Exploring trophic pathways in the juvenile salmonid food web of the lower Columbia River

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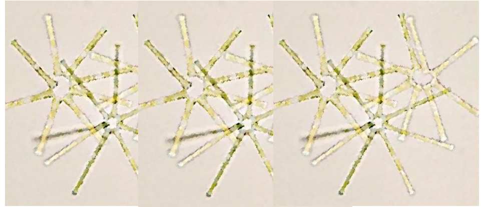
Ecosystem Monitoring Program seeks to inform wetland restoration activities by providing fundamental ecological knowledge about salmonid habitats and food webs in the Lower Columbia River.





Invertebrates



Vascular plants

Aquatic, terrestrial

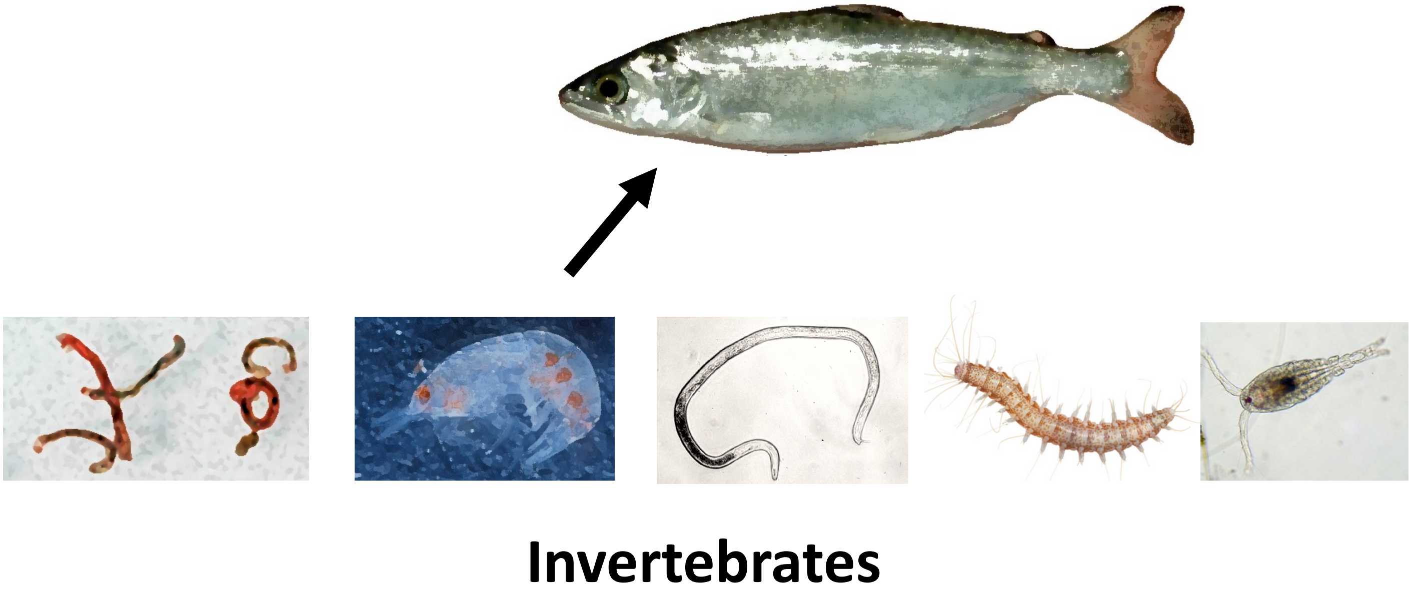
Freshwater & marine

Phytoplankton & macroalgae

Fluvial, benthic

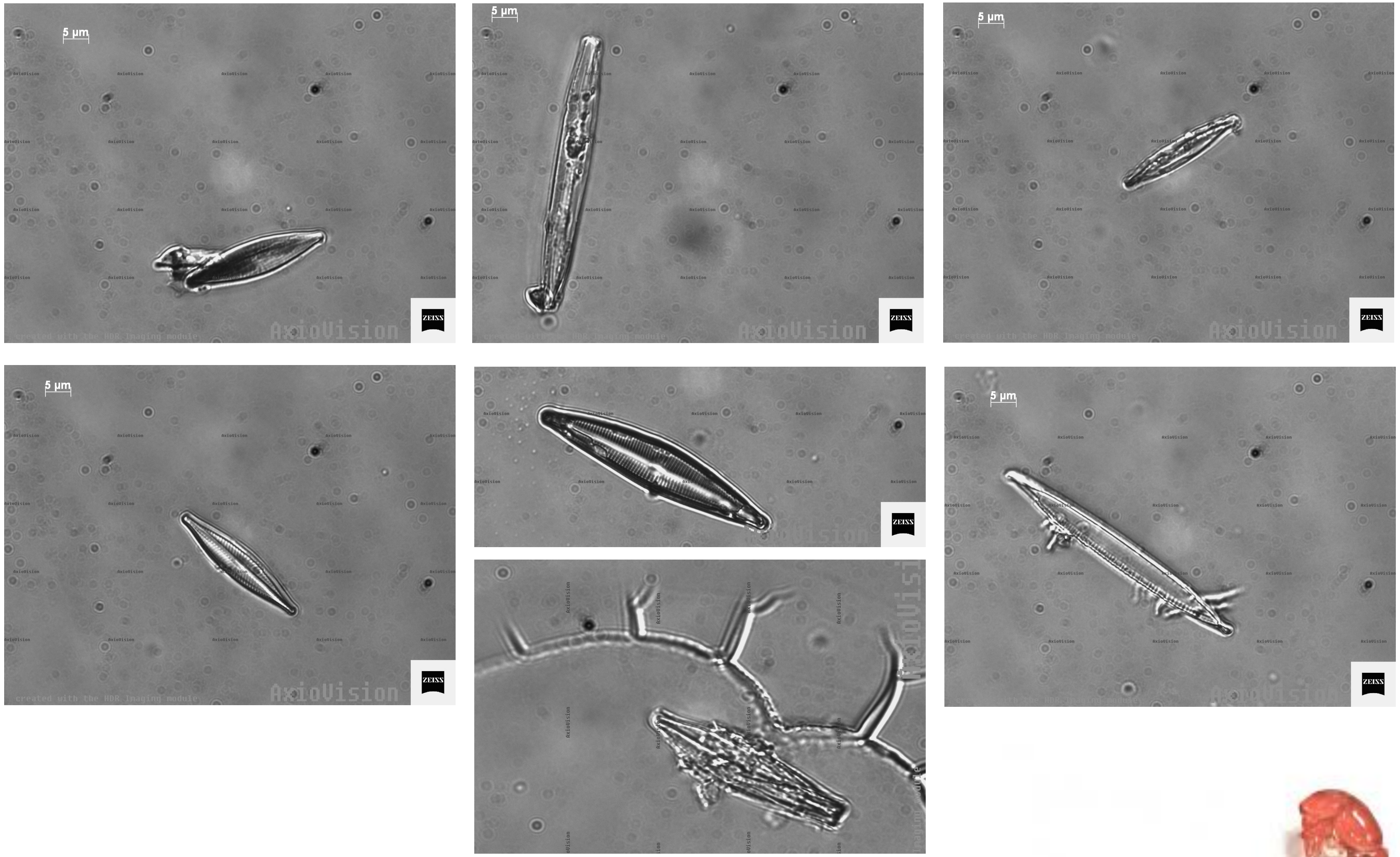
Freshwater & marine

Direct examination of stomach contents lets us know what salmonids have consumed recently.



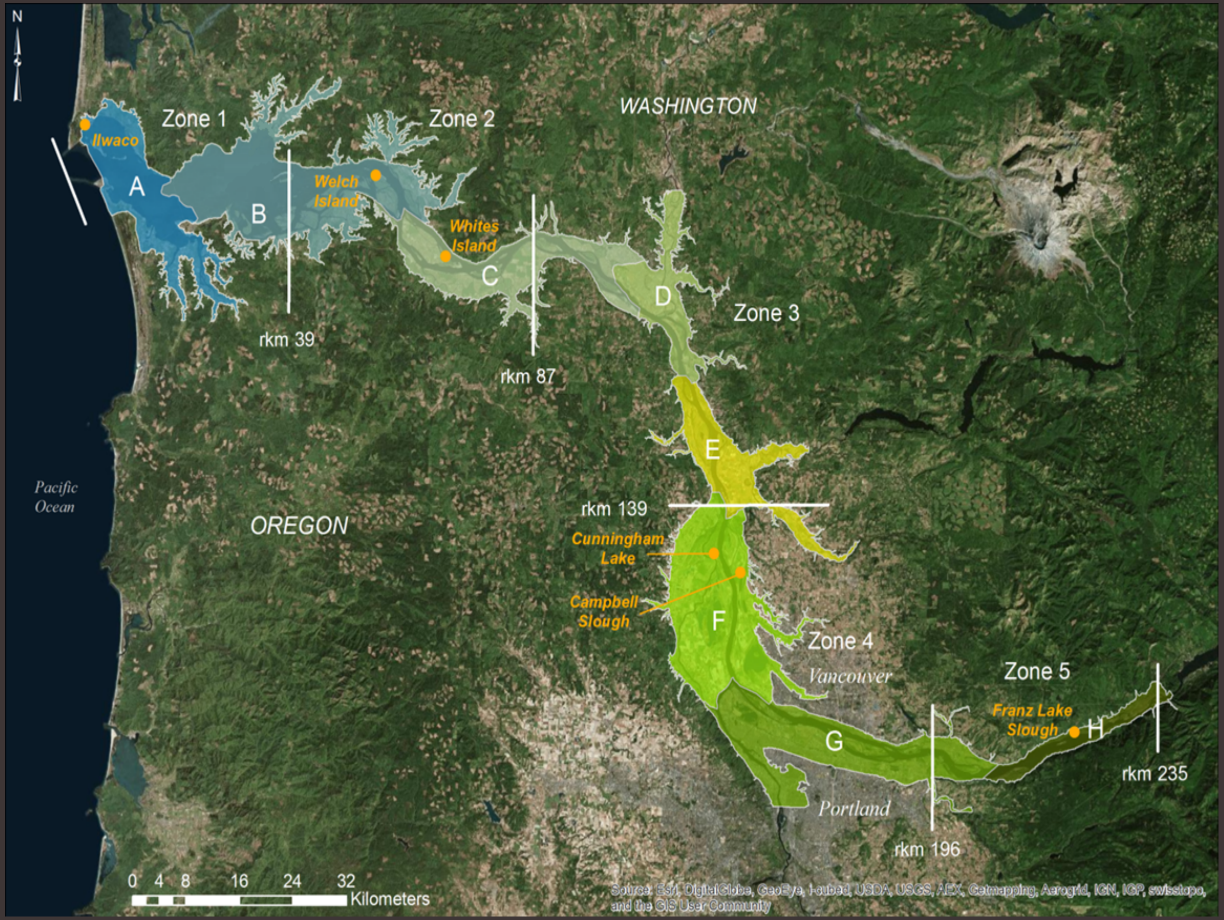
But sometimes gut contents are partially digested and difficult to identify; sometimes we'd like to know what a fish has assimilated over a longer period of time; and stomach contents don't reveal pathways linking primary production to fish.

