Hg and Se fate and interaction in fish: new insights and potential valorization of tuna byproducts on sustainable aquafeeds

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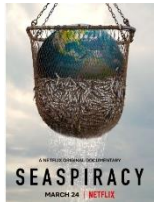
Context

Aquaculture

*one of the **fastest growing industry***

8% yearly increases in the last 10 years (FAO)



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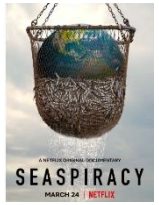
new alternatives to developing sustainable fishmeal



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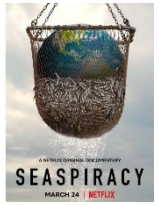

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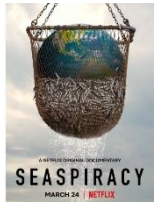

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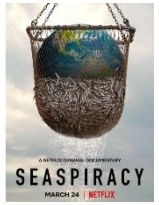

solid wastes generated by the tuna canning industry: up to 65%

- ~25.5 kg **tuna** Per capita fish consumption/year
- the **most-consumed** product in the EU
- the **high (Me)Hg concentrations**

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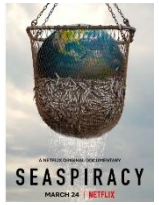

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fish byproducts

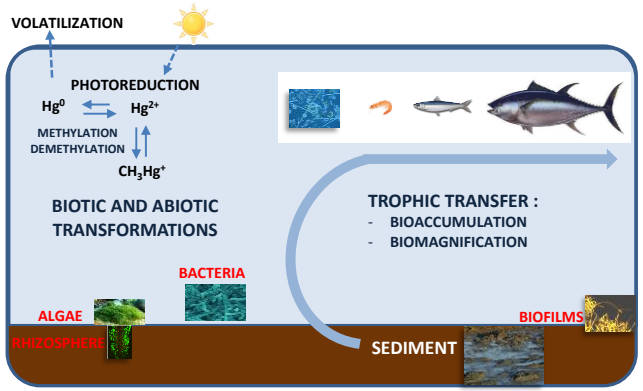
Plant based diet

…but also high Se levels

Hg **Top ten chemicals of major public health concern**

3rd position in the Substance Priority List (2019) Agency for Toxic Substances and Disease Registry (ATSDR)

AQUATIC ECOSYSTEM:
BIOACCUMULATION AND BIOTRANSFORMATION



HEALTH, SOCIETAL AND ECONOMICAL IMPACT

Fish-consumption **not precise risk assessment**
criterion based on **MeHg content** (0.5 mg/kg)

Seafood safety index (HBVSe): MeHg/Se
Ralston, 2016

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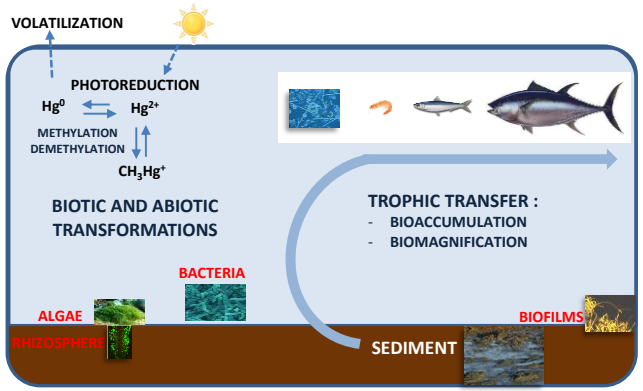

HEALTH, SOCIETAL AND ECONOMICAL IMPACT

Se antagonism?

HgSe NPs (tiemannite)

end-product of MeHg detoxification

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Ralston, 2016

Hg metabolic pathways in biota remain elusive

Understanding mercury-selenium interactions in fish

- **Hg and Se dietary fate**

- **Potential valorisation of tuna by-products**

?

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model aquaculture fish species
rainbow trout (*Oncorhynchus mykiss*)

2nd fish species produced in Europe

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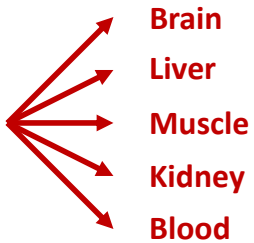

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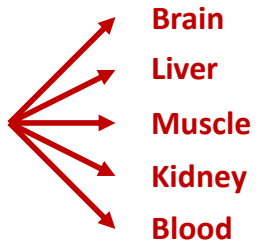

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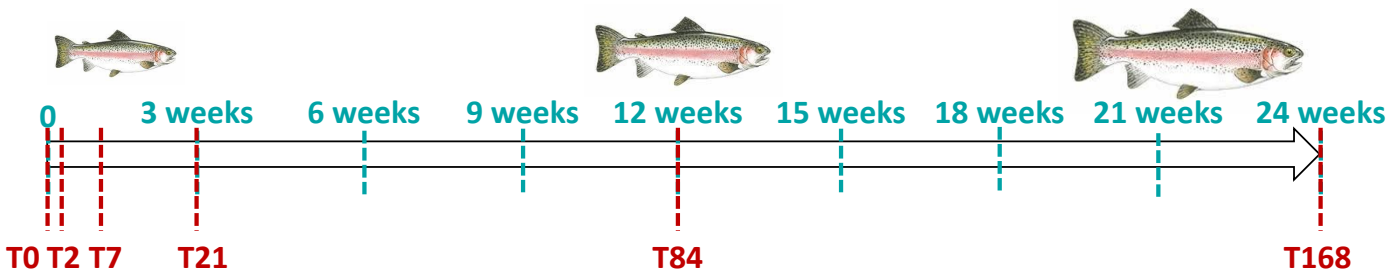

Understanding mercury-selenium interactions in fish

+ MeHg
+ Se(IV)
+ Se-Methionine

- Rainbow trout juveniles
- Mean initial body weight: 26 g
- 50 fish per tank

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Tuna meal-based diets

	Se (µg g^{-1})	**Hg** (µg g^{-1})
Control	8.0 ± 0.2	0.25 ± 0.02

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Plant-based diets

	Se (µg g^{-1})	**Hg** (µg g^{-1})
Control	0.25 ± 0.01	< LOD

Understanding mercury-selenium interactions in fish

+ MeHg
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- Mean initial body weight: 26 g
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Tuna meal-based diets

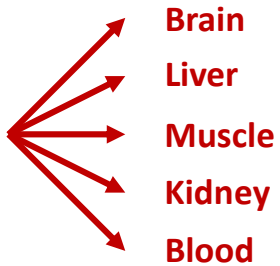
	Se (µg g^{-1})	**Hg** (µg g^{-1})
Control	8.0 ± 0.2	0.25 ± 0.02
Se(IV)	10.3 ± 0.6	0.19 ± 0.03
SeMet	10.3 ± 1.2	0.21 ± 0.02
MeHg	7.8 ± 0.3	2.13 ± 0.04
Se(IV)+MeHg	11.2 ± 1.4	2.2 ± 0.1
Se(IV)+MeHg	10.3 ± 0.9	2.0 ± 0.1

