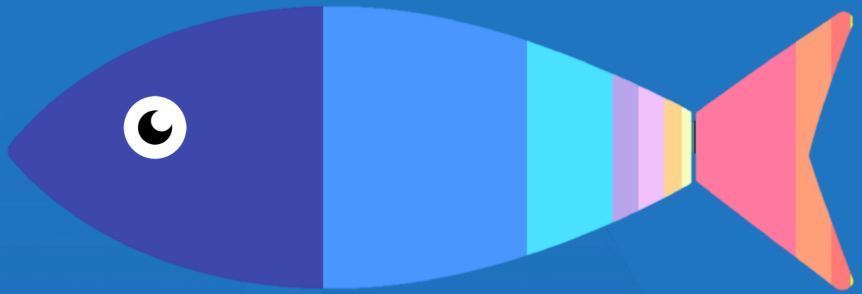
Global Seafood Dose

Status October 2023



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LaMer Coordinated Research Project: Behaviour and Effects of Natural and Anthropogenic Radionuclides in the Marine Environment and their use as Tracers for Oceanography Studies

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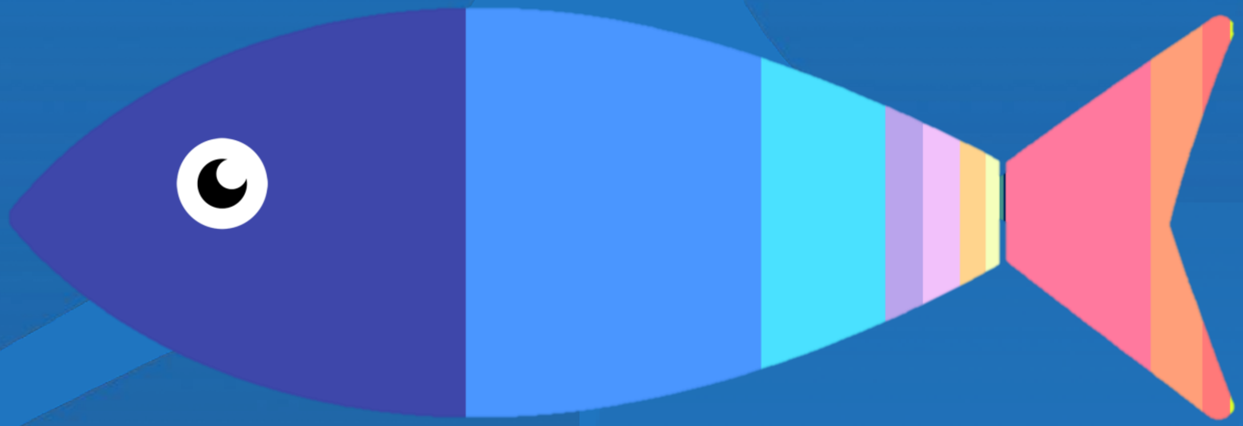

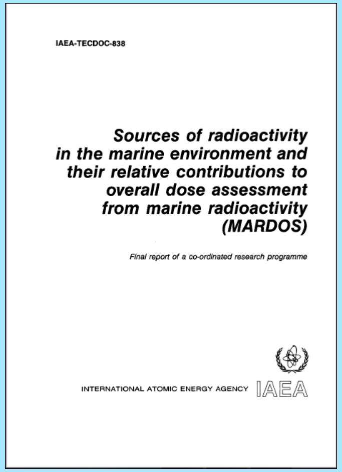

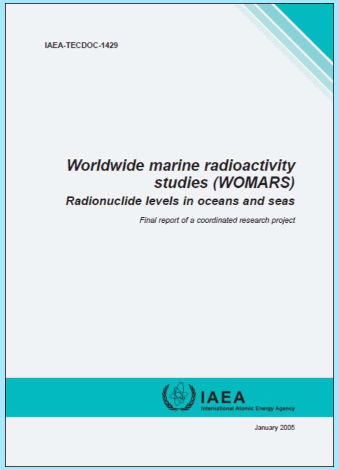

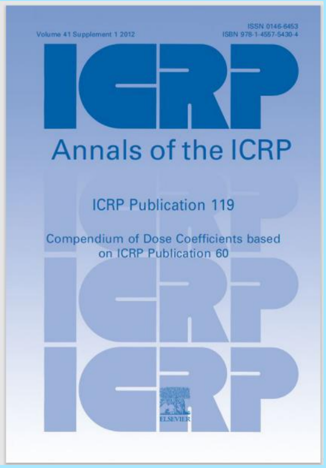

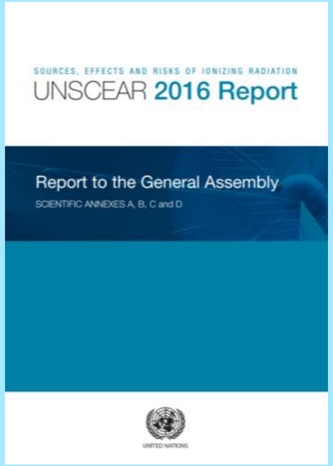

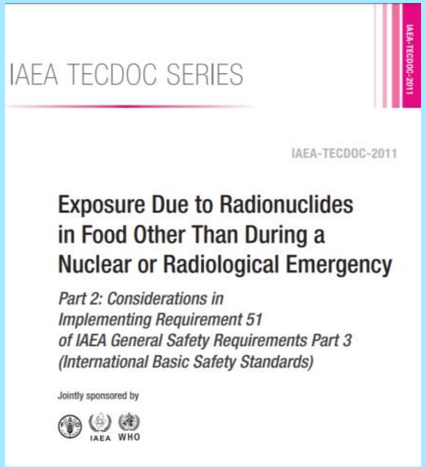

MARDOS (1995)

ICRP 101 & 119

IAEA-TECDOC-2011 (2022)

("Radionuclides in Foods")

WOMARS (2005)

UNSCEAR (2008, 2016)

1990 1995 2000 2005 2010 2015 2020 2025

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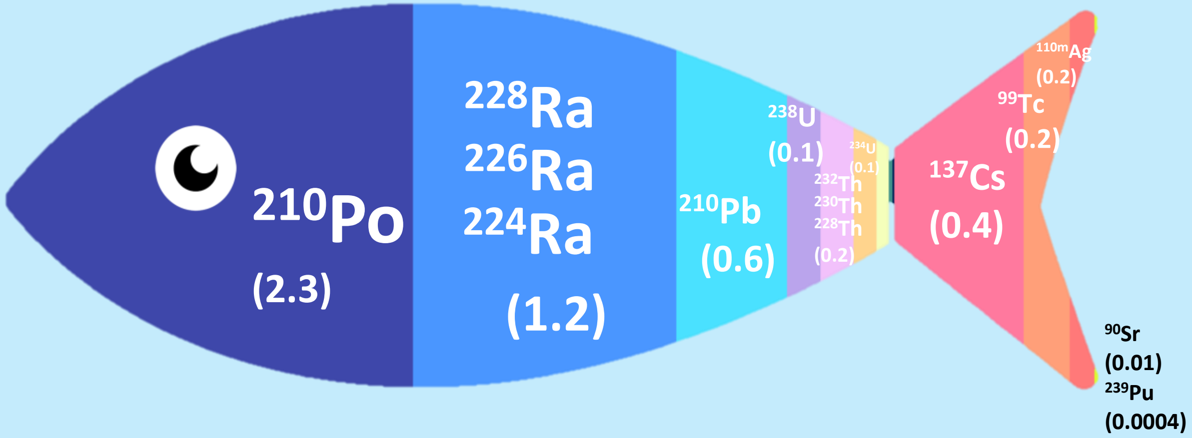
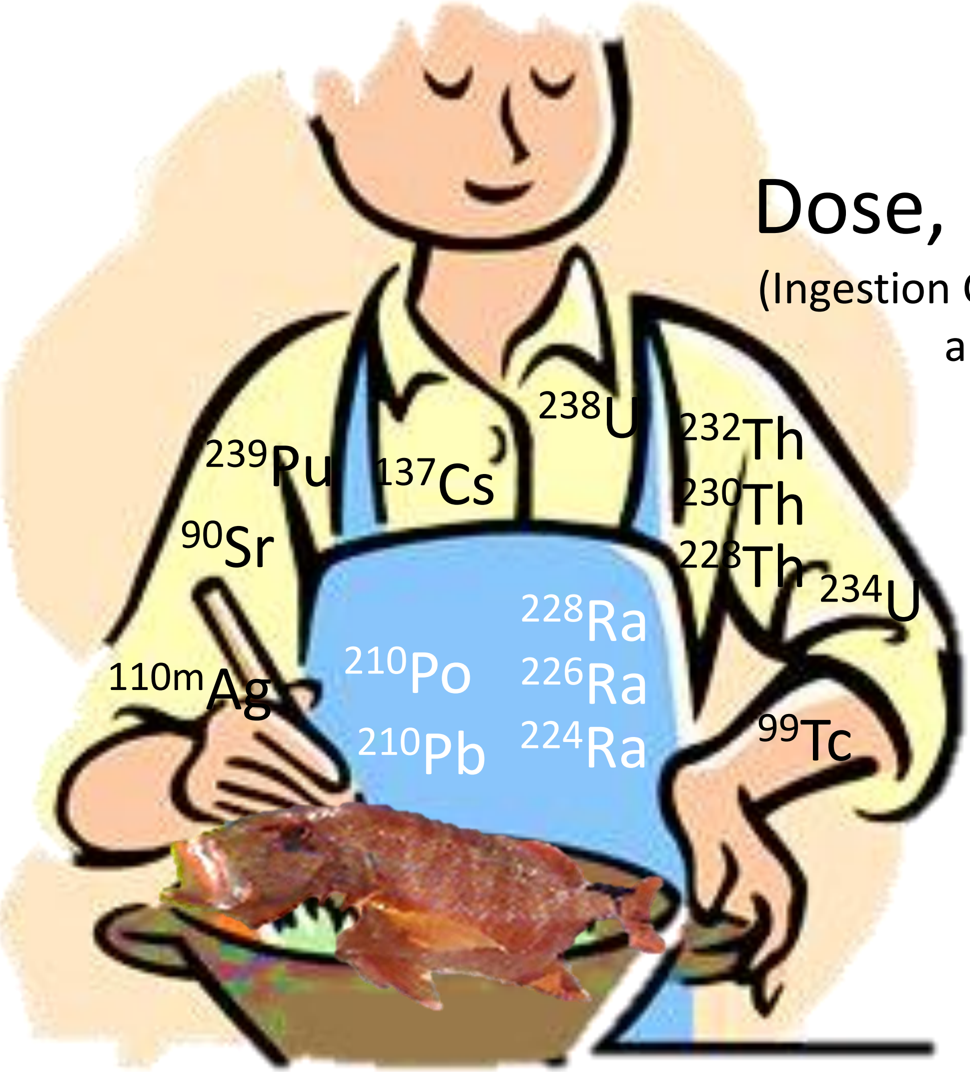
World medians, Bq/kg



