2019 Ecosystem Monitoring Program

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i. The lower food web: Algal biomass patterns in off-channel habitats of the lower Columbia River

2019 Ecosystem Monitoring Program

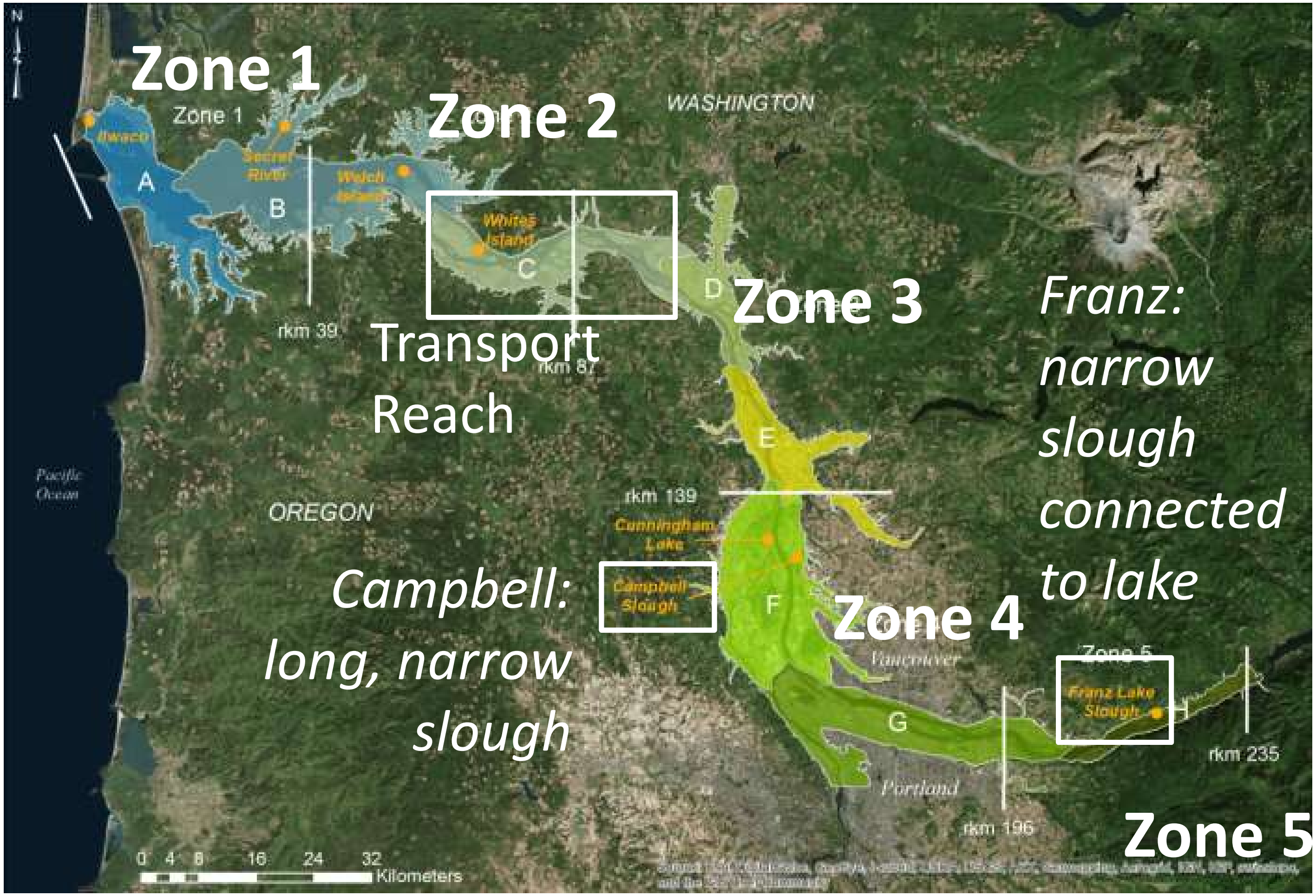
ii. Investigating diet of juvenile Chinook salmon using stable isotopes of carbon and nitrogen

Phytoplankton constitute an important component of off-channel habitats

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

Focus

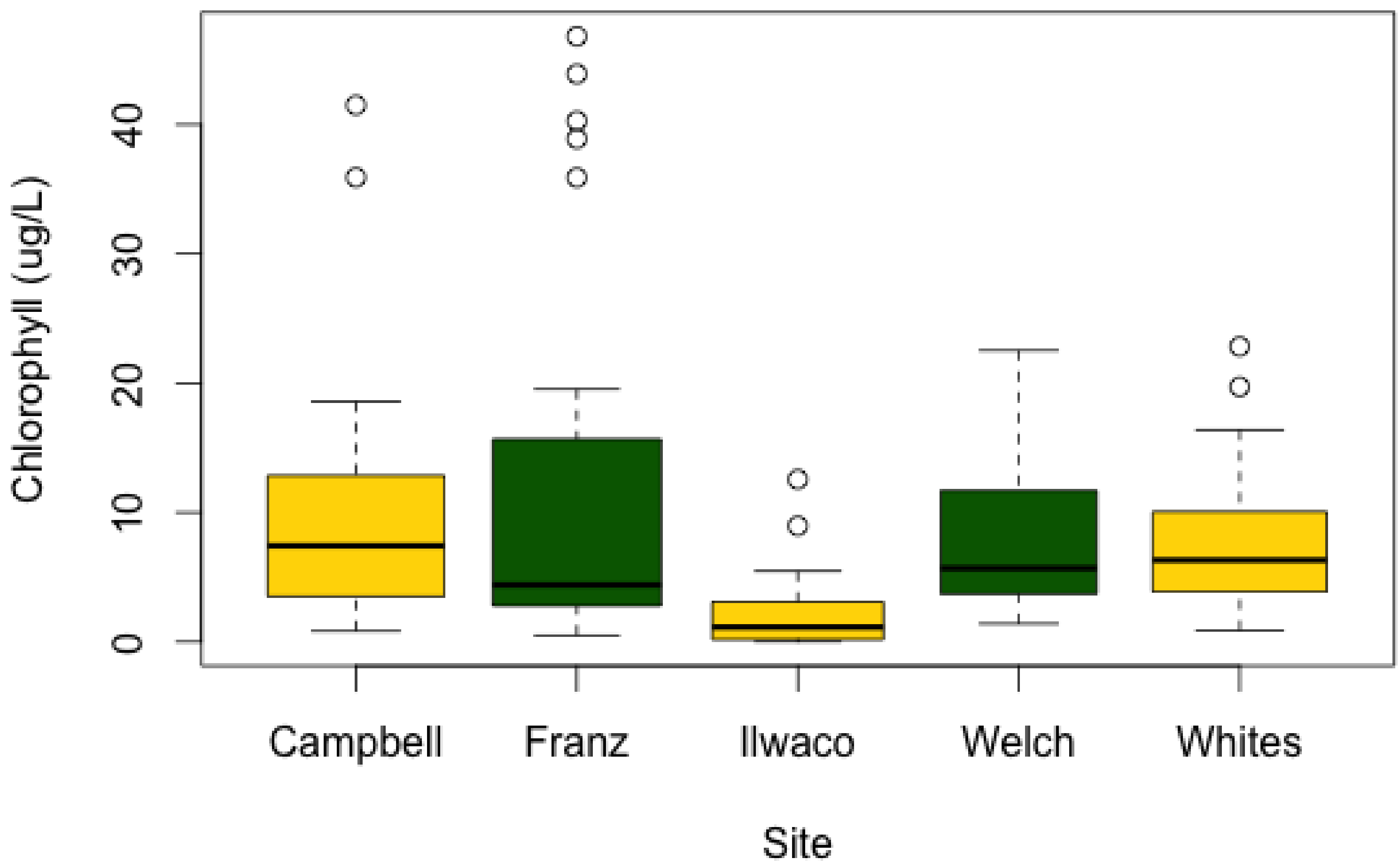
- What fish experience: Water quality
- What fish consume: Organic matter supporting juvenile salmon & prey



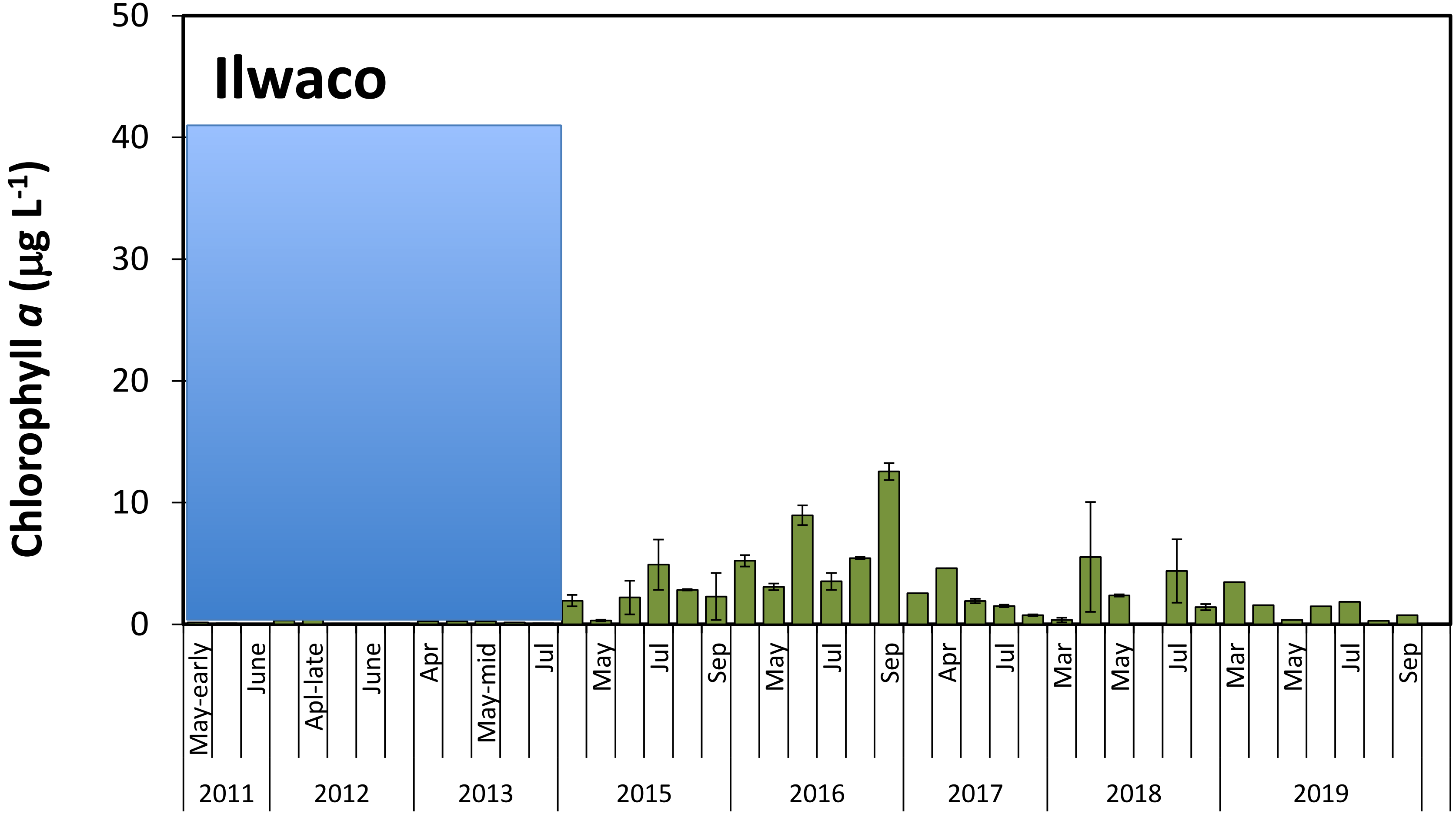
Jay et al., 2017

Increasing tidal influence

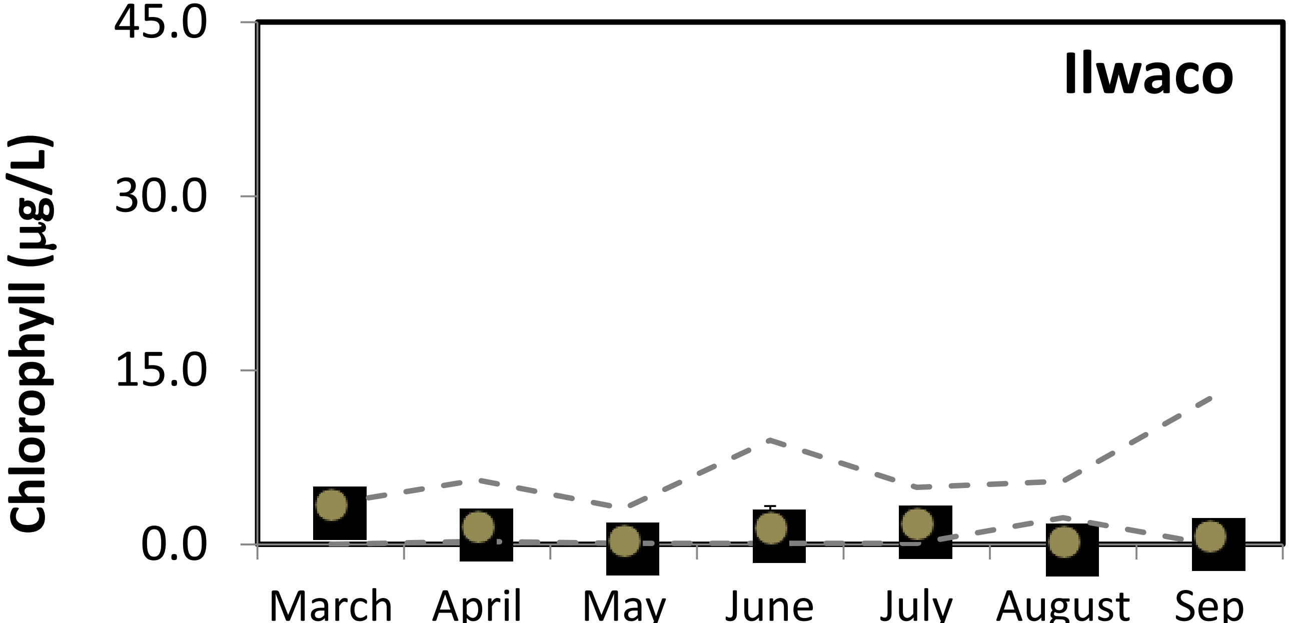
Episodic peaks in algal biomass occur at Campbell Slough and Franz Lake Slough (2011 – 2019)



2019: Algal biomass similar to previous years in early spring, relatively low in summer
(*Highest = summer 2016*)

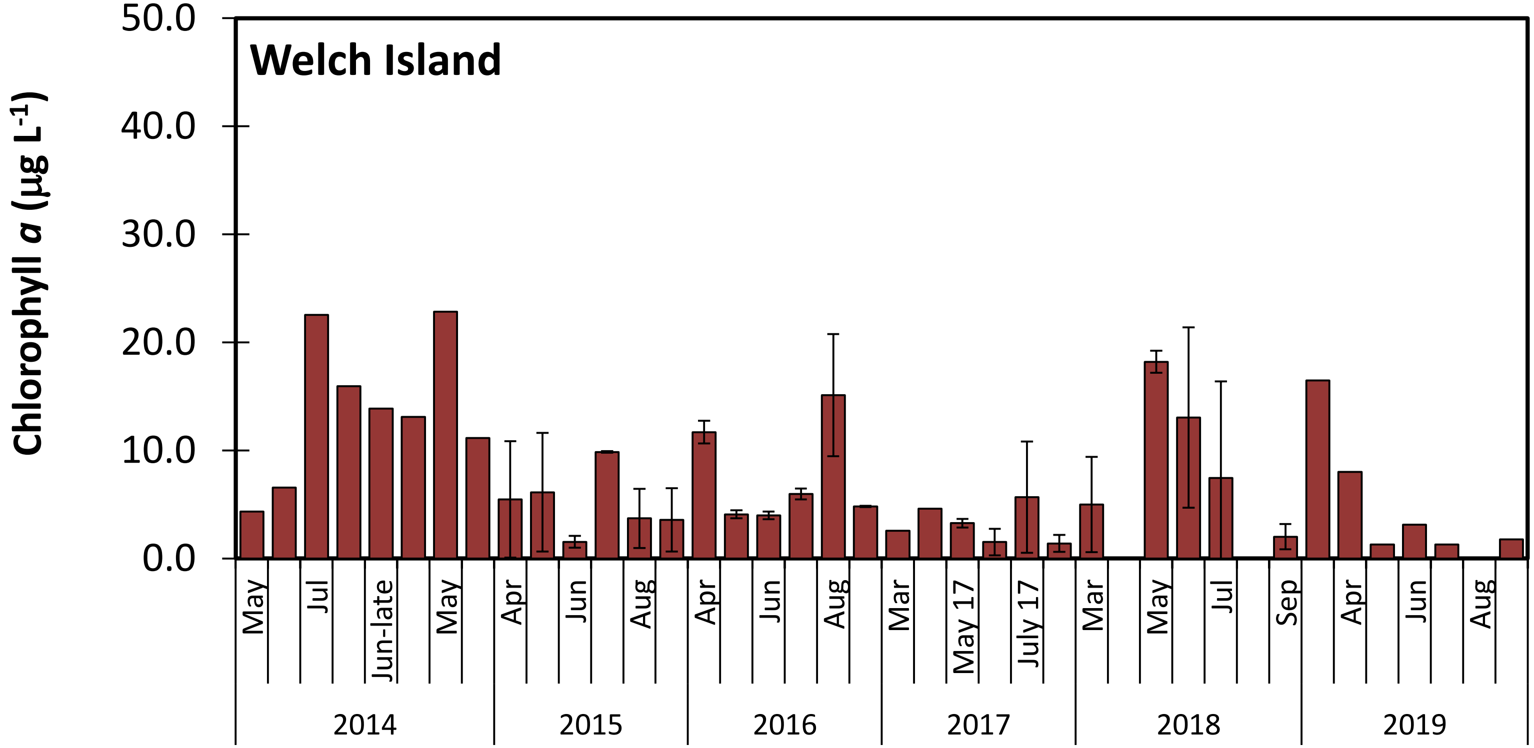


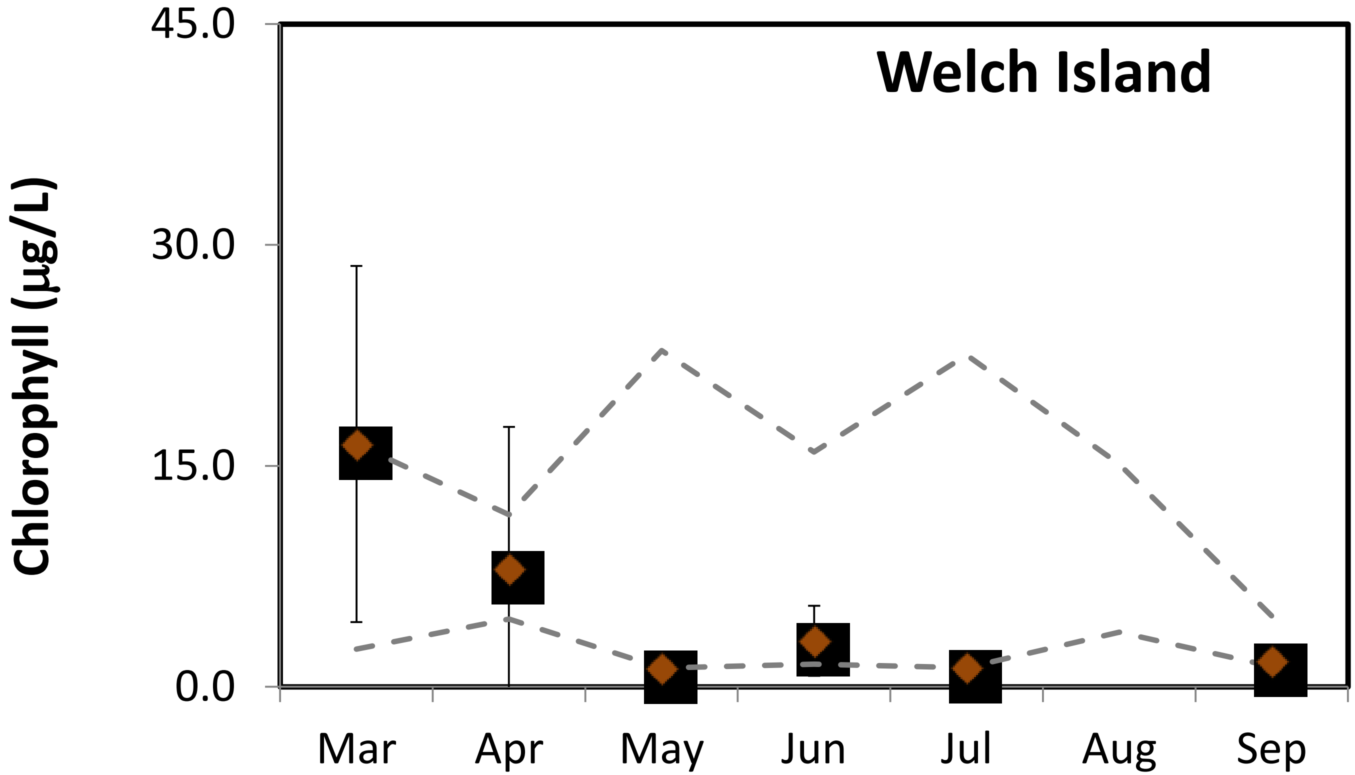
2019: Algal biomass similar to previous years in early spring, relatively low in summer (*Highest = summer 2016*)



2019

2019: Algal biomass among the highest in early spring, low later on
(*Highest = 2014*)

