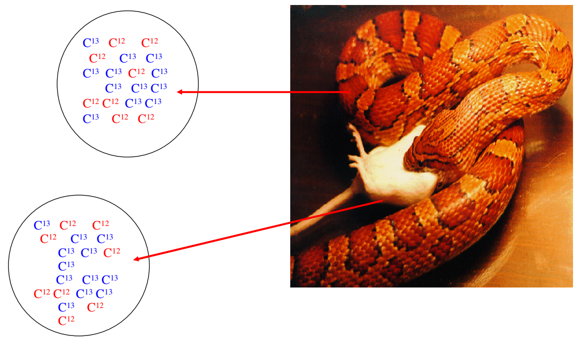
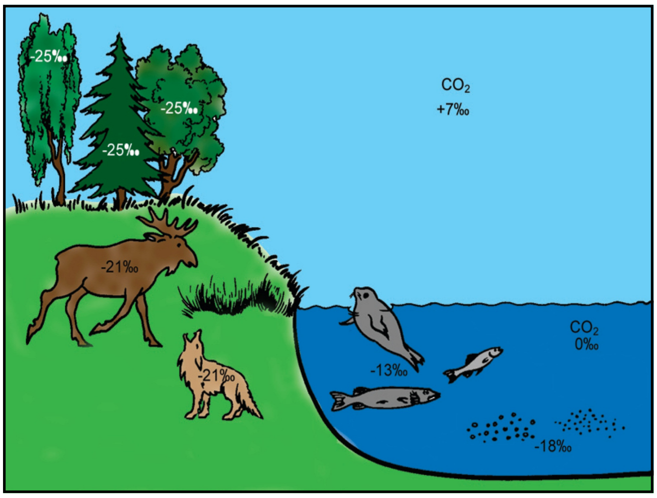
Stable isotopes in ecological studies

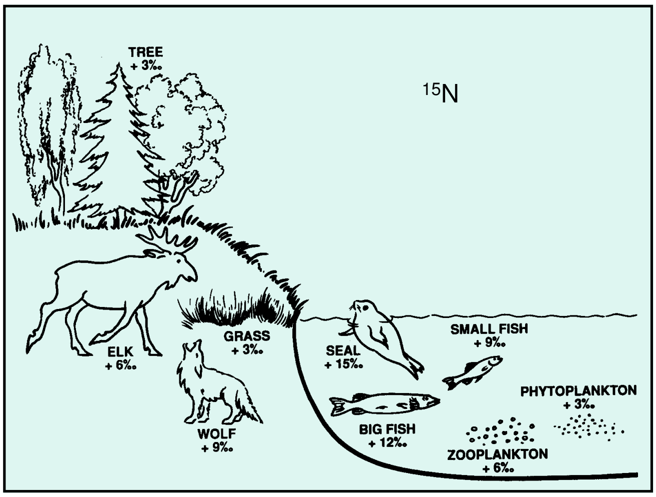
^{13}C ^{15}N

Anders Angerbjörn
Stockholm University

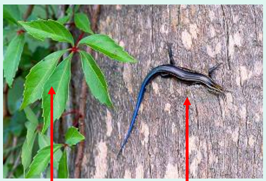
We are what we eat...
isotopically speaking.







Terminology



3‰ vs. 7‰

Heavy vs. Light
Enriched vs. Depleted

We are what we eat, or are we?

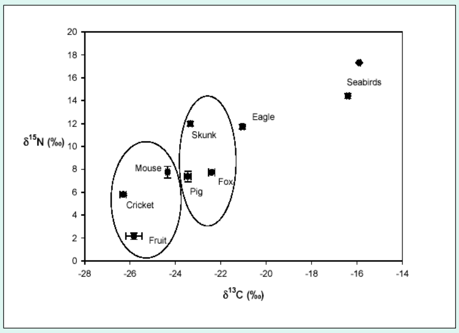
Snake + Mouse
Snake – Uric acid – Feces – Breath

So, the isotopic composition of a sample contains both source *and* process information.