We can sometimes infer what invertebrate prey have been eating directly, but not usually.



Microscope images showing cleaned gut contents from chironomid larvae

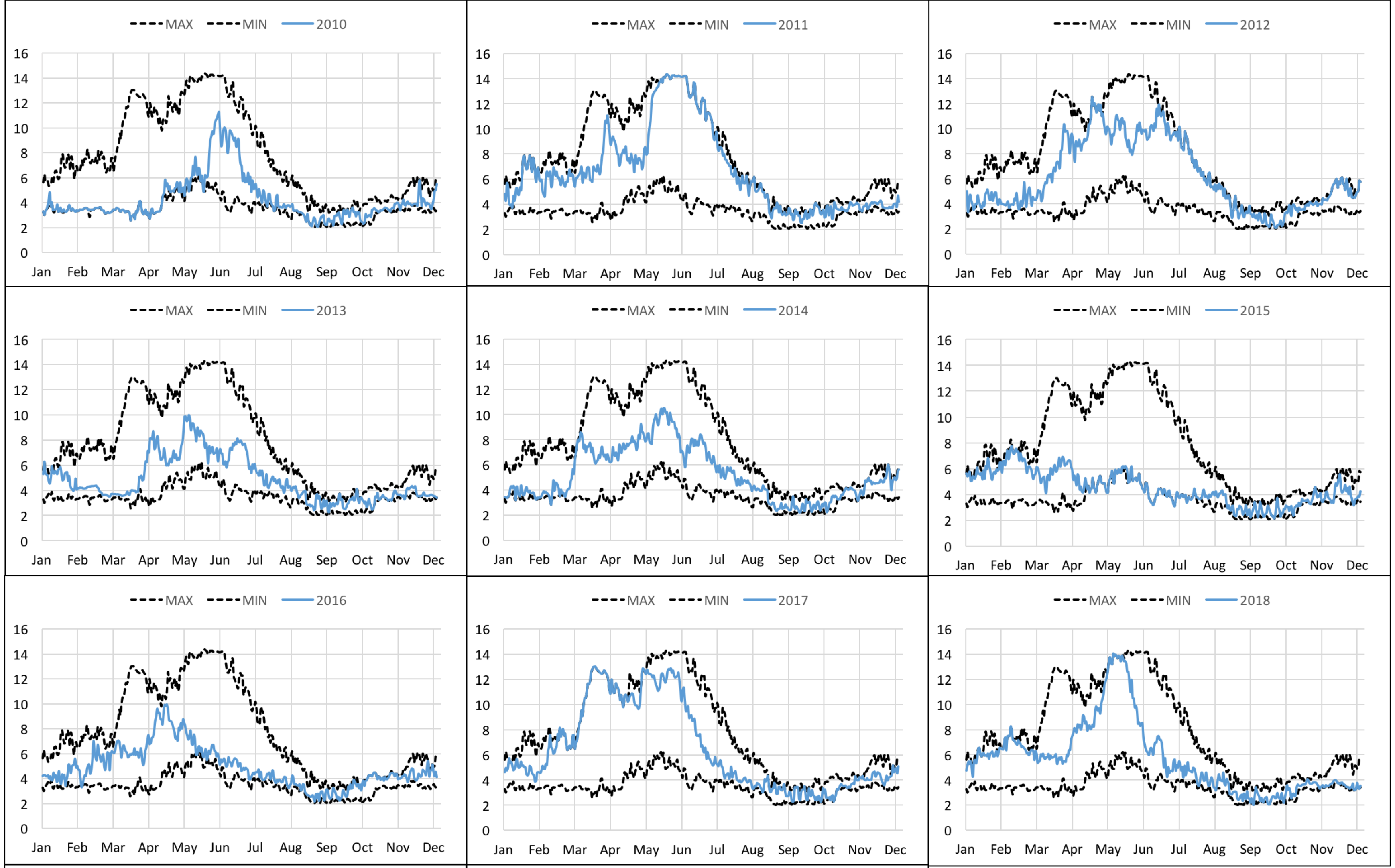
What factors influence the various components of aquatic food webs in the lower Columbia River?

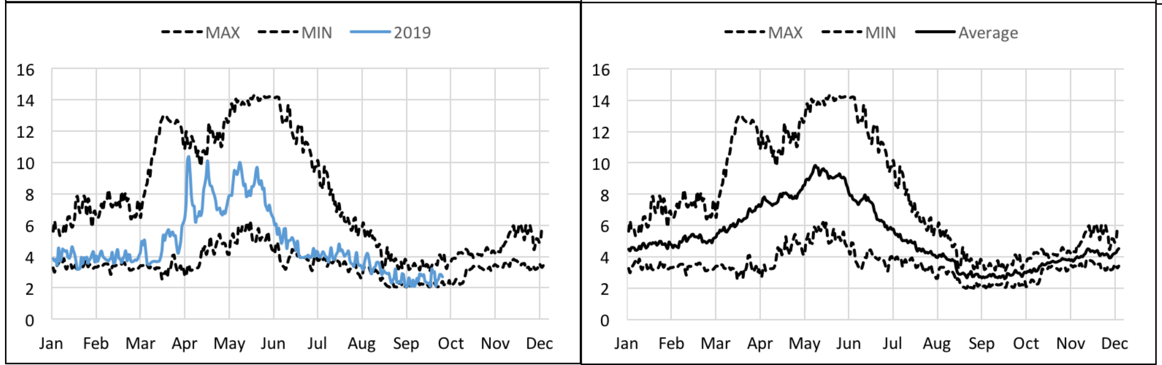


- Flow & connectivity
- Water retention time
- Competition
- Type of flow (pluvial vs. snowmelt)
- Marine influence

We know that flow varies from year to year, and this changes the characteristics of off-channel habitats.

We can predict how these changes affect salmonid food webs using knowledge about primary production, prey, and connectivity.

