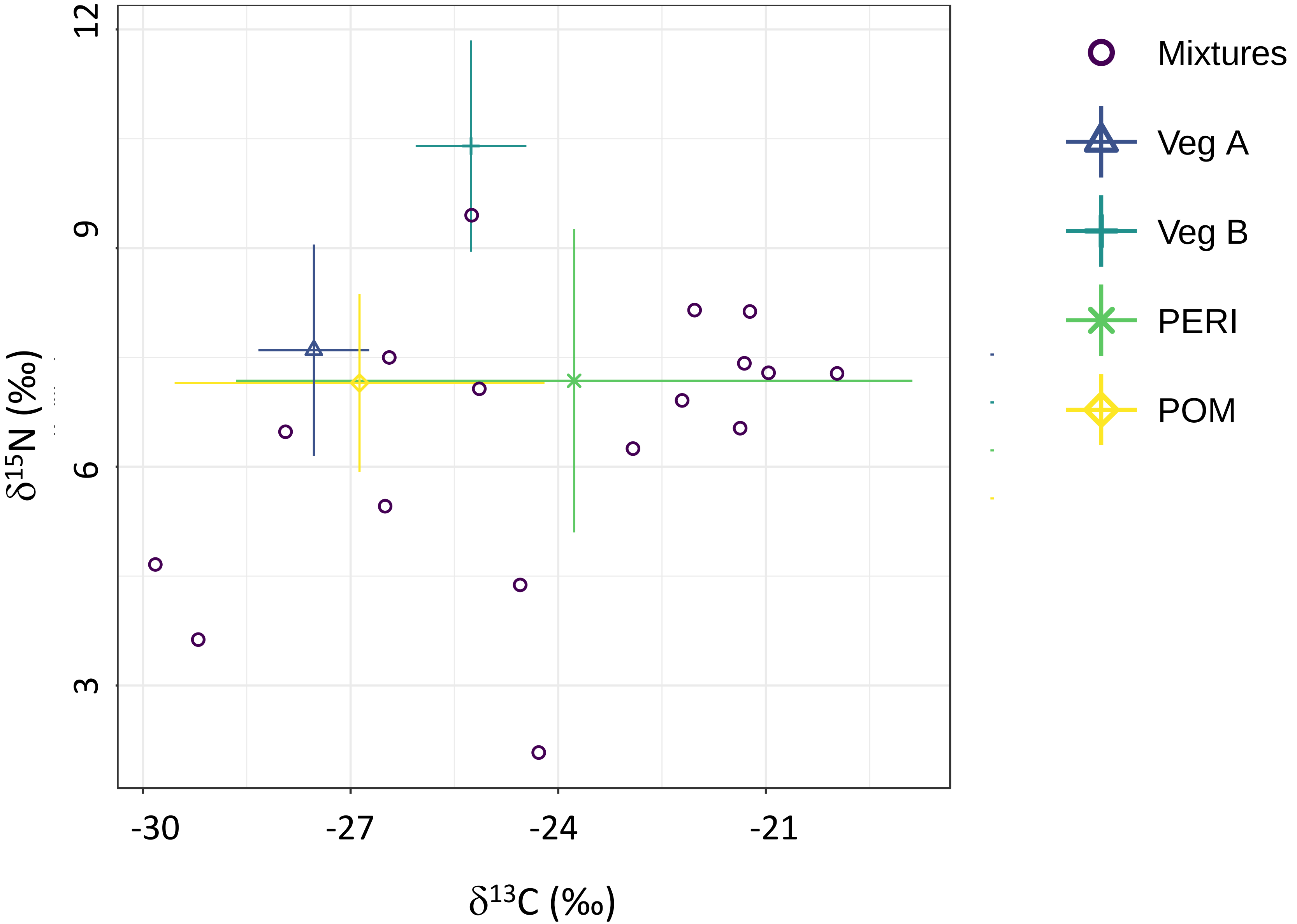
- April – August
- Franz, Campbell, Whites, Welch, Ilwaco
- Food sources: invertebrates (amphipods, chironomids, nematodes, polychaetes, oligochaetes, copepods, cladocerans, etc.)
- Primary producers (live & dead vegetation, periphyton, particulate organic matter)

- $\delta^{13}C = R_{sample} - R_{standard} / R_{standard} \times 1000$ (units = ‰)


a
Submerged vascular
Emergent vascular
Terrestrial woody
Sediments
Soils
First storm
Freshwater phytoplankton
Cyanobacterial bloom
Freshwater
$\delta^{15}N$ (‰)
$\delta^{13}C$ (‰)
14
12
10
8
6
4
2
0
-2
-4
-6
-34
-32
-30
-28
-26
-24

