

# Applications of N stable isotope in ecology

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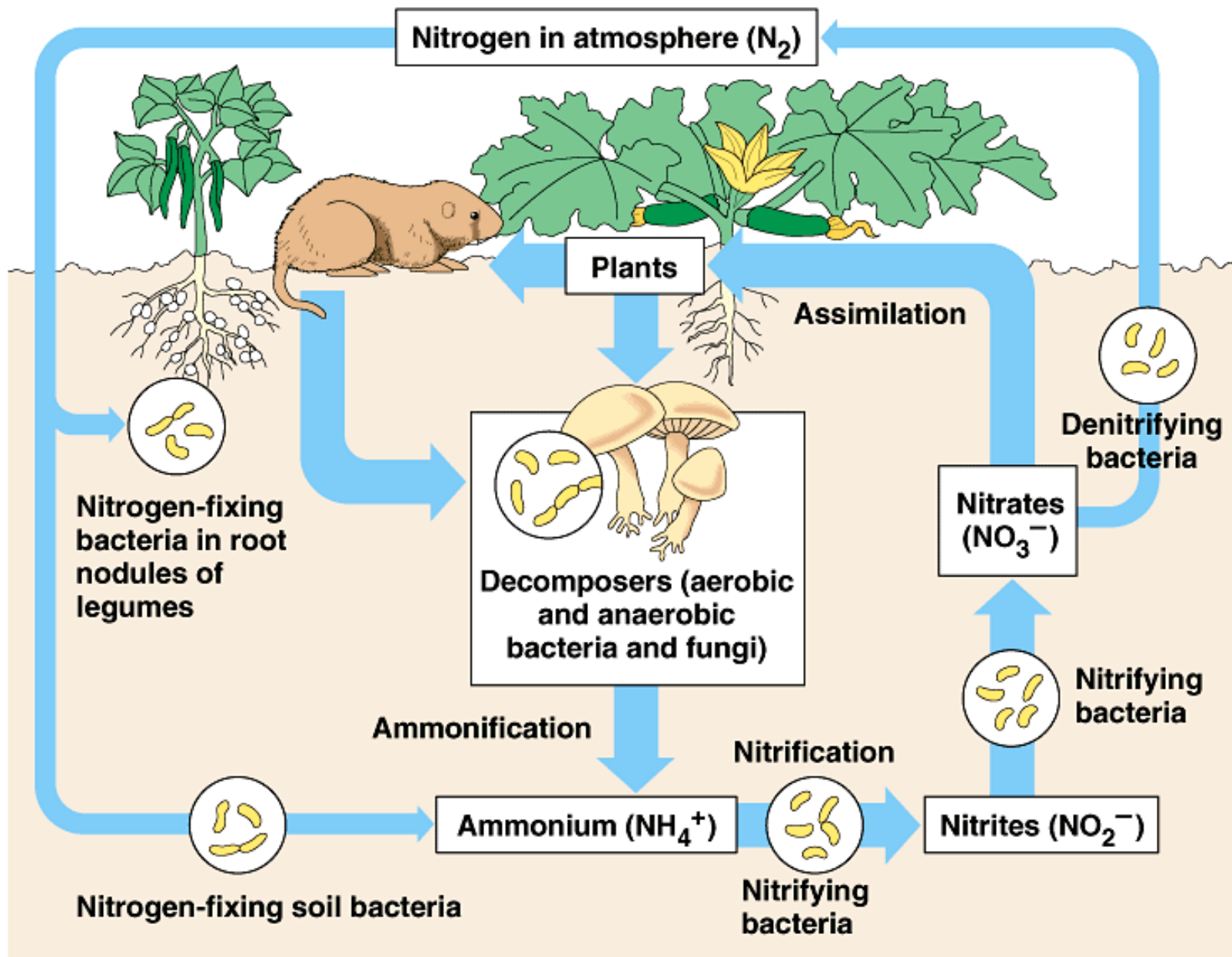
# $^{15}\text{N}$ and $^{14}\text{N}$

	$^{14}_7\text{N}$	$^{15}_7\text{N}$
<b>Stability</b>	Stable	Stable
<b>Natural abundance fraction</b>	99.63 %	0.37 %

- The isotope ratio  $^{15}\text{N}/^{14}\text{N}$  in the largest nitrogen reservoir, atmospheric  $\text{N}_2$ , is extremely constant, due to the relative inert character of nitrogen. The atmospheric  $^{15}\text{N}/^{14}\text{N}$  value is 0.0036765.

- Difference of  $^{15}\text{N}$  from  $^{13}\text{C}$ ,  $^{18}\text{O}$ , and D

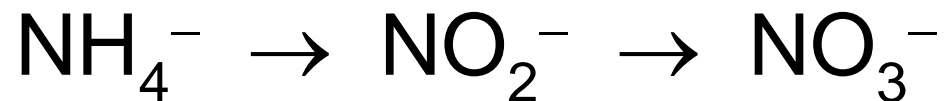
- Big challenge?



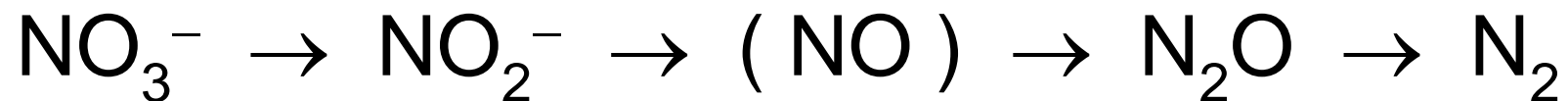
**The relevant biochemical processes in the water phase during which isotope fractionation**

**occurs are:**

**1) nitrification**, the oxidation from ammonia to nitrite and nitrate:

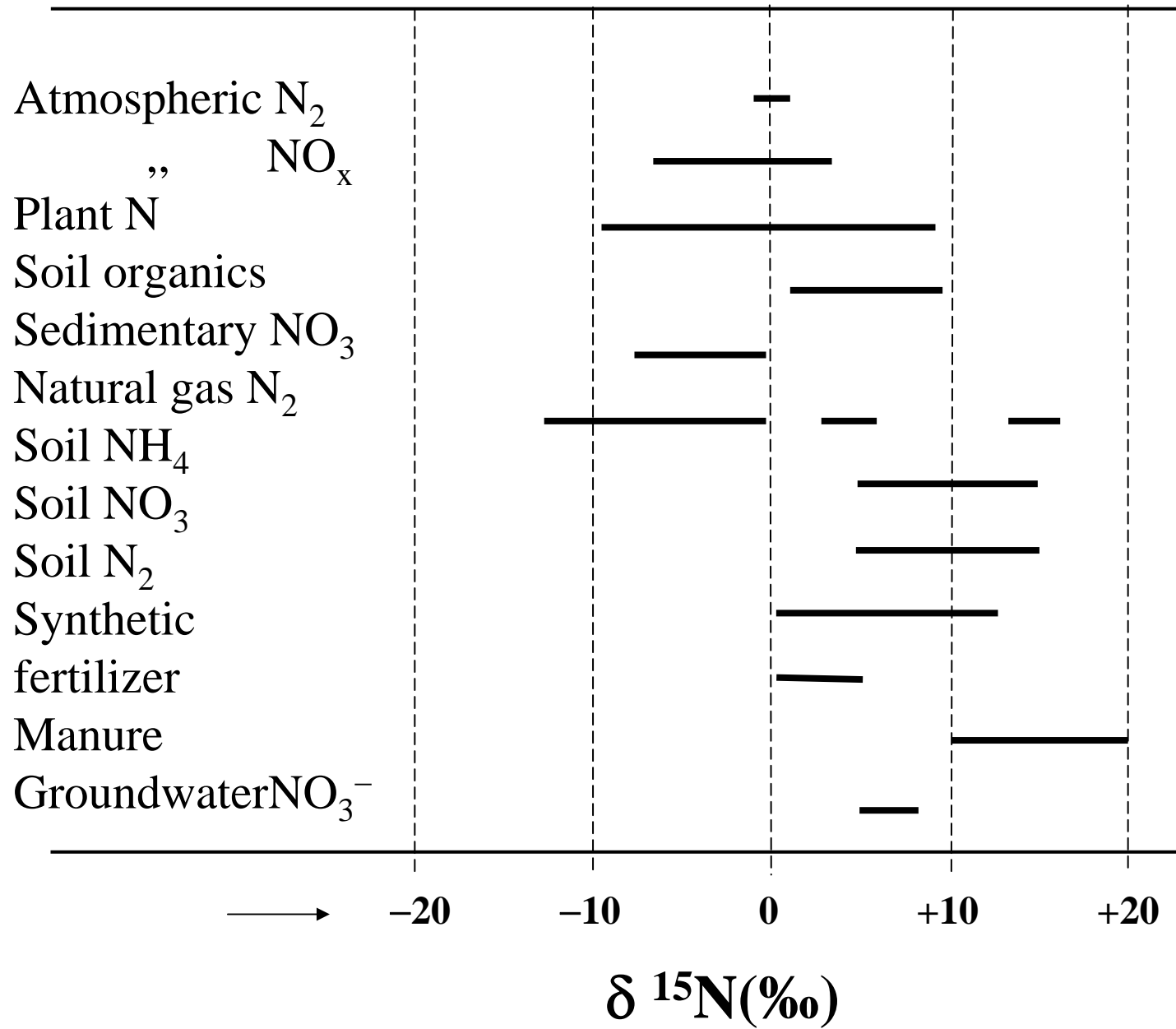


**2) denitrification**, the reduction of nitrate to molecular nitrogen:



- **3) nitrogen fixation**, the conversion of dissolved molecular nitrogen to organic compounds:





# Nitrogen Isotopes

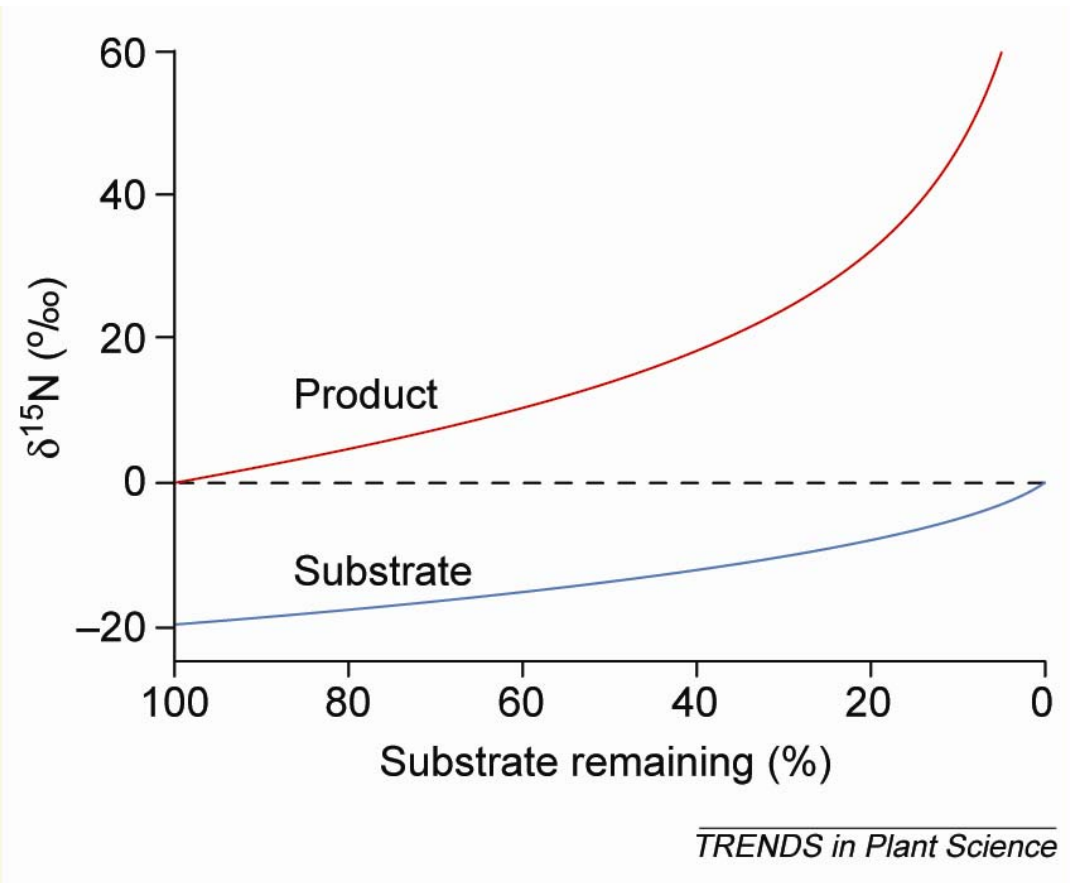
<u>Pool</u>	<u><math>\delta^{15}\text{N}</math> (‰)</u>
$\text{N}_2$	0
DIN	0-30
PN	0-30

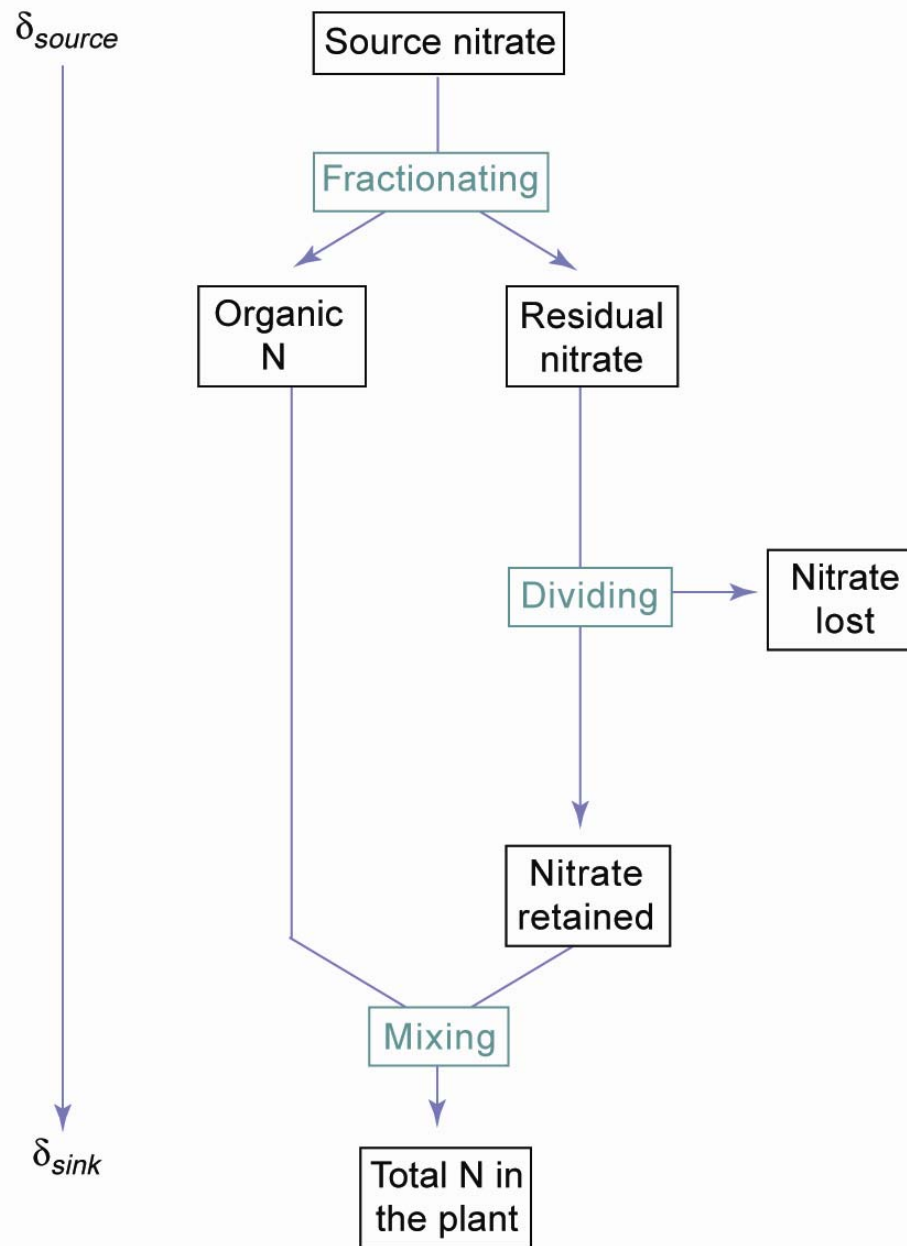
## Fractionation during:

- assimilation:
  - nitrate: 0 to -23 ‰
  - ammonium: 0 to -27 ‰
- nitrification: -18 to -36‰
- denitrification: -10 to -40 ‰
- nitrogen fixation:  $0 \pm 2$ ‰
- mineralisation: 0 to ?? ‰

# Heterogeneity in $^{15}\text{N}$ signature

- Factors affecting  $^{15}\text{N}$  fractionation in soils and plants
  - Soil age
  - Nitrogen fixing plants or nitrogen rich plant parts
  - Rainfall
  - Physiological or biochemical processes
  - Mycorrhization



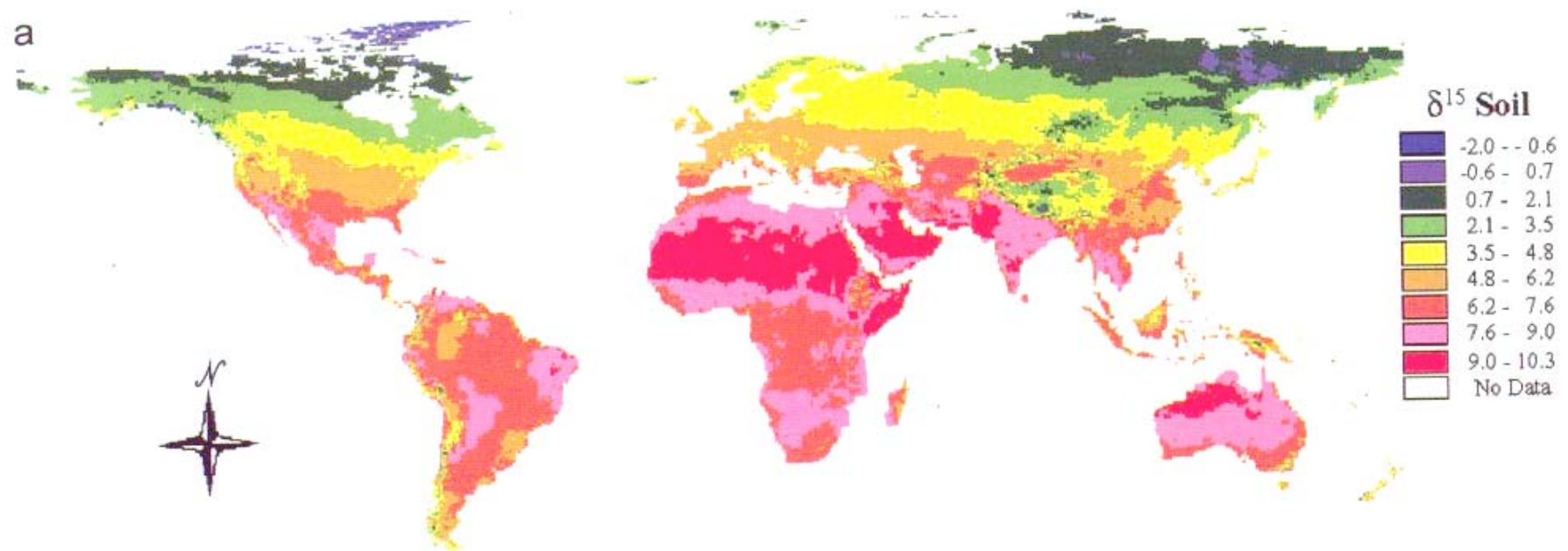


# Nitrogen isotope signatures at community level

*Table 1.* Foliar  $\delta^{15}\text{N}$  values of Australian Plant Communities. Plants were sampled and analysed as described in Erskine *et al.* (1998). Community mean and standard deviations are shown (adapted from Stewart and Schmidt 1999).

