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

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- Publications: tinyurl.com/GLepoint

a journey through stable isotopes applications in trophic ecology

Gilles LEPOINT

With the contributions of **SIESTE** group (past) members: Dr. Loïc MICHEL, Dr. Nicolas STURARO, Dr. Thibaud MASCART, Dr. Bruno FRÉDÉRICH, Baptiste LE BOURG, Benjamin LEJEUNE and Dr. François RÉMY

MarineTraining.eu

Benelux Association of Stable Isotopes Scientist

http://www.basis-online.eu/

Annual BASIS meeting 2018: 19-20 April Liège

Other meeting of interest: IsoEcol 2018, July 2018, CHILE

BASIS provides to young members money for technical training and congress

Stable Isotopes in Environmental Sciences and Trophic Ecology Group

- Thematics:
  - Trophic web delineation (seagrass beds & macrophytodetritus, other benthic ecosystems)
  - Trophic ecology of Antarctic benthos
  - Trophic ecology of coral fishes
  - Isotopic experimentation
  - Ecotoxicology

Stable Isotopes in Environmental Sciences and Trophic Ecology

- Facilities:
  - EA-IRMS (Isoprime 100, Elementar)
  - GC-C-IRMS (Agilent & Elementar)


elementar

Stable Isotopes Basics

Atomic notation

$$^{A}_{Z}X_{N}$$

With Z= proton number ; N= neutron number and A= mass number (= protons + neutrons)

$\Rightarrow$ Classical notation: ^{12}C, ^{13}C, ^{14}N, ^{15}N, etc.

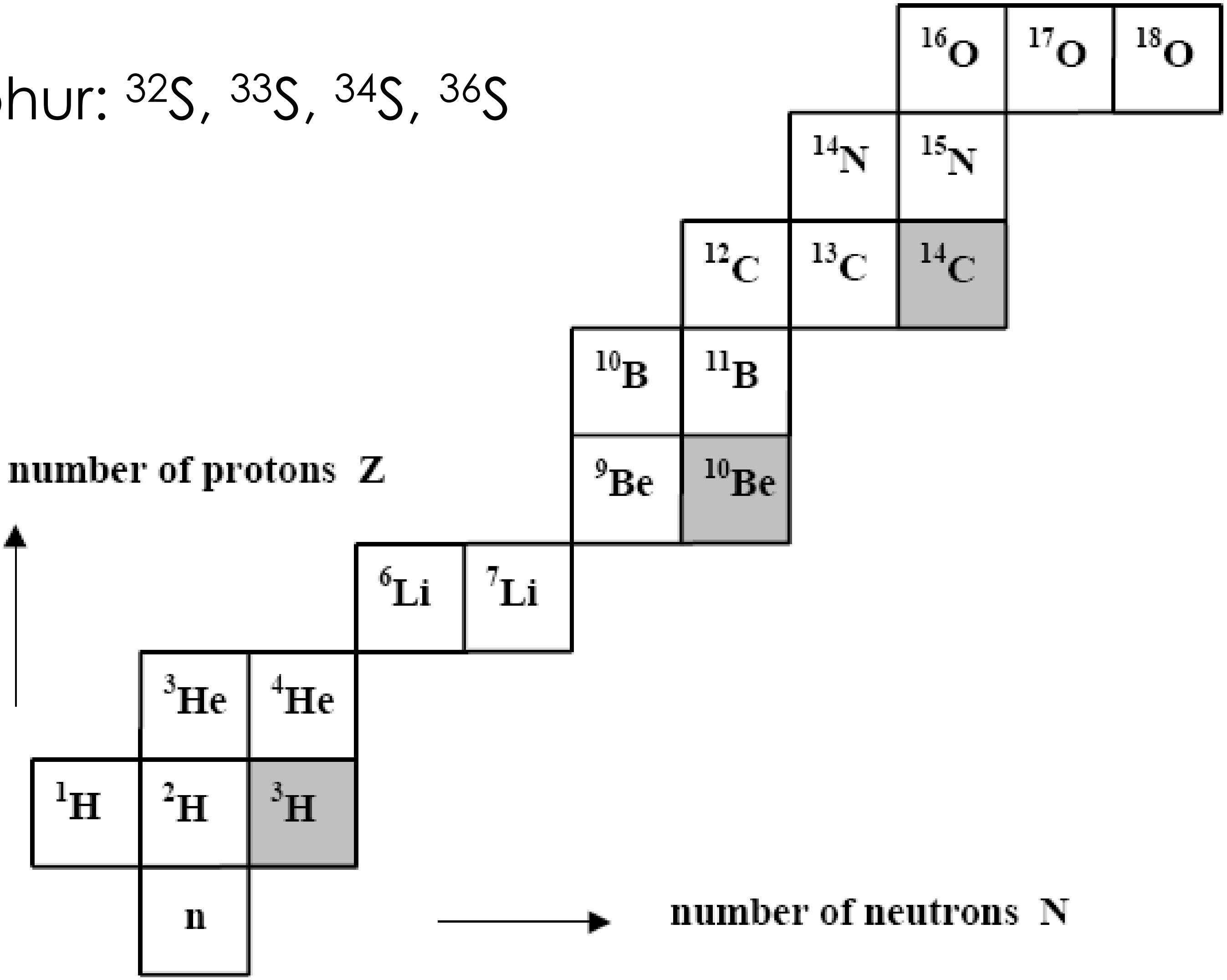
- Isotope: from ancient greek *ισο τοποσ* (same place) = same place in the Periodic table
  = same general chemical and physical properties

* Stable isotopes vs. radiactive isotopes

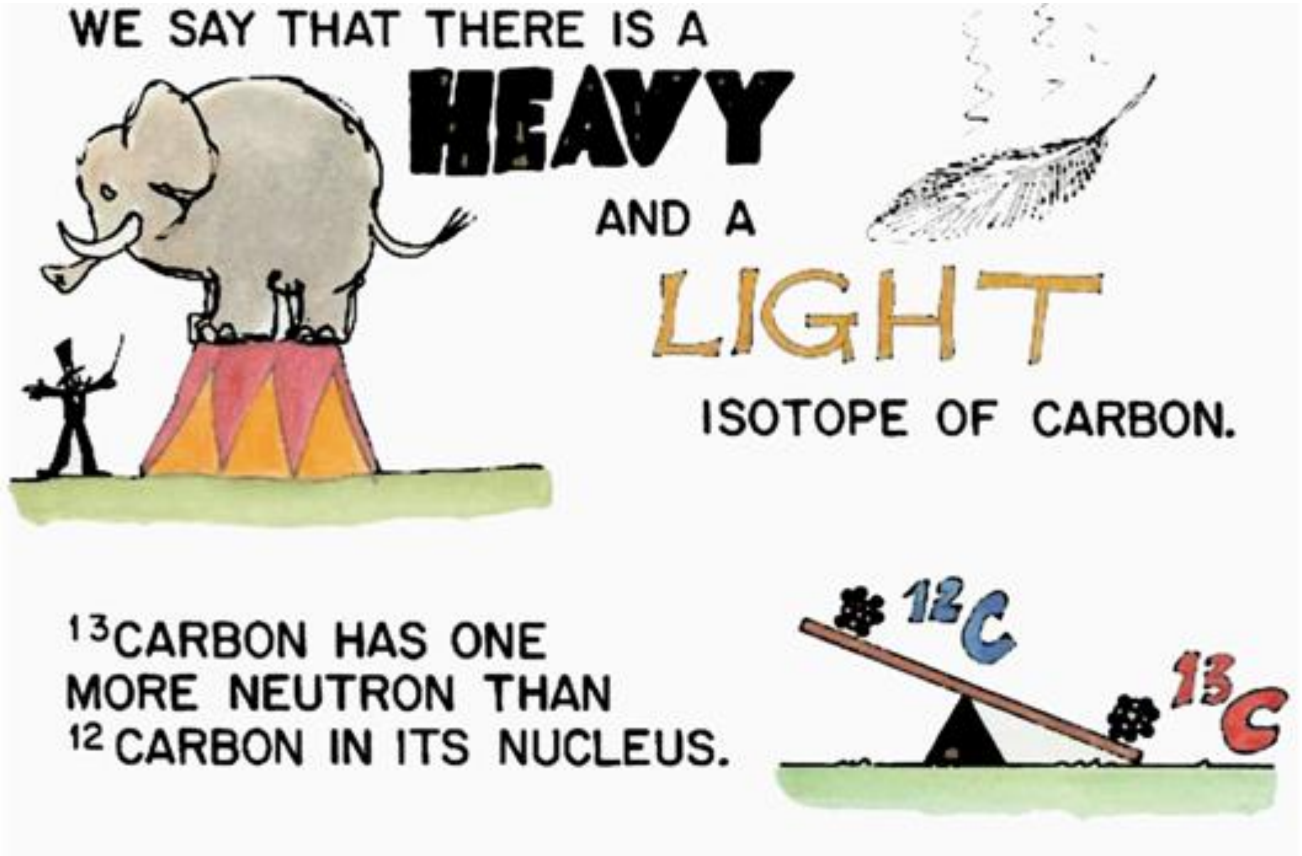
* Main element in organic matter: C H N O ~~P~~ S

Stable Isotopes Basics

Sulphur: ^{32}S, ^{33}S, ^{34}S, ^{36}S



Stable Isotopes Basics: Heavy vs. Light

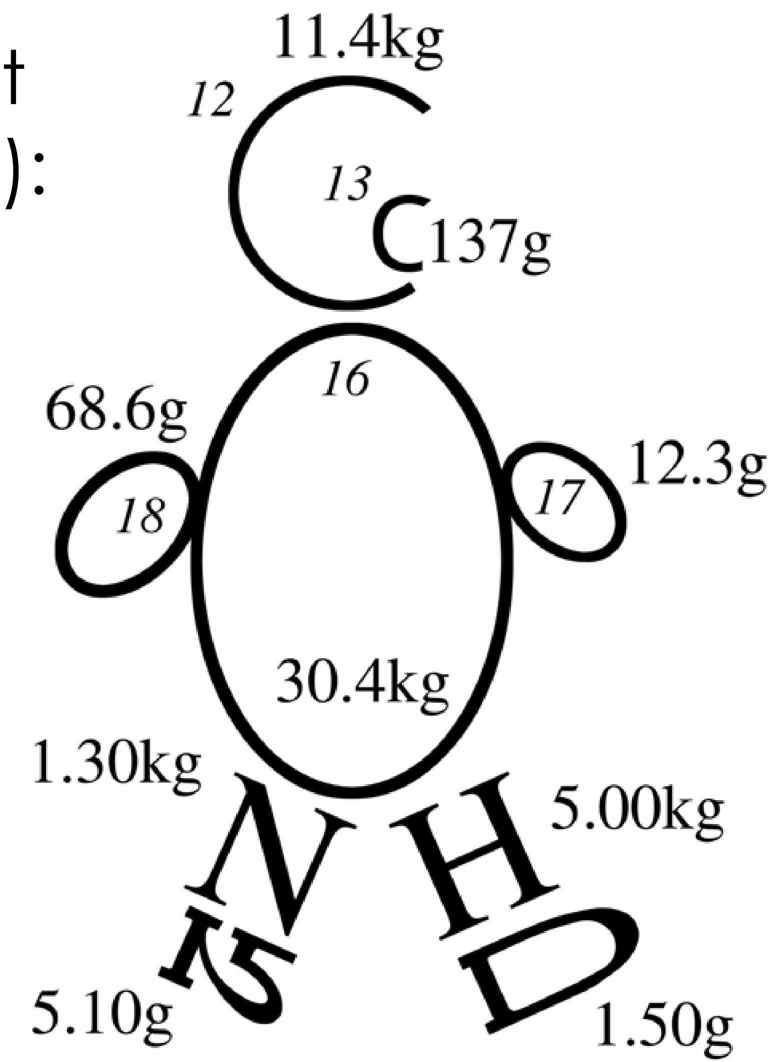


Stable Isotopes Basics: Isotopic ratios

Dominant isotope	Rarer isotope(s)	Isotopic ratios
99.985 ^{1}H%	0.015 ^{2}H (or D)%	D/H = 0.00015
98.9 ^{12}C%	1.1 ^{13}C%	$^{13}C/^{12}C$ = 0.011
99.6 ^{14}N%	0.36 ^{15}N%	$^{15}N/^{14}N$ =0.00367
99.76 ^{16}O%	0.035 ^{17}O% , et 0.2 ^{18}O%	$^{18}O/^{16}O$ = 0.002
95.02 ^{32}S%,	0.75 ^{33}S%, 4.21 ^{34}S% et 0.02 ^{36}S%	$^{34}S/^{32}S$ = 0.04505

STABLE ISOTOPES BASICS:

A human of 50 kg (not me), it is (very roughly):



Stable Isotopes Basics: What do we measure?

Isotopic ratios

$$^{X}R = \frac{Abondance X}{Abondance Y}$$

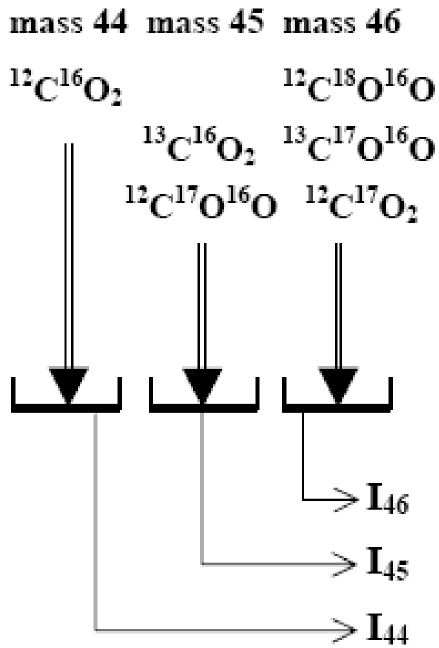
With X and Y = 2 stable isotopes of an element

$\Rightarrow$ *Isotopic ratios* = RELATIVE MEASUREMENT

$\Rightarrow$ *"Isotope Ratio Mass Spectrometry"* = ***IRMS***

Stable Isotopes Basics: How do we measure it?

•Measurements are done on simple gaz (CO_2, N_2, SO_2, H_2) NOT on atoms of C, N, O, H, S



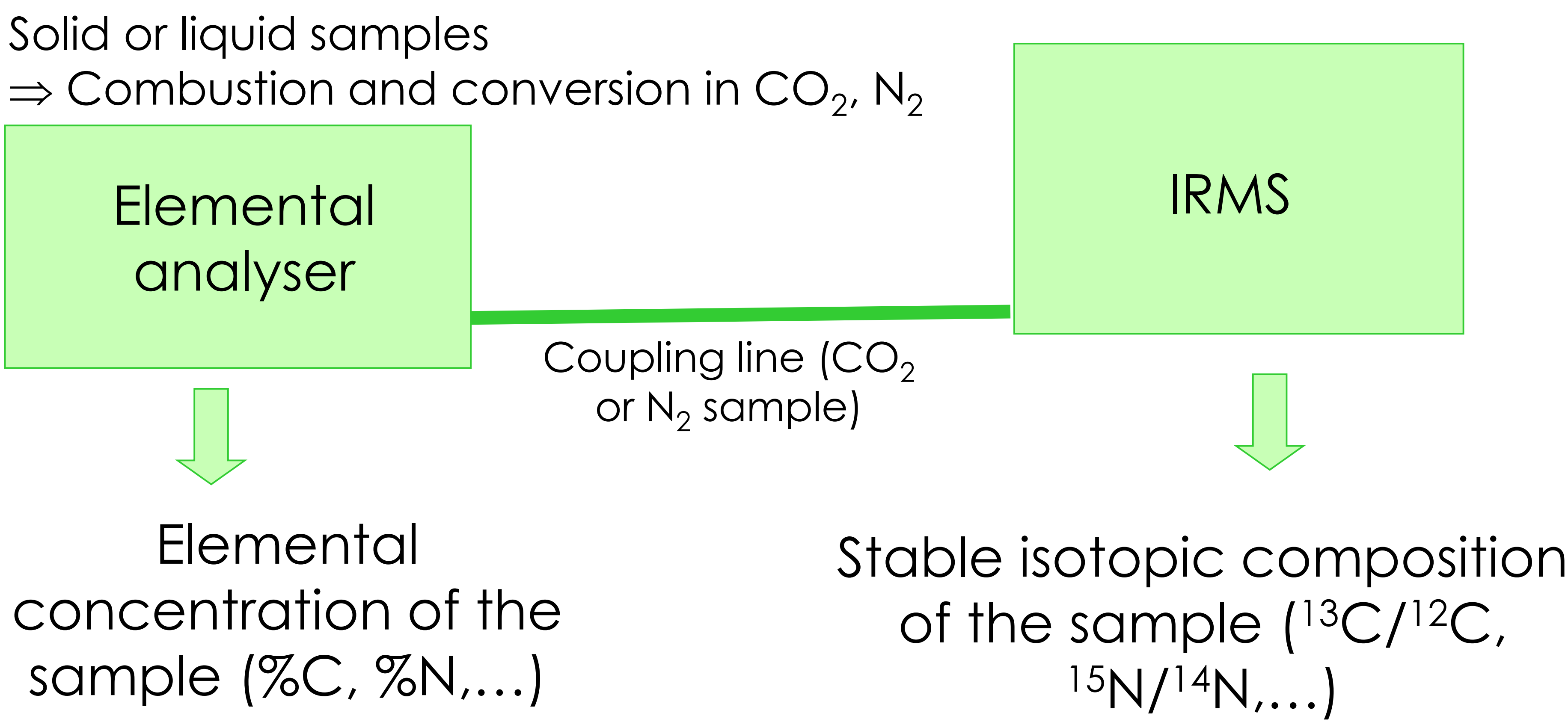
Collectors schema (for CO_2)

•Need to convert sample into simple gas

⇒ Preparation off line (till 1990') or on line = **coupling of 2 instruments**

STABLE ISOTOPES BASICS: HOW DO WE MEASURE IT?

Example 1: Coupling EA -IRMS



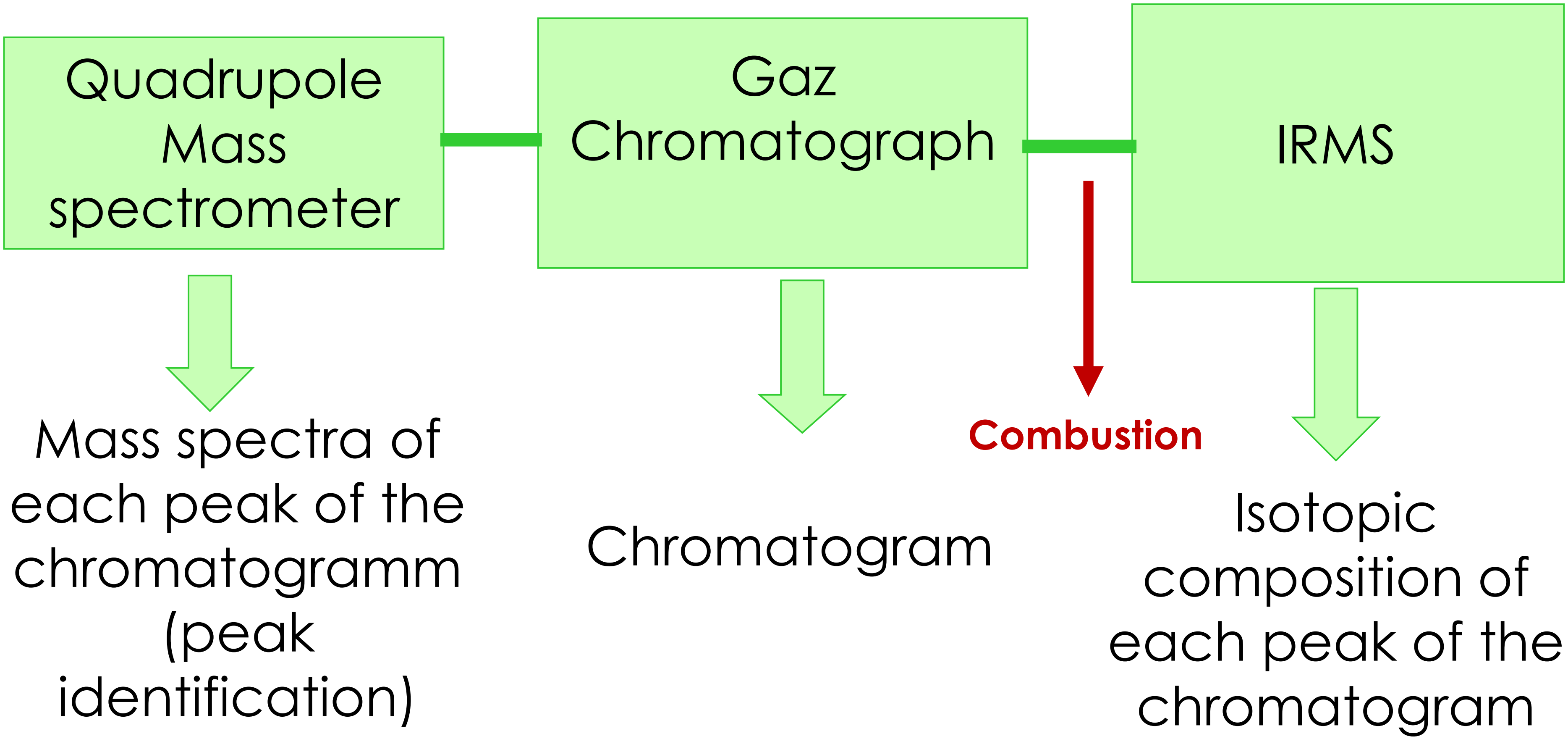
⇒ BULK stable isotopes composition

He: carrier gaz (<u>CONTINUOUS FLOW</u>)

Elemental Analyser (VarioMicro cube, Elementar, Germany)

Stable Isotopes Basics: How do we measure it?