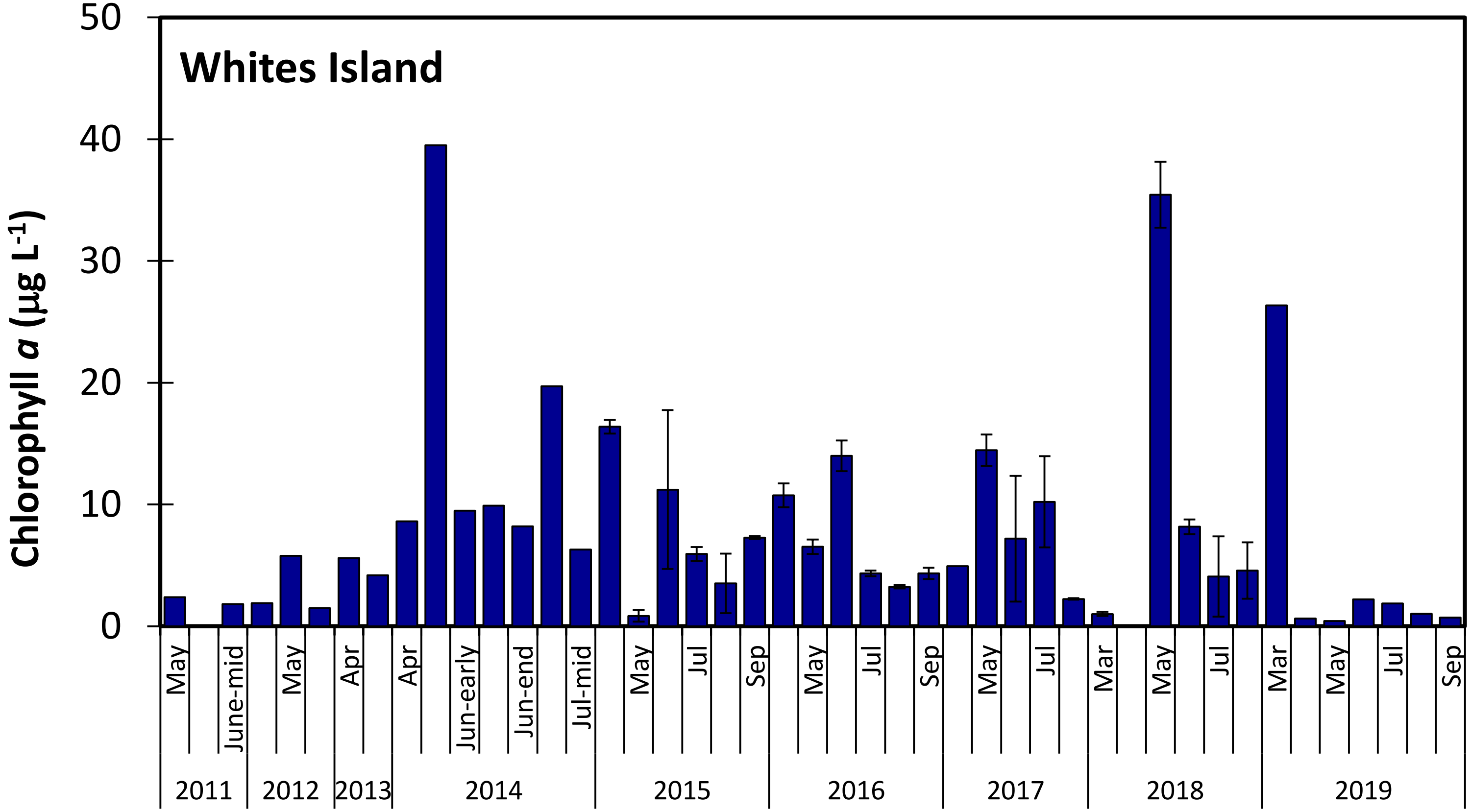


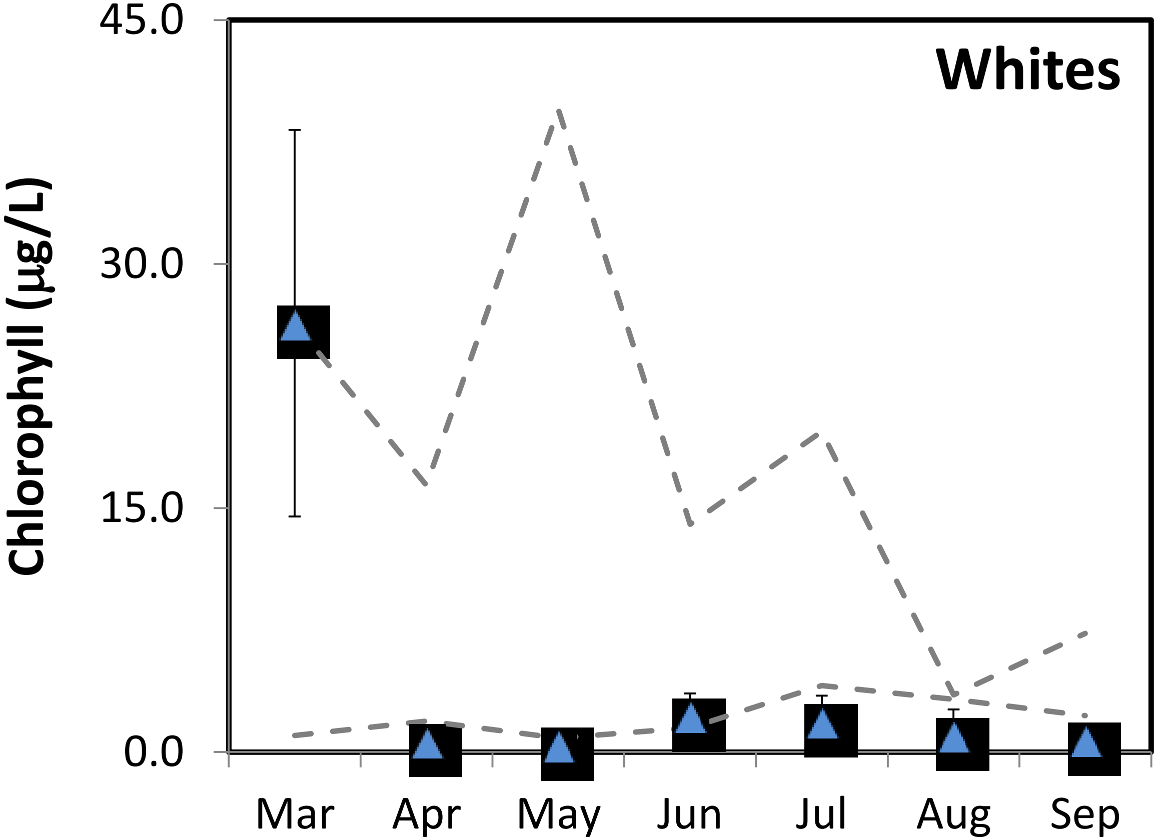


2019

- Early spring bloom was dense relative to the maximum levels observed (2011-2019)
- Less chlorophyll than Whites

2019: Spring peak algal biomass among the highest in early spring, then low afterwards (*Highest = 2014*)

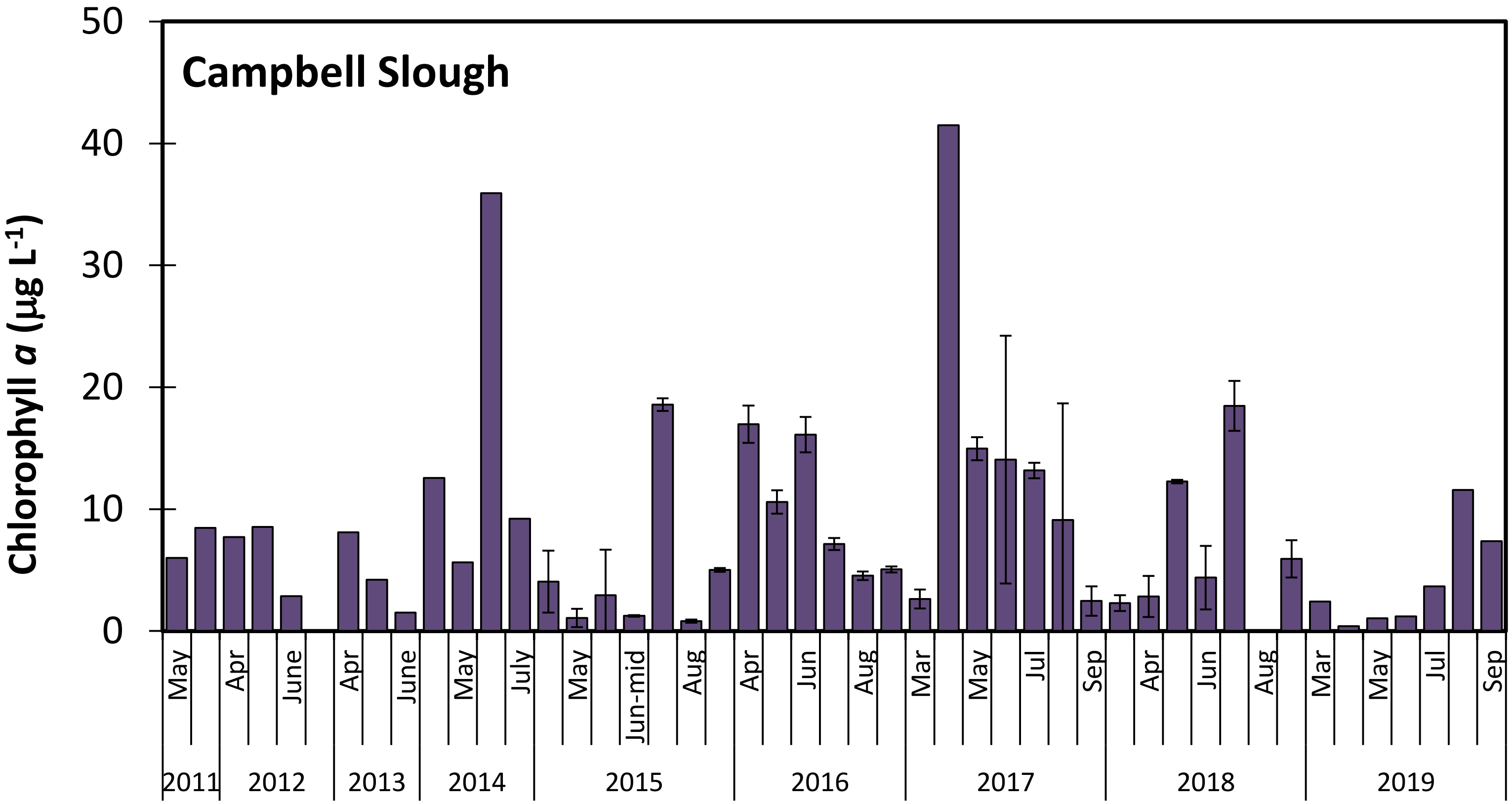


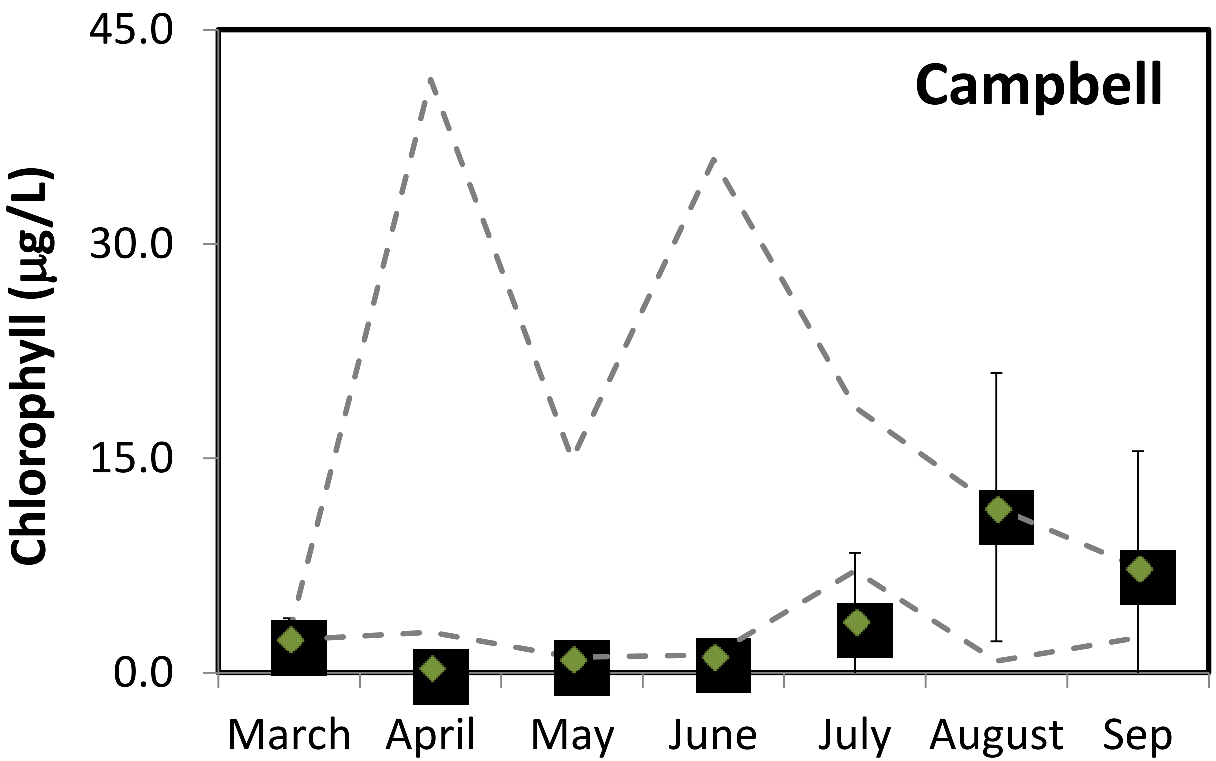


2019

Spring bloom was dense relative to the maximum levels observed in May and June (2011-2019)

2019: Spring peak algal biomass was low; moderate in summer, high in late summer (*Highest = 2017*)

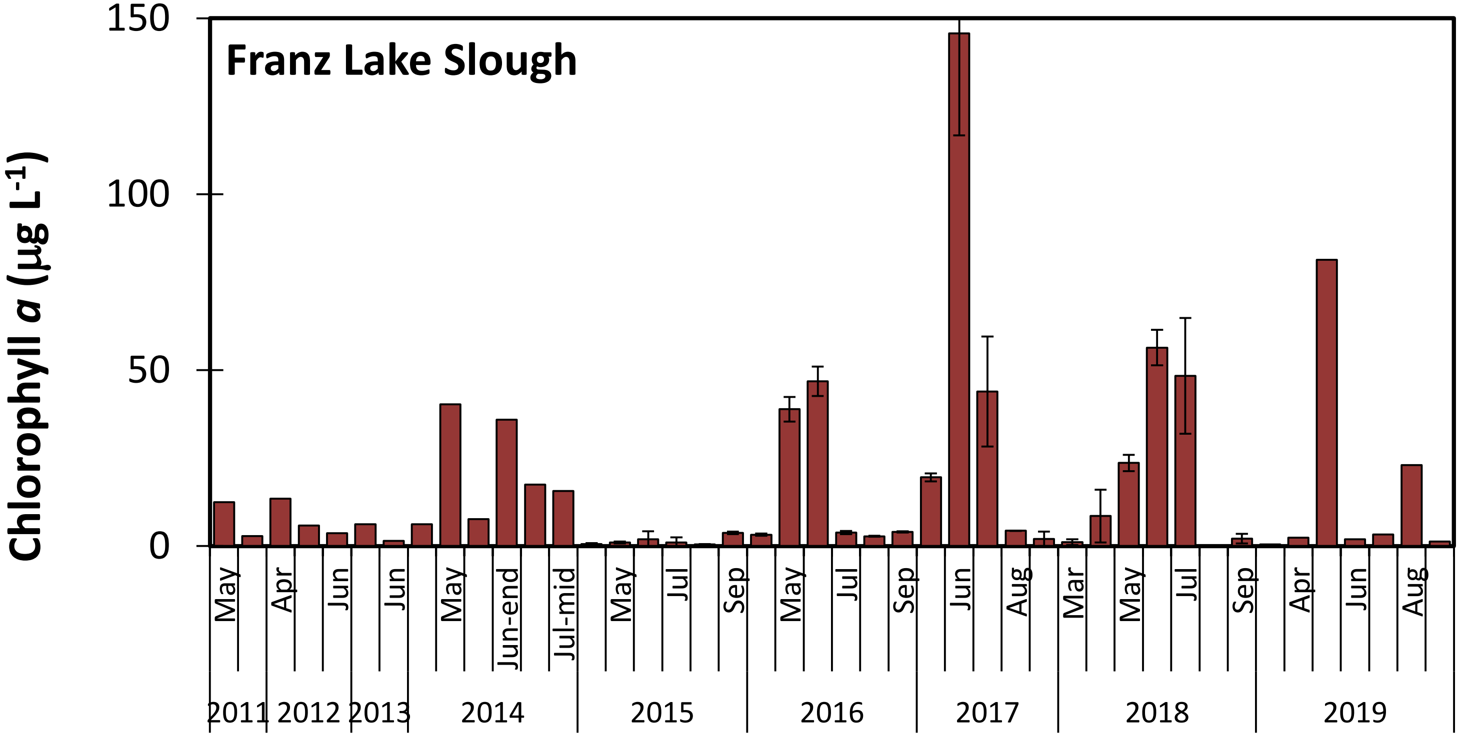




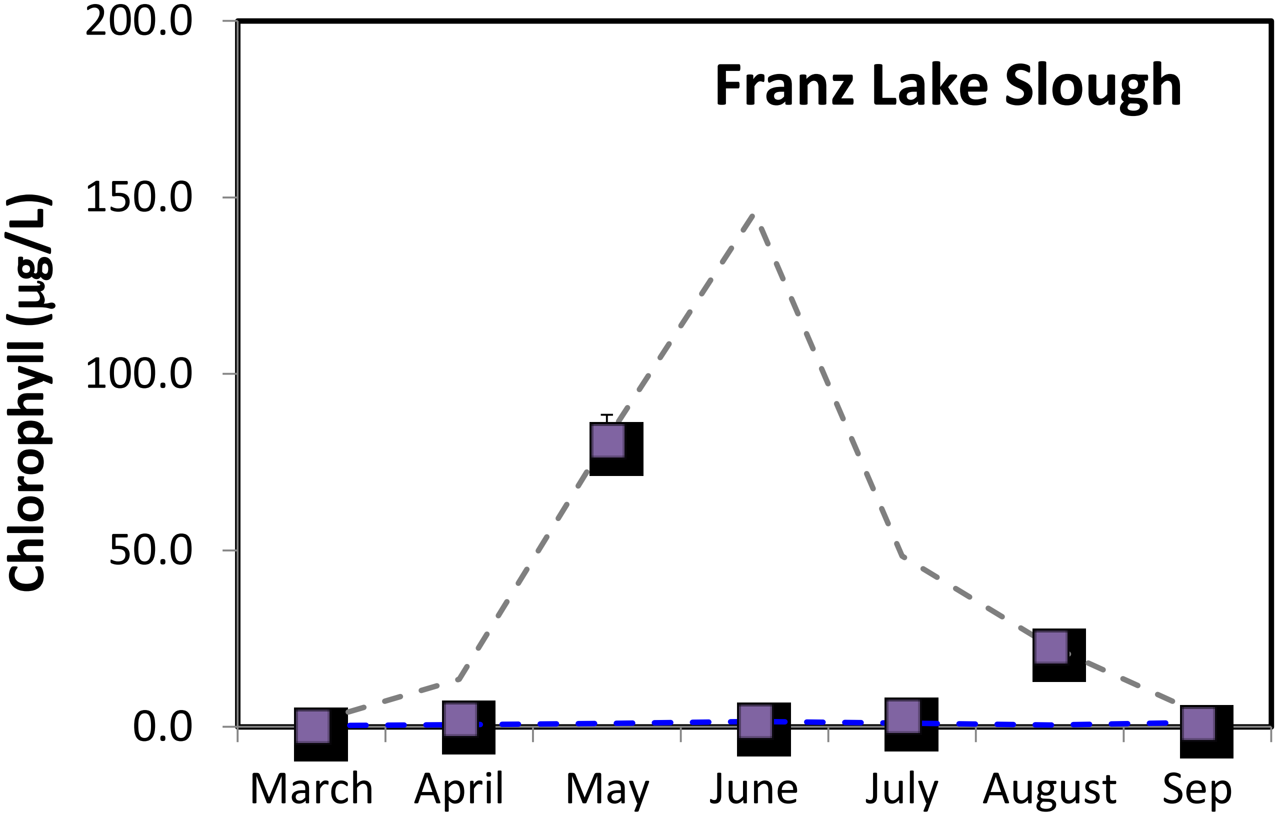
2019

- Spring bloom was **NOT** dense relative to the maximum levels observed (2011-2019)
- Chl was high in Aug and Sept

2019: Peaks observed in May and August; otherwise, low (*Highest = 2017*)



2019



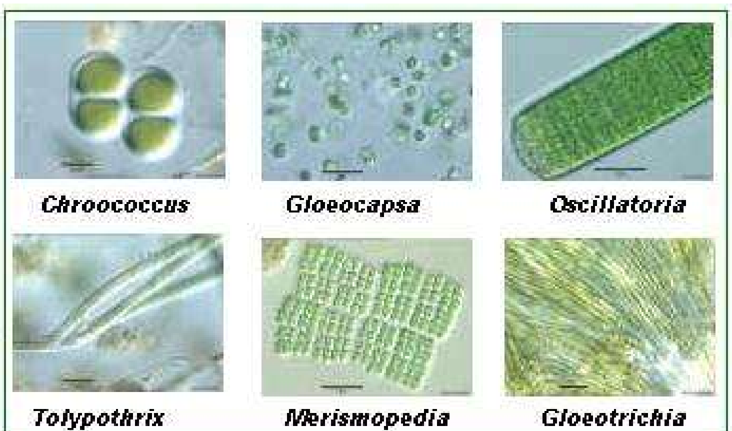
- Early spring growth was **NOT** dense relative to the maximum levels observed (2011-2019)
- Chl was high in May and August

