Radioecology

IAEA Environment Laboratories

works with its Member States and multiple partners worldwide to promote the safe, secure and peaceful use of nuclear technologies.

3 main areas of work underpin the IAEA's mission:

Safety and Security | Safeguards and Verification | **Science and Technology**

Department of Nuclear Sciences and Applications

Many applications

IAEA

Food & Agriculture

Human Health

Science & Industry

Water Resources

Environment


ENVIRONMENT

2 ZERO HUNGER

3 GOOD HEALTH

12 RESPONSIBLE CONSUMPTION

13 CLIMATE ACTION

14 LIFE BELOW WATER

17 PARTNERSHIPS FOR THE GOALS

Environmental issues

Ocean are increasingly threatened

- Historical chemical contamination (metal, nutrient, organics)
- Emerging new compounds
- Other pollutants (plastics)
- Change of abiotic conditions (pH, Temp and O_2)

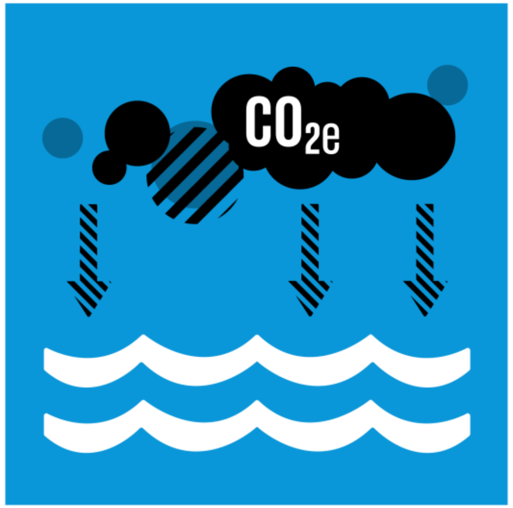
IAEA Environment Laboratories

14 LIFE BELOW WATER

TARGET 14·1

REDUCE MARINE POLLUTION

TARGET 14·3



REDUCE OCEAN ACIDIFICATION

TARGET 14·A

INCREASE SCIENTIFIC KNOWLEDGE, RESEARCH AND TECHNOLOGY FOR OCEAN HEALTH

14 LIFE BELOW WATER

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

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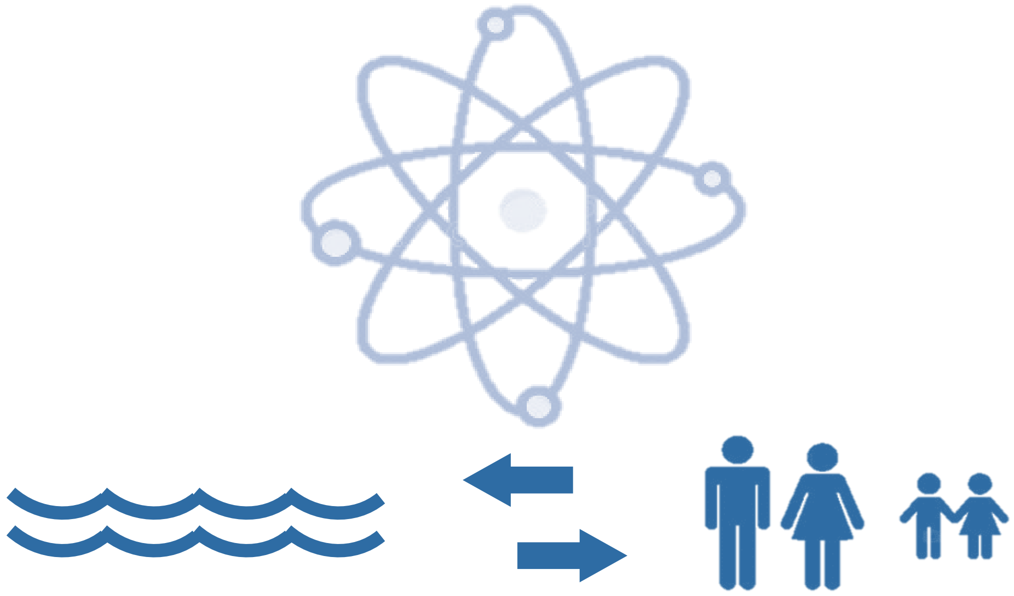
Important role of Science and Technology

in order to understand risks and to improve situation



This includes Nuclear and Isotopic techniques (NIT)

What are these techniques ?

Nuclear and Isotopic techniques (NIT):
Any techniques that are using the characteristics of radio-isotopes and isotopes

*Different **isotopes** of the same element have the same number of protons in their atomic nuclei but differing numbers of neutrons.*

Same > chemical element, number of protons (thus same atomic number)

Different > number of neutrons (thus different mass number)

***Radioisotopes** are **radioactive isotopes** of an element.*
They can also be defined as atoms that contain an unstable combination of neutrons and protons, or excess energy in their nucleus.

What are these techniques ?

Environment Laboratories

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Understanding the environment applying isotopic and nuclear techniques

- to study environmental processes in time and space;
- to study pollution and its temporal evolution;
- to recognise and identify polluters by their typical isotopic pattern;
- to contribute to climate change studies;
- to conduct radioecological studies and assessments;

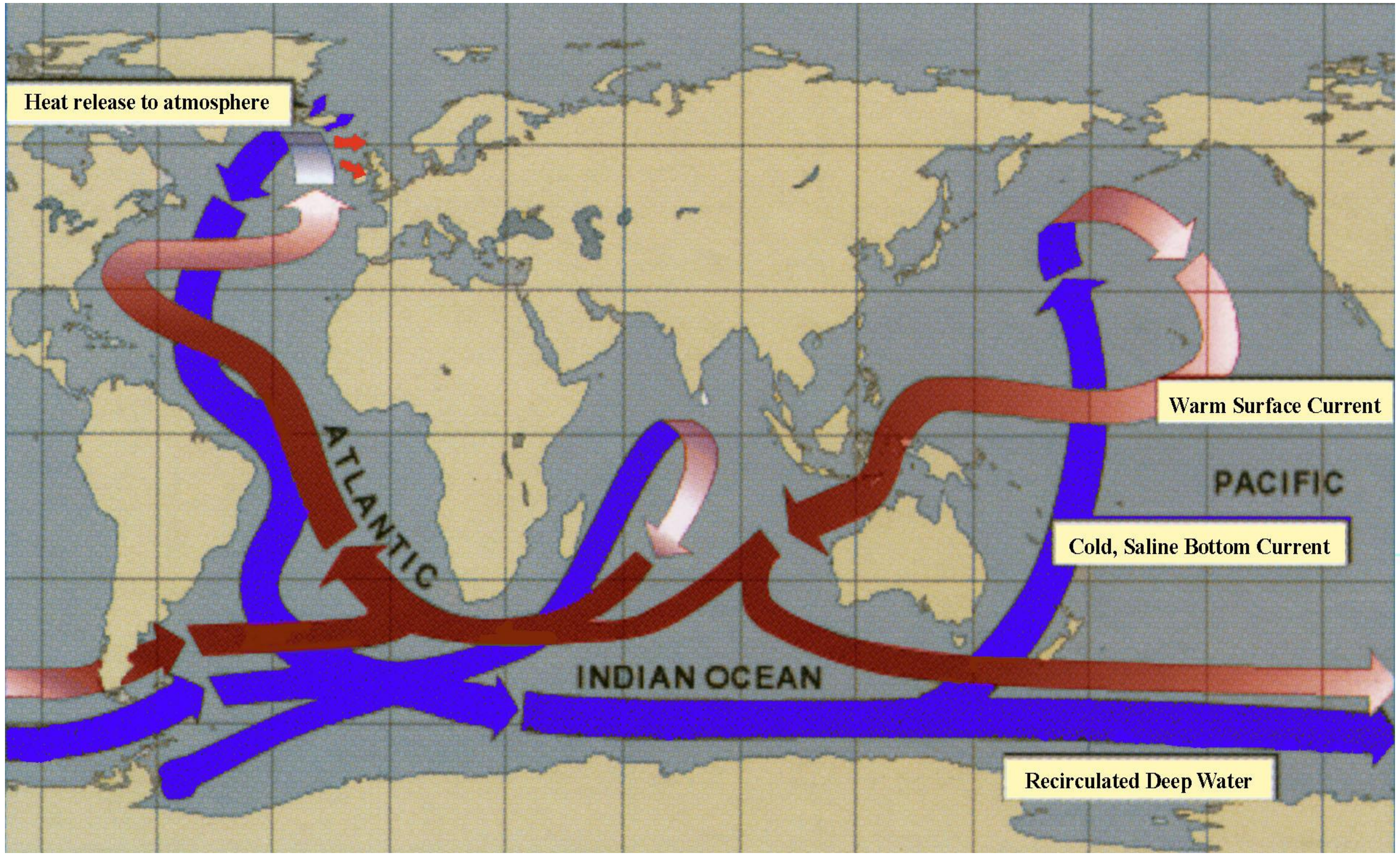
Marine radioecology

Marine radioecology examines how radioactive substances interact with marine environment and the various mechanisms and processes that influence radionuclides migration in the marine ecosystem

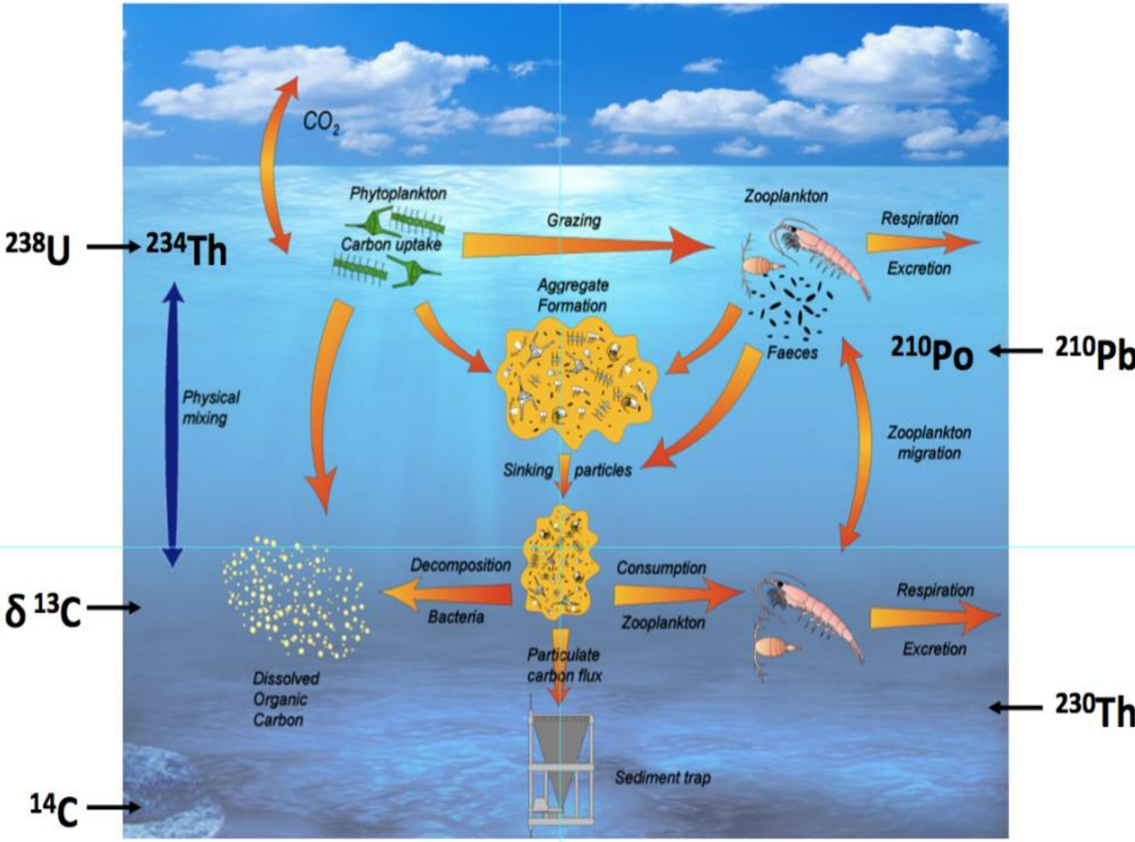
The field of study includes aspects of field sampling, design of the field and laboratory radiotracer experiments, the development of predictive simulation models, dose assessments to humans and biotas

From Scott W. Fowler

Radionuclides as tracers of oceanographic processes



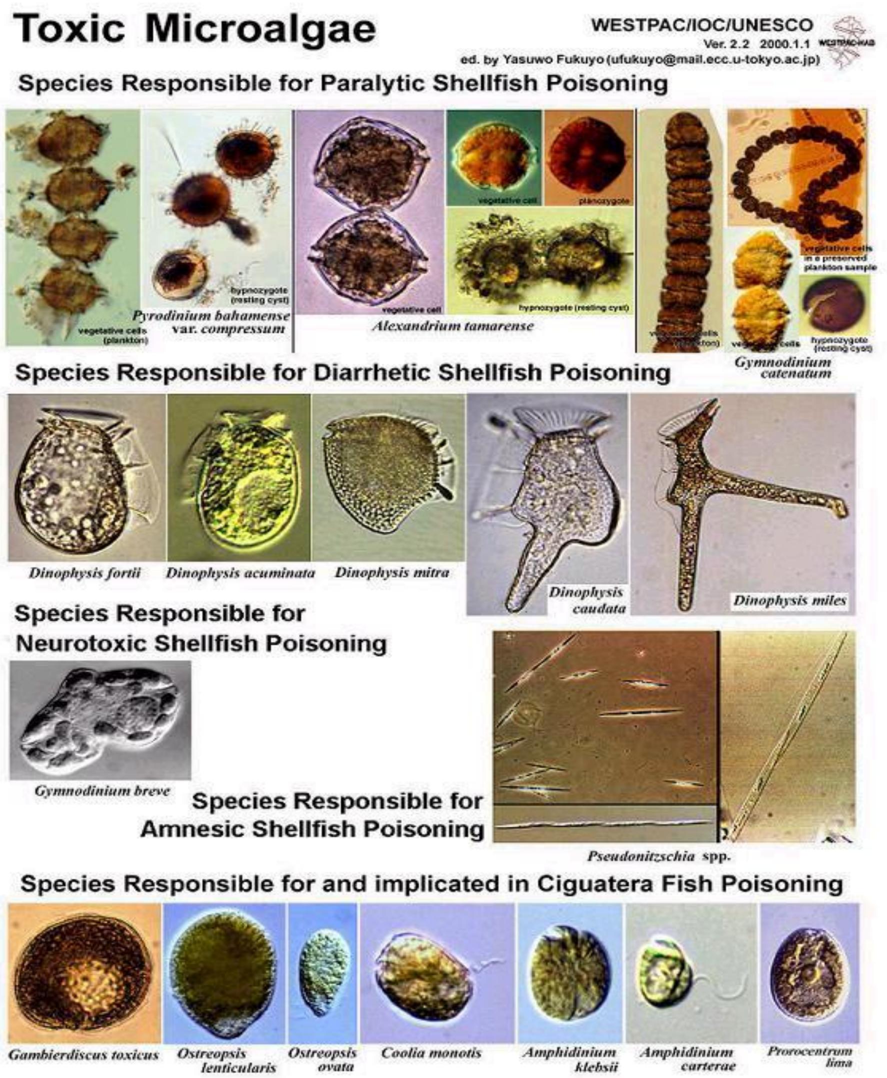
Conveyor Belt (earth climate driver)

