The Pacific Arctic Region: A Window into Shifting Benthic Populations in Response to Ecosystem Change

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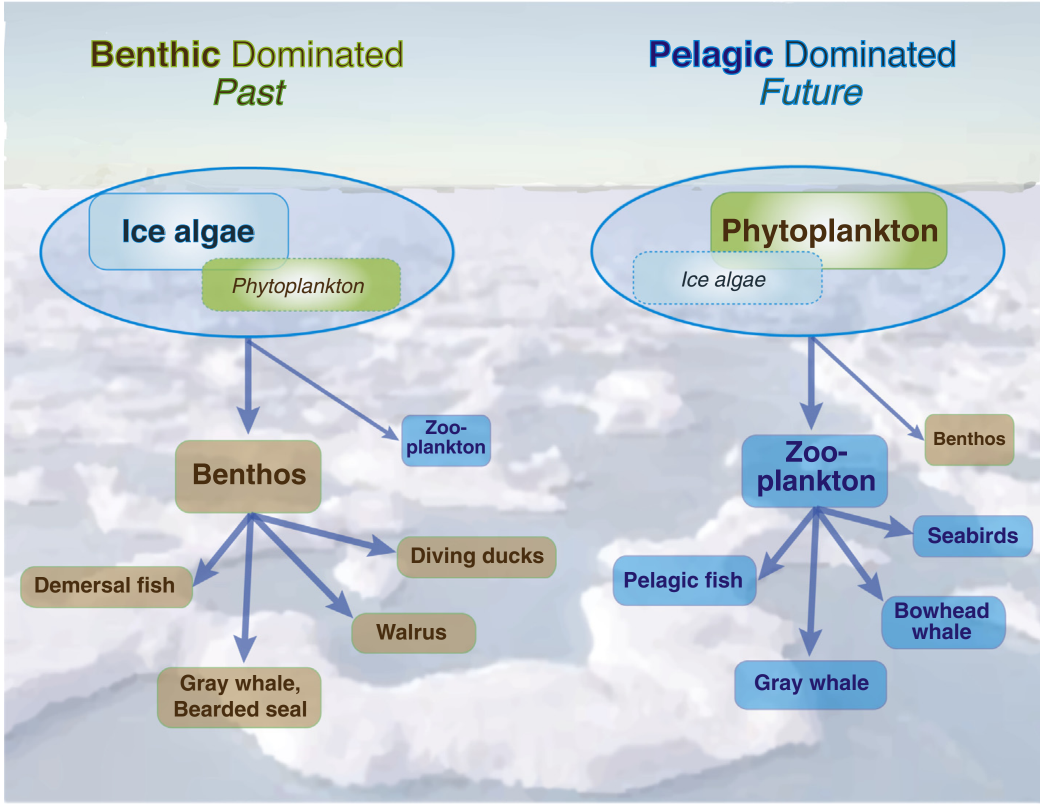
Thursday, July 28, 2016
10:45-11:15 am

Ocean Carbon and Biogeochemistry (OCB) Summer Workshop
Woods Hole Oceanographic Institution

INTRODUCTION

- A **key ecological organizing principle in** Pacific Arctic region is that the shallow, seasonally productive waters lead to strong pelagic-benthic coupling to the sea floor, with deposition of fresh chlorophyll coinciding with the spring bloom as sea ice retreats

- Benthic macrofauna dominated by **clams, polychaetes, sipunculids, and amphipods** feed on rapidly deposited carbon to the seafloor, which in turn serve as food resources for **diving mammals and seabirds,** such as gray whales, bearded seals, eiders, and walruses



Generalized conceptual model depicting the influence of sea ice on pelagic–benthic coupling on Pacific Arctic continental shelves.

Pelagic-Benthic Coupling Model

[Moore and Stabeno 2015, Prog. Oceangr.]

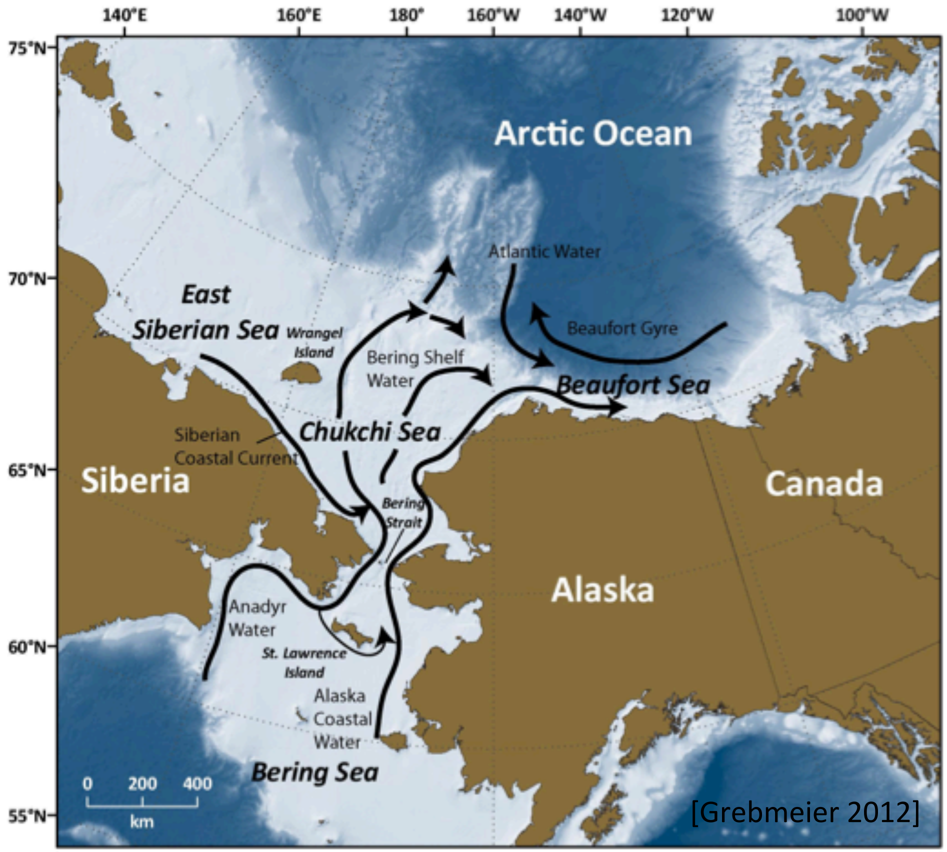
Key Points of Presentation

- Overview of key environmental drivers that influence benthic processes, prey-predator interactions, and ecosystem dynamics
  - Decrease in sea ice extent and duration
  - Seasonal warming bottom seawater temperatures
  - Change in prey concentrations
  - Northward movement of core benthic faunal biomass in hotspot areas associated with variable carbon deposition

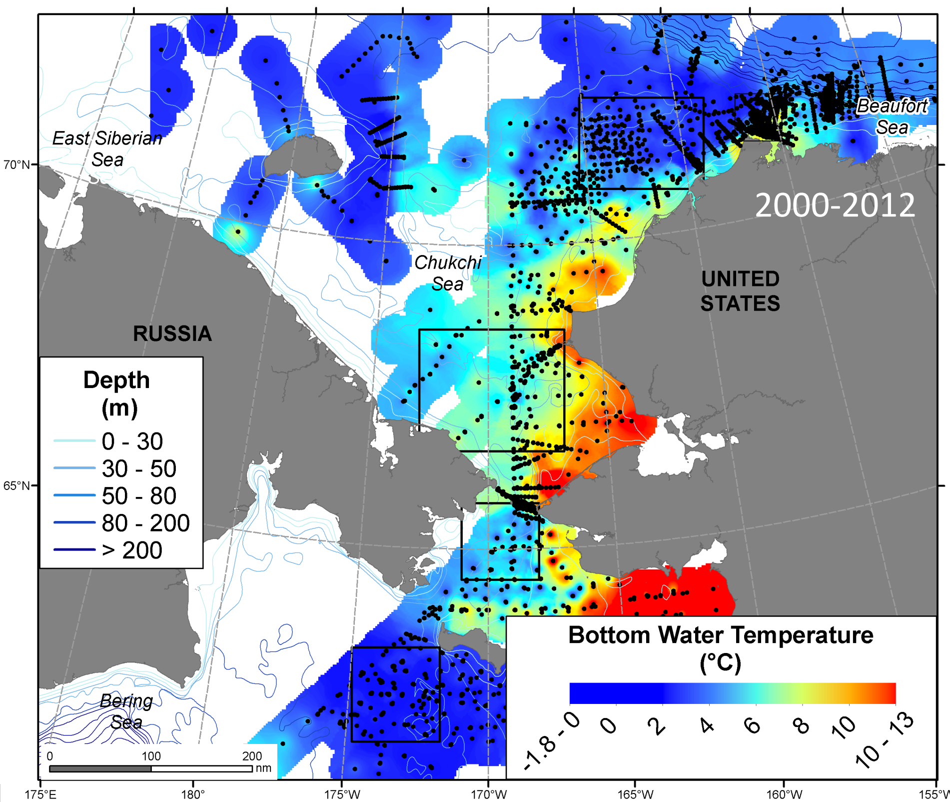
- Decadal scale studies provide status and trends of ecosystem response to advective shifts on the Arctic shelves

- Repeat sampling on both temporal and spatial scales facilitate evaluation of the seasonality of ecosystem status and trends, such as the international Distributed Biological Observatory (DBO)

Current flow and bottom water temperatures from March-October



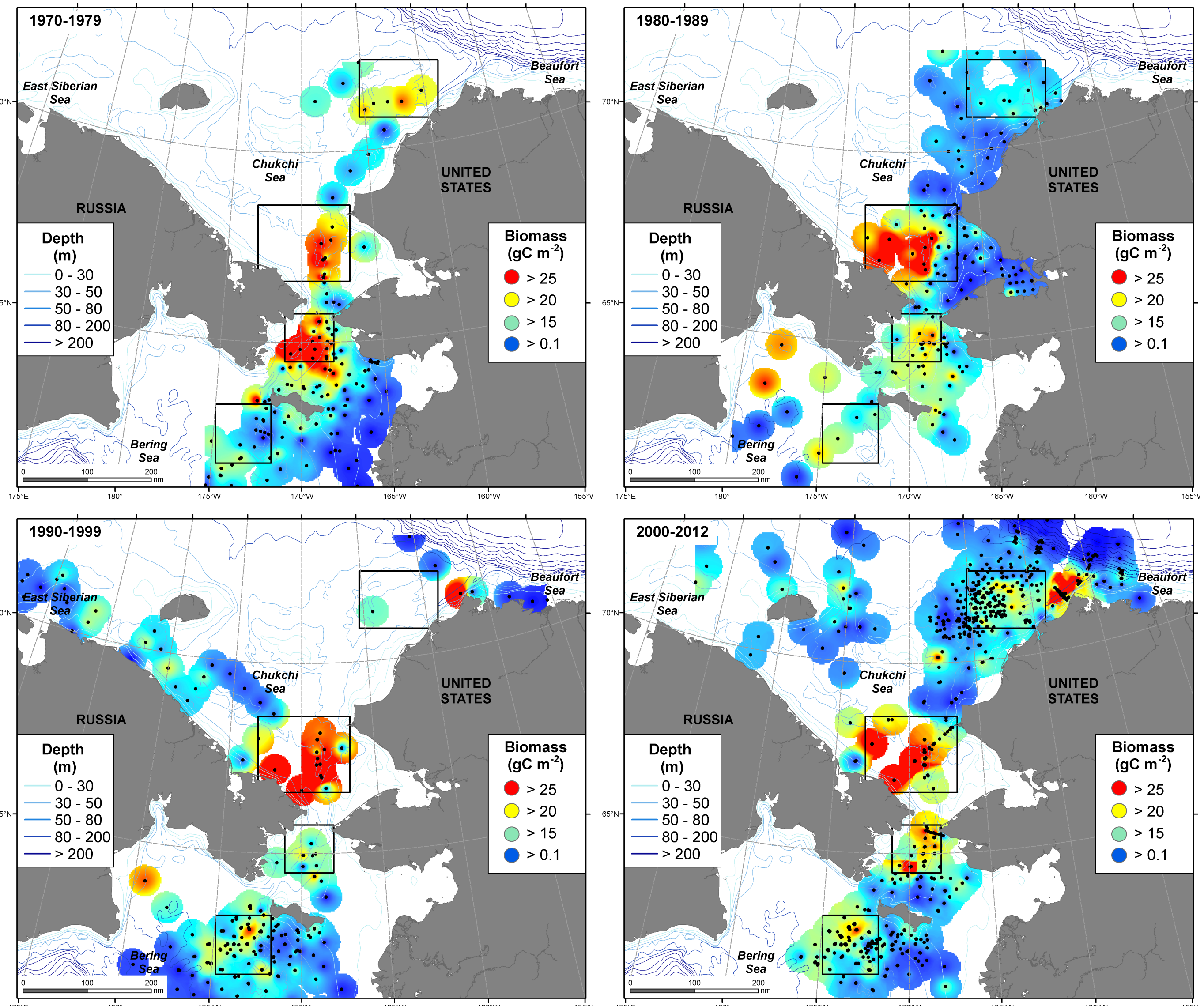
- Advective regime
- High nutrients western side
- Increasing volume of warm Pacific water through Bering Strait in recent years (Woodgate et al. 2012)



- Latitudinal warming bottom water temperatures
- Coldest: Northern Bering Sea south of St. Lawrence Island & Northeast Chukchi Sea, plus downslope western Chukchi Sea

[Grebmeier+17 co-authors, 2015 SOAR Prog. Oceangr.]

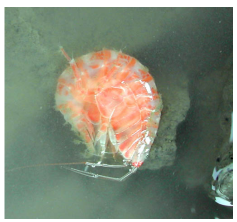
Persistent biological hotspots maintained by deposition of *in situ* and advected carbon to the benthos

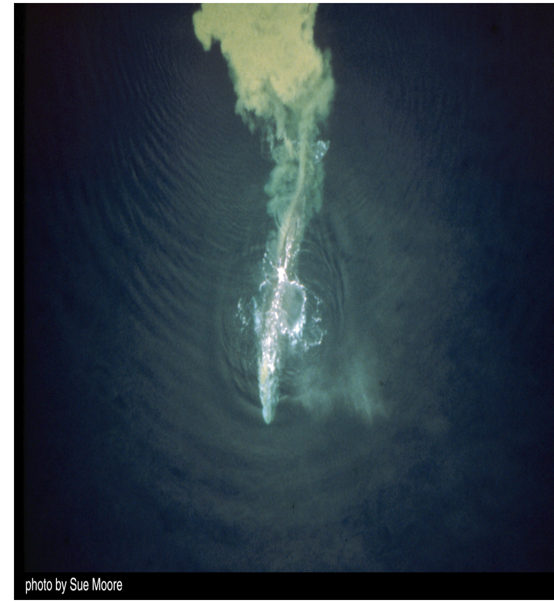


[Grebmeier et al. 2015, Prog. Oceangr.]

