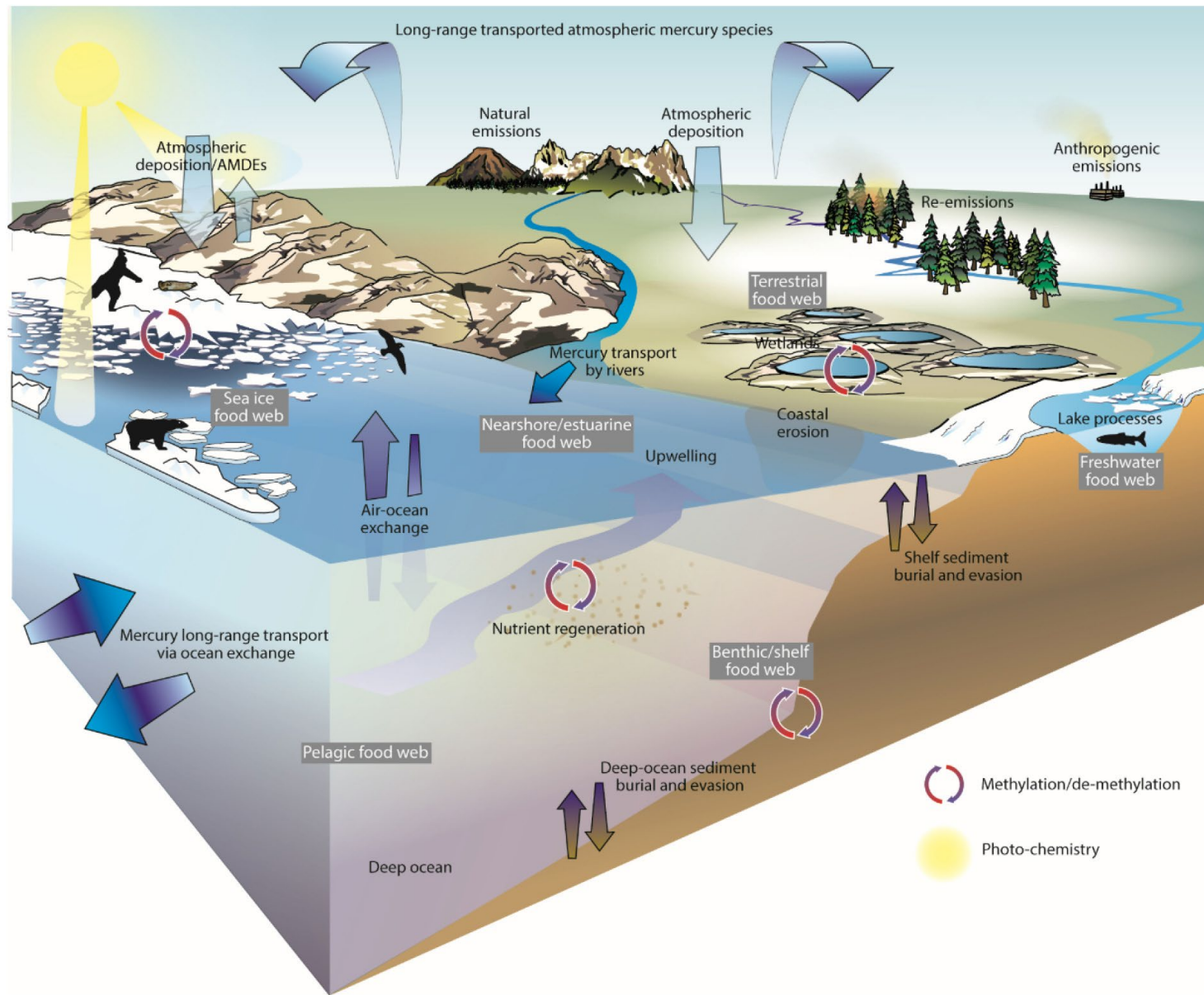




Mercury-Climate-Fish Nexus

Michael S. Bank, Ph.D.

- *Institute of Marine Research, Bergen, Norway*
- *University of Massachusetts, Amherst, MA, USA*
- *UN Scientific Advisor - Climate & Chemicals*
- Michael.Bank@hi.no





The Research
Council of Norway



GEO7



2021
2030 United Nations Decade
of Ocean Science
for Sustainable Development

Support, Network, & People

- R. Ingvaldsen, Q.T. Ho, A. Maage, M. Zhu, O. Travnikov, D. Amouroux, E. Tessier, Z. Pedrero, J. Barre, M. Horvat, and S. Berail



IAEA

International Atomic Energy Agency



Food and Agriculture
Organization of the
United Nations





Presentation Outline

Background

Blue Food System & NEAO Hg

Climate & NE Arctic Cod Mercury

Synthesis





Orca

Atlantic salmon

Northern krill

Sea trout

on's mane jellyfish

Atlantic mackerel

Blue whiting

Atlantic herring

Atlantic cod

Sugar kelp

European hake

Greenland halibut

European eel

Saithe

Plaice

Pollack

Atlantic halibut

Haddock

Brown crab

Blue Mussel

Blue ling

Common ling

Tusk

European wolfish

Norway lobster

Green urchin

European lobster

Starfish

Northern shrimp

Barents Sea Ecosystem & Northeast Atlantic Ocean (NEAO 2020 - 8.2M tons/yr.)



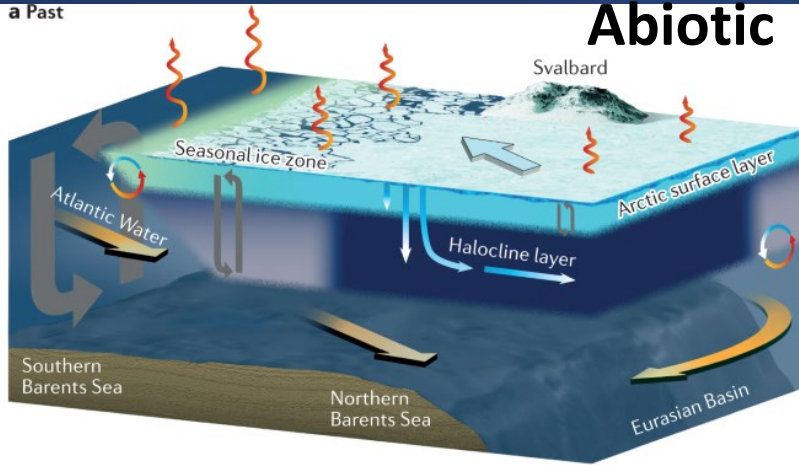
Barents Sea - Shallow Shelf Marginal Sea of the Arctic Ocean

- Productive sea with an average depth = 230m
- Turning into the Atlantic Ocean or “Atlantification”
- Arctic warming hot spot (Amplification)
- Atm. Dep. (all) & Rivers (South) are the dominant Hg sources

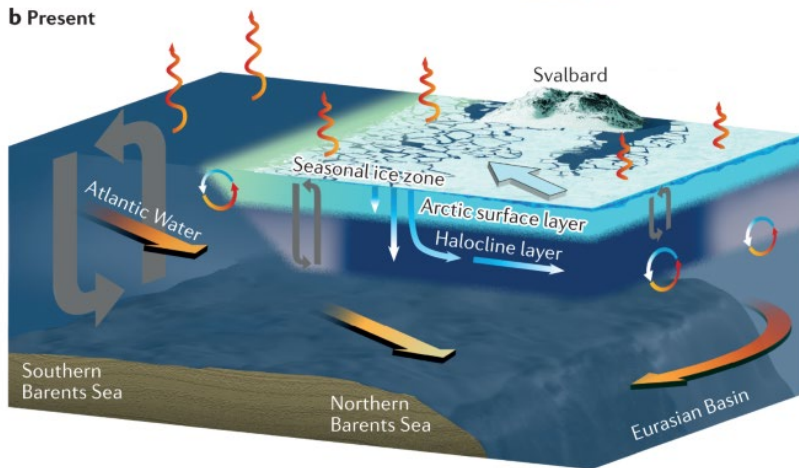
Ocean Warming and Earth System Change in the Arctic (Barents Sea Ecosystem)

