Investigating the diet of juvenile Chinook salmon using stable isotopes

Tawnya D. Peterson & Joseph A. Needoba

Oregon Health & Science University

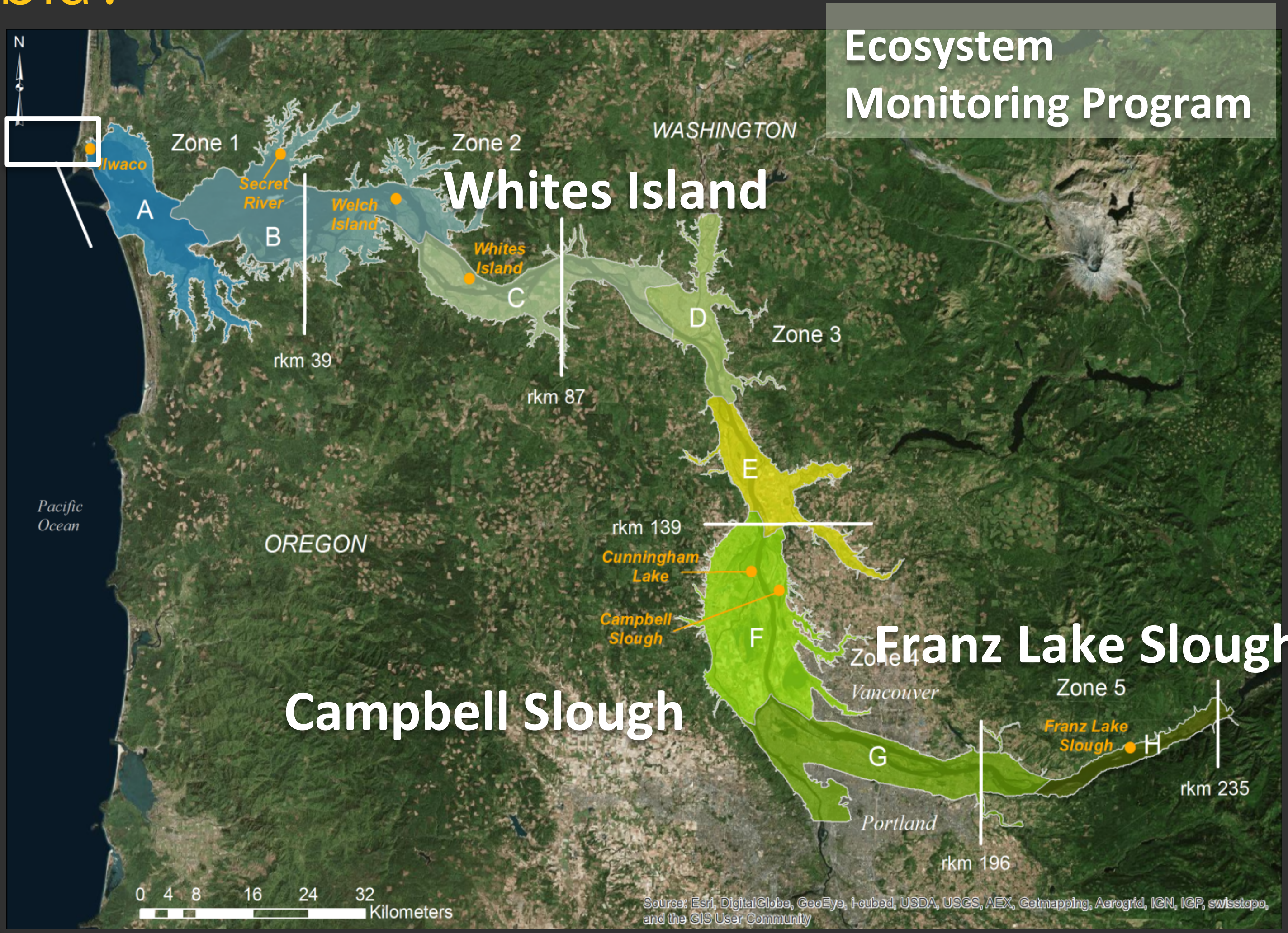
School of Public Health

A component of the Lower Columbia Estuary Partnership's Ecosystem Monitoring Program

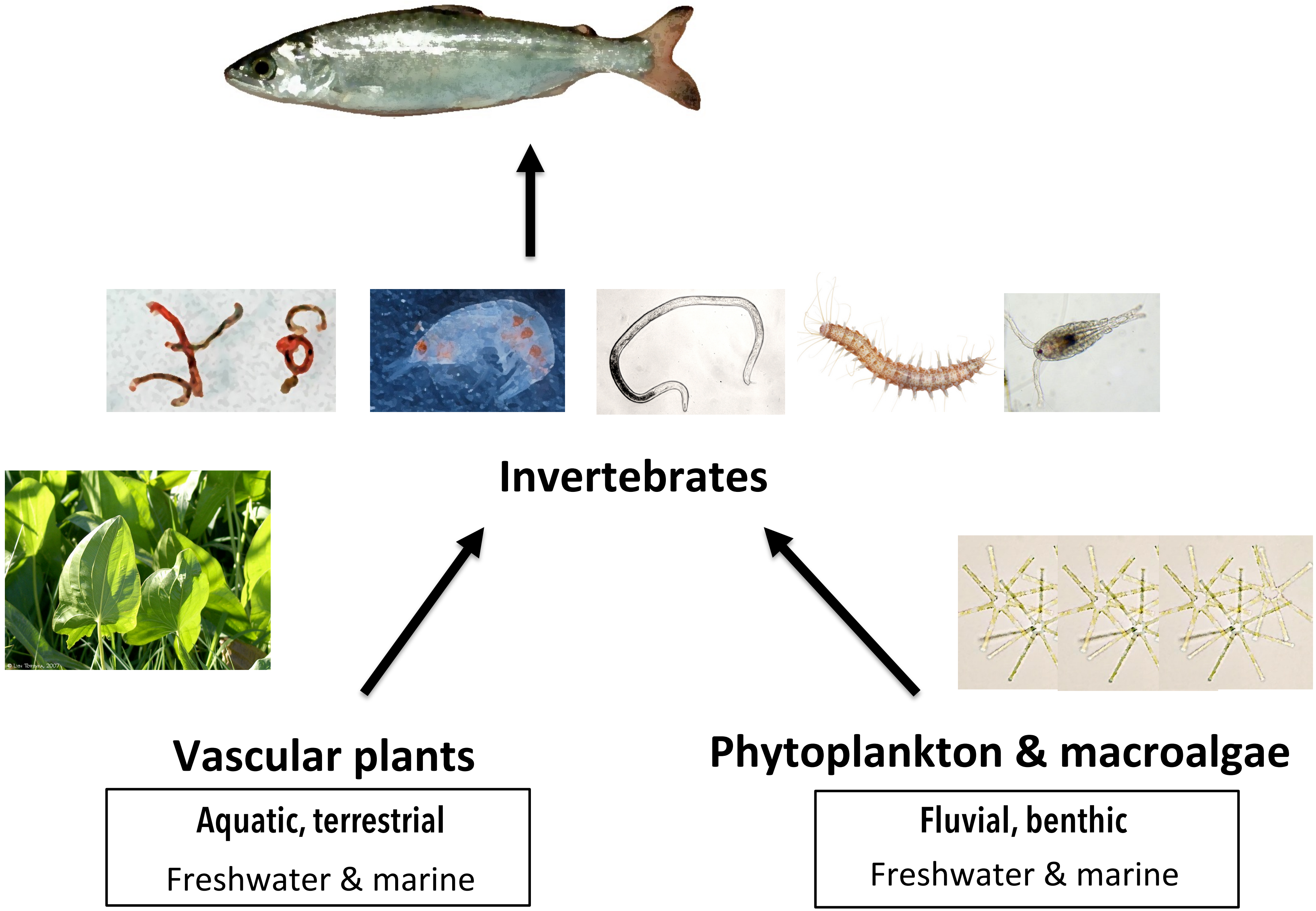
What are juvenile salmon eating?