DIATOMS

http://www.daviddarling.info

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

CYANOBACTERIA



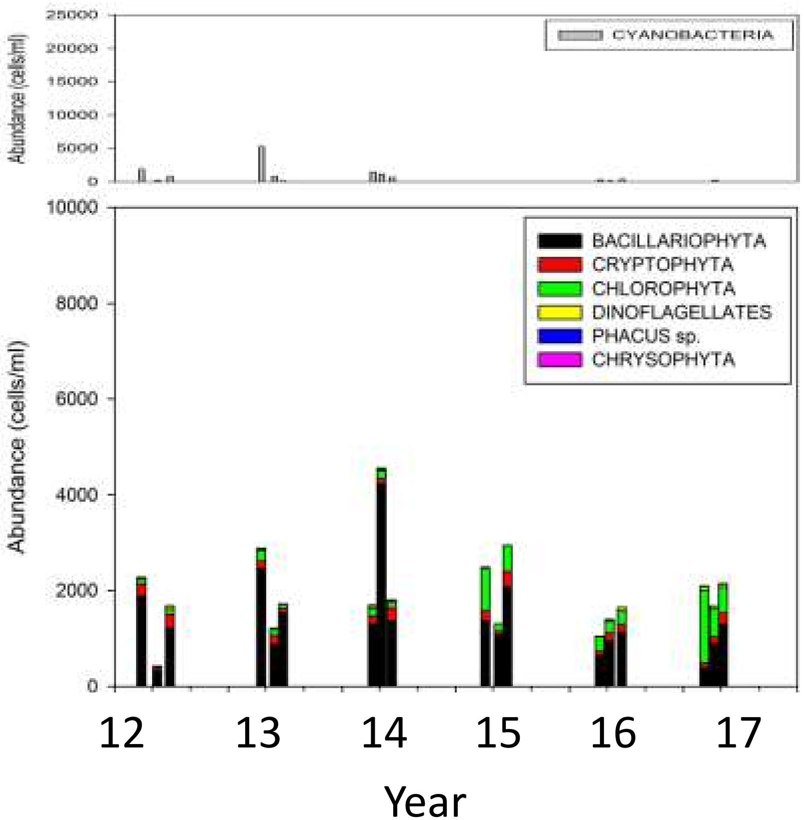
http://www.tutorvista.com

CHLOROPHYTES

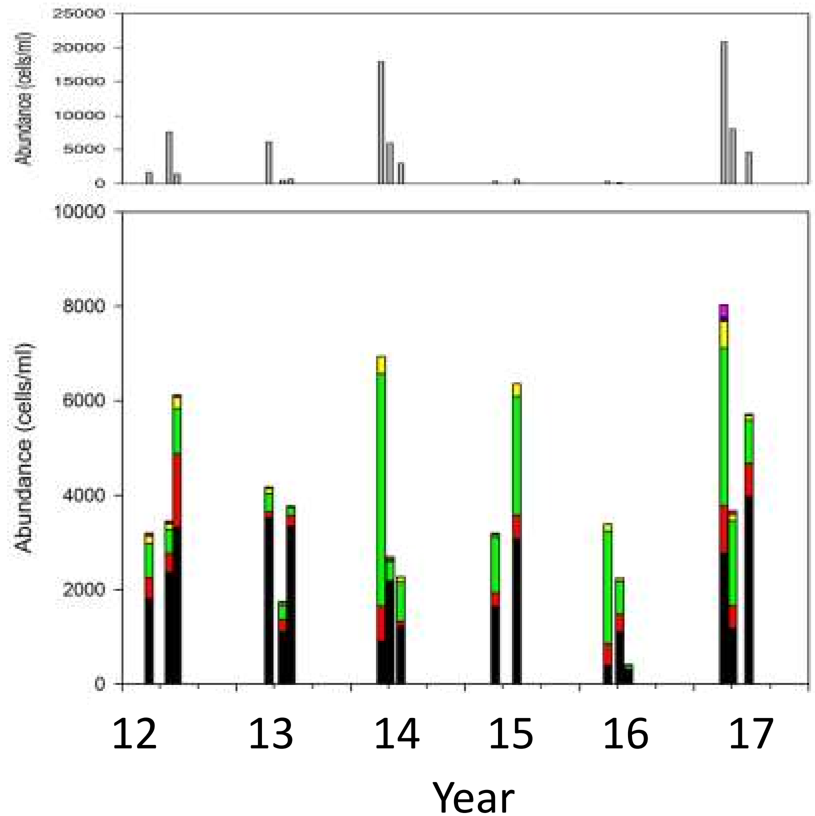
Mark Lane, slideplayer.com

Diatoms dominate at Whites Island but not always at Campbell Slough

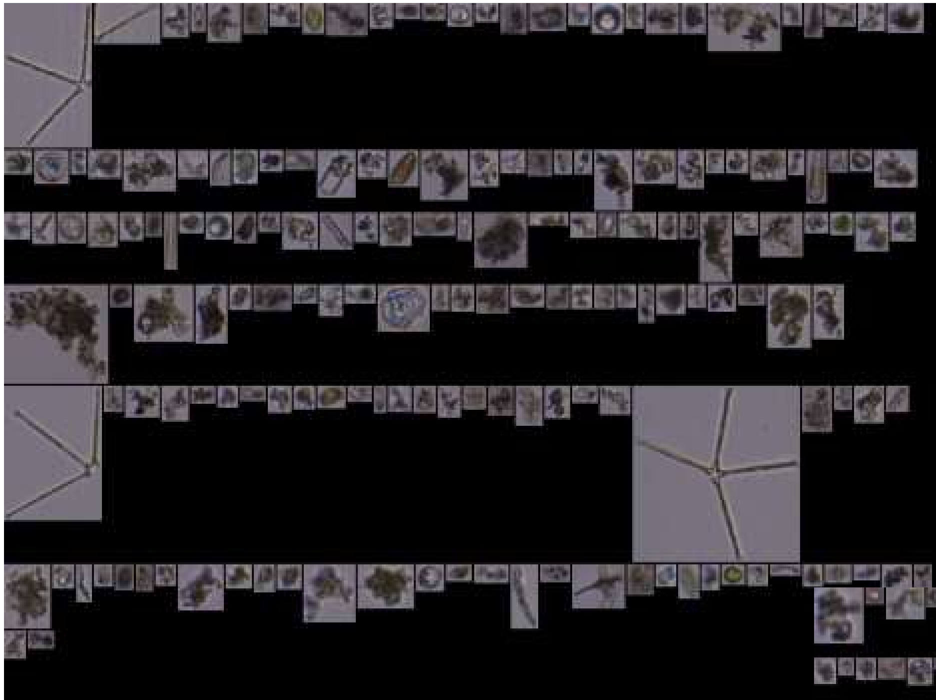
Whites Island



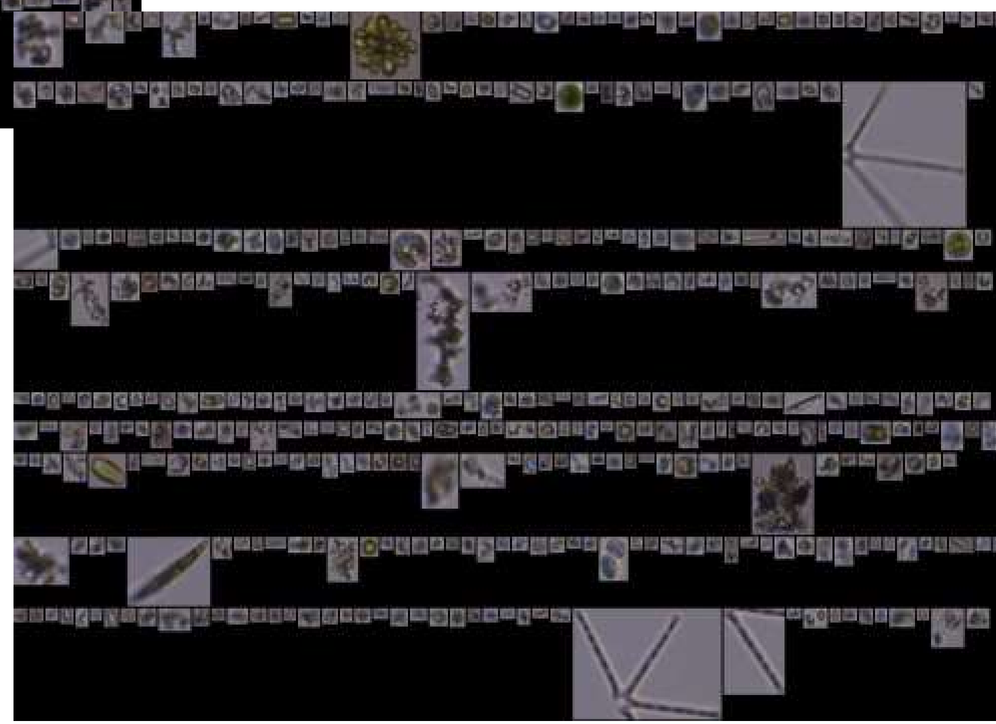
Campbell Slough

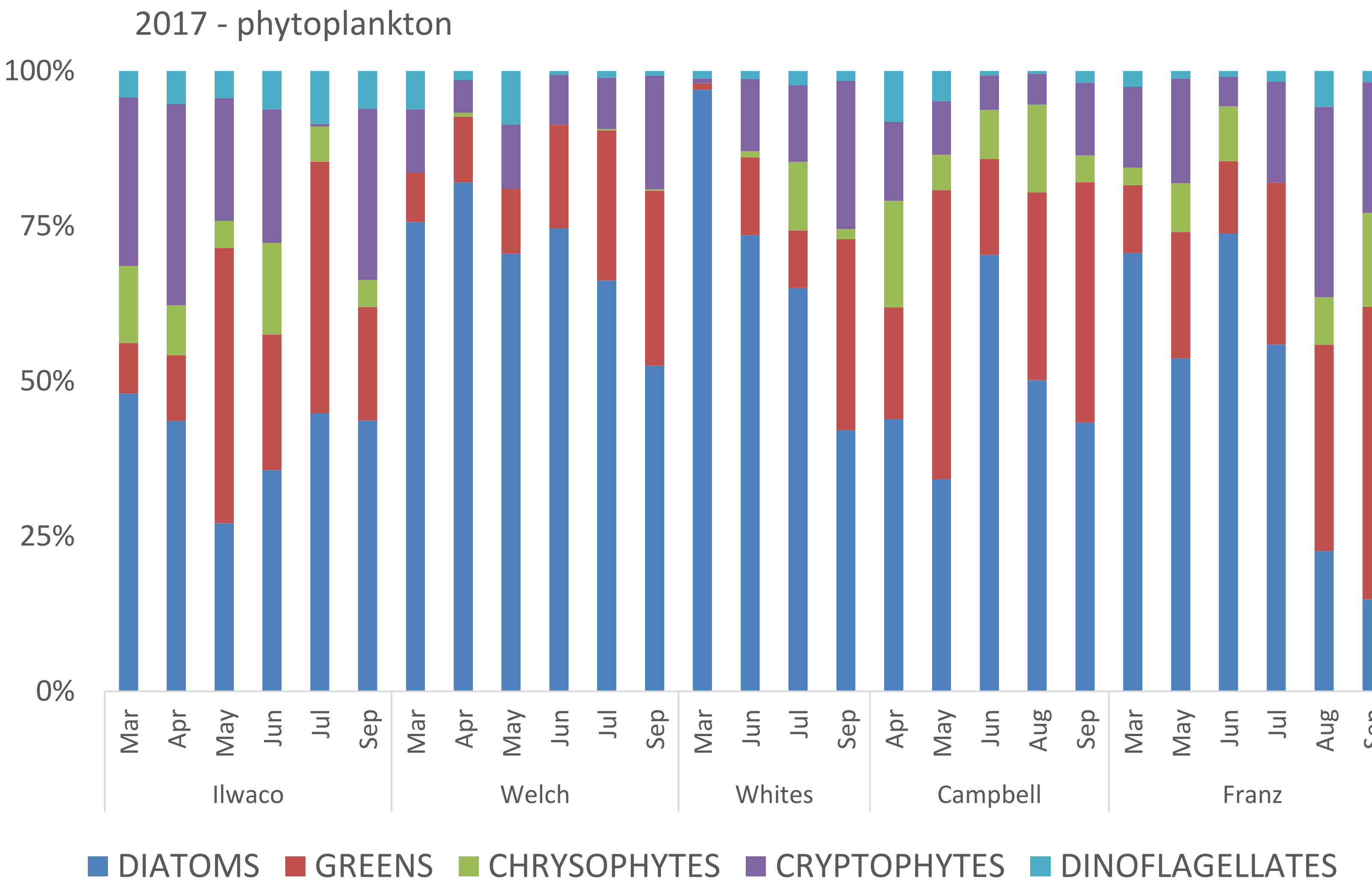


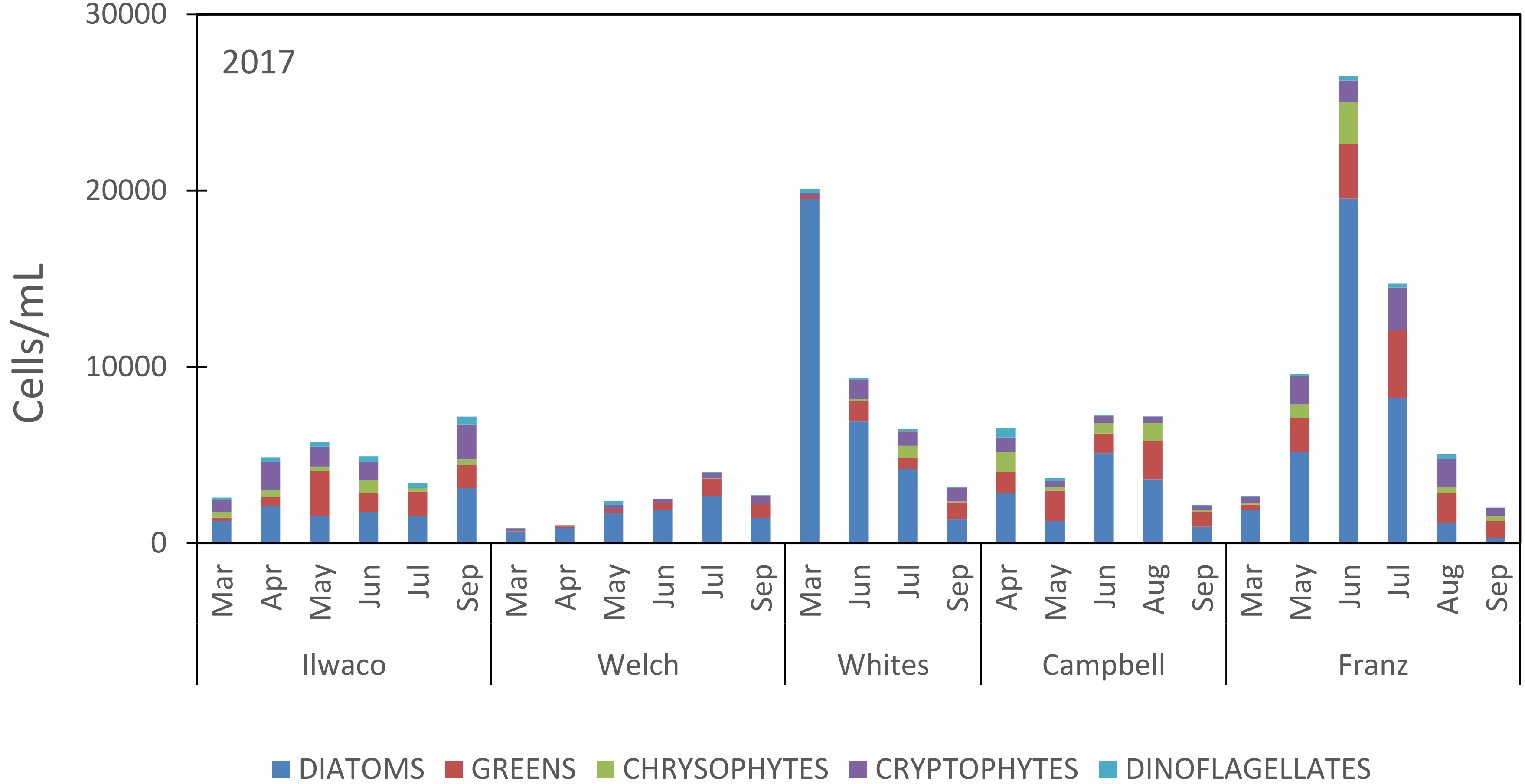
Whites



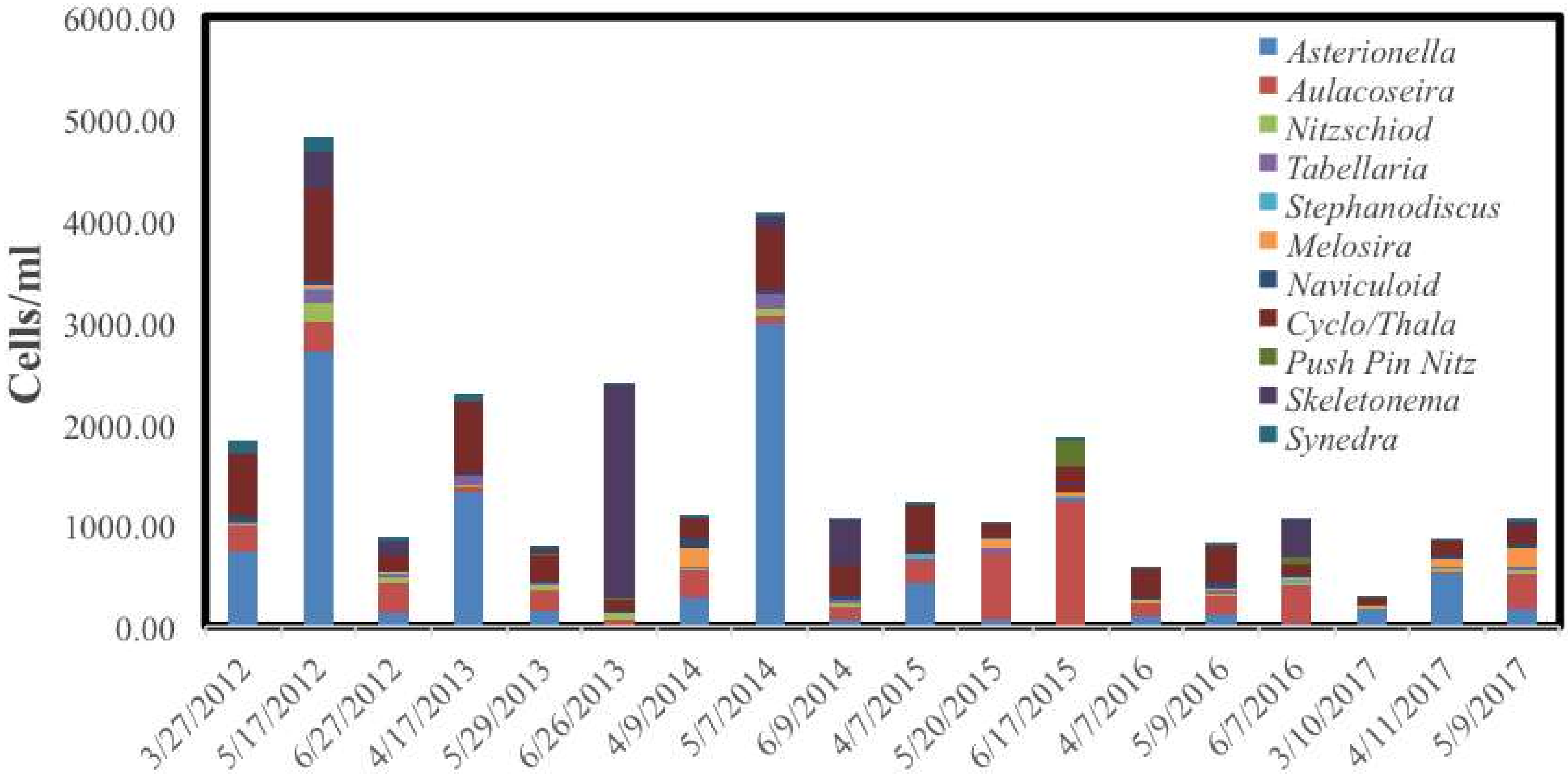
Campbell




2017 - phytoplankton
100%
75%
50%
25%
0%
Mar
Apr
May
Jun
Jul
Sep
Ilwaco
Mar
Apr
May
Jun
Jul
Sep
Welch
Mar
Jun
Jul
Sep
Whites
Apr
May
Jun
Aug
Sep
Campbell
Mar
May
Jun
Jul
Aug
Sep
Franz
DIATOMS
GREENS
CHRYSOPHYTES
CRYPTOPHYTES
DINOFLAGELLATES

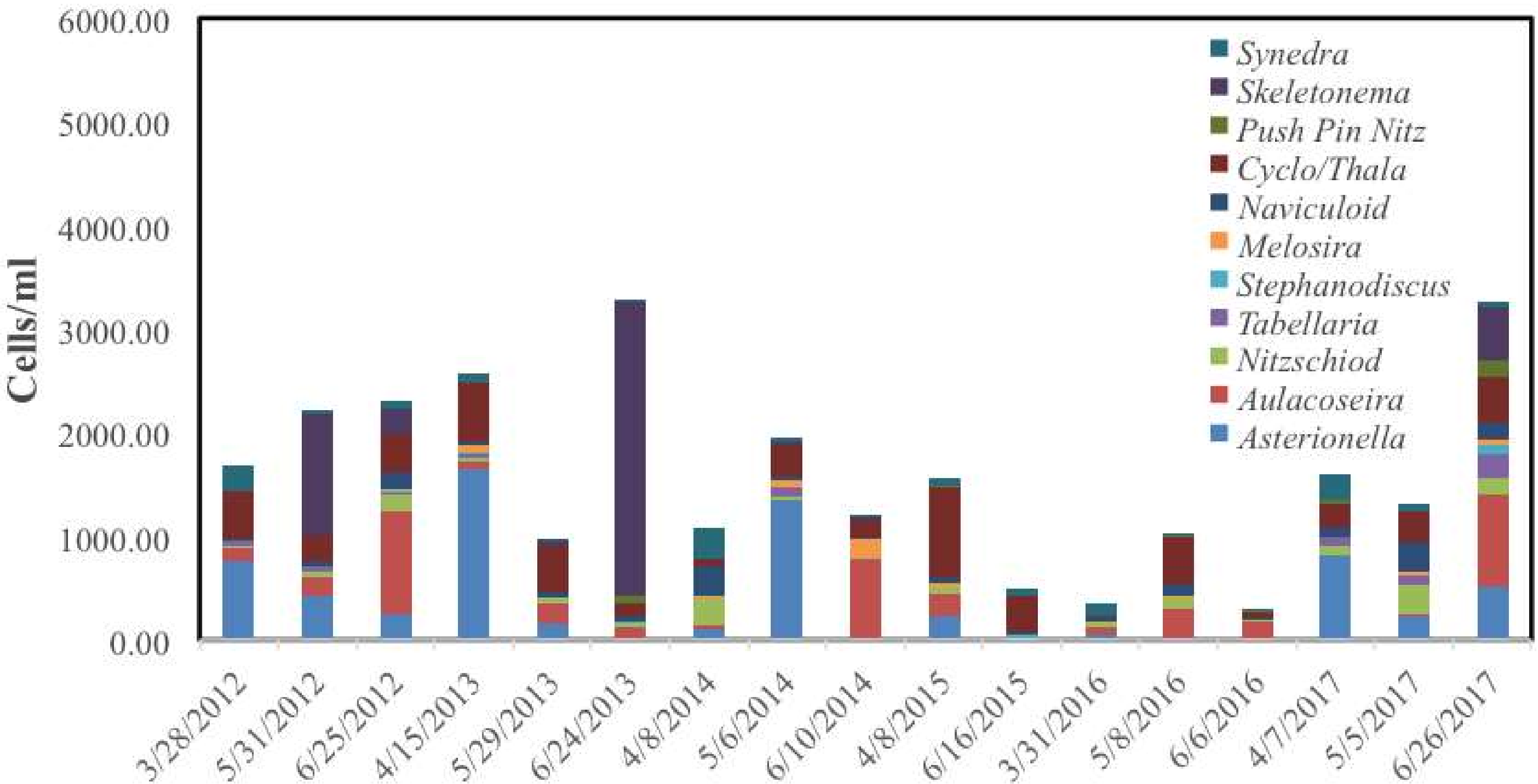

2017
Cells/mL
30000
20000
10000
0
Mar
Apr
May
Jun
Jul
Sep
Ilwaco
Welch
Whites
Campbell
Franz
Aug
DIATOMS
GREENS
CHRYSOPHYTES
CRYPTOPHYTES
DINOFLAGELLATES

Diatom densities, Whites Island



- Peak spring diatom densities dominated by *Asterionella formosa*

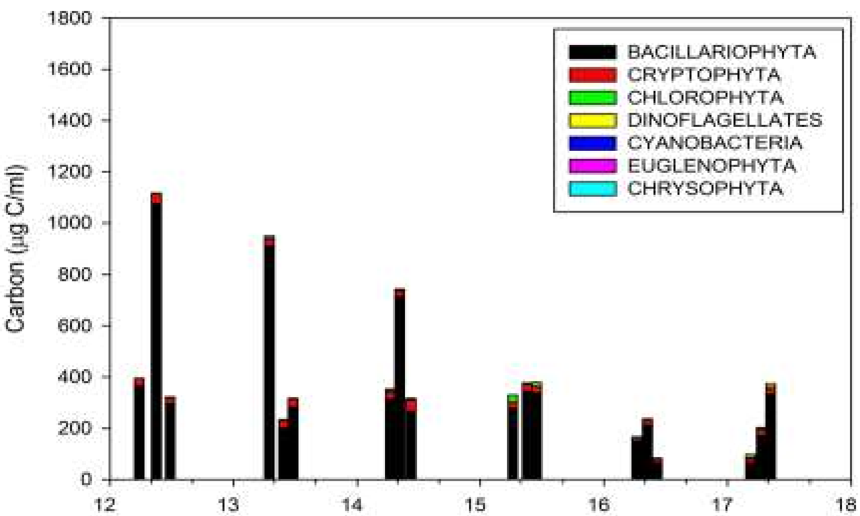
Diatom densities, Campbell Slough



- Peak spring diatom densities occur later in the season (June) when *A. formosa* not dominant