a Past

Abiotic

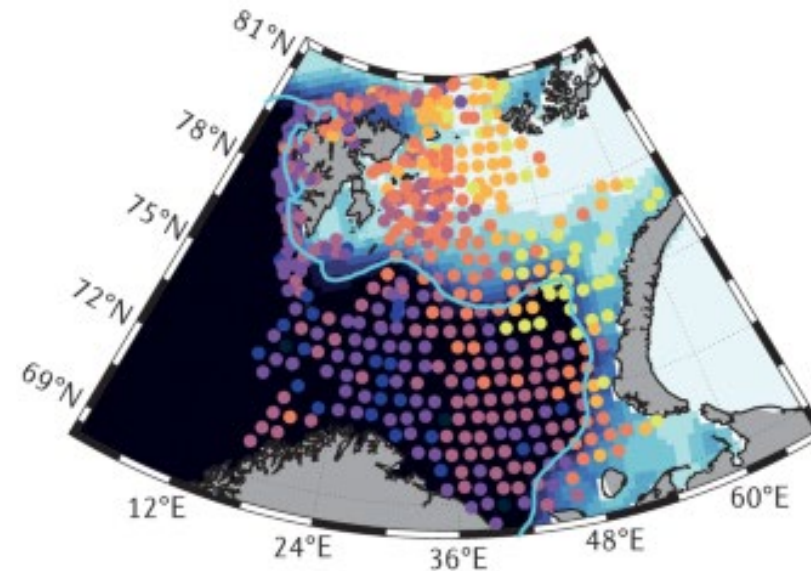


b Present

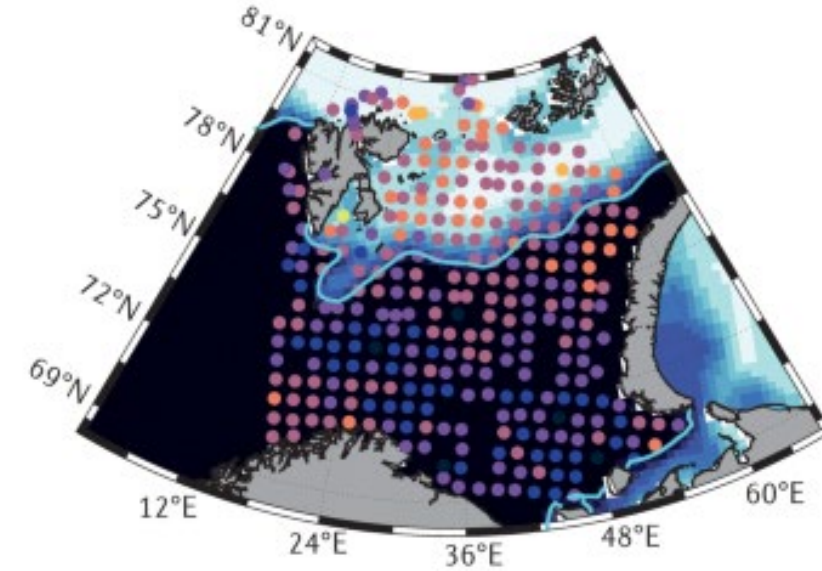


Biotic

a Feeding links 2004



b Feeding links 2017



Few Number of feeding links Many

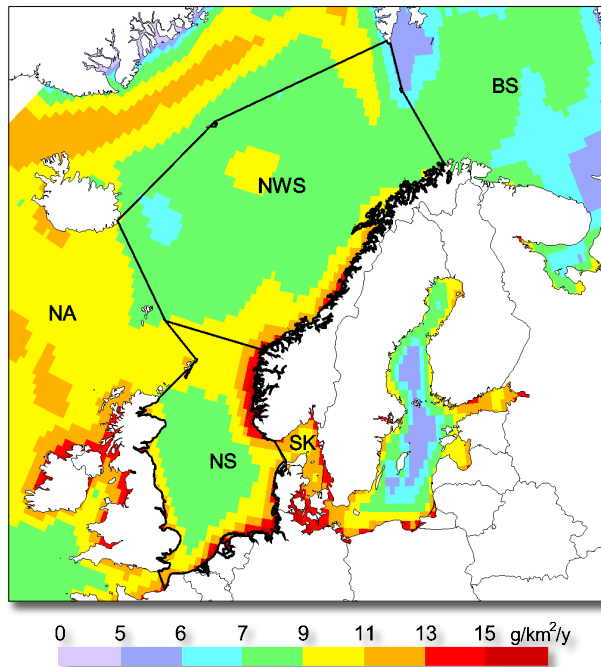
Ingvaldsen et al. 2021



NEAO Mercury Model

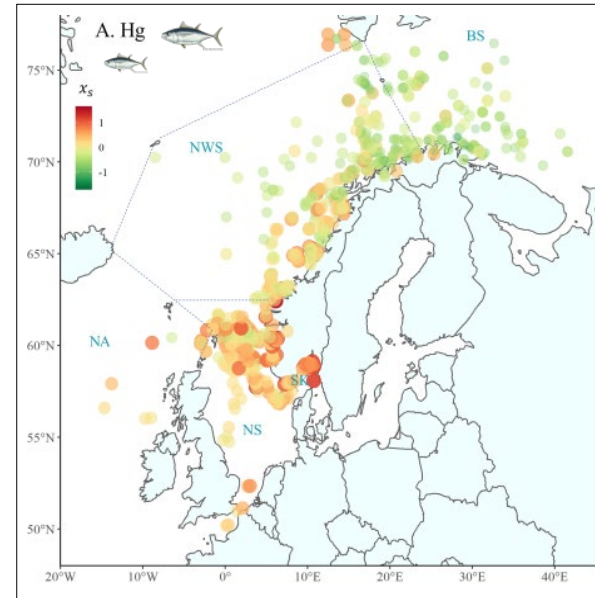
Atmospheric Chemistry-Trophic Transfer-Human Exposure

2015 Mercury Deposition to NEAO (NMA 2022)



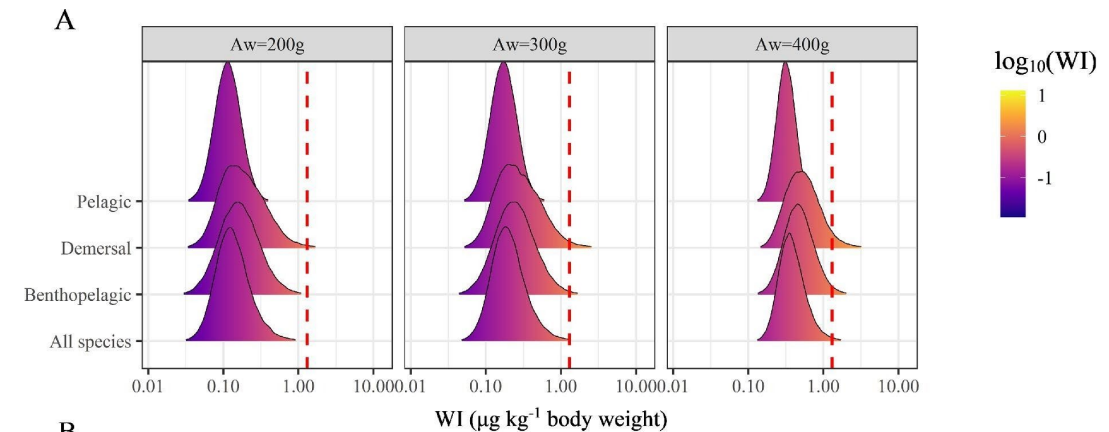
Multi-model simulations
AMAP Ensemble Model
Hg Assessment

Length-Adjusted Mercury Concentrations in Marine Fish ($n=25,631$, 2006-2019)



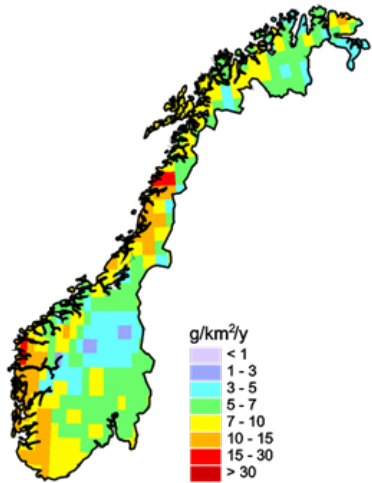
Fish measurements
(Ho* & Bank* et al., 2021)
*co-first authors

