Biomagnification of Methylmercury in a Marine Plankton Ecosystem

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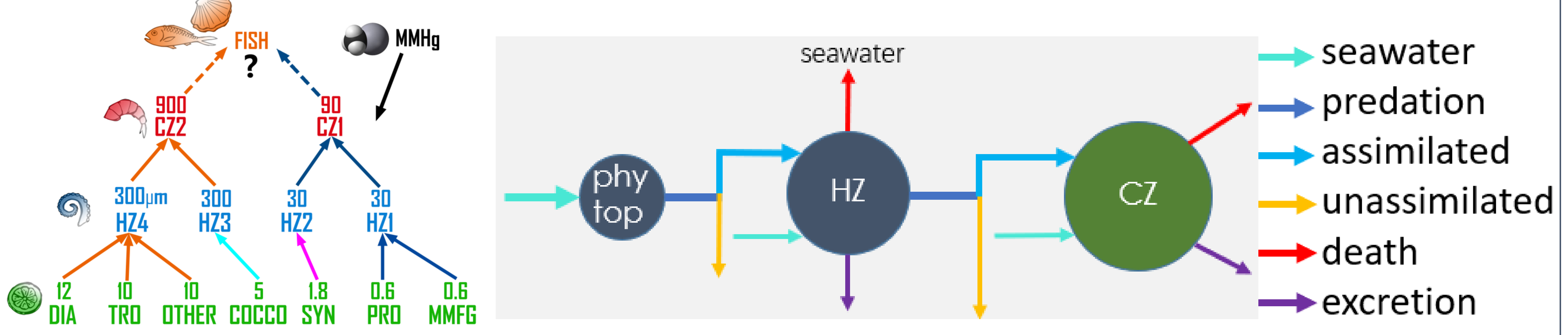
Introduction

- Methylmercury (MeHg) is a strong neurotoxin and is the only form of mercury (Hg) that biomagnifies in food webs.
- The properties of marine plankton ecosystem and environmental factors can influence trophic transfer of MMHg in the food web.
- A global model which simulates monomethylmercury (MMHg) biomagnification among three trophic levels (producers, primary and secondary consumers) is developed. We explore the regional variability of MMHg trophic transfer in these three trophic levels and the sensitivity of plankton physiological parameters on MMHg biomagnification.

Methods

- MMHg bioconcentration and biomagnification are simulated in the MITgcm framework.
  - The ocean plankton ecology and biogeochemistry is simulated by the GUD model [1]. We add two carnivorous zooplankton (CZ) groups, grazing on small herbivorous zooplankton (HZ) and large HZ respectively.
  - The Hg model can simulate the bioconcentration and biomagnification in the marine plankton food web.



