IRSN
INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

Faire avancer la sûreté nucléaire

Mechanistic and ecophysiologic study of carbon 14 transfer in fish

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PSE-ENV/SRTE/LECO

SOULOUMIAC Audrey

Context

- Natural sources: reaction of cosmic rays on nitrogen neutrons in the high atmosphere → carbon dating...

- With ^{3}H, ^{14}C is one of the radionuclides rejected in greatest amounts by Nuclear Power Plant in French rivers.

- Assimilated ^{14}C contributes in a major part to estimated – small – doses received by local human populations, essentially through fish ingestion.

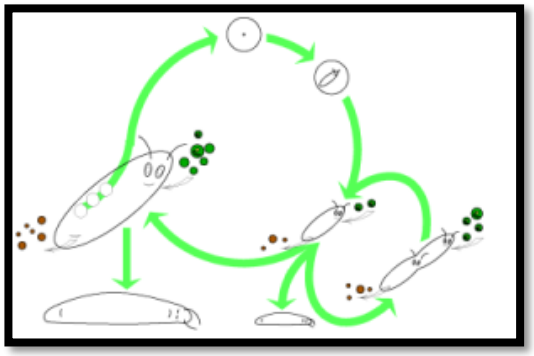
Need to better assess the environmental (both health and ecological) risks

Problem: Current models used to predict ^{14}C transfer in aquatic ecosystems are very simplistic:

- Unability to explain the variability in ^{14}C activity observed in fish samples collected from different rivers.

- Great variations in ^{14}C releases → No equilibrium in concentration (Sheppard et al., 2006 ; Smith, 2006).

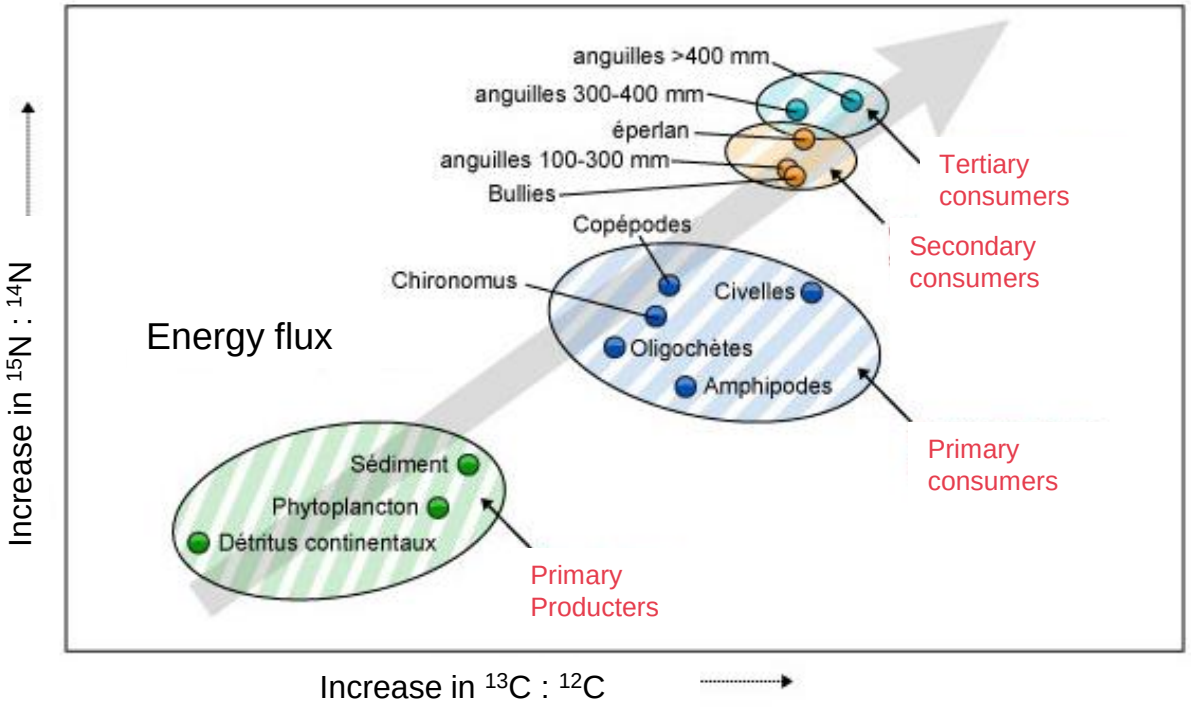
- Models of fish do not take account of the potential influence of fish physiology and environnemental factors, depending on species.



→ DEB model is a physiology-based dynamic model = more adequate to describe variation in ^{14}C activity in differents compartments of the aquatic ecosystem.

DIB model: Dynamic isotope budget

- Used in ecology to study the dynamics and structure of trophic networks and trace elements fluxes in ecosystems. (Post, David M. 2002. « Using Stable Isotopes to Estimate Trophic Position: Models, Methods, and Assumptions ». *Ecology* 83 (3): 703-18.).



→ Increase in stable isotopes with trophic level

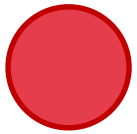
→ DIB model is used for stable isotope analyses

- Aim to quantify dynamics of four biogenic elements (C, H, N and O) and their isotopes within organism by coupling fluxes of elements with those of molecules involved in metabolism.