Methylmercury Human Exposure 2006-2019 Monte Carlo Simulation

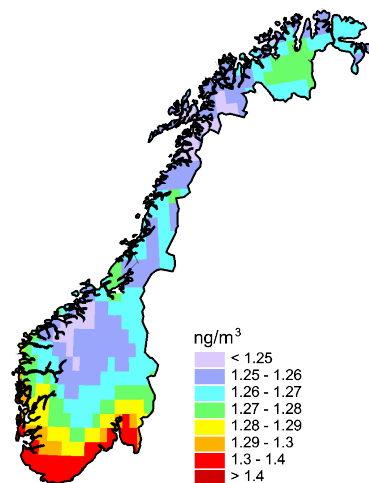


Long-Term Trends of Mercury Pollution in Norway

2019 Hg Wet Deposition Flux

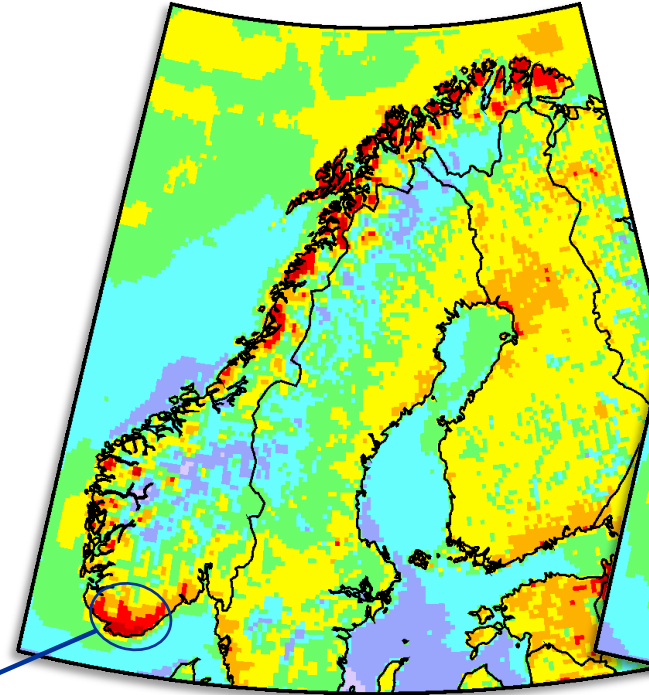


2019 Hg⁰ Air Concentration

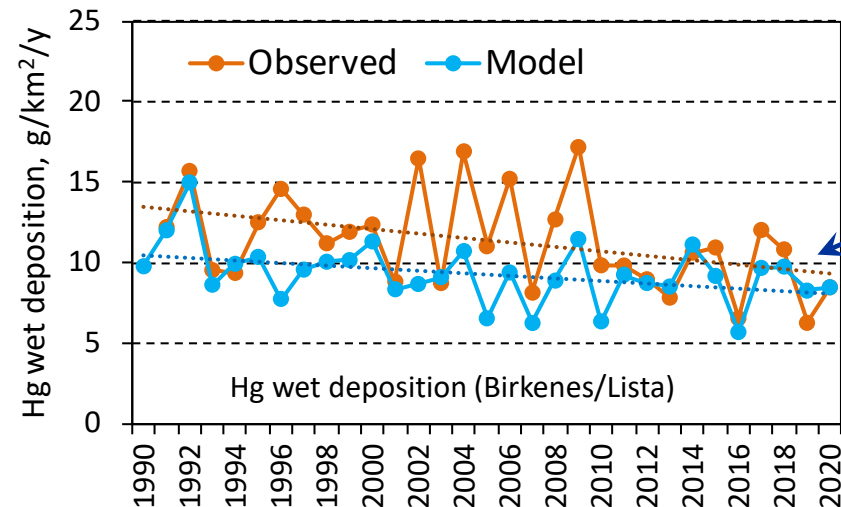
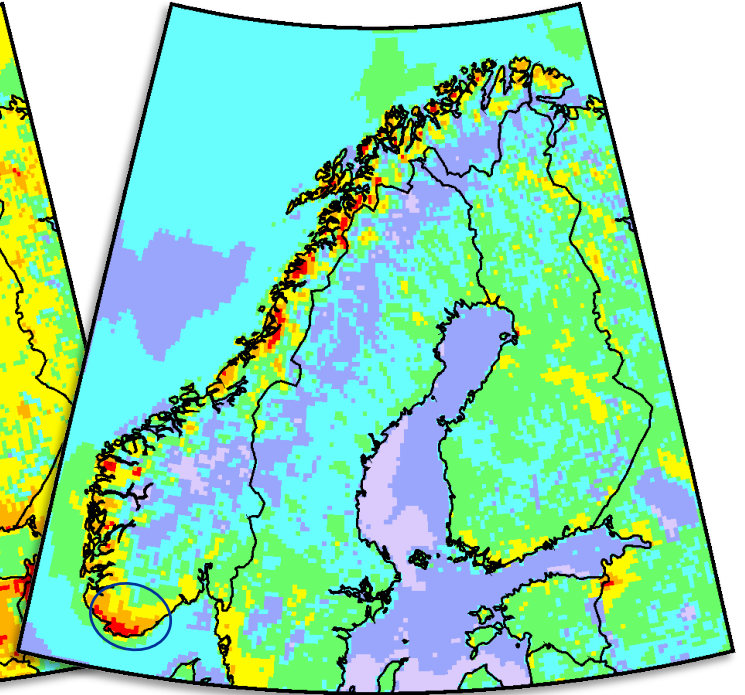


Hg Wet Atmospheric Deposition (GLEMOS Model)

2000



2015



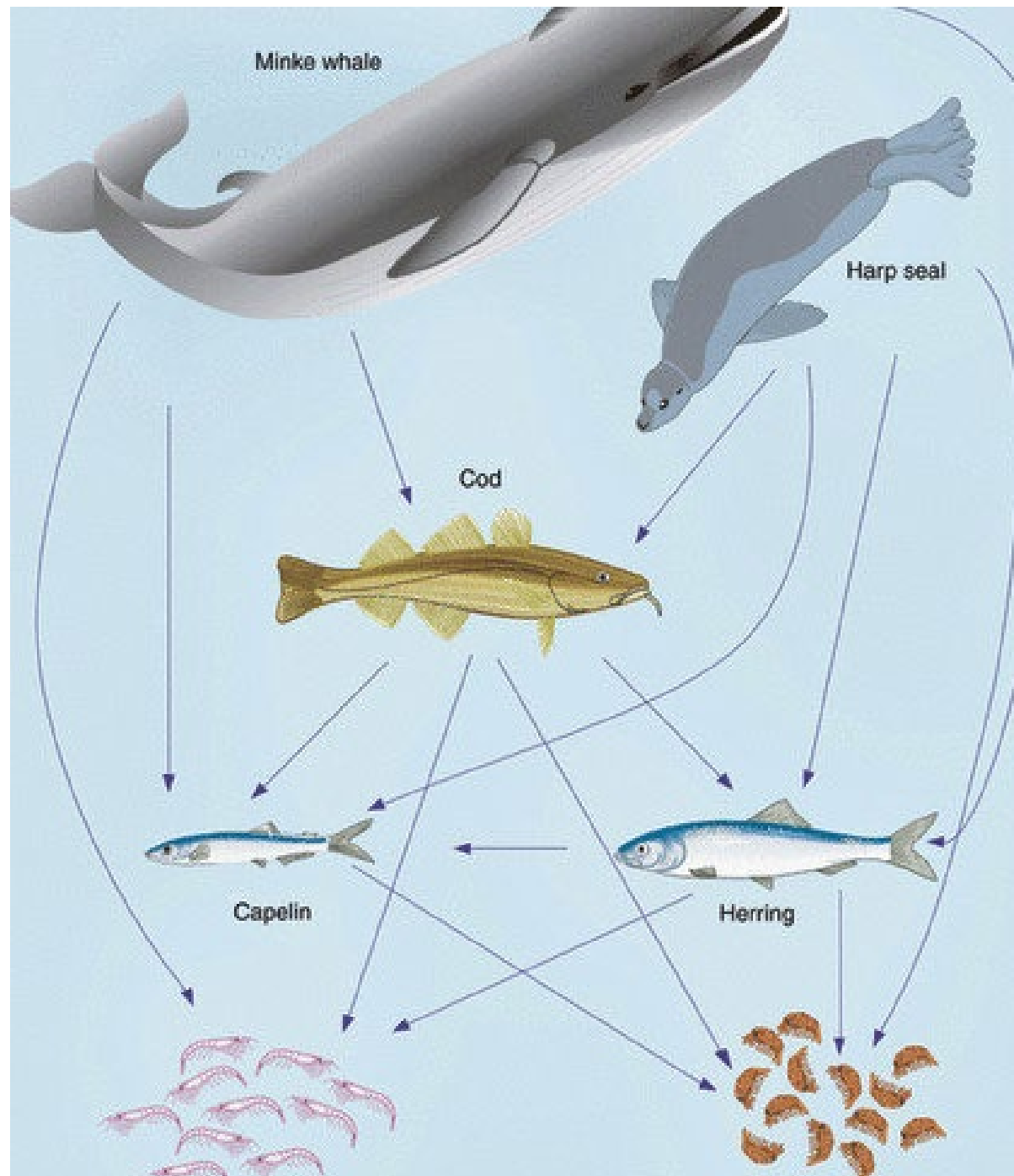
Human Cooperation:
Oleg Travnikov / AMAP