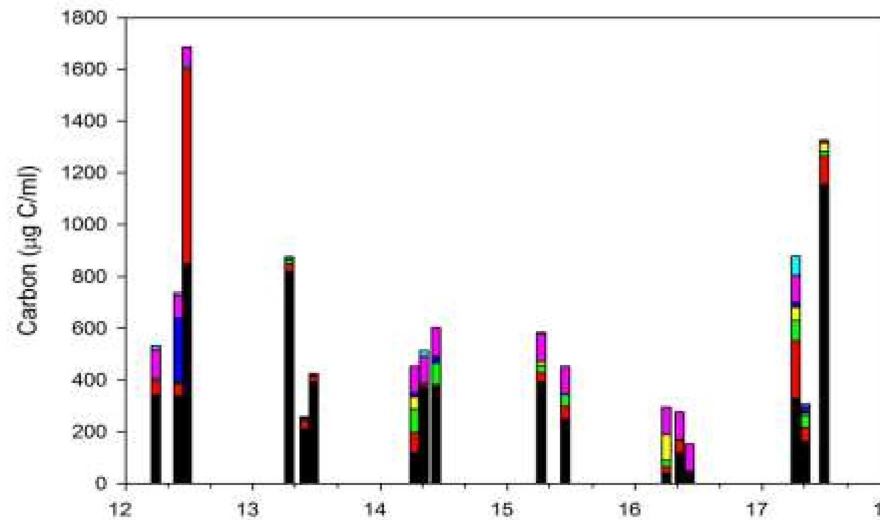
Amount of carbon is generally dominated by diatoms at both Whites Island and Campbell Slough

Whites Island



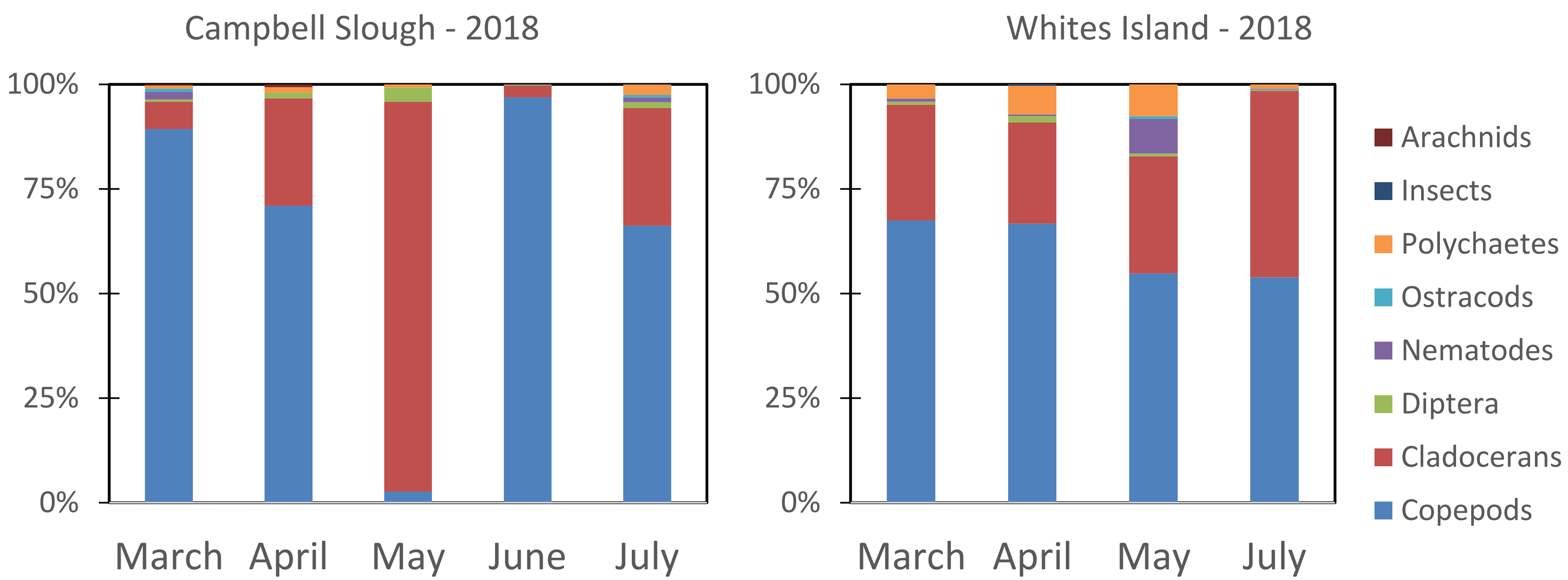
Year

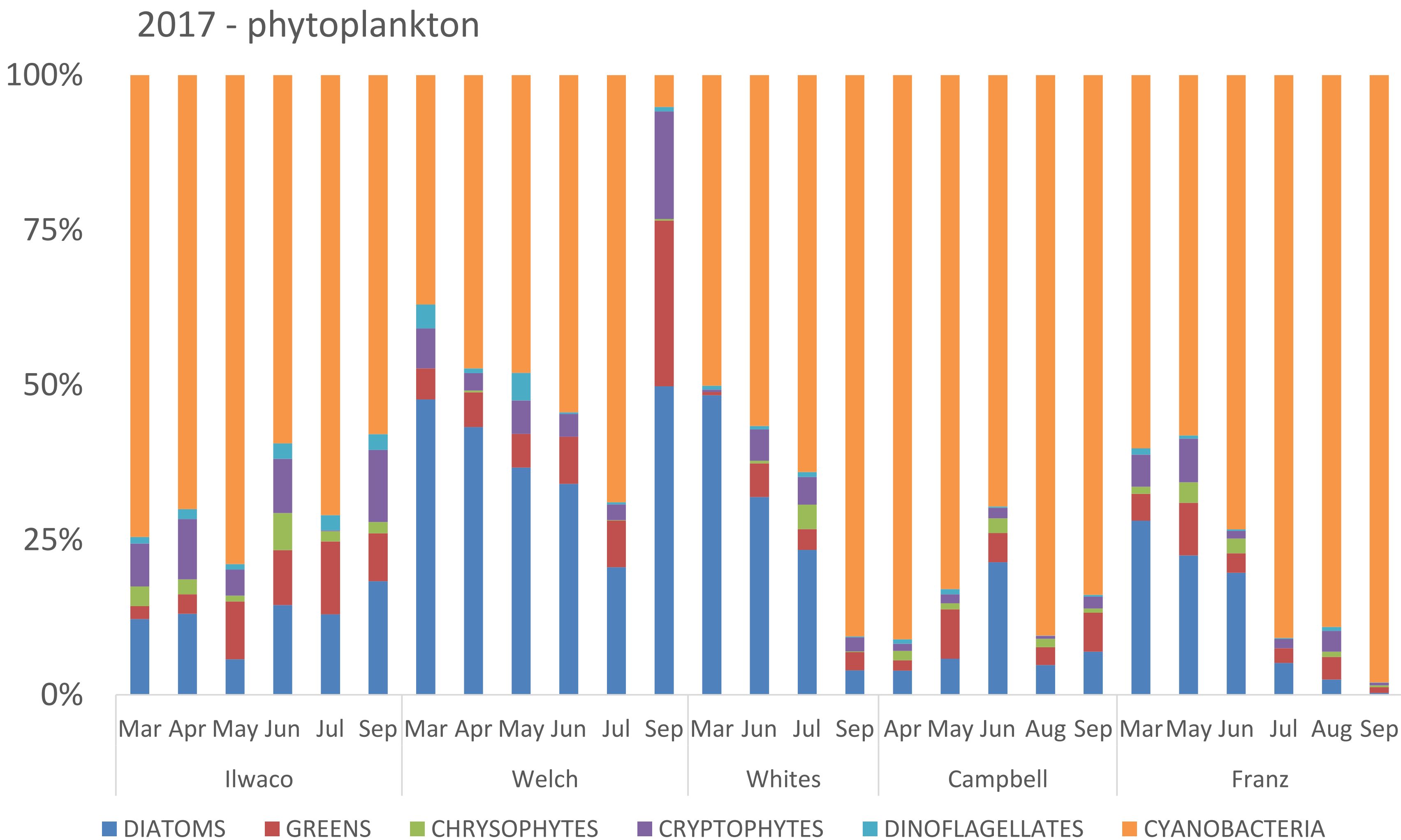
Campbell Slough

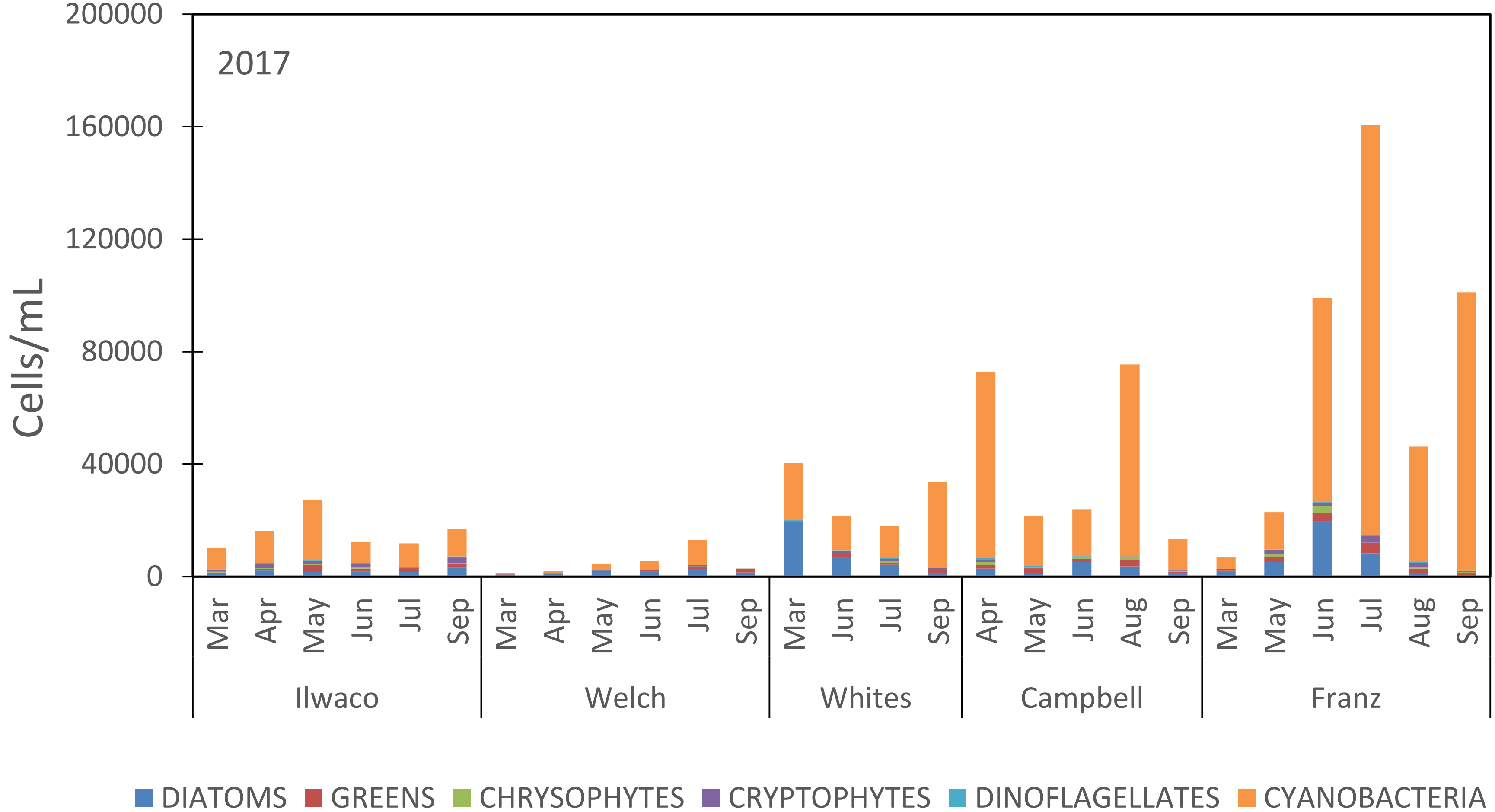


Year

Open water zooplankton




2017 - phytoplankton
100%
75%
50%
25%
0%
Mar Apr May Jun Jul Sep
Ilwaco
Mar Apr May Jun Jul Sep
Welch
Mar Jun Jul Sep
Whites
Apr May Jun Aug Sep
Campbell
Mar May Jun Jul Aug Sep
Franz
DIATOMS
GREENS
CHRYSOPHYTES
CRYPTOPHYTES
DINOFLAGELLATES
CYANOBACTERIA


2017
Cells/mL
200000
160000
120000
80000
40000
0
Mar
Apr
May
Jun
Jul
Sep
Ilwaco
Welch
Whites
Aug
Campbell
Franz
DIATOMS
GREENS
CHRYSOPHYTES
CRYPTOPHYTES
DINOFLAGELLATES
CYANOBACTERIA

Cyanobacteria blooms in the Columbia River have been repeatedly detected during the Ecosystem Monitoring Program

S. Dyer

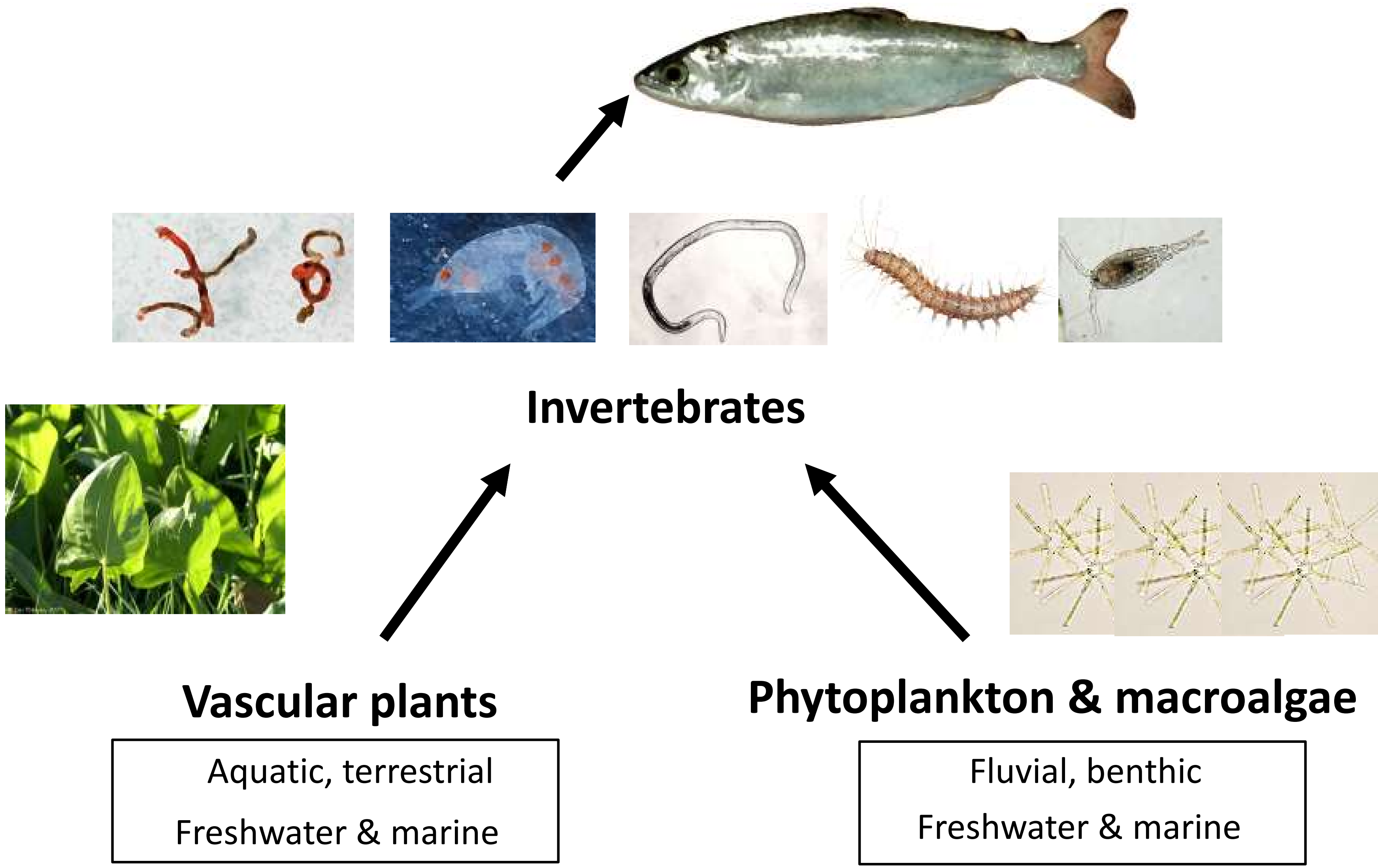
Conditions that favor cyanobacteria:

- High temperature
- Nutrients
- High light/stratification

ii. Investigating the diet of juvenile Chinook salmon using stable isotopes of carbon and nitrogen

Tawnya Peterson
Joseph Needoba

Ecosystem Monitoring Program seeks to inform wetland restoration activities by providing fundamental ecological knowledge about salmonid habitats and food webs



Stable isotope ratios can be used to infer relationships between consumers & food sources

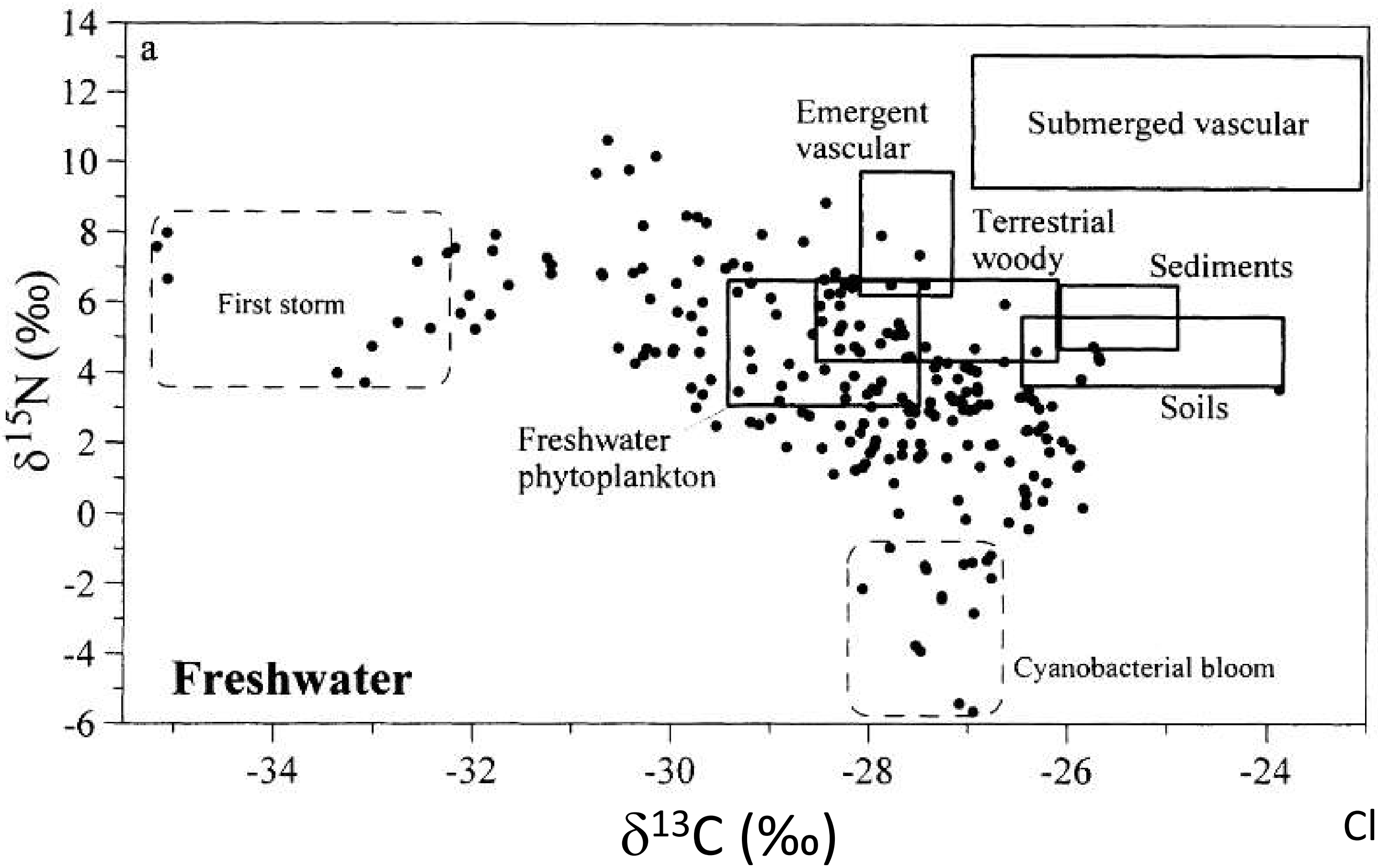
- Complements direct data (i.e., stomach contents)
  - Can overcomes biases associated with ingestion vs. assimilation, as well as difficulty identifying partially digested prey

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

- Input data into a stable isotope mixing model to predict contributions from different sources
  - SIMMR (Parnell et al., 2013): Bayesian mixing model fitting using Markov chain Monte Carlo

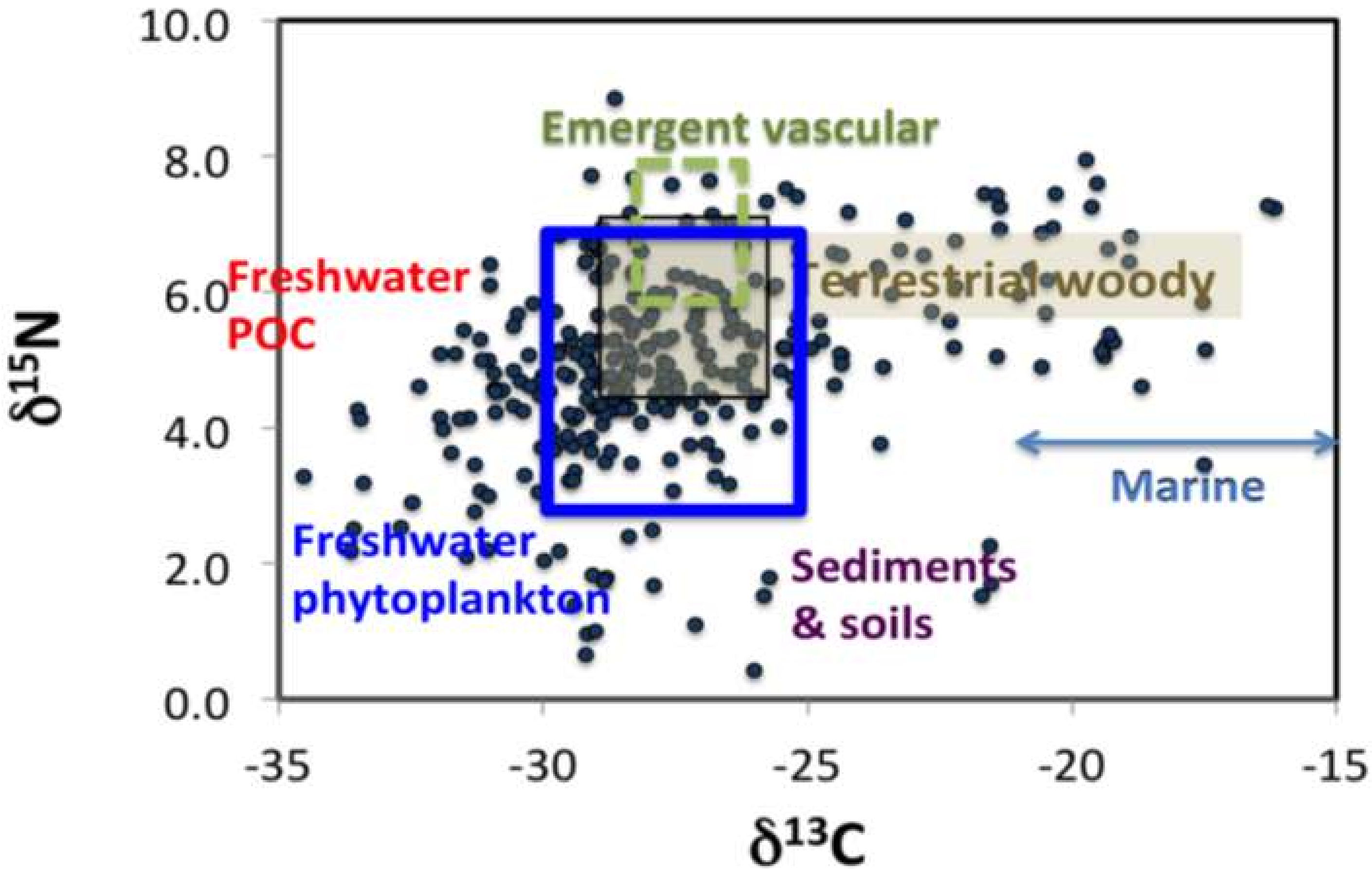
Carbon & nitrogen are building blocks of biomass

