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A potential role for HMA-sponges in the bioaccumulation of MeHg

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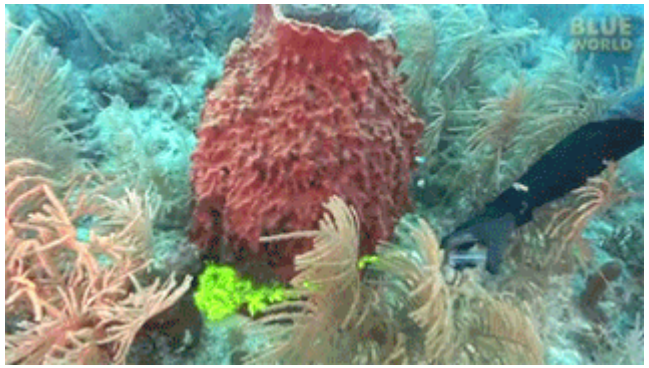
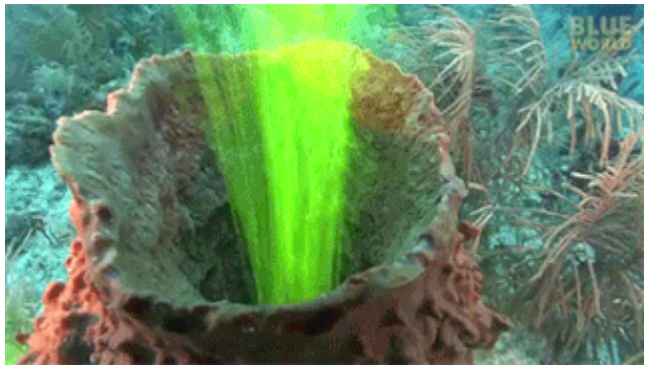
GMOS TRAIN

Introduction to sponges

- 30% of the biomass in sponges can be bacteria
- These bacteria can be sulfite-reducing bacteria
- Sponges create currents to feed these bacteria
- Sponges can create anoxic pockets for sulfite reducing bacteria





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GMOS TRAIN

Are sponges important?

- I would like to discuss:
  - The ability of sponges to consume DOM
    - de Goeij et al., 2008
  - The low tHg/MeHg ratio (4%) of sponges and potential demethylation in sponges
    - Orani et al., 2020
- And how this relates to bioaccumulation of MeHg in fish

- 1) de Goeij, J. M., van den Berg, H., van Oostveen, M. M., Epping, E. H., & Van Duyl, F. C. (2008). Major bulk dissolved organic carbon (DOC) removal by encrusting coral reef cavity sponges. *Marine Ecology Progress Series*, *357*, 139-151.
- 2) Orani, A. M., Vassileva, E., Azemard, S., & Thomas, O. P. (2020). Comparative study on Hg bioaccumulation and biotransformation in Mediterranean and Atlantic sponge species. *Chemosphere*, *260*, 127515.