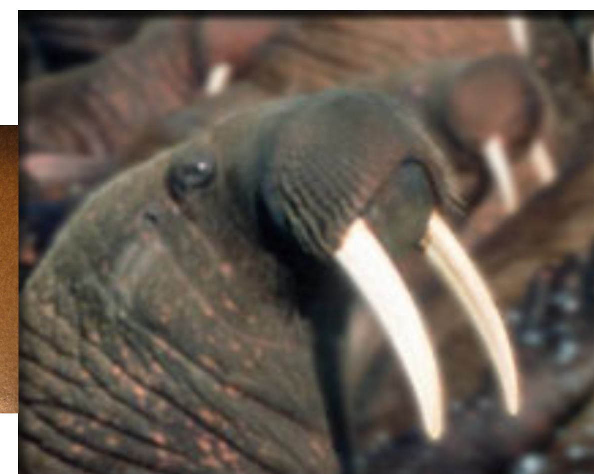
Benthic Foragers: Response to Changes in Sea Ice

Gray whales = shifts in distribution reflects sea-ice related prey decrease (amphipods: time and space), plus opportunity feed on euphausiids and staying longer north near Barrow to feed

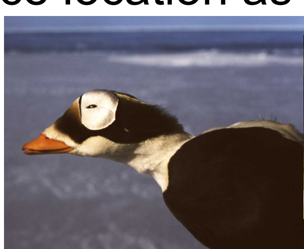




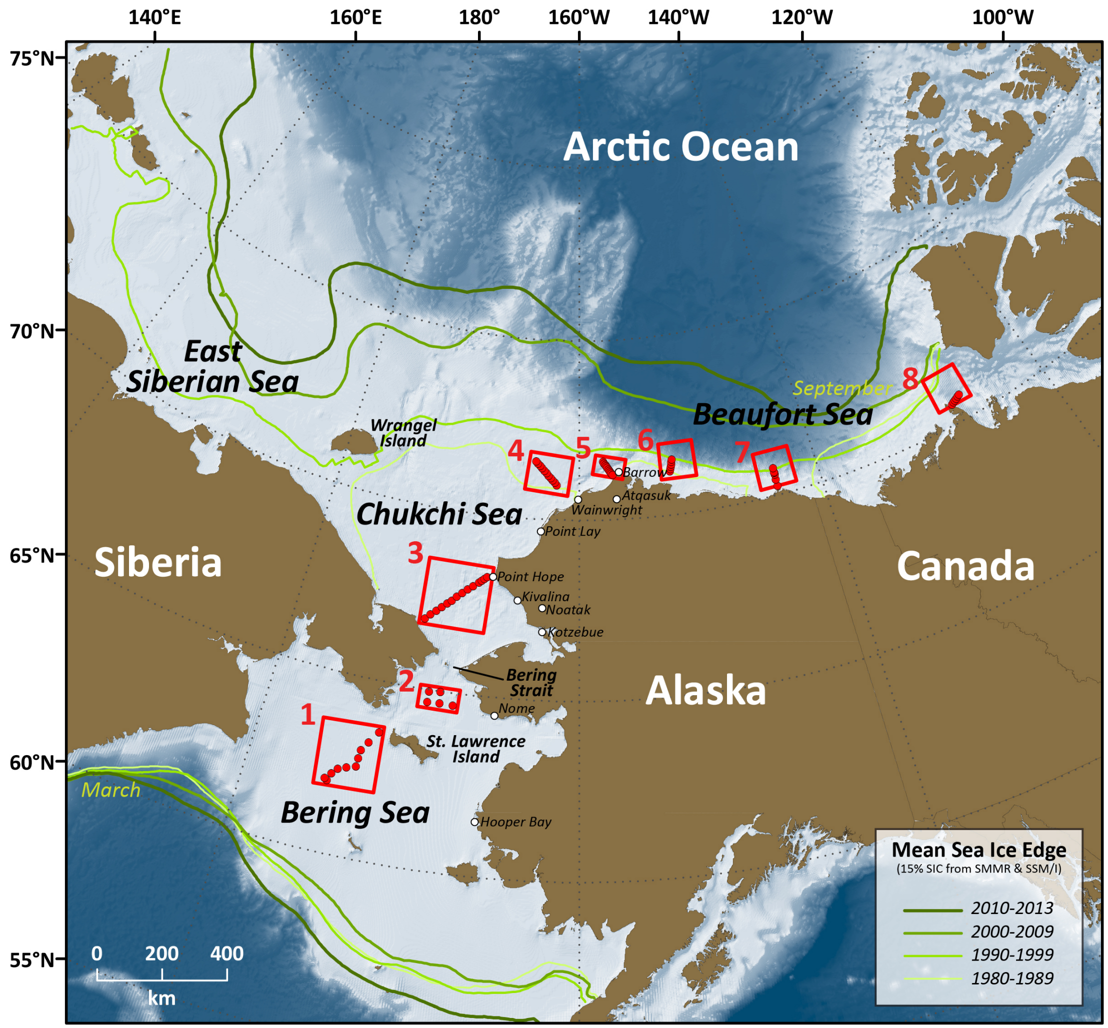
Walrus = loss of sea ice platform for riding, resting, nursing calves & <u>access</u> to Chukchi shelf feeding areas



Diving seaducks = changing sea ice location as resting platform



Linking Physics to Biology: the Distributed Biological Observatory (DBO) http://www.arctic.noaa.gov/dbo/



[modified by Karen Frey from Grebmeier et al. 2010, EOS 91]

- **DBO sites (red boxes) are regional "hotspot" transect lines and stations located along a latitudinal gradient (DBO1-5) and longitudinally (DBO6-8)**
- **DBO sites exhibit high productivity, biodiversity, and/or overall rates of change**
- **DBO sites serve as a change detection array for consistent monitoring of biophysical responses**
- **Sites occupied by national and international entities with shared data plan**

PAG PACIFIC ARCTIC GROUP

IASC

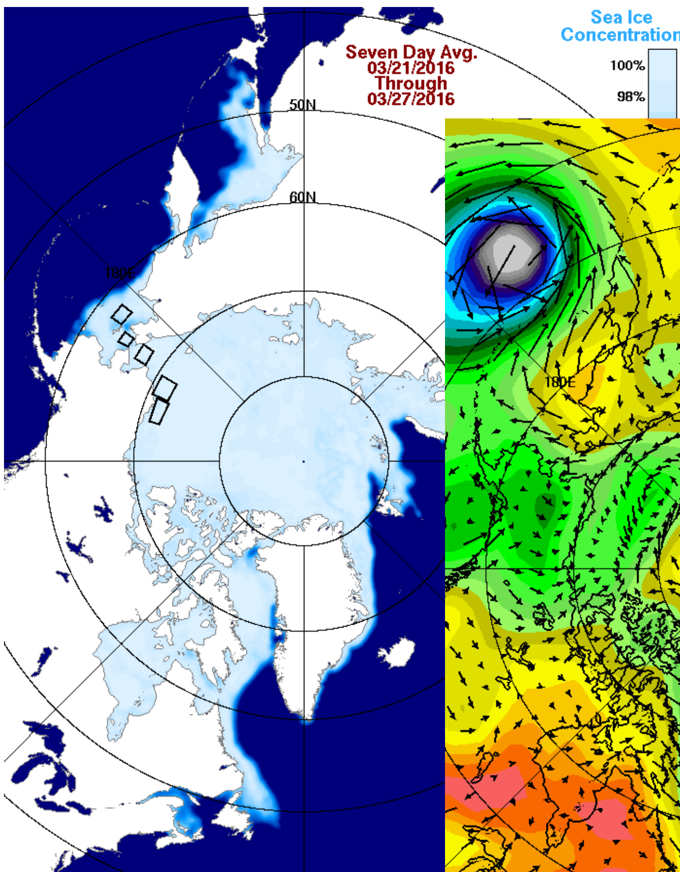
Distributed Biological Observatory Standardized Sampling Protocols

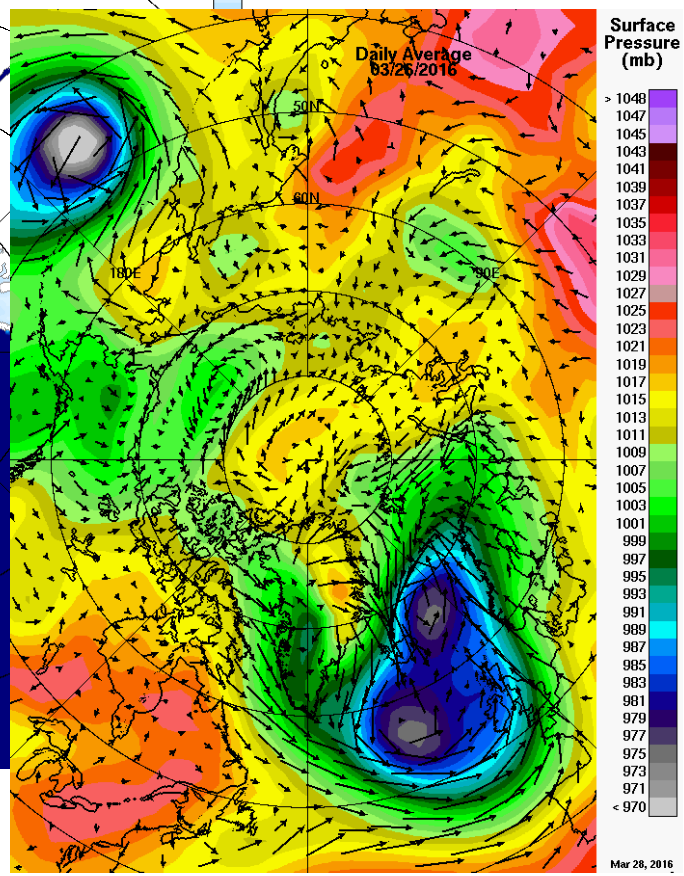
- Conductivity, Temperature, Depth (CTD), Acoustic Doppler Current Profiler (ADCP) data
- Bottle data for chlorophyll and nutrients
- Abundance, biomass and composition of ice algae, phytoplankton, zooplankton, benthic fauna (both infauna and epifauna), and fish
- Sediment parameters (grain size, organic carbon content, chlorophyll *a* content)
- Seabird and marine mammal surveys
- Mooring data (temperature (T), salinity (S), currents, fluorescence, nutrients, sediment traps
- Satellite data (data presented are weekly averages of most recent data on: (1) chlorophyll pigment concentration; (2) sea surface temperature (SST); (3) sea ice concentration; (4) cloud fraction, and (5) winds and sea level pressure

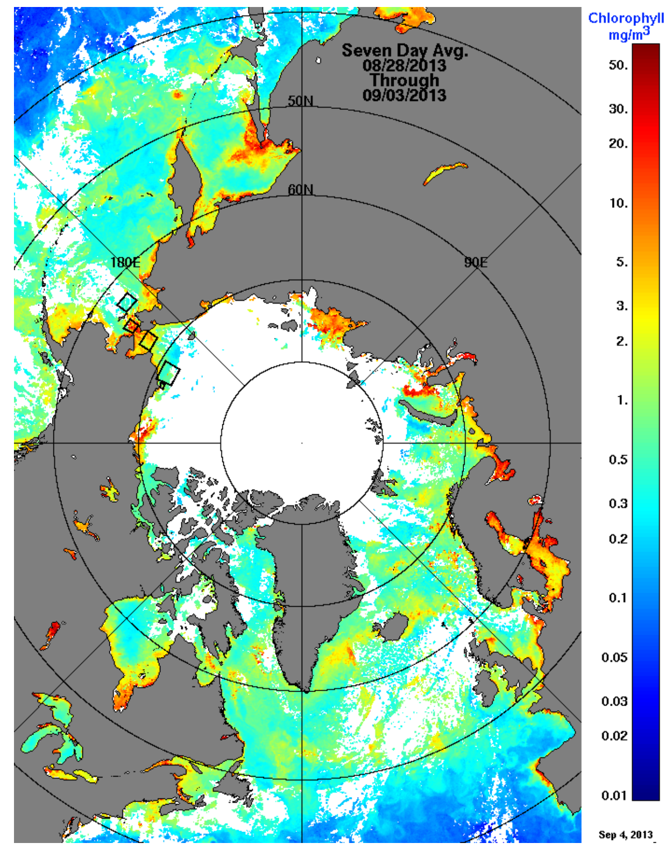
Satellite Visualization Data for the Distributed Biological Observatory (DBO)

J. C. Comiso, Karen Frey, L. V. Stock, R. A. Gersten, and H. Mitchell.
NASA Goddard Space Flight Center

IARPC DBO
Collaborative Team





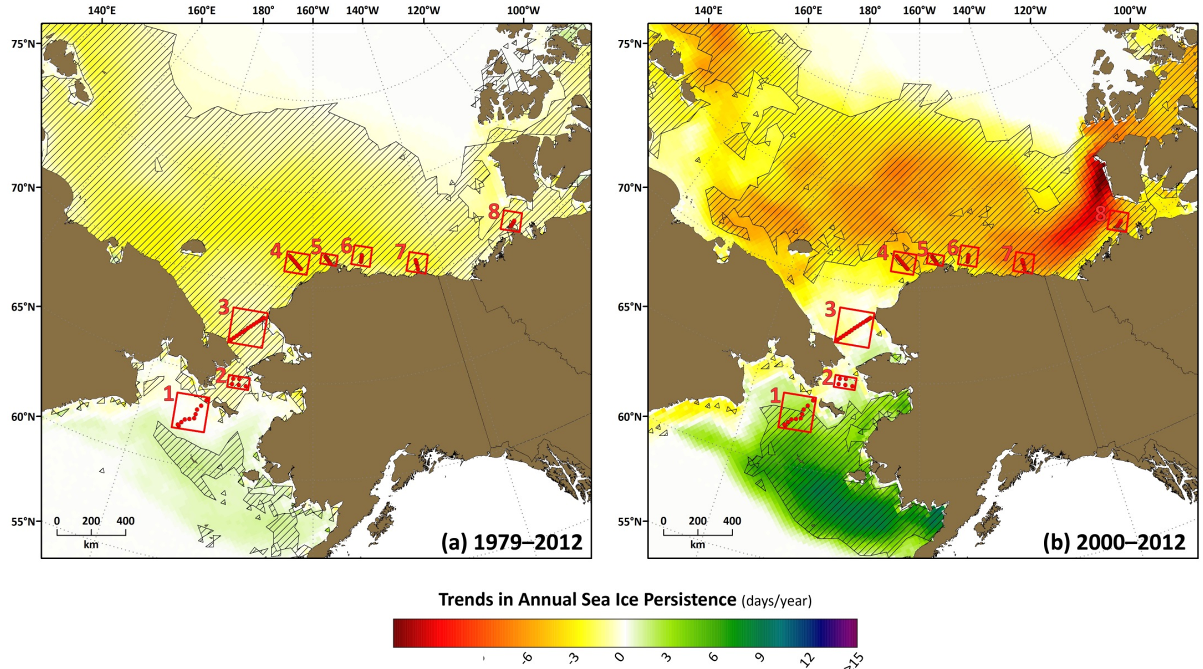


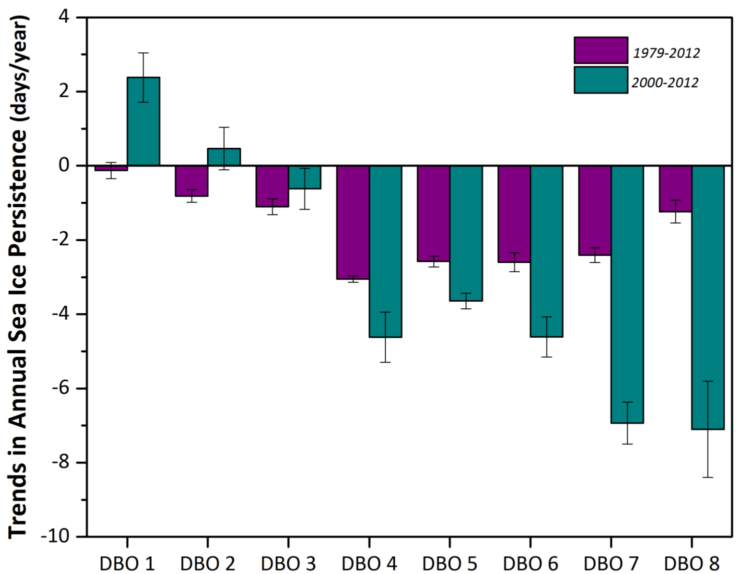
http://neptune.gsfc.nasa.gov/csb/index.php?section=270 (courtesy Joey Comiso)