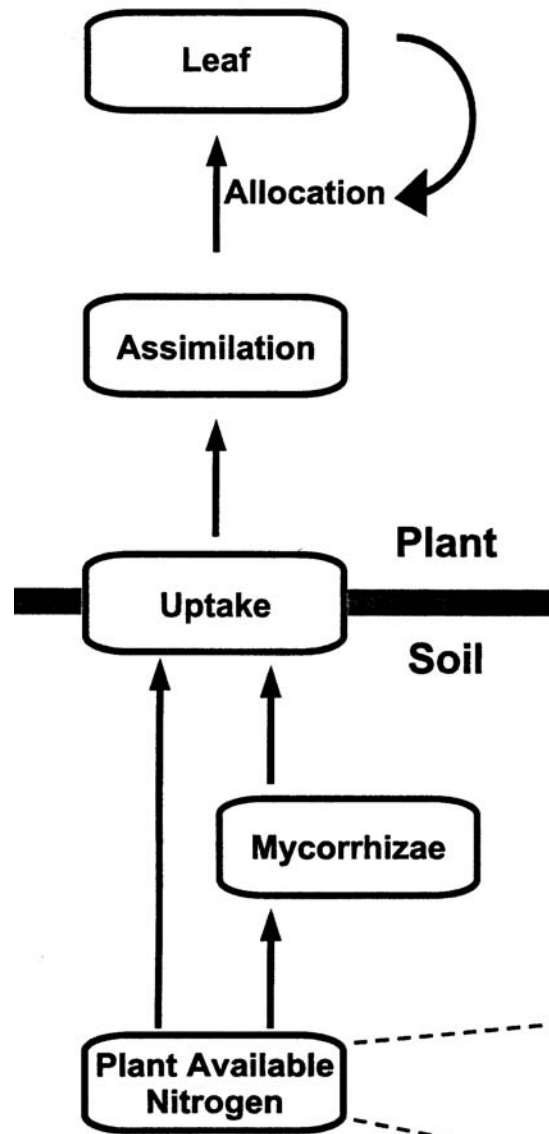
Plant Community	Foliar $\delta^{15}\text{N}$ (‰)
Alpine-subalpine Heathland	-4.5 (1.7)
Sub-antarctic Feldmark	-2.4 (1.7)
Sub-tropical Wallum Heathland	-1.7 (2.9)
Subtropical Woodland	0.2 (1.4)
Tropical Woodland	0.5 (1.3)
Deciduous Monsoon Forest	4.9 (1.3)
Semi-arid Mulga Woodland	8.6 (0.6)
Tropical Coral Cay	10.6 (1.1)
Sub-antarctic Bird Colonies	13.1 (2.5)

# Nitrogen isotope signatures at global level



# Nitrogen isotope signatures at population level

- Mycorrhizal-status and nitrogen isotope signatures
  - Certain groups of species tend to have higher (non-mycorrhizal) and others lower  $\delta^{15}\text{N}$  values, e.g., Proteaceae, Cyperaceae and Restionaceae
  - Mycorrhizal fungi enhance nitrogen uptake by plants
  - Physiological difference?



## Opportunities for $^{15}\text{N}$ discrimination within plants:

- Uptake
- Assimilation
- Allocation

- Nitrogen Form
- Active Rooting Depth
- Mycorrhizae vs Root
- Seasonal Changes
- Procedures (Extractant)

- $^{15}\text{N}$  signatures of rainforest epiphytes
  - Depleted relative to the trees
  - High  $\delta^{15}\text{N}$
  - Low  $\delta^{15}\text{N}$

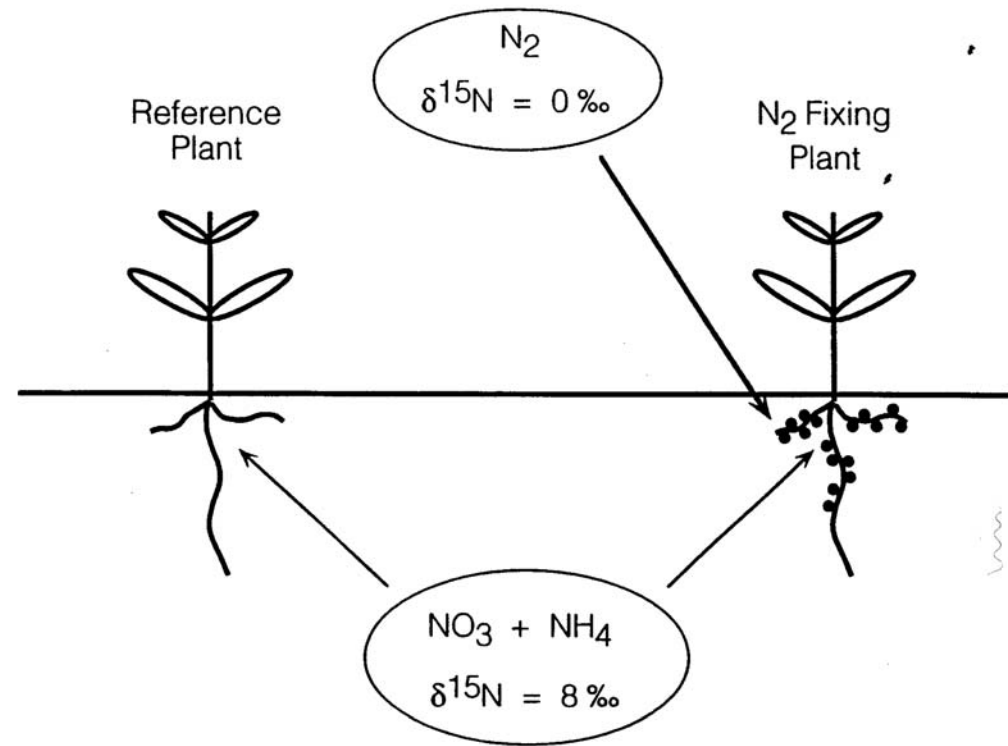
# General trends in soil

Observation: Soil  $\delta^{15}\text{N}$  is usually positive and increases with depth

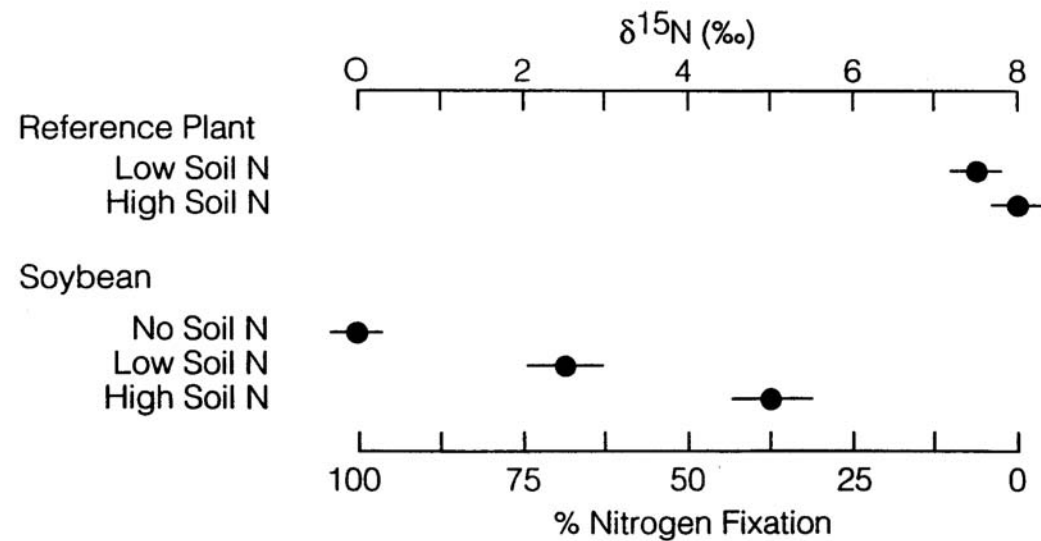
## Mechanisms

1.  $\delta^{15}\text{N}$  of nitrogen inputs into soil
2. Fractionation during internal transformations
3. Fractionation during nitrogen loss

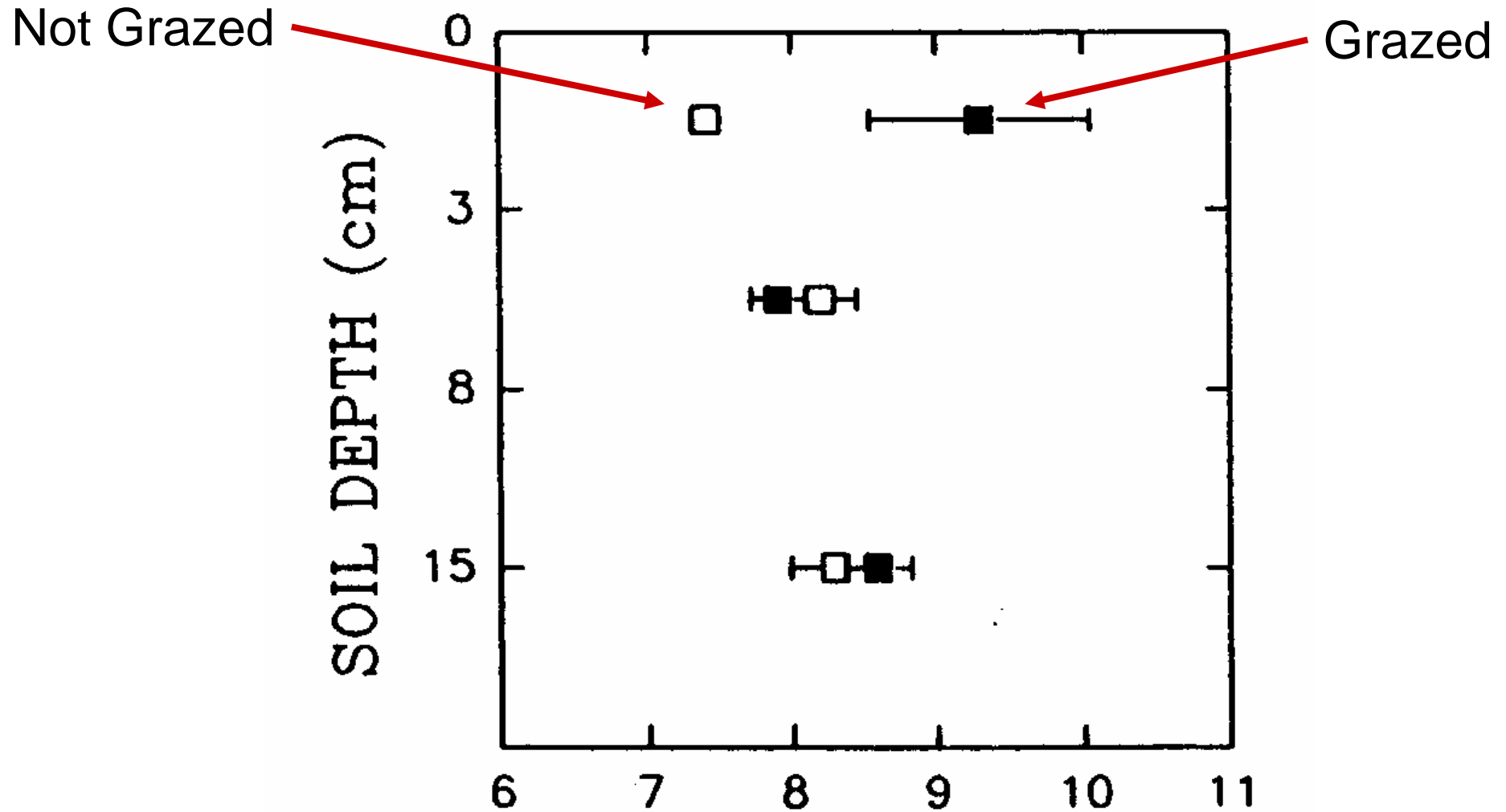
Input from  
biological nitrogen  
fixation = 0‰



