Recent Ecosystem Research in the Chukchi and North Bering Seas

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NOAA FISHERIES

Outline

- **Arctic Integrated Ecosystem Research Program (Arctic IERP): 2017-2019**
  - Physics & Nutrients
  - Phytoplankton
  - Harmful Algae Blooms
  - Zooplankton & Fish larvae
  - Fish
  - Pelagic Export & Benthic Carbon Consumption
- **Benthic-pelagic coupling in the Northern Bering Sea (NBS) and Chukchi Sea** (NPRB Synthesis proposal)
- **Integrated Ecosystem Assessment (IEA) of NBS and Chukchi seas** (PICES WG44)

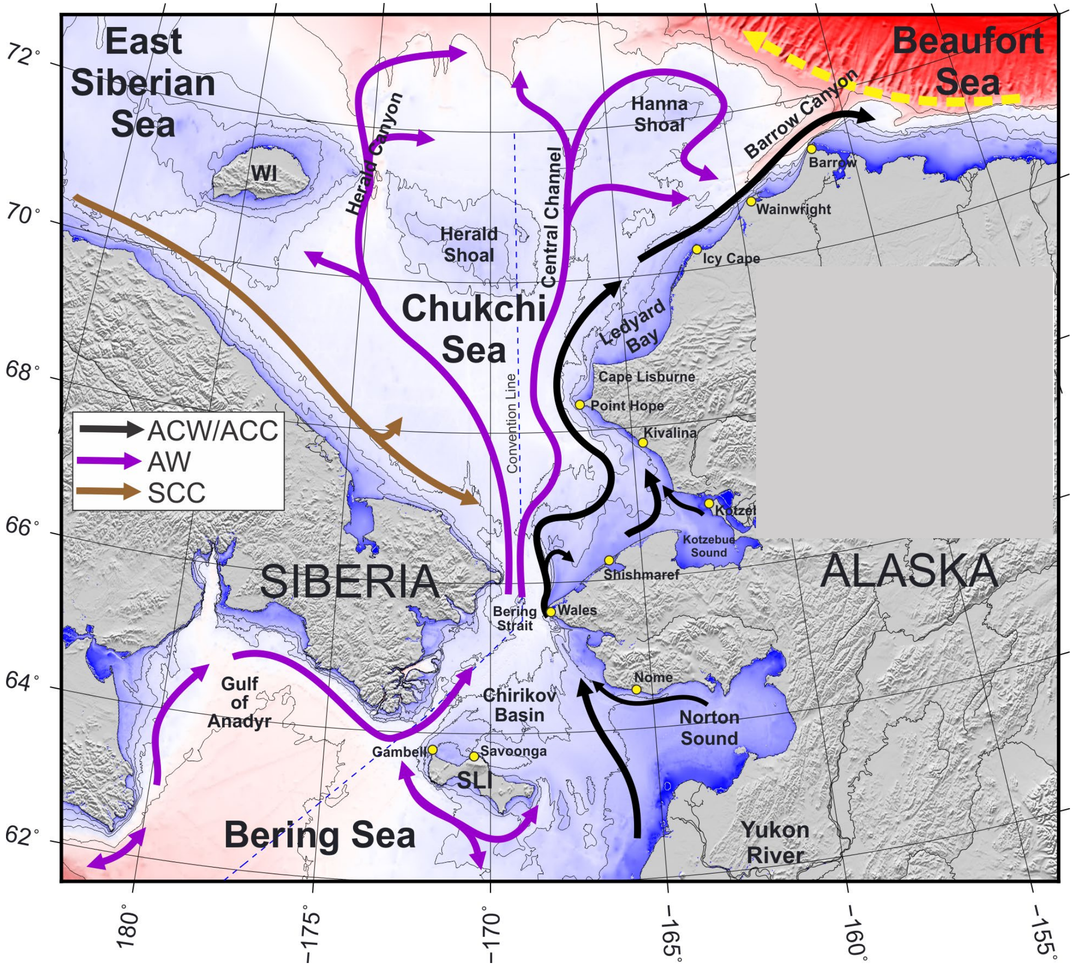


figure courtesy of Seth Danielson

Arctic Integrated Ecosystem Research Program (Arctic IERP)

Researchers from 11 institutions:

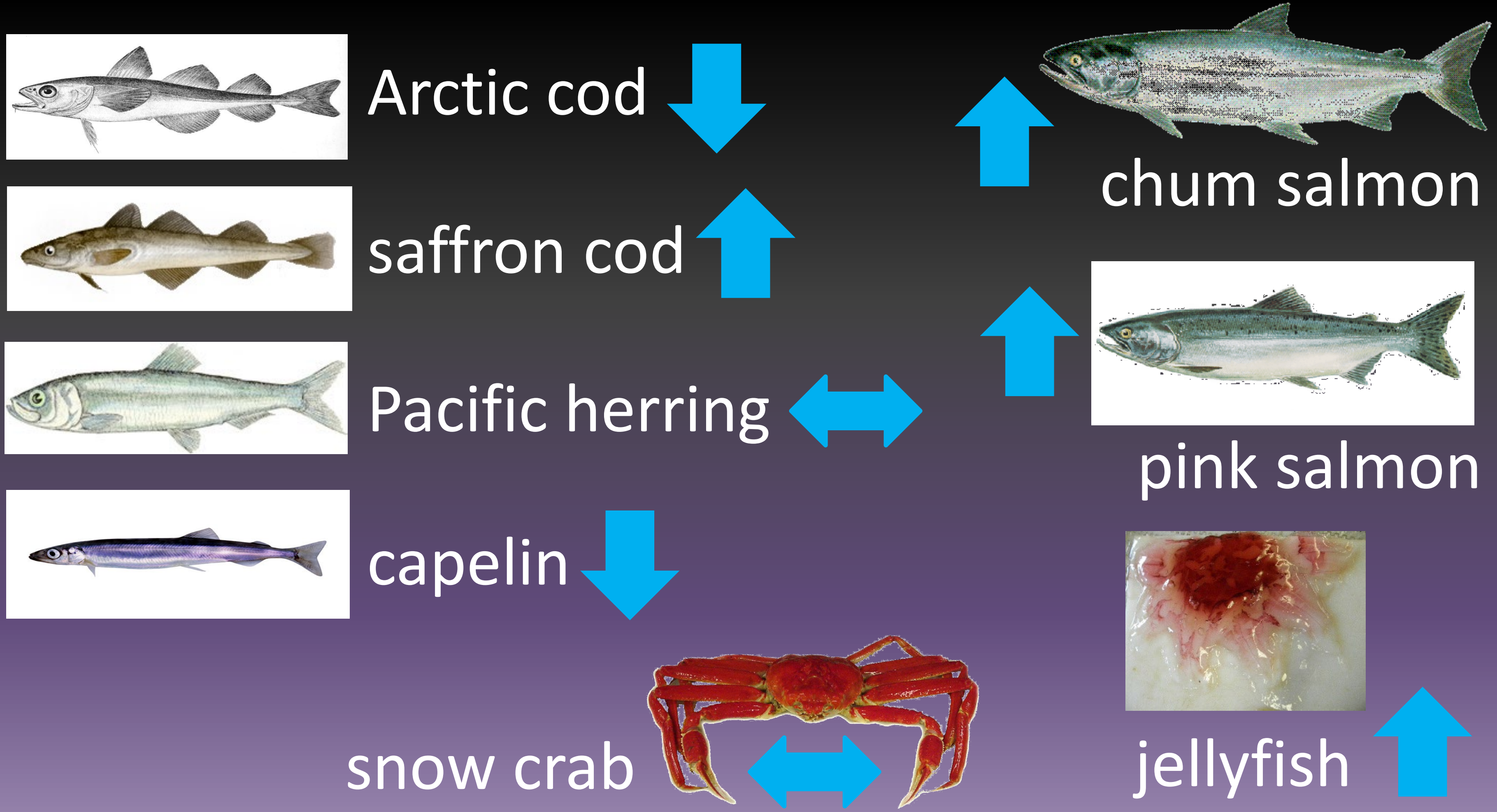
PI's include: Ed Farley, Carol Ladd, Kris Cieciel, Alex De Robertis, Janet Duffy-Anderson, Lisa Eisner, Jeff Guyon, Dave Kimmel, Johanna Vollenweider, Sharon Wildes, Libby Logerwell, Phyllis Stabeno, Chris Wilson, Seth Danielson, Franz Mueter, Arny Blanchard, Sarah Hardy, Russ Hopcroft, Andrew McDonnell, Dean Stockwell, Jared Weems, Louise Copeman, Kate Stafford, Robert Levine, Ryan McCabe, Calvin Mordy, and Danny Grunbaum, Kathy Kuletz, Elizabeth Labunski, Henry Huntington, Julie Raymond-Yakoubian (Kawerak), Noah Naylor, Michael Lomas, with assistance from many students, technicians, and colleagues.

Thank you
to all who have made the ASGARD and Arctic IES projects and the Arctic IERP possible. Including: the staff, students, collaborators, funding agencies, program managers, community participants, subsistence hunt co-management organizations, village tribal councils, ship captains and crews, & field logistics support.

www.nprb.org/arctic-program

How will reductions in sea ice & associated environmental changes influence the flow of energy through the northern Bering & Chukchi sea ecosystems?

How will warming likely affect abundance of fishes and invertebrates?



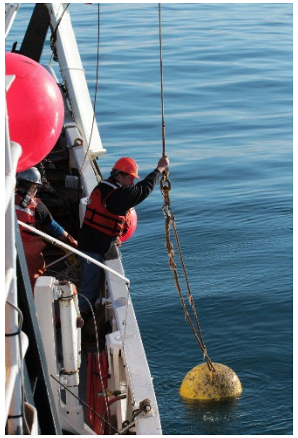
E. Farley, NOAA AFSC


How is food security influenced by environmental vs. socio-economic factors?

Arctic IERP Structure

1. **Spring** (June) Field Expeditions 2017 & 2018: Arctic Shelf Growth, Advection, Respiration & Deposition (ASGARD) Rate Experiments Project.

2. **Summer** (Aug-Sep) Field Expeditions 2017 & 2019: Arctic Integrated Ecosystem Survey (Arctic IES). Additional surveys in summer 2012 and 2013.

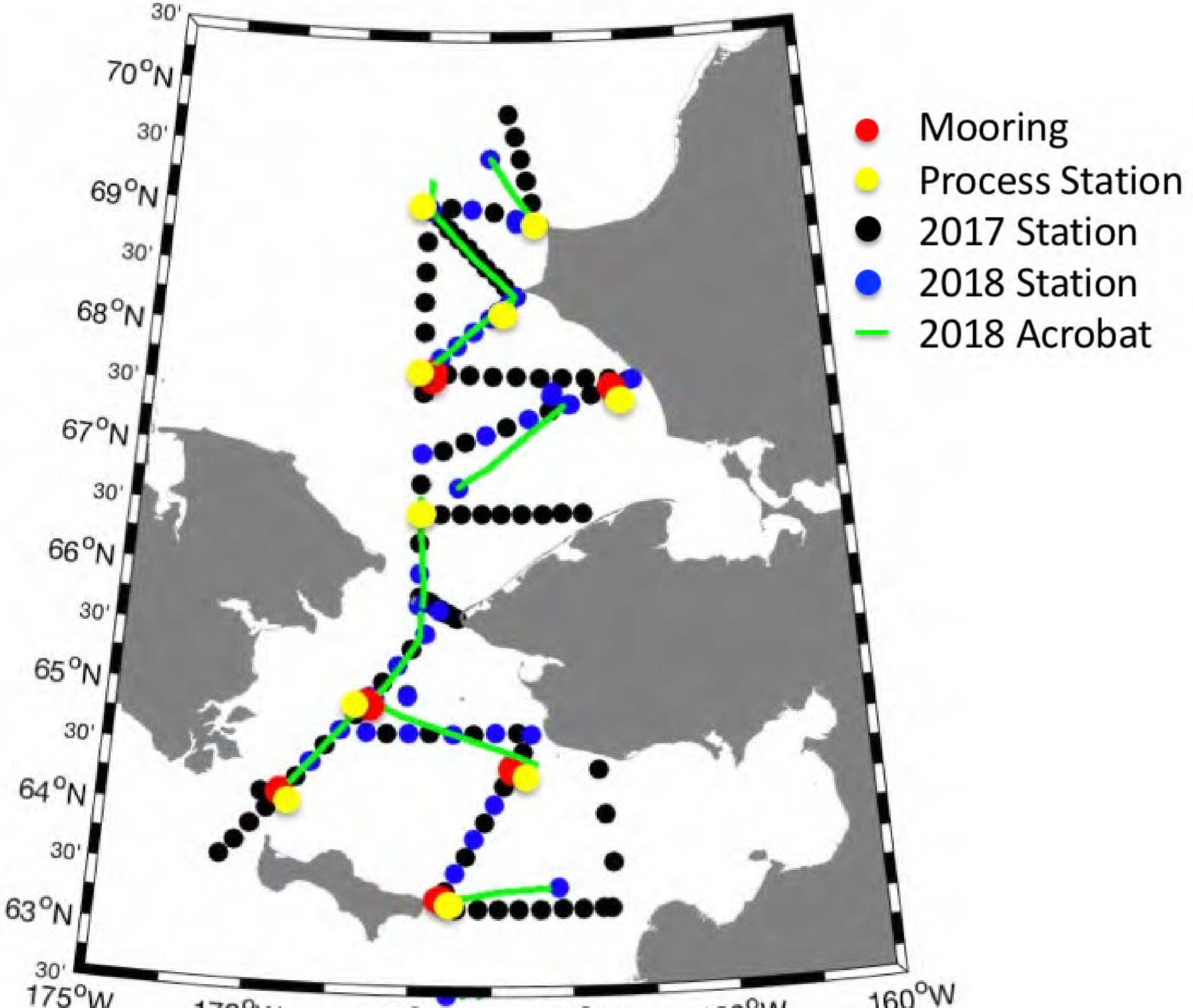


3. **Year-round** moorings

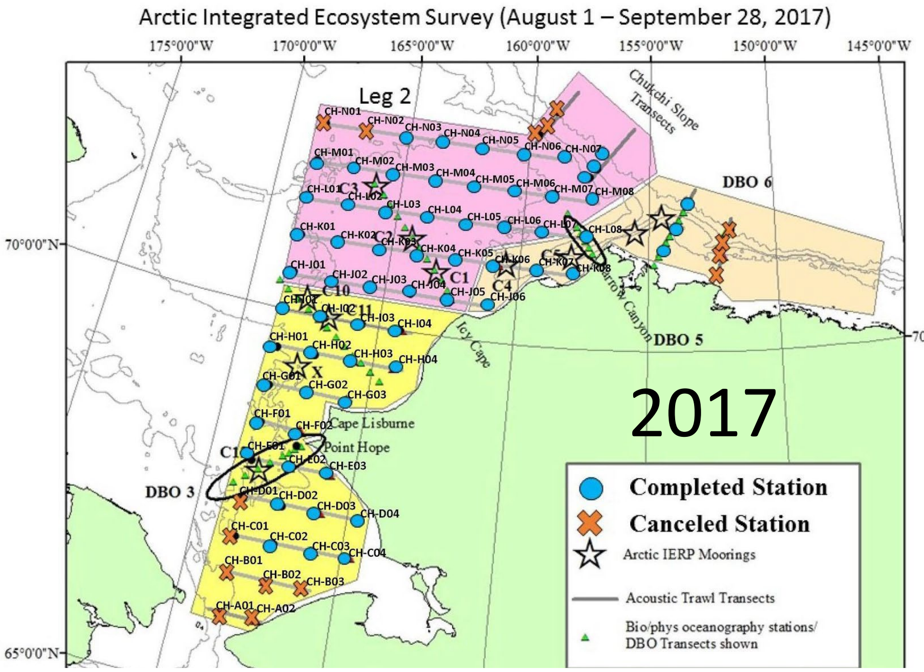
Many collaborating projects:
AMBON; ASAMM; BASIS; Bering Strait Moorings; CEO; CHESS; DBO; MARES; NBS Bottom Trawl Survey; RASM; Project Jukebox; Arctic Winds, Fish, Fins and Feathers

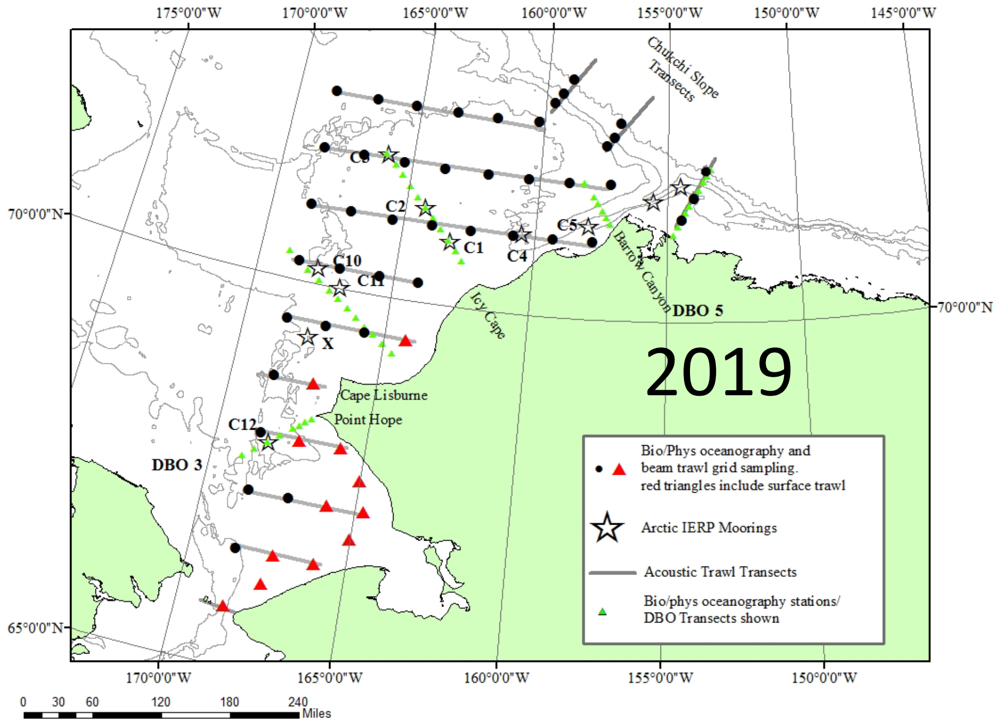
Stations

ASGARD (June):



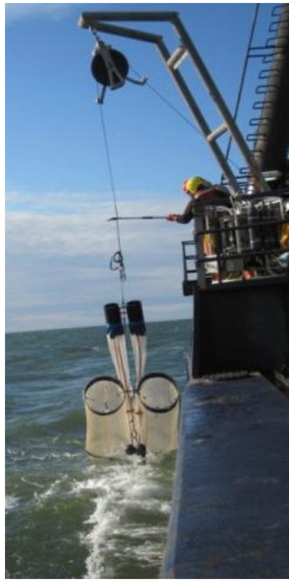
Arctic IES (Aug-Sep):

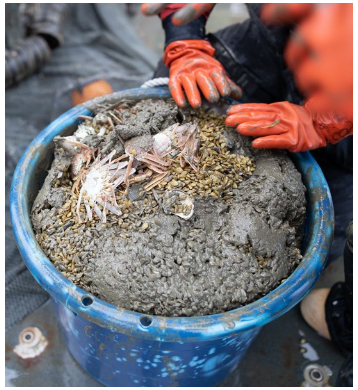




Survey Components
(biomass & rates)

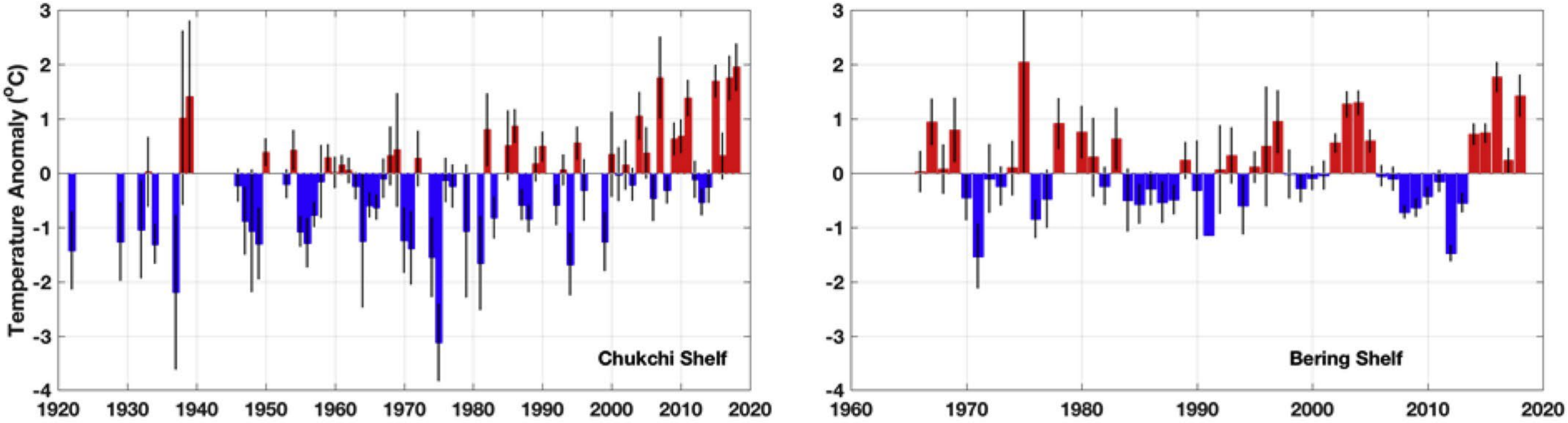
- Underway Currents & Atmospheric Data
- Water: physical, chemical, optical properties
- Particles & sedimentation (ASGARD)
- Microbes (ASGARD)
- Phytoplankton & Harmful Algae
- Microzooplankton
- Mesozooplankon
- Ichthyoplankton (Arctic IES)
- Fishes
- Epifauna & (Infauna ASGARD)
- Marine Mammals
- Seabirds
- Trophic transfer: fatty acids & fish diet (Arctic IES)





Physics and Nutrients

Annually averaged July - October temperature anomalies over the Chukchi and Bering shelves.