Example 2: GC-IRMS and even more MS-GC-IRMS



⇒ Compound specific stable isotope analysis (CSIA)

MS-GC-IRMS

Stable Isotopes Basics: Delta notation

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

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
- practical and international

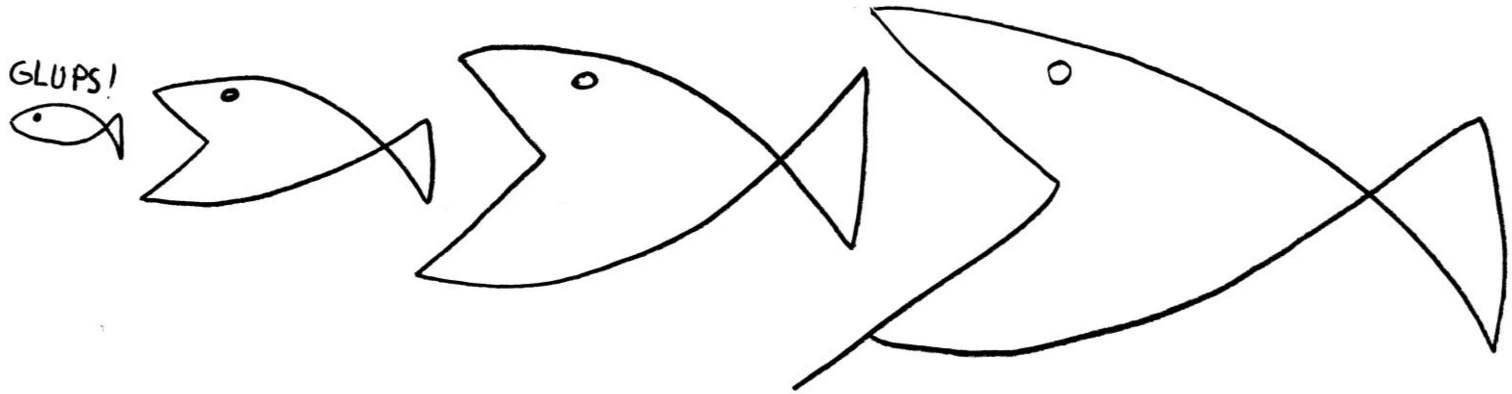
Stable Isotopes Basics: Meaning of the Delta notation

Value	Signification
$\delta = 0$	Isotopic ratio of SAMPLE **equal** the Isotopic ratio of REFERENCE
$\delta > 0$	Isotopic ratio of SAMPLE **higher than** Isotopic ratio of REFERENCE ⇒ heavy isotope more abundant in SAMPLE
$\delta < 0$	Isotopic ratio of SAMPLE **lower than** Isotopic ratio of REFERENCE ⇒ heavy isotope less abundant in SAMPLE

Stable Isotopes Basics: few good writting practice

Do not write	Write
$\delta^{13}C$ composition	$\delta^{13}C$ values <u>or</u> C isotopic composition
"*Heavy* (*light*)" $\delta^{13}C$	"*High* (*low*)" $\delta^{13}C$ values
Enriched $\delta^{13}C$	A higher $\delta^{13}C$ (or isotopic composition enriched in ^{13}C)
A water isotopically enriched	A water showing an isotopic composition enriched in ….
^{13}C content has been measured	The $^{13}C/^{12}C$ ratios have been measured

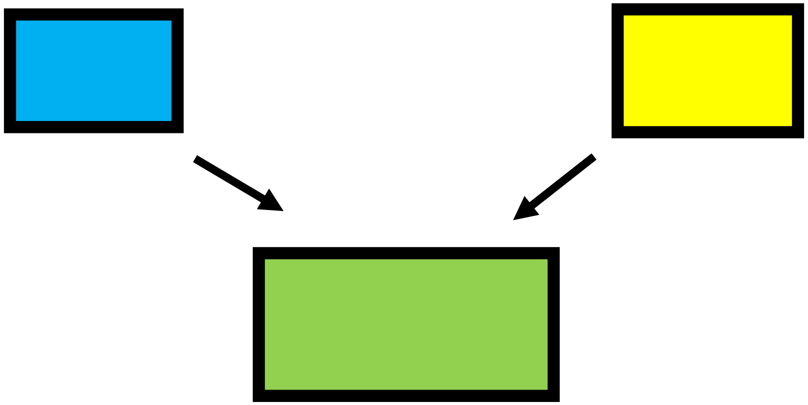
TROPHIC APPLICATIONS: BASICS, TROPHIC WEB DELINEATION AND TROPHIC ECOLOGY



TROPHIC APPLICATIONS: BASICS

Your mantra of this week:

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

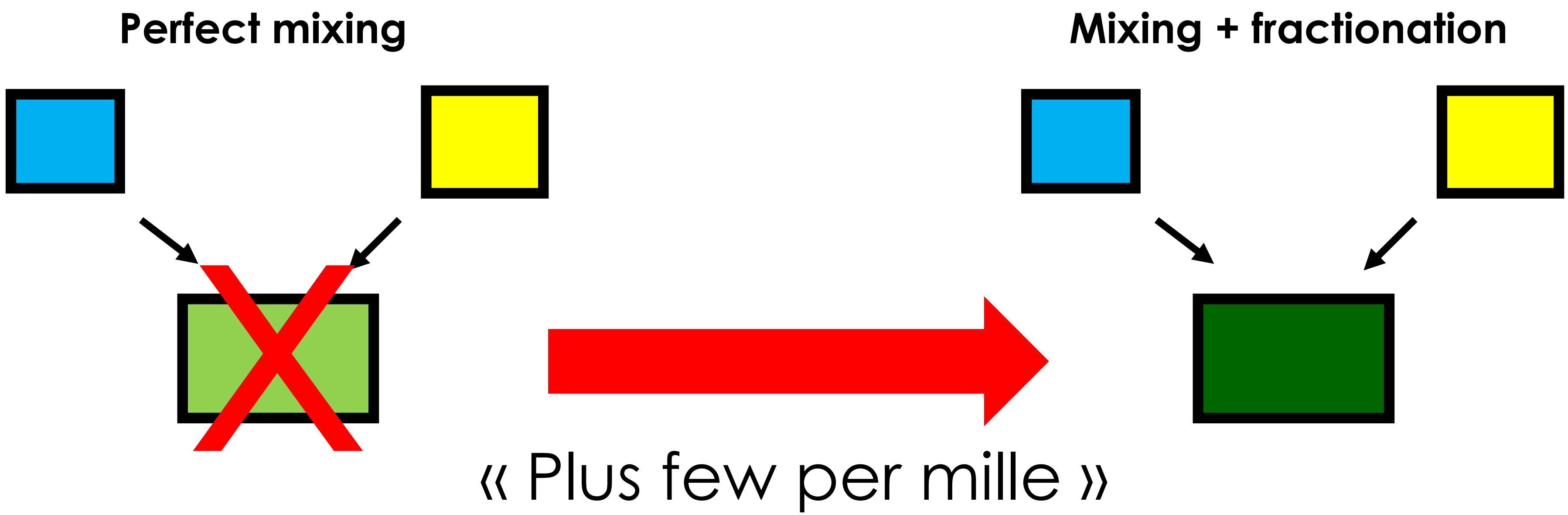


1. THE MIXING Law: "YOU ARE WHAT YOU EAT"

Isotopic composition of a consumer is the weighted mix of isotopic compositions of its food sources

TROPHIC APPLICATIONS: BASICS

2. **THE Fractionation** law: any chemical or physical "reaction" may affect the isotopic composition



- Generally, as a result of thousands fractionation processes, an increase of rarer isotope abundance in consumer tissues compared to food sources is observed
- Plus few per mille = trophic enrichment factor (TEF)

- For one food source:

$$\Delta = \delta_{consumer} - \delta_{food}$$

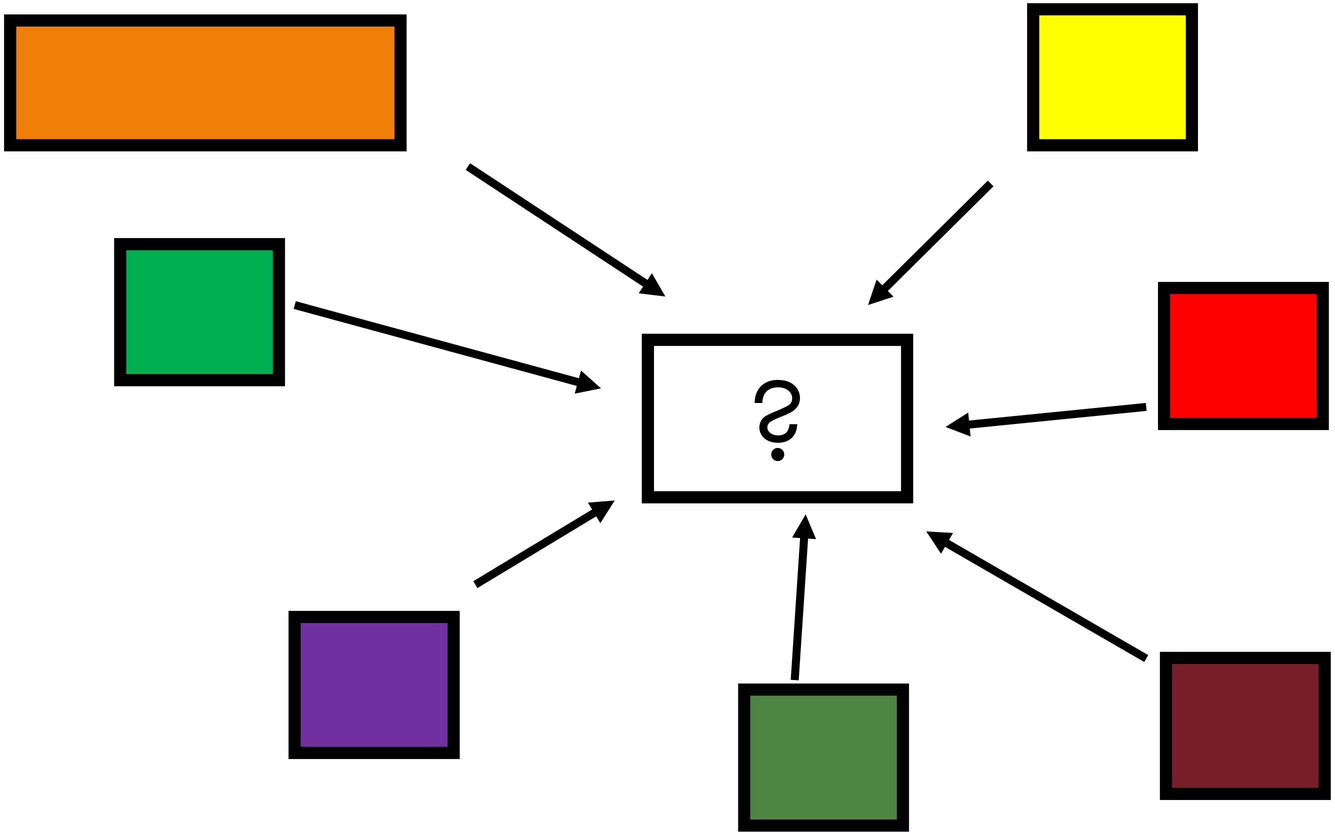
- = NET RESULTS OF ALL ISOTOPIC FRACTIONATIONS OCCURING DURING METABOLISM

- VARIABLE – NOT ALWAYS AN « ENRICHMENT » (i.e. an increase of the heaviest isotope abundance)

- Causes of variability (among other):

phylogeny/diet/individual variability/tissues type

Trophic applications: basics

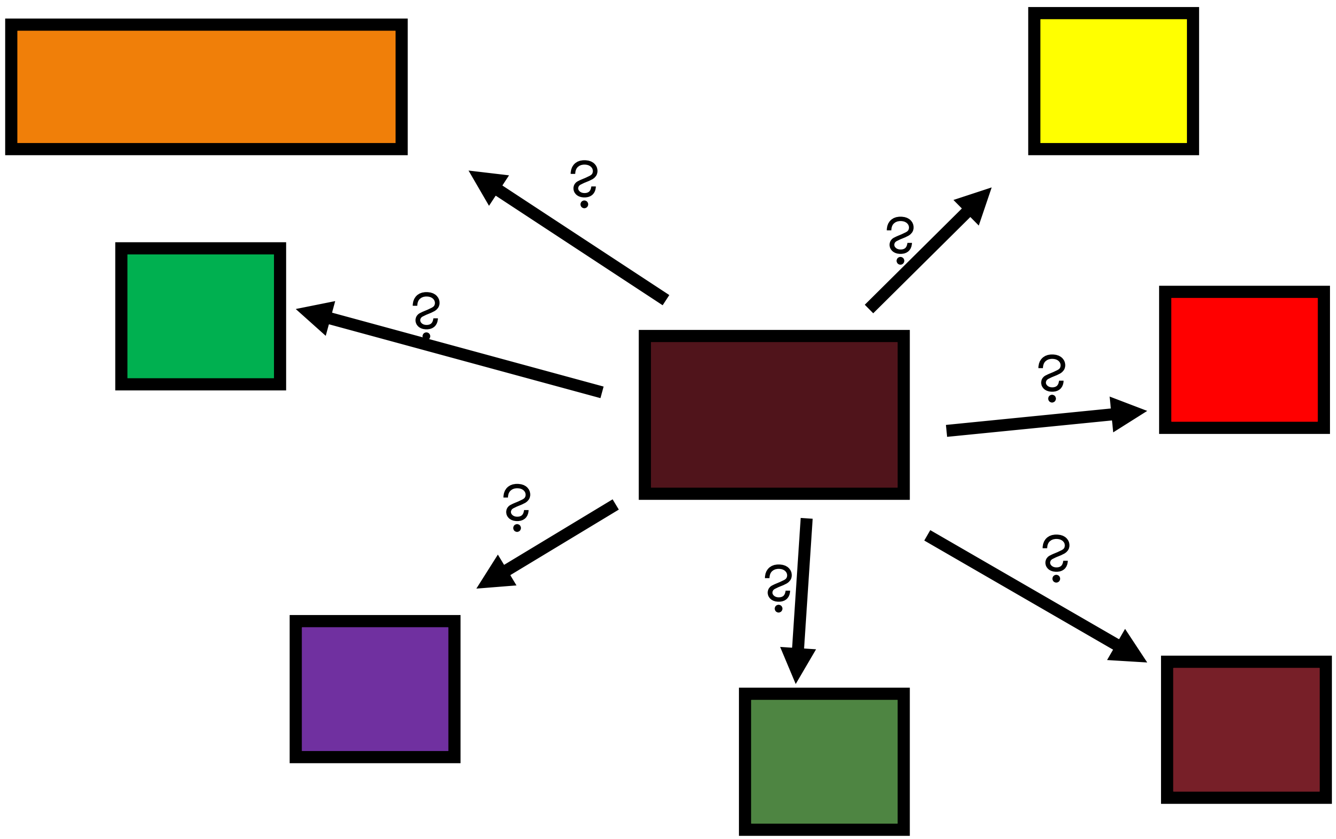


What is the isotopic composition of complex mix?

Trophic applications: basics

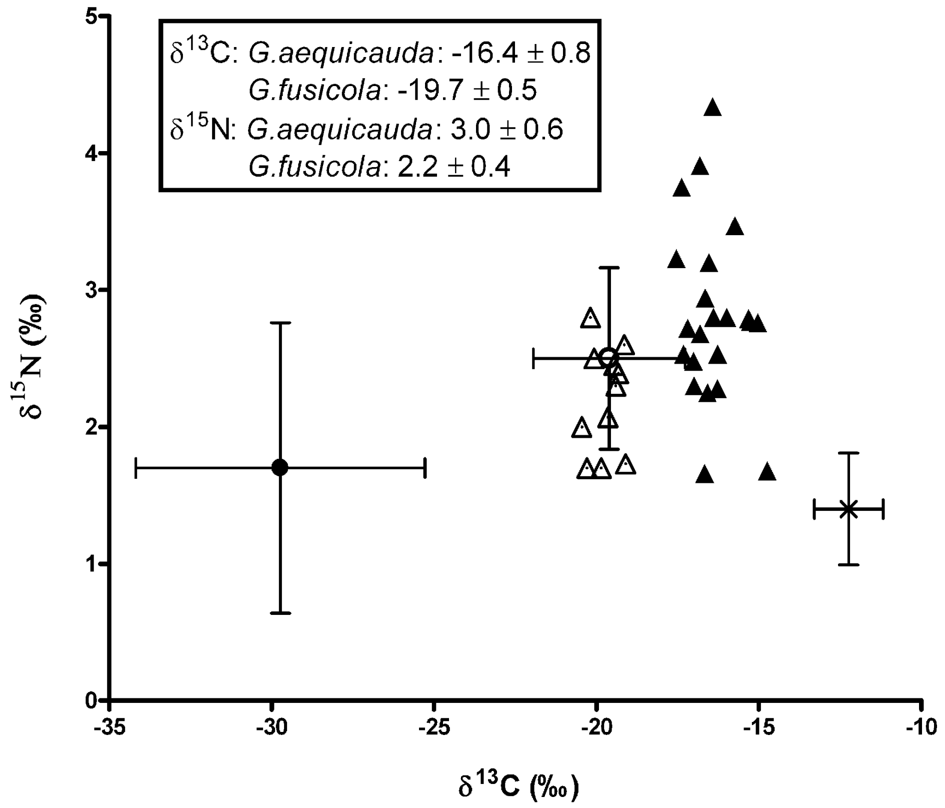
One possible question:

Is it possible from the natural isotopic composition of an animal to calculate the different contributions of its potential food sources to its diet?

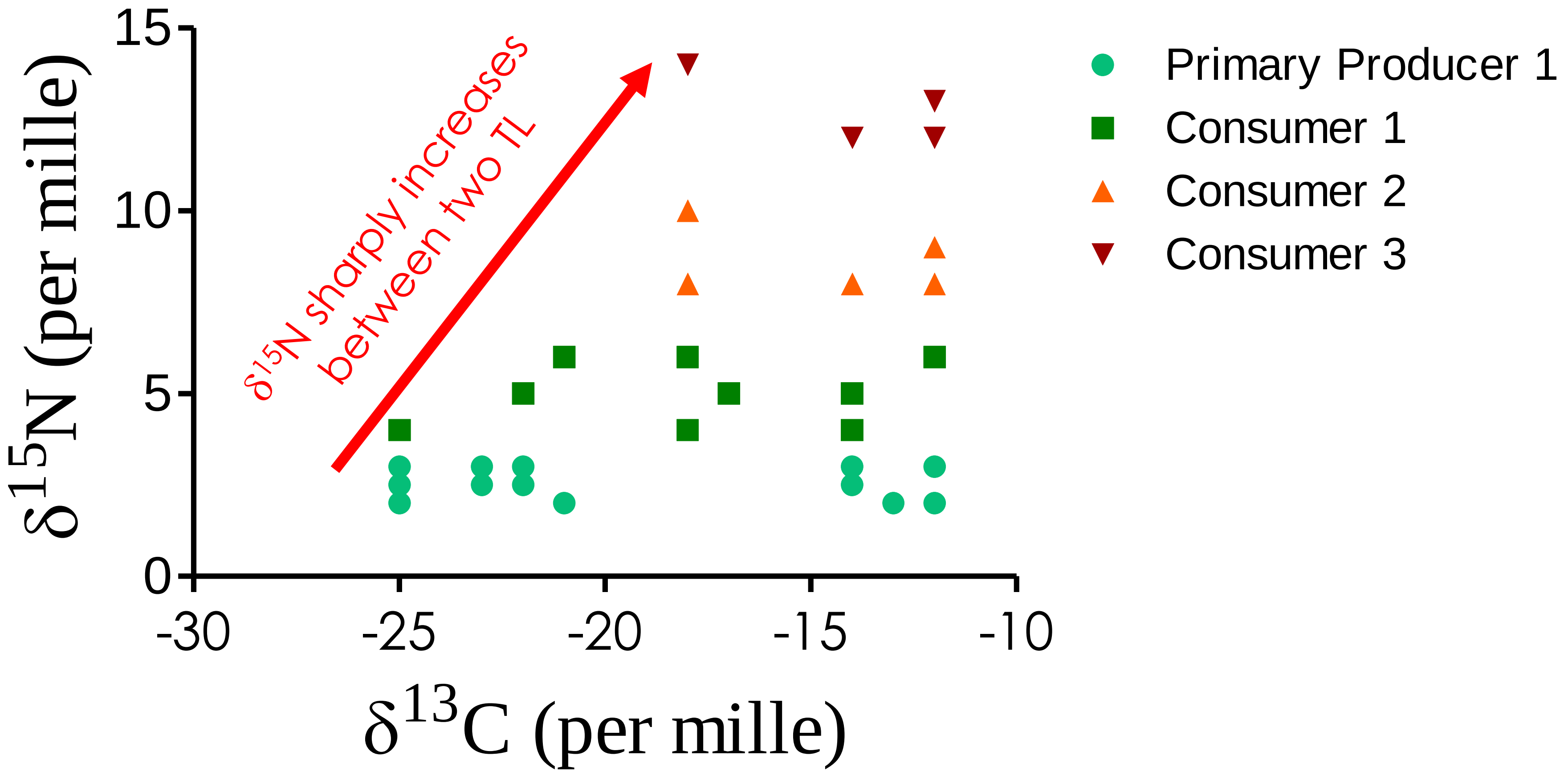


Trophic applications: Basics

Classical representation



TROPHIC APPLICATIONS: BASICS



$\delta^{13}C$: mixing law > fractionation law ⇒ **source indicator**

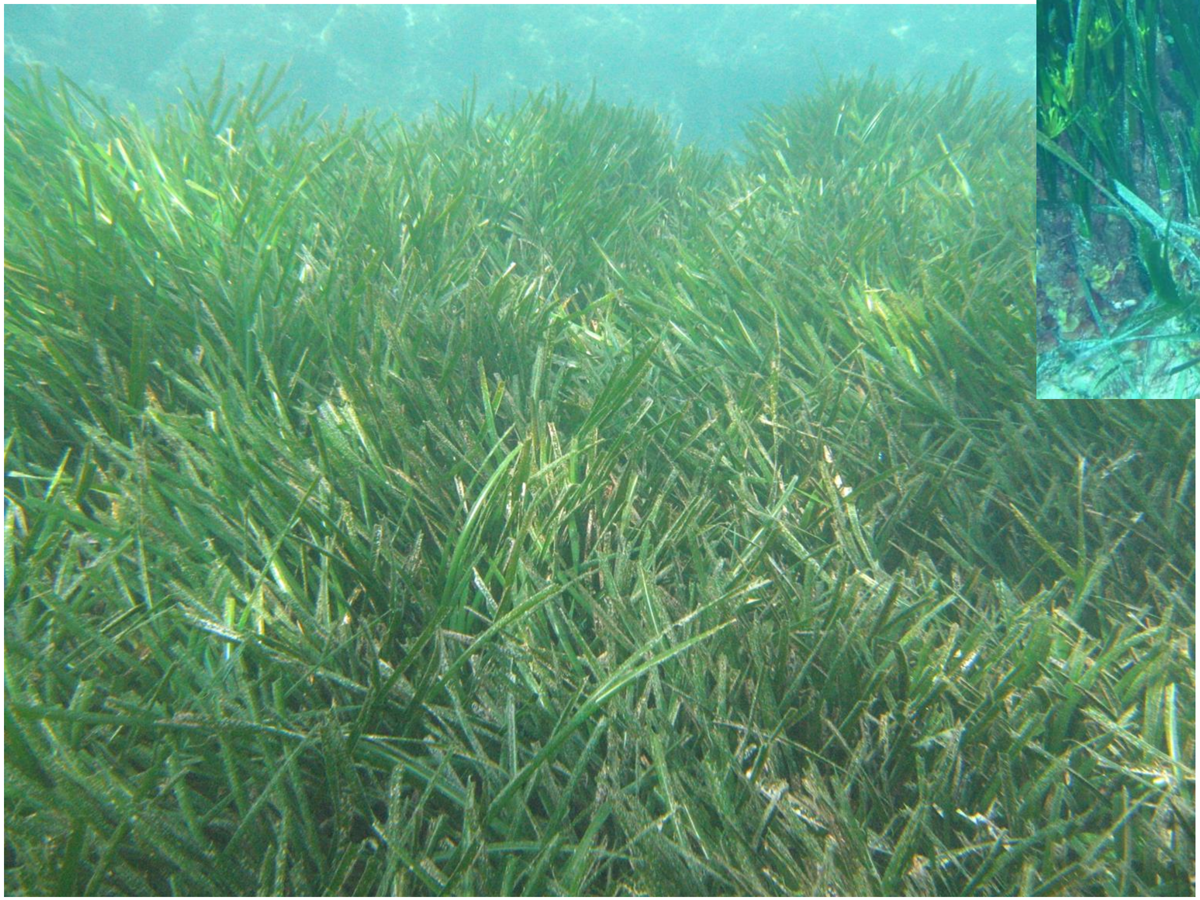
$\delta^{15}N$: mixing law and fractionation influence are variable
⇒ **Trophic level indicator and sources indicator**

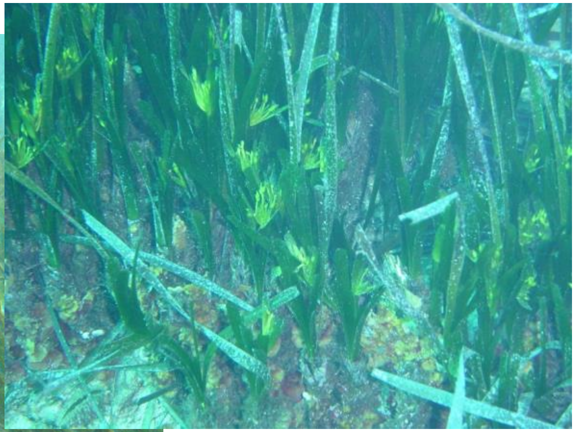
CASE STUDY 1 & 2:

TROPHIC WEB ASSOCIATED TO *POSIDONIA OCEANICA* MEADOWS (1) AND DETRITIC ACCUMULATION (2)

Case study 1 & 2: *Posidonia oceanica* meadows

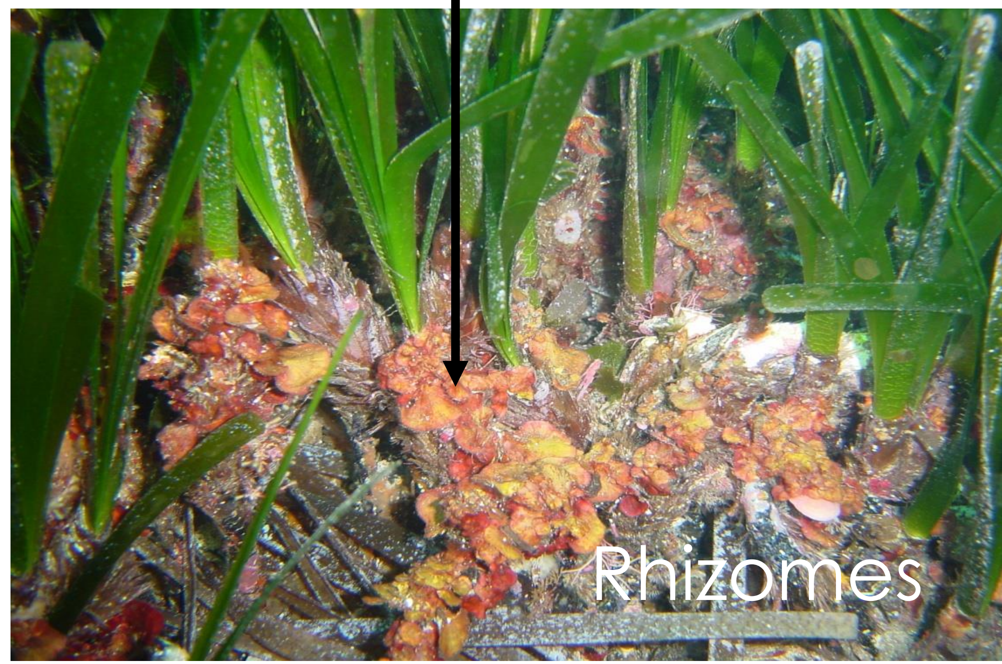
Seagrass meadow (*Posidonia oceanica*)(Mediterranean)





Posidonia oceanica meadows: primary potential food sources

Epiphytic organisms



Leaf litter

+ sestonic material

Case study 2: Exported detritic biomass

Accumulation of Exported Dead Leaves

Exportation (Autumn)

Case study 2: Exported detritic biomass

Gammarus aequicauda

Trophic applications: Why do food sources differ in their isotopic compositions?

