The Arctic Ocean Ecosystem: Status and Trends in the Pacific Arctic

Jacqueline M. Grebmeier

University of Maryland Center for Environmental Science
Chesapeake Biological Laboratory, Solomons, Maryland USA

School Yard Program:
Arctic Ocean Ecosystem Overview and
Arctic Science Goes to School

Barrow Arctic Research Center
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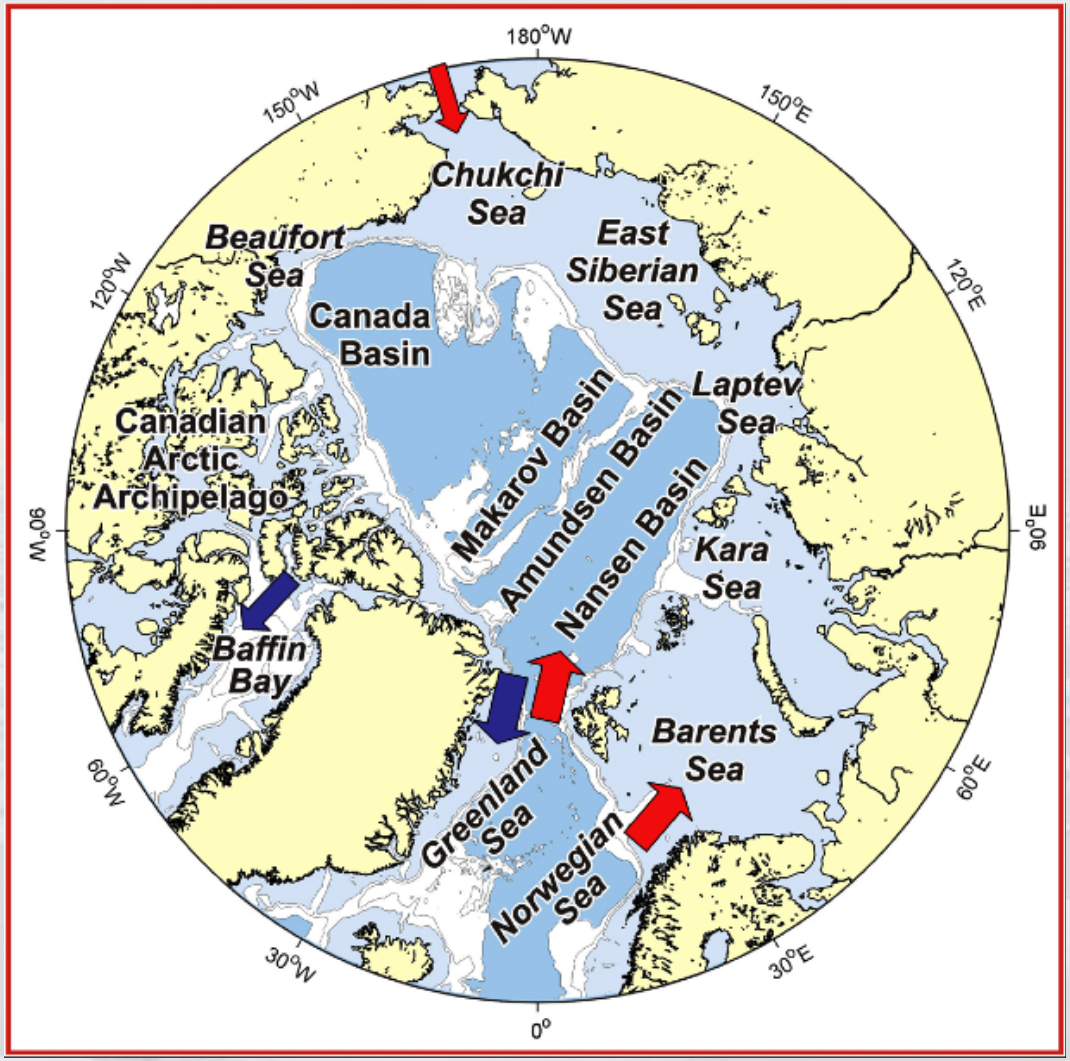
Barrow , Alaska

University of Maryland
CENTER FOR ENVIRONMENTAL SCIENCE
CHESAPEAKE BIOLOGICAL LABORATORY