Ecological use of stable isotopes:

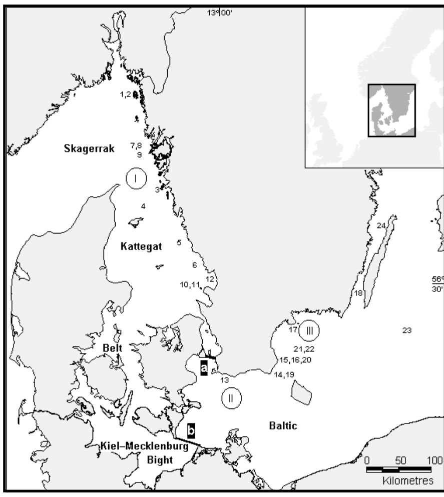
- Dietary reconstructions
- Analyses of trophic relationships

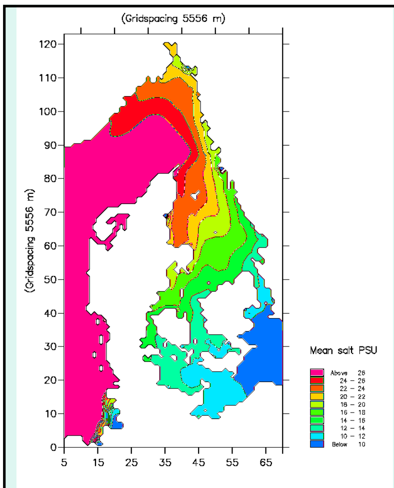
Eagles, foxes and pigs



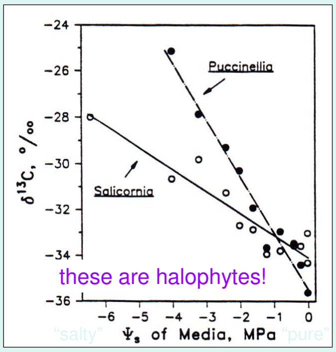
Porpoises in Baltic or Kattegatt?

Angerbjörn, Brandberg, Börjesson (2006)



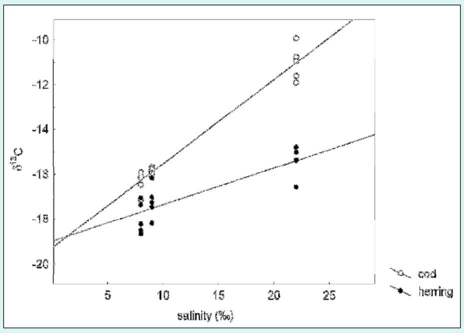


Effect of salinity on plants



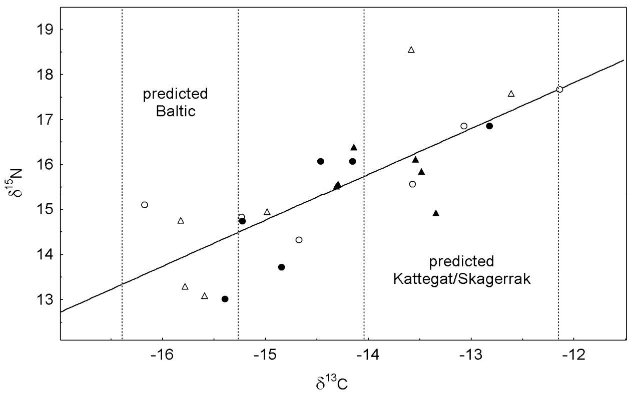
Guy et al. 1980

Cod and herring - salinity



Strong correlation: salinity vs 13C

Did they die where they lived? Collagen



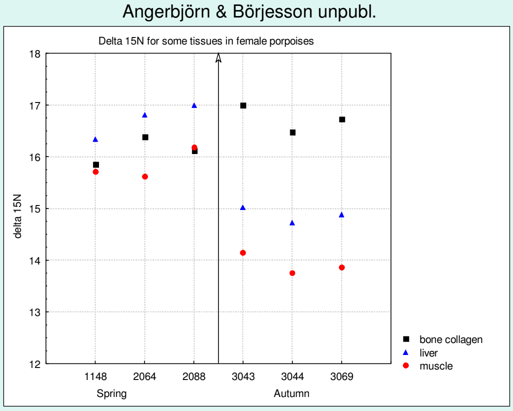
Problems

- Fractionation
- Different tissue
- Tissue turnover
- Metabolic processes
- Isotopic routing

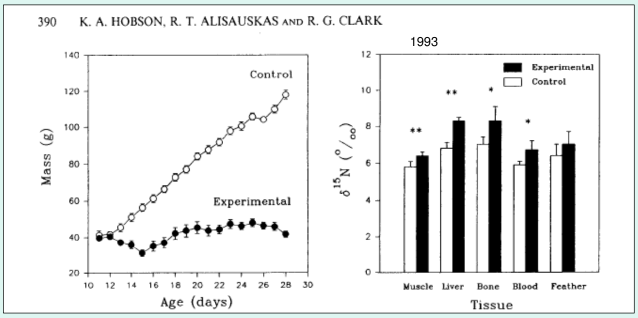
- Complex! F Courchamp
- Protein, lipids, etc
- Not constant!
- Catabolism
- What is going on?