Cloern, 2002

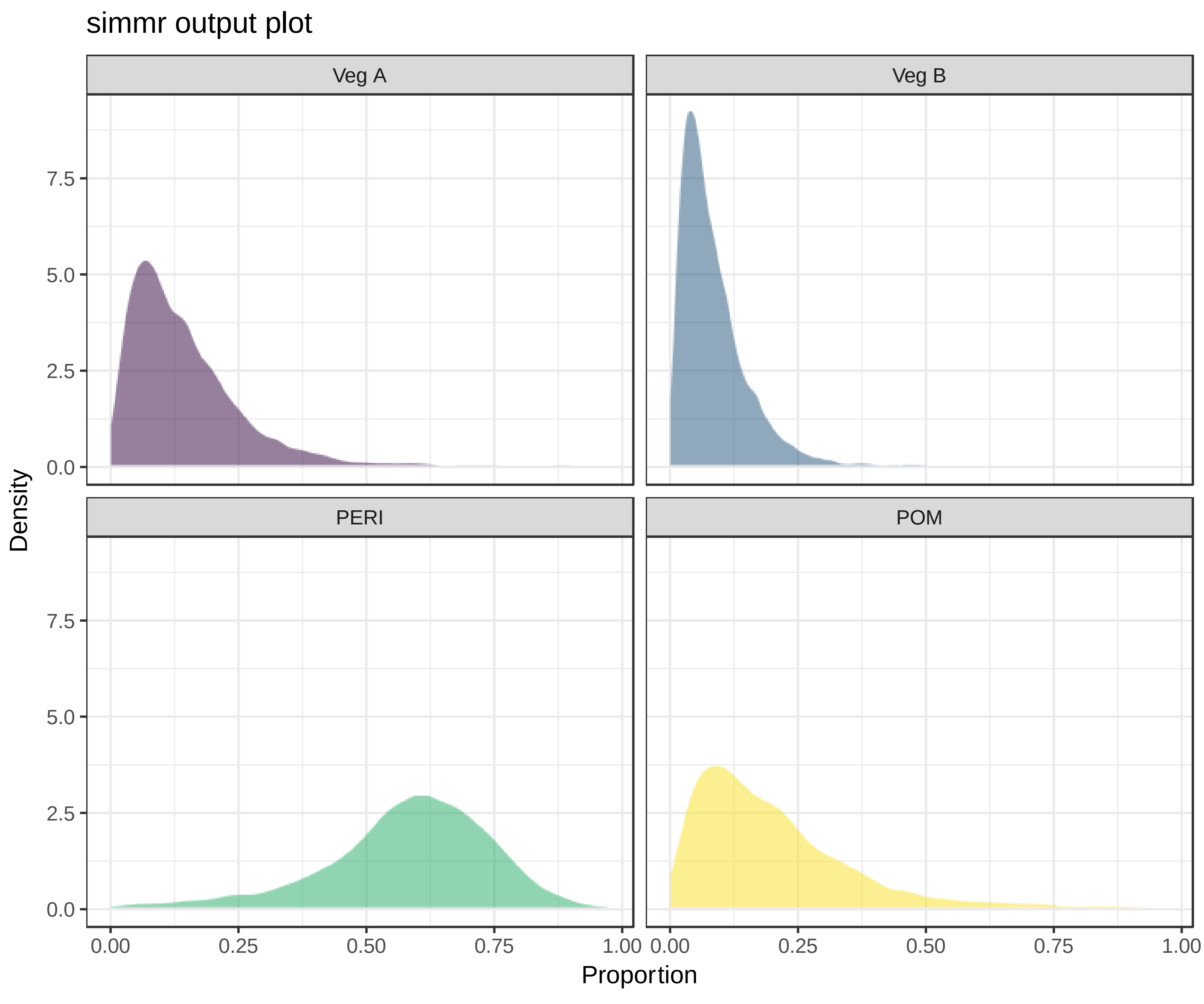
What source of primary production make up the diet of chironomids?



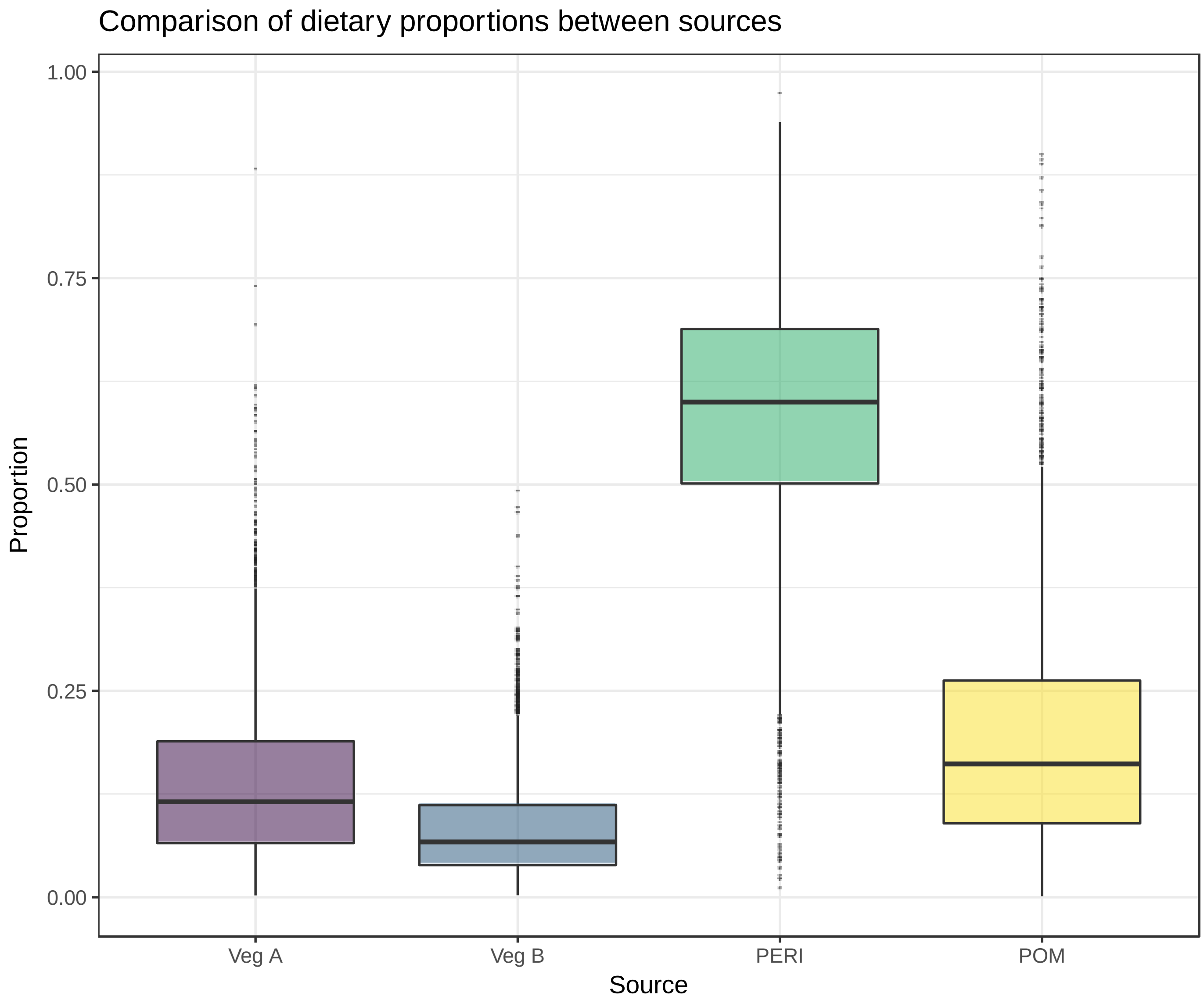
Methods

- A variety of Isotope mixing models try to predict who is eating what, when
- Bayesian mixing model: Simmr
- Sample several sources to determine $^{13}C/^{12}C$ and $^{15}N/^{14}N$ ratios and make a series of iterative "best guesses" about how a consumer is composed of combinations of sources

