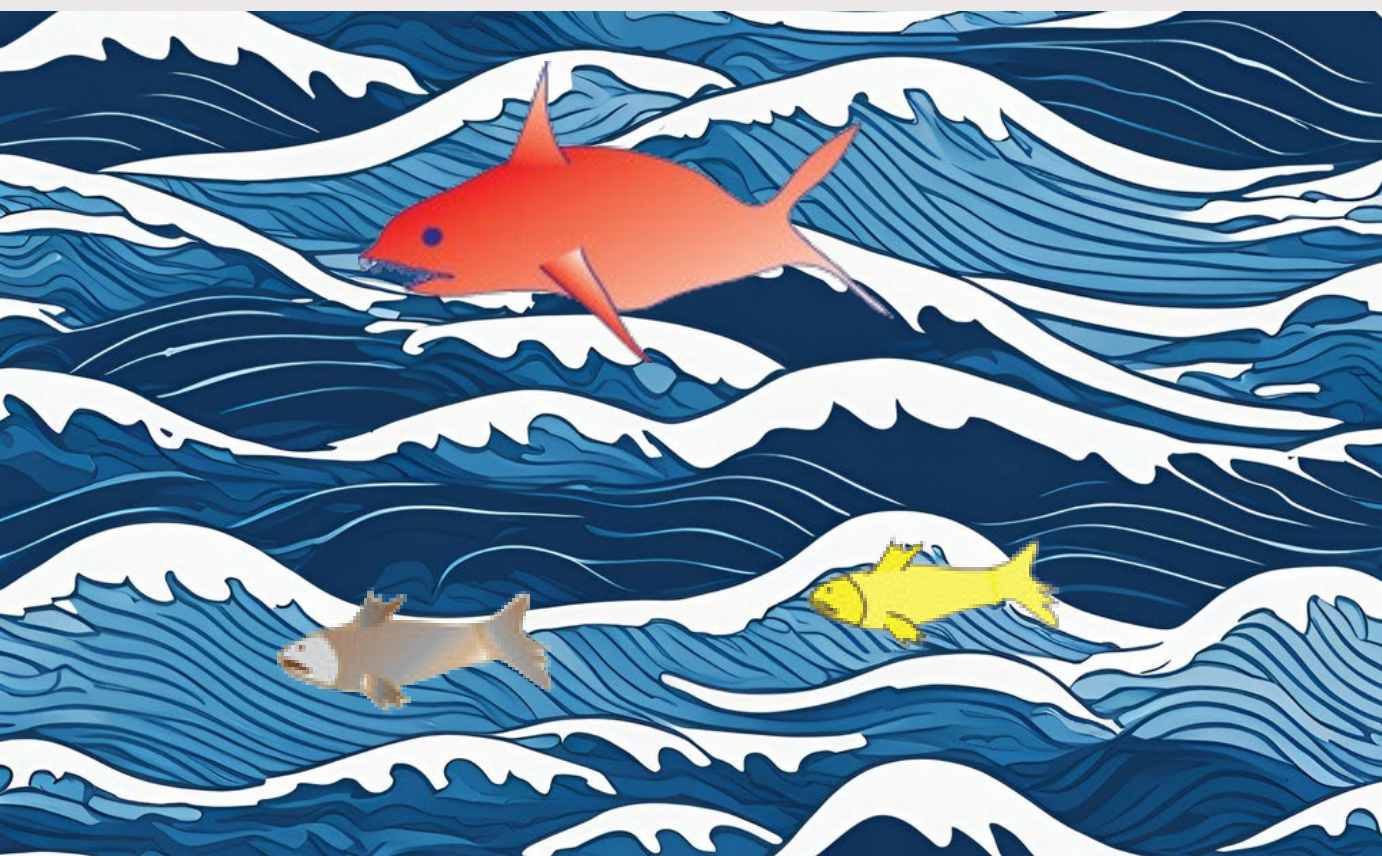


IF YOU DON'T SEE IT DOESN'T MEAN IT IS NOT WORKING.