Trends in Annual Sea Ice Persistence (DBO 1–8)

Hatching indicates statistically significant trends (Mann-Kendall $p<0.1$)

Trends in annual sea ice persistence have accelerated since 2000

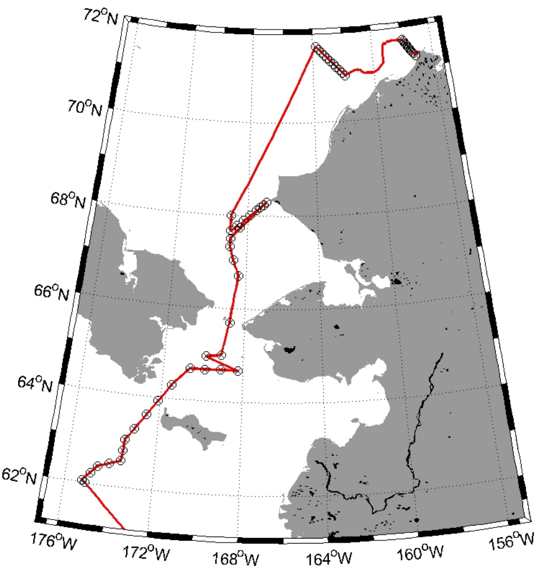




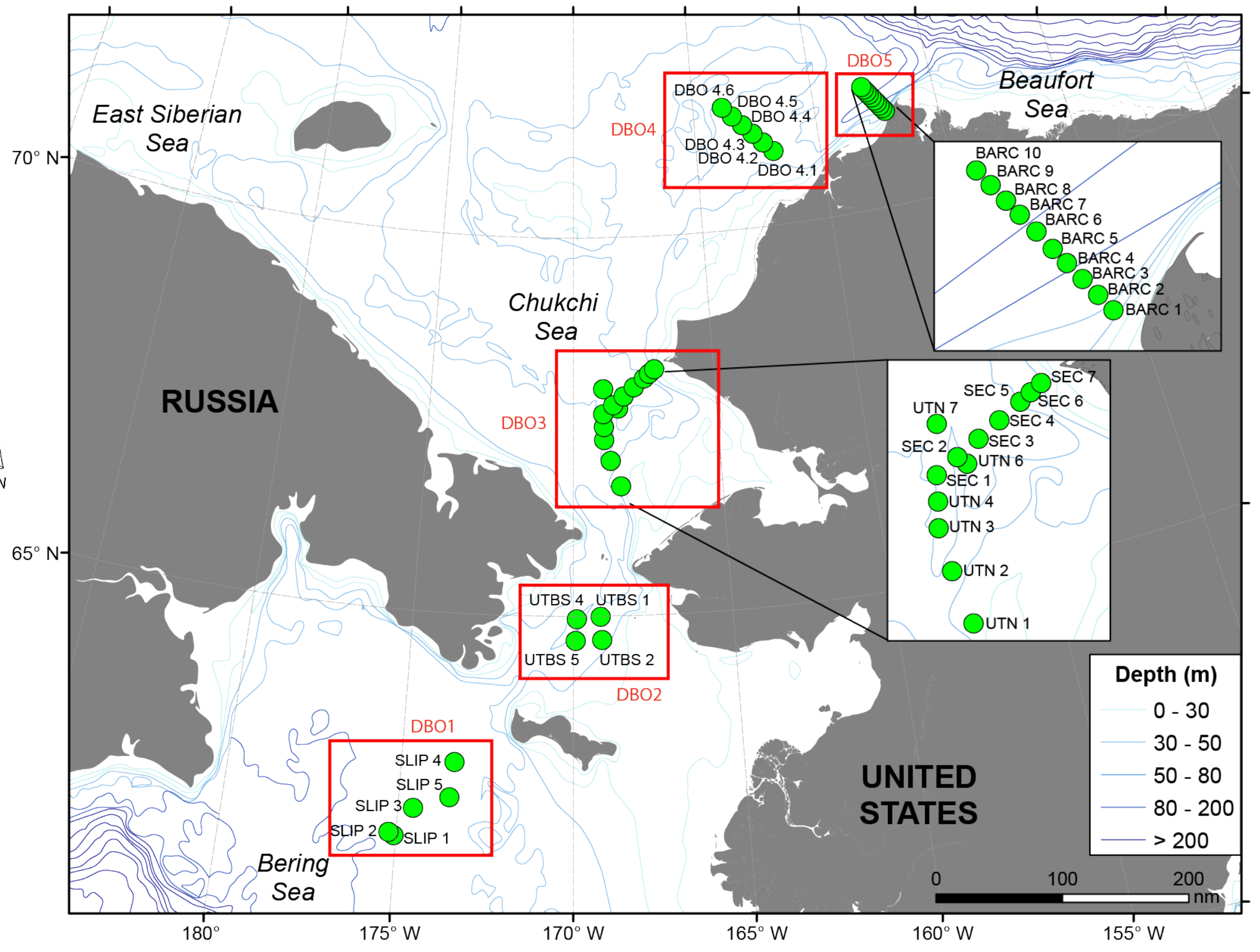
- *Trends in annual sea ice persistence have accelerated since 2000*
- *Recent gains in annual sea ice persistence in the south (DBO 1–2) transition to losses in the north (DBO 3–8)*

[Karen Frey, Clark University]

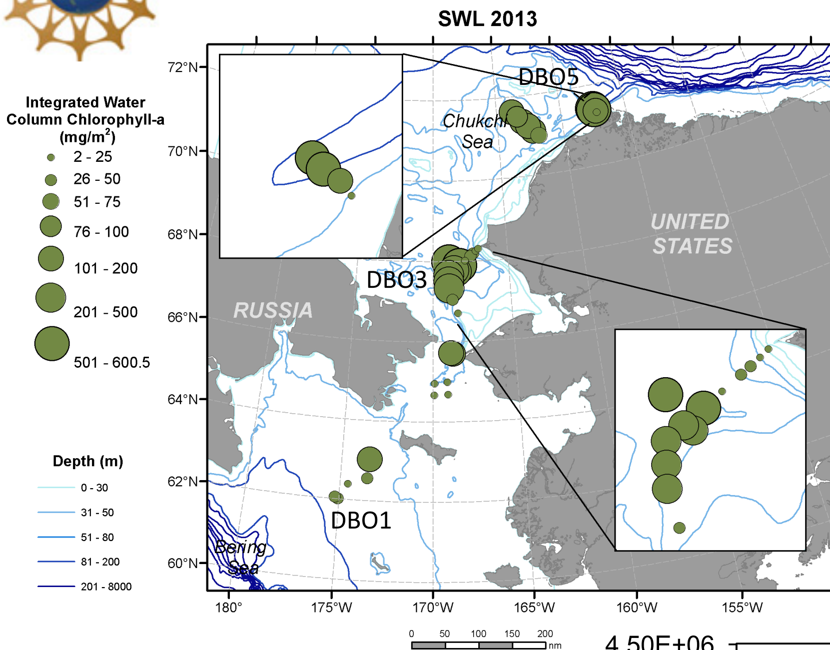
Canada' Three Oceans (C3O-DFO Canada) and the Distributed Biological Observatory (DBO-NSF, USA) 2015-AON Project



CCGS Sir Wilfrid Laurier July 2015



Chlorophyll and Phytoplankton Composition

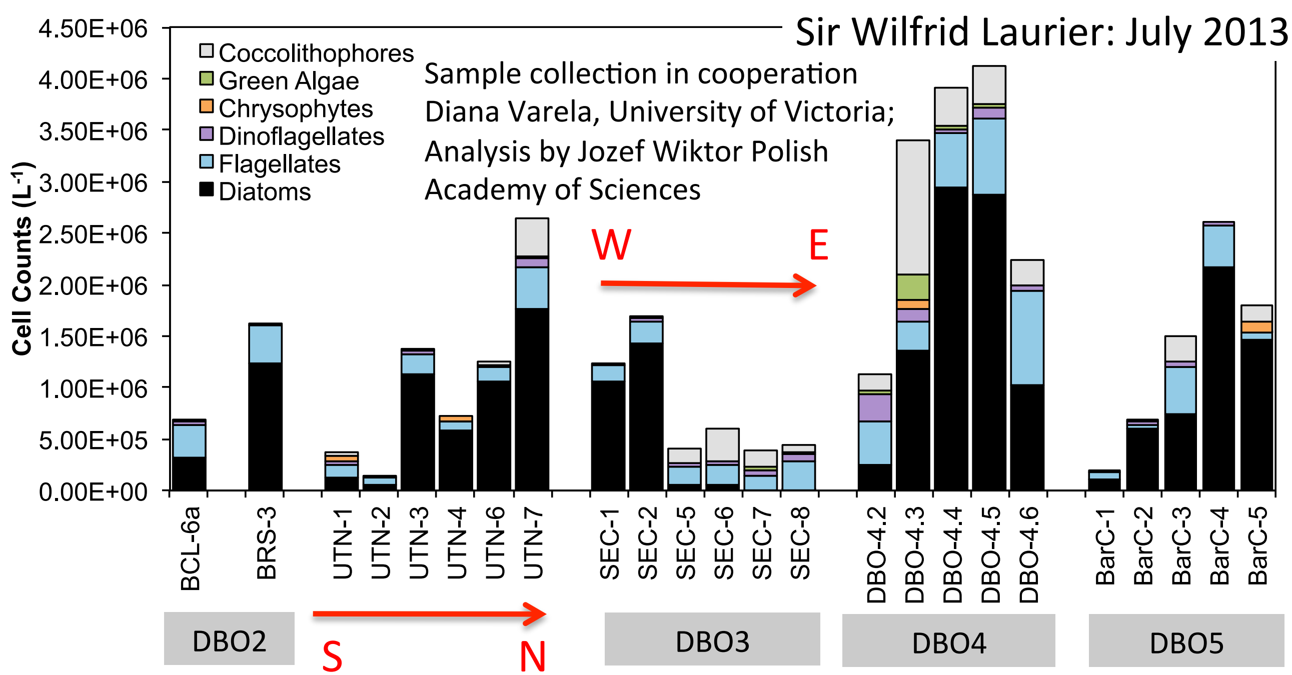


Left: Integrated Chlorophyll *a d*uring annual July DBO cruise in 2013

- DBO1 chl a highest in spring
- DBO2 high chl a late spring and early summer
- DBO3 high chl a early-late summer
- DBO4 high chl a late summer offshore
- DBO5 high chl a in center of upper canyon spring through summer

Right: Phytoplankton composition in July 2013 from the NE Bering Sea to the NE Chukchi Sea

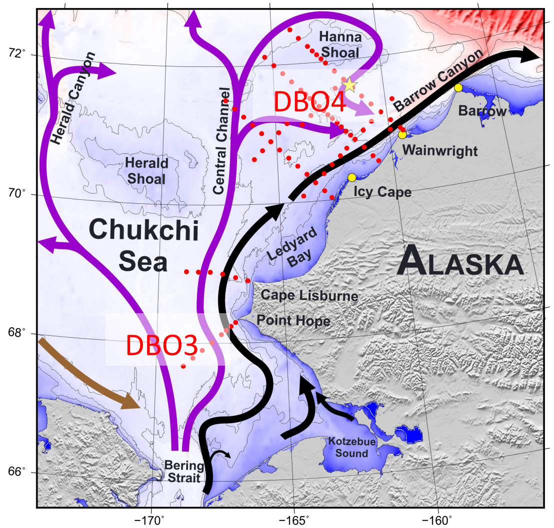
- Highest diatom content in offshore Bering Sea - Anadyr waters

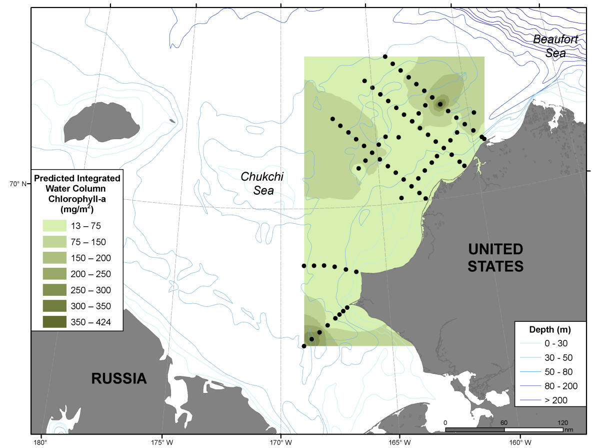


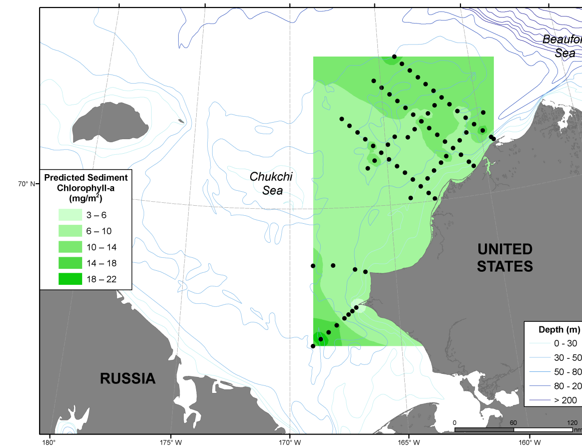
[Grebmeier and Cooper, USA]

AMBON 2015 Cruise: August-September

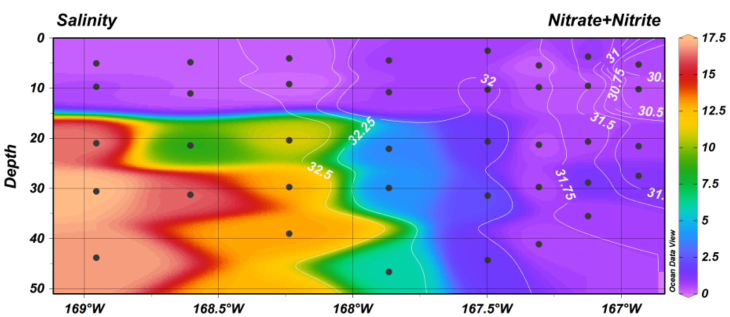
Goal: Evaluate faunal biodiversity and environmental drivers to understand Chukchi Sea ecosystem dynamics