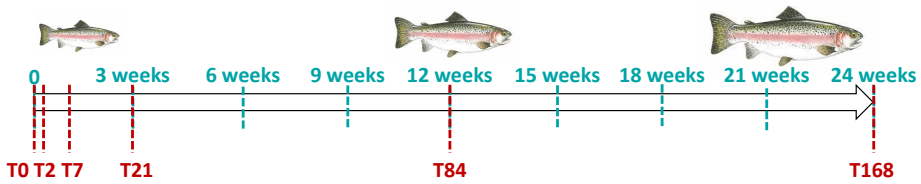
Plant-based diets

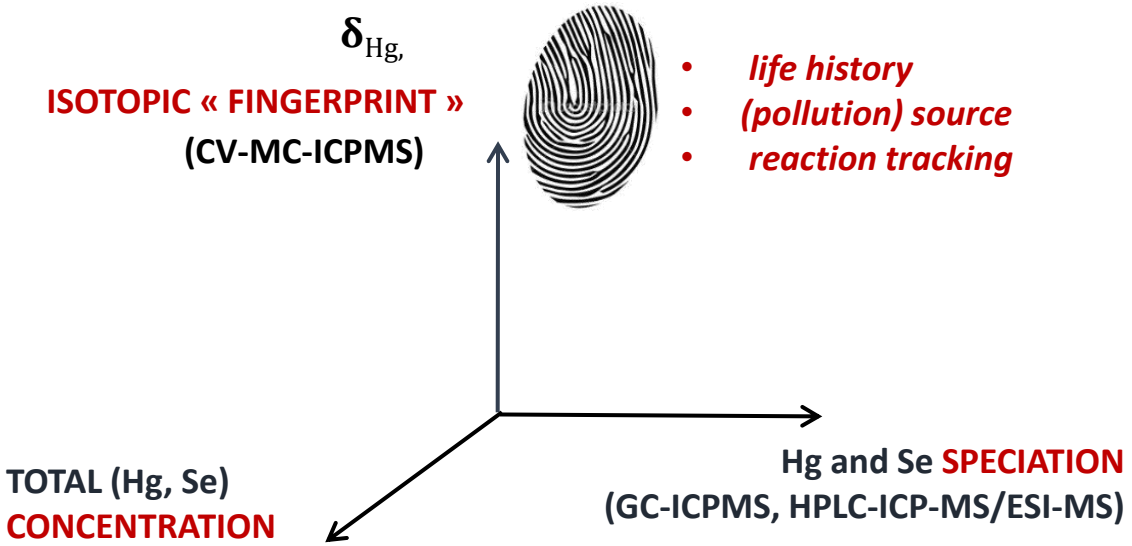
	Se (µg g^{-1})	**Hg** (µg g^{-1})
Control	0.25 ± 0.01	< LOD
Se(IV)	3.5 ± 0.2	< LOD
SeMet	2.3 ± 0. 1	< LOD
MeHg	0.28 ± 0.01	2.6 ± 0.2
Se(IV)+MeHg	2.3 ± 0.1	2.5 ± 0.1
Se(IV)+MeHg	2.2 ± 0.1	2.4 ± 0.2

80% of Se: naturally present in tuna byproducts

Understanding mercury-selenium interactions in fish

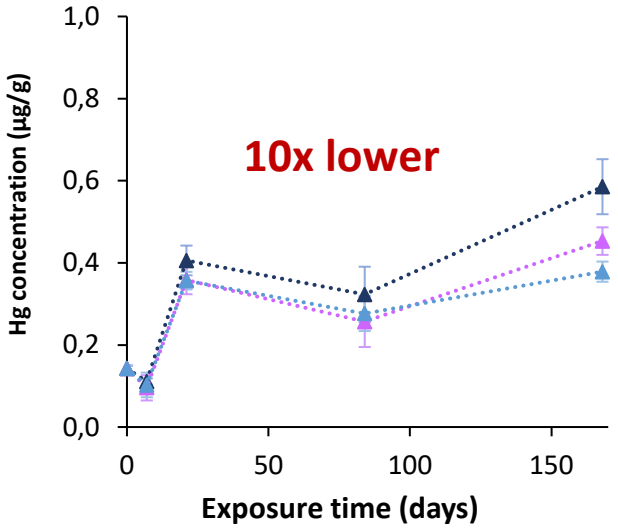






Resulting Hg concentration in muscle

Dietary exposed to tuna byproducts



Hg level below the threshold established for human consumption (5 µg g^{-1} dw)

Resulting Hg concentration in muscle

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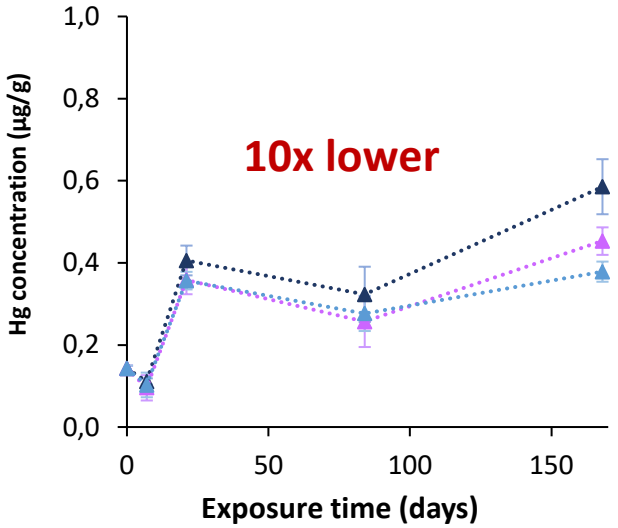


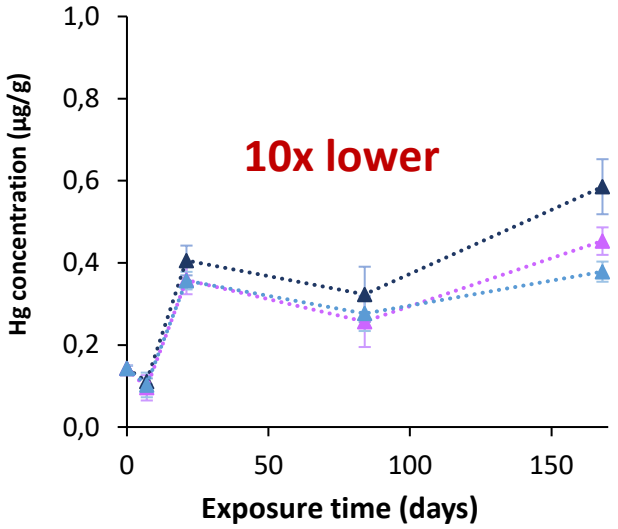
Dietary exposed to tuna byproducts + (2.5 (µg g^{-1}) MeHg

