Biodiversity changes along the Pacific Arctic corridor: From the Bering Sea to the Central Arctic Ocean

Franz J. Mueter[1], Katrin B. Iken[1], Irene D. Alabia[2], Lee W. Cooper[3], Seth L. Danielson[1], Jaqueline M. Grebmeier[3], Russell R. Hopcroft[1], Kaitlyn A. O'Brien[1], Kathleen M. Stafford[4]

[1] University of Alaska Fairbanks; [2] Hokkaido University; [3] University of Maryland; [4] Oregon State University;

(a fish-centric perspective)

Panarctic view

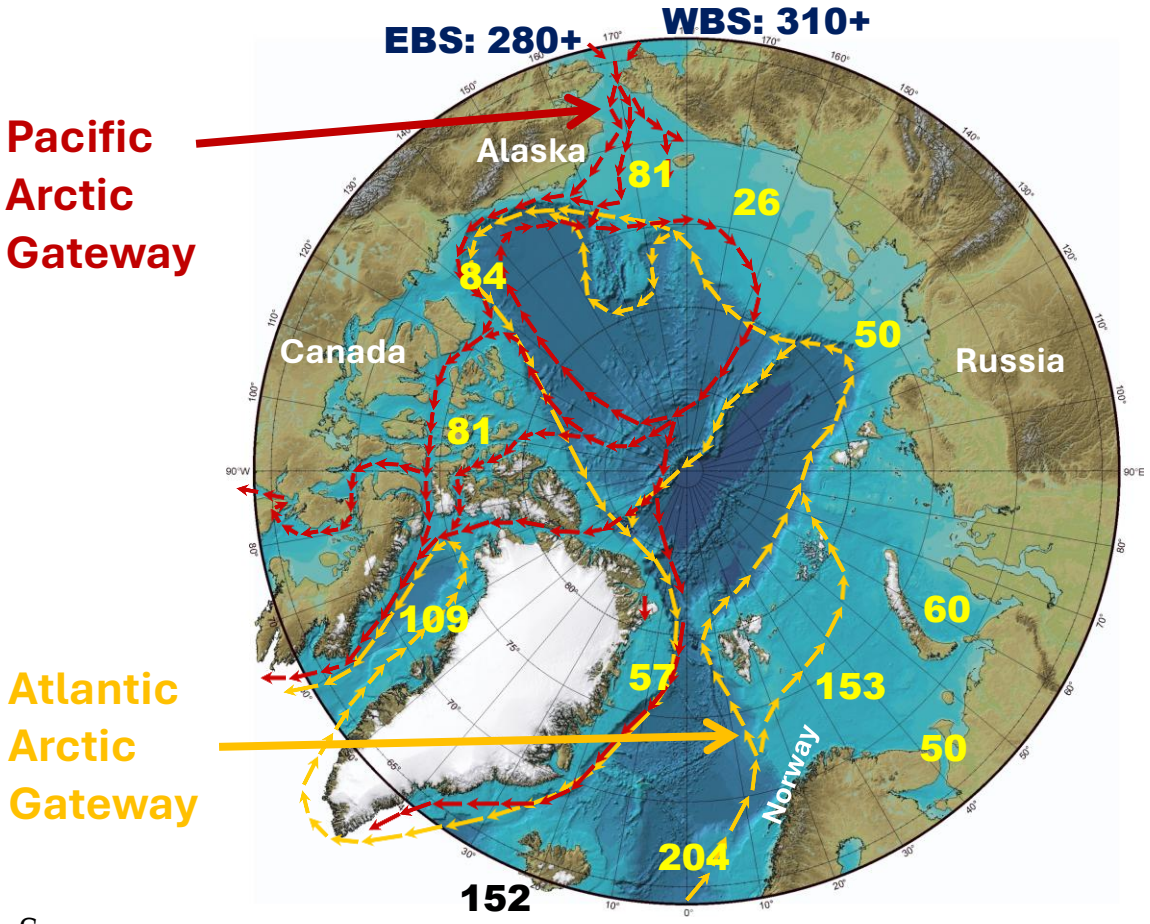
- Distribution of fishing activity around the Arctic
- Large commercial fisheries at the “doorsteps” to the Arctic, in particular on ‘inflow shelves’
- What does this mean for the CAO in a warming world?

Grebmeier et al. (Unpublished)



Panarctic view: Fish species diversity

Number of reported fish species by region



Sources:
Mueter et al (2013)
Mecklenburg et al (2002)
MRI, Iceland
www.FishBase.org

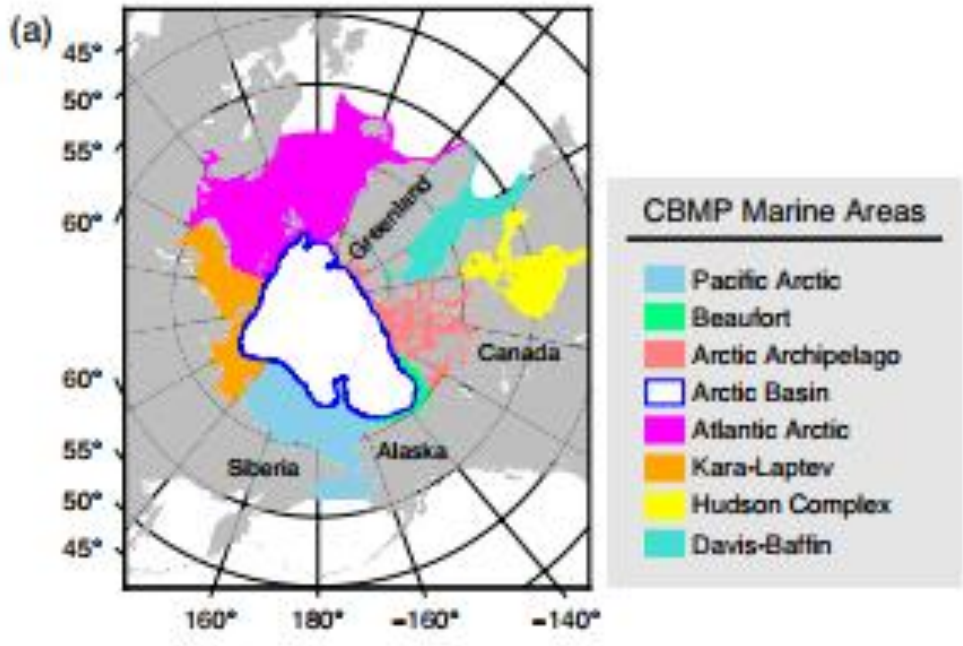
Currents compiled from various sources

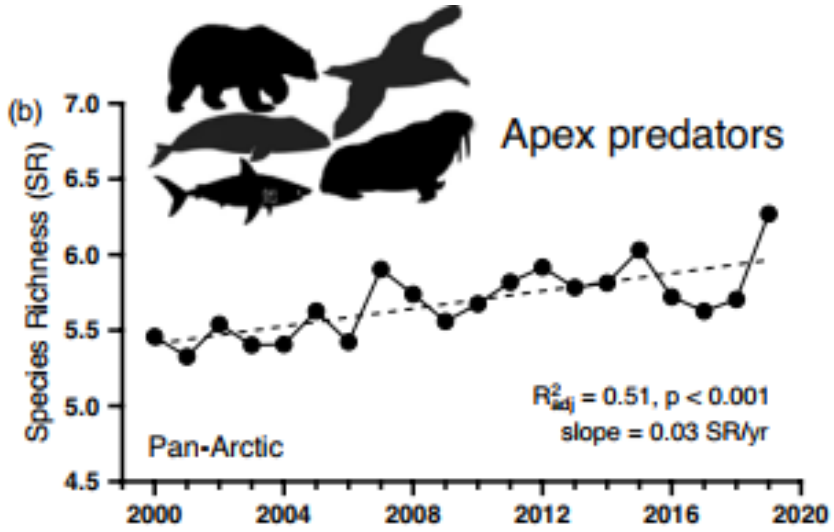
- Fish species richness considerably higher in the subarctic, <u>decreasing with temperature</u> to the North
- Fish diversity (richness) is higher in the Pacific than in the Atlantic
- Surface flow from Pacific to Atlantic
  - Pathway for fish and plankton
- Deep flow consists of Atlantic water & its plankton & fish communities
  - Pathway for Atlantification of Pacific Arctic

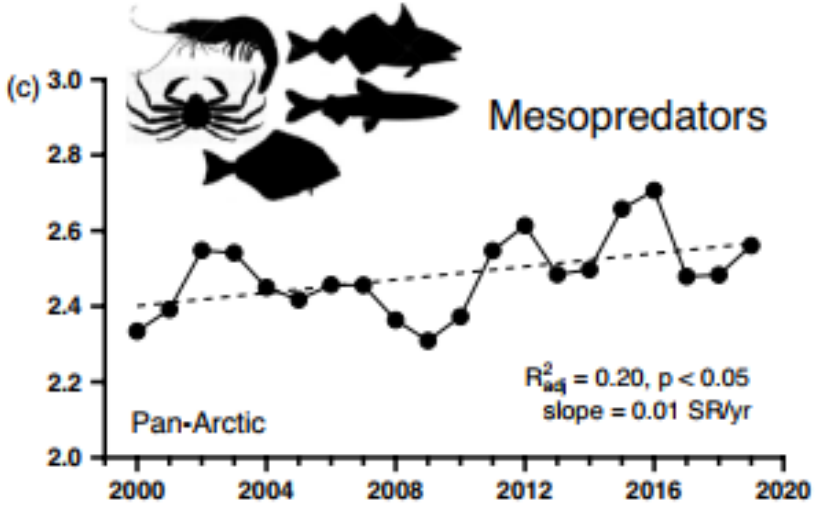
Panarctic view: Evidence from models

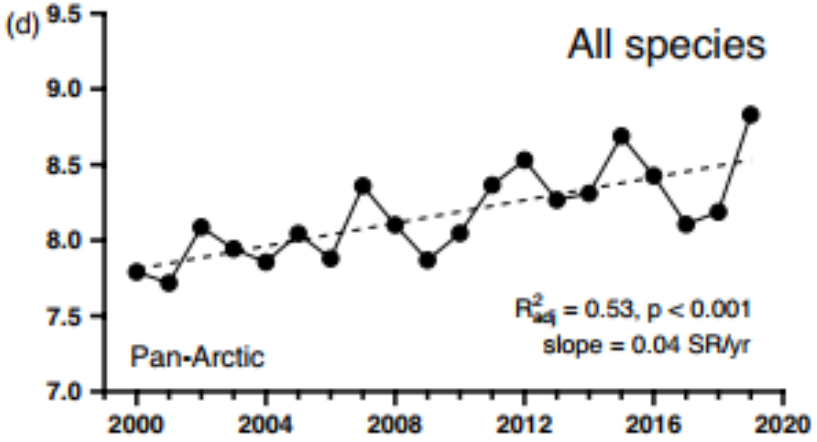
- Estimated average increases in species richness (per unit area) across the Arctic, 2000-2019

(*Alabia et al. 2023*)



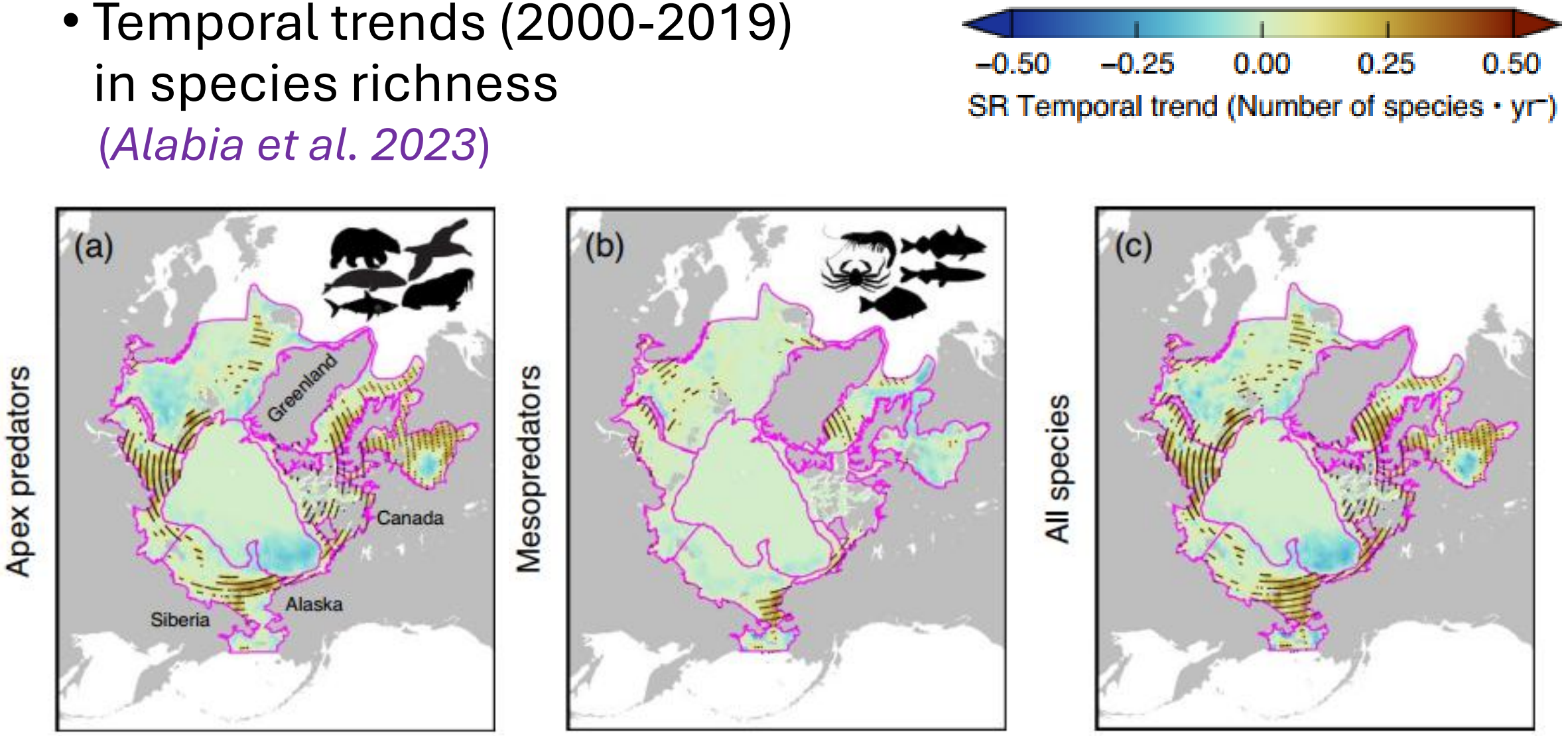






Panarctic view: Evidence from models

- Temporal trends (2000-2019) in species richness (*Alabia et al. 2023*)