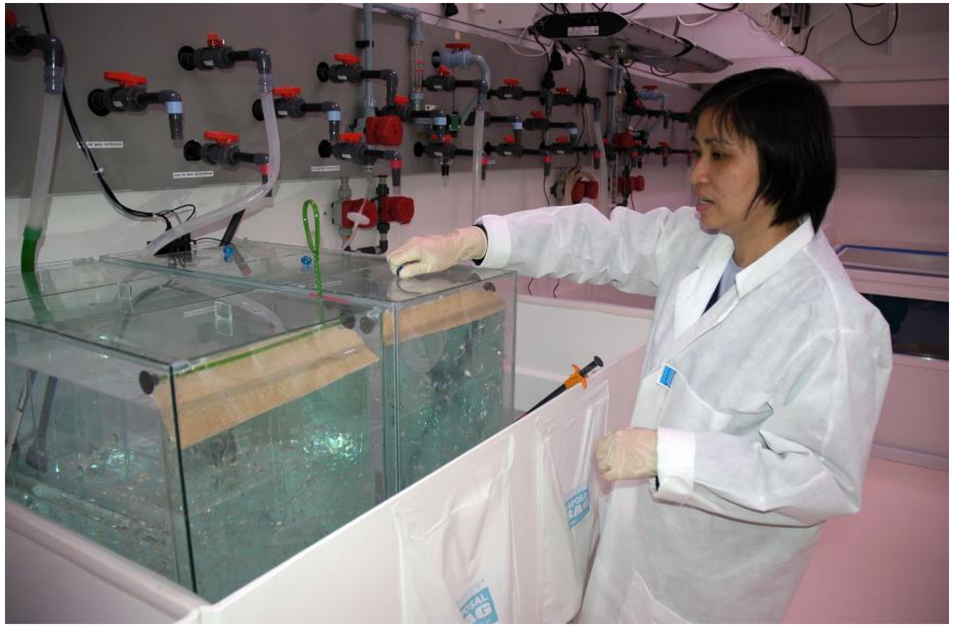


Carbon Cycle

^{3}H, ^{3}He, ^{14}C, ^{90}Sr, ^{99}Tc, ^{129}I, ^{137}Cs, ^{236}U

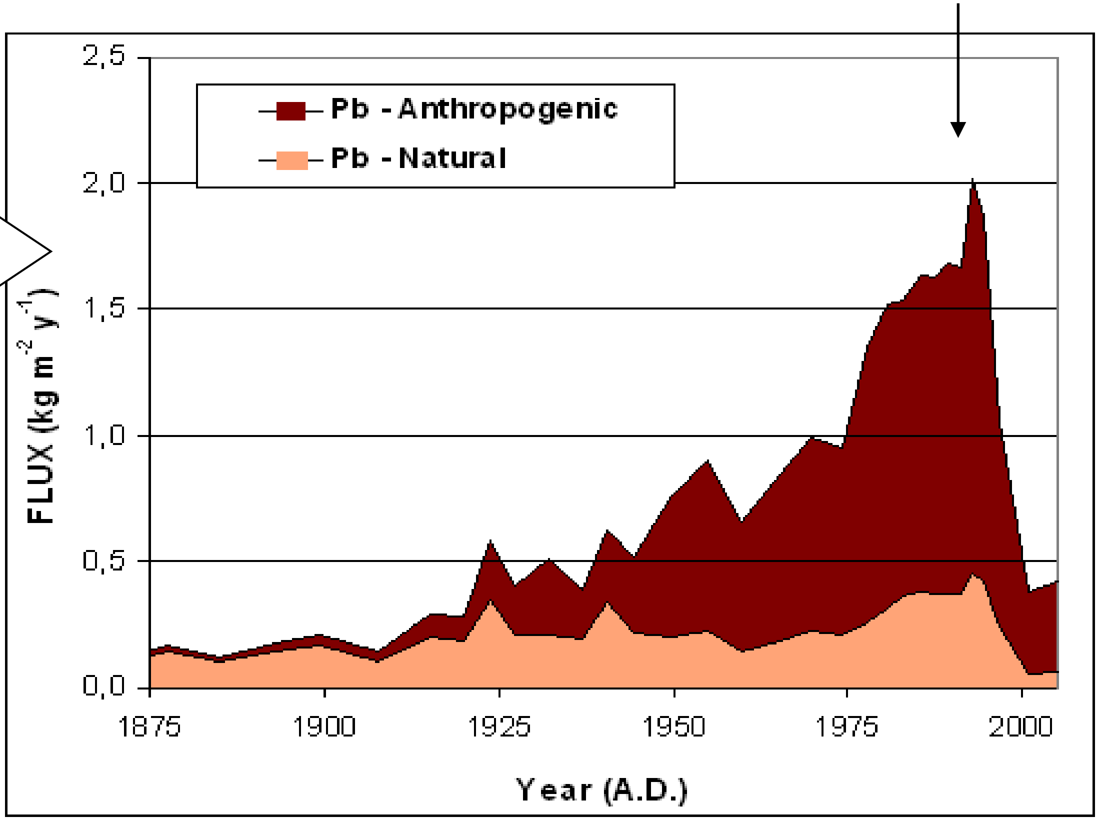
Seafood Safety - Harmful Algal Blooms (marine toxins)





Pollution studies, monitoring, coastal zone management

La Habana Bay: government implemented corrective actions in the 1990s



Main categories and interest (Marine Environment)

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Radioisotopes

- As a contaminant (^{134}Cs, ^{137}Cs, ^{60}Co, Po, Americium)
- As an element of interest (essential or not):
  - e.g. Ag, Pb, Cd, Hg, Ni, Ca, Zn, Co, Mn, Se, C
- To label a contaminant or molecule of interest (e.g. ^{14}C organics, ^{3}H-petides)
- As a proxi to highlight physiological effect of another stressor
  (e.g. plastics, Global and local, toxins,…)
  to understand environment such as water masses or geochronology
  (natural and anthropogenic radionuclides)

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  (e.g. plastics, Global and local, toxins,…)

  to understand environment such as water masses or geochronology

  (natural and anthropogenic radionuclides)

Stable isotopes

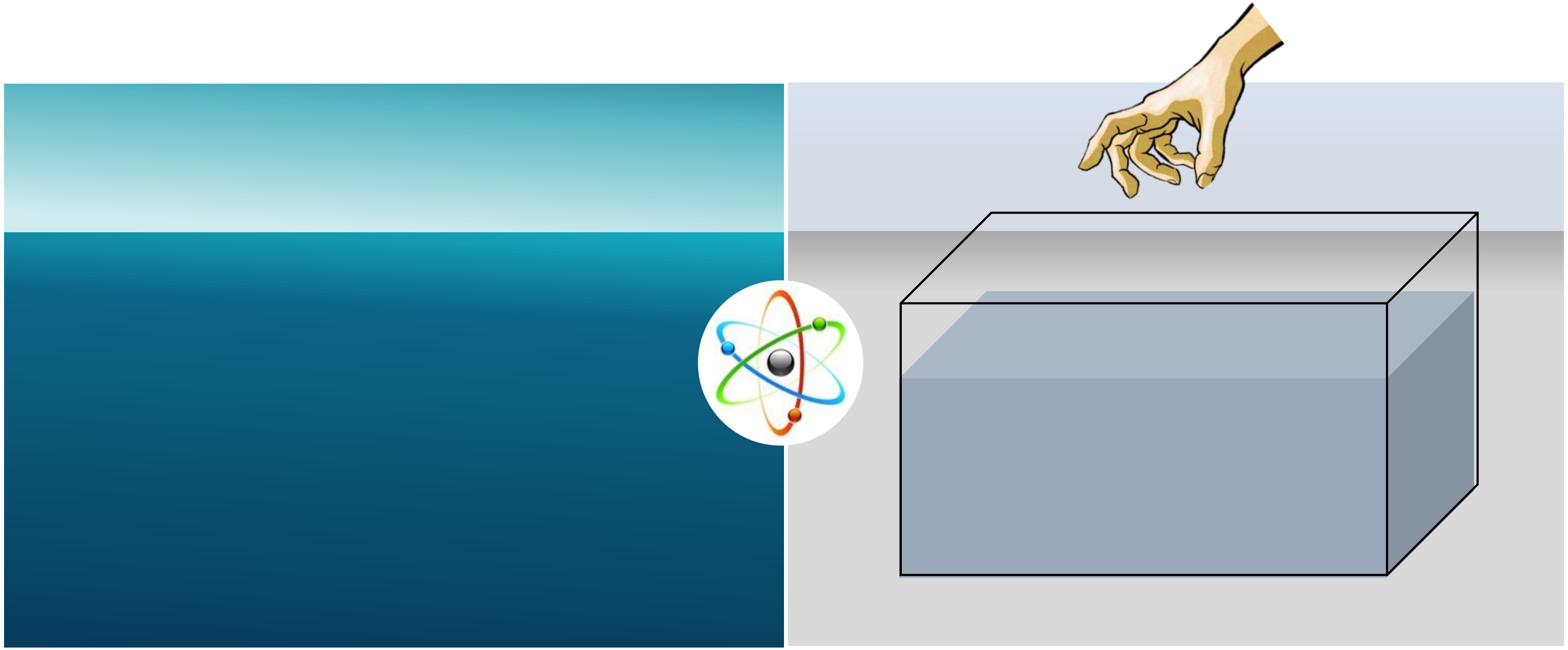
- As a proxi to characterize ecosystem dynamics or physiological effect of another stressor

Equipment/ Analytical techniques

Nuclear magnetic resonance (metabolites), IRMS (isotopes) FTIR (Plastics), X-ray spectrometry

Marine Environment Laboratories

Radioecology Laboratory



Experiments using NA for understanding:

Contamination, Biology, Ecology, Risk

Mimicking or predicting environmental conditions

Radiotracers used in experimental radioecology

Gamma emitters:

^{51}Cr, ^{54}Mn, ^{57}Co, ^{65}Zn, ^{73}As, ^{110m}Ag, ^{109}Cd, ^{134}Cs, ^{203}Hg, ^{210}Pb

Beta emitters:

^{14}C, ^{3}H, ^{45}Ca, ^{63}Ni

Surfactants, Pesticides, PCB

→ Bioaccumulation of contaminants

→ Physiological endpoints after exposure (proxy)

→ Sourcing main uptake pathway

A Unique Tool in Ecotoxicological Studies

Highly sensitive and the cost-effective

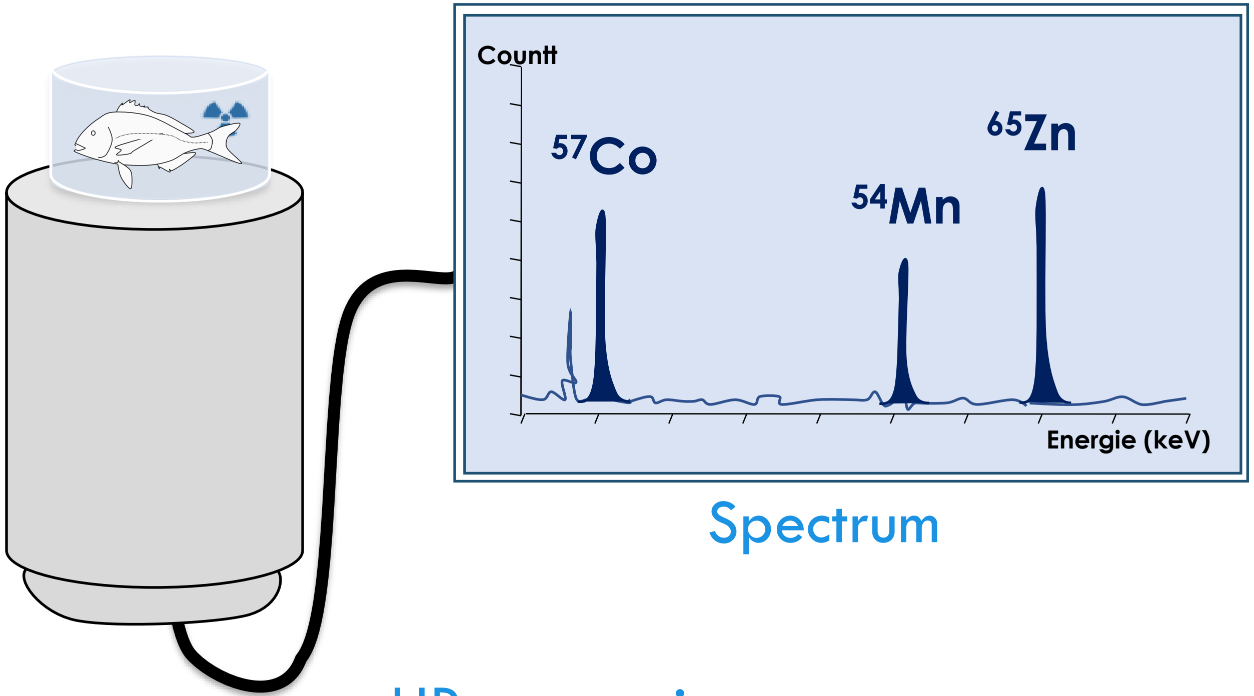
- Radioanalysis of live organisms (gamma)
- Experiments conducted under realistic exposure conditions
- Relative contribution of different contamination pathways