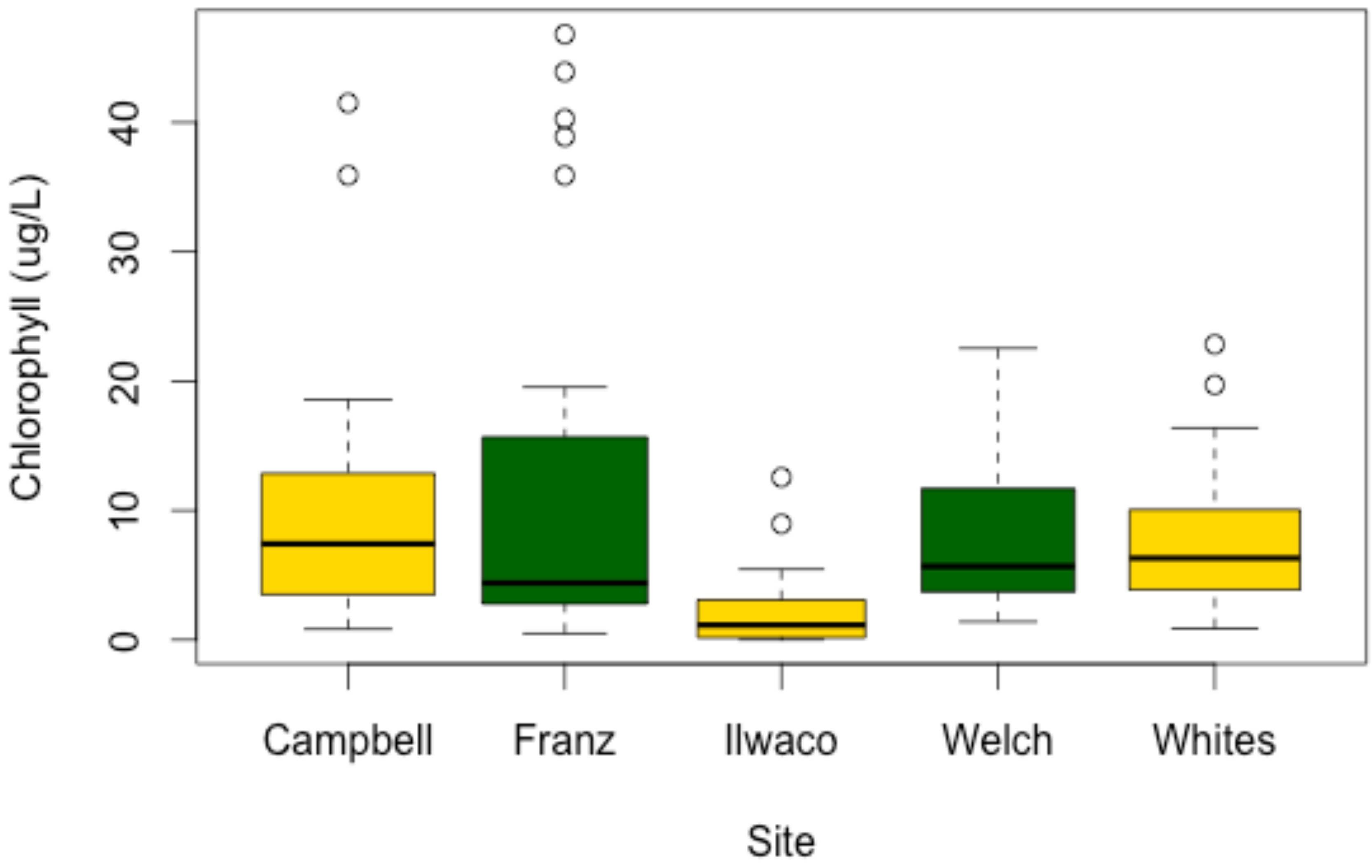




River discharge – each panel is a different year

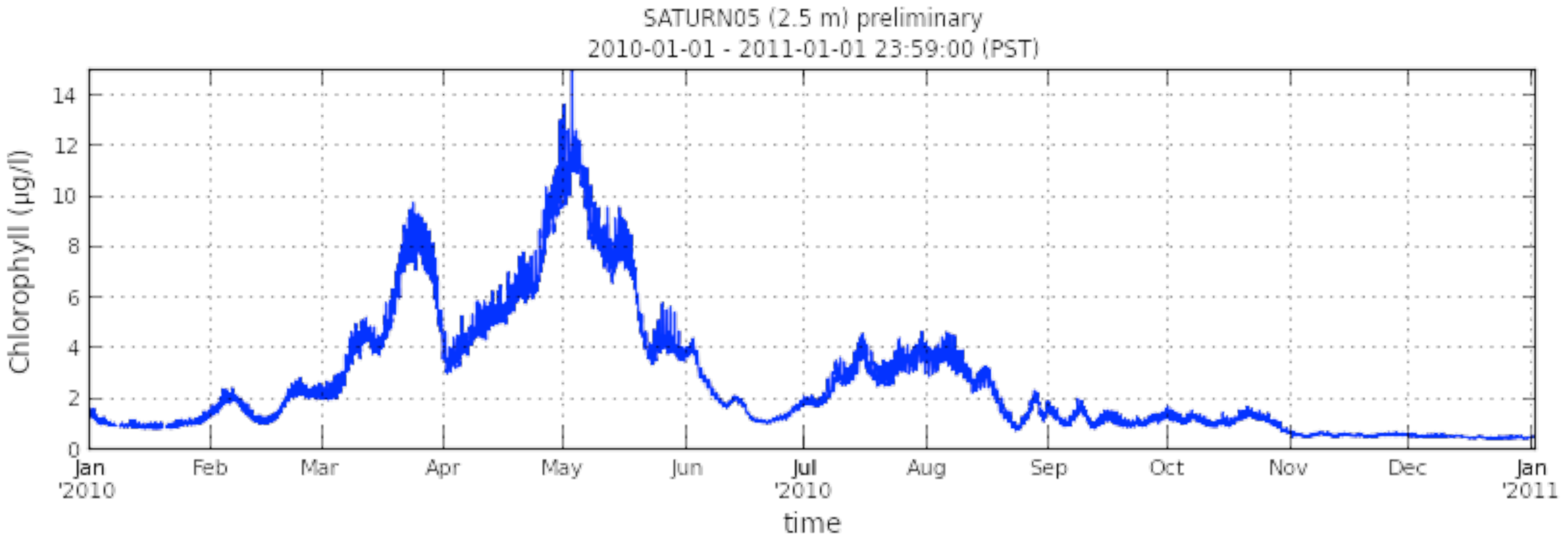
Bulk chlorophyll concentrations are higher at Campbell Slough and Franz Lake Slough than other sites

We know something about which **sites/habitats** tend to have high primary productivity, and which sites tend to have high productivity of zooplankton.



We know something about **when** primary productivity is high vs. low.

- Phytoplankton abundances consistently highest in early spring (Mar-May)
- Stable isotope data suggest phyto are important in the food web mainly in spring (Maier & Simenstad, 2009)



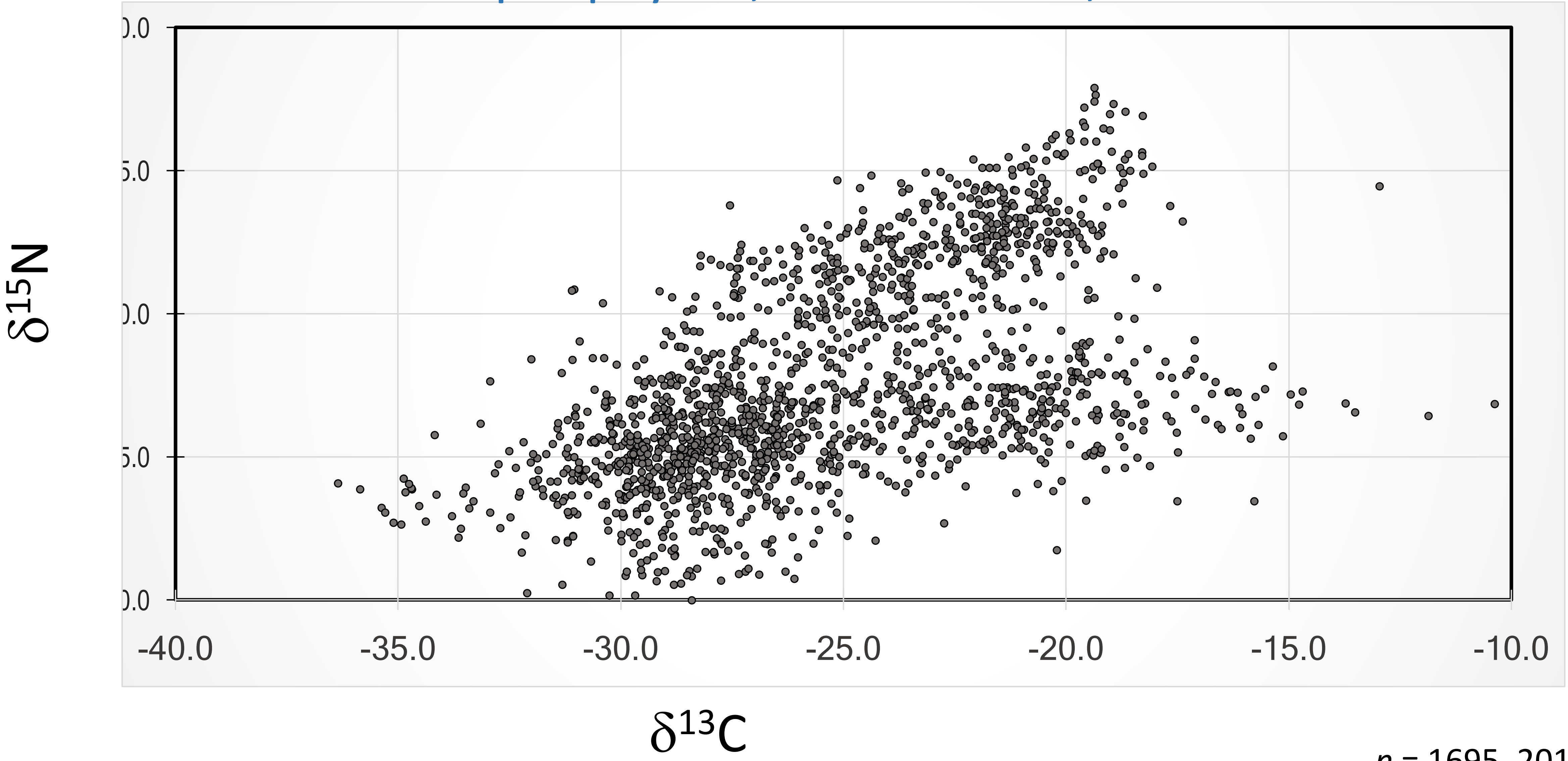
Stable isotope ratios can be used to infer relationships between consumers & food sources

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

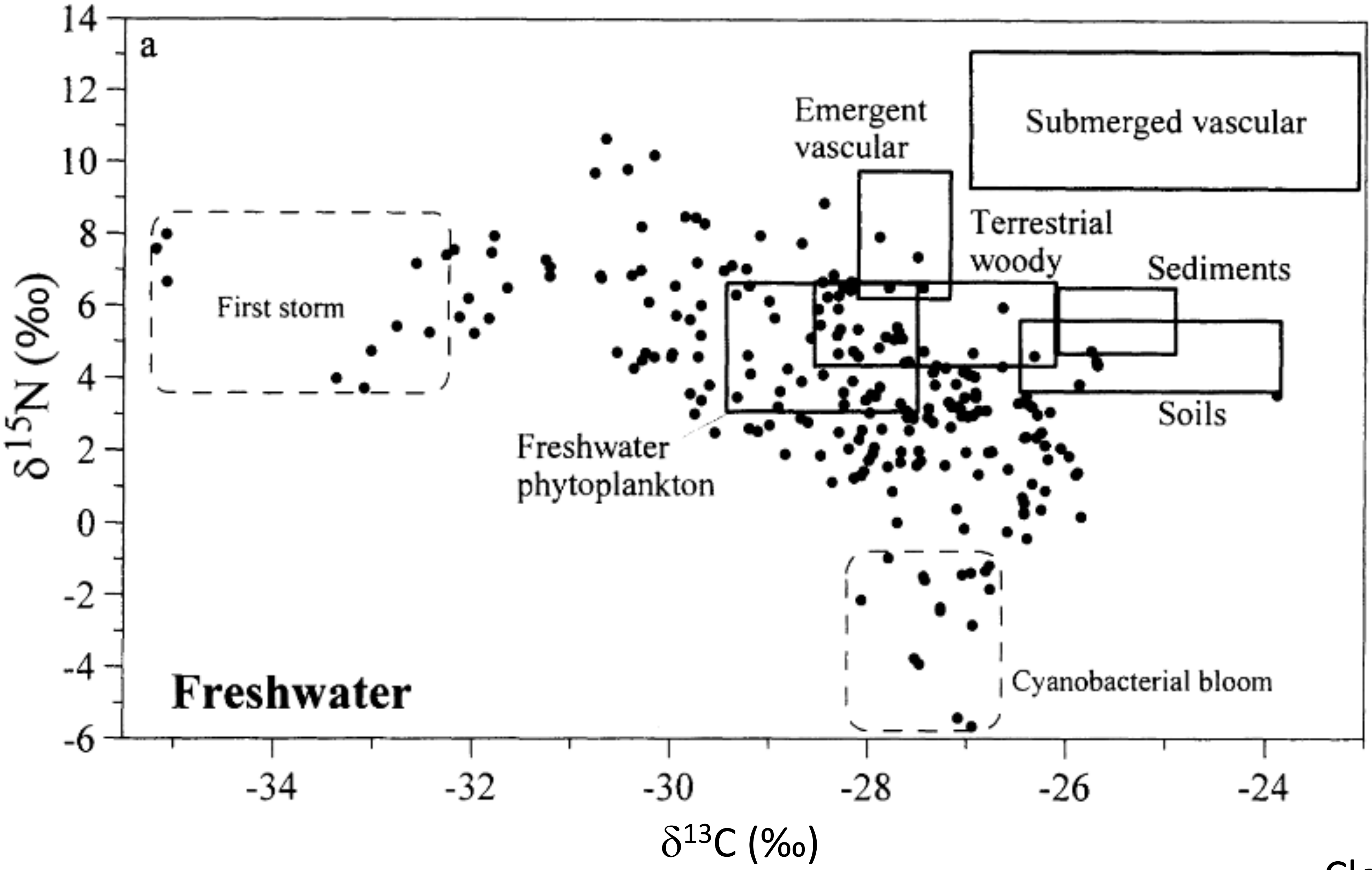
$$\delta^{13}C = (R_{sample} - R_{standard}) / R_{standard} \times 1000 \text{ (units = ‰)}$$

- 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
  - MixSIAR (Stock et al., 2018): Analyzing mixing systems using a new generation of Bayesian tracer mixing models

Stable isotope signatures of variety of materials: POM, plant matter, periphyton, invertebrates, fish



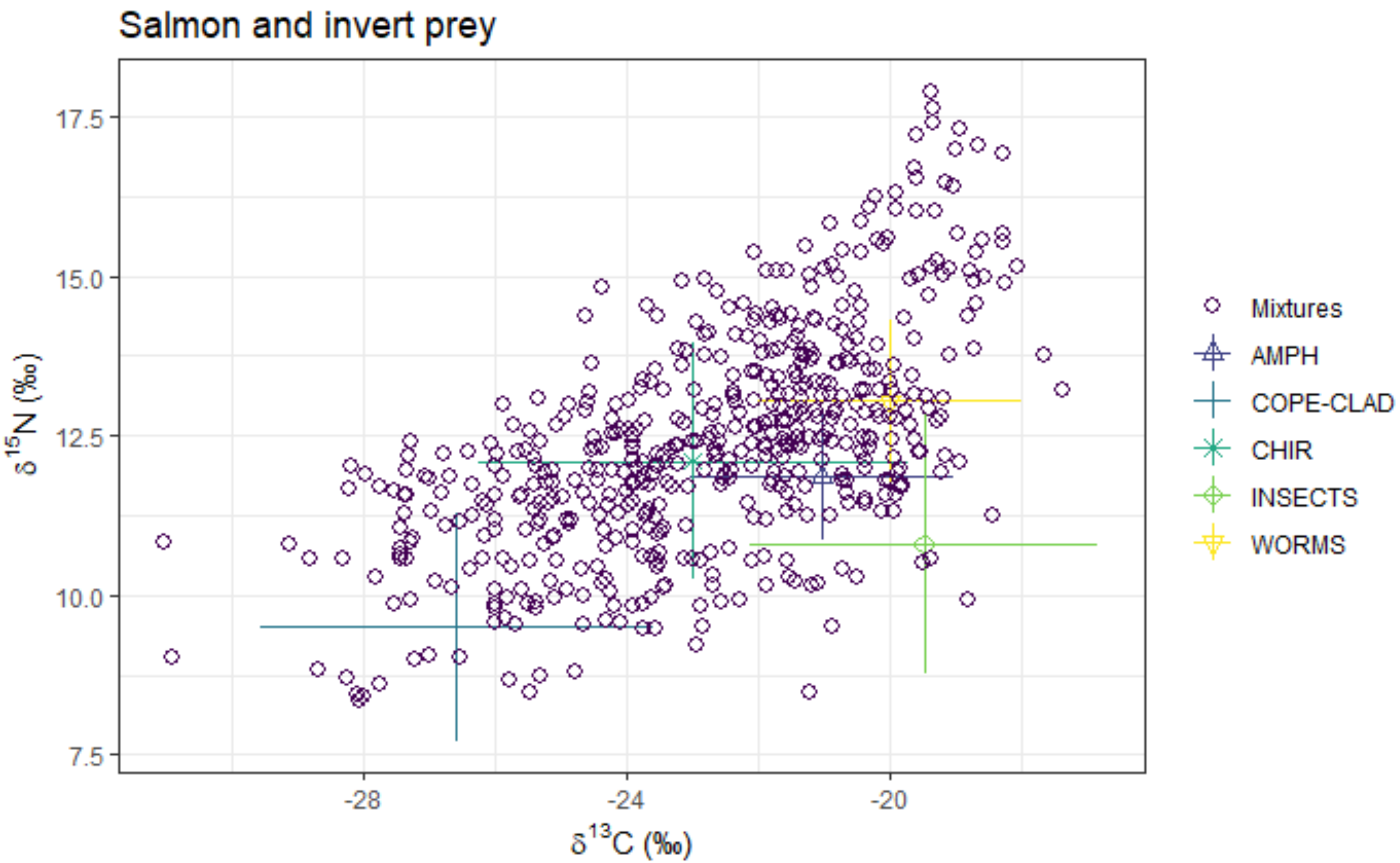
n = 1695, 2010 - 2019



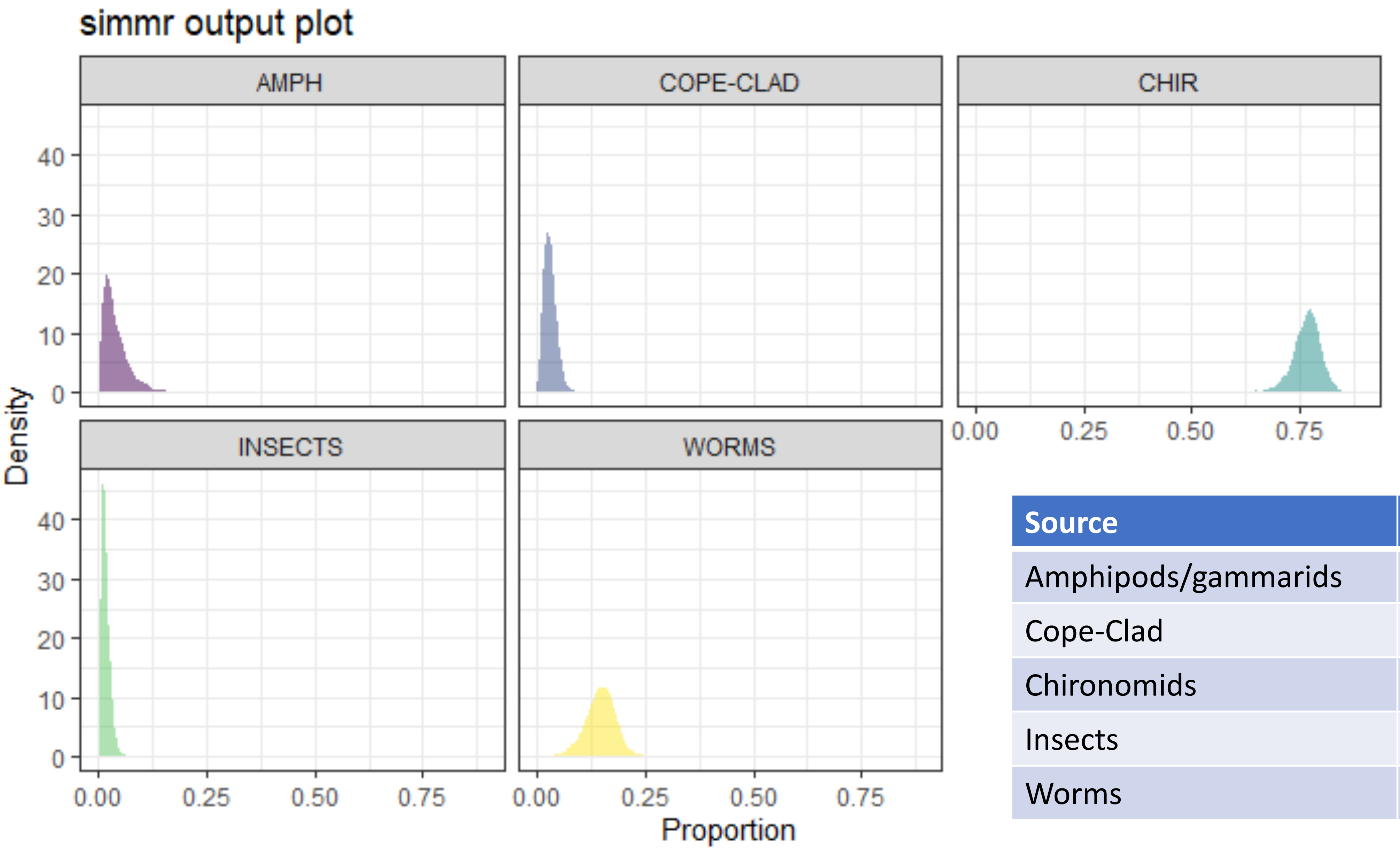
a
Submerged vascular
Emergent vascular
Terrestrial woody
Sediments
Soils
First storm
Freshwater phytoplankton
Cyanobacterial bloom
Freshwater
δ15N (‰)
δ13C (‰)
14
12
10
8
6
4
2
0
-2
-4
-6
-34
-32
-30
-28
-26
-24

Cloern, 2002

Isospace plot – Mixtures = juvenile salmon

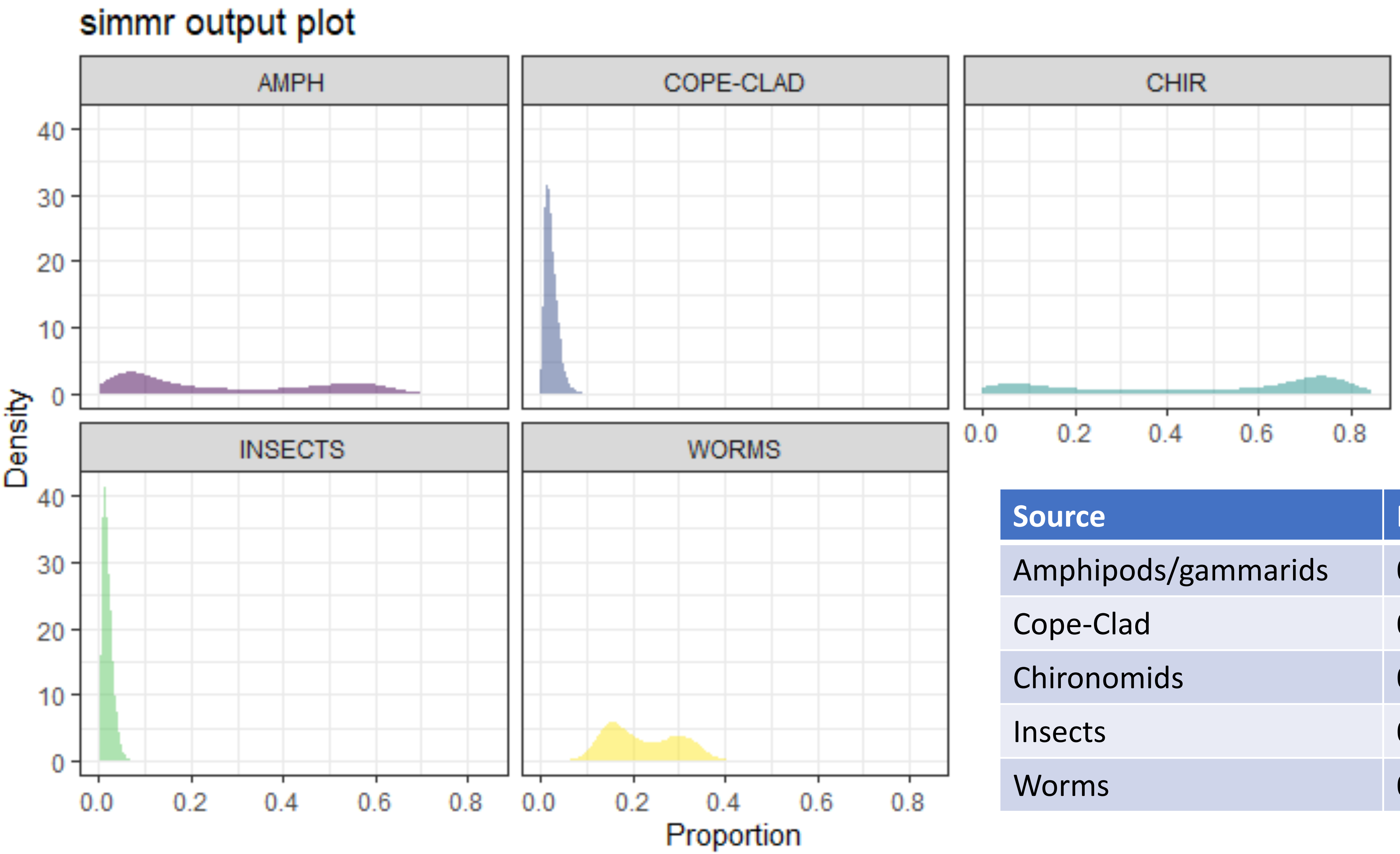


Model output estimates proportion of diet from input sources



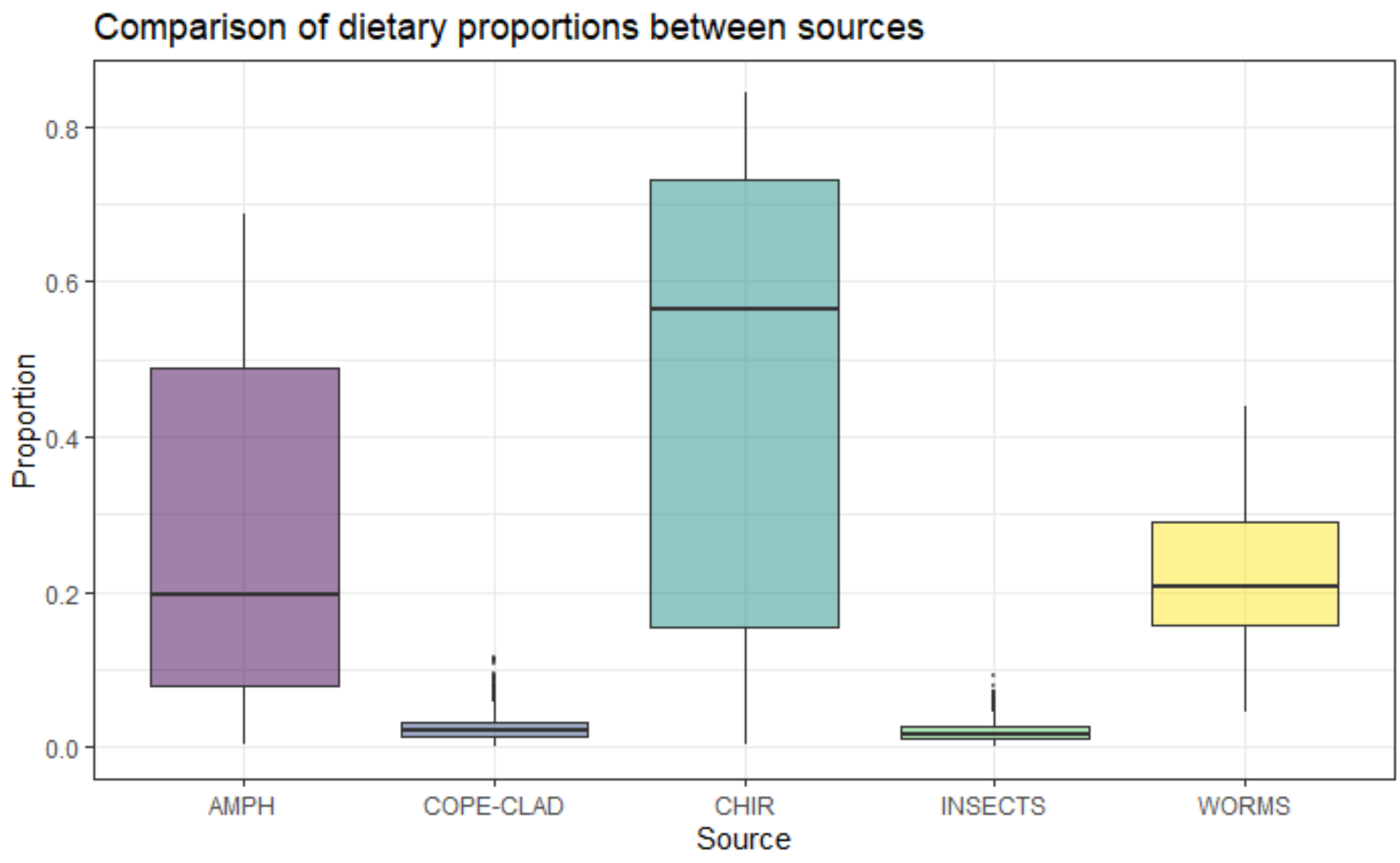
Source	Proportion
Amphipods/gammarids	0.031
Cope-Clad	0.028
Chironomids	0.770
Insects	0.015
Worms	0.149

Model output estimates proportion of diet from input sources

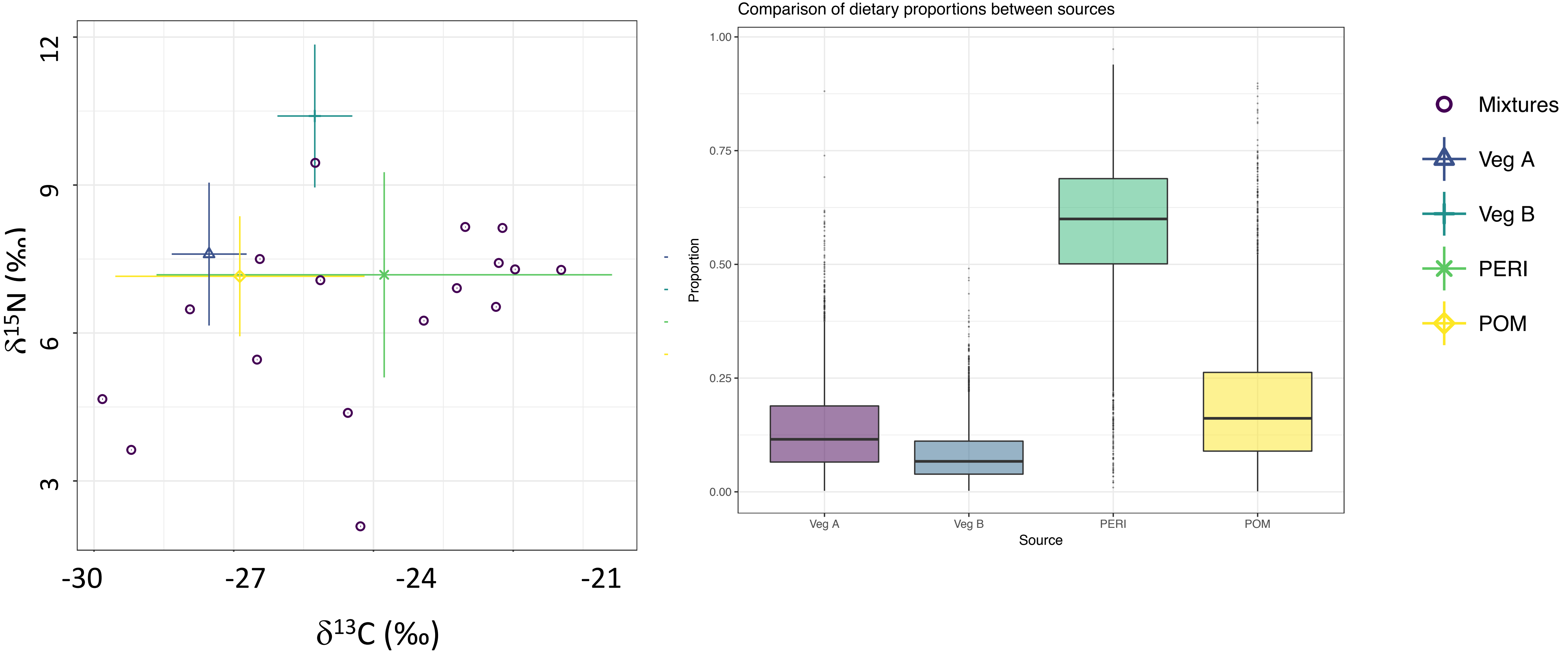


Source	Proportion
Amphipods/gammarids	0.272
Cope-Clad	0.024
Chironomids	0.463
Insects	0.019
Worms	0.222

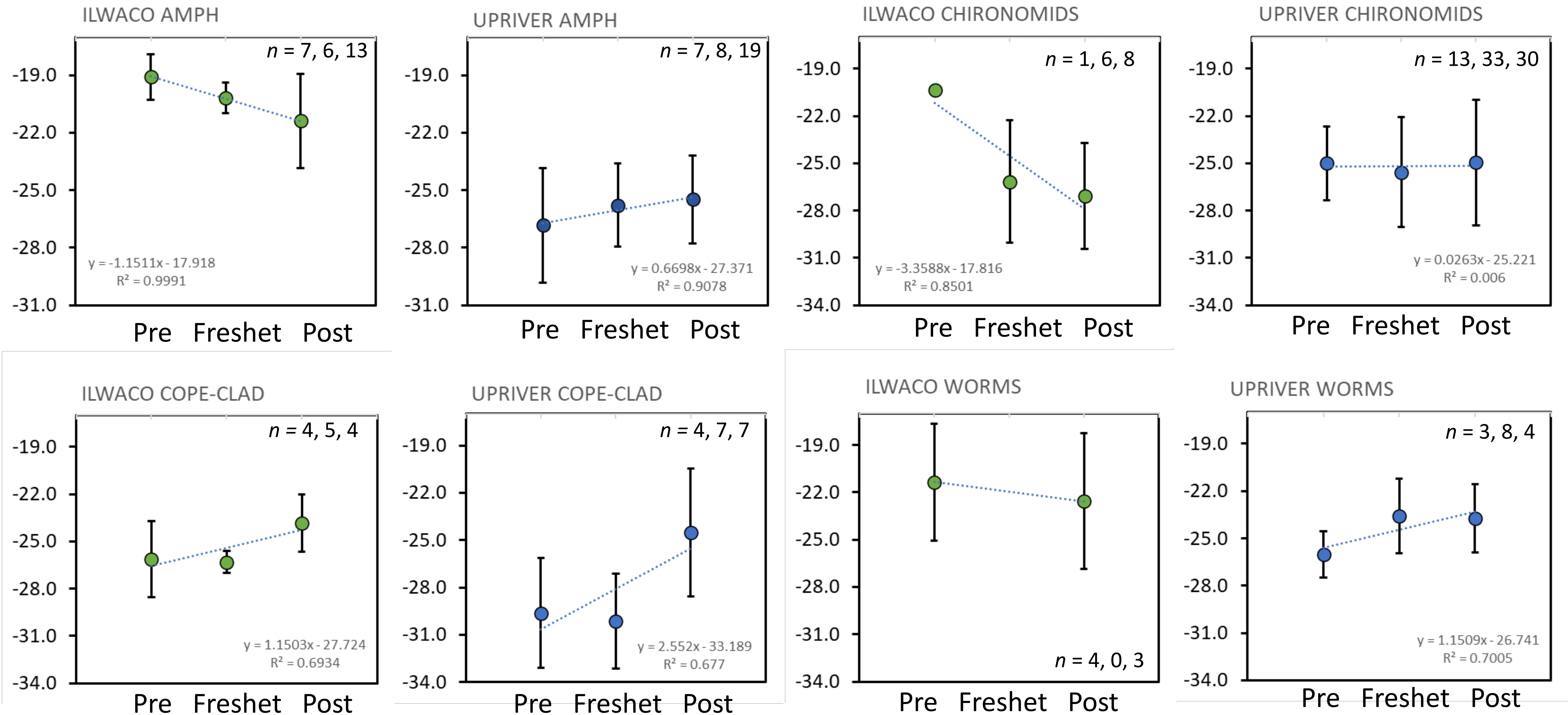
Model output estimates proportion of salmon diet from input sources



What sources of primary production make up the diet of chironomids (prey)?

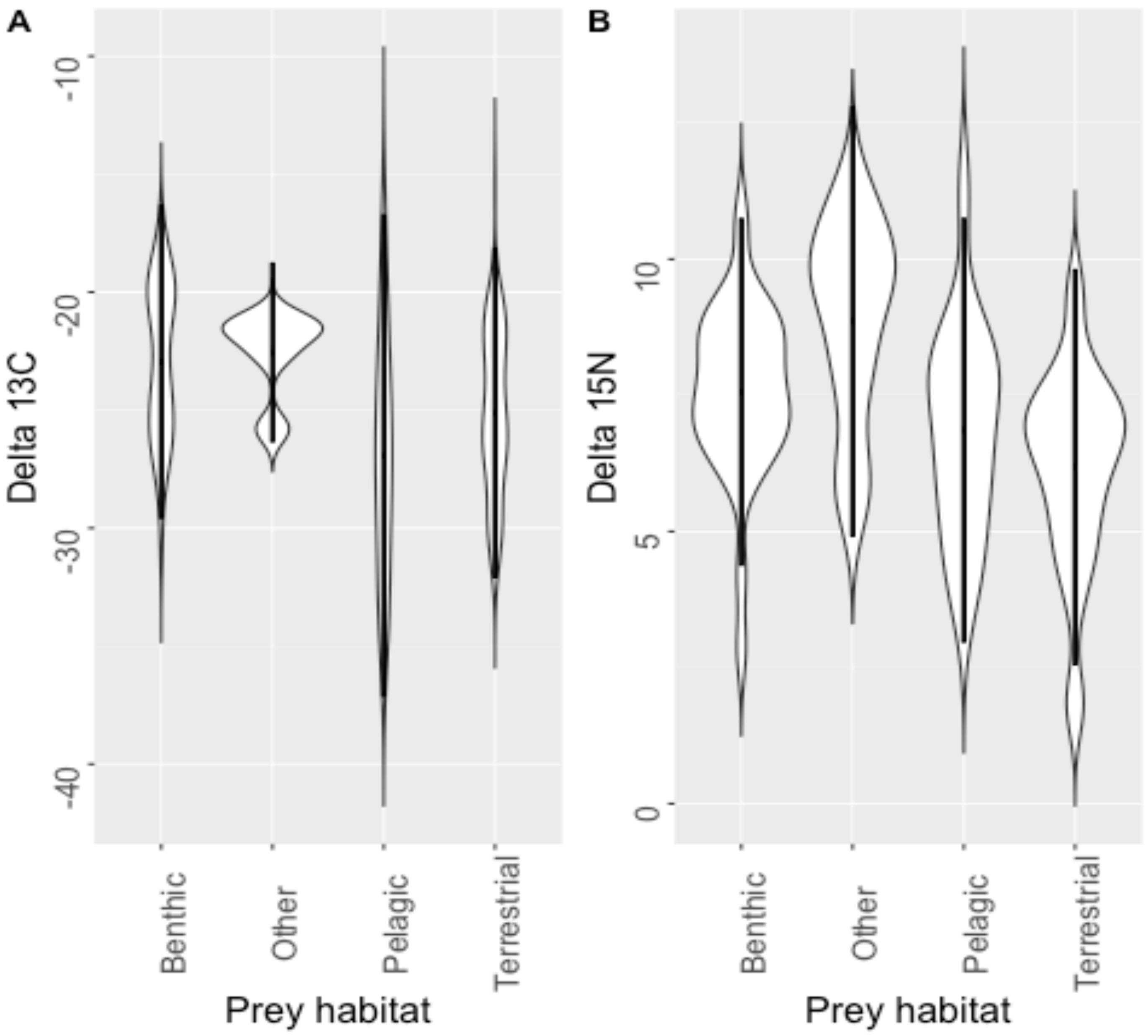


To improve models – explore data groupings
Average d^{13}C/d^{12}C signatures of invertebrate groups



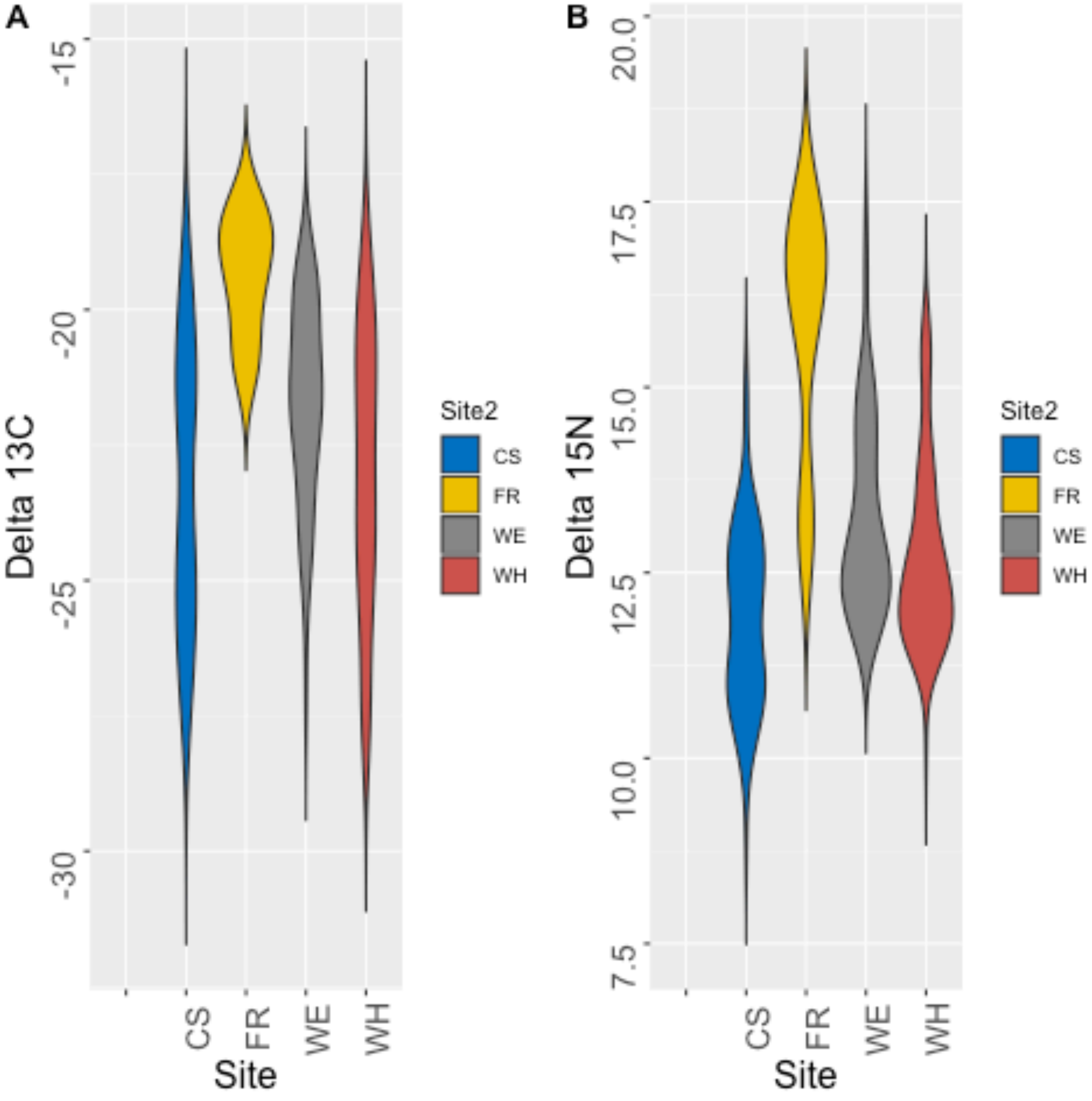
Data can be grouped according to meaningful characteristics based on what we know about the system - this guides interpretation of model outputs and helps refine the models.

The following slides show examples of how data might be grouped to guide model inputs as well as interpretation of model outputs.



Invertebrate prey by habitat

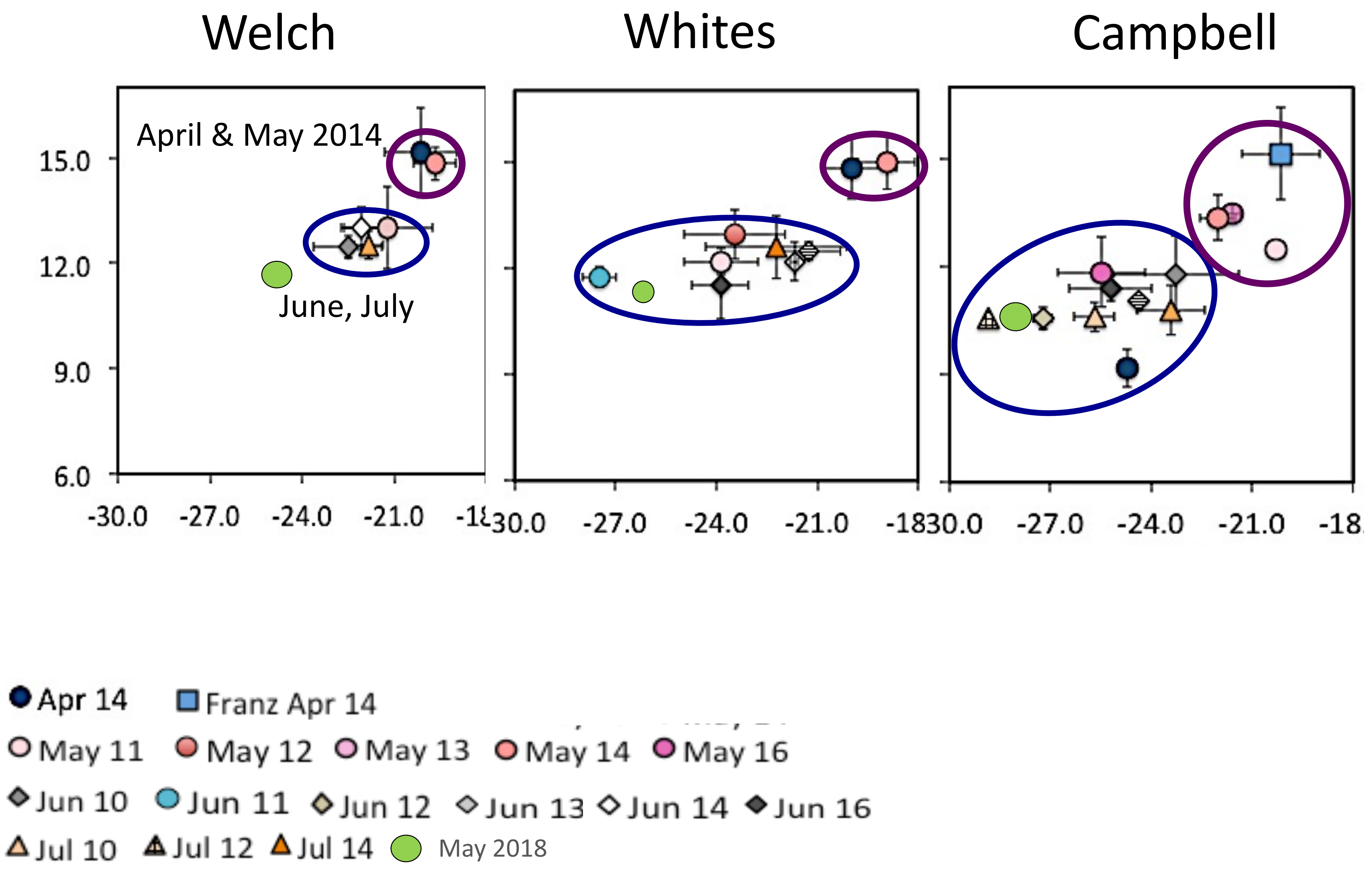
- Wide range of $\delta^{13}C$ values for pelagic, benthic, and terrestrial habitats
- $\delta^{15}N$ signatures of terrestrial material lighter than benthic or pelagic