(fish muscle, fresh mass)

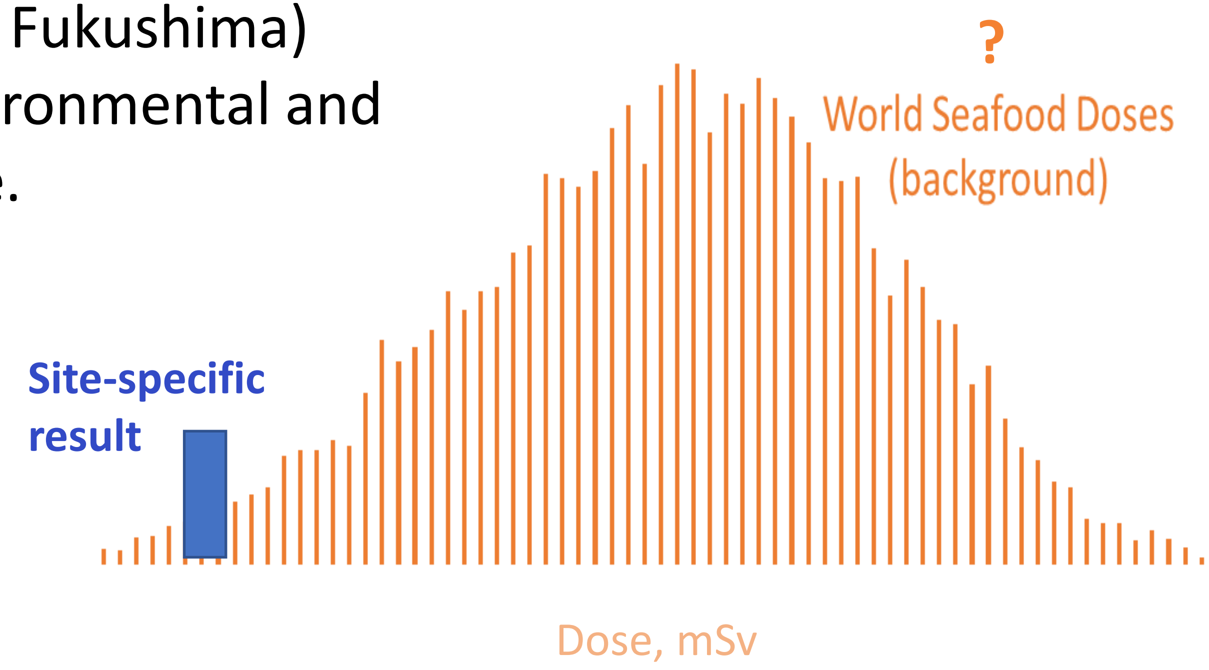


Dose, mSv

(Ingestion CED from annual intake)

Motives:

1. Quantify worldwide “background” seafood dose –an important component of overall background dose for billions of people.
2. Help explain site-specific studies (e.g., Fukushima)
3. Understand dose trends as global environmental and seafood consumption patterns change.
4. Update Guidance and parameters for calculating seafood dose.

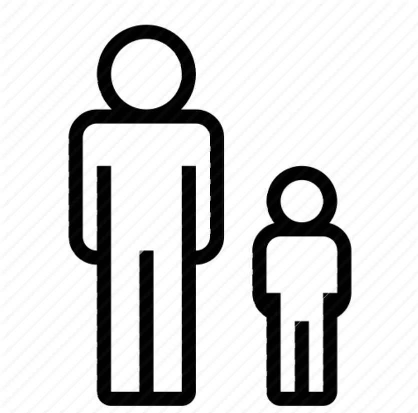


Methods-

$$\text{Ingestion Dose} = \sum_{i,j} \left(\frac{\text{Bq}}{\text{kg}}\right)(\text{kg})\left(\frac{m\text{Sv}}{\text{Bq}}\right)$$

Study subjects:

1. **World Adults who eat seafood**
2. **10-yr olds who eat seafood**

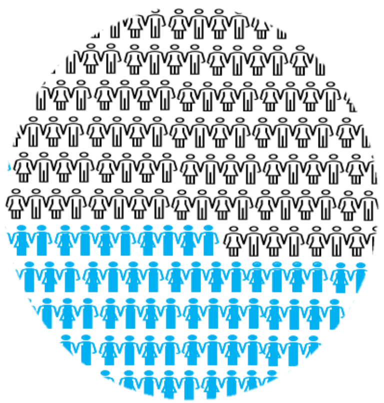


Ingestion Dose Conversion Factors (adult, 10 yrs, ICRP)

N= 348 Seafood ingestion amounts from published **diet studies.**

N(surveyed)= 1,256,319 individuals

N(represented)= 2,770,769,711
(~35% of world population)



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Methods-

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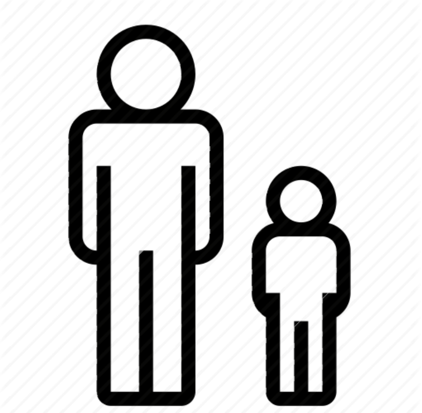

Ingestion Dose Conversion Factors (adult, 10 yrs, ICRP)

N= 348 Seafood ingestion amounts from published **diet studies.**

j = Six Seafood categories

Fish, Crustaceans, Bivalves, Gastropods, Cephalopods, Seaweed

Methods-

$$\text{Ingestion Dose} = \sum_{i,j} \left(\frac{\text{Bq}}{\text{kg}}\right)(\text{kg})\left(\frac{m\text{Sv}}{\text{Bq}}\right)$$

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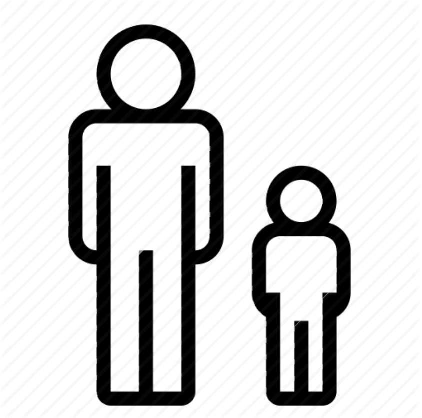

Ingestion Dose Conversion Factors (adult, 10 yrs, ICRP)

N=348 Seafood ingestion amounts from published **diet studies.**

j = Six Seafood categories

Fish, Crustaceans, Bivalves, Gastropods, Cephalopods, Seaweed

i = 16 radionuclides

^{210}Po, ^{210}Pb, ^{228}Ra, ^{228}Ra, ^{232}Th, ^{230}Th, ^{224}Ra, ^{228}Th, ^{238}U, ^{234}U, ^{14}C and ^{137}Cs, ^{239}Pu, ^{90}Sr, ^{99}Tc, ^{110m}Ag

N=9,456 $\left(\frac{\text{Bq}}{\text{kg}}\right)$ Activity Concentrations in seafood (IAEA MARIS database)