Important processes for isotope allocation during metabolic reactions

$$S1 + S2 \rightarrow P1 + P2$$

1) Mobilisation : Mobilisation of atoms from a pool of atoms. **Does not change isotopic ratio**

2)  Molecular selection

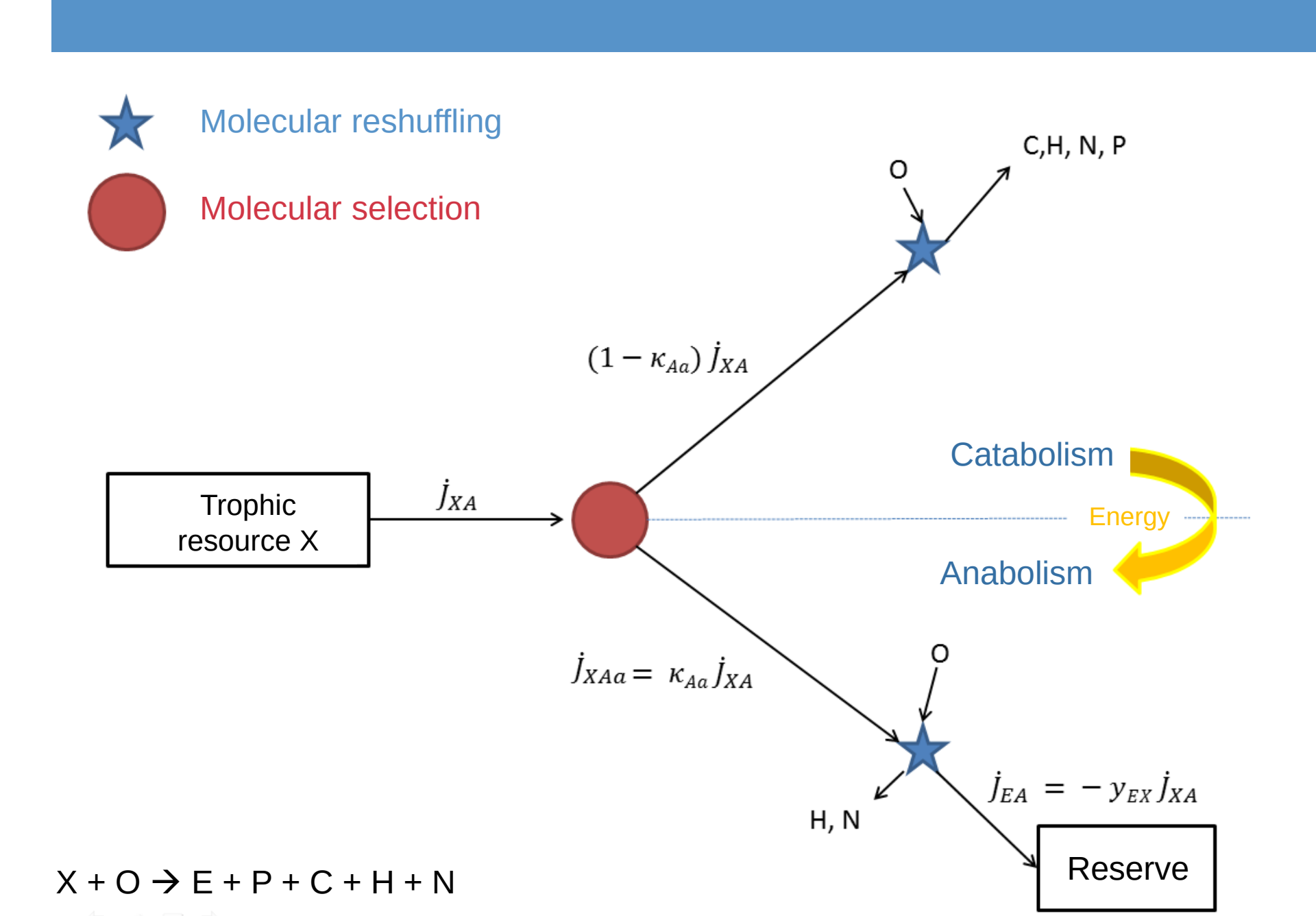
Selection for anabolic or catabolic routes. Probability depends on atomic mass.

3)  Molecular reshuffling

The concept of atom reshuffling recognizes that molecules are not completely disassembled into elements during chemical reactions.