See review of Warnau & Bustamante 2007

Measurements of radiotracers

Gamma spectroscopy

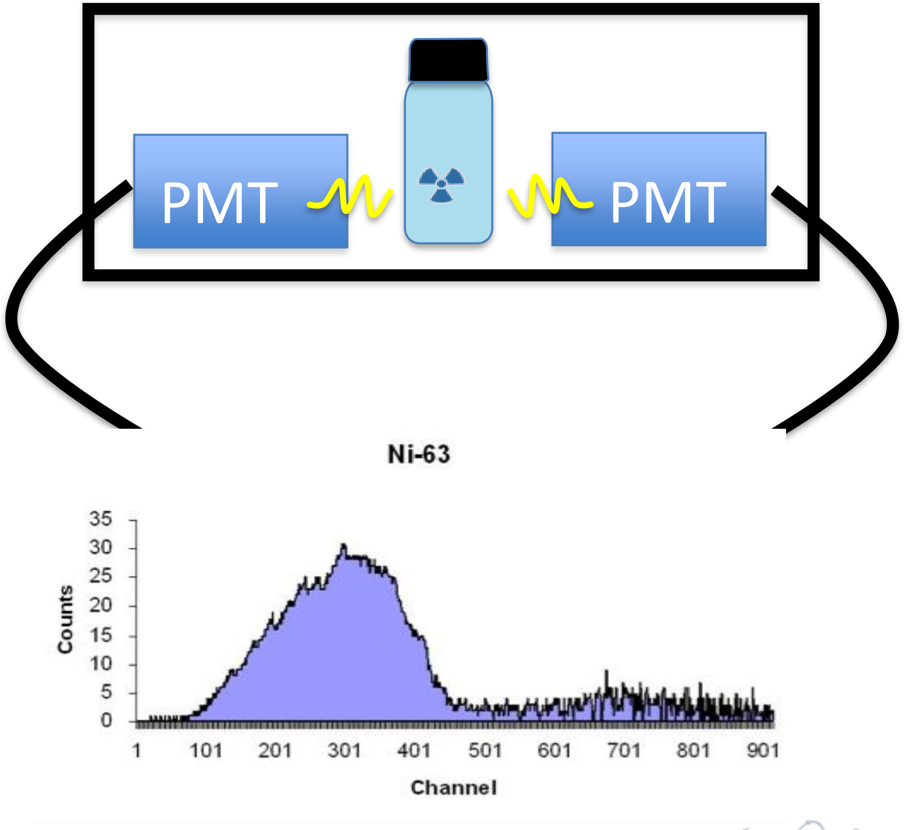
Germanium or NaI counters

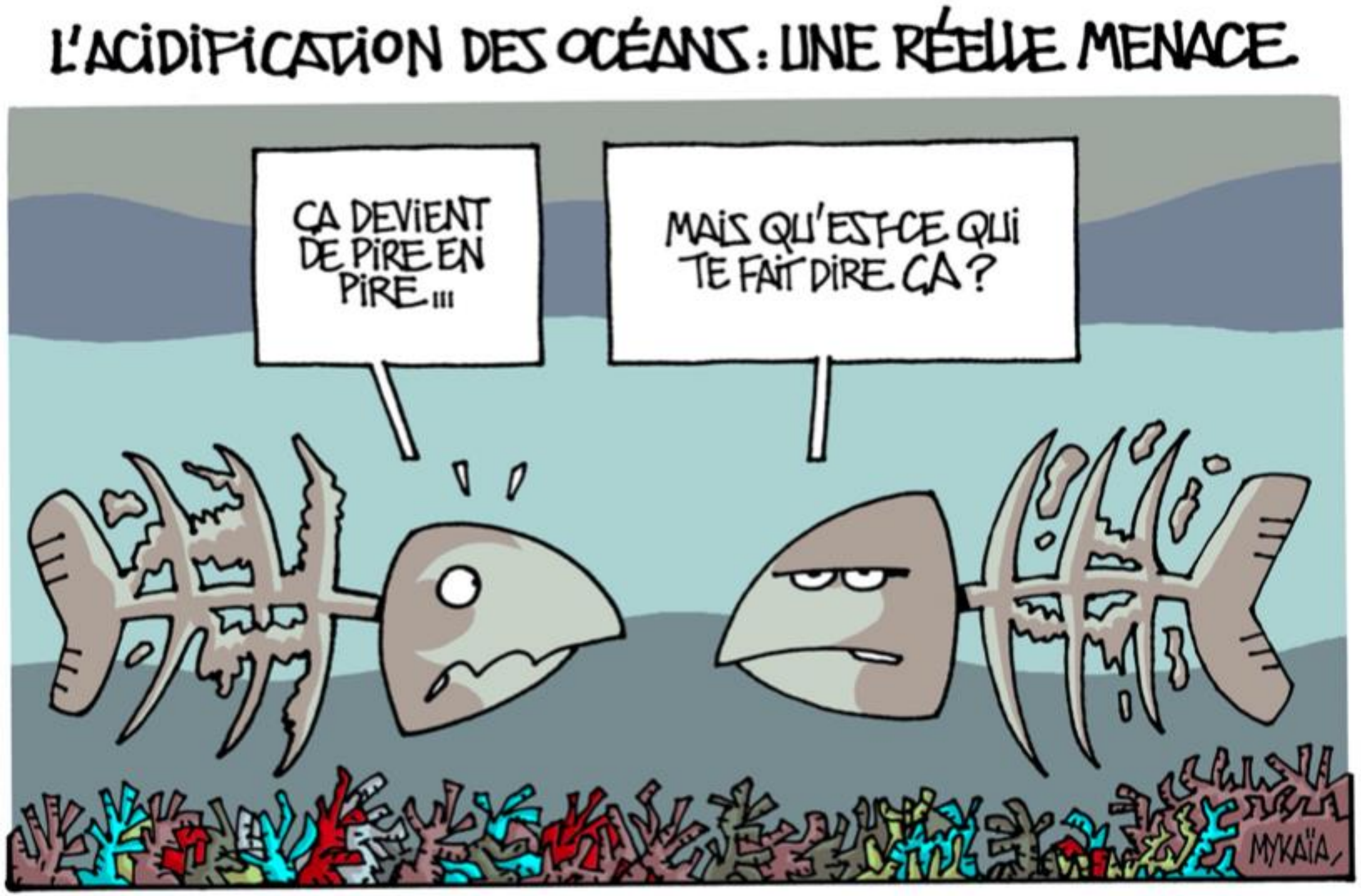


Spectrum

HP germanium
HPGe detector

Liquid scintillation counters





« It seems that worse comes to worst »

« Why are you saying that ? »

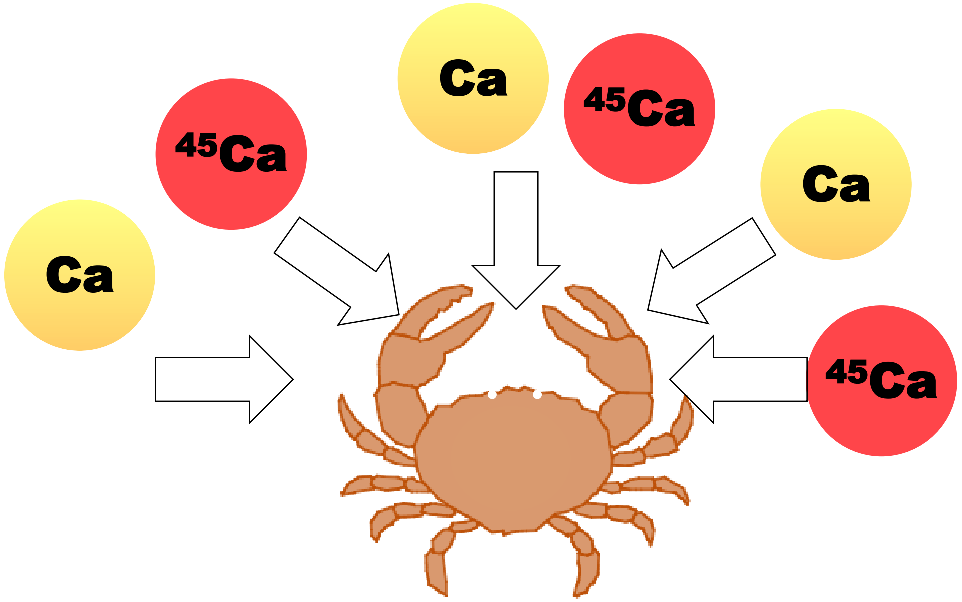
ACID REEFS. N°3

CRIOBE USR3278

Fondation de France

Radiotracers and Ocean Acidification

Calcification



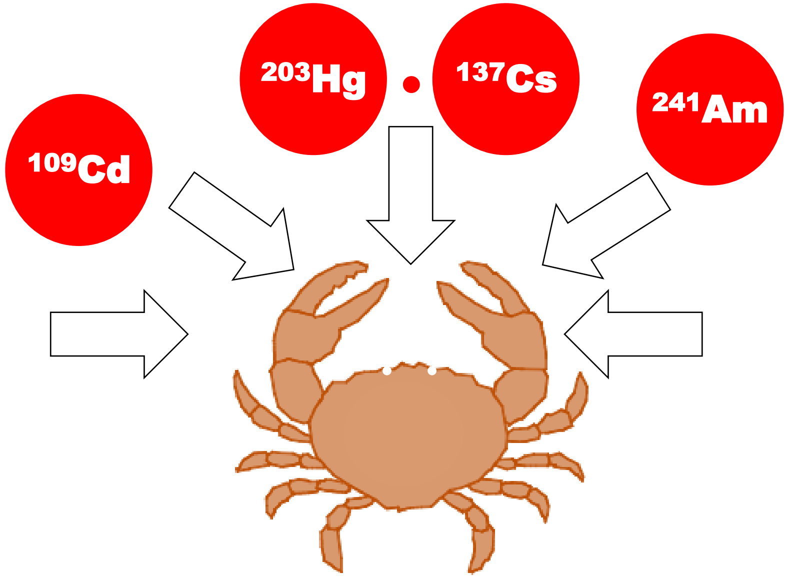
Use of radiotracer (ß-emitter) to measure impact of OA on calcifiers

↓

Production of commercial species (mussel, oyster, sea urchin, squid,…)

High-value ecosystem such as coral reefs (high biodiversity, tourism,…)

Accumulation (multiple stress)



Use of radiotracer (γ-emitter) to measure impact of OA on pollutants availability

↓

Possible toxic impact on organisms

Concentration in seafood for human risk assessment

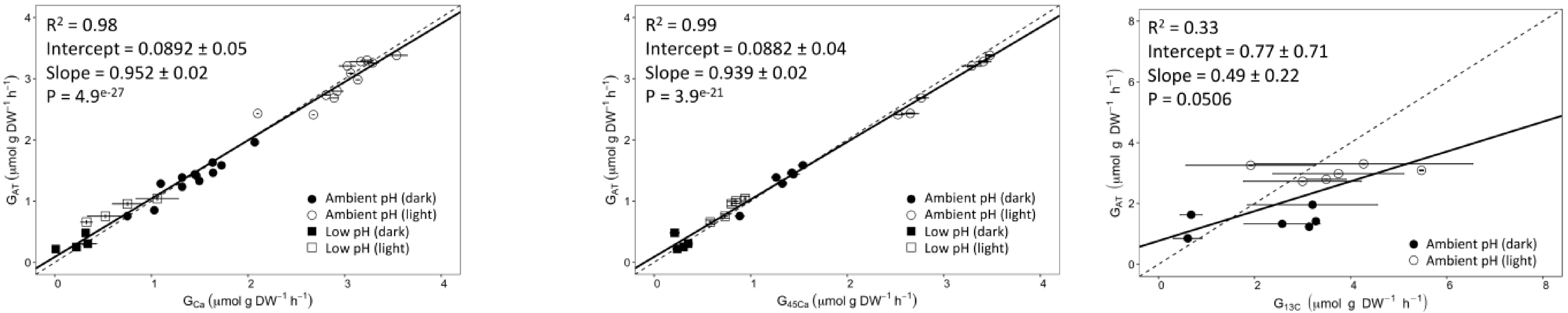
Biogeosciences, 17, 887–899, 2020
https://doi.org/10.5194/bg-17-887-2020

Biogeosciences Open Access EGU

Intercomparison of four methods to estimate coral calcification under various environmental conditions

Miguel Gómez Batista[1], Marc Metian[2], François Oberhänsli[2], Simon Pouil[2], Peter W. Swarzenski[2], Eric Tambutté[3], Jean-Pierre Gattuso[4,5], Carlos M. Alonso Hernández[1], and Frédéric Gazeau[4]

Total alkalinity anomaly (TAA) vs calcium anomaly vs ^{45}Ca incorporation vs ^{13}C incorporation



Coral Reefs (2020) 39:1635–1647
https://doi.org/10.1007/s00338-020-01991-x

Check for updates

REPORT

Ocean acidification effects on calcification and dissolution in tropical reef macroalgae

C. McNicholl[1,2] · M. S. Koch[1] · P. W. Swarzenski[2] · F. R. Oberhaensli[2] · A. Taylor[2] · M. Gómez Batista[3] · M. Metian[2]

Ca45 --> Gross calcification

Total alkalinity anomaly (TAA) --> Net calcification = gross calcification minus gross dissolution

Techniques used in tandem

provide the best opportunity to separate the effects of OA on calcification versus dissolution

Effect on the chemistry (not only on arbonate chemistry)

Example with metals

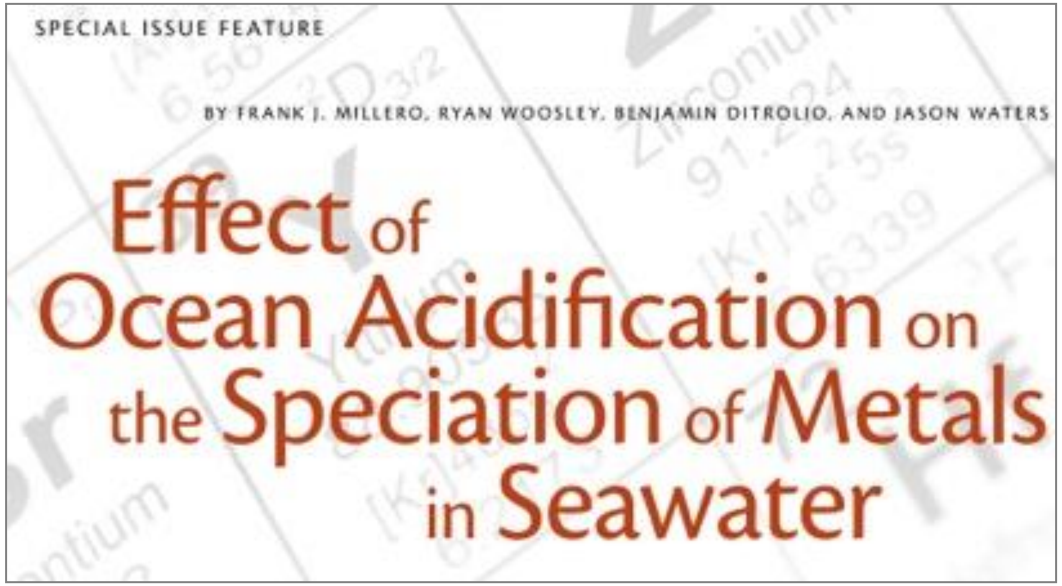


Table 1. The fraction forms of metals in seawater as a function of pH and time (Caldeira and Wickett, 2003) at 25°C and salinity of 35. Species contributing less than 5% are not included. All the calculations are made on the free pH scale.