Dietary exposed to plant based diet + (2.5 (µg g^{-1}) MeHg

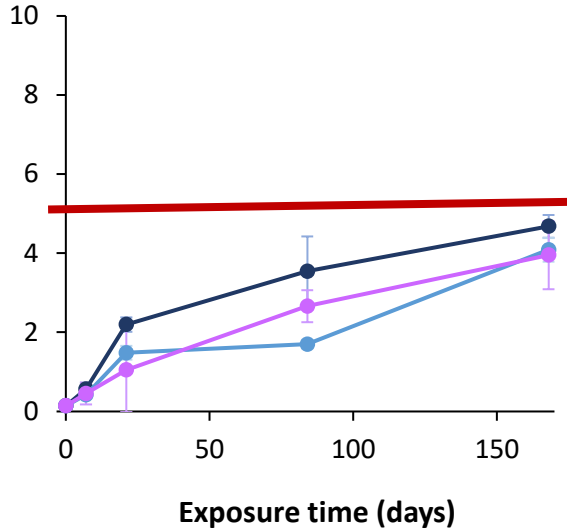
Hg level below the threshold established for human consumption (5 µg g^{-1} dw)

Resulting Hg concentration in muscle

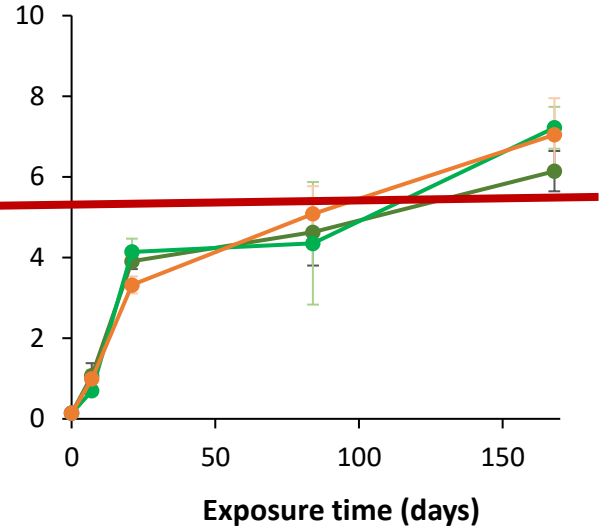
Dietary exposed to tuna byproducts



Dietary exposed to tuna byproducts + (2.5 (µg g^{-1}) MeHg



Dietary exposed to plant based diet + (2.5 (µg g^{-1}) MeHg



Hg level below the threshold established for human consumption (5 µg g^{-1} dw)

= MeHg dietary exposure levels

≠ Hg bioaccumulation

Is it due to the Se naturally present in the tuna byproducts?

Effect of dietary Se (species) Hg bioaccumulation

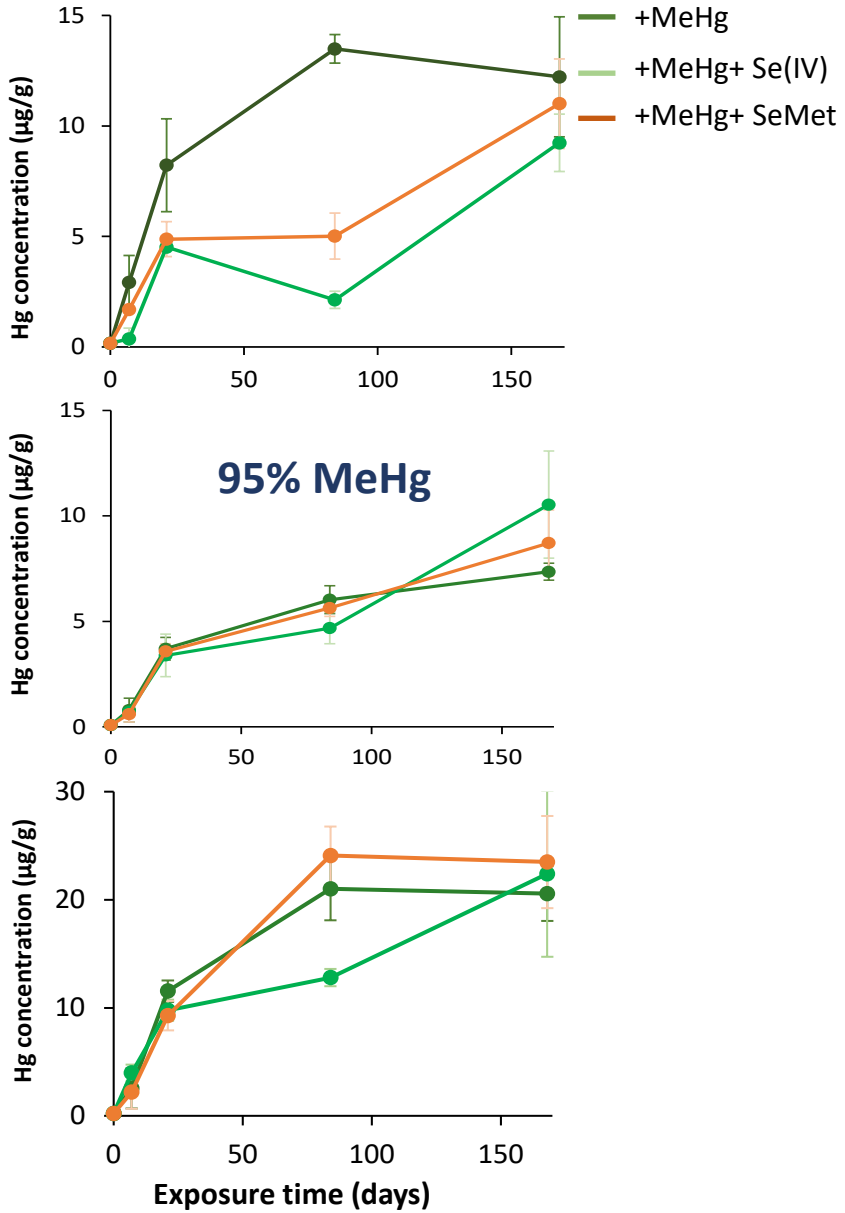
Dietary exposed to plant based diet + MeHg

