Resolving Issues Related to Diet Estimation with Stable Isotopes

There are several hurdles to properly estimating diet proportions with stable isotopes. Deciding whether to group sources *a priori* or *a posteriori* will depend on the number of diet sources in the model, the similarity of the source signatures, and the uncertainty around the diet estimates. Accounting for trophic discrimination is also important and can have large effects on diet estimates. Below I address these two issues. As a note, I have not included any fixed effects or groups in this analysis.

# Determination of Necessity to Group Sources

Introduction

Sources that are isotopically similar makes it difficult for the model to differentiate between the sources and you can end up with estimates with a lot of uncertainty around them. It is recommended that if you are going to group sources, you do it *a posteriori*. Our diet sources are isotopically similar, even between sources that we might expect to be quite distinct like moose and ants (Figure 1). One indication that sources are too isotopically similar for the model to differentiate between them are strong negative correlations. Below I provide diet estimates, model output, and an argument not to group any sources, despite their isotopic similarities.

Summary

There is a lot of overlap between many of the diet sources within our system. We could combine ants and moose into one group representing available nitrogen on the landscape and combine all three berry species into a single group. The correlation plot from the mixing model indicates that crowberry and lingonberry are indistinguishable (correlation = -0.76), while ants and moose are also indistinguishable (correlation = -0.71). Lingonberry and Bilberry have a marginal negative correlation. However, the model seems to have estimated dietary proportions for each source with high precision (Table 1).

To explore further, I combined sources one step at a time beginning with the most negative correlation. While combining sources does decrease the uncertainty around our diet estimates, it does not eliminate strong negative correlations between food sources. Once crowberry and lingon berry are combined, the correlation between bilberry and the other two berry species is inflated, creating an even larger negative correlation. Once all three berry species are combined, there is a strong negative correlation between ants and the three berry species. Given that the model provides robust estimates without combining food sources, I would recommend not combining sources. There are other tools within mixing model packages that I can use if I need to draw inferences about differences between two specific food sources and as long as we are explicit about the negative correlations and the limitations of our dataset, I do not think this will be a problem.

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Figure 1. Plot of the mixing space containing Swedish brown bears (mixtures) and five diet sources. These sources have been corrected with a trophic discrimination factor that was derived from several published bear feeding studies (see next section for more information)

Table 1. Estimated dietary proportions of brown bear in Sweden from hair stable isotopes

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Source | Dietary Proportion | SD | LCI | UCI |
| Ants | 0.07 | 0.01 | 0.06 | 0.08 |
| Bilberry | 0.47 | 0.01 | 0.45 | 0.50 |
| Crowberry | 0.14 | 0.02 | 0.10 | 0.17 |
| Lingonberry | 0.29 | 0.02 | 0.25 | 0.33 |
| Moose | 0.04 | 0.00 | 0.03 | 0.04 |

# Sensitivity of Estimates to Trophic Discrimination Factors

Introduction

Since I concluded from my previous analysis not to group sources (pending comments from collaborators), I went forward with looking at the sensitivity of my diet estimates to different tropic discrimination factors, hereafter abbreviated as TDF. Below I generated several models with different discrimination factors to estimate how this effects my diet estimates. I compare 6 models, all with uninformative priors. The first model will have the specific TDFs that I derived from the linear equations of Hilderbrand et al. (1996), Felicetti et al. (2003) and Rode et al. (2016). For each group of TDFs, I include the same variance around the TDFs of standard deviations of 2‰.

### Model list:

Model 1: My derived TDF (hereafter referred to as Mikkelsen)

Model 2: TDF calculated from Hilderbrand et al 1996

Model 3: TDF calculated from Felicetti et al. 2003

Model 4: My TDFs -1 per mil

Model 5: My TDFs +1 per mil

Model 6: No TDF as in Ro et al. 2021

# Summary

Brown bear diet estimates are sensitive to changes in the trophic discrimination factor—changing the TDF by only 1‰ changed the estimated proportion of a given source by 11–216% depending on the source and the direction of the change (increasing or decreasing the TDF; Table 2). The greatest changes were seen in proteins sources when the TDFs were decreased by one, which resulted in an increased proportion of ants from 0.07 to 0.22 and moose from 0.04 to 0.09. Disregarding the Ro Model with no TDFs, bilberries had the most variation across the models and moose had the least variability (Figure 2).

Small changes in the linear regression used to predict the stable isotope signatures resulted in changes in the TDFs, which resulted in large differences in the estimated proportions of bear diets. For example, the linear equations to estimate δ13C from Hilderbrand et al. (1996) and Felicetti et al. (2003) are miraculously similar— their intercepts differ by 0.52 while both beta estimates are 0.42 (Table 1). This difference resulted in TDFs from Hilerbrand et al. (1996) being 0.52‰ higher than those derived from Felicetti et al. (2003) and proportional dietary estimates that varied by 0.02–0.22, depending on the food source. Ants and moose changed very little, but bilberries accounted for either 0.59 (Hilderbrand) of brown bear diets or 0.47 (Felicetti) of brown bear diets. Both model estimates had high precision (0.35 – 0.40 and 0.56 – 0.61, respectively).

Examining the sensitivity of my estimates and models to different TDFs was recommend by Keith Hobson, however now that it is completed, I need guidance on next steps. Basically

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Figure 2. Estimated Dietary proportions of each diet source with different columns representing the different models used to estimate trophic discrimination factors and the resulting dietary proportions illustrated by different colors.

Table 2. Model output summary used to calculate trophic discrimination factors and dietary estimates of brown bears in Sweden

