Lab 2: Food chain length using stable isotopes

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Introduction

Analysis of stable isotopes is a common method employed in trophic ecology research. Typically, most atoms have the same number of protons and neutrons within their nucleus. Occasionally, isotopes occur which are “heavy” variants of atoms where the nucleus contains more neutrons than protons. In some instances, isotopes are radioactive and decay over time. In other instances, isotopes are stable and do not decay over time. For example, nitrogen-14 is the most common version of nitrogen on the planet and has a nucleus with 7 protons and 7 neutrons. Nitrogen-15 is a stable isotope version of nitrogen with 7 protons and 8 neutrons. Nitrogen-15 participates in all of the same biological reactions as nitrogen-14, but the rate at which nitrogen-15 participates differs from that of nitrogen-14 due to the additional weight for nitrogen-15. Because the reaction rates for the two isotopes differs, measuring isotope values can reveal insights into many biological and ecological processes.

Within the field of trophic ecology, nitrogen stable isotopes are used to determine the trophic level of an organism. Nitrogen isotopes fractionate up a food web. That is, the heavy version of nitrogen (nitrogen-15) tends to accumulate up a food web. Higher trophic levels have higher levels of the nitrogen-15 stable isotope. In addition, the rate of enrichment (how much of an increase in nitrogen-15 occurs between two trophic levels) is generally considered to be consistent within a food web. This rate is known as the trophic enrichment factor (TEF). Therefore, by measuring nitrogen isotope values of consumers and primary producers and by knowing the TEF for a system, a researcher can gain knowledge regarding the trophic position that a consumer is occupying within that system.

Methods

To extract data from Figure 2 of Post 2002, I visually estimated each datum point’s δ15N value. The method suggested by the lab document (<https://apps.automeris.io/wpd/>) was not intuitive for me to use. Estimated δ15N values were then summarized for pelagic production to estimate a median δ15N value for small and large seston production in each lake location (n = 3). These pelagic producer median δ15N values were then subtracted from the estimated mussel δ15N value for that respective lake and divided by a trophic enrichment factor to produce an estimated trophic position value for mussels in each lake.

Equation 1: TPmussel = (δ15Nmussel - δ15Nproducer)/TEF + 1,

where TPmussel is the estimated mussel trophic position, δ15Nmussel is the mussel δ15N value, δ15Nproducer is the primary producer δ15N value, and TEF is the trophic enrichment factor. Trophic enrichment factors were allowed to vary according to reported results in Fig 6A of Post 2002 (TEF range = 0.5-5.5).

Results

The δ15N values for primary producers varied throughout the summer (Fig 2 of Post 2002). However, Post notes that primary consumers do not have a significantly different δ15N value from the median of the primary producer δ15N value summer time-series. Thus, the median of each primary producer over the course of the summer was chosen as the representative value for determining trophic position estimates for mussels later.

Trophic position estimates (TPE) for mussels varied according to the TEF that was chosen (Table 1). By nature of Equation 1, TPEs were highest when smaller TEFs were chosen. TPEs were below 1 when the δ15N value of the consumer (mussels) was lower than the δ15N value of the producers (small or large seston). This occurred when using small seston as the primary producer to make TPEs of mussels in Oneida Lake. Trophic positions less than 1 are impossible (primary production is designated as level 1) and are thus uninformative.

Table 1 Trophic position estimates for mussels in three lakes with varying trophic enrichment factors. Mussels were analyzed from three lakes with two pelagic producer groups. The median δ15N value was determined for each lake/primary producer combination (median.d15N). The mussel δ15N value was determined for each lake. Trophic position estimates were determined according to Equation 1 with TEFs chosen according to Fig 6A of Post 2002. Trophic position estimates were populated into the table where the name of the column corresponds to the TEF that was chosen for that respective trophic position estimate (e.g., column “tef\_0.5” corresponds to a trophic position estimated with a TEF = 0.5).



Discussion

The choice of trophic enrichment factor greatly influences the resulting estimate of trophic position for a consumer. David Post determined that the mean value was 3.4 per mil for δ15N values. However, there is significant variation around this value, with a range from 0.5 to 5.5 per mil (Fig 6A from Post 2002). In this exercise, varying the δ15N TEF from 0.5 to 5.5 changed the trophic position significantly. For example, when examining the Cayuga Lake system with large seston used as the primary producer, mussels have an estimated trophic position of 3.4 when the TEF was 0.5. However, when the TEF was on the alternative end of the spectrum at 5.5, the TPE for mussels dropped to 1.22. A trophic position of 1.22 would indicate that mussels are just barely above the level of primary production (TL = 1). We know that mussels must at least be at the second trophic level because they are unable to perform primary production; they are an obligate consumer and thus their trophic level must be greater than or equal to 2. On the other hand, a TPE of 3.4 would indicate that mussels are consuming a fraction of their diet that was at or above the third trophic level. This would mean they are consuming predators, which could be possible if they were consuming predatory zooplankton. With the mean TEF of 3.4 posited by Post, the TPE for mussels in this lake would be 1.35. Once again, this is an uninterpretable result because we know mussels must at least be at a trophic level of 2 or greater.

Based upon this analysis, it is important to choose a TEF that is reasonable for the system-of-interest. The best way to do this would be to collect primary producers and primary consumers within the system and within the time series relevant to the research. The primary consumer should be a grazer/herbivore, not an omnivore. Omnivores confound results that could be gleaned from estimating the system’s TEF. For a given primary consumer, a sample representative of the primary producers it is consuming is necessary, not just any primary producers in the system. With a δ15N value for a primary consumer and the primary producers it consumes, then you could determine the amount of enrichment that occurred for that 1-trophic level jump and apply that TEF to the rest of the system.

Alternatively, if you are not able to collect both primary producers and primary consumers from a system, you should collect at least one of these and then use a TEF published in the literature that is most relevant to a system similar to the one you’re studying. It is important to collect either a primary producer or primary consumer to calibrate the data you produce. Values of δ15N are known to vary spatially and temporally, and collecting a base level organism can correct for this variation.

References

Post, D. M. 2002. Using stable isotopes to estimate trophic position: models, methods, and assumptions. Ecology 83(3):703–718.