YEAR	2000	2050	2070	2085	2100	2150	2200	2250
pH	8.1	8	7.9	7.8	7.7	7.6	7.5	7.4
MAJOR SPECIES								
Cu^{2+}	7.67	9.64	12.04	14.92	18.32	22.26	26.75	31.76
$CuOH^{+}$	4.70	4.70	4.66	4.59	4.47	4.30	4.12	3.88
$CuCO_3$	66.98	68.51	69.25	69.14	68.14	66.25	63.50	59.96
$Cu(CO_3)_2^{2-}$	18.34	15.26	12.49	10.05	7.95	6.18	4.70	3.55
$CuSO_4$	-	-	-	-	-	-	-	-

Free ions

Most toxic form

$[Cu^{2+}]$ augmente!!!

Marine Pollution Bulletin 156 (2020) 111203

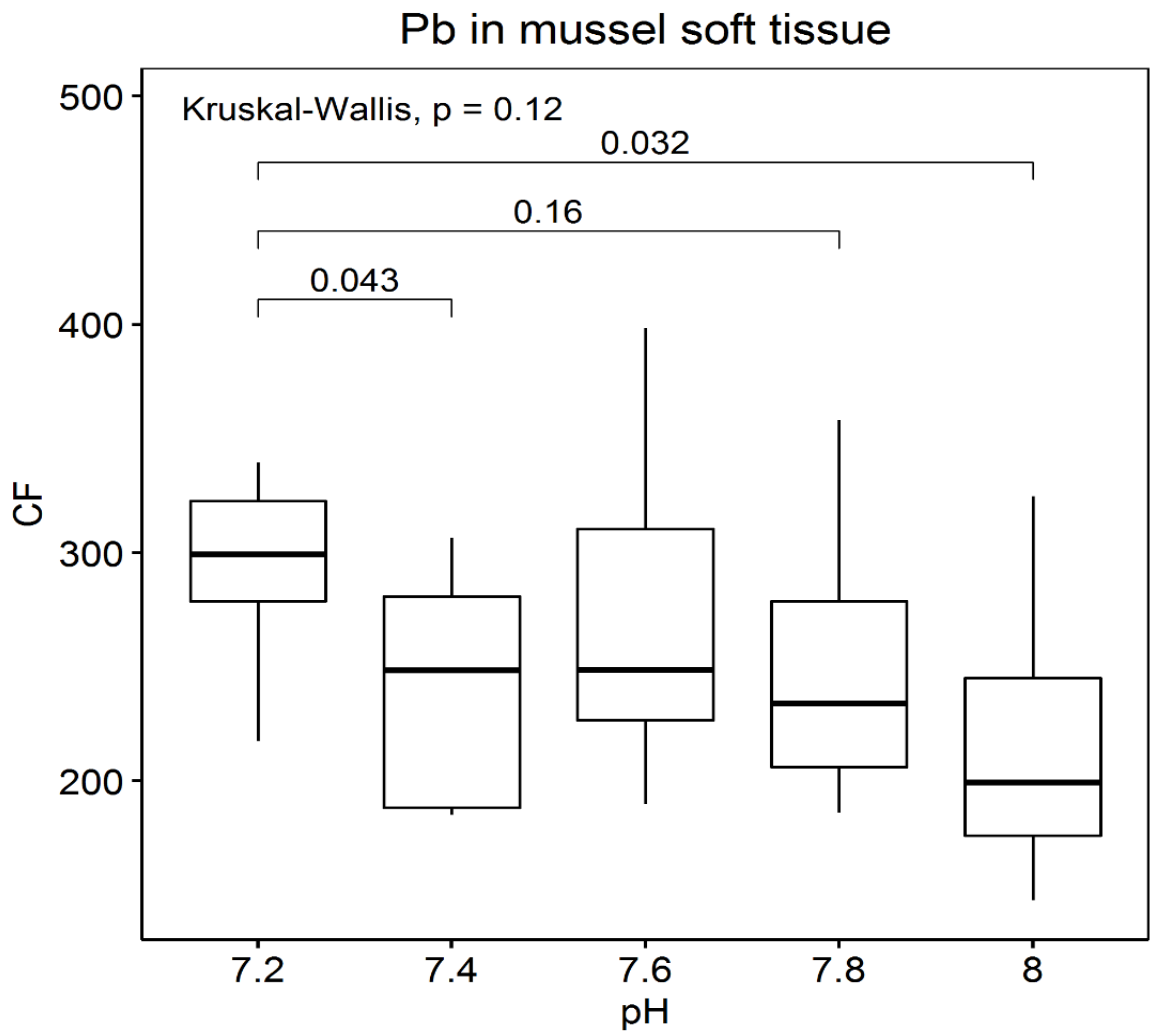
Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Influence of pH on Pb accumulation in the blue mussel, *Mytilus edulis*

Murat Belivermiş[a,*], Marc Besson[b], Peter Swarzenski[b], François Oberhaensli[b], Angus Taylor[b], Marc Metian[b]



SPECIAL ISSUE FEATURE

BY FRANK J. MILLERO, RYAN WOOSLEY, BENJAMIN DITROLIO, AND JASON WATERS

Effect of Ocean Acidification on the Speciation of Metals in Seawater

WELL KNOWN FOR COPPER

Free ions

Most toxic form

[Cu^{2+}] Increase!!!

YEAR	2000	2050	2070	2085	2100	2150	2200	2250
pH	8.1	8	7.9	7.8	7.7	7.6	7.5	7.4
MAJOR SPECIES								
Pb^{2+}	2.89	3.29	3.70	4.13	4.56	4.99	5.39	5.77
$PbOH^{+}$	4.24	3.83	3.40	3.03	2.66	2.31	1.98	1.68
$PbCO_3$	59.03	54.53	49.72	44.71	39.64	34.65	29.88	25.43
$PbCl^{+}$	13.09	14.86	16.74	18.68	20.63	22.54	24.37	26.07
$PbCl_2$	14.09	16.00	18.02	20.10	22.21	24.60	26.23	28.06
$PbCl_3^-$	6.40	7.27	8.19	9.14	10.09	11.03	11.93	12.76

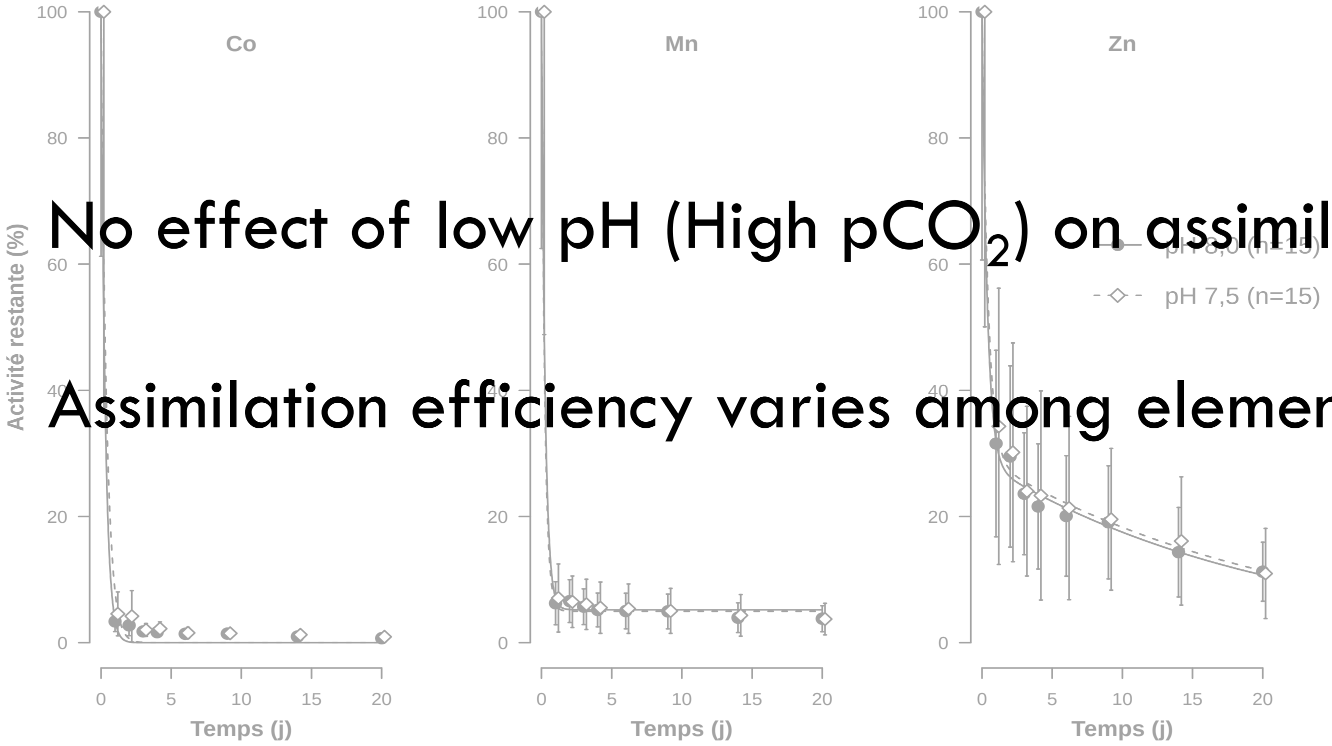
For Pb > big shift of fraction in major species

PLOS | ONE

RESEARCH ARTICLE

Trophic transfer of essential elements in the clownfish *Amphiprion ocellaris* in the context of ocean acidification

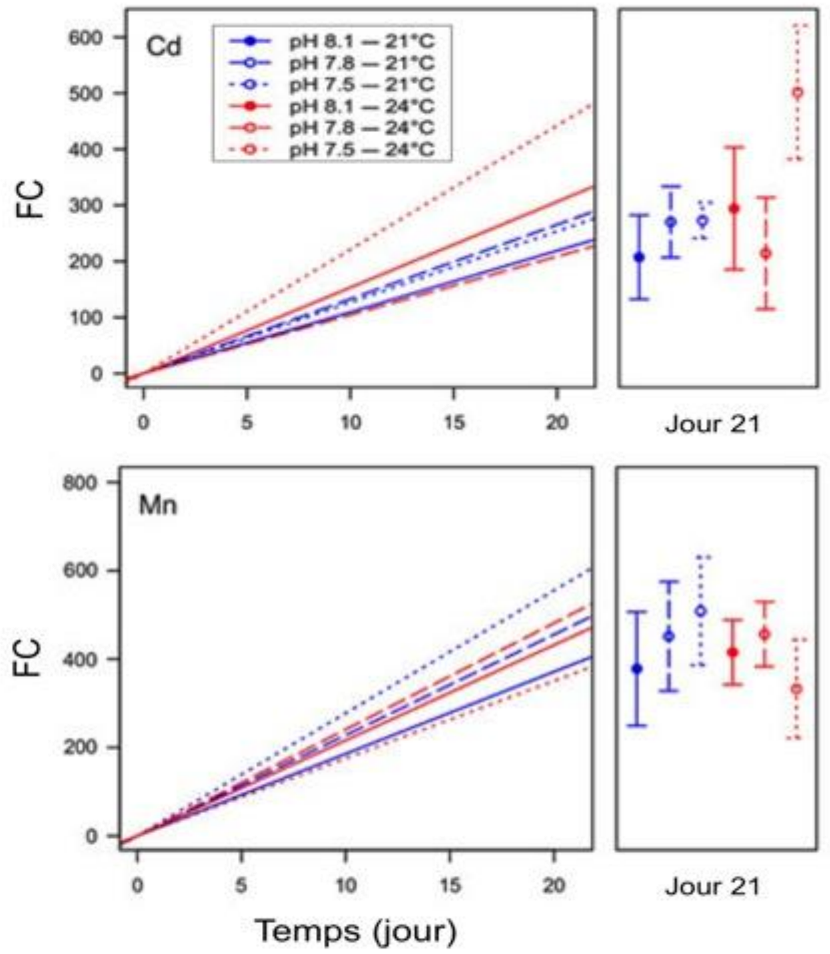
Hugo Jacob[1,2], Simon Pouil[1,3], David Lecchini[2,4], François Oberhänsli[1], Peter Swarzenski[1], Marc Metian[1]*