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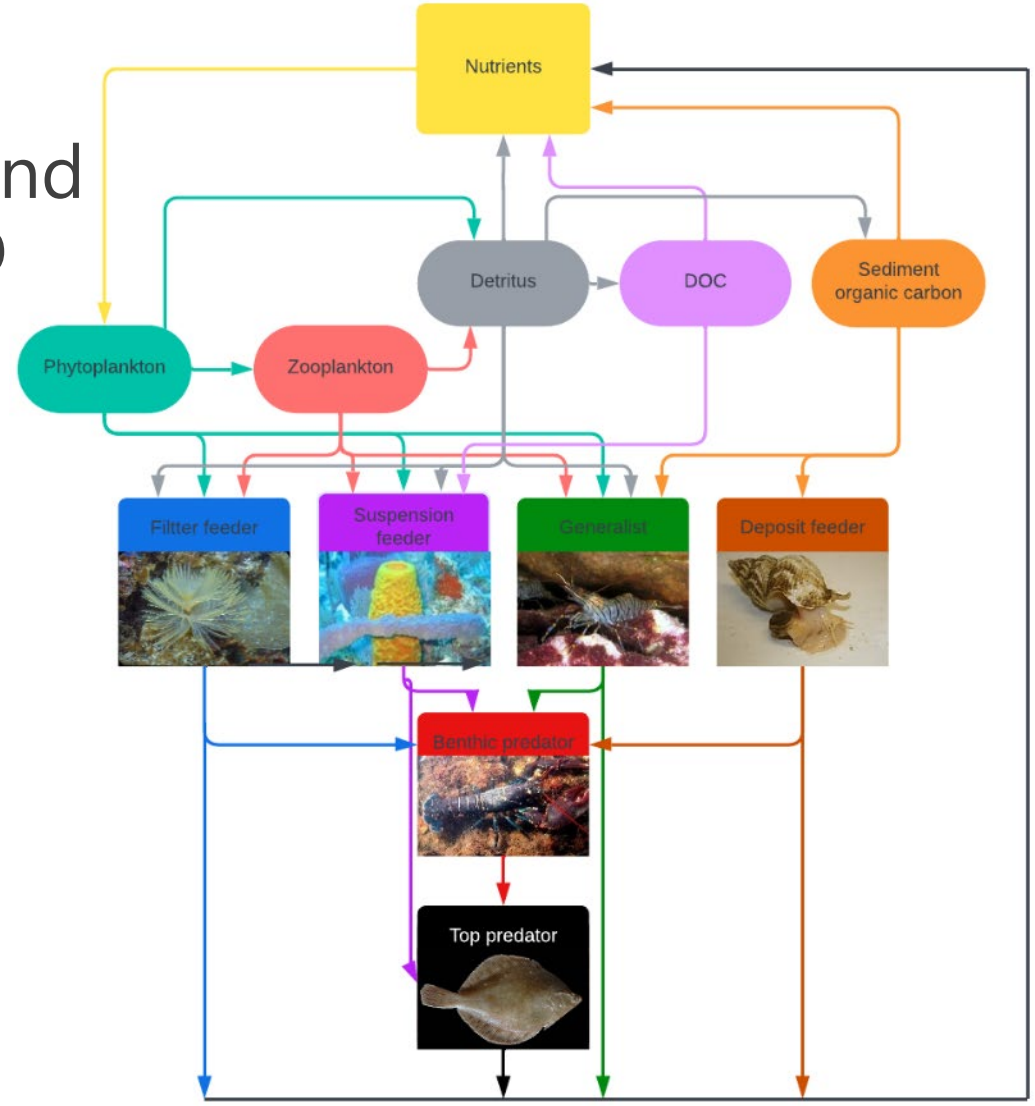
The macrobenthos model

- I modeled sponge Hg and MeHg uptake and MeHg demethylation in a fully coupled 1D water column model
- They compete for food with other macrobenthos and are consumed by predators