NMA 2022, Bank et al. 2025
(in prep, STOTEN)



Case Study Northeast Arctic Cod Climate Change-Hg

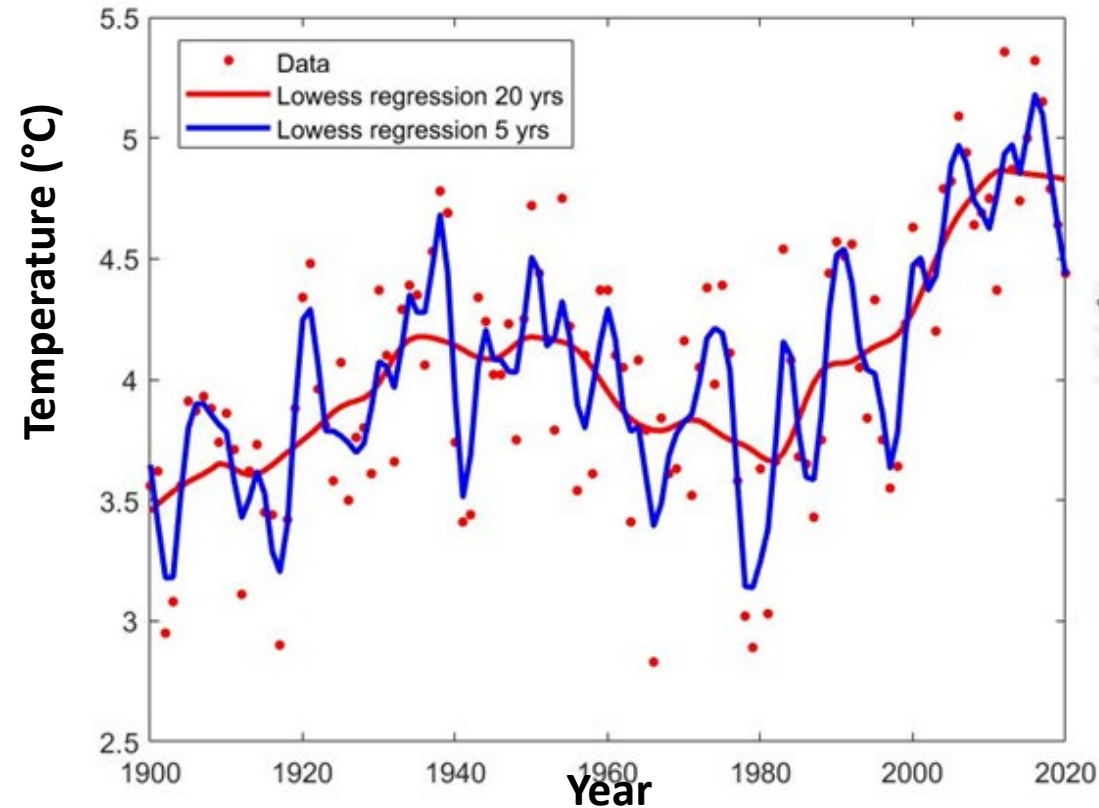
Bank et al. 2023
Environmental Pollution



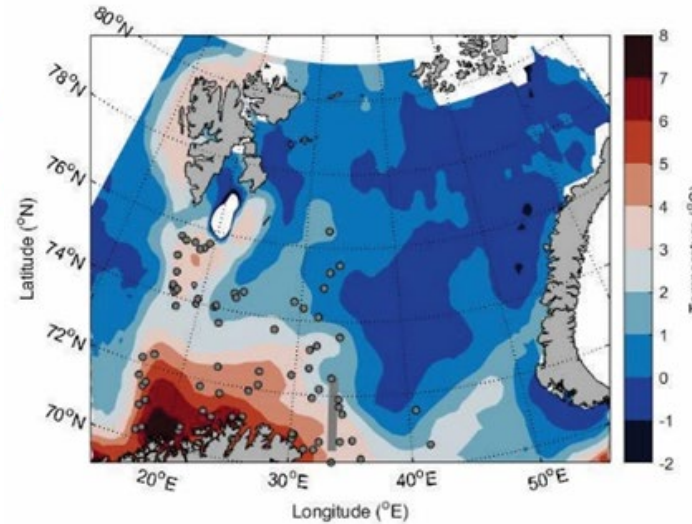


Kola Transect: Long Term Barents Sea Temperature (°C)

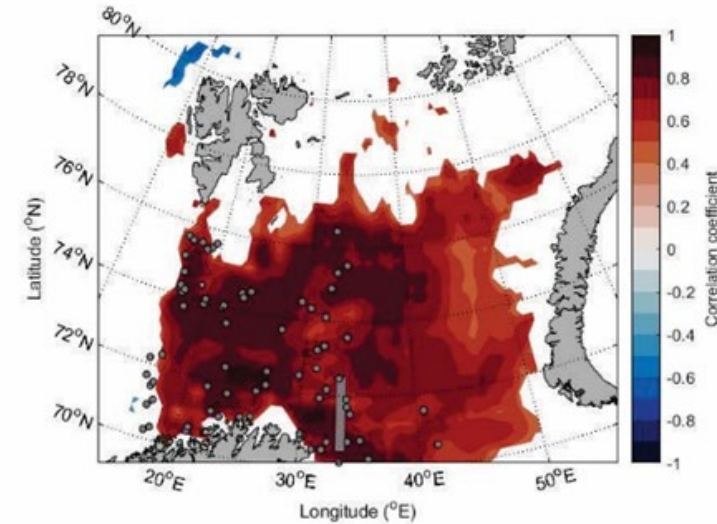
Yearly Mean
Lowess Regression (5 & 20 year)