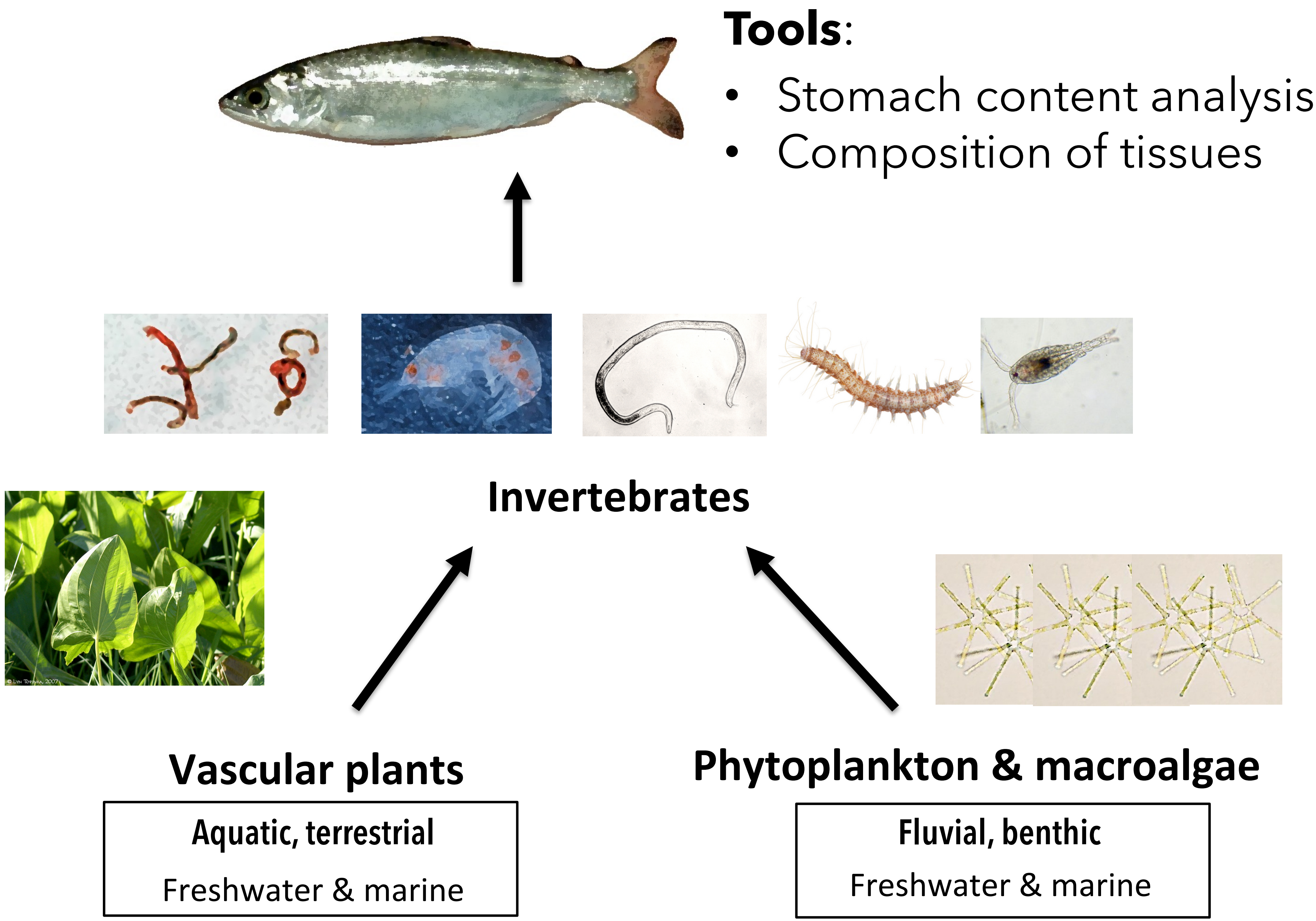
- **What is the on the menu?**
- **What are they consuming and assimilating?**

What are juvenile Chinook eating in the lower Columbia?



Increasing tidal influence

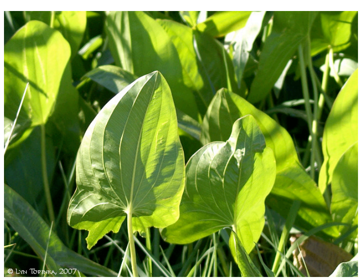

Invertebrates
Vascular plants
Aquatic, terrestrial
Freshwater & marine
Phytoplankton & macroalgae
Fluvial, benthic
Freshwater & marine


Tools:
• Stomach content analysis
• Composition of tissues
Invertebrates
Vascular plants
Aquatic, terrestrial
Freshwater & marine
Phytoplankton & macroalgae
Fluvial, benthic
Freshwater & marine

Tools:

- Stomach content analysis
  - Recent consumption
- Composition of tissues
  - Longer integration times

Invertebrates



Vascular plants

Aquatic, terrestrial
Freshwater & marine

Phytoplankton & macroalgae

Fluvial, benthic
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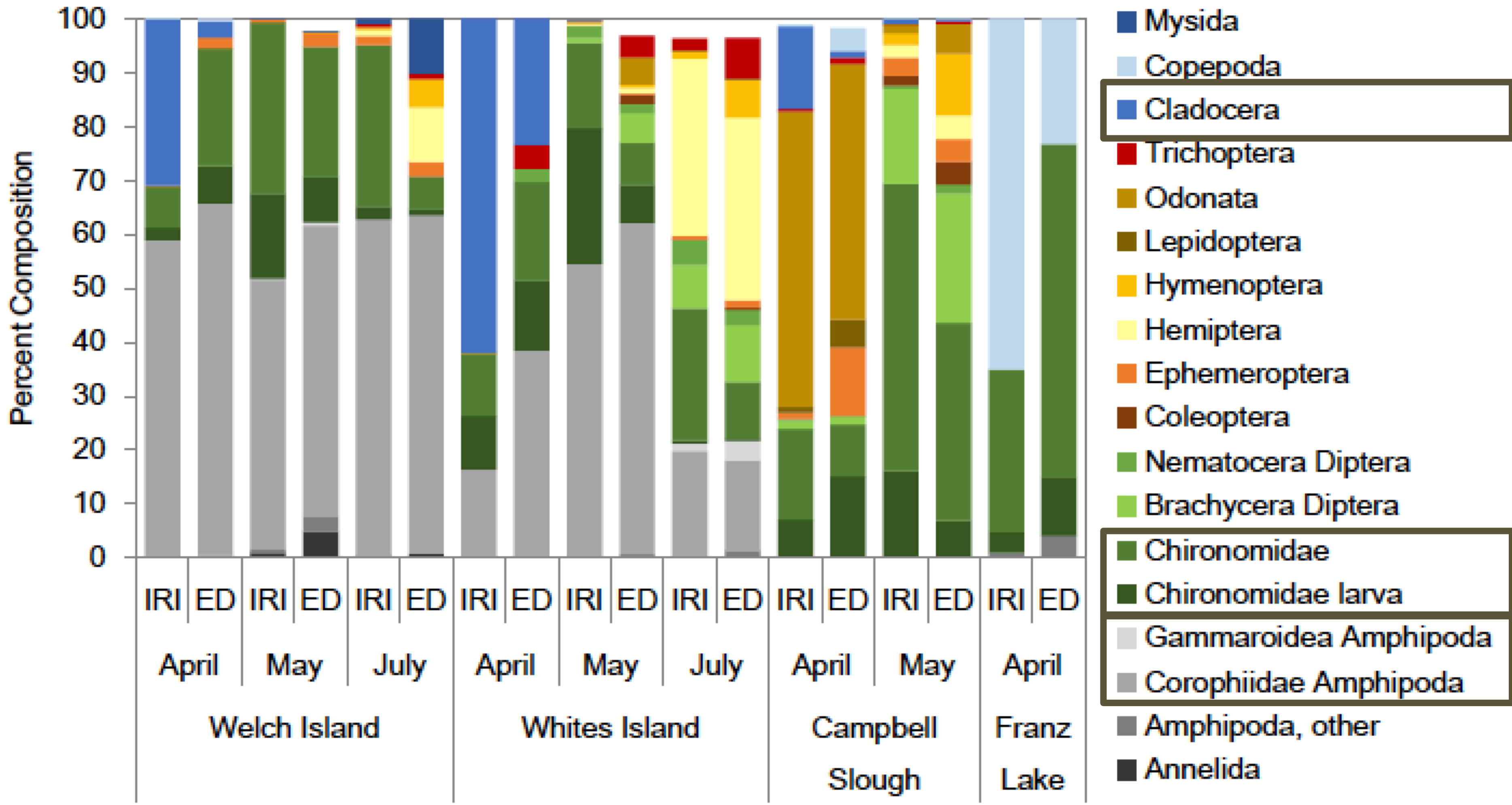
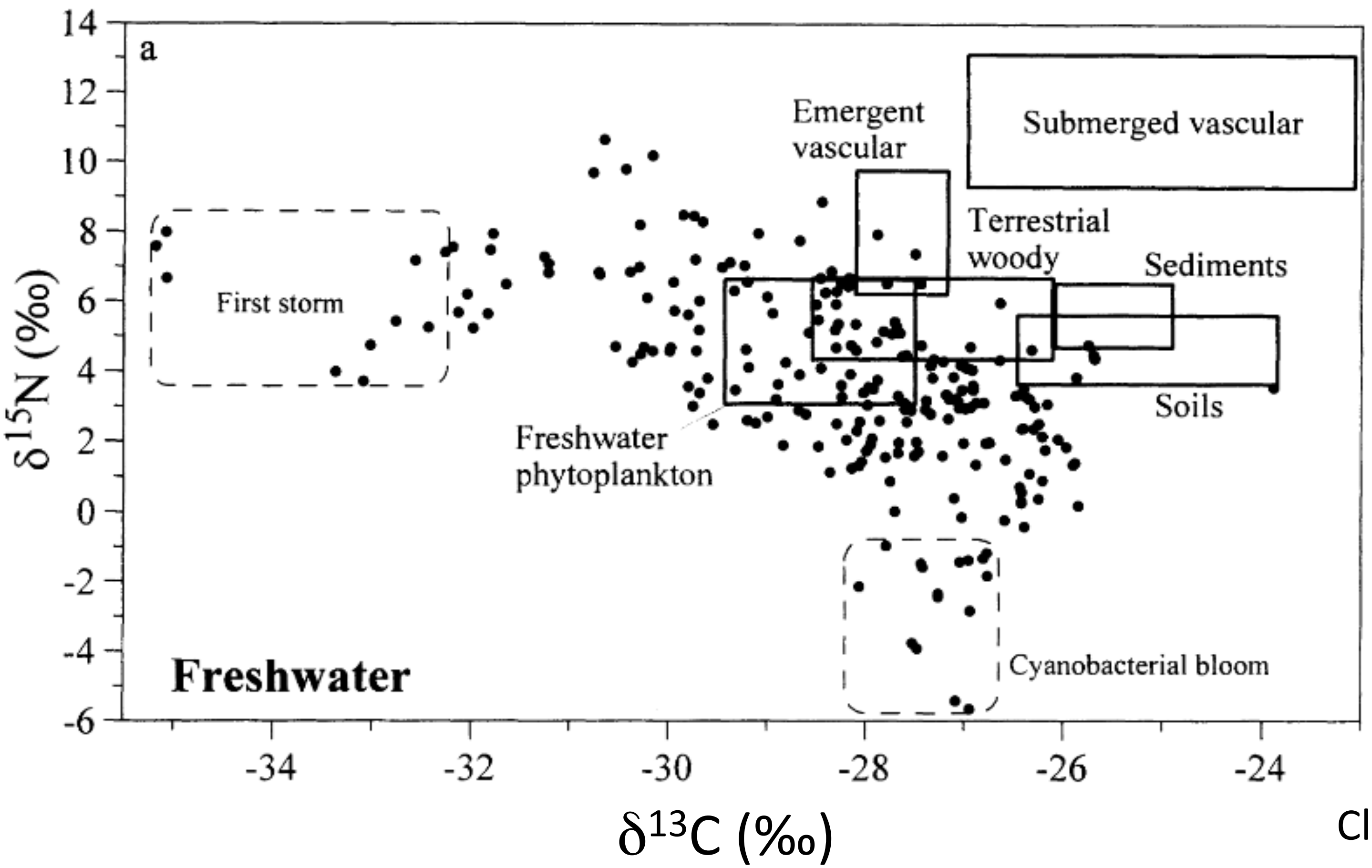
Composition of consumed prey