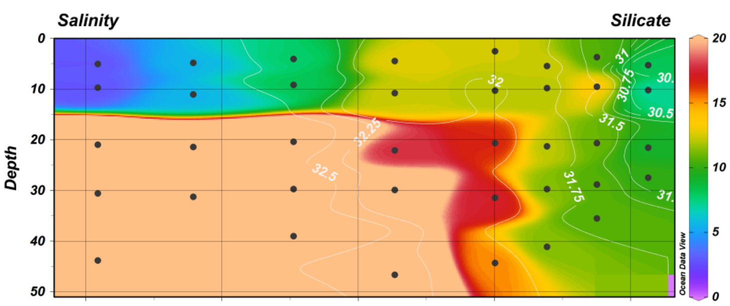




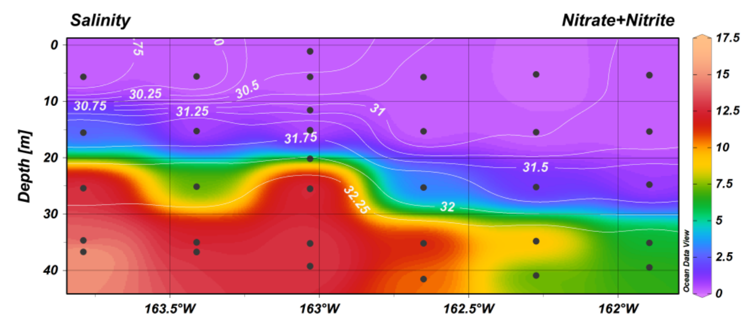


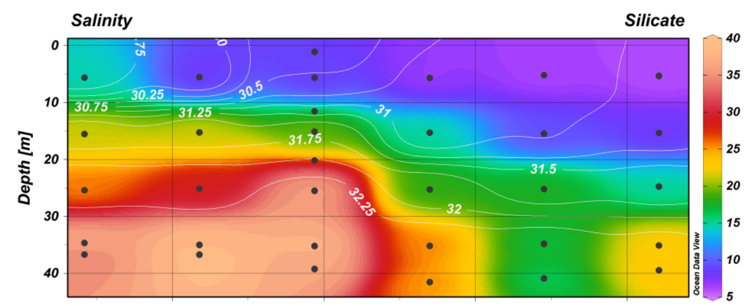
- Integrated water column chl *a* (left) and sediment chl *a* (right)





- Water column nutrients at DBO3 (left) and DBO4 (right)- August 2015

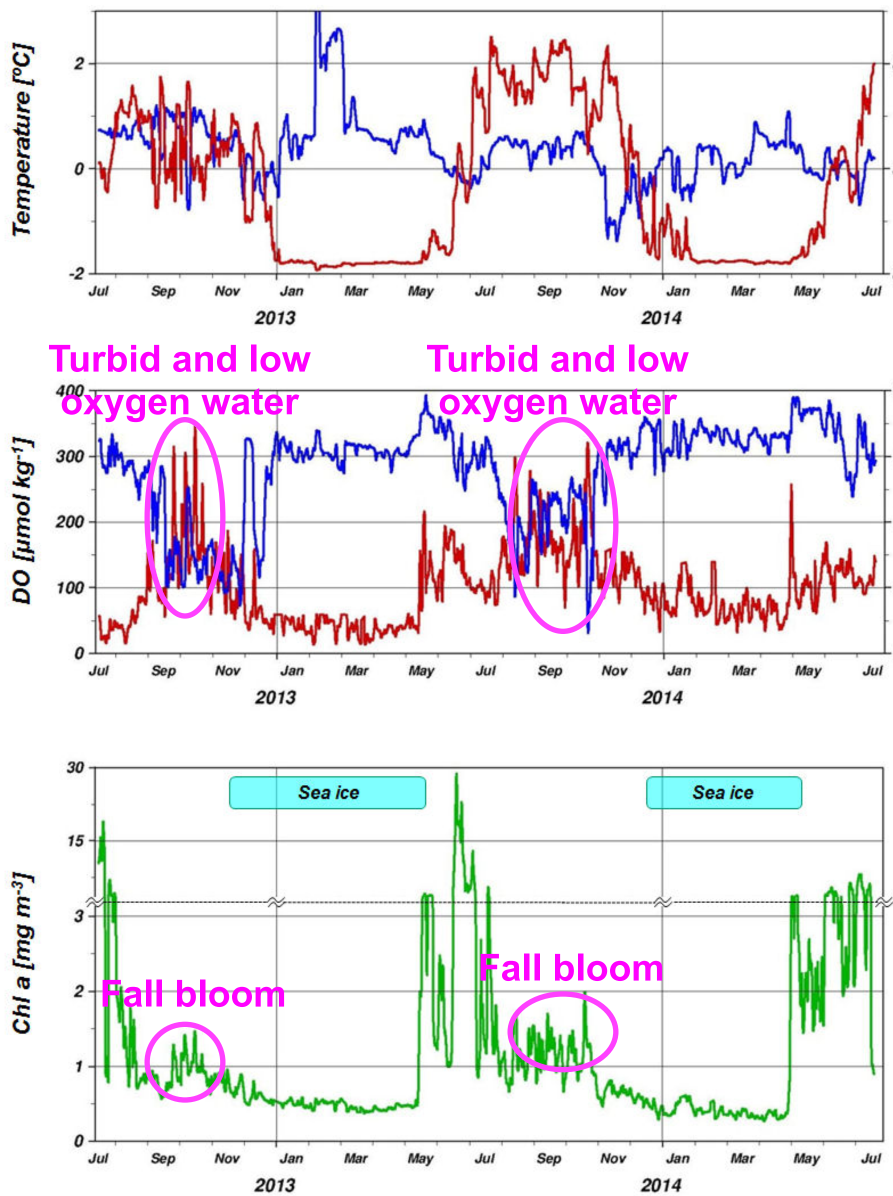


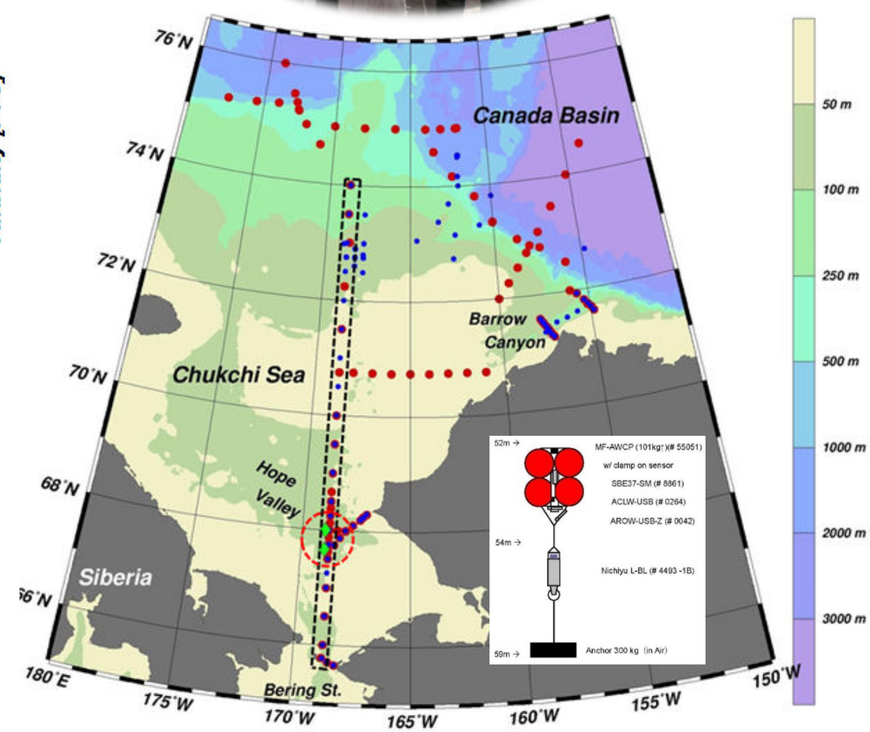


[funding through NOPP from NOAA, BOEM and Shell Oil]

DBO3 moorings during July 2012 to July 2014

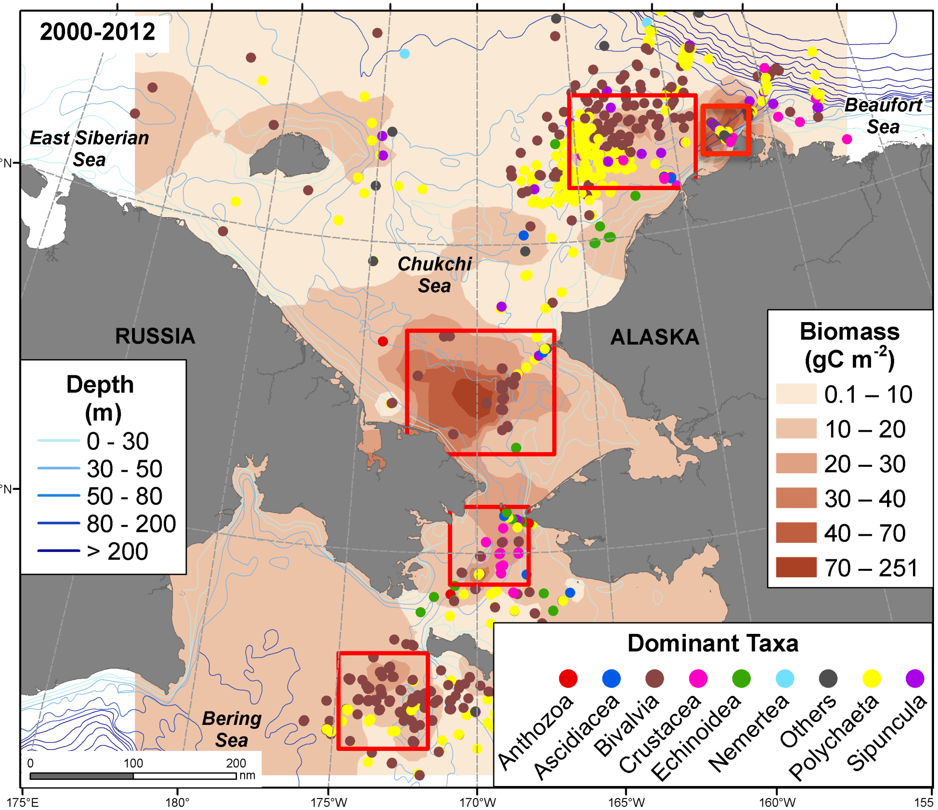
*** In 2016: DBO1-5 each has a mooring array**

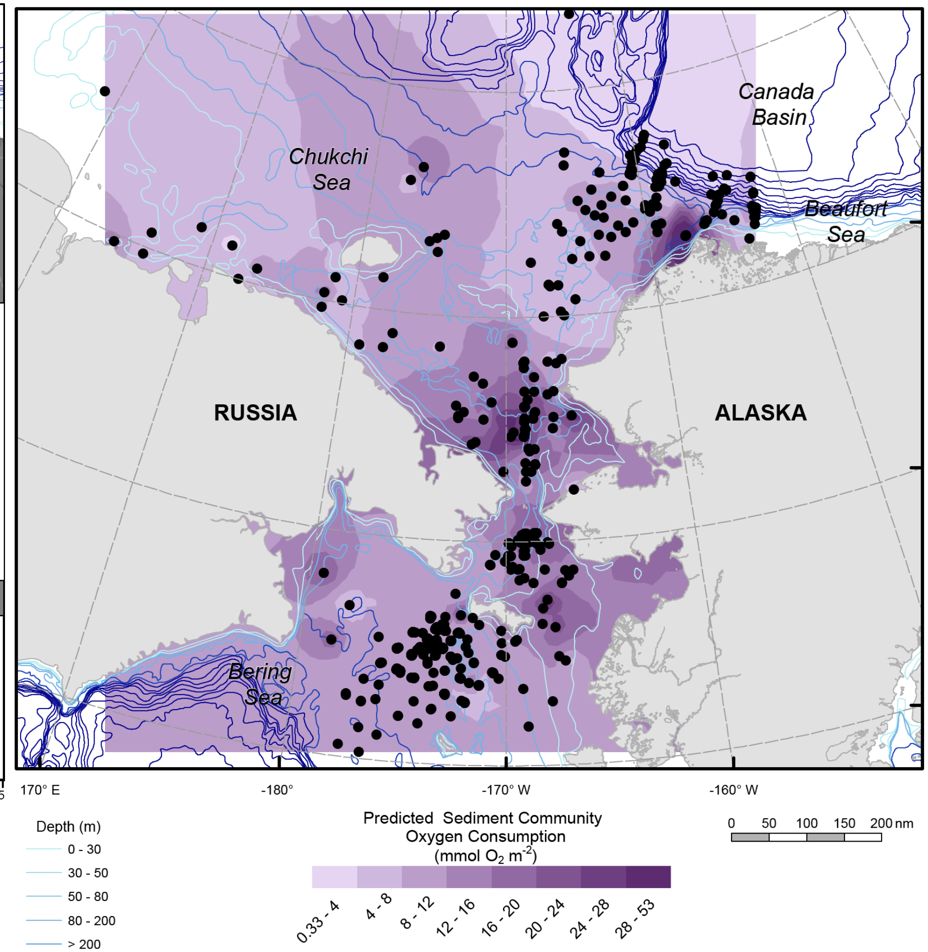




[Nishino *et al.*, 2015b]

Distribution of benthic biomass and dominant fauna (left with bounding boxes) and carbon supply (right)



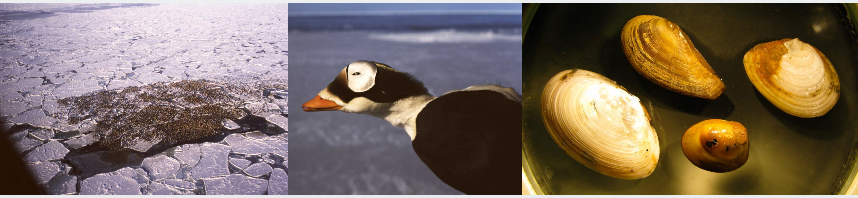


- Macrofaunal biomass increasing along a latitudinal gradient from northern Bering Sea to southern Chukchi Sea
- Recently hotspot areas sampled as part of Distributed Biological Observatory effort

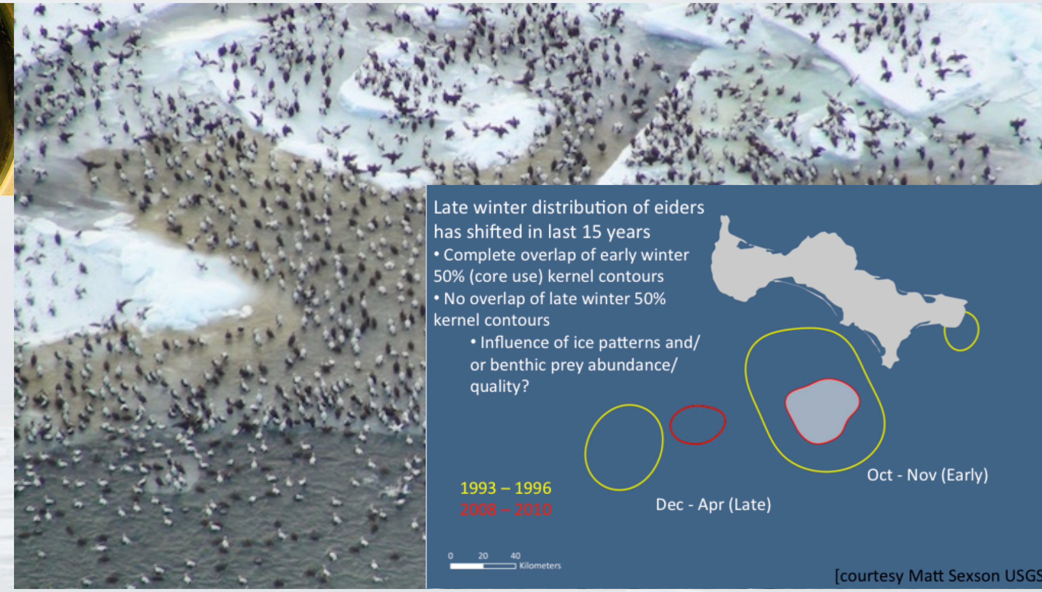
- Sediment community oxygen consumption as indicator of carbon supply to the benthos