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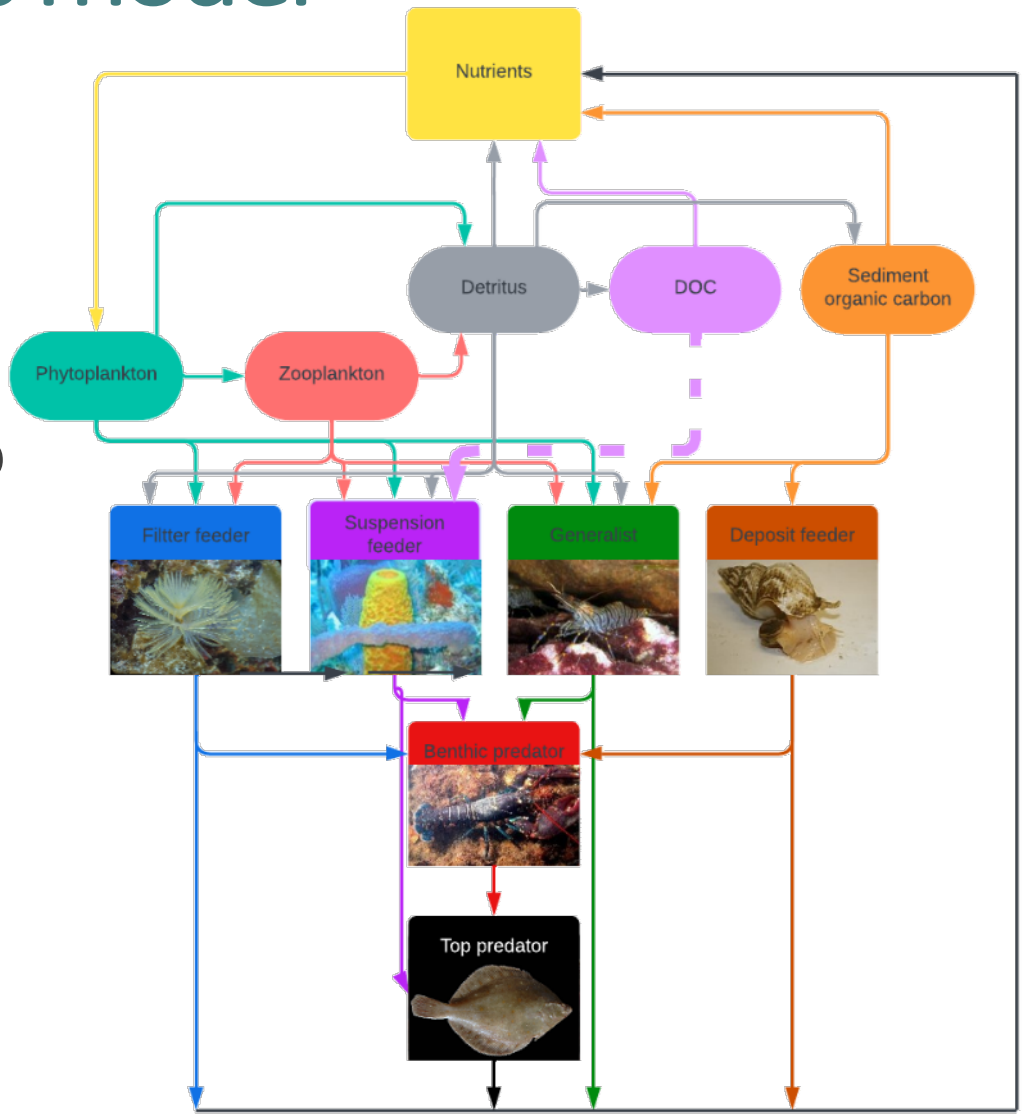
GMOS TRAIN

The macrobenthos model

- The model is an modified version of the ECOSMO End to End model
- Key interaction is that sponges eat DOM, while all other groups of macrobenthos do not



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Bay of Villefrance

- I run the model in the Bay of Villefranche at 17m deep (Mediterranean Sea)
- Model is setup as a fully coupled 1D model driven by local observations for both atmospheric concentrations and depositions of Hg and physical drivers such as solar radiation, wind speed, and precipitation

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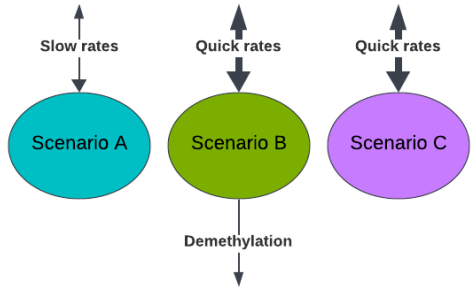
Different sponge regimes



- We add increasing amounts of refractory DOM (rDOM) to the model
- rDOM is only consumed by the symbiotic bacteria in sponges
- rDOM can bind Hg and MeHg and reduce phytoplankton uptake
- When sponges or predators respirate or die, the organic carbon is not released as usable nutrients for phytoplankton

- So an increase in rDOM will:
  - Reduce phytoplankton MeHg and Hg uptake
  - Increase sponges and predators
    - But it will ***not*** cause eutrophication for phytoplankton

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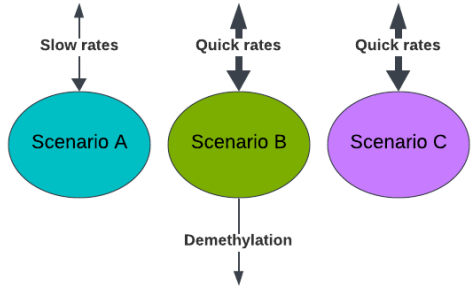
3 sponge Hg cycling scenairos