Ramirez & Cordell, in Hanson et al., 2016

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

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

- 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

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

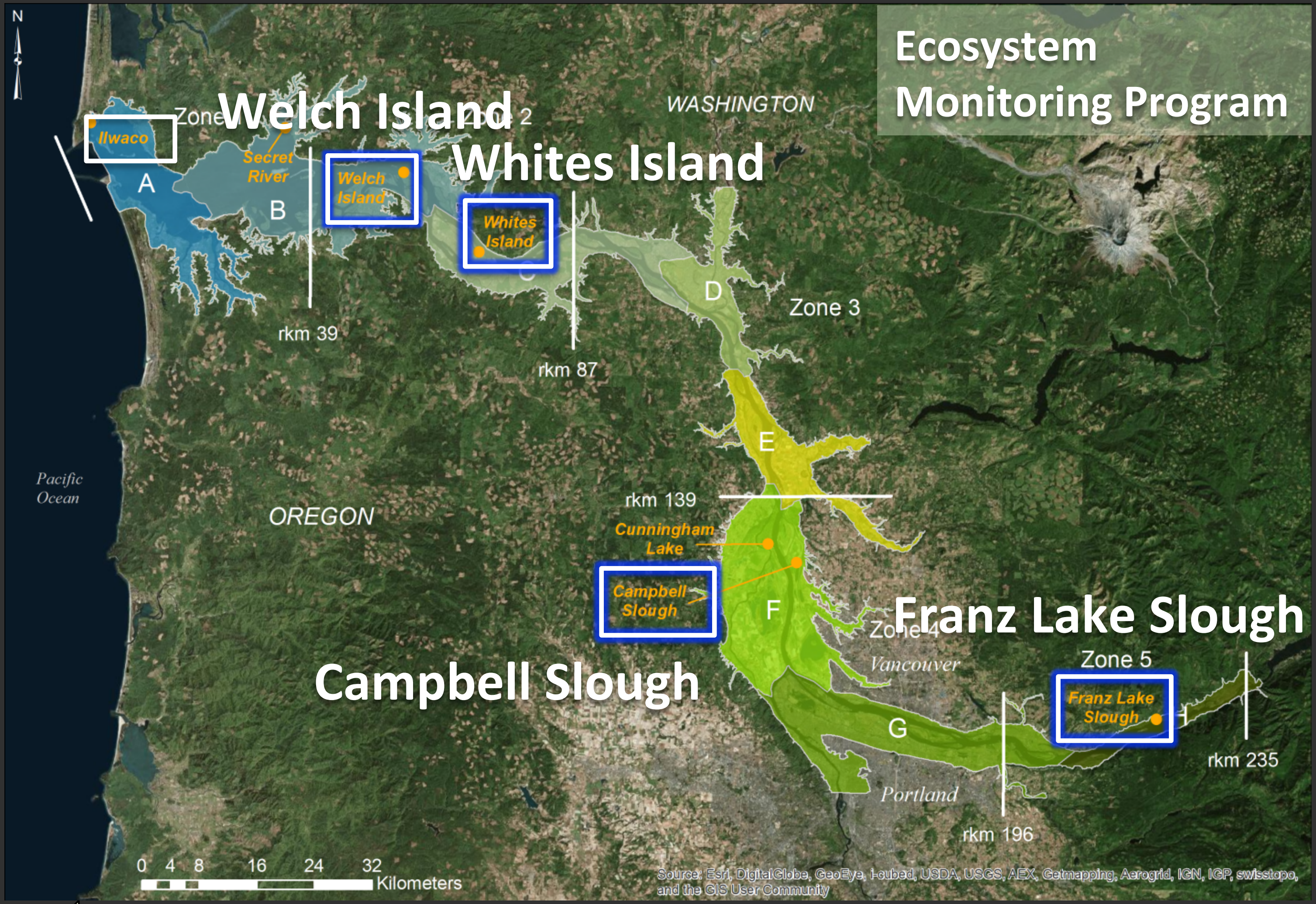
Questions

- 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

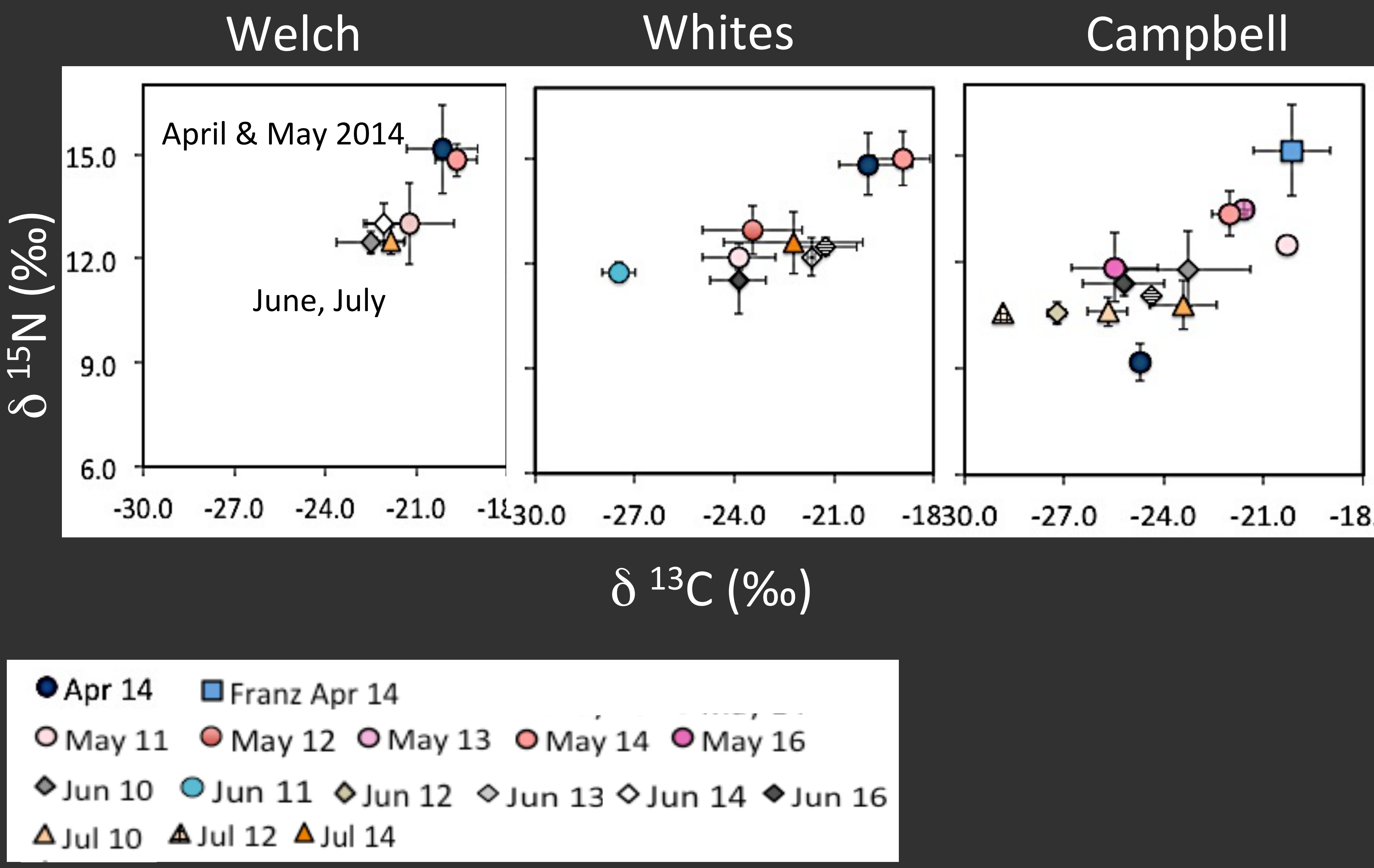
- Samples
  - Juvenile Chinook salmon muscle (and some livers)
- Food sources
  - Invertebrates (amphipods, chironomids, nematodes, polychaetes, oligochaetes, copepods, cladocerans, etc.)
  - Primary producers (live & dead vegetation, periphyton, particulate organic matter)