SAMPLE SIZE AND THE EFFECTIVENESS EVALUATION OF MINAMATA CONVENTION

Asif Qureshi, Elsie Sunderland
IIT Hyderabad, Harvard University

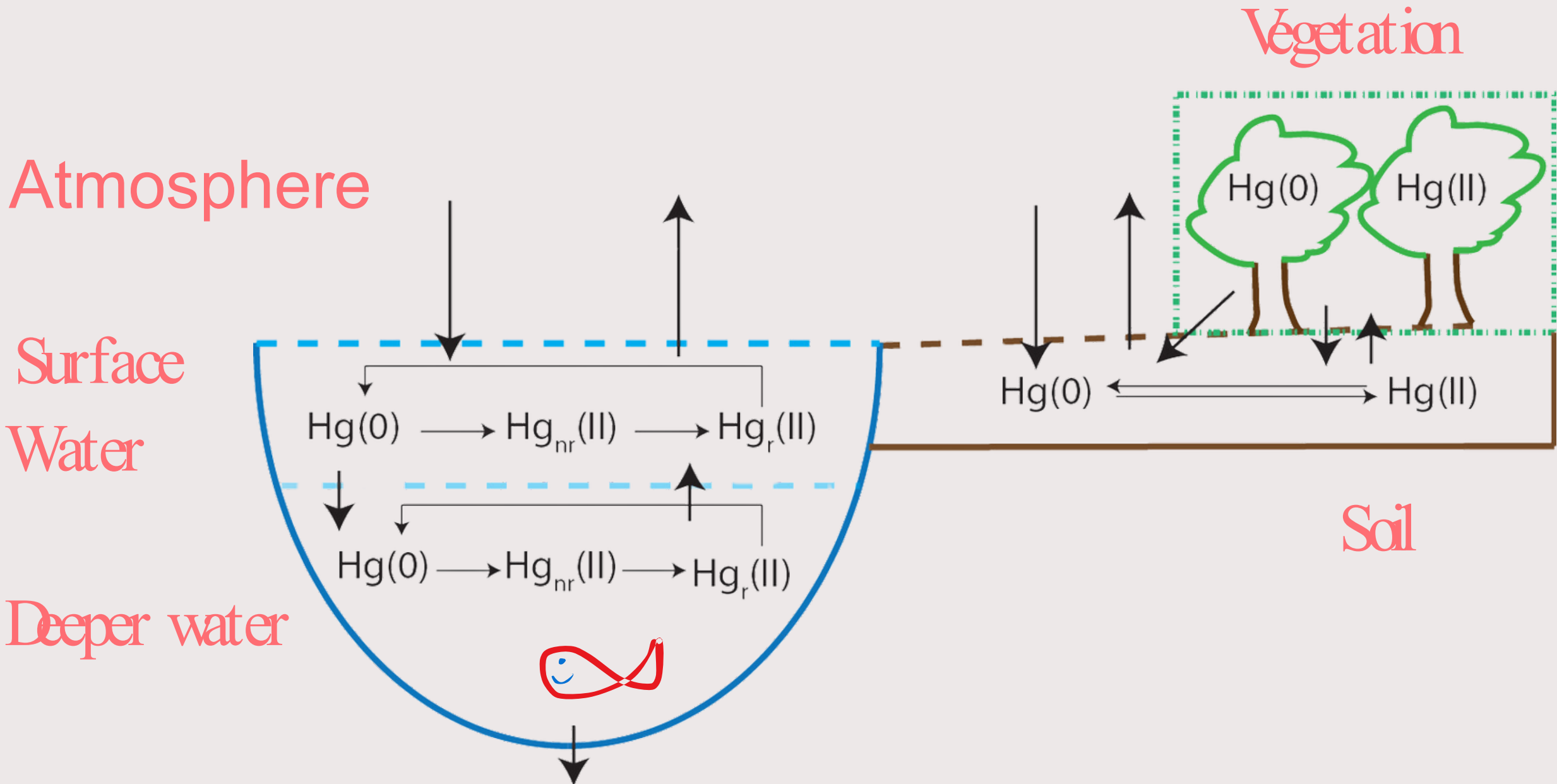


26 July 2024



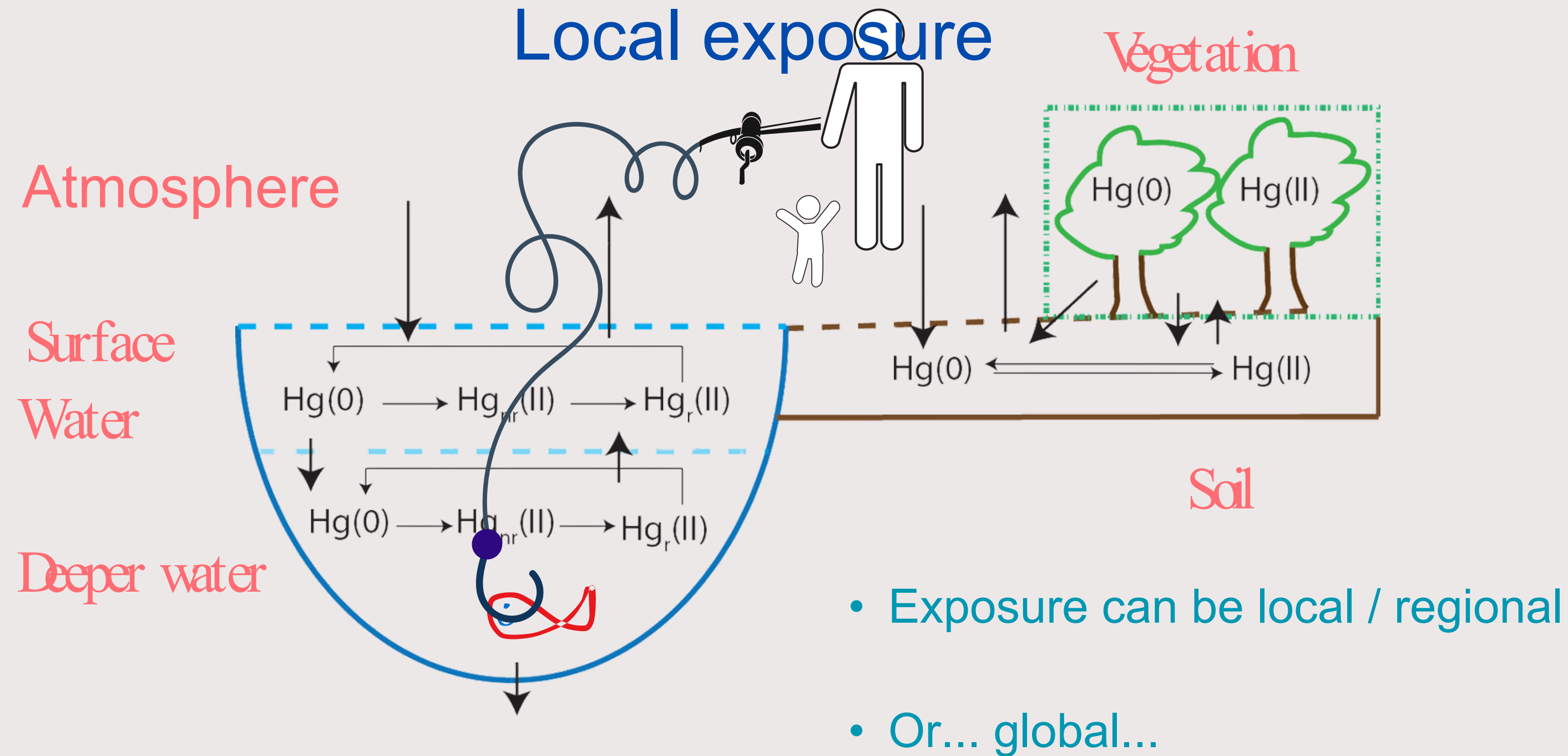
Globally fish is a major nutrition source

Concurrently people are exposed to mercury (& other contaminants)



Globally fish is a major nutrition source

Concurrently people are exposed to mercury (& other contaminants)



Ocean Environment

(let us say, global exposure)



Ocean Environment

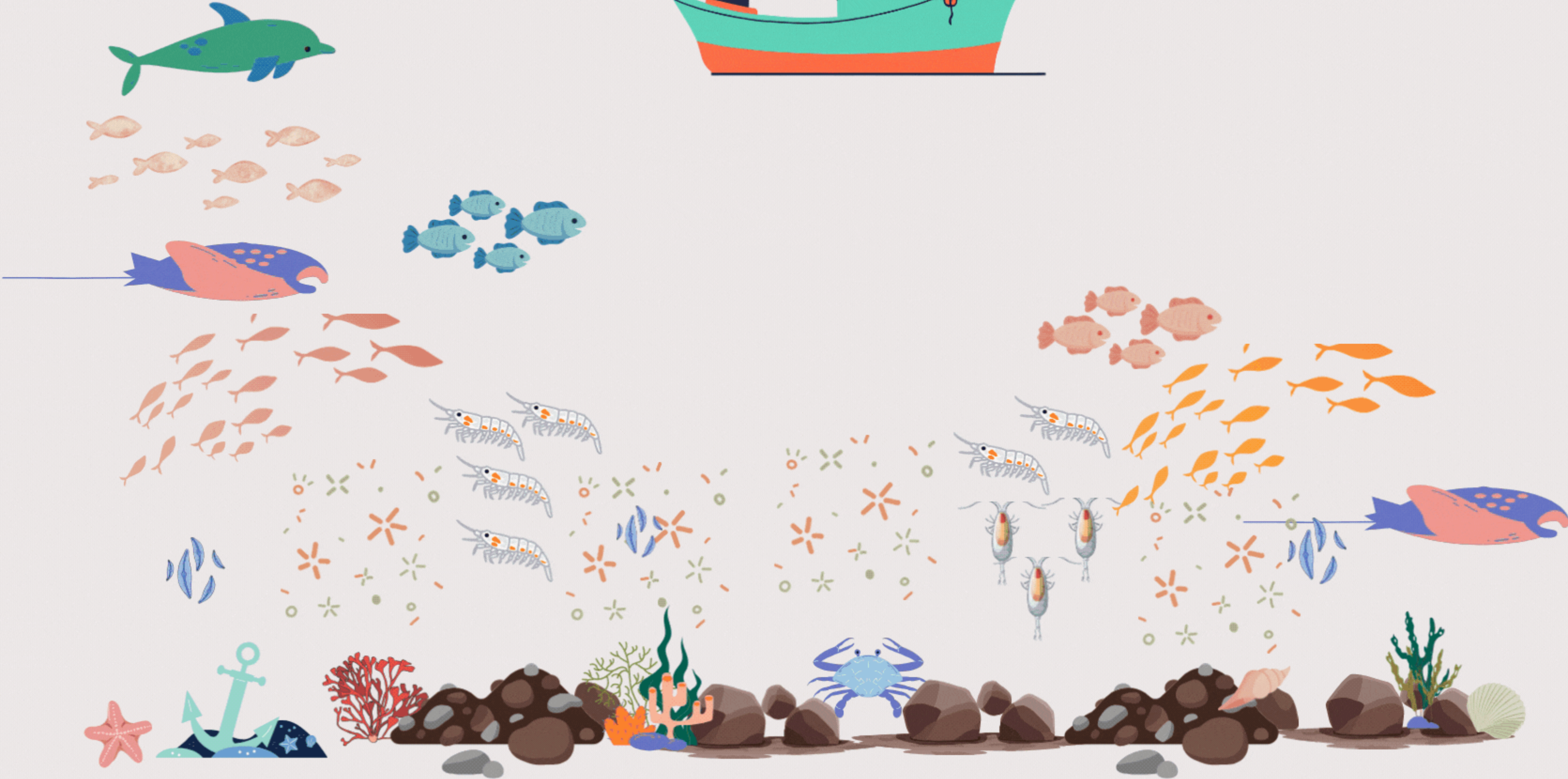
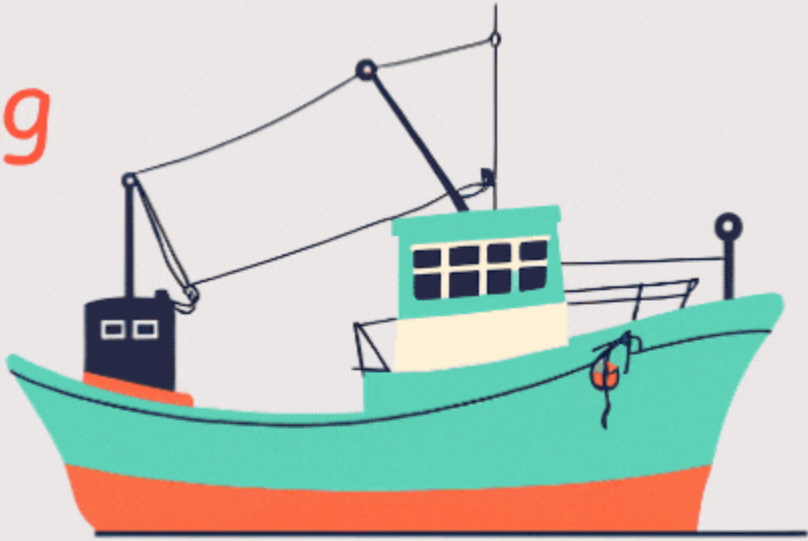
Fishing



