Stable isotope ratios of light biogenic elements: Trophic applications basis

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"The main use of stable isotopes involves magic. We cannot see, feel, touch, hear, smell, or taste stable isotopes with our normal senses, yet there they are, magical scraps of information fluttering gently all around us"
Brian Fry, 2006

Liège, 13 December 2014 - Zoology 2014
Congress - Technical session 2

GENERALITIES

- Isotope = any forms of an element having the same protons numbers and similar chemical properties but differing in atomic weight (i.e. neutrons number)
- Isotope = same place in ancient greek (i.e. are in the same place of the periodic table)
- Stable vs. Radioactive = stable isotopes do not disintegrate
- Light isotopes of the Life: CHNOPS

❖ What we measure?

$$ {}^{X}R = \frac{AbondanceX}{AbondanceY} $$

With X and Y = 2 stable isotopes of an element

⇒ Isotopic ratios = RELATIVE MEASUREMENT

⇒ "Isotope Ratio Mass Spectrometry" = **IRMS**

❖ Isotopic ratios currently used: $^{13}C/^{12}C$, D/H, $^{15}N/^{14}N$, $^{18}O/^{16}O$, $^{34}S/^{32}S$ (NOT POSIBLE FOR P)

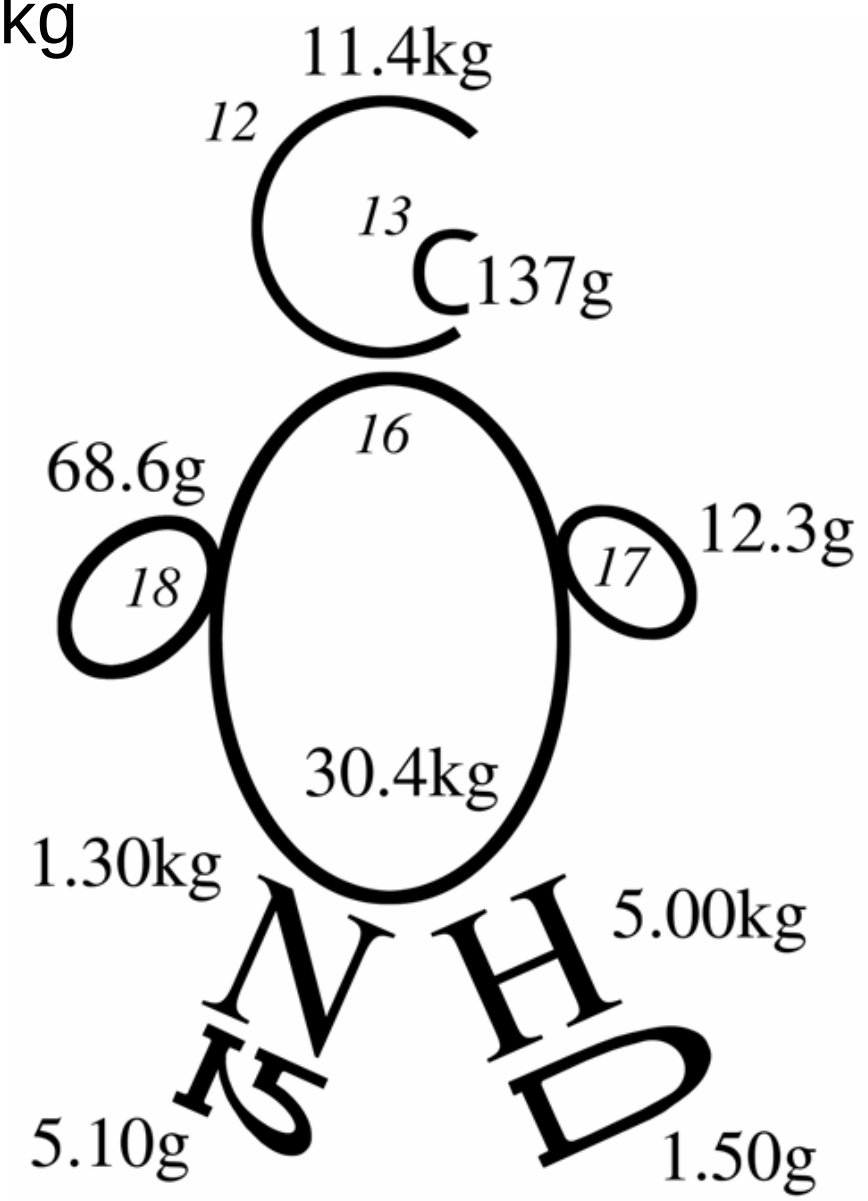
❖ Delta notation : practical and international

$$\delta X = \left(\frac{R_{sample} - R_{standard}}{R_{standard}}\right) \times 1000$$

δ = deviation (in per mille) between the isotopic ratio of a sample and of an INTERNATIONAL standard

❖ Delta ^{13}C is NOT the quantity of ^{13}C in a sample but the deviation in per mille between the ratio $^{13}C/^{12}C$ of a sample and the ratio $^{13}C/^{12}C$ of a standard