Sites where juvenile Chinook salmon and prey were caught

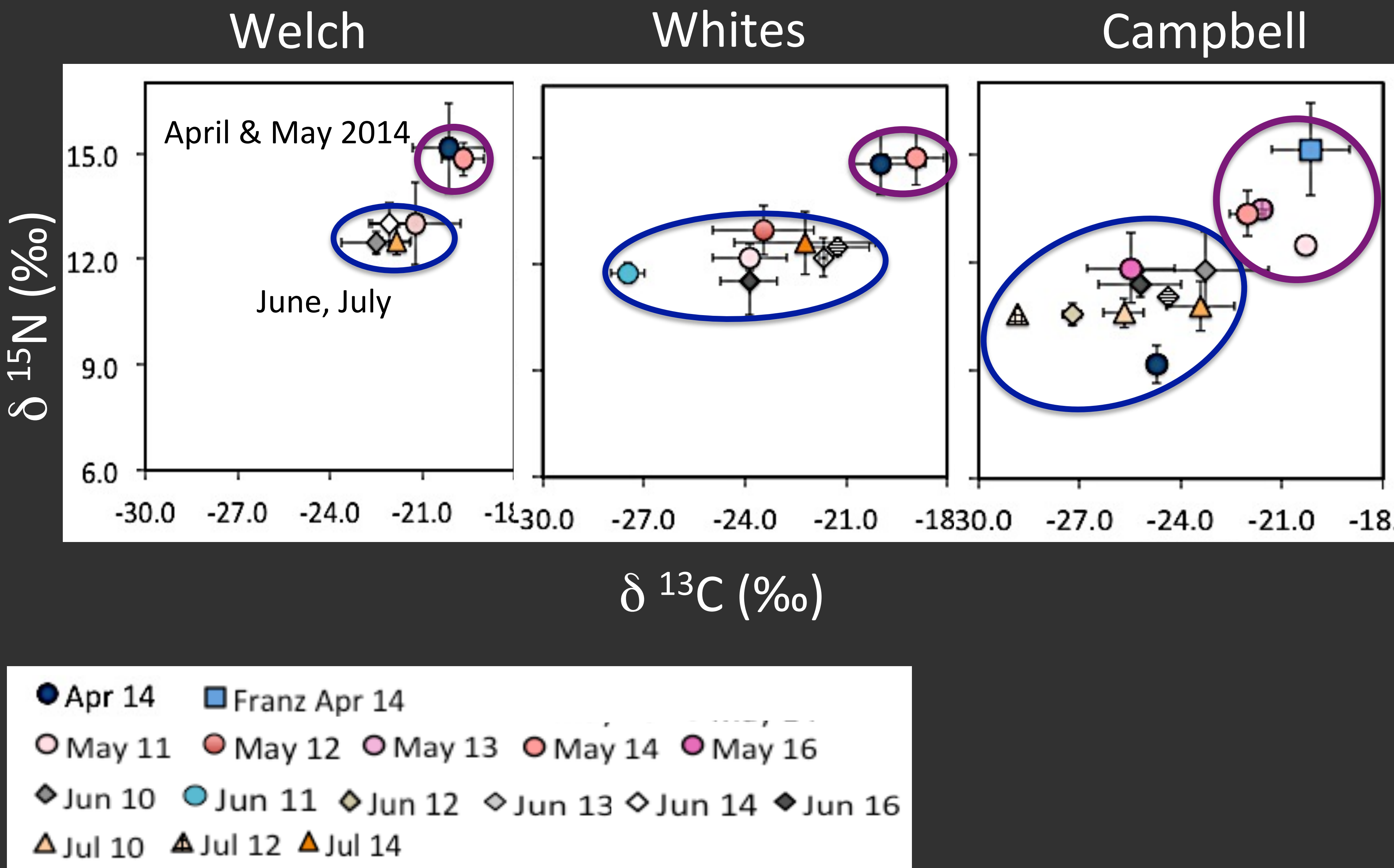


Increasing tidal influence

Juvenile Chinook muscle



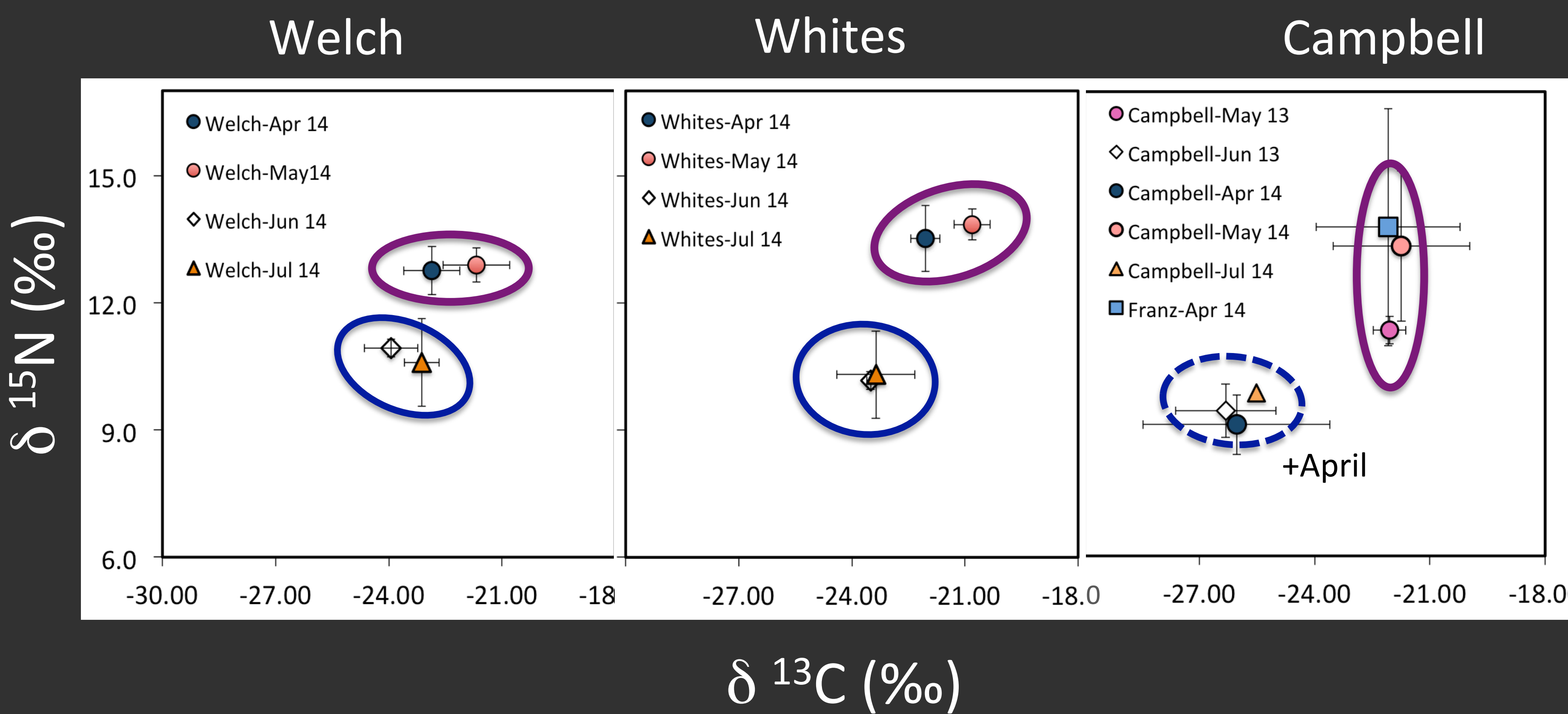
Juvenile Chinook muscle

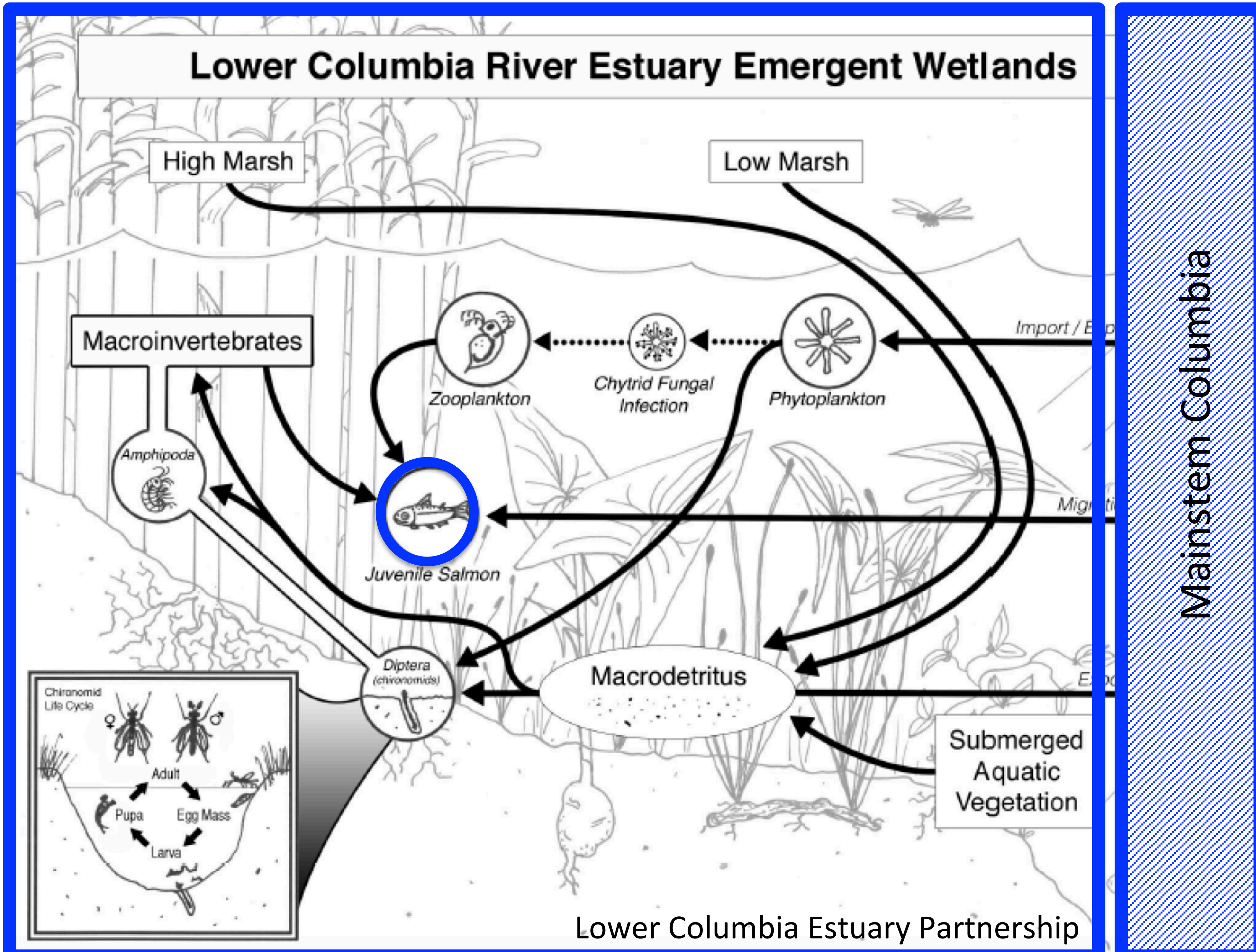


Juvenile Chinook livers

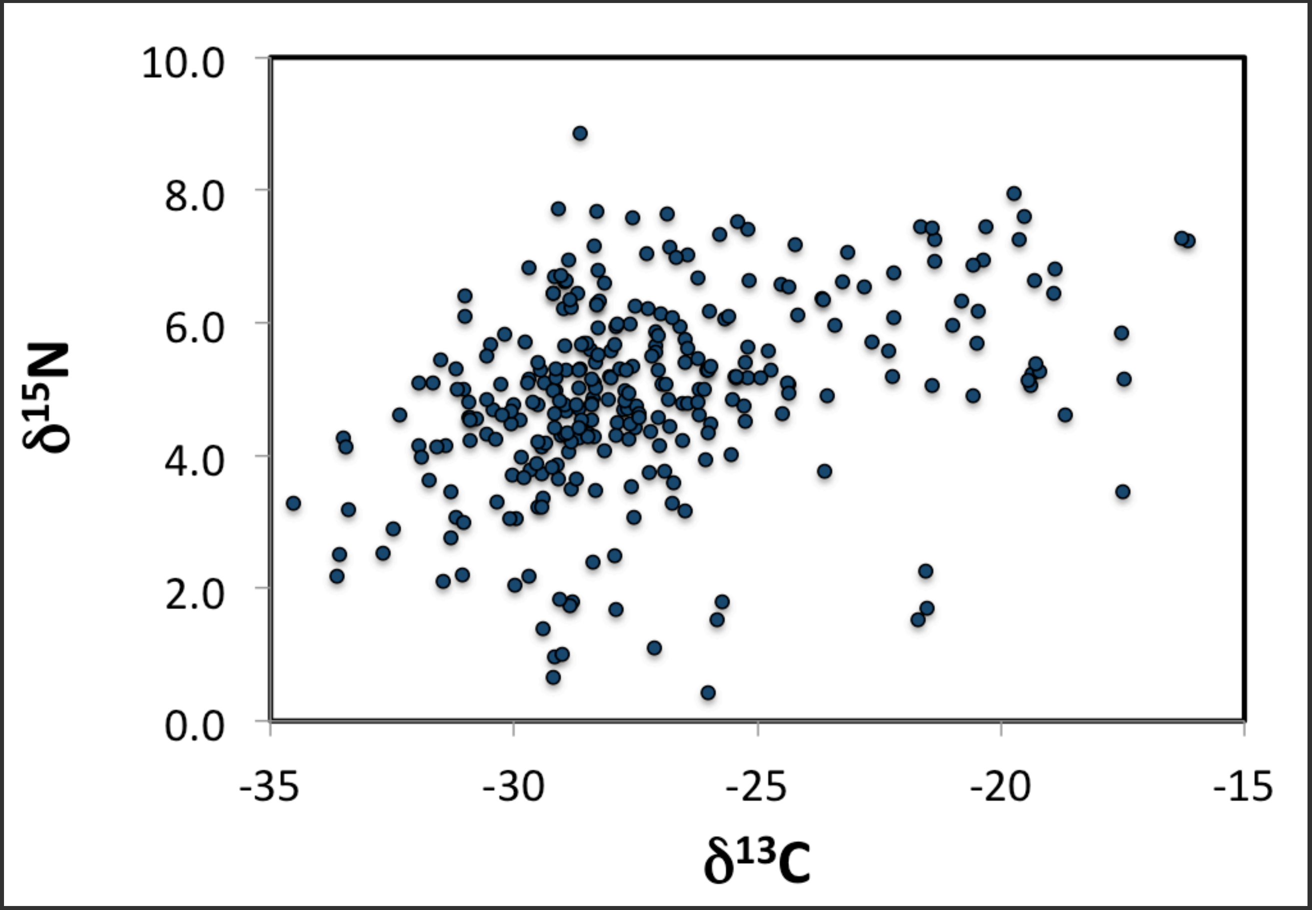
Isospace plots show

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