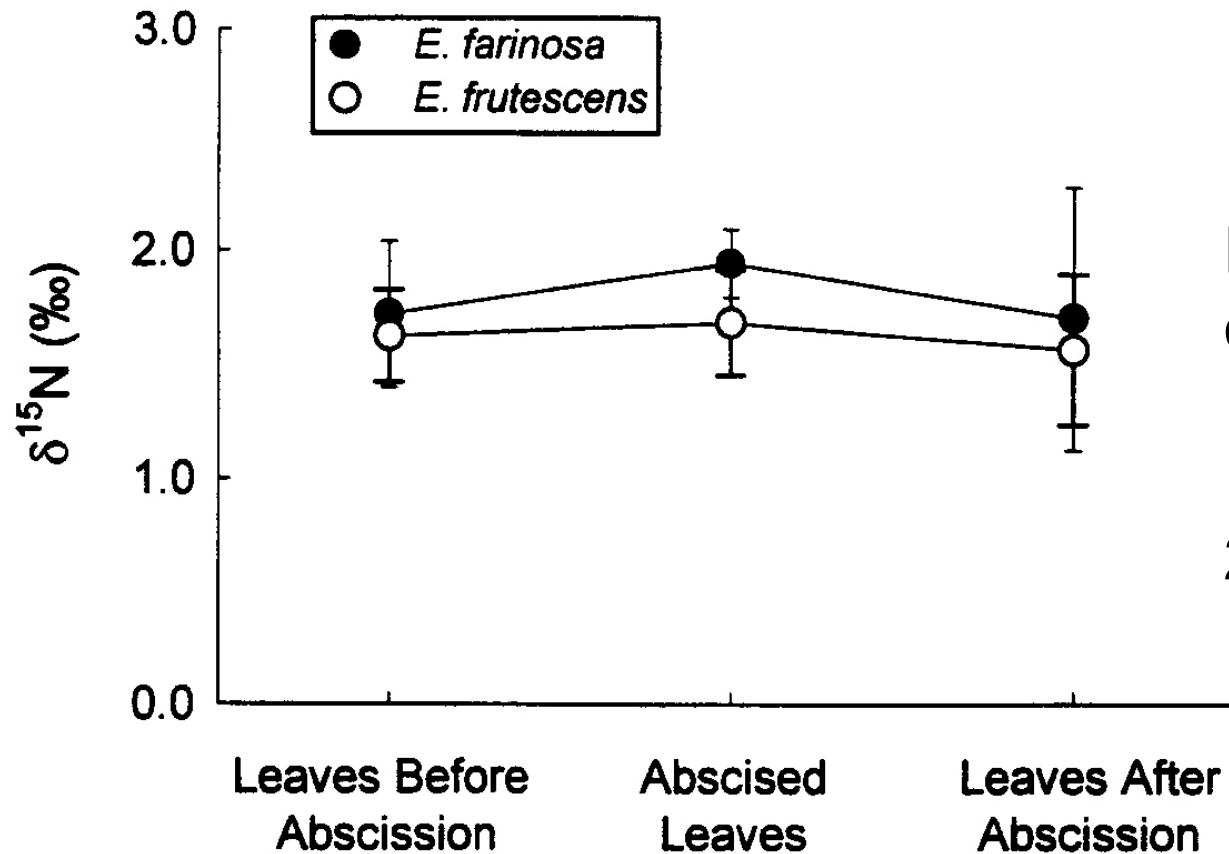
Method for  
determining % N  
fixation in  
legumes



Loss of N (volatilization) causes enrichment in soil



# Internal reallocation apparently does not result in discrimination



Discrimination not observed with:

1. Resorption
2. Reallocation

# Application of N stable isotope in Ecology

- Food chain and food web
- Assessing N<sub>2</sub> fixation in legumes
- Tracing the pollution
- Dilution method used in gross N mineralization

# Food chain and food web analysis

- $\delta^{13}\text{C}$  of animal tissues can reflect the isotopic signature of a consumers diet
- magnitude of isotopic fractionation depends on that during metabolism
- $\delta^{15}\text{N}$  can also be used for amino acids - **enriched** compared to food source
- fractionation of  $\delta^{15}\text{N}$  is more pronounced than that of  $\delta^{13}\text{C}$

# Fractionation during consumption

- $\delta^{13}\text{C}$  and  $\delta^{34}\text{S}$ : little or no fractionation:  
YOU ARE WHAT YOU EAT

- $\delta^{15}\text{N}$ : 3.4 ‰ heavier per trophic level:

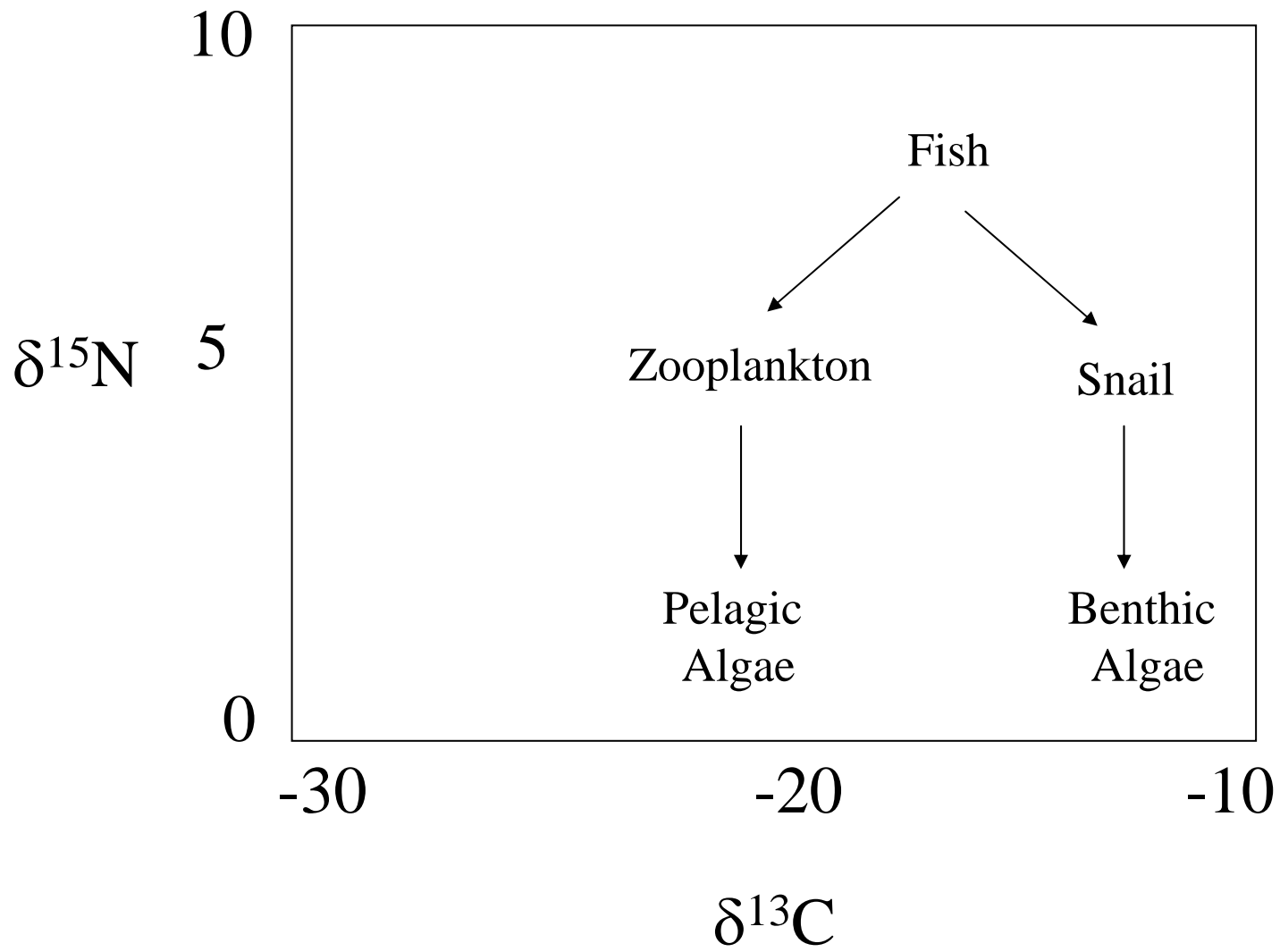
$$\lambda = 1 + (\delta^{15}\text{N}_{\text{consumer}} - \delta^{15}\text{N}_{\text{base}}) / \Delta\delta^{15}\text{N}$$

Example  $\delta^{15}\text{N}$ :

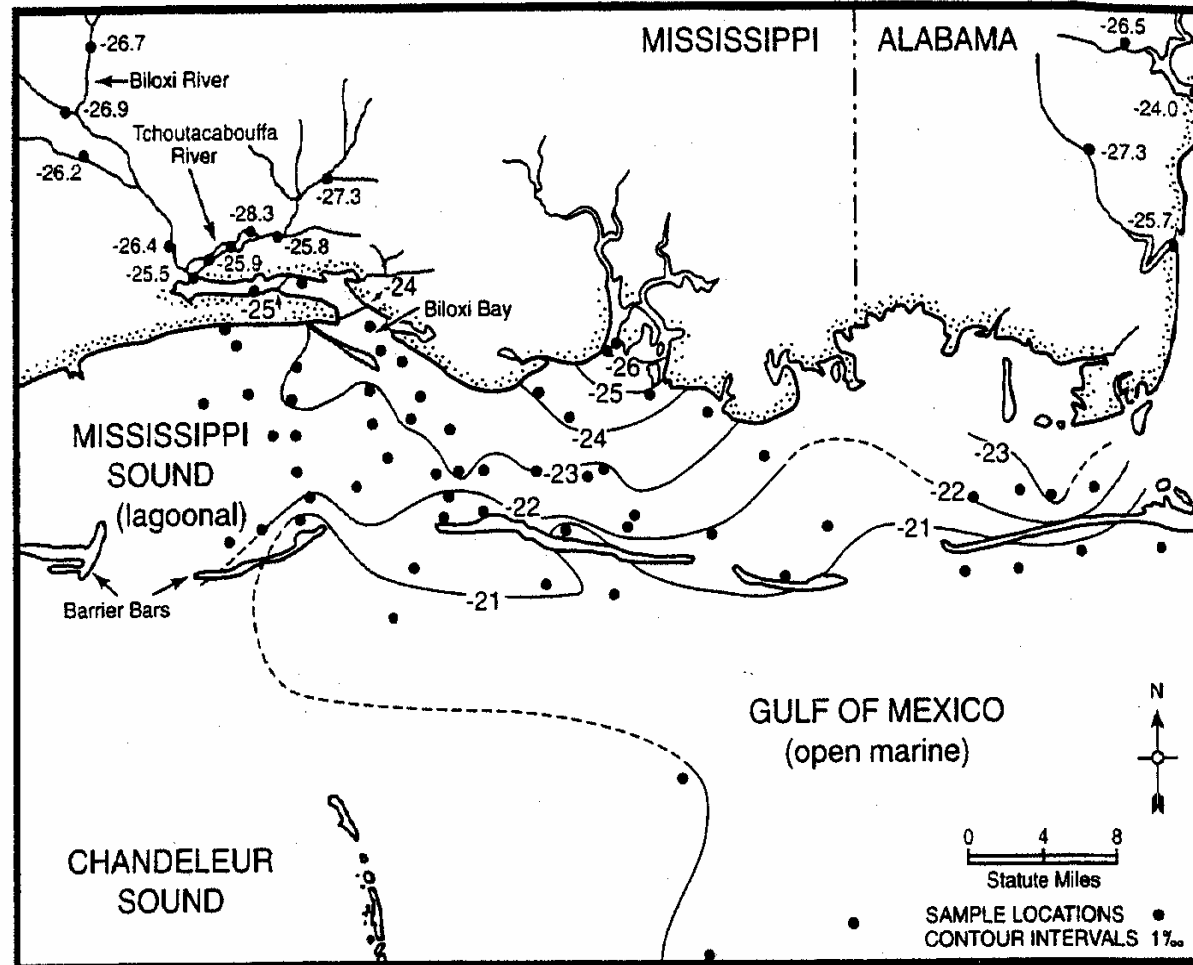
- algae: 10 ‰
- Zooplankton: 13.5 ‰
- Fish: 17 ‰
- Predatory Fish: 20 ‰