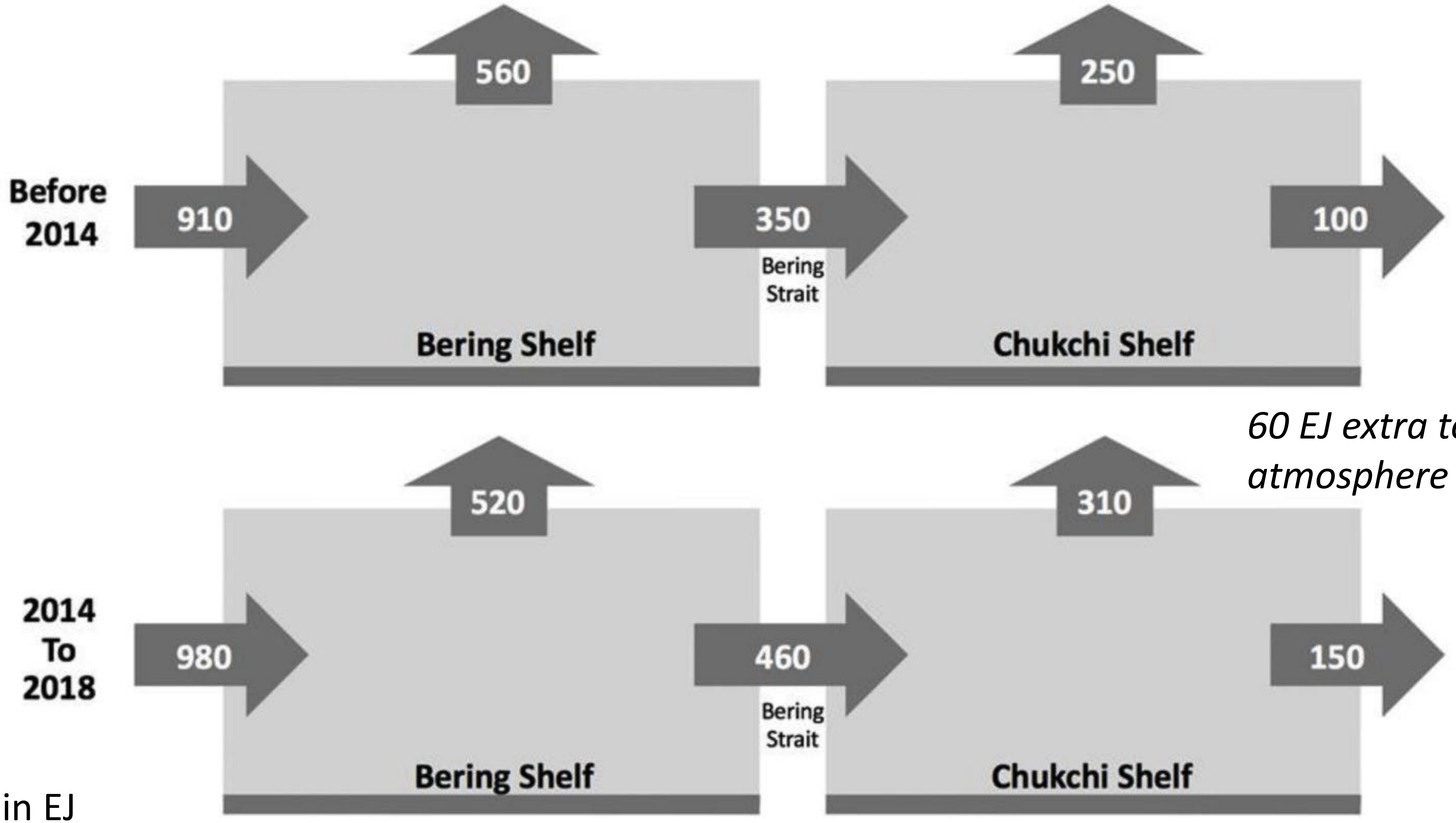


- Bering and Chukchi shelves are differently impacted by climate change - including the magnitude of warming trends.
- The heat engines of both shelves accelerated over 2014-2018, with increased surface heat flux and increased lateral oceanic heat advection.
- Arctic IERP occurred during these anomalously warm years – **Are we experiencing the future Arctic?**

Danielson et al. 2020

Steady-state solution to the heat balance for the Bering-Chukchi Shelf system

Gulf of Alaska /Aleutian Basin



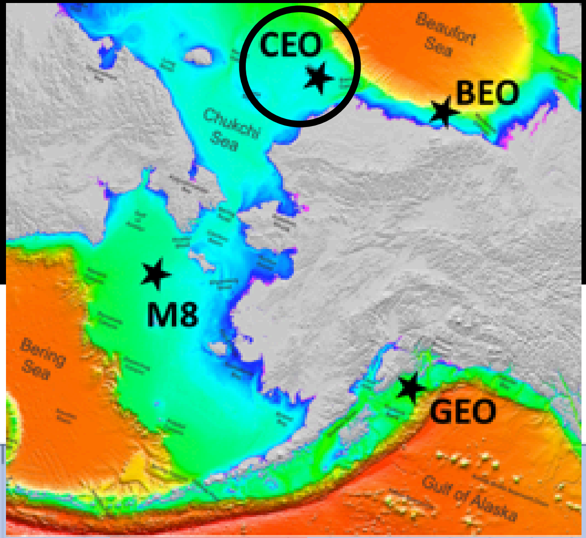
60 EJ extra to atmosphere

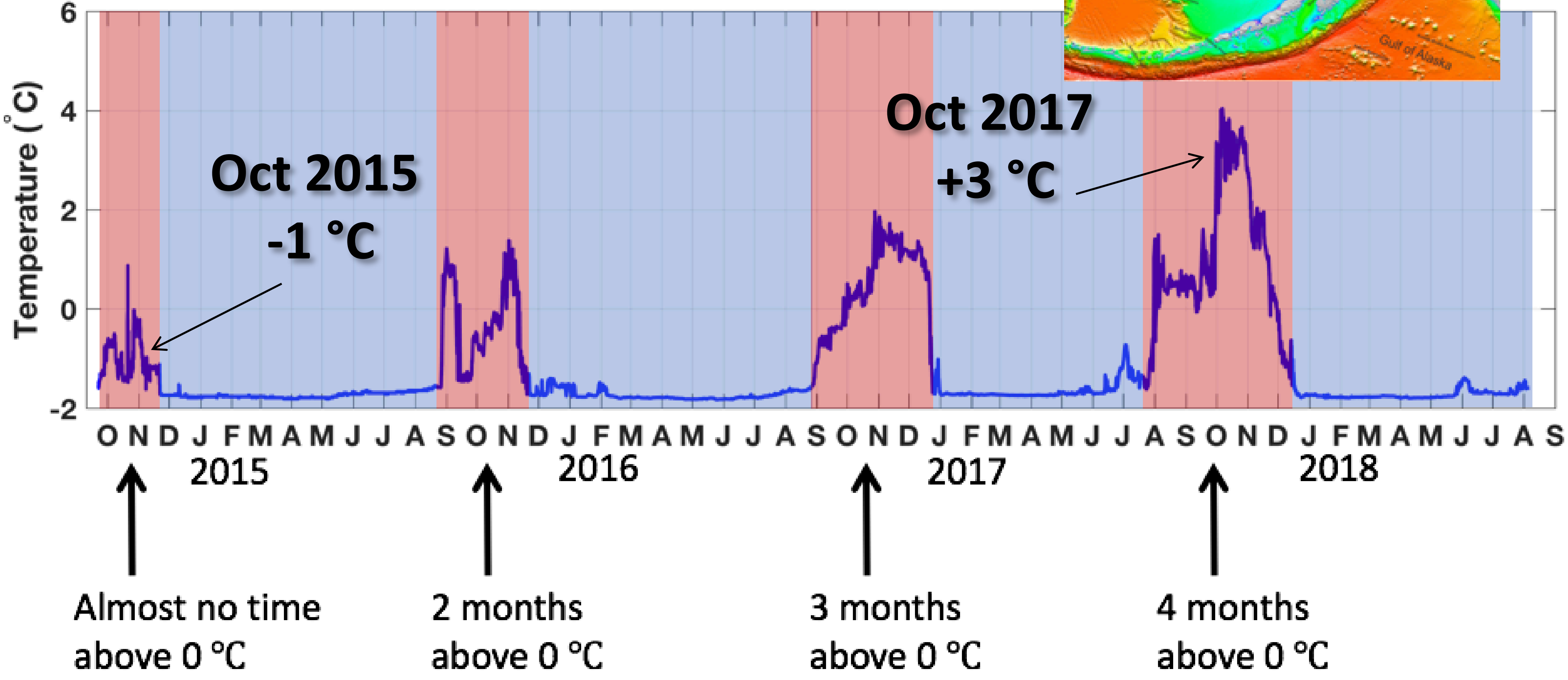
50 EJ extra to Arctic basin or sea-ice melt

All values reported in EJ
1 EJ = 10^{18} Joules.

Danielson et al. 2020

CEO Near-Seafloor Temperature
Sep. 2014 to Aug. 2018



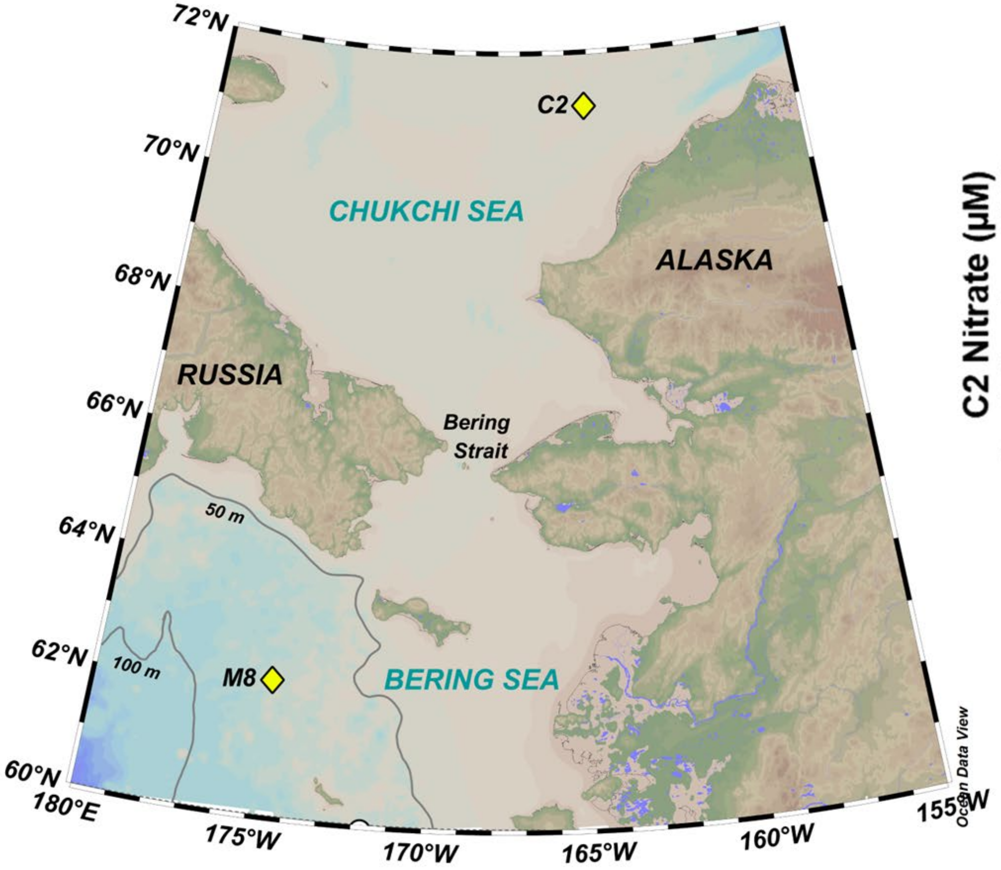


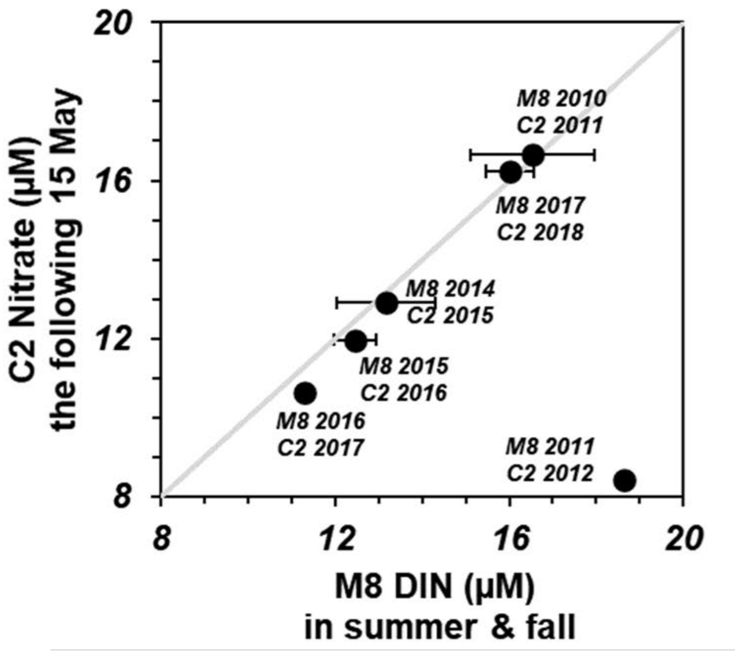
Maximum temperature and duration of warming increased.

S. Danielson, UAF

Variability of nutrient content in the Chukchi Sea is tied to the northward transport of water across the Chukchi Sea and source water in the Bering Sea

M8 in late summer (Sept), C2 in following spring (mid-May)





Seasonality important.
Year round bag samples on NBS mooring in Anadyr Current showed:

- Maximum flux of nutrients in April, exceeding mean by ~50%.
- Minimum flux in December.
- Interannual variability ~30%. *T. Hennon UAF*

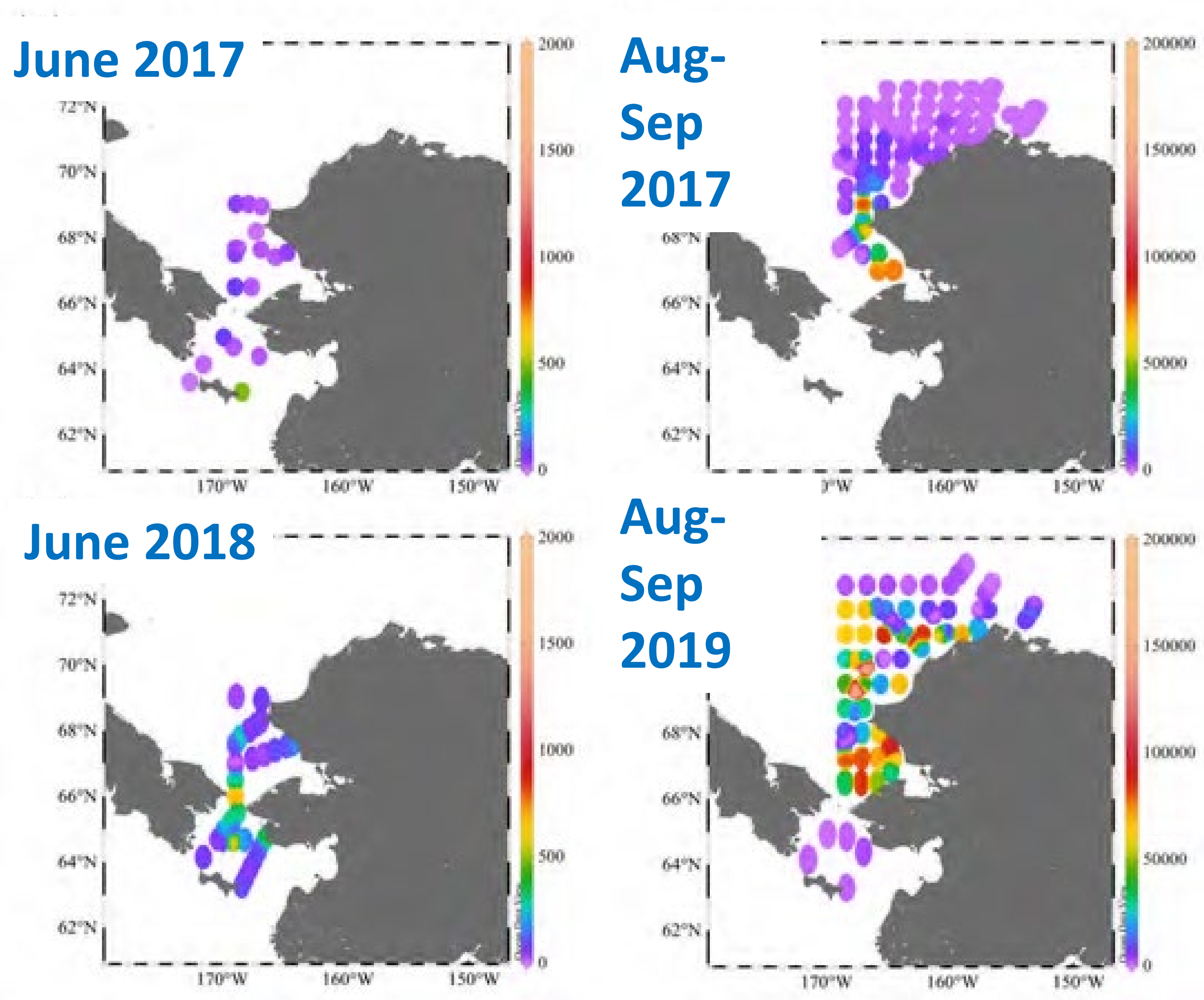
Mordy et al. 2020

Phytoplankton

Expansion of picoplankton populations in the Chukchi Sea

Spatial and seasonal distribution of *Synechococcus* (cells/ml) in surface waters of the NBS and Chukchi Sea.