- ***Scenario A (No demethylation, no bacterial uptake)***
  - Sponges have the same uptake and release rate as other macrobenthos but they can consume DOM
- ***Scenario B (Demethylation, bacterial uptake)***
  - The uptake and release rate of sponges is 70% that of macrobenthos and 30% that of bacteria
  - This means much higher uptake and release rates
  - They consume 100% of Hg and MMHg attached to DOM when consumed
- ***Scenario C (No demethylation, bacterial uptake)***
  - Scenario B without demethylation

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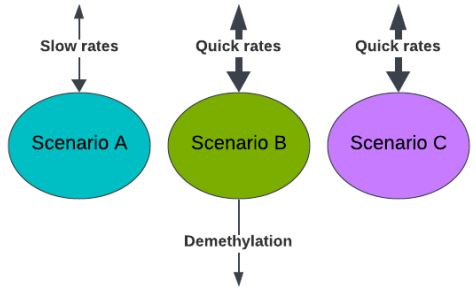
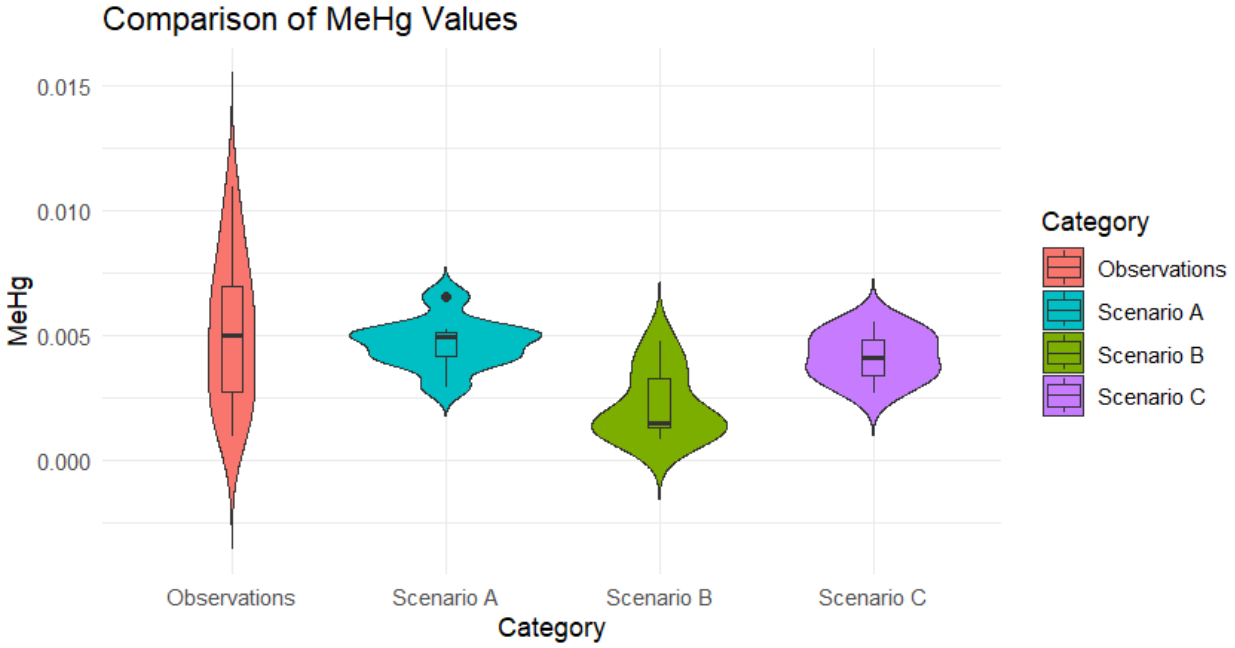
Expected demethylation rate



- Scenario B replicates the lowest MeHg values
- Demethylation rate of MeHg sponges likely <48% d^{-1} or less
- For the followup plots:
  - **Scenario B: 48% demethylation d^{-1}**
  - Scanario A and C: no demethylation
- Permutation test:
  - No setup a significant outlier
- T-squared test:
  - Scenario C best agreement



	Hotelling's T-squared test	Multivariate permutation test
Scenario A	*<0.5*	*0.12*
Scenario B	*<0.5*	*0.13*
Scenario C	*0.28*	*0.13*