Different tissues - different signatures

Angerbjörn & Börjesson unpubl.



Catabolism: Quails and physiologic stress

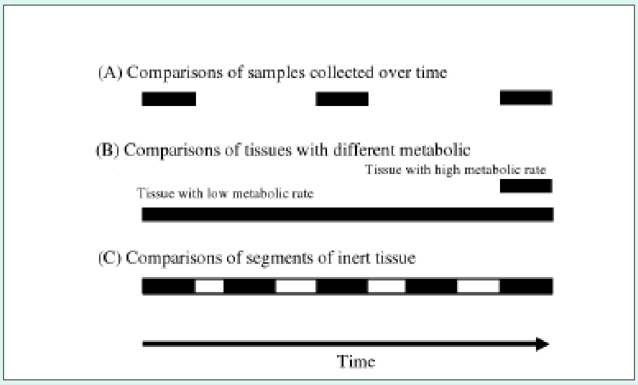


Variation in stable isotopes

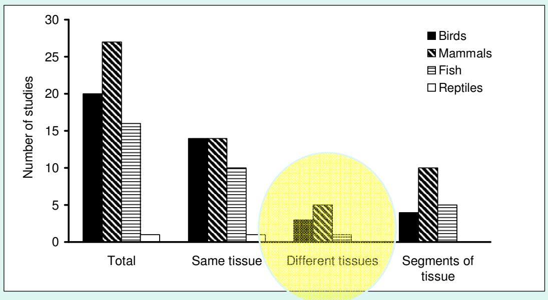
- But is this always a problem?
- Can we use this instead?

Tissue turnover: Temporal variation in diets

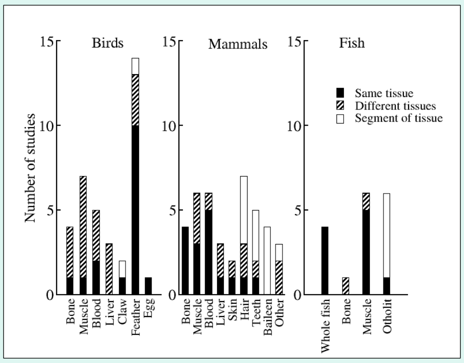
Dalerum and Angerbjörn 2005



Dalerum & Angerbjörn 2005



Dalerum & Angerbjörn 2005



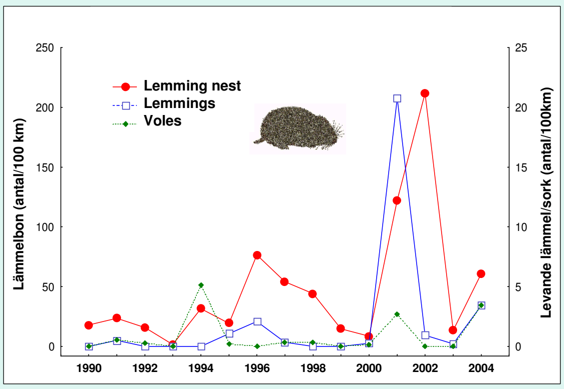
Different tissues

- Dentine in teeth: no turnover
- Hair: no turnover
- Collagen in bones: turnover 10-15 yrs
- Muscle: fast turnover
- Kidney: very fast turnover

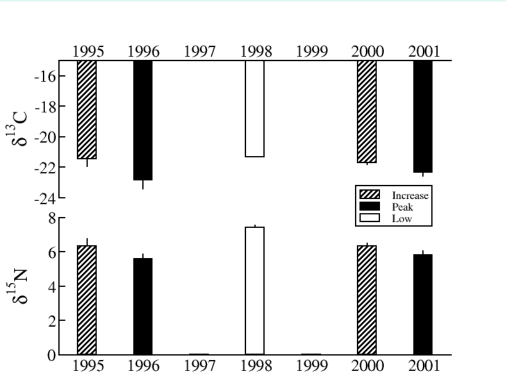
Arctic fox– lemming cycle

Angerbjörn unpubl.