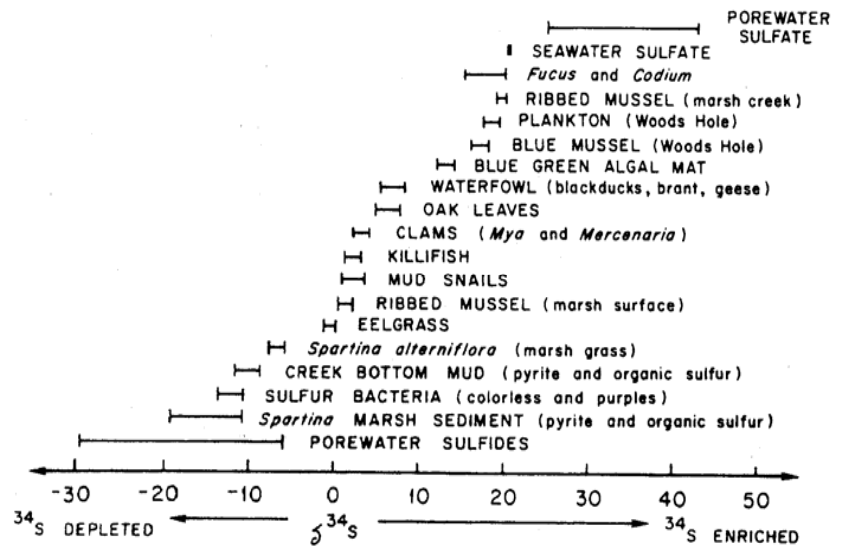
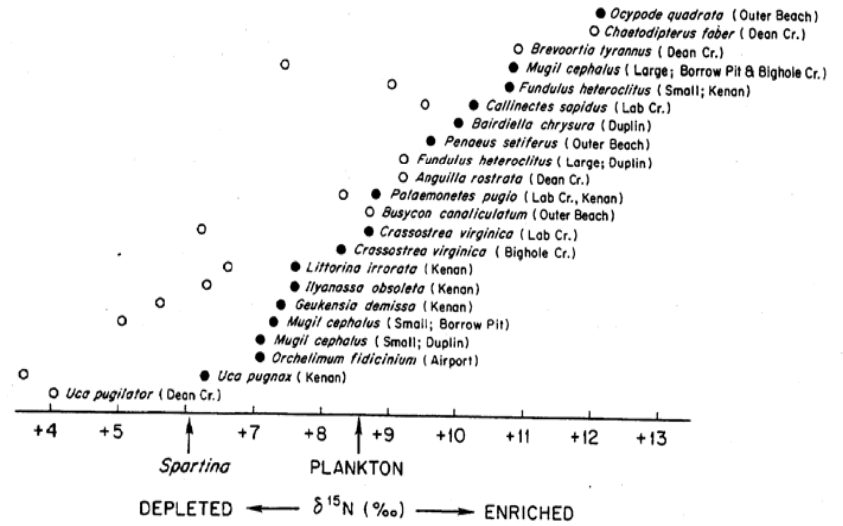
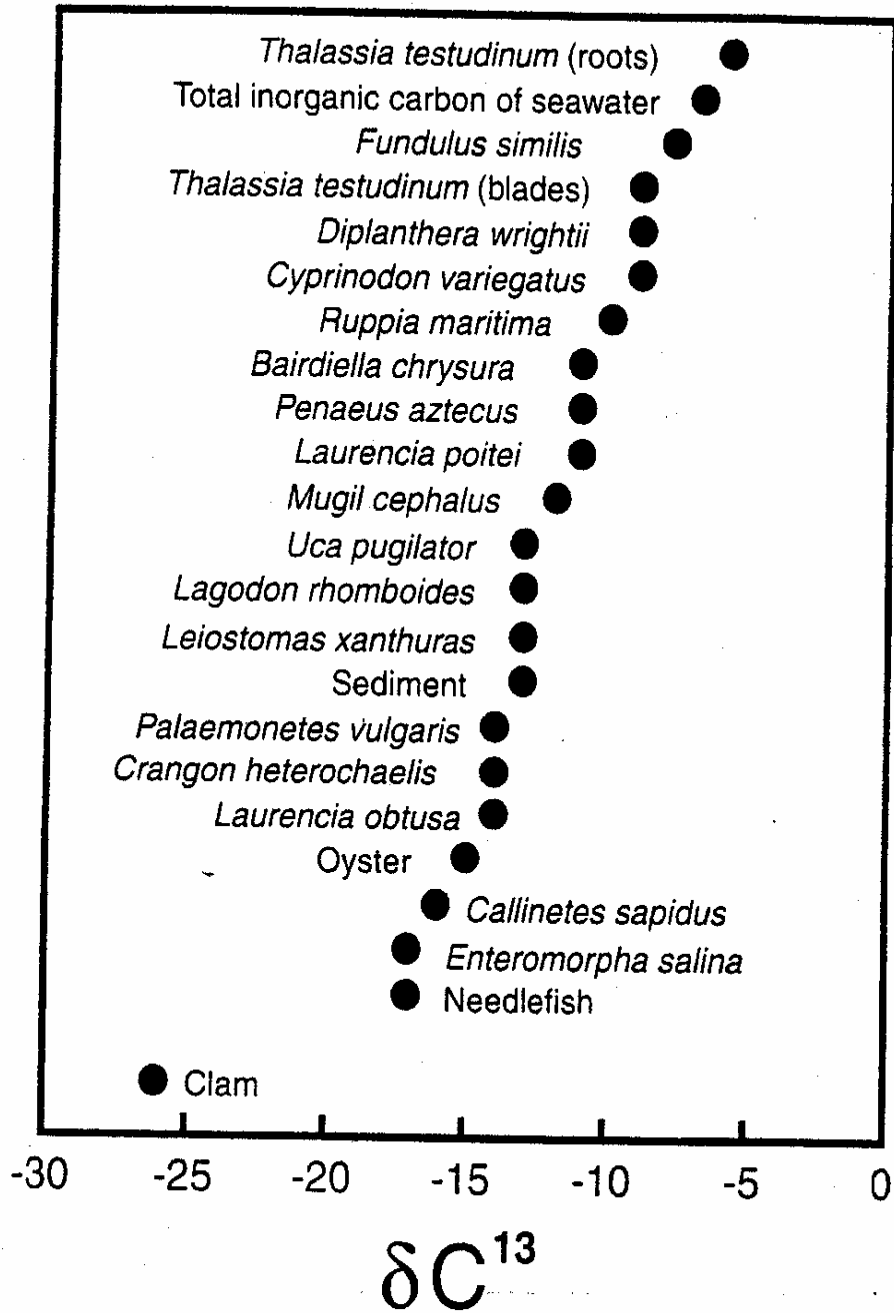
# Stable Isotopes in Ecology

- Food characterisation
  - Time-integrative view compared to stomach content
  - Food consumption in natural system
  - All heterotrophs including bacteria/protozoa without stomach, etc.
- Food-web relationships
  - Elucidation present-day food-webs by single event sampling
  - Ancient food-webs