O

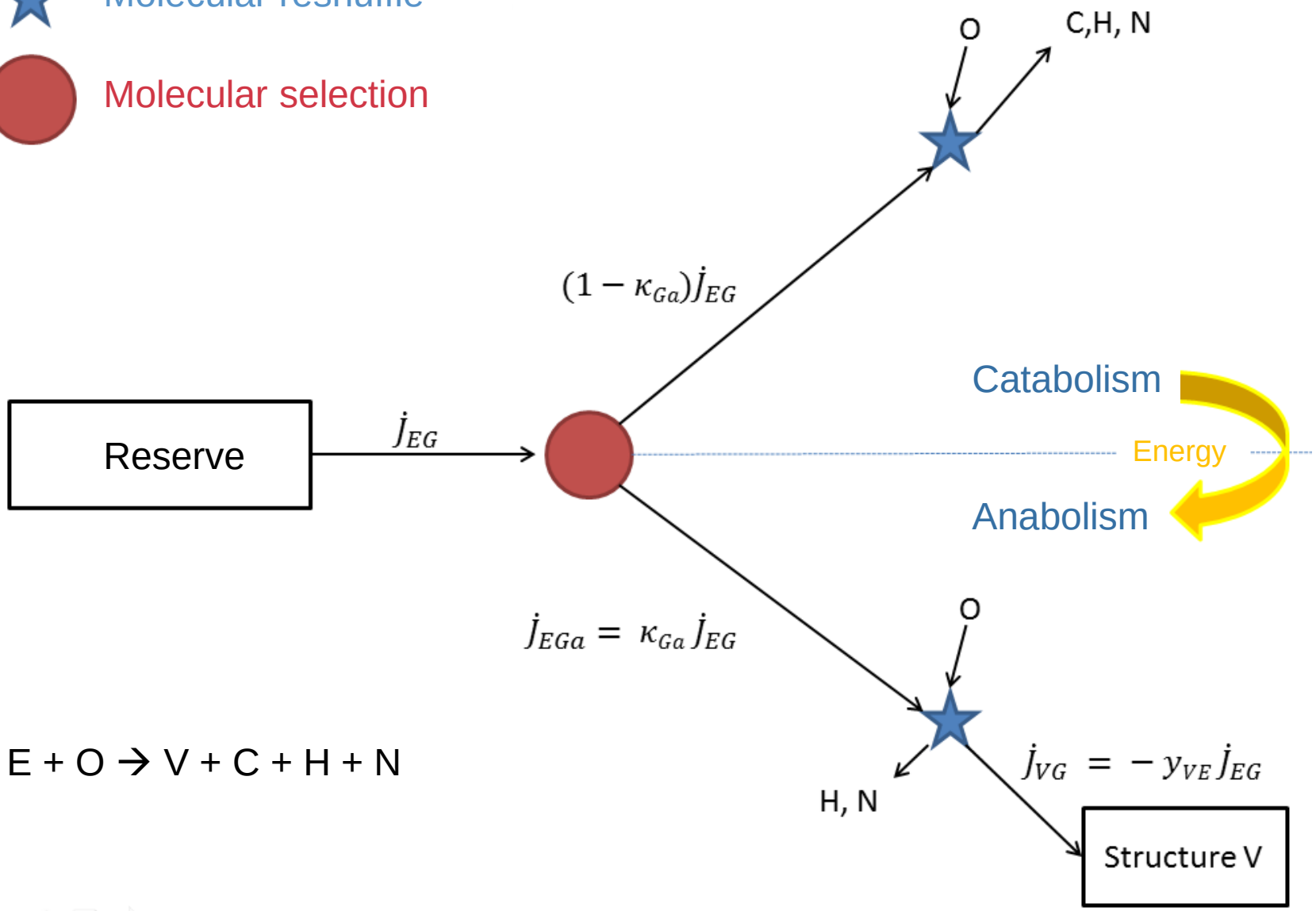
C,H, N


Molecular reshuffling
Molecular selection
C,H, N, P
O
$(1-\kappa_{Aa})\,\dot{j}_{XA}$
Catabolism
Energy
Anabolism
Trophic resource X
$\dot{j}_{XA}$
$\dot{j}_{XAa} = \kappa_{Aa}\,\dot{j}_{XA}$
O
H, N
$\dot{j}_{EA} = -y_{EX}\,\dot{j}_{XA}$
Reserve

X + O → E + P + C + H + N

Molecular reshuffle

Molecular selection



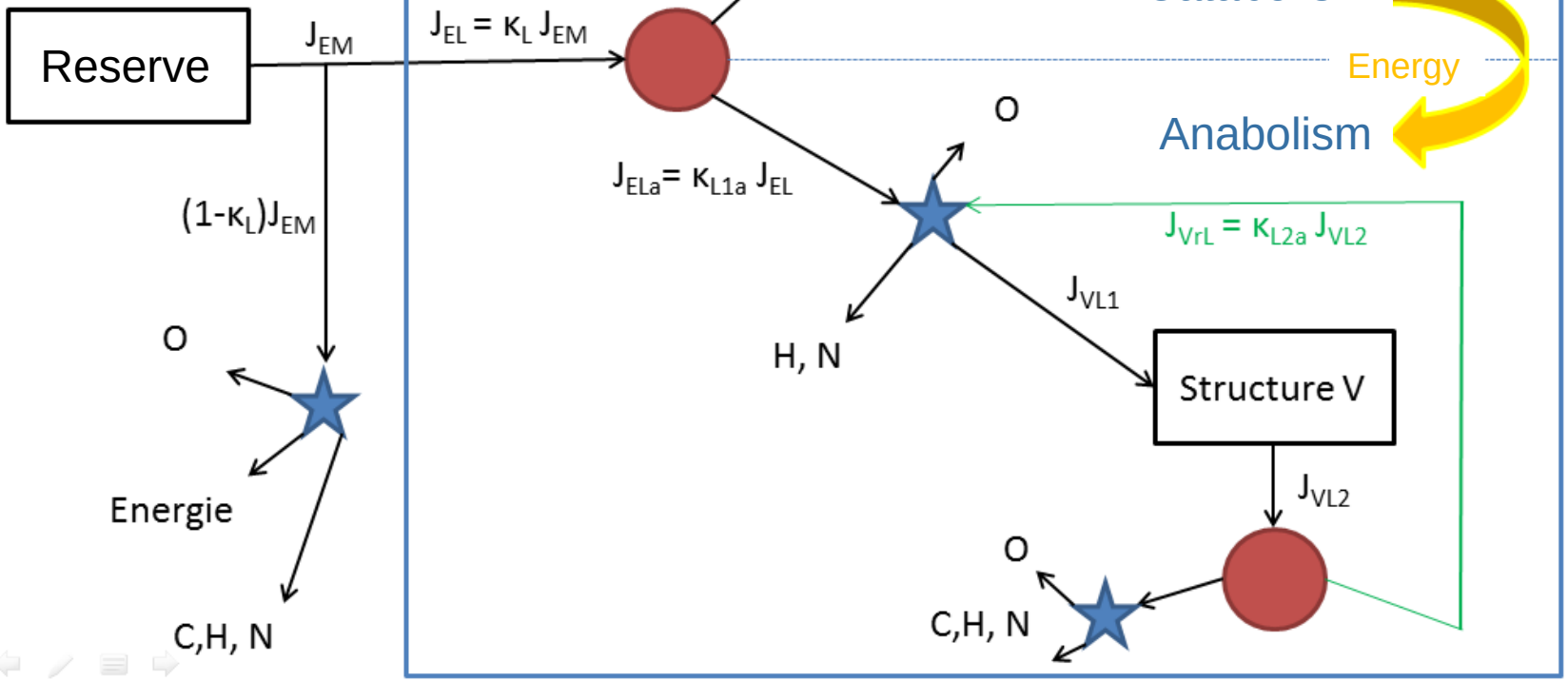
E + O → V + C + H + N

Structure turnover

Molecular reshuffle

Molecular selection

E + V + O → V + C + H + N
E + V + O → C + H + N



Theoretical values of DIB parameters are available for stable isotopes ^{15}N and ^{13}C and are validated in *Crassostrea gigas* (Pacific oyster).