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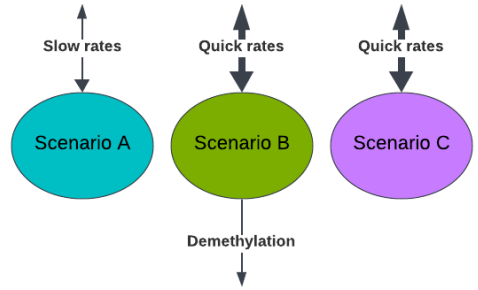
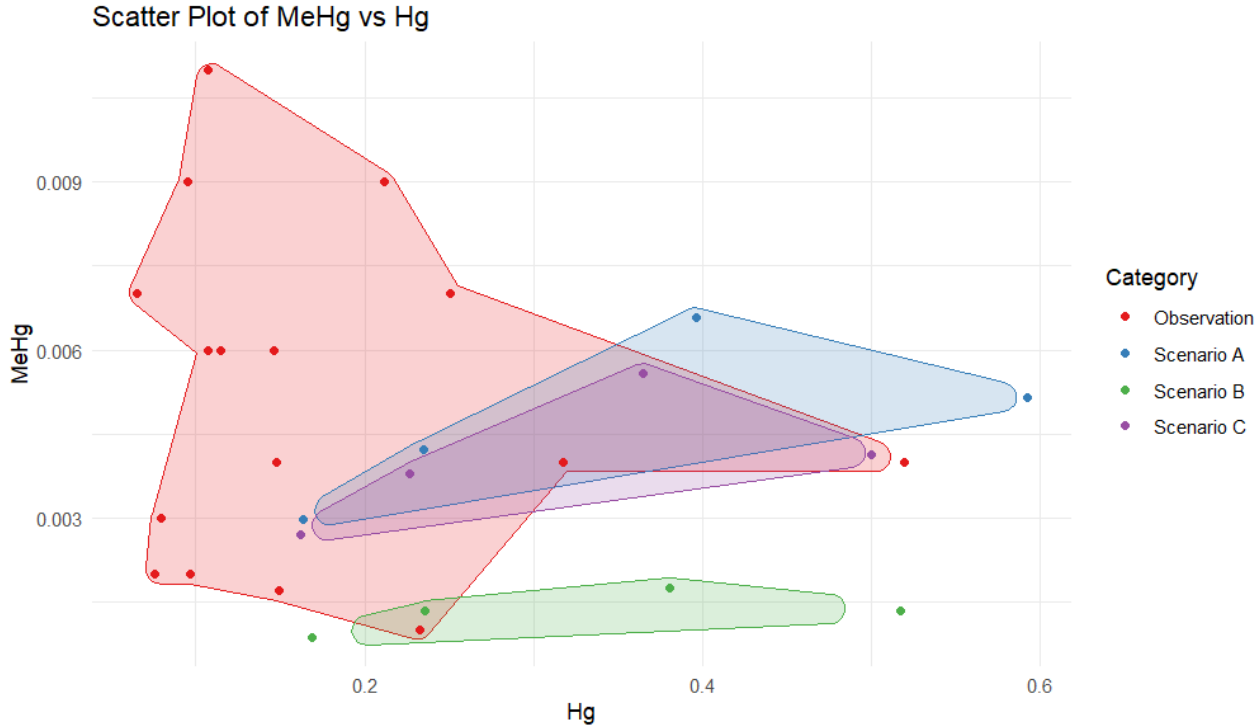
Model agreement



- We compare the model and observations
- Overall we can recreate low MeHg and high tHg values in ***all*** scenarios
- The demethylation rate in Scenario B recreates the lowest tHg/MeHg ratios of 4%
- So the consumption of DOM explain a major part of the low MeHg values found in sponges