Lemmings and voles in Vindelfjällen



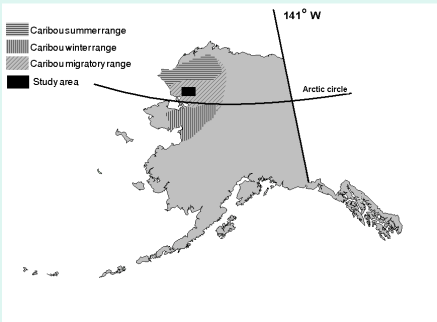
Arctic fox fur samples – rodent dynamics



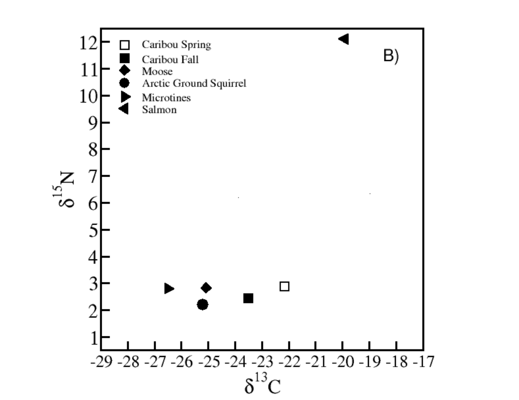
Wolverines in Alaska, using several tissues

Dalerum et al.

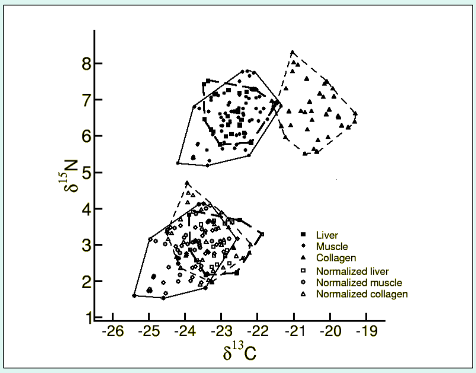
Migrating caribou

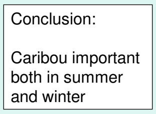


Available prey



Seasonal diet shift?





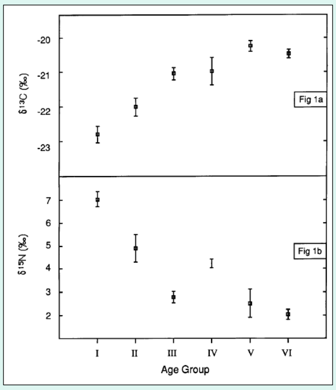
Ursus spelaeus

Cave bears

Nelson DE, Angerbjörn A, Liden K, Turk I. 1998 Stable isotopes and the metabolism of the European cave bear. *Oecologia* **116**, 177-181.

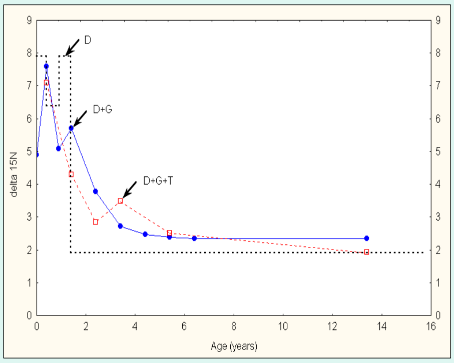
	age class	age (year	weight class	(kg)	□15N	s.d.	n
Neonates	0		rat	1			
Neonates 1st winter	0-0.3			10	7.1	0.48	4
Cubs 1st summer	0.3-0.9			25			
Cubs 2nd winter	0.9-1.4		wolf	32	4.3	0.41	4
Yearlings	1.4-2.4	2.2	hyena	65	2.8	0.54	5
Juveniles	2.4-3.4	3.2	lion	150	4.2	0.28	2
Sub adults	3.4-5.4	4.2		210	2.5	1.23	4
Adult	5.4-7.4	6.4		250	1.9	0.7	11
Adult	7.4-20	13.2		270			

Cave bears



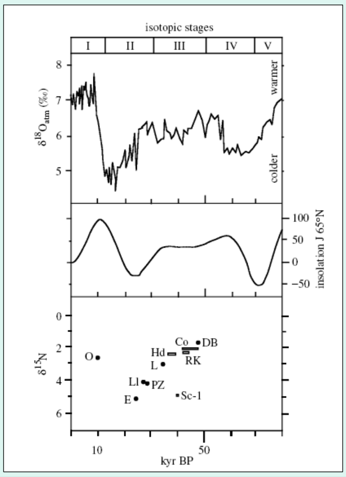
Strong age effect in both 13C and 15N

Liden K, Angerbjörn A. 1999 Dietary change and stable isotopes: a model of growth and dormancy in cave bears.
Proc.R. Soc. Lond. B **266**, 1779-1783.