Dietary exposed to tuna byproducts + MeHg

Liver

Brain

Blood



✓ **In general, tuna byproducts diets result in lower Hg levels**

Fate of dietary Se

Dietary exposed to plant based diet

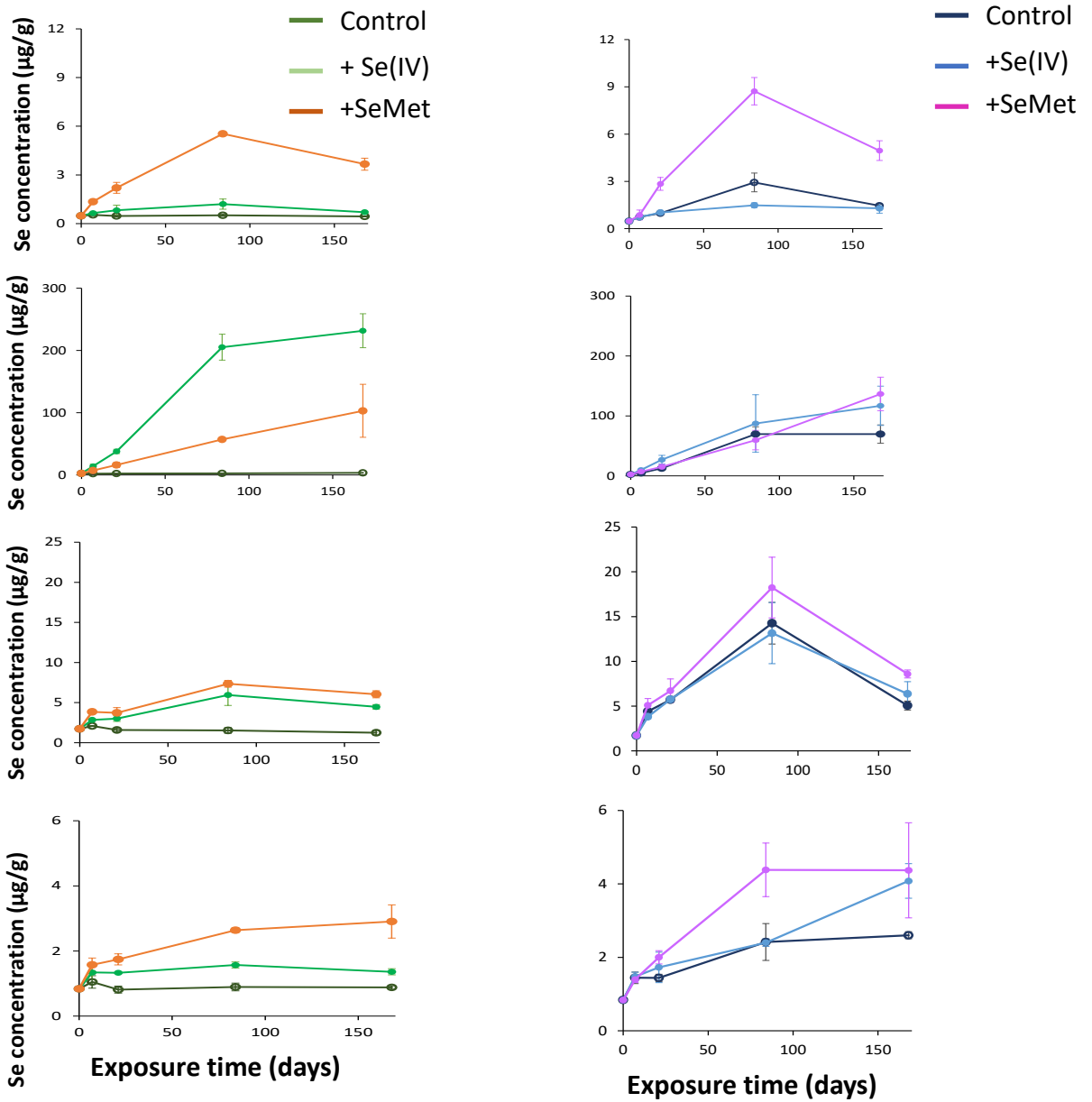
Dietary exposed to tuna byproducts

Muscle

Liver

Blood

Brain



✓ **Tuna byproducts based diets lead to higher Se bioaccumulation (except in liver)**

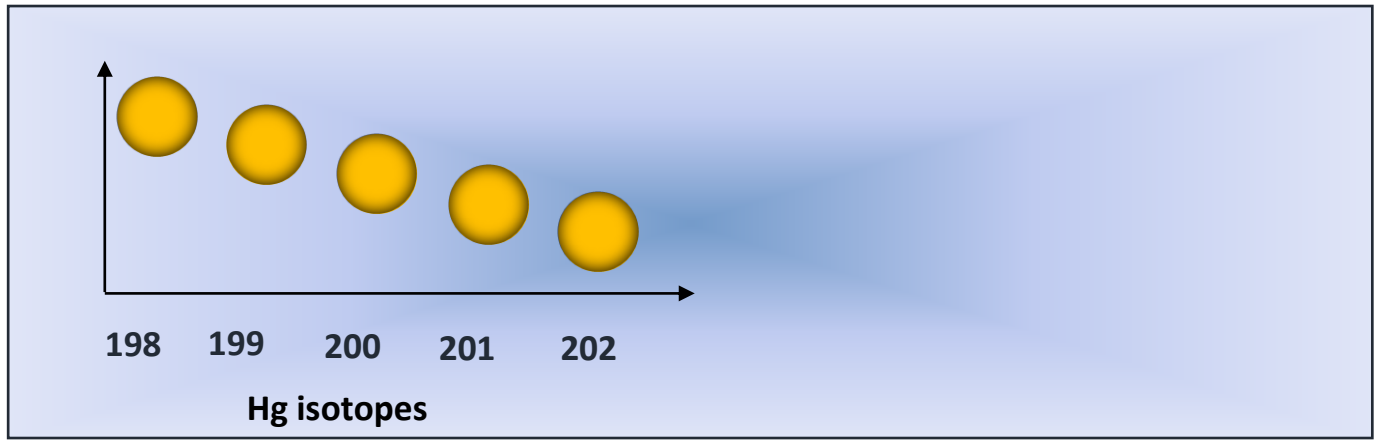
The differences of Se bioaccumulated <<< than the Se dietary content

Regulation of tuna basal Se?

✓ **Dietary SeMet > Se in muscle and brain**

Hg isotopic fractionation

Chemical processes **Physical processes** **Biological processes**



$\delta_{Hg,}$

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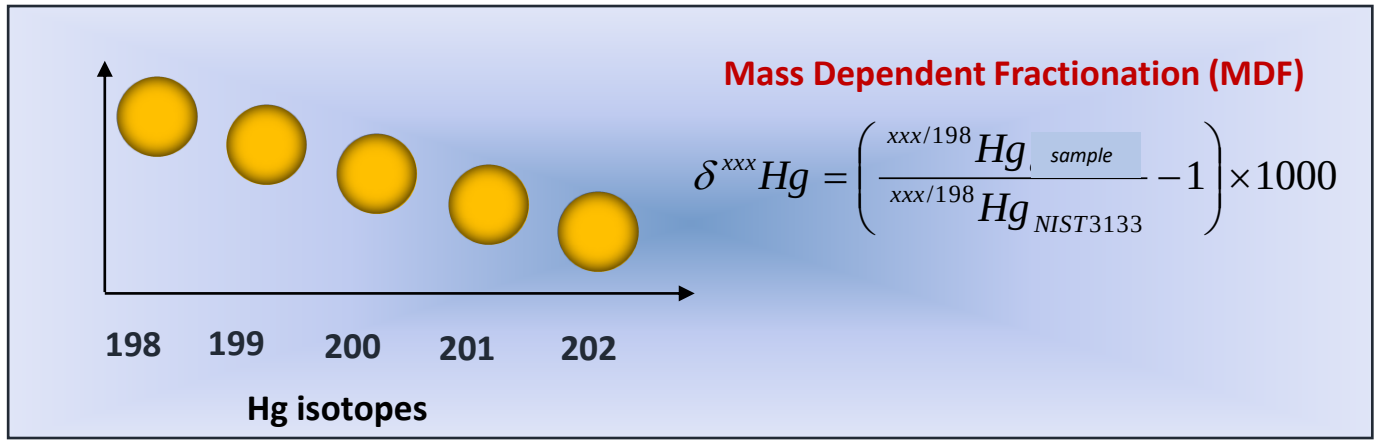
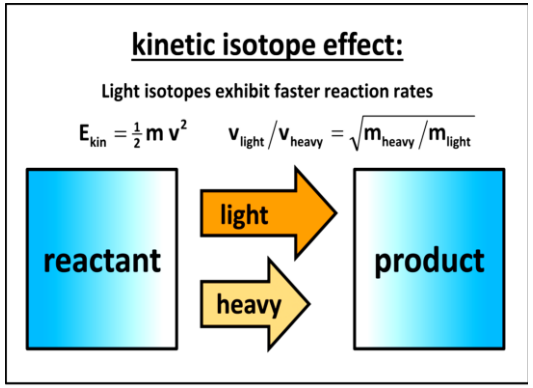
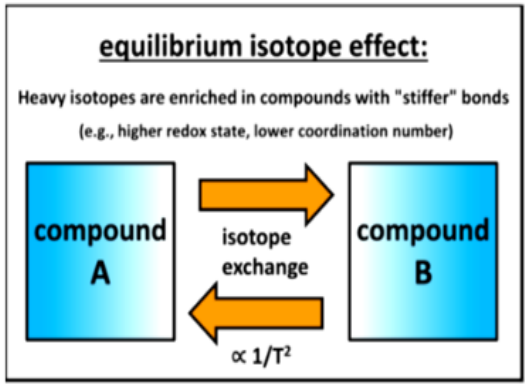