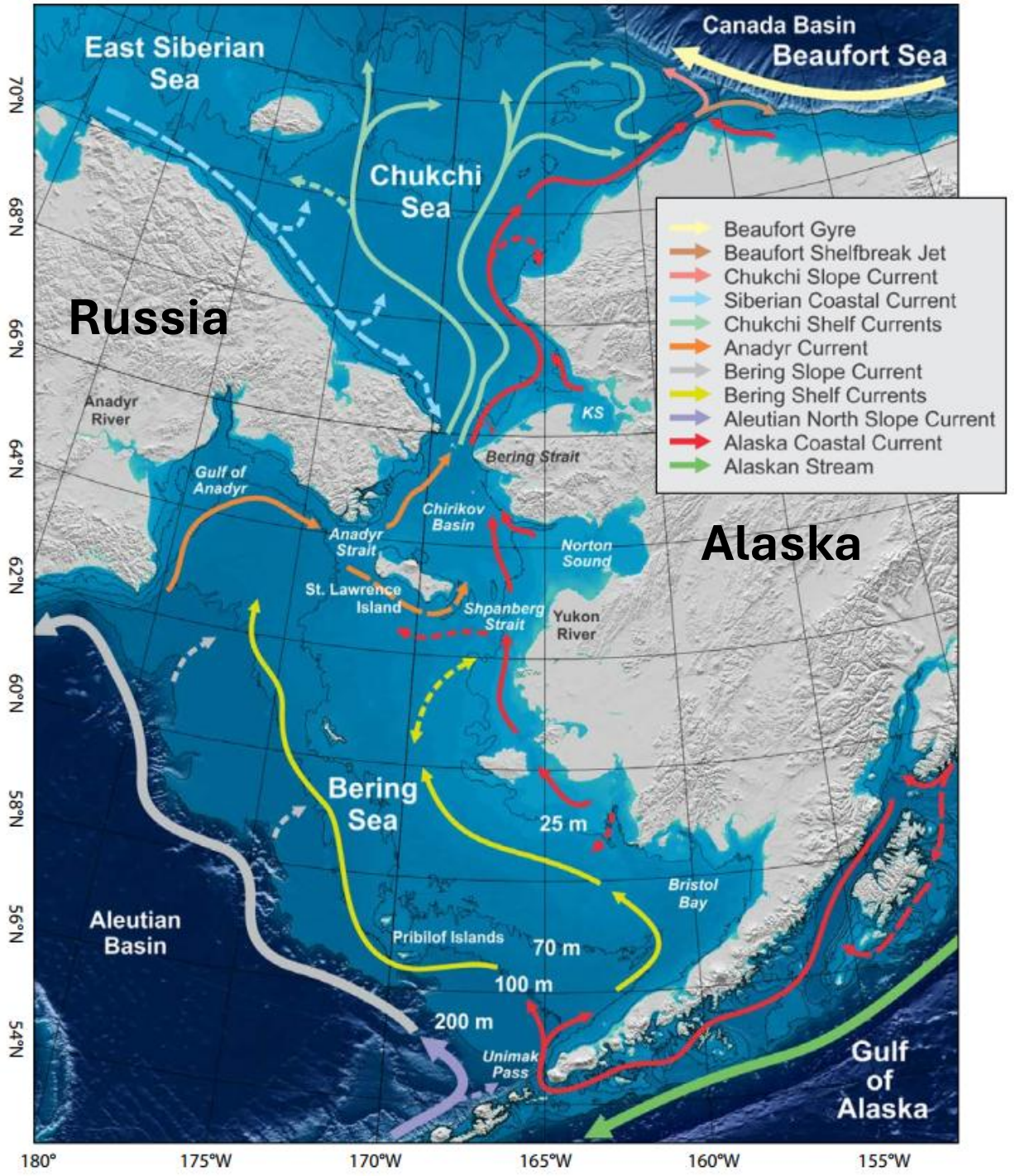


Focus on Pacific Arctic

- Highly advective system
- Generally northward flow through Bering Strait

Objective for talk:

- Summarize observational evidence for changing biodiversity in Pacific Arctic corridor
- Implications for CAO



Pacific-Arctic Connectivity

How are changes in the Pacific Arctic gateway transmitted into the Central Arctic Ocean?

Bering Sea → Bering Strait region → Chukchi Sea → Central Arctic Ocean

Bio-physical changes › Biological transport › Ecological filtering › CAO response

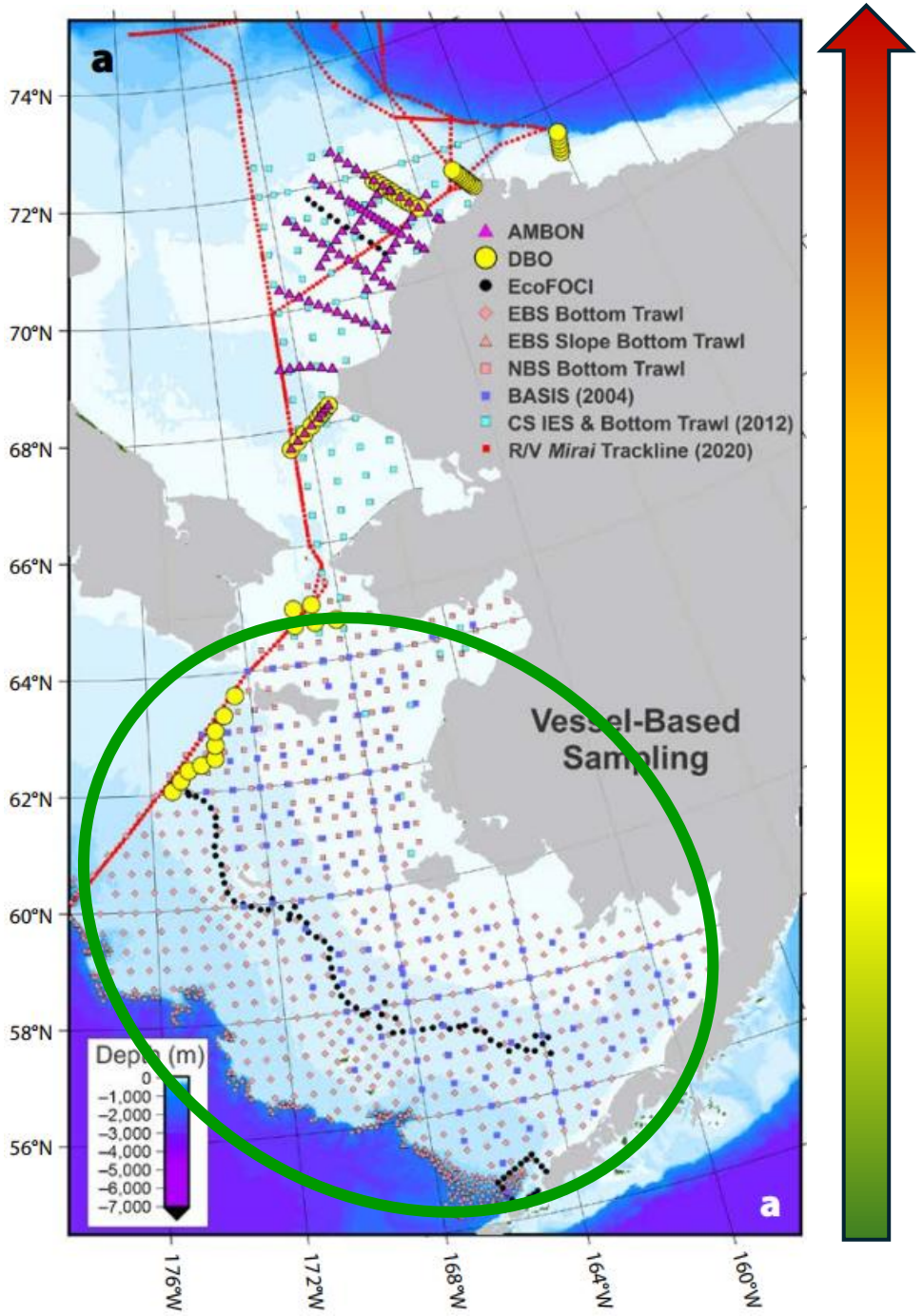
Evidence becomes thinner moving north





Data availability decreases from Bering Sea to CAO

- Major US vessel-based monitoring efforts in the Pacific Arctic
- Limited (biological) sampling in the CAO
- Japanese, Korean, Canadian and Chinese research efforts in the Chukchi Sea, Beaufort Sea and Central Arctic Ocean
- Russian sampling in the western Chukchi Sea and East Siberian Sea
- Extensive Indigenous Knowledge

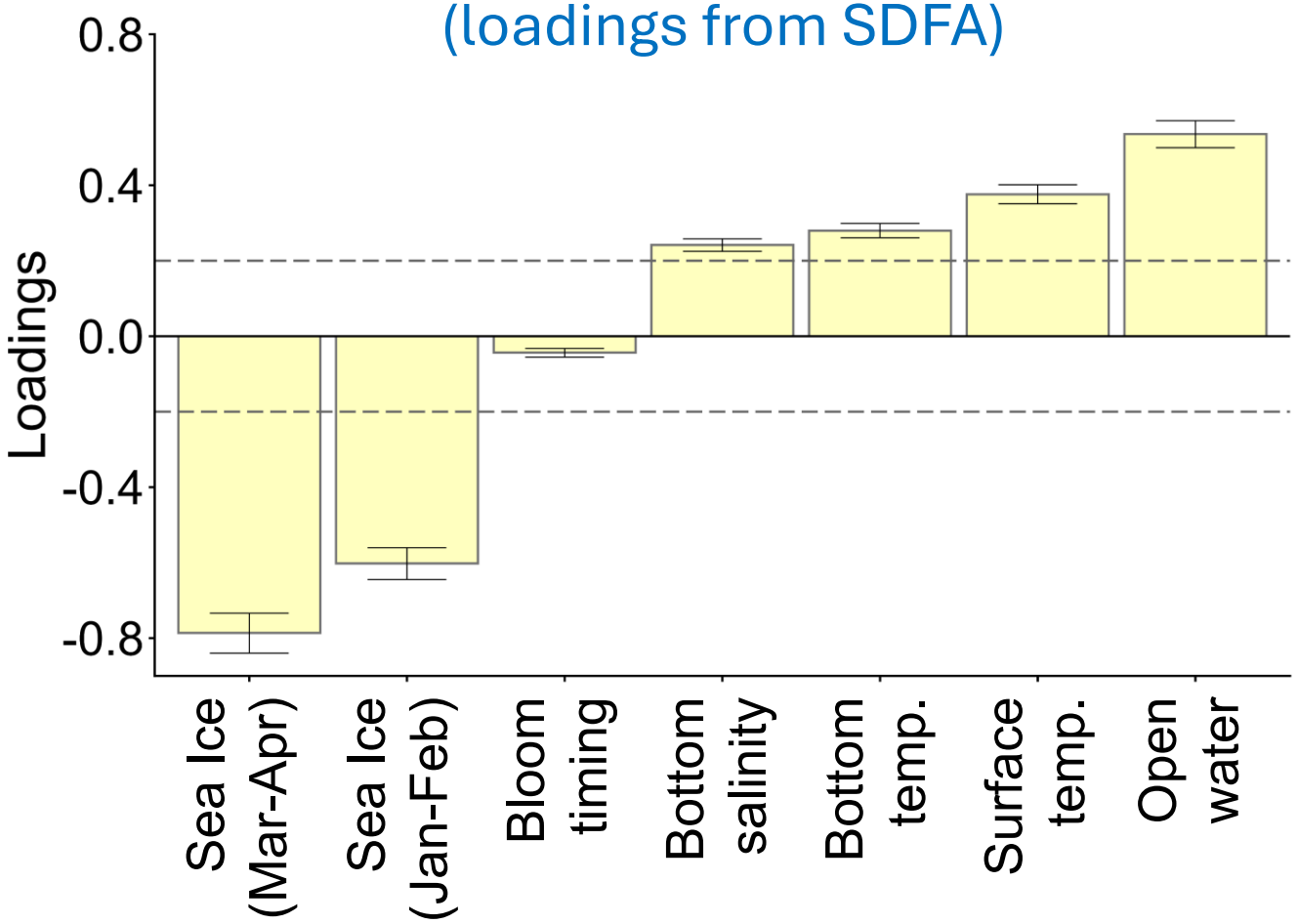


Bio-physical change – Bering Sea

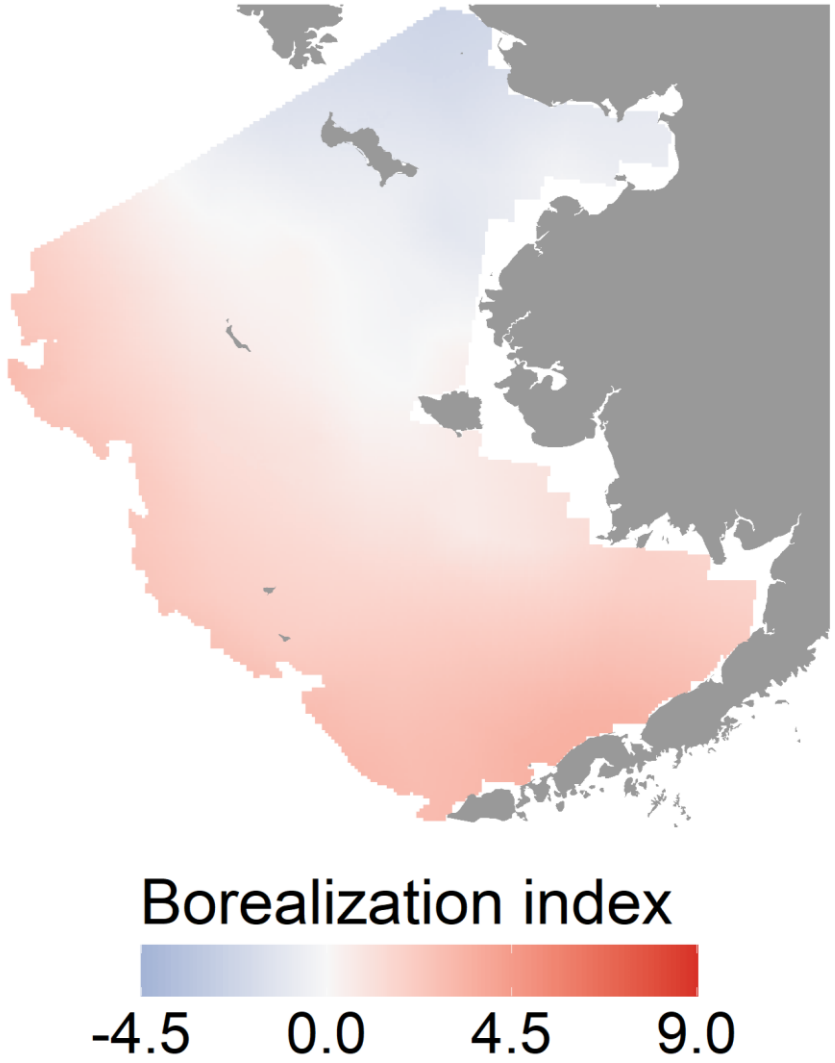
Spatial index of borealization 1958-2025