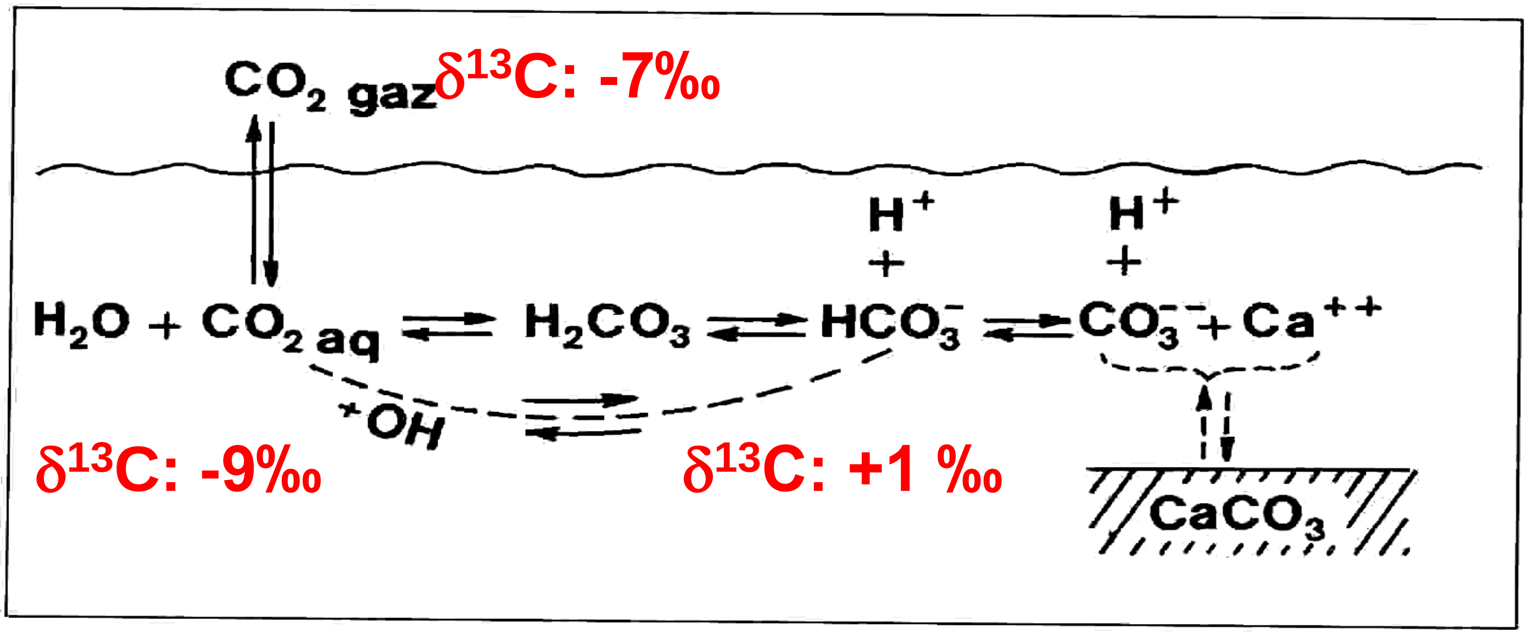
- Food sources MUST differ by their isotopic composition

- Remark: generally, not possible at specific level (keep stomach content or other approaches in mind)

- Why do food sources differ in their isotopic compositions?

TROPHIC APPLICATIONS: $\delta^{13}C$ AQUATIC PRIMARY PRODUCERS

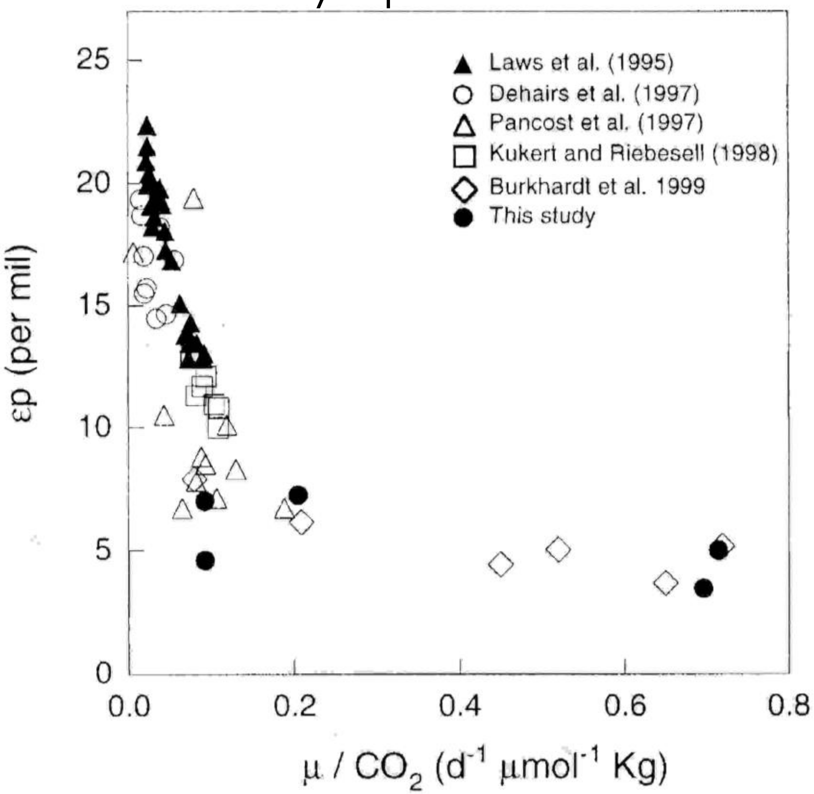
- Isotopic carbon composition is determined during primary production, then by C biochemistry inside the plant/cell
- Importance of the C_{inorg} source



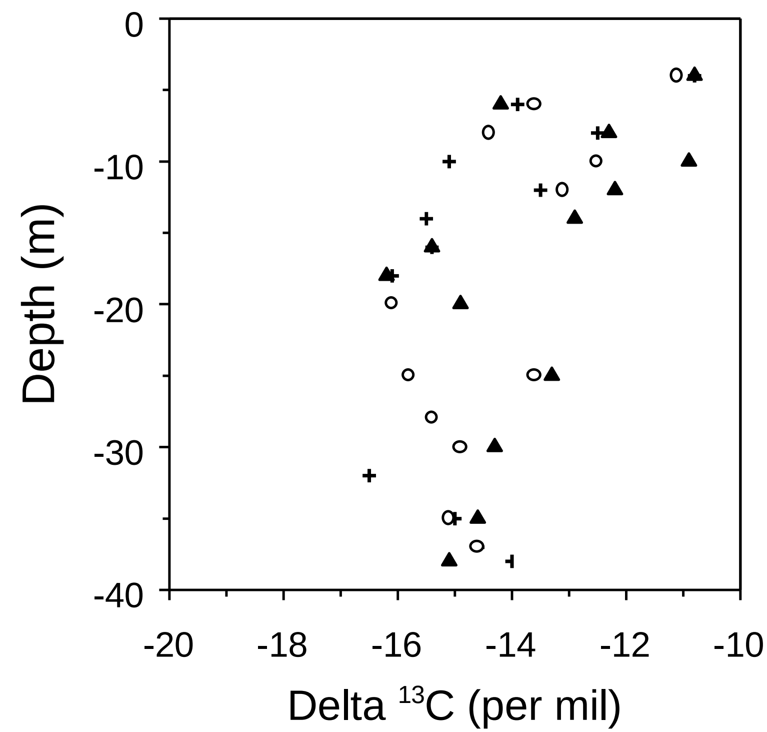
TROPHIC APPLICATIONS: $\delta^{13}C$ AQUATIC PRIMARY PRODUCERS

- Importance of primary production rate vs. C_{inorg} availability

Phytoplankton



Seagrass



Trophic applications: $\delta^{13}C$ aquatic Primary producers

In addition:

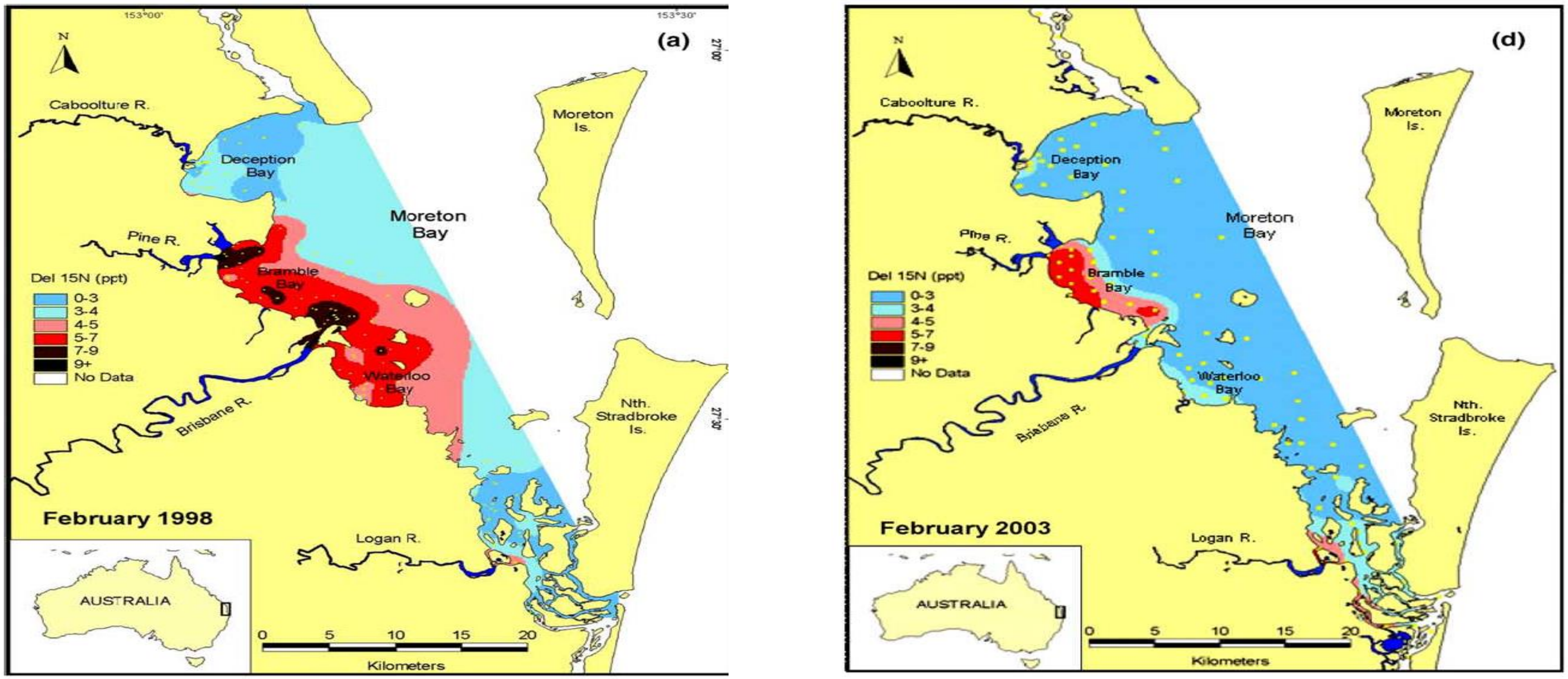
- Importance of systematics, of biochemical composition, of plant form, etc.

- multicellular plant vs. phytoplankton or microphytobenthos

- Perenial vs. ephemeral

TROPHIC APPLICATIONS: δ^{15}N AQUATIC PROD. 1

- N isotopic composition of primary producers is determined by N sources (type and isotopic compositions) and assimilation processes (AA biosynthesis)

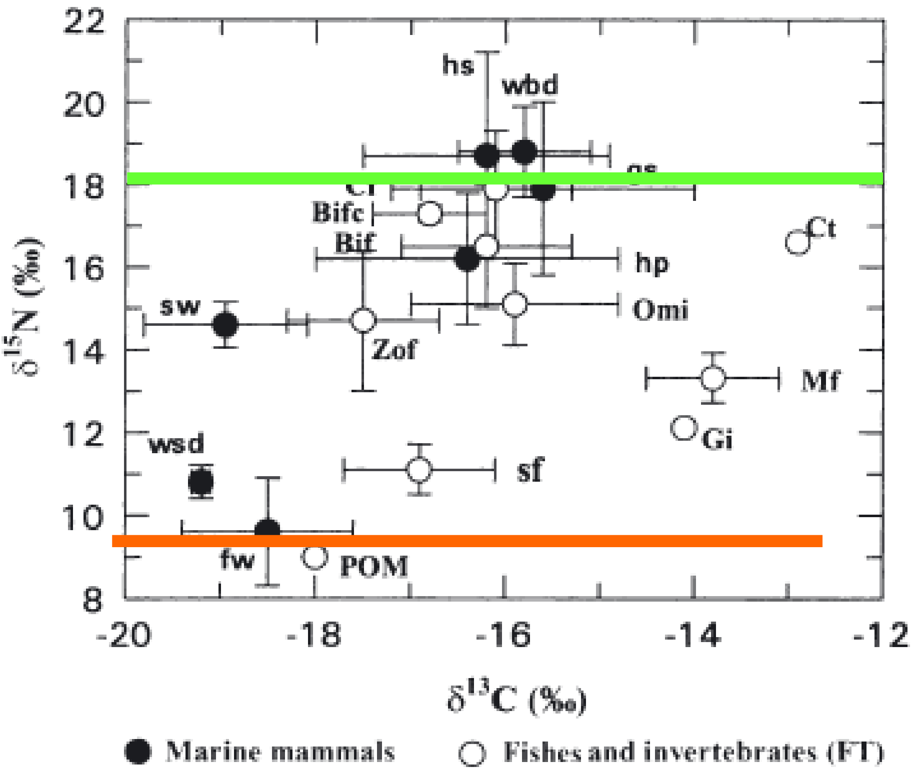


⇒ Isotopic mapping (IsoMap) or isototopic landscape/seascape (IsoScape) (www.isoscape.org)

Source: Costanzo et al. (2005), Mar Pollut Bull 54: 212-217

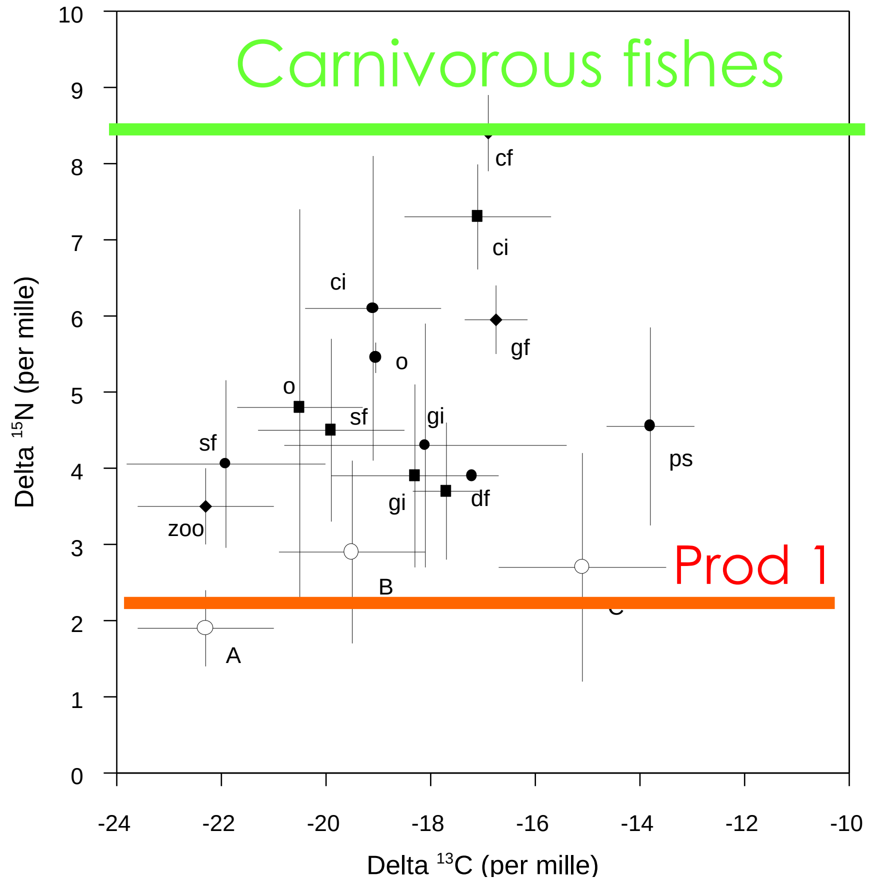
TROPHIC APPLICATIONS: ISOTOPIC BASELINE VARIABILITY

North Sea



Das et al. MEPS 2003

Mediterranean Sea



Lepoint et al. Mar Biol 2000

Trophic applications: Isotopic baseline variability

- Small scale spatial variability or gradient

- Temporal variability

- ⇒ To adapt your sampling strategy

Case study 1: *P. oceanica* primary producers

- Comparative food web studies between *P. oceanica* and adjacent algae habitat

- Qualitative sampling as broad as possible: consumer and primary food sources

- **For such type of study**:

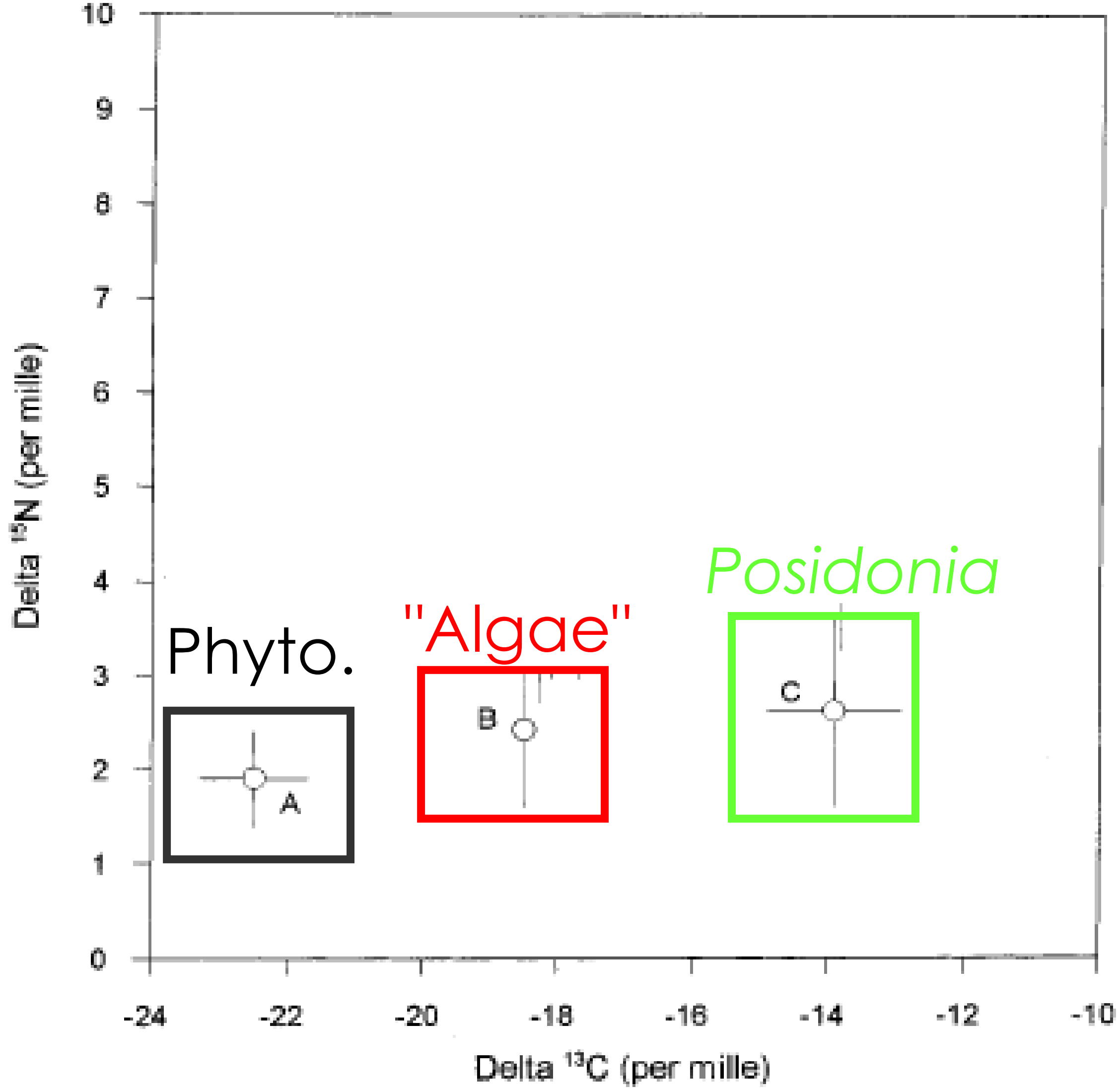
-Minimal n per consumer: if possible 6 (individual or pool) (a compromise between statistical power and feasibility)

-Be aware of spatial and seasonal variability

Case study 1: Primary producers

Biota	Groups	Species	n	$\delta^{15}N$	$\delta^{13}C$
Rocks	Macroalgae				
	Green algae	*Acetabularia acetabulum*	3	2.1 ± 1.1	−11.1
		Cladophora proliphera	1	4.0	−17.5
		Codium bursa	6	3.1 ± 1.2	−10.3 ± 0.7
		Halimeda tuna	3	1.3 ± 0.3	−19.3 ± 1.7
		Udotea petiolata	16	1.8 ± 0.9	−32.6 ± 1.1
	Brown algae	*Dictyota* spp.	30	3.6 ± 1.7	−17.4 ± 1.4
		Halopteris scoparia	43	1.8 ± 1.2	−20.7 ± 1.7
		Nematochrisopsis sp.	2	4.0 ± 0.3	−25.4 ± 0.6
		Padina pavonica	5	4.3 ± 0.8	−11.9 ± 1.1
	Red algae	*Corallina* sp.	4	3.8 ± 0.4	−18.1 ± 2.6
		Peysonelia sp.	8	3.2 ± 0.9	−21.7 ± 2.6
		Sphaerococcus coronopifolius	3	2.4 ± 0.4	−33.4 ± 1.3
	Dominant algae	Weighted averages		1.8	−18.3
Seagrass bed	Phanerogam	*Posidonia oceanica* (living leaves)	28	2.6 ± 1.0	−13.9 ± 1.0
		Posidonia leaf epifauna (fixed epifauna)	6	3.4 ± 0.6	−19.4 ± 0.8
	Epiphytic algae	*Posidonia* leaf epiflora	6	3.0 ± 0.9	−18.6 ± 1.9
Water column		Organic suspended particulate matter	19	1.9 ± 0.5	−22.5 ± 0.8

