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HARVARD T.H. CHAN SCHOOL OF PUBLIC HEALTH
Powerful ideas for a healthier world

Impacts of Global Change on Cycling and Bioaccumulation of Anthropogenic Pollutants

SRP Risk e-Learning Webinar Series: Climate Change and Health

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November 4, 2022

Biogeochemistry of Global Contaminants HARVARD

STEEP
Sources, Transport, Exposure & Effects of PFASs
UNIVERSITY OF RHODE ISLAND SUPERFUND RESEARCH PROGRAM

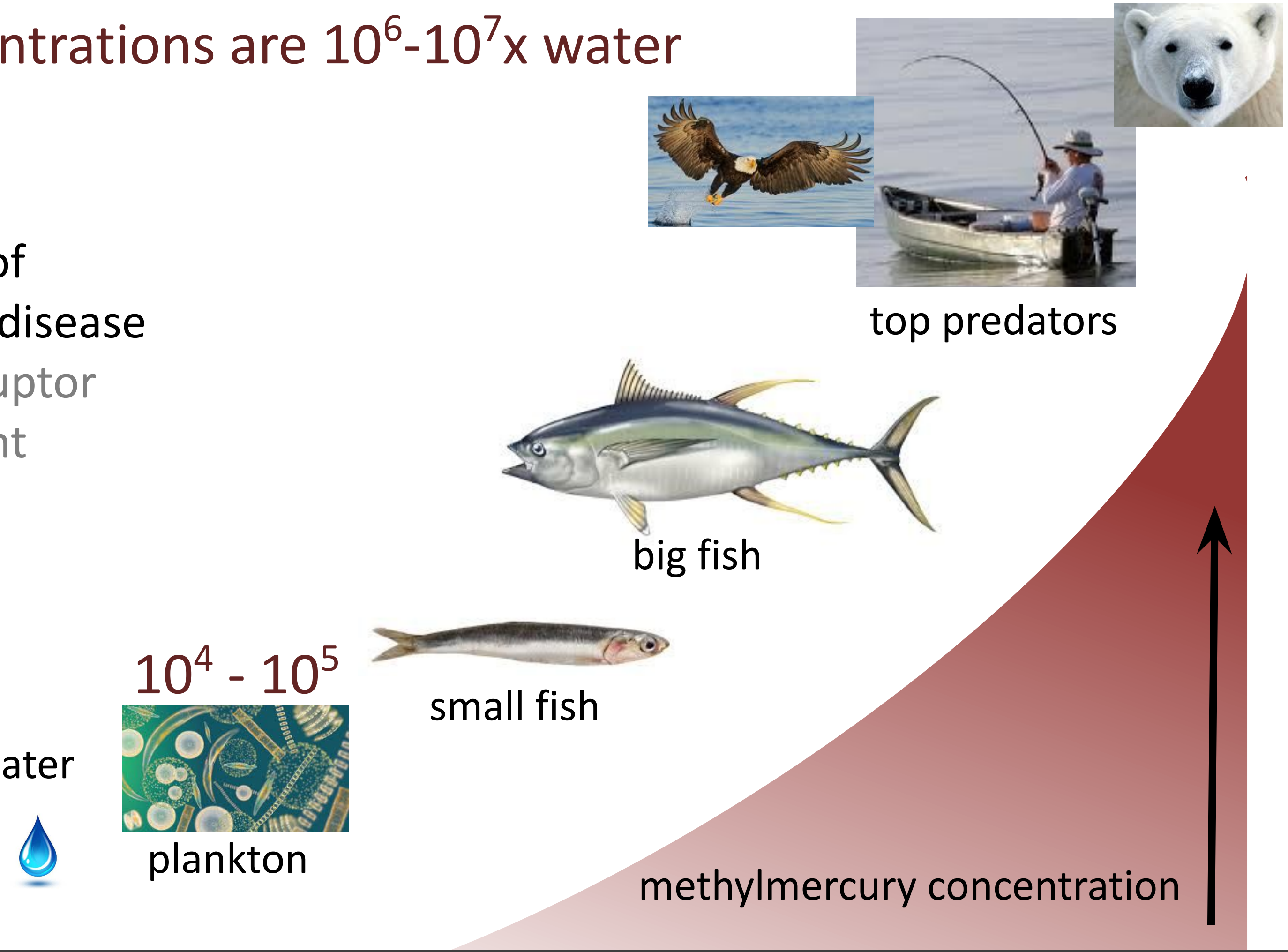
HARVARD John A. Paulson School of Engineering and Applied Sciences

Bioaccumulation results in magnification of chemical concentrations at each trophic level in a food web

Concentrations are 10^6-10^7x water

- Neurotoxicant
- Increased risk of cardiovascular disease
- Endocrine disruptor
- Immunotoxicant

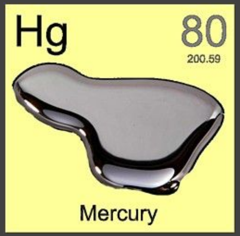
CH_3Hg
methylmercury

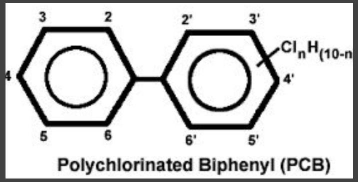


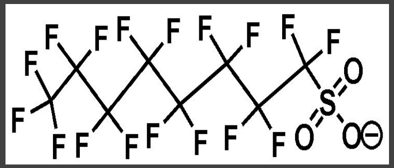
Societal Costs of methymercury exposure in US are large:
https://www.hsph.harvard.edu/c-change/news/mercury-emissions-reductions/

Research Question

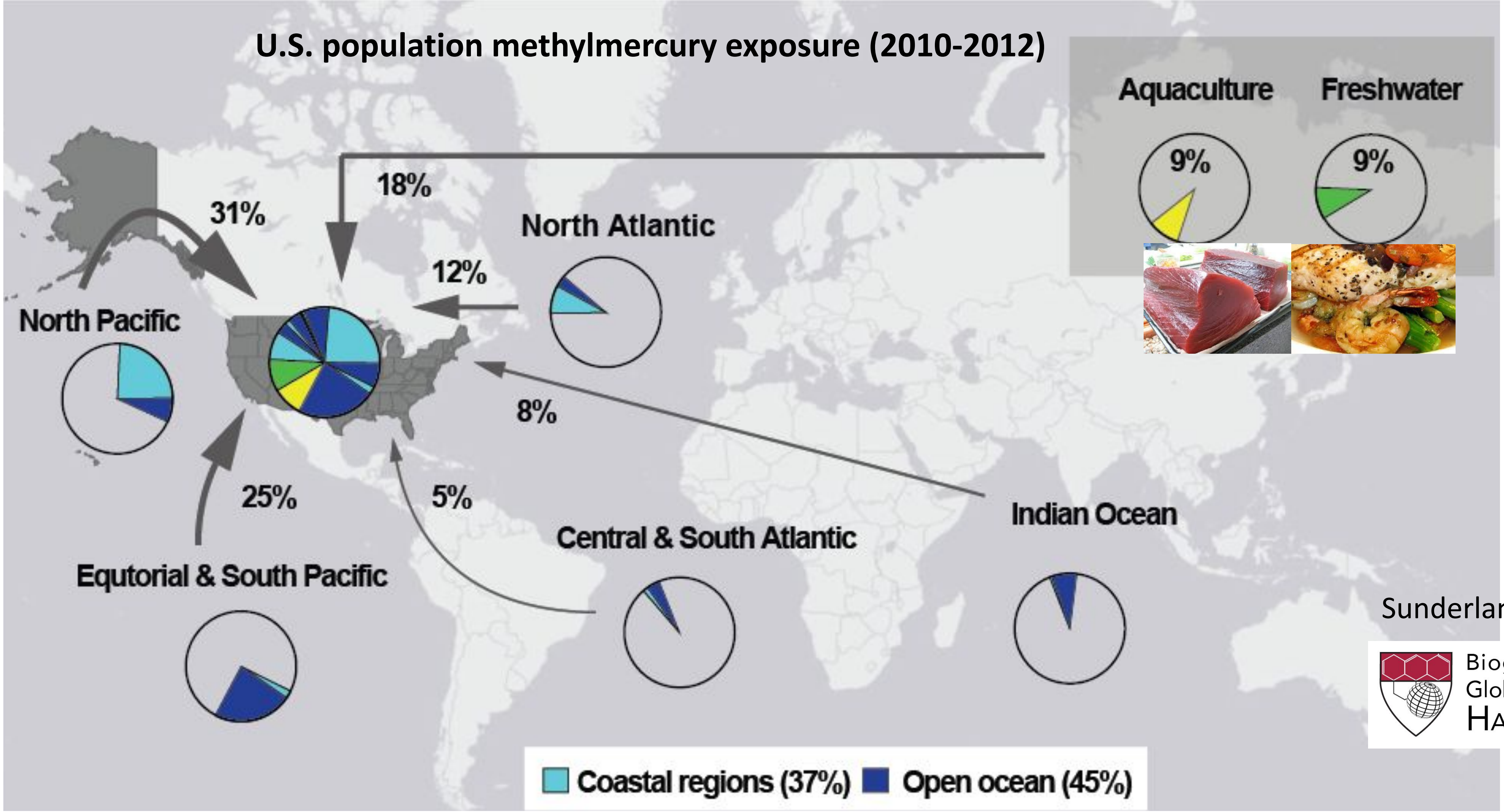
- How are climate-driven changes affecting the distribution and bioaccumulation of:
- **Mercury (Hg)**
- **Polychlorinated biphenyls (PCBs)**
- **Perfluorooctane sulfonate (PFOS)**