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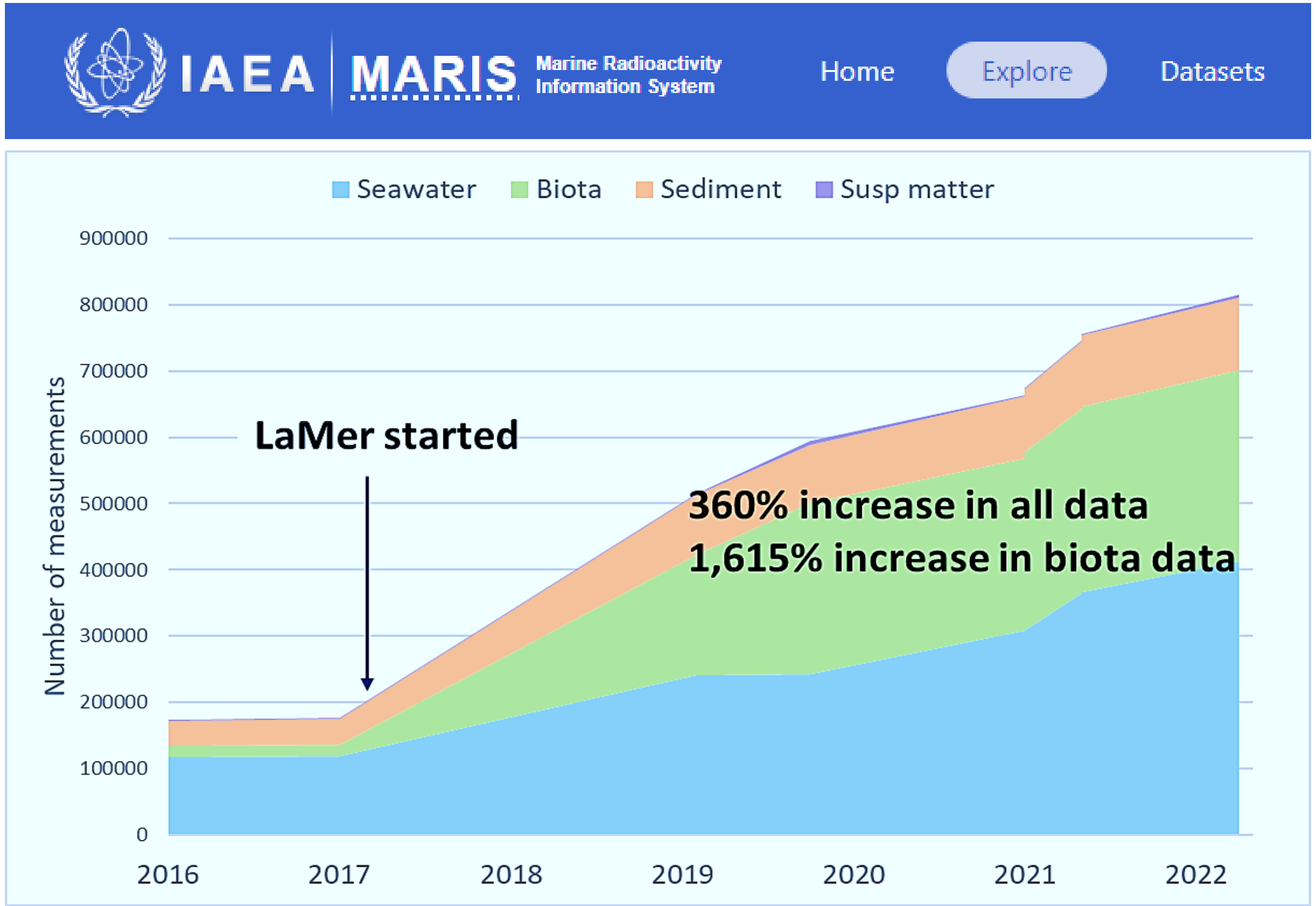
Methods-Activity Concentrations

$$\text{Dose} = \sum_{i,j}^{n} \left(\frac{\text{Bq}}{\text{kg}}\right)(\text{kg})\left(\frac{mSv}{\text{Bq}}\right)$$



https://www.iaea.org/resources/databases/marine-radioactivity-information-system-maris

LaMer: Behaviour and Effects of Natural and Anthropogenic Radionuclides in the Marine Environment and their use as Tracers for Oceanography Studies, Coordinated Research Project.

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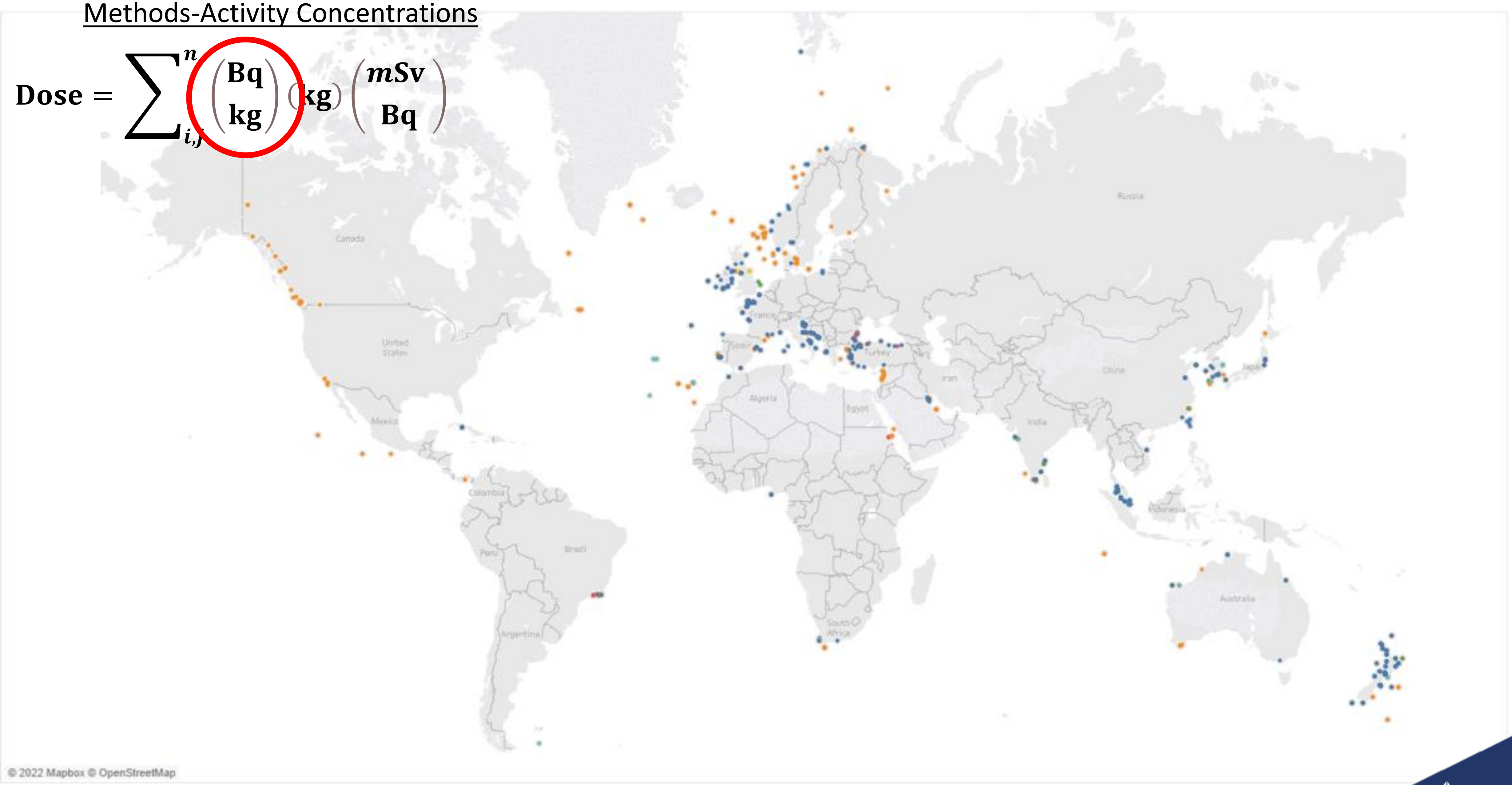
Po-210

Methods-Activity Concentrations

$$\text{Dose} = \sum_{i,j}^{n} \left(\frac{\text{Bq}}{\text{kg}}\right)(\text{kg})\left(\frac{mSv}{\text{Bq}}\right)$$



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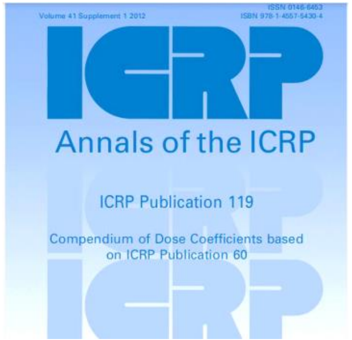
Methods-dose conversion factors

$$\text{Dose} = \sum_{i,j=0}^{n} \left(\frac{\text{Bq}}{\text{kg}}\right)(\text{kg})\left(\frac{\text{mSv}}{\text{Bq}}\right)$$

16 = radionuclides, 6= Seafood categories

Solved by Monte Carlo for:

- 16 radionuclides
- 6 seafood categories
- World diet distributions
- ICRP DCFs



6 seafood categories

Monte Carlo

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Results:

1. Global seafood doses

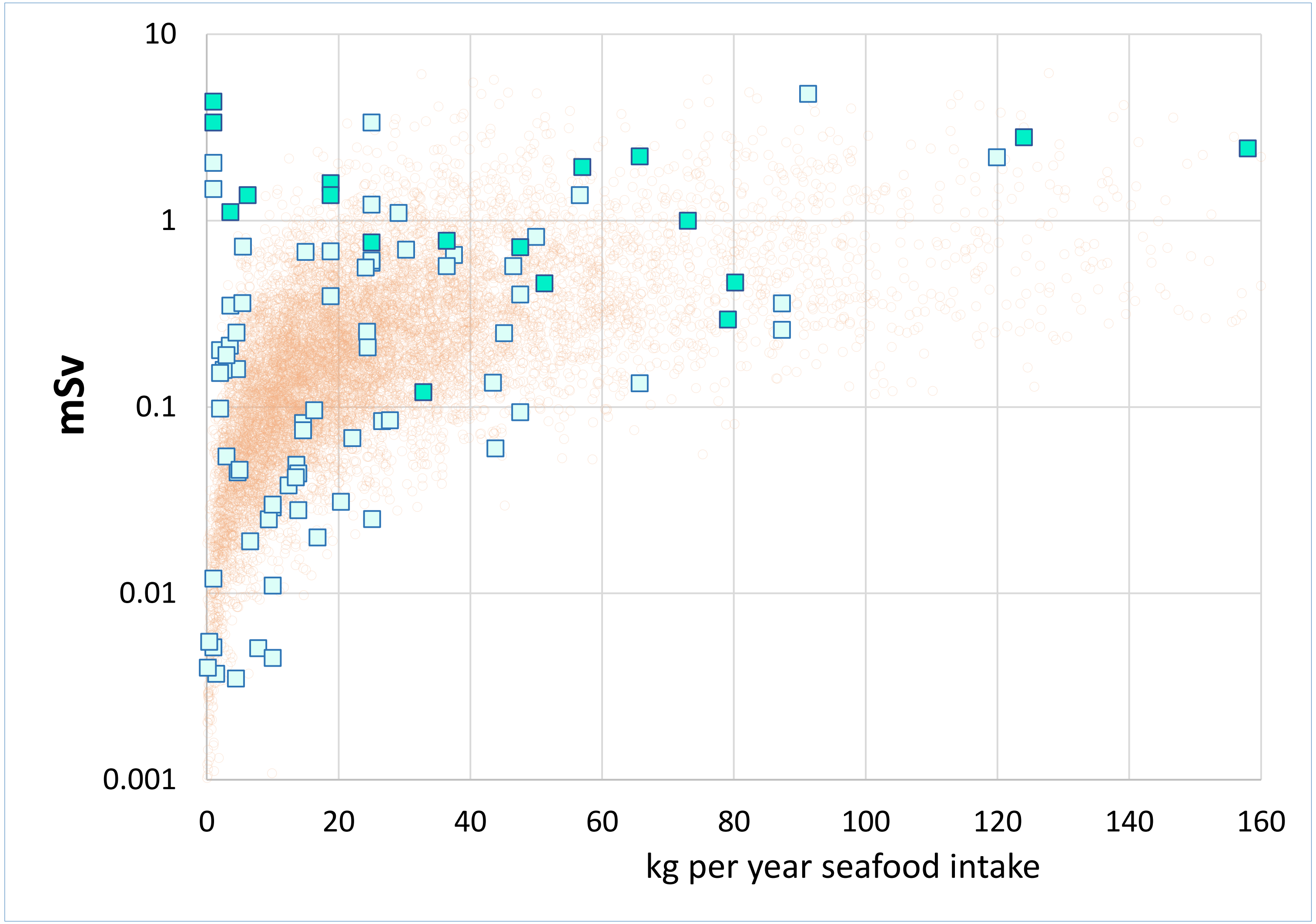
   A. From published studies that include ^{210}Po:

   Best estimate (N=82)

   High-rate (N=20)

   B. From This Study

   Adult Seafood Consumers, Global diet and $\left(\frac{Bq}{kg}\right)$ data (N= 10,000)



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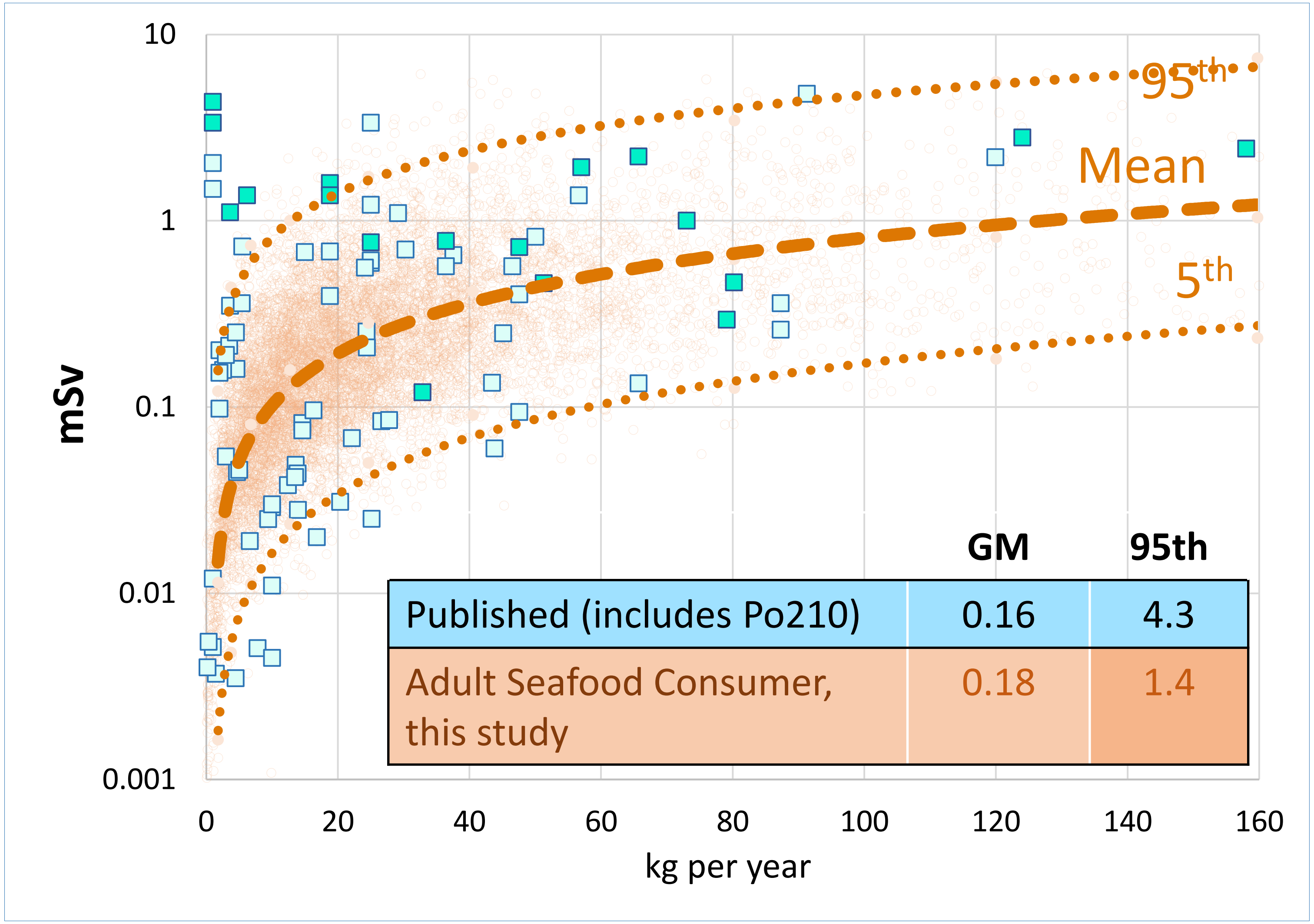
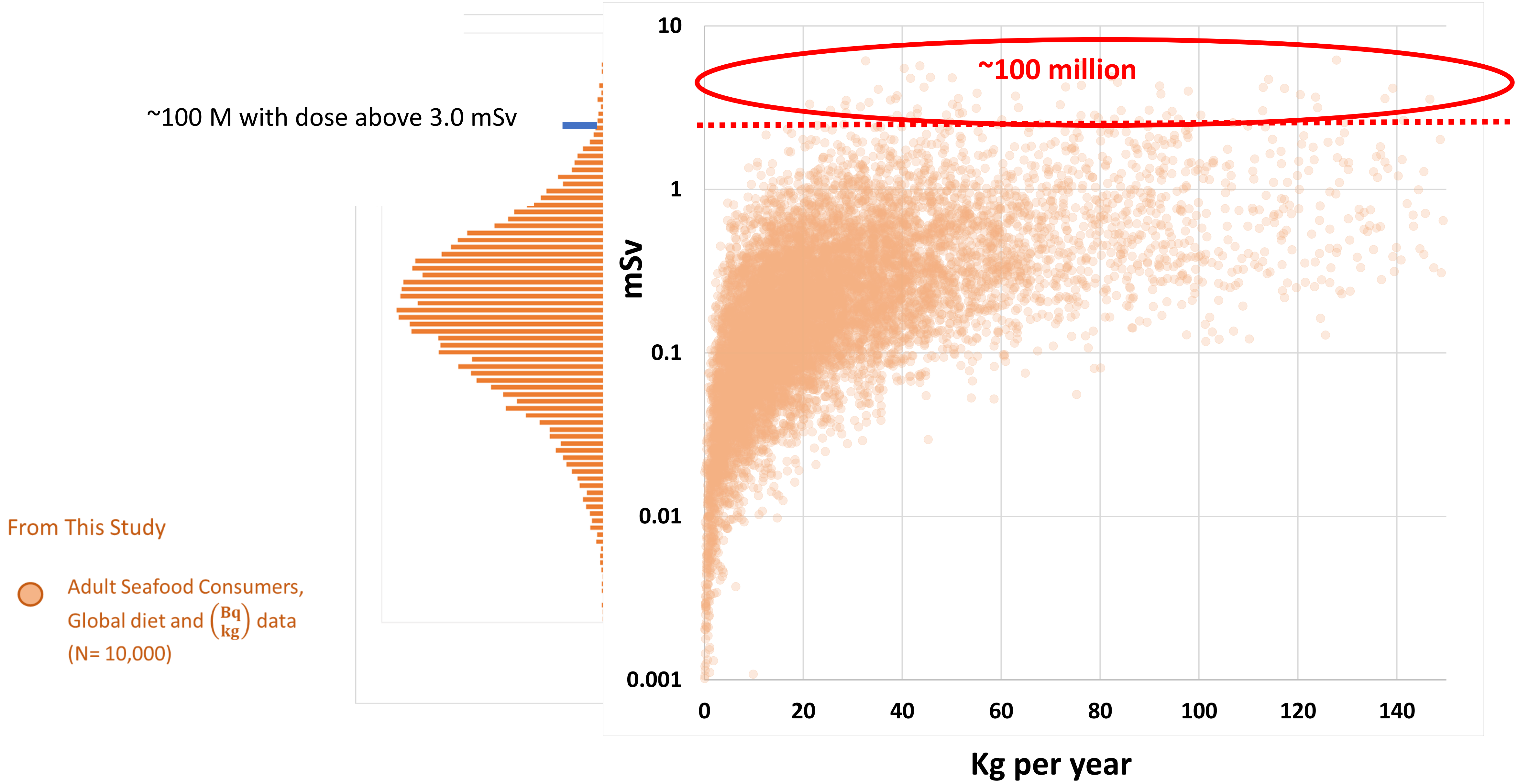