Ocean Environment

Fishing

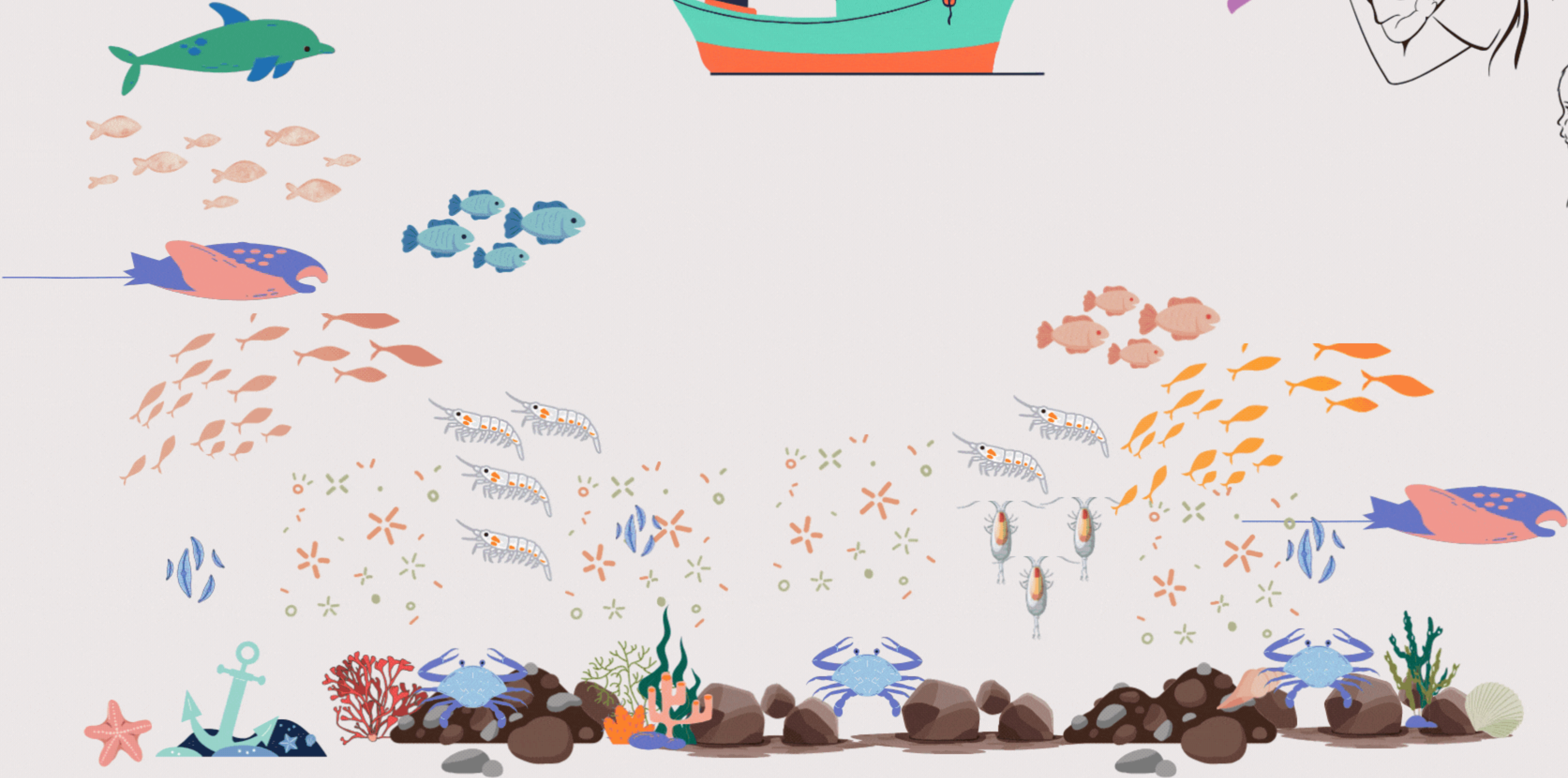
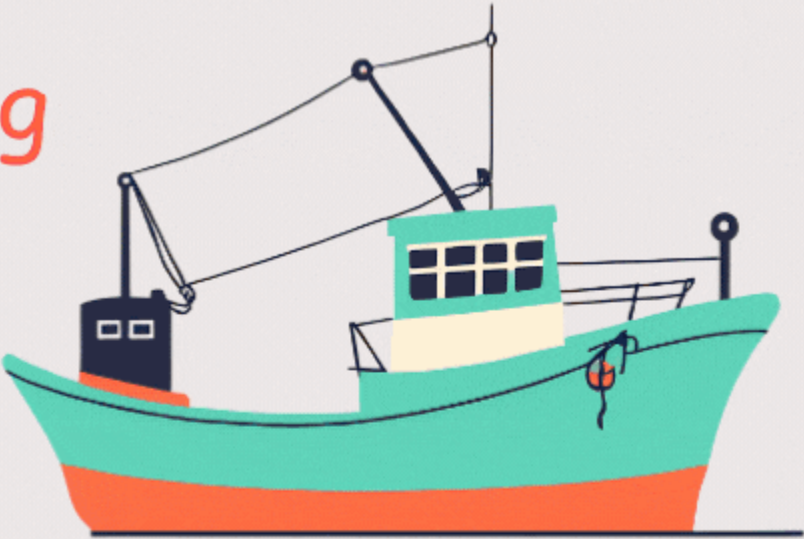
Take it home...



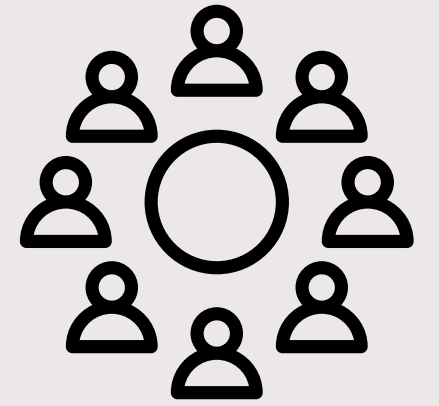
Ocean Environment

Fishing

Exposure



Minamata Convention on Mercury



Primary goal: to reduce human exposure to mercury

Important to assess how effective are policy measures in reducing the exposure

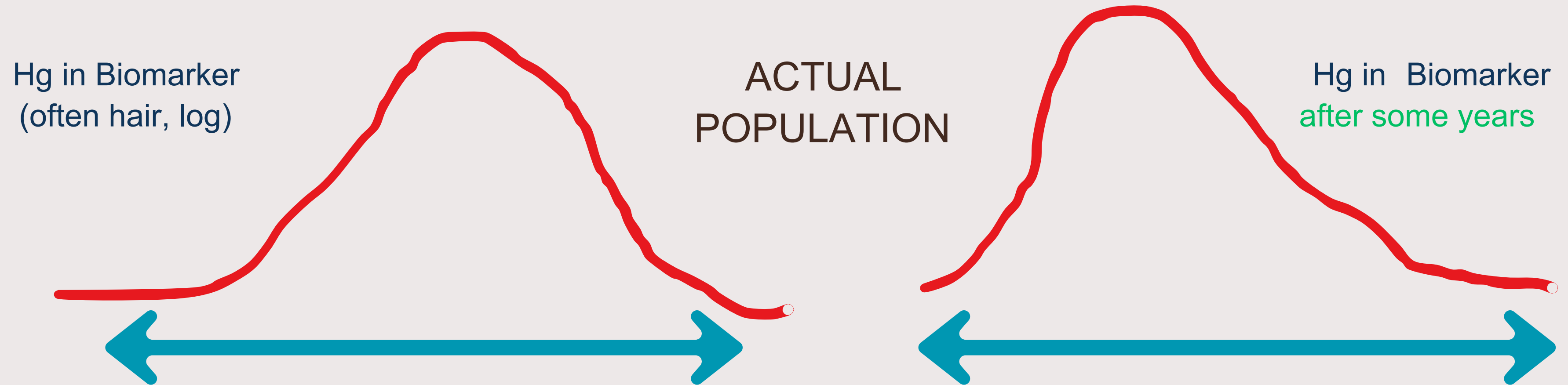
One of the approaches

- To monitor, and assess changes in, mercury in human biomarker over time
- Anything decreased or not

Minamata Convention on Mercury

One of the approaches

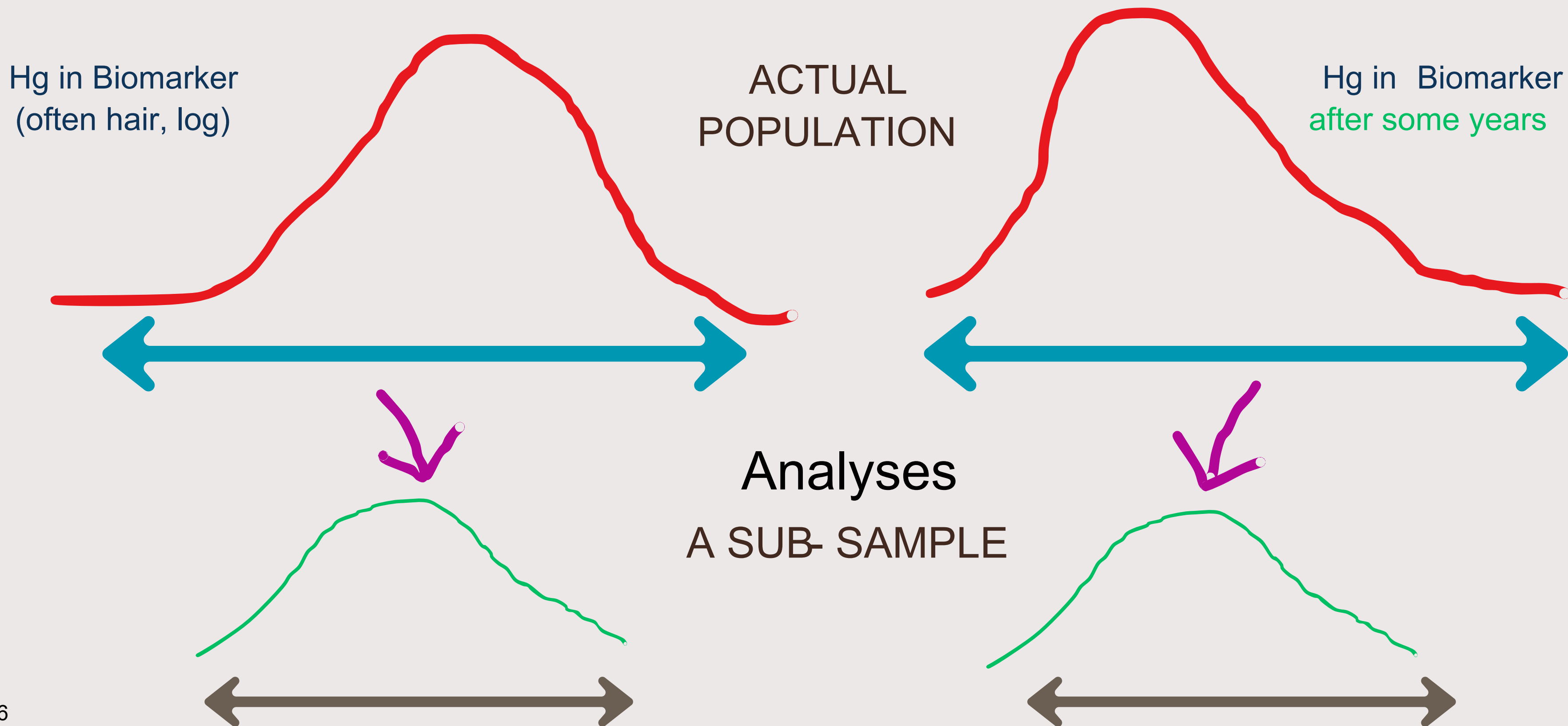
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Minamata Convention on Mercury