Case study 1: Primary producers

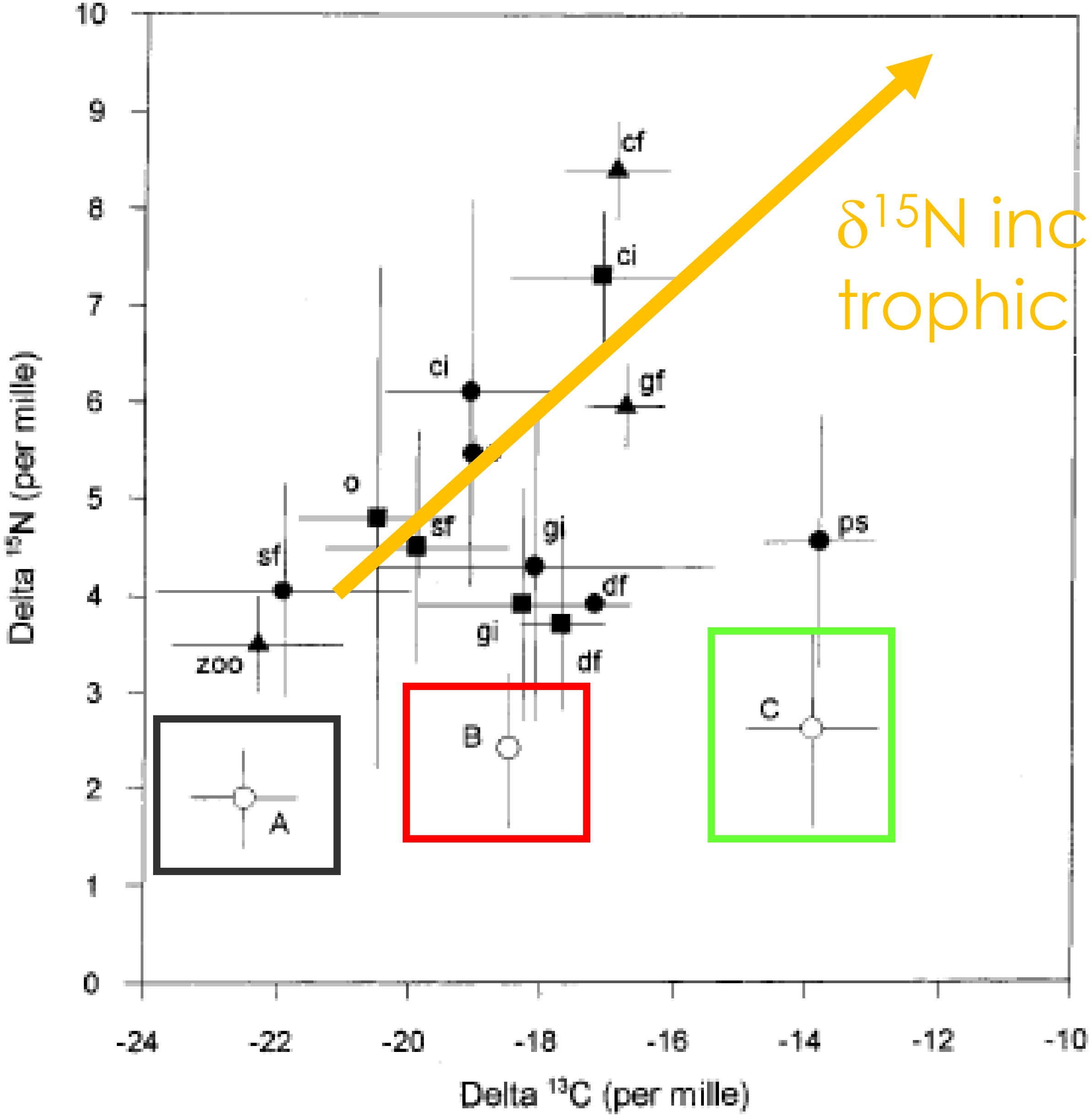


Dominant algae and epiphytes do not differ ⇒ source aggregations

Lepoint et al 2000

Case study 1: Consumers

Biota, group	Species	FFG	n	$\delta^{15}N$	$\delta^{13}C$
Seagrass bed					
	Fixed leaf epifauna	sf	15	3.4 ± 1.3	−19 ± 1.7
Sponge	*Crambe crambe*	sf	1	4.2	−22.2
Cnidarian	*Cerianthus* sp.	ci	1	8.5	−18.0
Echiurian	*Bonellia veridis*	df	1	3.9	−17.2
Annelid	*Sabella pavonina*	sf	1	3.4	−20.9
Mollusc	*Pecten* sp.	sf	2	5.3 ± 0.3	−19.5 ± 1.4
	Bittium reticulatum	gi	2	3.2 ± 0.3	−18.0 ± 1.2
	Calliostoma sp.	gi	1	5.1	−14.6
	Emarginula sp.	gi	1	4.1	−16.2
	Gibbula sp.	gi	1	3.3	−16.5
	Jujubinus sp.	gi	1	2.9	−18.3
	Rissoa auriscalpium	gi	2	3.6 ± 0.1	−19.2 ± 3.5
	Tricolia sp.	gi	2	3.4 ± 1.3	−14.2
	Aplysia punctata	gi	2	2.5 ± 1.8	−24.2 ± 5.9
	Nudibranch (mixed species)	ci	1	3.7	−20.0
Crustacean	Amphipods (mixed species)	gi	2	3.5 ± 0.2	−20.1 ± 1.0
	Isopods (mixed species)	gi	1	8.7	−17.2
	Idotea sp.	gi	2	4.1	−15.1 ± 1.3
	Sphaeroma sp.	gi	1	3.7	−19.1
	Mysidiacae (mixed species)	sf	2	6.0	−23.1 ± 1.4
	Paguridae (mixed species)	o	7	5.3 ± 1.1	−19.1
	Galatheidae (mixed species)	o	1	5.6	−19.0
	Thoralus cranchii	gi	2	4.6 ± 0.4	−18.6 ± 0.6
	Hippolyte inermis	gi	2	6.4 ± 0.3	−18.3 ± 0.1
	Palaemon sp.	ci	3	7.8 ± 1.2	−17.5 ± 0.7
Bryozoan	*Electra posidoniae* (leaf epiphytes)	sf	2	4.7 ± 1.6	−22.6
Echinoderm	*Asterina gibbosa*	ci	2	5.0 ± 1.3	−20.1 ± 0.4
	Holothuria stellati	ps	1	3.6	−14.4
	Holothuria tubulosa	ps	8	5.5 ± 1.0	−13.2 ± 1.7
	Sphaerechinus granularis	gi	2	5.3 ± 2.4	−22.1 ± 1.1
Tunicate	Didemnidae (leaf epiphytes)	sf	1	3.5	−25.3
	Botryllus schlosserii (leaf epiphytes)	sf	1	2.5	−22.3
Water column					
Crustacean (mainly)	Zooplankton	sf	20	3.5 ± 0.5	−22.3 ± 1.3
Fish	*Cantharus cantharus*	cf	1	8.5	−17.0
	Coris julis	cf	2	9.1 ± 0.4	−17.0 ± 0.4
	Diplodus anularis	cf	2	8.2 ± 0.4	−17.9 ± 1.5
	Mullus surmulletus	cf	1	8.6	−15.2
	Oblada melanura	cf	3	8.5 ± 0.9	−17.6 ± 1.3
	Sarpa salpa (young)	gf	8	5.4 ± 0.4	−17.4 ± 0.6
	Sarpa salpa (adult)	gf	3	6.5 ± 0.5	−16.1 ± 0.6
	Scorparia porcus (young)	cf	2	7.5 ± 0.1	−16.6 ± 0.1



$\delta^{15}N$ increases with trophic level

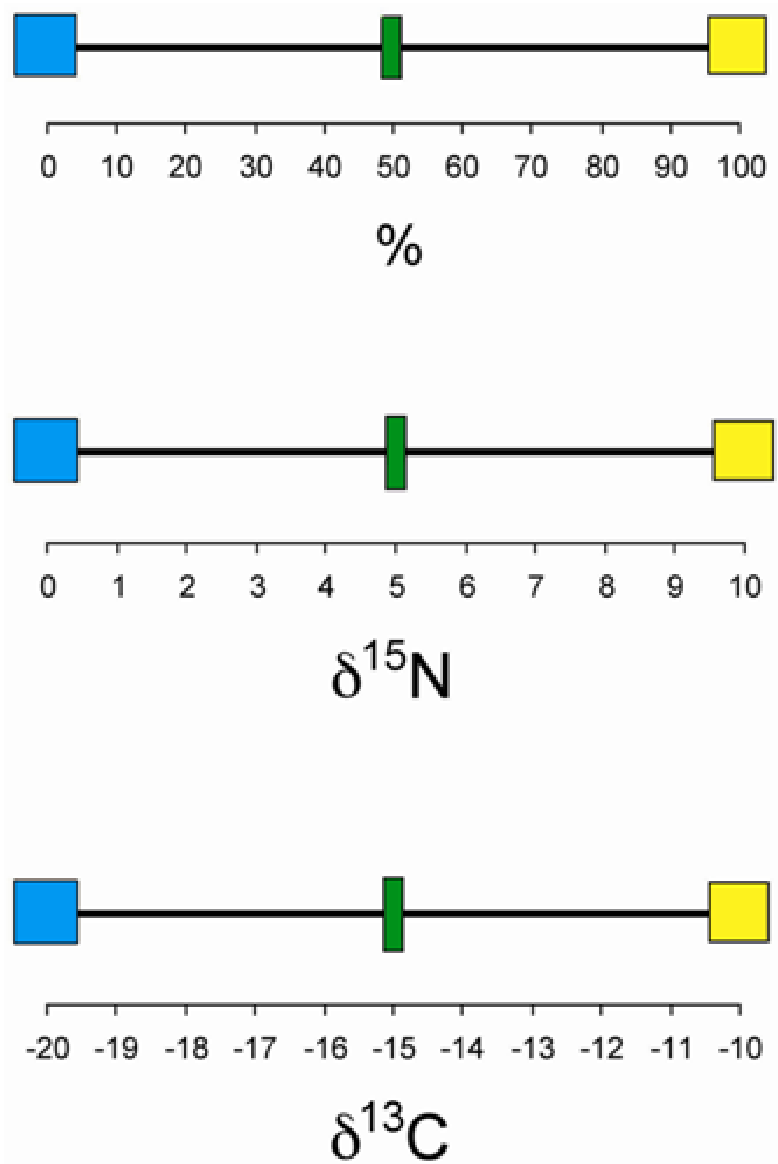
Mixing equation for 2 sources:

$$f_1 + f_2 = 1$$

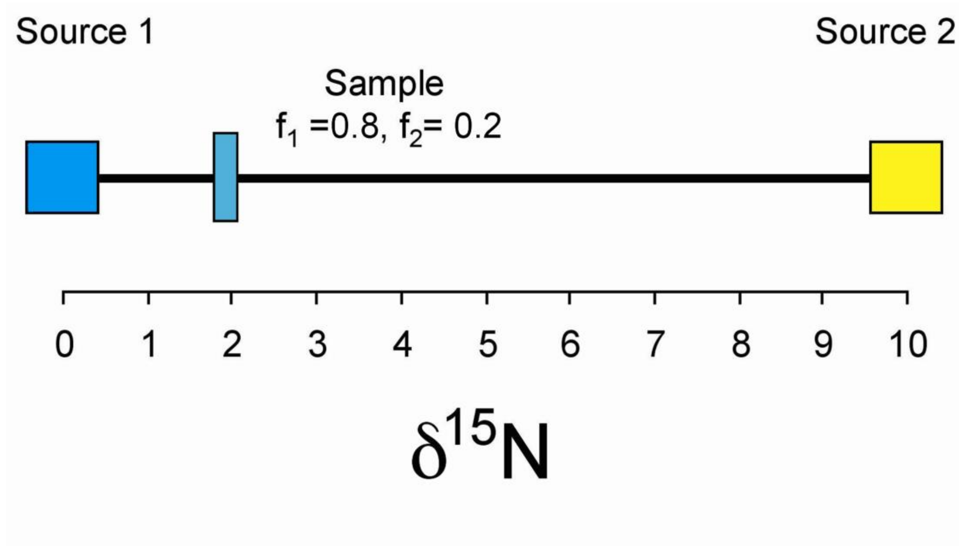
$$\delta m = (\delta_{source1} \times f_1) + (\delta_{source2} \times f2)$$

$$\delta_{mix} = \delta_{organism} - \delta_{fractionation}$$

Source A Source B



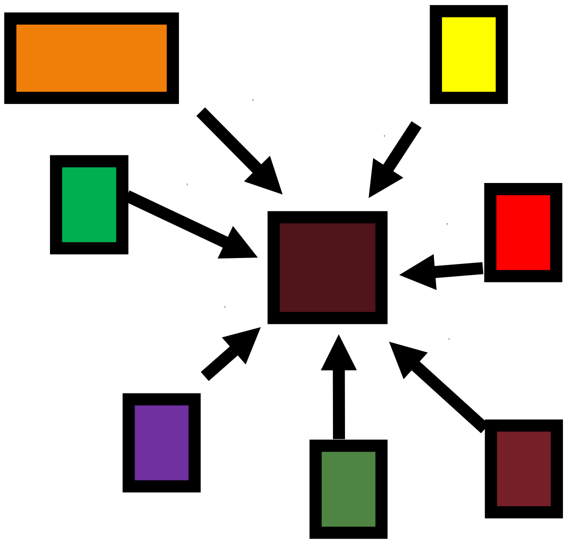
Source: Fry 2006



Source: Fry 2006

Trophic applications: Mixing Models

- How to deal with multiple sources (or complexity)?



- How to deal with variability of isotopic composition (sources, consumers, trophic enrichment)

Trophic applications: Mixing Models

Mixing equation for n sources:

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

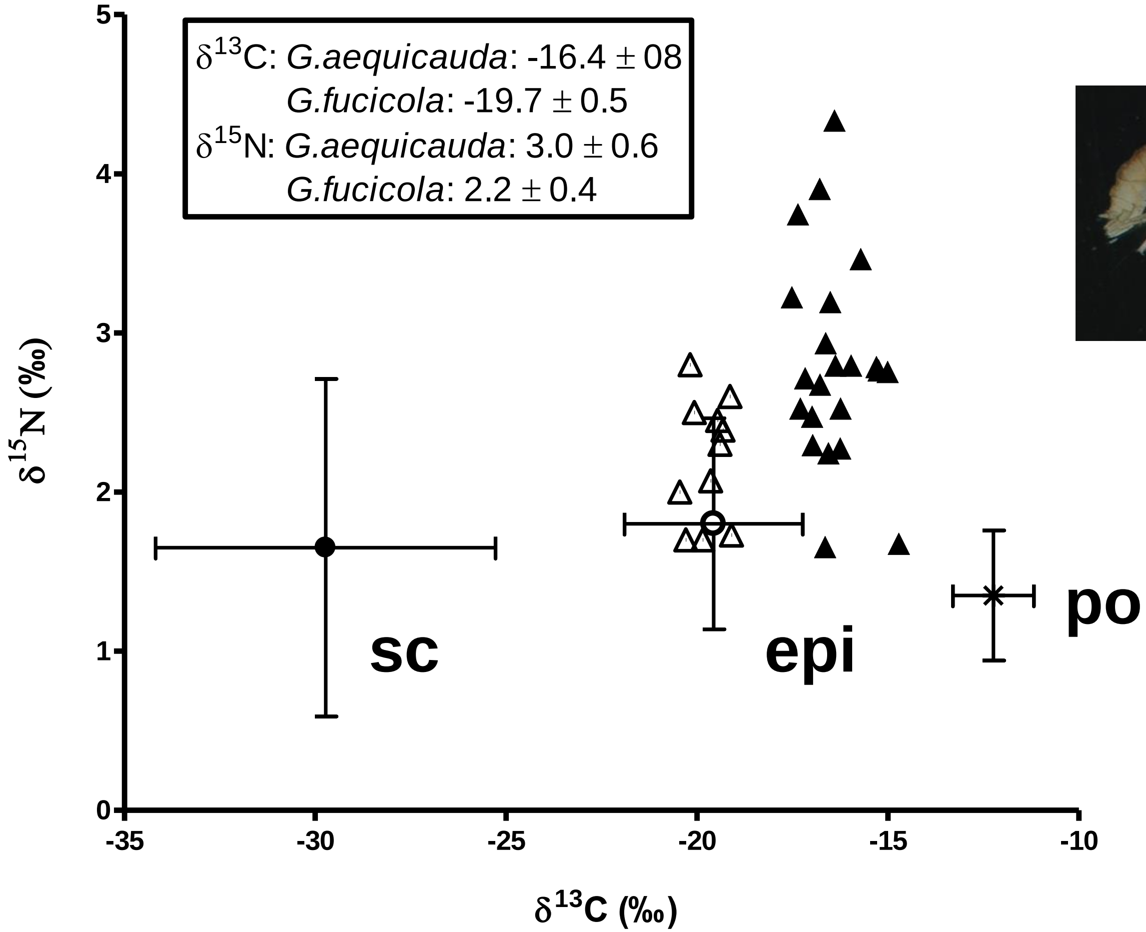
⇒ Complex mixing modelling

Examples:

A. Isosource (Philips & Gregg 2001)
(www.epa.gov/wed/pages/models/isotopes/isosource.htm)

B. SIAR (Parnell et al. 2010)
(cran.r-project.org/web/packages/siar)
Or MixSIAR

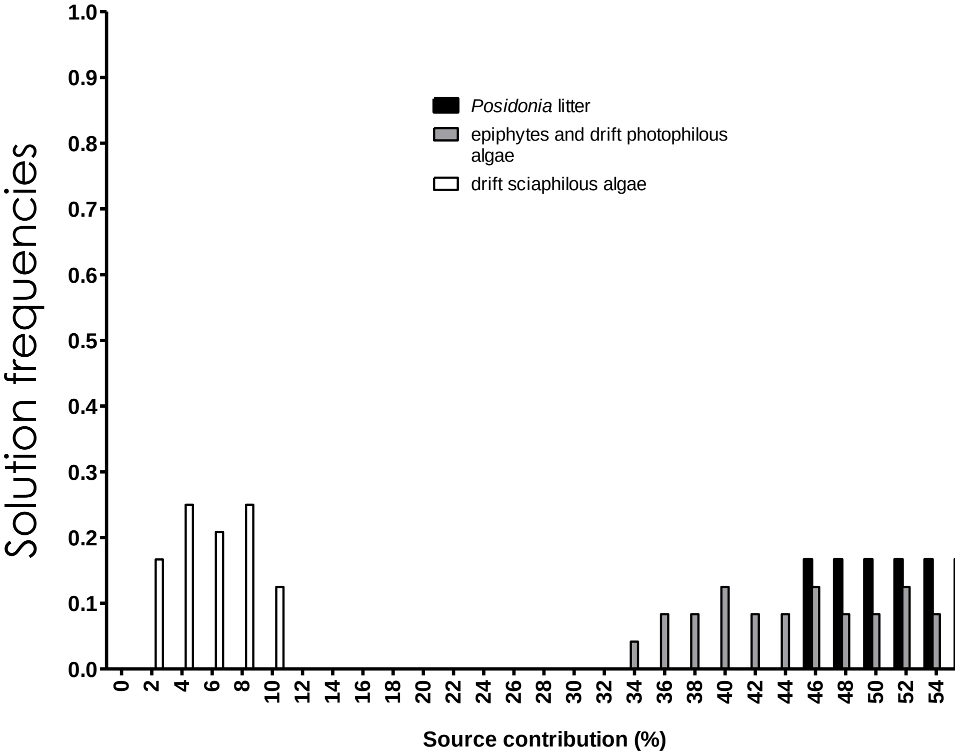
Case study 2: Amphipod in Macrophytodetritus



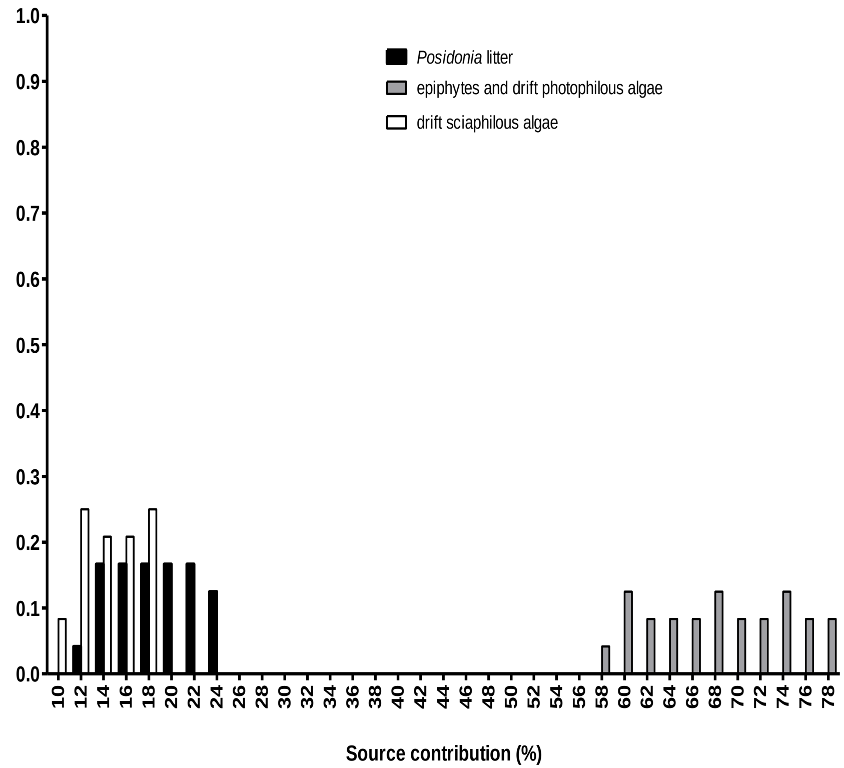
Source Lepoint et al. 2006

CASE STUDY 2: ISOSOURCE MODELLING

Gammarus aequicauda



Gammarella fucicola



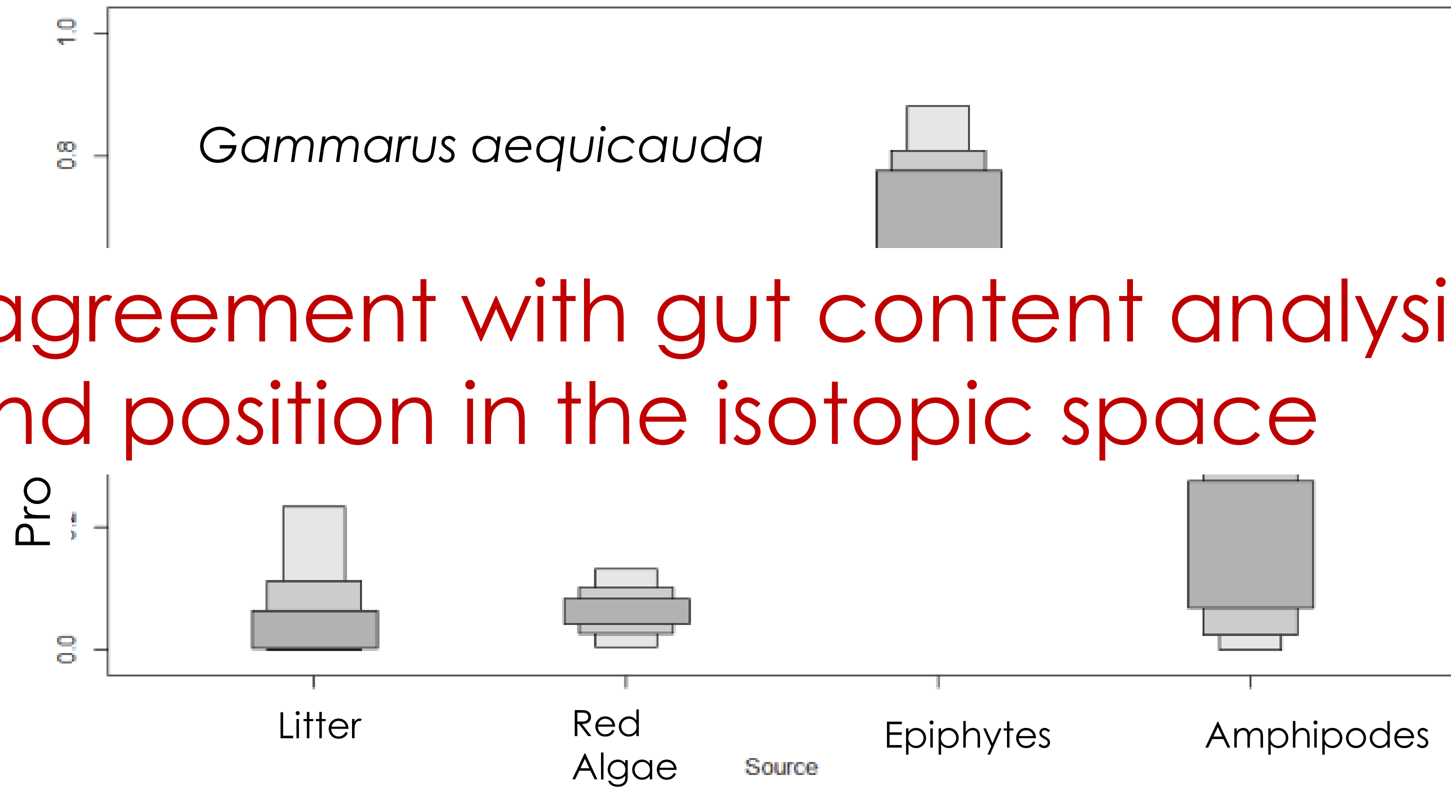
- IsoSource does not take into account variability