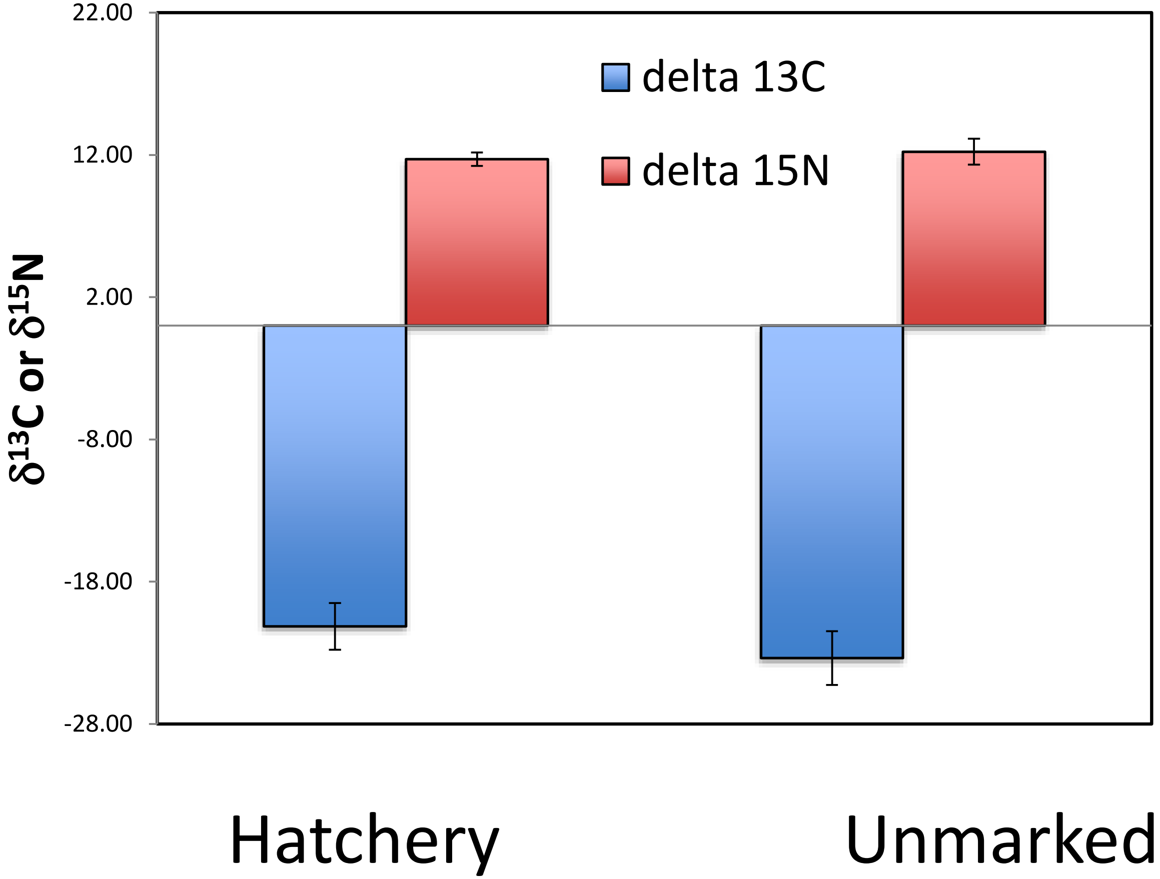
Dietary proportions of 4 sources supporting chironomids



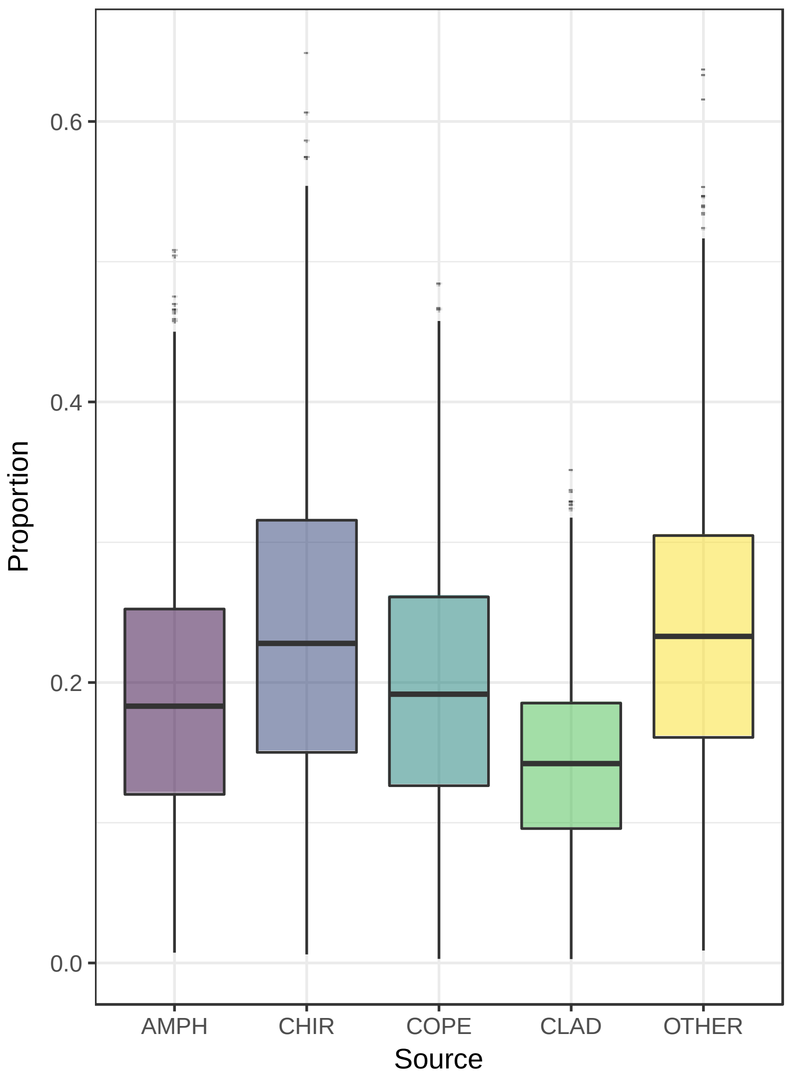
Dietary proportions of 4 food sources supporting chironomids