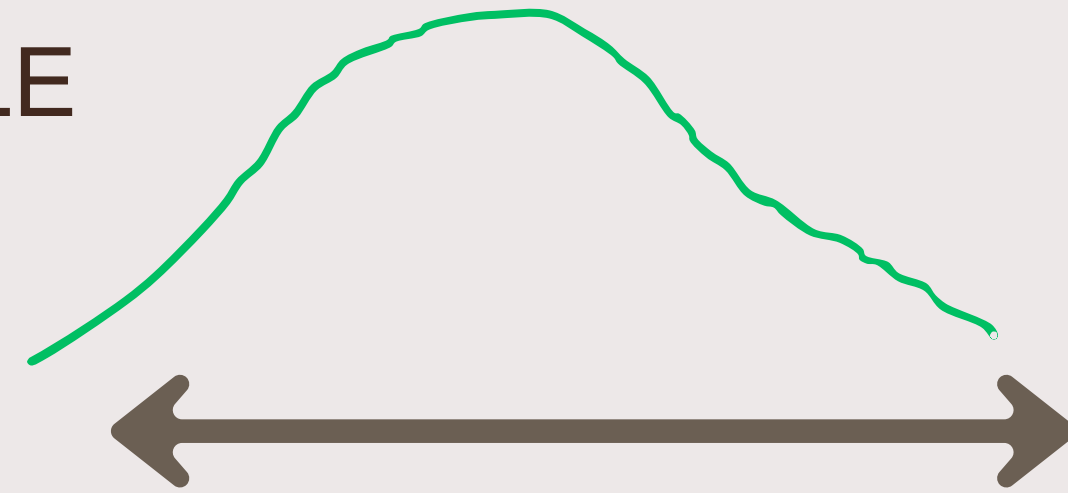
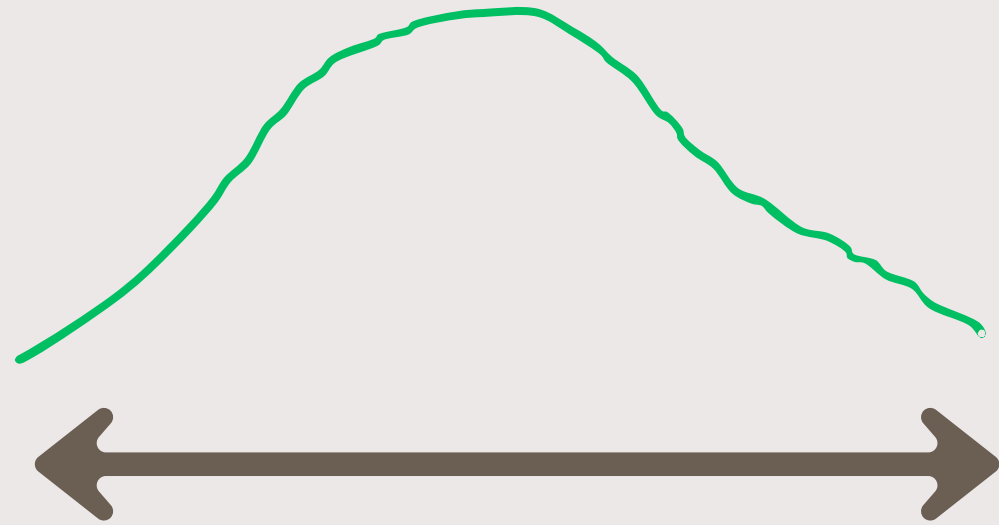
One of the approaches

- To monitor, and assess changes in, mercury in human biomarker over time
- Anything decreased or not



Analyses

A SUB- SAMPLE



Key considerations

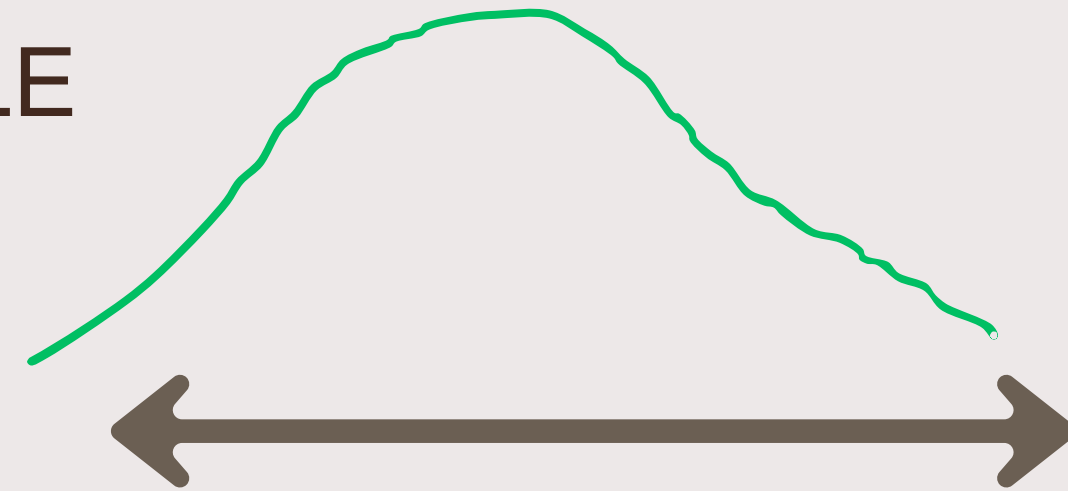
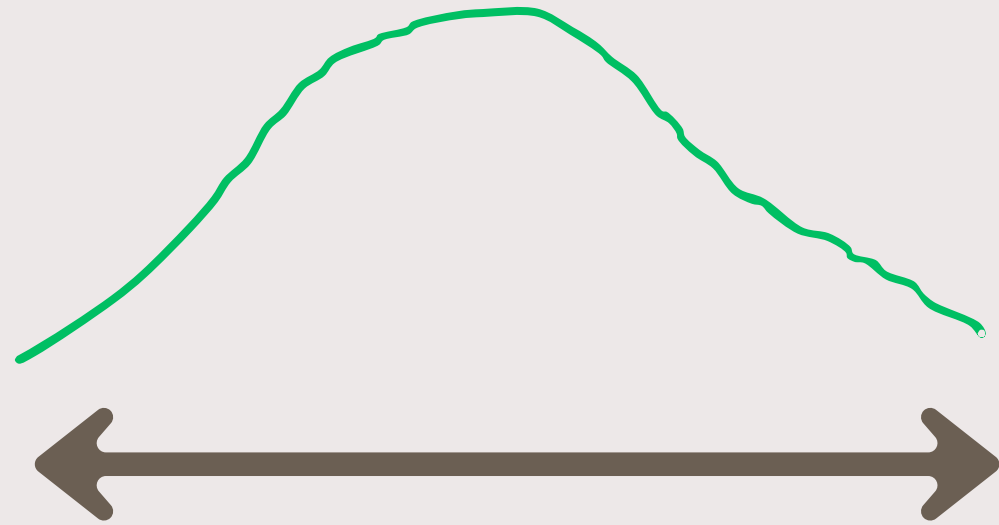
If there is a change, we should be able to detect it..

OR

If we are not detecting, is it because there is no change, or because there are sampling limitations?

Analyses

A SUB- SAMPLE



Key considerations

If there is a change, we should be able to detect it..

OR

If we are not detecting, is it because there is no change, or because there are sampling limitations?

THE GAME OF....



SAMPLE SIZE !

(RE-) INTRODUCING STATISTICAL POWER

= (1- probability of failing to reject null hypothesis, when in fact it was false)

= “probability of making correct decisions” “detect an effect when one exists”

<https://www.ncbi.nlm.nih.gov/books/NBK557530/>

Non-consideration could lead to:

- poor reproducibility
- inability to assess impacts (= lead to regulatory disappointment and inaction)

f[sample size, effect size (mean diff.), variance, significance]

- Typically, one goes for a power of 80%, and significance level of 5%
- And determine the sample size that can detect a certain target trend

While all of us want to sample as many people as possible, it is not always possible...

- E.g., a global analyses by Basu et al (2018) had to constrain their a priori sample size cutoff by regions

“Because we anticipated fewer studies in low- and middle income countries, we reduced the minimum sample size so as to be able to report at least some data.”

Basu et al. (2018) EHP

General population (LMIC): 100

General population (HIC): 200

Vulnerable population (HIC): 100

Vulnerable population (LMIC): 50

Sample-size in cross-sectional studies ranged from 50 to 1910

Background populations

South-east Asia: 1 sub-population with 80 individuals

Africa: 2 sub-populations with 162 individuals

Americas: 14 with 7622 (== ave = 544)

East Med.: 4 with 1072 (== ave = 268)

West Pacific: 30 with 36,259 (== ave = 1208)

ASGM: 30 sub-populations with 7800 individuals (== ave = 260)

If there is an intervention: WHEN ABOVE IS OK, WHEN NOT OK?

Key considerations

If there is a change, we should be able to detect it..

OR

If we are not detecting, is it because there is no change, or because there are sampling limitations?

MOTIVATION

For typical sample sizes in cross-sectional studies (tens to thousands)

- How well placed are we in reliably detecting trends, when they do exist?
- And not miss them.