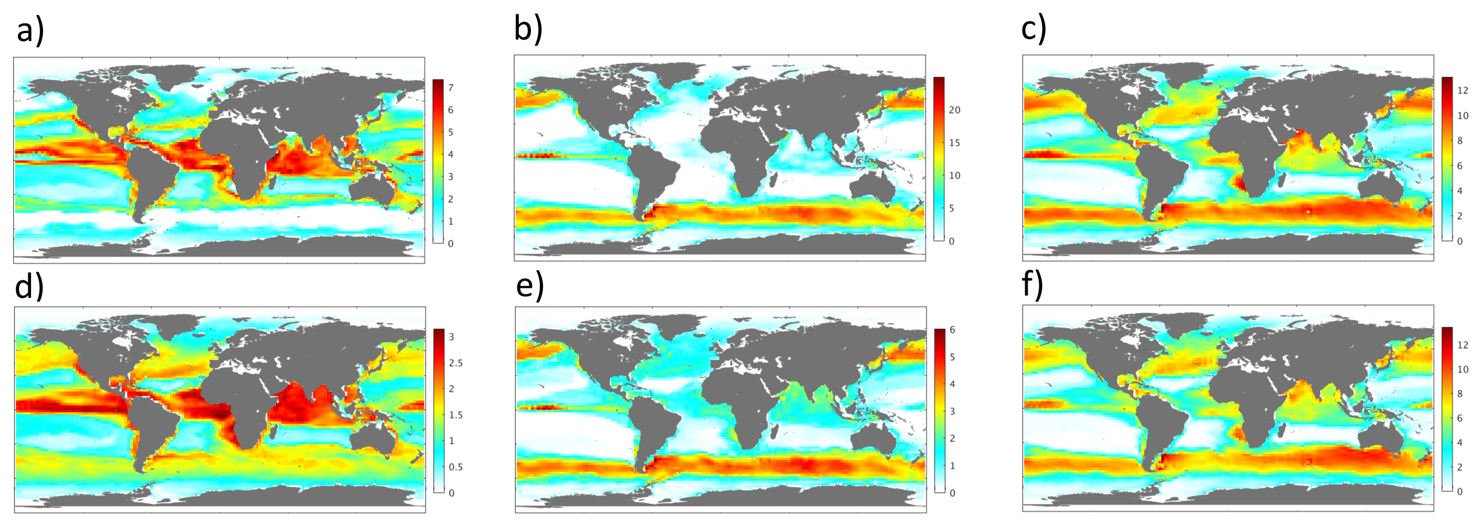
Marine food web

MMHg transfer in food web

- Sensitive analyses
  - Varying grazing, excretion, and mortality rates
  - Varying food assimilation efficiencies

Results

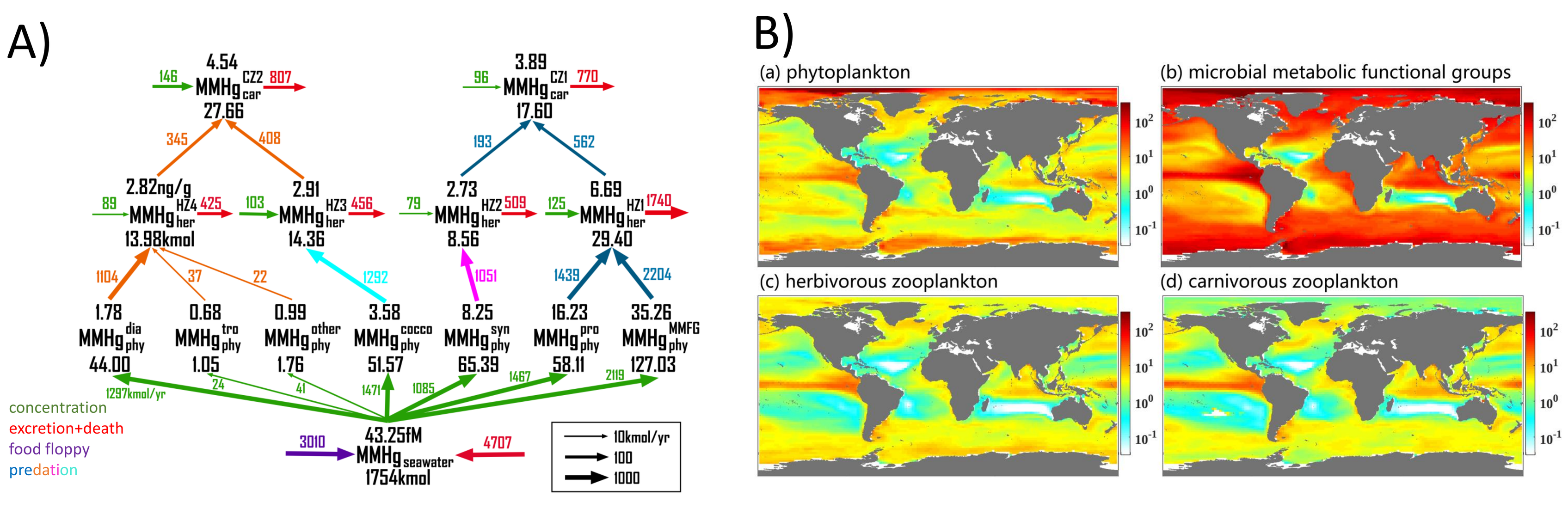
I. Marine plankton system



Distributions of a) prochlorococcus, b) diatoms, c) bacteria, d) HZ1: graze on prochlorococcus, e) HZ4: graze on diatoms, f) CZ [Gmol C].

- The spatial pattern of phytoplankton and bacteria is not much affected by predators at high trophic level.
- The addition of CZ put predation stress on HZ thus changing the the biomass of HZ and phytoplankton.