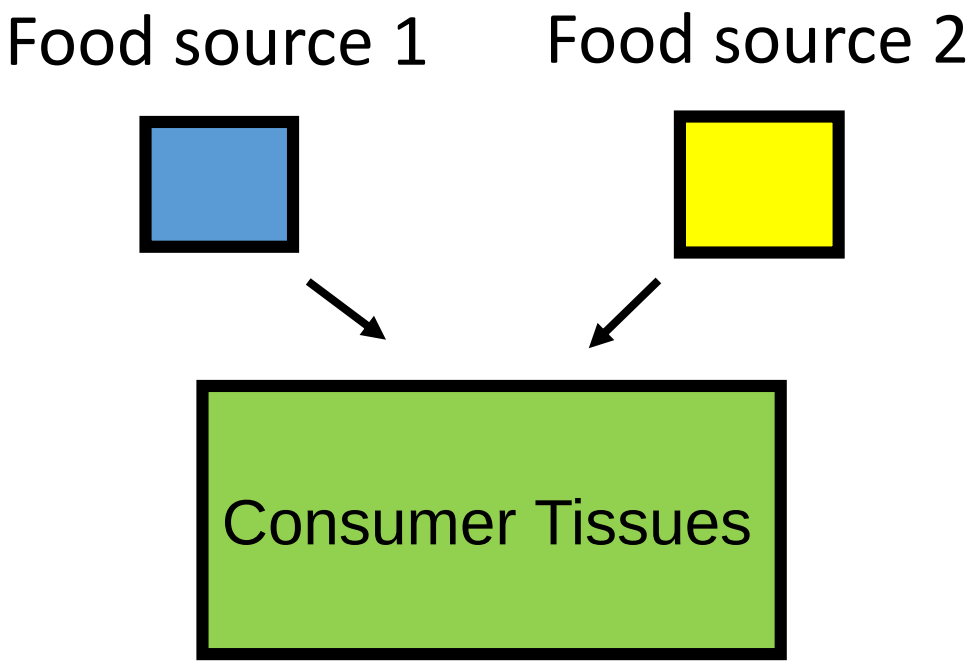
For a human of 50 kg



Fry 2006

TROPHIC APPLICATIONS: BASICS

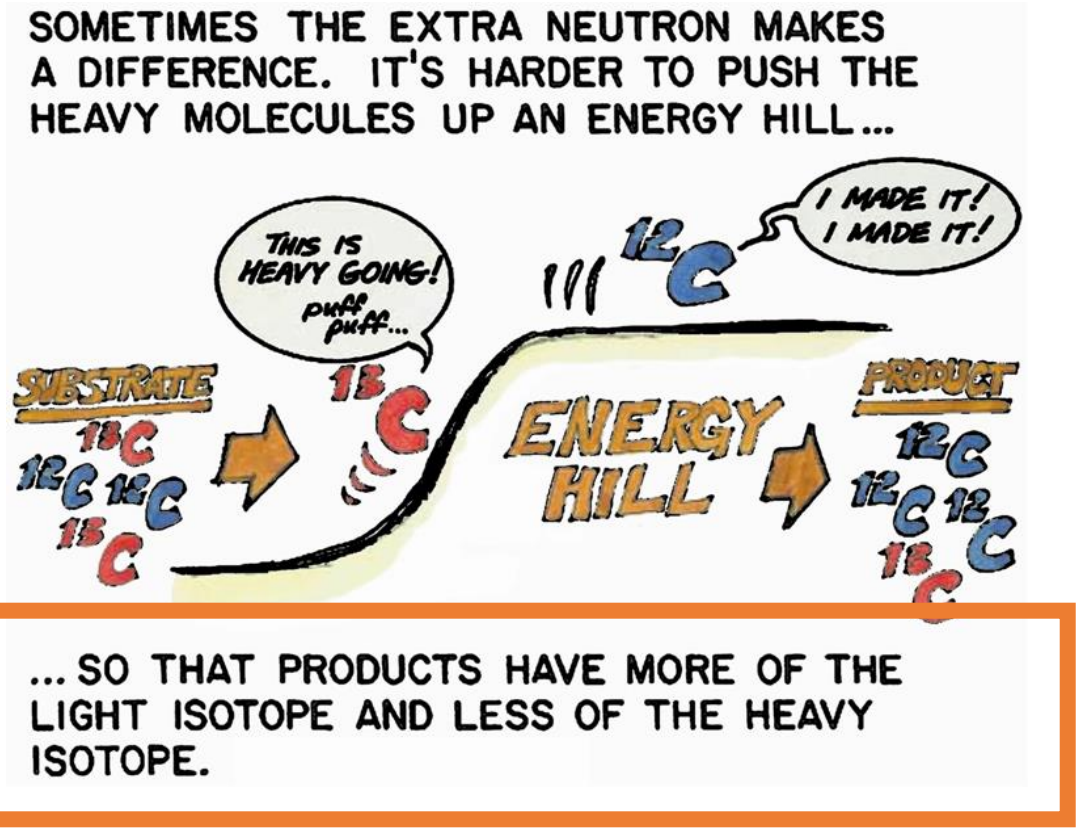
"*You are what you eat…plus a few per mille*"
DeNiro & Epstein, 1978