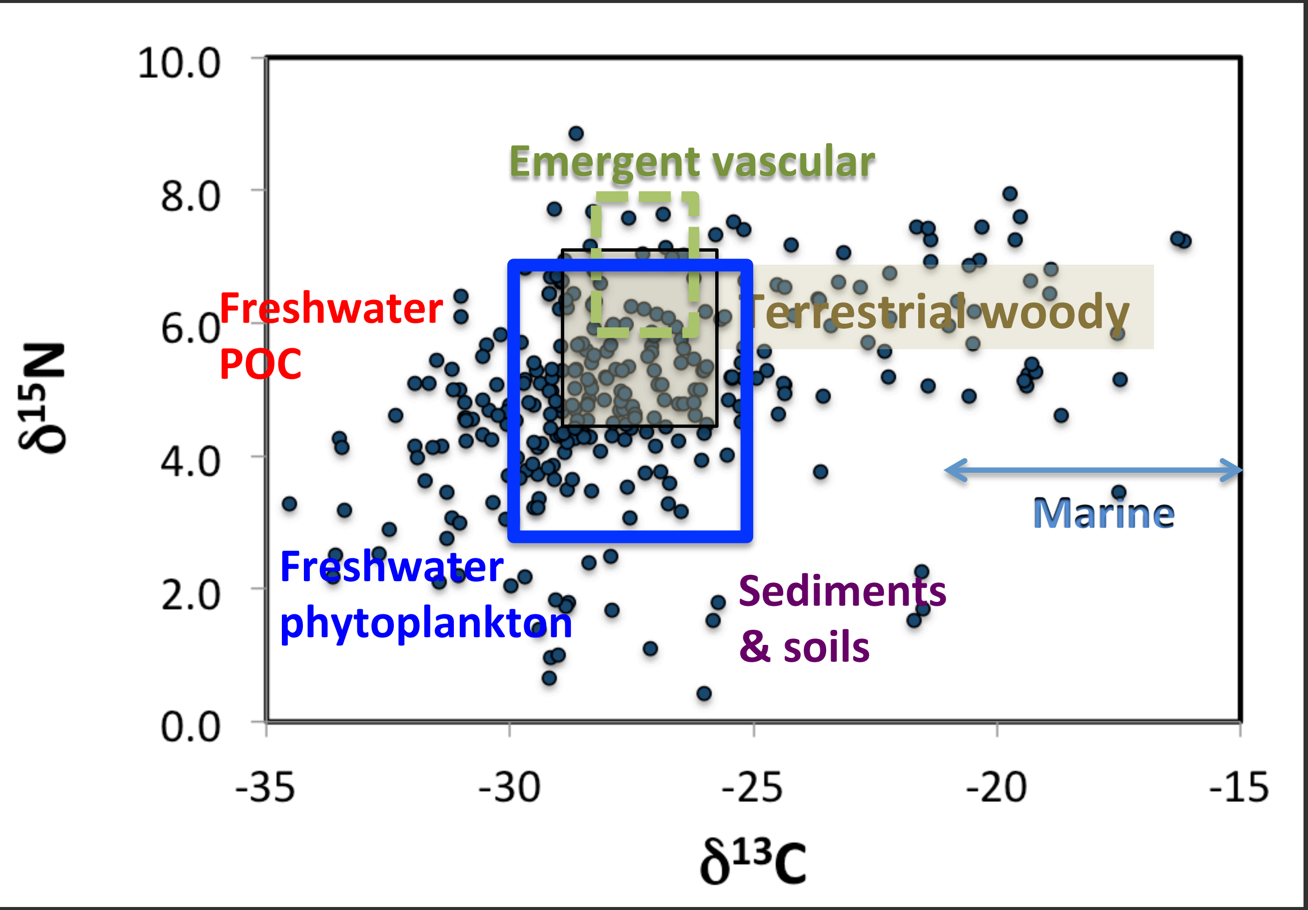



Lower Columbia River Estuary Emergent Wetlands
High Marsh
Low Marsh
Macroinvertebrates
Zooplankton
Chytrid Fungal Infection
Phytoplankton
Amphipoda
Juvenile Salmon
Diptera (chironomids)
Macrodetritus
Submerged Aquatic Vegetation
Chironomid Life Cycle
Adult
Pupa
Egg Mass
Larva
Lower Columbia Estuary Partnership
Mainstem Columbia