Seabed Data



Seabed Model

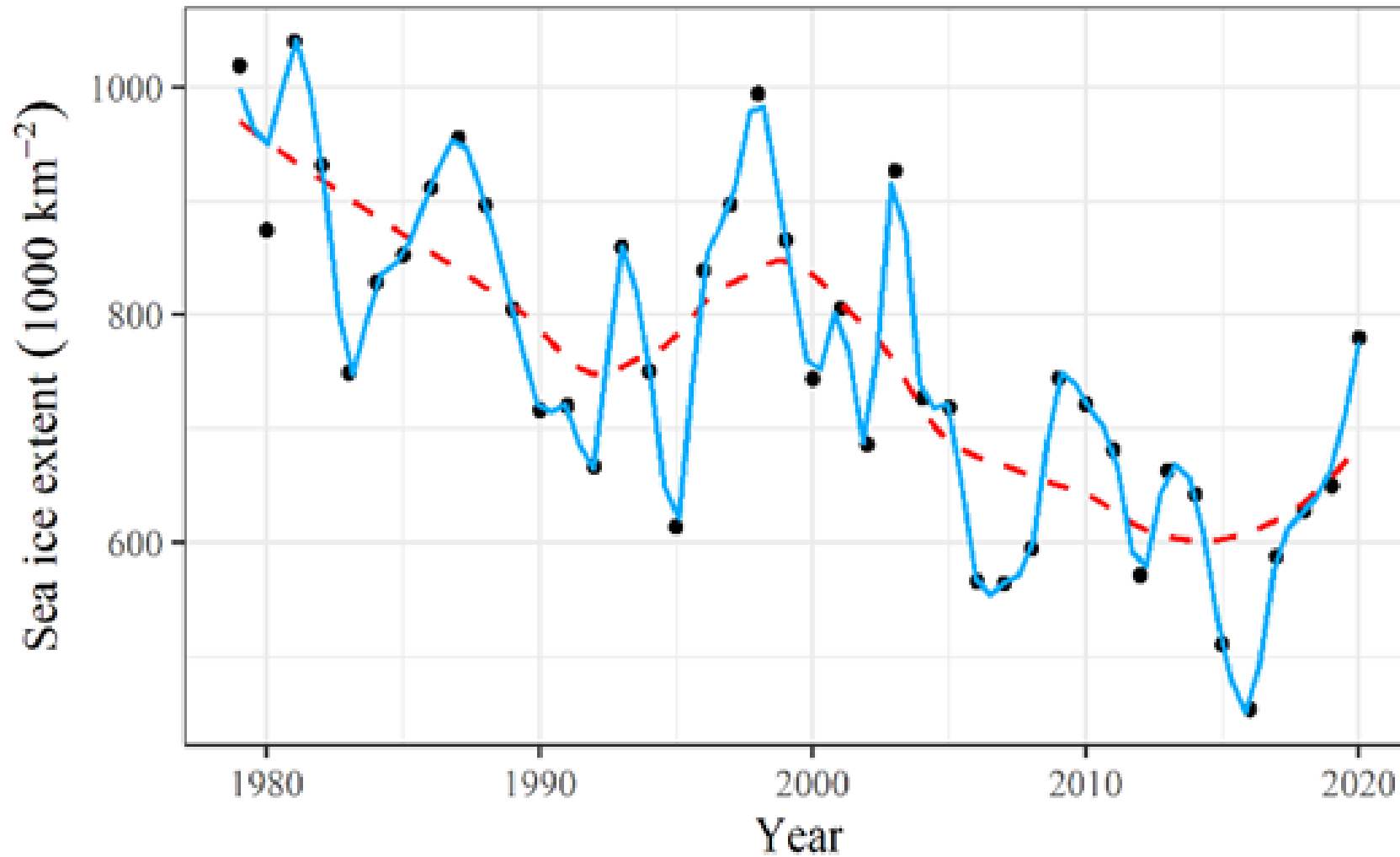


Kola transect data does a good job of predicting seabed temperature!

Mean water temperature at seabed during August–September 1994–2021 (left). Correlation coefficients between annual mean Kola section transect temperature and seabed temperature during 1994–2021 (right).

Vanishing Arctic Ice:

Decline of Barents Sea Ice Extent (APRIL - 1979-2020)



Symbol: data from NPI & used with permission*

Solid line: Lowess regression 5 years

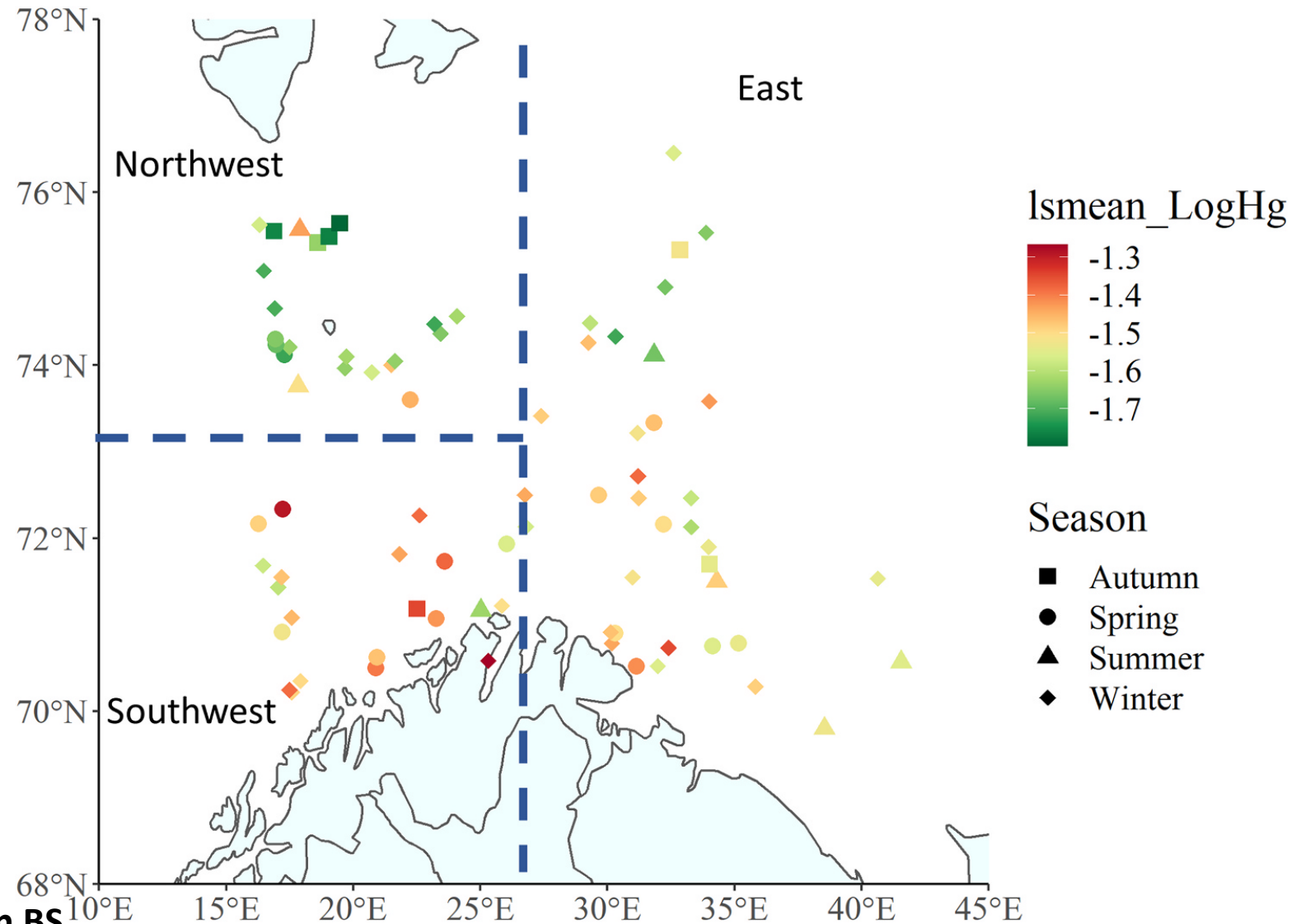
Dashed line: Lowess regression 20 years





Spatial Distribution & Seasonality of Mercury in Cod

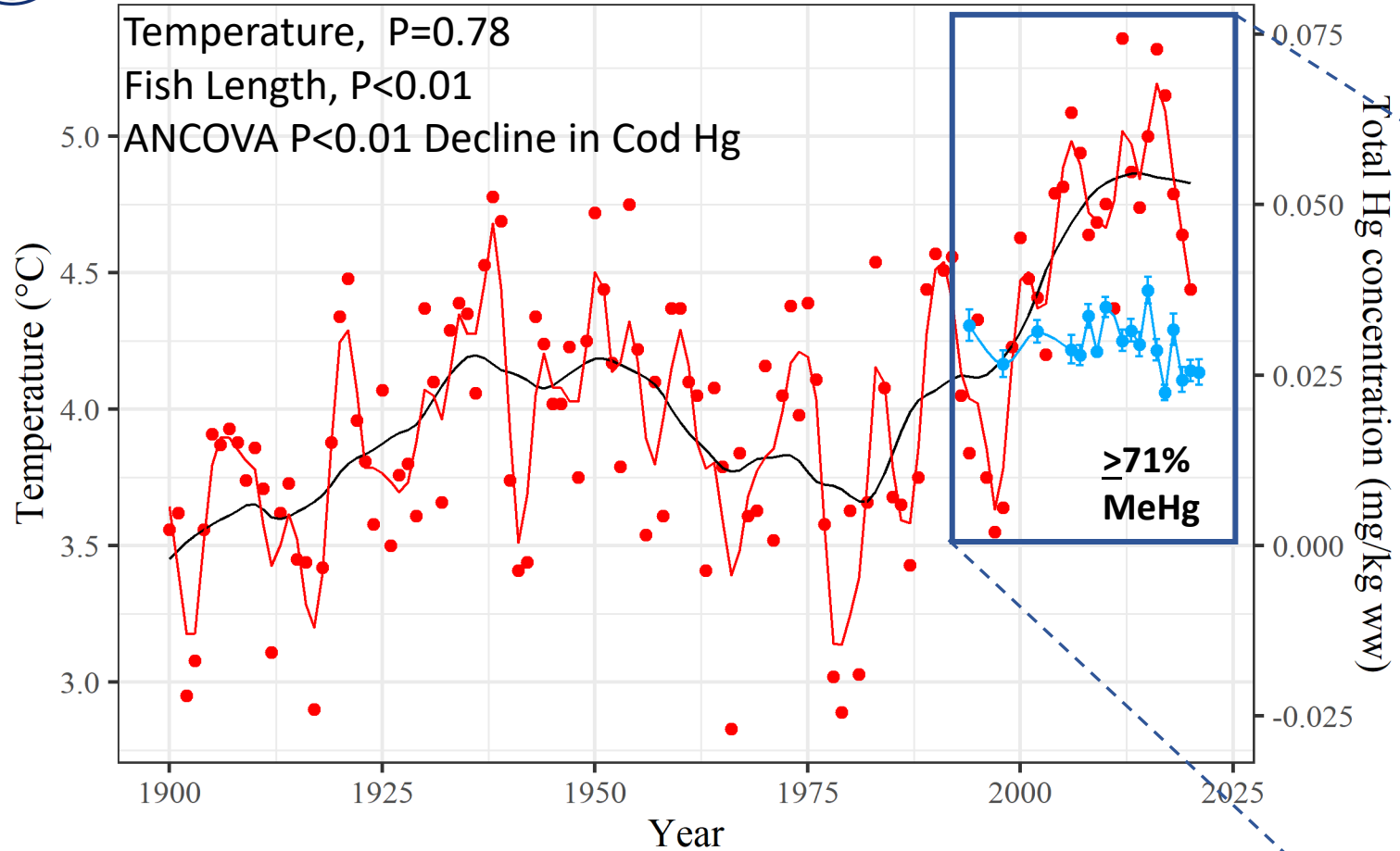
- Fish Data are Length-Adjusted
- >71% MeHg in Fillet Tissue
- Atm. Dep + Rivers dominant sources of Hg in BS
- Rivers - less influence in the north BS
- Small seasonal and spatial differences in Cod Hg (10 ppb)