	GM	95th
Published (includes Po210)	0.16	4.3
Adult Seafood Consumer, this study	0.18	1.4

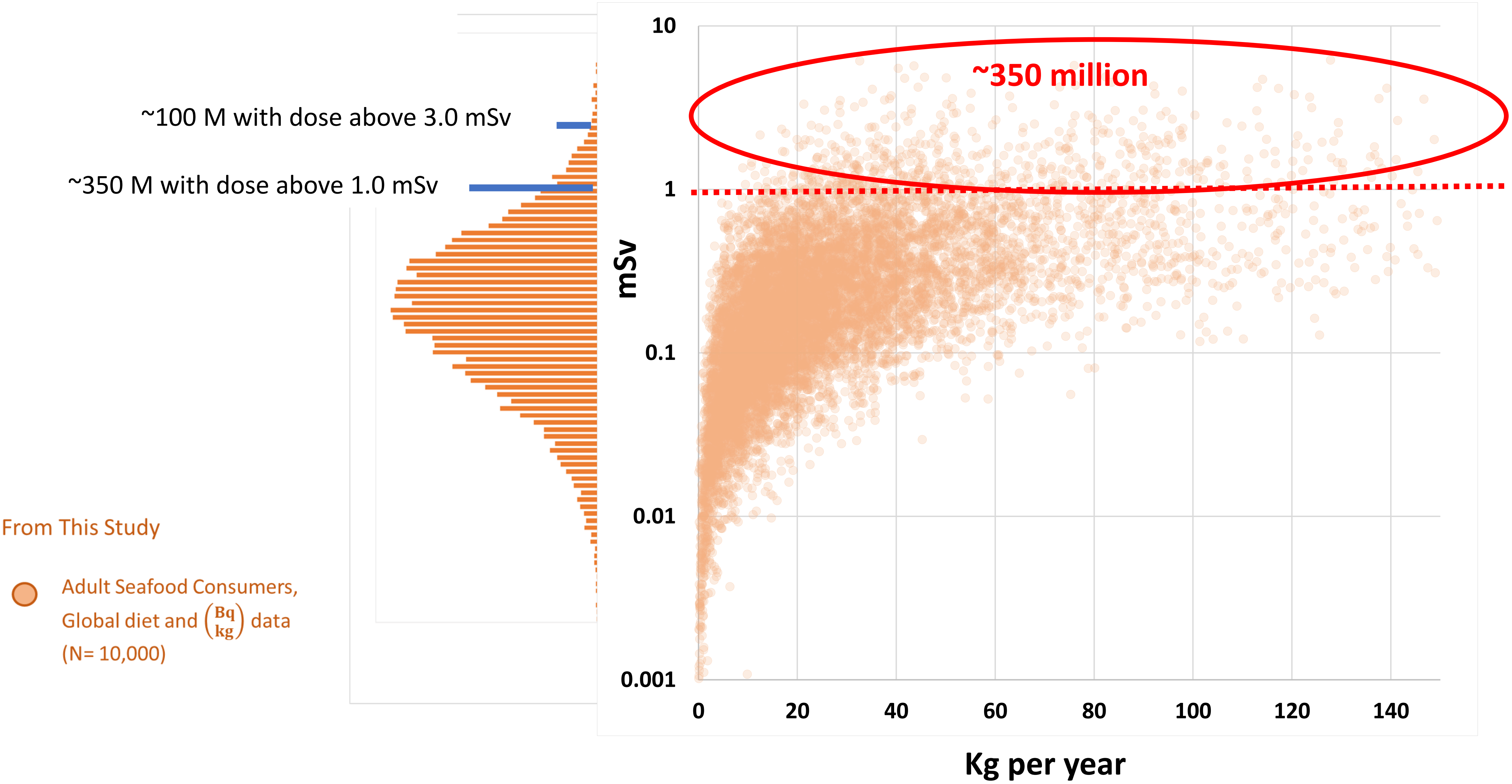
Results:

1. Global seafood doses



Results:

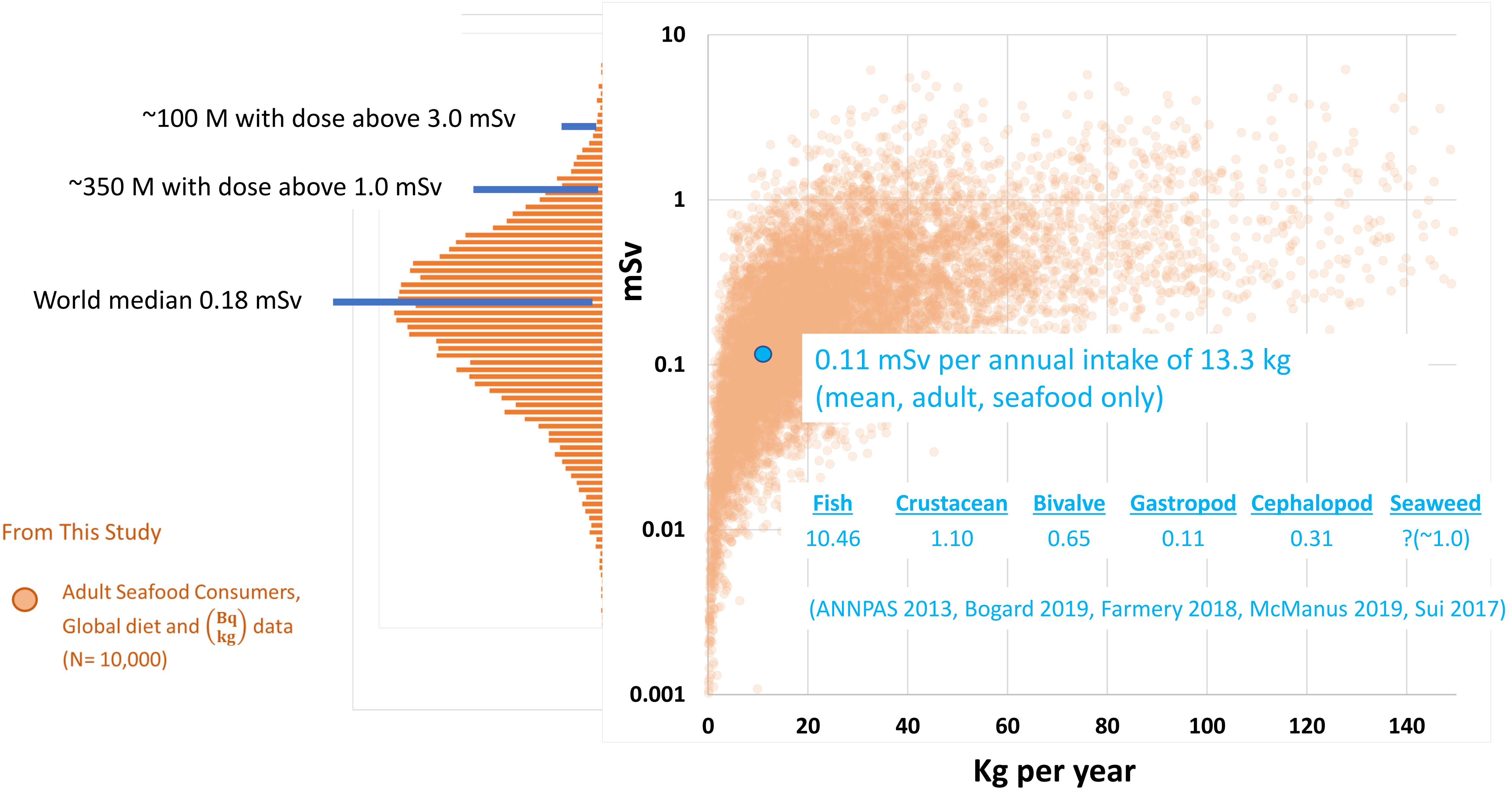
1. Global seafood doses



Results:

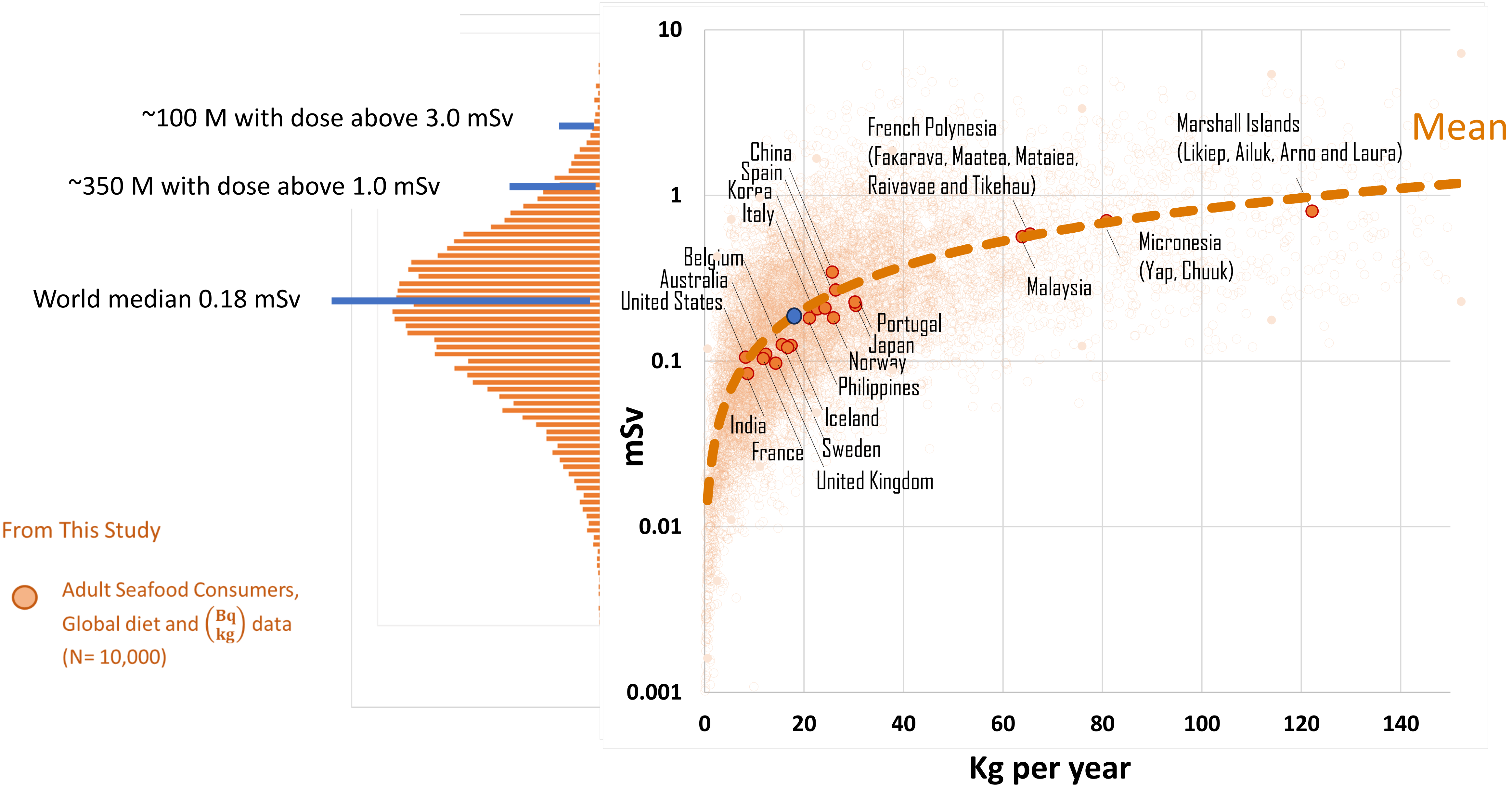
1. Global seafood doses

Mean for Australia?



Results:

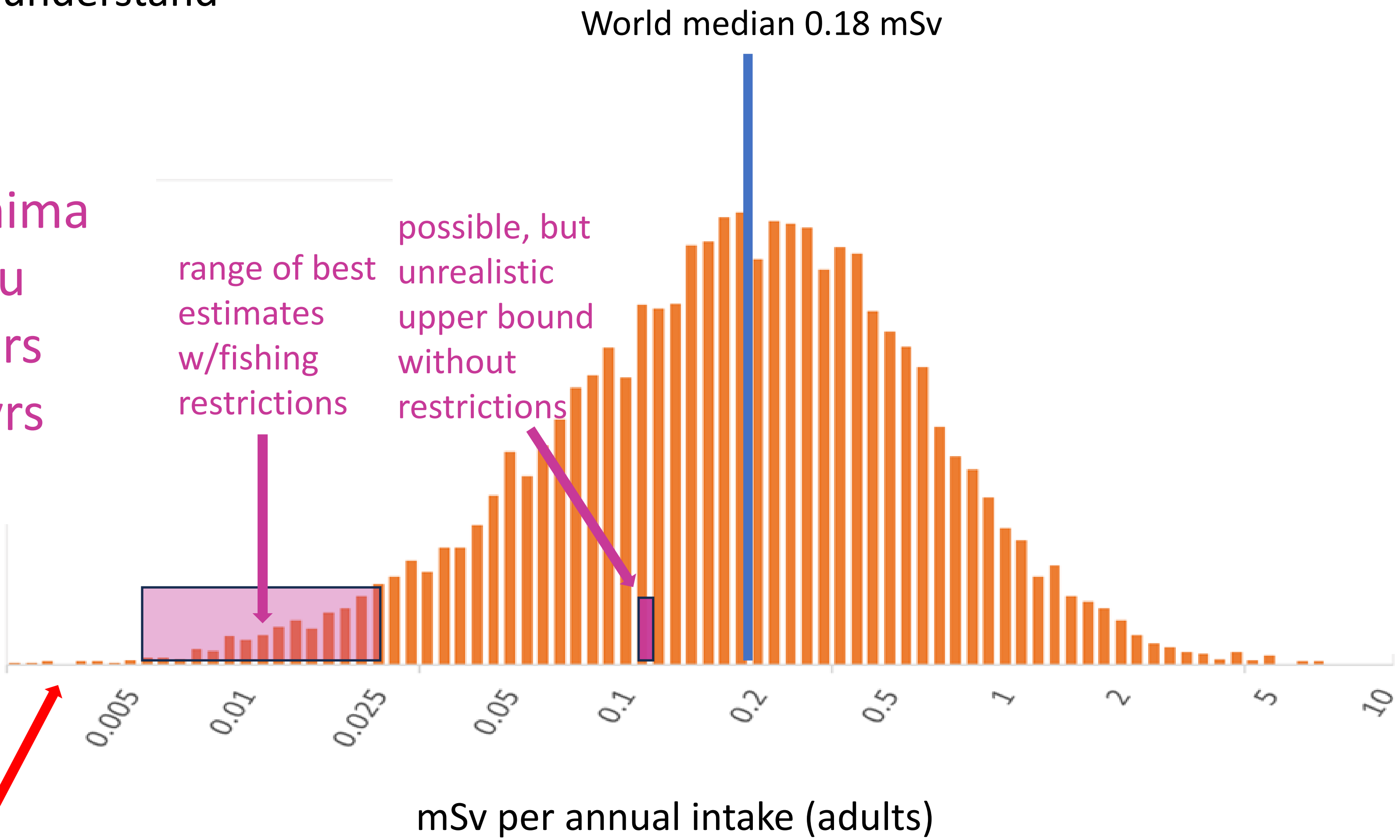
1. Global seafood doses



Results:

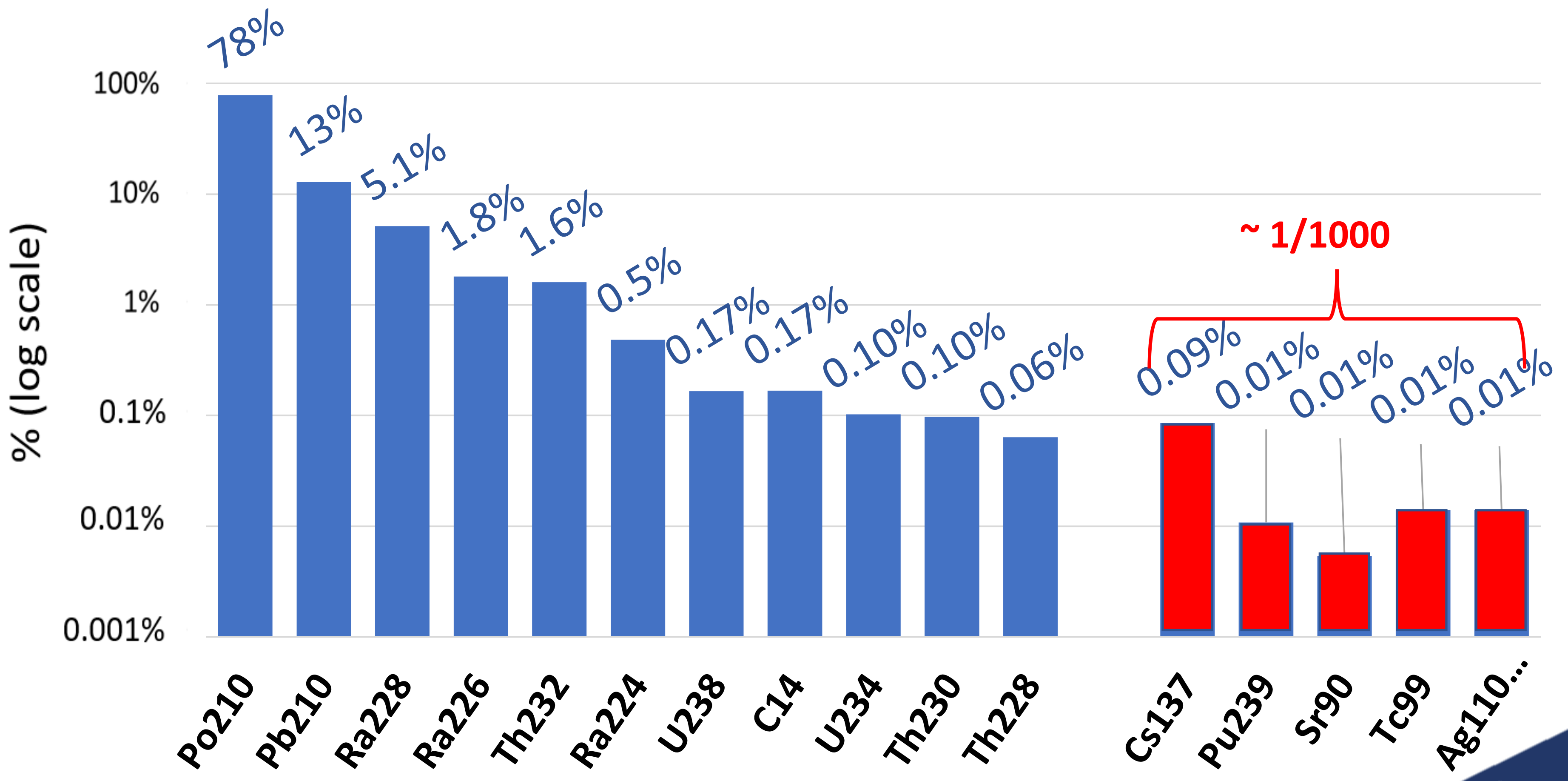
1. Global seafood doses –helping understand site studies

Added Dose from Fukushima accident to typical Tohoku Region seafood consumers (retrospective data, 1-3 yrs after accident)



Predicted seafood doses from ALPS releases are lower 1-2 orders of magnitude lower.

16 Radionuclides
% Contribution to total dose (log scale)



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Results: Which seafood groups contribute most dose?

6 Seafood types


Fish


Crustacean


Bivalve


Gastropod


Cephalopod


Seaweed

Consumption		Dose
62%	Fish	37%
10%	Crustacean	14%
13%	Bivalve	41%
2%	Gastropod	3%
3%	Cephalopod	1%
9%	Seaweed	4%

Bivalves are known to have higher ^{210}Po

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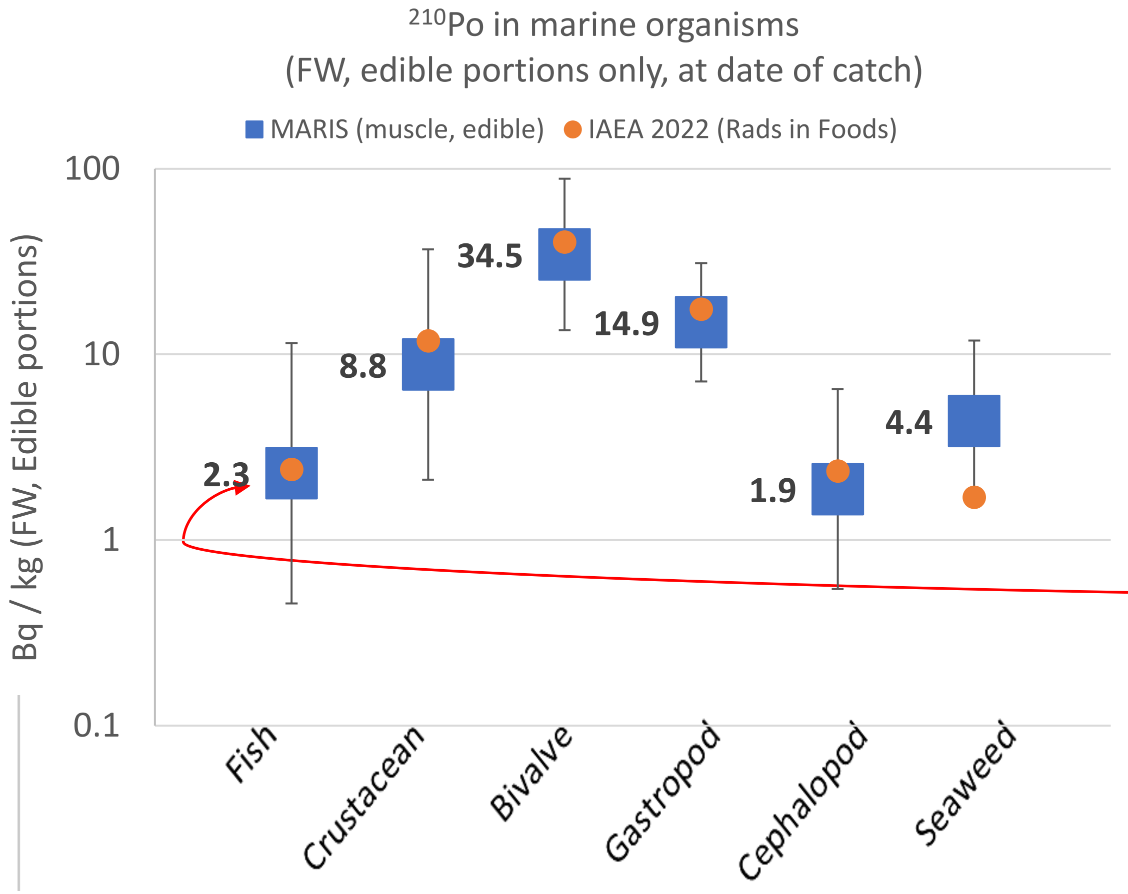
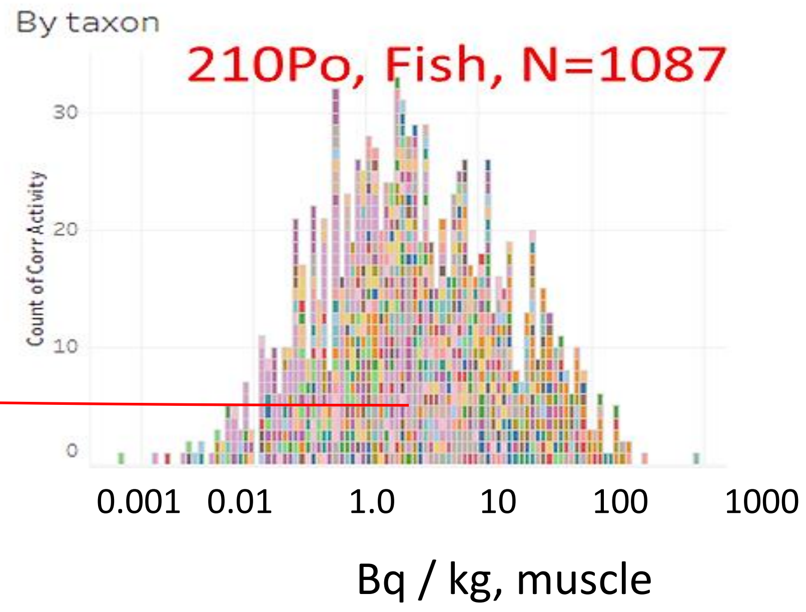
Methods-Activity Concentrations

$$\text{Dose} = \sum_{i,j}^{n} \left(\frac{\text{Bq}}{\text{kg}}\right)(\text{kg})\left(\frac{mSv}{\text{Bq}}\right)$$

^{210}Po Activity Concentrations



Example of one distribution:



	Fish	Crust	Biv	Gast	Ceph	Seaweed	Total
Po-210	1087	183	857	266	51	68	2512

N= for each category

Why do Bivalves have higher ^{210}Po?

1) Filter Feeders:
The ^{210}Po in marine waters readily integrates into plankton, algae, and attaches to small particles.
These are taken in by oysters, clams and mussels as they filter feed.

2) In most seafood, we do not eat the digestive organs. For bivalves, we typically do.
Most people eat all bivalve soft tissues, including the hepatopancreas in the digestive tract.