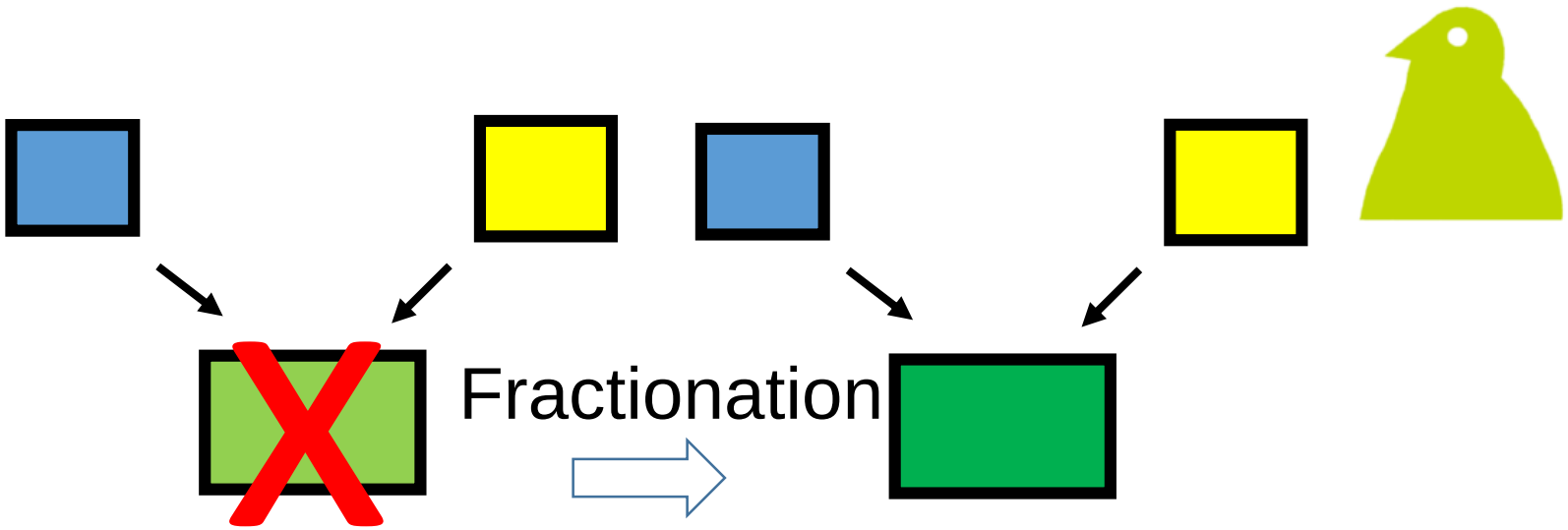
MIXING Law:
"YOU ARE WHAT YOU EAT"

But “heavy” and “light” stable isotopes of an element do not have exactly the same chemical properties

⇒ FRACTIONATION



Fry 2006



- generally an enrichment in heavy isotopes (« Plus few per mille »)
- = Trophic Enrichment Factor (TEF)
- TEF= net result of ALL metabolism isotopic fractionations

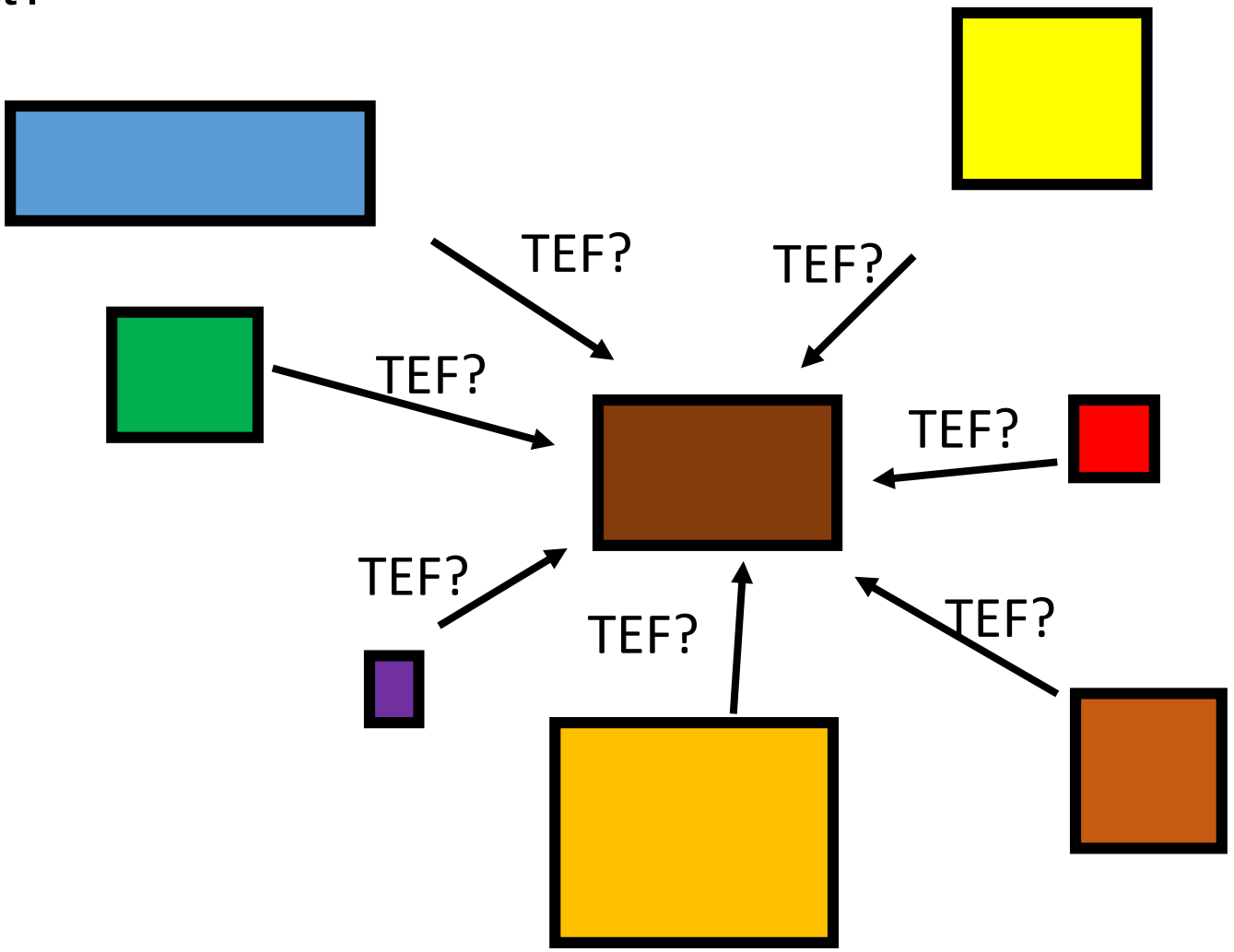
In summary,

Stable isotope trophic applications rely on 2 opposite principles:

- Fractionation which explains isotopic change and difference between food web components

- Mixing law which explains that the composition of a consumer is primarily the weighted average of the isotopic composition of its food sources

Our first question:
Is it possible from isotopic composition of an animal to calculate the different contribution of potential food sources to its diet?



