Natural trophic variability in a large, near-pristine lake: What are the implications for studying change in other lakes?

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Introduction

Historical stable isotope studies have proven to be a powerful tool for elucidating how anthropogenic changes, such as invasive species and nutrient pollution, have impacted aquatic food webs (1-3). Such studies compare stable isotope samples from recently collected fish to those from specimens collected before the disturbance. But such studies are difficult to interpret precisely without an adequate understanding of natural background variability in those systems.

In order to establish a baseline of natural variability across species, space and time in the absence of anthropogenic effects, we used carbon (C) and nitrogen (N) stable isotopes to examine the fish community of a large, oligotrophic, near-pristine system.

We asked three questions:

1) What patterns of trophic variability did we see overall?
2) Which has a greater effect on trophic variability: time or space?
3) How large must a trophic change be in order to be detectable against such background variability, and what sample sizes do we need to detect such a change?

Study site & methods

Lake Hövsgöl:

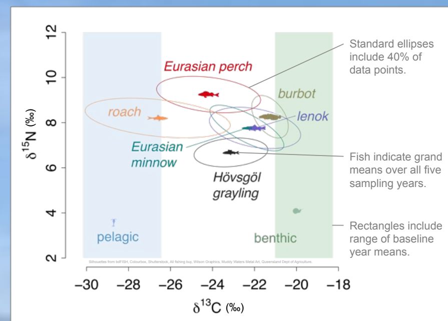
- 19th largest lake in the world by volume (383 km³, mean depth 138 m)
- Dimictic and ultra-oligotrophic (Secchi depth: >18 m)
- Located in Mongolia: the least densely populated country in the world
- Only 10 species of fish
- Subject to minimal development and fishing within the watershed

Sample collection & analysis:

- Muscle tissue samples from 6 fish species and benthic (snail) and pelagic (zooplankton) baseline species (mean sample size: 10 samples/species/year)
- 5 collection years: 2006, 2009, 2011, 2012 and 2013
- 7 collection locations around the lake
- Samples dried in solar oven
- Isotope analysis conducted at UC Davis Stable Isotope Facility
- Isotope results expressed using δ notation: ppt (‰) from standard (Vienna PDB for C and air for N)
- Isotope values lipid-corrected based on (4).

Results

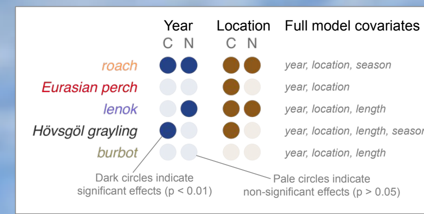
1) Overall food web variability



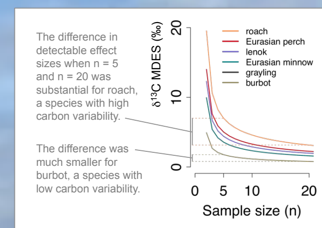
Lake fish showed a wide range of carbon signatures, with burbot the most benthic and roach the most pelagic. Carbon variability was higher in pelagic species than in benthic species (i.e., roach demonstrated more variable carbon signals than burbot did).

2) Effect of time and space

ANOVAs comparing mixed effects models (with length and season as fixed effects and year and location as random effects) indicated that year was significant for only two species for both nitrogen and carbon while location had a significant effect on carbon for almost all species and on nitrogen for two species.



3) Power analysis



This power analysis shows the smallest difference (or effect size) detectable with a *t* test for a range of sample sizes given variability similar to what we observed. Populations with low variability have small minimum detectable effect sizes (MDES) and those with high variability have large ones. As sample size increases, MDES decreases.

Our calculated MDES shrank considerably between n = 5 and n = 20 for species with high variability (such as roach for carbon), but sample size had a smaller impact on MDES for species with low variability (such as burbot for carbon).

Conclusions

- Isotope signatures varied by both location and year, but more by location than by year; samples collected in a single year or location may not be useful for generalizing across a system over multiple years. If resources are limited, samples from multiple locations in a system may prove more illuminative than samples from multiple years.
- Fish species demonstrated a broad range of minimum detectable effect sizes (MDES) depending on their isotopic variability. Appropriate sample sizes for any stable isotope study are best determined both by the questions asked in the study and the variability likely to be found in the population sampled.

References

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