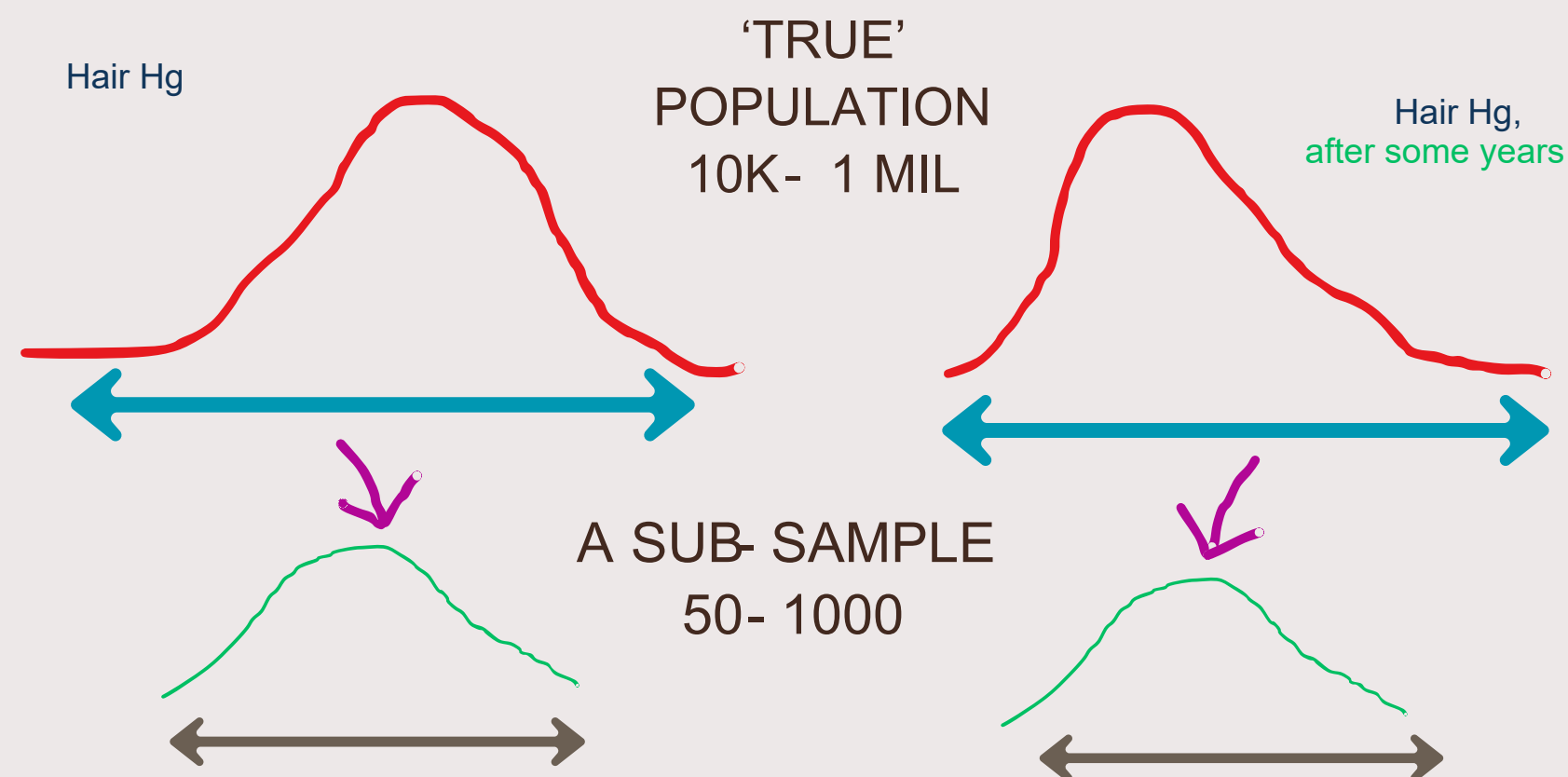
OBJECTIVES

To assess

- A sampling strategy for evaluating trends of mercury concentrations in populations using human hair as the biomarker

METHODS

- Three initial mercury doses: 0.01, 0.05, 0.1 g/kg bw - d
- Using the USEPA one - box model for mercury toxico - kinetics
 - Generate a distribution of mercury concentrations of
 - Three 'true' populations: 10 000, 100 000, 1 000 000
 - Decrease dose by 1%, 5%, 10%, 20%, 30% (Could be emissions reductions)
 - Take before and after sub-samples (as in a biomonitoring program)
 - 50, 100, 500, 1000 samples



1. Test reproducibility (1 mil pop)

- Draw sub - samples 10000 times
- 50, 100, 500, 1000
- Conduct a t - test
- How many times null hypothesis is rejected

2. Determine sample sizes

- a. 3 x 5 scenarios (10 000 - 10 000 000 population, three doses)
- b. To achieve $\alpha = 0.05$ and power = 80%
- c. At steady state
- d. Using MATLAB (samplesizepwr)

3. 'MC scenario'

- Decisions to reduce emissions by 30% over 20 years
- Hair biomarker measured every 4 years
- Decreased in exposure assumed as step-wise linear (decreases, then remains steady for one year, and so on) --> steady state is achieved for hair mercury
- Calculate sample size for $\alpha = 0.05$ and power = 80%

4. Comment on the scenario of changes in dietary habits

- Decisions to reduce emissions by 30% over 20 years
- Hair biomarker measured every 4 years

RESULTS (1)

Probability of not rejecting the null hypothesis (that human exposure to mercury has not reduced) when it was false