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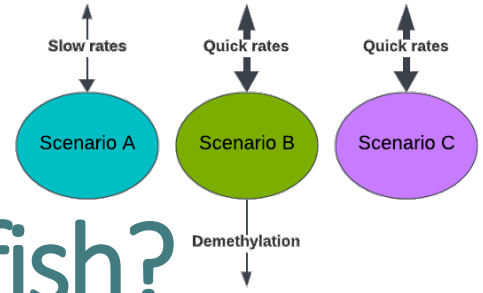
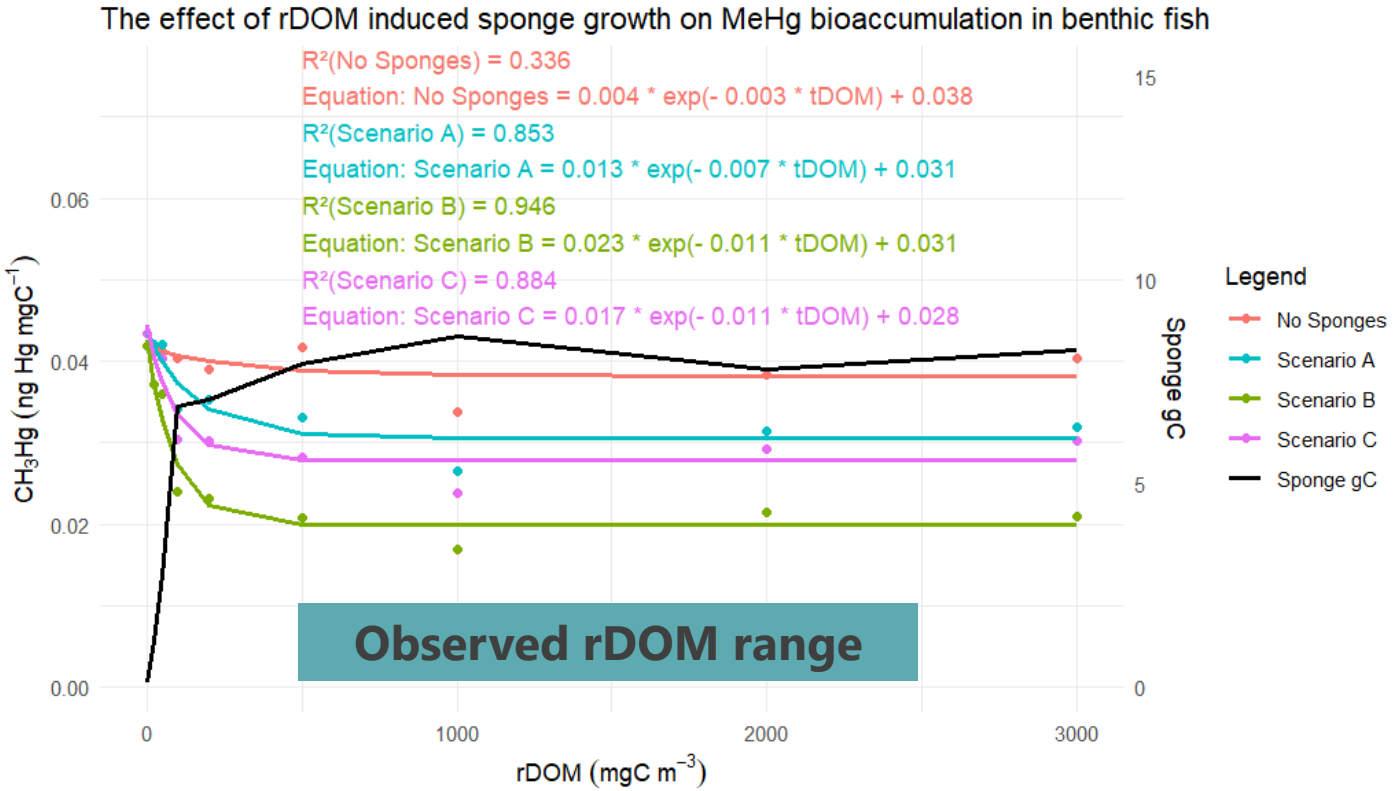


How much do sponges effect MeHg in fish?