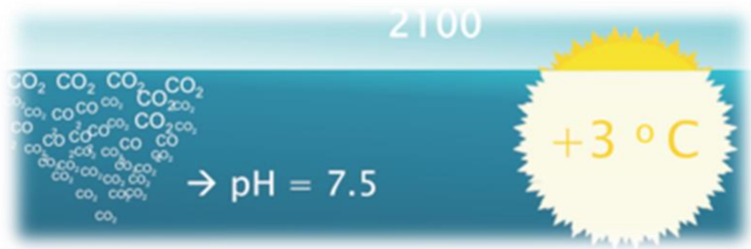


- No effect of low pH (High pCO_2) on assimilation
- Assimilation efficiency varies among elements

OA and temperature on element bioaccumulation

3 pH & 2 temperatures – waterborne - oysters





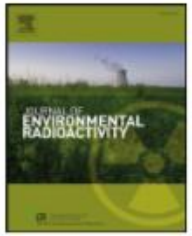
Belivermiş et al. ICES J Mar Sci 2016

Journal of Environmental Radioactivity 192 (2018) 10–13

Contents lists available at ScienceDirect

Journal of Environmental Radioactivity

journal homepage: www.elsevier.com/locate/jenvrad



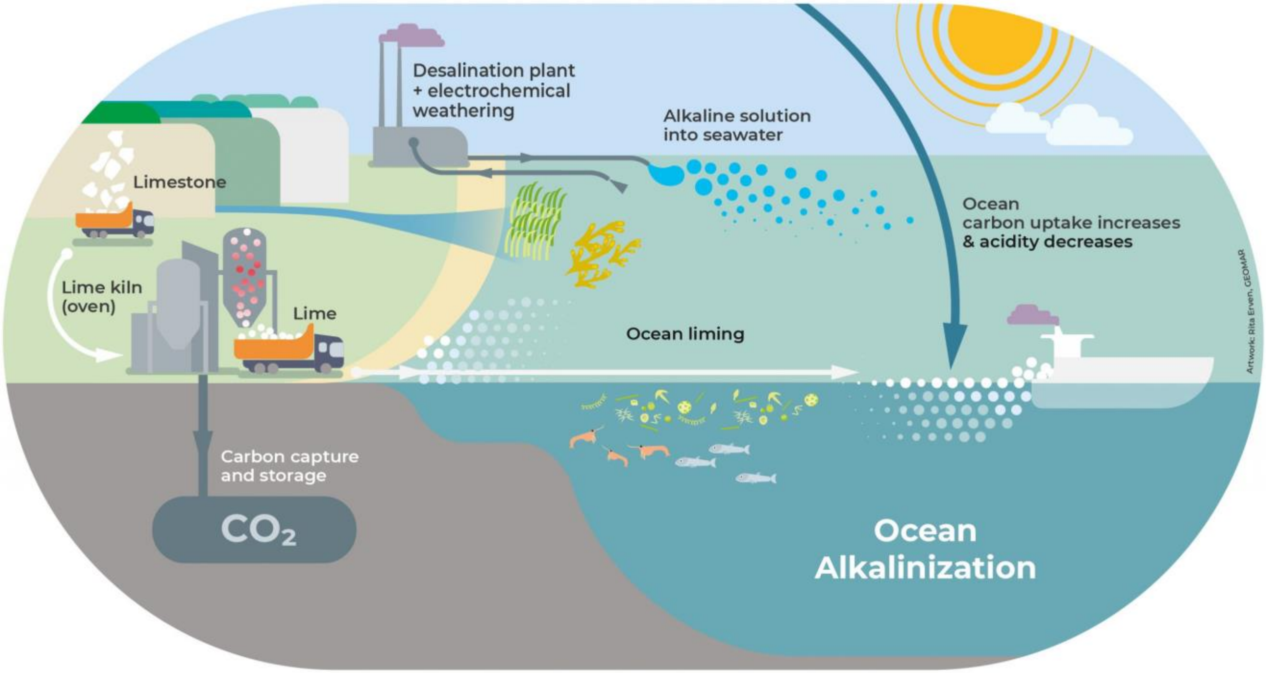
The absence of the pCO$_2$ effect on dissolved ^{134}Cs uptake in select marine organisms

Thomas Lacoue-Labarthe[a,b,*], François Oberhänsli[a], Jean-Louis Teyssié[a], Marc Metian[a]

[a] *International Atomic Energy Agency, Environment Laboratories, 4a Quai Antoine Ier, Monaco*

[b] *Littoral Environnement et Sociétés (LIENSs), UMR 7266 CNRS, Université de La Rochelle, 2 rue Olympe de Gouges, La Rochelle, France*

Next step in our lab … alkalinization.



Published: 24 February 2016

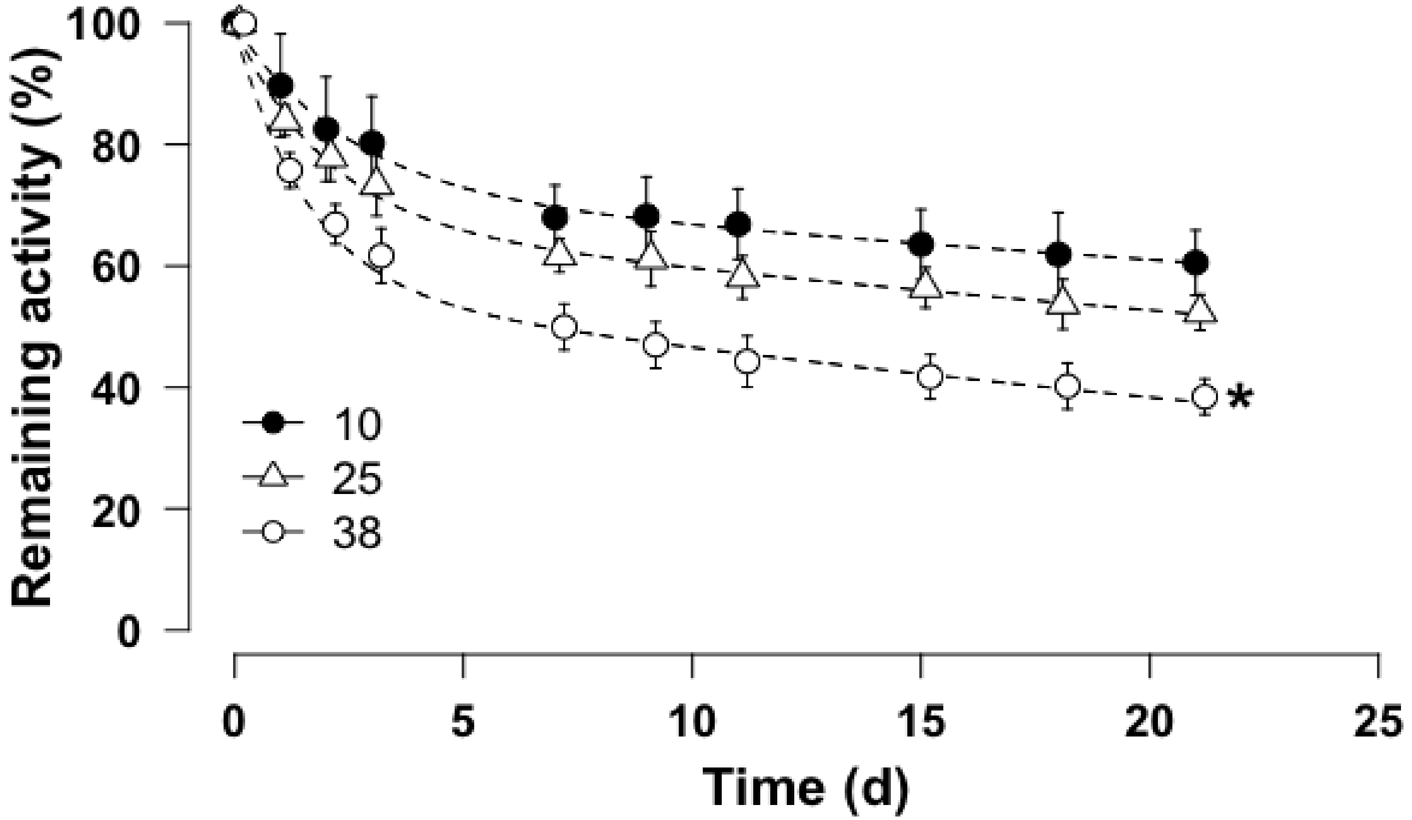
Reversal of ocean acidification enhances net coral reef calcification

Rebecca Albright, Lilian Caldeira, Jessica Hosfelt, Lester Kwiatkowski, Jana K. Maclaren, Benjamin M. Mason, Yana Nebuchina, Aaron Ninokawa, Julia Pongratz, Katharine L. Ricke, Tanya Rivlin, Kenneth Schneider, Marine Sesboüé, Kathryn Shamberger, Jacob Silverman, Kennedy Wolfe, Kai Zhu & Ken Caldeira

Nature **531**, 362–365 (2016) | Cite this article

Environmental variable or issues

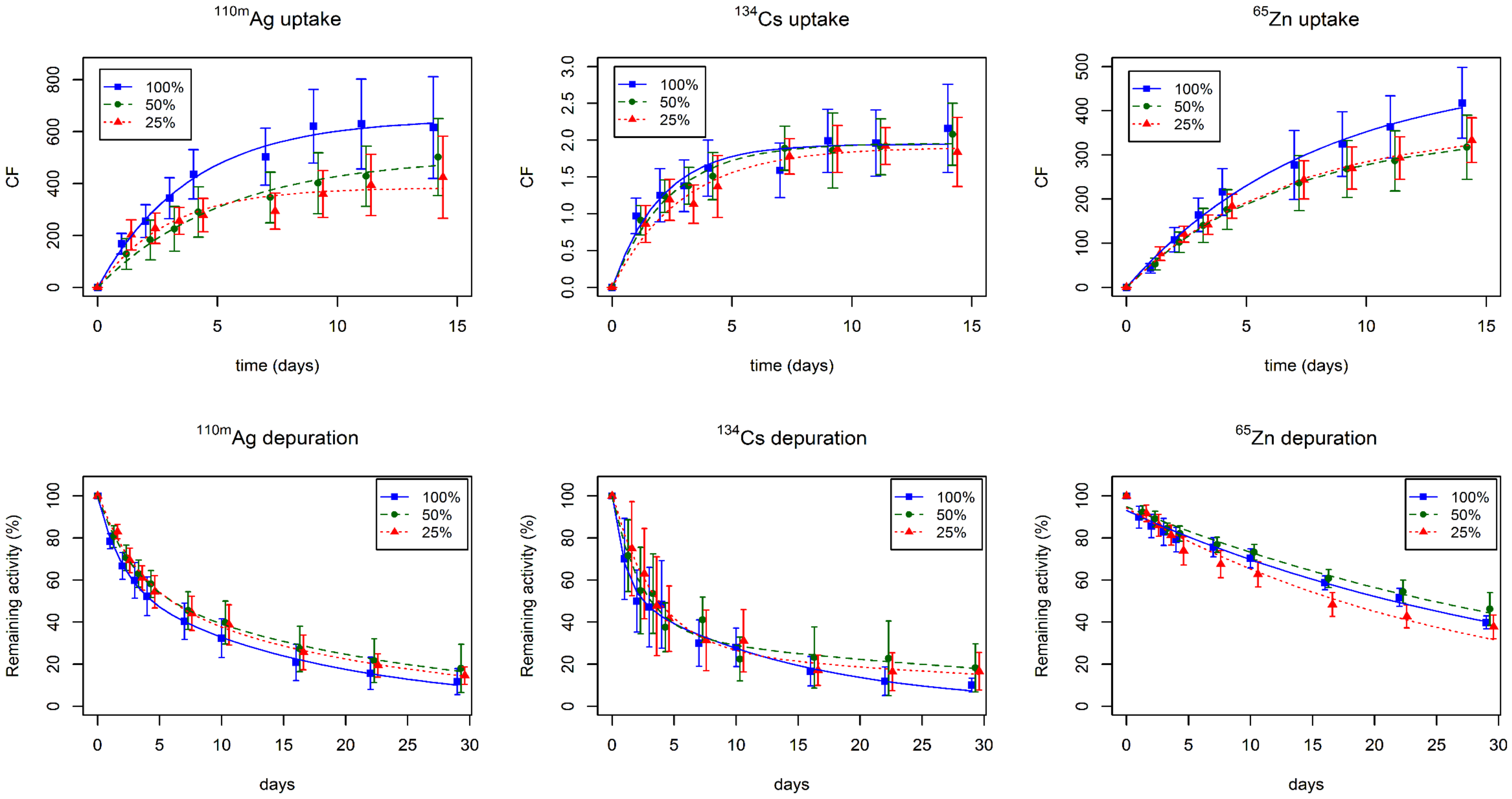
Assimilation of Cs in Turbots :
Influence of salinity