Contributions of environmental drivers

(loadings from SDFA)



Year: 1958



O'Brien et al (in prep)

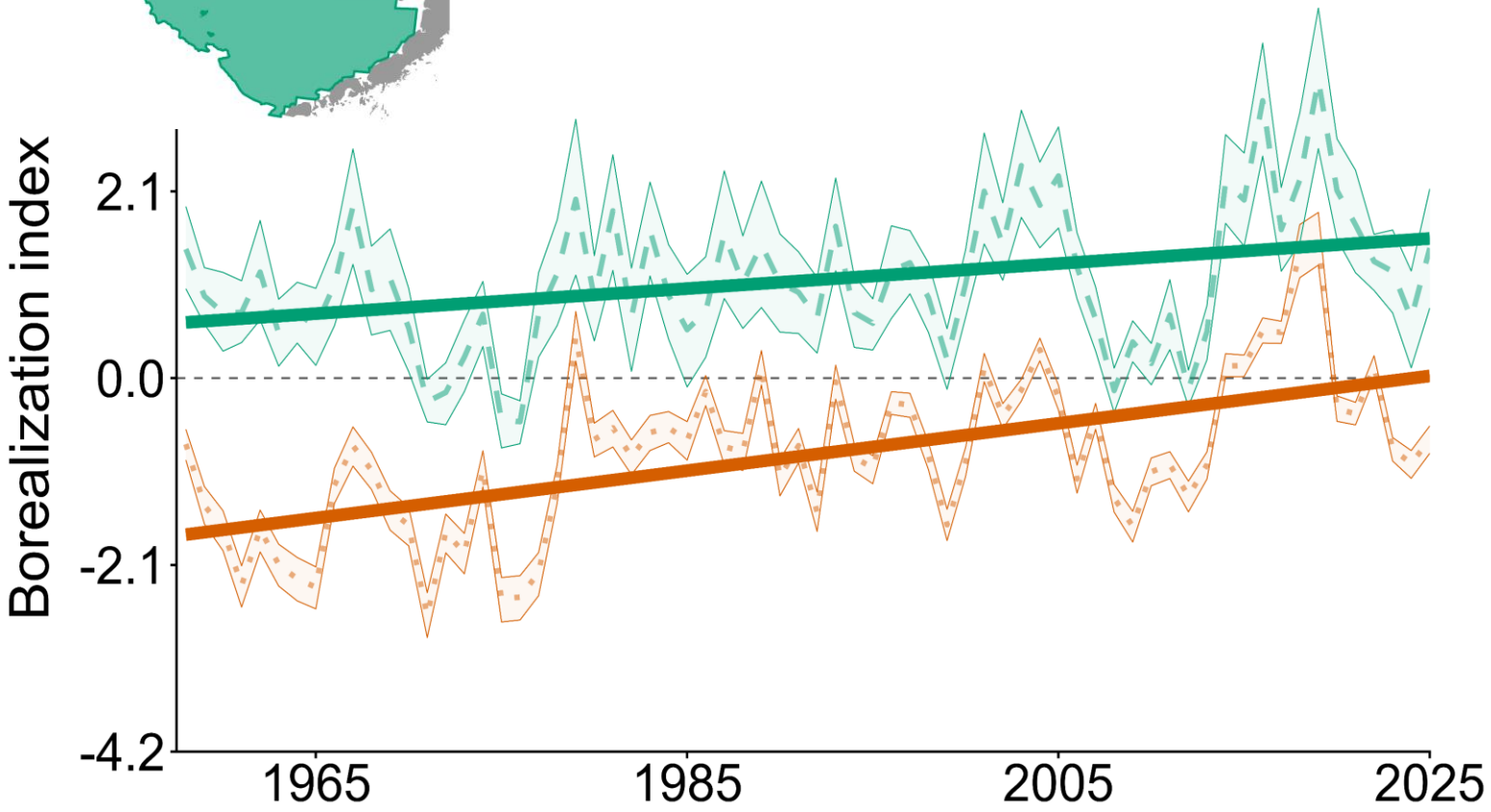
Bio-physical change – Bering Sea

Spatial index of borealization 1958-2025

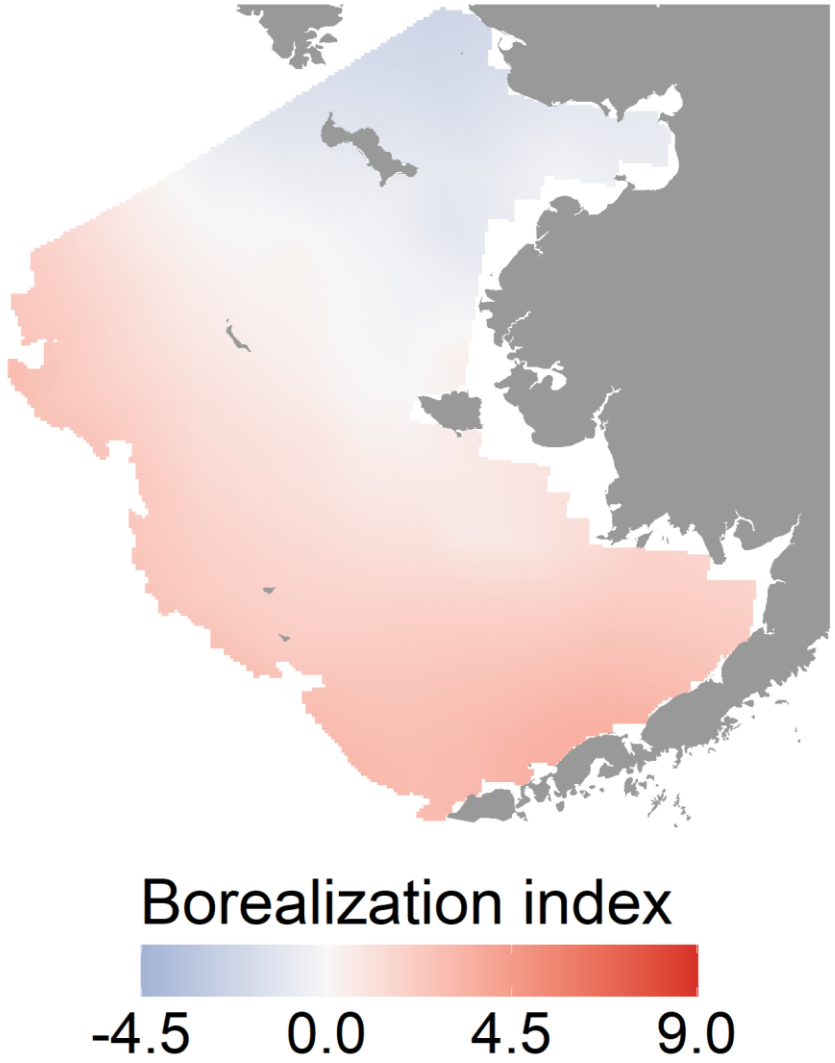


Mean temporal trends

North vs **South**

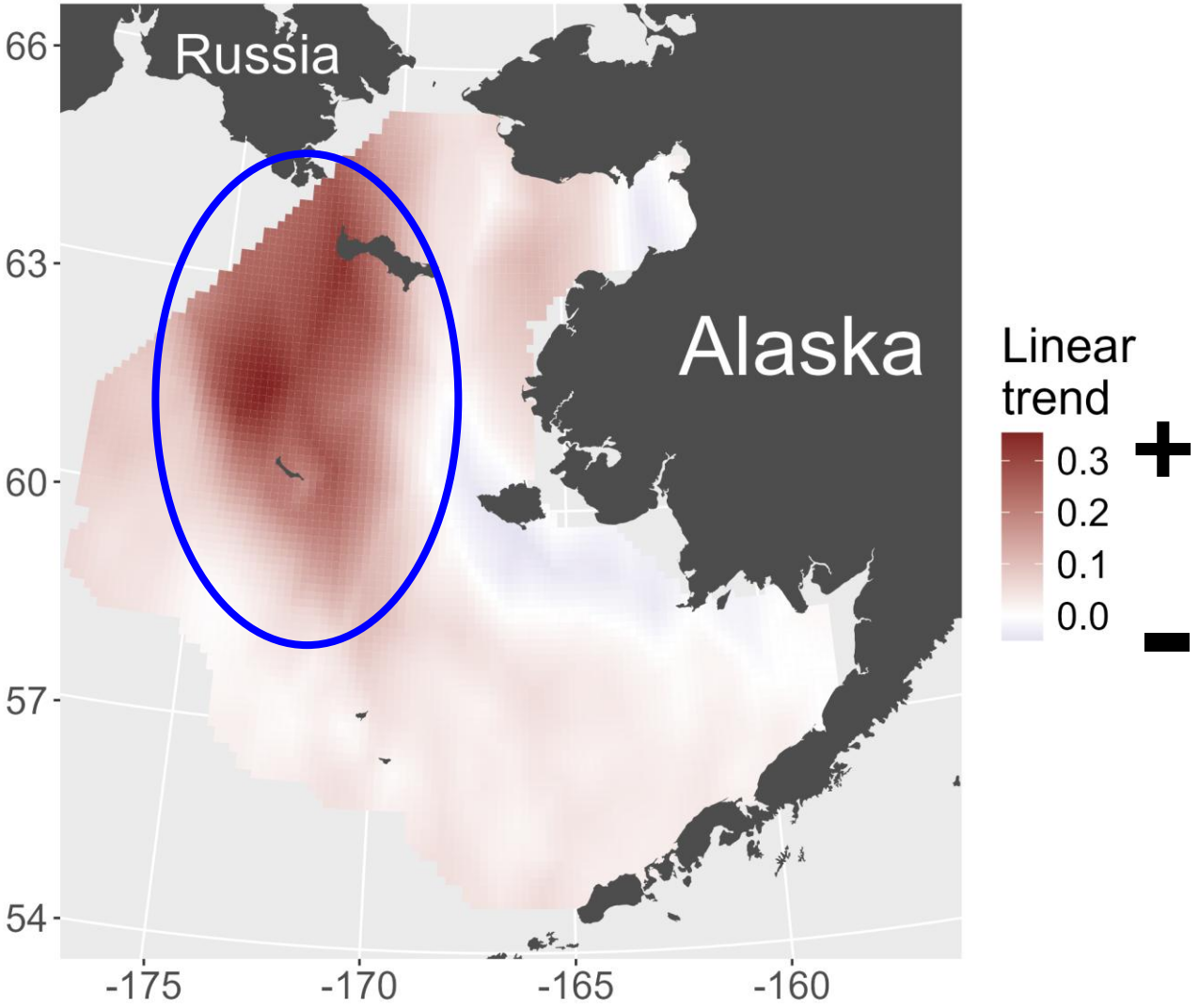


Year: 1958



O'Brien et al (in prep)