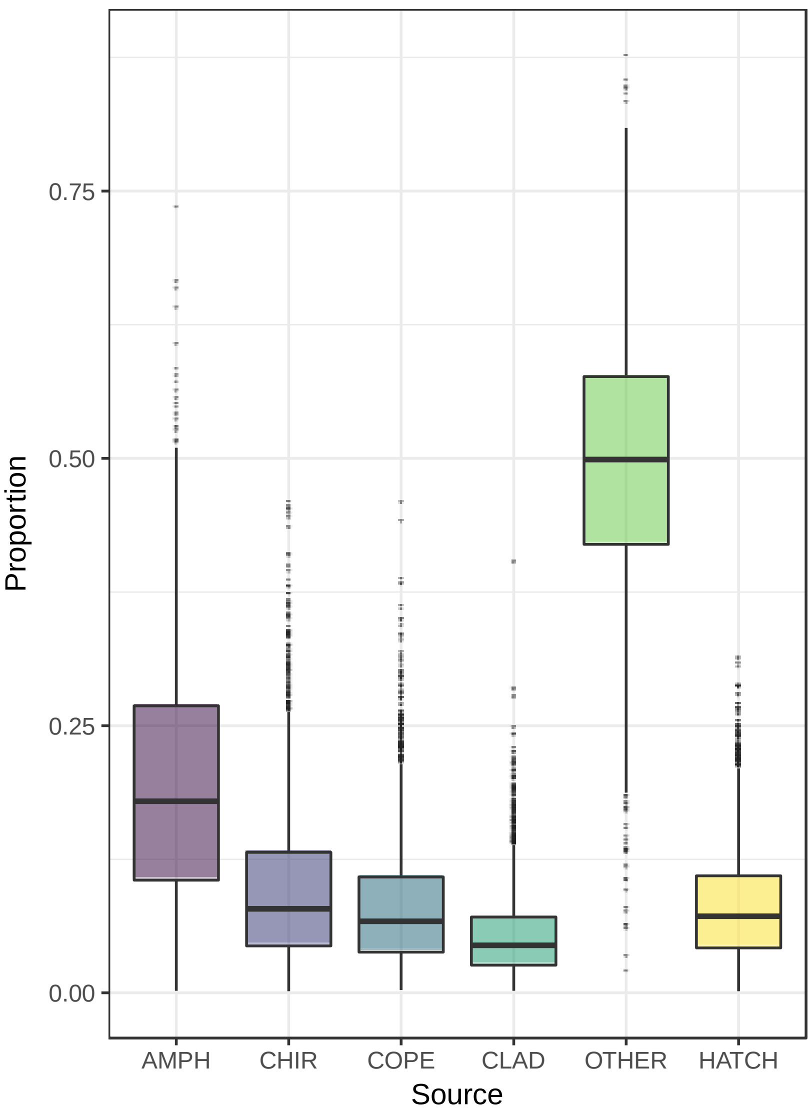


Average isotopic signatures of Juvenile Chinook salmon muscle



UNMARKED vs. HATCHERY fish: comparison of dietary proportions of different food sources