- Isotope ratios of carbon ($^{13}C/^{12}C$): characteristic of source of primary production
- Isotope ratios of nitrogen ($^{15}N/^{14}N$) are characteristic of trophic position



Cloern, 2002

Columbia River



Assumptions

- Different food sources have distinct enough signatures to discriminate between them
- There is an increase in ^{13}C and ^{15}N with each ascending trophic level of ~1 ‰ and ~3.5 ‰, respectively

"Isotopes are not a magic bullet for determining or comparing diets… As is often the case with ecology, you also need a little luck in there too in terms of the geometry of your system in isotope space, which impacts on the mathematical and statistical power you will have to answer your questions." – Andrew Jackson

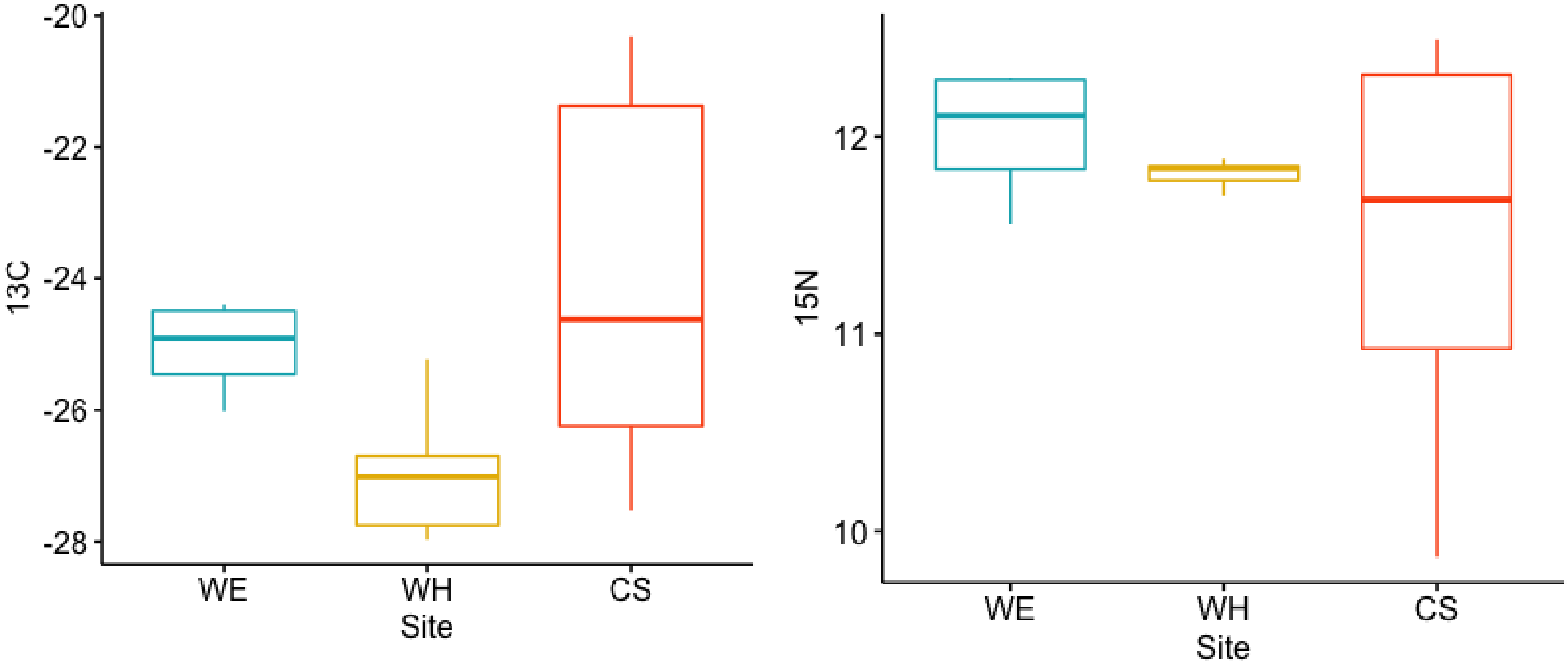
Questions

- What food sources are juvenile salmon assimilating in the Columbia River estuary?
  - Does the isotopic composition of organic matter sources change in space or time?
- What are their prey eating?
  - Do different prey consume different sources of organic matter?
  - Does organic matter source vary with the hydrograph or environmental conditions?

Methods

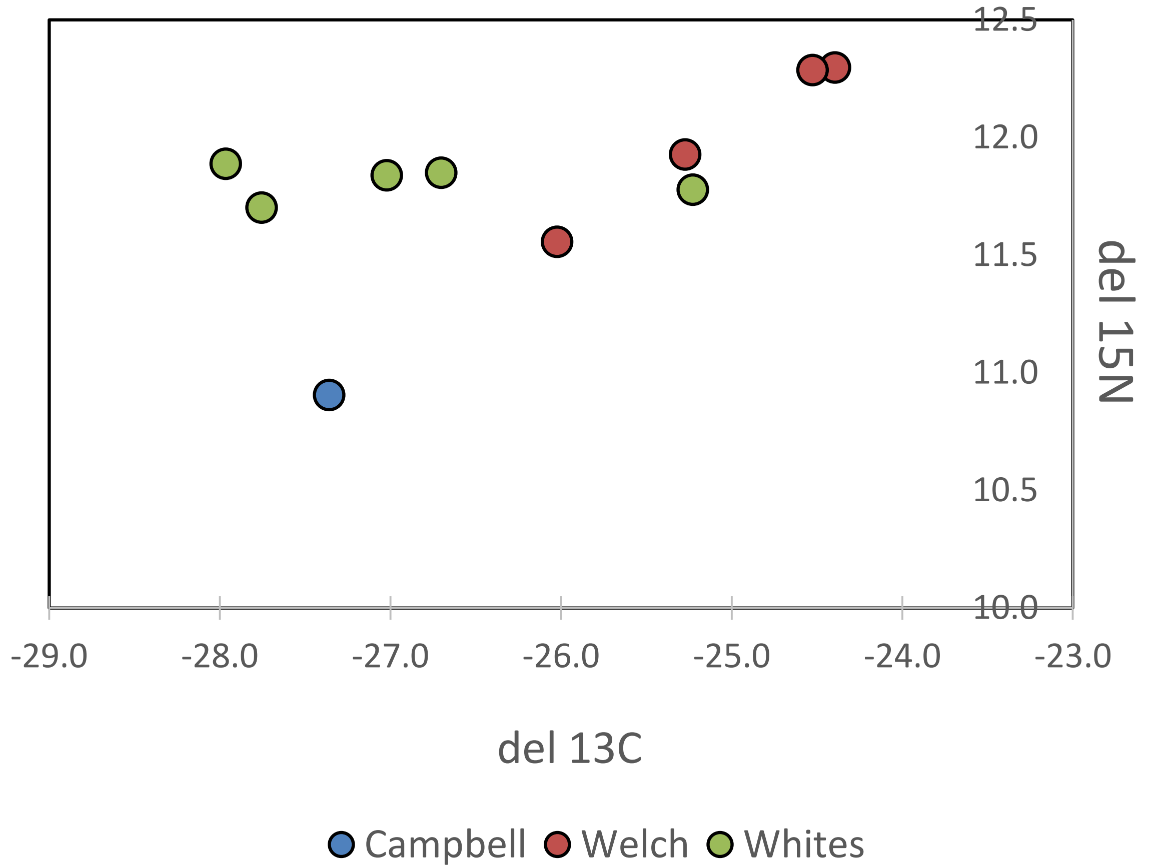
- Samples
  - Juvenile Chinook salmon muscle (and some livers)
- Food sources
  - Invertebrates (amphipods, chironomids, nematodes, polychaetes, oligochaetes, copepods, cladocerans, etc.)
  - Primary producers (live & dead vegetation, periphyton, particulate organic matter)

2018 Fish muscle (May)

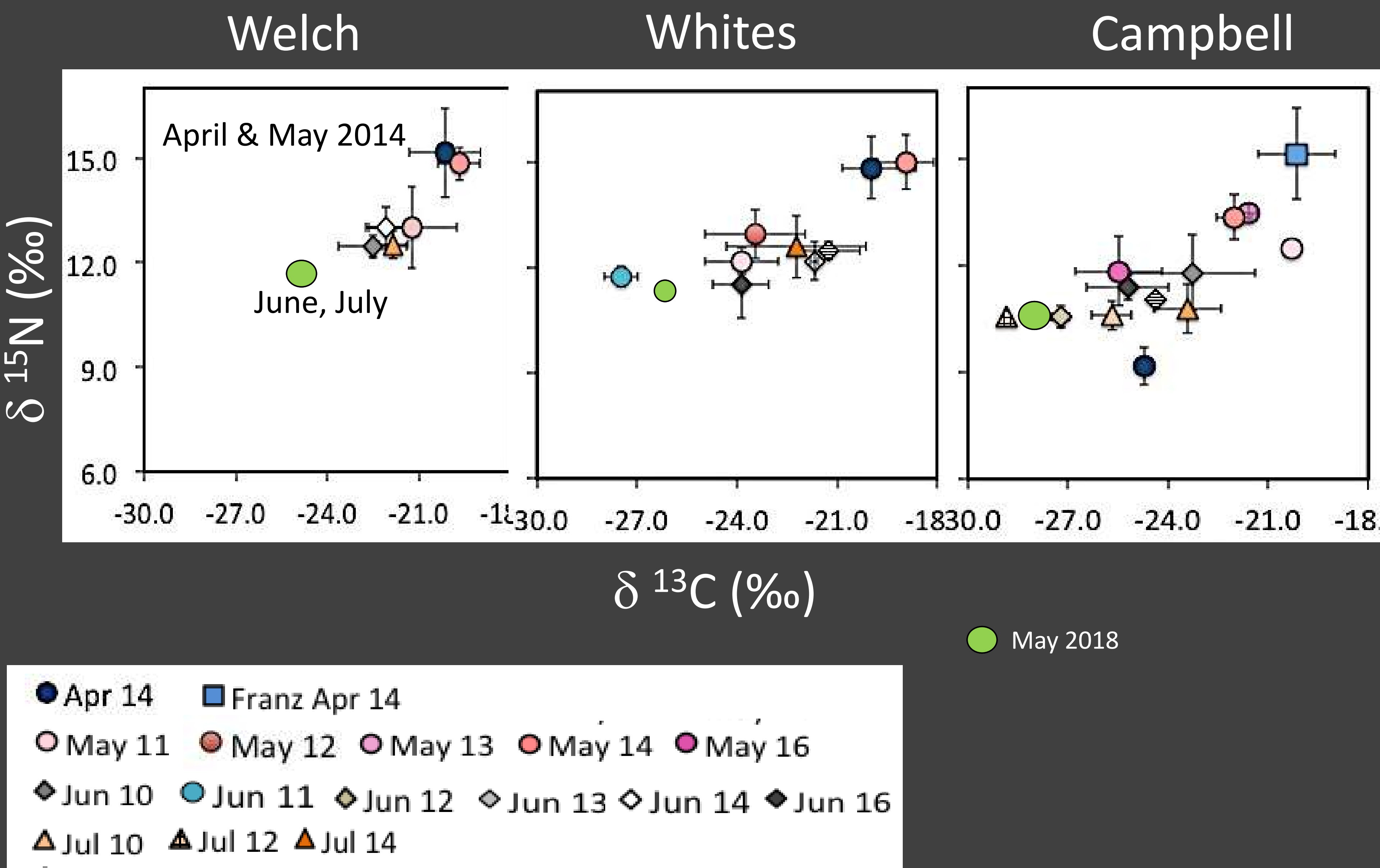


WE = Welch Island
WH = Whites Island
CS = Campbell Slough

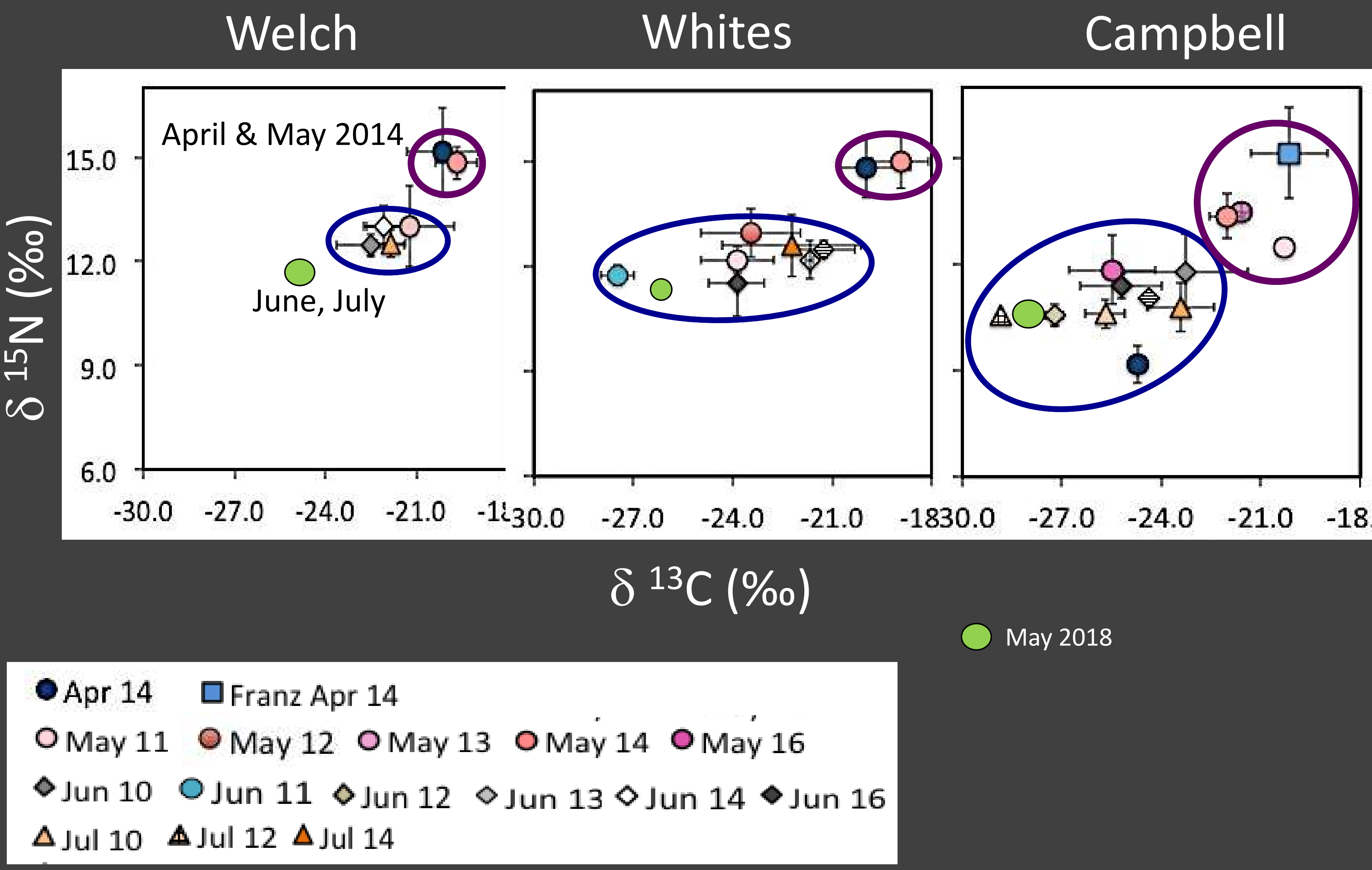
2018 Fish muscle (May)