Model

Growth
Lactation
1st winter
2nd winter
Diet
summer
Turnover



Fernandez-Mosquera, Vila-Taboada, Grandal-d'Anglade (2001)

Ursus spelaeus (13C, *15N) and palaeoclimate*

Proc. R. Soc. Lond. B 268, 1159-1164

More cave bears: Routing

Oecologia (2001) 127:495–500
DOI 10.1007/s004420000611

C.I. Keeling · D.E. Nelson

Changes in the intramolecular stable carbon isotope ratios with age of the European cave bear (*Ursus spelaeus*)

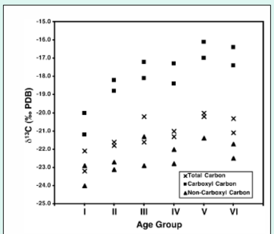


Fig. 1 Changes in the carbon isotope ratios with cave bear age

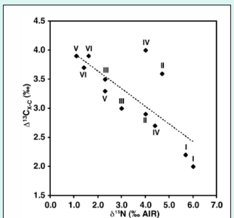


Fig. 2 The relationship between $\delta^{15}N$ and $\Delta^{13}C_{X-C}$ values. The *Roman numerals* indicate the age group for each data point. Linear least-squares regression: $\Delta^{13}C_{X-C}$=4.25±0.31-0.31±0.08×$\delta^{15}N$ (±SE), r^2=0.58 (including the two outliers)

498

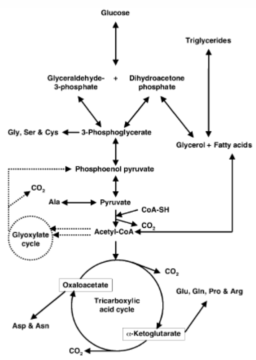


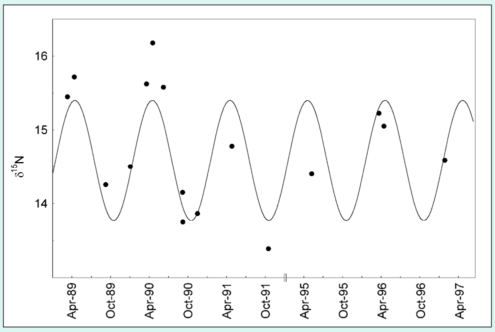
Fig. 3 Simplified outline of the biosynthetic pathways discussed (based on Zubay 1983). Enzymes, intermediates, and co-factors are omitted for clarity. *Double-headed arrows* suggest the two can be inter-converted either by equilibrium or by separate pathways that may involve different intermediates. *Dotted lines* indicate that the existence of this pathway in hibernating bears is uncertain

- Conclusions
- Cave bears use urea for proteins
- They use lipids for proteins
- Dormancy or hyperfagia?

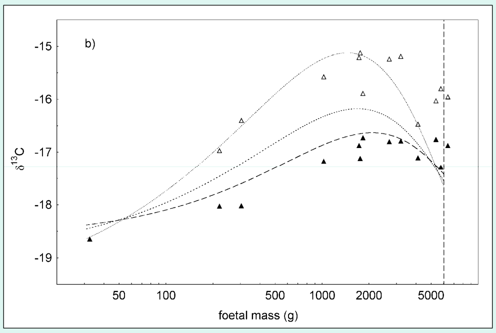
Porpoises – reproductive strategy?

Angerbjörn, Brandberg, Börjesson (unpubl.)