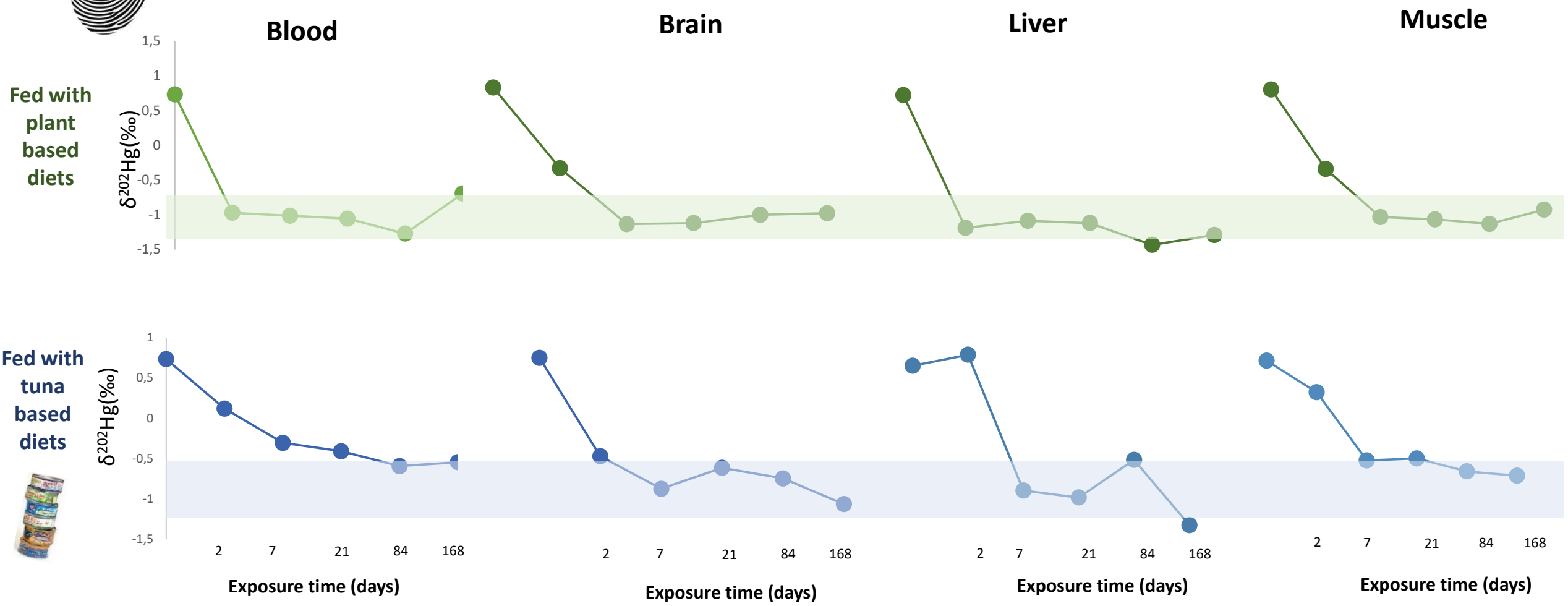
MDF **Species transformation, transport, trophic transfer, etc…**

$\delta_{Hg,}$





$\delta_{Hg,}$ Kinetic Hg isotopic signature of dietary MeHg

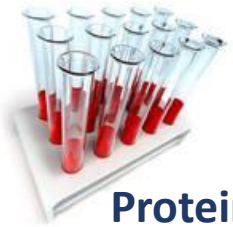


✓ Faster Hg bioaccumulation from vegetal diets than from tuna

Role of Se naturally present in tuna byproducts?

Screening of Hg and Se in the water soluble protein fraction

USP



Protein extract

HPLC-ICP-MS/ESI-MS

Hg (liver)

Size exclusion chromatography-ICPMS Superdex 200: 600 -3 kDa

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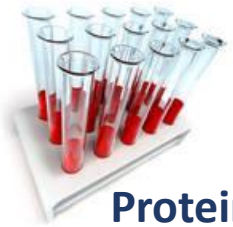

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21 days of exposure

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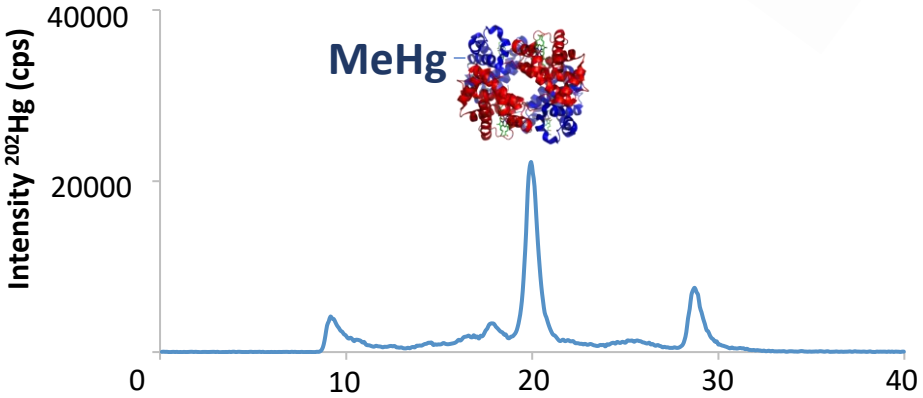

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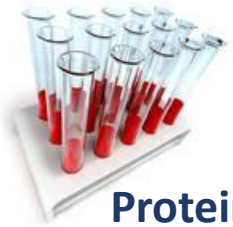