BOLD = < 80% power

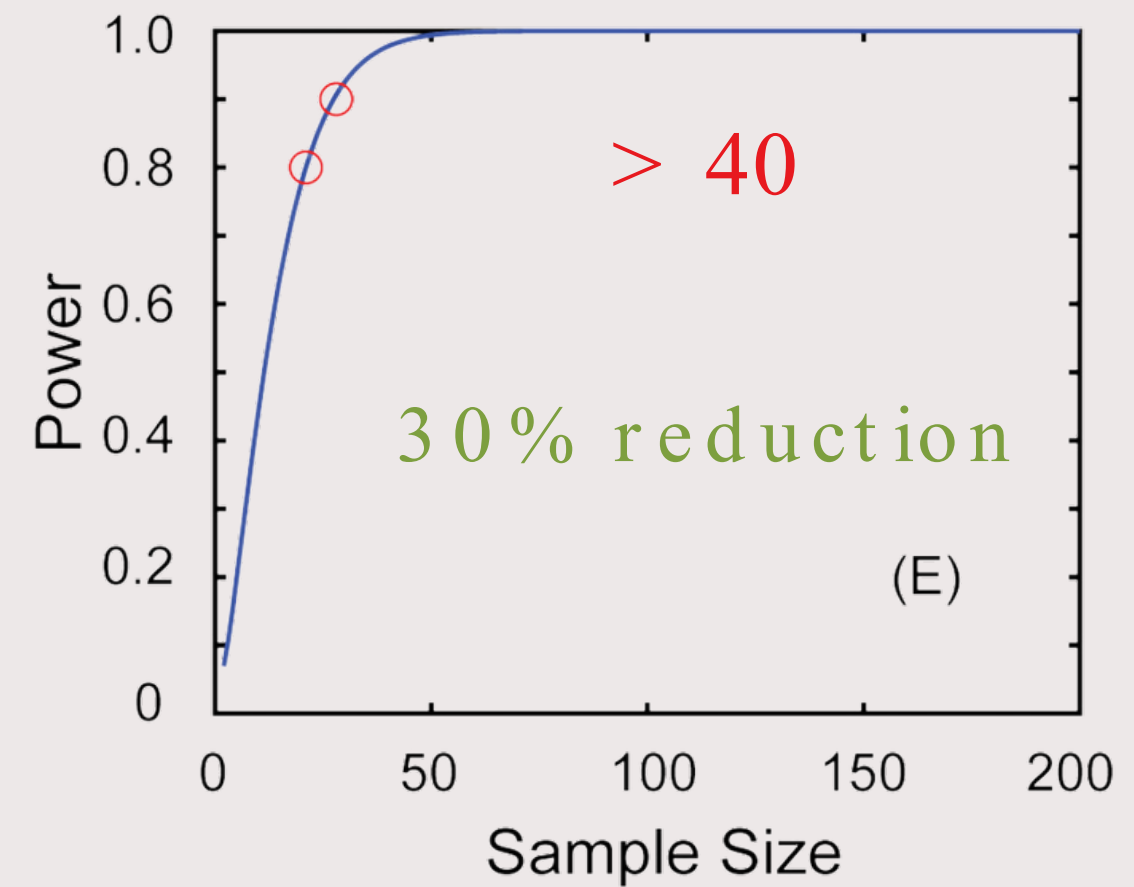
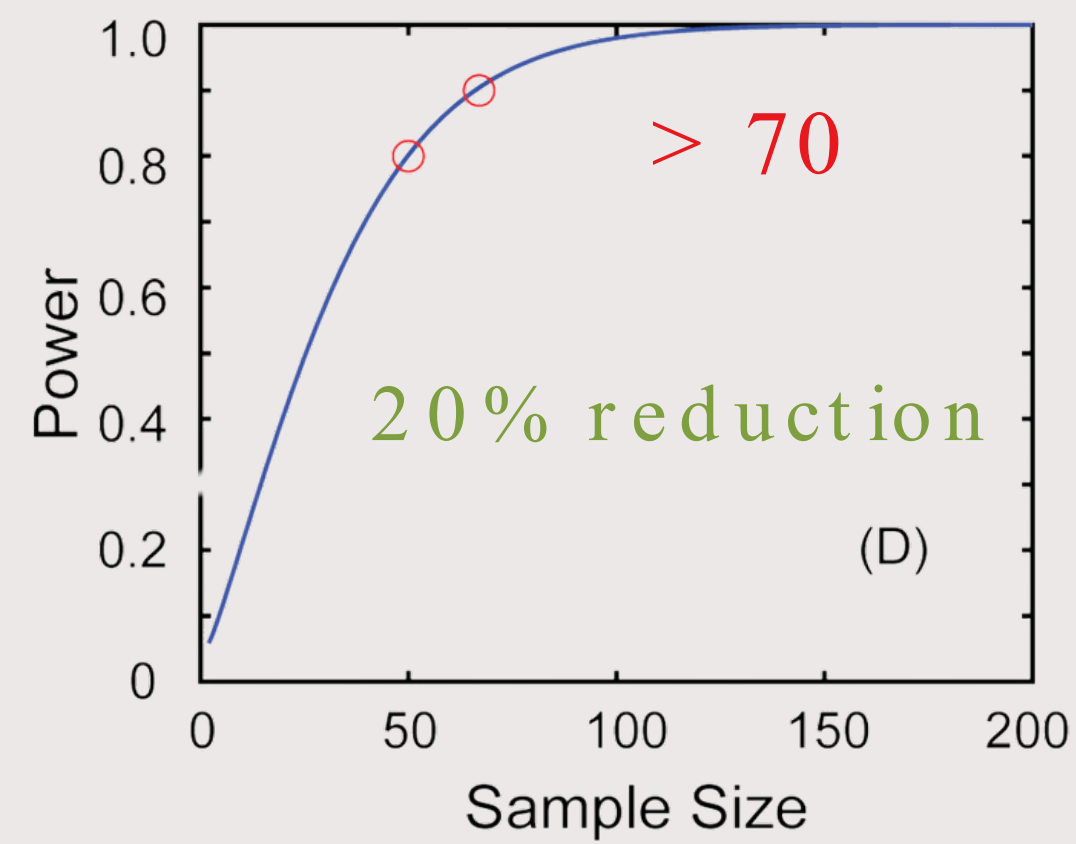
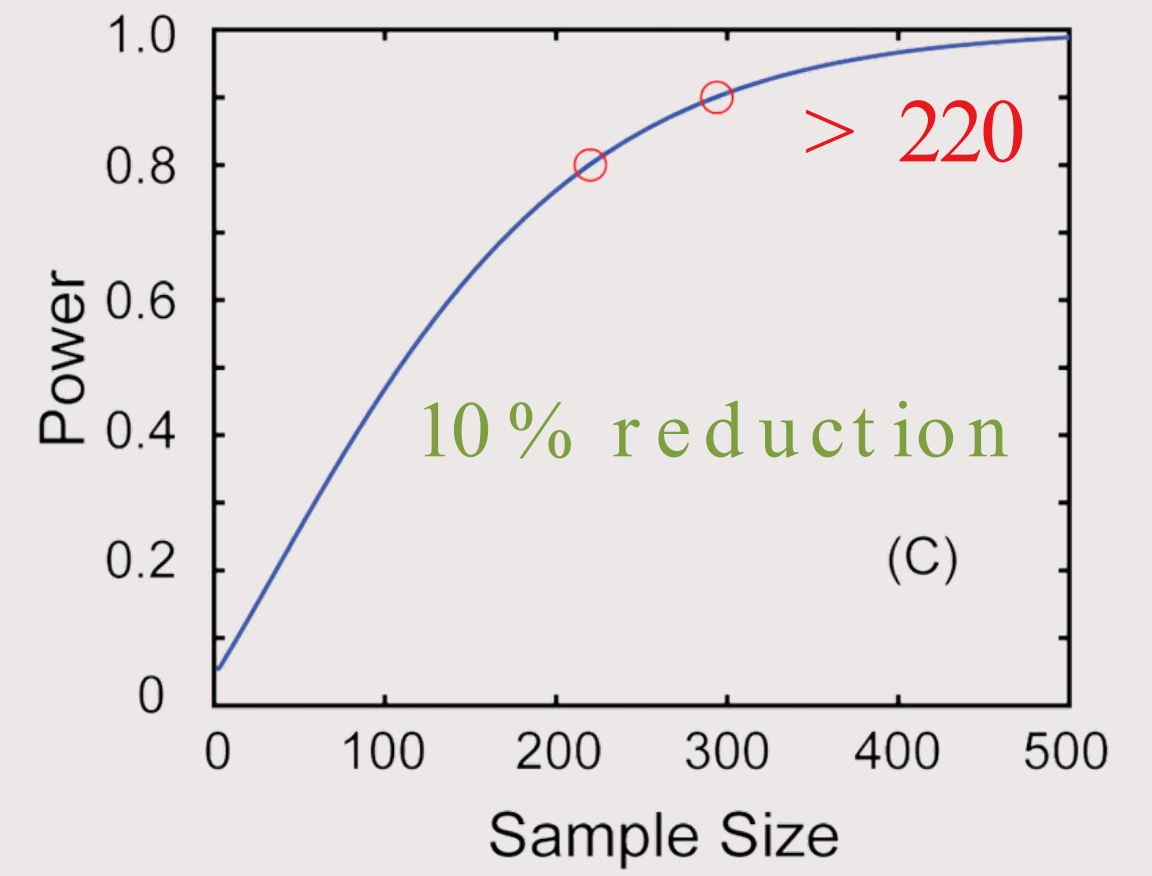
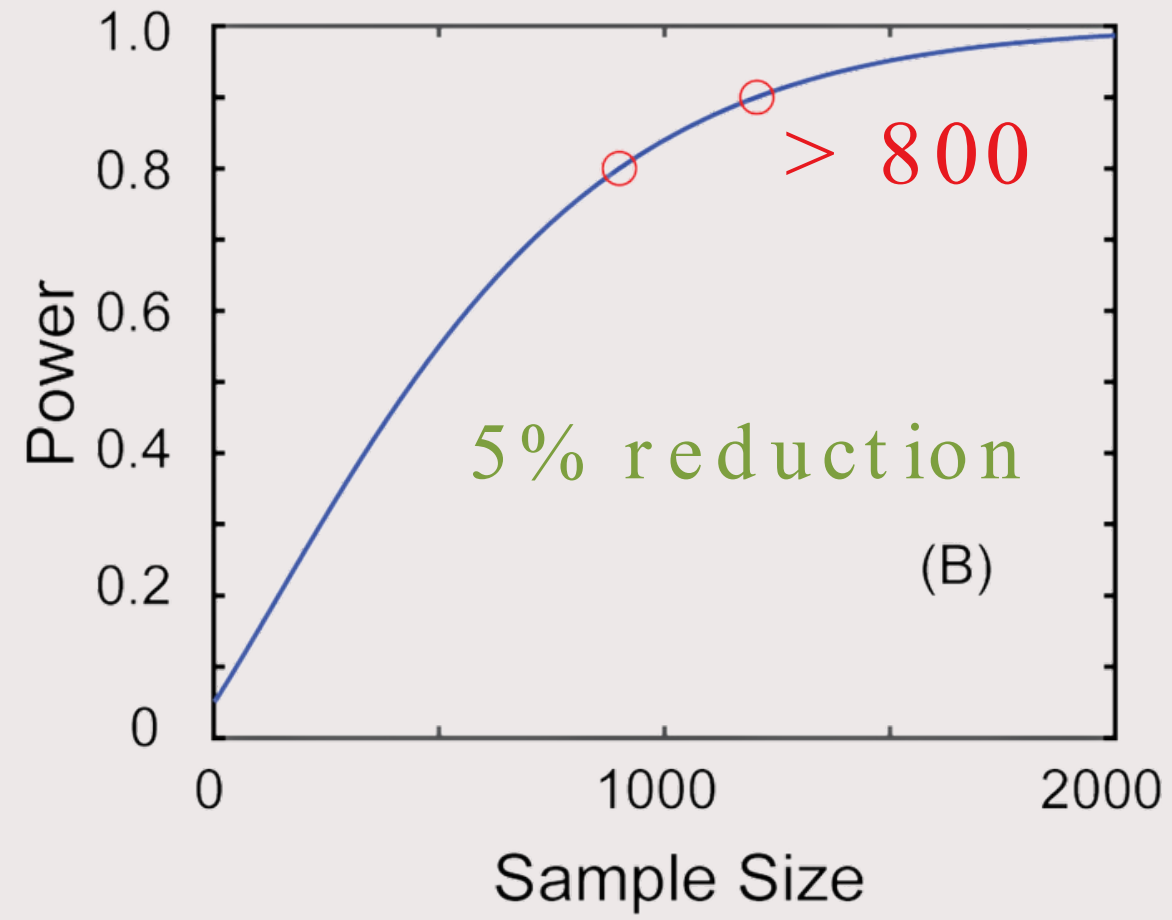
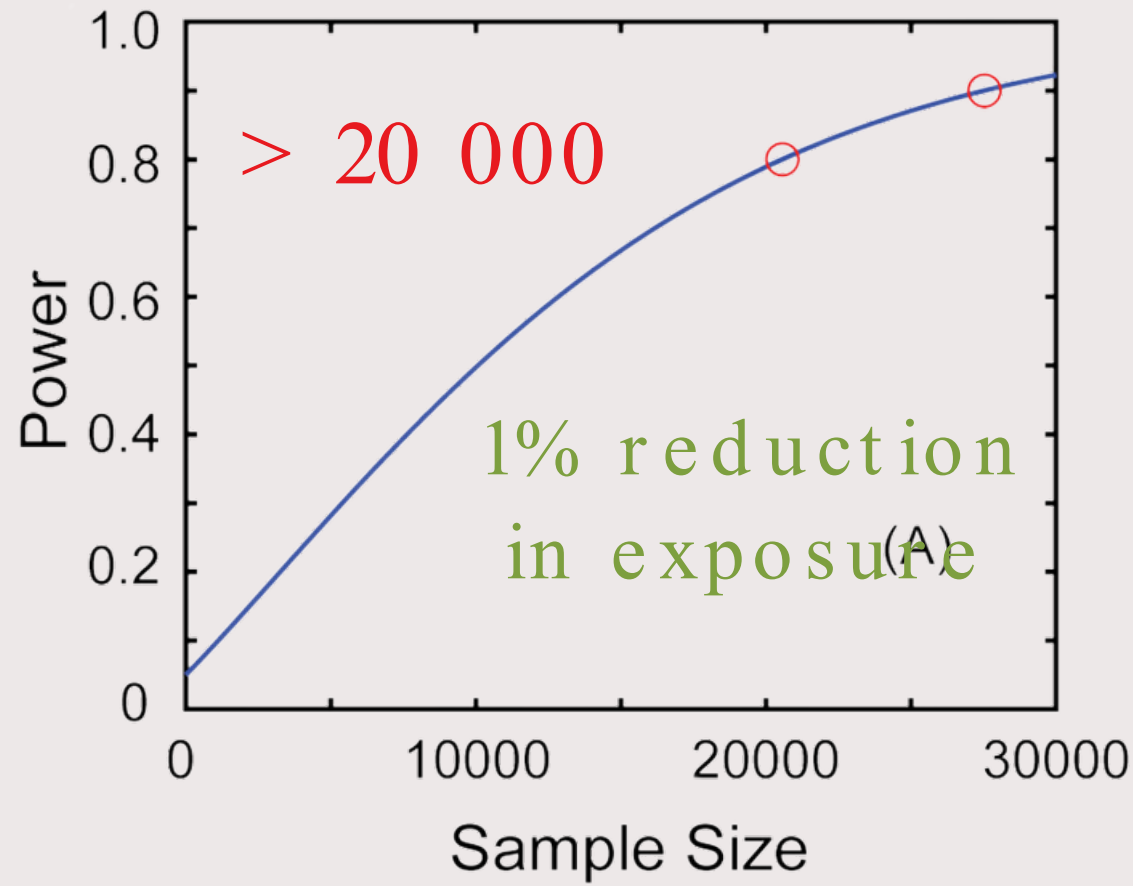
1. Test reproducibility (1 mil pop)

