Stable isotopes as descriptors of trophic niches
What’s a trophic niche?

Concept of **ecological niche** (sensu Hutchinson, 1957):

A hypervolume set in n-dimensional space where each of the axes represents an environmental parameter.

**Concluding Remarks**

G. Evelyn Hutchinson

Cold Spring Harbor symposia on quantitative biology 22: 415-427
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2 categories of dimensions: **habitat**- and **resource**-related.

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What’s a trophic niche?

Concept of **ecological niche** (sensu Hutchinson, 1957):

A hypervolume set in n-dimensional space where each of the axes represents an environmental parameter.

**Trophic niche** = part of the ecological niche built using the **subset** of dimensions related to trophic resources.

2 categories of dimensions: **habitat-** and **resource-related**
Identify **feeding strategies**: specialists (narrow trophic niches) vs. generalists (wide trophic niche)
Trophic niche study: why?

- Identify feeding strategies: specialists (narrow trophic niches) vs. generalists (wide trophic niche)
- Understand how trophic interactions can affect community structure
Trophic niche study: why?

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- Understand how trophic interactions can affect community structure
- Highlight diet shifts and study trophic plasticity
Trophic niche study: why?

- The trophic niche concept is useful to address many fundamental ecological questions.
- For decades: practical issues to provide quantitative estimates of niche parameters.
Trophic niche study: why?

- The trophic niche concept is useful to address many fundamental ecological questions
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Increase of trophic niche use is linked with emergence of new analytical and computational tools
Trophic niche study: why?

- The trophic niche concept is useful to address many fundamental ecological questions.
- For decades: practical issues to provide quantitative estimates of niche parameters.

Graph: Number of referenced articles (Scopus)
- TITLE-ABS-KEY(trophic niche)
- TITLE-ABS-KEY(trophic niche) AND (isotop*)

Years: 2001 to 2013

Number of articles: 0 to 250
1. δ-space plots and convex hulls

**Position** of consumers in the δ-space (= isospace) is mainly driven by differences in foraging habits and **resource use**.

**Metrics** based on these positions can provide insights about **trophic niche**.
CAN STABLE ISOTOPE RATIOS PROVIDE FOR COMMUNITY-WIDE MEASURES OF TROPHIC STRUCTURE?

1. δ-sp

Craig A. Layman,①,⑤ D. Albrey Arrington, ② Carmen G. Montaña, ③ and David M. Post ④


Geometric approach (Layman et al., 07):

Fit a convex hull (i.e., the smallest possible surface that encompasses all points) to the 2D data

This convex hull represents the isotopic niche of the group of consumers (proxy for their trophic niche)
Can Stable Isotope Ratios Provide for Community-Wide Measures of Trophic Structure?

Craig A. Layman, D. Albrey Arrington, Carmen G. Montaña, and David M. Post


1. δ-sp

Geometric approach (Layman et al., 07):

Fit a convex hull to the 2D data

Calculate 6 parameters used as descriptors of the trophic niche
1. δ-sp

**Abstract.** Stable isotope ratios (typically of carbon and nitrogen) provide one of the most common tools employed in the study of food web structure. Yet stable isotopes have not been applied to quantitatively characterize community-wide aspects of trophic structure (i.e., at the level of an entire food web). We present a novel analytical approach to calculate "Layman metrics" (δ-sp) in δ15N vs. δ13C bi-plots with species (or individuals, populations) plotted based on their mean stable isotope measures. δ-sp is a measure of the δ13C range of a population (species), where greater range indicates the organisms are consuming a more variable source of dietary carbon, and therefore are located further away from their primary producers. δ-sp therefore provides one way to determine ultimate sources of dietary carbon and can be informative in some instances. Recent research has sought to provide more quantitative measures based on niche shifts (Post 2002), packing within trophic niche space. To facilitate discussion of opportunities and limitations of δ-sp, well-established niche metrics are presented: species packing, mean nearest neighbor distance, and convex hull area. Practitioners contemplating the use of δ-sp in their work should be aware of these and other limitations, and also the strengths of the method.
1. δ-sp

CRAIG A. LAYMAN,¹⁵ D. ALBREY ARRINGTON,² CARMEN G. MONTAÑA,³ AND DAVID M. POST⁴


Descriptors
("Layman metrics")

δ¹³C range
δ¹⁵N range

Greater when consumers belong to more "trophic levels"
CRAIG A. LAYMAN, D. ALBREY ARRINGTON, CARMEN G. MONTAÑA, AND DAVID M. POST


1. δ-sp

Descriptors
("Layman metrics")

δ\(^{13}\)C range
δ\(^{15}\)N range
Total area of the convex hull

Greater when trophic niche is wider, i.e. when overall trophic diversity is greater
1. δ-σp

CRAIG A. LAYMAN,1,5 D. ALBREY ARRINGTON,2 CARMEN G. MONTAÑA,3 AND DAVID M. POST4


Descriptive statistics of δ13C and δ15N values from aquatic species in a Bahamian tidal creek ecosystem. The graph illustrates the isotopic niche space of species, with descriptors such as δ13C range, δ15N range, total area of the convex hull, and mean distance to centroid. These metrics provide insights into the trophic diversity and ecological structure of the system.
CAN STABLE ISOTOPE RATIOS PROVIDE FOR COMMUNITY-WIDE MEASURES OF TROPHIC STRUCTURE?