Fish use of estuarine resources: Insights from stable isotopes

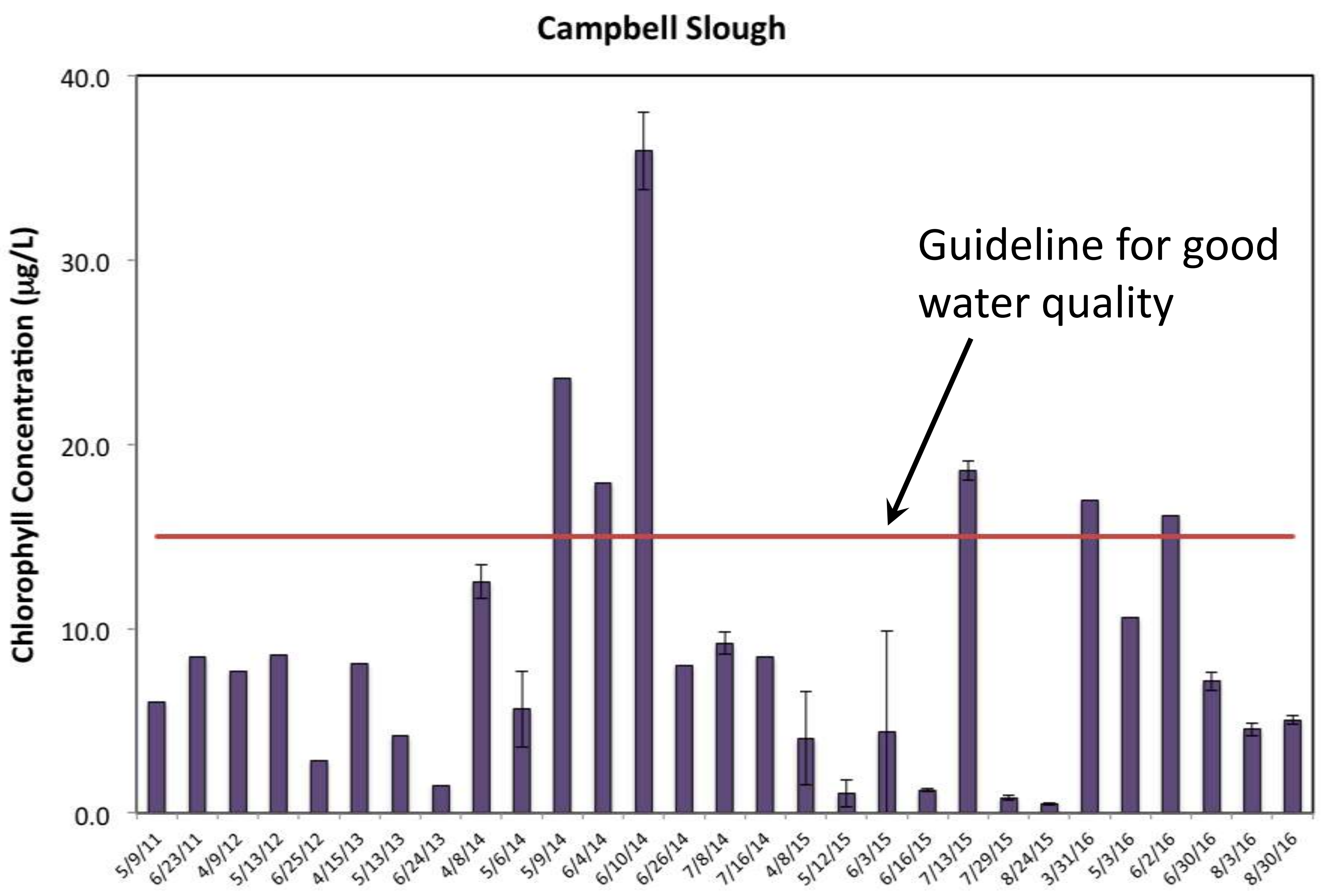
- Hatchery fish are heavier with respect to carbon, but lighter with respect to nitrogen than unmarked fish
- Summer source values were heavier than spring
- There were only small differences between living and dead plant matter
- Livers were lighter in C and N compared to muscle (data not shown here)

Conclusions

- 2017 had high primary production
- Chlorophyll concentrations in some off-channel habitats are sometimes at or near the criteria for good water quality
- Dense cyanobacteria populations have appeared in Campbell and Franz Lake sloughs for at the least the past several years
- Unmarked juvenile salmon differ in their isotope signatures from marked hatchery fish
- Chironomids have isotope signatures suggesting they mainly consume organic matter heavier than vascular plants (periphyton, POM, and potentially benthic diatoms)

Ongoing work

- Separate isotope data spatially and temporally
- Compare liver and muscle tissues of fish to discern differences at varying time scales
- Explore source concentration effects and integrate with stomach contents data
- Ideally, integrate molecular approaches to trace prey consumption and assimilation patterns