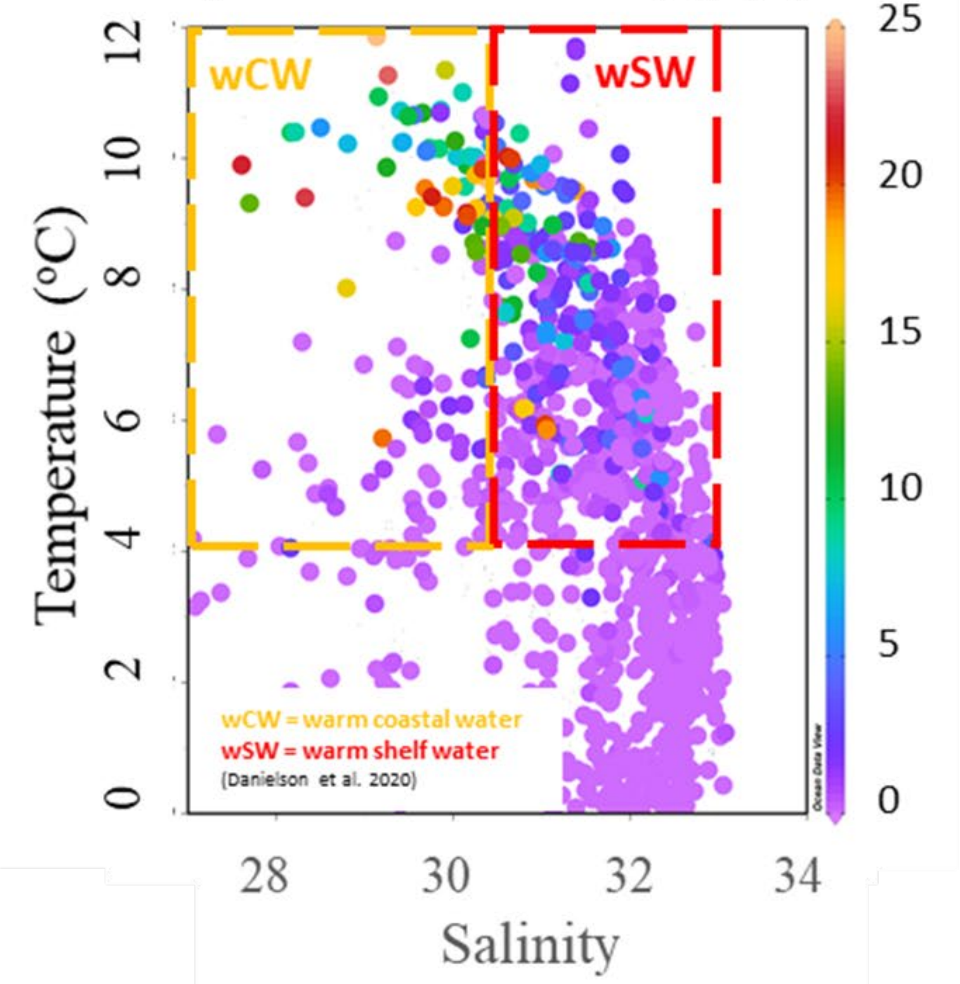
Note the 100-fold difference in scales between spring and late summer.



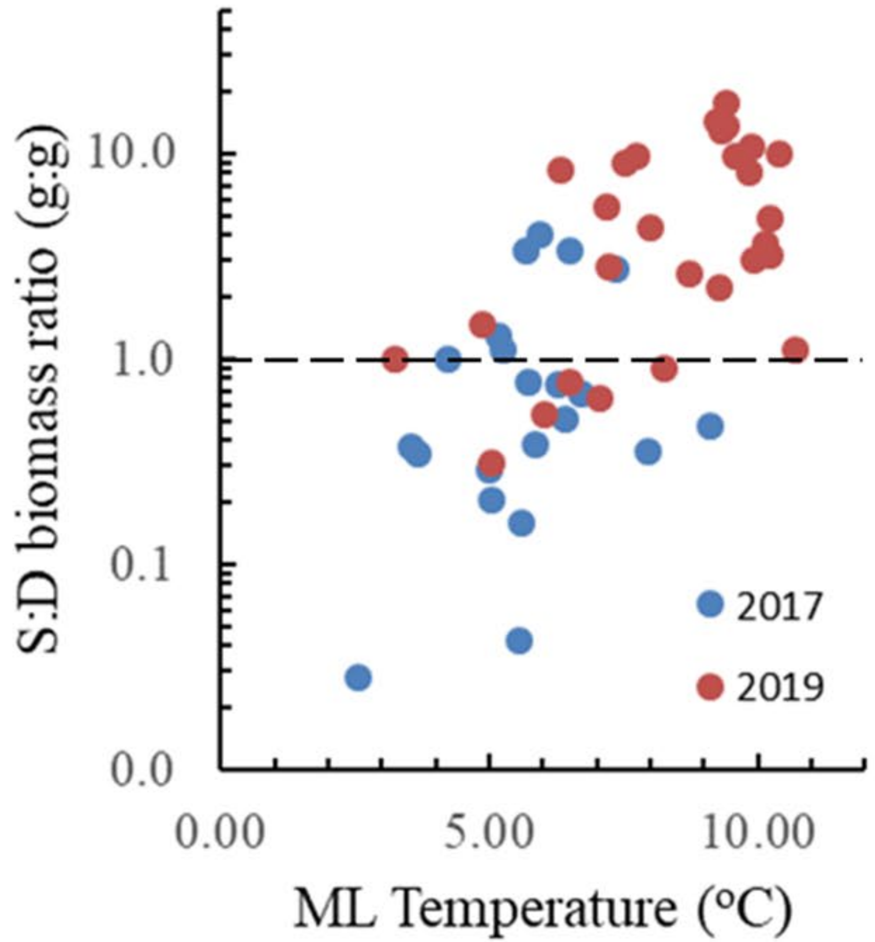
M. Lomas, Bigelow

Expansion of picoplankton populations in the Chukchi Sea

Biomass of *Synechococcus* (color scale, ugC/L) plotted against T and S.



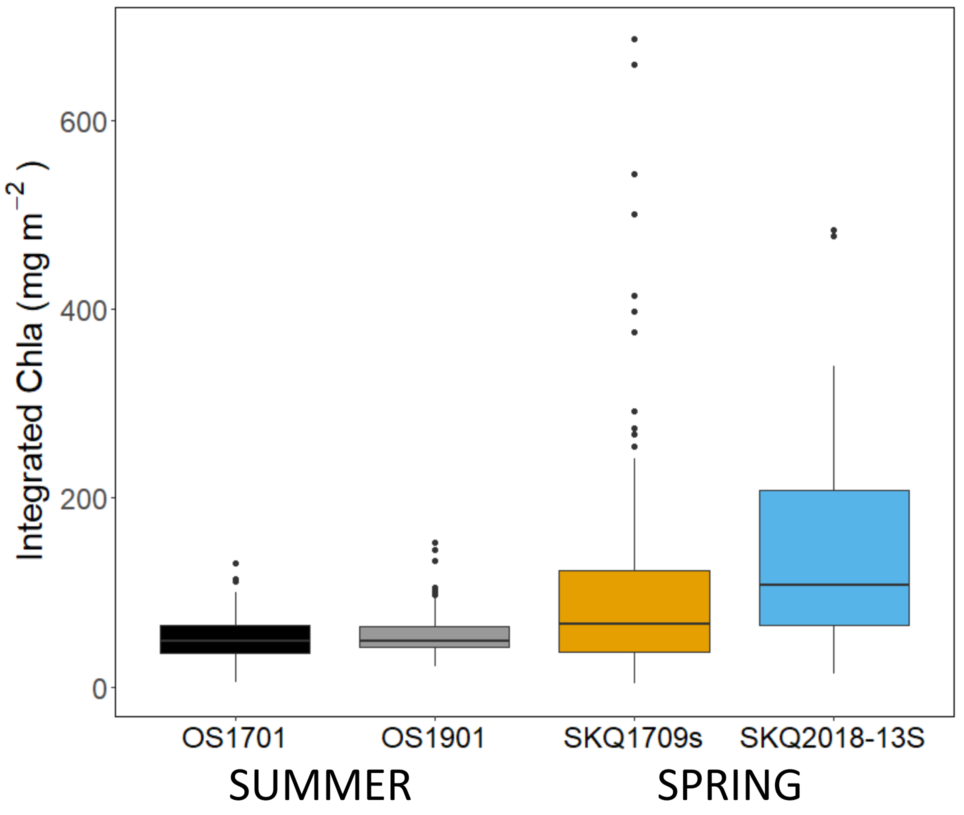
Ratio of *Synechococcus:* Diatom biomass (S:D) as a function of mixed layer (ML) temperature.



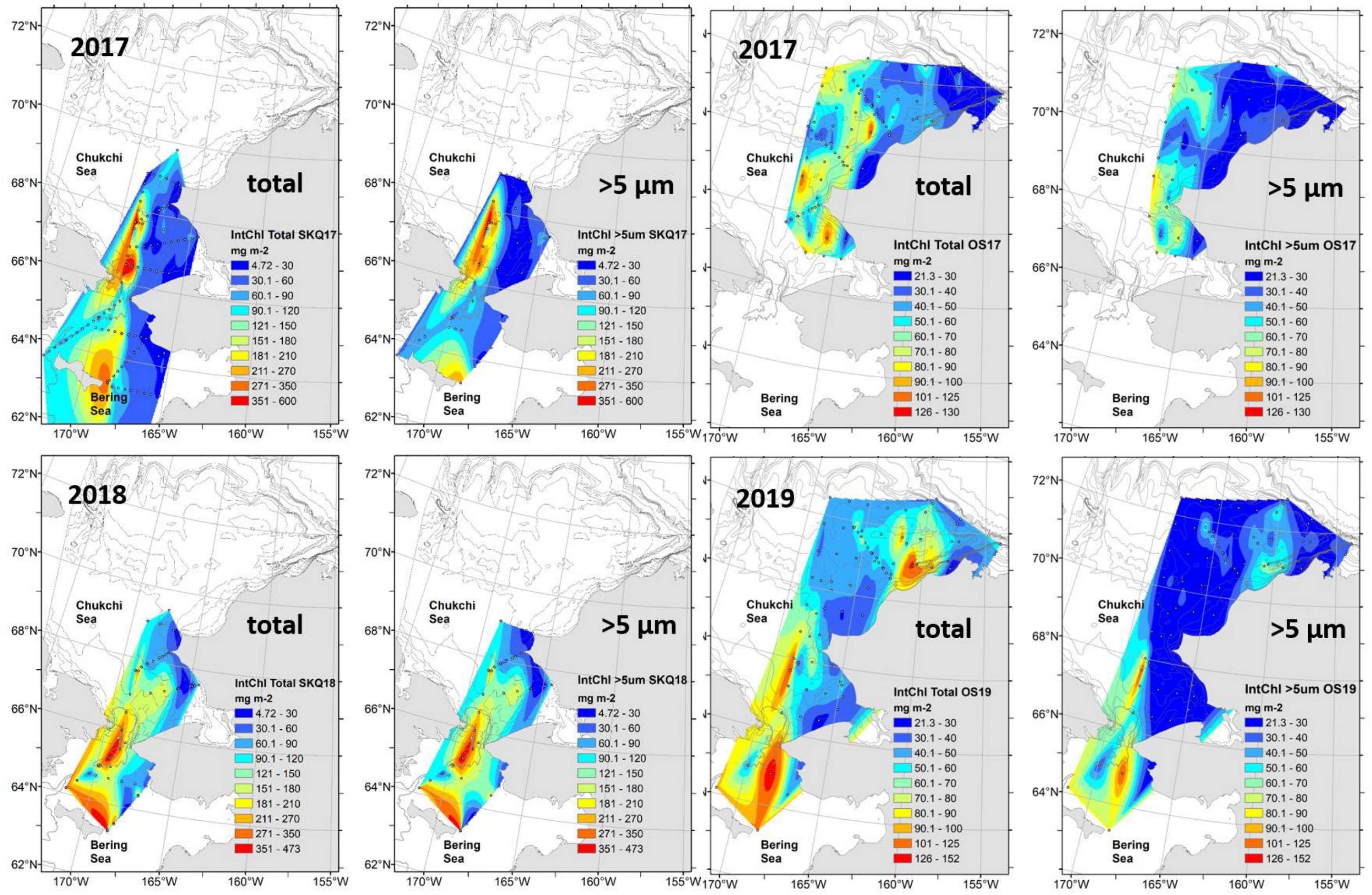
M. Lomas, Bigelow

Chlorophyll a biomass: total and >5 µm (large) size fraction

Average Integrated Chla



Spring (June) Summer (Aug/Sep)



Different color scale in spring (max 475-600) and summer (max 130-150)

- **Higher Chla in spring than summer.**
- **Most Chla was large (> 5 µm) fraction in spring.**
- **Large fraction Chla was lowest in summer 2019 (warmest year).**

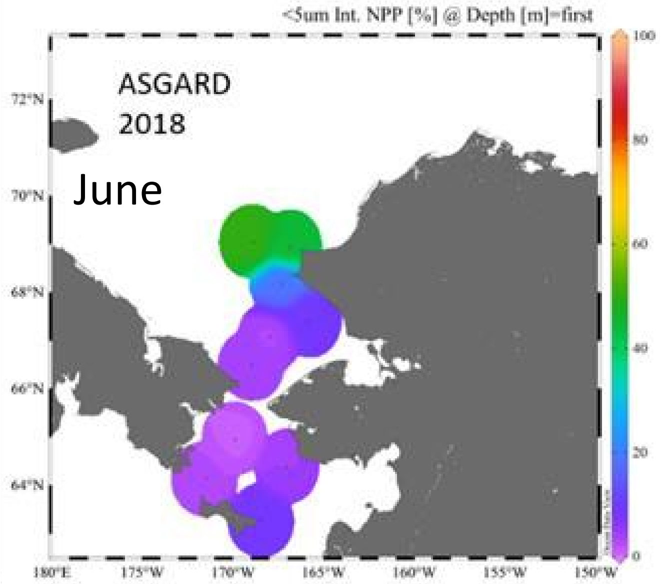
Eisner, Lomas, in prep

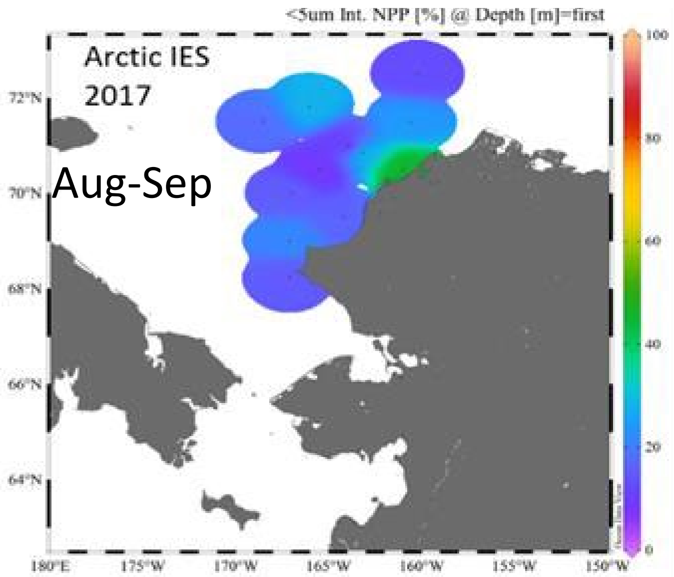
Phytoplankton Primary Productivity

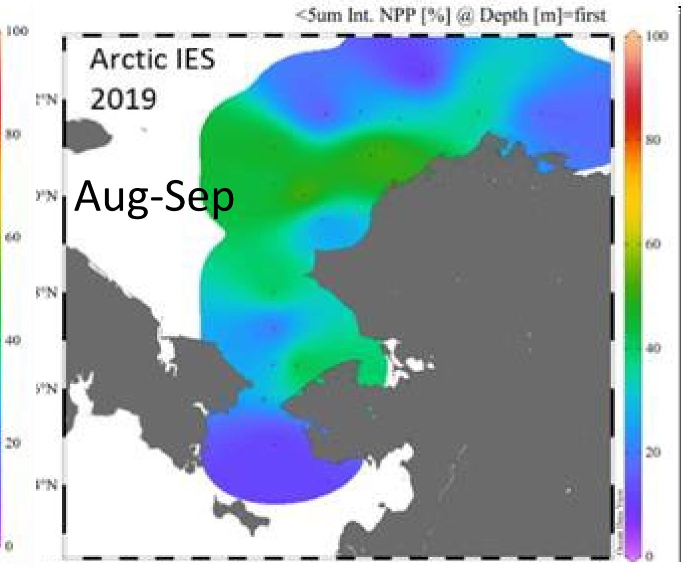
- Spring primary productivity is extremely patchy, 0.1 to 14 gC m^2/day. Average ~ 2 gC m^2/day.
- Summer primary productivity lower than in spring.
- Primary Productivity < 5 µm (small) phytoplankton
  - 0-20% in June 2018
  - 20-50% in Aug/Sept 2017, 2019

Figure: Percent of primary productivity in the < 5 µm size fraction (small).