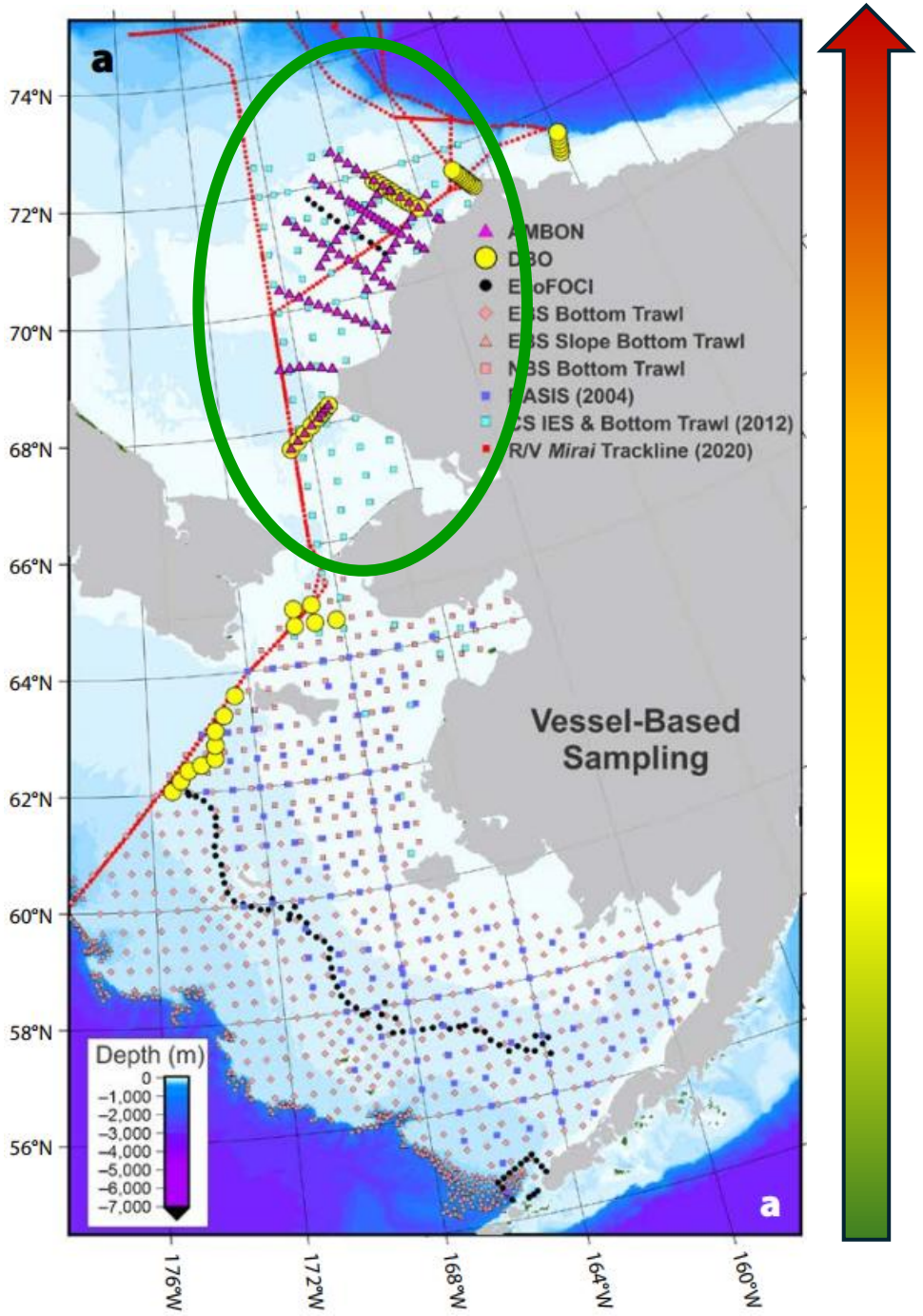
Linear trends in borealization:
Groundfish community (1986-2025)



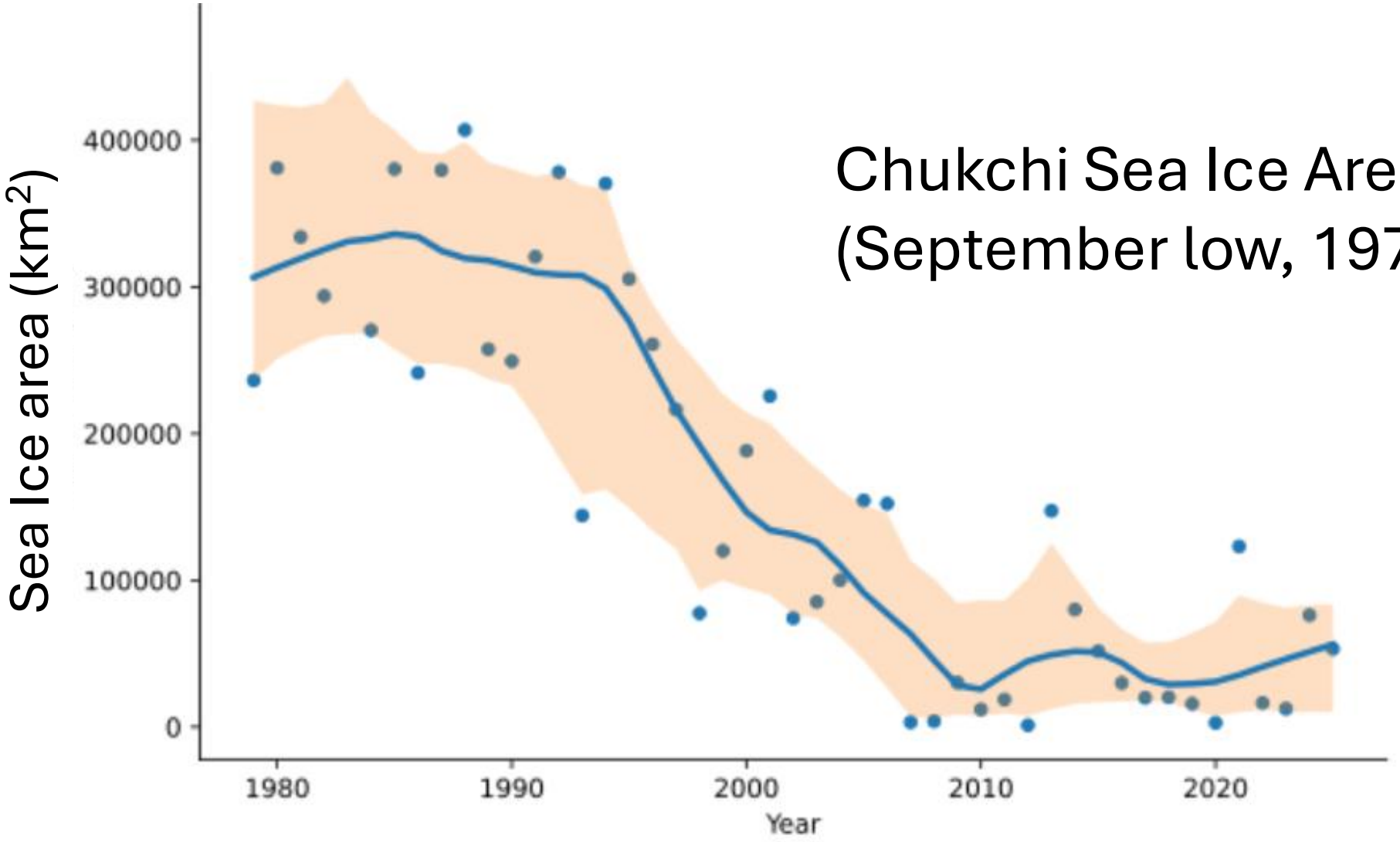
- Linear trend in "**community-weighted median temperature preference**"
- Increase reflects
  - increases in density of species with boreal affinity and/or
  - decreases in density of species with Arctic affinity
- 40-year increases over much of the area
- Pronounced increases over northern middle shelf ('cold pool' region)

Chukchi Sea observations

- Long-term trends largely unknown
- Strong evidence for borealization of communities in the Chukchi Sea
- Major drivers:
  - Advection / transport of warmer water from the South (plankton, fish)
  - Seasonal migrations (large fish, seabirds, mammals)
  - Increased local production of some species with southern affinity (poorly understood)



Chukchi Sea observations: Sea Ice



Chukchi Sea Ice Area
(September low, 1979-2025)

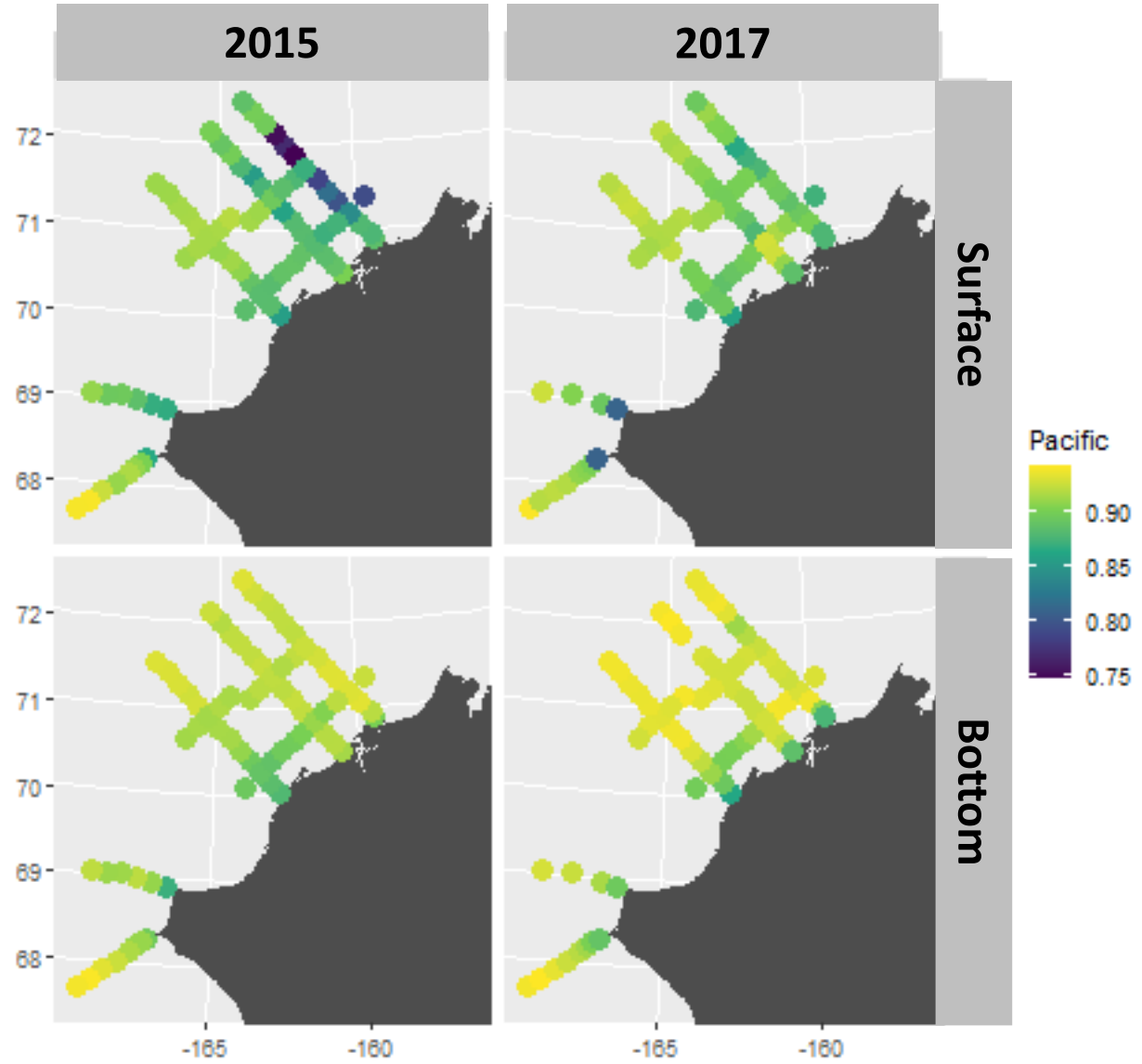
Chukchi Sea observations

Two contrasting years (2015/2017)

Fraction of Pacific-origin water

→ **More Pacific water** on the northern Chukchi Sea shelf in 2017 compared to 2015

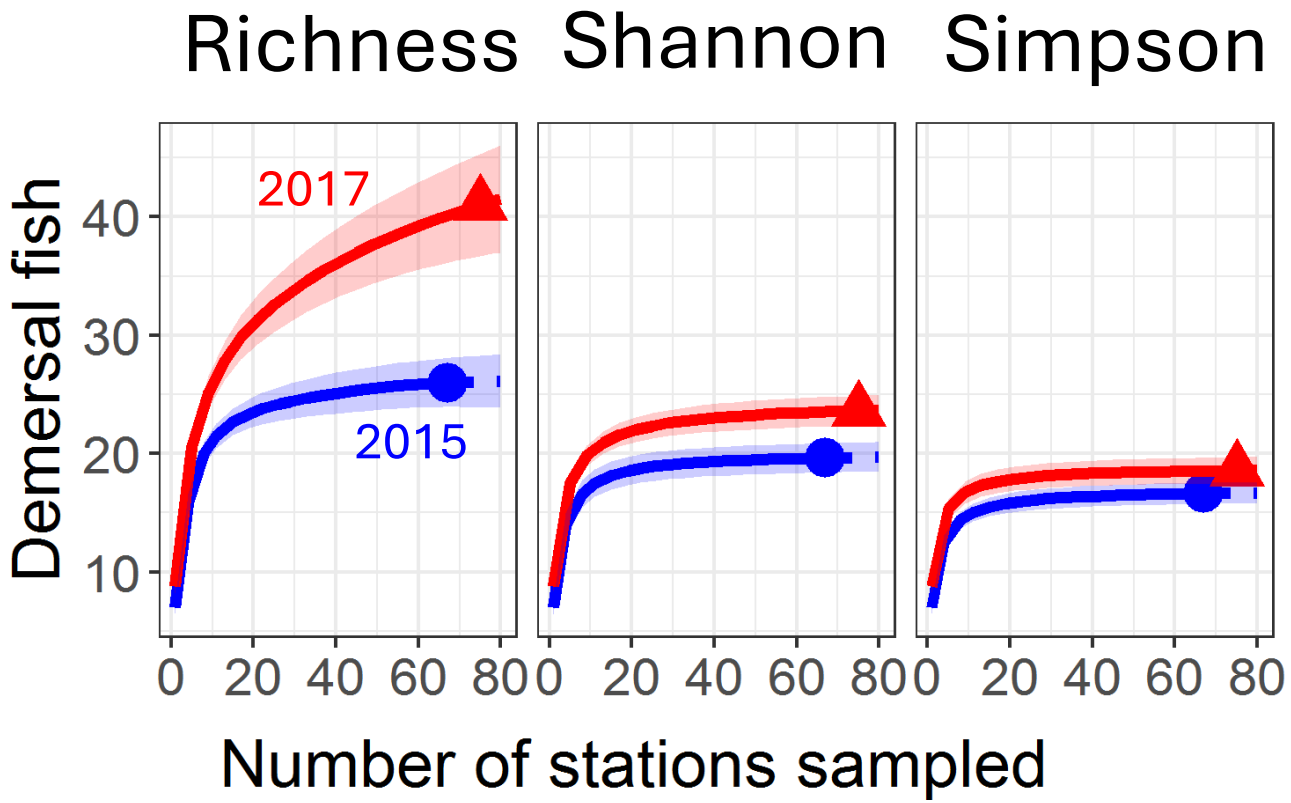
→ Consequences for plankton and mobile species