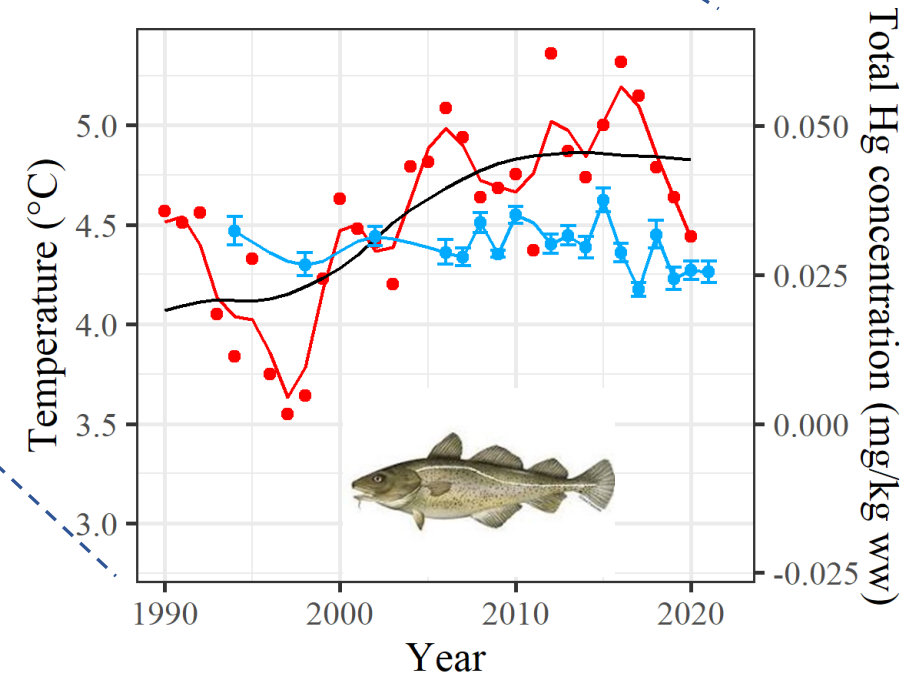
The Signal and The Noise:

Barents Sea Temperature (Red) & Hg (mg/kg ww) in Cod Fillets (Blue) (n=1999)



*"The signal is the truth.
The noise is what distracts
us from the truth."*

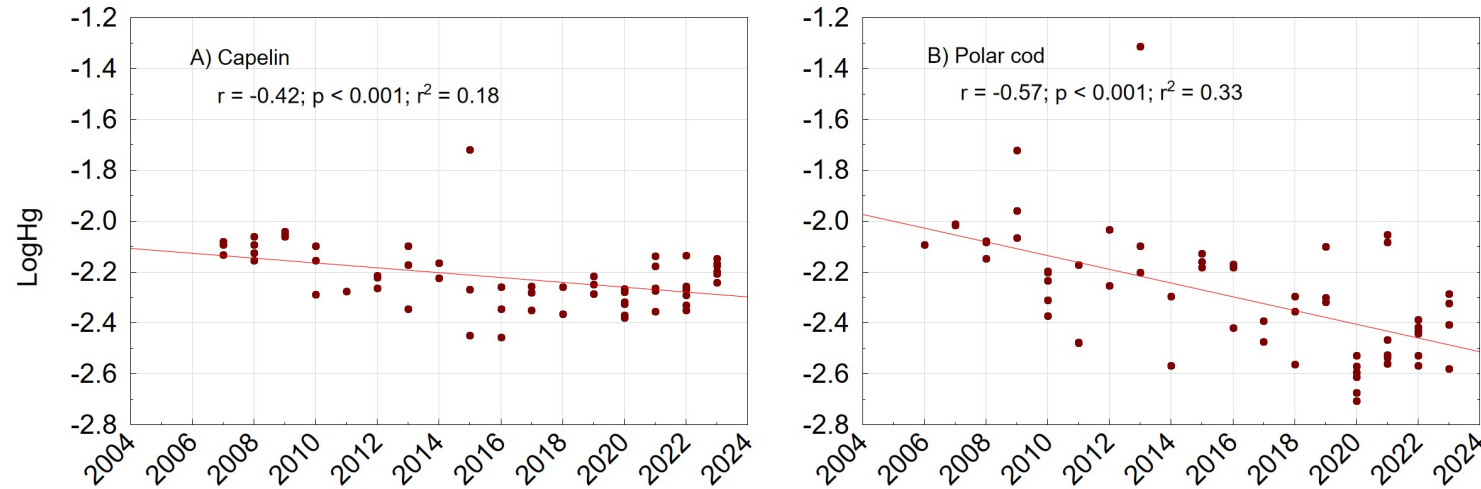
— Nate Silver



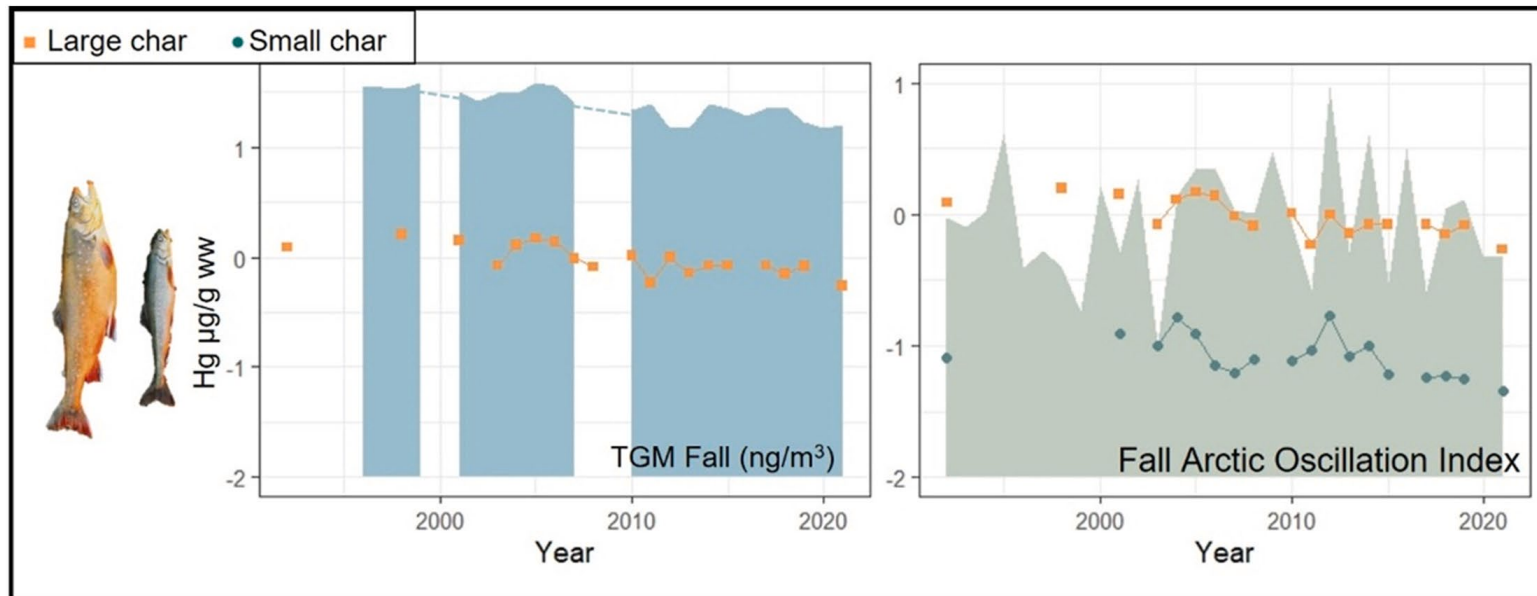
- Symbol + bar: data $\pm$ standard error
- Red solid line: lowess regression 5 years for temperature
- Black solid line: lowess regression 20 years for temperature
- Blue solid line: lowess regression 5 years for cod Hg concentration
- Growth was relatively unchanged during the study period (data limited)