⇒ Bayesian models (SIAR; MixSIAR; and many others)

Source Lepoint et al. 2006

CASE STUDY 2: SIAR MODELLING

- To account variability on consumers, sources and TEF (detail tomorrow by Thibaud Mascart)



In disagreement with gut content analysis and position in the isotopic space

First scenario: TEF All the same: $\Delta^{13}C = +1$ and $\Delta^{15}N = +3.4$

Remy 2016

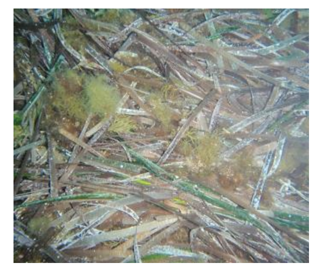
CASE STUDY 2: SIAR MODELLING
TEF DETERMINATION FOR G. *AEQUICAUDA*

- Experimental design

3 different treatments :

- ✓ Freshwater amphipod powder
- ✓ Green algae powder
- ✓ Dead *P. oceanica* powder

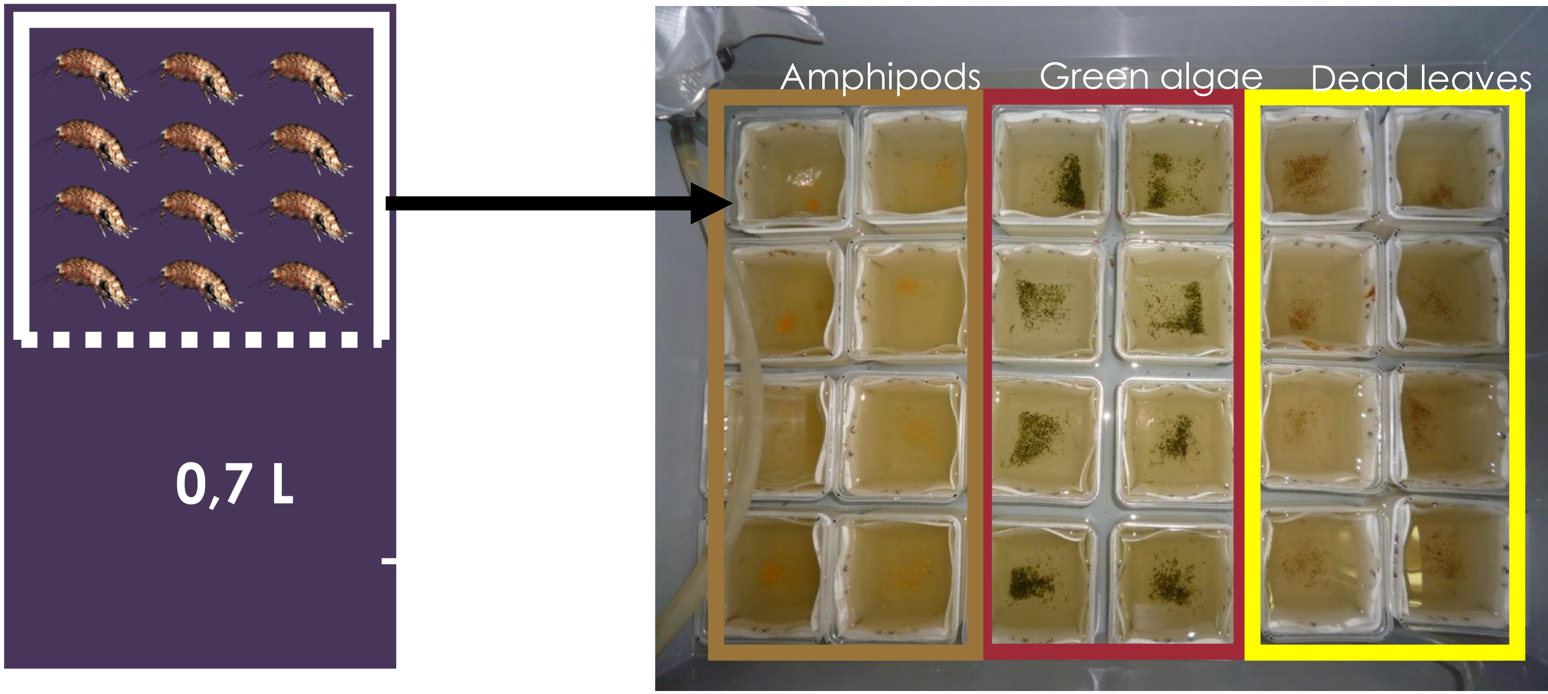




- ✓ Different carbon and nitrogen isotopic compositions
- ✓ Different quality (C/N ratios)
- ✓ All <u>potentially</u> ingestible by G. *aequicauda*

Source: Remy et al., JEMBE 2016

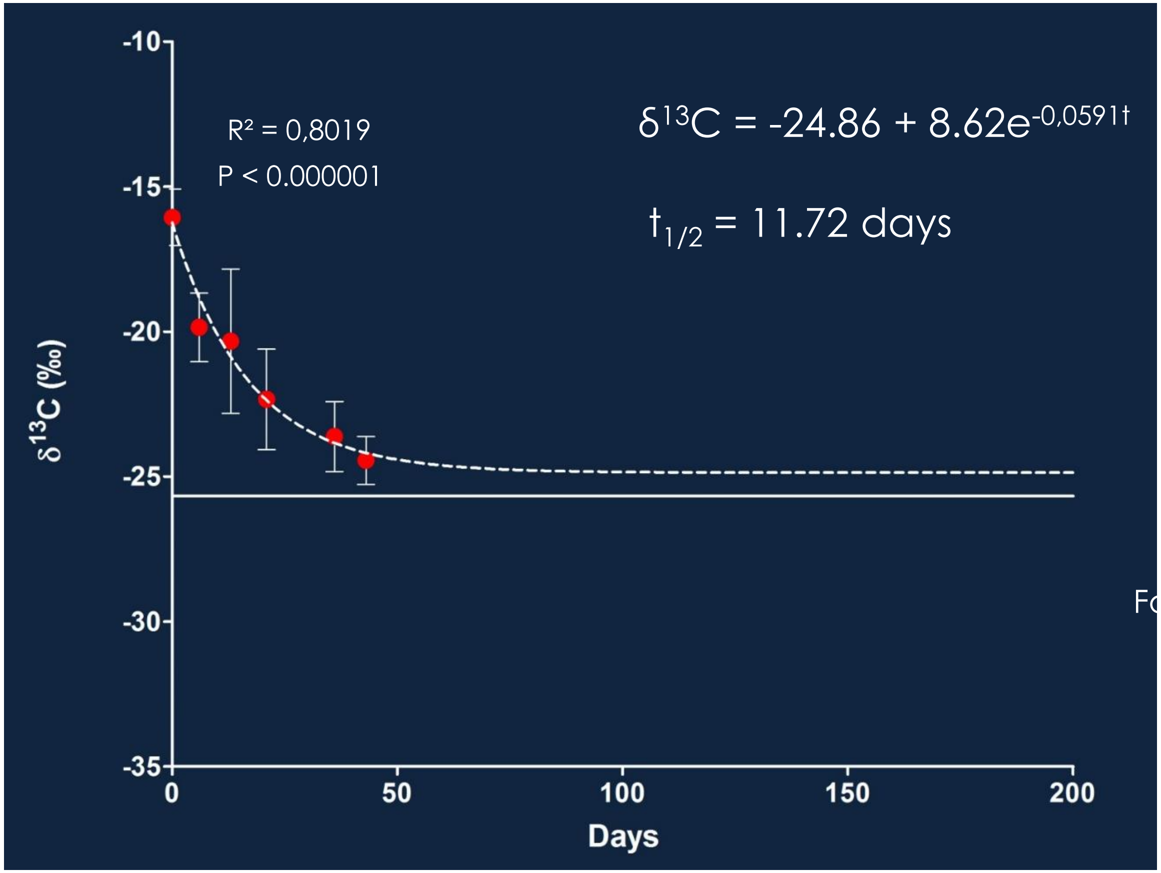
Case study 2: TEF Determination for G. *aequicauda*



- Controled conditions – feeded *ad libidum*
- 96 ind / treatment (individual isotopic compositions)

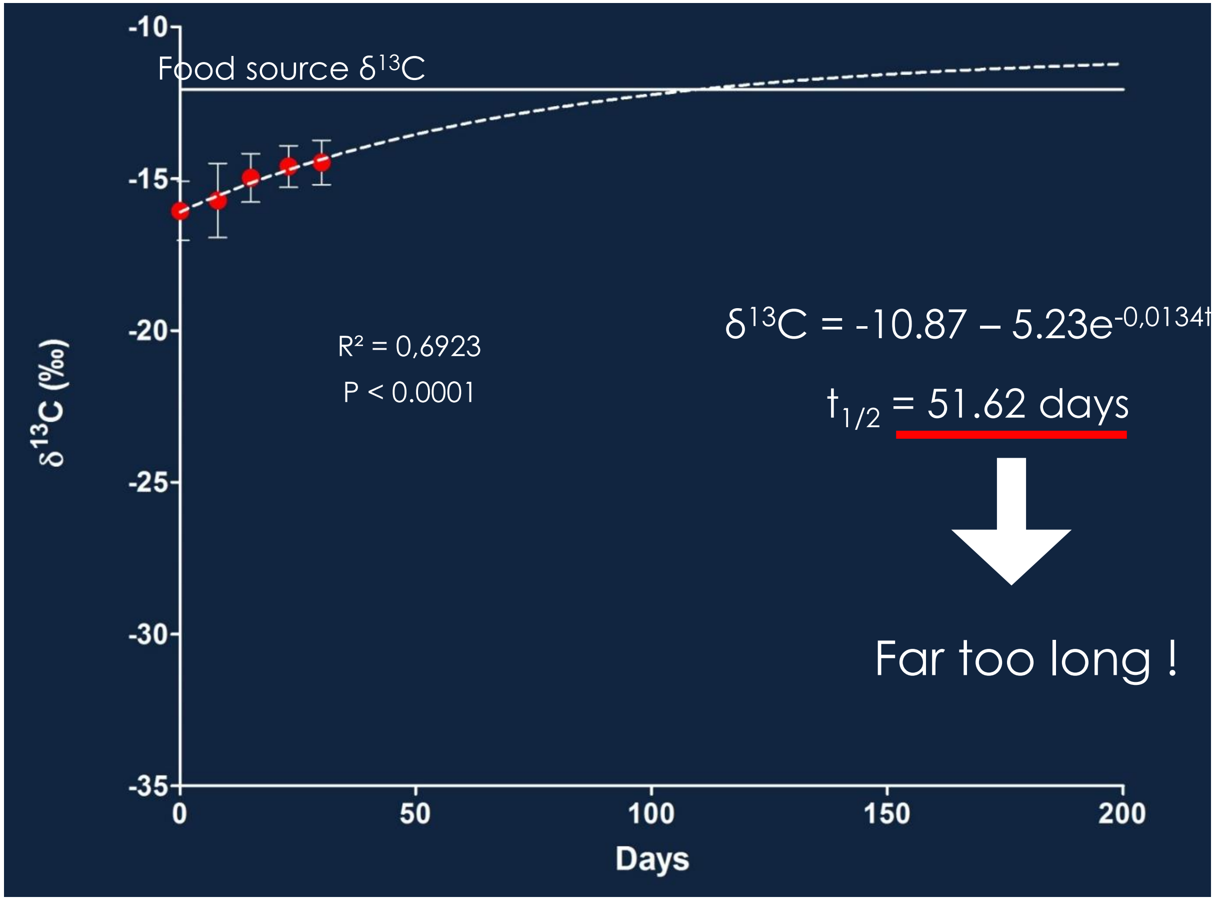
CASE STUDY 2: TEF DETERMINATION FOR G. *AEQUICAUDA*

Amphipod as food



CASE STUDY 2: TEF DETERMINATION FOR G. *AEQUICAUDA*

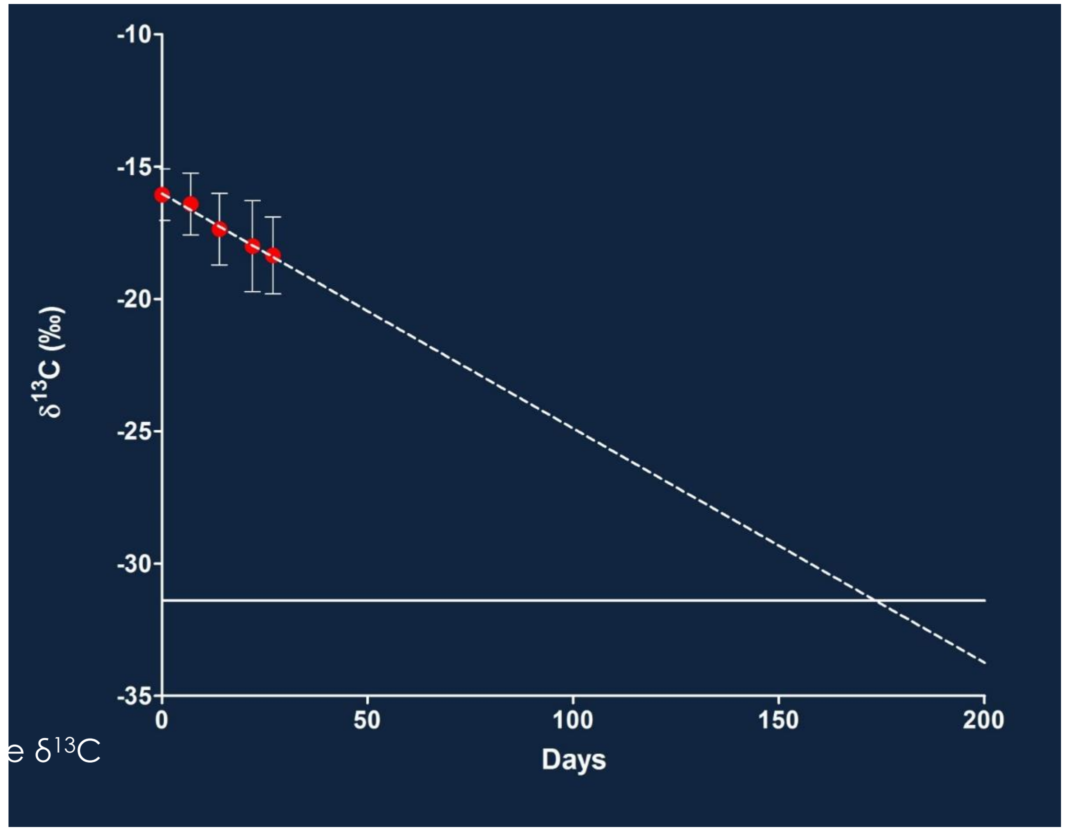
Posidonia litter as food



- High mortality
- Very slow assimilation

CASE STUDY 2: TEF DETERMINATION FOR G. *AEQUICAUDA*

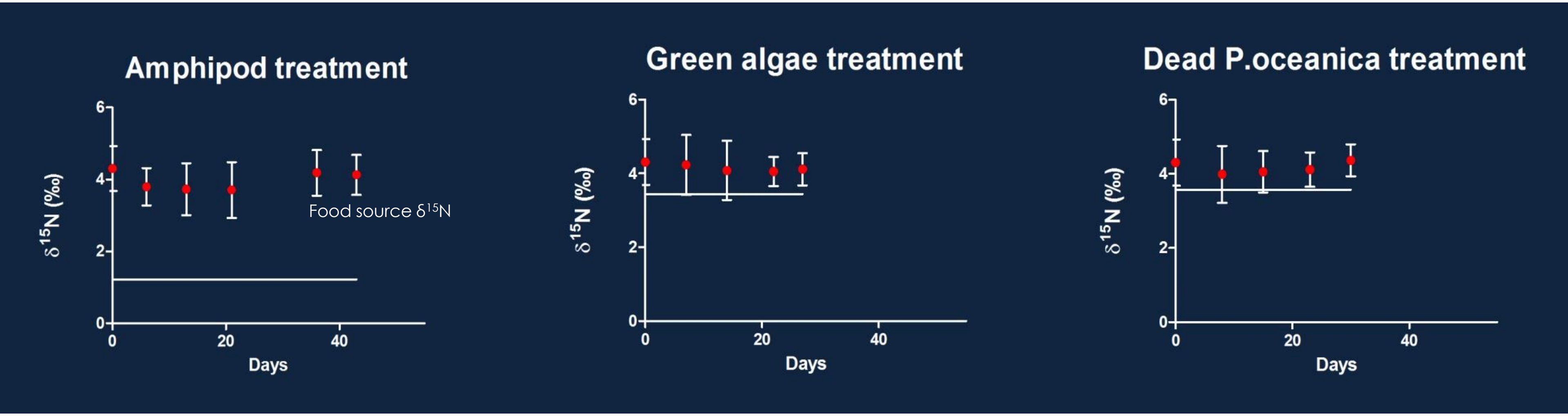
Green Algae as food:



- Even worst (algae toxicity)

CASE STUDY 2: TEF DETERMINATION FOR G. *AEQUICAUDA*

For ^{15}N



No significant change of isotopic composition

➔ No turnover rates calculation

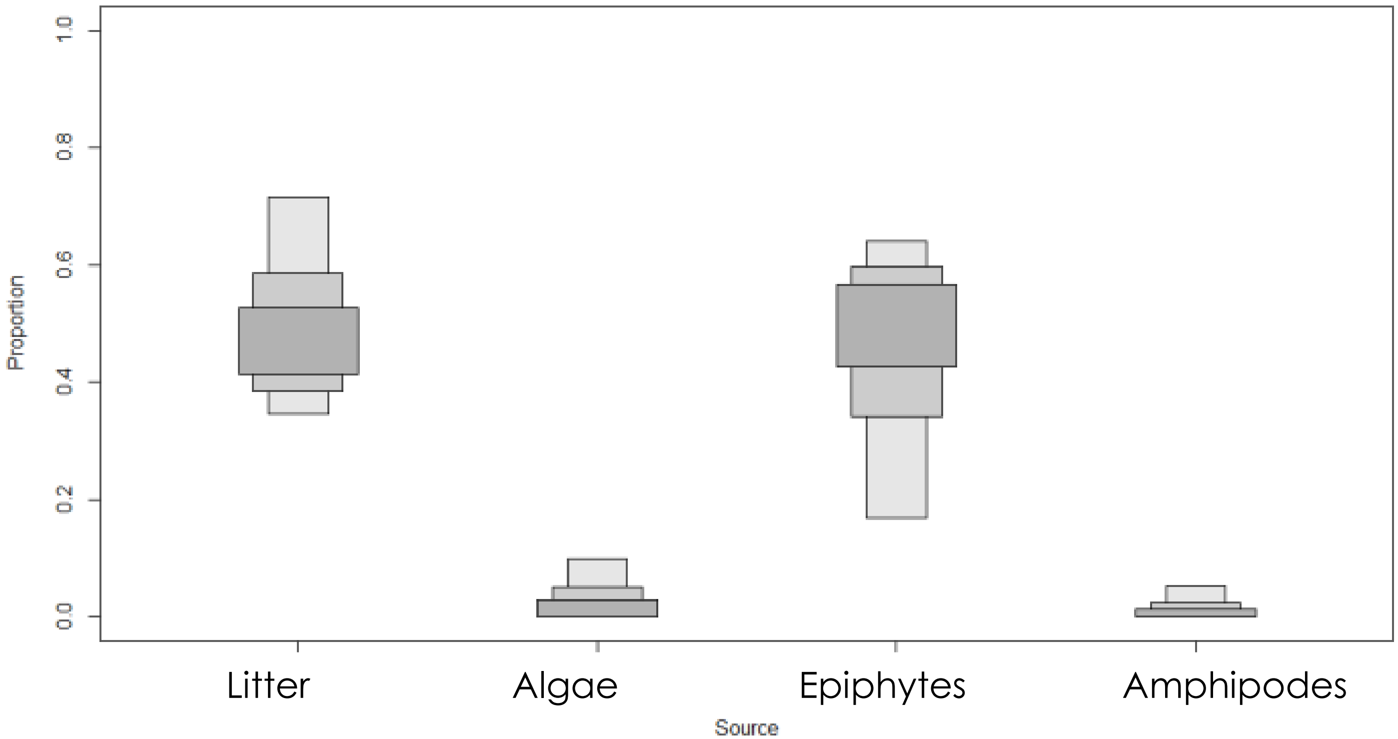
Case study 2: TEF Determination for *G. aequicauda*

	1	2	
	Amphipod treatment	Algae treatment	Litter treatment
$\Delta^{13}C$ (‰)	0.81 ± 0.39	/	1.19 ± 0.13
$\Delta^{15}N$ (‰)	2.91 ± 0.56	0.53 ± 0.44	0.96 ± 0.42

- Treatment 1 ➔ TEF typical of predator
- Treatments 2 & 3 ➔ TEF typical of primary detritic-feeder

CASE STUDY 2: SIAR MODELING : THE RETURN

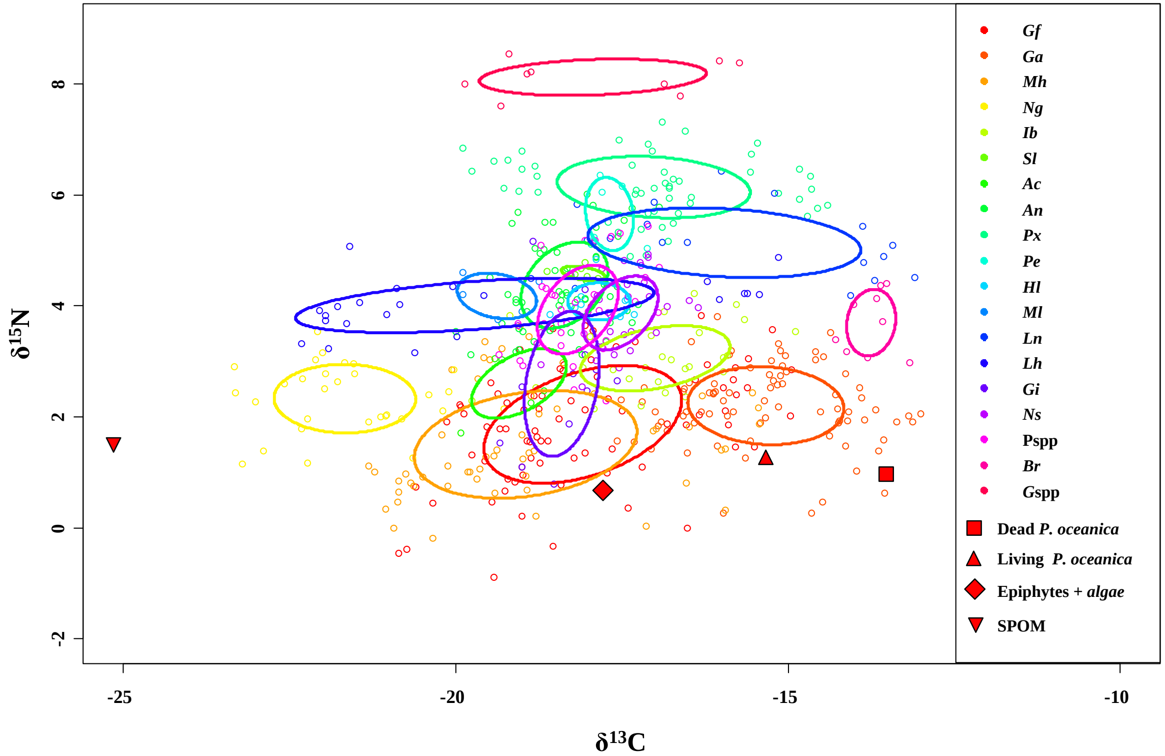
TEF: food source specific (experimentally determined by Michel for epiphytes and by Remy for litter, sciaphilous algae and animal diets)