- Draw sub-samples 10 000 times; 50, 100, 500, 1000;
Conduct a t-test

Observations' Sample Size / Reduction in Exposure	50	100	500	1000
1 %	0.95	0.95	0.93	0.93
5 %	0.93	0.89	0.69	0.45
10 %	0.84	0.73	0.15	0.01
20 %	0.48	0.19	0	0
30 %	0.12	0.01	0	0

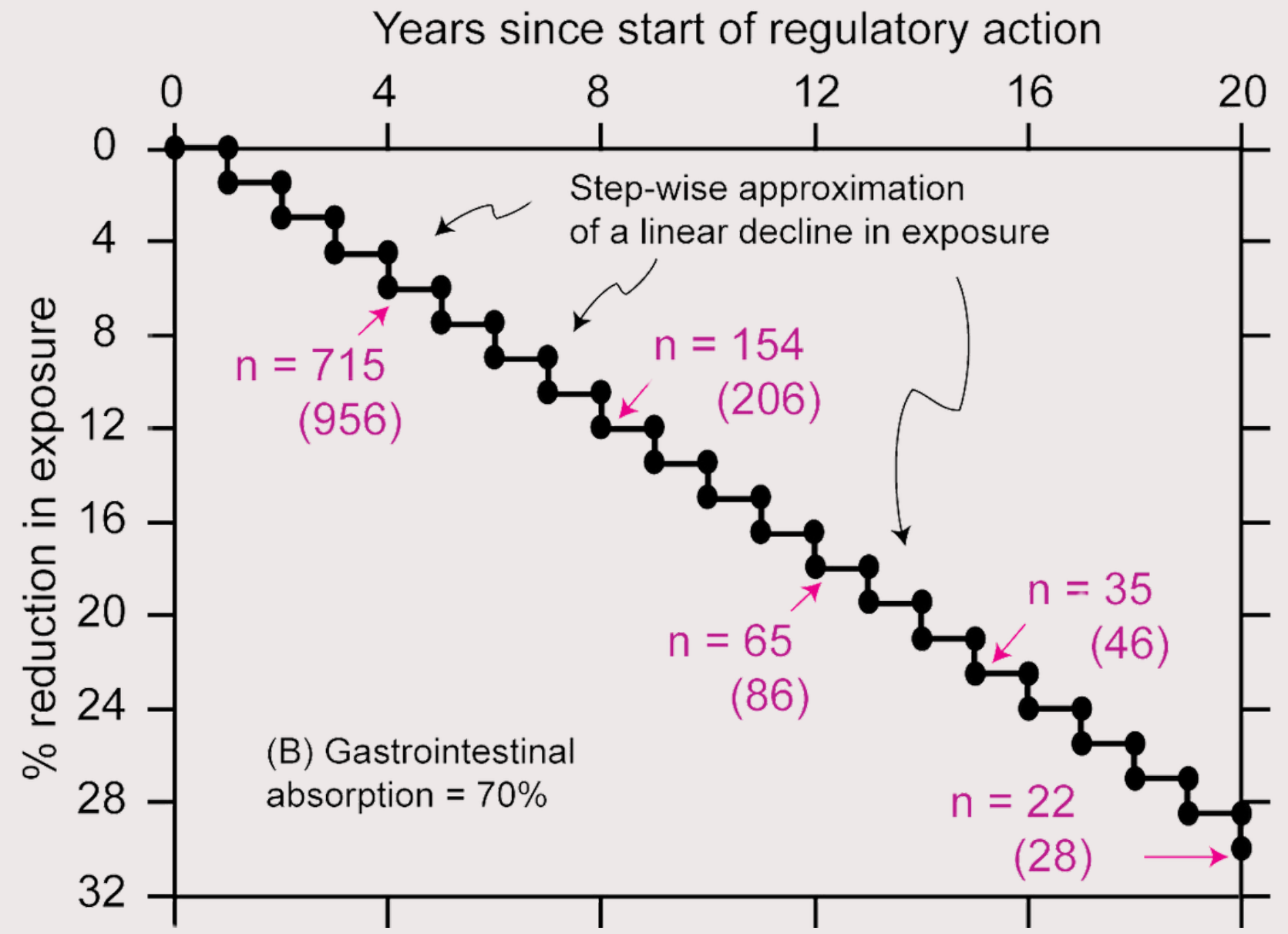
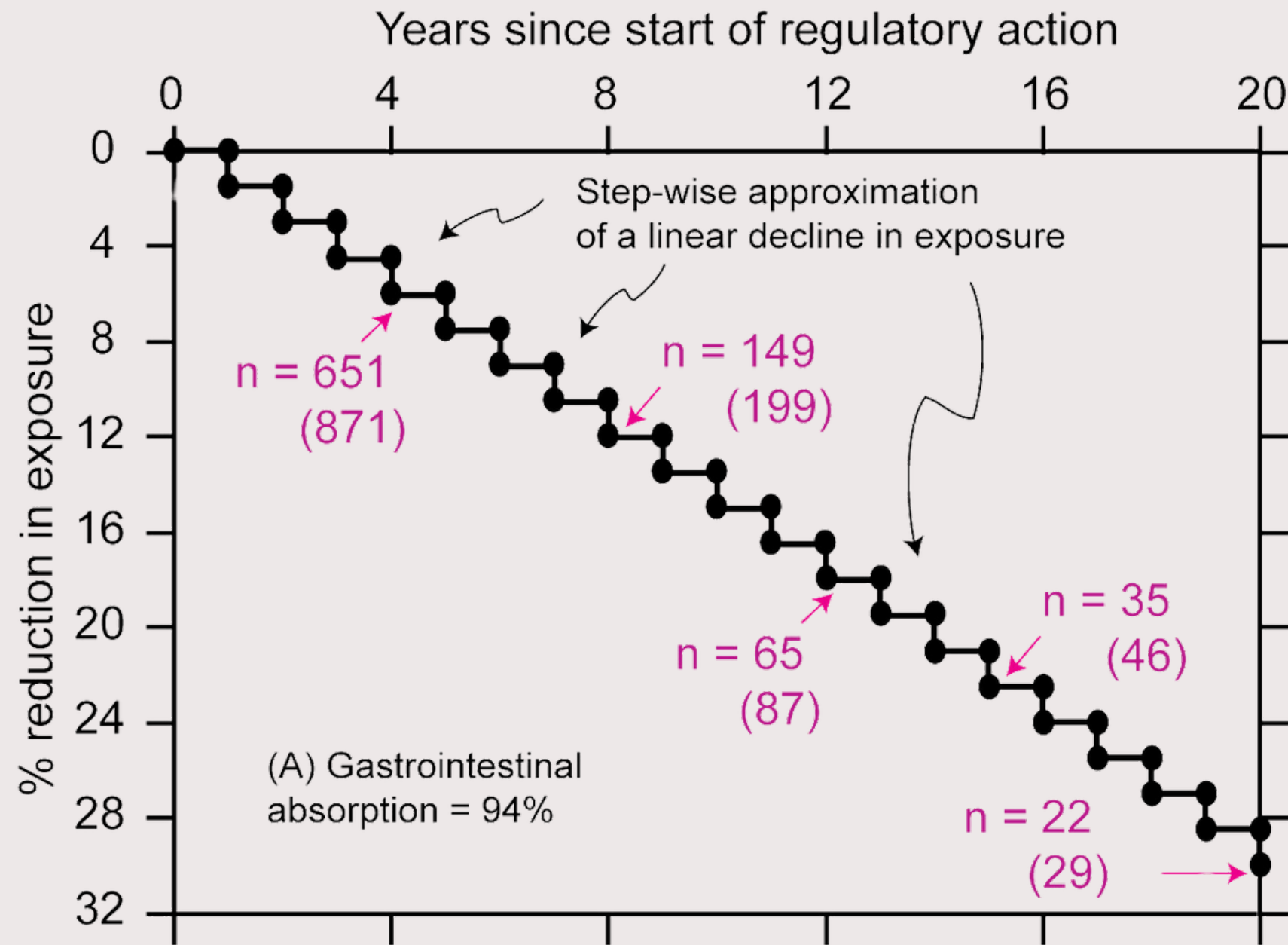
Even with 1000 sample size, studies will be divergent 45% of the times if reduction is < 5%

RESULTS (2)



Sample sizes to achieve 80% power (1 mil population)

RESULTS (3)



- 900 samples required to reliably detect change after 4 years
- 200 after 8 years
- So, if $n < 900$, non-observance of change should not deter continued reduction of emissions after the first 4-yearly evaluation