Color scale 0-100%



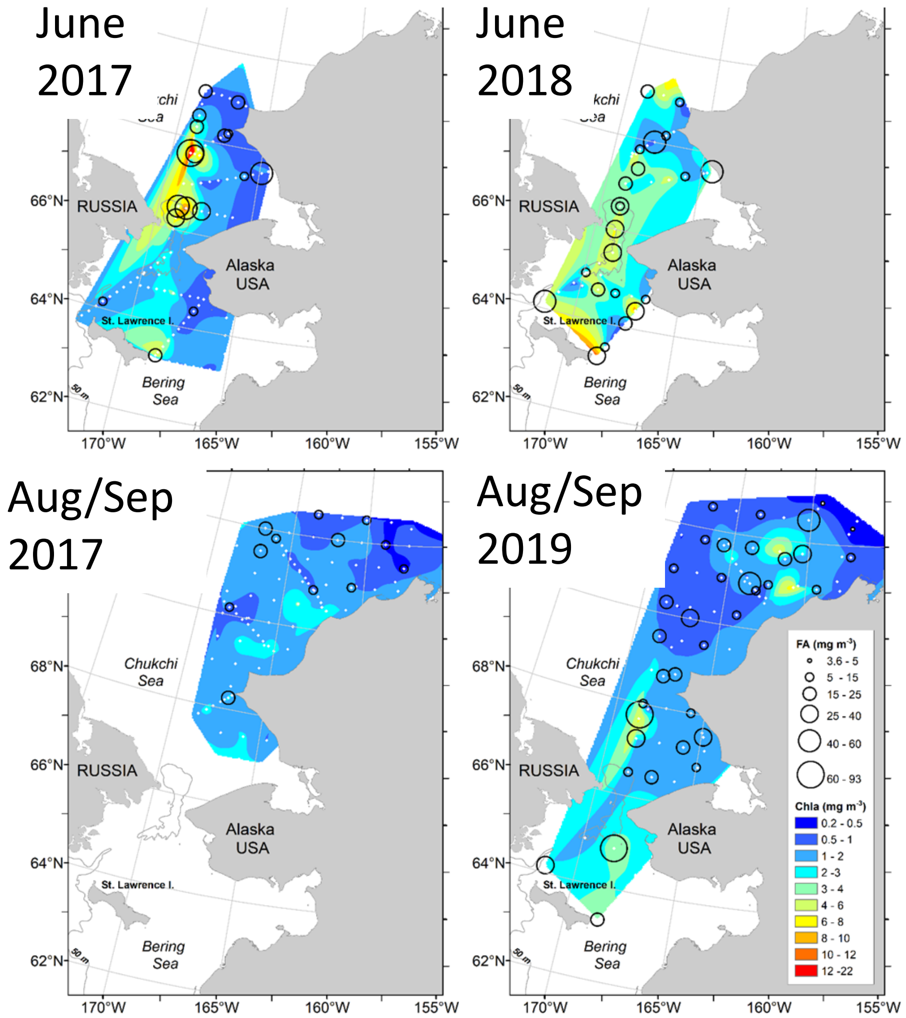




Eisner, Lomas

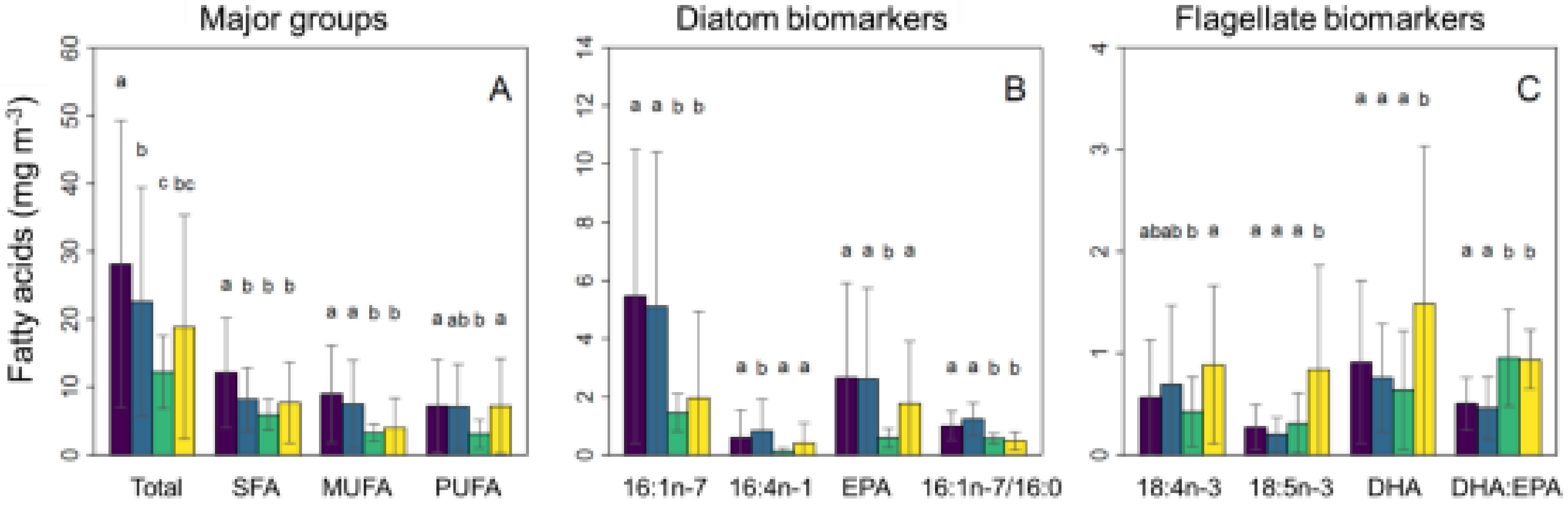
Phytoplankton and seston fatty acids (FA) dynamics in the northern Bering-Chukchi Sea

Mean chla (color) with total FA concentration (open circles)



Mean FA by survey:

Purple spring 2017, **Blue** spring 2018, **Green** summer 2017, **Yellow** summer 2019

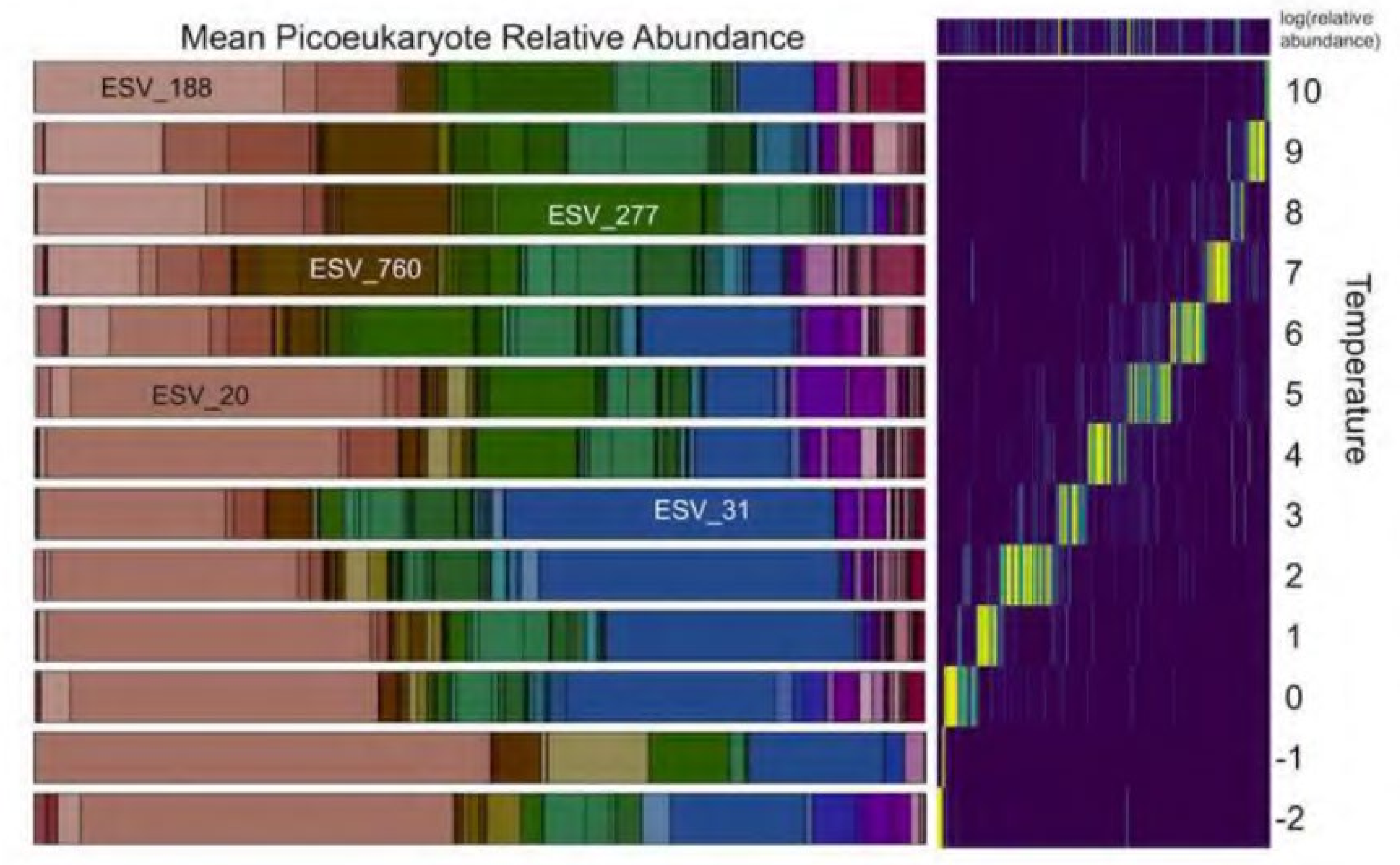


- Diatom FA more prevalent in spring;
- Dinoflagellate and small flagellate FA more prevalent in late summer/ fall.

Nielsen et al. 2022

Diversity and community structure of eukaryotic phototrophs in the north Bering and Chukchi seas:

Summer (June, Aug, Sep 2017) metabarcoding survey of 18S rRNA gene diversity



Based on their biogeographical distributions, abundant taxa that may be negatively affected as the region warms include:

Diatoms:

- *Chaetoceros sp.*
- *Pseudo–nitzschia sp.*

Picoplankton:*

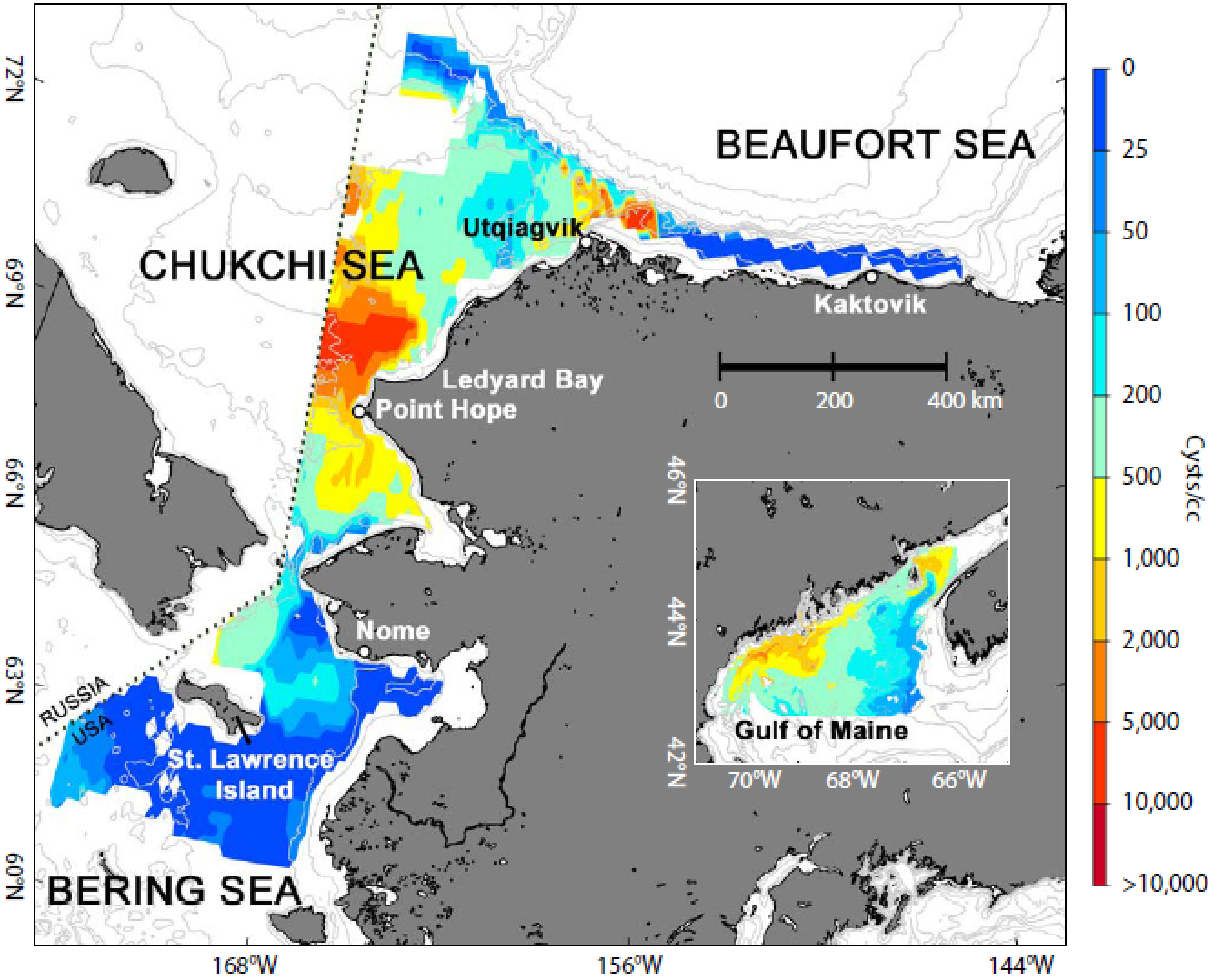
- *Micromonas sp.*
- *Phaeocystis sp.*

* “Picophytoplankton” defined as Chlorophyta, Haptophyta, and Chrysophyceae

Lekanoff et al. 2020

Harmful Algae Blooms

Evidence for massive and recurrent toxic blooms of *Alexandrium catenella* in the Alaskan Arctic



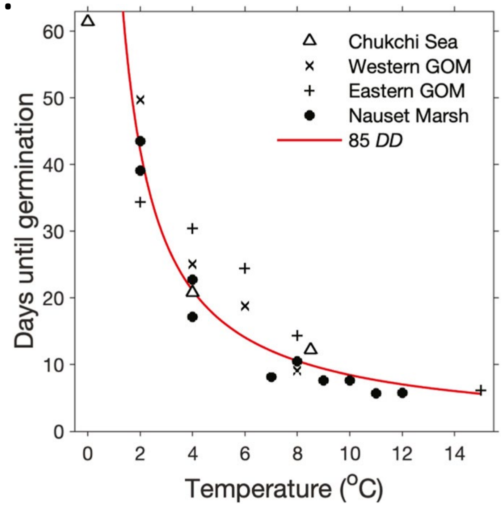
Alaskan (2018–2020) and Gulf of Maine (2004–2012) *Alexandrium catenella* cyst abundance in surface sediments, depicted on the same scale.

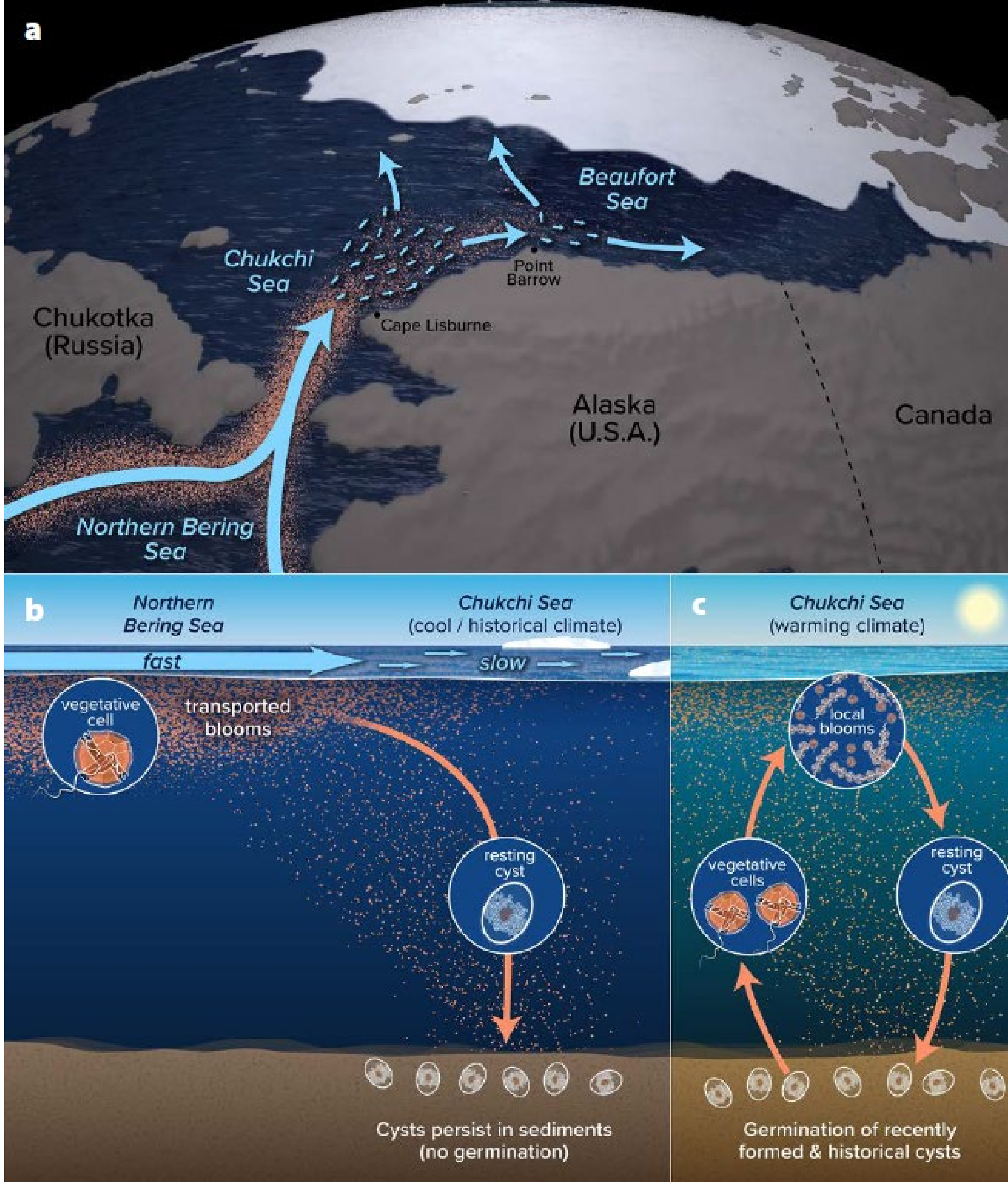
Sites visited across multiple years were averaged to create maps.