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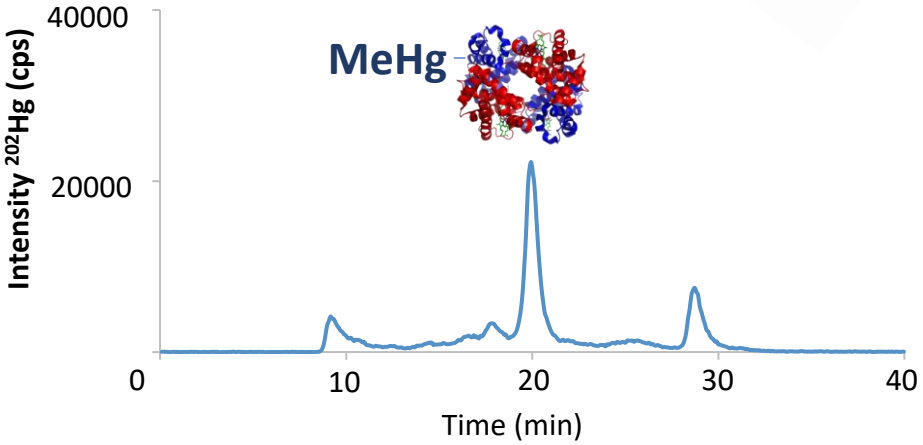
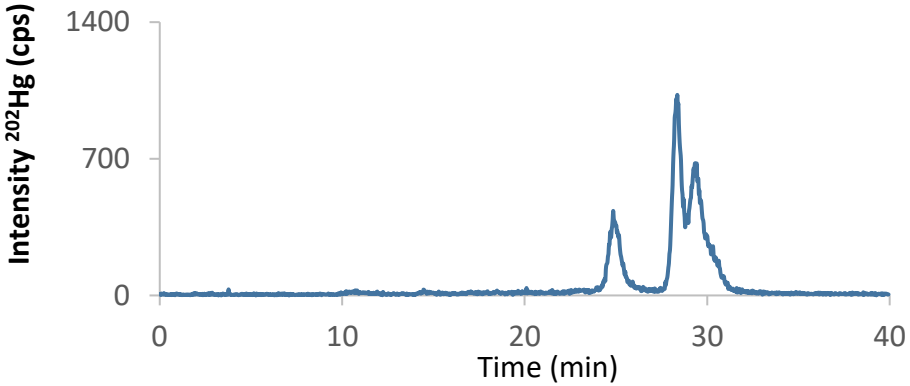


168 days of exposure



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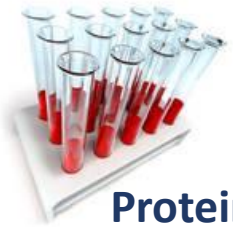

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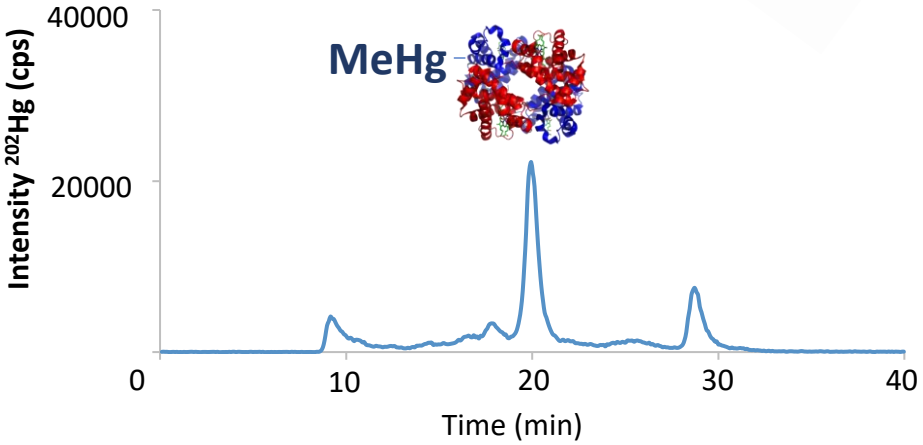

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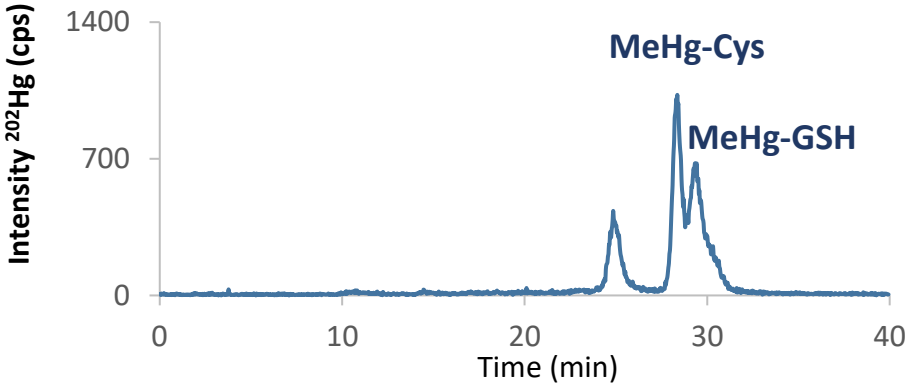


✓ **MeHg kinetically transferred from Hb to low molecular weight compounds**

involved on storage and/or detoxification **?**

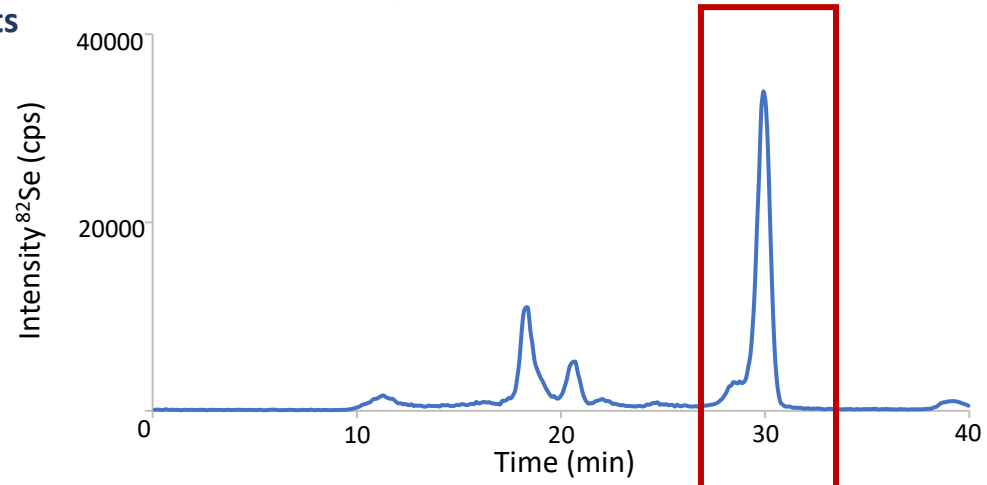
Screening of Hg and Se in the water soluble protein fraction

Se (blood)