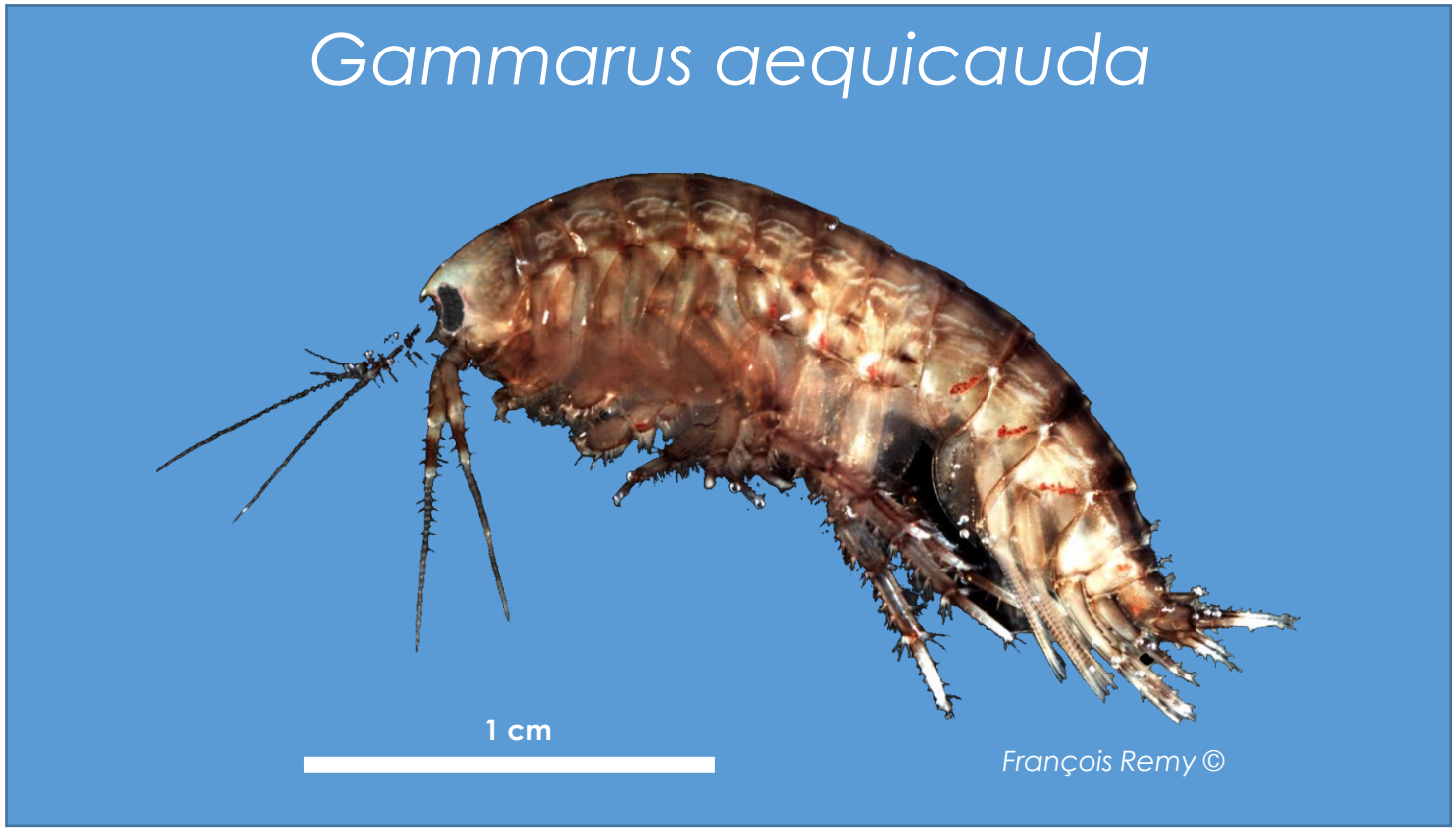
Mixing equation for n sources:

$$\delta_m = (f_a\delta_a + f_b\delta_b + f_c\delta_c + \ldots)$$

$\Rightarrow$ Complex mixing modelling

$\Rightarrow$ IsoSource (Philips et al., 2001) or SIAR (Parnell et al. 2010) or ….