→ Parameterize values for the case of ^{14}C
→ Improvement of DEB model for Common carp (literature search)
→ Validation of predictive capacity in Zebrafish

Cyprinus carpio

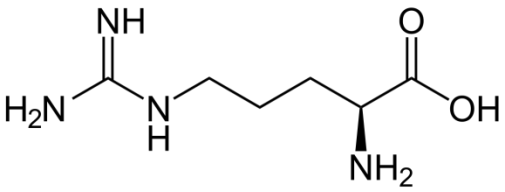
Danio rerio

Measurements of **^{14}C assimilation**, **incorporation** and **elimination** kinetics depending the biochemical composition of **^{14}C sources**.

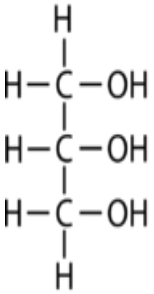
Different sources of ^{14}C

→ To explore how transfer efficiency to different compartments of the model varies with the biochemical composition of the ^{14}C provided we used :

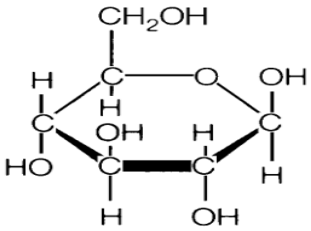
Amino acid: Arginine



Glycerol



Glucose

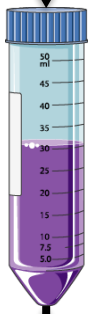


PROTEIN METABOLISM

LIPID METABOLISM

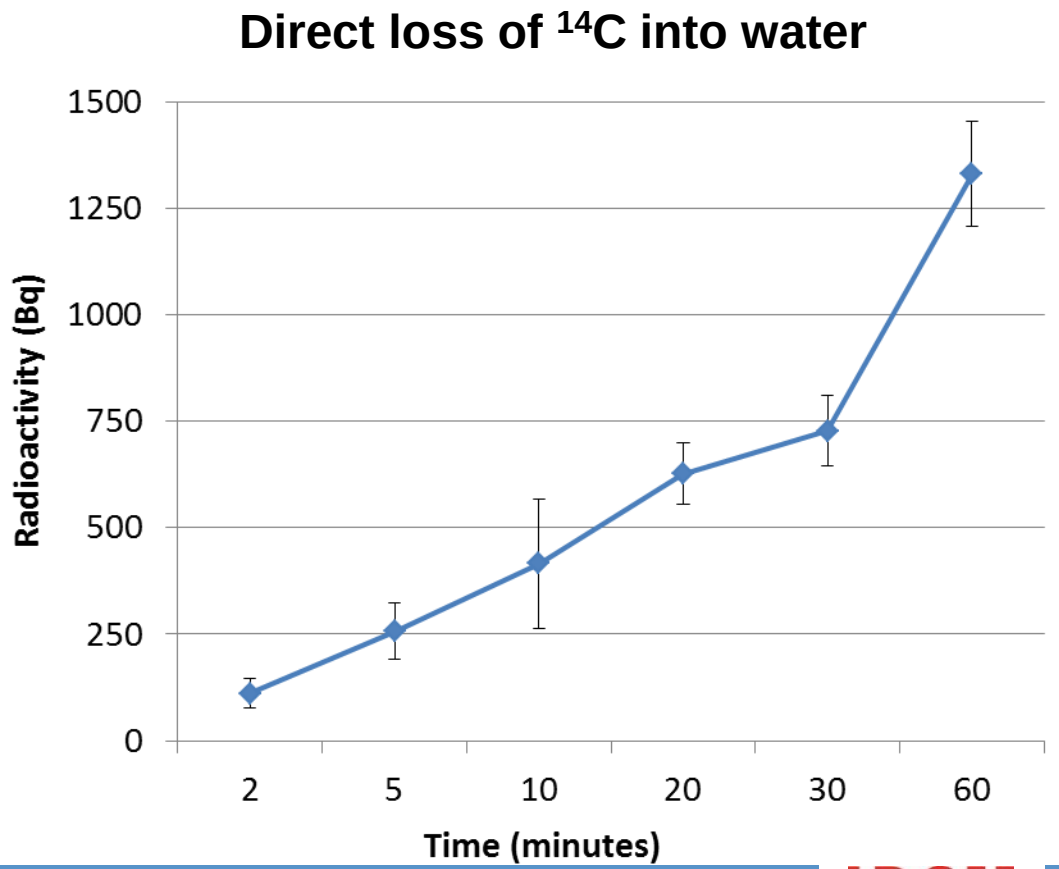
CARBOHYDRATE METABOLISM

Conception of contaminated food



5mL water

→ Mineralisation in NaOH for **48 hours**
→ Quantification by liquid scintillation analysis



Preliminary experiment

Contamination duration: range of **1 to 4 days**
Dissection **24h** after last food supply