Mercury Temporal Declines in other Arctic Fish (Barents Sea - Capelin & Polar Cod / Lake Hazen – Arctic Char)

**Barents Sea, Norway
(Bank et al. 2023)**

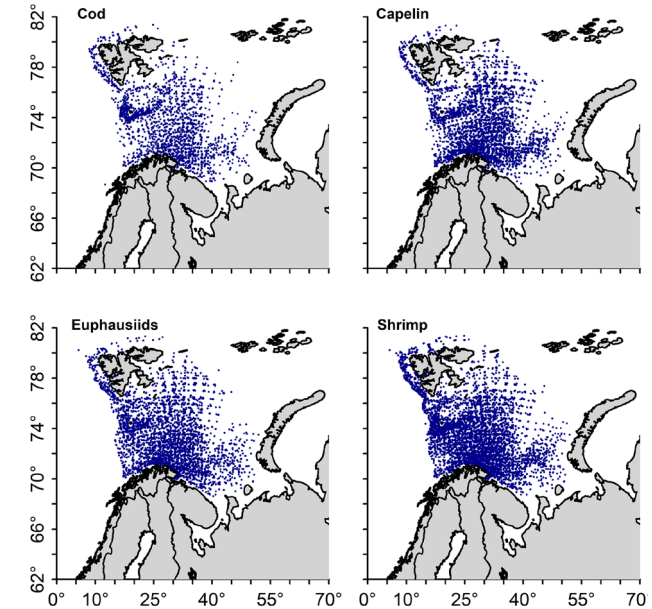
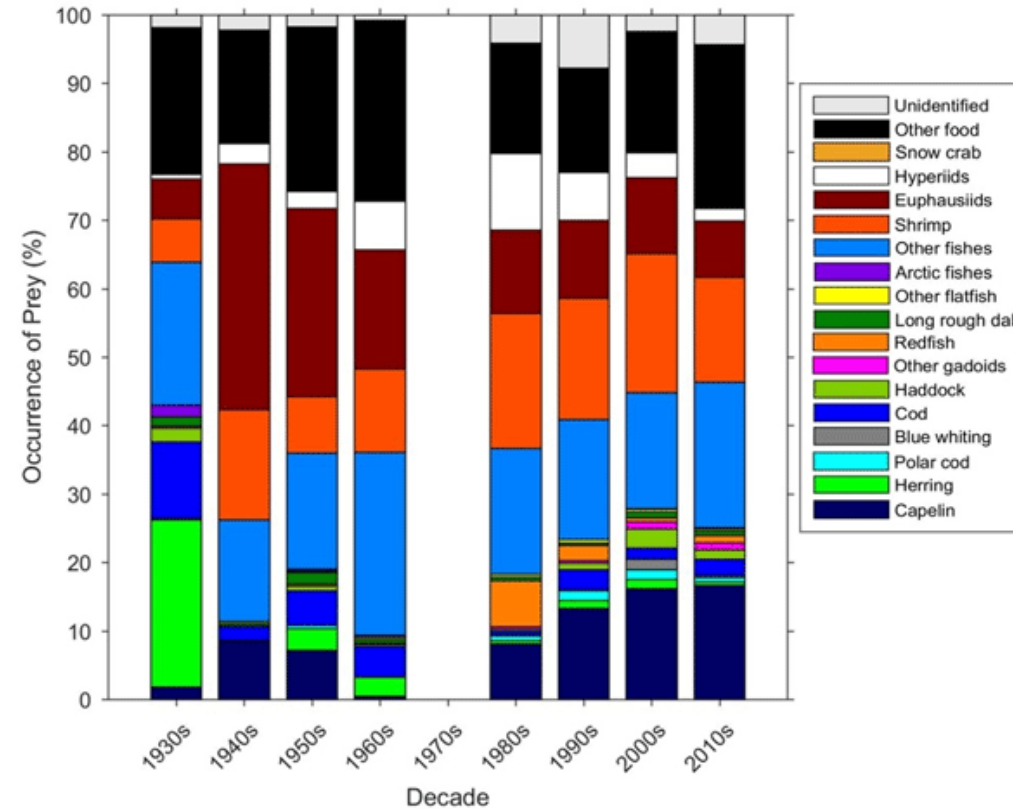
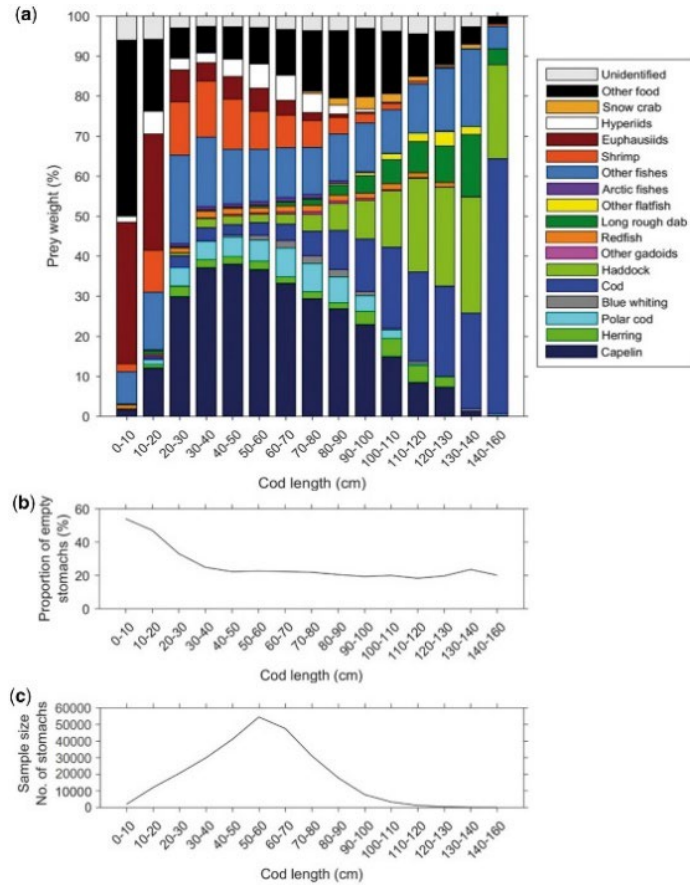


**Lake Hazen, Canada
(Hudelson et al. 2023)**



Long-term declines in bluefin tuna (Lee et al. 2016), bluefish (Cross et al. 2015), and Greenland Halibut (Bank et al. 2021).