P. Stepnowski, B. Skwarzec / J. Environ. Radioactivity 49 (2000)

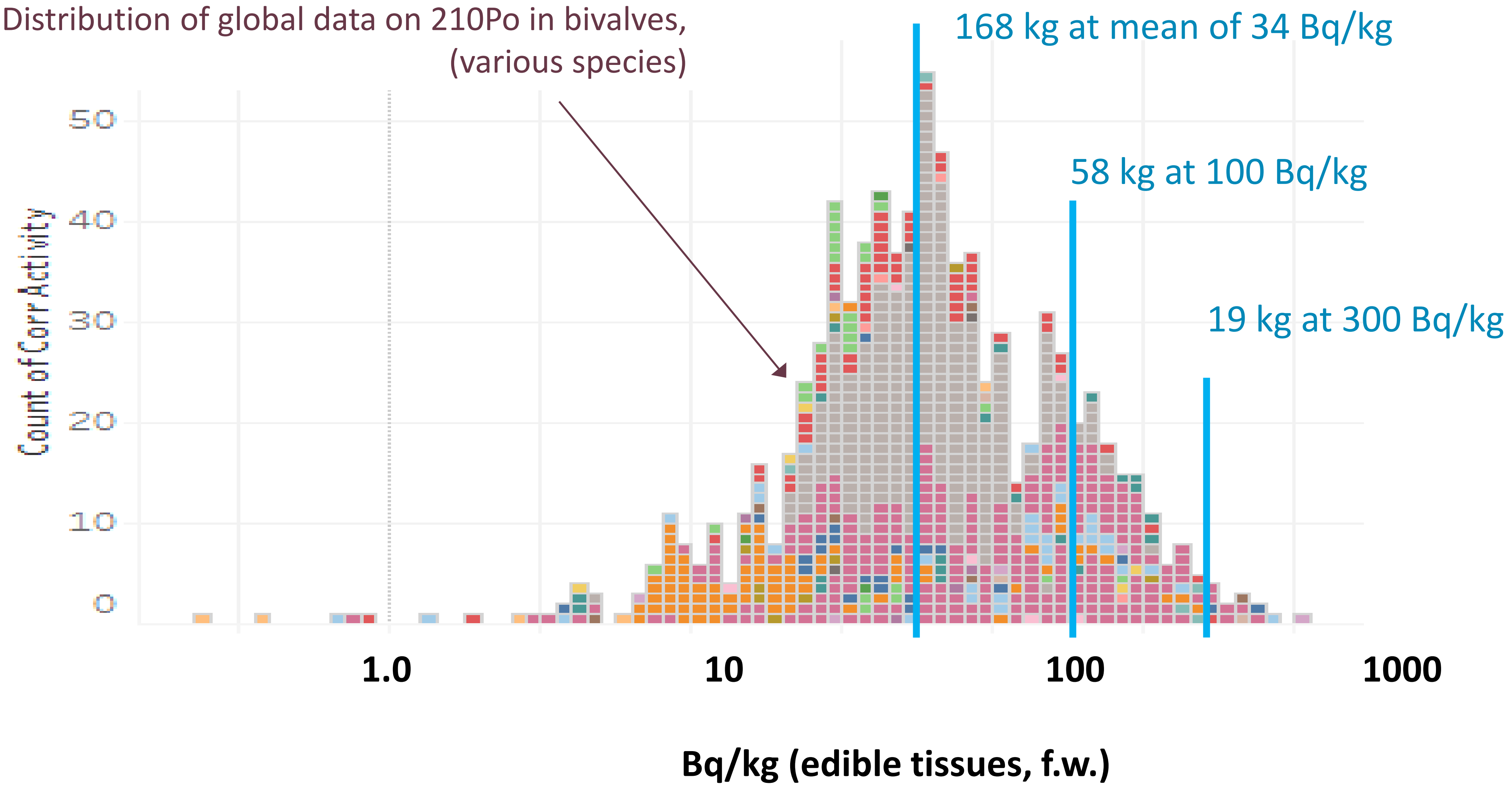
Table 1
The ^{210}Po concentrations, ^{210}Po/^{210}Pb activity ratios, CFs and wet:dry ratios *trossulus* and *Mya arenaria* (Bq kg^{-1} dry wt ± 1SD)

Organ, tissue		*Mytilus trossulus*		
	^{210}Po	^{210}Po/^{210}Pb	wet:dry	^{210}Po
Hepatopancreas	1026.0 ± 107.0	68.4	7.7	87.0 ± 17.0
Gills	232.0 ± 10.0	21.0		
Muscle	56.5 ± 8.4	41.8		
Shell	0.9 ± 0.1	6.0		
Byssal threads[a]	30.0 ± 1.7	1.4		
Residue[b]	—	—		
Fat[b]	—	—		
Total soft tissue	271.7 ± 27.6	48.3		
Concentration factor[c]	24,000			

Stepnowski et al. 2000

What seafood consumption leads to a 10 mSv dose?

Eating only bivalves, a 10 mSv dose occurs when an adult eats:



^{210}Po decreases between sampling and consumption:

Journal of Environmental Radioactivity 268-269 (2023) 107243

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

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Seafood dose parameters: Updating ^{210}Po retention factors for cooking, decay loss and mariculture

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ABSTRACT

^{210}Po has been identified as one of the main contributors to ingestion doses to humans, particularly from the consumption of seafood. The amount of ^{210}Po activity concentration data for various types of seafood has increased greatly in recent times. However, to provide realistic seafood dose assessments, most ^{210}Po data requires correction to account for losses that can occur before the seafood is actually consumed. Here we develop generic correction factors for the main processes associated with reduction of ^{210}Po in seafood – leaching during cooking, radioactive decay between harvest and consumption, and sourcing from mariculture versus wild-caught.

When seafood is cooked, the overall mean fraction of ^{210}Po retained is 0.74 for all cooking and seafood types, with the means for various seafood types and cooking categories ranging from 0.56 to 1.03. When considering radioactive decay during the period between harvest and consumption, the overall mean fraction remaining is 0.81 across all seafood preservation/packaging types, with estimates ranging from 0.50 (canned seafood) to 0.98 (fresh seafood). Regarding mariculture influence, the available limited data suggest marine fish and crustaceans raised with processed feed have about one order of magnitude lower (×0.10) ^{210}Po muscle content than wild-caught seafood of the same or similar species, although this ratio varies.

Overall, this study concludes that ^{210}Po activity concentrations in seafood at the time of ingestion may be reduced to only about 55% compared to when it was harvested. Therefore, correction factors must be applied to any data derived from environmental monitoring in order to achieve realistic dose estimates. The data also suggest lower ^{210}Po ingestion doses for consumers who routinely favour cooked, long shelf-life and farmed fish/crustaceans. However, more data is needed in some categories, especially for cooking of molluscs and seaweed, and for the ^{210}Po content in all farmed seafood.

Johansen et al. 2023
https://doi.org/10.1016/j.jenvrad.2023.107243

- Catch-to-Plate decay

Table 3. Recommended R_{decay} factors representing the fractions of ^{210}Po remaining after typical Harvest-to-Consumption durations for various seafood processing/preservation types See Tables S2, S3 for supporting information.

	Total delay, Harvest-to-Consumption[1] 50th (range) [3] (days)	Recommended R_{decay} factors Recommended (range)	References[2]
Fresh	5 (0-17)	**0.98** (0.93-1.0)	1-5
Frozen	89 (1-540)	**0.70** (0.21-1.0)	6-10
Canned	177 (10-2070)	**0.50** (0.14-0.96)	9-11
Dried	51 (10-410)	**0.81** (0.14-0.96)	12-15
Smoked	13 (2-62)	**0.95** (0.78-0.99)	6,16-22
All seafood (weighted)[4]	57 (0-2070)	**0.81** (0.14-0.1.0)	

[1] Harvest-to-Consumption includes Harvest-to-Market (transport, processing and storage times from the time of removal from the ocean until arrival at retail marketplace) and Market-to-Consumption (warehouse, display and consumer storage times from the time of arrival at the market until consumption).

Mean for all processing types **=0.81** (retained)

- Leaching during cooking

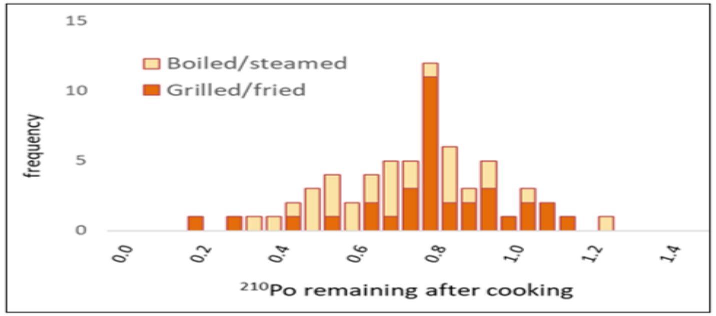
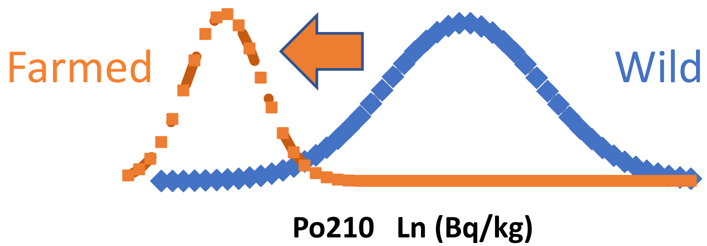


Figure 1. Histogram of published values of the fraction of ^{210}Po activit cooking. Data include marine fish, crustaceans, and bivalves (cephalo data not available). Data are for the edible tissues, without stock, brc text). See Table 2 and Table S1.1 for source data summaries and refe

Mean for all cooking methods **=0.74** (retained)

- Depletion in farmed fish



Fish raised with processed feed **= ~0.2**

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Summary

- A well-supported distribution, mean of global seafood dose is now available
- Dose from anthropogenic radionuclides (^{137}Cs, ^{239}Pu) is relatively low, even following major releases.
- ^{210}Po is, by far, the most important radionuclide for seafood dose
- ^{210}Po Bq/kg levels vary greatly in different types of marine organisms and in their various tissues, which in turn causes large variation in global seafood doses.
- Massive increase in ^{210}Po Bq/kg data in Seafood (MARIS)
- Updated ^{210}Po delay, cooking and aquaculture factors

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