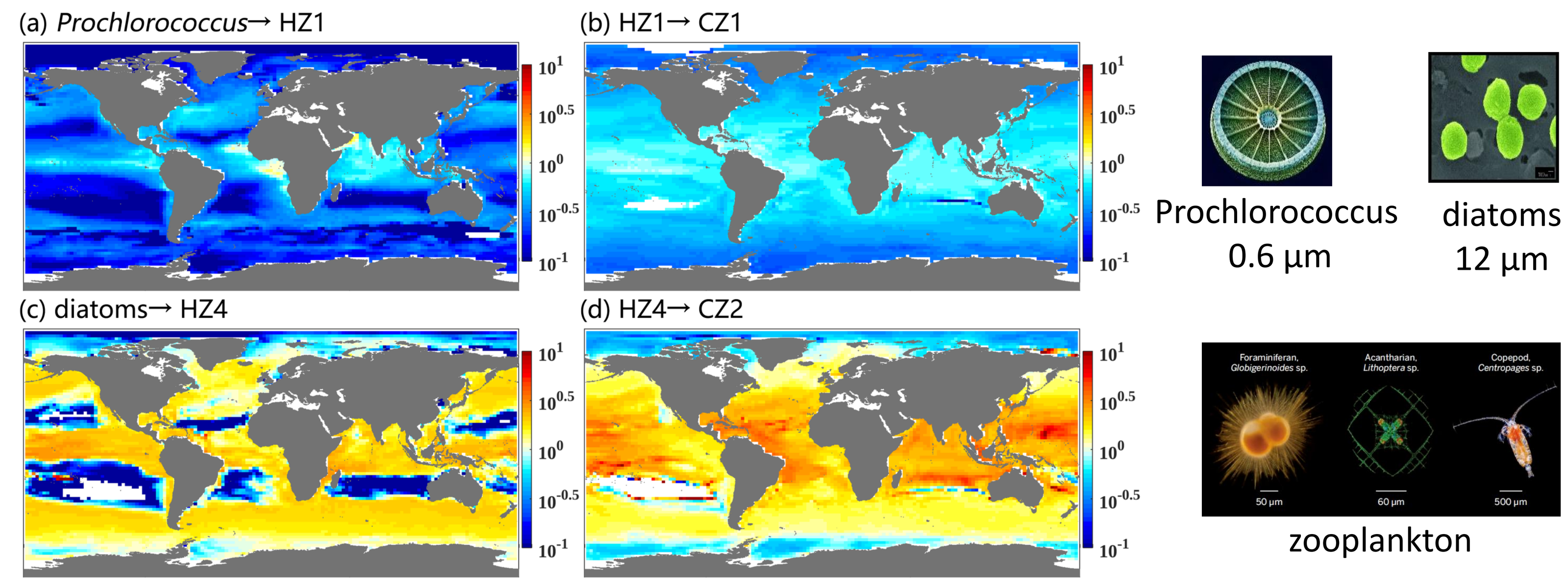
II. MMHg in plankton



(A) MMHg plankton food web dynamics for the global ocean. The numbers above planktons are the MMHg concentrations per wet weight of plankton cells in the unit of ng/g. (B) MMHg in plankton [ng/g]. a) phytoplankton, b)bacteria, c)HZ, d)CZ.

- The spatial pattern of MMHg in zooplankton is similar to that of phytoplankton, as MMHg from food is the main source for MMHg in zooplankton. The microbial community plays an important role in the trophic transfer of MMHg.