[modified from Grebmeier 2012; Grebmeier et al. 2015]

Threatened spectacled eiders keyed to sea ice and specific bivalves (Northern Bering Sea-DBO1)



[Andrew Trites]



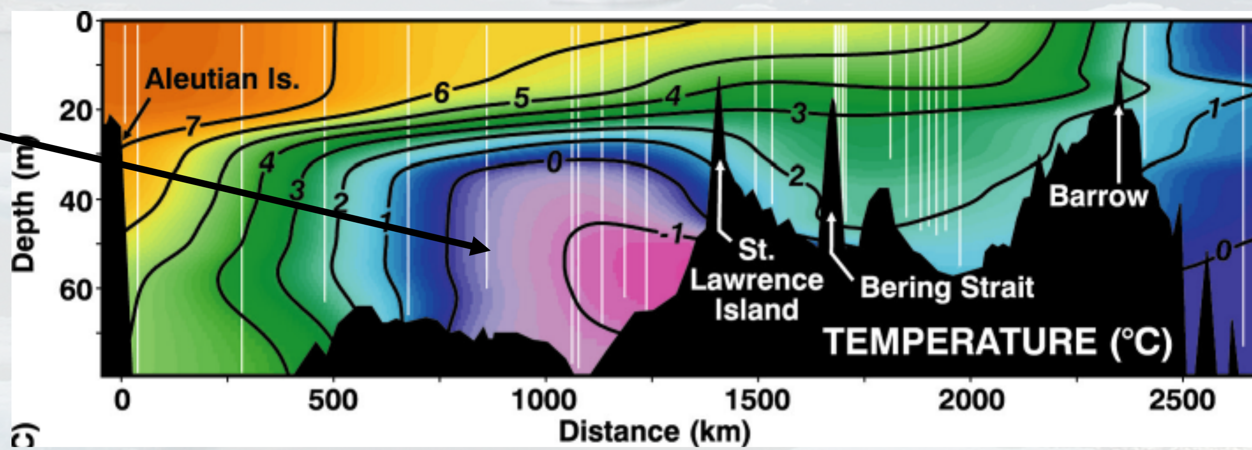
[courtesy Matt Sexson]

• feed on 3 species of bivalves

• shallow shelf system, high cascade potential lower to higher trophic levels

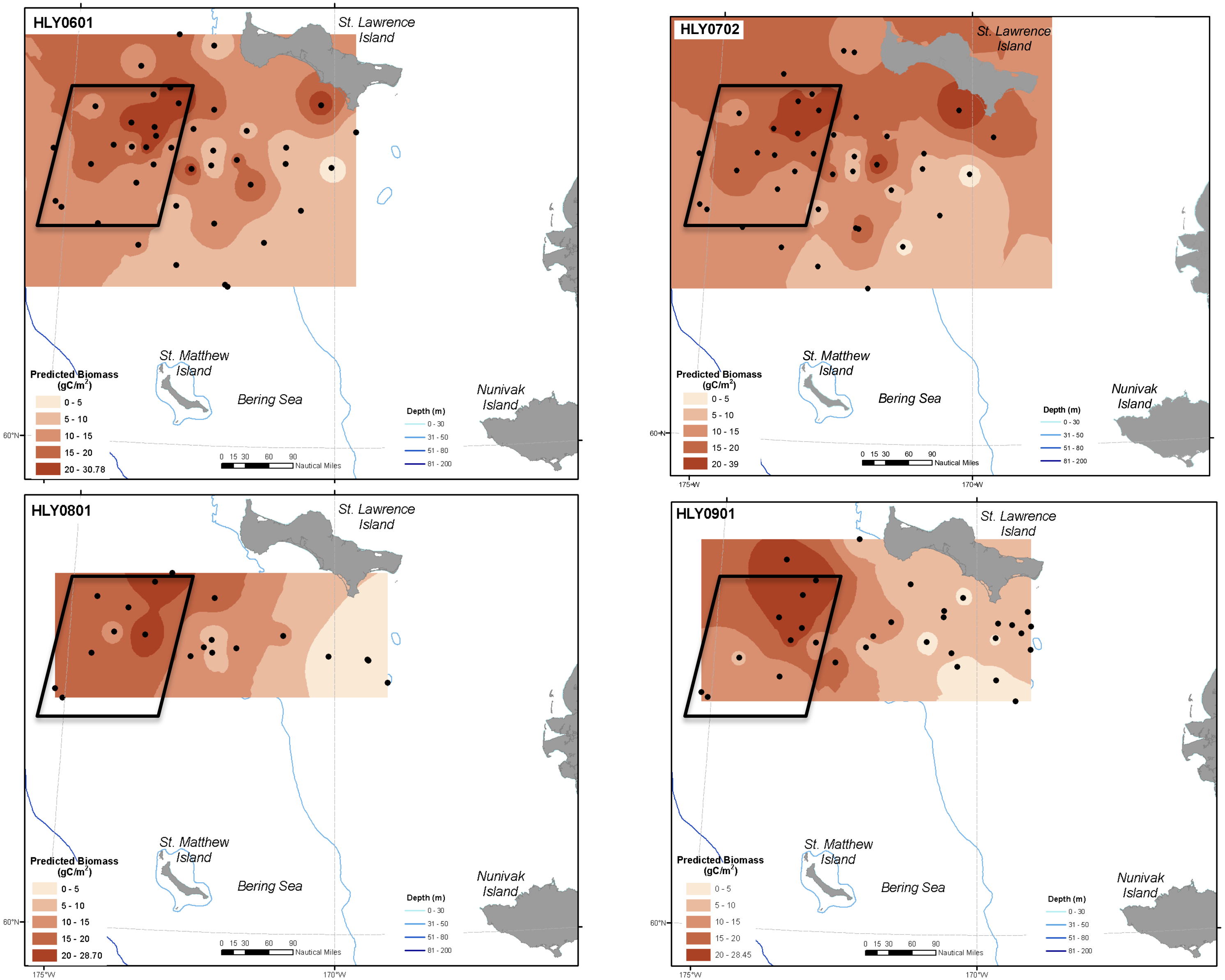
• ocean acidification potential dissolve bivalve shells

• extent & duration cold pool (<0°C) critical to benthic infauna by exclusion of benthic fish and epibenthic predators



[Grebmeier et al. 2006, Science 311]

Spatial gradient in benthic biomass (gC/m^2) in the northern Bering Sea-high west to low east trend; northward focus high biomass zone

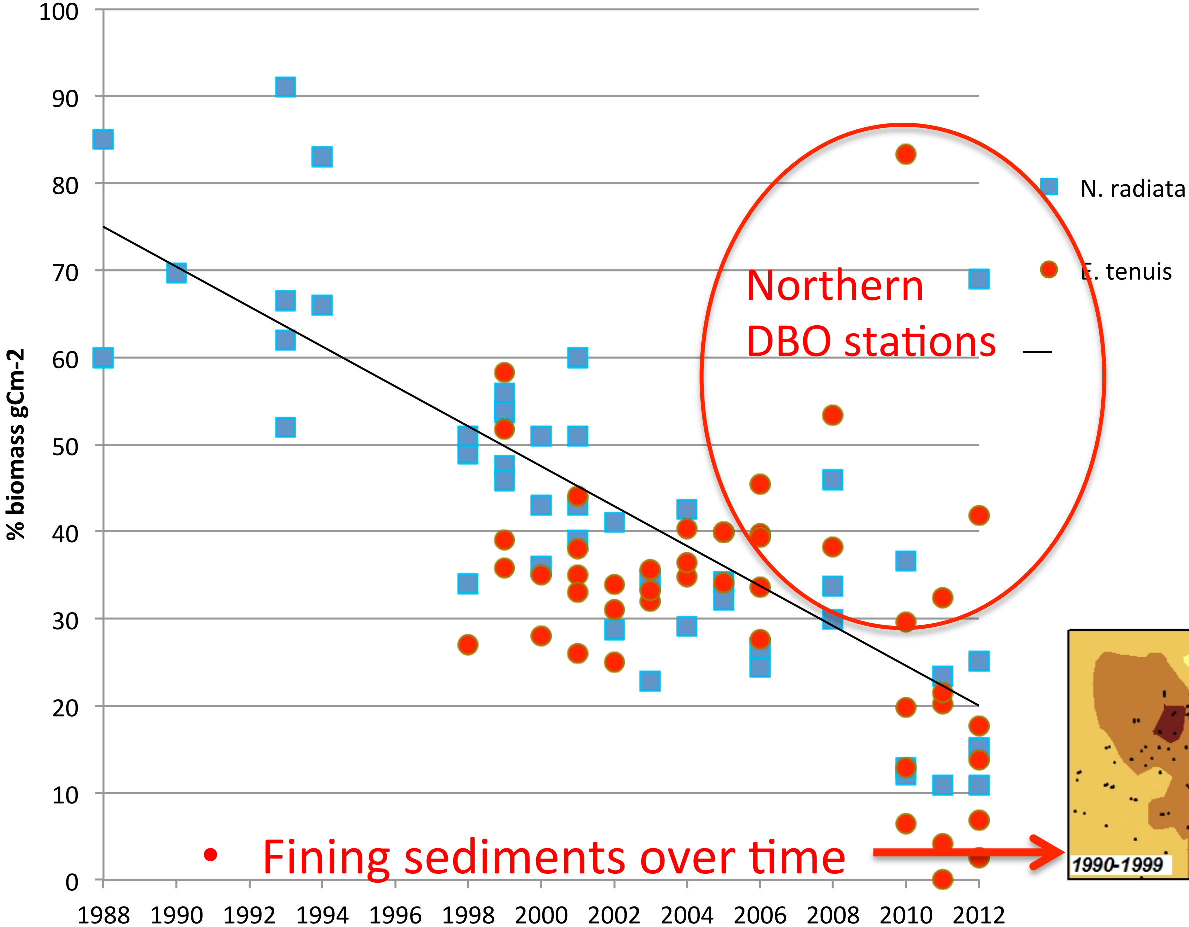


- Northward direction of core benthic biomass in hotspot

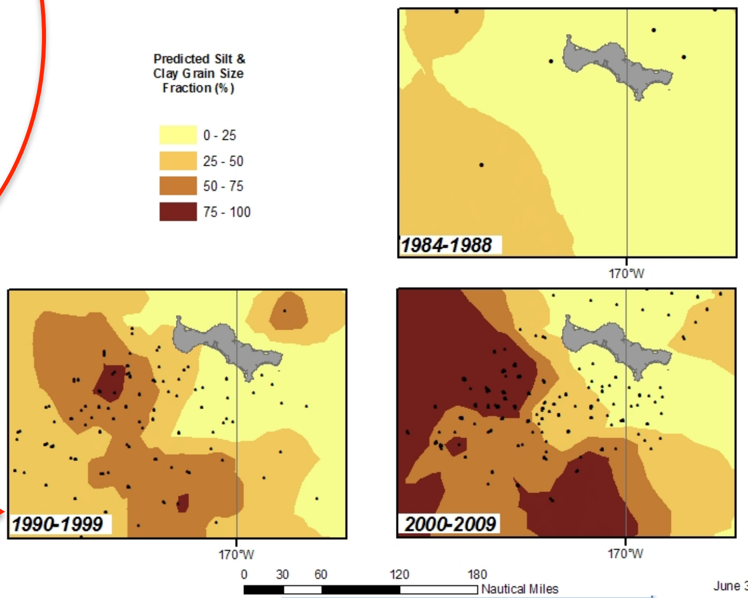
[Grebmeier and Cooper 2016, Springer Dual Career book chapter]

Regional decline in dominant bivalve (*N. radiata*), with shift to smaller bivalve (*E. tenuis*) (SLIP-DBO1)

- Coincident decline in sediment community oxygen consumption indicative of reduced carbon supply to the benthos
- Impact on declining spectacled eider populations



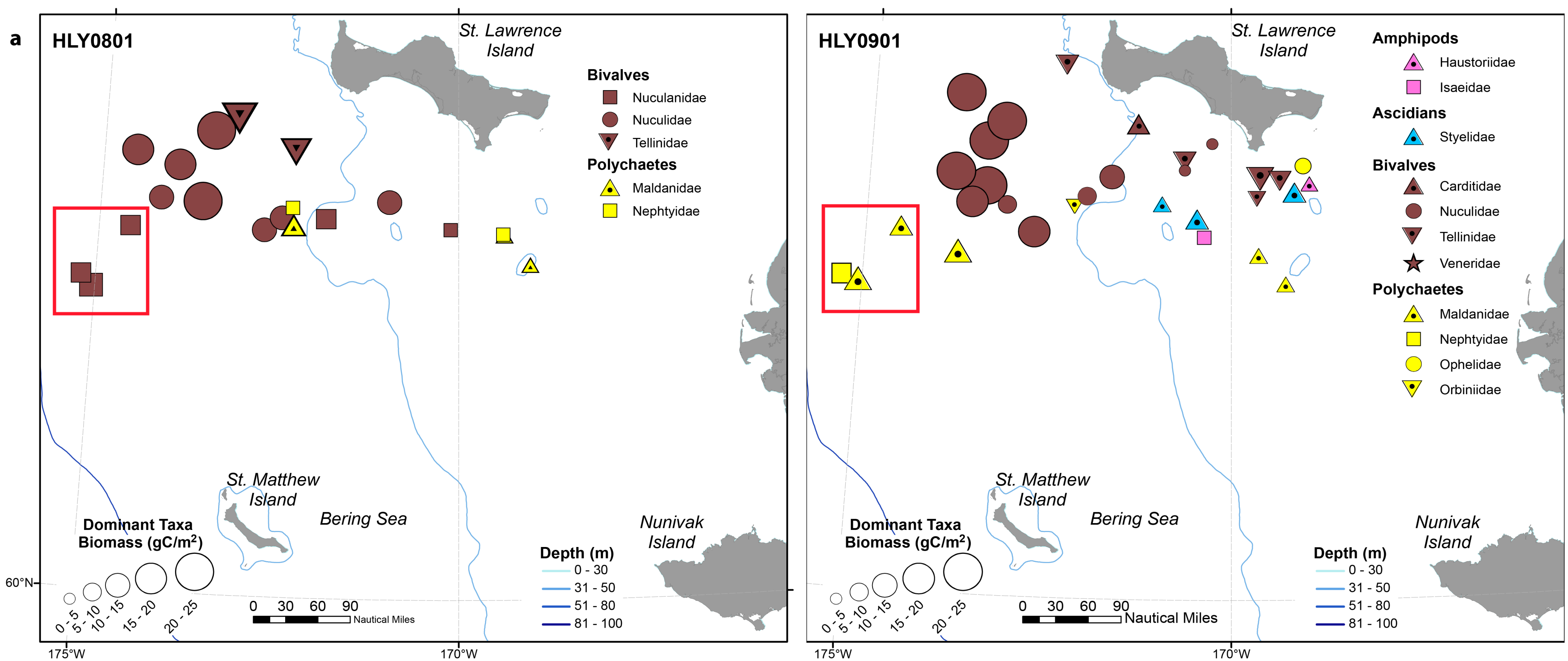
[updated from Grebmeier Ann. Rev. Mar. Sci. 4, 2012]