Porpoises - muscle



Porpoises maternal and foetal 13C

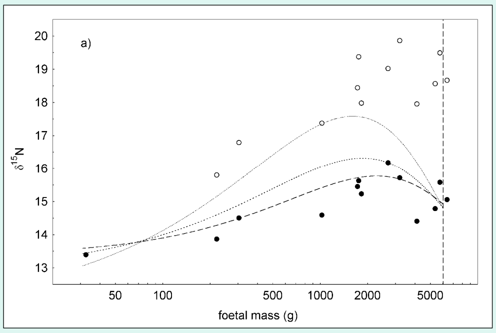


Model

Turnover
Growth
Diet

▲ maternal
Δ foetal

Porpoises maternal and foetal 15N

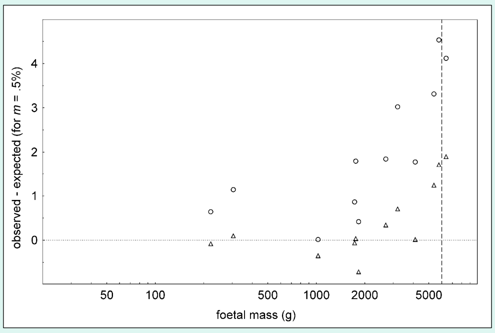


Model

Turnover
Growth
Diet

● maternal
○ foetal

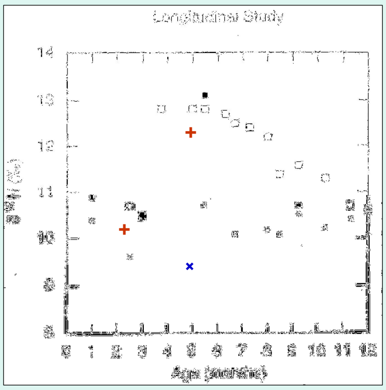
Observed – predicted



Decidous teeth – weaning

Lidén, Olsson, Eriksson & Angerbjörn unpubl. Nitrogen Isotope Analysis of Teeth: A Tool to Trace Individual Dietary Change

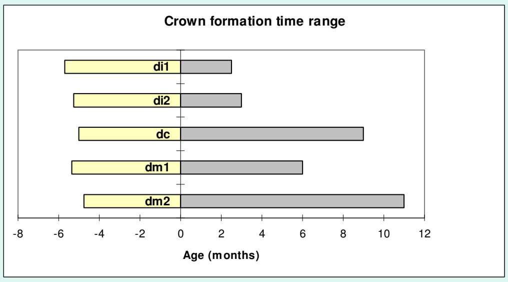
Fogel et al. 1989, *Ann Rep Director Geophys Lab Carnegie Inst 1988-1989*, 111--117



× my wife Kerstin
+ my daughter Karin

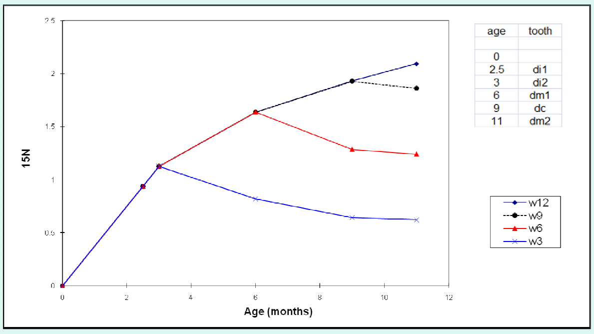
Decidous teeth – weaning

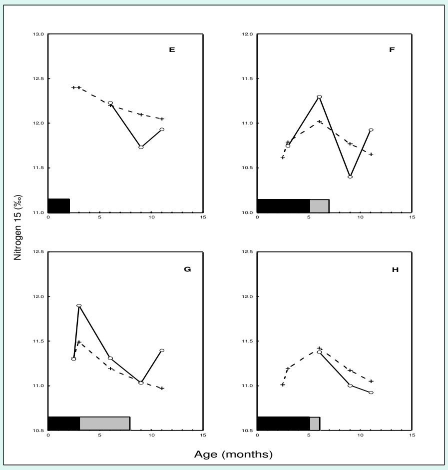
Lidén, Olsson, Eriksson & Angerbjörn unpubl. Nitrogen Isotope Analysis of Teeth: A Tool to Trace Individual Dietary Change



Decidous teeth – weaning

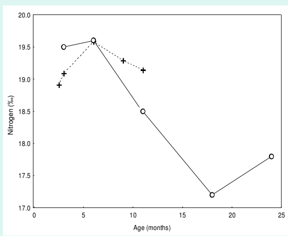
Lidén, Olsson, Eriksson & Angerbjörn unpubl. Nitrogen Isotope Analysis of Teeth: A Tool to Trace Individual Dietary Change