(Mueter et al. 2021)

Chukchi Sea observations (diversity):

Two contrasting years (2015/2017)



2015 (fresher, cooler, more 'Arctic')

2017 (saltier, warmer, more 'Pacific')

(Mueter et al. 2021)

Richness:

→ 'Raw' number of species (each species weighted equally)

(exponential of) **Shannon** entropy

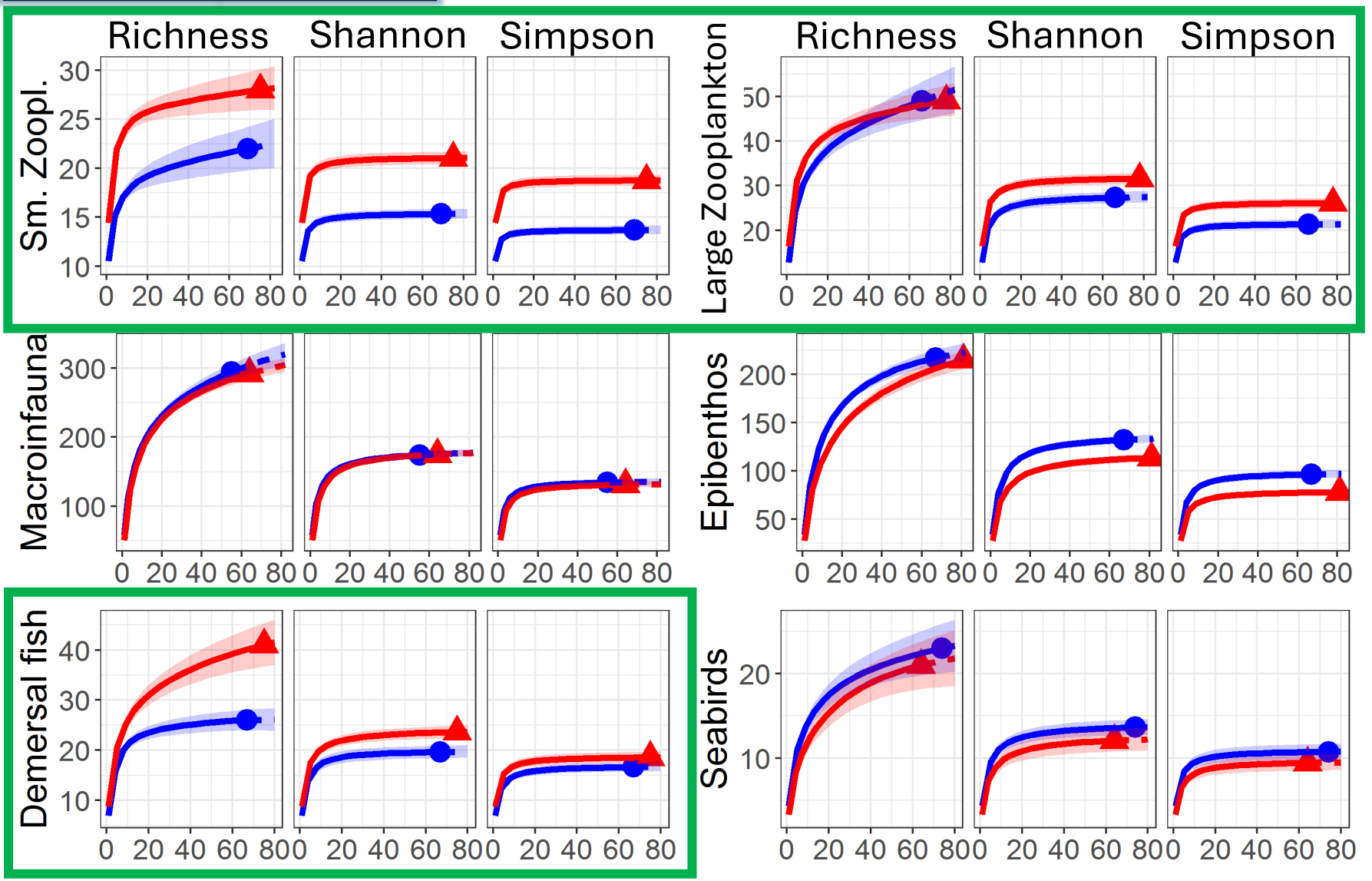
→ Equivalent number of 'common' species

(inverse of) **Simpson** diversity

→ Equivalent number of 'dominant' species

Chukchi Sea observations (diversity):

Two contrasting years (2015/2017)



2015 (fresher, cooler, more 'Arctic')

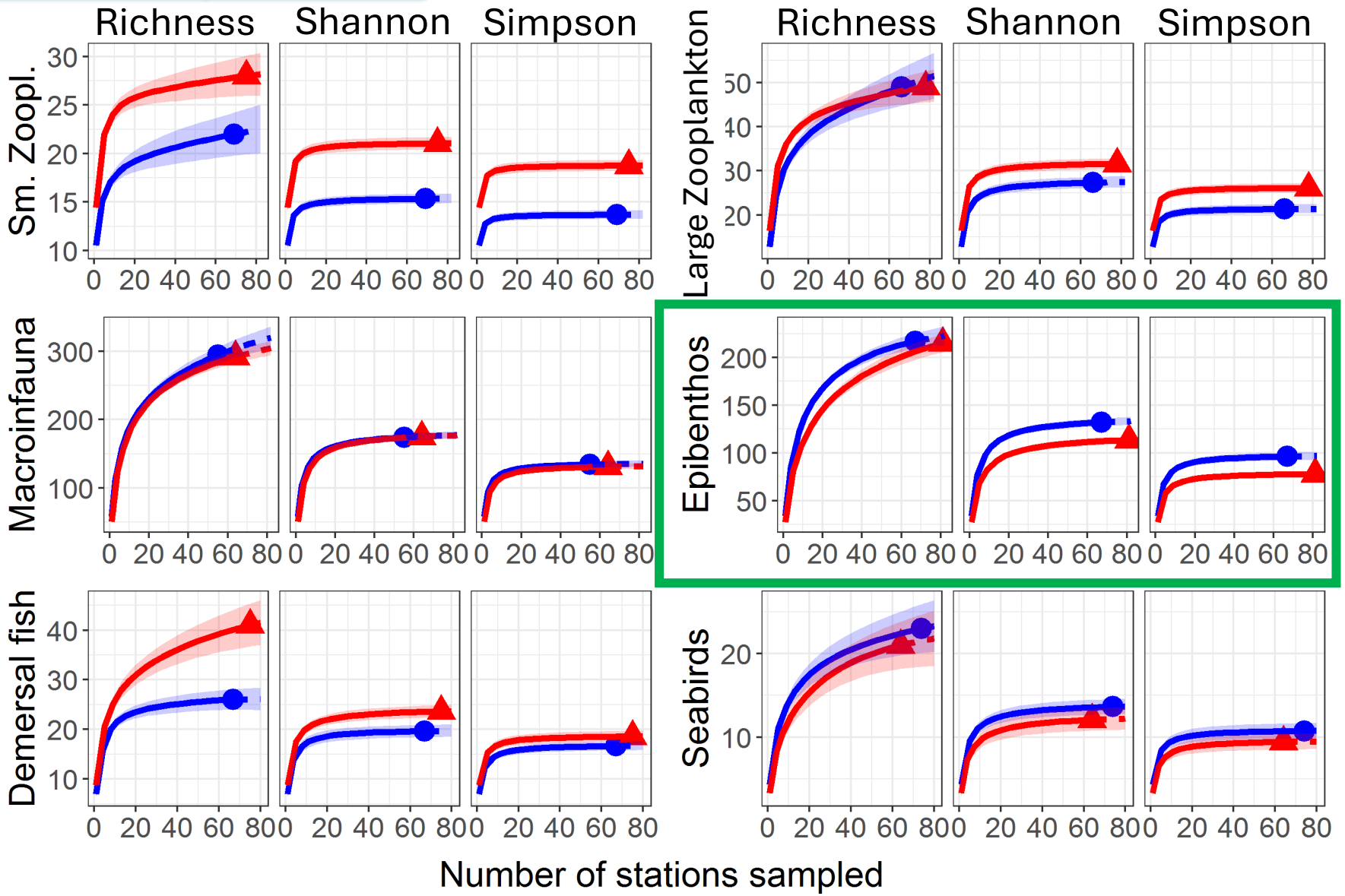
2017 (saltier, warmer, more 'Pacific')

→ Higher diversity of zooplankton and small fish in 2017 (advection of Pacific species)

(Mueter et al. 2021)

Chukchi Sea observations (diversity):

Two contrasting years (2015/2017)



2015 (fresher, cooler, more 'Arctic')

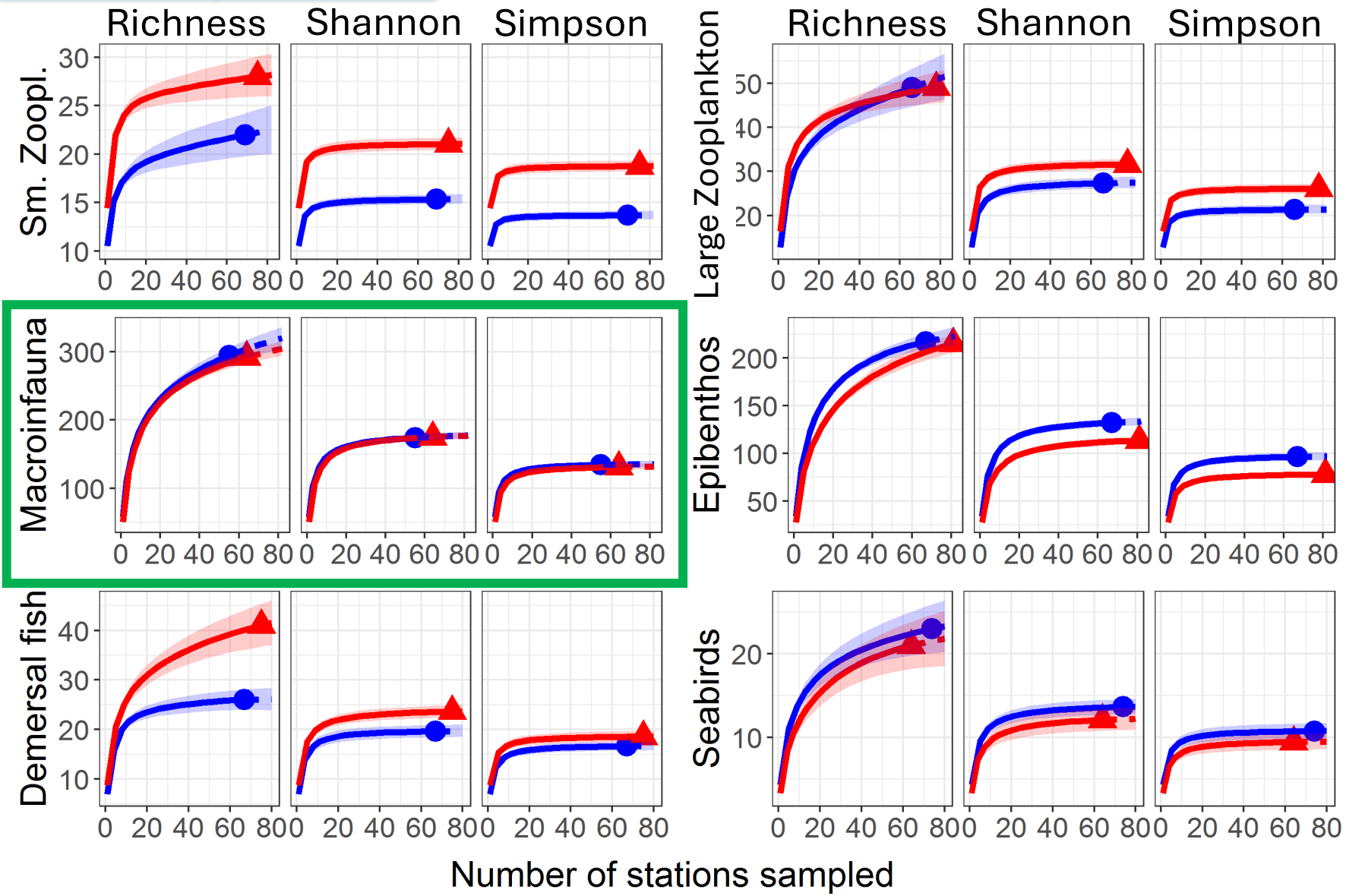
2017 (saltier, warmer, more 'Pacific')

→ Higher diversity of epibenthos and small fish in 2015

(Mueter et al. 2021)

Chukchi Sea observations (diversity):

Two contrasting years (2015/2017)



2015 (fresher, cooler, more 'Arctic')