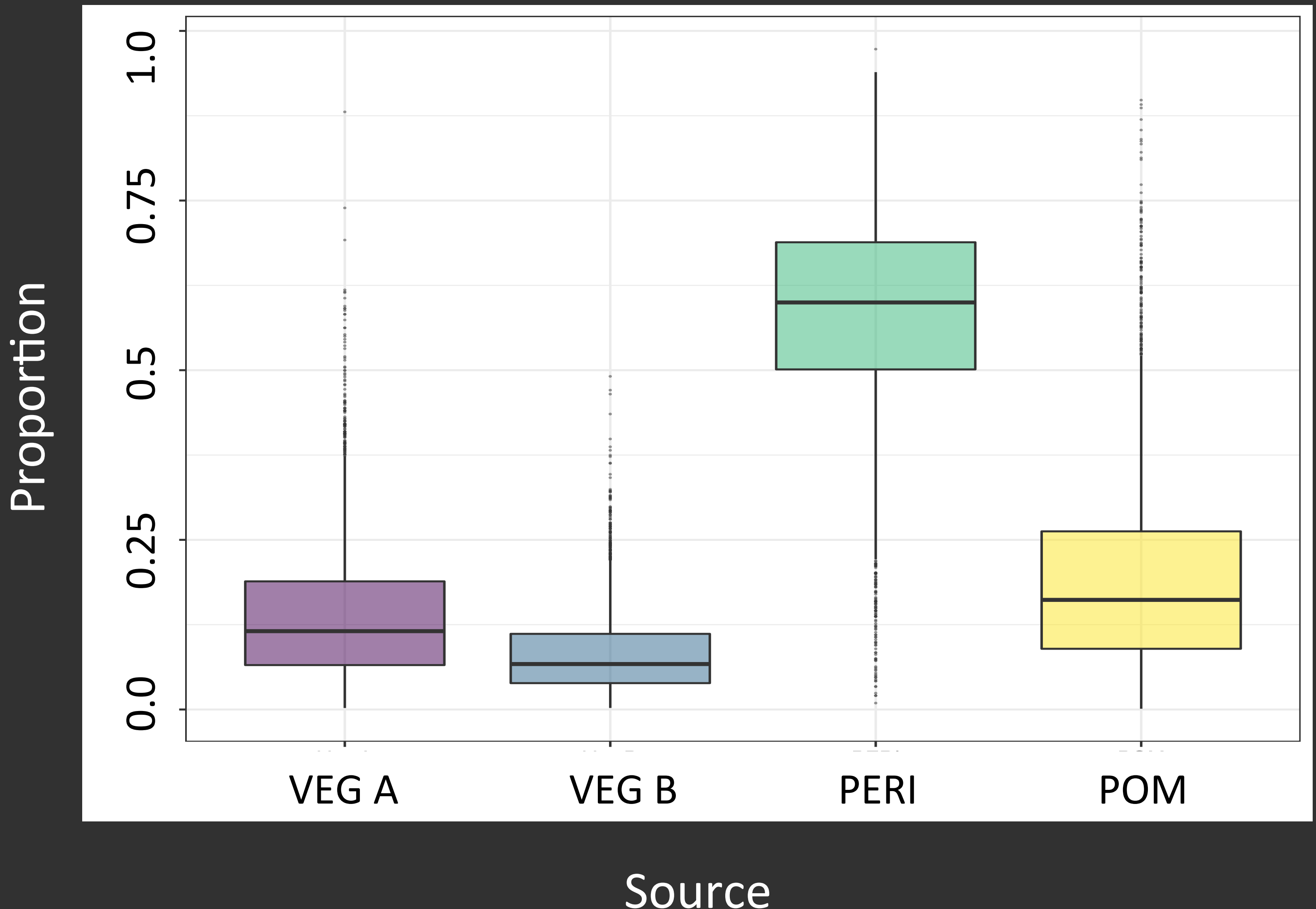
Isotopic signatures of primary producers (plants, periphyton, POM) in the Columbia River estuary



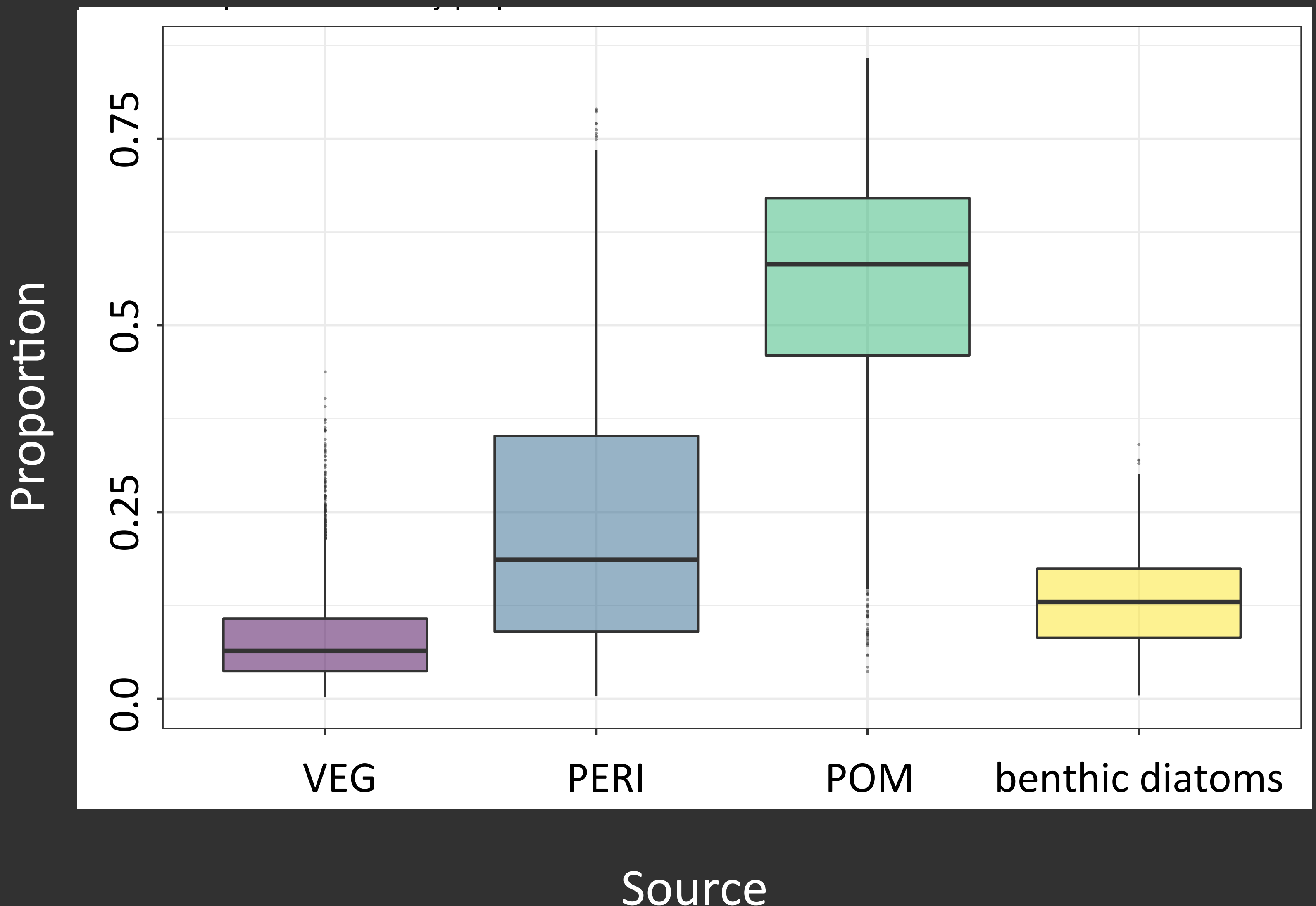
Isotopic signatures of primary producers (plants, periphyton, POM) in the Columbia River estuary



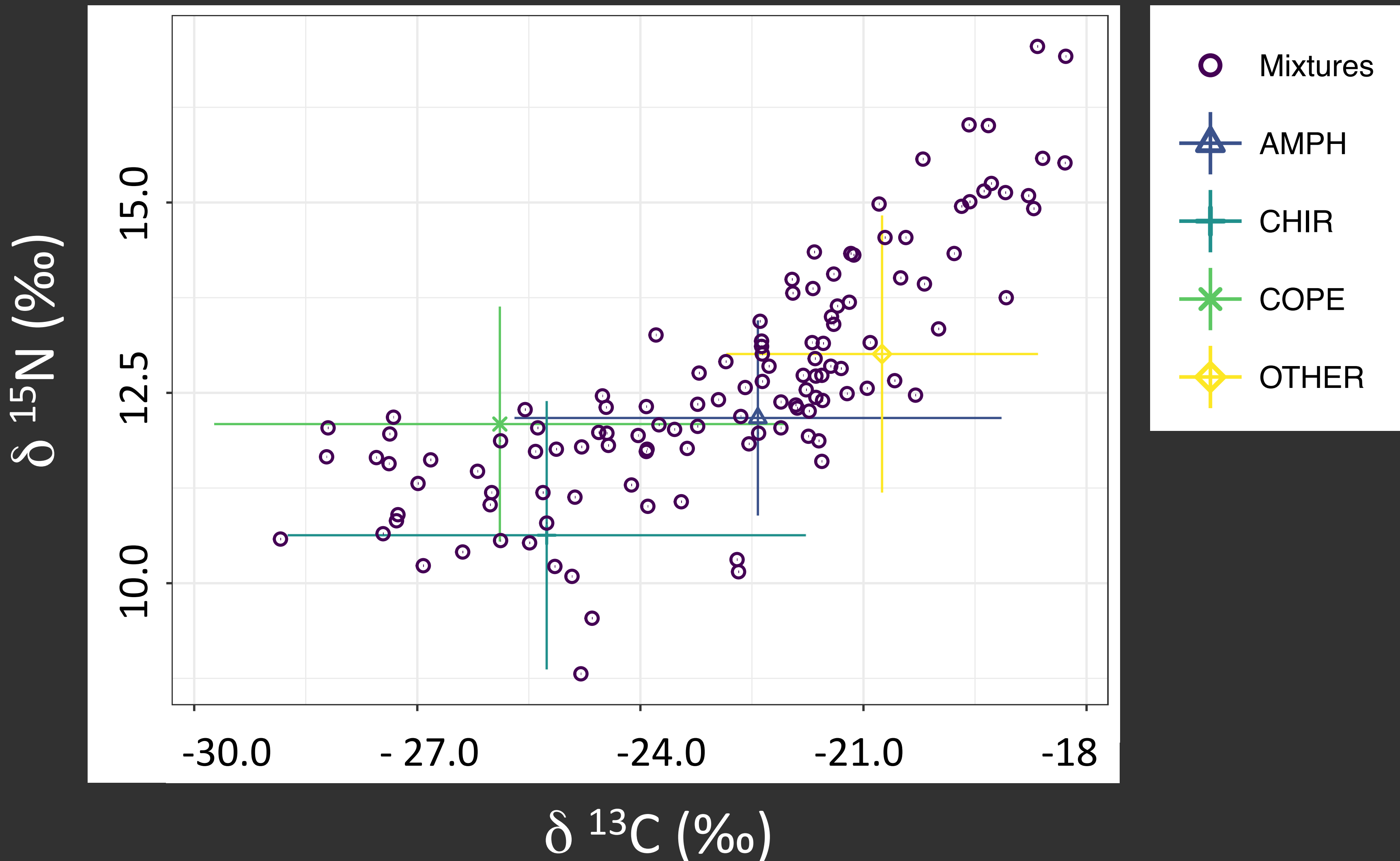
Based on mixing model results, chironomids assimilate organic matter from periphyton