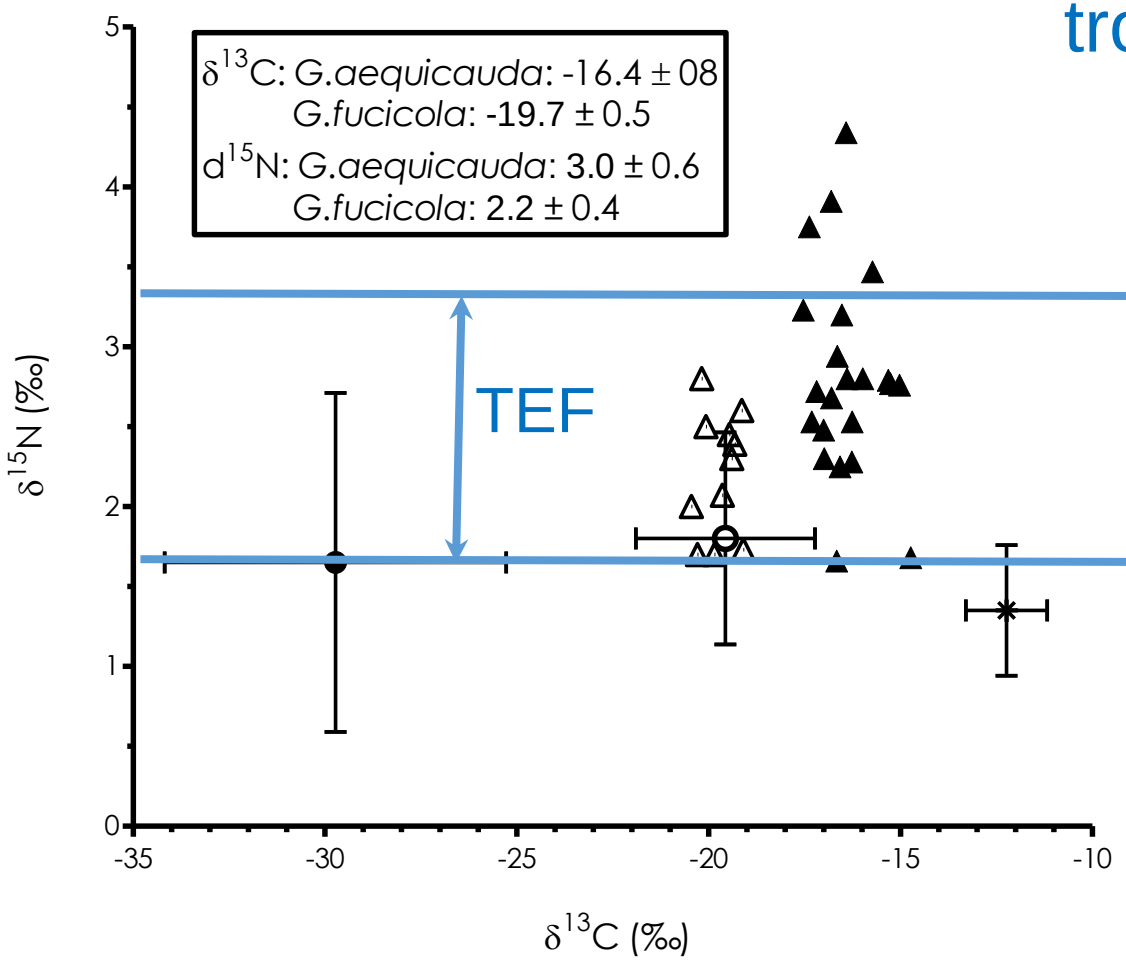
Case study: Trophic ecology of *Gammarus aequicauda* (amphipoda)