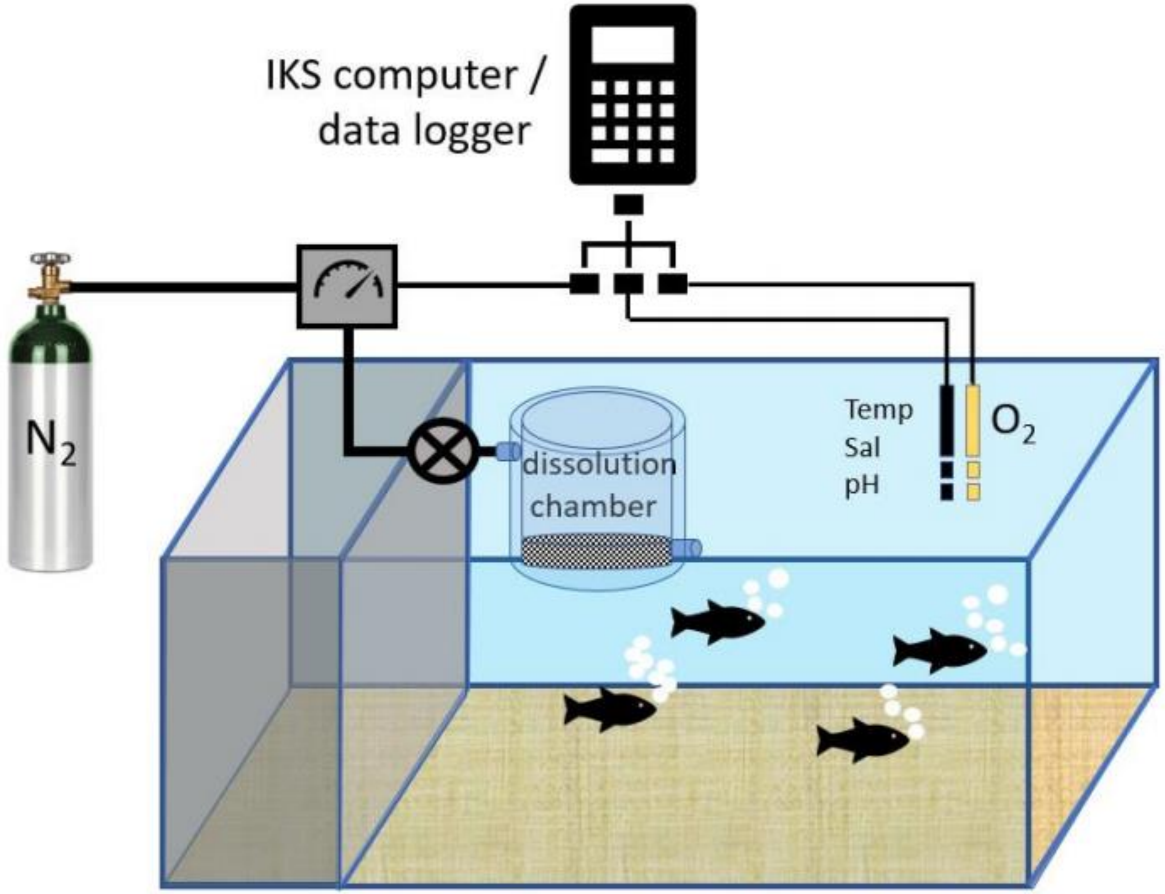
Pouil et al. *(2018)* JEnvRad

Bioaccumulation of elements in mussels:

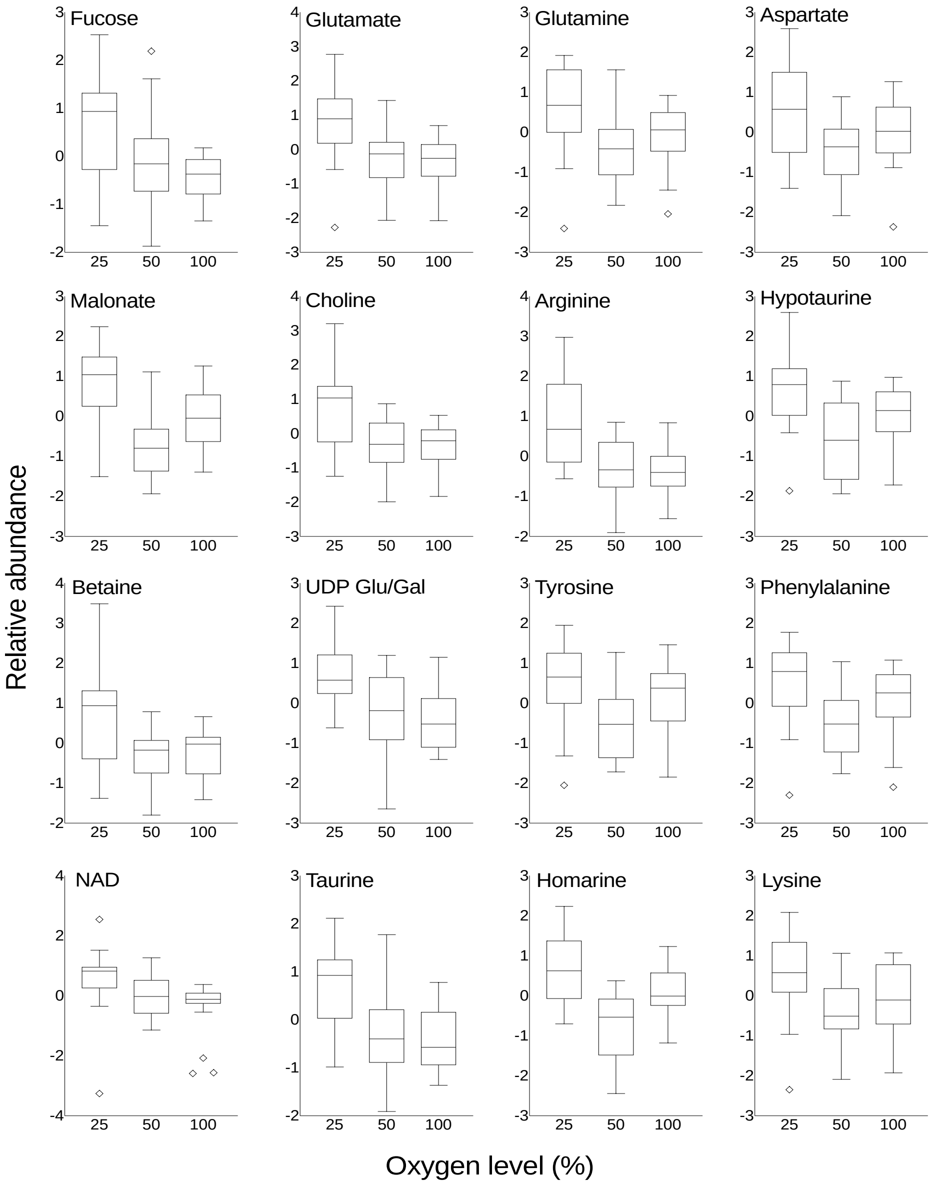
Influence of dissolved O_2 decrease



Belivermis et al (*2020*)


IKS computer /
data logger
N_2
dissolution
chamber
Temp
Sal
pH
O_2

metabolomics



Belivermis et al (*2020*)