Campbell Slough
Chlorophyll Concentration (µg/L)
40.0
30.0
20.0
10.0
0.0
Guideline for good water quality
5/9/11
6/23/11
4/9/12
5/13/12
6/25/12
4/15/13
5/13/13
6/24/13
4/8/14
5/6/14
5/9/14
6/4/14
6/10/14
6/26/14
7/8/14
7/16/14
4/8/15
5/12/15
6/3/15
6/16/15
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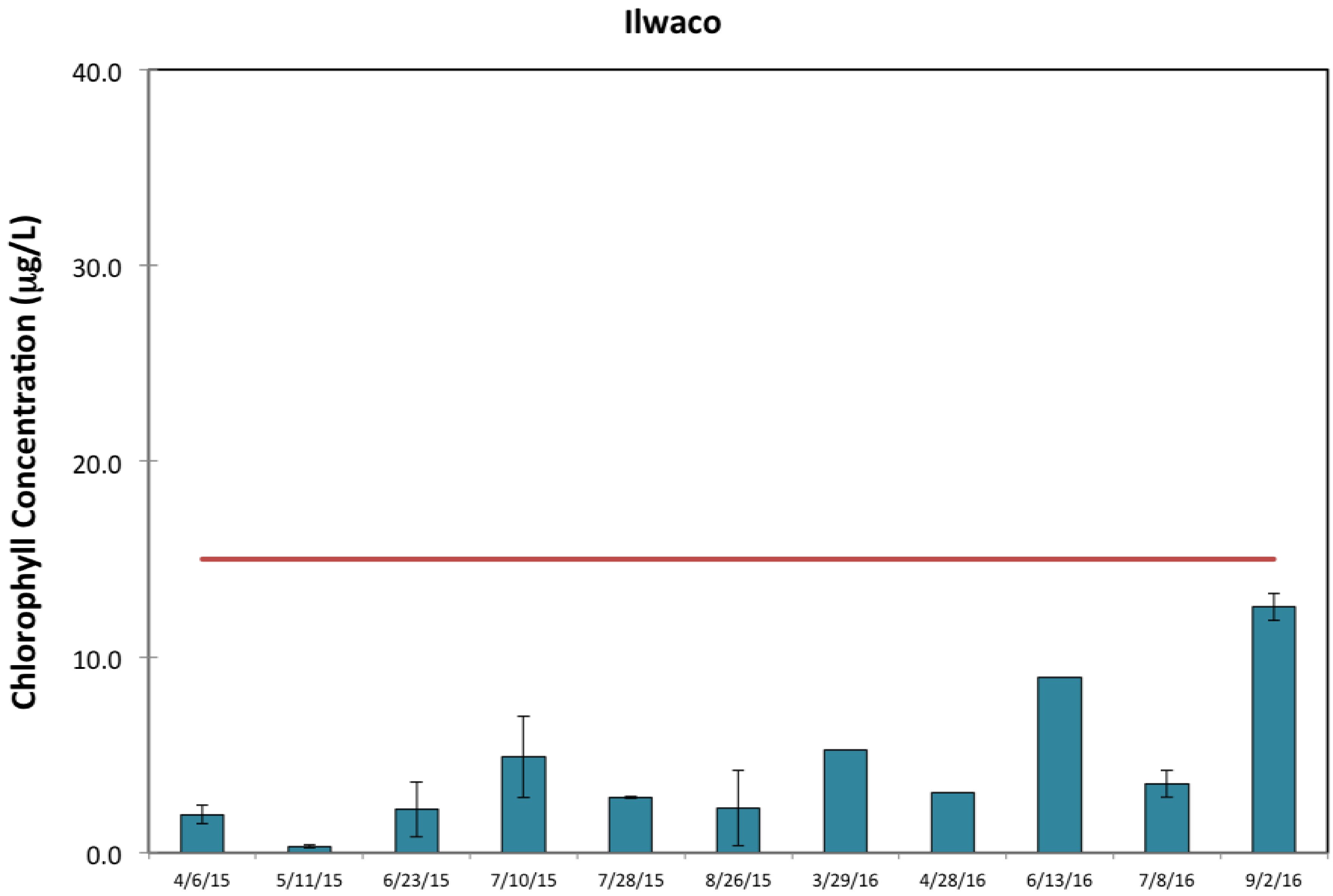
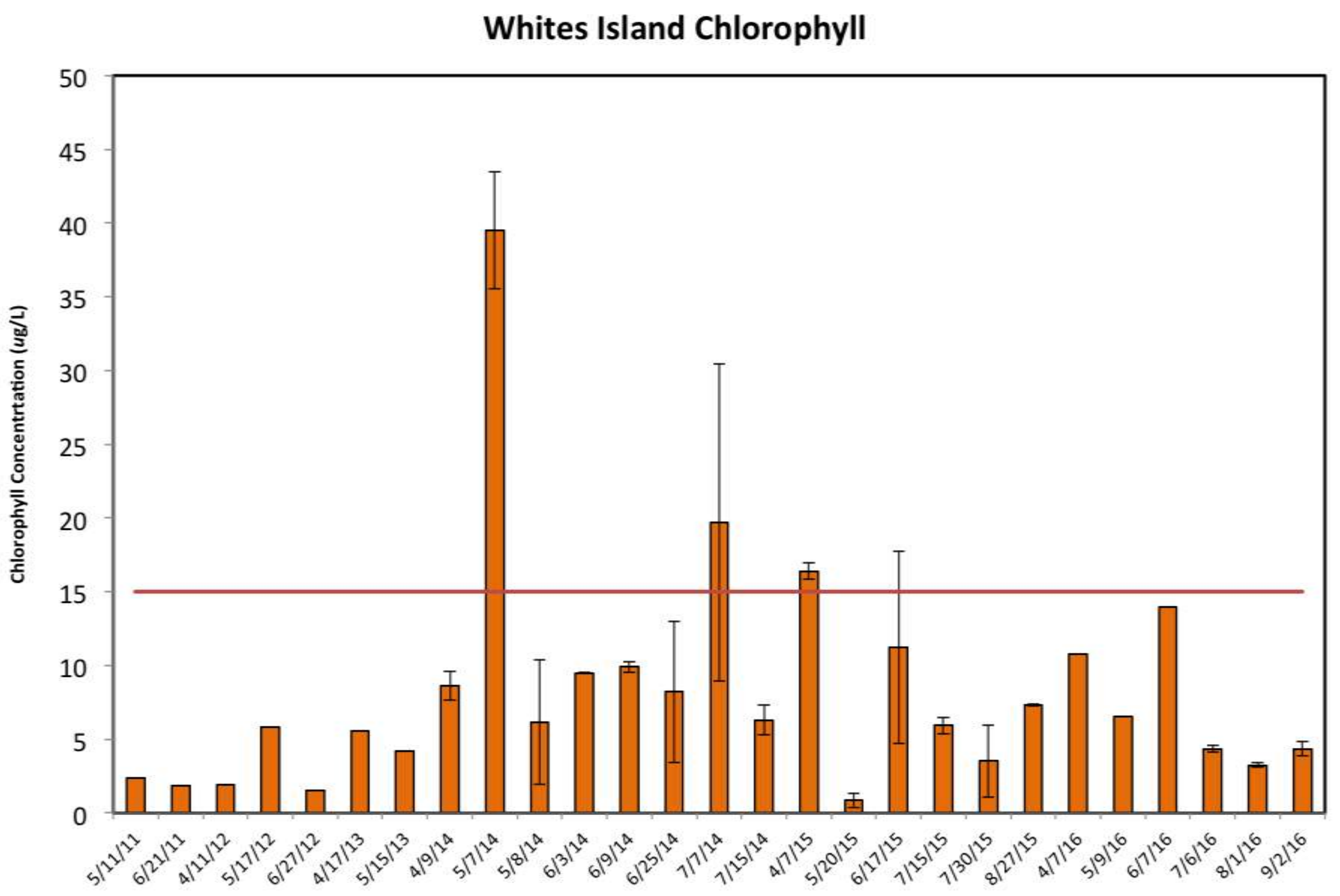
8/3/16
8/30/16



Ilwaco
Chlorophyll Concentration (µg/L)
40.0
30.0
20.0
10.0
0.0
4/6/15
5/11/15
6/23/15
7/10/15
7/28/15
8/26/15
3/29/16
4/28/16
6/13/16
7/8/16
9/2/16