Exported Dead Leaves

Neptune grass meadow

= indication of both food sources and trophic level

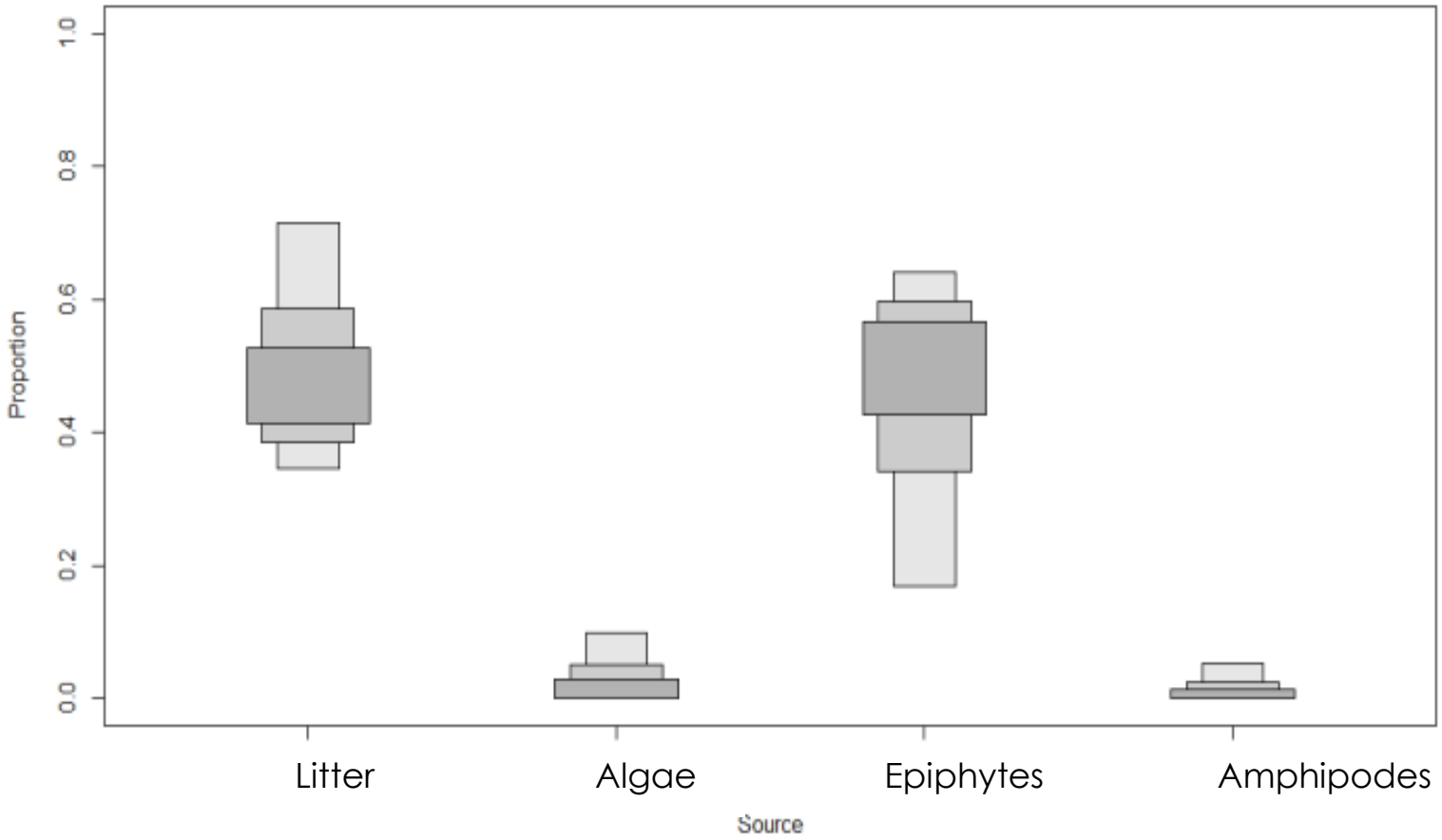


Primary Consumers

Primary Producers

Source: Lepoint et al. 2006

SIAR Modeling of *G. aequicauda* diet



TEF: food source specific

(experimentally determined by Michel for epiphytes and by Remy for litter, sciaphilous algae and animal diets)

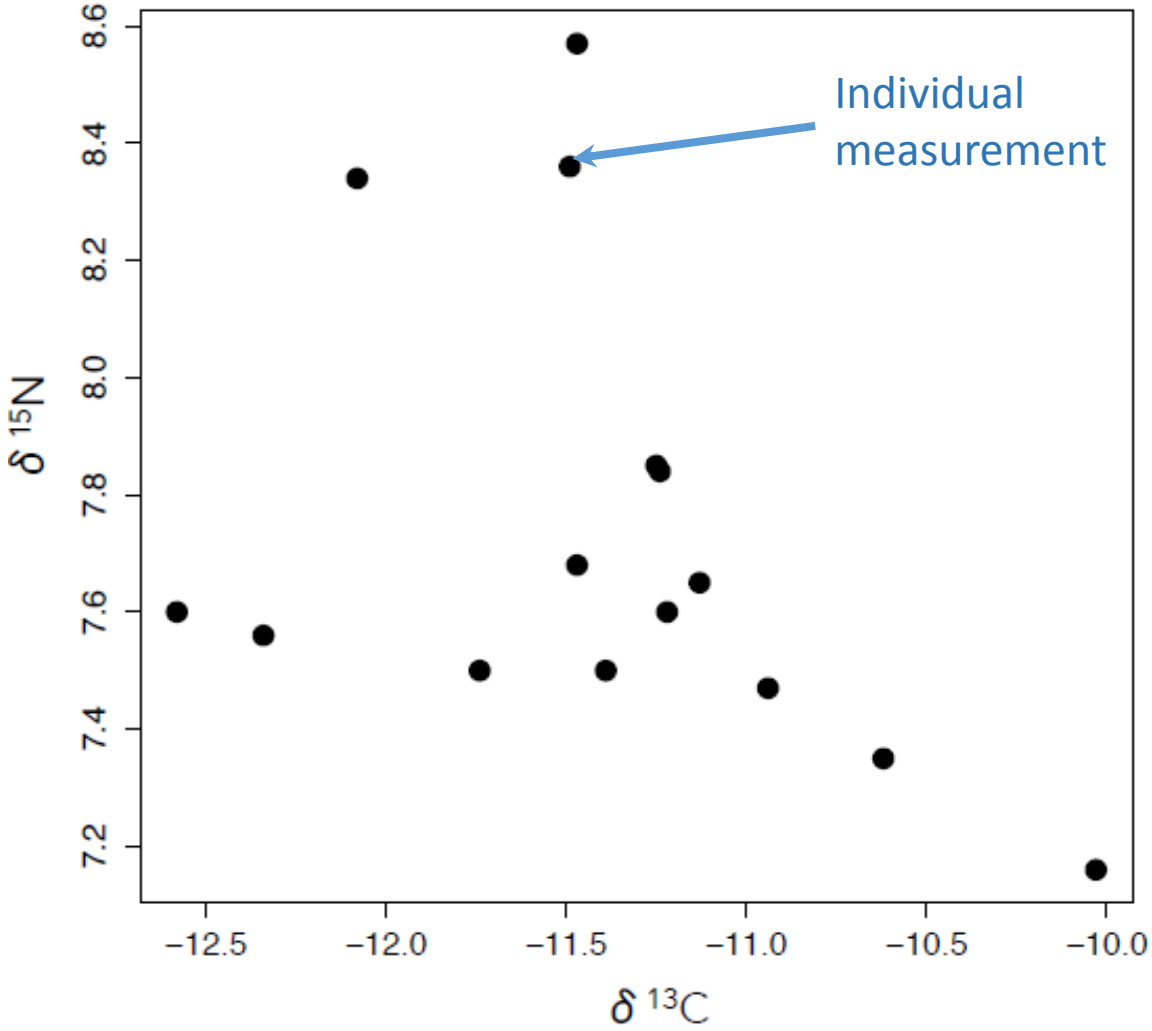
Advantages:

- Assessment of assimilated food
- Assessment of trophic level
- Integration over variable time (depending of investigated tissues)

Caveats:

- Variability of isotopic baseline and of TEF
- Diet determination rarely at specific level
- Dependence on difference between food sources isotopic composition

Question 2: May we use stable isotope variability as a proxy of trophic niche?