The Arctic Ocean is a Mediterranean Sea



Carmack & Wassmann 2006

About 50% of the surface is comprised by shallow shelves with depth < 300m

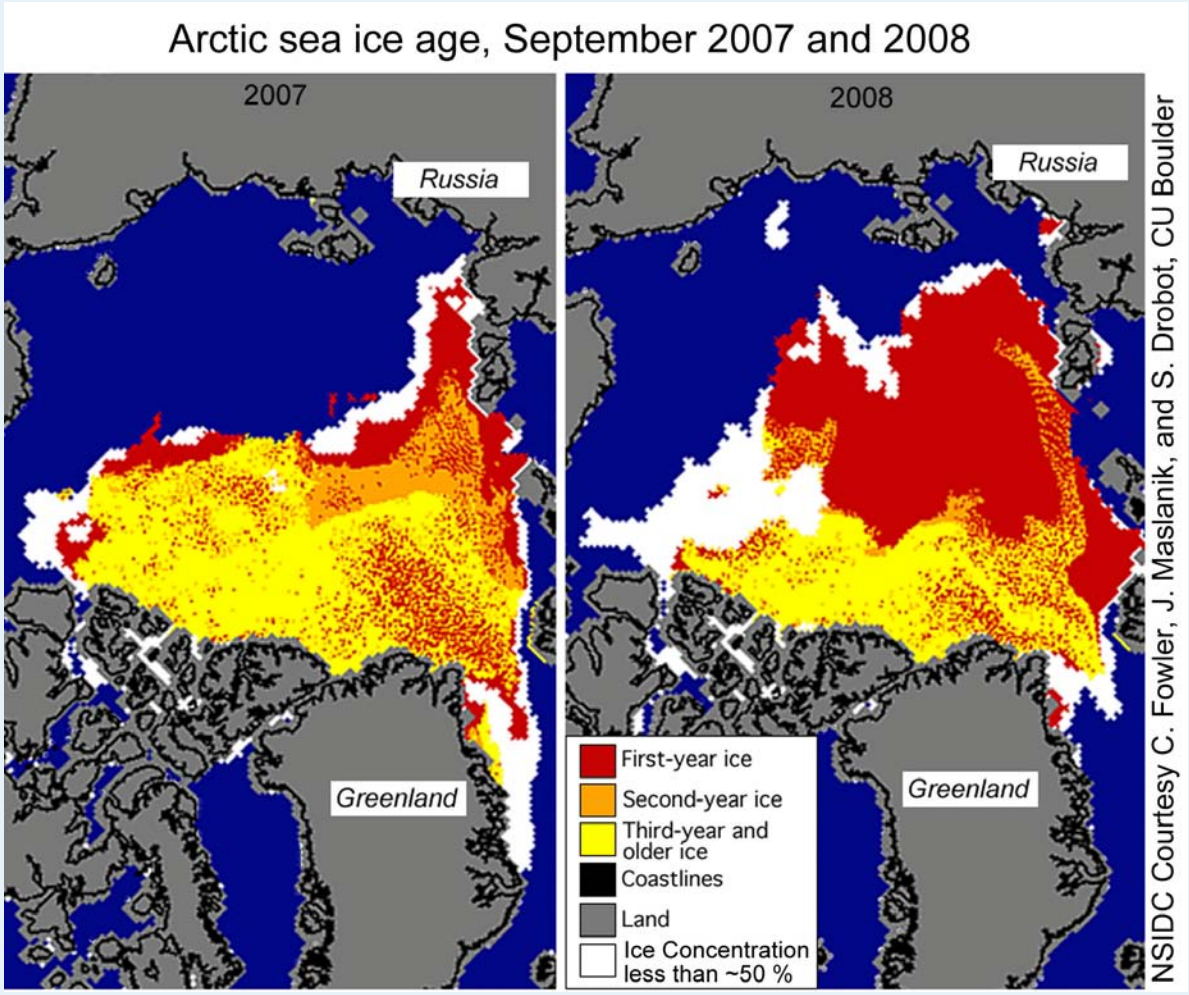
While 50% for the world ocean is > 4000 m.

This leads to a generally stronger pelagic benthic coupling in the Arctic compared to other systems

Key Environmental Factors Influencing Arctic Marine Food webs

- **Shrinking sea ice cover** - reduced ice algae, but increase "open water" algae will likely drive significant changes
- **Warming surface seawater** - increased bacteria and zooplankton means less food reaching ocean bottom to feed animals
- **Freshening of Arctic seawater** - less salty water impacts biodiversity
- **Coastal erosion -** changes "carbon cycle", dilutes rich marine food for coastal organisms