Global environmental quality affects chemical exposures from your food



Sunderland et al., 2018

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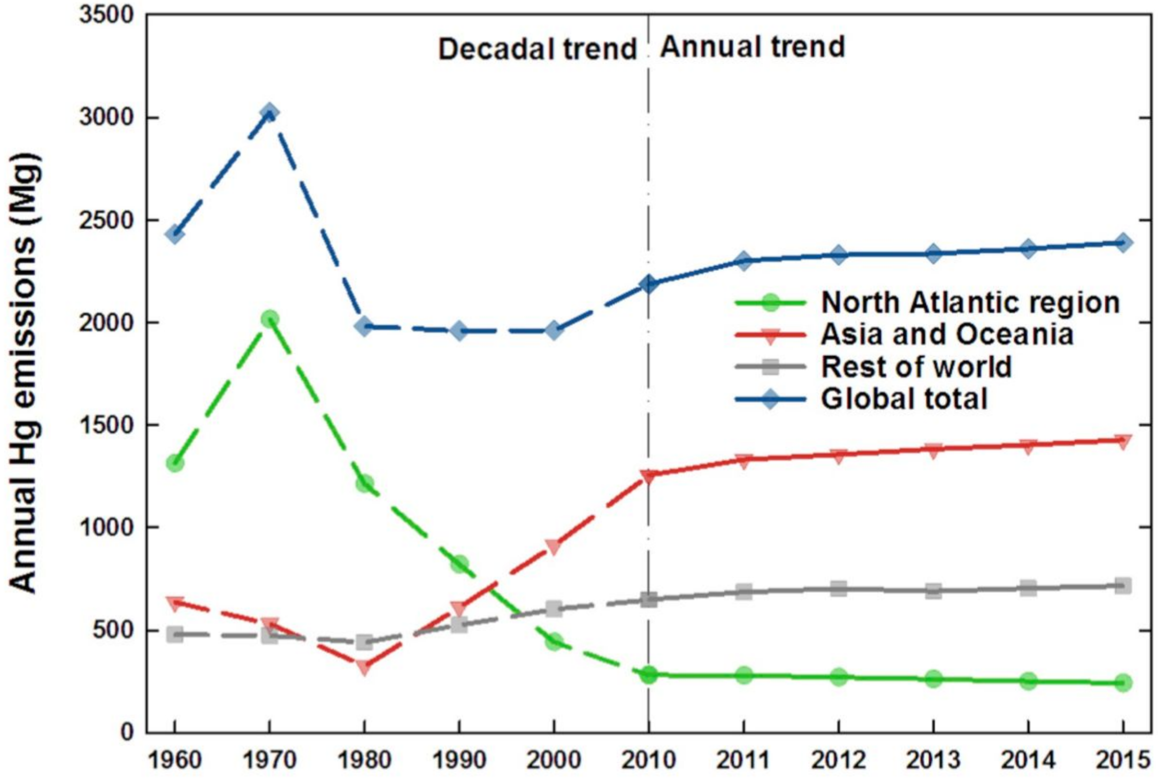
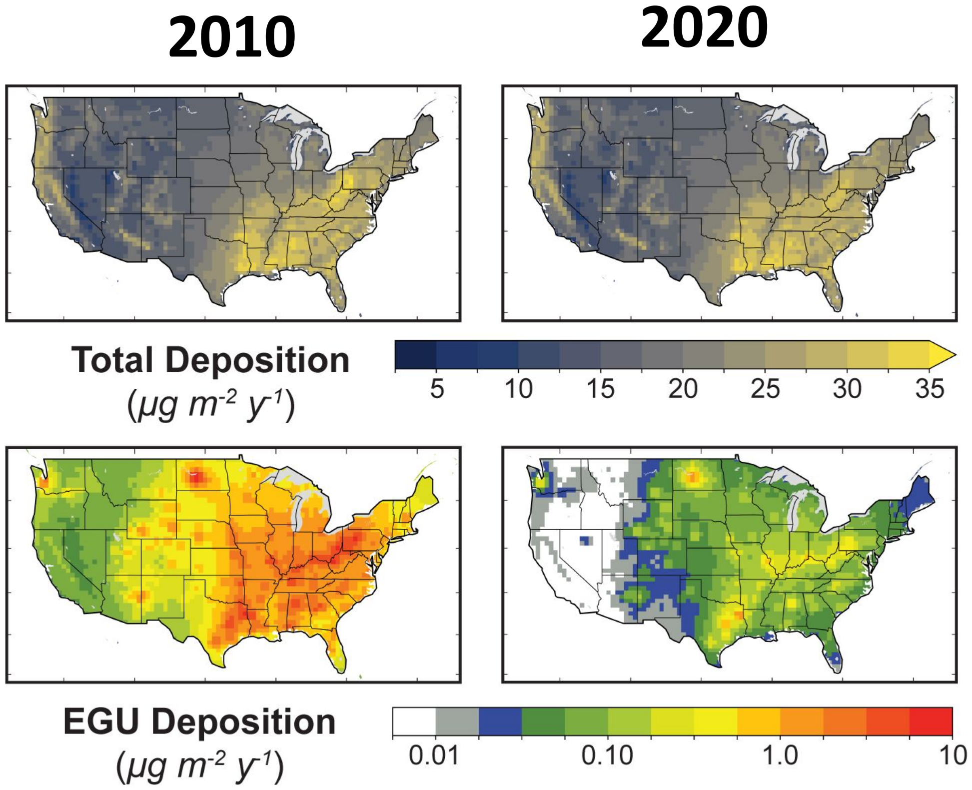
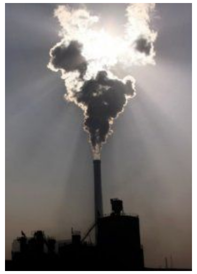
What does the future hold?

Global mercury emissions roughly constant ca. 2010



Streets et al. (2019)





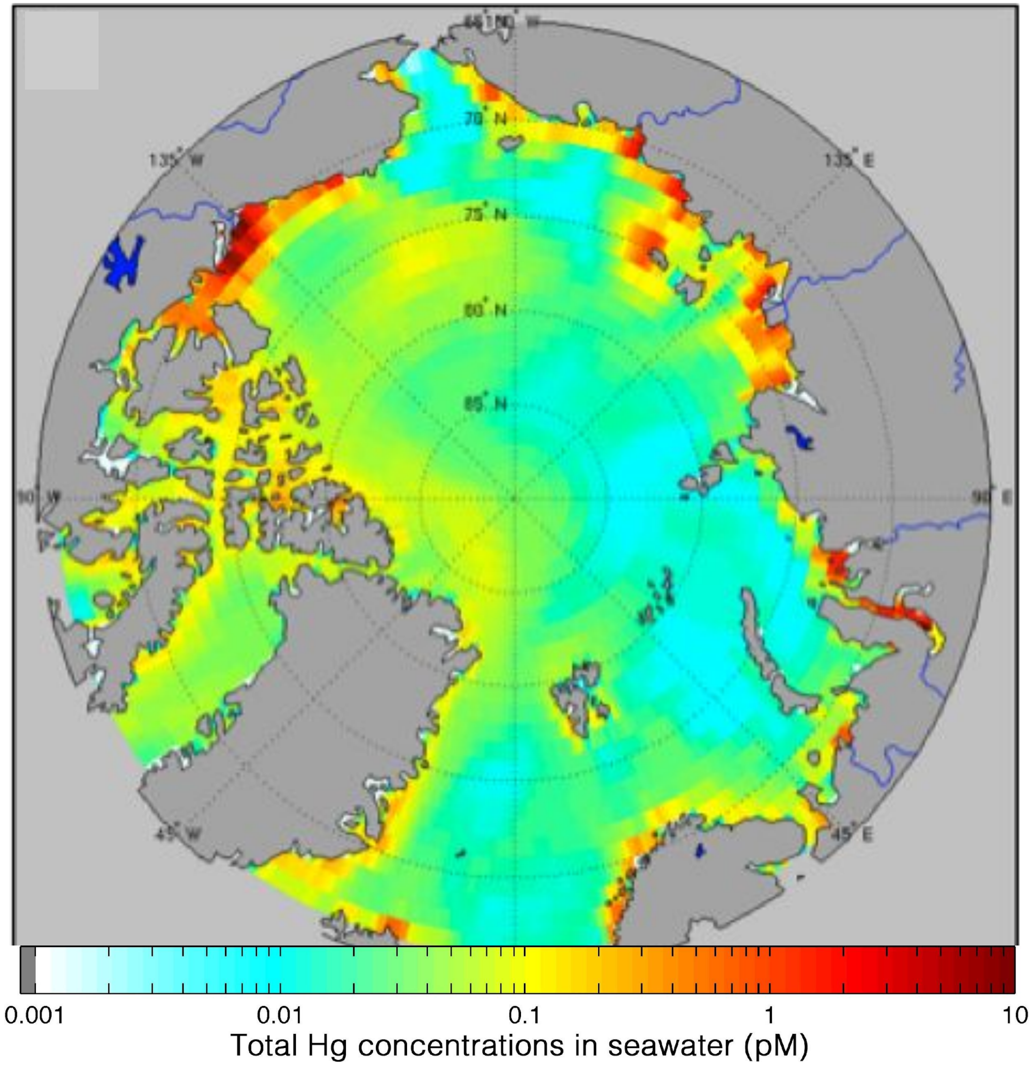
Arctic region is particularly vulnerable to climate driven changes