Hypothesis:

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**

Source: Michel 2014

Journal of Animal Ecology

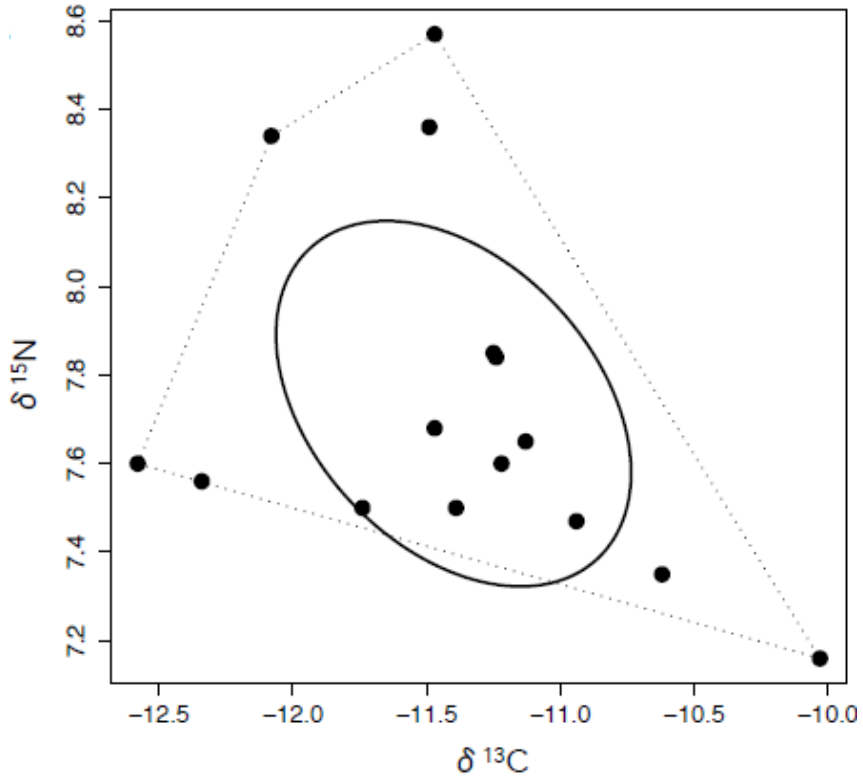
British Ecological Society

Journal of Animal Ecology 2011 doi: 10.1111/j.1365-2656.2011.01806.x

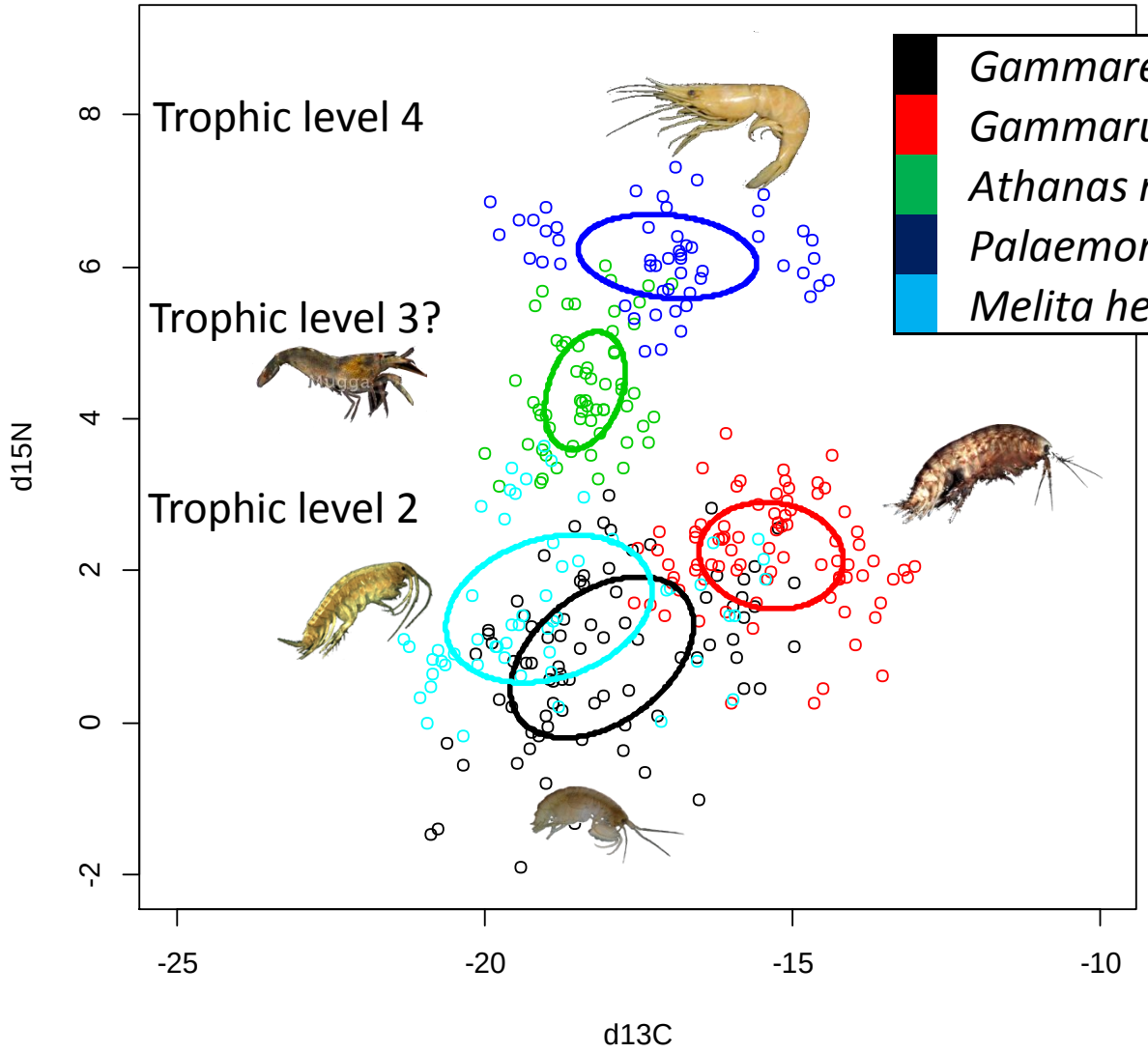
Comparing isotopic niche widths among and within communities: SIBER – Stable Isotope Bayesian Ellipses in R