- Fining sediments over time

Dominant macrofaunal biomass (gC/m2) in March 2008 and 2009 south of St. Lawrence Island in the northern Bering Sea

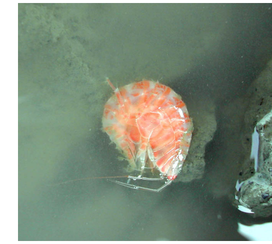
- The red box surrounds the three time series sites where decadal biomass declines have been observed and indicates the change in dominance from bivalves to polychaetes that occurred in 2009

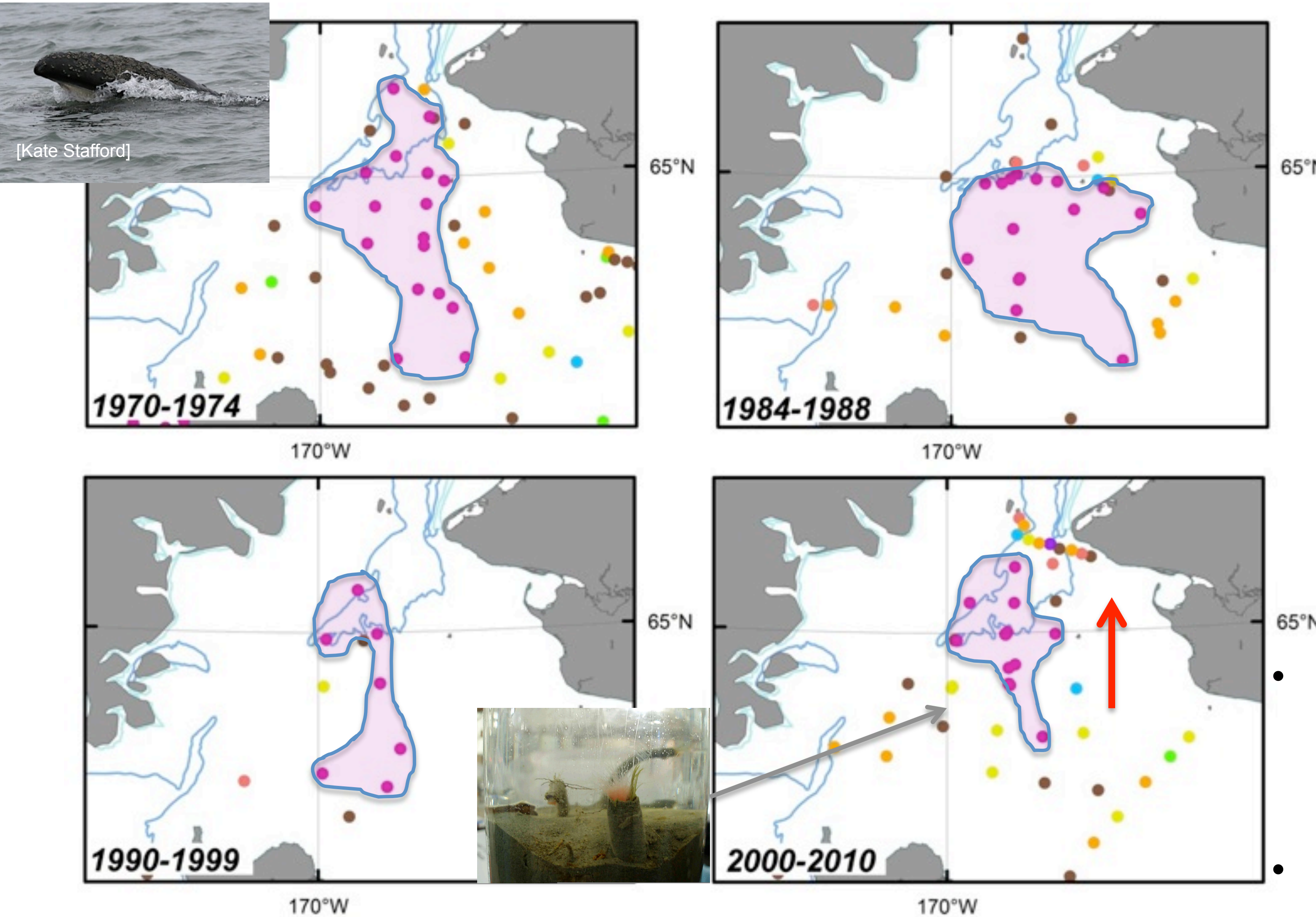


[Grebmeier and Cooper 2016, Springer Dual Career book chapter]

DBO1: South St. Lawrence Island-decline bivalves (July 2016)

“Footprint” of ampeliscid amphipod prey hotspot contracting spatially northward in Chirikov Basin (DBO2)





- Northward direction of core benthic biomass in hotspot
- Polychaetes replacing amphipods

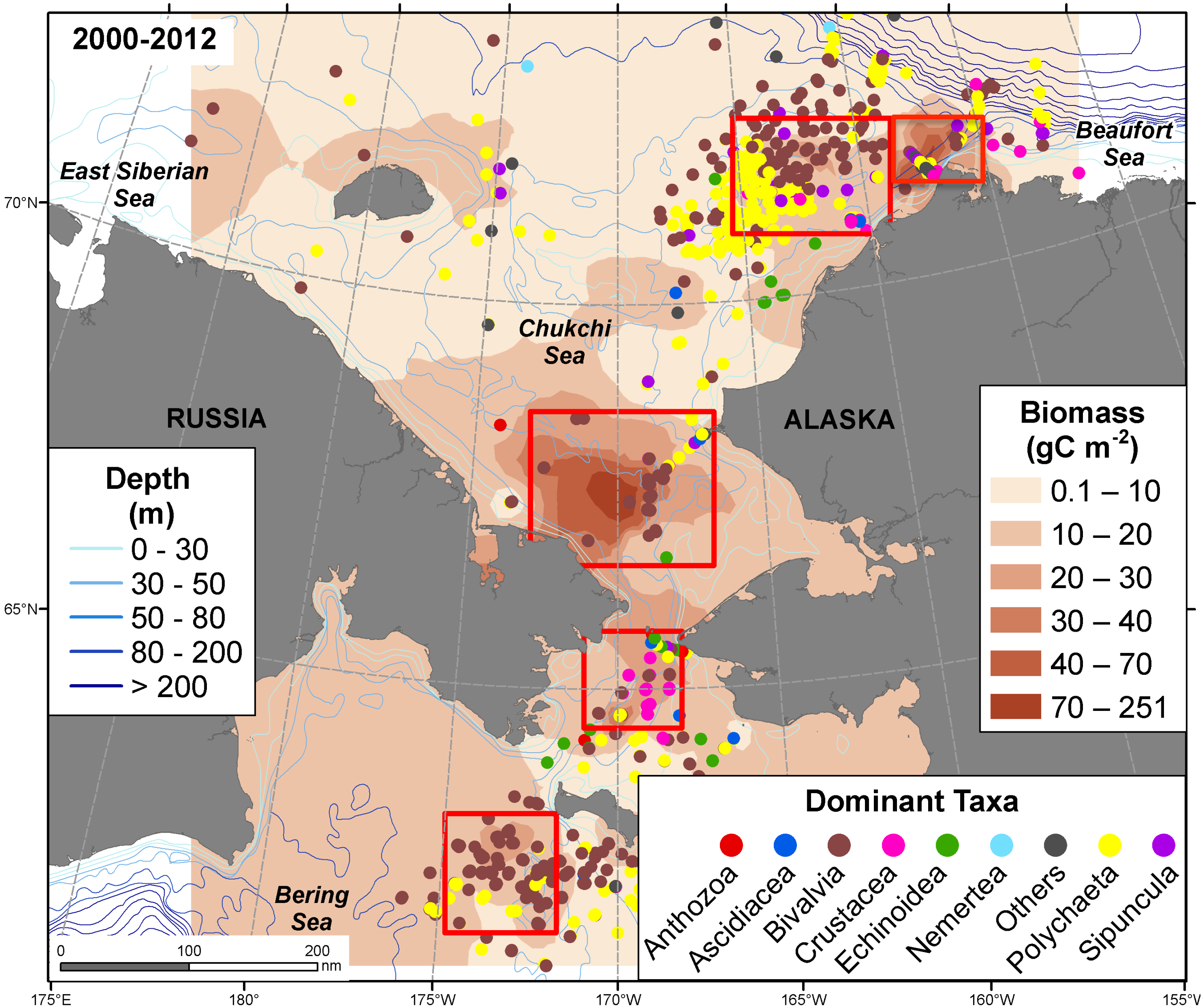
Graphic: Grebmeier, unpubl. data, see http://www.arctic.noaa.gov/dbo/dbo2-related-time-series; also Coyle et al., 2007

0 25 50 100 150 Nautical Miles

DBO2: Chirikov Basin-amphipods (July 2016)

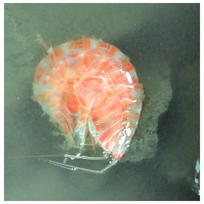
DBO2: Chirikov Basin-changed to polychaetes (July 2016)

Rich benthic communities on the western side of the Bering/Chukchi Sea system 2000-2012

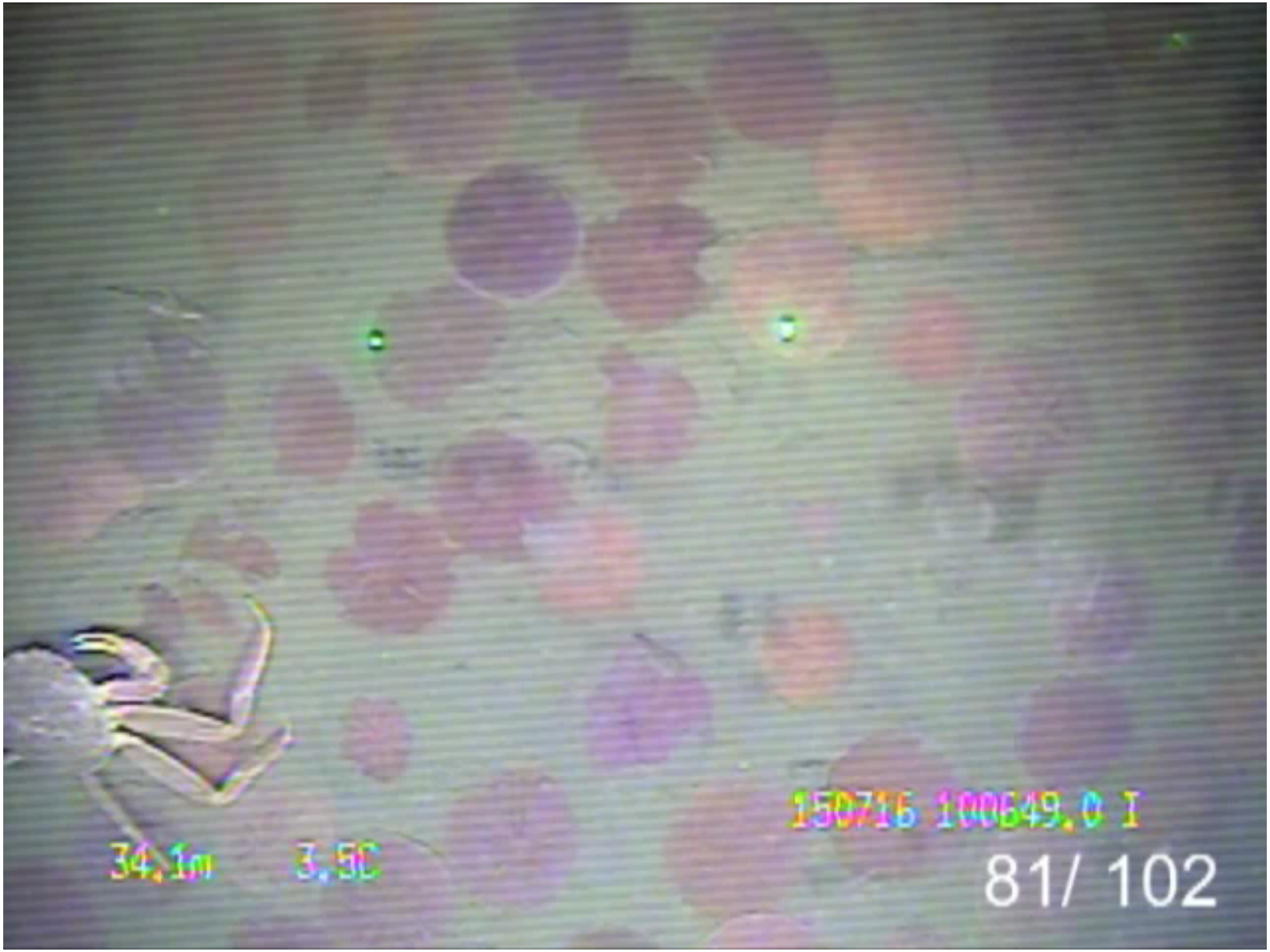


[modified from Grebmeier et al. 2015, Prog. Oceangr.]