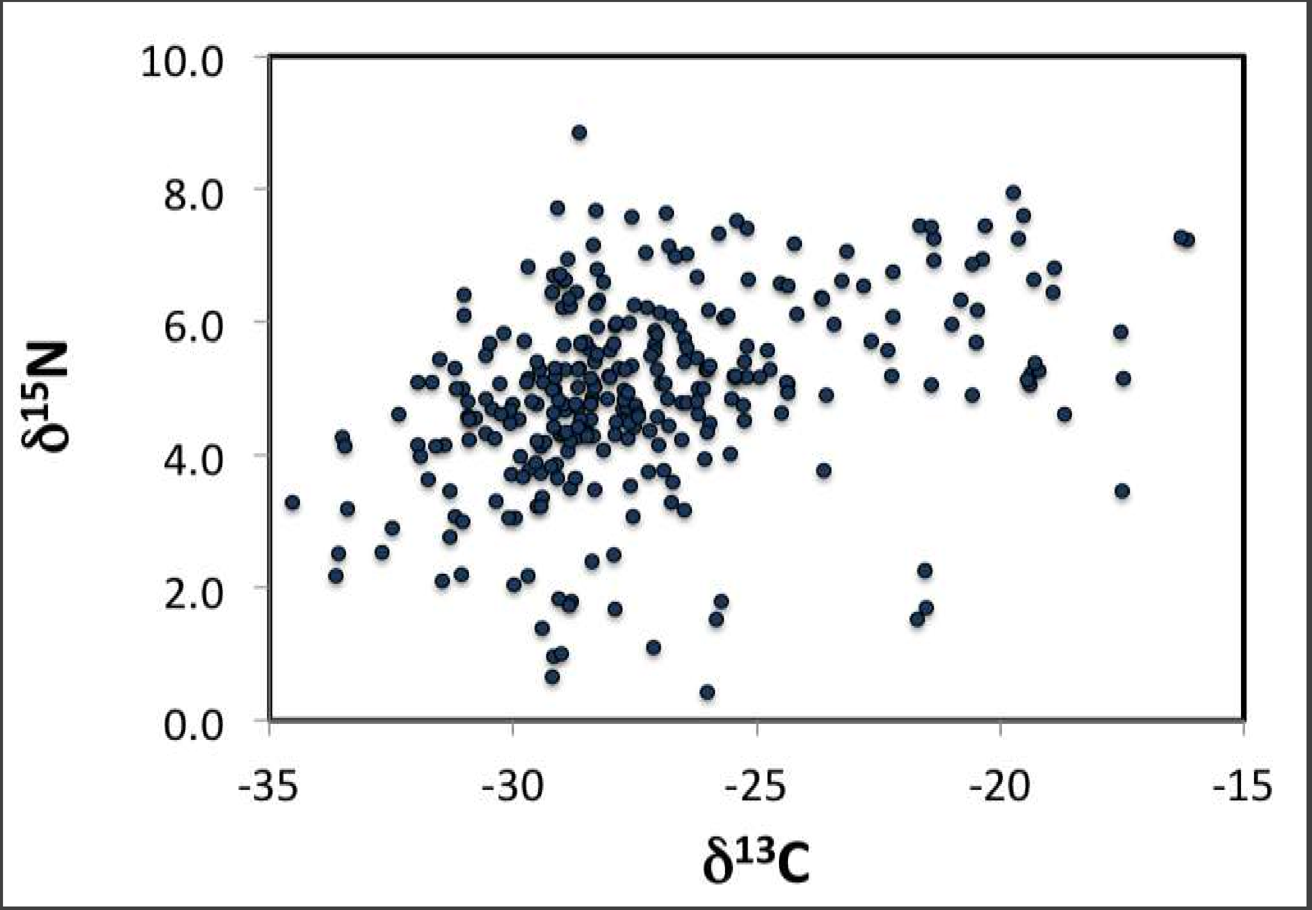
Juvenile Chinook muscl



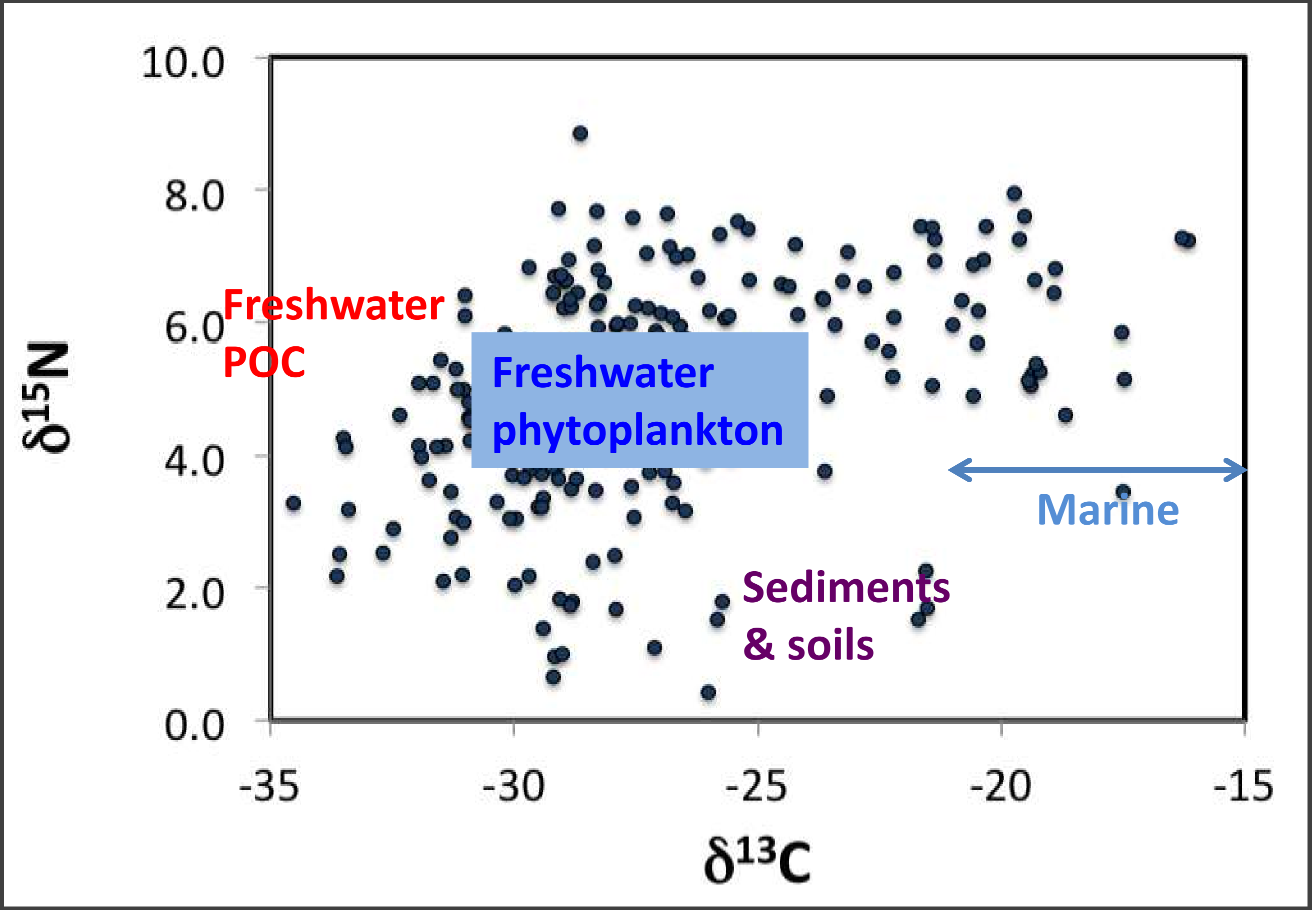
Juvenile Chinook muscl



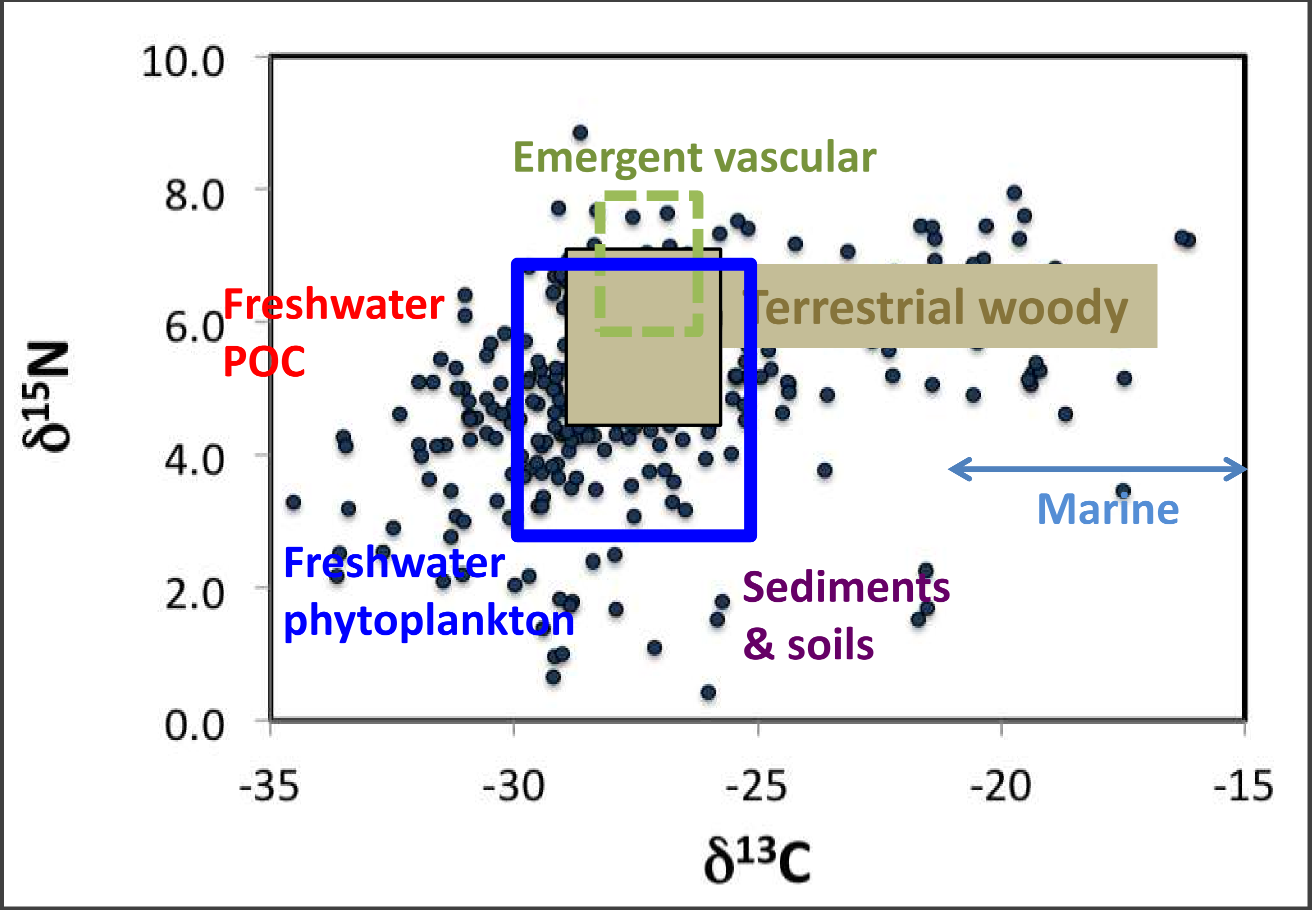
Isotopic signatures of primary producers (plants, periphyton, POM) in the Columbia River estuary

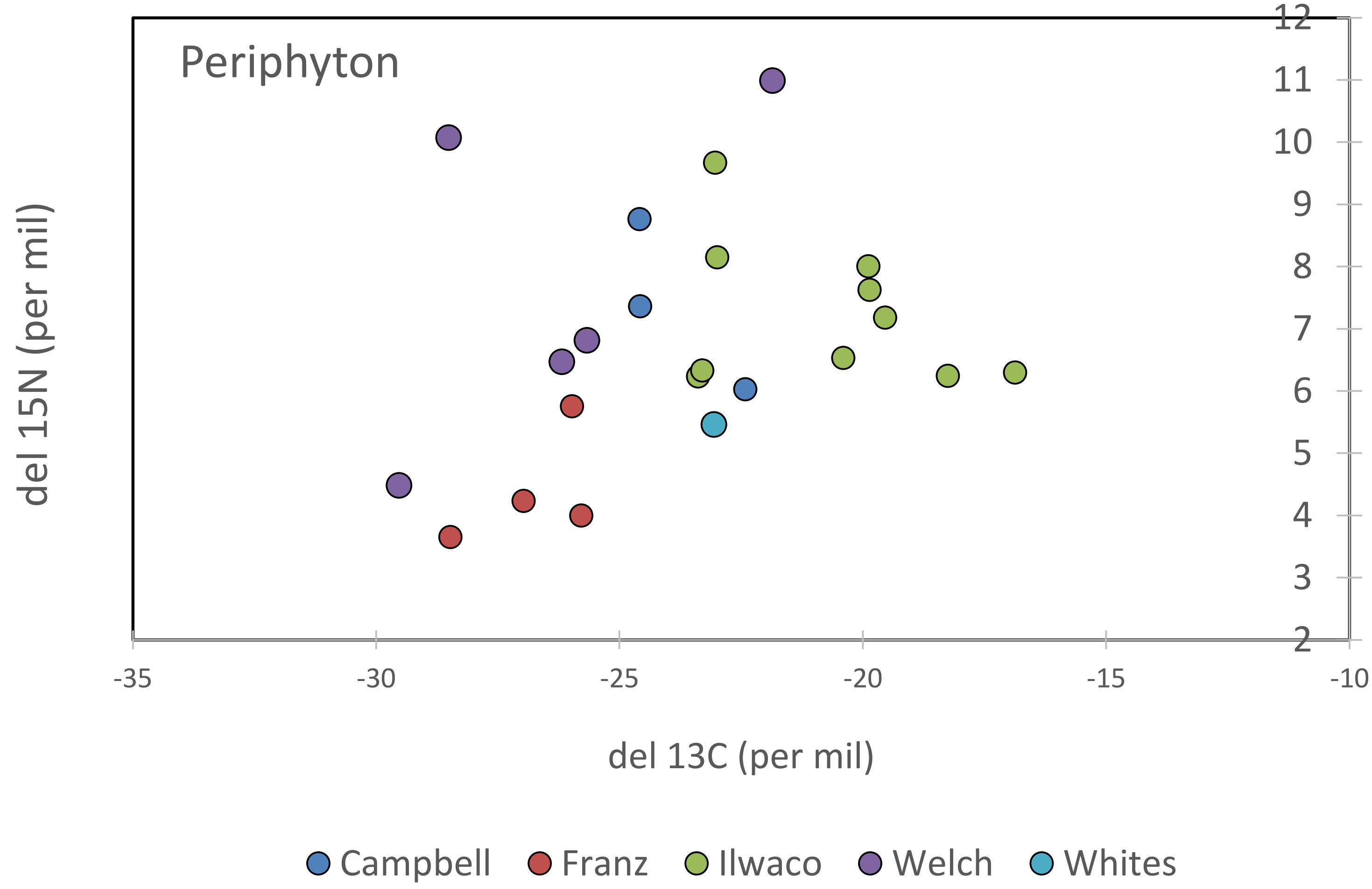


Isotopic signatures of primary producers in the Columbia River estuary

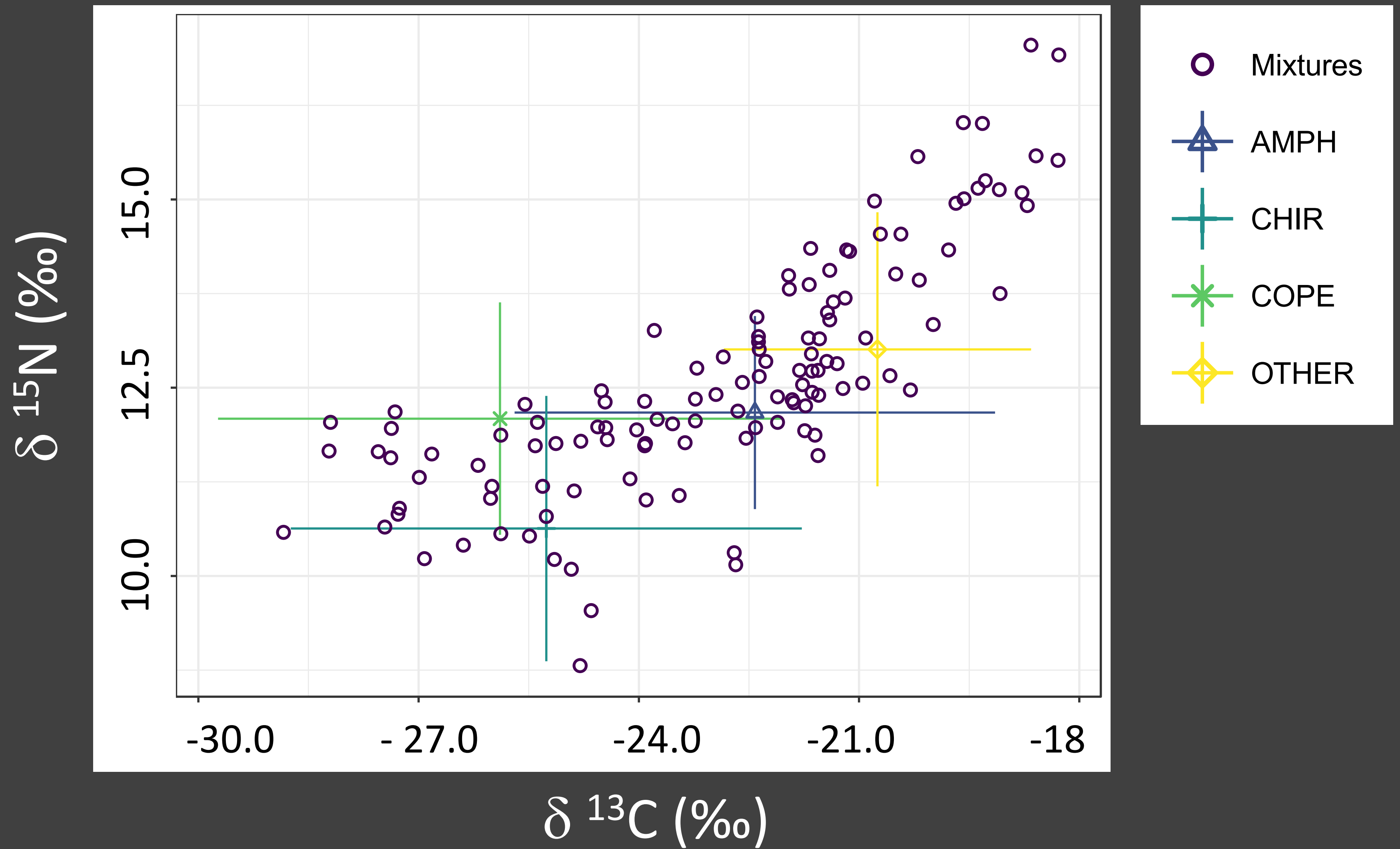


Isotopic signatures of primary producers (plants, periphyton, POM) in the Columbia River estuary




Periphyton
del 15N (per mil)
12
11
10
9
8
7
6
5
4
3
2
-35
-30
-25
-20
-15
-10
del 13C (per mil)
Campbell
Franz
Ilwaco
Welch
Whites

Isotopic signatures of juvenile Chinook & prey used to infer assimilation (SIMMR)



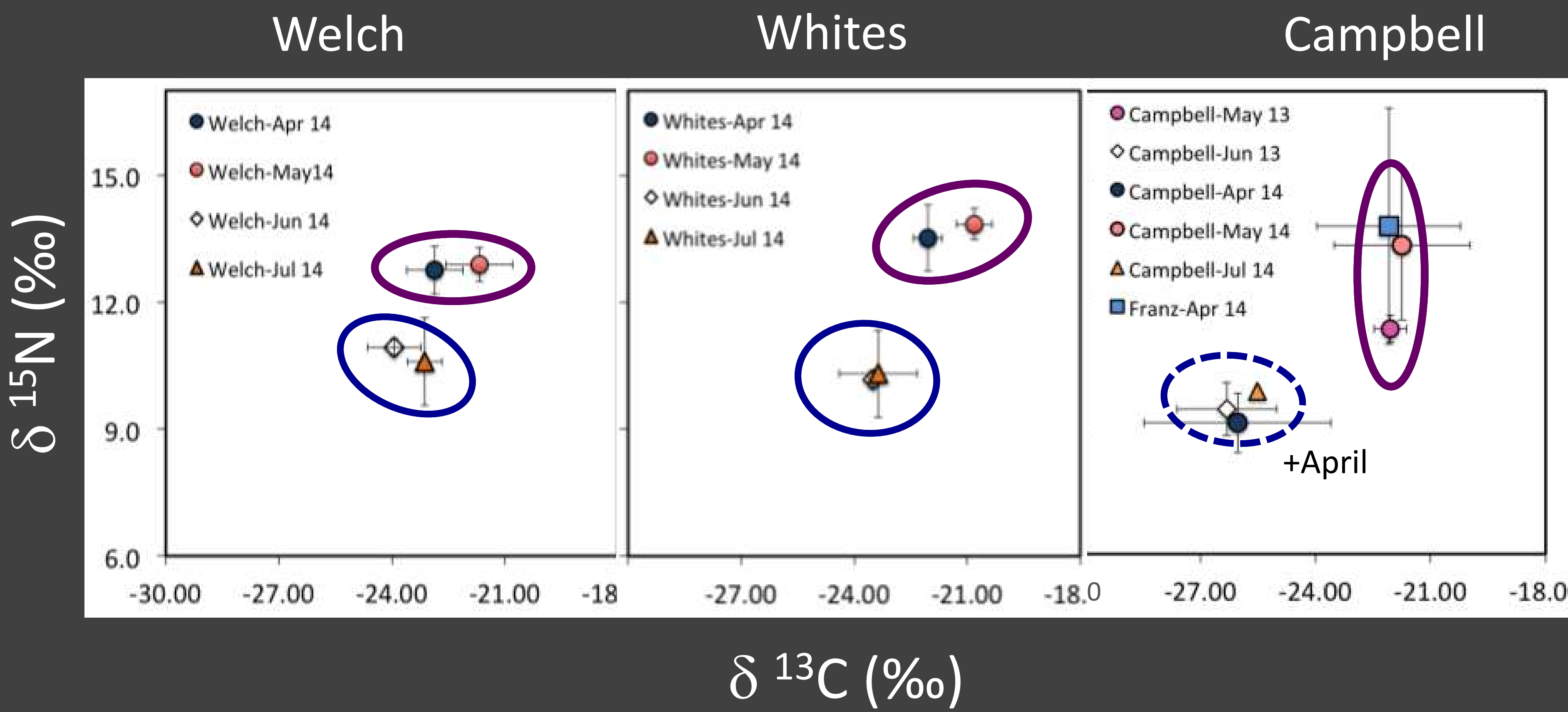
Summary of findings

- Stable isotopes of C and N varied in time, with differences likely tied to the hydrograph
- Prey: Amphipods & chironomids consume mainly POM and periphyton, respectively
- Diet: Model suggested that Juvenile Chinook salmon assimilate OM from invertebrates other than chironomids and amphipods
- Juvenile Chinook salmon tissues were isotopically heavier compared to measured sources
- Marked fish were heavier in C compared to unmarked fish

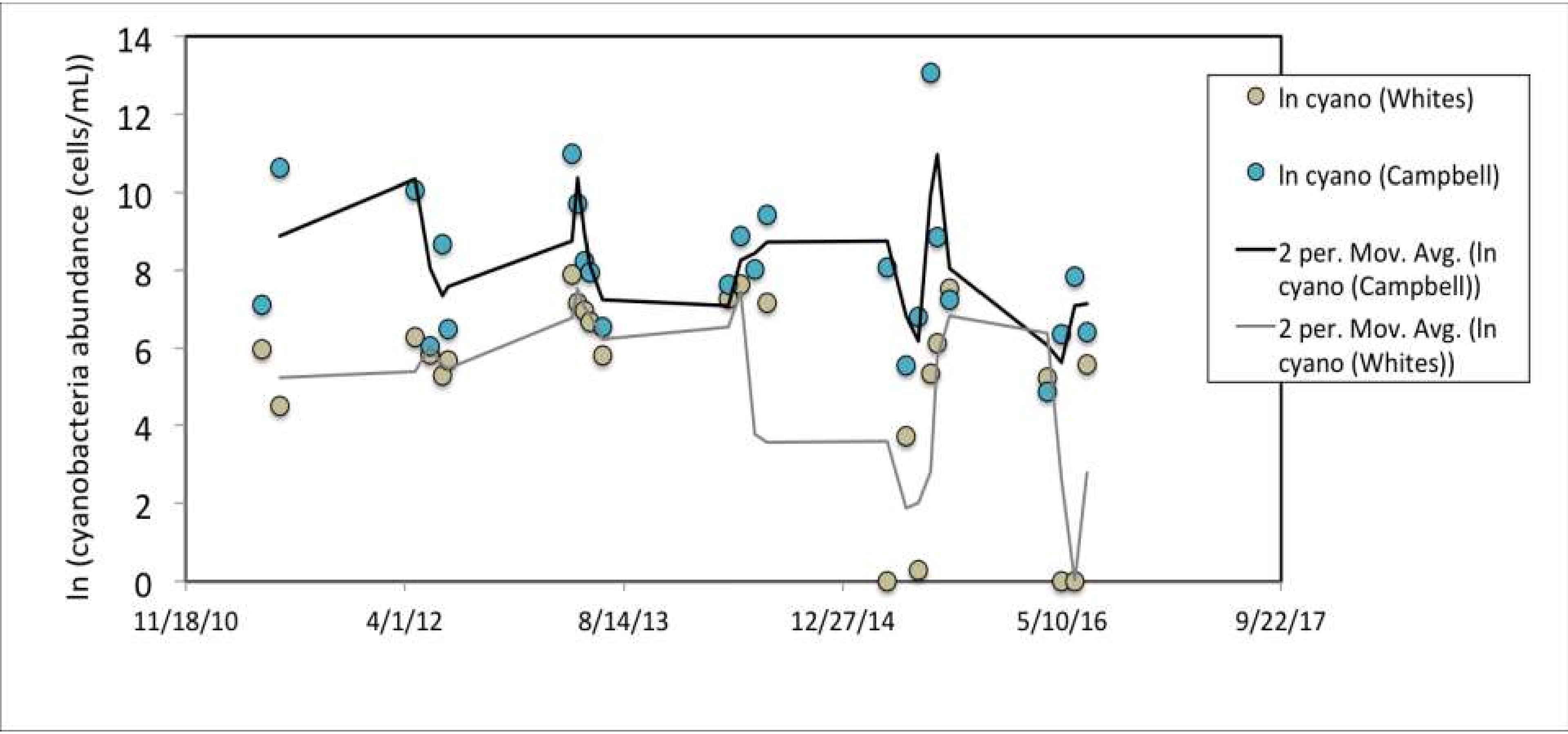
Juvenile Chinook liver

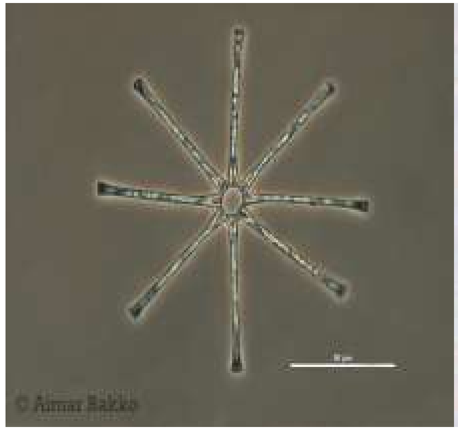
Isospace plots show

- Similarity between April & May
- Similarity between June & July

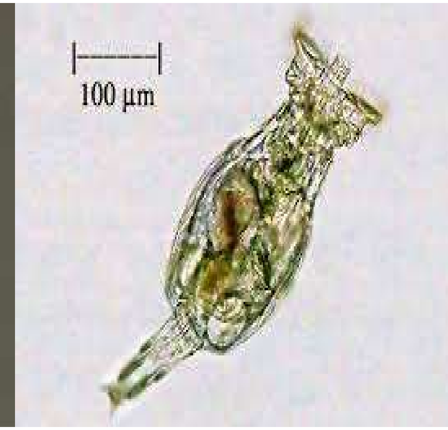


Total cyanobacteria densities tend to be higher at Campbell Slough than Whites Island