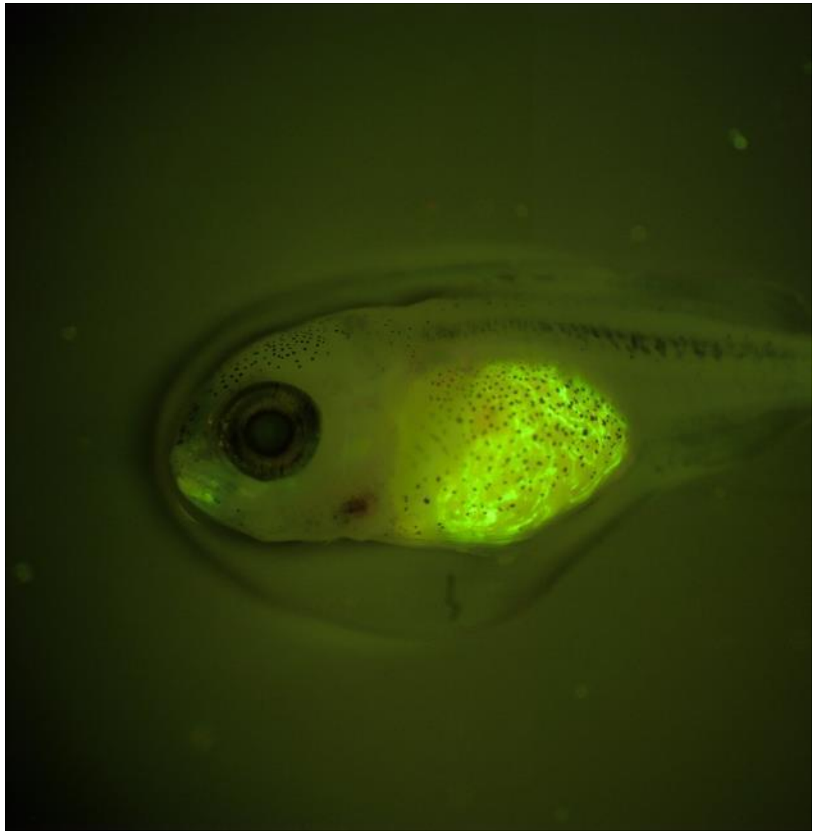
Emerging environmental issue

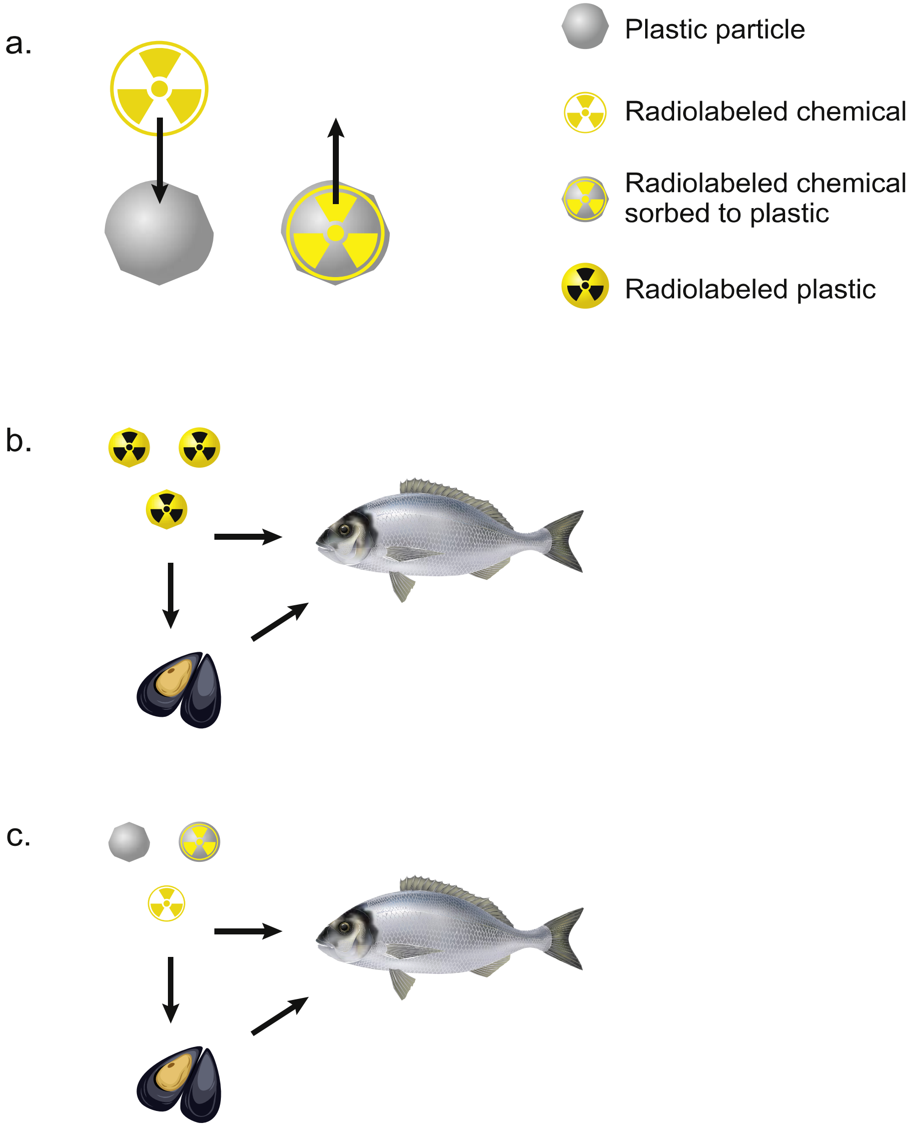
Marine Plastics

Plastics – development of tools & research

Nuclear and isotopes techniques

To complement other techniques

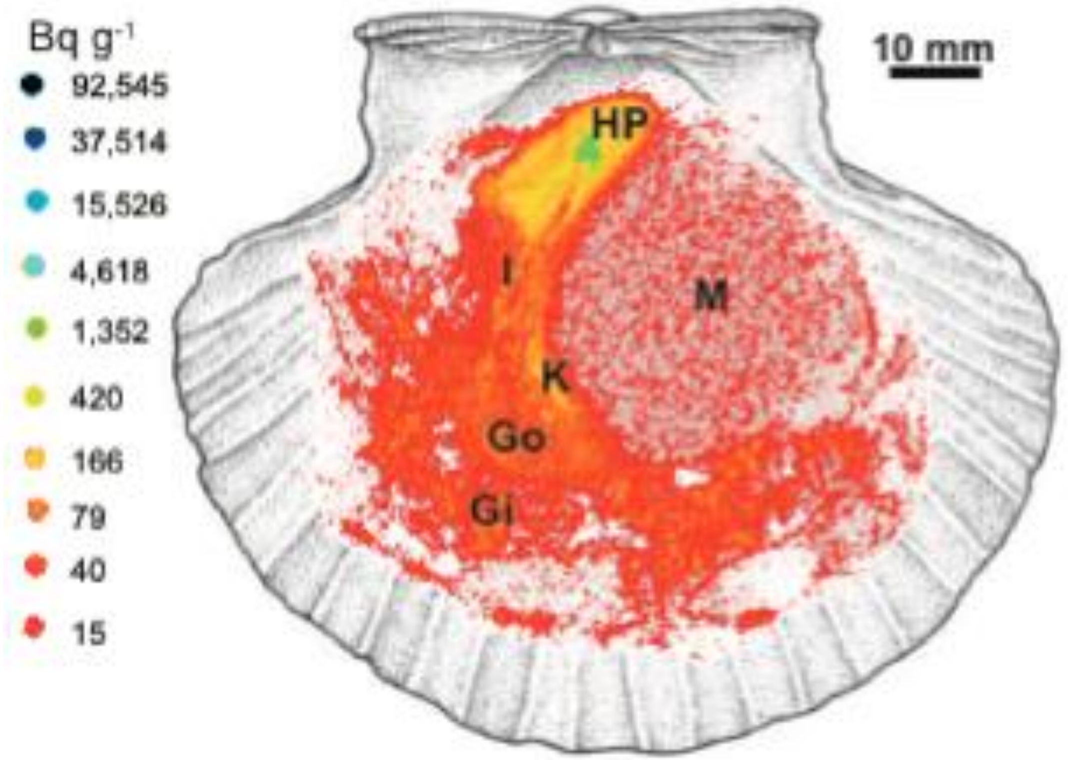




Behavior and fate of marine plastics

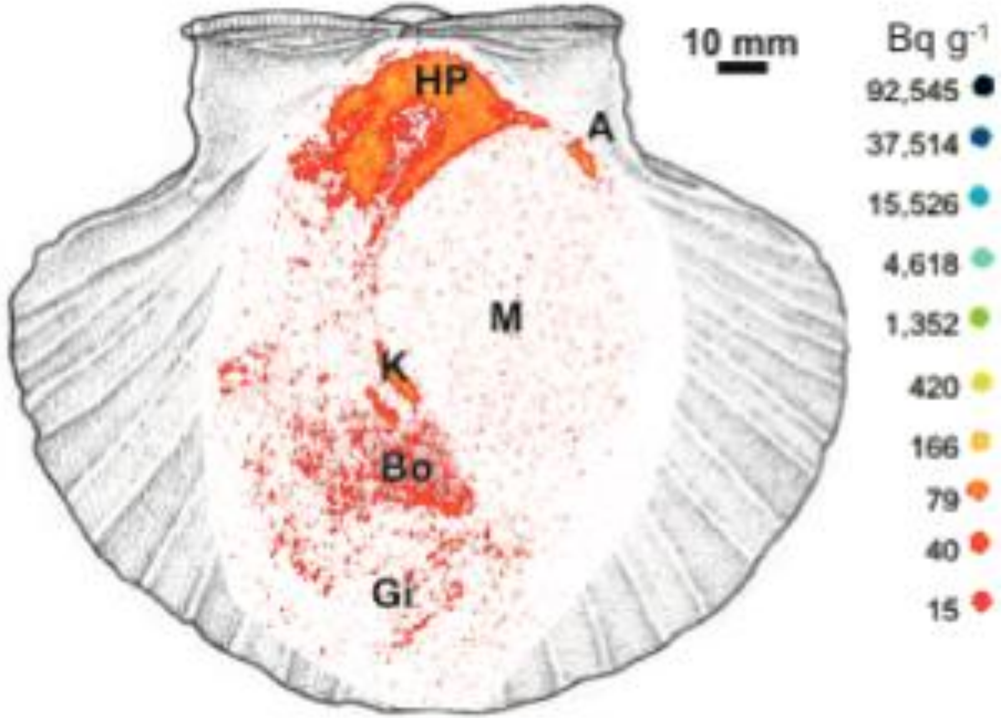
Environment Laboratories

T = 6 hours



Uptake phase

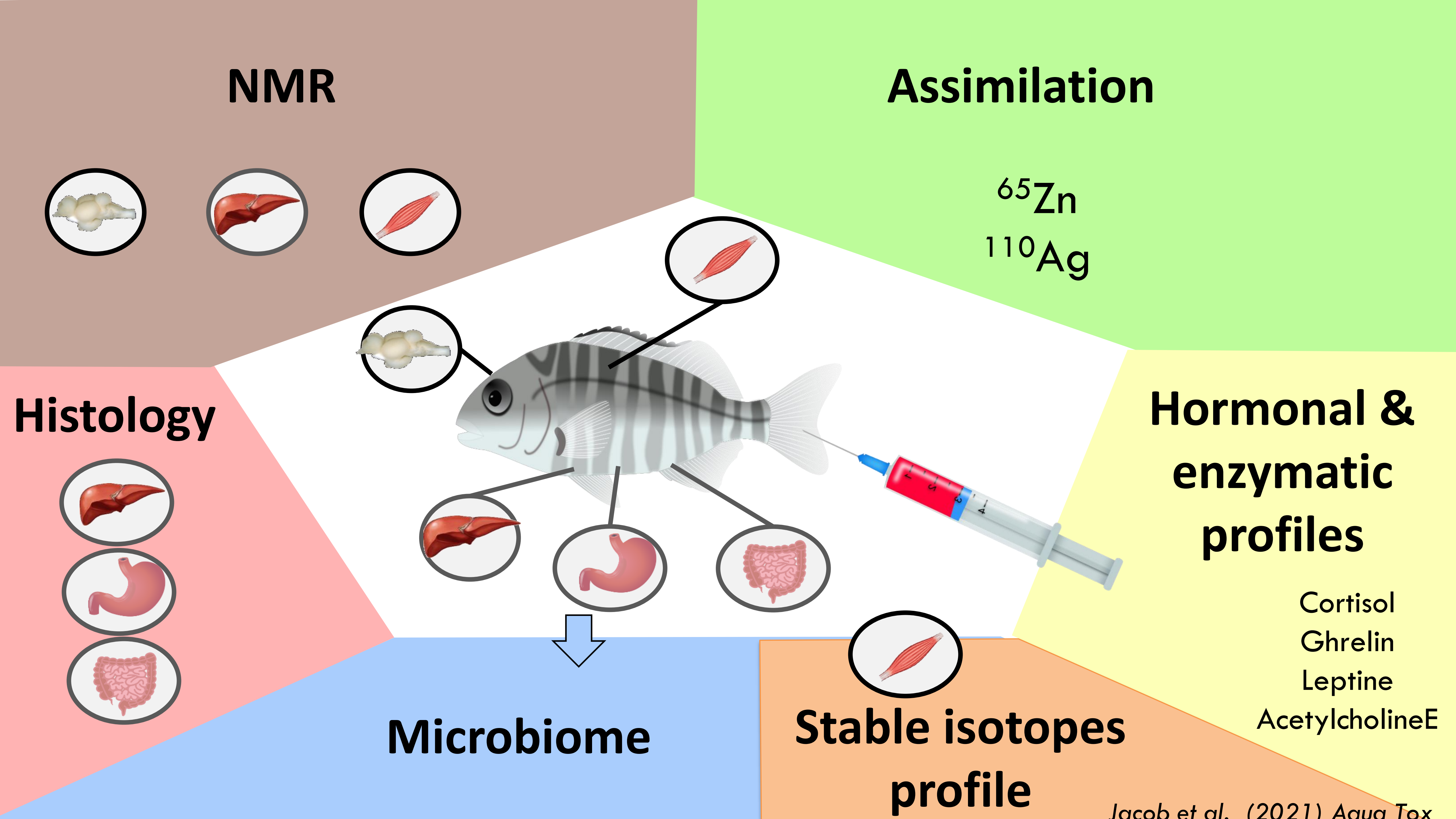
8 days after exposure



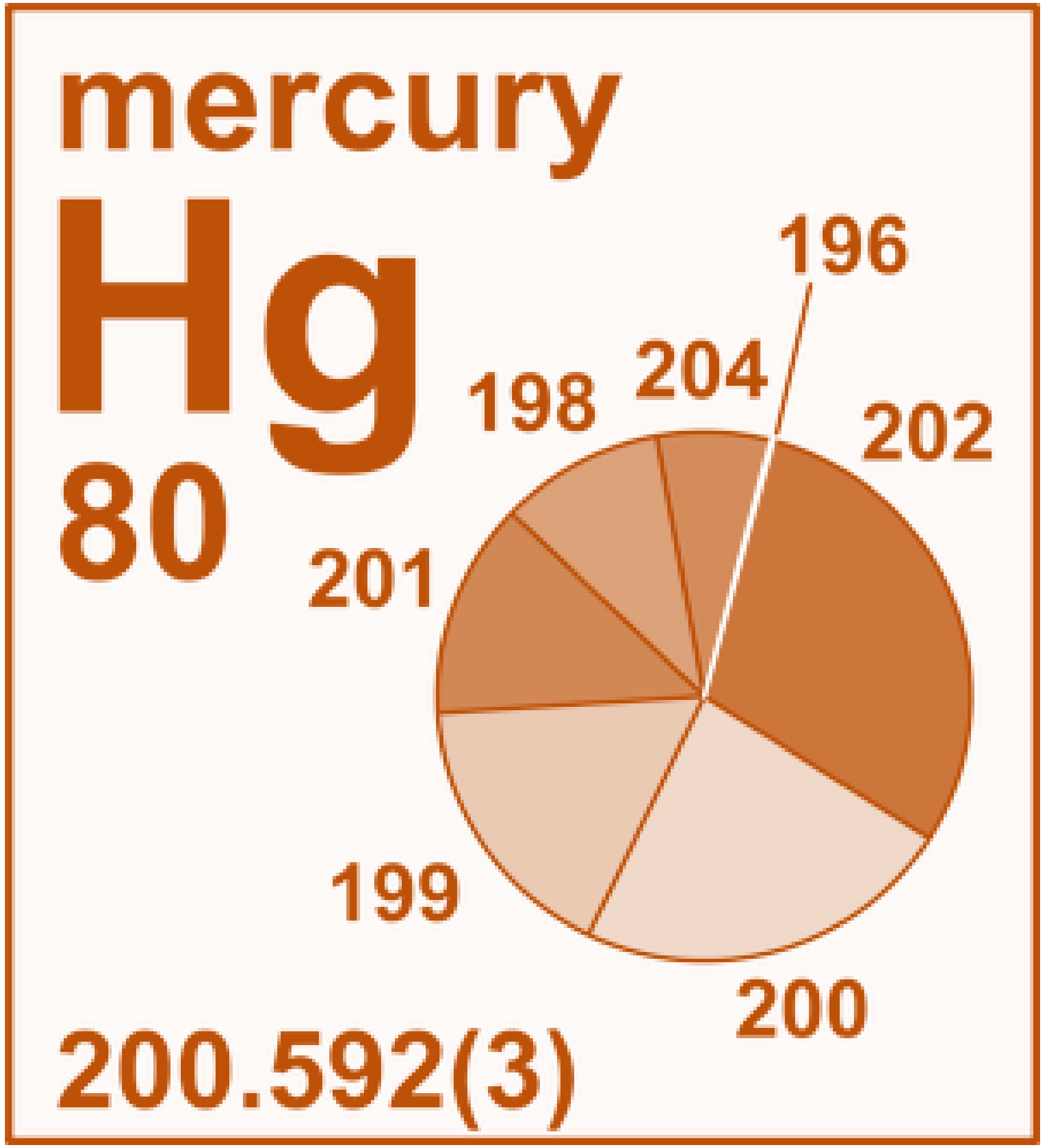
Depuration phase

scallops exposed to radiolabelled nanoplastics

Al-Sid-Cheikh et al. 2018. *Environ. Sci. Tech.*


NMR
Assimilation
^{65}Zn
^{110}Ag
Histology
Hormonal & enzymatic profiles
Cortisol
Ghrelin
Leptine
AcetylcholineE
Microbiome
Stable isotopes profile
Jacob et al., (2021) Aqua Tox

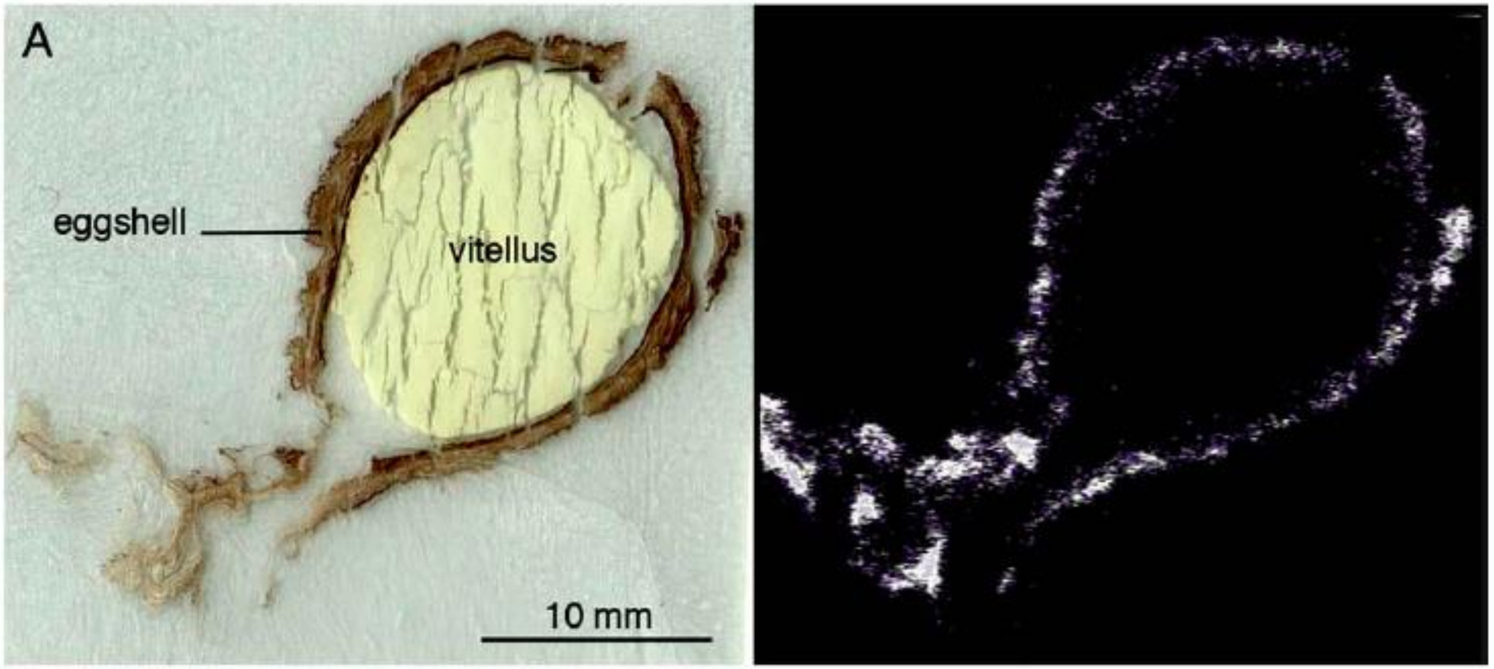
IAEA | Environment Laboratories



+ ^{203}Hg

Radioisotopic approach: use of ^{203}Hg

Hg accumulation in the encapsulated egg of the common cuttlefish *Sepia officinalis*