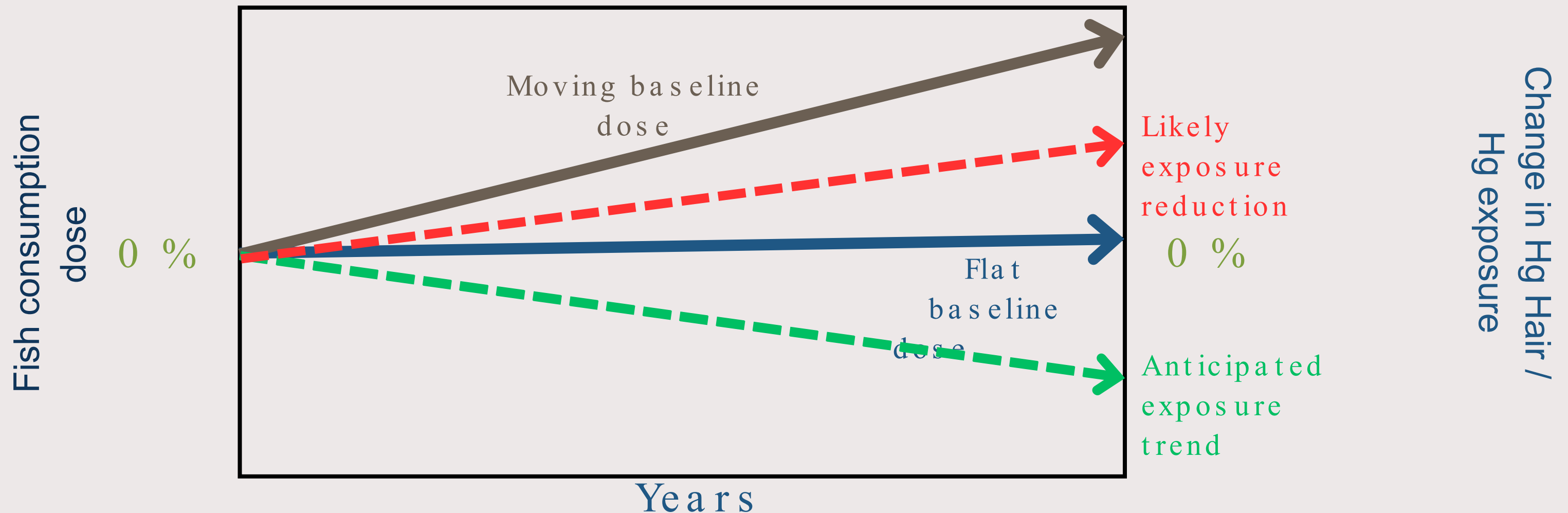
(4) COMMENT

As an example

- All Adult mean seafood intake: 158 +/- 6 g/week

Jahns (2014) <https://doi.org/10.3390/nu6126060>

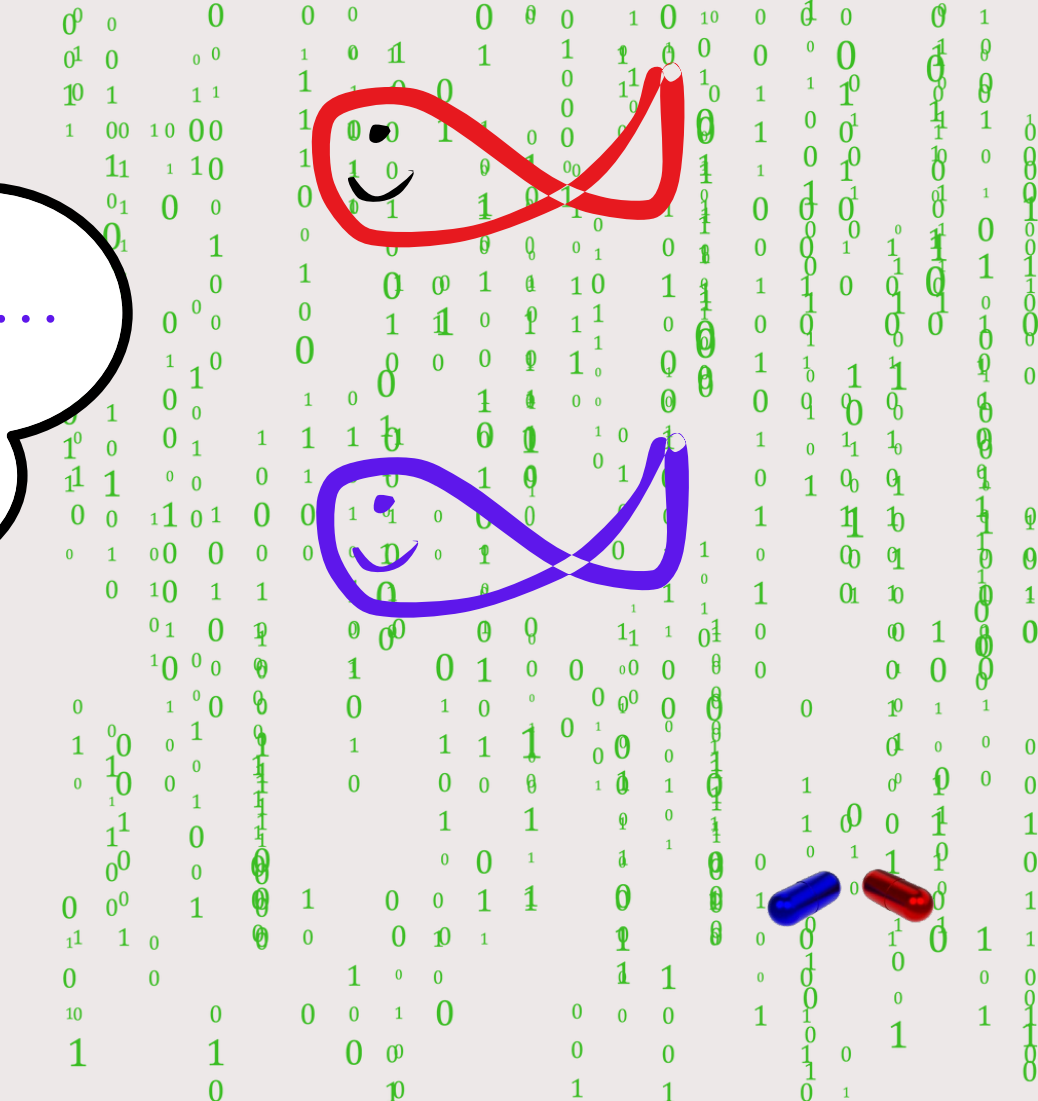
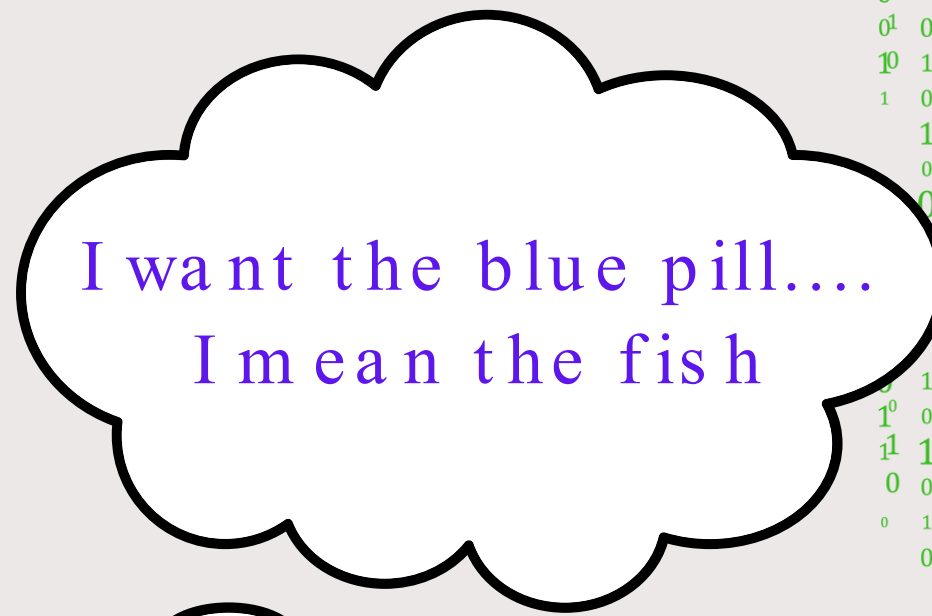
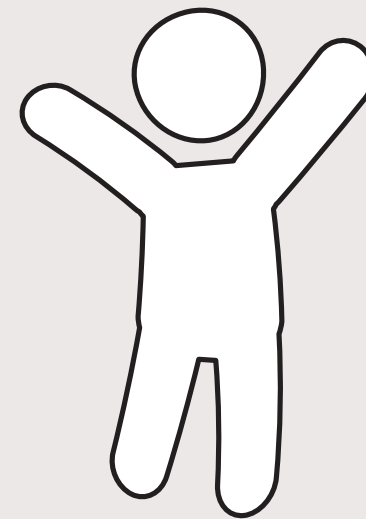
- Says, seafood intake should increase
- FAO: global fish consumption has increased 22% between 1990 and 2018
- If consumption increases, say 10%, it is unlikely we will see any reduction in hair Hg anytime soon
- Even though the convention is working effectively



(4) COMMENT

What about feeding preference changes?

Fish	Mean Hg (ppm)
Mackerel	0.05
Cod	0.111
Salmon	0.022
Pollock	0.031
Shrimp	0.009
Herring	0.078
Sardine	0.013



What is feeding preference changes?

- Marginally switching diet from **mackerel** to **cod** could lead to increased Hg exposure by 10-20%
- Again, is unlikely we will see any reduction in hair Hg anytime soon
- Even though the convention is working effectively

SUMMARY

- For studies of sizes 50 - 500, it will be difficult to reliably detect the effectiveness of emissions reduction if the magnitude of change is lower than 5% or so
- Effectiveness is easier to detect with smaller sample size in highly impacted populations, where direct interventions could lead to 20% reductions or more
- For gradual decrease in emissions, effectiveness may anyway not be visible in early years, unless sample size is of order of thousands
 - Observations will be complicated if the population changes diet in terms of sea (or fish) food intake or sea (or fish) food preference

This should not discourage parties from taking more action

Without action, we would be actually increasing exposure (even if we don't detect it for the first few years)!