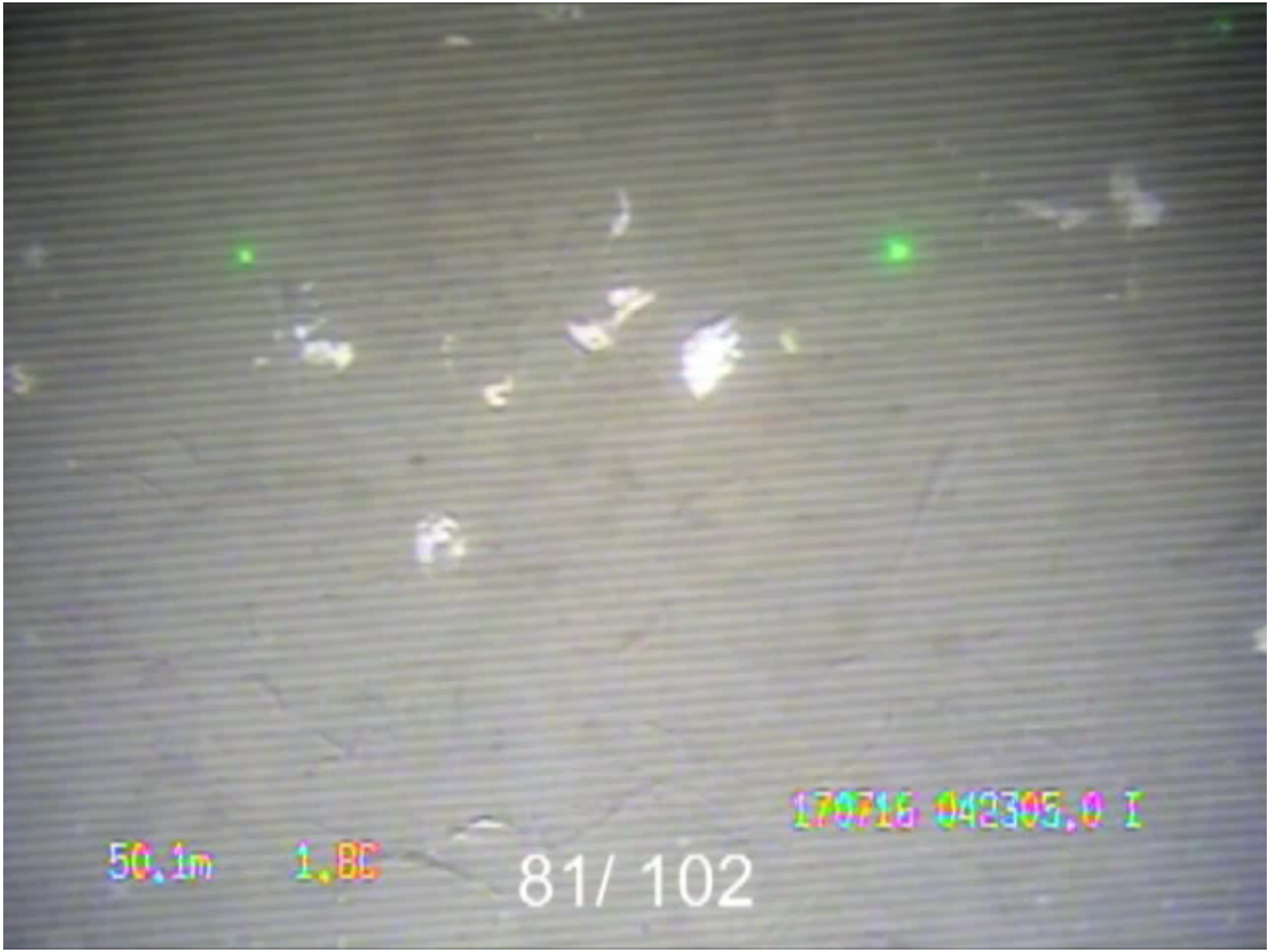
- **"foot prints"** of high benthic biomass reflect pelagic-benthic coupling and export of carbon to sediments
- infauna dominated by amphipods, bivalves, polychaetes, and sipunculids



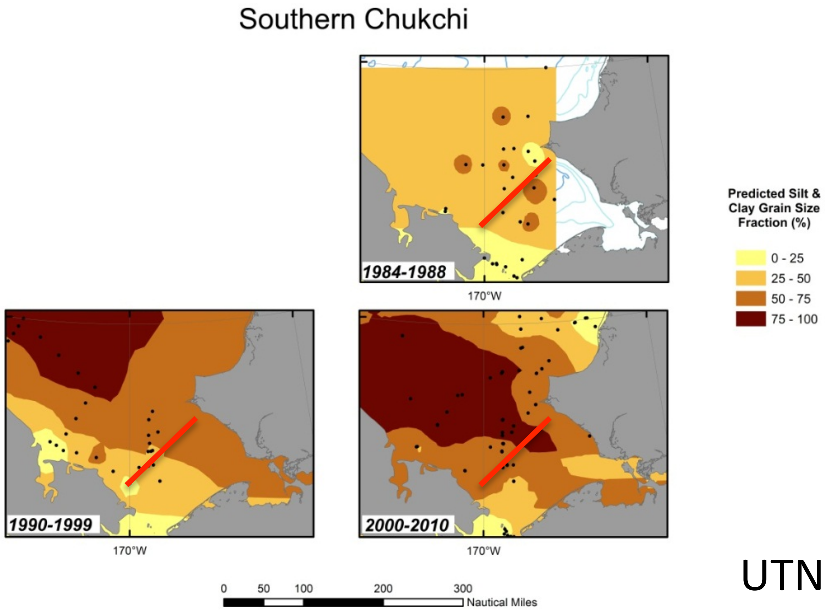
North Bering Strait (UTN1): SE Chukchi Sea-sand dollars (July 2016)



DBO3 (SEC1): SE Chukchi Sea-bivalves (July 2016)

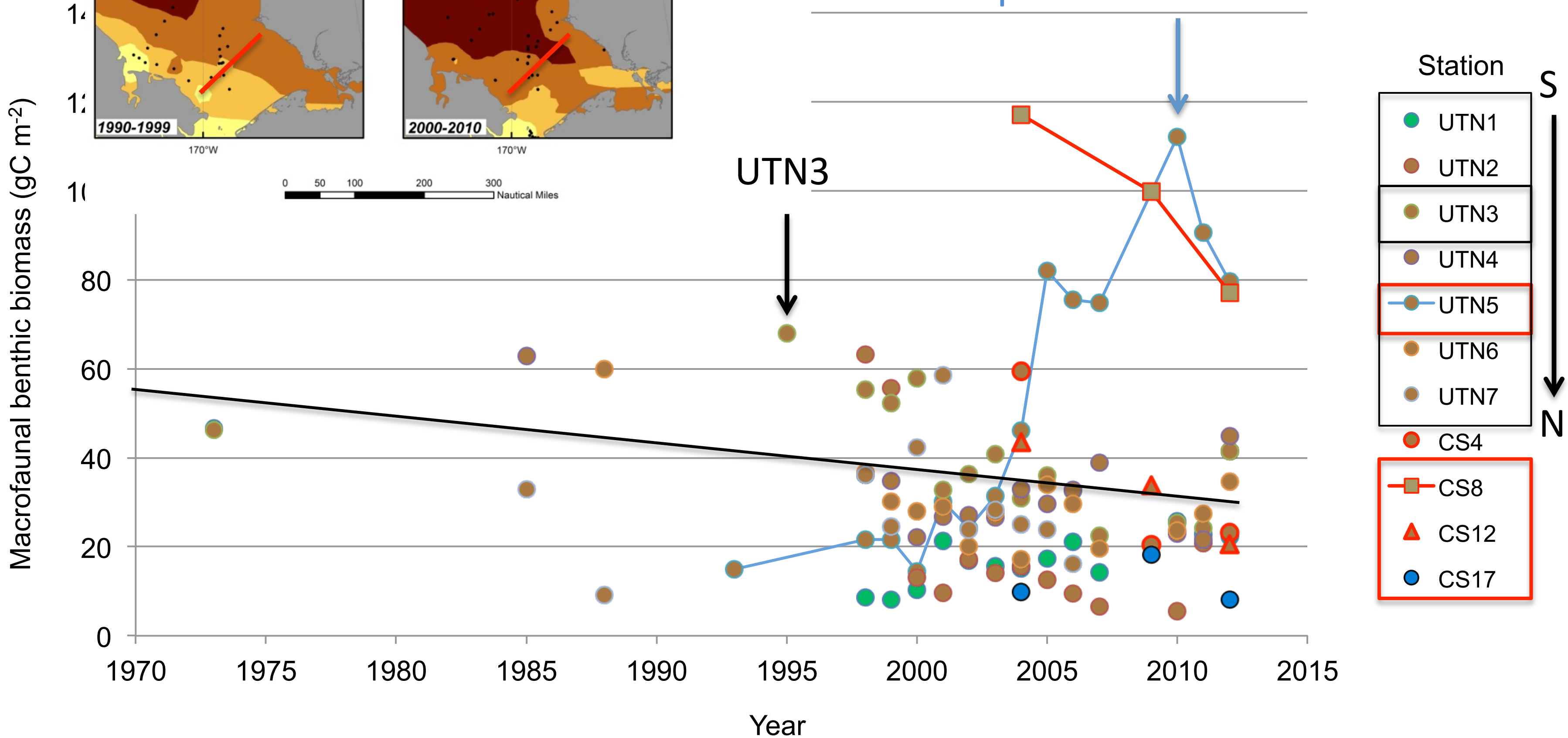


SE Chukchi Sea (DBO3)



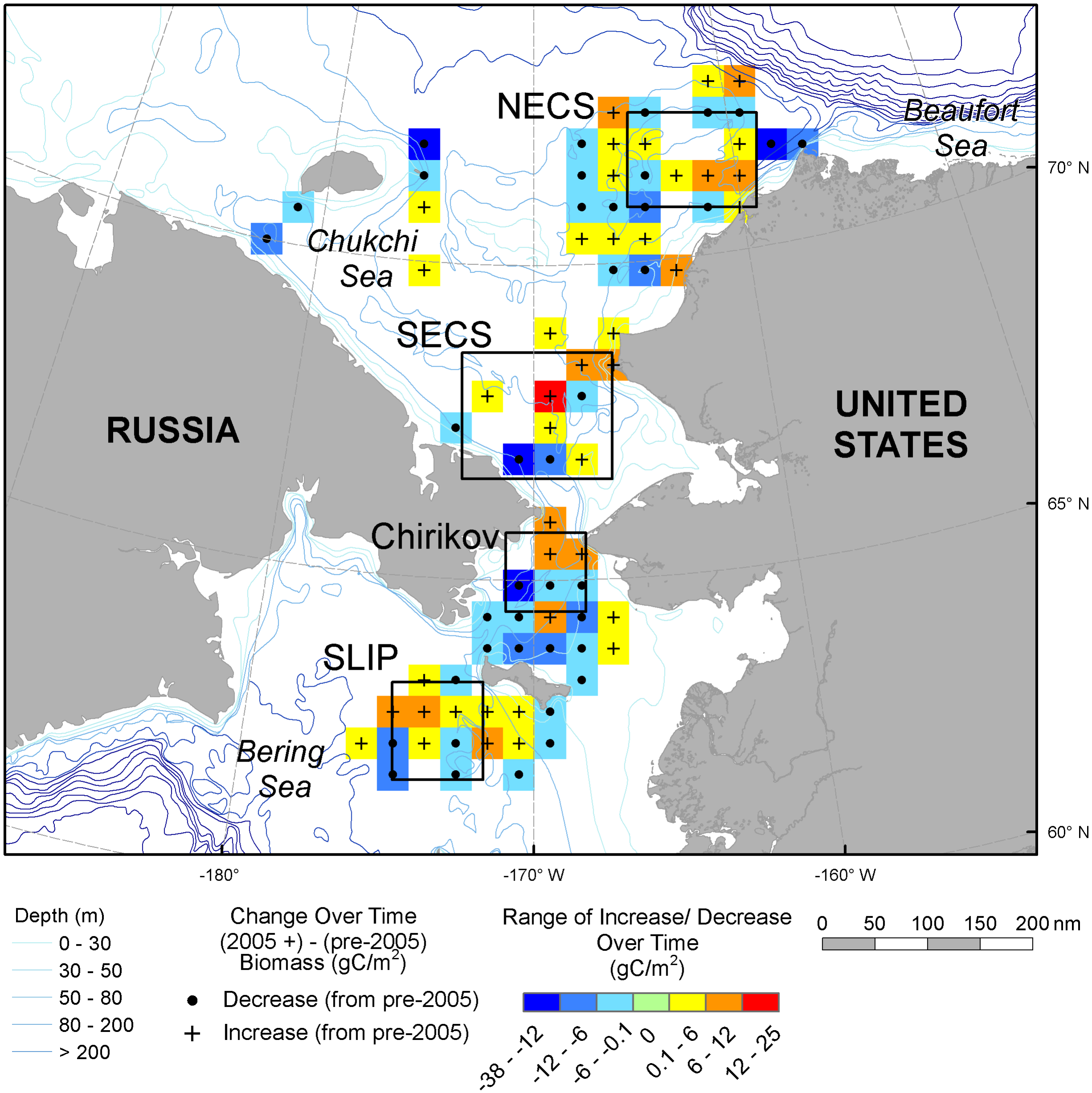
- Northward direction of core benthic biomass in hotspot to UTN5

[Stations on CS line]