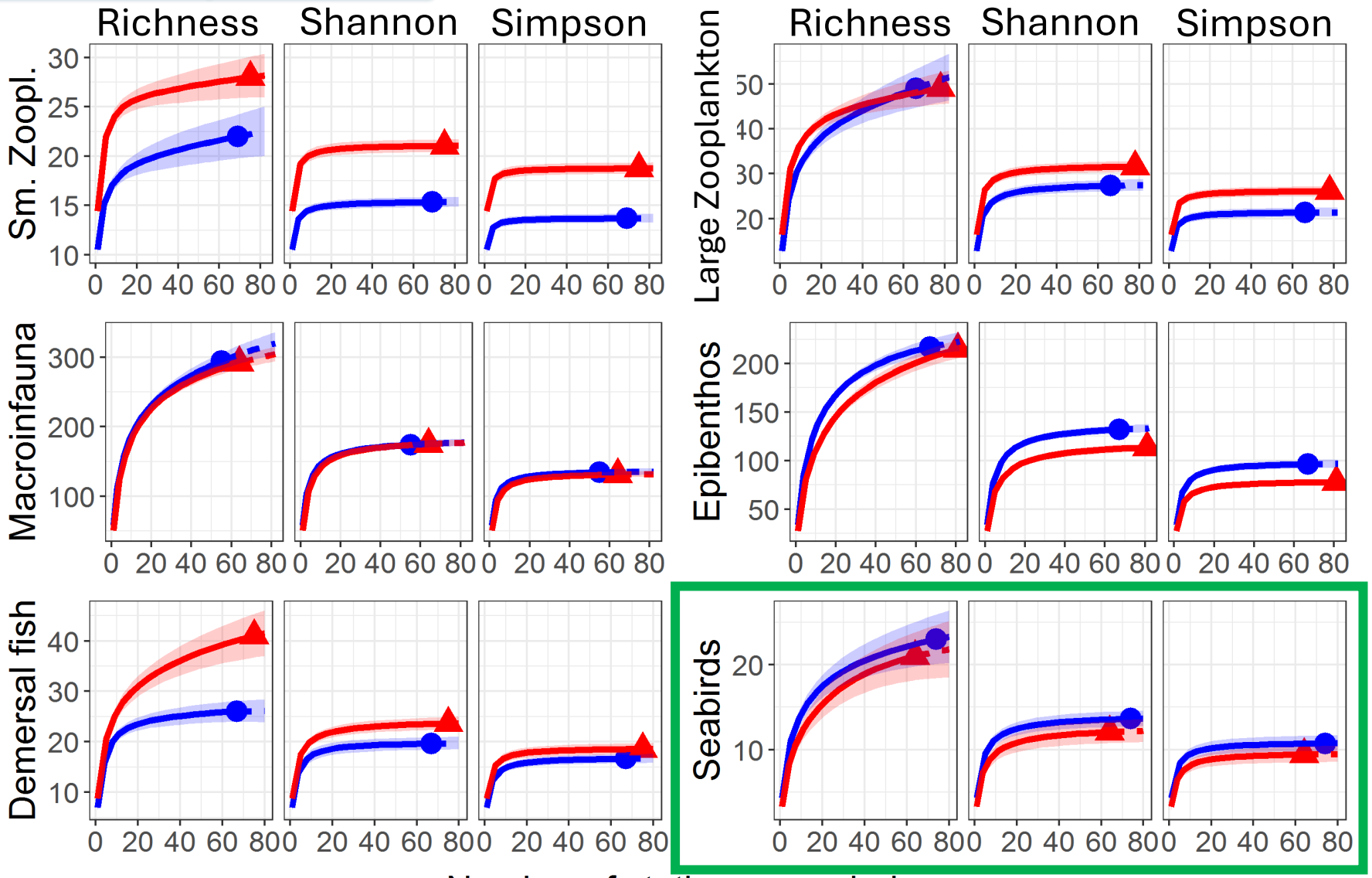
2017 (saltier, warmer, more 'Pacific')

→ No change in infauna

(Mueter et al. 2021)

Chukchi Sea observations (diversity):

Two contrasting years (2015/2017)



2015 (fresher, cooler, more 'Arctic')

2017 (saltier, warmer, more 'Pacific')

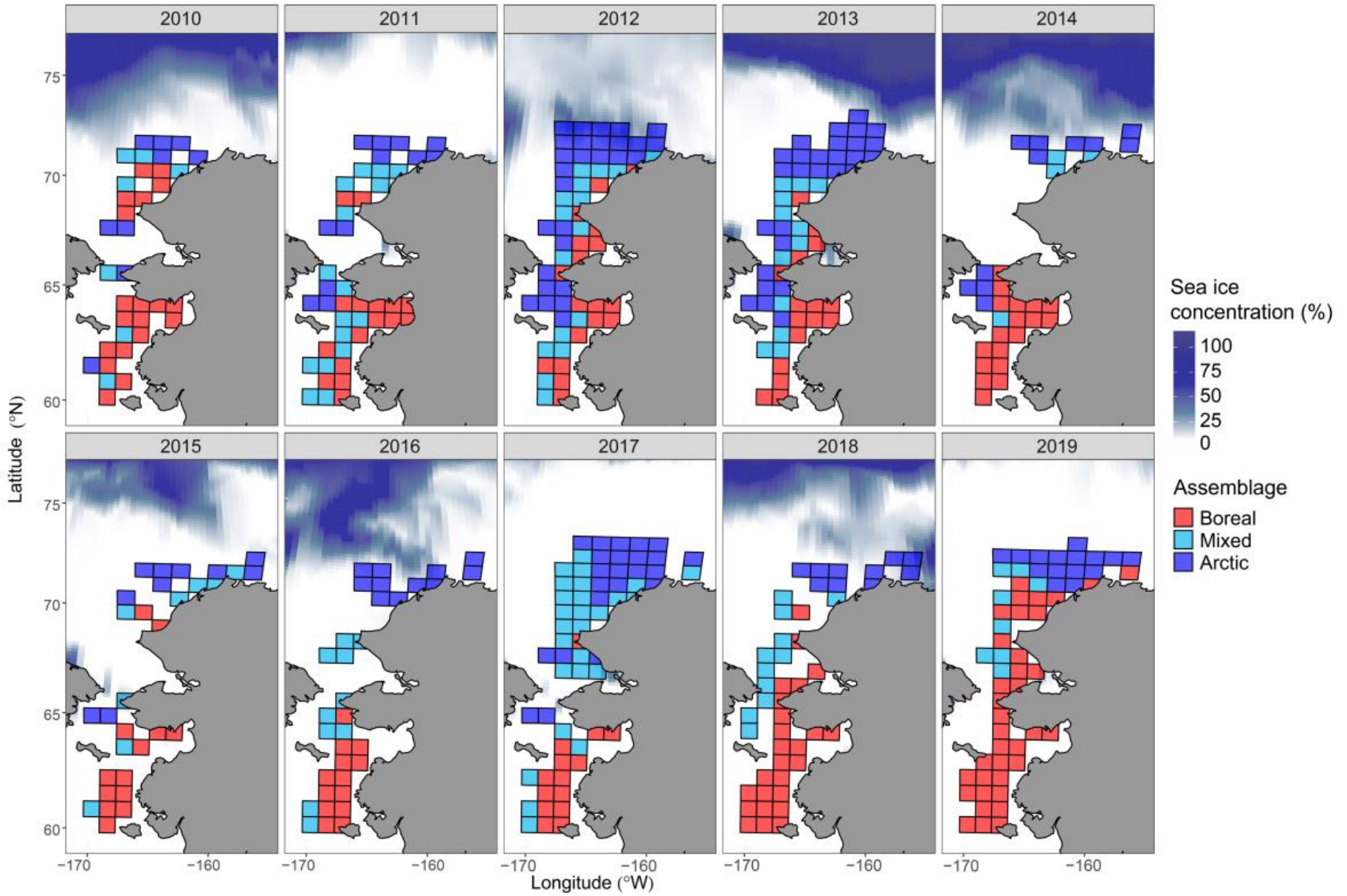
→ Little change in seabird diversity

→ Seabirds were decoupled from other assemblages in **2017**

(Mueter et al. 2021)

Chukchi Sea observations: Larval fish

- Inflow of warm Pacific water evident in 2017 and intensifying in 2018/2019
- Boreal assemblage extending across much of the shelf in 2019

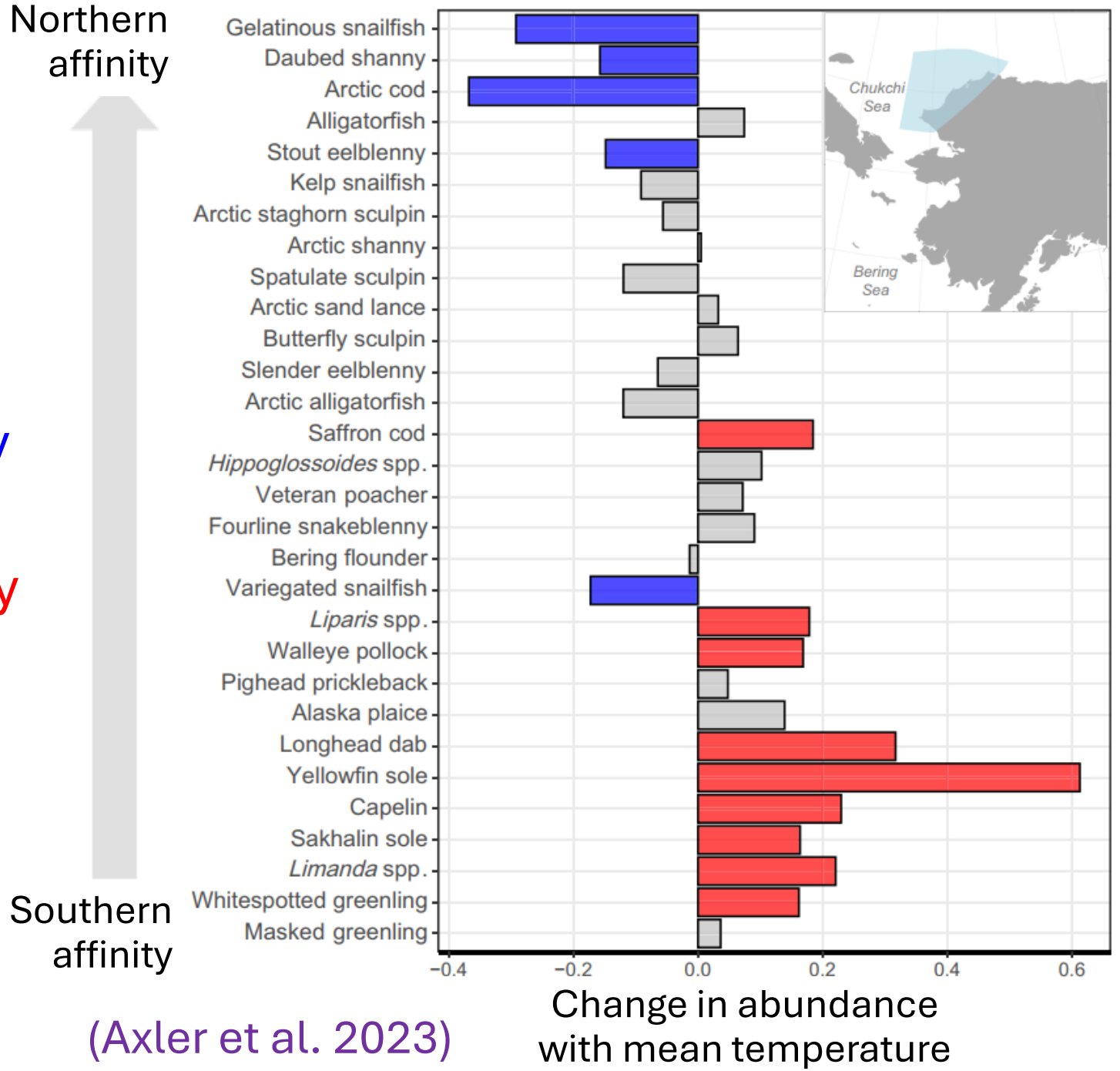


(Axler et al. 2023)

Chukchi Sea: Larval fish

Change in abundance with temperature, 2010 - 2019

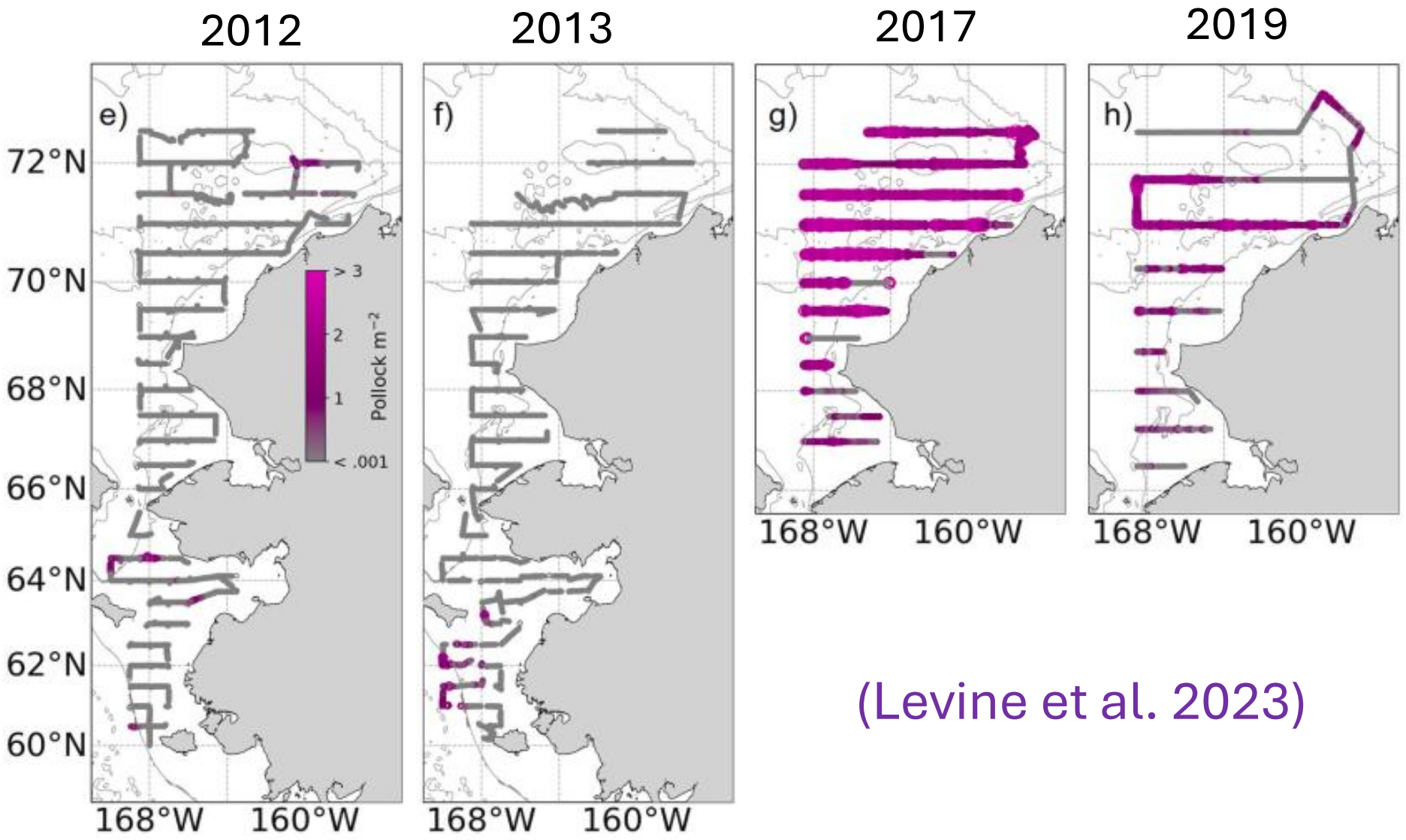
- Species with northern affinity declined significantly
- Species with southern affinity increased significantly



(Axler et al. 2023)

Chukchi Sea observations: juvenile walleye pollock

- Backscatter from acoustic surveys attributed to walleye pollock



(Levine et al. 2023)

What is the fate of advected plankton and juvenile fish from the Subarctic?