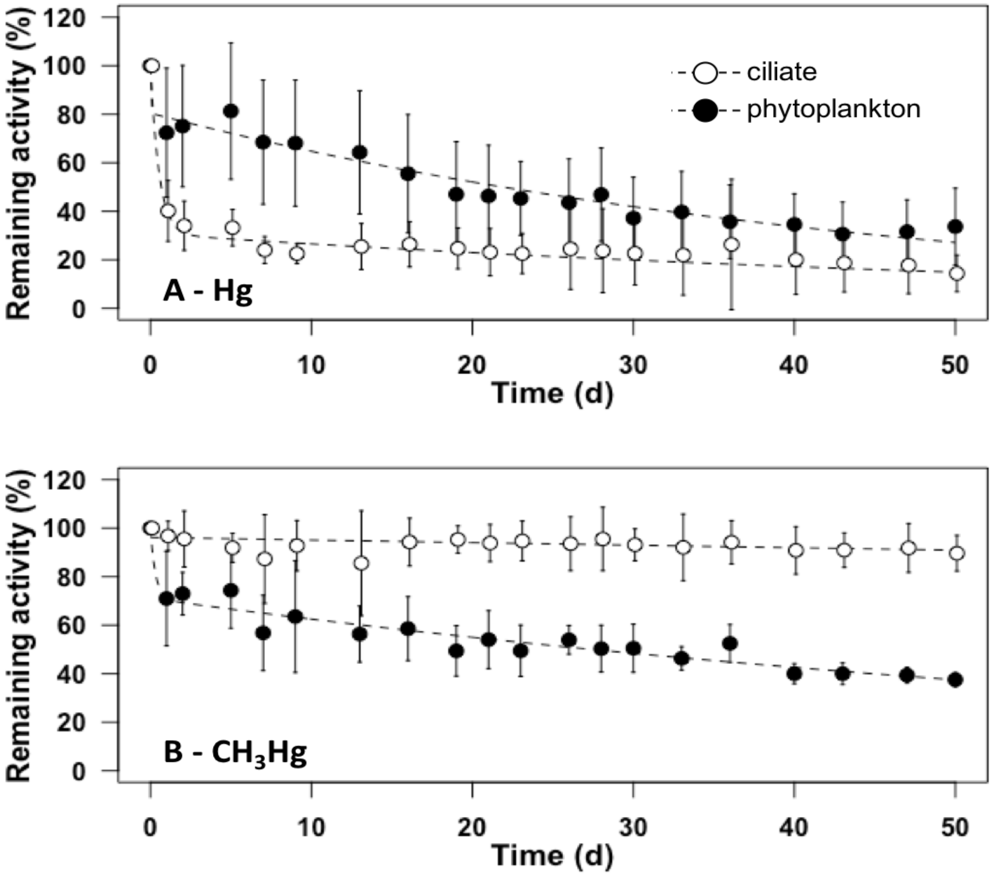
Lacoue-Labarthe et al., 2009

Radioisotopic approach: use of ^{203}Hg

Environment Laboratories

Influence of food (ciliate and phytoplankton) in the trophic transfer of mercury (Hg and CH_3Hg) in the Pacific cupped oyster *Crassostrea gigas*

Metian et al. (2019) Env Pol



Radioisotopic approach: use of ^{203}Hg

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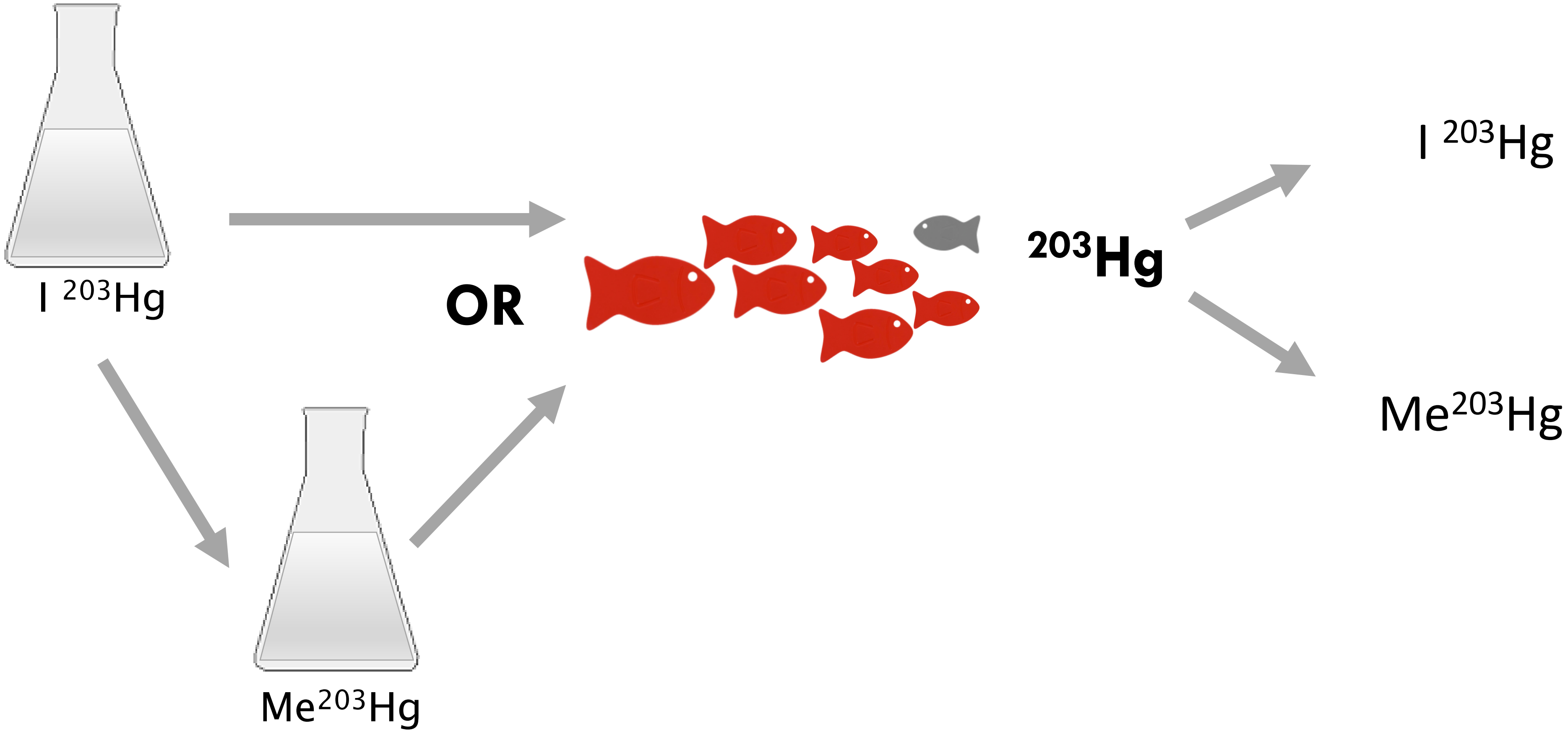
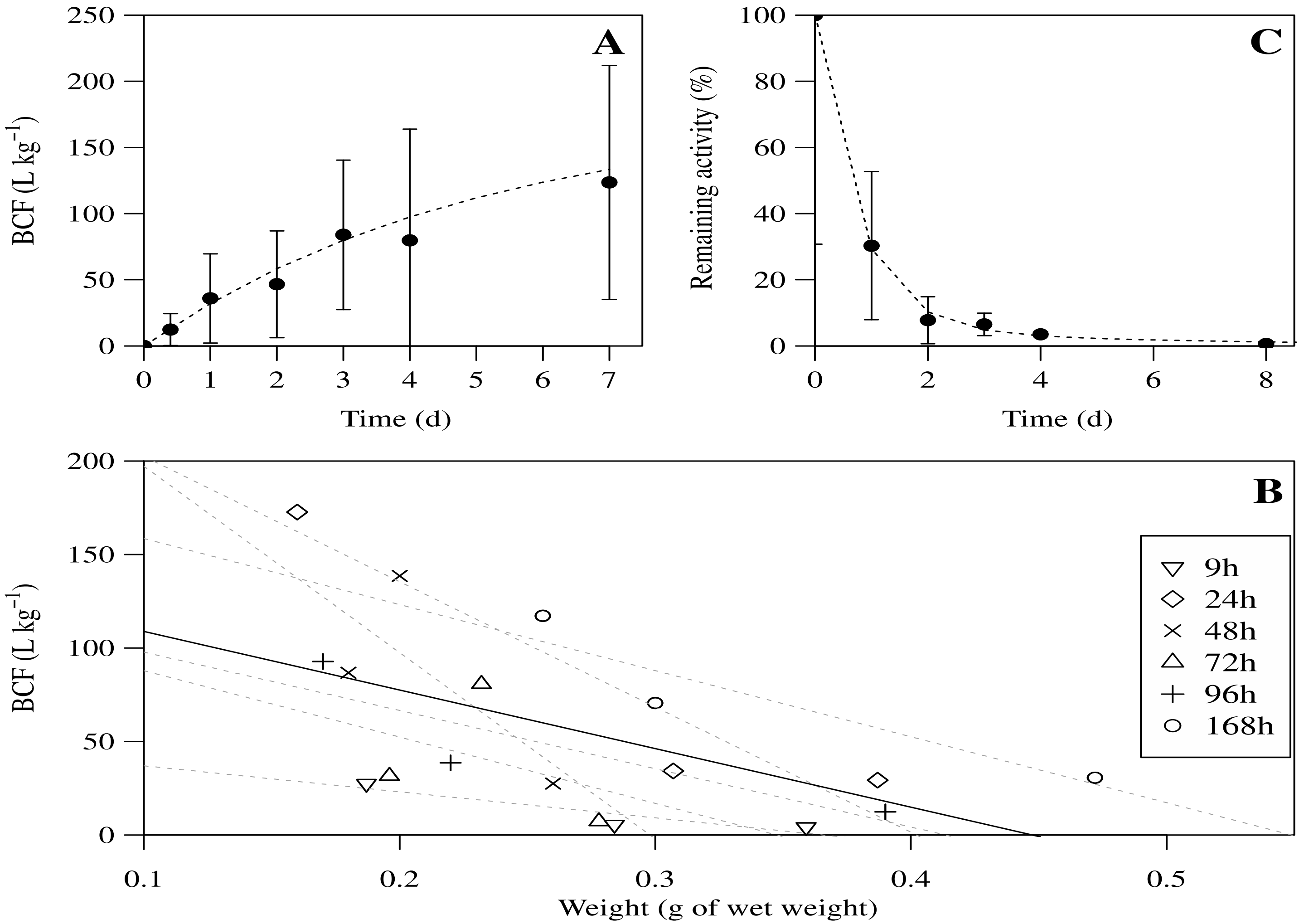
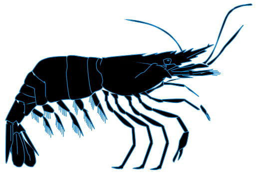
IAEA

New development with radio - Hg



Uptake and loss of ^{14}C-LAS in shrimp



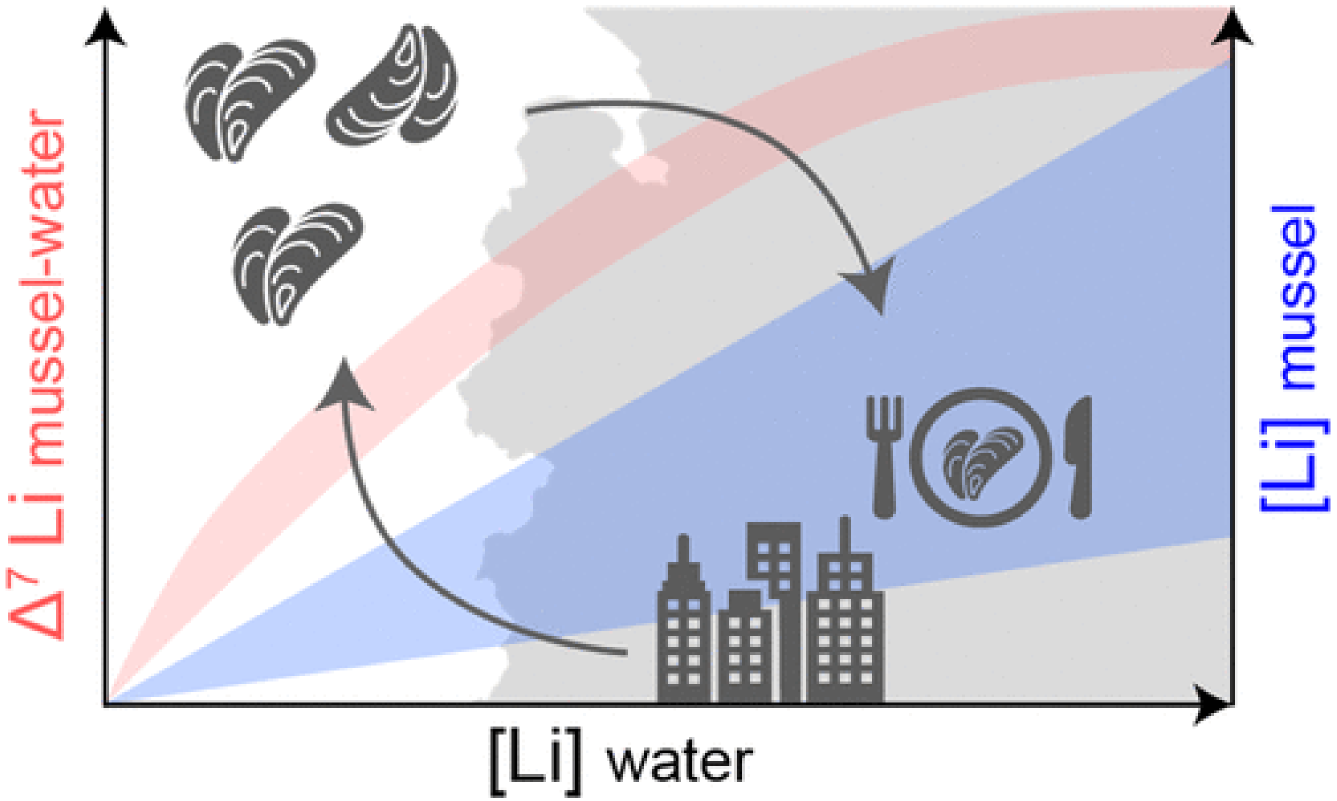


Renaud et al. (2014) MPB

Metian et al. (2019) Aqua Tox

*linear alkylbenzene sulfonate

Lithium



Δ^7Li: ($^7Li/^6Li$)

- Li stable isotope ratios in tissues correlate positively with water Li concentrations
- Presence of a threshold Li ratios above which mussels shift their metabolism

Thibon et al. (2021) ACS Earth and Space Chem

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