# Fry and Peterson's study in USA





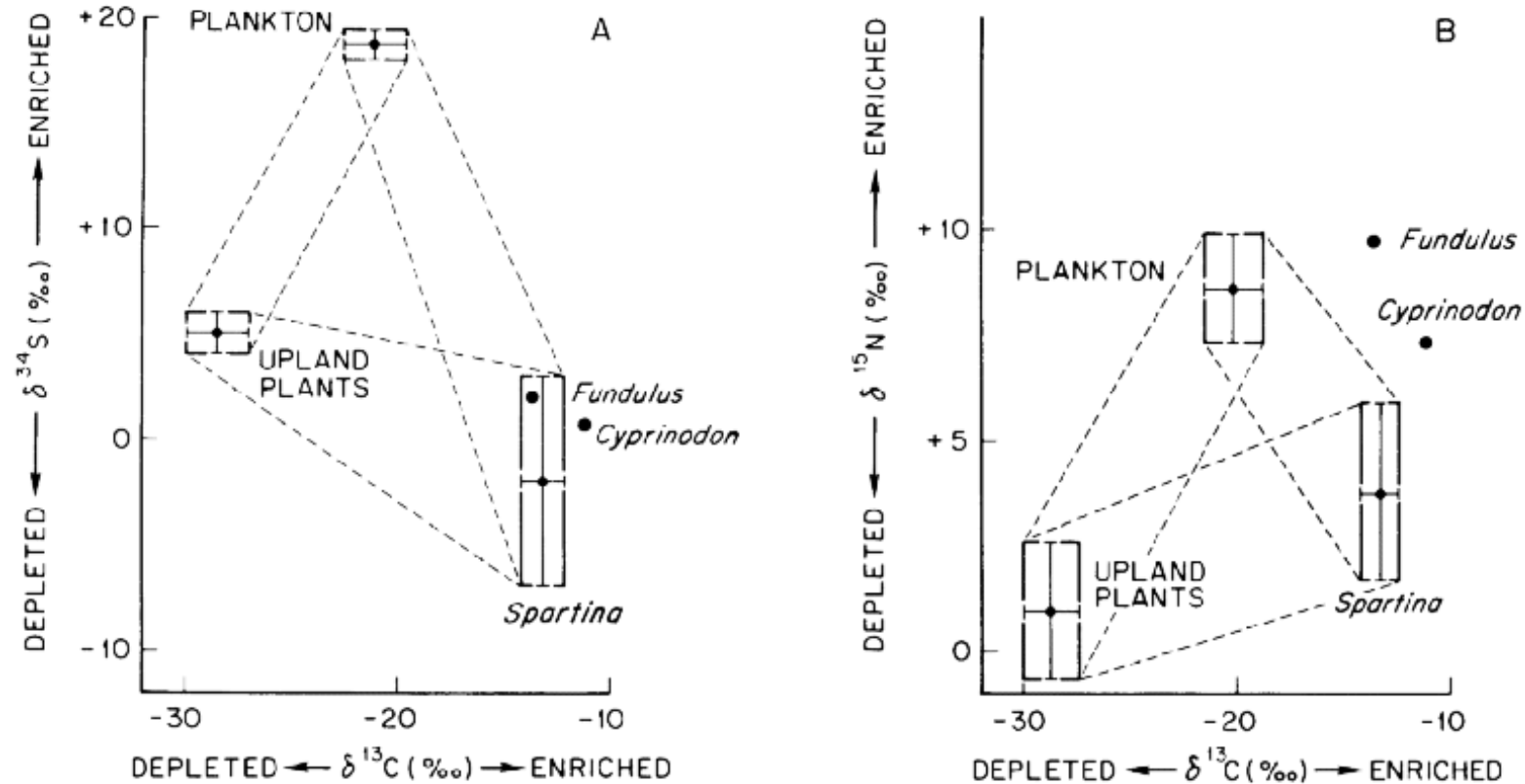
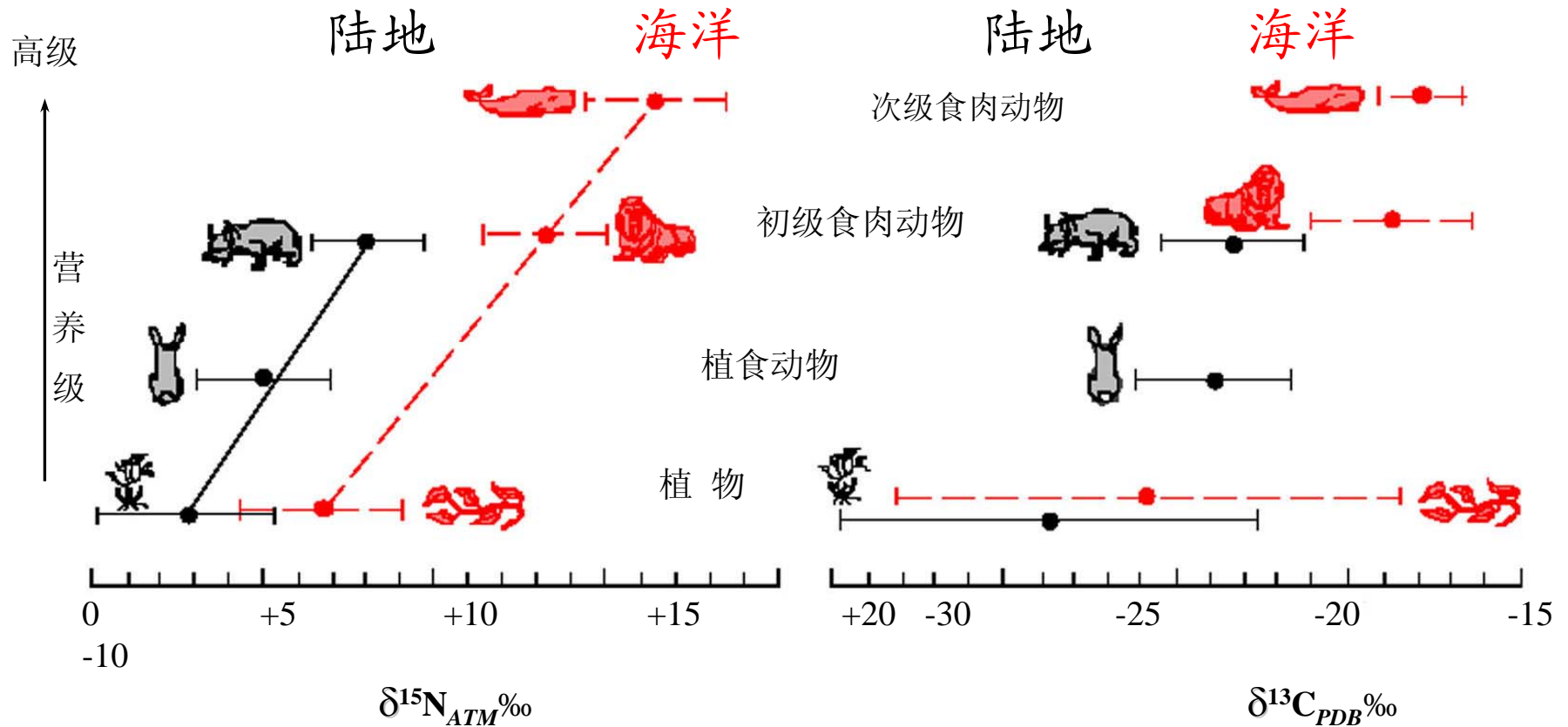


FIG. 7. A comparison of the isotopic compositions of *Fundulus heteroclitus* and *Cyprinodon variegatus*. The values for the producers are from Peterson et al. (1985).

Ecologists often construct “stable isotope maps” that show how organisms assimilate organic matter

Can sometimes get C, N, S, etc from different sources

# You are what you eat, plus a few per mil!



不同生态系统动—植物中的 $\delta^{13}\text{C}$ 和 $\delta^{15}\text{N}$ 值(引自Schoeninger和DeNiro) (略作修改)

- Mixing models

$$\delta^{13}C_T = f_X \delta^{13}C_X + f_Y \delta^{13}C_Y + \Delta \delta^{13}C,$$

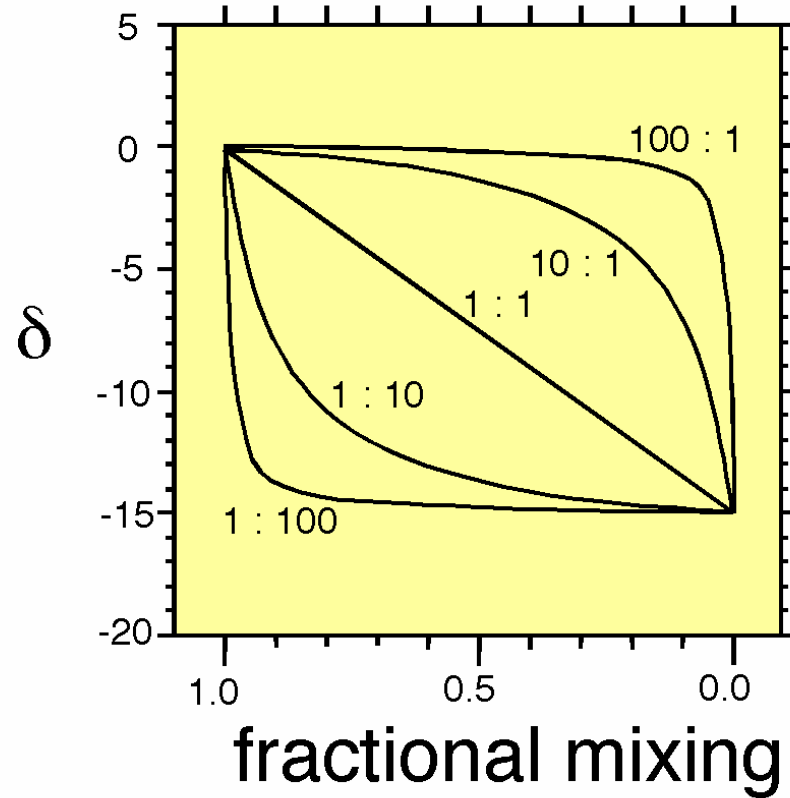
$$1 = f_X + f_Y$$

$$\delta^{13}C_T = f_X \delta^{13}C_X + f_Y \delta^{13}C_Y + f_Z \delta^{13}C_Z + \Delta \delta^{13}C$$

$$\delta^{15}N_T = f_X \delta^{15}N_X + f_Y \delta^{15}N_Y + f_Z \delta^{15}N_Z + \Delta \delta^{15}N$$