WATER

DIGESTIVE TRACT

LIVER

GILLS

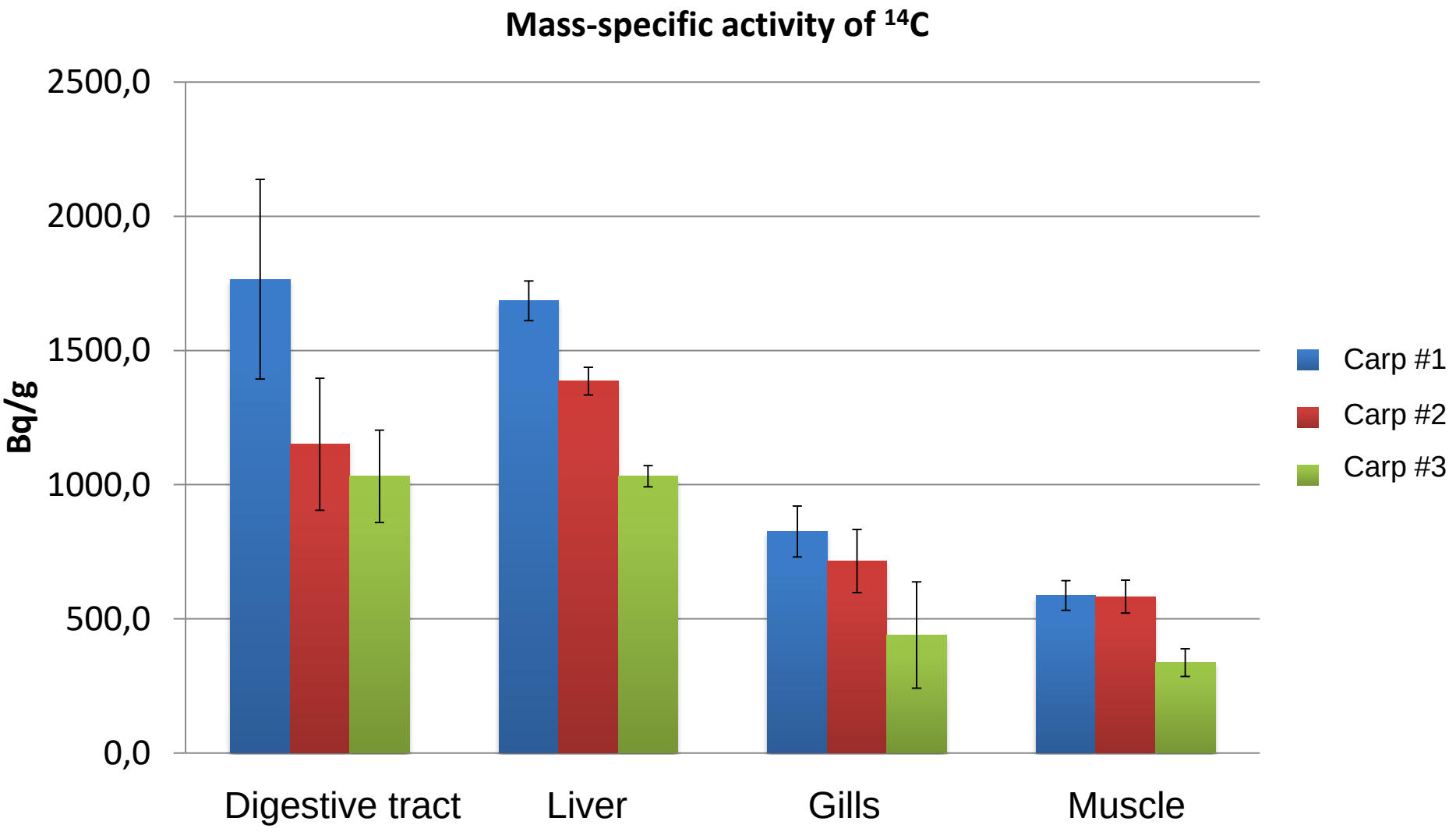
MUSCLES

TOTAL CARBON

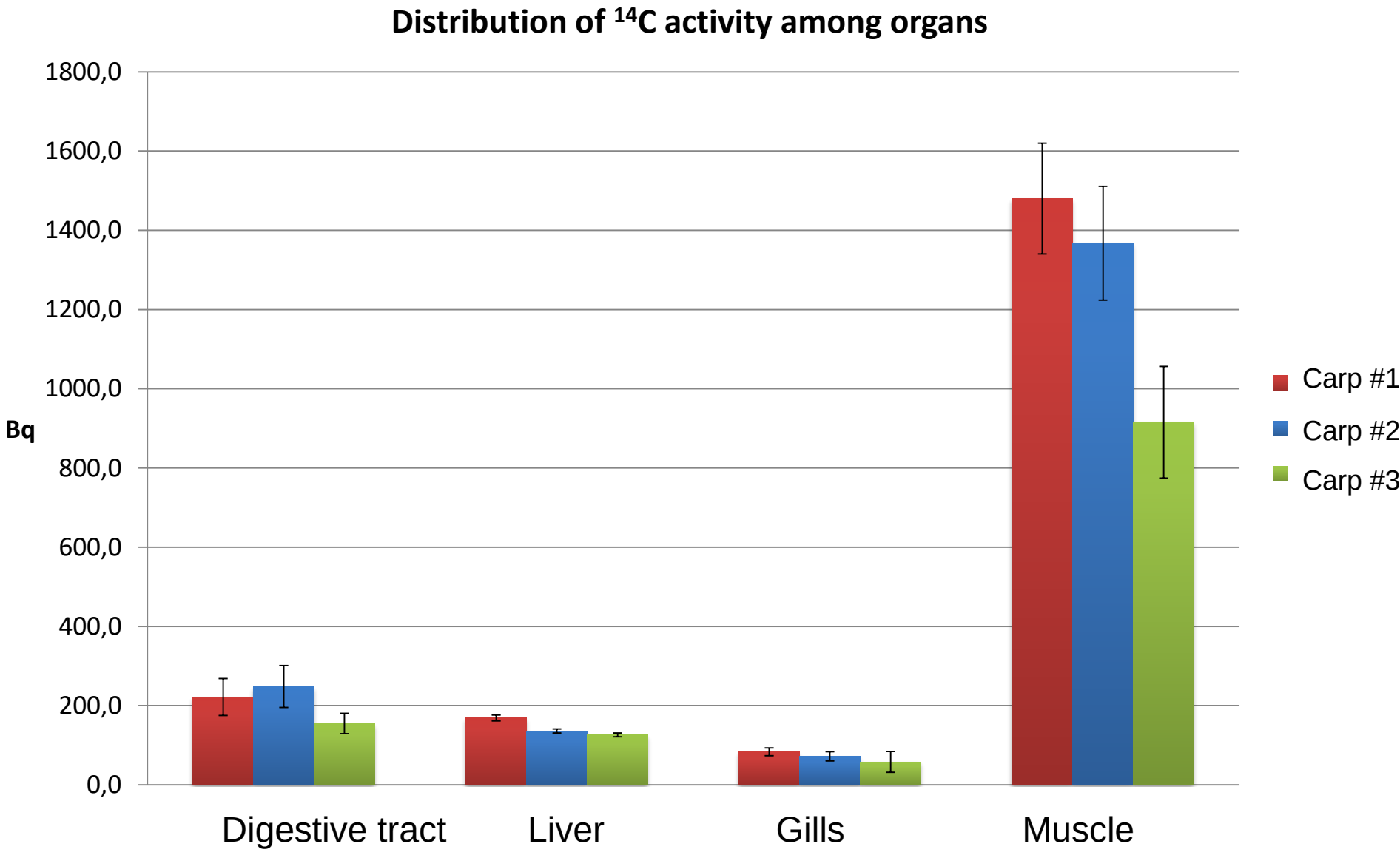
CONTAMINATION

1 2 3 4