Warming 2 x Global Average

Melting Permafrost

Loss of Sea Ice

Modeled (MITgcm) Hg inputs to the Arctic Ocean from rivers



Vulnerable Human Populations

Fisher et al., 2012; 2013; Zhang et al., 2015; Soerensen et al., 2016, Sonke et al., 2019; Zolkos et al., 2022

Melting permafrost and wildfires in the Arctic expected to have large impacts on the global Hg cycle

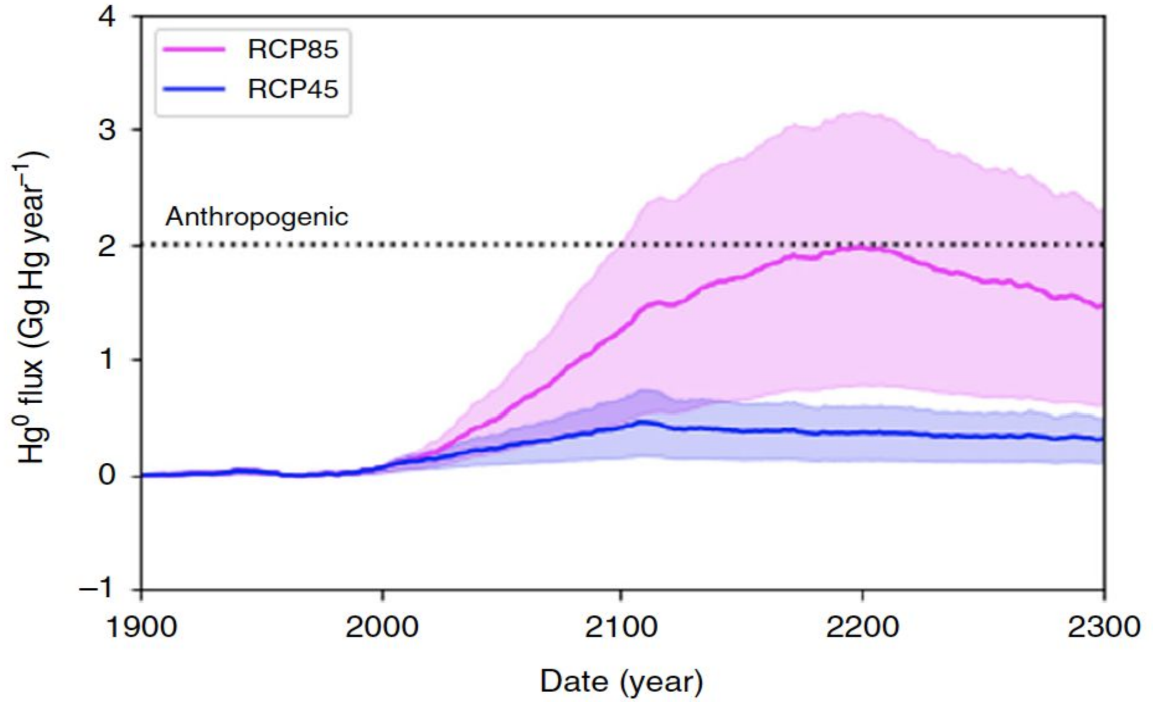
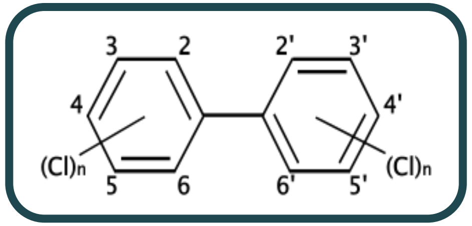


Fig. 2 Annual net elemental mercury (Hg^0) flux into the atmosphere. The net flux is Hg^0 evasion into the atmosphere minus Hg^0 deposition from the atmosphere, summed across all permafrost regions. The shaded areas represent uncertainty in the net Hg^0 flux and the dashed line represents current global anthropogenic emissions.

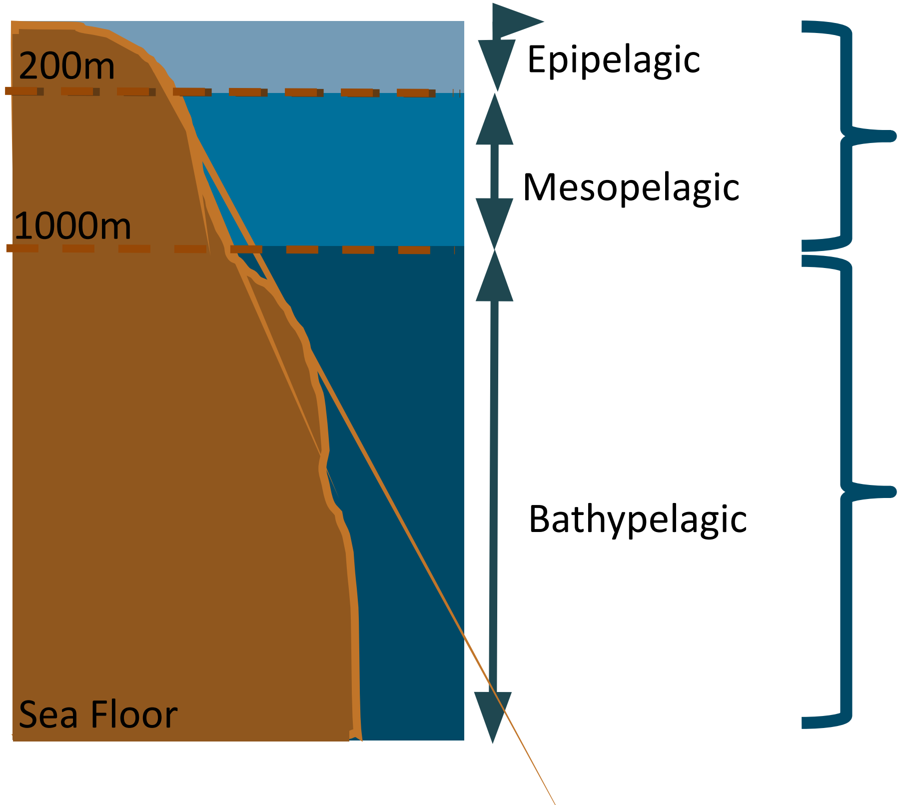
Schaefer et et al., 2020

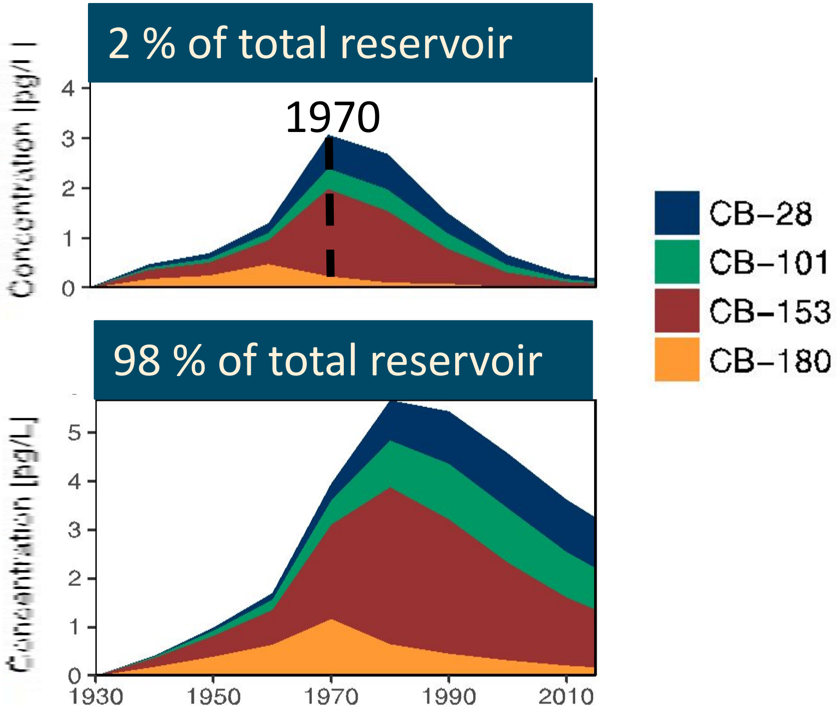
Stronger affinity of PCBs for particles than Hg leads to more rapid accumulation in the deep ocean



- 209 congeners; carcinogenic, neurotoxic
- Extremely hydrophobic
- Strong affinity for particles
- Variable volatility depending on MW