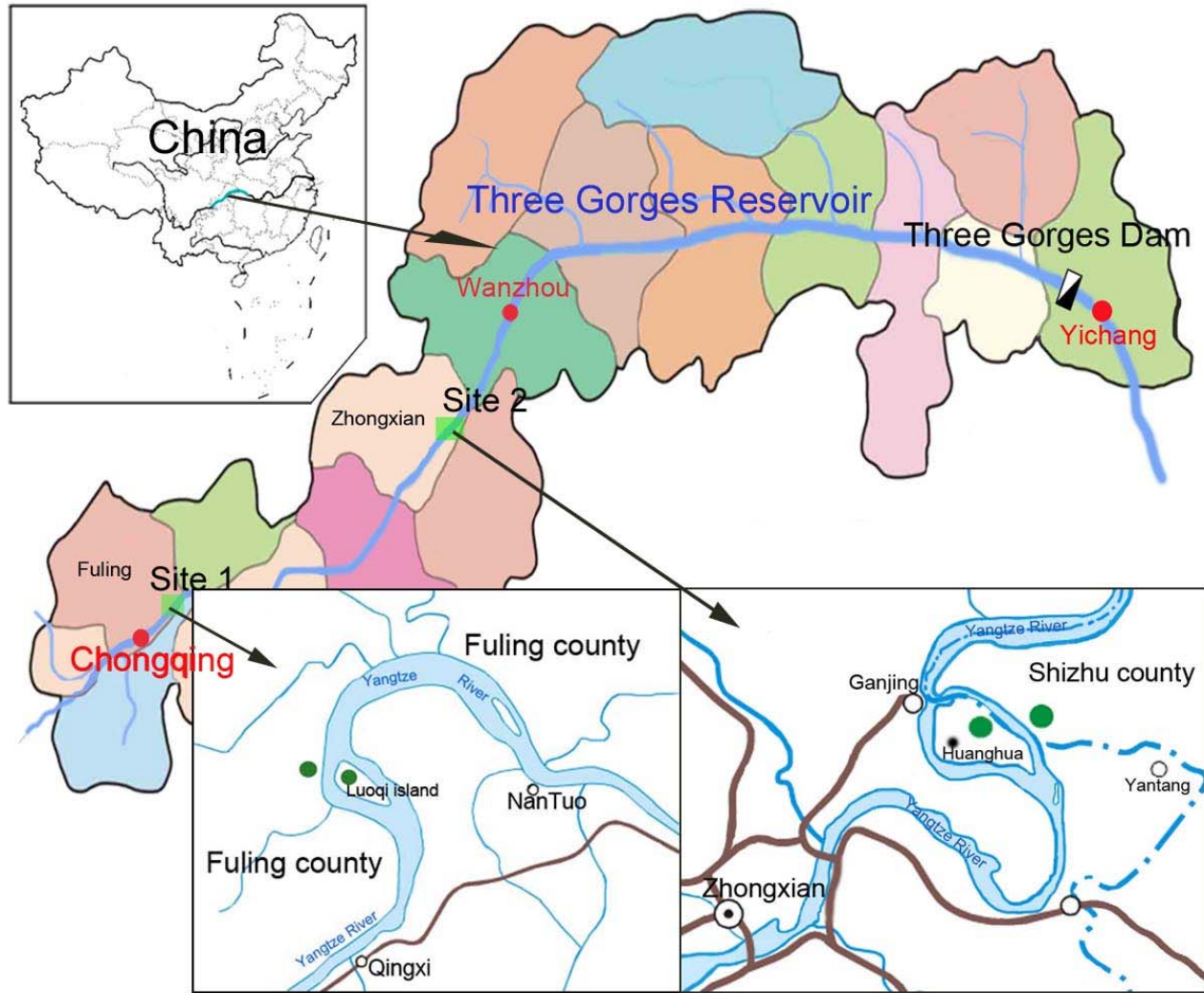
$$1 = f_X + f_Y + f_Z ,$$

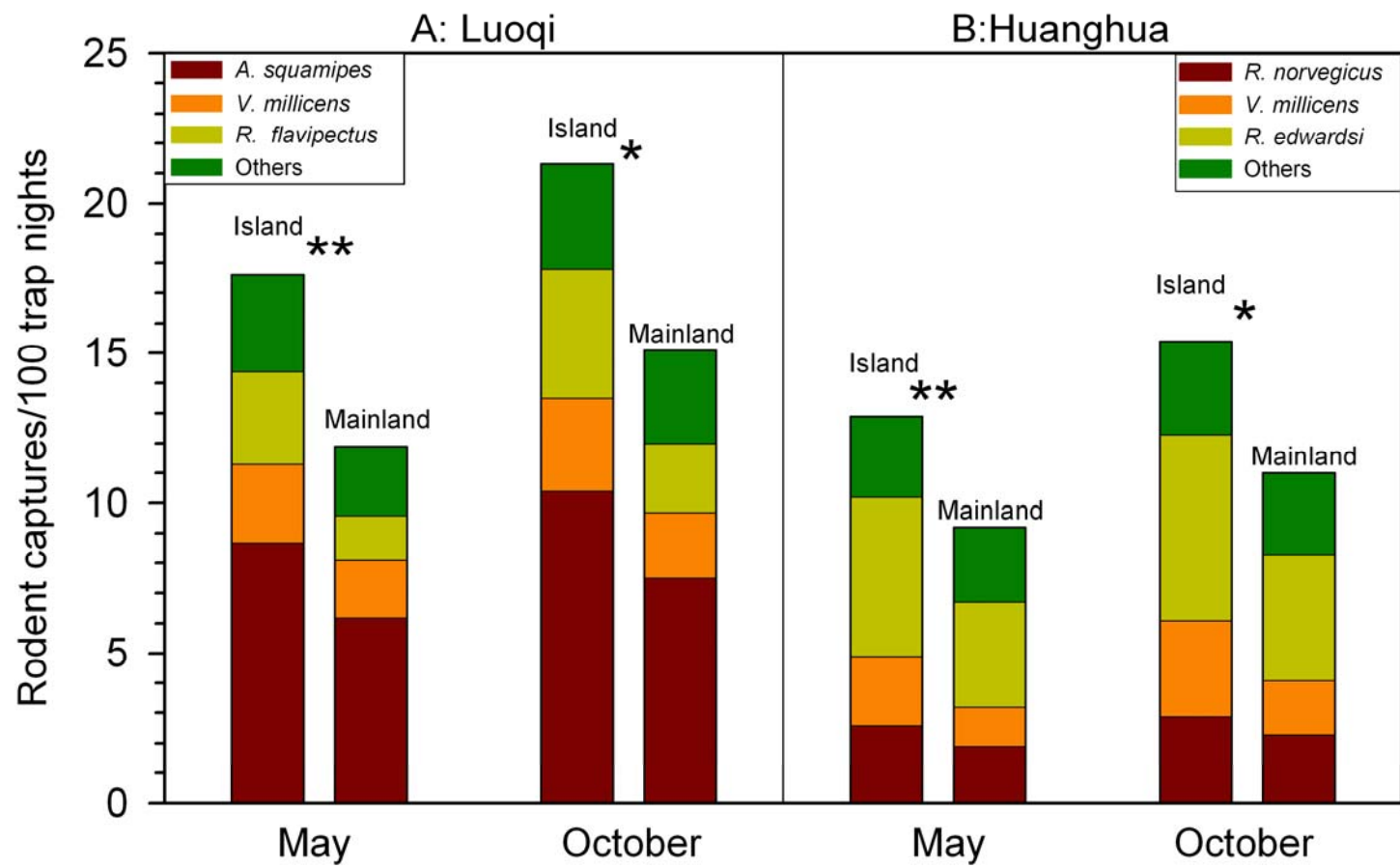
# Fractionational mixing

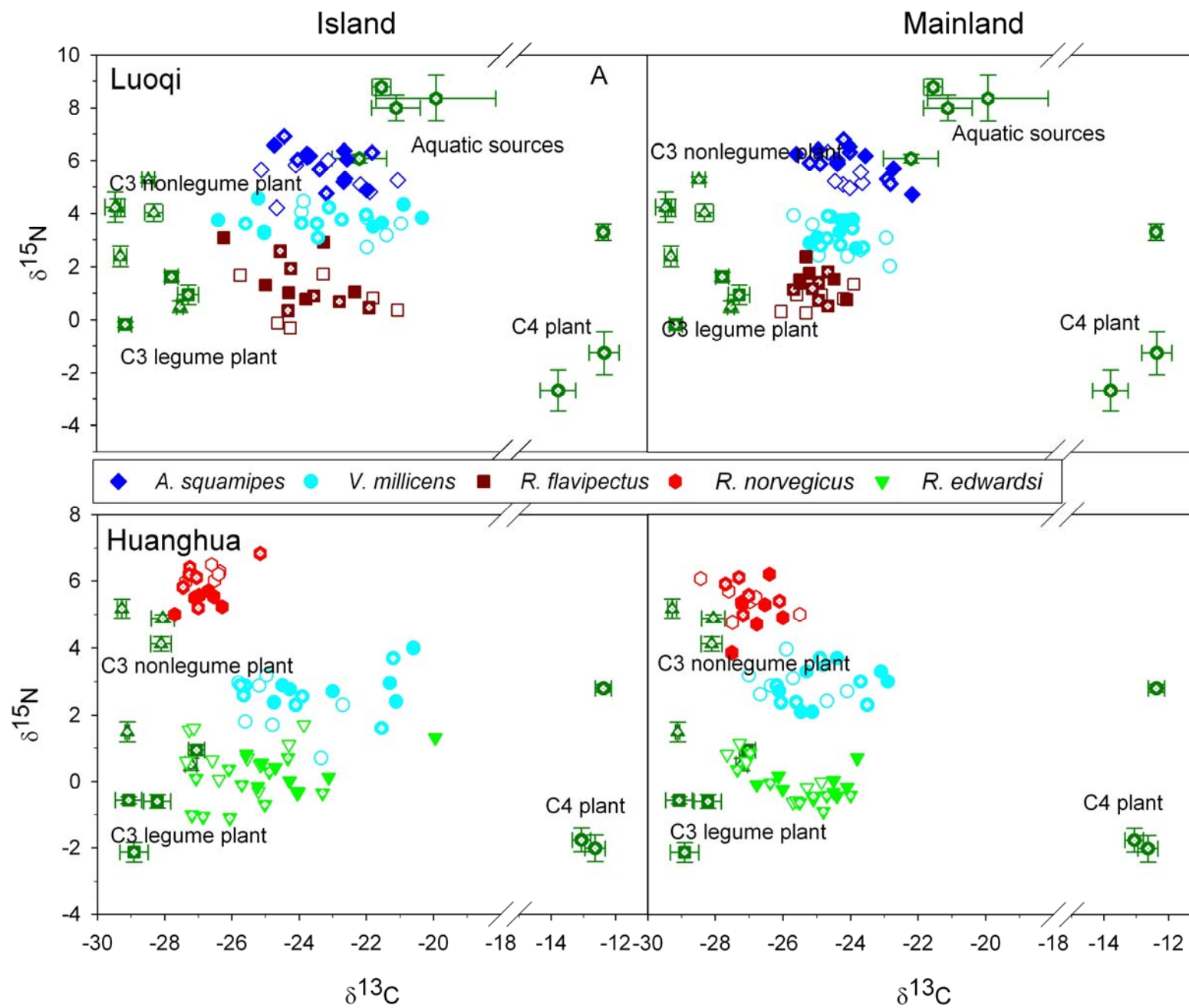


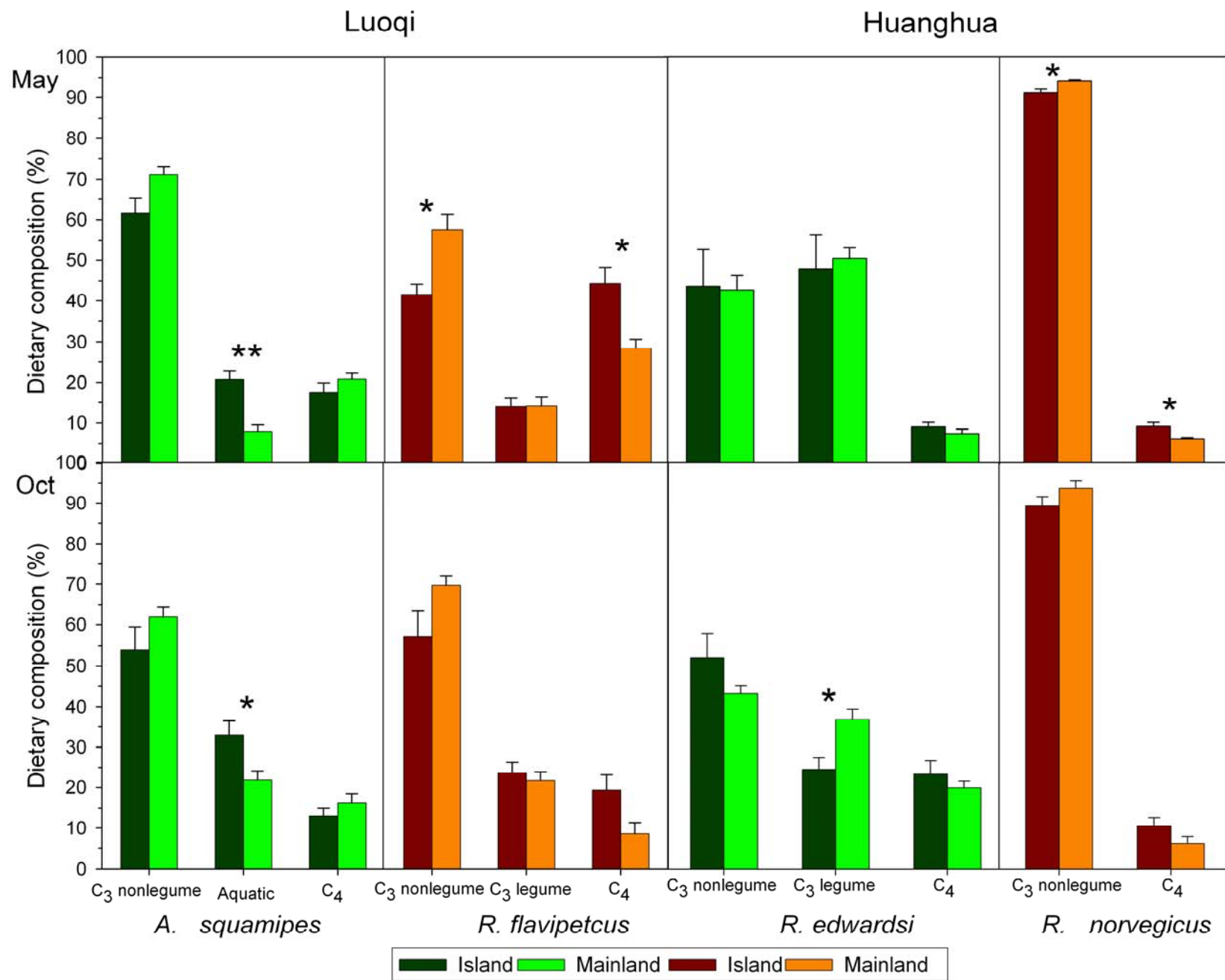
Isotope mixing between two reservoirs with  $\delta = 0\text{‰}$  and  $-15\text{‰}$ , respectively.