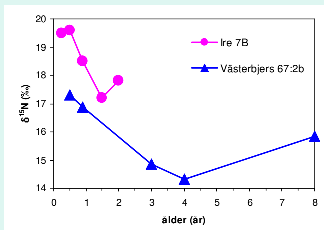




Teeth and weaning: Data & predicted

Stone age children –weaning at 6 months Gotland 5000 yrs BP





Problems and perspectives

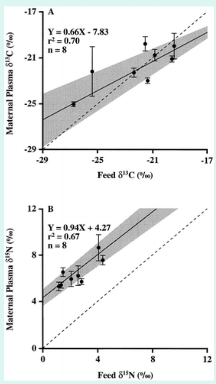
- Fractionation
- Different tissue
- Tissue turnover
- Metabolic processes
- Isotopic routing

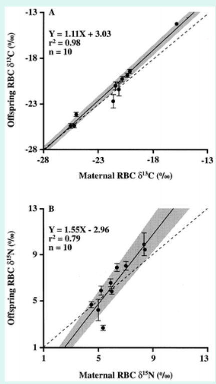
- Physiological strategy
- Temporal patterns
- Temporal patterns
- Reproductive strategy
- Physiological strategy

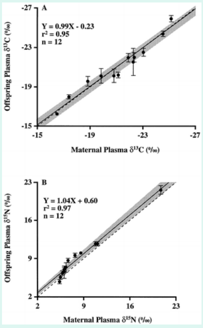
Jenkins SG, Partridge ST, Stephenson TR, et al. 2001

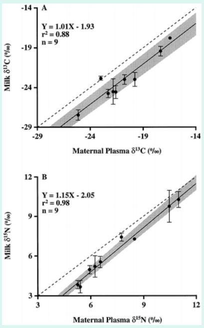
Nitrogen and carbon isotope fractionation between mothers, neonates, and nursing offspring

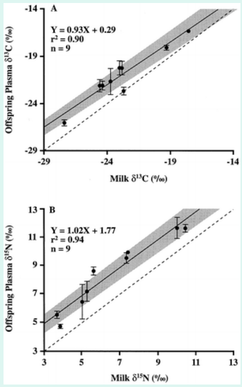
OECOLOGIA 129: 336-341

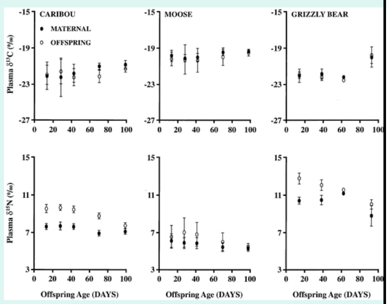












Summary

Hypothesis:
Nursing vs. offspring - higher δ15N than their mothers in 11 carnivores, hibernators, and nonhibernators.

Adult females δ15N - diets 4.1±0.7‰

Offspring plasma δ15N enrichment 0.9±0.8‰ and no C enrichment (0.0±0.6‰)

But milk was depleted in both δ15N (1.0±0.5‰) and δ13C (2.1±0.9‰)

Milk to offspring plasma enrichment (δ15N 1.9±0.7‰ and δ13C 1.9±0.8‰)

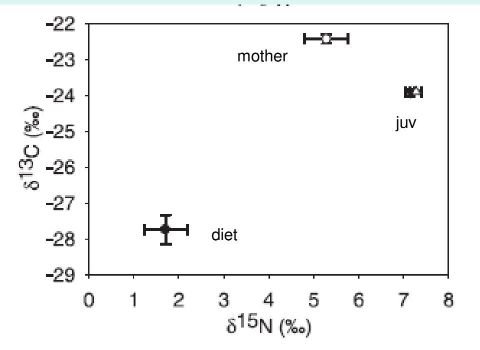
Some species had significant differences between mother and offspring,

Red-backed voles (Clethrionomys gapperi)

Sare DTJ, Millar JS, Longstaffe FJ 2005

Nitrogen- and carbon-isotope fractionation between mothers and offspring in red-backed voles (Clethrionomys gapperi)