Global Environmental Change & Barents Sea Northeast Arctic Cod Diet



Bank et al. (2021), Holt et al. (2019), Townhill et al. (2021)



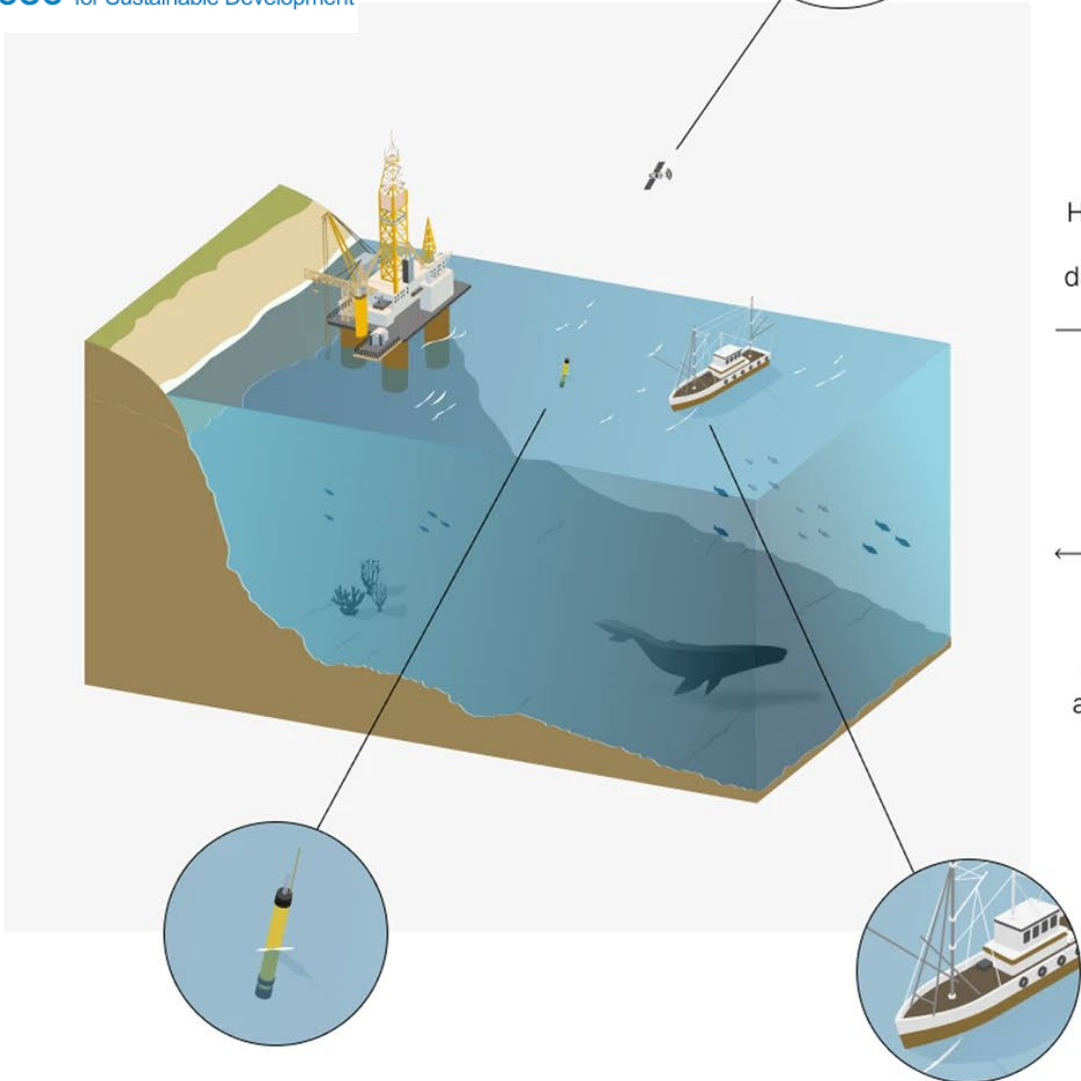
Synthesis

- **Atlantification of Barents Sea** - inflow of warm Atlantic Water is a major oceanic source of heat to the Arctic Ocean
- **Barents Sea ecosystem changes** include ocean warming, receding seasonal sea ice, and increases in boreal taxa
- **Feedback loops exist**, and problems could accelerate
- **Despite these ecosystem changes, cod Hg was low and stable** perhaps due to ecosystem resilience, diverse diets, or potential off-setting climate impacts?
- **Hg reactivity, Hg(II) measurements**, and a lack of good, legacy **re-emission data** limit Hg models.



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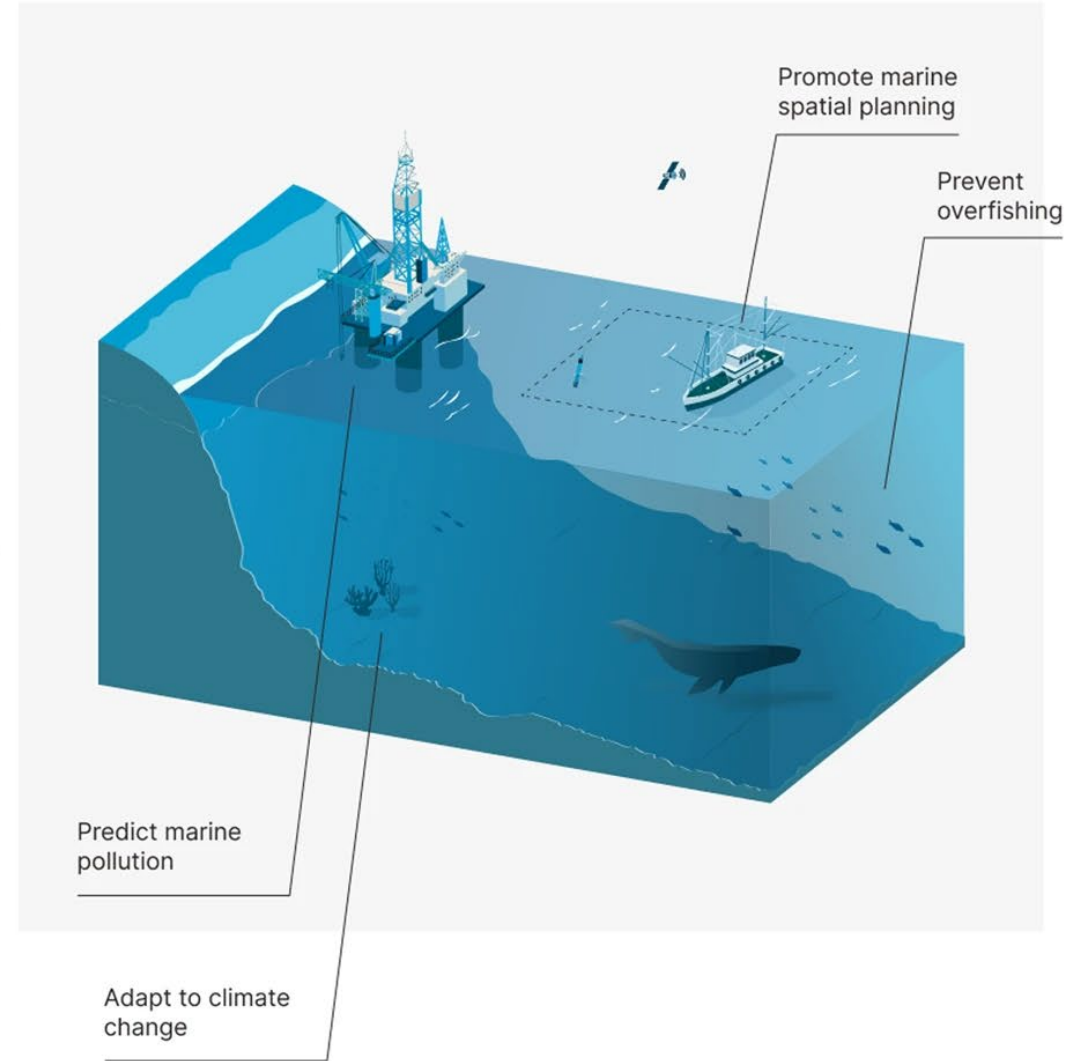
Physical Twin



Historic data, and
near real-time
data from sensors

Feedback and
intervention
through human
and autonomous
actuators

Digital Twin



Tzachor et al. 2023 To appreciate these prospects, we acknowledge potential applications of DTs across four thematic areas: (a) reducing and preventing overfishing, (b) modeling and predicting marine pollution, (c) adapting to climate change, and (d) marine spatial planning (see Fig. 1).

Capacity Building in Africa & Asia

- Largest Ocean Science Capacity Building Program in the World (Africa to the Bay of Bengal Region of Asia)
- Project is designated as 'Aid' (UN-FAO, NORAD & IMR)
- Collaboration with 60 Countries & Celebrating 50 Years of service this year!
- Scientists from Africa & Asia learn about ***chemical pollution***, fisheries, ecosystem dynamics, and oceanography, etc.
- Contact [**Michael.Bank@hi.no**](mailto:Michael.Bank@hi.no) for more information.