Typical diatom species that blooms in the spring

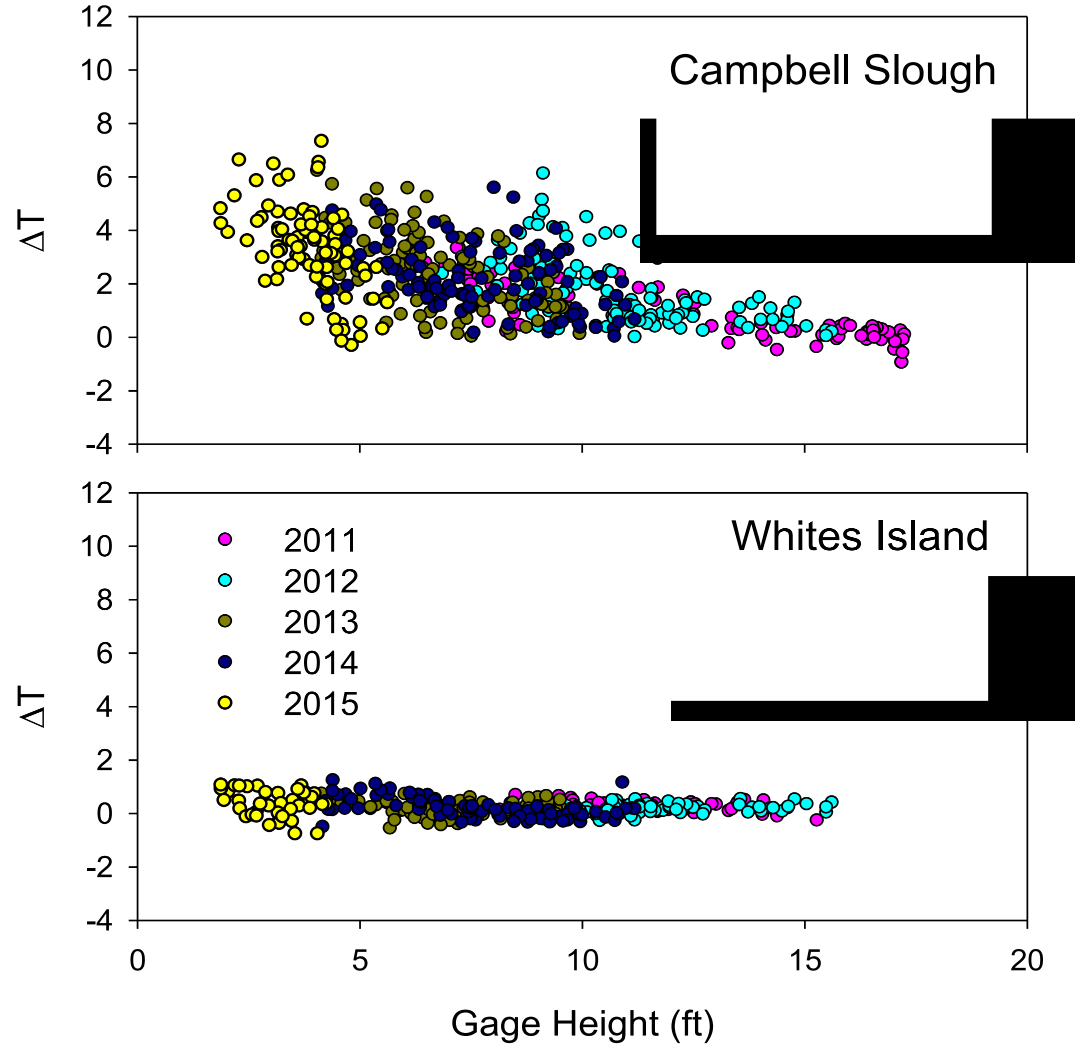


Typical rotifer grazer found in the spring

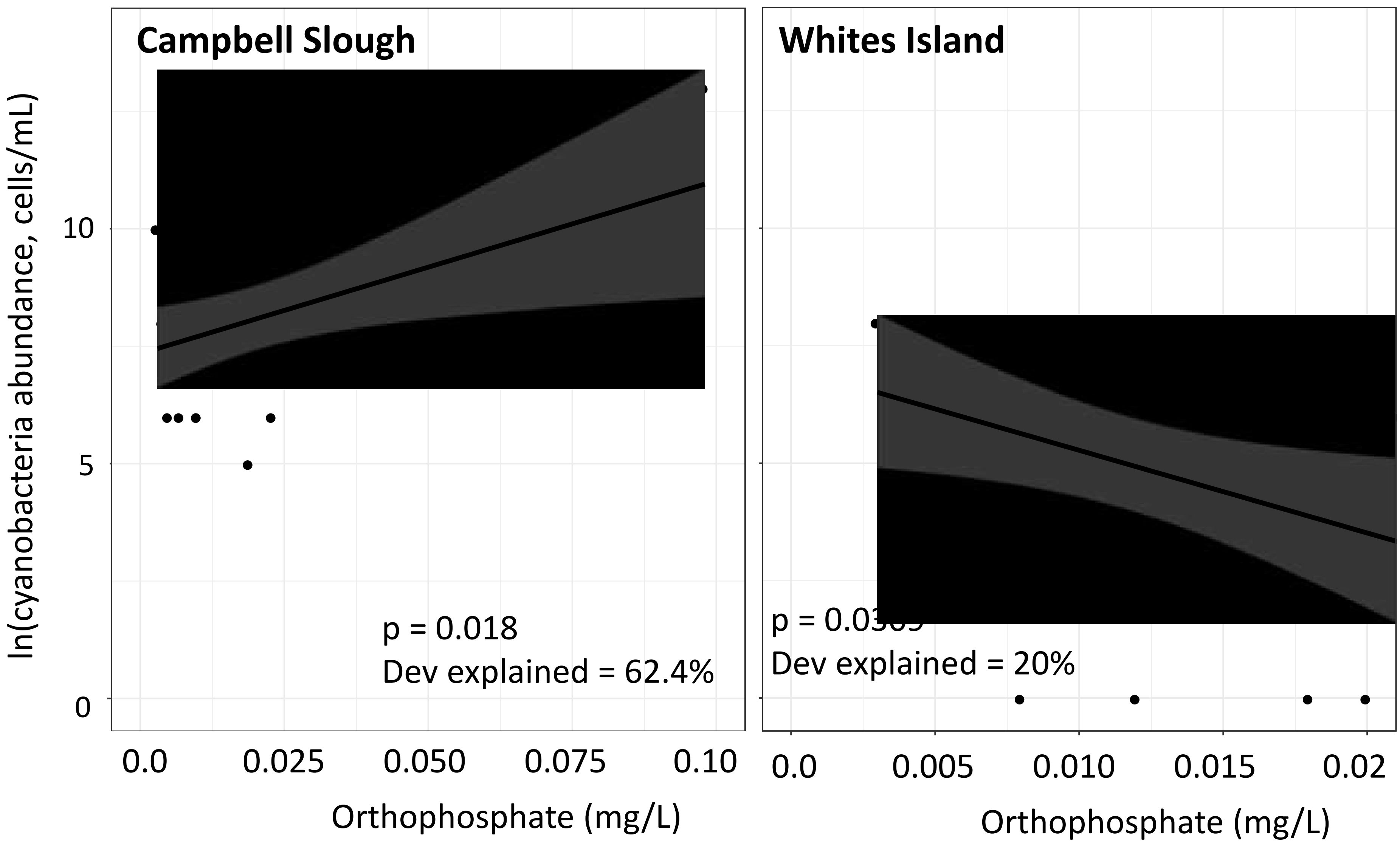
Large, colonial diatoms are too big for zooplankton to consume, and are therefore they are exported and lost to the ecosystem.

As water levels drop, Campbell Slough diverges from mainstem conditions more than Whites Island

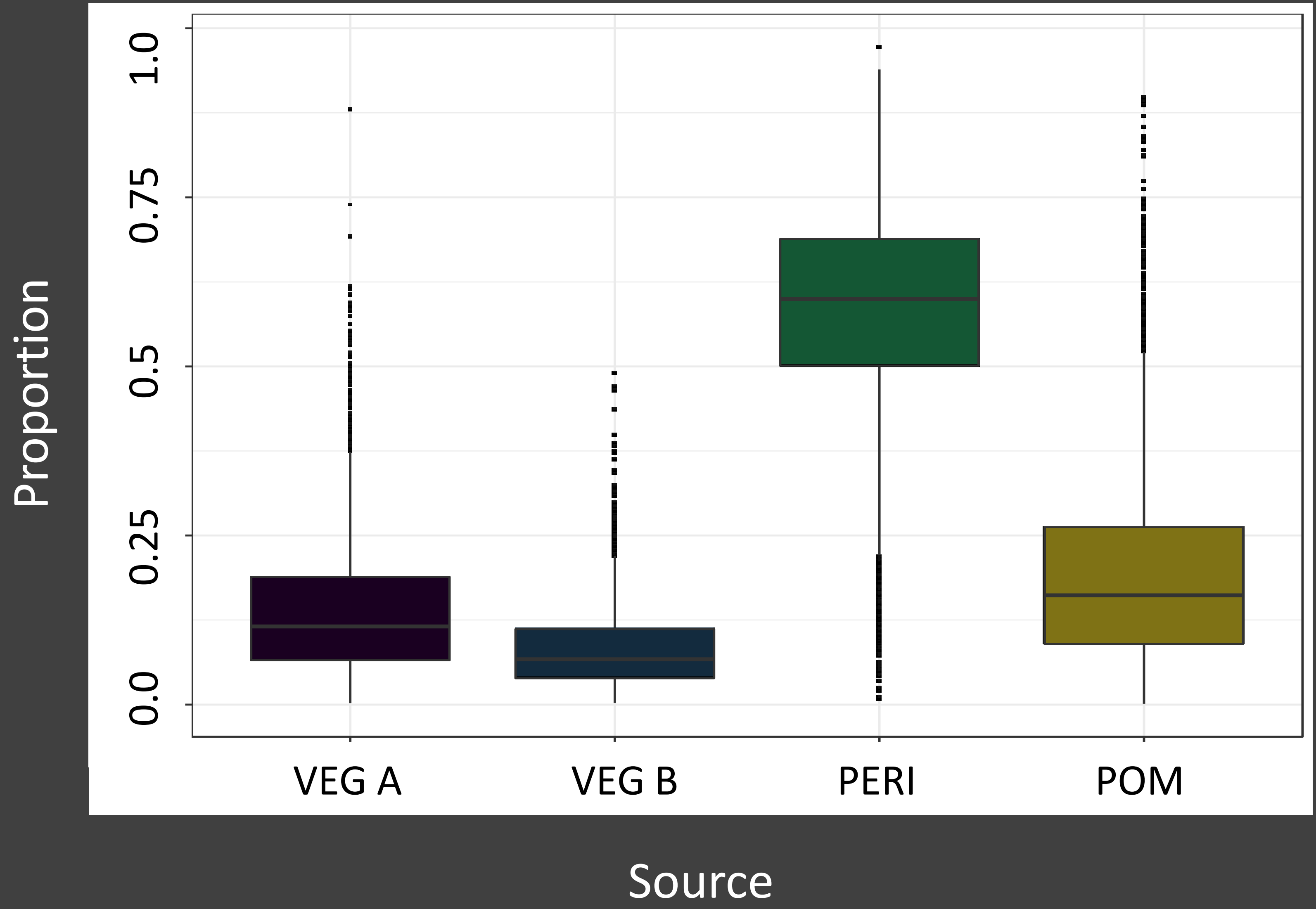
ΔT is the difference in temperature between the off-channel site and the mainstem, as measured by continuous, in situ sensors



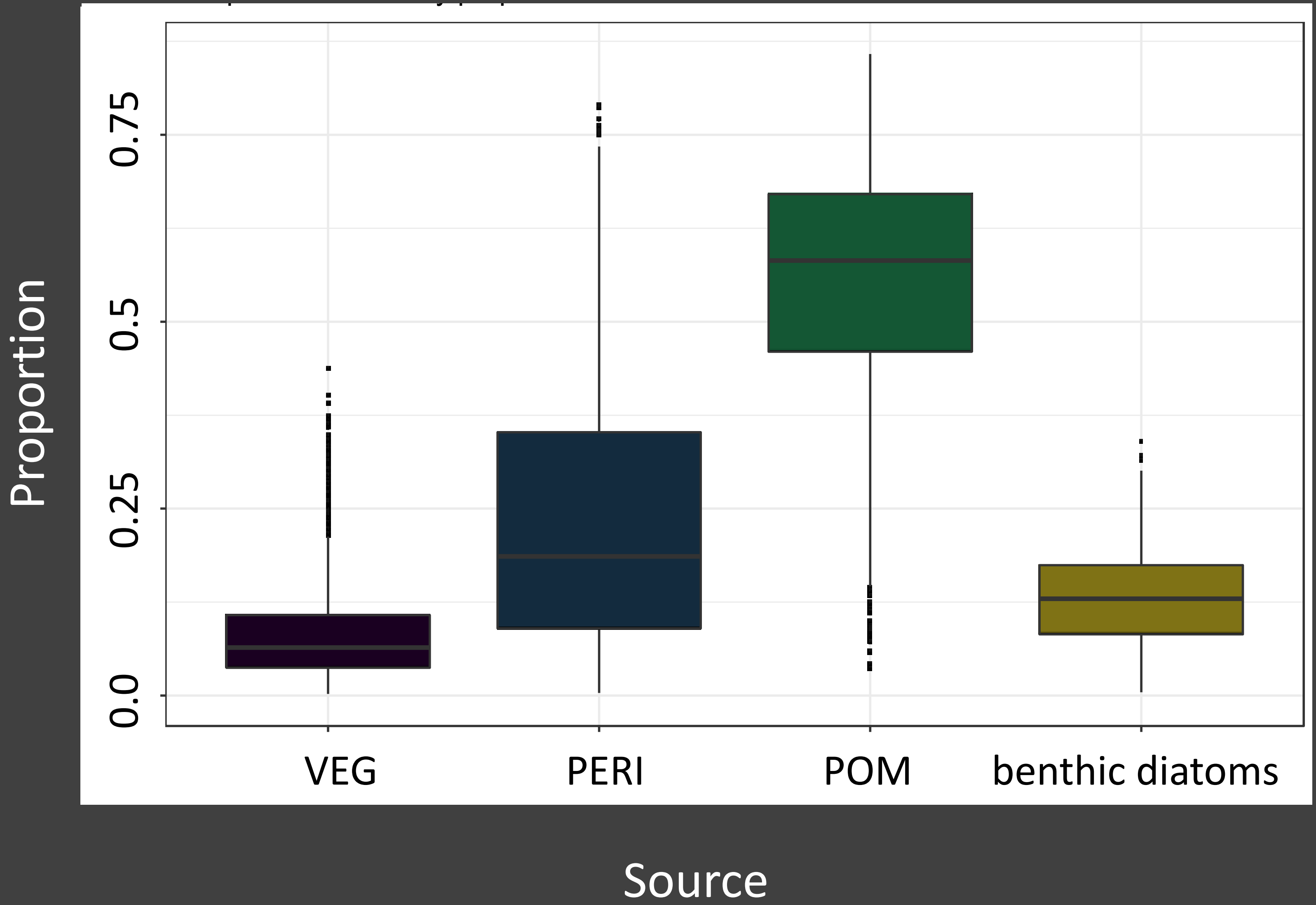
Phosphate concentrations predict cyanobacteria abundance, particularly at Campbell Slough



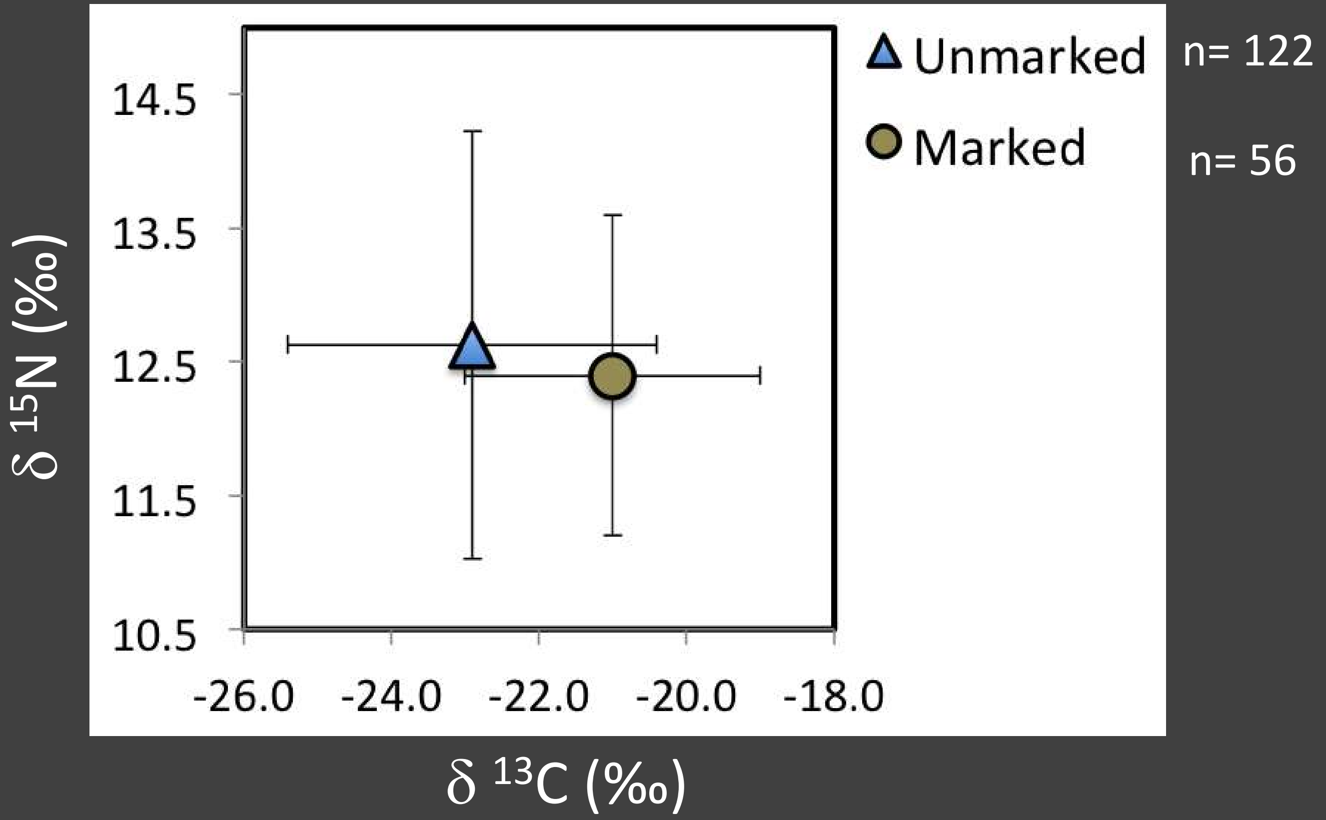
Based on mixing model results, chironomids assimilate organic matter from periphyton



Based on mixing model results, amphipods mainly assimilate particulate matter

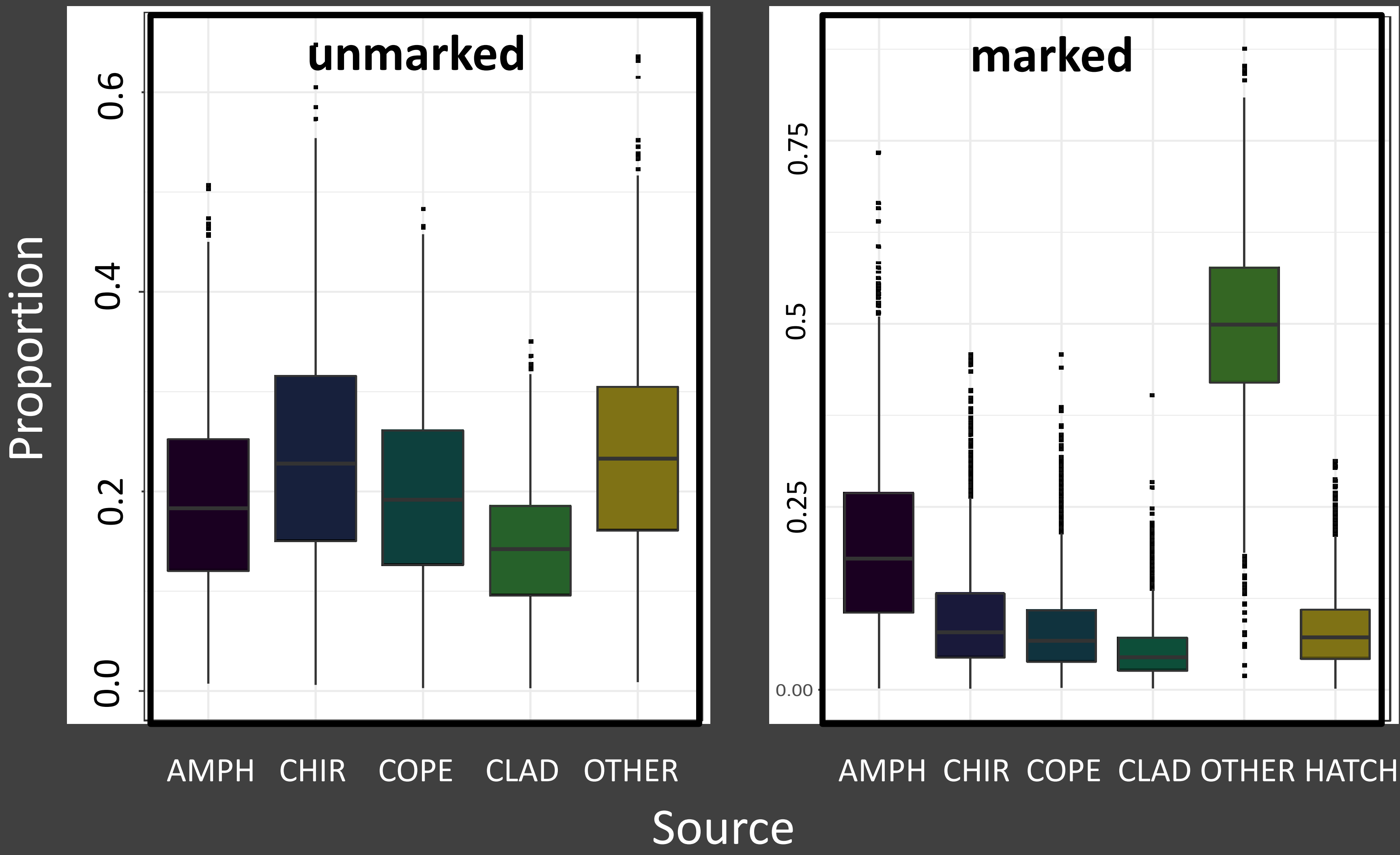


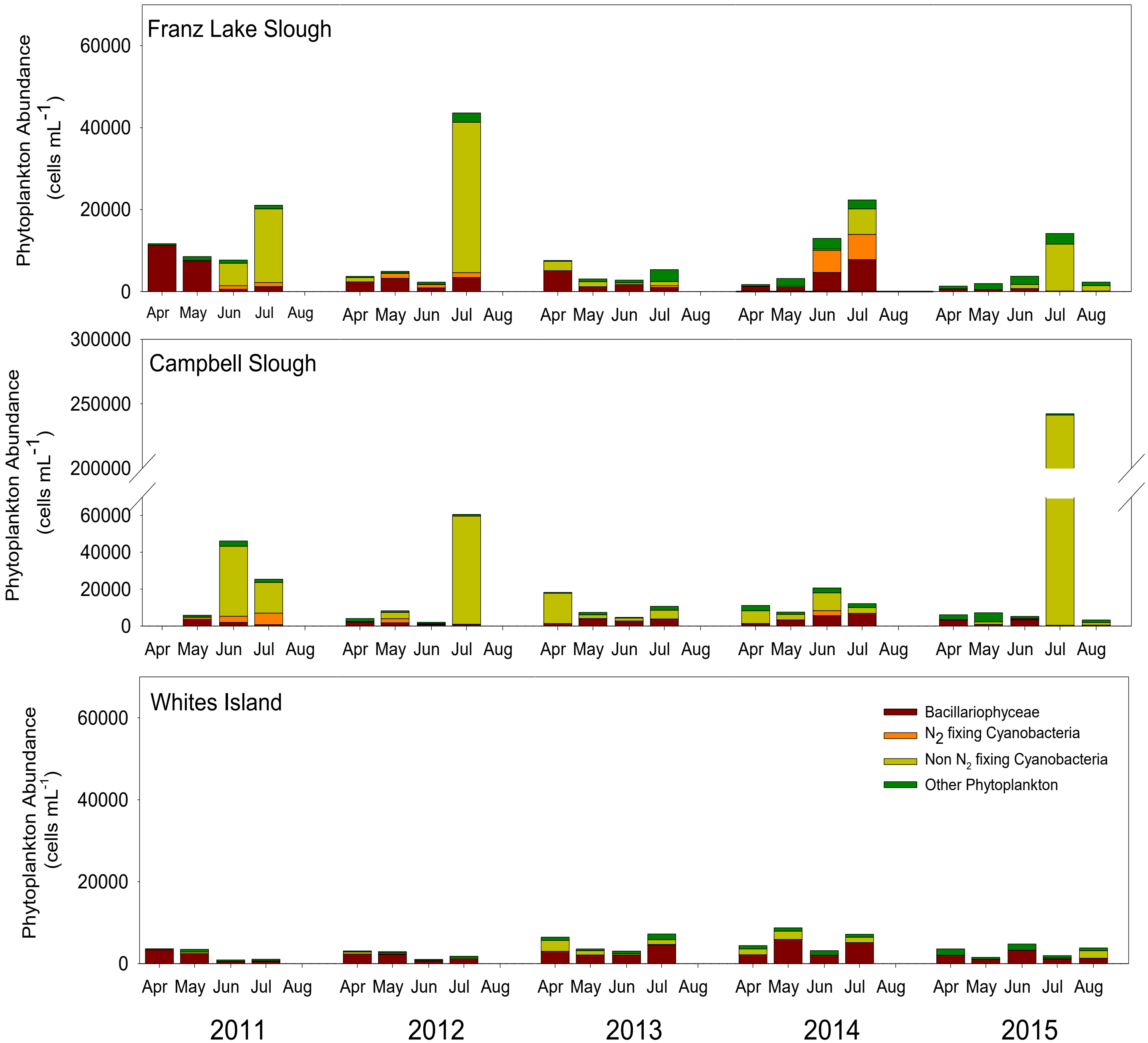
Stable isotope signatures of marked fish differ from unmarked fish