Ocean water column





Wagner et al., 2019

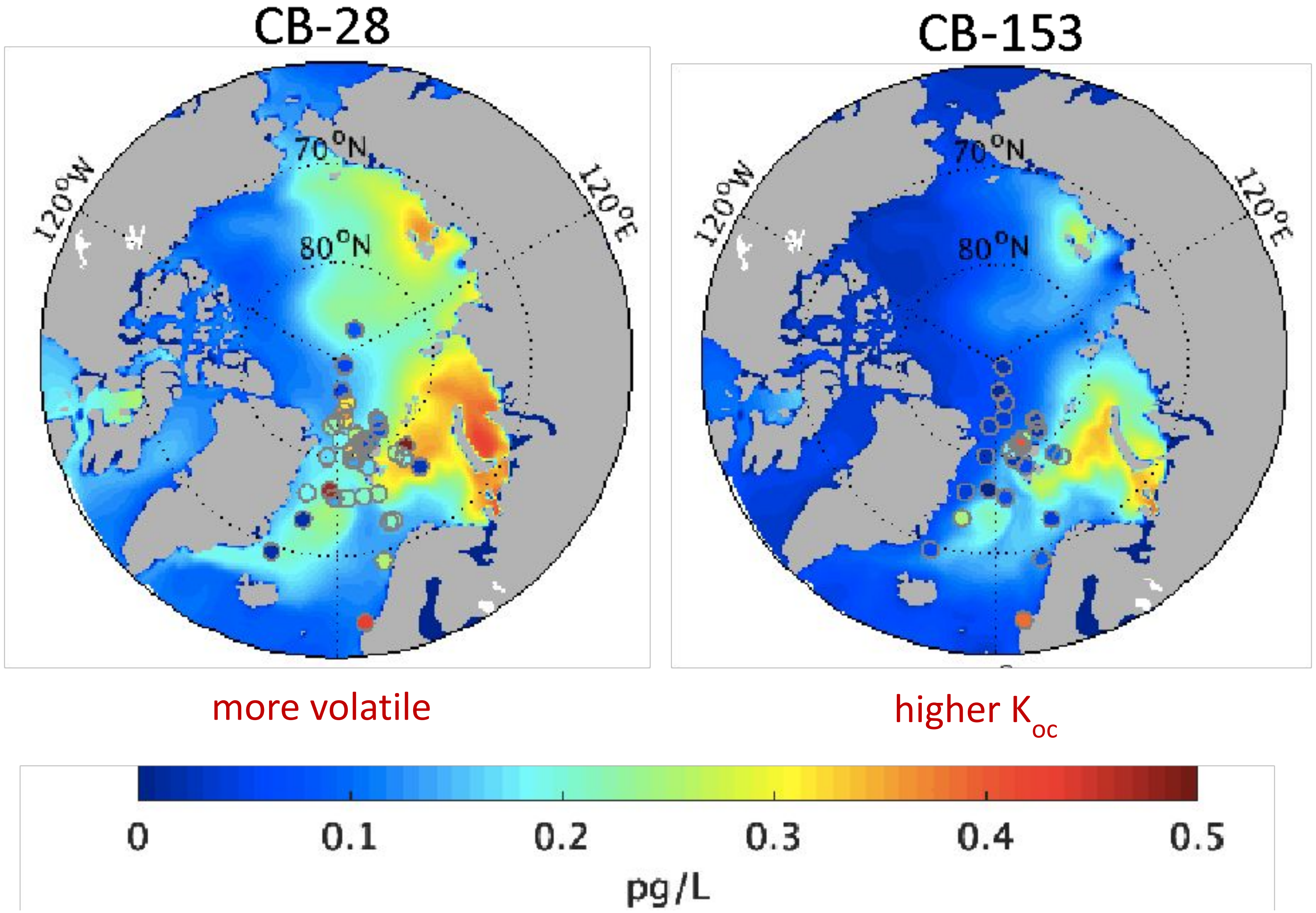
Log K_{oc} CB 153: 5.8-8.3

Log K_d Hg: ~4-6

Relative enrichment of volatile congeners in the Arctic sustaining biological concentrations 30 years after ban

24% of ocean inputs

59% of concentration

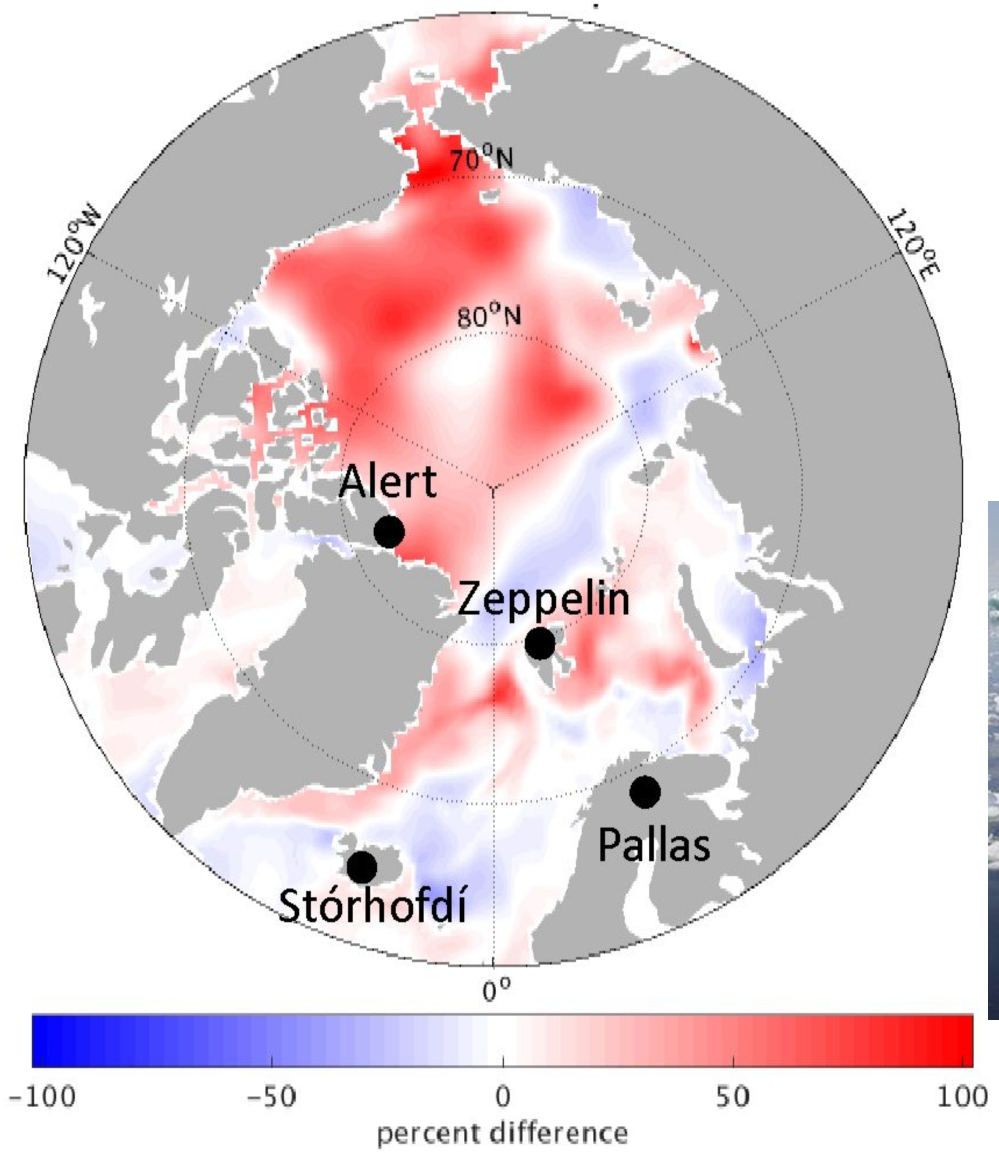


61% of ocean inputs

33% of concentration

Wagner et al., 2019

Sea-ice melt enhancing modeled concentrations of PCBs in some regions of the Arctic