- Plankton advected into the Arctic on inflow shelves may be largely lost to predation
- Establishments in the high Arctic requires suitable conditions for spawning, nursery areas, and completing the life cycle

Contents lists available at ScienceDirect

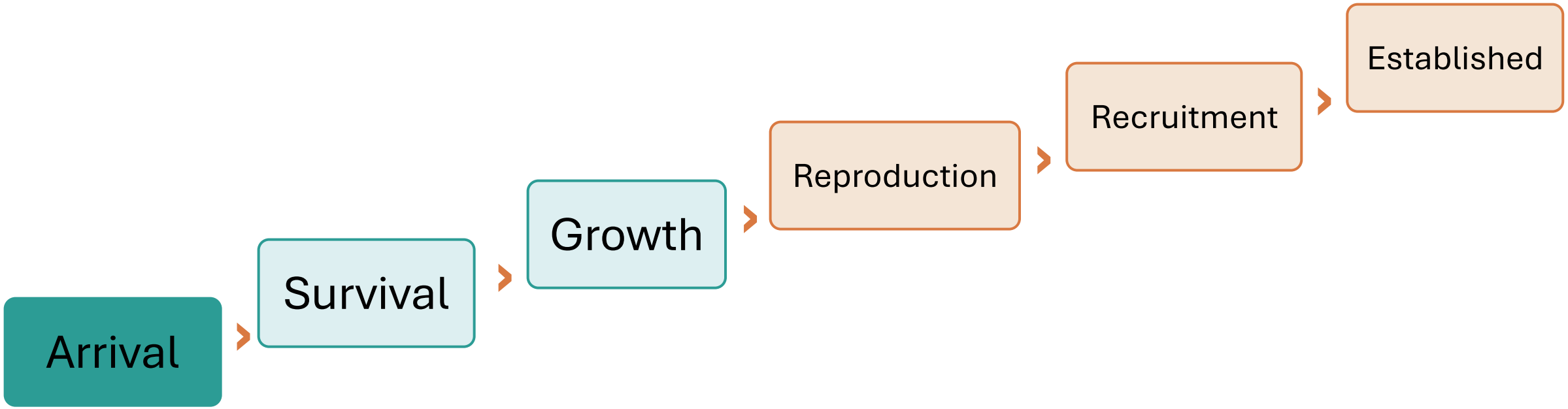
Progress in Oceanography

journal homepage: www.elsevier.com/locate/pocean

The contiguous domains of Arctic Ocean advection: Trails of life and death

P. Wassmann [a,*], K.N. Kosobokova [b], D. Slagstad [c], K.F. Drinkwater [d], R.R. Hopcroft [e], S.E. Moore [f], I. Ellingsen [c], R.J. Nelson [g], E. Carmack [g], E. Popova [h], J. Berge [a]

From Arrival to Establishment



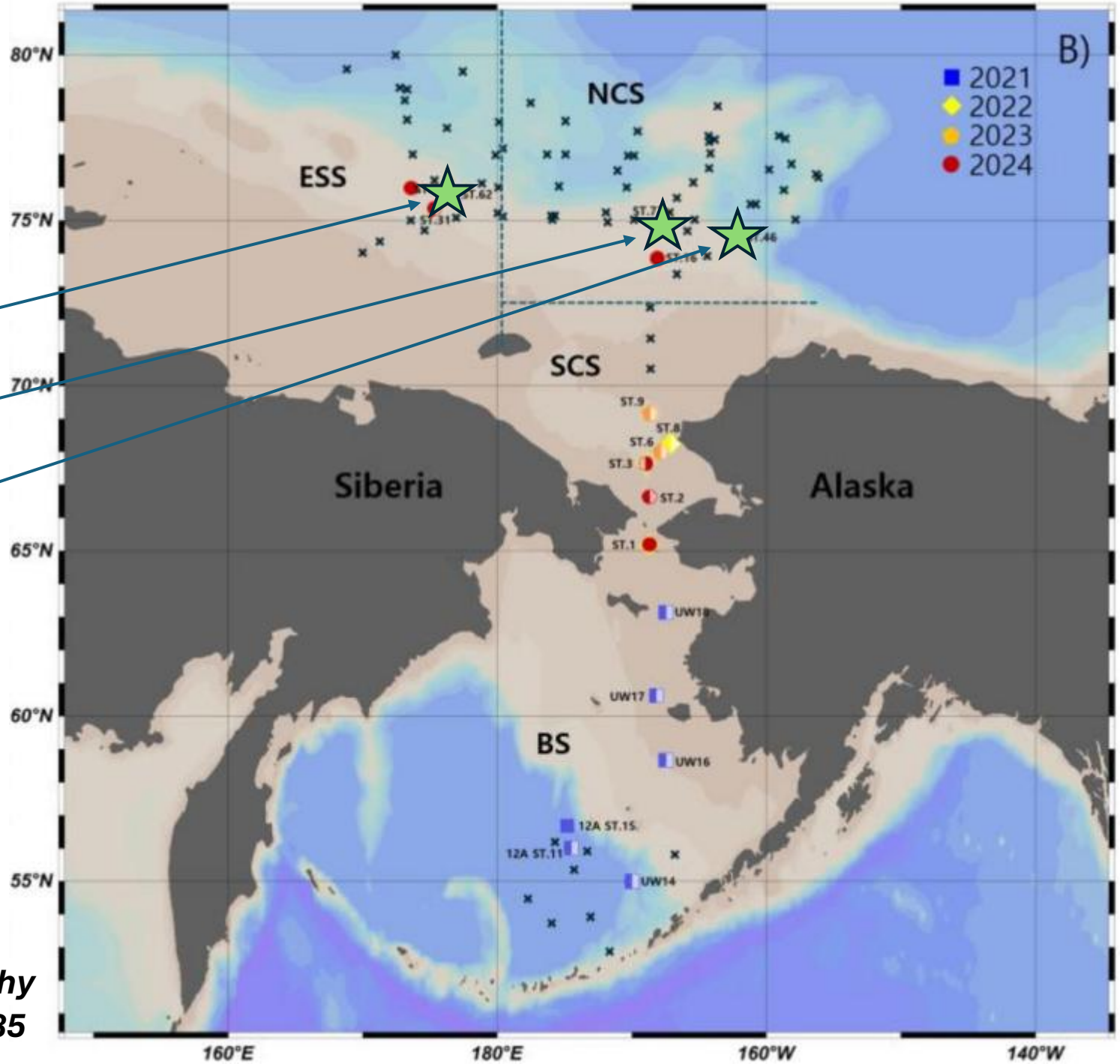
- Larval observations provide evidence mainly for Arrival
- Some evidence of survival & growth of expanding subarctic species in the Pacific Arctic
  - Salmon (successful spawning, no evidence of overwintering in CAO)
  - Walleye pollock (*Gadus chalcogrammus*)

Evidence from eDNA

walleye pollock (*Gadus chalcogrammus*) **at depth** (*Gwak et al. 2026, Li et al. 2026*)

- 74.50 °N, **1585 m**
- 74.81 °N, **170 m**
- 75.98 °N, **260 m**

Trawl sampling at depth confirmed pollock presence in Chukchi Borderlands (*Li et al. 2026*)



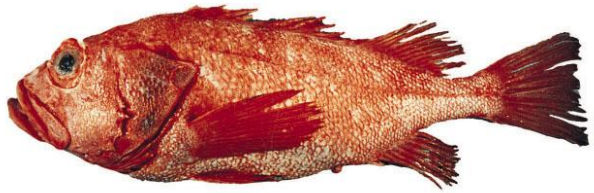
Gwak et al (2026) Fisheries Oceanography https://doi.org/10.1111/fog.70085

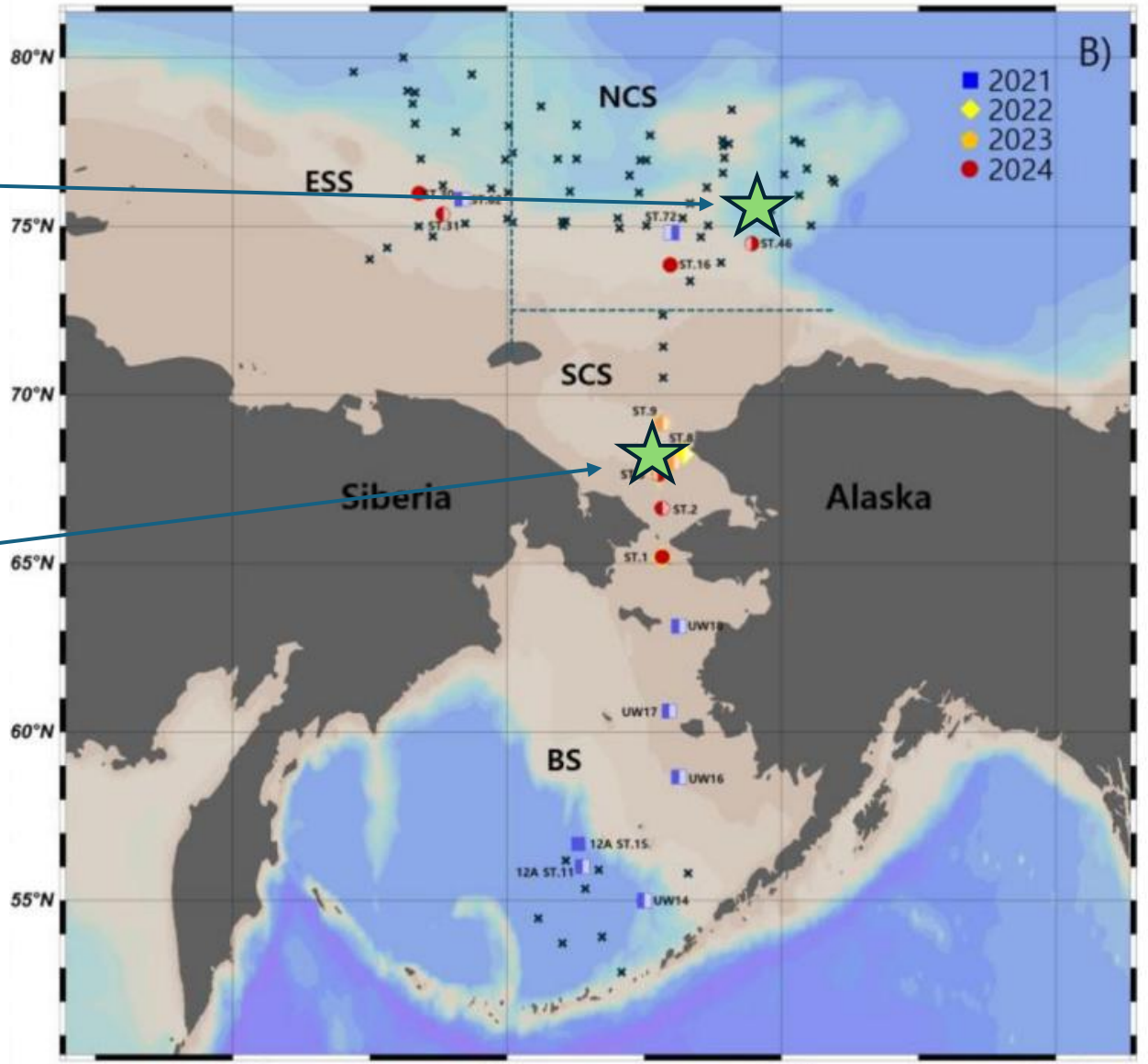
Evidence from eDNA: *Sebastes spp*

- ***Sebastes alutus***
  (Pacific ocean perch)
  - *Gwak et al. 2026*



- ***Sebastes borealis***
  (shortraker rockfish)
  - *Kim Ledger, NOAA, pers. comm*