- Not always possible to have experimental TEF – at minimum, please do not choose TEF randomly

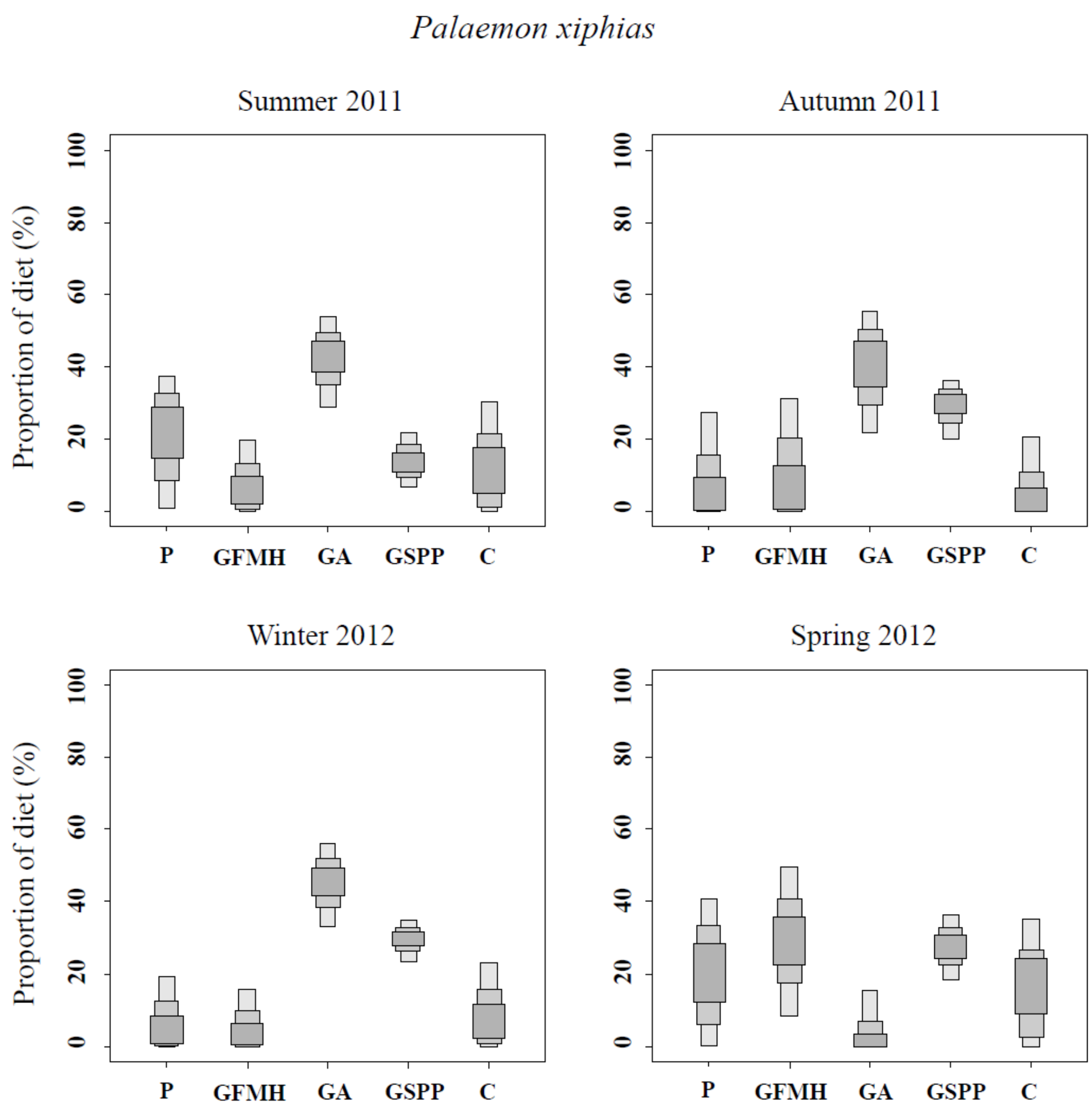
CASE STUDY 2: TO SUMMARIZE

1. Plotting



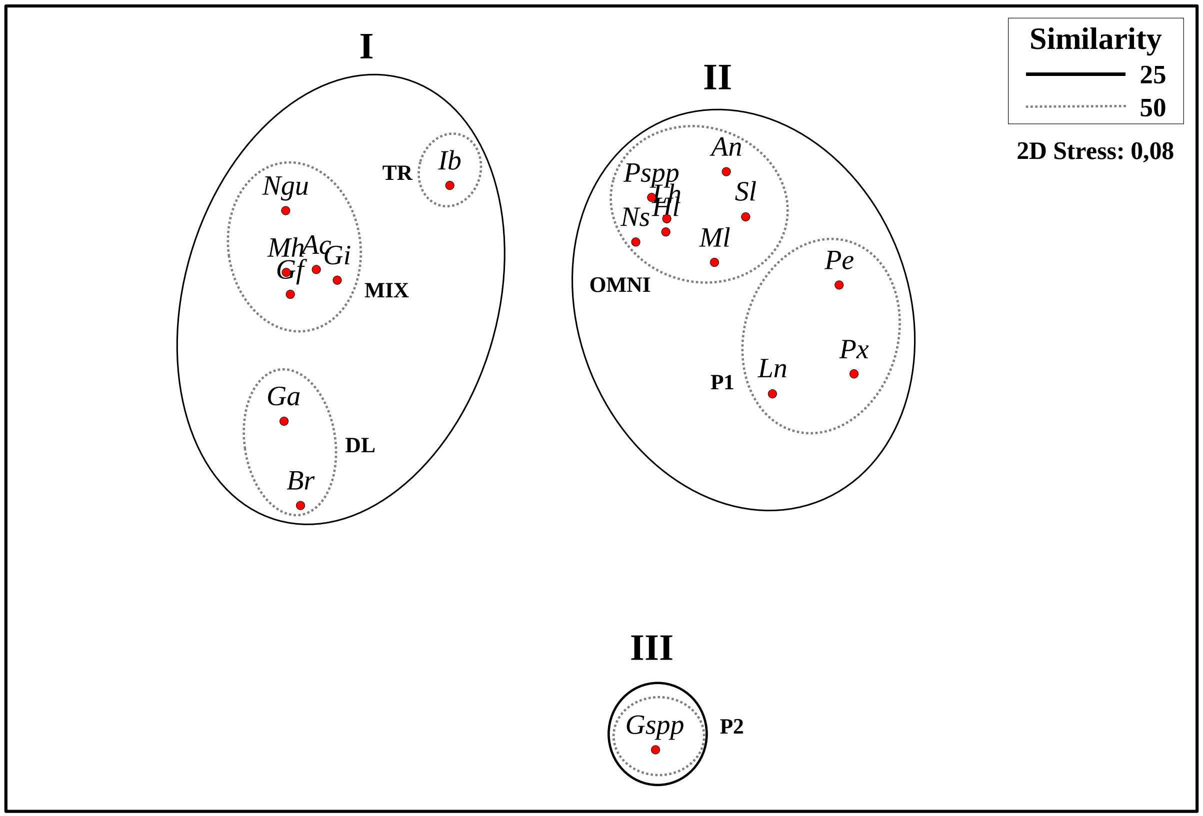
CASE STUDY 2: TO SUMMARIZE

2. Modelling



CASE STUDY 2: IN ADDITION

- To construct similarity matrix using SIAR output (Bray-Curtis for example)
- To produce MDS to show the groups



Remy et al. submitted

Trophic applications: Trophic level calculation

- $\delta^{15}N$ increases at each trophic step

⇒ Possibility to calculate Trophic Level

Vol. 84: 9–18, 1992 | MARINE ECOLOGY PROGRESS SERIES Mar. Ecol. Prog. Ser. | Published July 23

Determination of trophic relationships within a high Arctic marine food web using $\delta^{13}C$ and $\delta^{15}N$ analysis*

Keith A. Hobson[1,2], Harold E. Welch[2]

$$TL = 1 + (\delta^{15}N_{cons} - \delta^{15}N_{baseline})/\Delta^{15}N$$

Trophic applications: Trophic level calculation

- Does not account for variability of TEF and of isotopic baseline

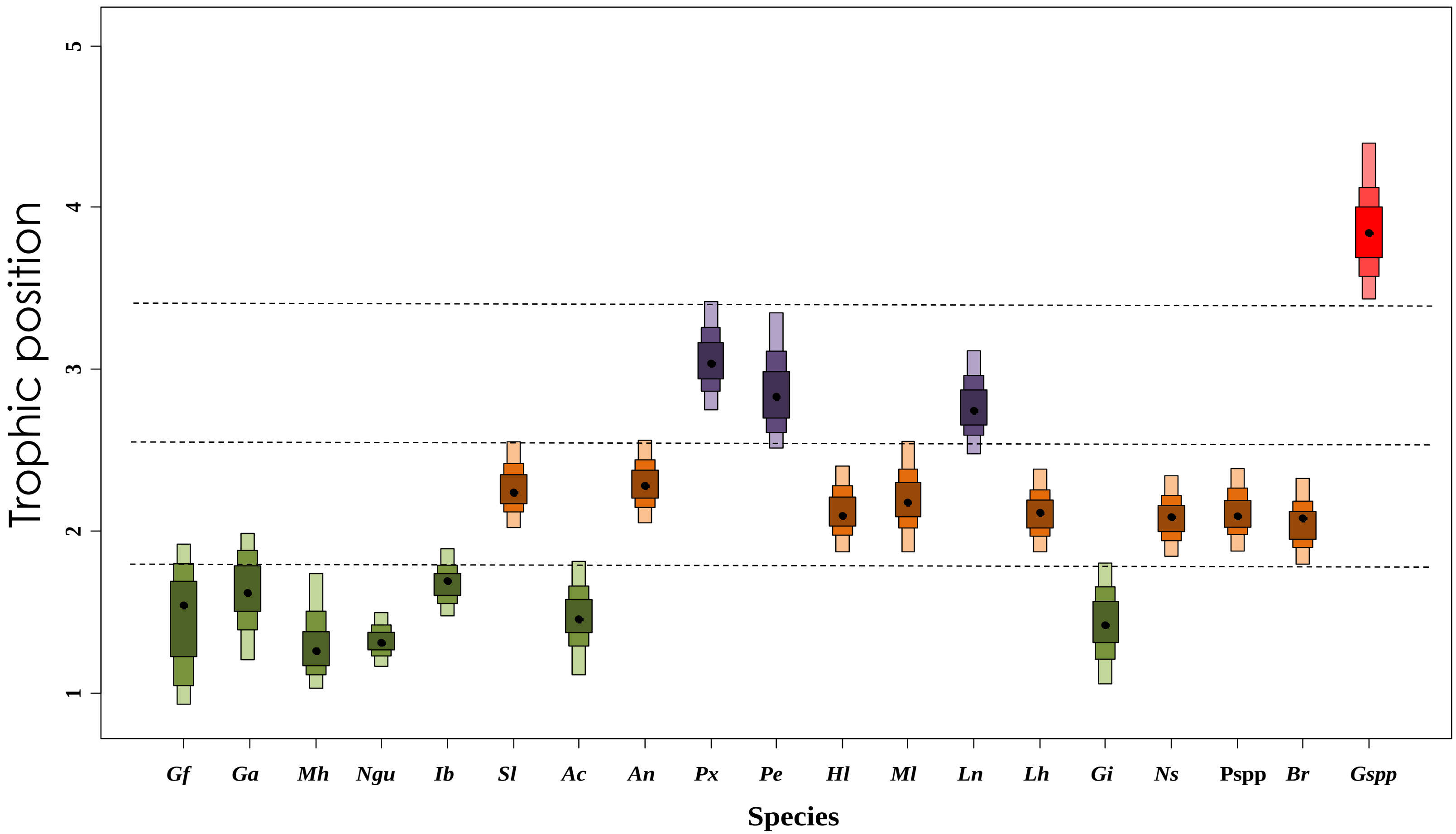
  ⇒ Bayesian modelling of trophic level

tRophicPosition model package (Quezada-Romegialli *et al*., 2016)

https://cran.r-project.org/package=tRophicPosition

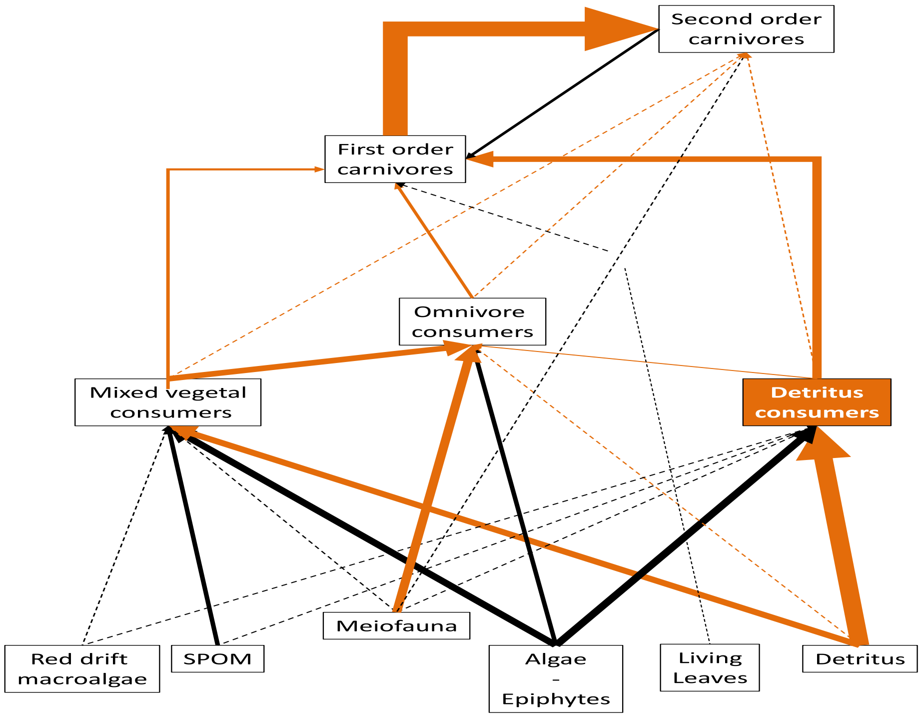
- Principle: simplified mixing model acknowledging consumer, baseline and TEF variability

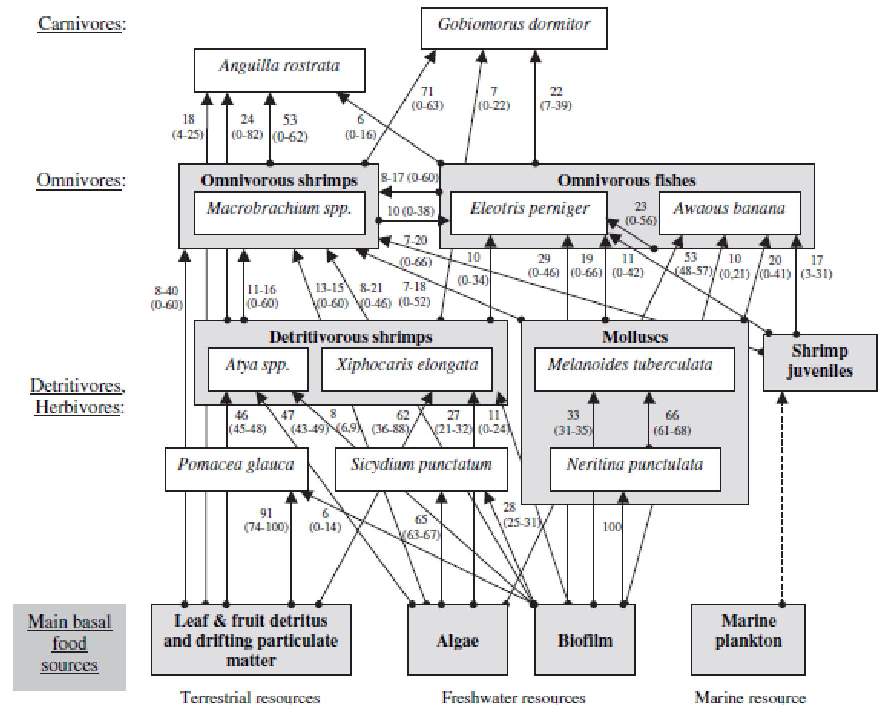
Case study 2: Trophic level of each species



Remy et al. submitted

CASE STUDY 2: CONCEPTUAL MODEL OF THE FOOD WEB





Coat et al 2009

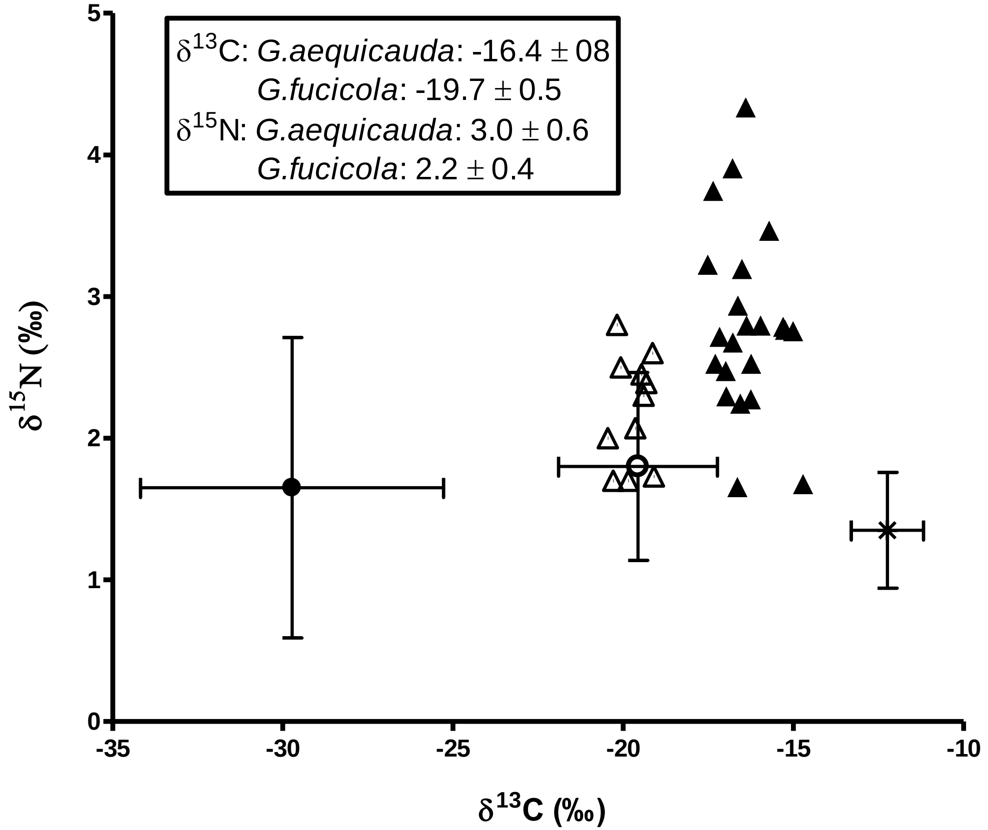
⇒ Potential following step Mathematical modelling

Remarks: if mathematical modelling involved, do not forget quantitative data such as biomass when you collect samples

TROPHIC APPLICATIONS: TROPHIC ECOLOGY OF CONSUMERS

TROPHIC APPLICATIONS: ISOTOPIC VARIABILITY 1

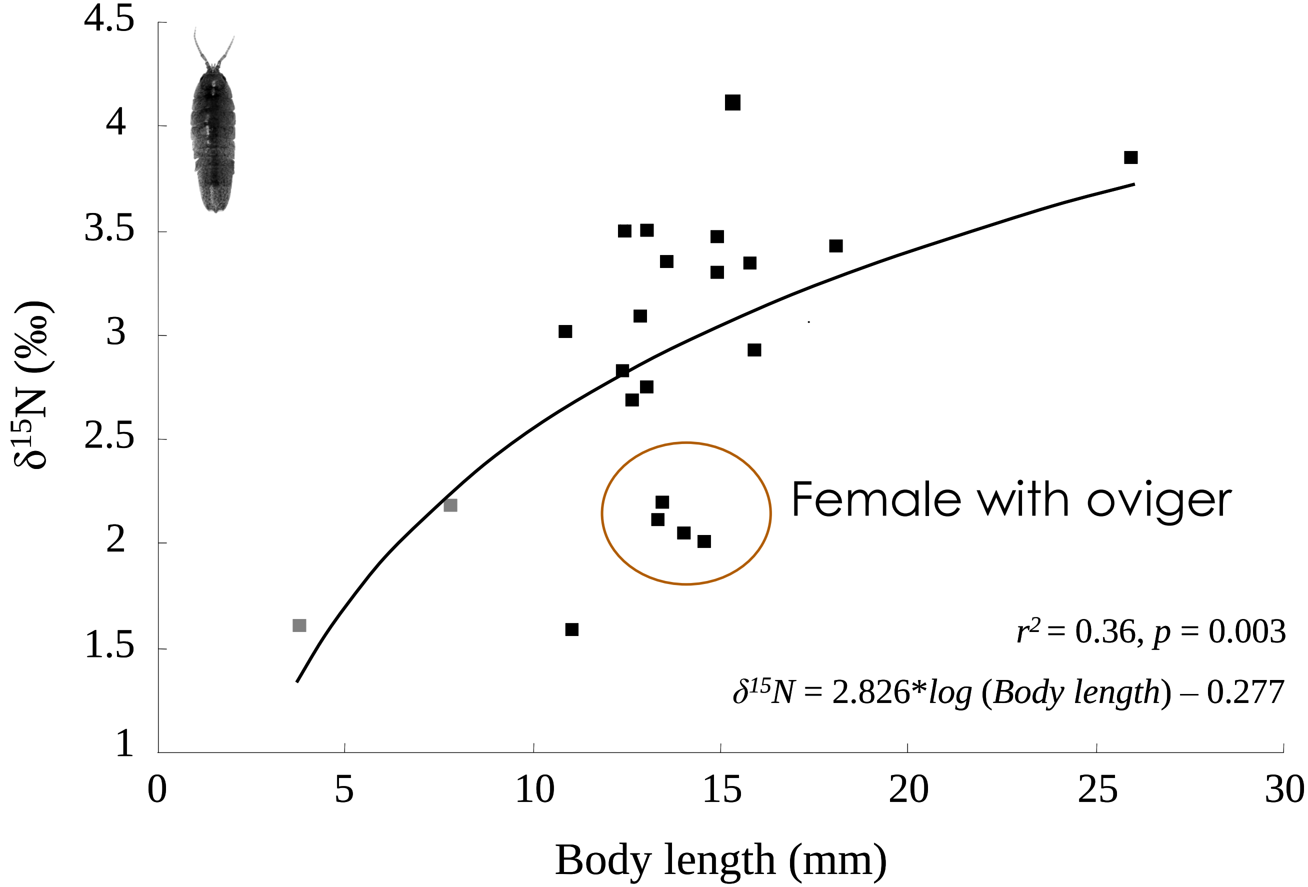
- does isotopic variability of consumer means something?