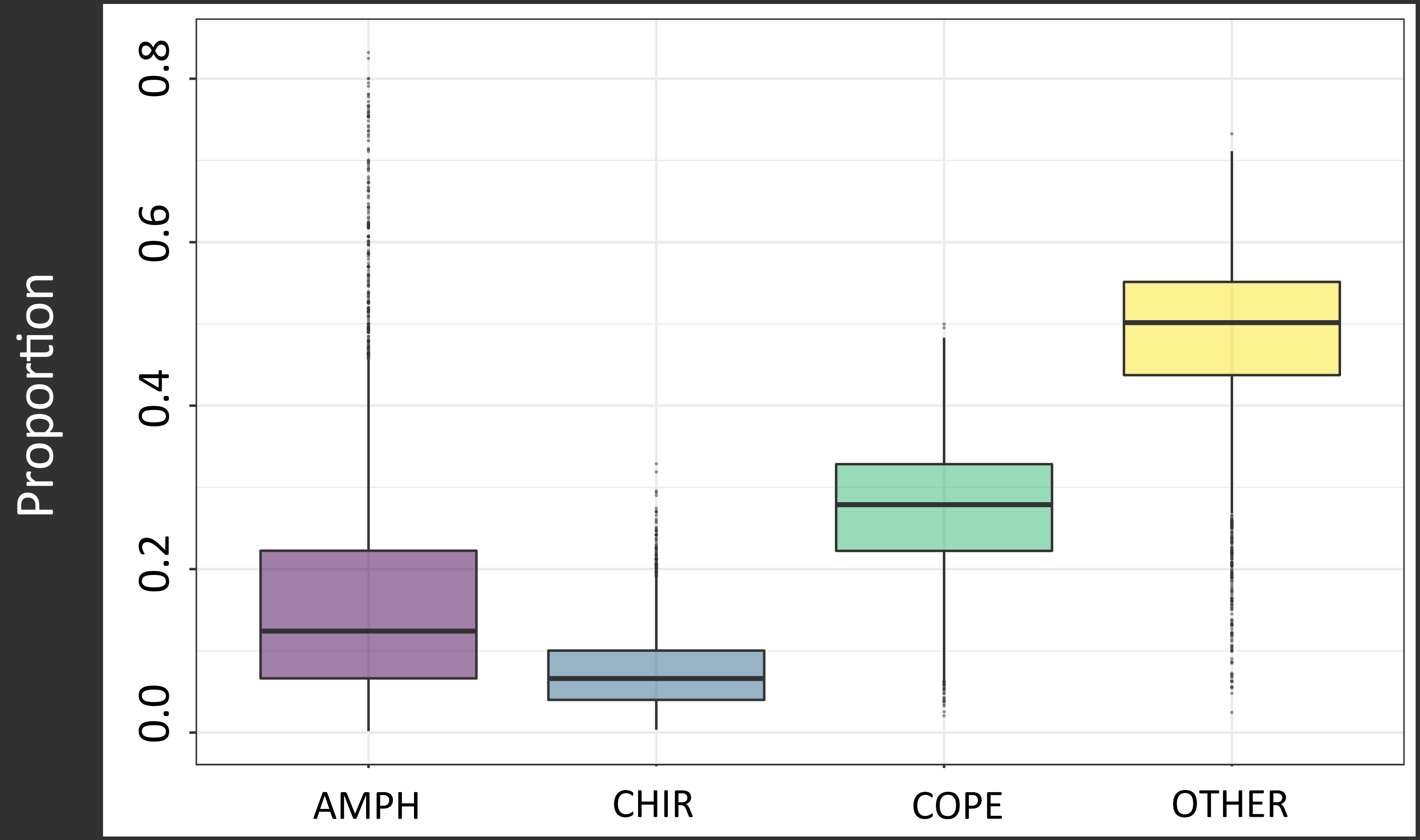
Based on mixing model results, amphipods mainly assimilate particulate matter



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

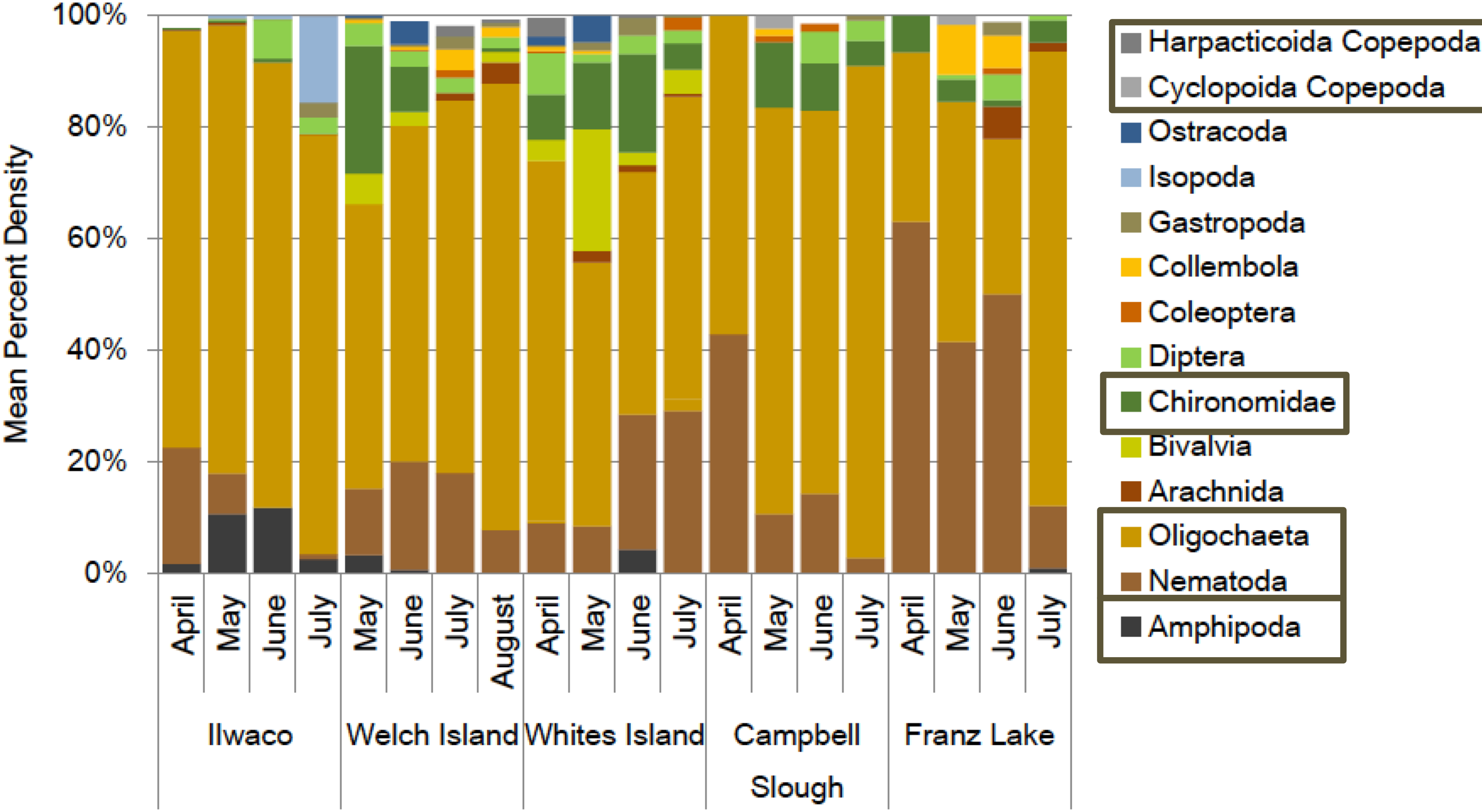


Comparison of dietary proportions in unmarked juvenile Chinook muscle (SIMMR)