CRAIG A. LAYMAN,1,5 D. ALBREY ARRINGTON,2 CARMEN G. MONTAÑA,3 AND DAVID M. POST4

Ecosystem, 88(1), 2007, pp. 42–48

1. δ-σp

Descriptive
("Layman metrics")

δ\(^{13}\)C range
δ\(^{15}\)N range

Total area of the convex hull
Mean distance to centroid
Mean nearest neighbor distance

Lower when trophic niches of consumers are similar (trophic redundancy)
**Abstract.** Since the earliest applications of stable isotope ratios, we now seek to provide more quantitative measures based on stable isotope ratios. This approach draws on techniques that are frequently applied in ecomorphology literature, where stable isotope ratios are used to depict the trophic niche of an organism. For example, they can be used to calculate the specific energy flow pathways leading to one (or a few) consumer species of interest. Stable isotope ratios provide a new perspective on food web structure, function, and dynamics. For instance, the mean nearest neighbor distance among all species pairs is a measure of species diversity, whereas the mean nearest neighbor distance among one species and all other species is a measure of trophic redundancy in food webs, as well as to link individual species to the specific energy flow pathways leading to one (or a few) consumer species of interest.

**Keywords:** biodiversity; diet; ecomorphology; food webs; functional groups; niche; predator–prey interactions; trophic guild; trophic redundancy.

**Descriptors ("Layman metrics")**

- $\delta^{13}$C range
- $\delta^{15}$N range
- Total area of the convex hull
- Mean distance to centroid
- Mean nearest neighbor distance
- SD of nearest neighbor distance

Measures how evenly trophic diversity is distributed among the studied group.
Trophic niche study: how?

1. δ-space plots and convex hulls

Designed for study of whole communities, but can also be used for populations.

Useful set of tools that provide complementary information about trophic diversity and niche extent, but...

Metrics (especially TA) sensitive to sample size and presence of "extreme" points.
2. $\delta$-space plots and standard ellipses (Jackson et al., 2011)

**Standard ellipse** vs. convex hull
(SD vs. full range)

Single metric: **standard ellipse area**
Represents "core isotopic niche" of the group of consumers

More **robust** and less sensitive to extreme values and small sample size (SEAc)

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Journal of Animal Ecology

Comparing isotopic niche widths among and within communities: SIBER – Stable Isotope Bayesian Ellipses

in R  Andrew L. Jackson$^1$, Richard Inger$^2$, Andrew C. Parnell$^3$ and Stuart Bearhop$^2$
Trophic niche study: how?

2. δ-space plots and standard ellipses (Jackson et al., 2011)

Comparisons of groups

Quantification of isotopic niche overlap

Comparison of isotopic niche width: bayesian modelling approach

Journal of Animal Ecology

Comparing isotopic niche widths among and within communities: SIBER – Stable Isotope Bayesian Ellipses in R

Andrew L. Jackson¹*, Richard Inger², Andrew C. Parnell³ and Stuart Bearhop²
Instead of calculating SEA from SD: estimation using bayesian inference

More robust + takes uncertainty into account

Outputs: frequency distribution of model solutions

Easy to compare SEA across groups

Comparing isotopic niche widths among and within communities: SIBER – Stable Isotope Bayesian Ellipses in R

10^5 solutions

SEA_1 < SEA_2 in 98.14 % P-value analogy
Comparing isotopic niche widths among and within communities: SIBER – Stable Isotope Bayesian Ellipses in R

Andrew L. Jackson¹*, Richard Inger², Andrew C. Parnell³ and Stuart Bearhop²

Part of SIAR (Stable Isotope Analysis in R): R package, freely available from the CRAN repository

Allows

- Fitting of convex hulls and standard ellipses to isotopic data
- Computation of "Layman" metrics and SEA
- Model estimations of these parameters
  - ...

More info, example scripts, podcasts available at http://www.tcd.ie/Zoology/research/research/theoretical/siar.php
Isotopic niches: an example

Characterizing trophic ecology of generalist consumers: a case study of the invasive lionfish in The Bahamas
Craig A. Layman¹*, Jacob E. Allgeier²

Present in the Caribbean and US Atlantic waters since early 2000’s

Lionfish (Pterois volitans/miles) Native from Indo-Pacific regions
Characterizing trophic ecology of generalist consumers: a case study of the invasive lionfish in The Bahamas

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Isotopic niches: an example

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Generalist predator (> 40 fish species, benthic crustaceans)
Negative impact on prey populations
Competition with native predators? Trophic niche overlap?

Schoolmaster snapper (Lutjanus apodus)
Grey snapper (Lutjanus griseus)
Isotopic niches: an example

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Isotopic biplot suggest important similarity in resource use
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Isotopic **biplot** suggest important **similarity** in resource use

**Convex hulls** (proxy for the total, realized trophic niche) suggest **overlap** between the 3 species

**Standard ellipses** (proxy for "core niche", i.e. most frequent utilization of resources): **Competition** is most likely to occur between lionfish and schoolmaster

Supported by **gut contents**: grey snappers ingest more benthic crustaceans

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Caution on isotopic niche use

The **isotopic niche** is a proxy! It is not an actual depiction of the trophic niche, since its axes are not actual resource use (i.e., not dimensions of the ecological niche).

**Position of consumers** in the δ-space is mostly driven by differences in resource use, but other factors also influence it: isotopic variability of baseline producers and/or prey items.

Although not necessary, isotopic data on food sources can help avoiding interpretation mistakes.

Adapt your **sampling strategies**!
Caution on isotopic niche use

"Remember that all models are wrong; the practical question is how wrong do they have to be to not be useful."

Isotopic niche study is a rapidly evolving field supported by many different approaches and concepts.

When used sensibly, it is a robust and widely applicable method that can help solving many ecological questions linked with resource partitioning among consumers.

George E.P. Box
1919-2013