- δ^{13}C was significantly more depleted in unmarked fish compared to marked fish ($p < 0.0001$)
- There was no difference in δ^{15}N ($p = 0.4057$)

Dietary proportions in unmarked vs. marked juvenile Chinook salmon (SIMMR)




Franz Lake Slough
Campbell Slough
Whites Island
Phytoplankton Abundance (cells mL^{-1})
60000
40000
20000
0
300000
250000
200000
Apr May Jun Jul Aug
Bacillariophyceae
N_2 fixing Cyanobacteria
Non N_2 fixing Cyanobacteria
Other Phytoplankton
2011
2012
2013
2014
2015

- Ecosystem metabolism
- pH
- Food quantity
- Food quality
- Energy flow

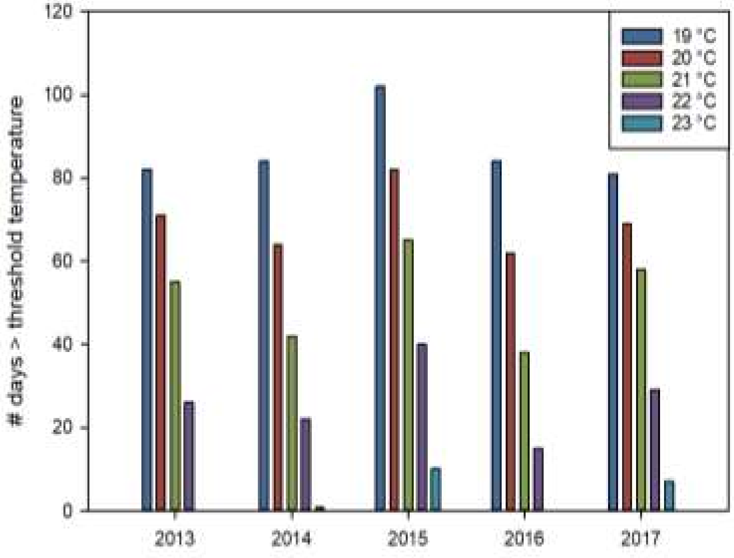
Link between phytoplankton and salmon

- Fish catches and satellite chlorophyll paper

Link between benthos and pelagic habitat

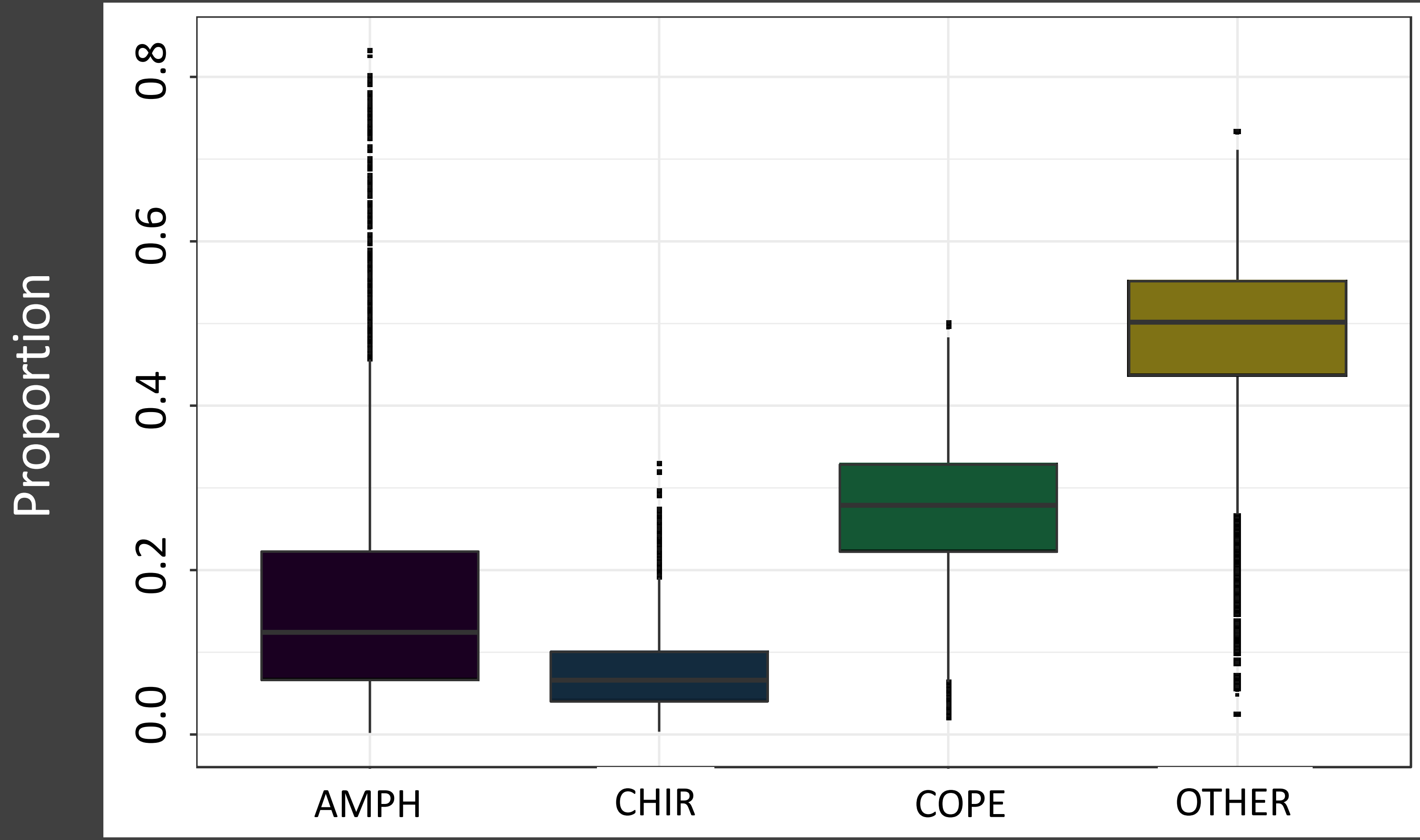
Cyanobacteria: an emerging threat

Parasites



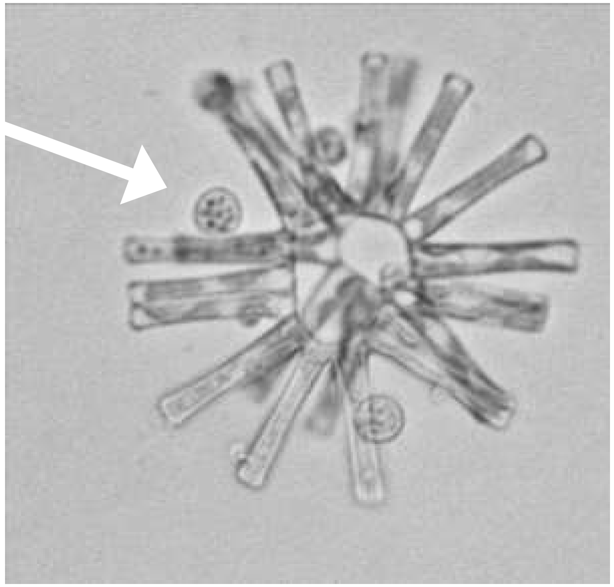
120
100
80
60
40
20
0
days > threshold temperature
19 °C
20 °C
21 °C
22 °C
23 °C
2013
2014
2015
2016
2017

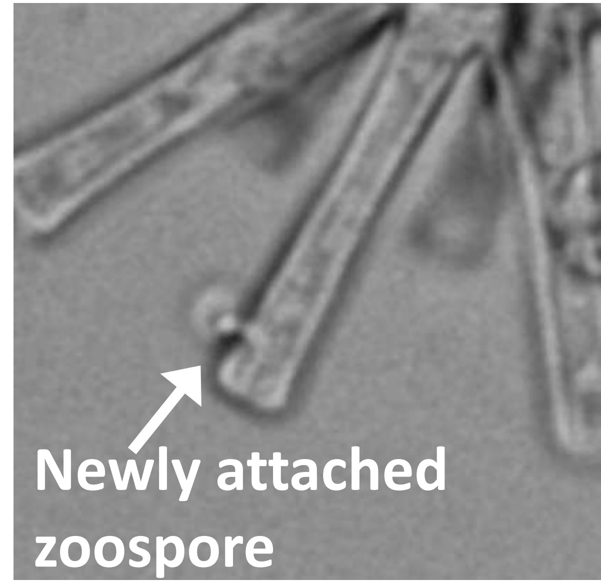
Comparison of dietary proportions in unmarked juvenile Chinook muscle (SIMMR)



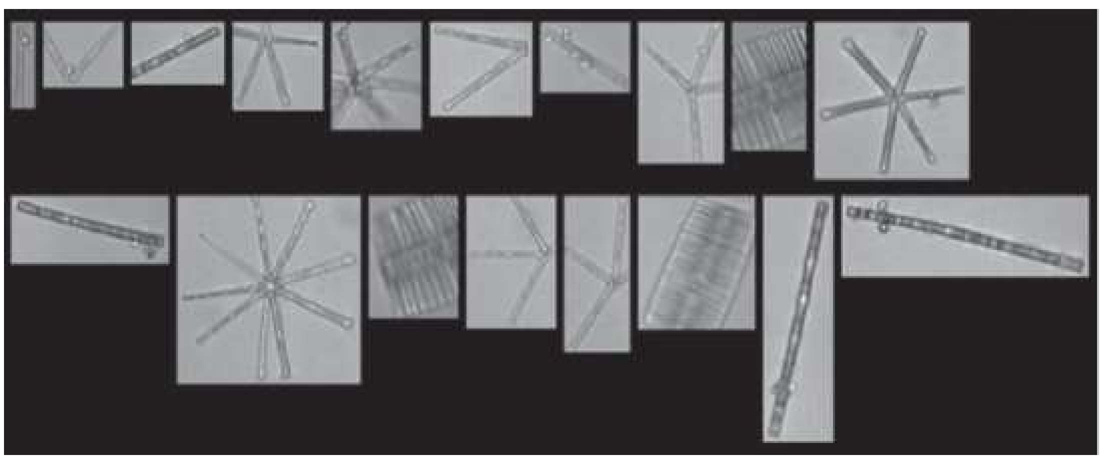
n = 122

Developed sporangium

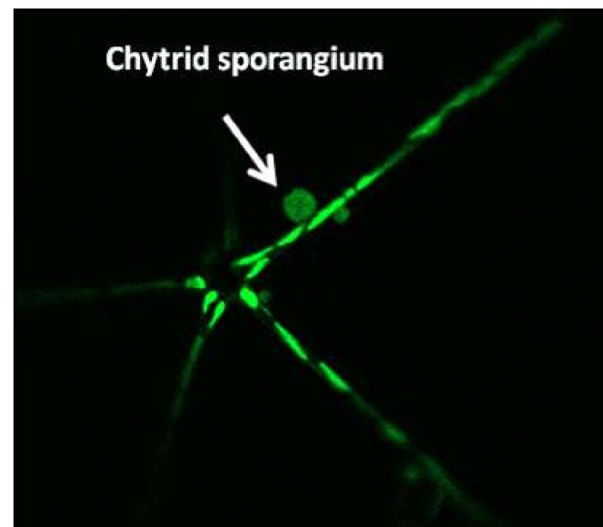




LIGHT MICROSCOPY

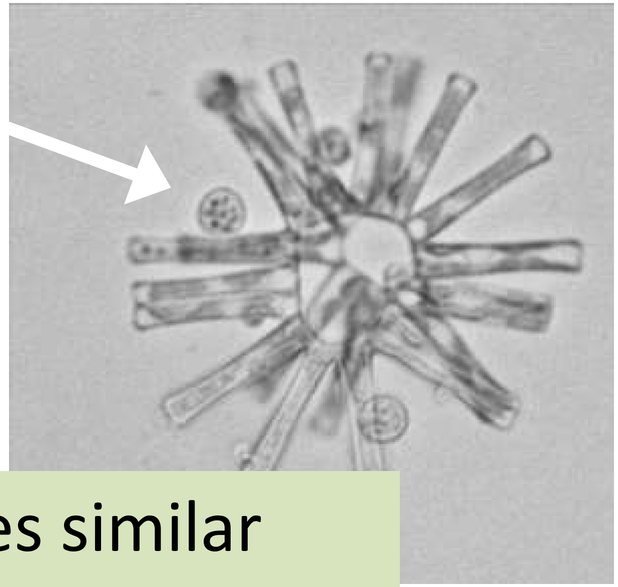


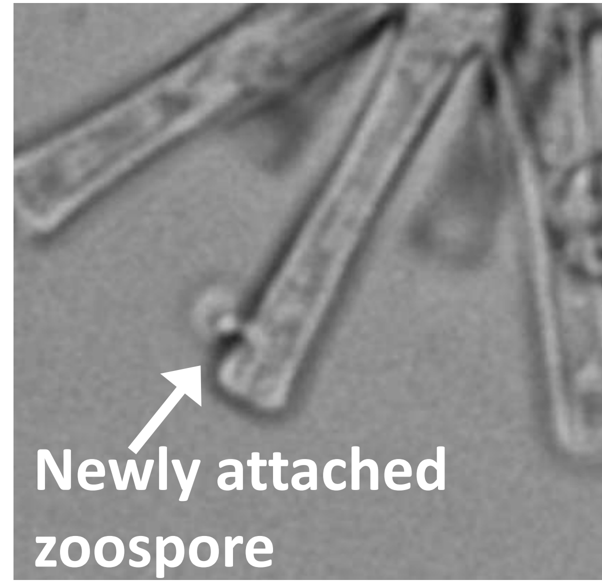
IMAGING FLOW CYTOMETRY



FLUORESCENCE MICROSCOPY

Maier & Peterson, 2014



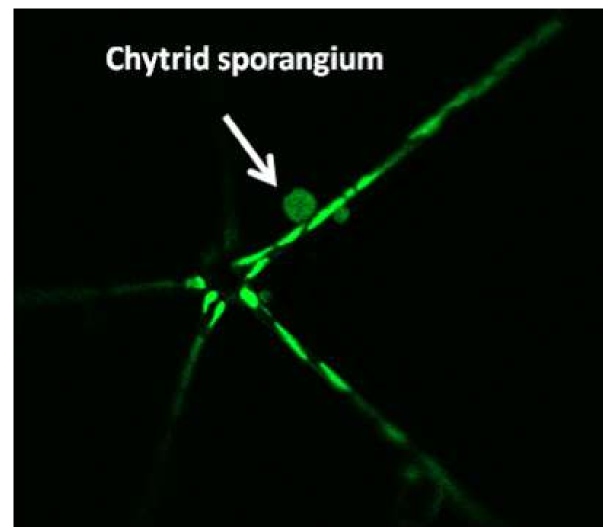


Average I_p values similar between mainstem(10%) and off-channel sites (14%)

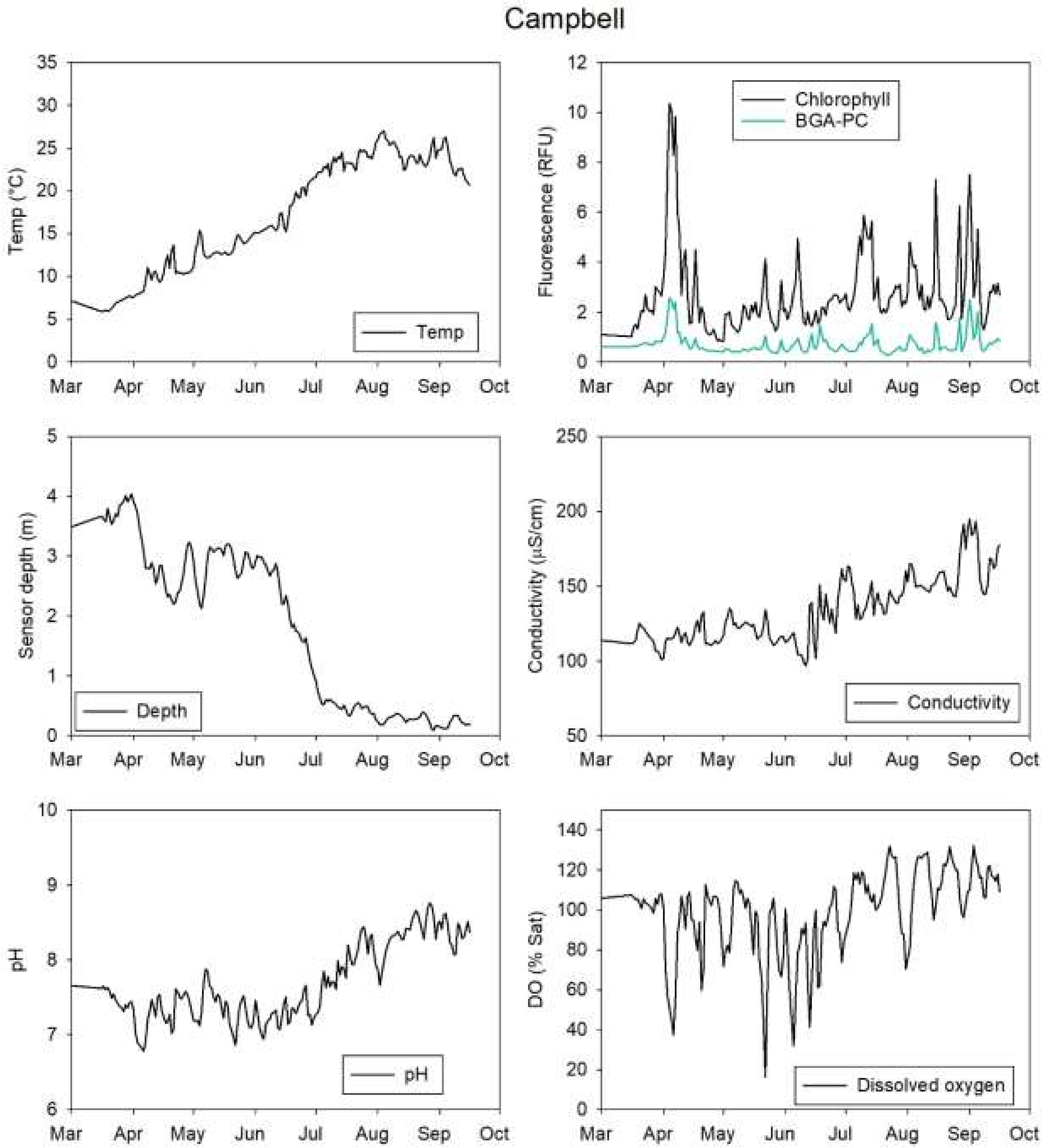
(Maier & Peterson, 2014; Cook & Peterson, 2018)

LIGHT MICROSCOPY

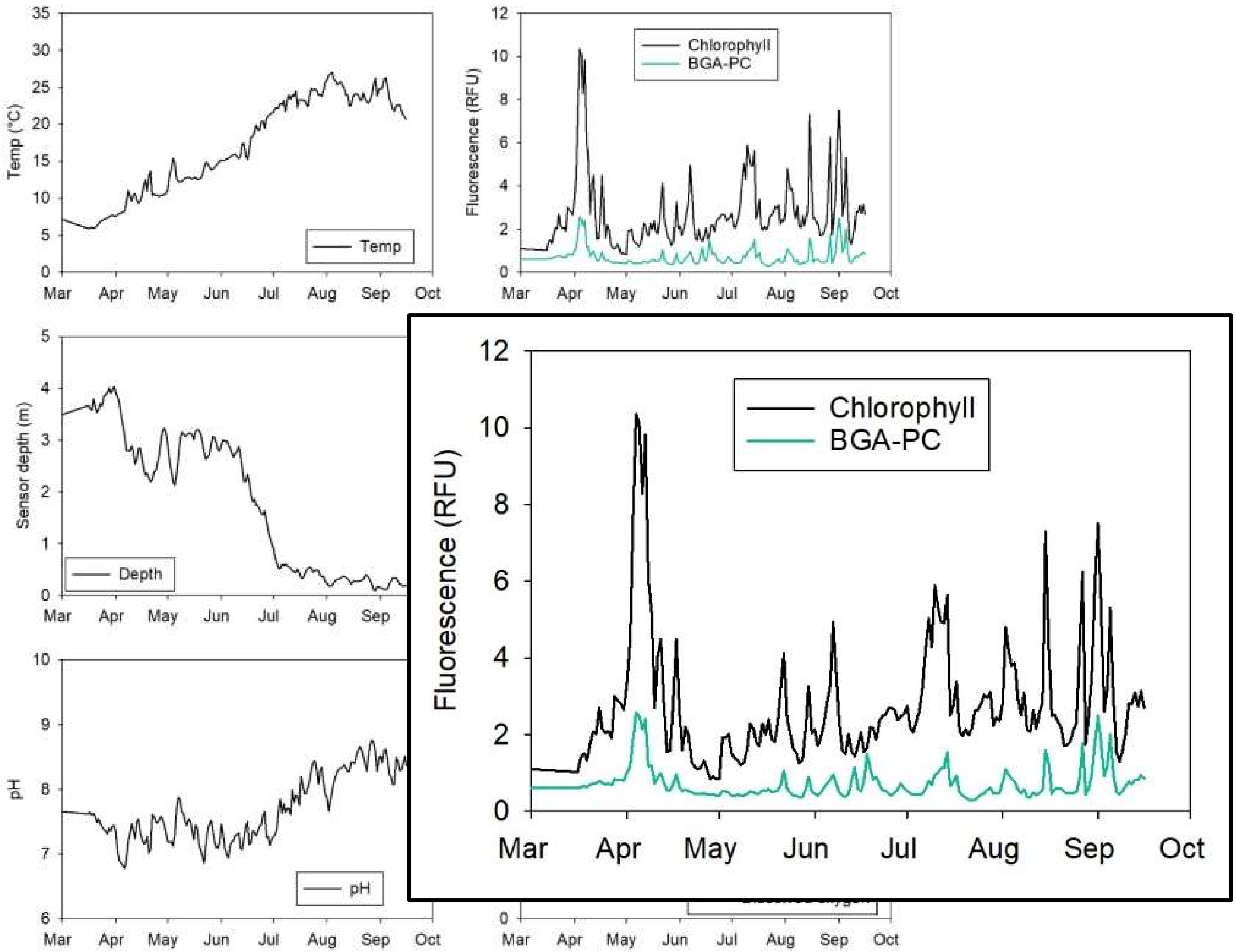
IMAGING FLOW CYTOMETRY



FLUORESCENCE MICROSCOPY


Campbell
Temp (°C)
Temp
Fluorescence (RFU)
Chlorophyll
BGA-PC
Sensor depth (m)
Depth
Conductivity (µS/cm)
Conductivity
pH
pH
DO (% Sat)
Dissolved oxygen
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct

Campbell


Temp (°C)
Temp
Fluorescence (RFU)
Chlorophyll
BGA-PC
Sensor depth (m)
Depth
pH
pH
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct