Carbon, nitrogen and sulfur stable isotopes reveal strong Lake Trout reliance on profundal energy pathway

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Introduction

- Stable isotopes have emerged as a powerful tool to quantify foraging patterns and food web dynamics in aquatic systems.
- Conventional dual stable isotope approaches generally use carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) stable isotopes to estimate trophic position and reliance on pelagic and benthic energy pathways.
- Employing a tri-isotope approach, including sulfur stable isotopes ($\delta^{34}S$), could be a useful tool to quantify ontogenetic shifts in Lake Trout (*Salvelinus namaycush*) foraging on pelagic, benthic, and profundal energy pathways in Flaming Gorge Reservoir, Wyoming and Utah.
- **We predict that Lake Trout will have high reliance on invertebrate prey as juveniles and transition to fish as adults and implementing a tri-isotope approach will allow greater differentiation of Lake Trout reliance on pelagic and profundal energy pathways.**

Research Objectives

1) **Do Lake Trout stable isotope signatures occur within the appropriate carbon, nitrogen, and sulfur isotope space of their prey?**
2) **Does inclusion of sulfur isotope modify estimates of diet proportions in Lake Trout?**

Methods

Field Sampling

- Lake Trout were sampled with the use of multi-mesh gill nets and angling from each region of Flaming Gorge Reservoir during June 2019 to May 2020.

Lab Processing

- Muscle samples were dried to a constant mass and homogenized into a fine powder using a mortar and pestle.
- 1.0g of each sample was weighed into a tin capsule and analyzed using a Thermo EA Isolink coupled with an Isotope Ratio Mass Spectrometer (IRMS) at the University of Wyoming Stable Isotope Facility (UWSIF).

Lake Trout Size Classes

- Juveniles (≤482 mm: ≤19 in).
- Pups (482 mm through 711 mm: 19 in through 28 in).
- Trophy (>711 mm: >28 in).

Modeling

- Bayesian Stable Isotope Mixing Models in R (SIMMR) were used to quantify diet proportions of different prey items [1].

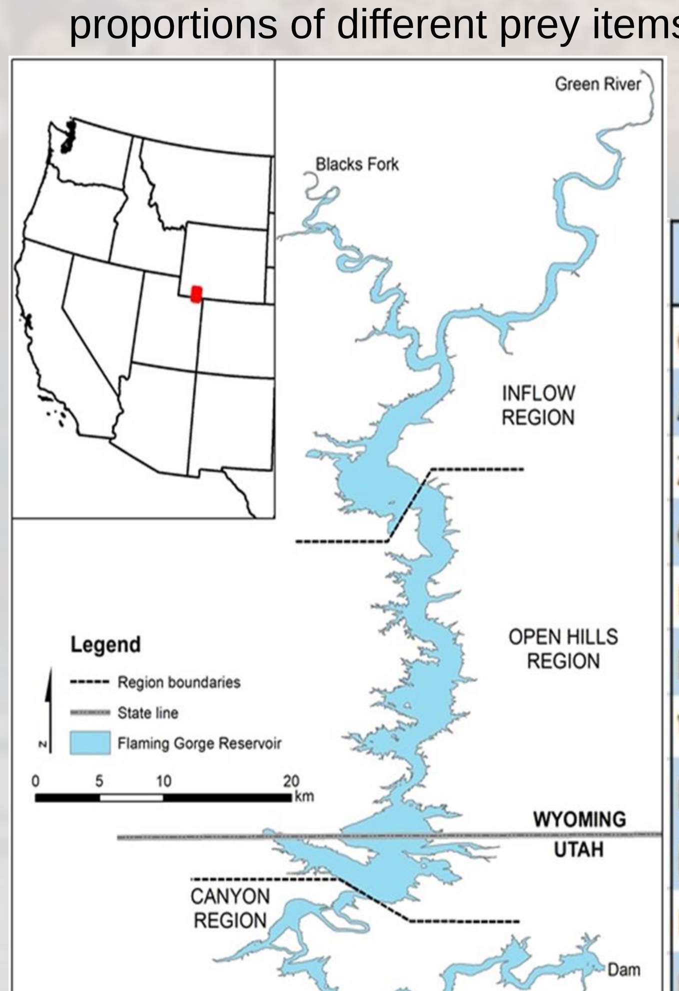

Figure1. Map of Flaming Gorge Reservoir illustrating geophysical location and the dividing lines between the three regions.

Table 1. Potential Lake Trout prey items within Flaming Gorge Reservoir with mean (sd) values of carbon, nitrogen, and sulfur stable isotope values.

Prey Items (n)	$\delta^{13}C$	$\delta^{15}N$	$\delta^{34}S$
Chironomids (1)	-34.21 [-]	13.72 [-]	2.59 [-]
Amphipods (3)	-34.55 [1.69]	11.9 [1.46]	3.27 [0.88]
Zooplankton (1)	-34.99 [-]	13.81 [-]	3.99 [-]
Crayfish (12)	-28.37 [1.04]	10.99 [1.12]	0.14 [1.72]
Burbot (34)	-30.73 [1.32]	14.41 [0.87]	4.67 [1.97]
Rainbow Trout (29)	-26.28 [2.02]	11.7 [1.12]	6.17 [0.44]
White Sucker (26)	-28.14 [1.24]	12.2 [1.24]	4.59 [1.42]
Bonneville Cutthroat (19)	-22.05 [1.63]	10.09 [0.56]	5.69 [0.42]
Utah Chub (8)	-30.47 [0.46]	13.54 [0.55]	5.24 [1.37]
Kokanee Salmon (39)	-31.74 [3]	15.33 [0.66]	6.07 [0.57]

Do Lake Trout occur within the appropriate carbon, nitrogen, and sulfur isotope space of their prey?

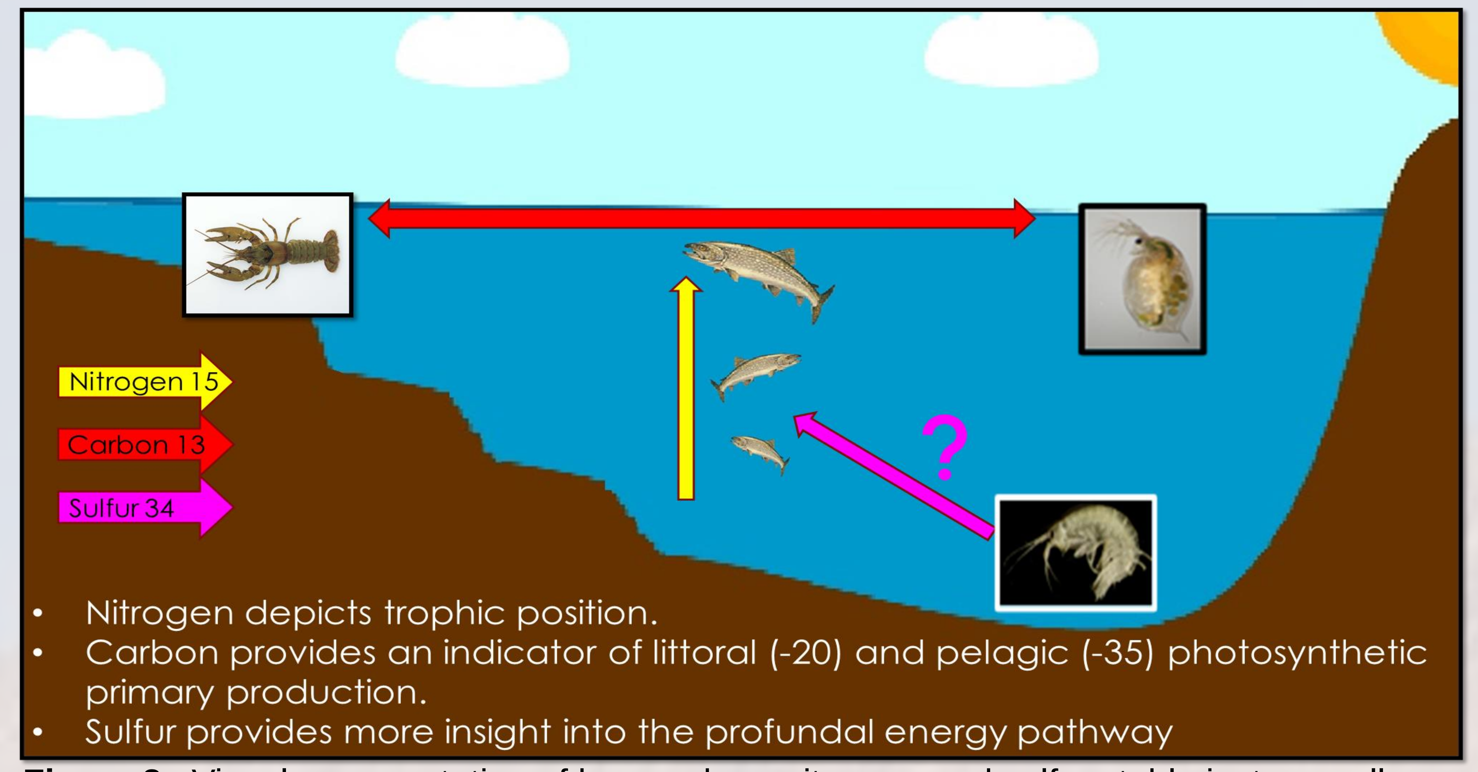

Figure 2 . Visual representation of how carbon, nitrogen, and sulfur stable isotopes allow differentiation of Lake Trout foraging on benthic, pelagic, and profundal energy pathways. Each isotope is represented by a specific color and arrows that depict the energy pathway they map.

Results:

- Juvenile and Pup Lake Trout overlap with potential prey items is consistent with a priori expectations (e.g., +3.4‰ for nitrogen and bound by carbon and sulfur).
- Several Trophy Lake Trout occur outside of observed isotopic prey space.
- Results suggest likely diet items were accurately identified for Juvenile and Pup Lake Trout, but additional prey items are needed for Trophy Lake Trout.

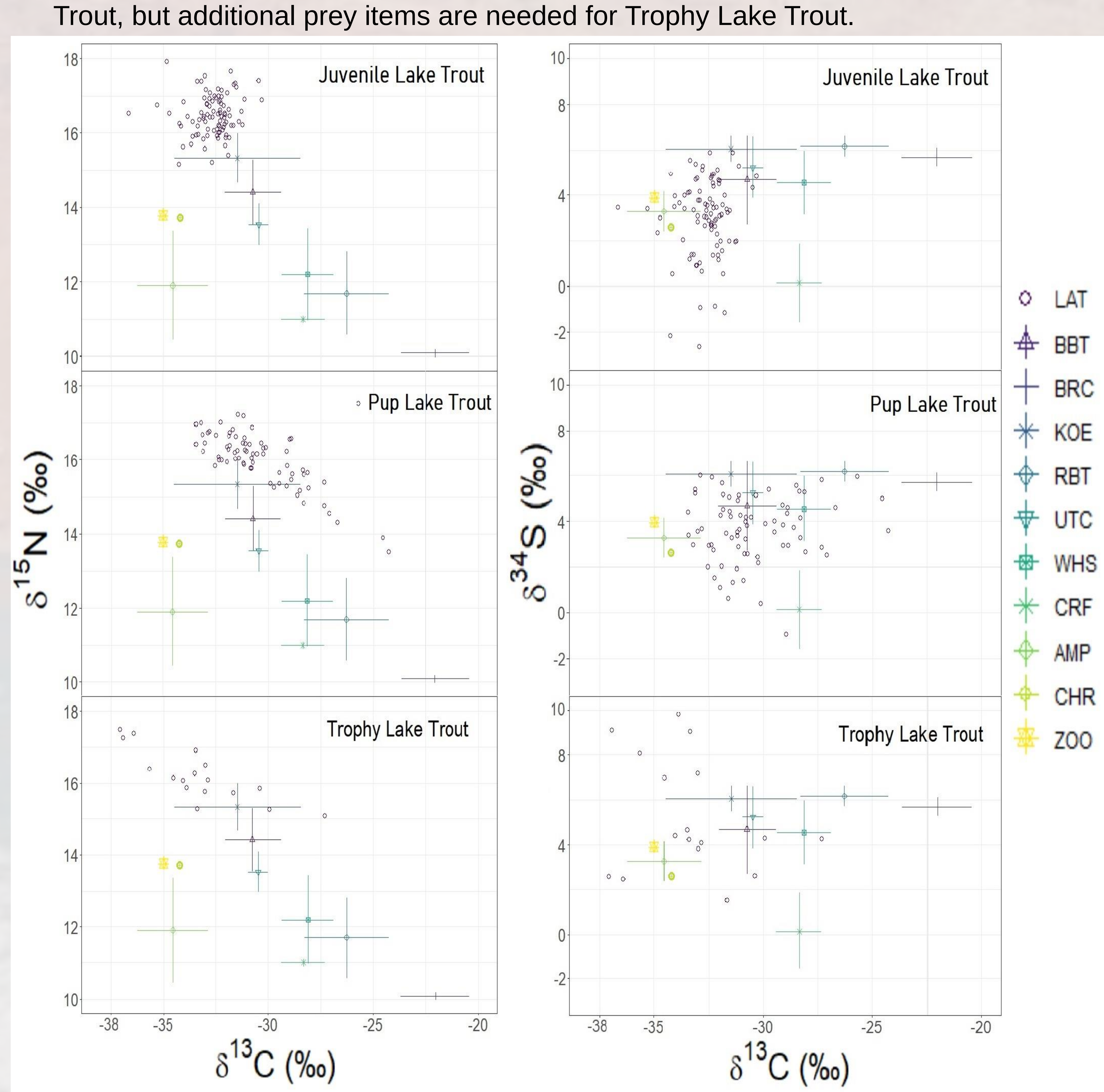

Figure 3. Dual-isotope plots of carbon verse nitrogen (left) and carbon verse sulfur (right) of muscle samples from Lake Trout and their prey items. Lake Trout muscle samples are separated by size class in each of the left and right isotope plots. Prey samples are separated by color and symbol.

Does inclusion of sulfur isotope modify estimates of diet proportions in Lake Trout?

- Diet proportions estimated from a dual isotope and a tri-isotope approach are consistent and confirm our expectation that Lake Trout transition from invertebrates to a greater reliance on fish throughout their ontogeny.
- Juvenile Lake Trout diets are dominated by zooplankton and benthic invertebrates.
- Pups show a high degree of variation in prey use, with individuals specializing on invertebrates, invertebrates and fish, and likely fish only.
- Estimates of Trophy Lake Trout diet proportions are likely not reflective of reality because we are missing likely prey items (Figure 3).
- Preliminary results suggest kokanee *(Oncorhynchus nerka)* and other stocked salmonids make up a smaller proportion of Lake Trout diets than expected.

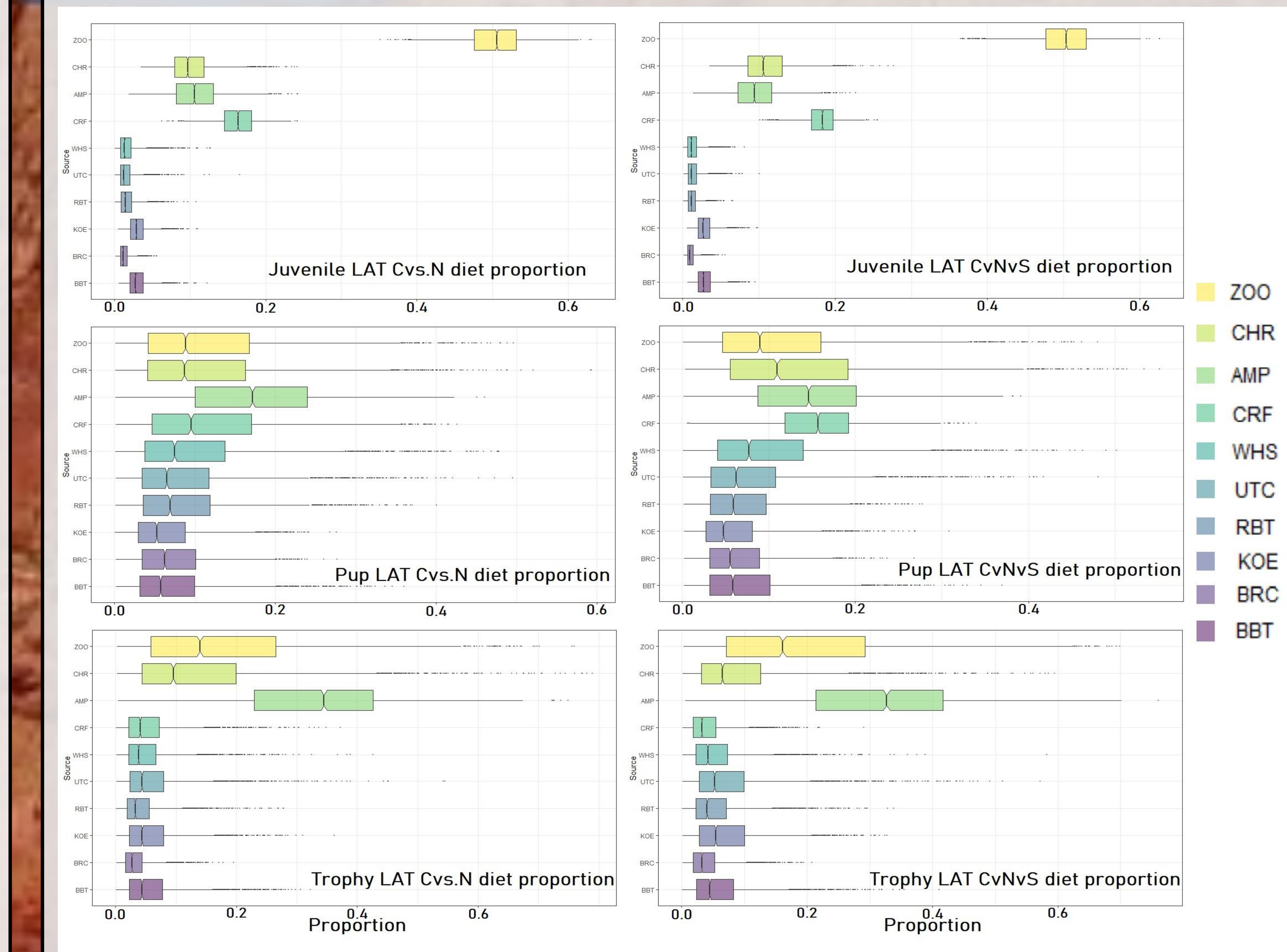

Figure 4. Dual-isotope approach (left) and tri-isotope approach (right) of SIMMR estimates of Lake Trout diet proportions. Each plot is separated by size class of Lake Trout while different diet items are separated by color. Order in legend matches order in plot.

Conclusions

- The dual and tri-isotope approaches produced consistent estimates of diet proportions.
- Across all Lake Trout sizes, invertebrate prey were the dominant diet items.
- Consumption of fish was dominated by White Sucker *(Catostomus commersonii)*.
- The results presented here are based on Lake Trout from bottom-set gill nets and angling on the bottom. This may have inflated the importance of profundal diet items. However, limited data from pelagic gillnetting and angling suggest that there are not many pelagic Lake Trout relative to benthic Lake Trout in this system.
- Future analyses will expand potential prey items by breaking up individual prey species into size classes to account for ontogenetic shifts in their isotopic signatures (e.g., Kokanee from stocking to adulthood) and assessing seasonal foraging patterns through analyses of diets and liver stable isotope signatures

Acknowledgements and References

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[1] Parnell, A. (2019). SIMMR: A stable isotope mixing model. R package version 0.4.1.