Anderson et al. 2021, 2022

Alexandrium catenella in the Alaskan Arctic

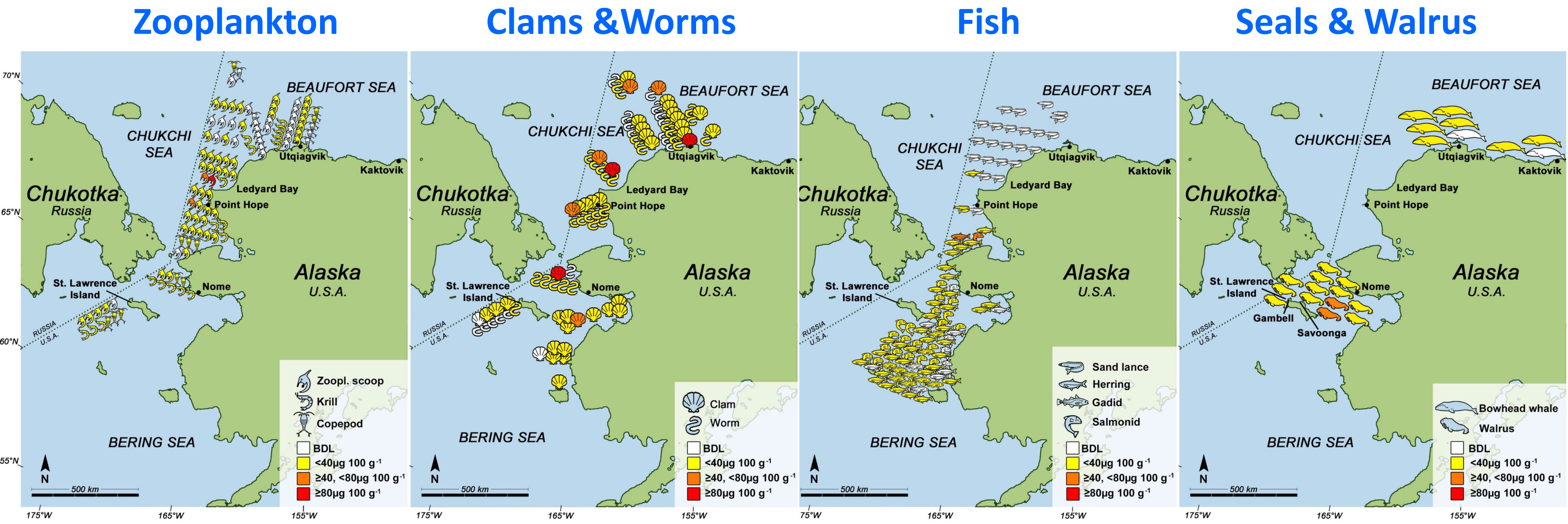
(a) Transport of blooms (orange dots) from NBS into the Chukchi Sea. Flow speeds decrease allowing *Alexandrium* cysts to be deposited (b).
(b) Bottom waters historically too cold to promote germination of cysts. Continued deposition of new cysts from the south.
(c) In warmer bottom water, cysts are able to germinate and initiate local blooms that in turn deposit new cysts. Locally formed cysts are supplemented with those produced by transported blooms.





Anderson et al. 2021, 2022

Paralytic shellfish toxins (PSTs) in Arctic food webs in 2019

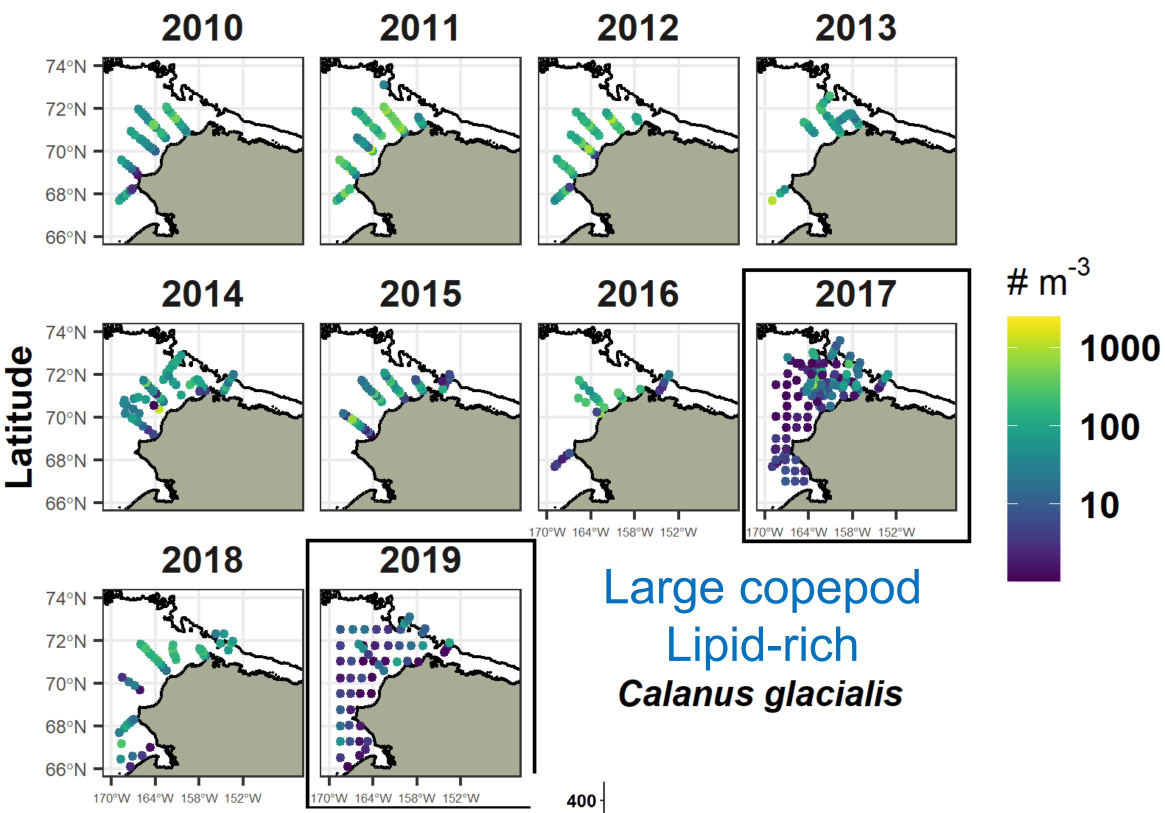


- PSTs were detected in all trophic levels with the highest concentrations in benthic clams.
- Fecal samples of Pacific walrus near St. Lawrence Is. contained PST (walrus known to forage for clams in that area)

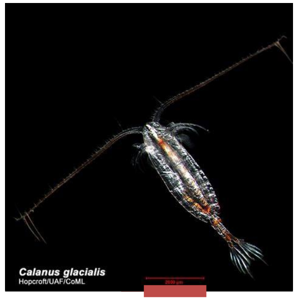
Lefebvre et al. 2022

Zooplankton and Fish larvae

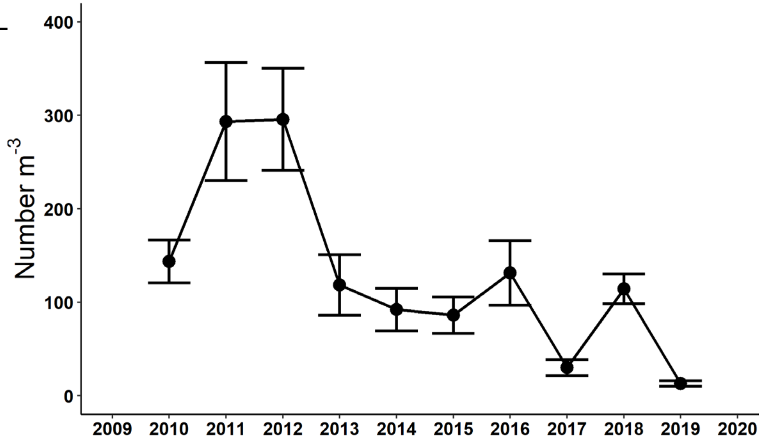
Zooplankton Abundance in the Chukchi Sea (summer)

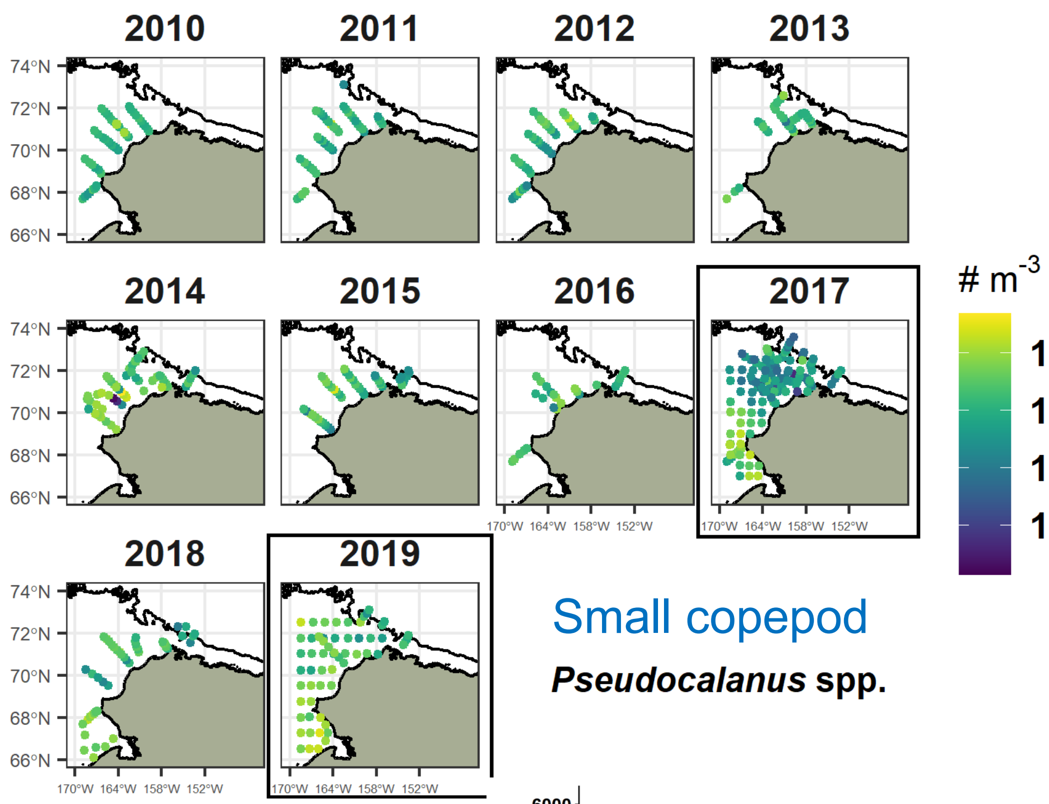


Large copepod
Lipid-rich
Calanus glacialis



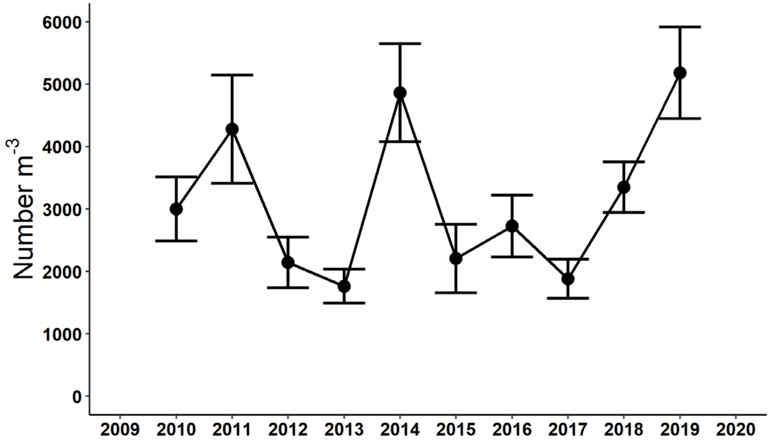
2000 µm





Small copepod
***Pseudocalanus* spp.**

500 µm



Spear, Kimmel, in prep

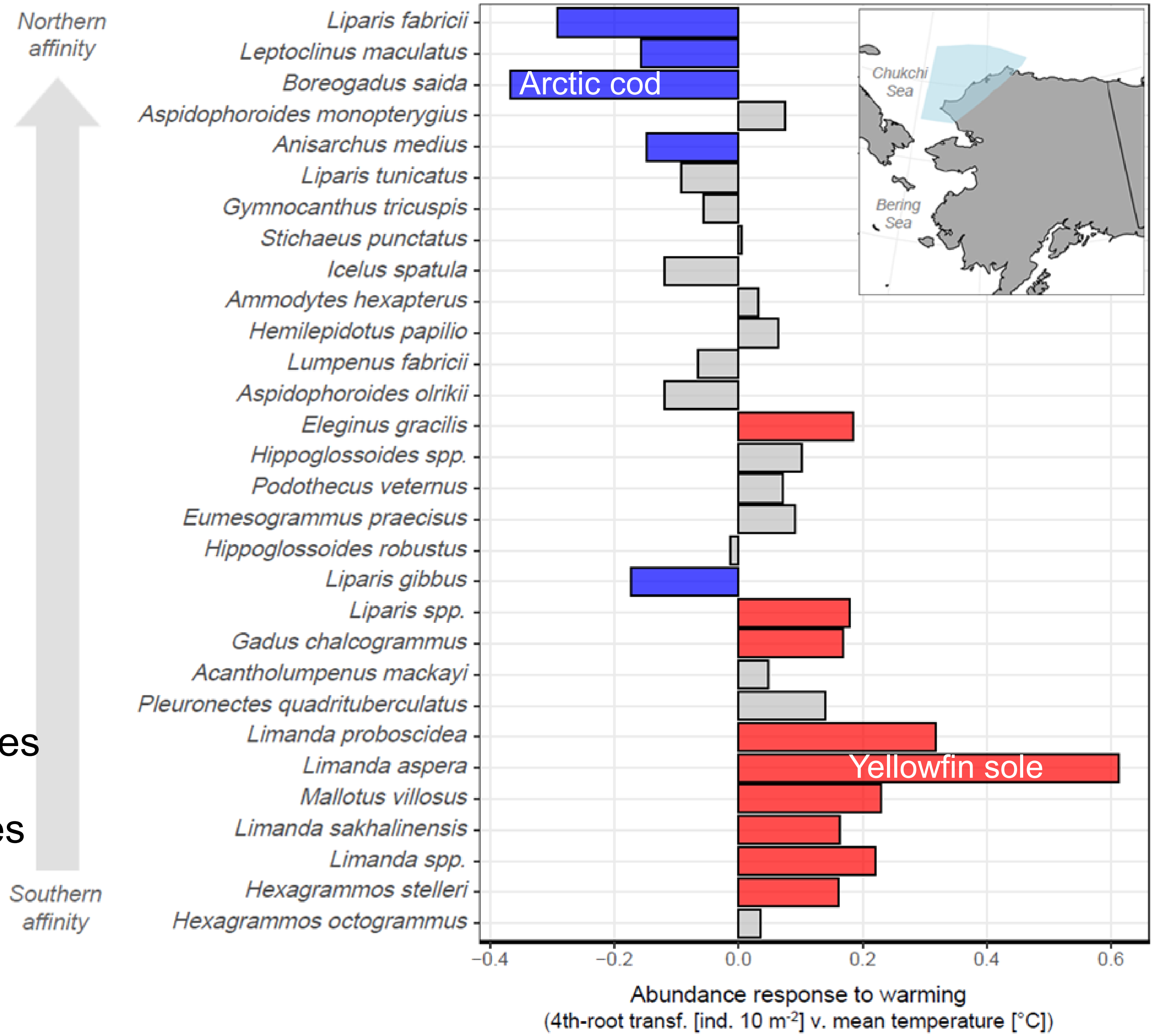
Arctic larval fish community changes (summer 2010-2019)

Taxa are sorted based on their mean latitudinal distribution in cold years (i.e., 2012-2013; proxy for average baseline Arctic conditions).

Years with higher SST:

⬆ Areal coverage of **Warm** water species

⬇ Areal coverage of **Cold** water species



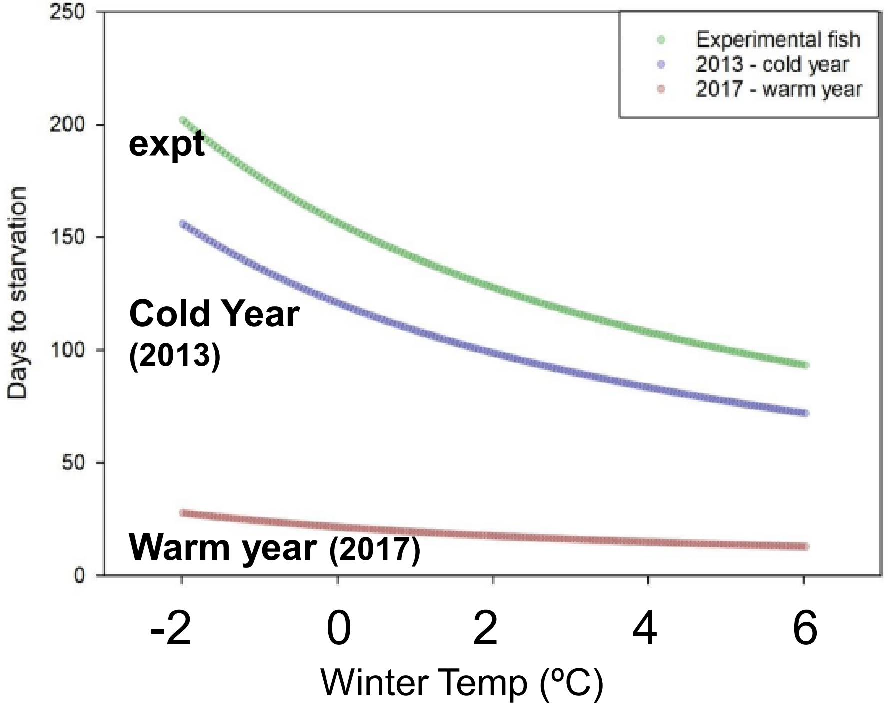
Axler et al. in prep

Fish

Changing fats in cod species from the Arctic

Experimental set-up of Arctic cod in tanks

Days to starvation based on the lab-determined temperature-dependent fat loss models



- Arctic cod has a unique fat storage strategy compared to other cods in the region.
- High levels of Arctic cod starvation are likely to follow a warm fall; better survival after a cold fall.
- Arctic cod with high levels of fat storage showed elevated biomarkers characteristic of diatom- and *Calanus*-copepod-sources.