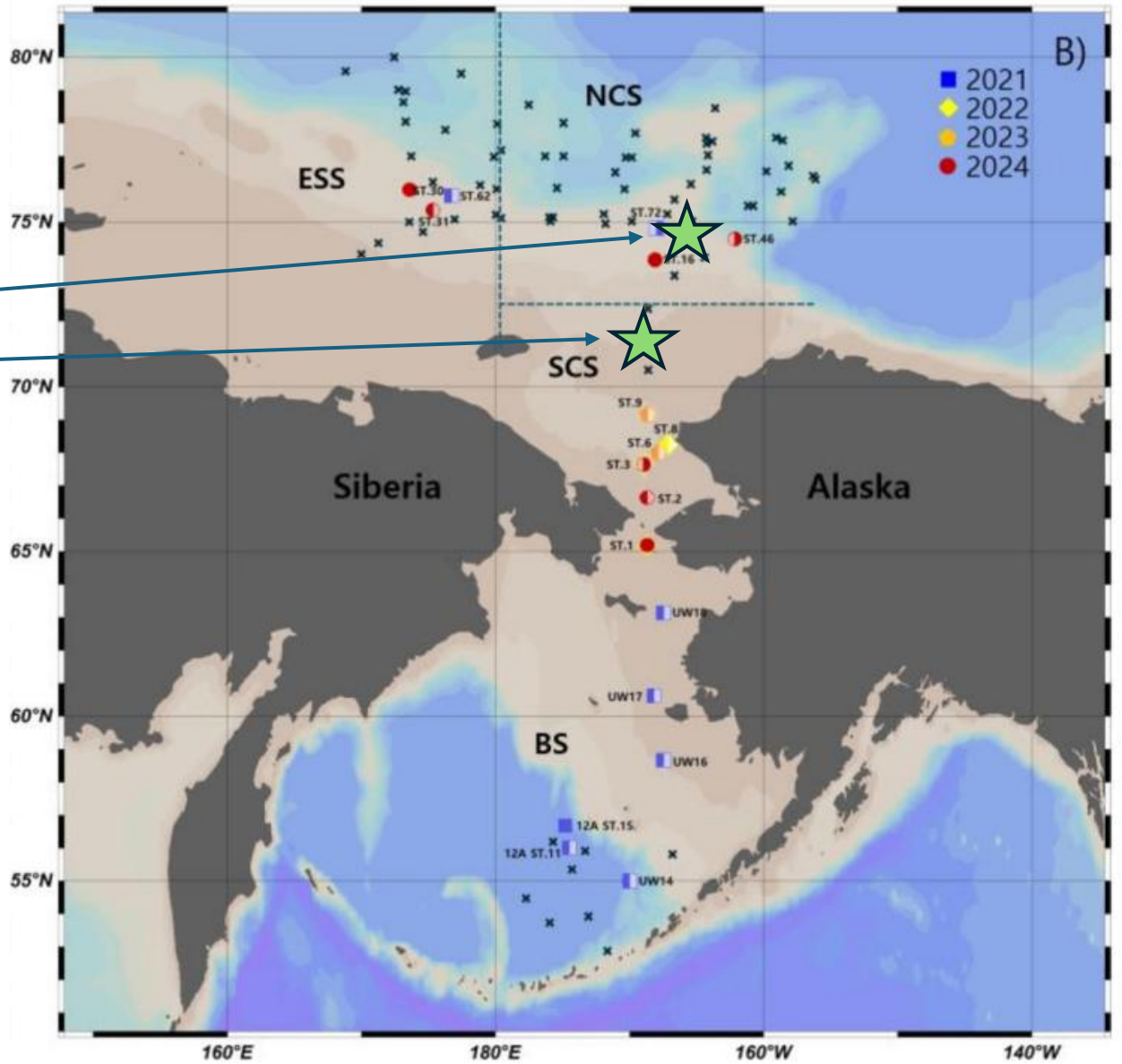




Evidence from eDNA: flatfish

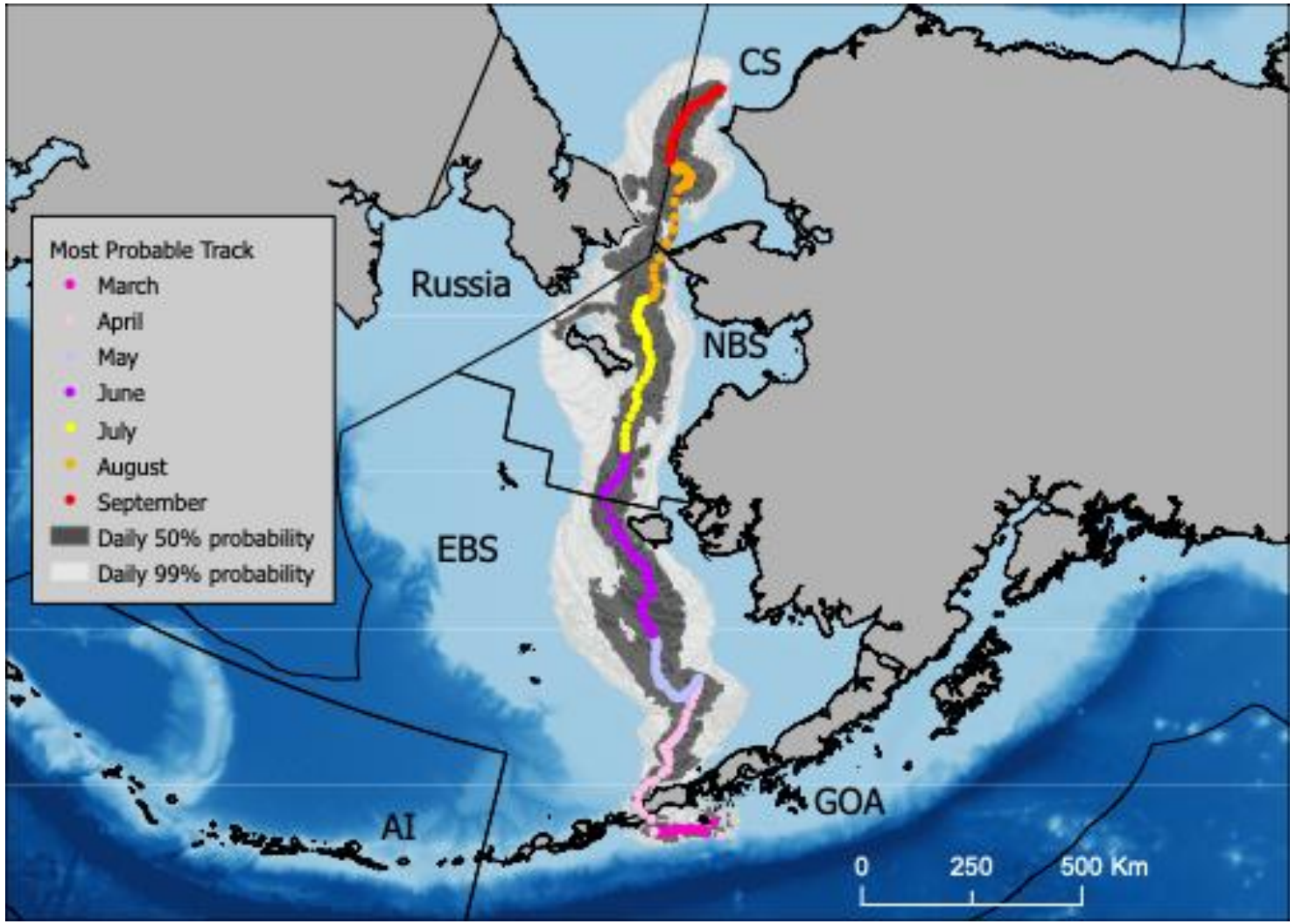
- ***Acanthopsetta nadeshnyi***
  (scale-eye plaice)
  bottom sample, 215 m
  surface sample
    - *Gwak et al. 2026*
- ***Hippoglossoides platessoides***
  (American Plaice)
  Atlantic species??
    - *Li et al. 2026*

    (possibly ***Hippoglossoides robustus)?***



Seasonal migrants

- Large fish
- Seabirds
- Marine mammals

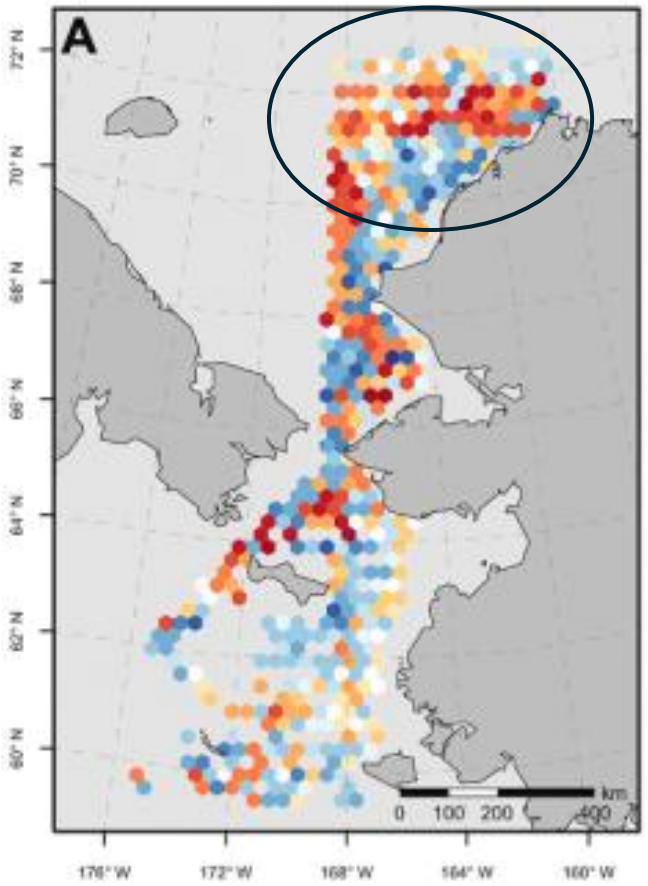


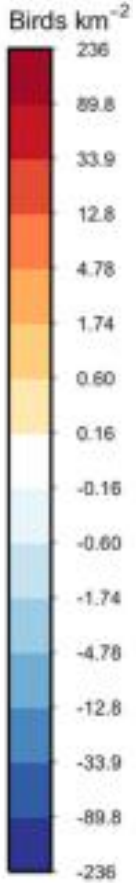
Julie Nielsen / Susanne McDermott

Seasonal migrants: seabirds

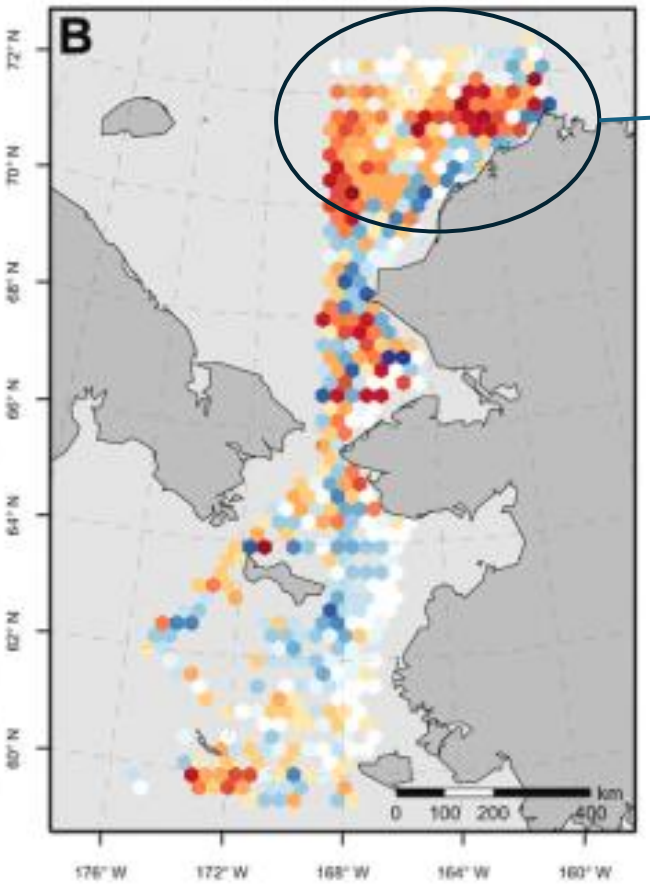
Increases and **decreases** in density (2017-2019 relative to 2007-2016)

Total seabirds

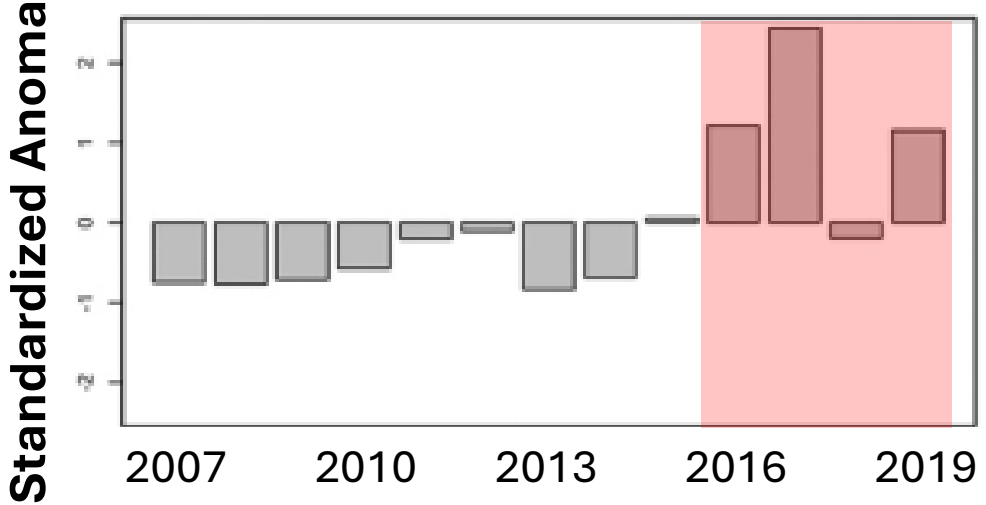




Short-tailed shearwater



Northern Chukchi Sea
Total Seabird density



(Kuletz et al. 2020)

Seasonal migrants: marine mammals

- Arctic whales (**bowhead, beluga**) migrate south later *(Stafford et al. 2021, Citta et al. 2023)*
- Subarctic baleen whales (**humpback, fin whale**) are moving north and staying longer *(Stafford et al. 2023)*
- **Killer whales** are moving north and staying longer *(Stafford 2018, Sawyer et al. 2024, Kimber et al. 2025)*

Research questions

- Which boreal species are most likely to progress from transport to establishment? (update to Hollowed et al. 2011)
- What are the main ecological filters? What are the barriers to establishment?
- How will changing connectivity through the Arctic gateways influence the organization of biological communities in the CAO?
- How will inflows and Subarctic-Arctic connectivity change?
- How will changing Pacific inputs alter the CAO food web and fisheries potential?
- What biodiversity indicators can help detect emerging ecological reorganization in the CAO beyond changes in species distributions and richness?

Approaches

- Expand year-round observations in CAO (moorings)
- Expand eDNA monitoring, including year-round samples (moorings)
- Establish transects from the shelf to the basin for long-term ecosystem observations (DBO model?)
- Conduct large-mesh trawl surveys on Chukchi Sea shelf **& slope**
- Strategically combine molecular approaches, net sampling and autonomous observations