Concentration ratios range from 100:1 to 1:100.







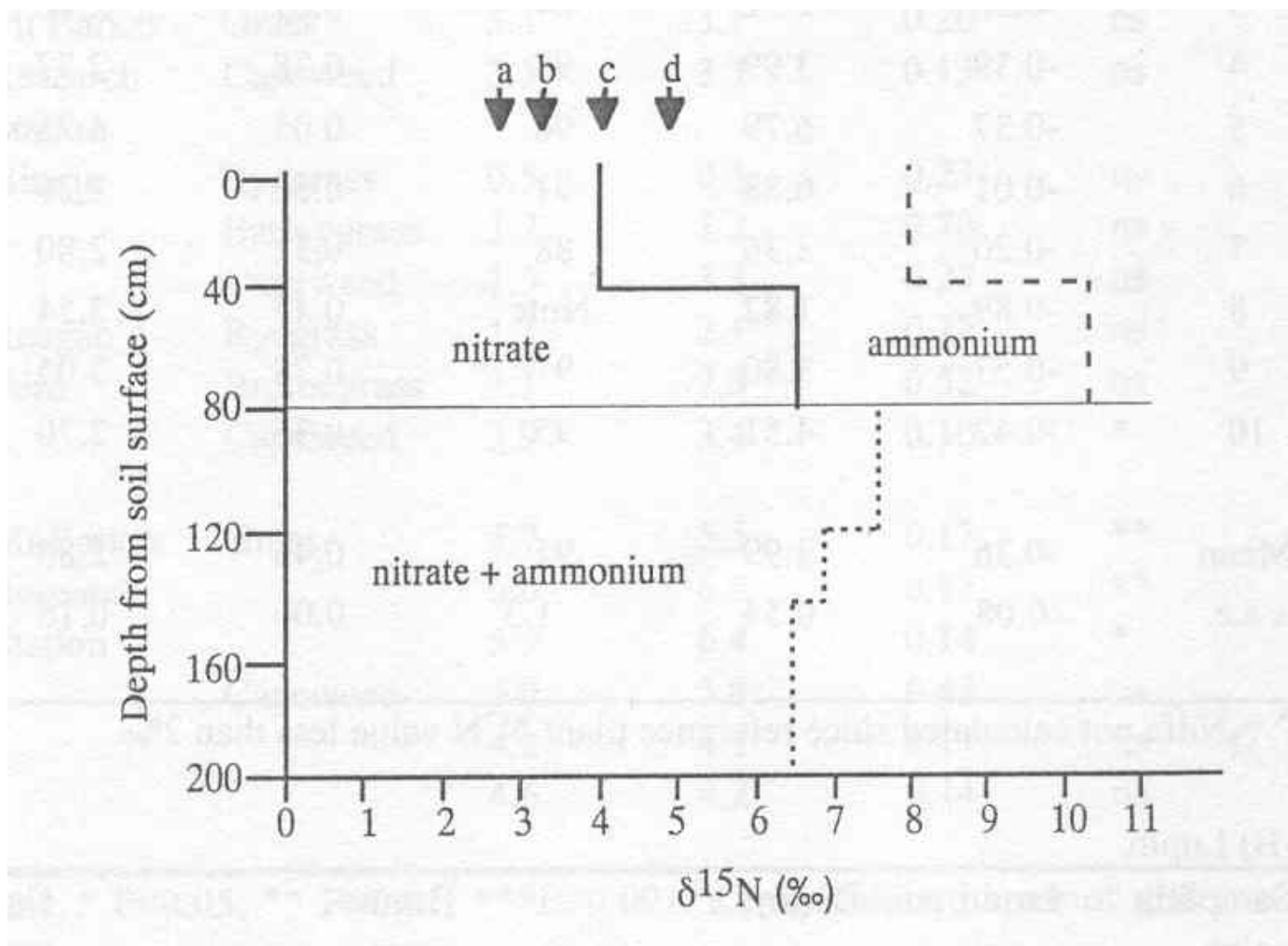


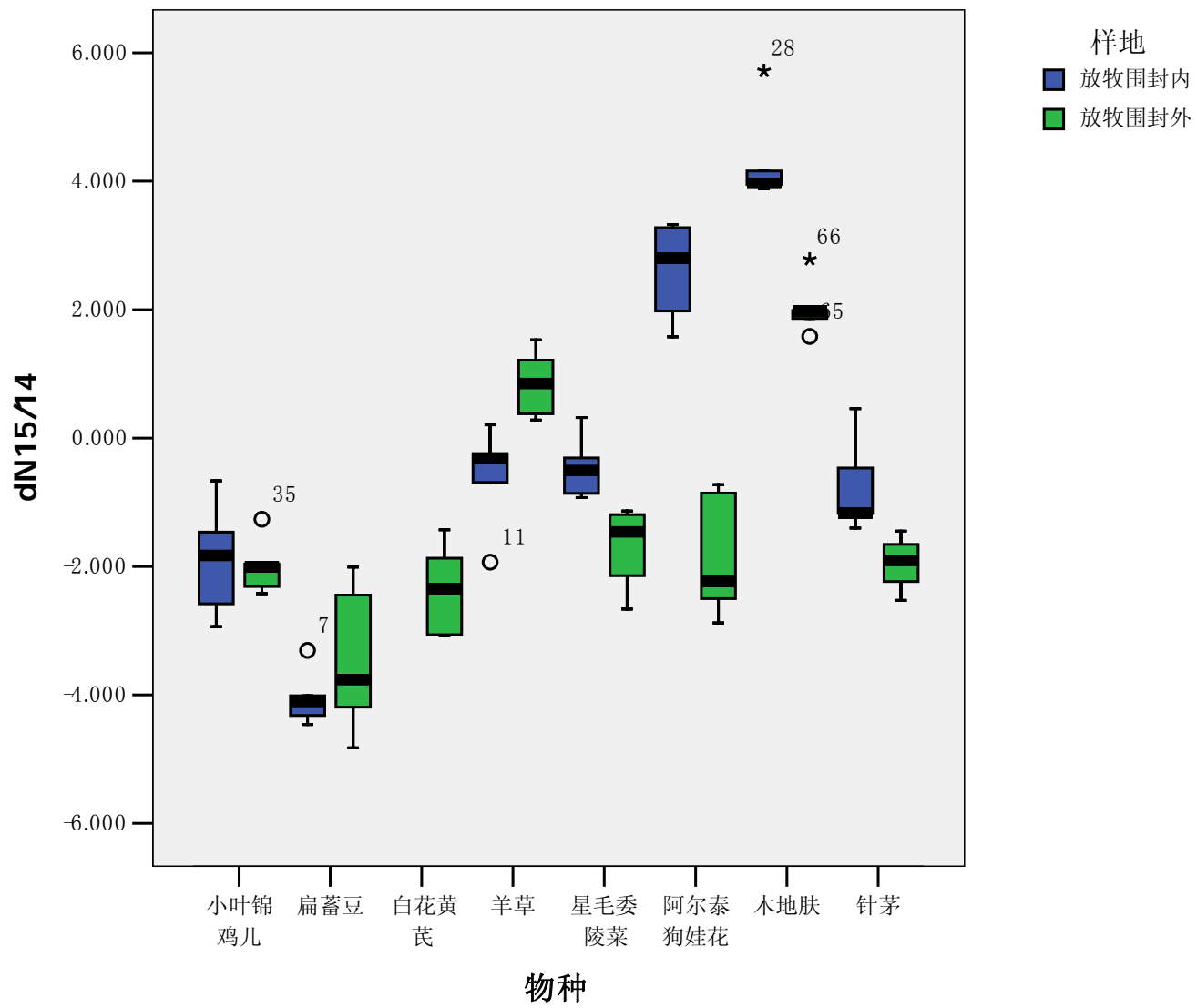
# Assessing N<sub>2</sub> fixation in legumes

- N fixed by a legume crop calculated by %Ndfa and N content in its total biomass
  - Xylem solute analysis
  - <sup>15</sup>N isotope dilution
  - <sup>15</sup>N natural abundance (NA)

- Pre-requisites for the use of NA
  - Only two pools exist for legume growth
  - The two pools are sufficiently different
  - Biological variability of these abundances is small compared to the difference between them

- But be careful with NA method
  - Variation in  $\delta^{15}\text{N}$  enrichment of soil and non  $\text{N}_2$ -fixing reference plants
  - Selection of non  $\text{N}_2$ -fixing reference plants





# Gross N Mineralization

## Isotope pool dilution technique

- natural abundance of  $^{15}\text{N} = 0.37 \text{ atom\% } ^{15}\text{N}$
- add small amount of HIGHLY ENRICHED  $\text{NH}_4$
- assume no fractionation by outputs from the pool
- inputs from GROSS MINERALIZATION will dilute the  $^{15}\text{N}$  content of the pool
- possible to calculate gross N min. rate

# Tracing the source of pollution

- The dominance of terrestrial inputs of the Changjiang could be observed 250 km far from the river mouth in the East China Sea.
- Synthetic fertilisers, animal wastes, and sludges and effluents from waste-water treatment plants

Thank you for your  
patience!