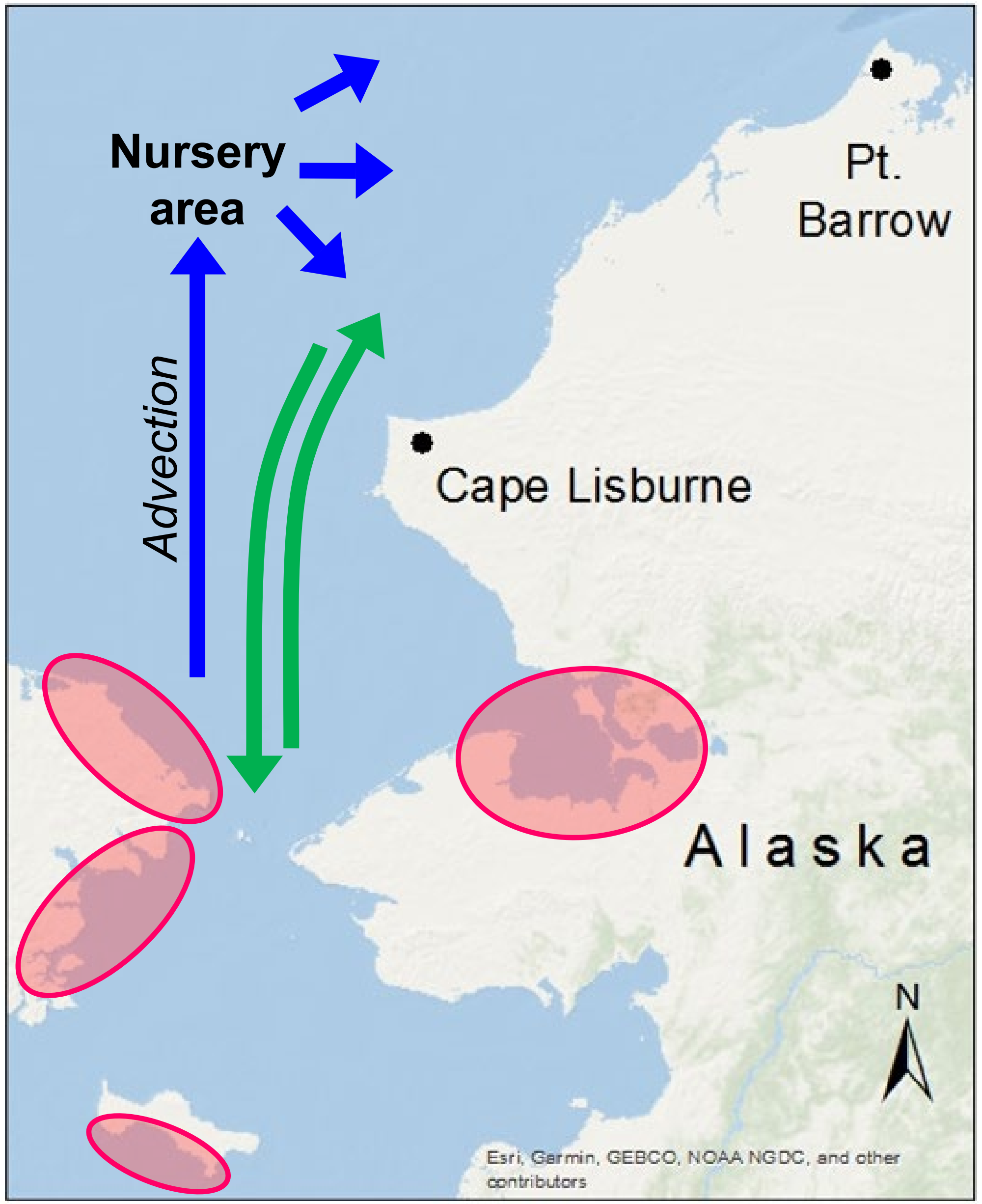
L. Copeman, NOAA

Arctic Cod (*Boreogadus Saida)*

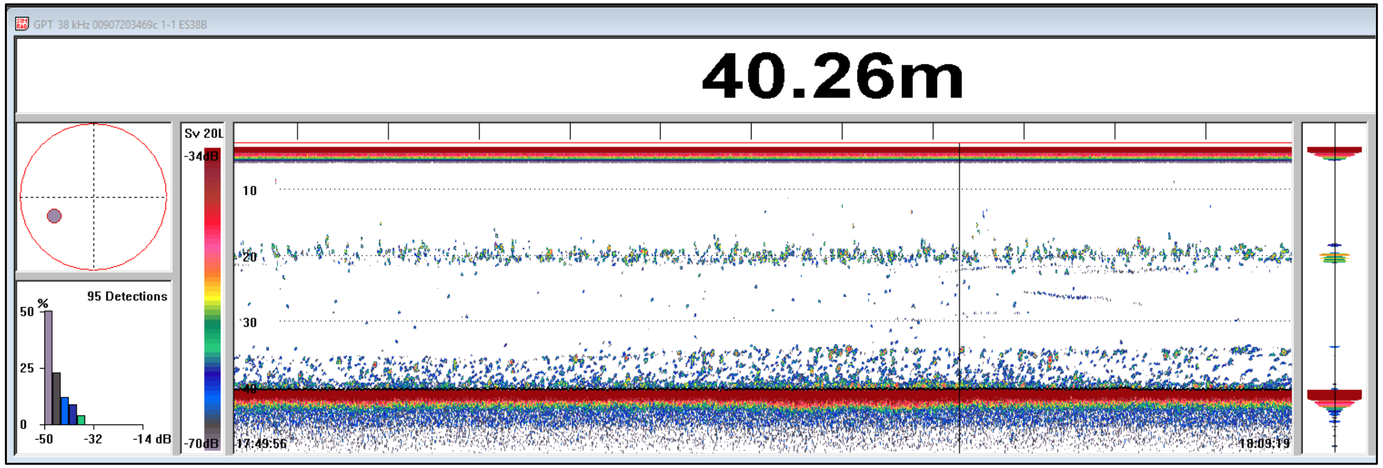
Life History
Conceptual Model
Seasonal Data

Results indicate potential spawning areas (pink) during late winter/early spring and advection of larvae northward to the Chukchi Sea (nursery area) during spring/summer.

The adult model (green arrows) indicates most of these fish are off the shelf during summer and they migrate during late fall south, spawn during late winter/early spring, and migrate back north during spring.

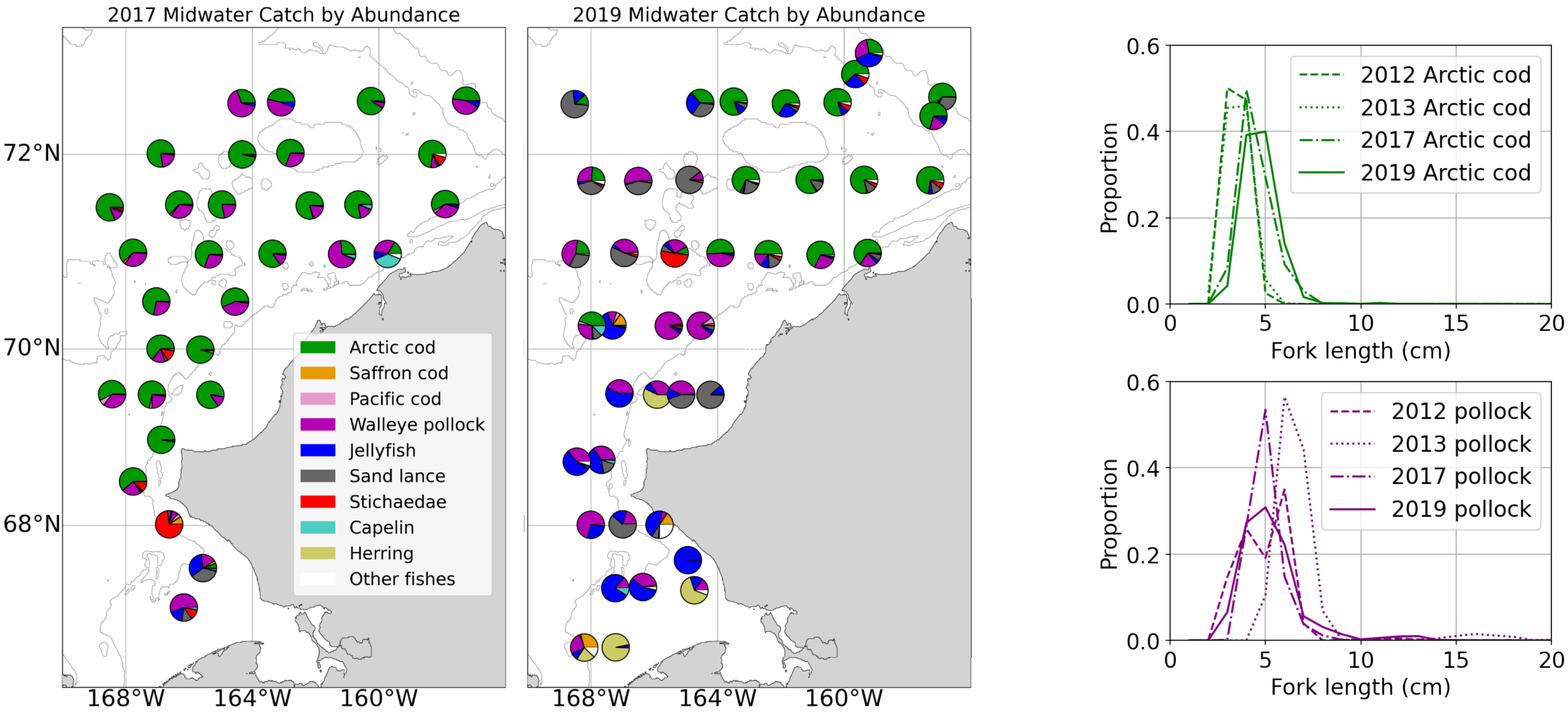


C. Vestfalls, F. Mueter
C. Forster, B. Norcross

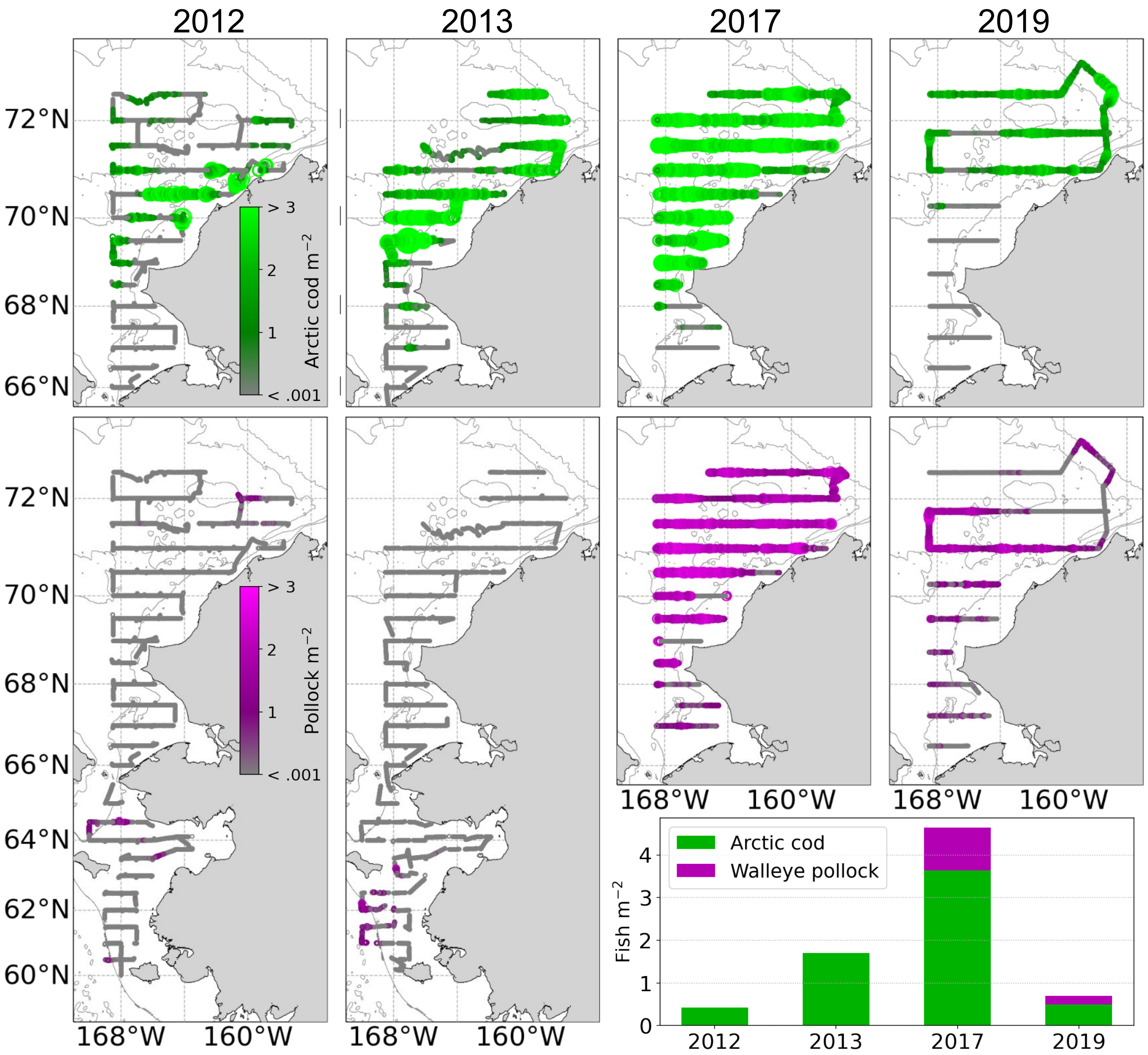


Acoustic-trawl surveys conducted in 2017 and 2019

Pelagic fishes are dominated by small age-0 Arctic cod and pollock



Levine et al., in review

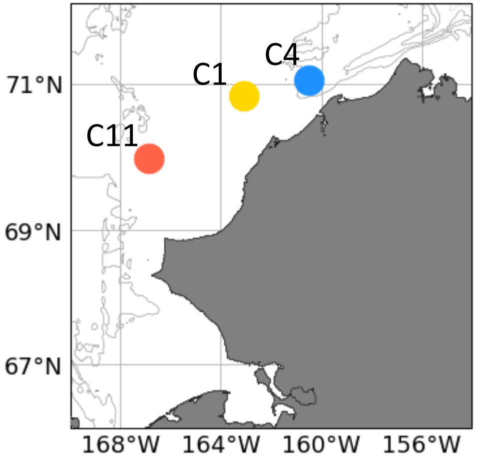


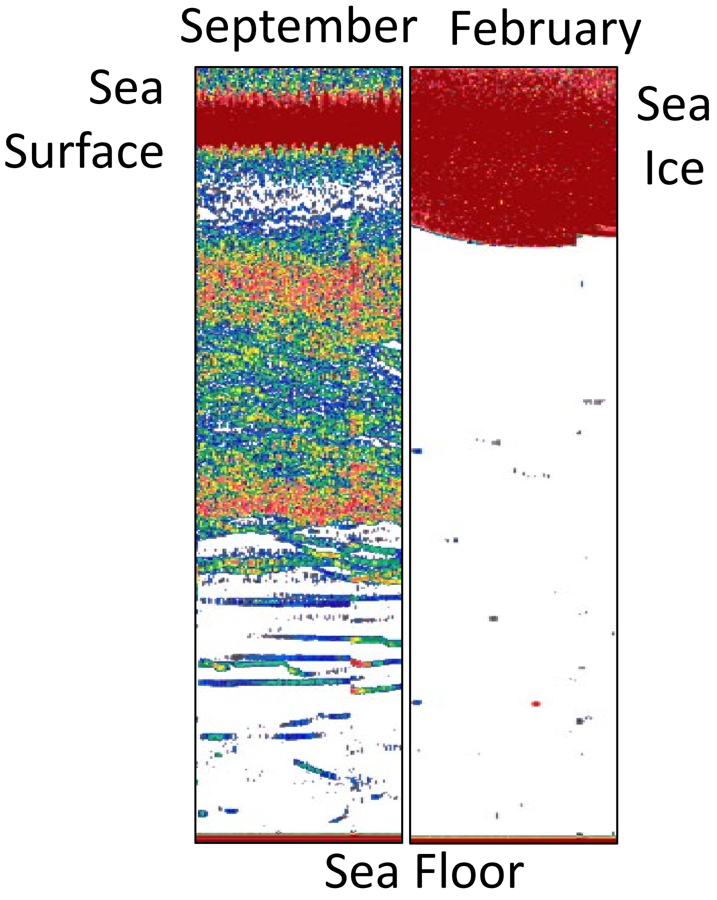
High interannual variability in abundance and distribution

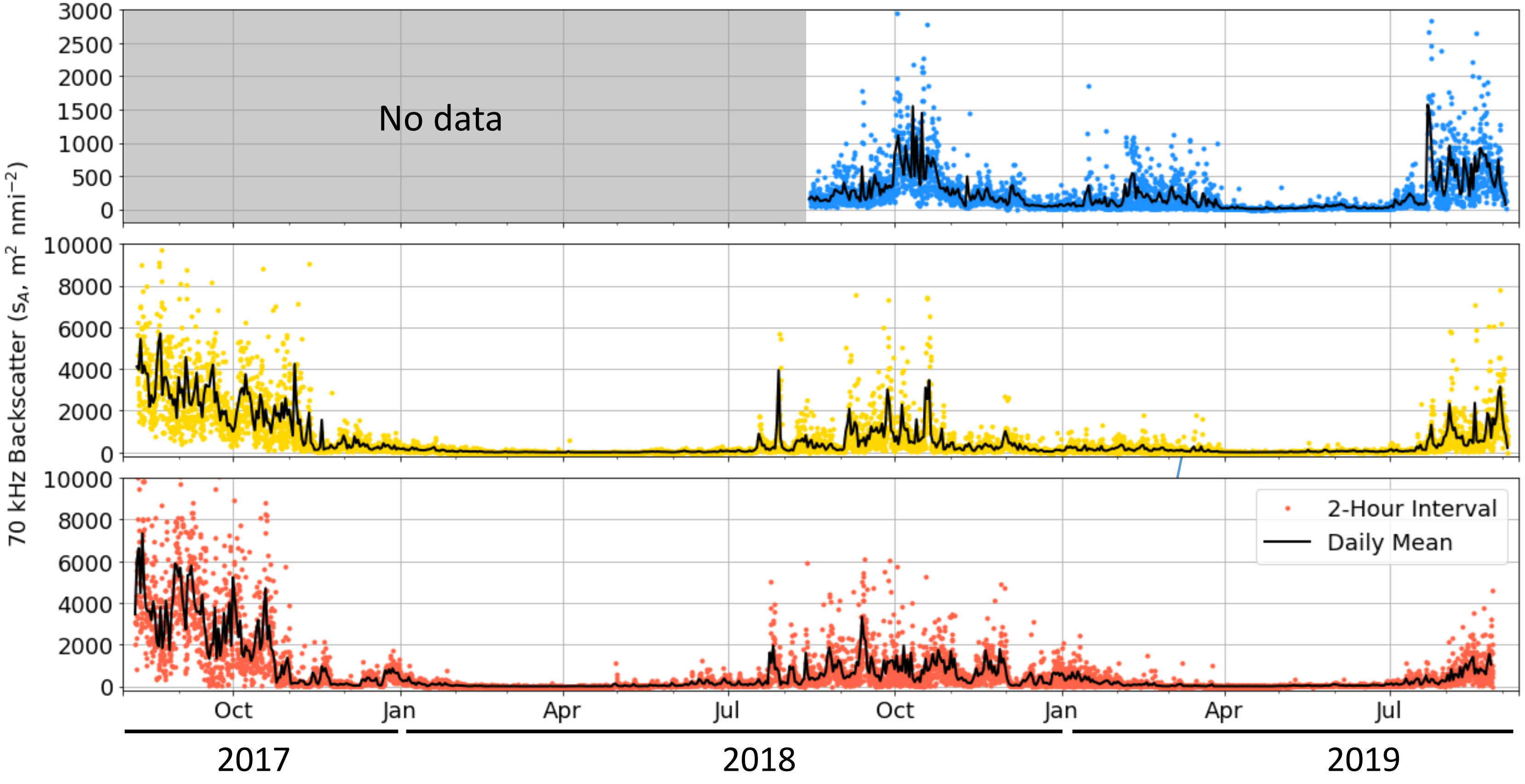
- **Age-0 Arctic cod** continue to dominate the pelagic fish community
- **Walleye pollock** accounted for approximately 21% in 2017 and over 26% in 2019 (<1% in 2012 and 2013)