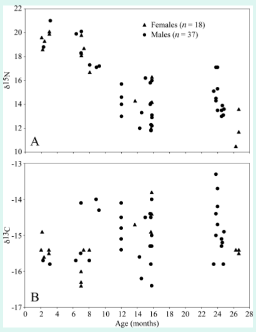
CAN J ZOOL 83: 712-716

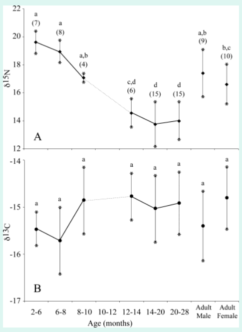


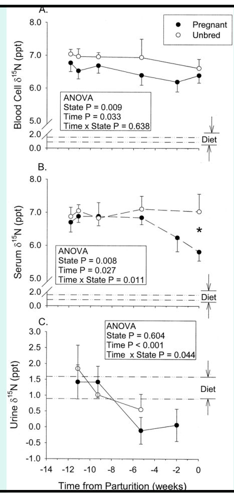
Northern Fur Seal

Newsome, Koch, Etnier, Aurioles-Gamboa, USING CARBON AND NITROGEN ISOTOPE VALUES TO INVESTIGATE MATERNAL STRATEGIES IN NORTHEAST PACIFIC OTARIIDS.

Marine Mammal Science **22** (3), 556-572



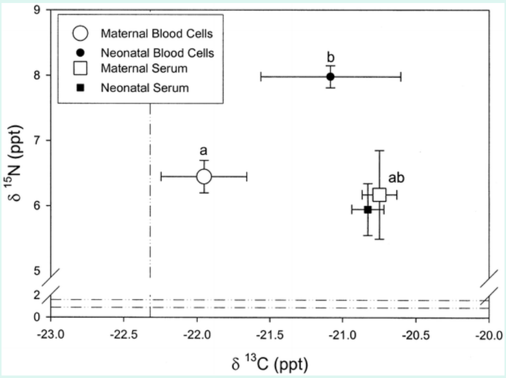


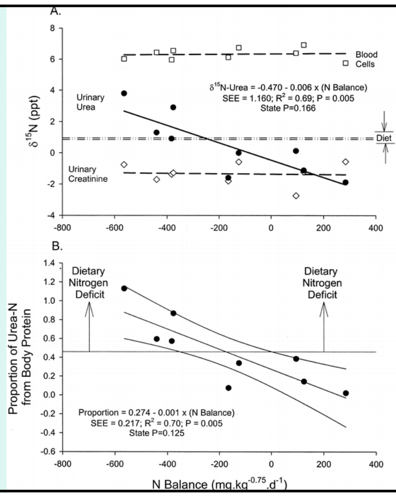


Barboza PS, Parker KL 2006

Body protein stores and isotopic indicators of N balance in female reindeer (Rangifer tarandus) during winter

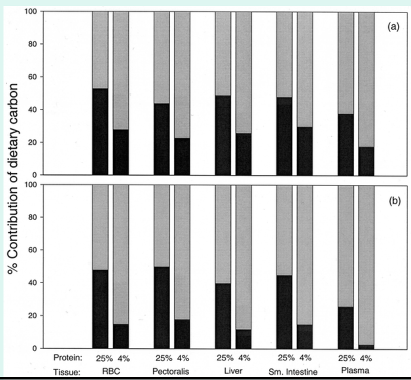
PHYSIOL BIOCHEM ZOOL 79: 628-644



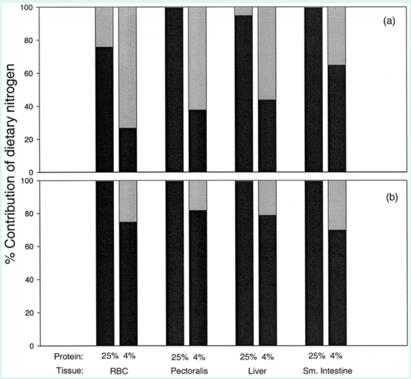


Yellow rumped warbler

Podlesak DW, McWilliams SR 2006.
Metabolic routing of dietary nutrients in birds: effects of diet quality and macronutrient composition revealed using stable isotopes. Physiol Biochem Zool. 79:534-49



Dietary nitrogen to tissue nitrogen for warblers switched 15 d ago from the C3 acclimation diet (*a*) and for birds switched 15 d ago from the C4 acclimation diet (*b*). Black - dietary protein, and gray - amount of tissue unchanged by dietary protein.



Metabolic analysis with stable isotopes

- Tissue
- Nutrition
- Lactation
- Starvation
- Routing