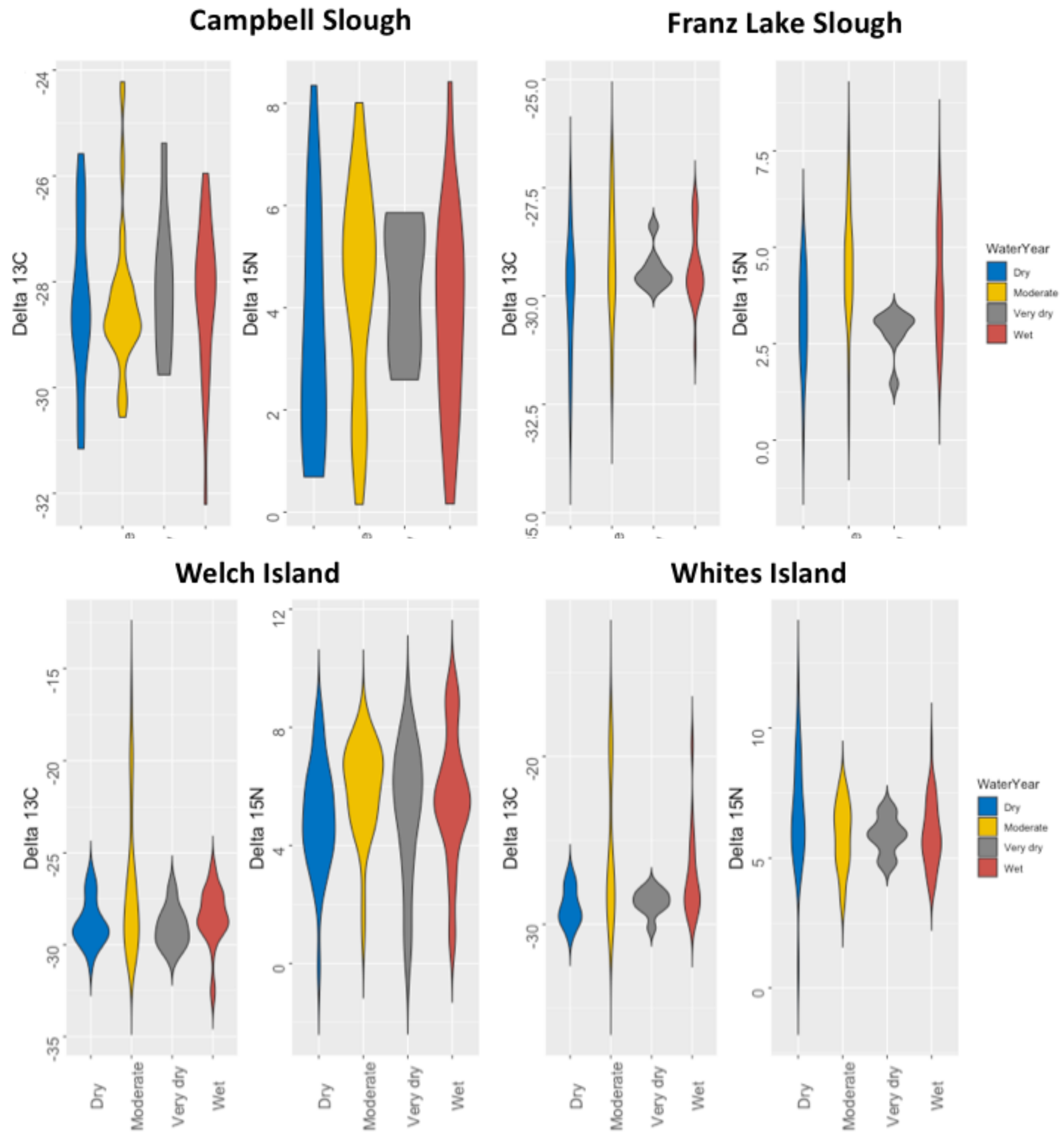
Salmon muscle by site

- Franz Lake Slough differs from other sites
- Fewer samples
- Test for bias in sample number and timing
- Whites & Welch have similar data distributions

Juvenile Chinook muscle – by year



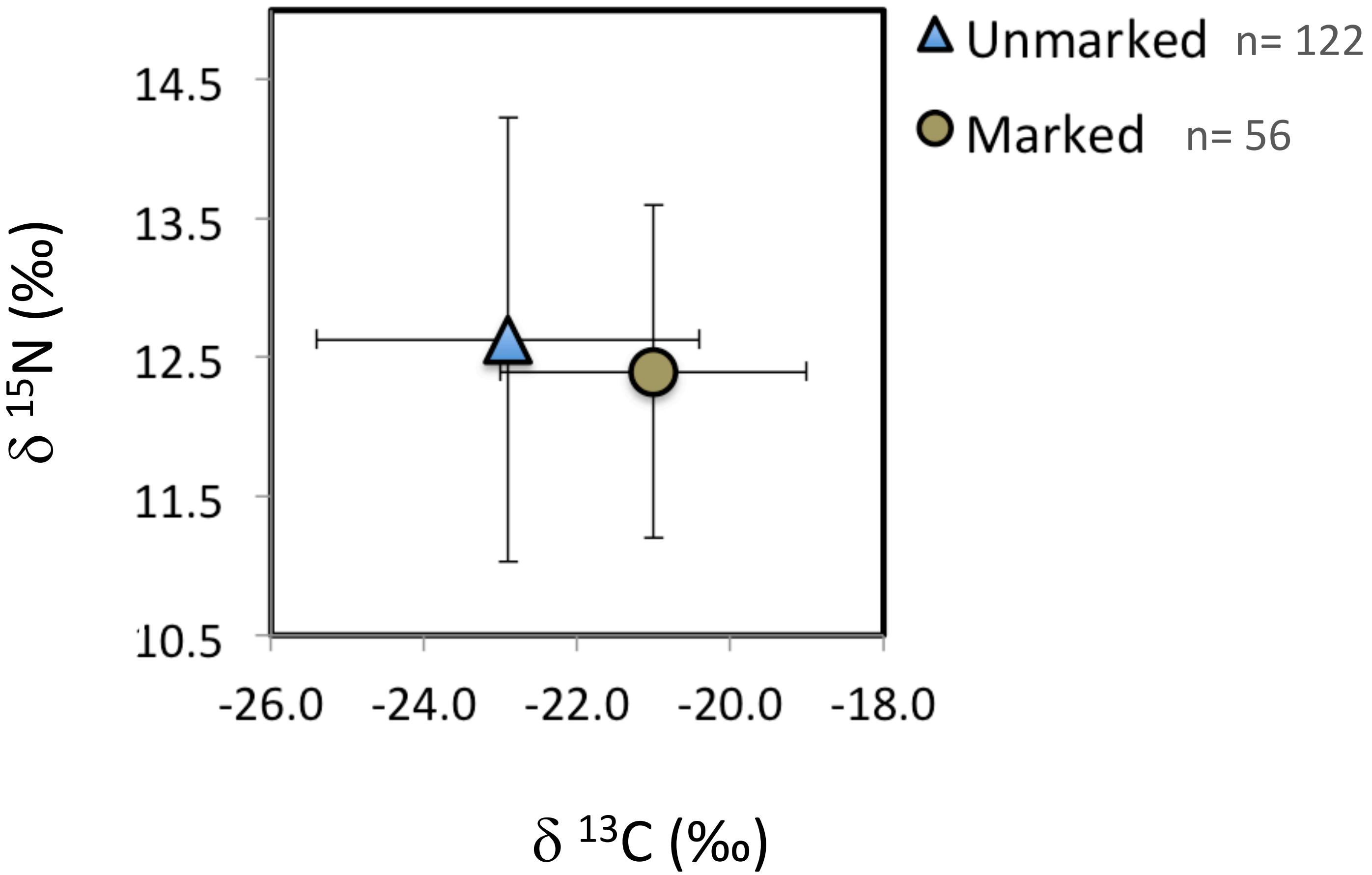
Vegetation sources – grouping by water year and by site



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 $\delta^{15}N$ ($p = 0.4057$)



Ongoing work

- Sensitivity analysis: variation in Trophic Enrichment Factors (TEF), or Trophic Discrimination Factors (TDF) – *how much change in isotope value with trophic level*

- Incorporate stomach content data into MixSIAR models as priors

- Explore fish groupings by year/month

- Incorporate new sources – ongoing lab analysis, values from literature (benthic diatoms, SAV, green filamentous algae)

- Deeper exploration of statistical differences among source contributions