Levine et al., in review

Year-round acoustic observations from moorings

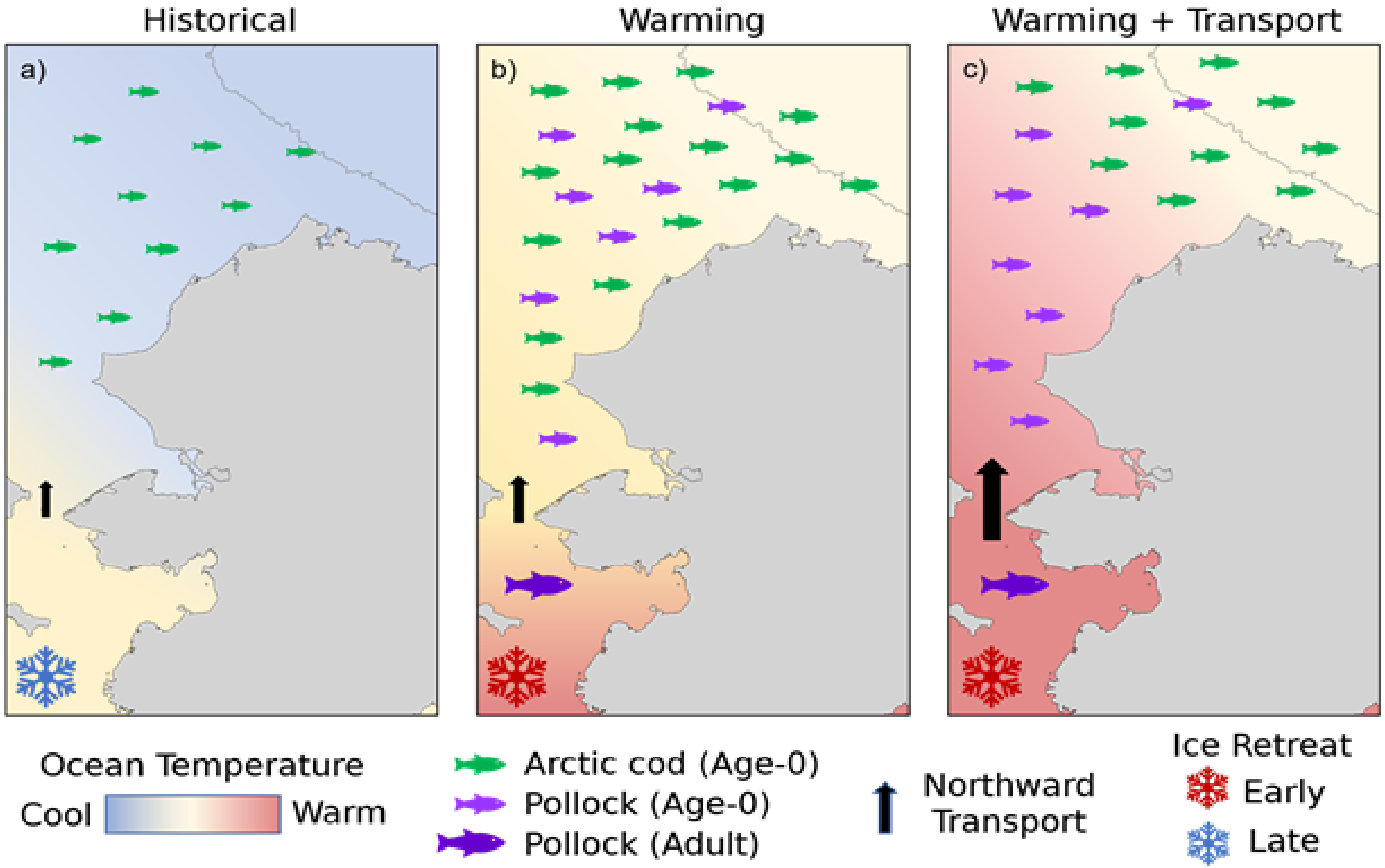






Levine et al., in review

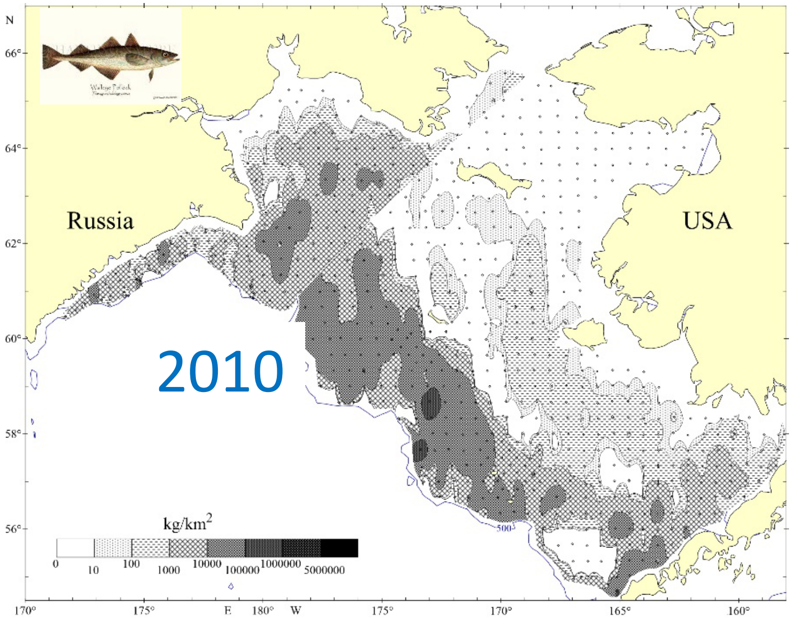
Hypothesized Scenarios for the Gadid Community

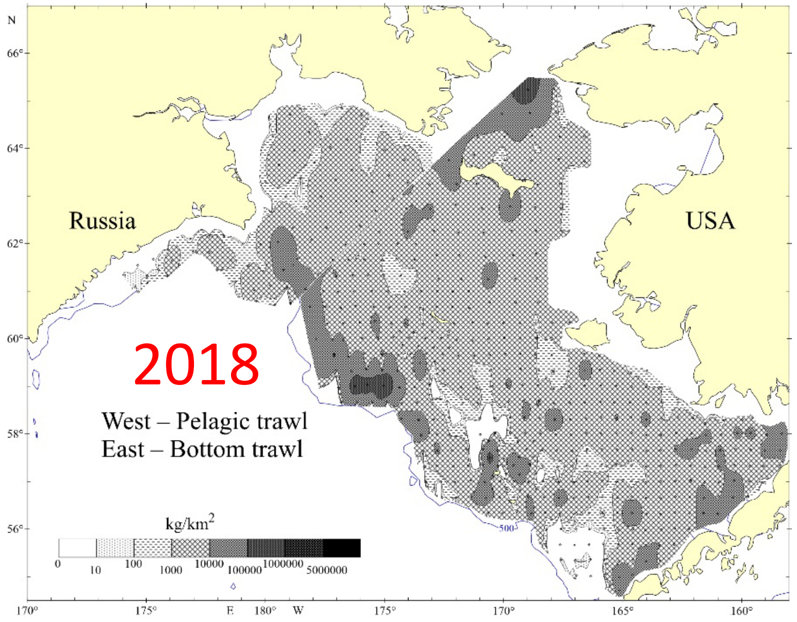


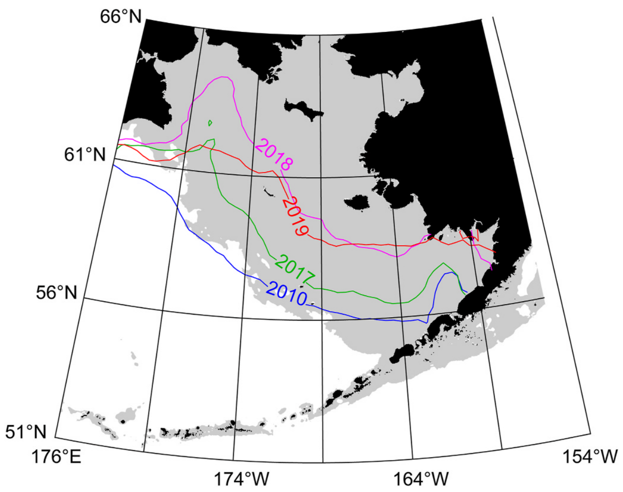
The 1000-m depth contour is shown to indicate the Chukchi shelf break.

Levine et al., in review

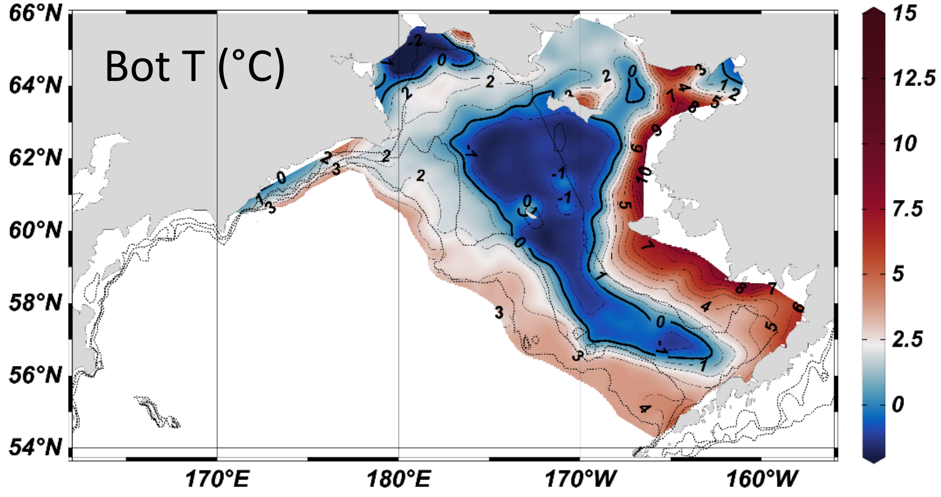
Adult pollock distribution and bottom temperature in cold high ice (2010) and warm very low ice (2018) years

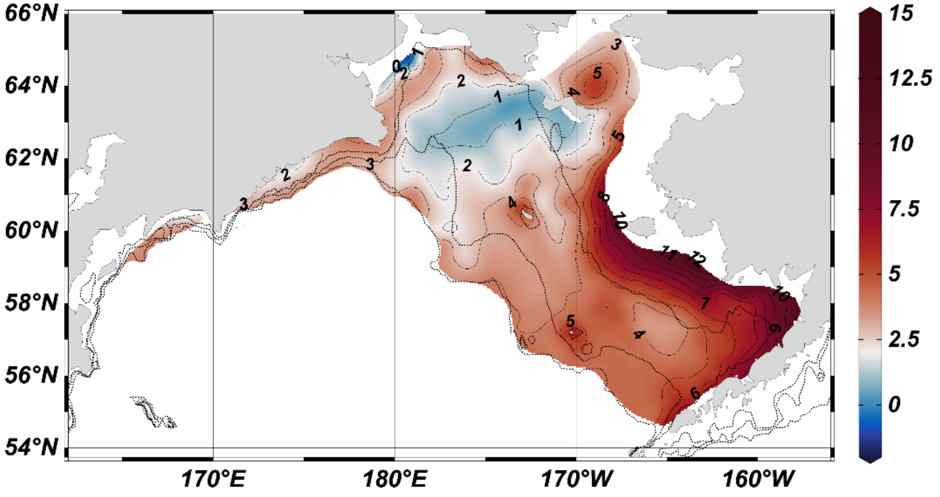






Maximum sea-ice extent in the Bering Sea for 2010, 2017, 2018, 2019.

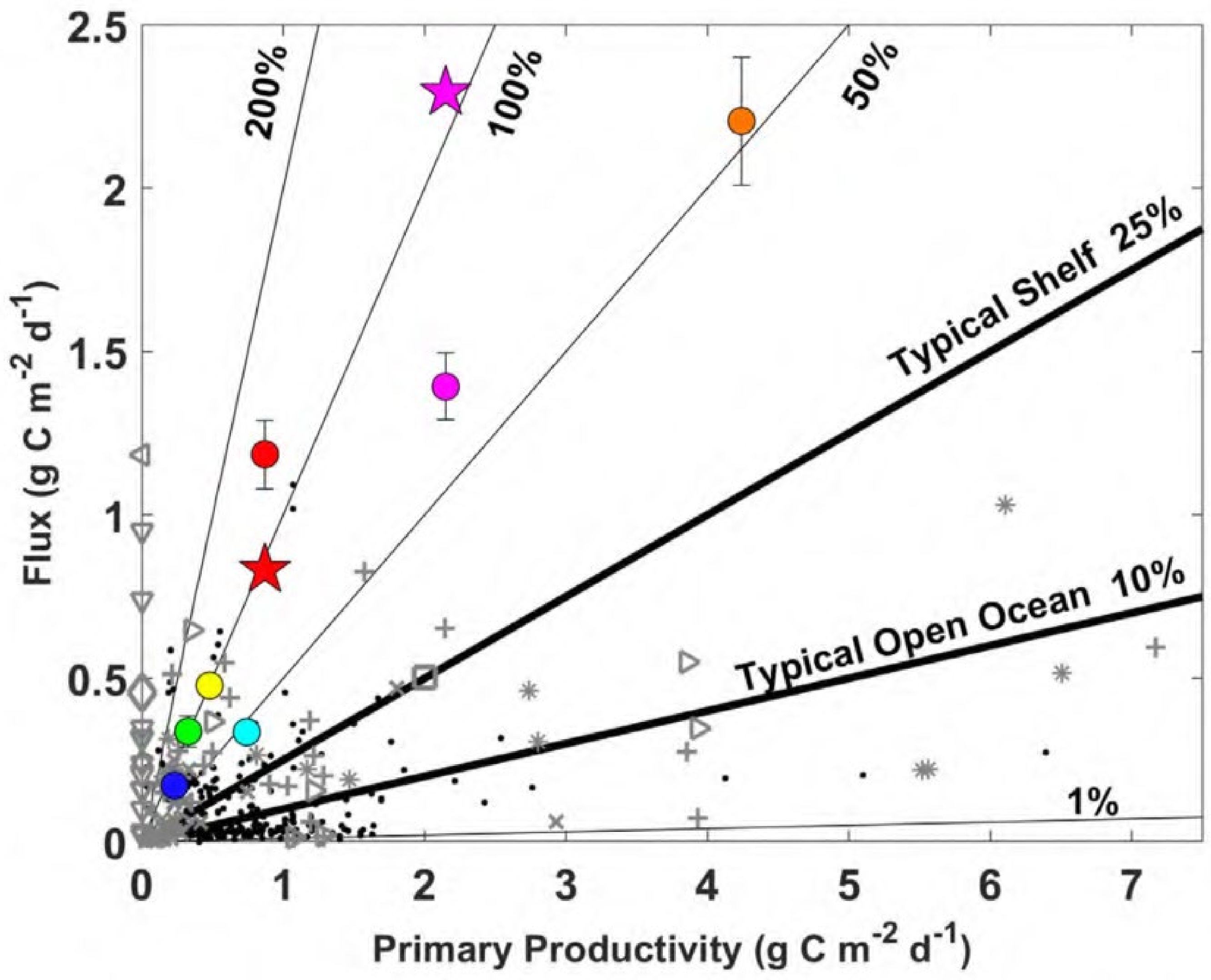




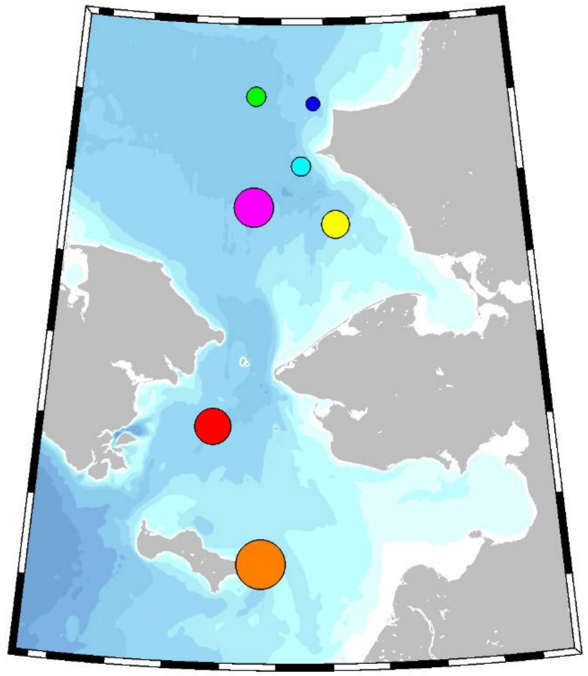
Eisner et al., 2020

Pelagic Export & Benthic Carbon Consumption

Pelagic Export- Highly efficient



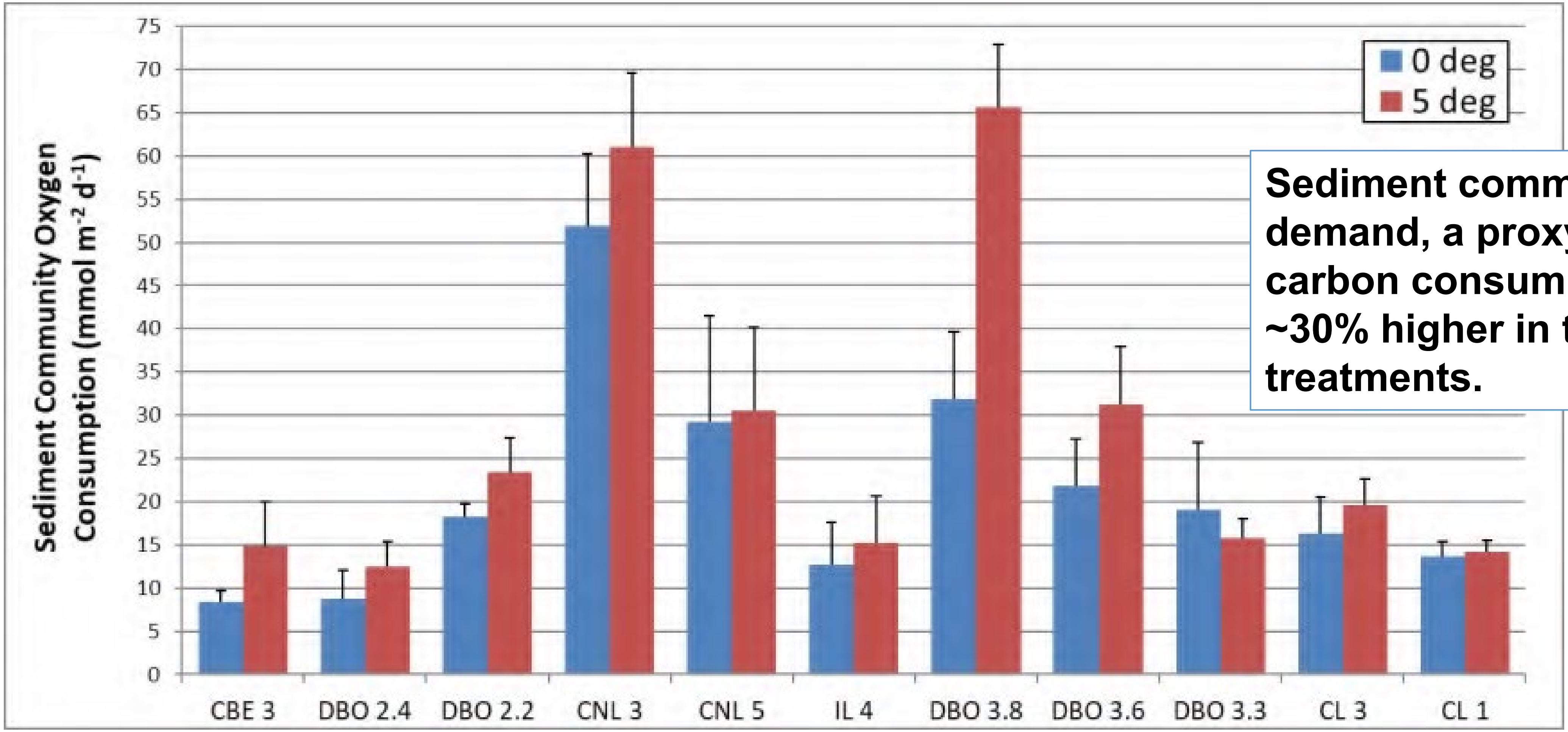
Carbon flux
June 2018



Export Ratio = $\frac{\textbf{Sinking Flux}}{\textbf{Primary Productivity}}$ **X 100%**

O'Daly et al. 2020

Spatial patterns and effects of temperature on rates of organic matter processing in sediments (microbes and metazoans) across the NBS and southern Chukchi Sea



Sediment community oxygen demand, a proxy for organic carbon consumption, was ~30% higher in the warmer treatments.