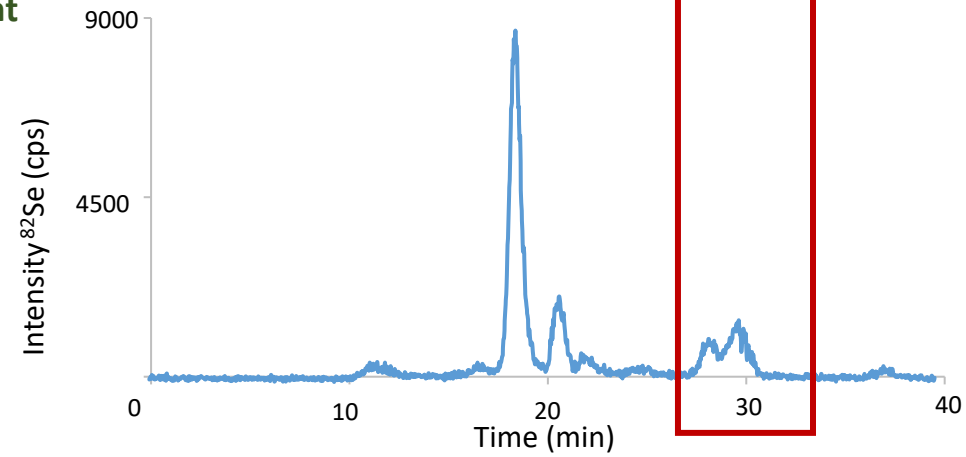
Size exclusion chromatography-ICPMS

Superdex 200: 600 -3 kDa

Fed with tuna based diets



Fed with plant based diets



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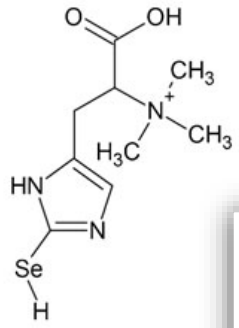
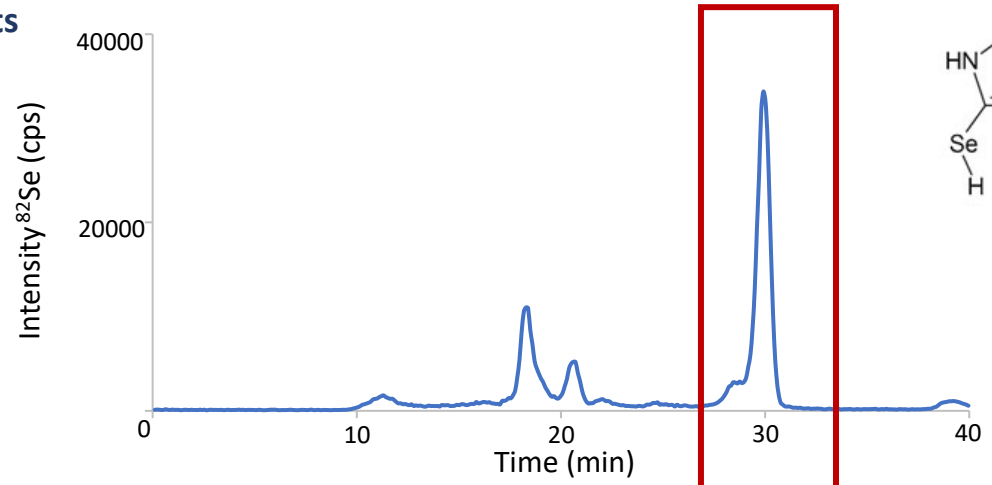
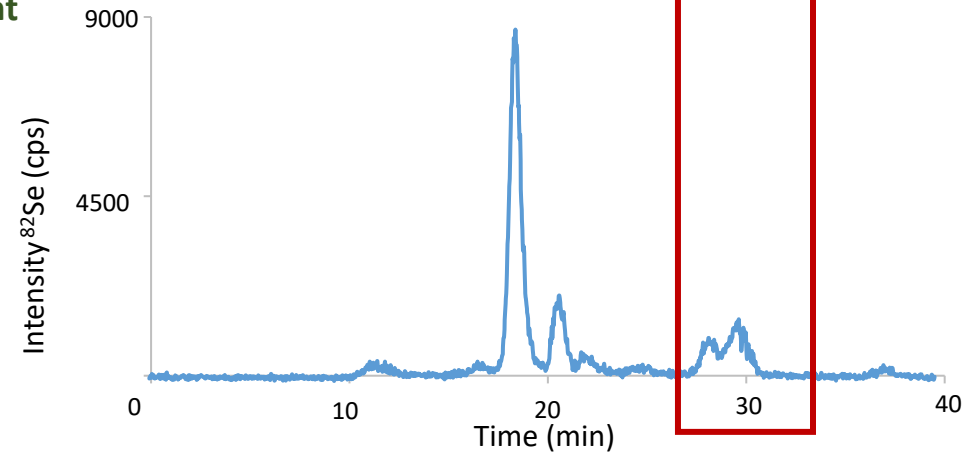