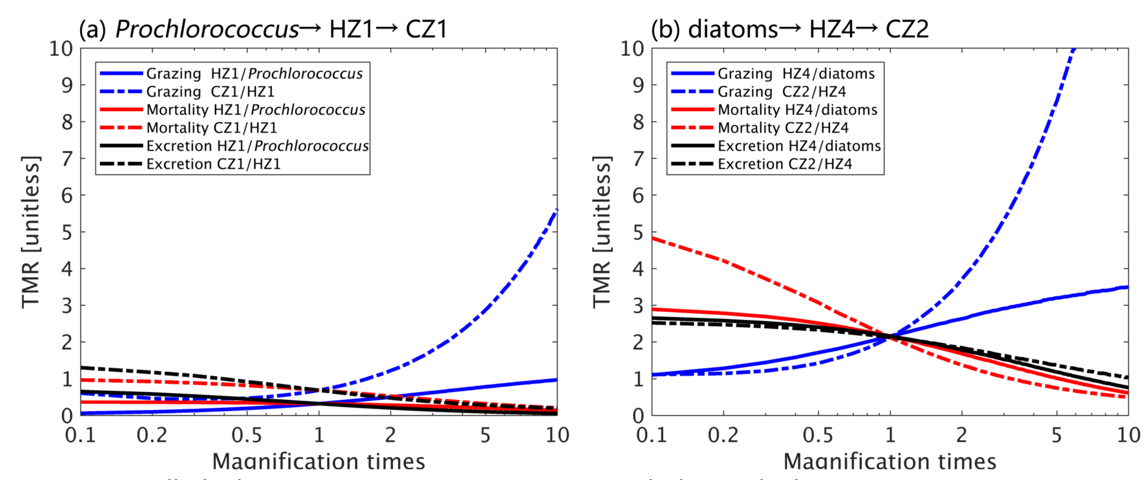
III. MMHg biomagnification



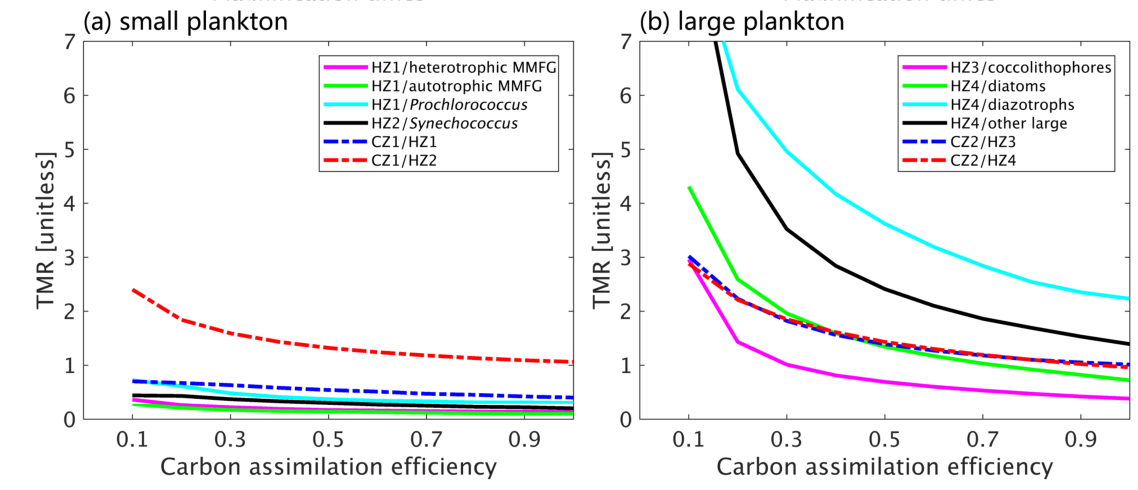
Magnification ratios between trophic levels (TMRs) in two representative food chains: prochlorococcus (small)-> HZ1 (a)-> CZ1 (b) and diatoms (large)-> HZ4 (c)-> CZ2 (d).

- There is almost no MMHg magnification in small zooplankton, which is opposite to large zooplankton.
- Large zooplankton dominant in eutrophic oceans have sufficient food intake, which results in higher accumulated MMHg than their prey.
- In oligotrophic oceans, e.g. subtropical oceans in the Southern Hemisphere, TMRs of HZ are low, while TMRs of CZ are high.
- In oligotrophic oceans, phytoplankton grow slow and suffer less grazing stress. So the grazing flux for HZ is lower than in eutrophic oceans. For CZ, despite sufficient food in the eutrophic oceans, the larger food uptake fails to compensate for the reduced MMHg concentrations caused by larger biomass.

IV. Effects of physiological rates and assimilation efficiencies



The effects of grazing, mortality, and excretion rates on the TMR in two selected food chains.



The effects of changing carbon assimilation efficiency on the TMR in all possible food chains in this study: (a) small plankton, (b) large plankton.

- With increasing body size, the sensitivity of TMR to grazing, mortality rates, and food assimilation efficiency increases, while the sensitivity to excretion rates decreases.
- TMRs of small zooplankton are insensitive to the existing physiological rates, except CZ1 to the grazing rates. It means that in real ocean environment MMHg biomagnification is absent in small zooplankton.
- Low food assimilation efficiencies bring out more obvious MMHg biomagnification. However, MMHg biomagnification is still absent in small zooplankton. Zooplankton tend to eat more when food assimilation efficiency is low, which induces more MMHg transferred from prey to predator.

References

[1] Zakem, E. J., A. Alhaj, M. J. Church, G. L. V. Dijken, S. Dutkiewicz, S. Q. Foster, R. W. Fulweiler, M. M. Mills, and M. J. Follows (2018), Ecological control of nitrite in the upper ocean, Nature Communications, 9(1), 1206.

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