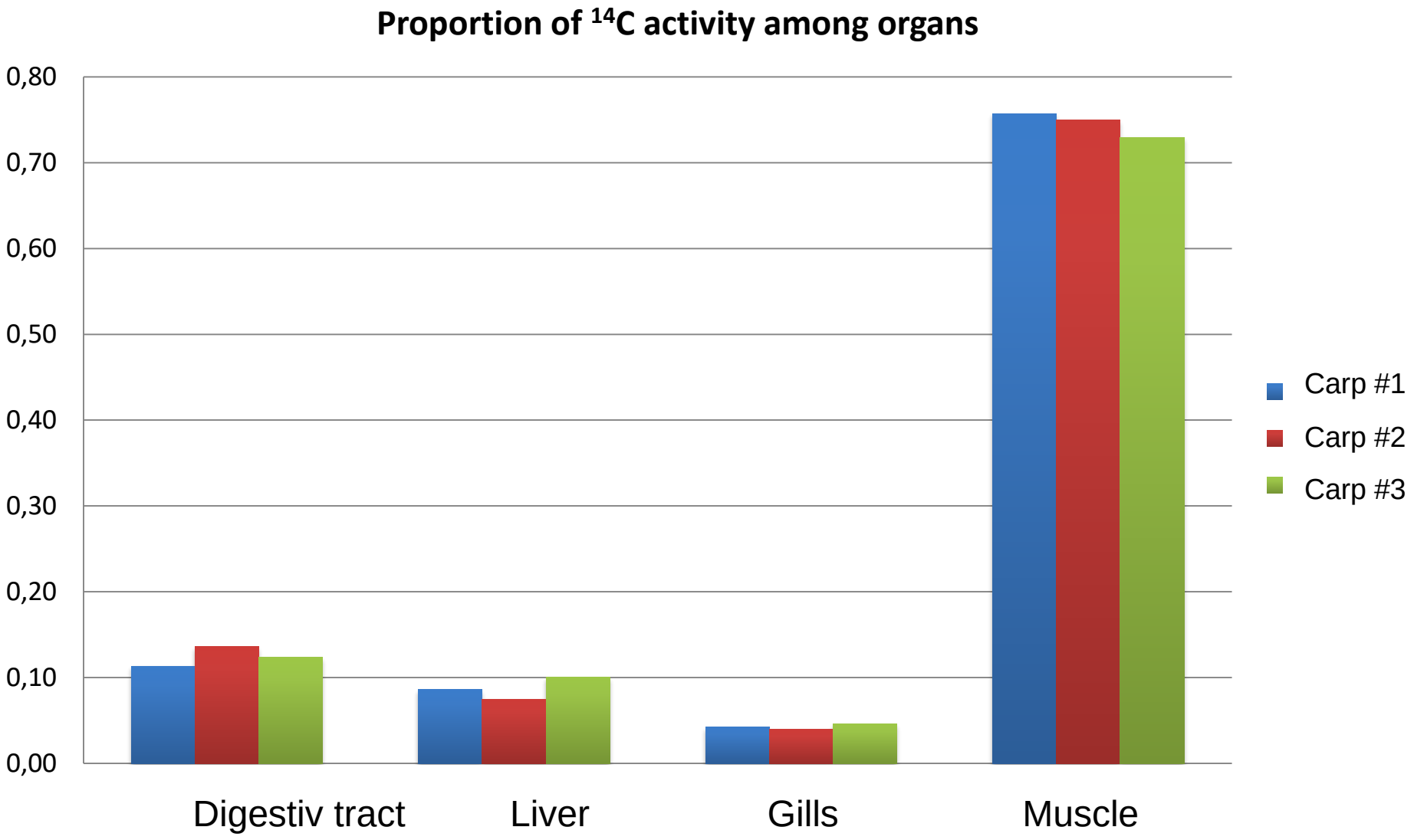
Results


Mass-specific activity of ^{14}C
2500,0
2000,0
1500,0
1000,0
500,0
0,0
Bq/g
Digestive tract
Liver
Gills
Muscle
Carp #1
Carp #2
Carp #3