S. Mincks UAF

Summary

- Increased surface heat flux exchanges and oceanic heat advection over the Bering and Chukchi shelves during our study years.
- Majority of Primary Production and Chla biomass from large phytoplankton, but small phytoplankton important (e.g. *Synechococcous*) in regard to carbon contribution, particularly in summer and in warmer years (2019).
- Small phytoplankton and small copepods increased and large lipid-rich copepods (Calanus glacialis) decreased in warm years.
- Harmful Algae Blooms (*Alexandrium* sp.) are increasing with warming in the Chukchi Sea; blooms advected into Chukchi and locally produced from extensive cyst beds. Toxins found in food web.
- Borealization evident for many taxa with expansion north of warmer water species (e.g., yellowfin sole larvae, age-0 Pollock and Pacific cod) and contraction north of cold water species (e.g., Arctic cod larvae and age-0s).
- Higher metabolic requirements at higher temperatures (e.g., increased sediment carbon consumption) or lack of high energy prey resources (e.g., reduction of large lipid rich copepods in age-0 Arctic cod diets) will likely impact community structure at many trophic levels.

Climate change predictions for gateway seas (Mueter et al. 2021):

Shifts in spatial distribution of boreal species;

Shift to smaller less nutritious zooplankton prey with detrimental affect on fisheries;

Shift to pelagic from benthic -dominated food webs (new Project).

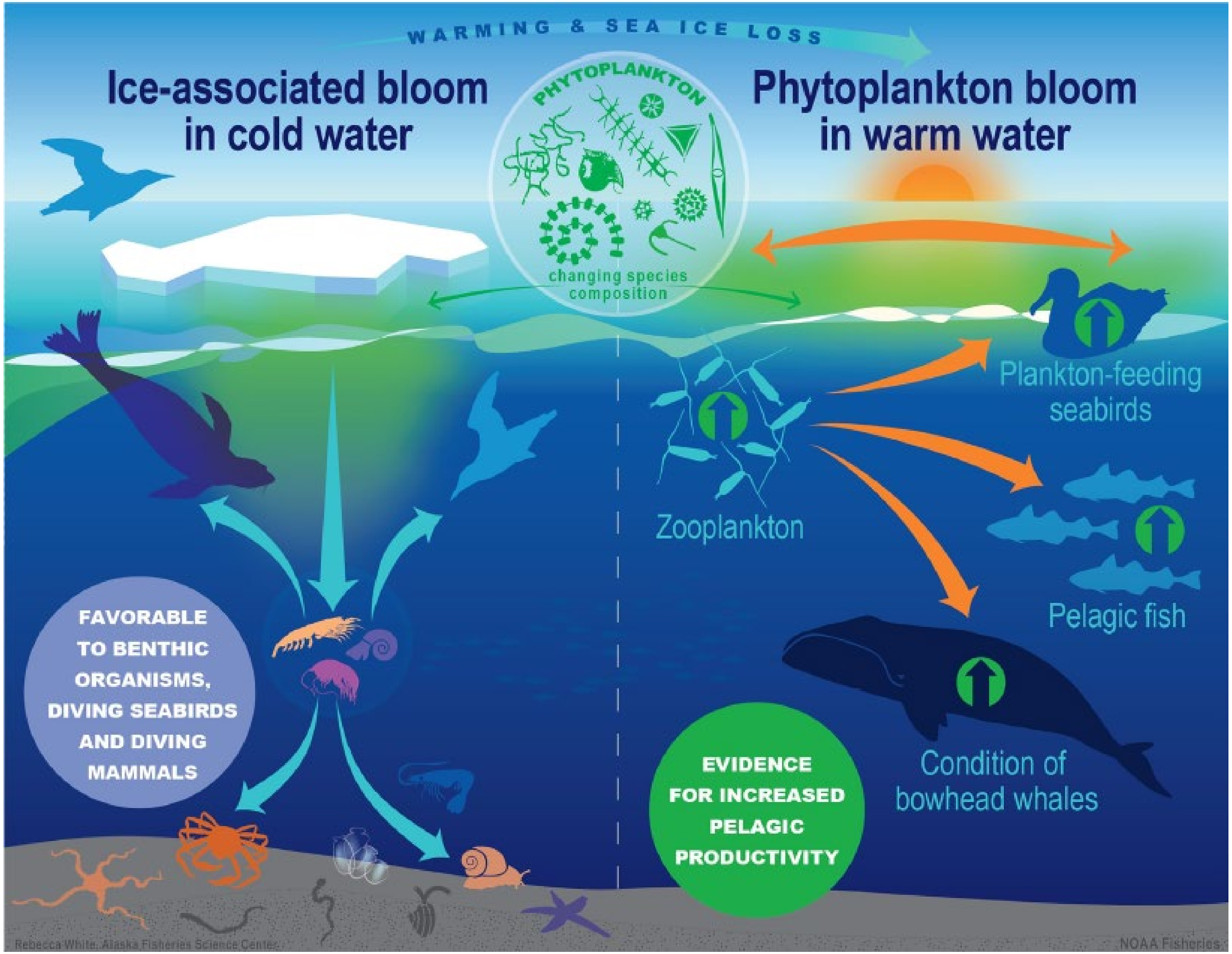


Figure: Mueter et al. 2021; https://doi.org/10.1093/icesjms/fsab

Pelagic-Benthic Synthesis Project

Benthic-pelagic de-coupling: Ecosystem re-assembly in the Northern Bering and Chukchi seas

Institutional Principle Investigators (alphabetical order):

Jackie Grebmeier and Lee Cooper (University of Maryland Center for Environmental Science)

Katrin Iken (University of Alaska Fairbanks)

Elizabeth Logerwell* and James Thorson (NOAA Alaska Fisheries Science Center)

Mike Lomas (Bigelow Laboratory for Ocean Sciences)

Ryan McCabe (NOAA Pacific Marine Environmental Laboratory)

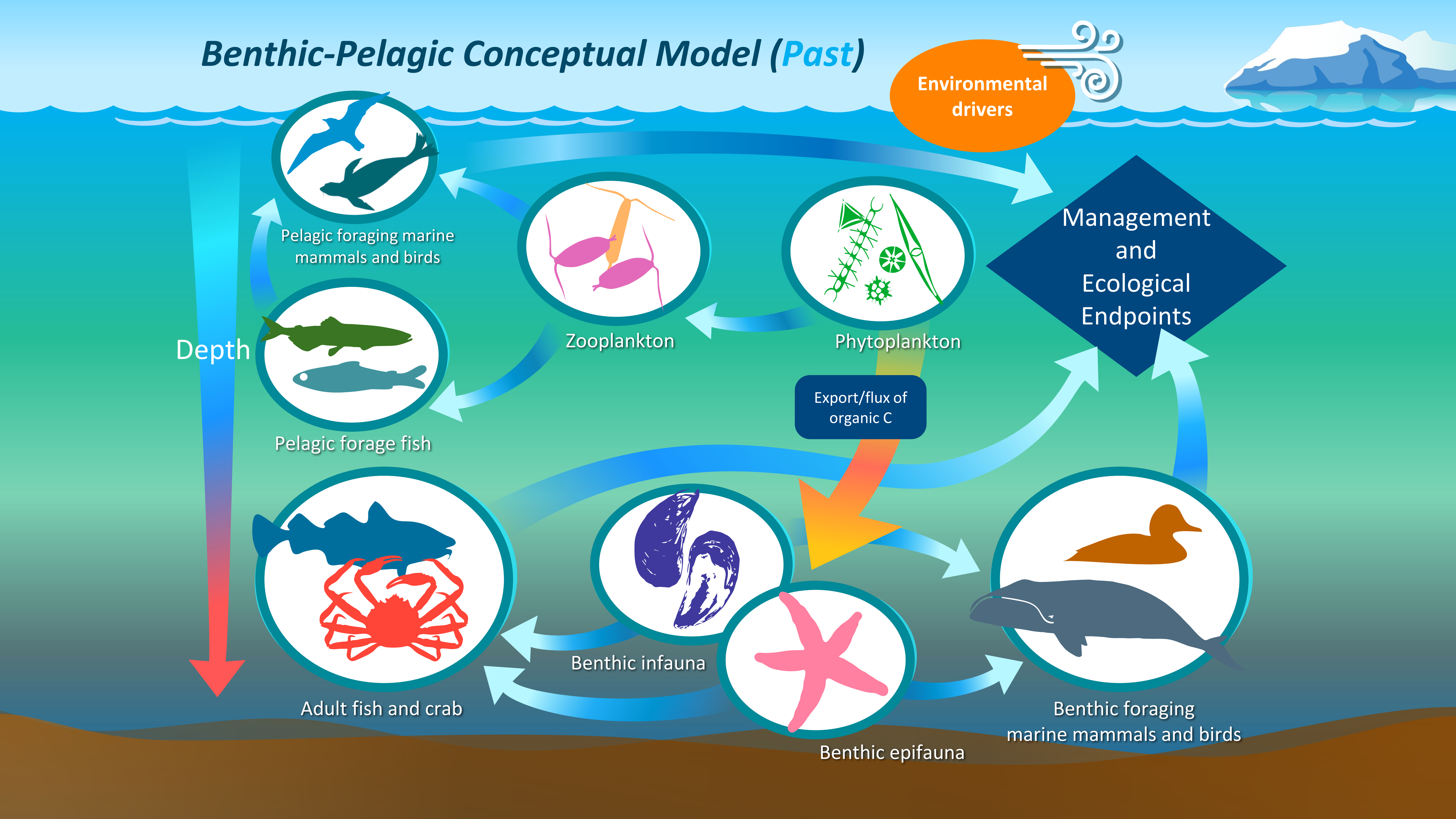
Calvin Mordy (University of Washington)

Astrid Schnetzer (North Carolina State University)

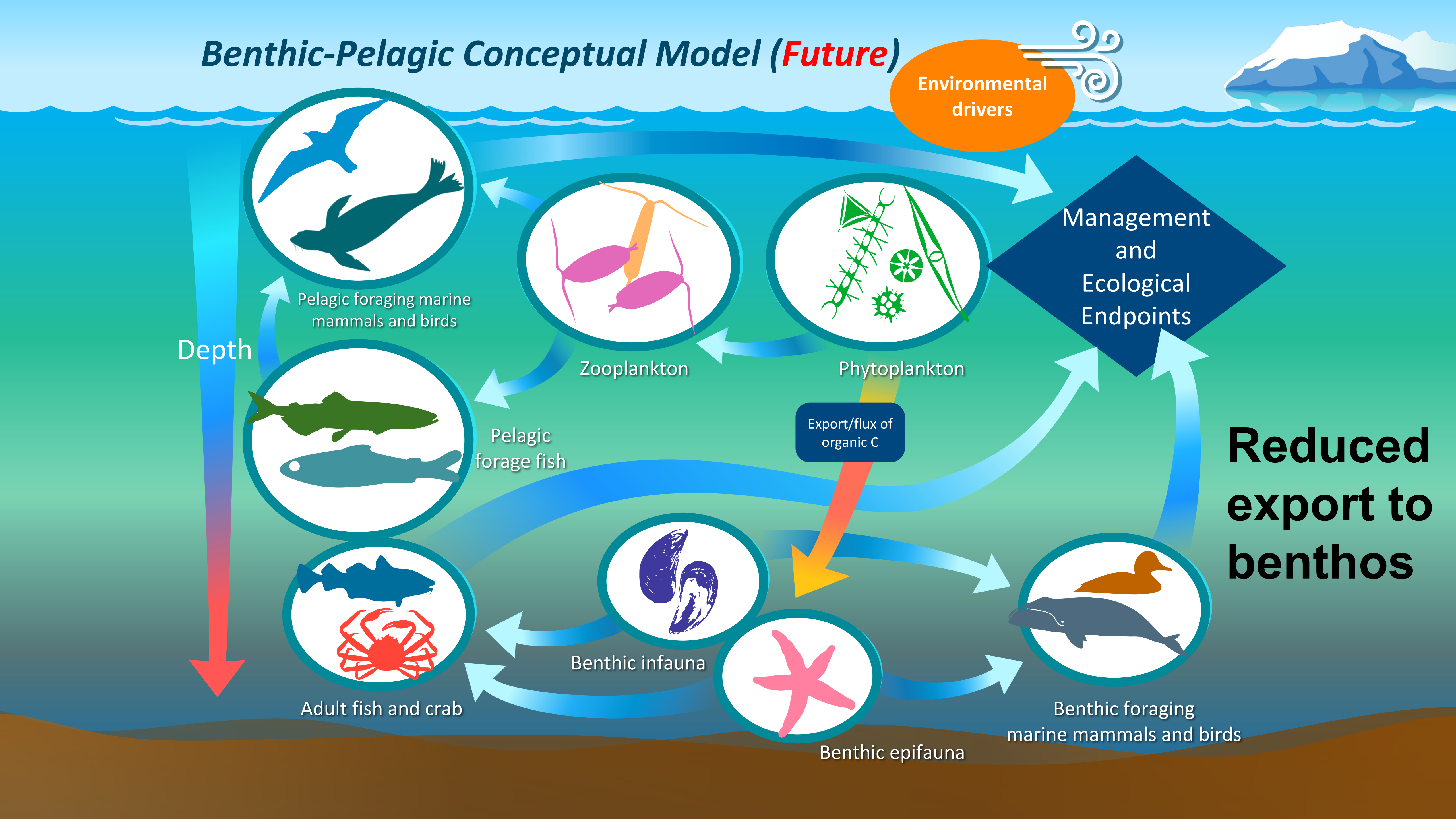
**Lead PI*

Overarching questions

- Has there been and will there continue to be a reorganization of the Northern Bering - Chukchi Sea ecosystem resulting from a breakdown in benthic-pelagic coupling?
- Has the prey base for subsistence resources (e.g., benthic foraging marine mammals and birds) and commercial groundfish and crab declined or increased?
- What are the observed and predicted spatial patterns of temporal change?



Benthic-Pelagic Conceptual Model (Past)
Environmental drivers
Management and Ecological Endpoints
Pelagic foraging marine mammals and birds
Zooplankton
Phytoplankton
Depth
Pelagic forage fish
Export/flux of organic C
Adult fish and crab
Benthic infauna
Benthic epifauna
Benthic foraging marine mammals and birds



Benthic-Pelagic Conceptual Model (Future)
Environmental drivers
Management and Ecological Endpoints
Pelagic foraging marine mammals and birds
Zooplankton
Phytoplankton
Depth
Pelagic forage fish
Export/flux of organic C
Reduced export to benthos
Benthic infauna
Adult fish and crab
Benthic epifauna
Benthic foraging marine mammals and birds

PICES WG-44

INTEGRATED ECOSYSTEM ASSESSMENT OF THE NORTHERN BERING SEA – CHUKCHI SEA (NBS-CS) (WG 44)
PICES/ICES

Chairs: Yury Zuenko and Libby Logerwell

Terms of reference - General

- Convene an interdisciplinary and international working group
- Include Arctic peoples and Indigenous Knowledge systems
- Identify and consult with partners and institutions

Goals

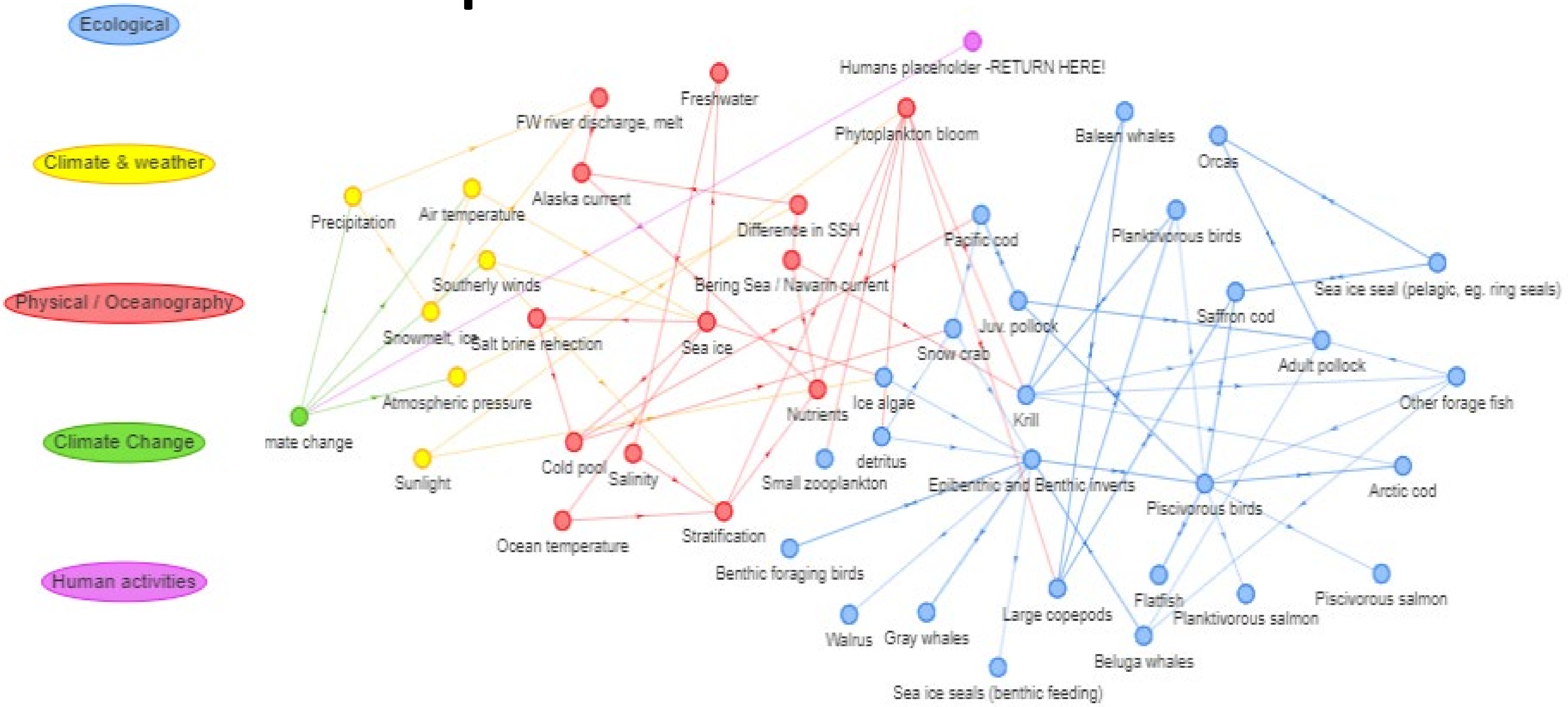
Activities

- Assess ecosystem status and trends
- Identify potential impacts/risks
- Knowledge gap analysis

Deliverables

- Integrated Ecosystem Assessment for the Northern Bering Sea-Chukchi Sea LME.
- Journal articles
- Outreach activities
- Knowledge Gap and Next Steps Report

Example Model



The Ecological Model. All nodes