Andrew L. Jackson[1]*, Richard Inger[2], Andrew C. Parnell[3] and Stuart Bearhop[2]

Single metric: standard ellipse area: Represents “core isotopic niche of the consumers



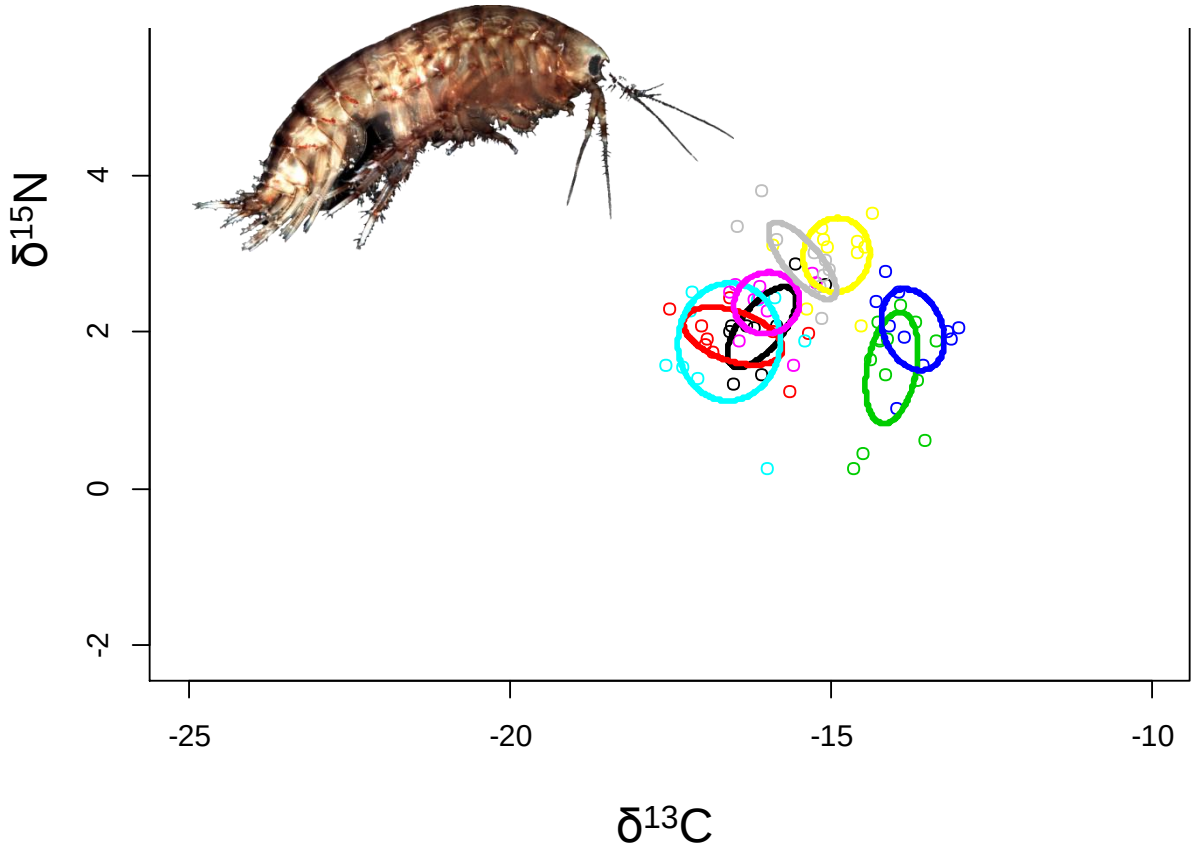
Come back to litter fauna



Distinct isotopic niches between amphipoda species with some overlaps between certain species

Source: Remy (zoology 2014)

Gammarus aequicauda isotopic niche change with season and site



Source: Remy (zoology 2014)

SAMPLING RECOMMENDATION

❖ Animal diet: * sampling of consumer (individual measurements if possible) and of potential sources

* as much as possible (depends on ethics, cost, field constrainst) to assess diet variability

❖ Isotopic niches: * only consumers must be sampled – but knowing general isotopic environment is better

* as much as possible (INDIVIDUAL measurements) because application based on isotopic variability

Thank you