Results

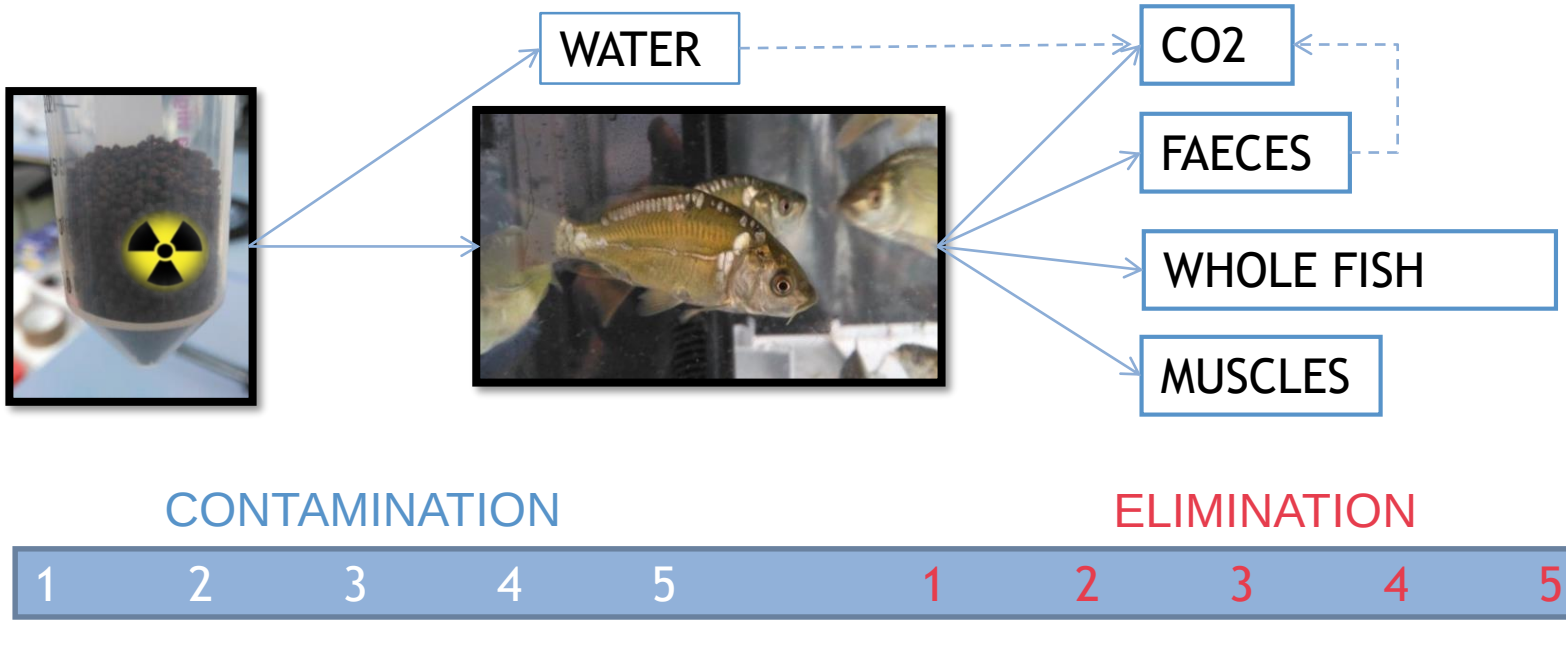

Distribution of 14C activity among organs
Bq
1800,0
1600,0
1400,0
1200,0
1000,0
800,0
600,0
400,0
200,0
0,0
Digestive tract
Liver
Gills
Muscle
Carp #1
Carp #2
Carp #3

Résults


Proportion of 14C activity among organs
0,80
0,70
0,60
0,50
0,40
0,30
0,20
0,10
0,00
Digestiv tract
Liver
Gills
Muscle
Carp #1
Carp #2
Carp #3