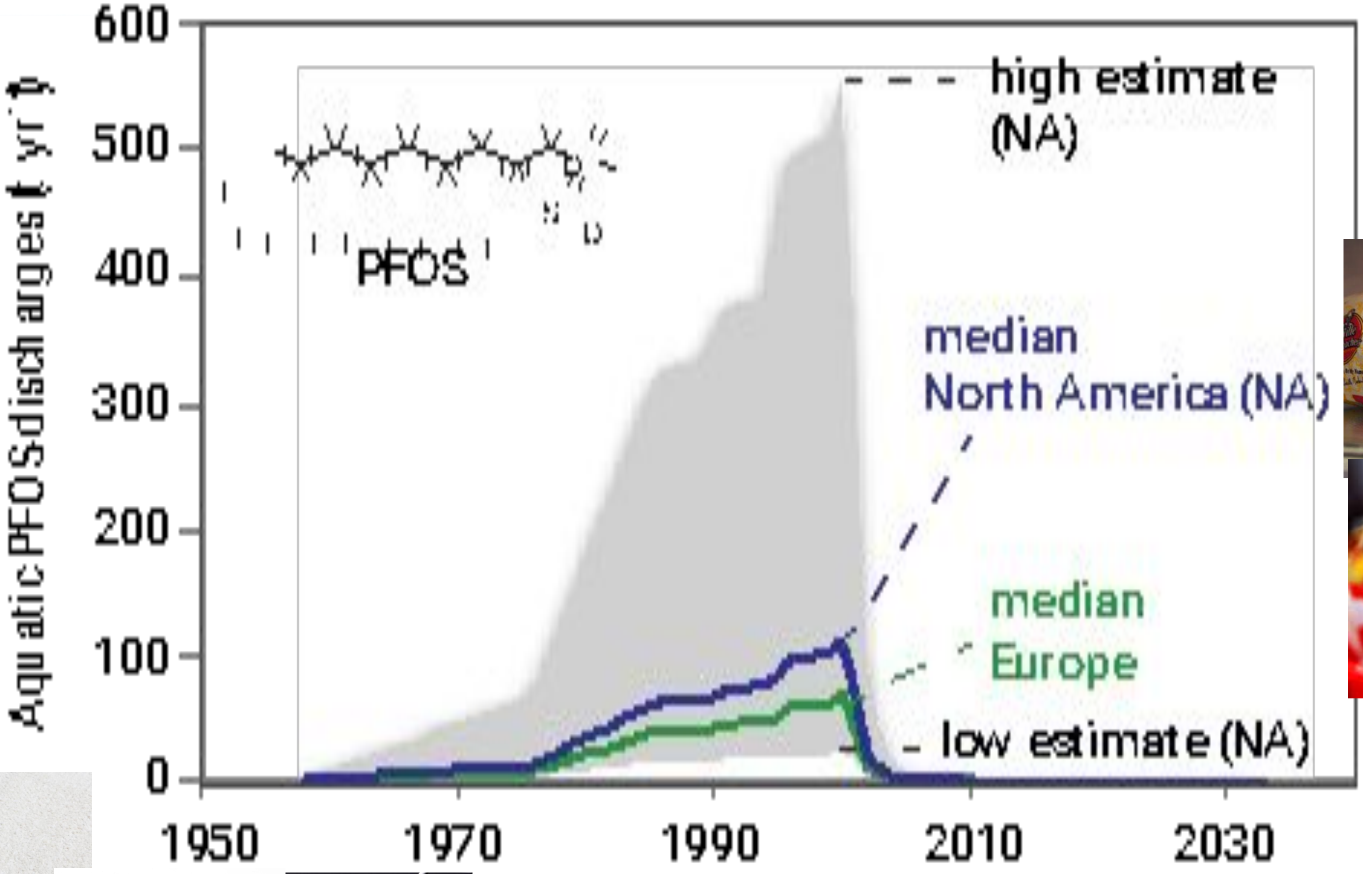


Difference between simulated concentrations of chlorinated biphenyl 153 (CB-153) with constant 1992-1996 meteorology and 1992 to 2015 meteorology

Wagner et al., 2019

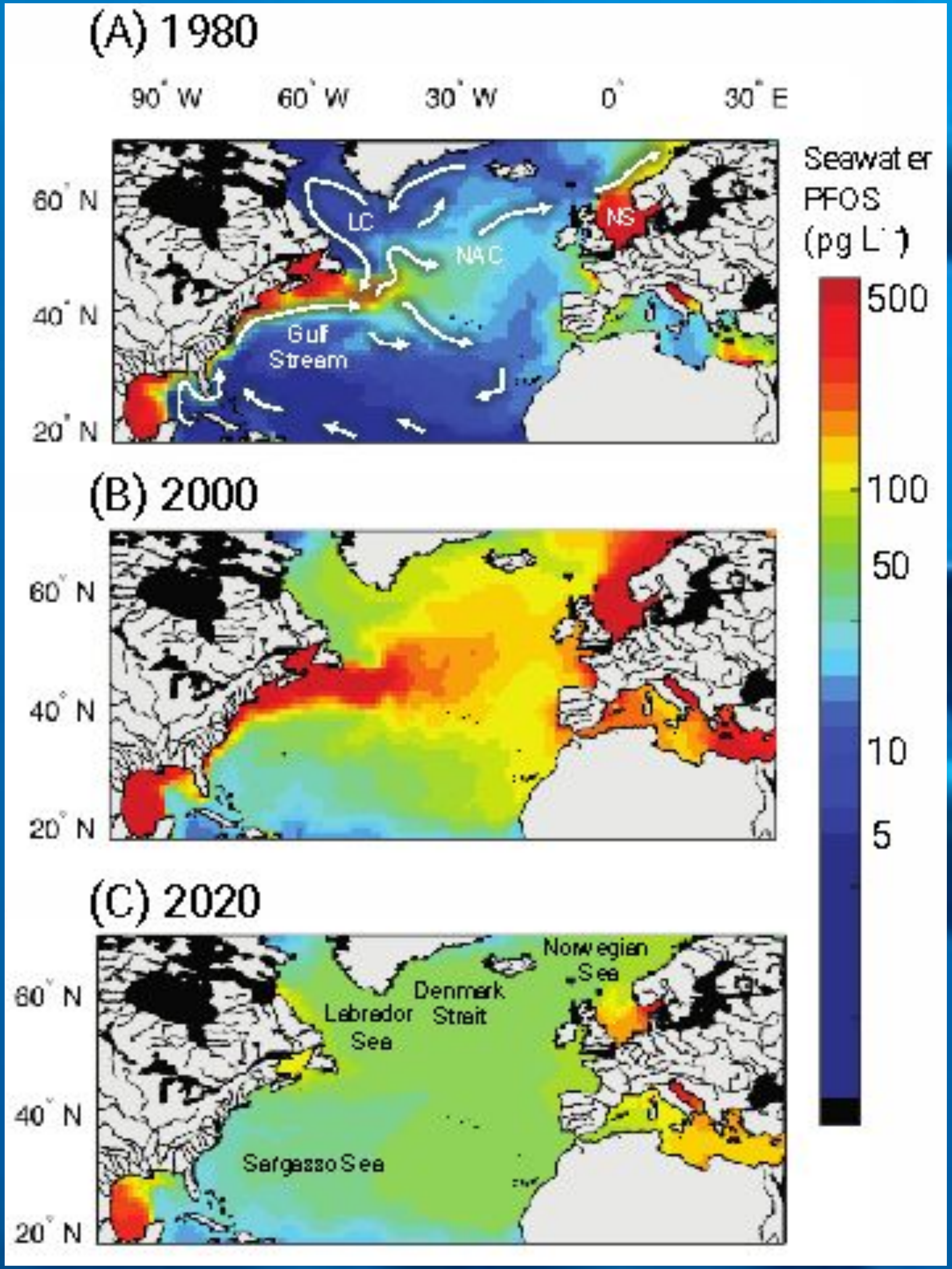
Parent chemical to perfluorooctane sulfonate (PFOS) phased out by 3M between 2000-2002

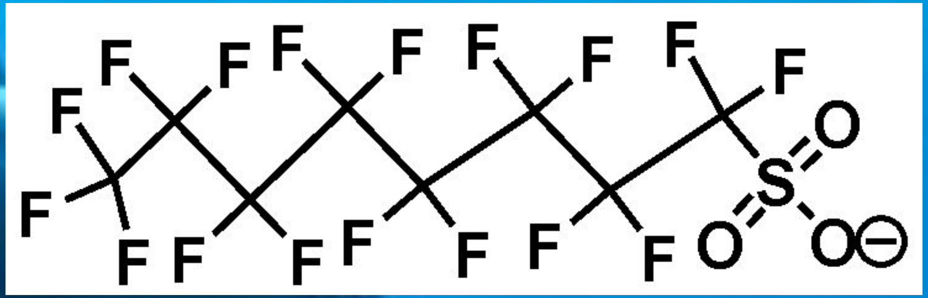
Riverine discharges to the North Atlantic Ocean