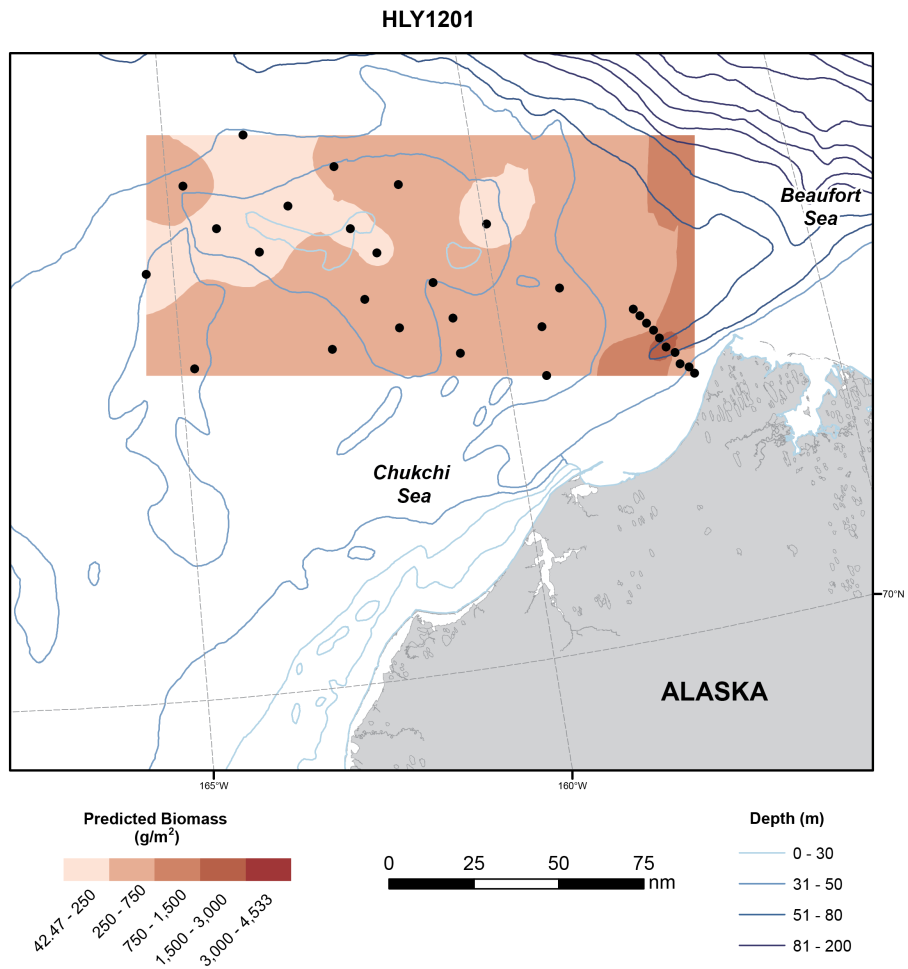


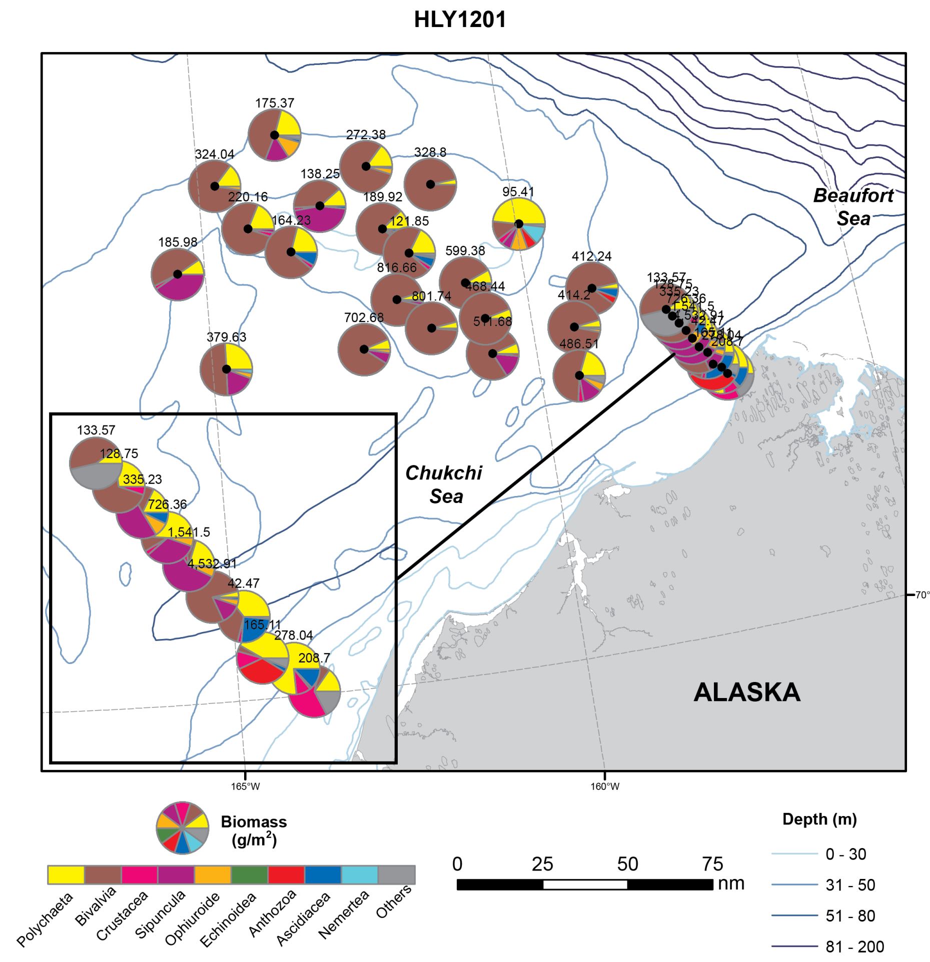
[Grebmeier et al. 2015 Oceanography]

Benthic macrofaunal biomass pre- and post-2005 shows northward migration benthic hotspots: SLIP, Chirikov, SECS



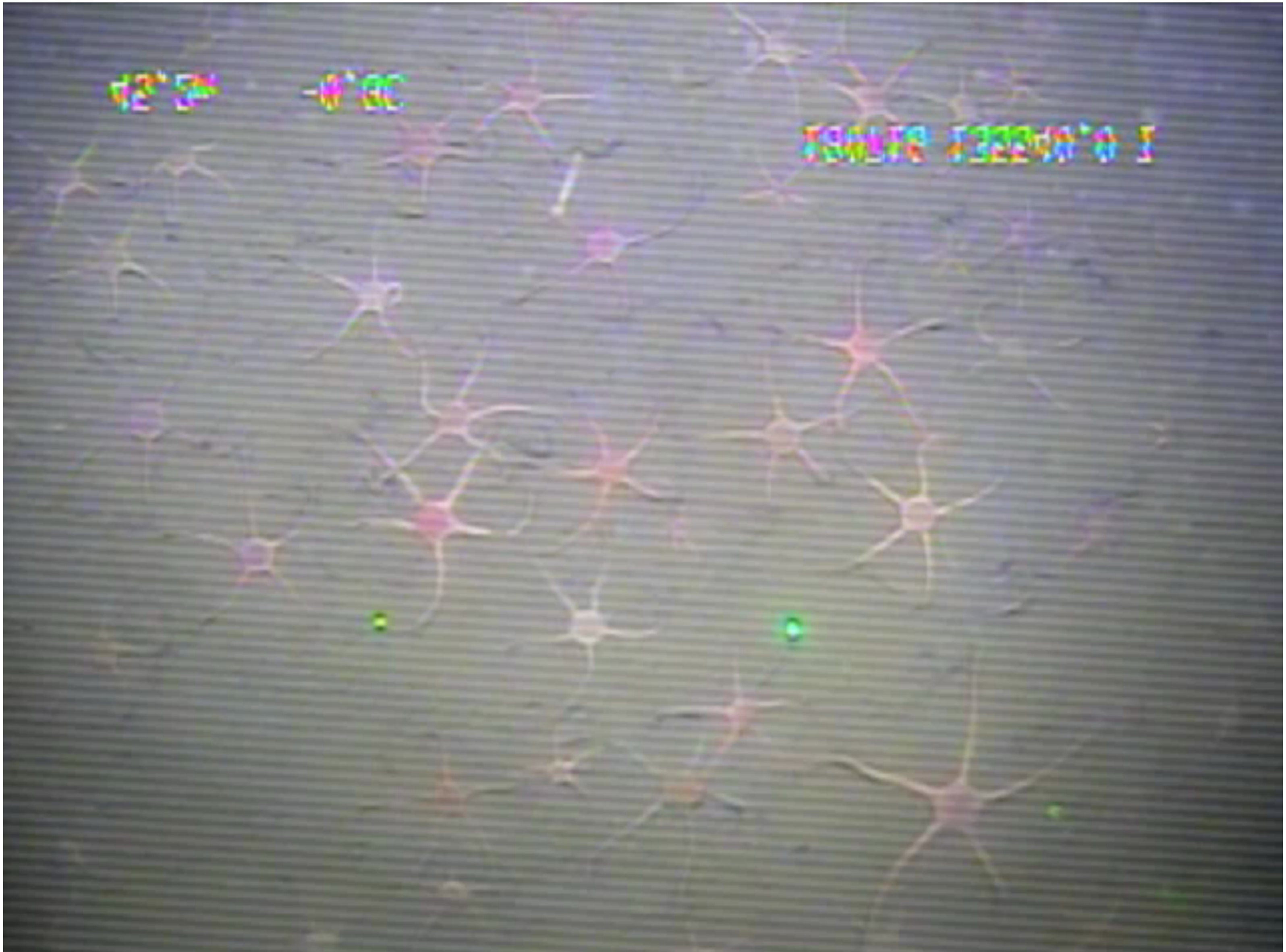
NE Chukchi Sea Benthos
-DBO4 region: bivalves, polychaetes and sipunculids
-DBO5 (Barrow Canyon): higher diversity benthic fauna



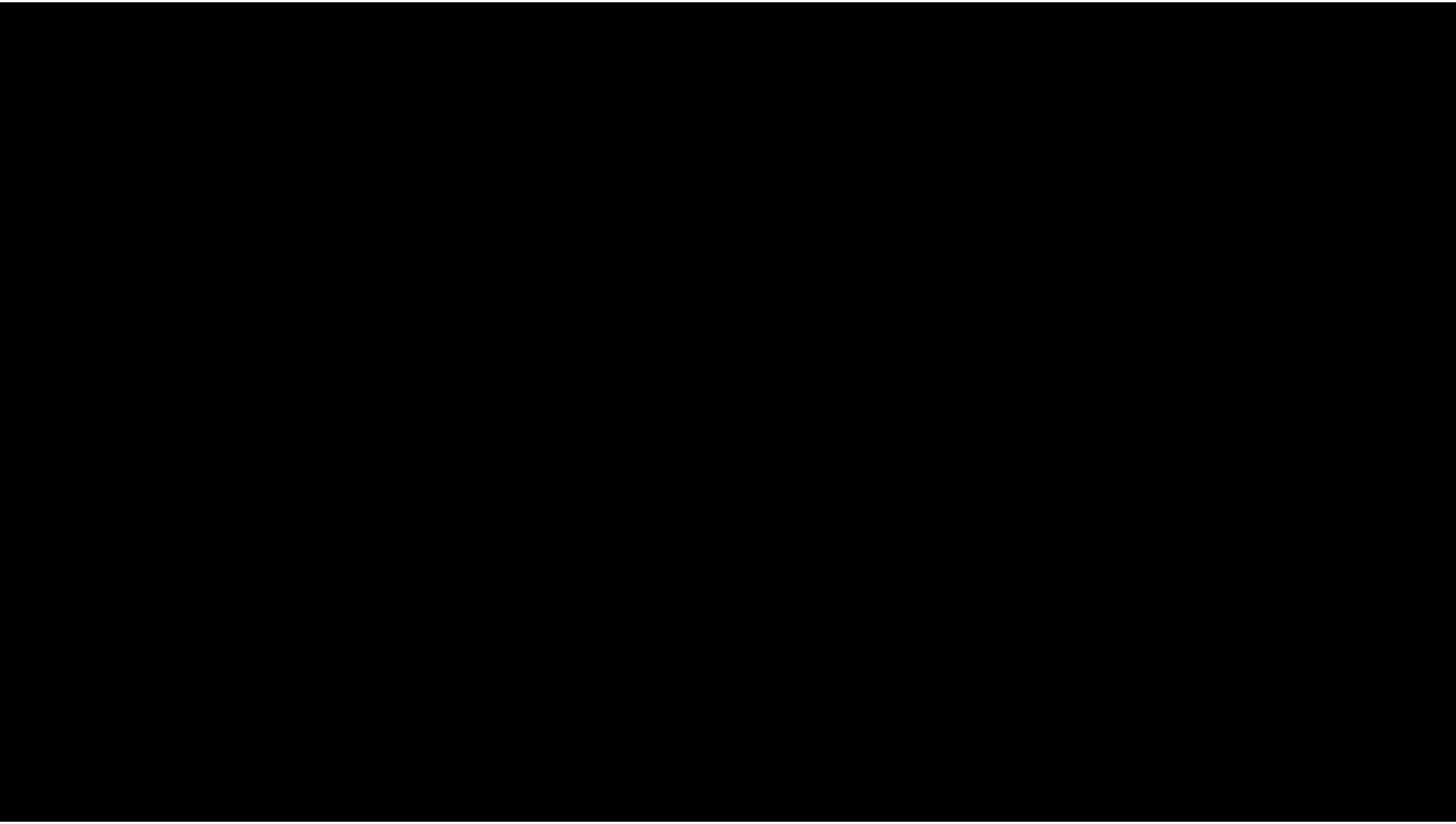


[Grebmeier et al. in prep]

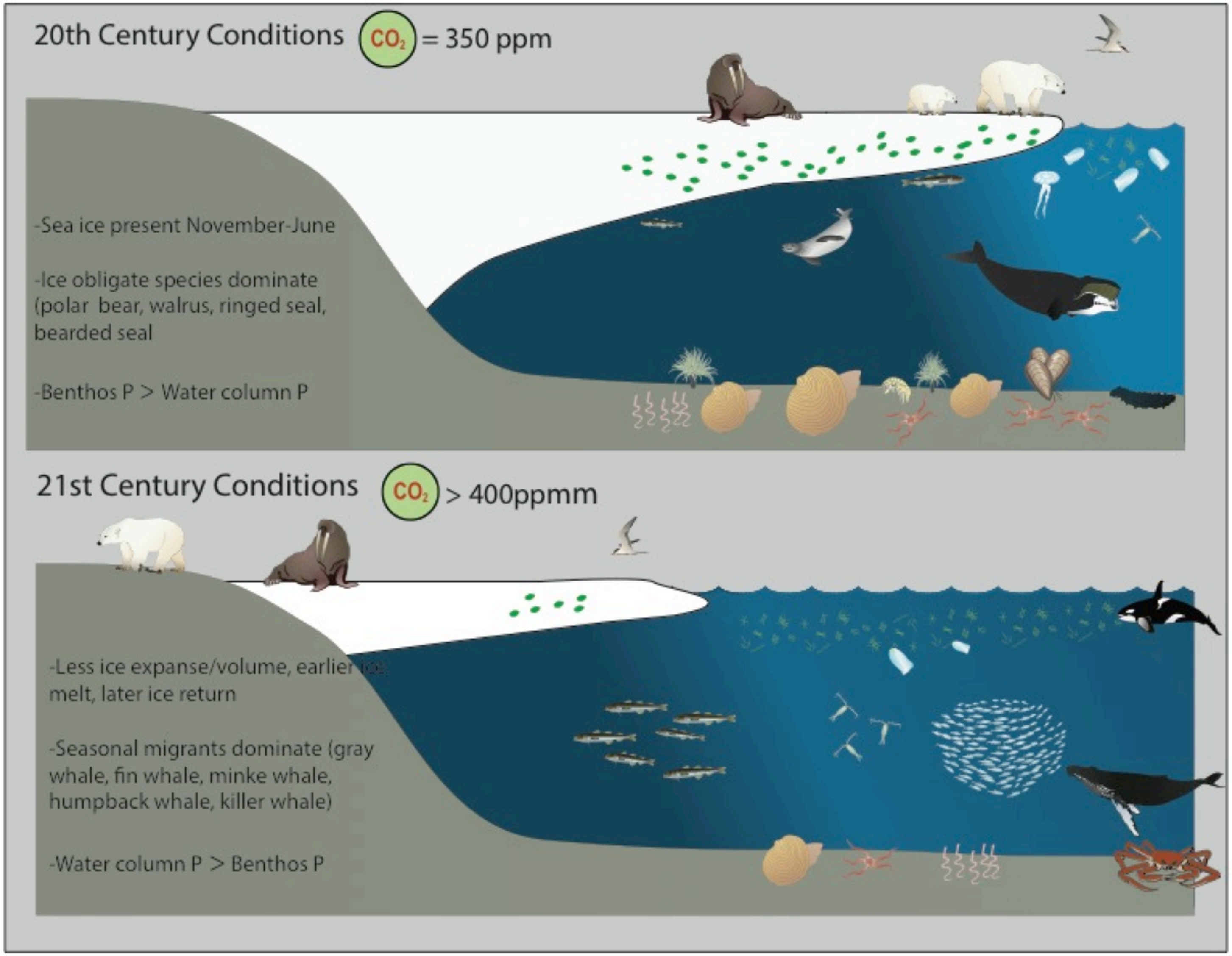
DBO4 (4.3): NE Chukchi Sea-bivalves (July 2016)



DBO5: Barrow Canyon (August 2009)



Major ecological shifts expected with reduced sea ice conditions



[Cooper and Grebmeier-Chukchi Sea case study, 2016, "*Climate Change and Biodiversity*", 2nd edition. Thomas Lovejoy and Lee Hannah, editors. Yale University Press]

Summary

- Biological sampling across a range of spatio-temporal scales is required to detect ecological shifts in response to environmental forcing
- Repeat time and space collections of various environmental and biological parameters, coincident with process studies, is allowing us to evaluate seasonality and interannual Arctic ecosystem status and trends
- Strong need for time series analyses in multiple components of the biological and biogeochemical system in relation to changes in physical forcing factors
- Benthic macrofaunal time series data indicate a northward shift in the core benthic biomass in the persistent biological hotspot areas in the Bering Strait region
- Tracking macrofaunal prey base with associated seasonal benthivore feeding and movement providing insight of ecosystem status and trends at the subarctic-arctic interface in the Pacific Arctic

Thank you for your attention.

Questions and comments?

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