Experimental plan

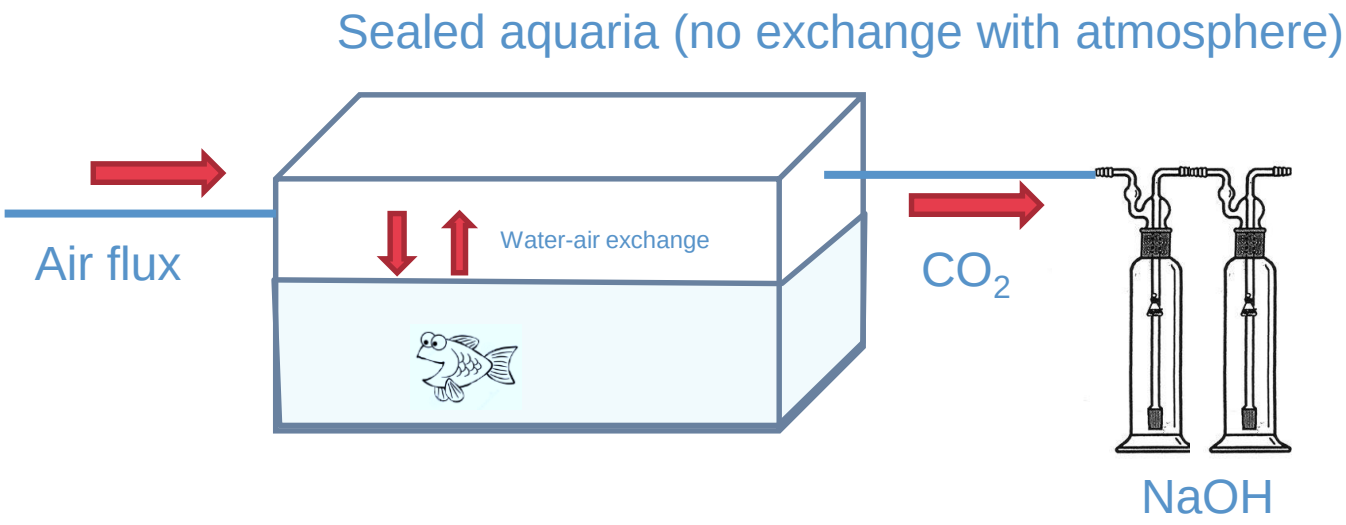
- ^{14}C kinetics in Common carp



CO_2 traps

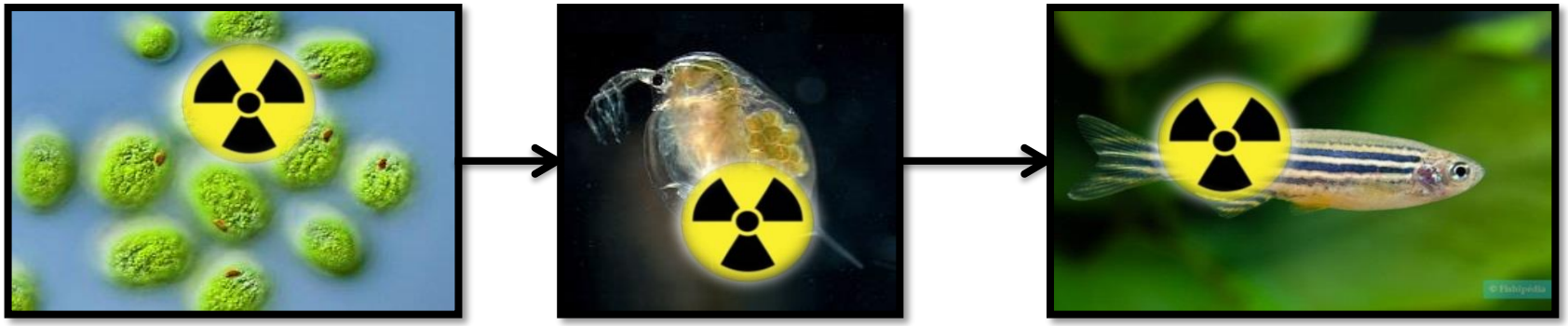
Objectif : Quantification of ^{14}C released through respiration

- To obtain ^{14}C complete budget among all metabolic processes.
- CO_2 gas traps will be set up with air bubbling in NaOH solution (1M).

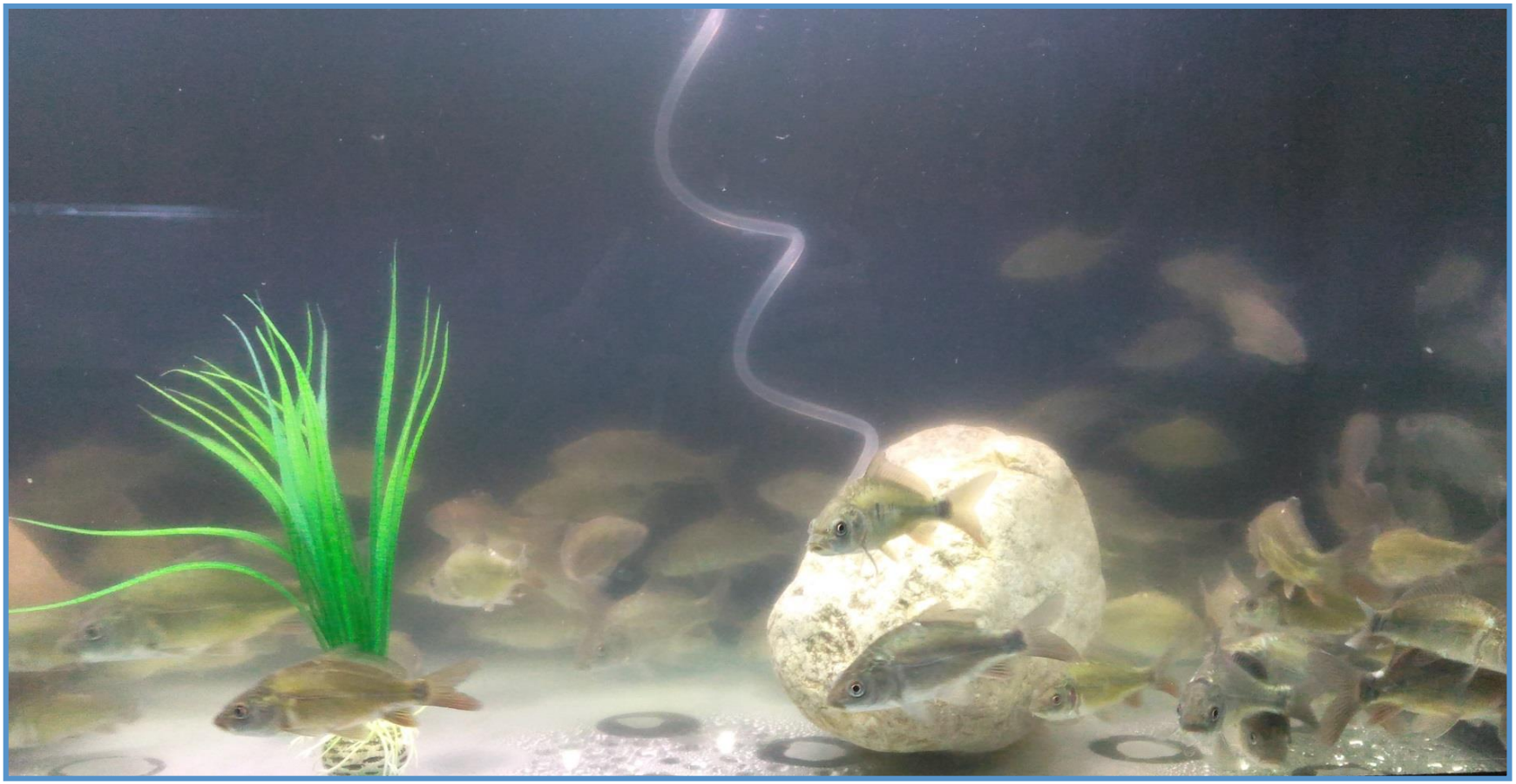


Experimental plan

- Model validation on a simple trophic chain

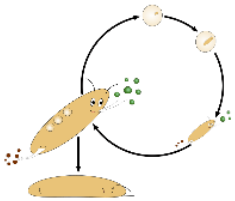


Thank for attention!



Scientific communication

- IRSN PhD congress 2018 (Poster) and 2019 (platform)
- Congress of Doctoral school (Aix-Marseille University)(Poster)
- Sixth International Symposium on DEB theory (Brest)



DEB2019 1-12 April 2019 / Brest (France)

Sixth International Symposium and Thematic School
on DEB theory for metabolic organization

	Bq/kg C		
Espèces	Min	Max	Moyenne
Silure glane	237	334	286
Perche	234	931	466
Lamproie marine	247		
Hotu	202	212	207
Grande alose	249		
Gardon	231	1262	453
Chevesne	200	2000	465
Carpe commune	559	581	570
Brochet	234	340	270
Brème commune	201	2830	1138
Barbeau fluviatile	204	2300	528
Anguille	213	1393	587