Selenoneine: major Se species

Fed with tuna based diets



Fed with plant based diets



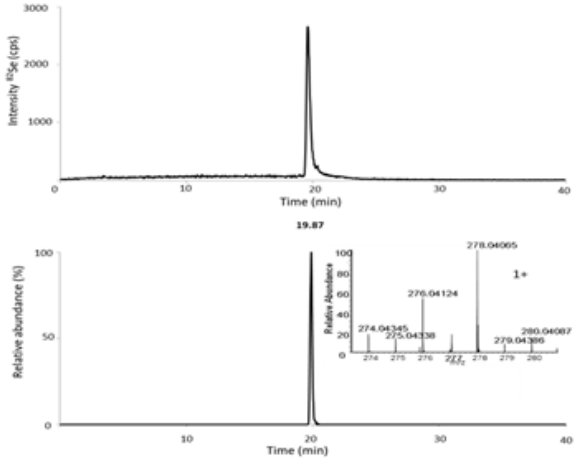
Water-soluble extract

Dilution 1:3 with Acetonitrile

Centrifugation 10000 g, 3 min

HILIC-ICPMS/ESI-MS

Mobile phase: Gradient ACN
Flow: 50µl min^{-1}
Injection volume: 8 µL



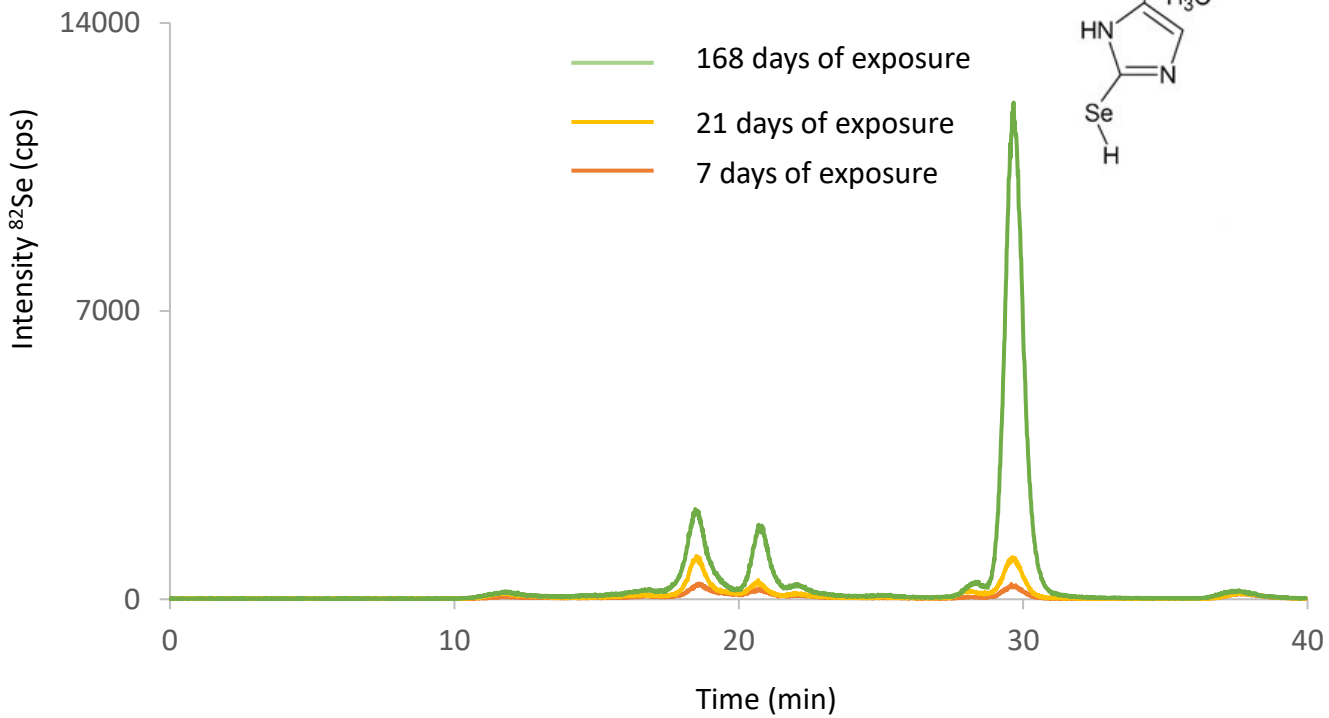
Selenoneine: Kinetic trend

Size exclusion chromatography-ICPMS

Superdex 200: 600 -3 kDa

Se (blood)

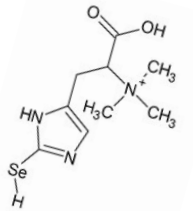
Fed with tuna based diets



✓ **Increases of Selenoneine fraction with the exposure time**

Trophic transfer evidence!

First-time selenoneine identification in freshwater fish



blood, muscle

Yamashita et al. J. Biol. Chem. 2010

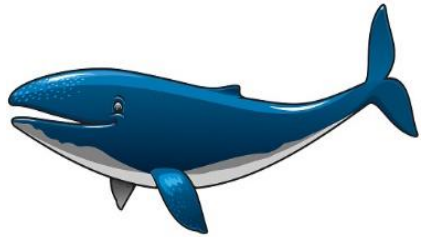
blood

urine

Klein et al. Metallomics 2011, Achouba et al. Chemosphere 2019, Kroepfl et al. JAAS 2019

liver

Anan et al. JAAS, 2011; Pedrerp et al. 2014

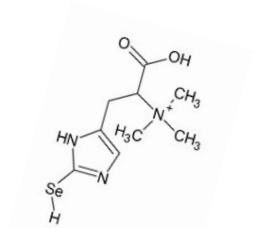


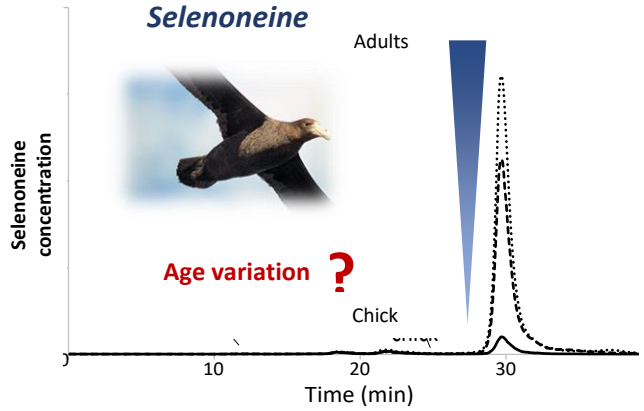
skin

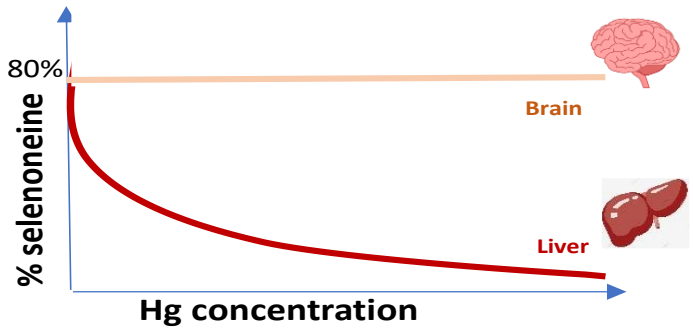
Achouba et al. Chemosphere 2019

Role?

Role?







Specific role(s) in the nervous system?

Involved in MeHg demethylation?

✓ Decrease of the selenoneine proportions with increasing Hg concentration

El Hanafi et al. Env. Sci.Tech. 2023
Queipo-Abad et al. J. haz. Mat. 2023

- **Tuna byproducts-based diets resulted in muscle Hg content below the threshold established for human consumption**

- **Potential valorization of tuna by products on sustainable aquafeed production**

- **Selenoneine trophic transfer for the first time in freshwater fish: Relevant for farmed animals**

H2020 MSCA RISE "MERFISH" project:
Health-benefit understanding of mercury-selenium interactions from fish to human

MERFISH

PI: Zoyne Pedrero Zayas

COMPLEMENTARY COMPETENCES

FISH NUTRITION

ANALYTICAL CHEMISTRY

ENVIRONMENTAL SCIENCE

COMMUNICATION

AQUACULTURE

TOXICOLOGY

Long-term goal: **understanding of the source, transport, fate and effects of Hg from fish to humans and the detoxification role of Se**

Build a lasting research network to answer emerging challenges in analytical chemistry, food safety, trophic transfer, fish nutrition and environmental and human health related to the global mercury issue.

H2020 MSCA RISE "MERFISH" project:
Health-benefit understanding of mercury-selenium interactions from fish to human

MERFISH

PI: Zoyne Pedrero Zayas

COMPLEMENTARY COMPETENCES

FISH NUTRITION

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COMMUNICATION

AQUACULTURE

TOXICOLOGY

Come to the MERFISH Science Café to find out!

science cafe

Today! 14h

Milena Horvat: ***Mercury exposure and health effects: do we know enough about what is safe?***

Janja Snoj Tratnik: ***Mercury exposure in prenatal life and neurodevelopment: findings from the Northern Adriatic birth cohort study***

MERFISH

Claudia Marchan Moreno
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Silvia Queipo Abad
(Postdoc researcher)

Khouloud El Hanafi
(PhD student)

Thank you for your attention!

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