Whites Island Chlorophyll
Chlorophyll Concentrtation (ug/L)
50
45
40
35
30
25
20
15
10
5
0
5/11/11
6/21/11
4/11/12
5/17/12
6/27/12
4/17/13
5/15/13
4/9/14
5/7/14
5/8/14
6/3/14
6/9/14
6/25/14
7/7/14
7/15/14
4/7/15
5/20/15
6/17/15
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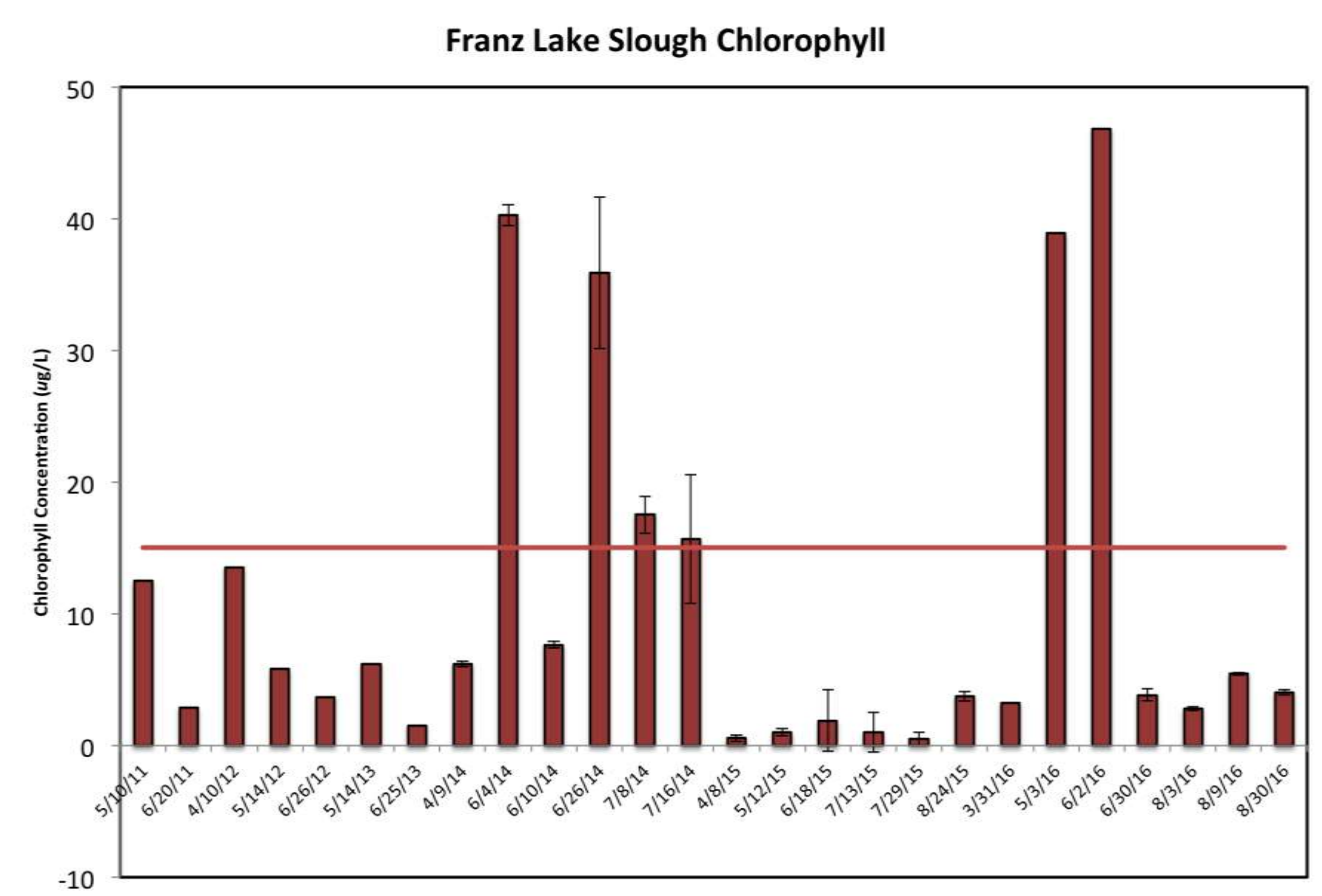
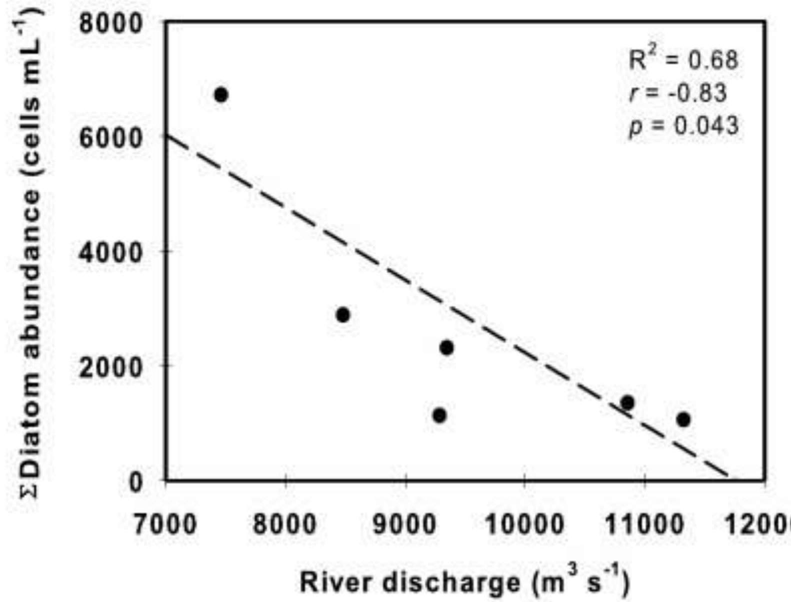
8/1/16
9/2/16