PFOS
Log K_{oc} = 2.6
pK_a = -3

Zhang et al., 2017

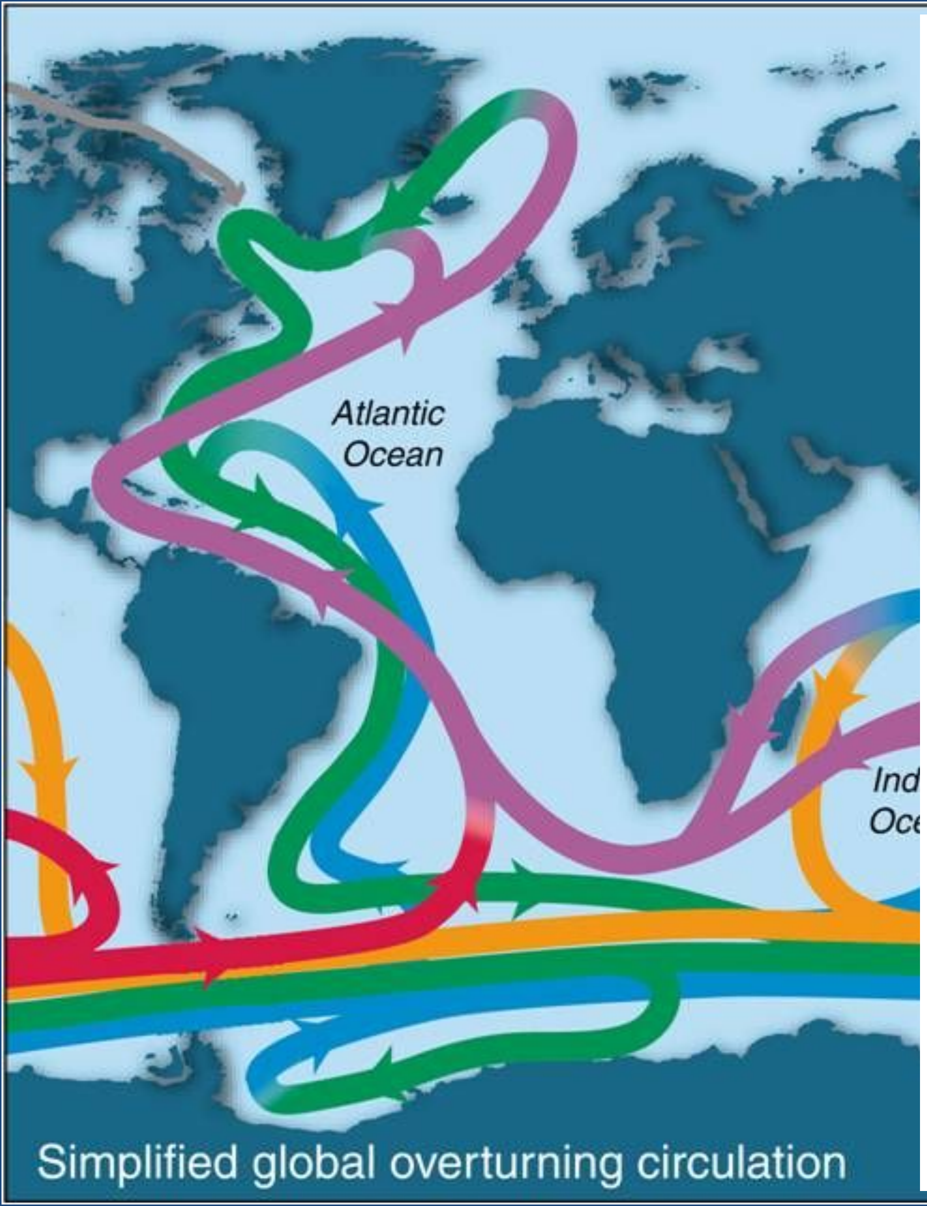


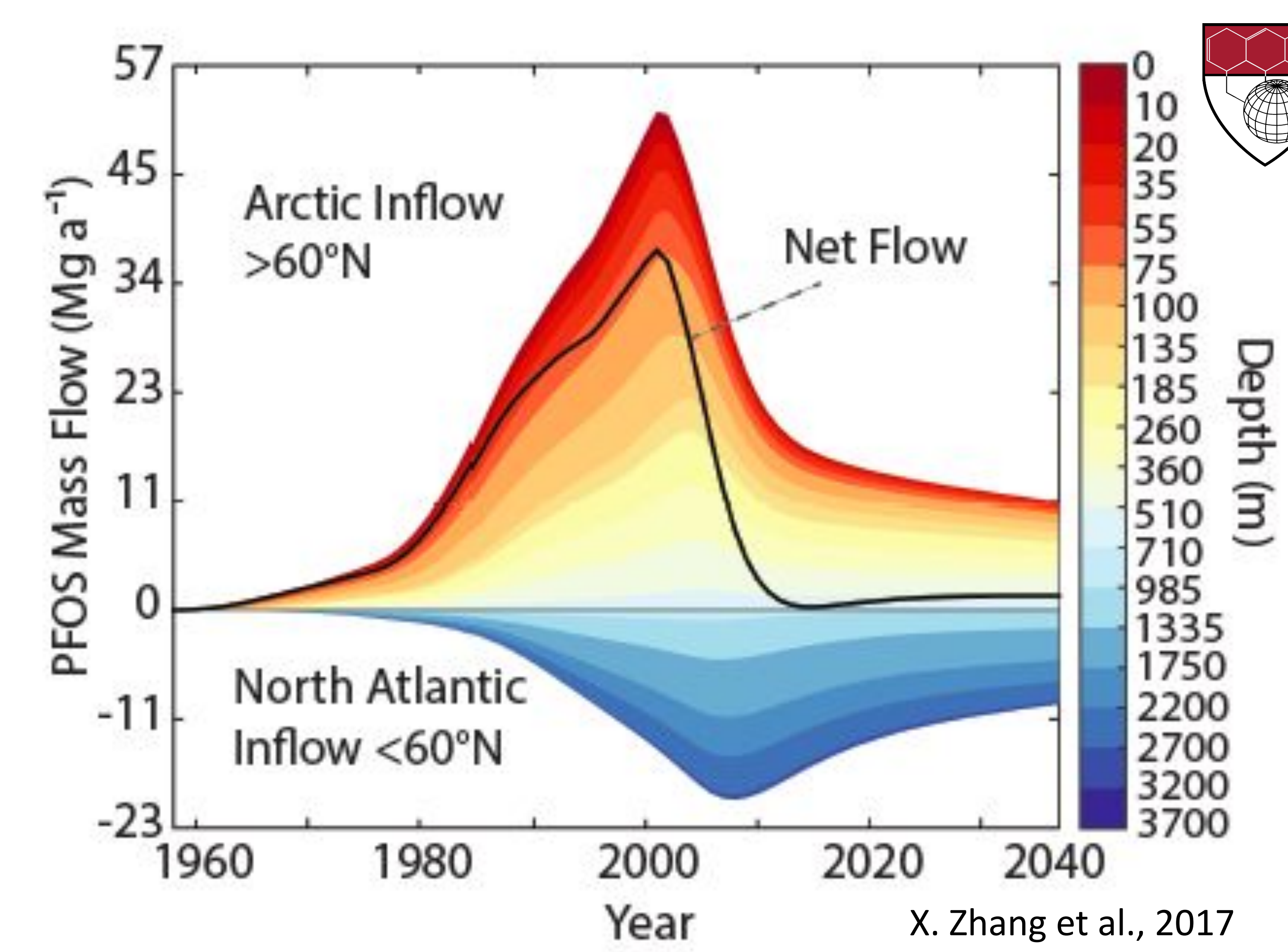


Modeled PFOS in North Atlantic seawater (10 m)

X. Zhang et al., 2017

For chemicals like PFOS with weak sorption to organic carbon
Weakened AMOC = >>>bioaccumulative contaminants to the Arctic