Trophic applications: Cause of Isotopic variability

- Analytical error (or s.d. on measurements)**(do not forget this one)**
- Difference in physiology/body conditions between individuals
- Difference in diet/resource use/habitat (= difference in ecological niches)

Case study 1: *Idotea baltica* in Macrophytodetritus

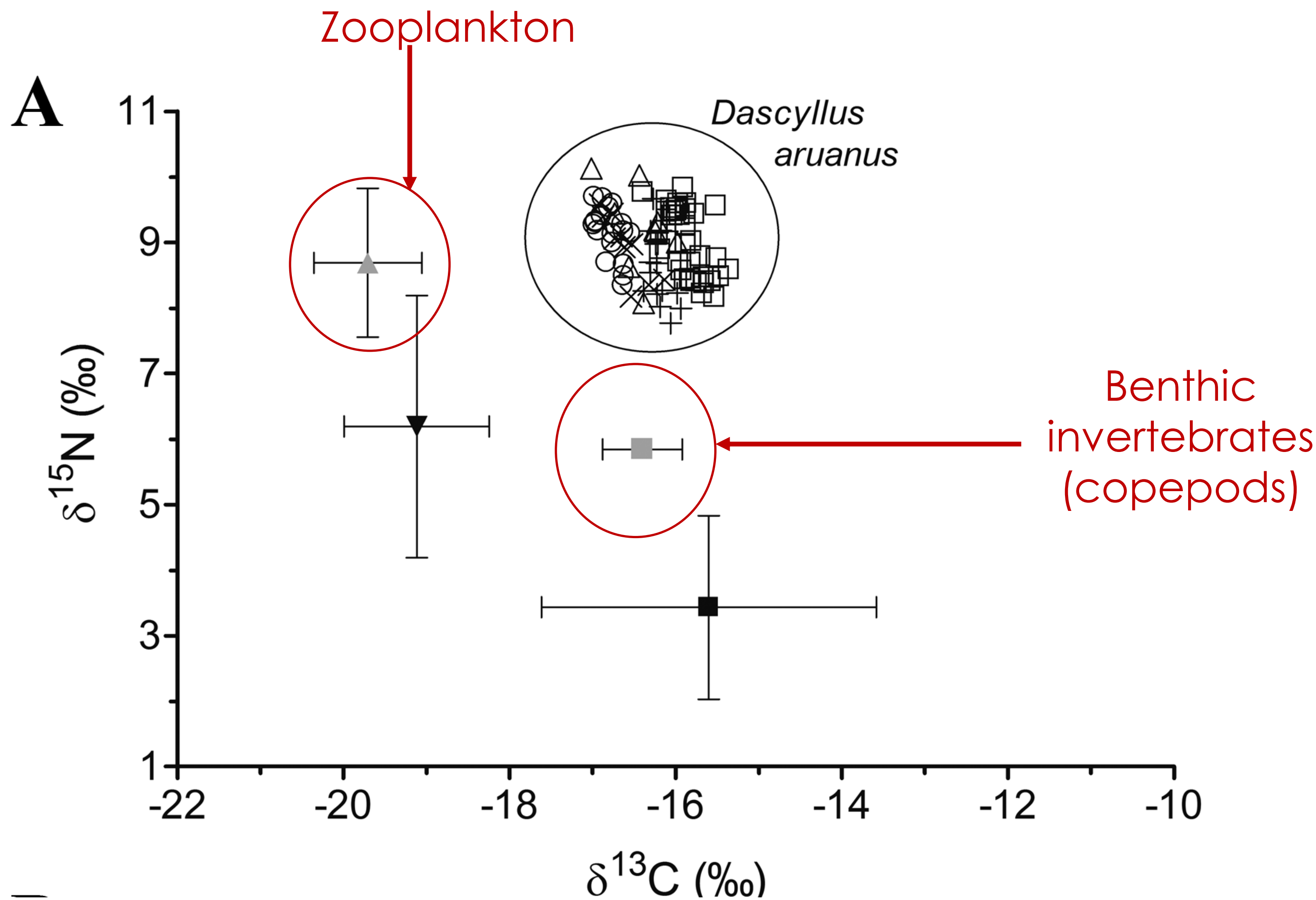


Sturaro et al. 2010

CASE STUDY 2: *DASCYLLUS ARUANUS* (DAMSELFISH)

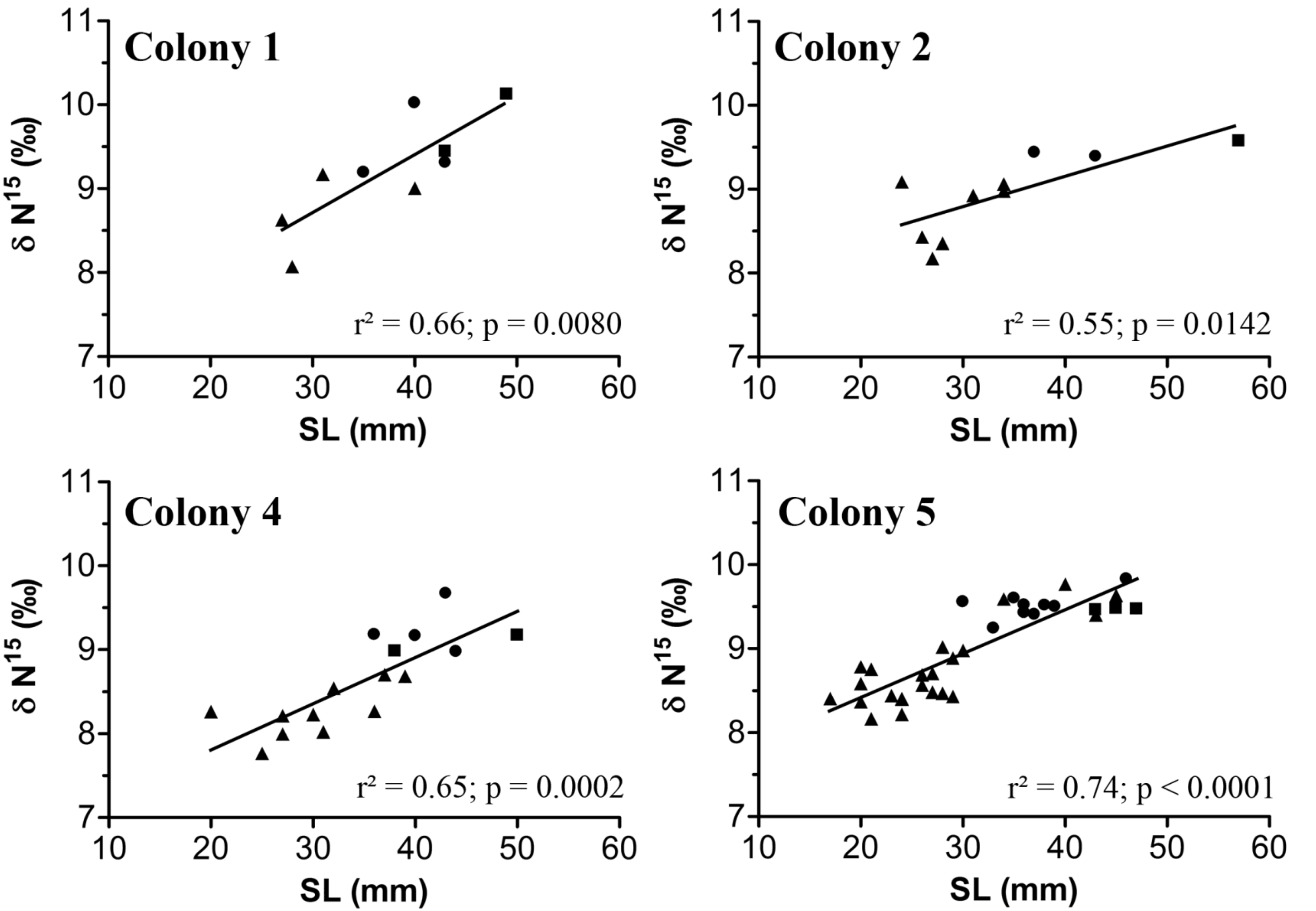
Dascyllus aruanus

Case study 2: *Dascyllus aruanus* (Damselfish)



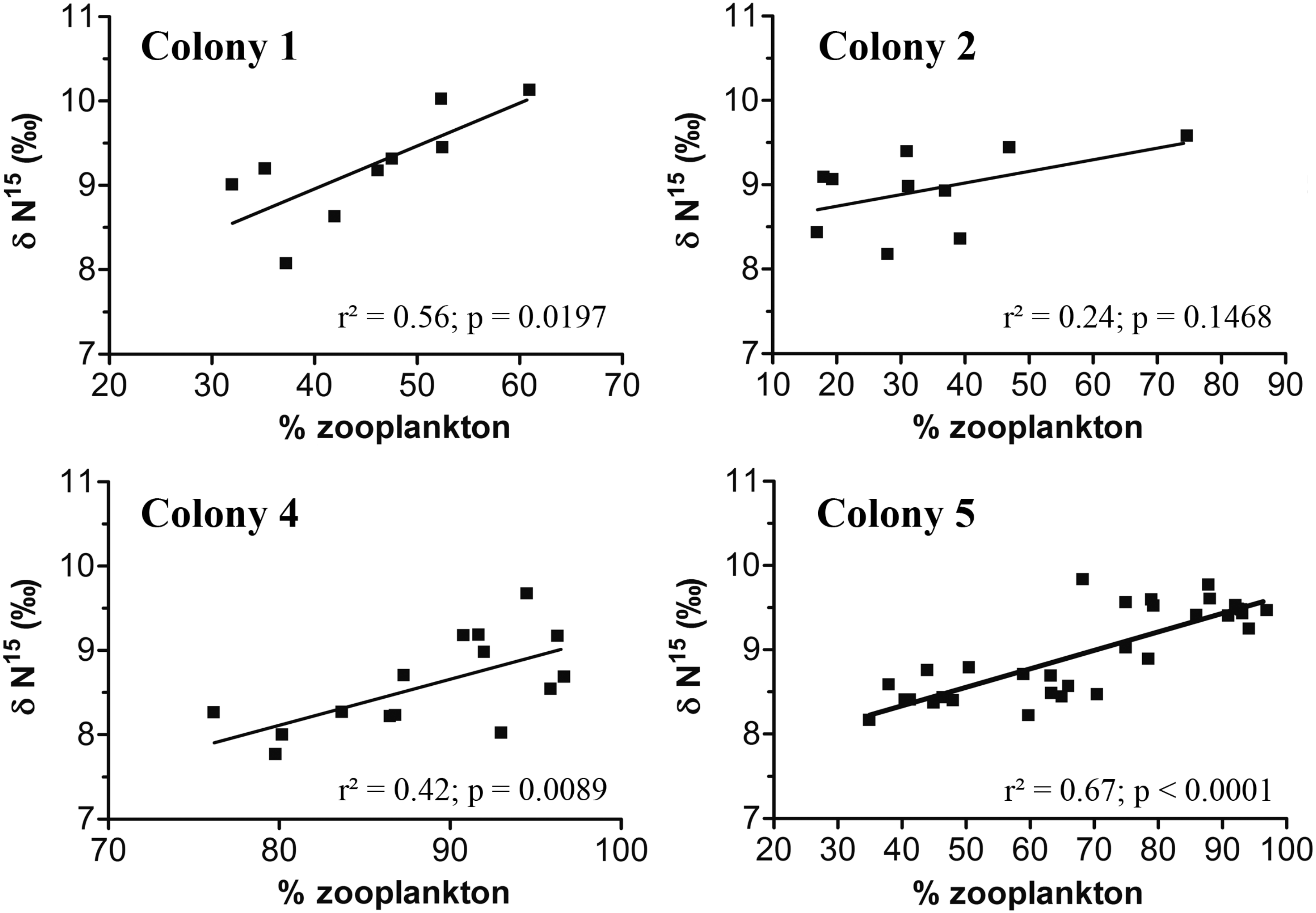
Frédérich et al. 2010, Copeia

CASE STUDY 2: *DASCYLLUS ARUANUS* (DAMSELFISH)



Source: Frédérich et al. 2010, Copeia

Case study 2: *Dascyllus aruanus* (Damselfish)



Source: Frédérich et al. 2010, Copeia

Trophic applications: Isotopic variability 2
Isotopic niches

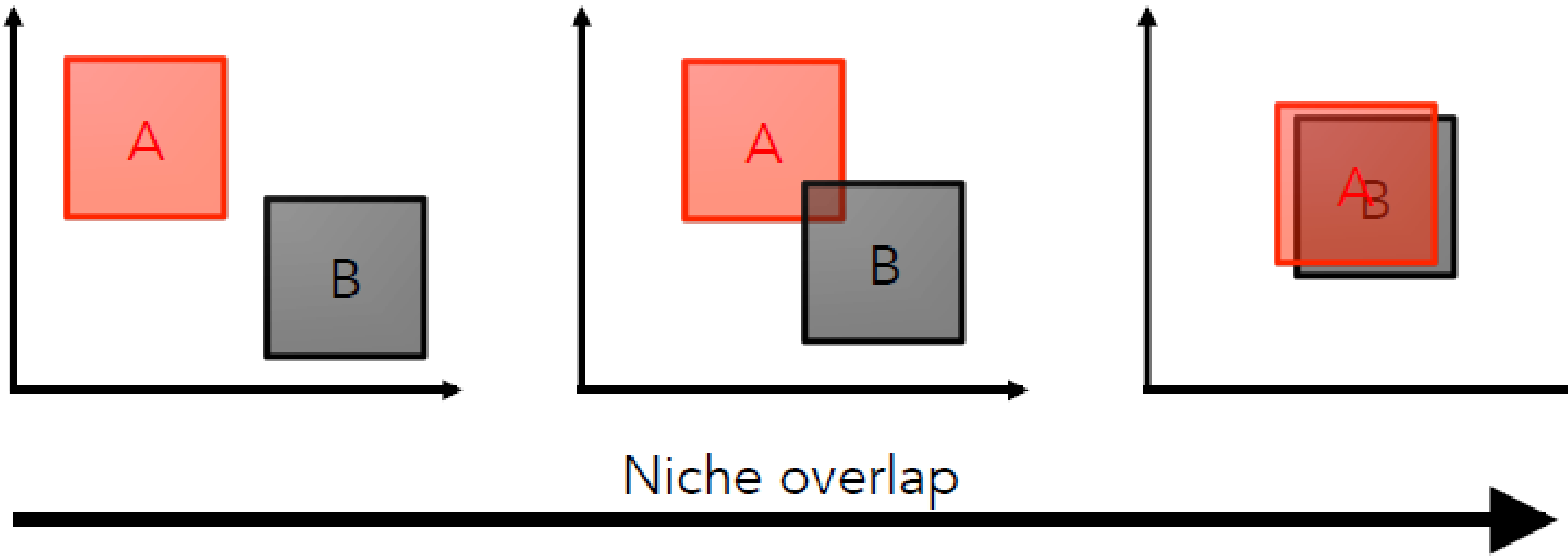
- Concept of ecological niche (*sensu* Hutchinson, 1957): A hypervolume set in n-dimensional space where each of the axes represents an environmental parameter

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

  - Identify trophic strategies: specialists (narrow trophic niches) vs. generalists (wide trophic niche)

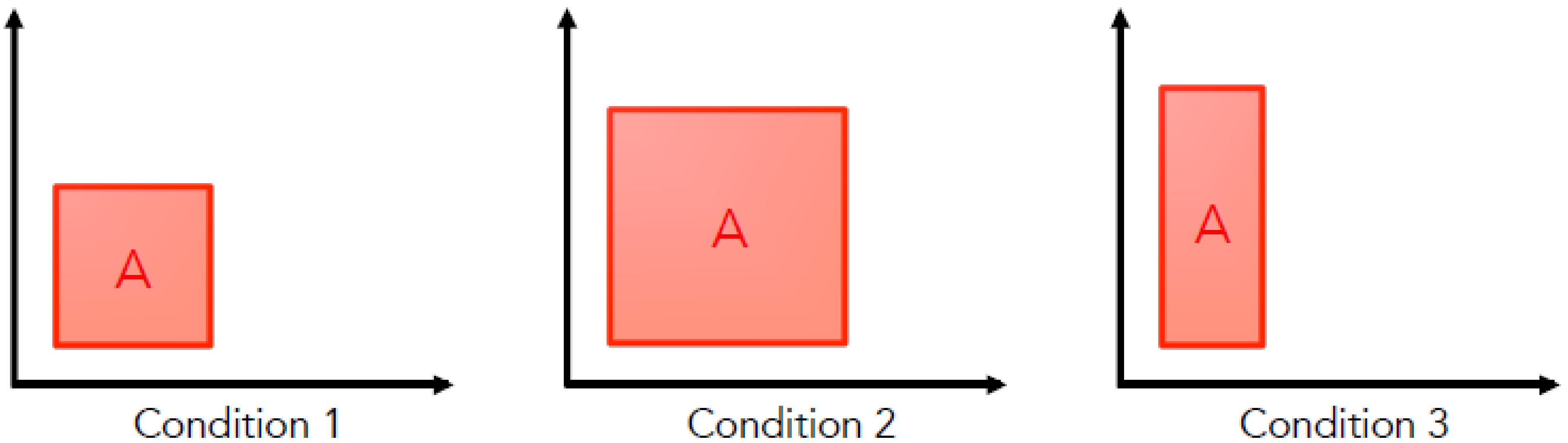
TROPHIC APPLICATIONS: ISOTOPIC VARIABILITY 2
ISOTOPIC NICHES

- Understand how trophic interactions can affect community structure



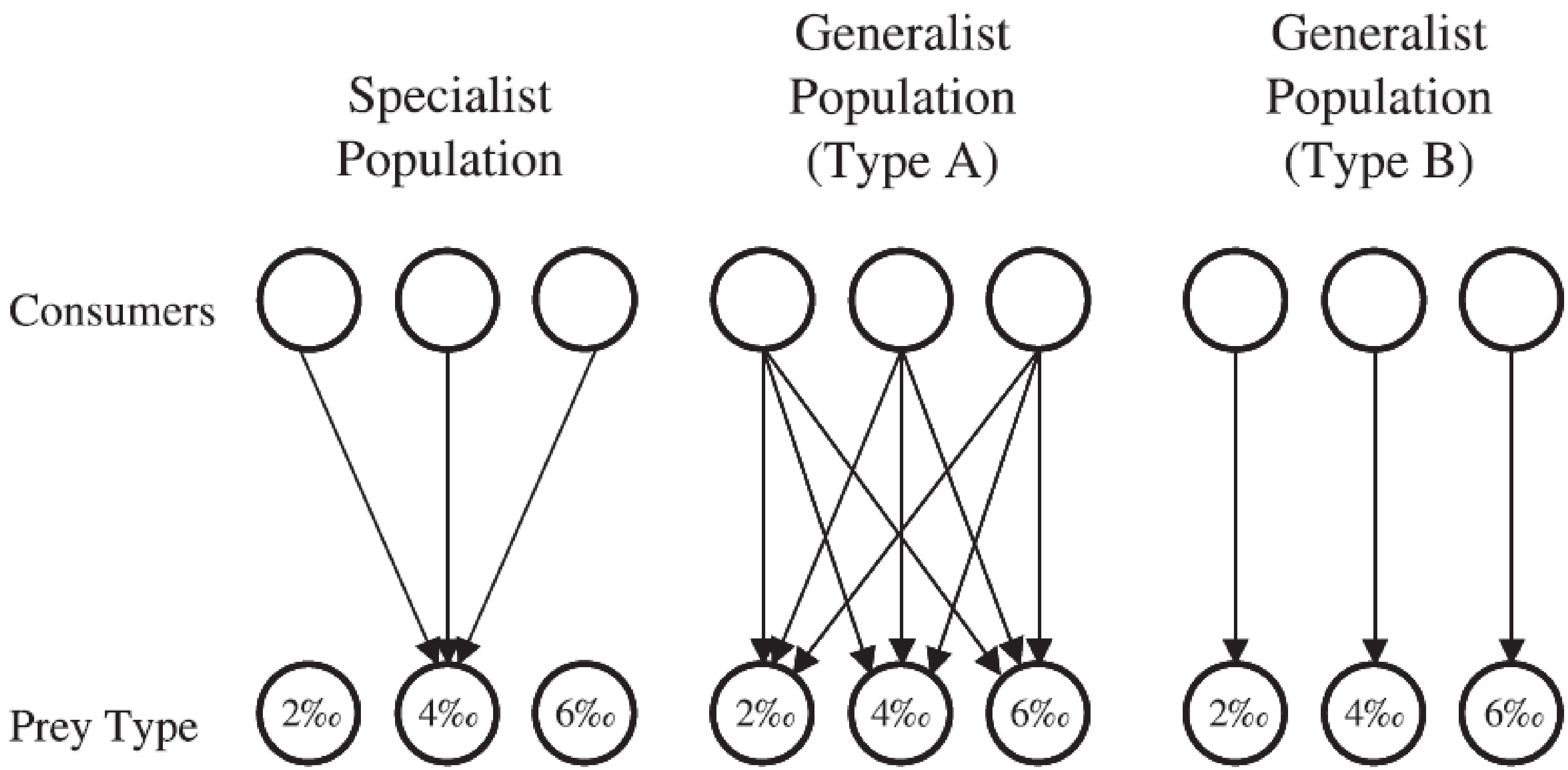
Trophic applications: Isotopic variability 2
Isotopic niches

- Identify trophic shift (ontogenic, environmental, etc.) and trophic plasticity



TROPHIC APPLICATIONS: ISOTOPIC VARIABILITY 2
ISOTOPIC NICHES

- Pioneer study : **Bearhop** et al., J Anim Ecol 2004: 73, 1007-1012



TROPHIC APPLICATIONS: ISOTOPIC VARIABILITY 2
ISOTOPIC NICHES

(A) Sampling a tissue that integrated dietary information over long temporal scales would likely give consumer population values (mean ± s^2) of

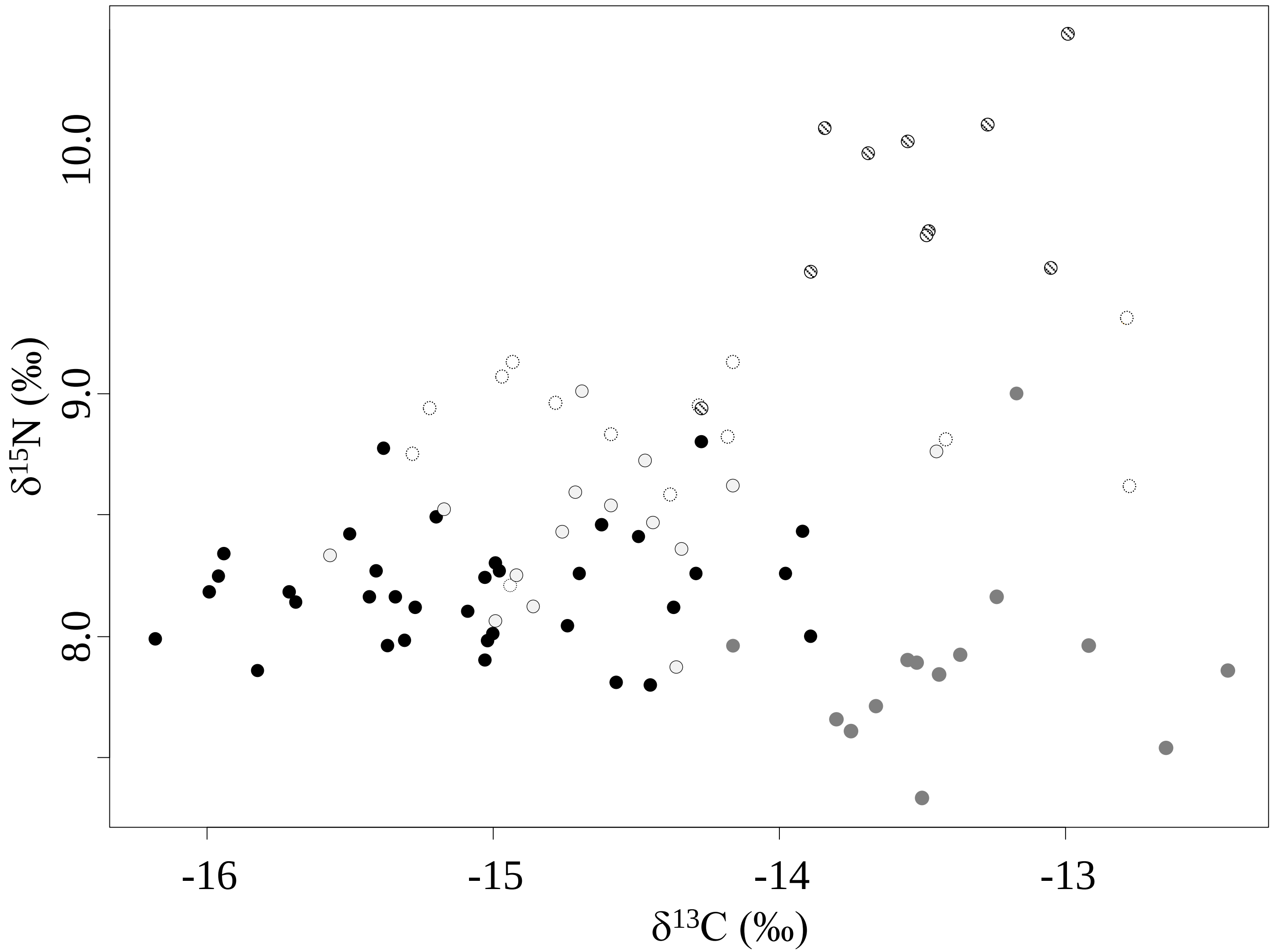
Specialist	Generalist (Type A)	Generalist (Type B)
8‰ ± 0	**8‰ ± 0**	**8‰ ± 4**

(B) Sampling a tissue that integrated dietary information over short temporal scales (with a large sample size) would likely give consumer population values (mean ± s^2) of

Specialist	Generalist (Type A)	Generalist (Type B)
8‰ ± 0	**8‰ ± 4**	**8‰ ± 4**

Source: **Bearhop** et al., J Anim Ecol 2004: 73, 1007-1012

TROPHIC APPLICATIONS: ISOTOPIC VARIABILITY 2
ISOTOPIC NICHES



Trophic applications: Isotopic variability 2
Isotopic niches

- **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
- Geometric approaches (Layman et al. 2007) vs. Bayesian approaches (e.g. SIBER, Jackson et al. 2011
- 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, organism mobility

TROPHIC APPLICATIONS: ISOTOPIC VARIABILITY 2
ISOTOPIC NICHES

Journal of Animal Ecology
British Ecological Society

Journal of Animal Ecology 2011, **80**, 595–602 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]

A niche for isotopic ecology

Seth D Newsome[1*], Carlos Martinez del Rio[2], Stuart Bearhop[3], and Donald L Phillips[4]

Fifty years ago, GE Hutchinson defined the ecological niche as a hypervolume in n-dimensional space with environmental variables as axes. Ecologists have recently developed renewed interest in the concept, and technological advances now allow us to use stable isotope analyses to quantify these niche dimensions. Analogously, we define the isotopic niche as an area (in δ-space) with isotopic values (δ-values) as coordinates. To make isotopic measurements comparable to other niche formulations, we propose transforming δ-space to p-space, where axes represent relative proportions of isotopically distinct resources incorporated into an animal's tissues. We illustrate the isotopic niche with two examples: the application of historic ecology to conservation biology and ontogenetic niche shifts. Sustaining renewed interest in the niche requires novel methods to measure the variables that define it. Stable isotope analyses are a natural, perhaps crucial, tool in contemporary studies of the ecological niche.