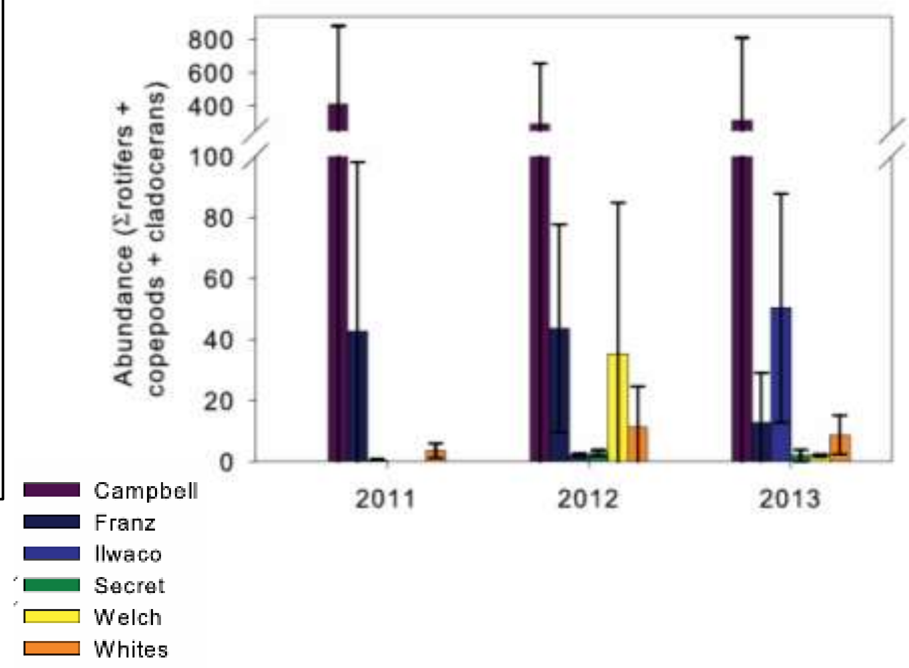


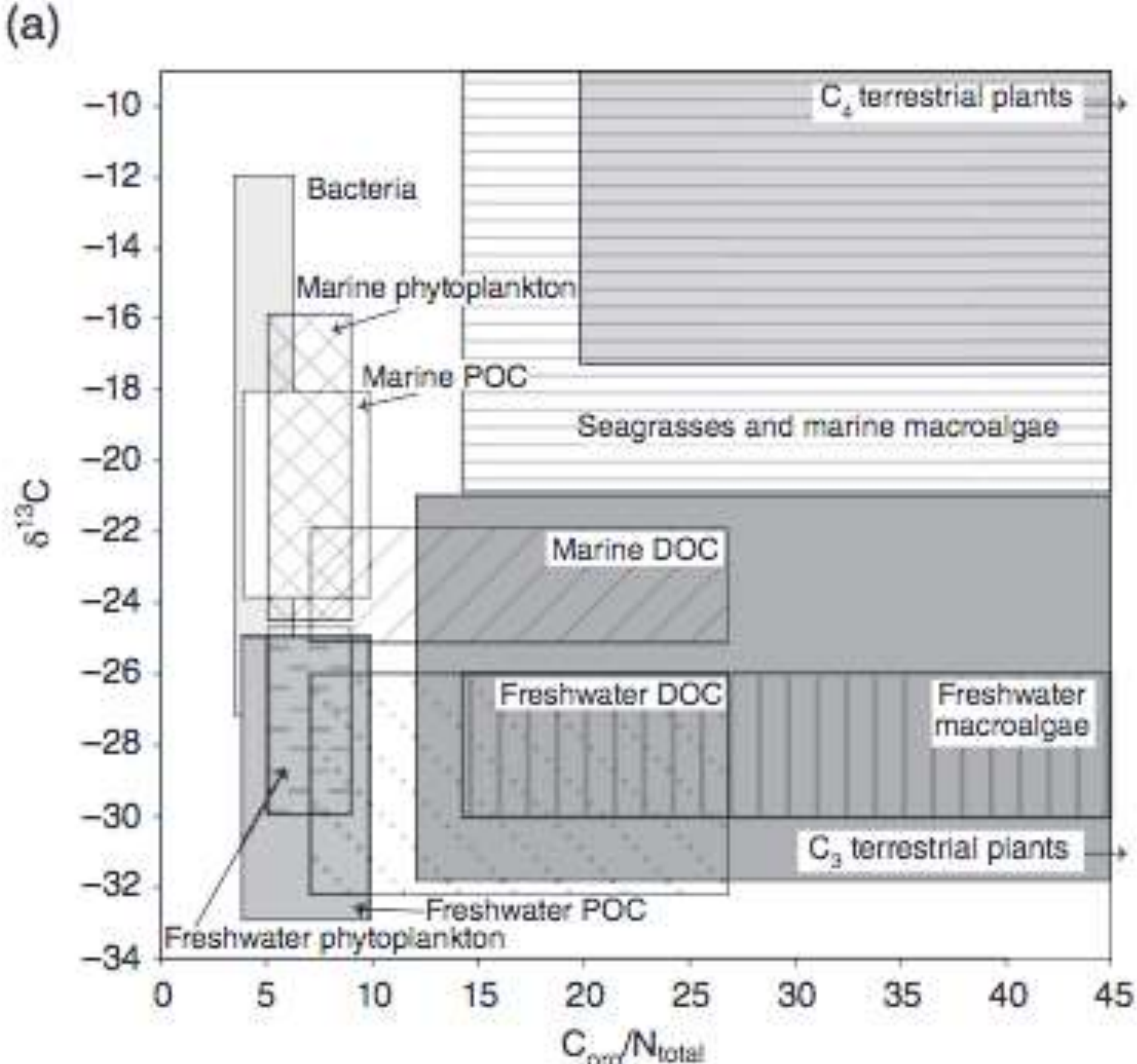
Franz Lake Slough Chlorophyll
Chlorophyll Concentration (ug/L)
50
40
30
20
10
0
-10
5/10/11
6/20/11
4/10/12
5/14/12
6/26/12
5/14/13
6/25/13
4/9/14
6/4/14
6/10/14
6/26/14
7/8/14
7/16/14
4/8/15
5/12/15
6/18/15
7/13/15
7/29/15
8/24/15
3/31/16
5/3/16
6/2/16
6/30/16
8/3/16
8/9/16
8/30/16

Trends in plankton abundance

- Phytoplankton abundance
  - inversely correlated with river discharge;
  - Diatoms ~10% higher in shallow water habitats compared to mainstem;
  - abundances can be higher in areas of longer retention than well-flushed areas
- Zooplankton abundance
  - highest at Campbell Slough







Khan et al., 2015