- Reduction in fish MeHg due to sponges
  - *(1-Scenario/No Sponges)*100*
  - Scenario A
    - Due to the consumption of DOM: **<21%**
  - Scenario B
    - Due to the consumption of DOM and demethylation: **<50%**
  - Scenario C
    - Due to the consumption of DOM and higher uptake and release: **<32%**



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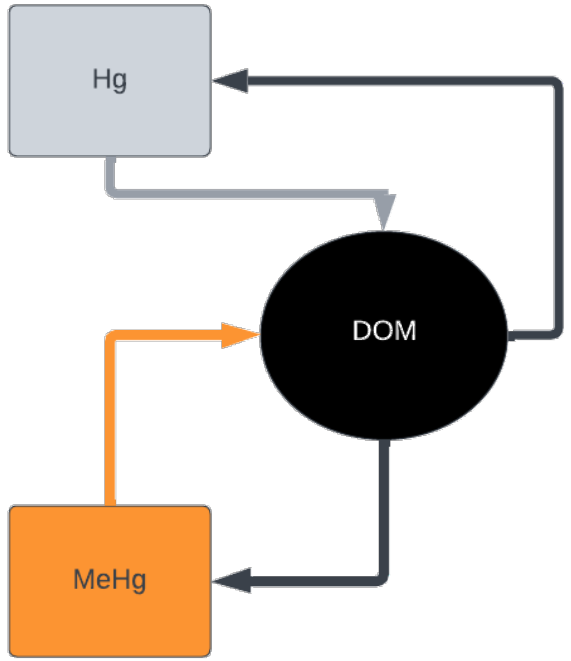
Why is this happening (from a model technical pov)

- DOM has an active and fast equilibrium with Hg and MeHg in the water
  - Instant in the model



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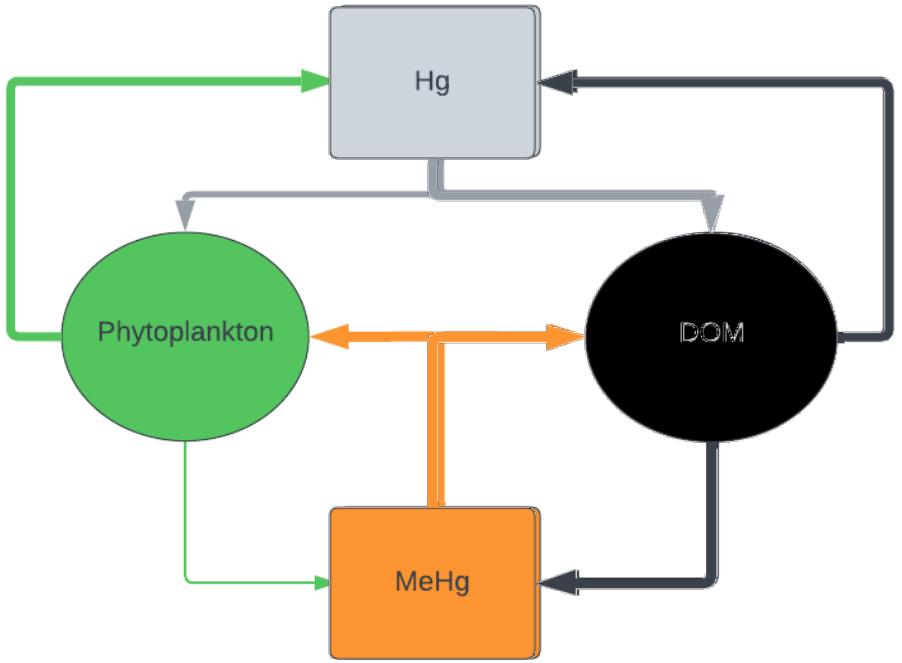
Why is this happening (from a model technical pov)

- DOM has an active and fast equilibrium with Hg and MeHg in the water
  - Instant in the model
- Phytoplankton takes up both Hg and MeHg, but release MeHg slow
- Because of this phytoplankton has a higher tHg/MeHg ratio than DOM