Front Ecol Environ 2007; 5(8): 429–436, doi:10.1890/060150.01

TROPHIC APPLICATIONS: ISOTOPIC VARIABILITY 2
ISOTOPIC NICHES

At community scale:

Ecology, 88(1), 2007, pp. 42–48

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. POST[4]

Quantifying the multiple facets of isotopic diversity: New metrics for stable isotope ecology

- Cucherousset, J., Villéger, S.
- Ecological Indicators Volume 56, 2015, 152-160

Trophic applications: Isotopic variability 2
Isotopic niches

Remarks:

Presently the difficulty is not to find metrics based on isotope composition variability (tens are available)

but to choose the ones that are appropriate to ask your scientific question

Trophic applications: Isotopic variability 2
Isotopic niches

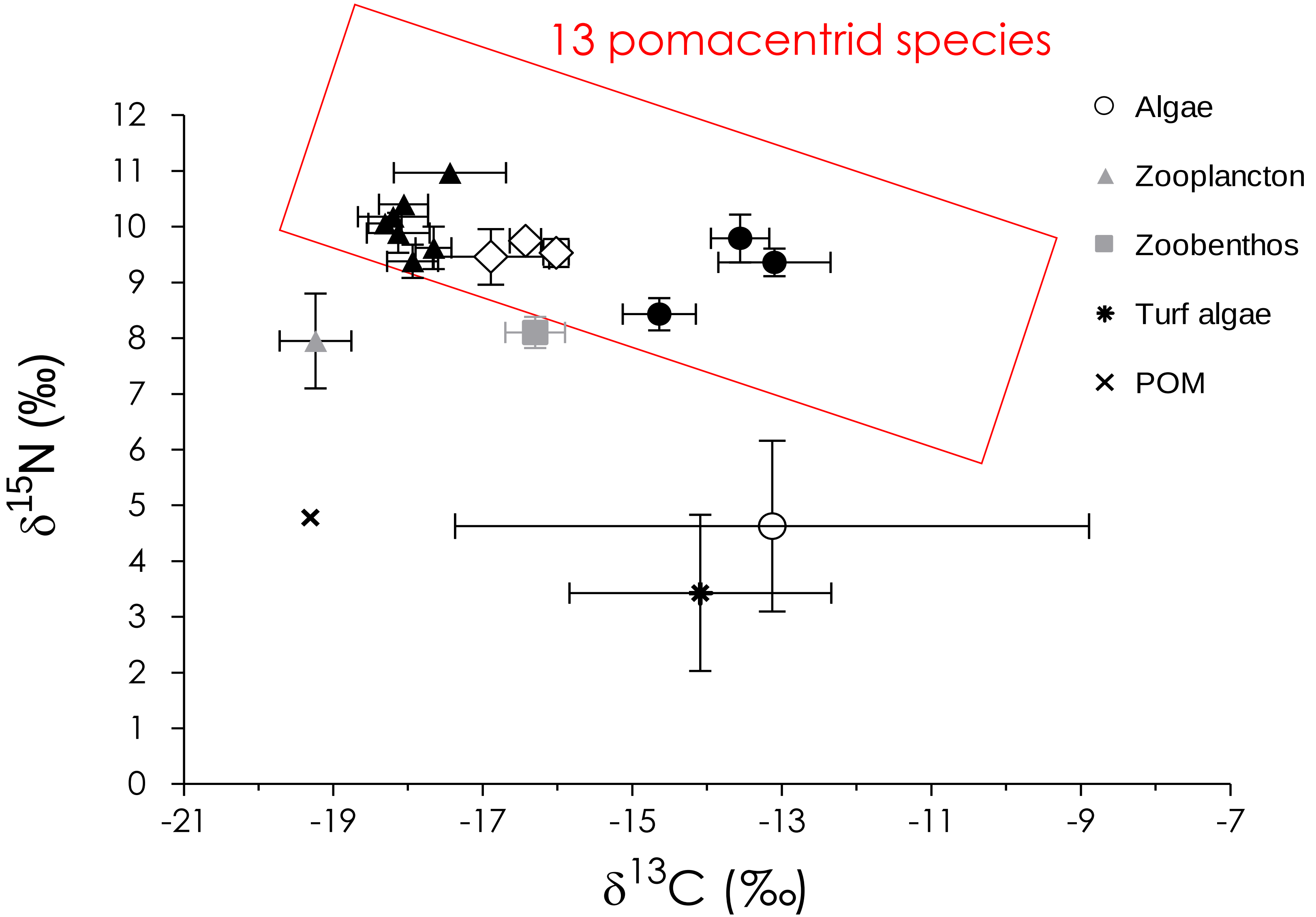
Sampling design:

- To focus on consumers with enough replicate to constrain isotopic variability
- This is study specific, but n = 30 per item (population, species or community) is optimum
- With ellipse approach, n=10 per item is often a good compromise less is possible but be careful with interpretation

Remark: to have a general knowledge of isotopic environment is often necessary (baseline shift, spatial variability)

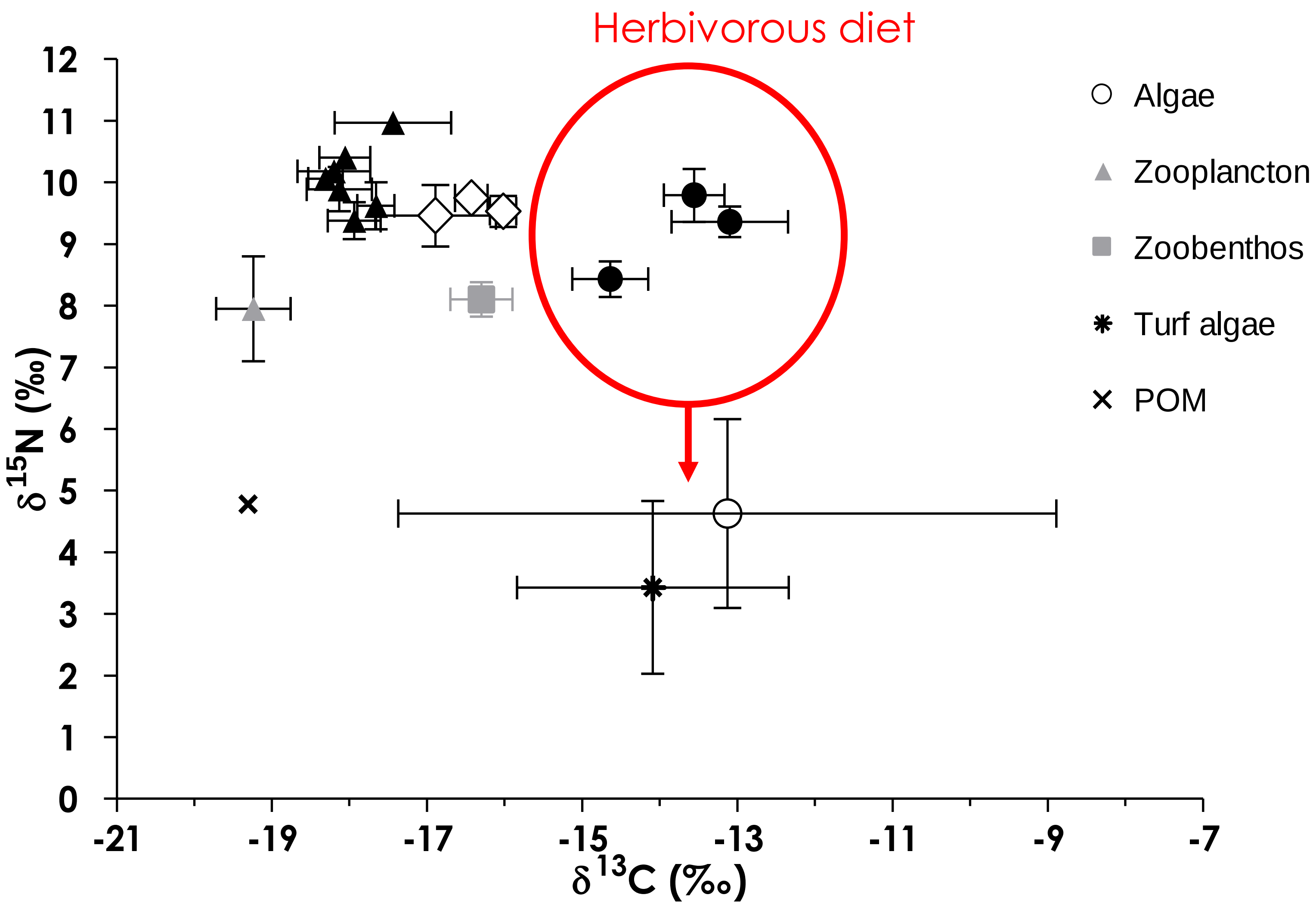
Case study 1: Trophic diversity of Damselfishes

CASE STUDY 1: TROPHIC DIVERSITY OF DAMSELFISHES



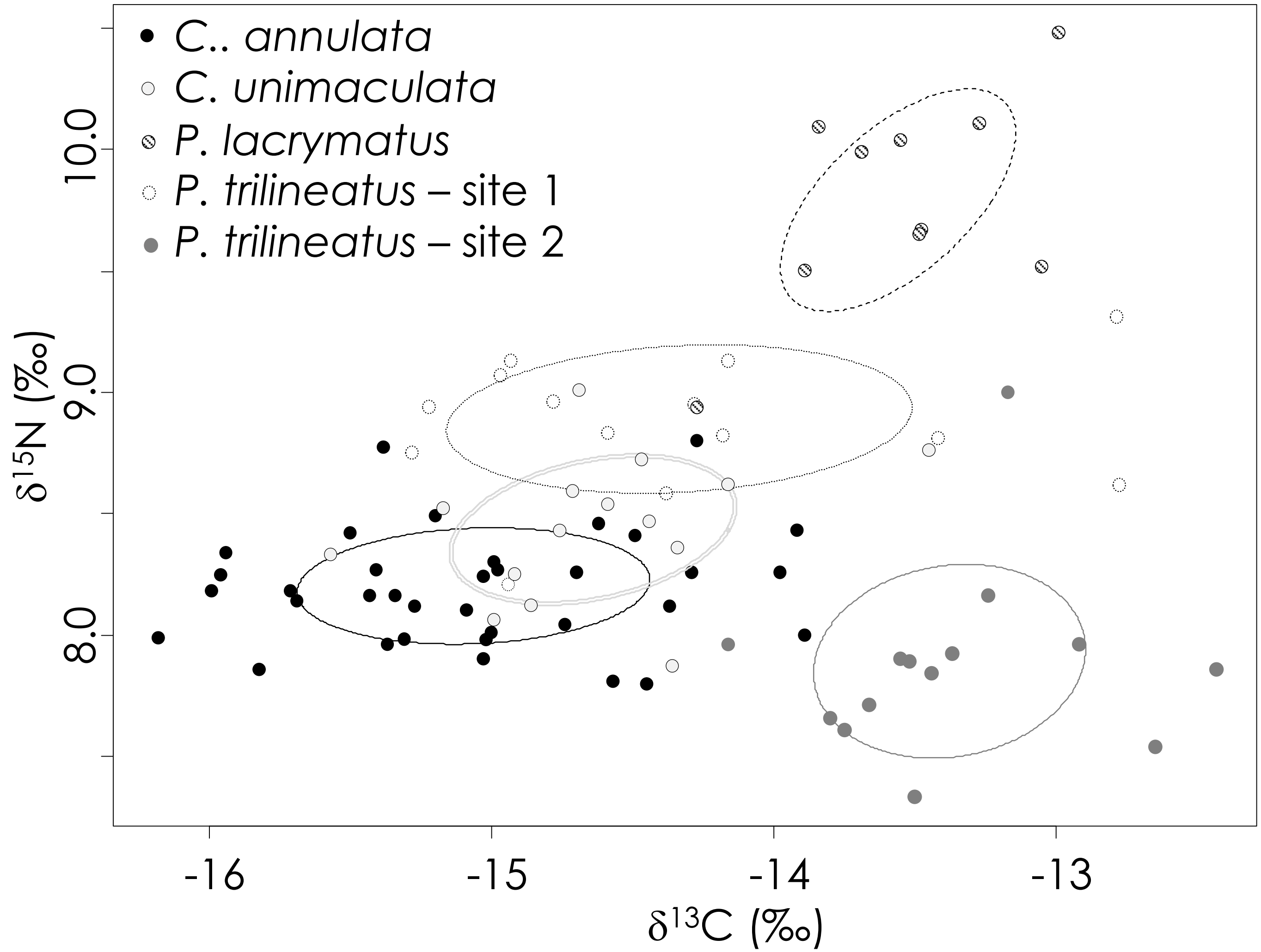
Source: Frédérich et al. 2008, Ichtyological Research

Case study 1: Trophic diversity of Damselfishes



Source: Frédérich et al. 2008, Ichtyological Research

Case study 1: Trophic diversity of Damselfishes

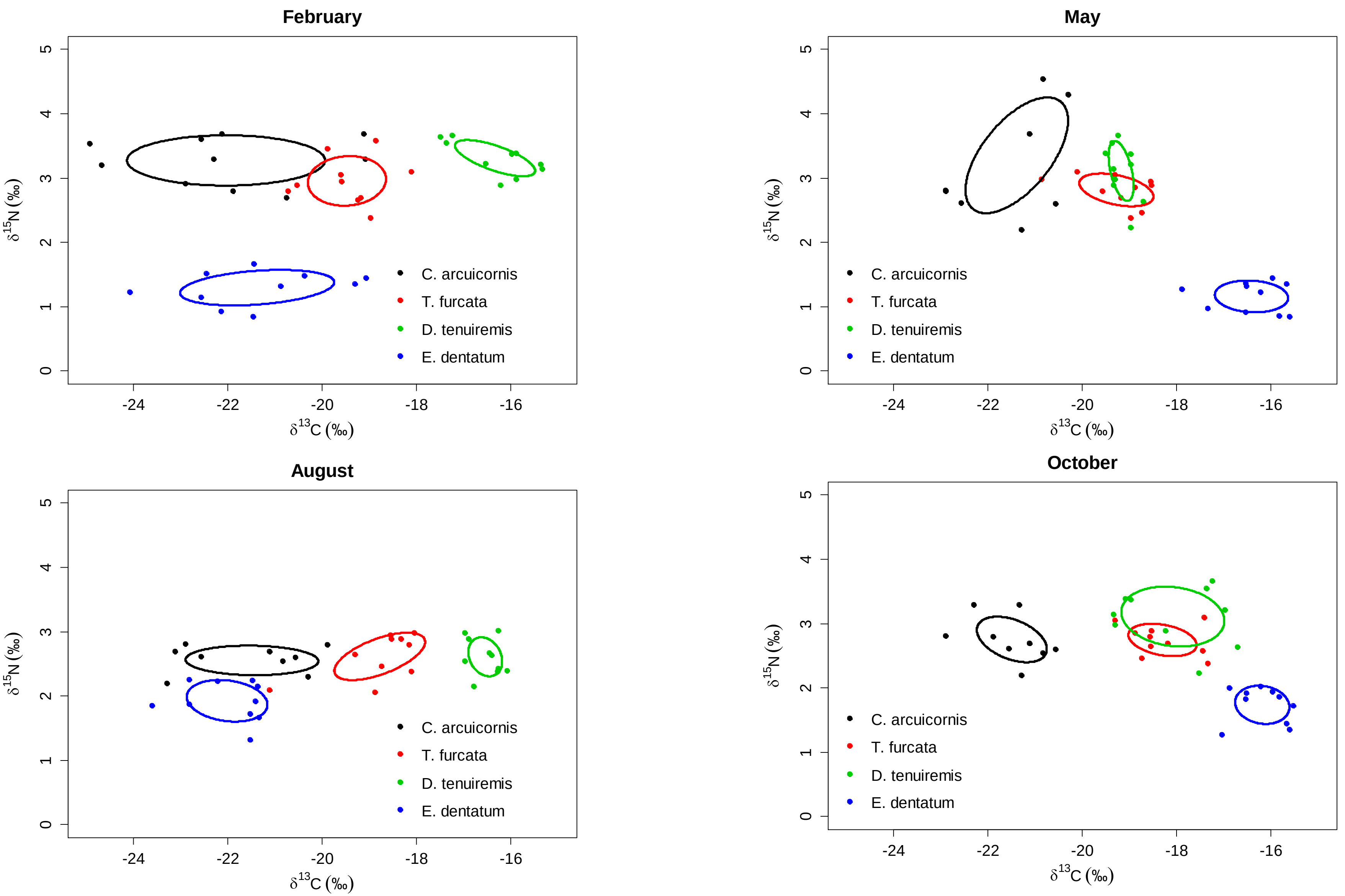


Lepoint et al. 2016

Case study 2: Trophic diversity of copepods in macrophytodetritus

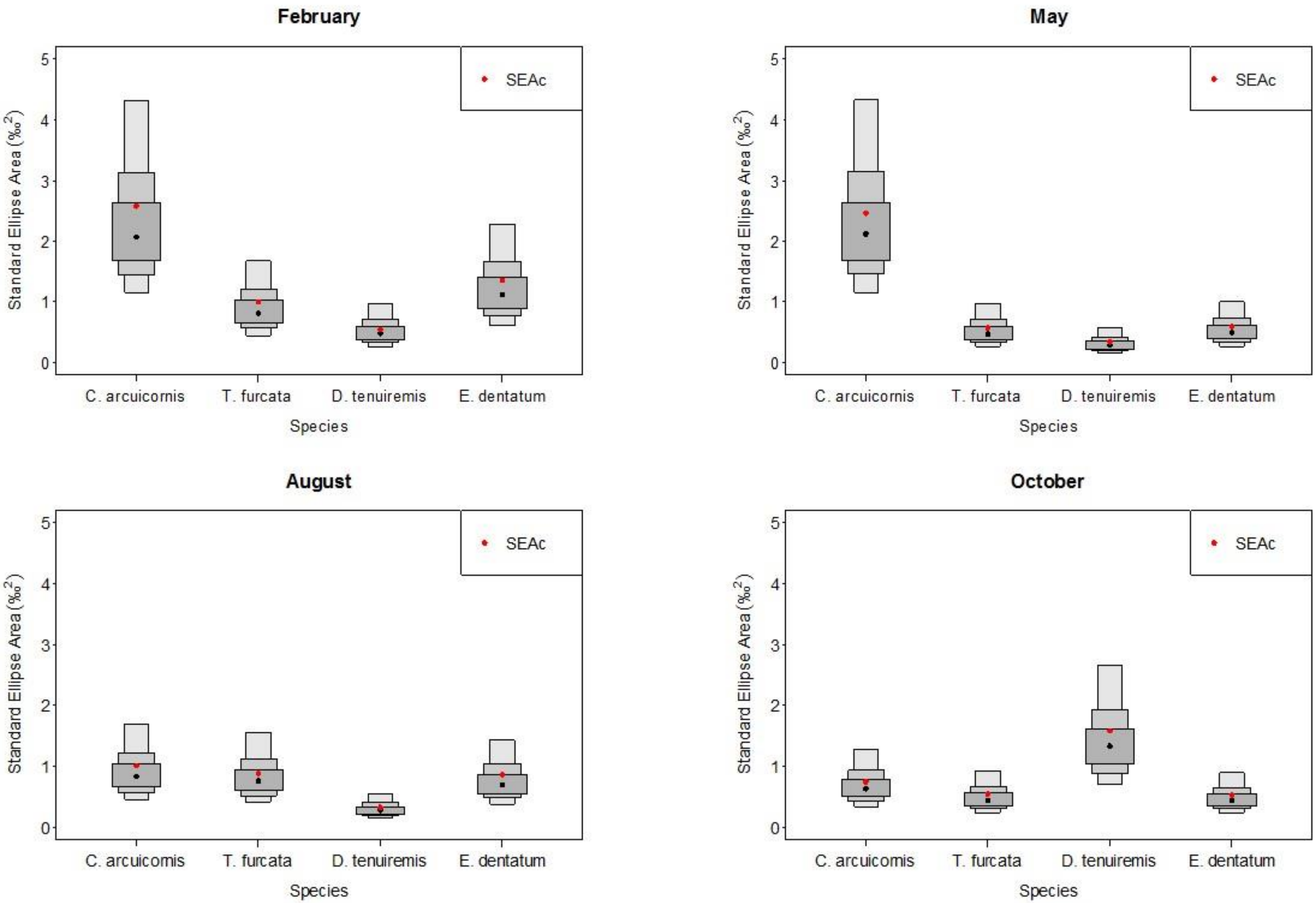
Mascart et al. submitted

CASE STUDY 2: TROPHIC DIVERSITY OF COPEPODS IN MACROPHYTODETRITUS



Mascart et al. submitted

CASE STUDY 2: TROPHIC DIVERSITY OF COPEPODS IN MACROPHYTODETRITUS



Mascart et al. submitted

TAKE HOME MESSAGE

- Isotopic approach is a powerful technique <u>(particularly when associated with other approaches</u>)

- but numerous limitations and assumptions

- First the question, then the sampling design and methodological choice

Thank you for your attention