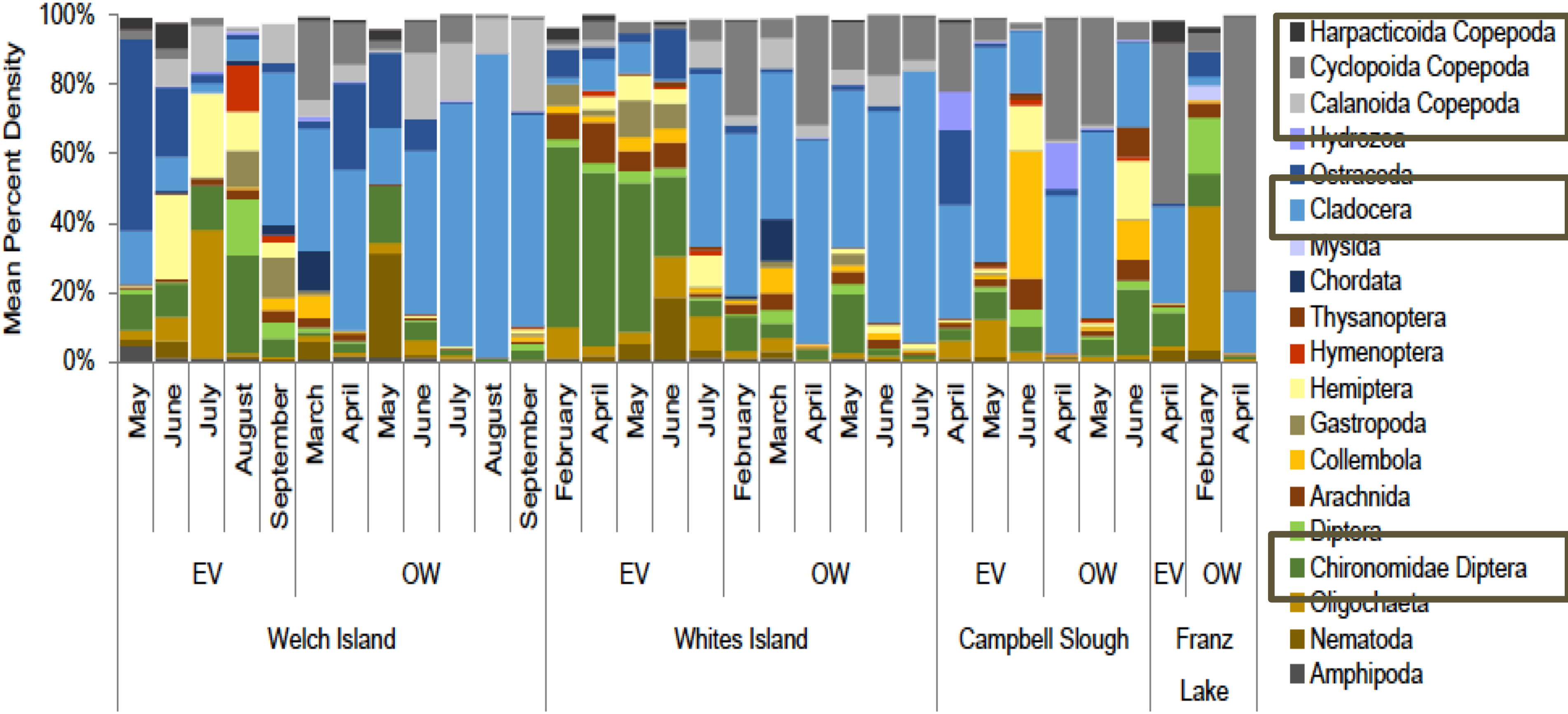
n = 122

Distribution of available prey: benthos



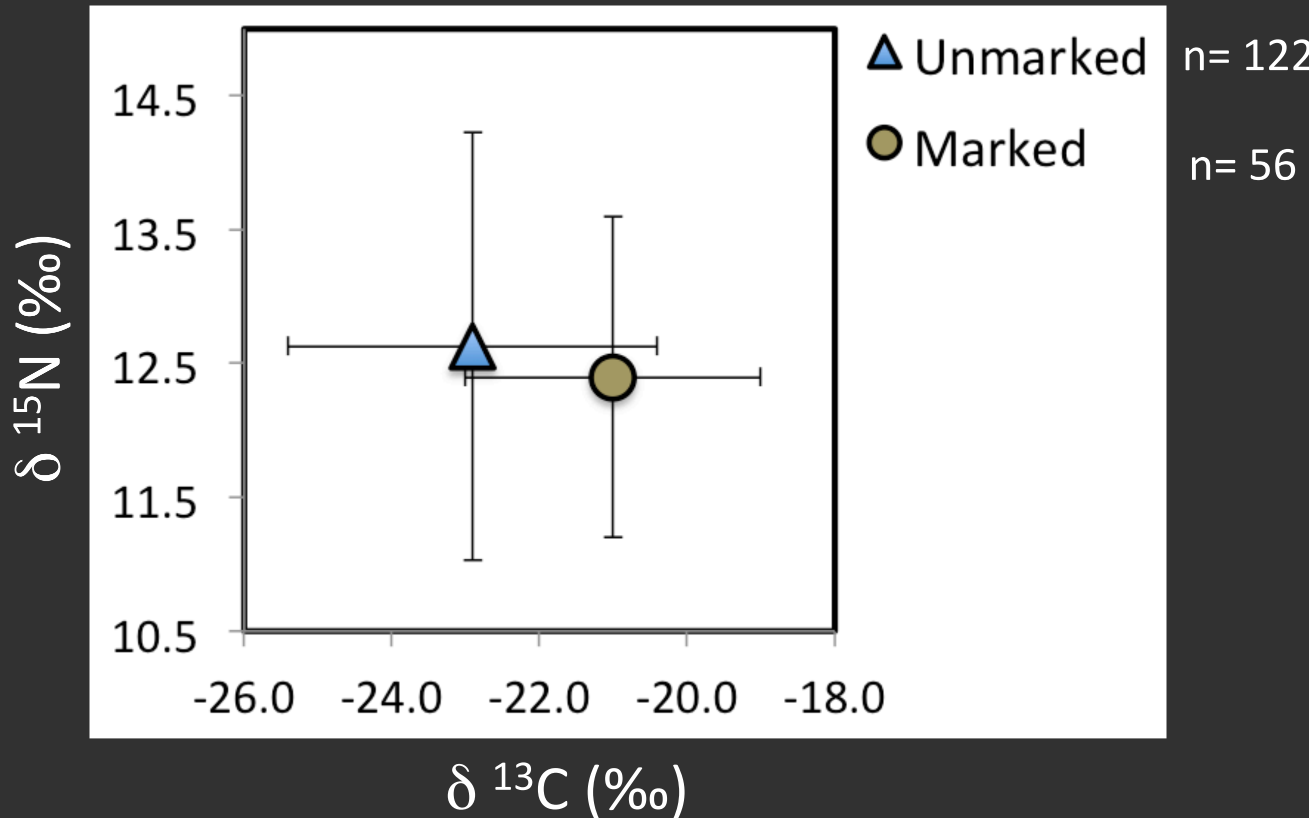
Ramirez & Cordell, in Hanson et al., 2016

Distribution of available prey: neuston



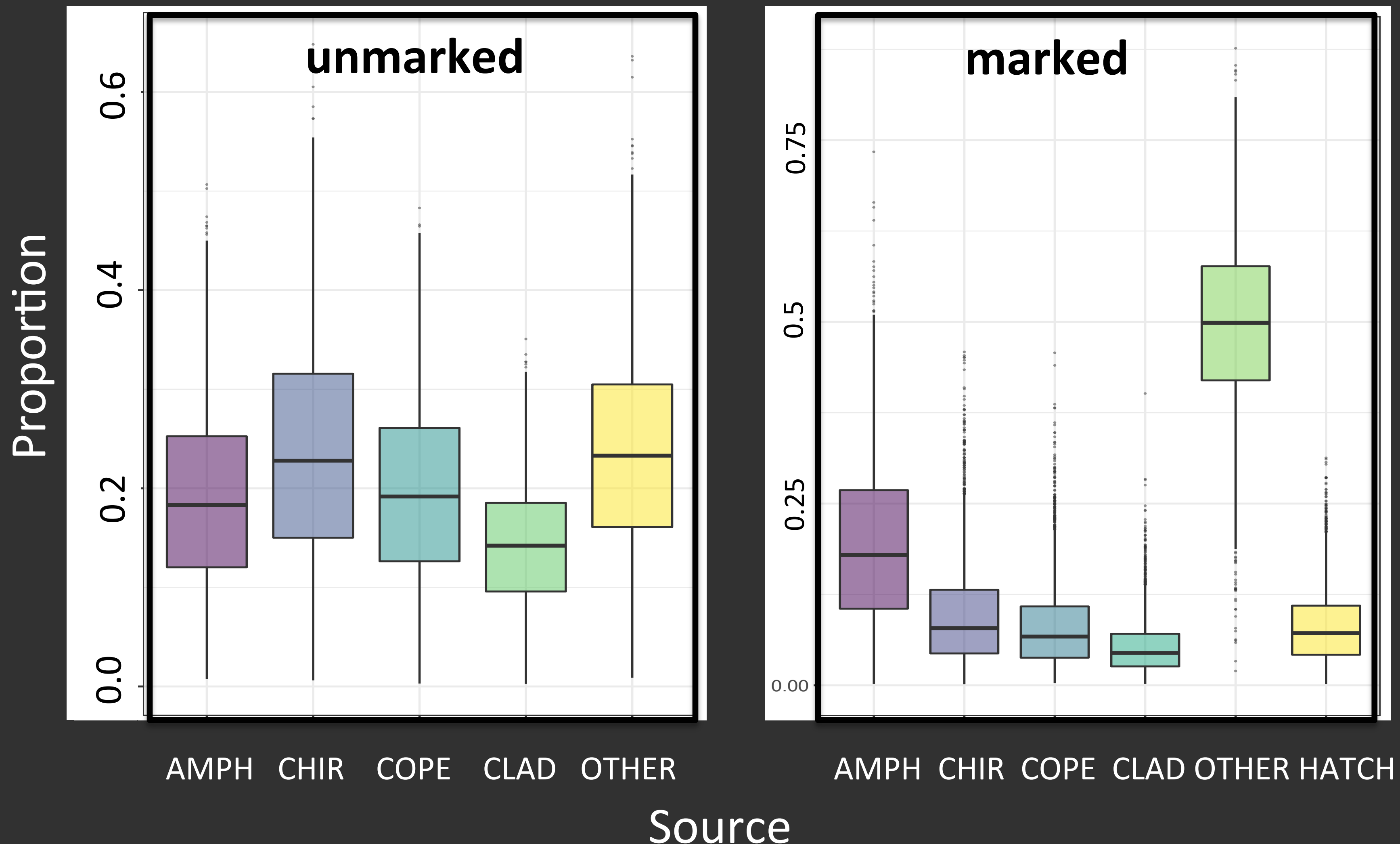
Ramirez & Cordell, in Hanson et al., 2016

Stable isotope signatures of marked fish differ from unmarked fish



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

Dietary proportions in unmarked vs. marked juvenile Chinook salmon (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 wild fish

Some next steps

- Reanalyze data to consider differences in isotope signatures of mixtures and sources in space and time
- Build mixing models using a priori knowledge of consumption patterns from diet analysis (stomach contents)

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