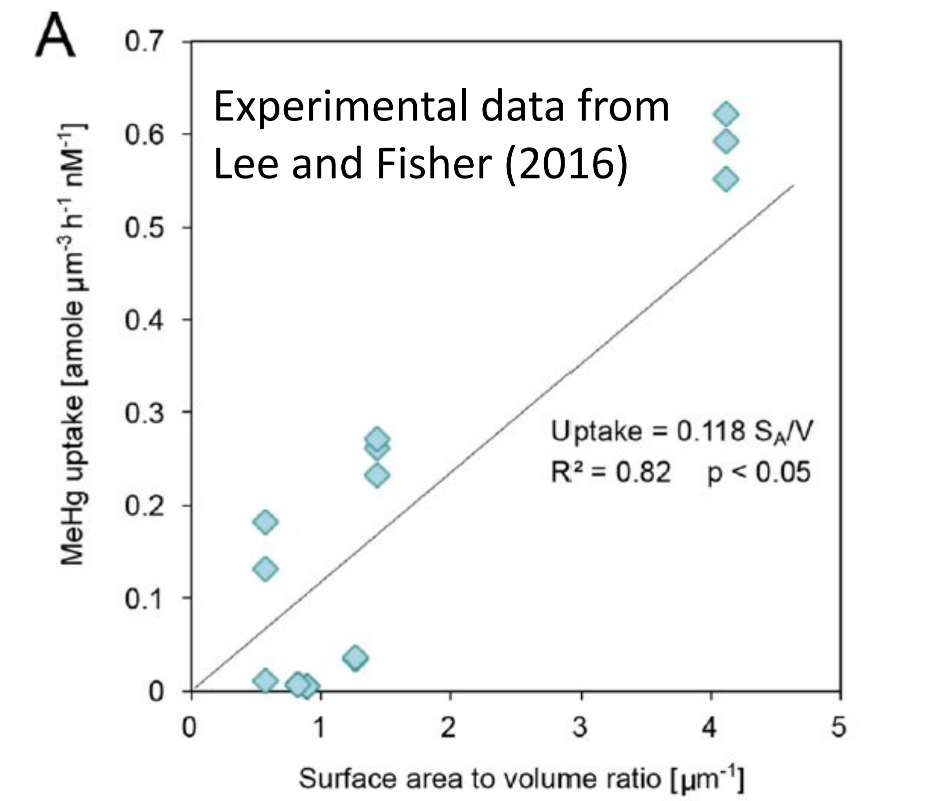




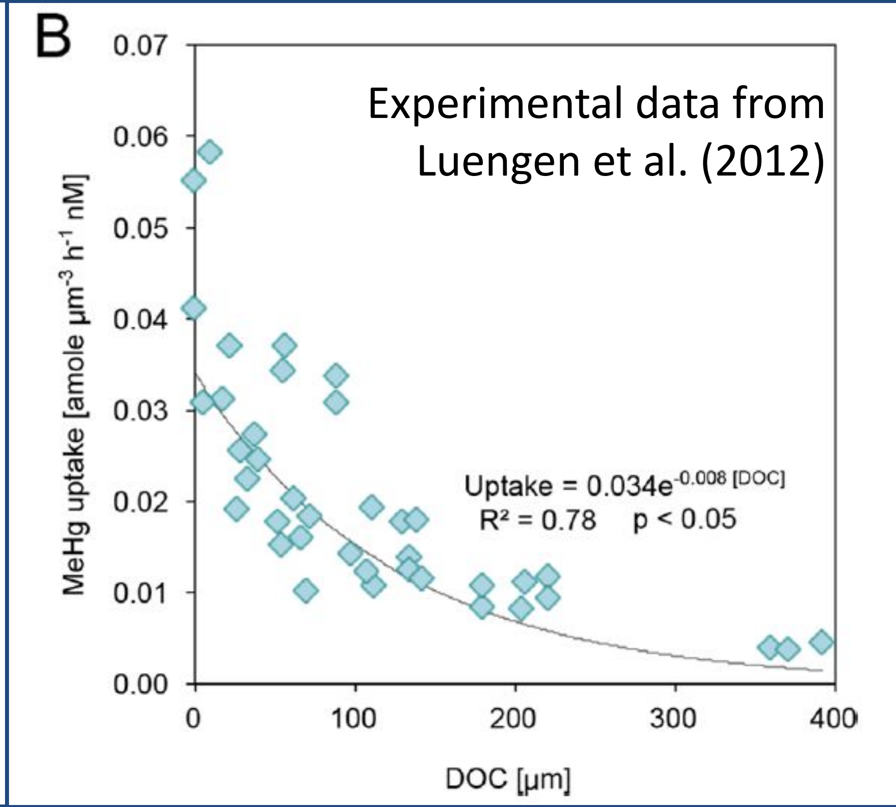
X. Zhang et al., 2017

Rivers are a major source of nutrients to the marine environment

Effect of Phytoplankton Size on Methylmercury Uptake



Effect of DOC on Methylmercury Uptake



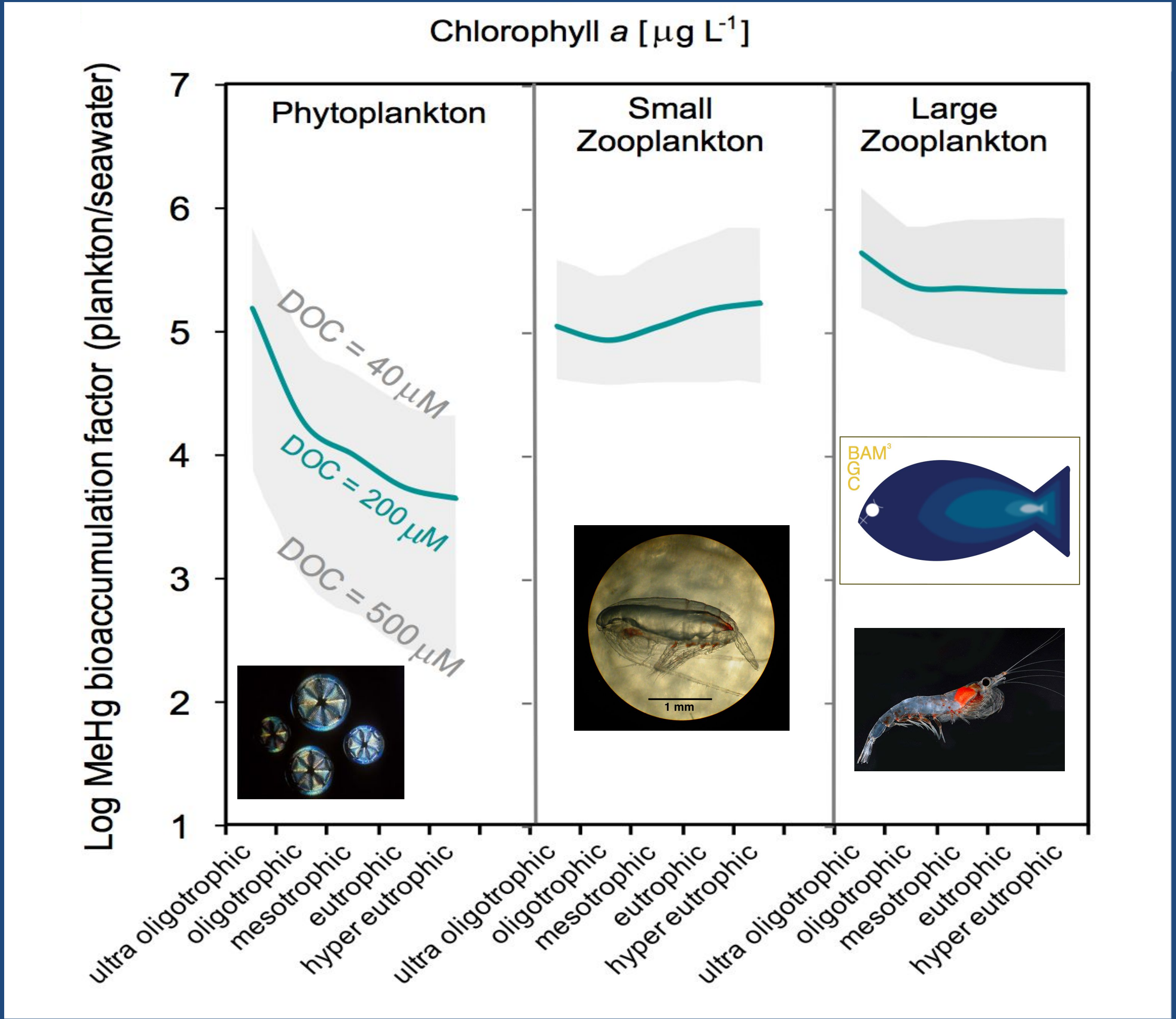
High nutrients = larger cells, lower S_A/V

Low nutrients = Smaller cells, higher S_A/V

Schartup et al., 2018

Impacts of shifts in DOC and nutrients are dampened in zooplankton due to competing intake vs. growth

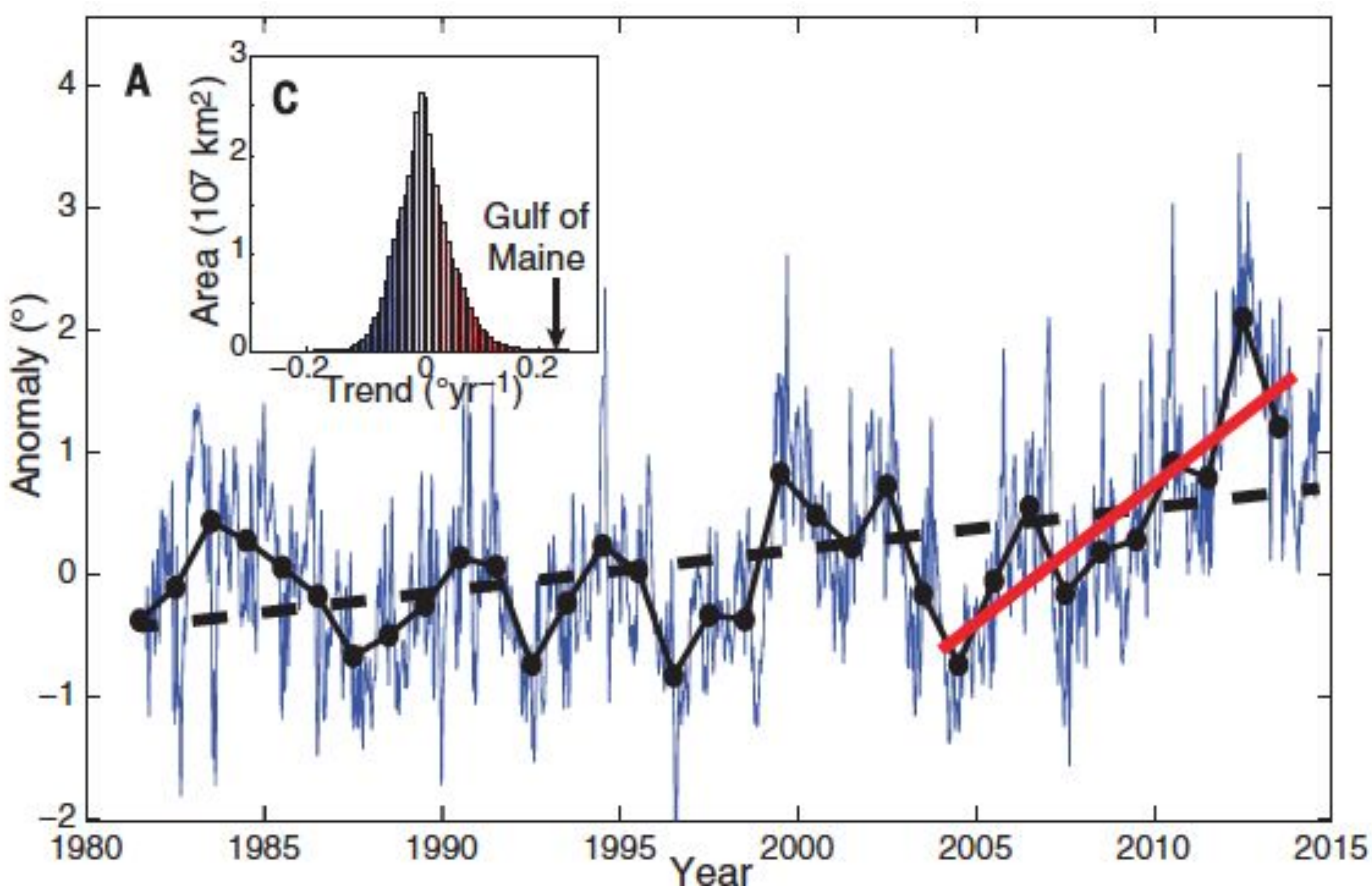
Log BAF (Plankton/Seawater)