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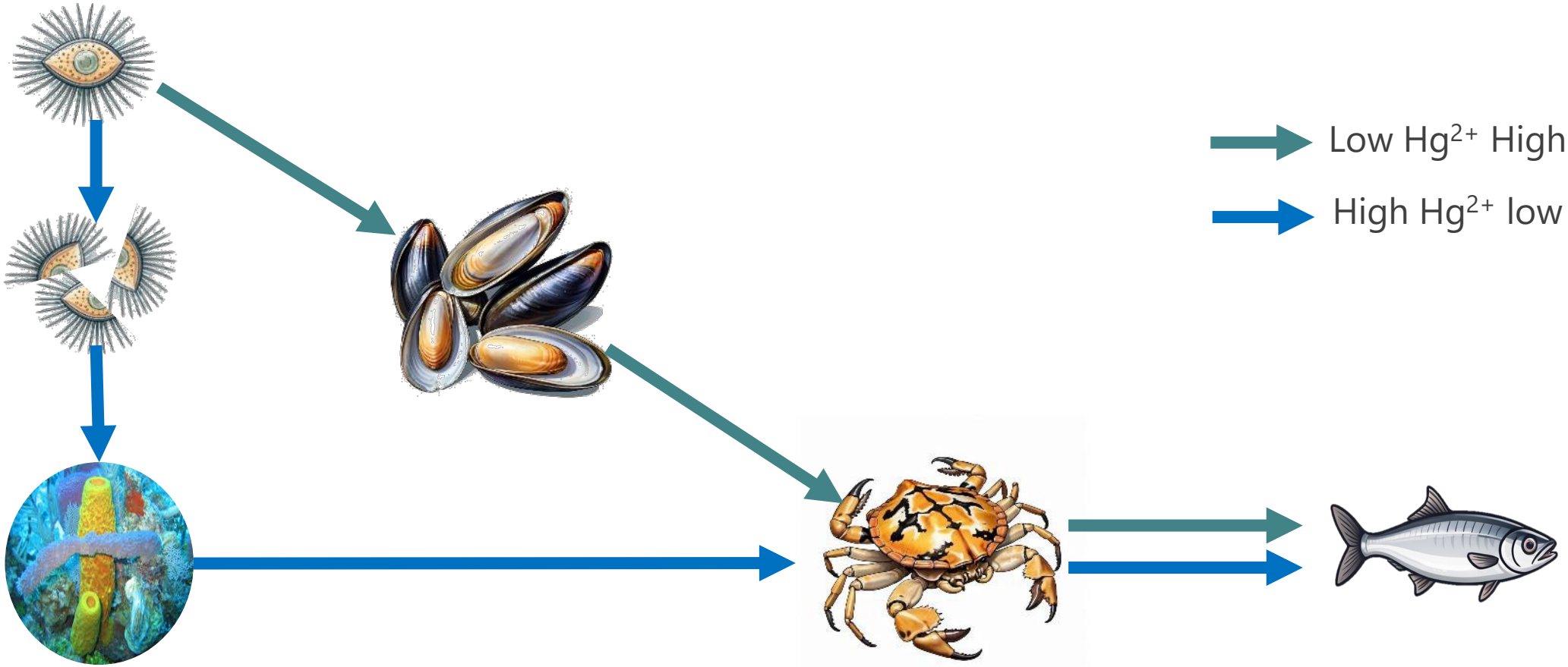
Sponge reduce fish MeHg without demethylation?



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Conclusion

- Sponge demethylation of MeHg is likely between 0 and 48% d^{-1} of bioaccumulated MeHg
  - Demethylation in seawater is up to 24% d^{-1} (Monperrus et al., 2007)
- Demethylation is not necessary to explain the low tHg/MeHg ratio
- Sponges reduce MeHg in fish (<32%), Because they consume DOM that is lower in MeHg.
- Sponge can reduce MeHg in fish further (<50%) if demethylation occurs

- Monperrus, M., Tessier, E., Amouroux, D., Leynaert, A., Huonnic, P., & Donard, O. F. X. (2007). Mercury methylation, demethylation and reduction rates in coastal and marine surface waters of the Mediterranean Sea. *Marine Chemistry*, *107*(1), 49-63.

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Remarks

- Composition and thiol content of DOM likely crucial factor
  - Refractory DOM expected to be low in thiol groups
  - I would expect DOM rich in thiol groups to lead to high sponge MeHg content
- All sponge scenarios can be true at the same time in different sponges
  - Consumption of DOM is proposed to be possible for Ascidians. Therefore similar interactions could play a role in eutrophic systems even if there are no sponges
- The available data is very limited, and I believe improving our understanding of the bioaccumulation at the base of the food web can improve our ability to predict MeHg concentration in seafood

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Questions or suggestions?

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