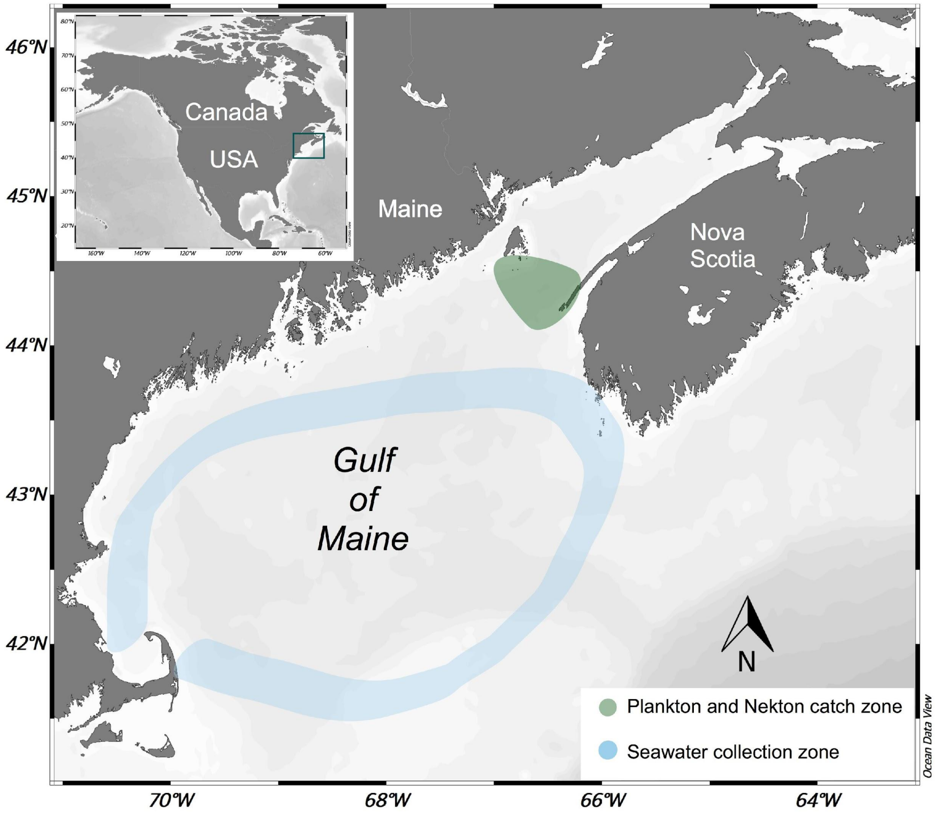


Schartup et al., 2018

Seawater warming affects fish metabolism and growth, MeHg elimination, prey availability, and species habitat

Unprecedented warming in the Gulf of Maine

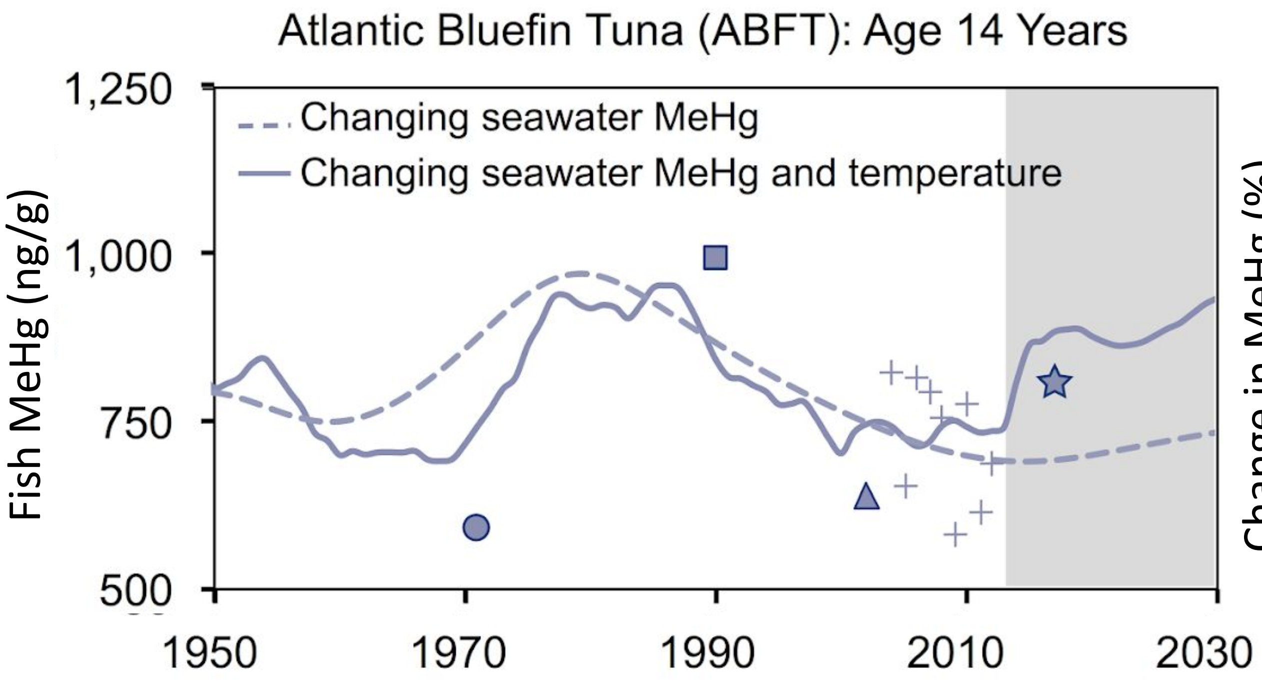


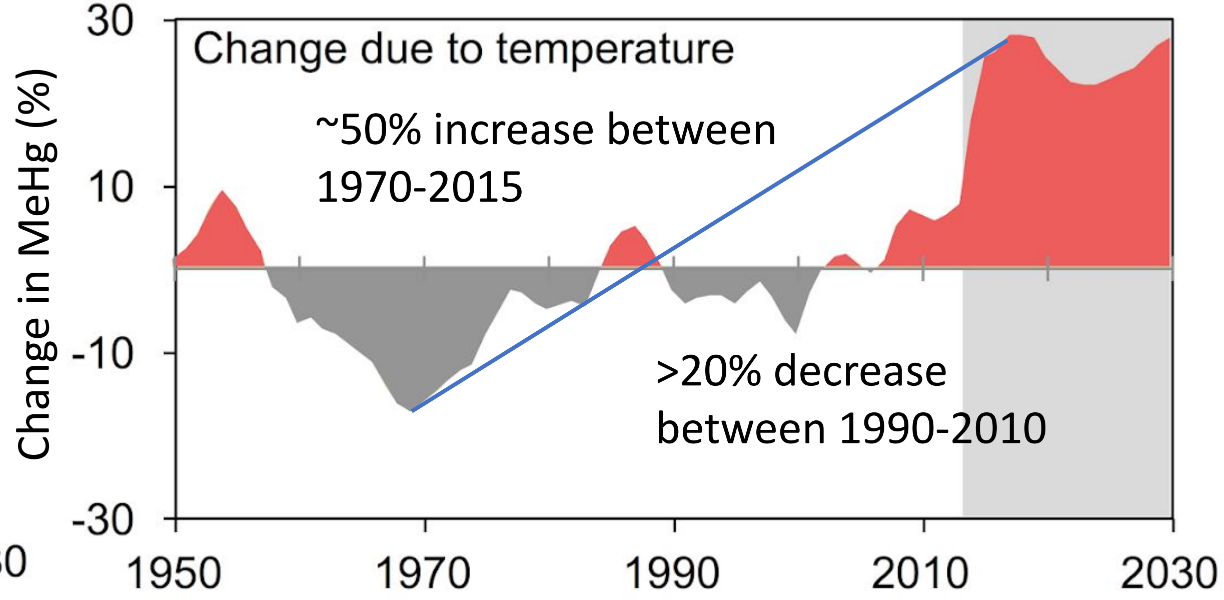


Pershing et al., 2015

Large temperature driven fluctuations in MeHg concentrations in Atlantic bluefin tuna

Seawater warming affects fish metabolism and growth, MeHg elimination, prey availability, and species habitat





Year ABFT Captured

Schartup et al., 2019

Summary

- Future increases in freshwater discharges likely to enhance direct inputs of contaminants to the ocean & increase stratification, leading to >> concentrations in biota

- Declines in sea-ice cover may lead to greater evasion and lower seawater concentrations of the most volatile compounds in the Arctic, redistribution to lower latitudes

- Climate driven changes in trophic structure and bioenergetics likely to exacerbate bioaccumulation of toxicants in predatory fish & marine mammals

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