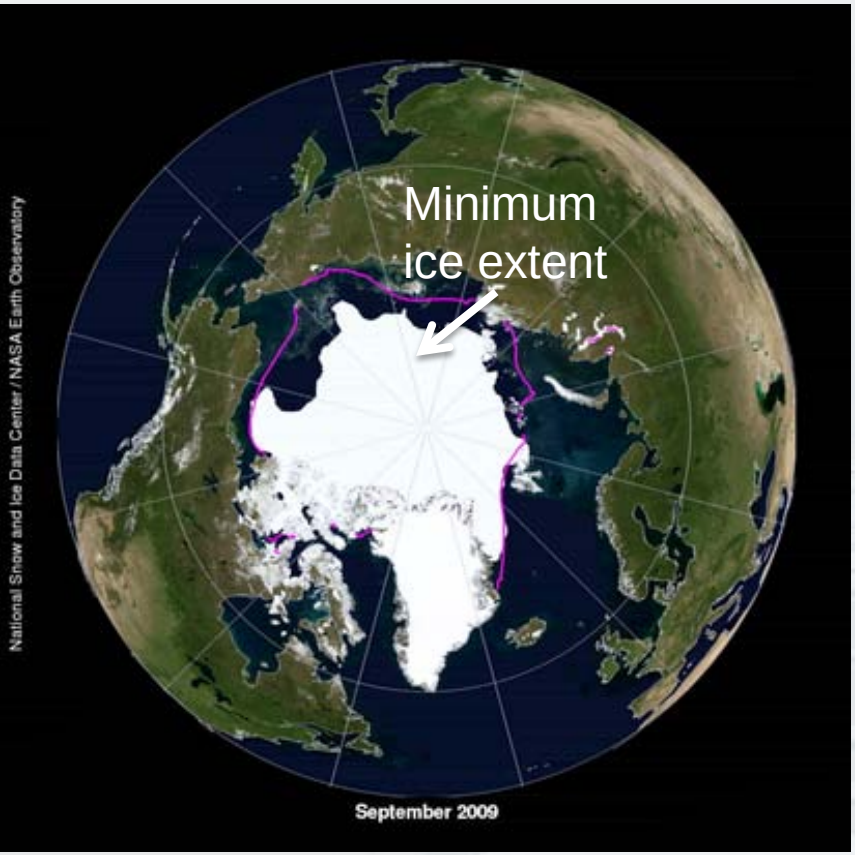
Dramatic decline old, multi-year ice in 2008 vs 2007

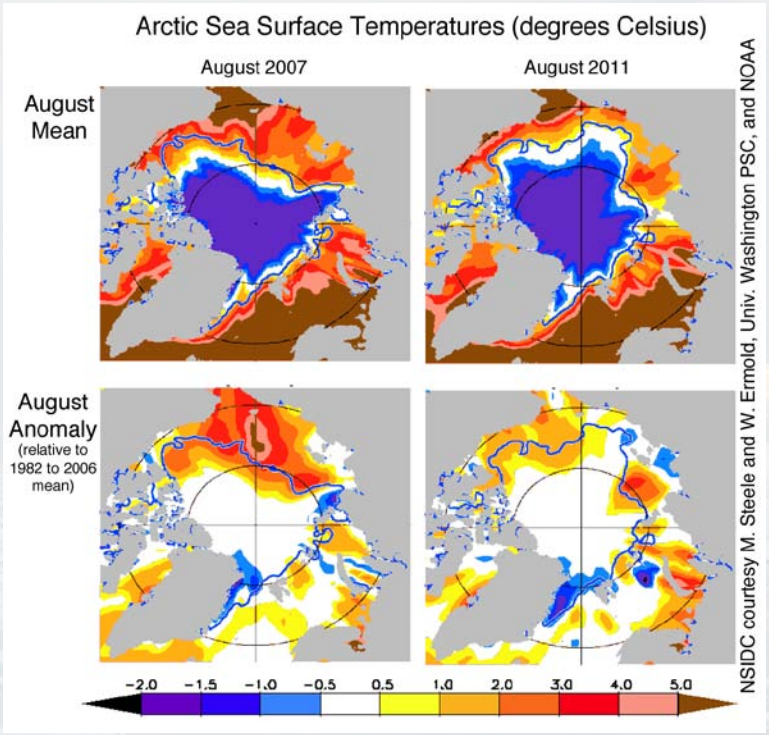


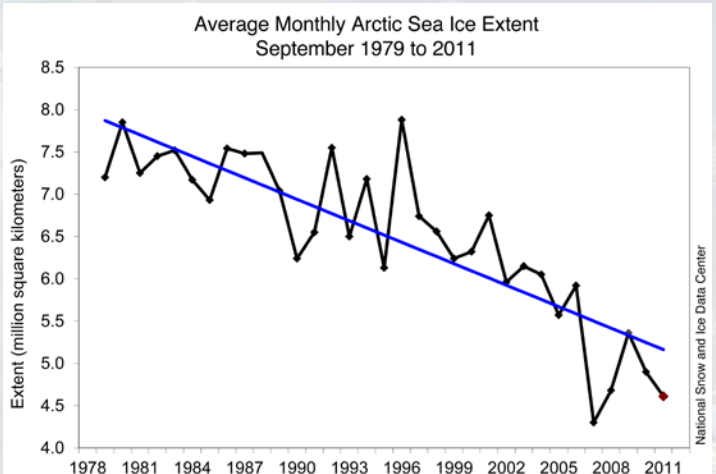
[NSIDC, 2008; see http://www.nsidc.org]

- maximum ice retreat in 2007 set up system for large first-year, thin ice in 2008, with dramatic loss of older, thick multi-year ice

Sea ice extent (2011) and surface sea water temperatures (2007-2011) in Pacific region

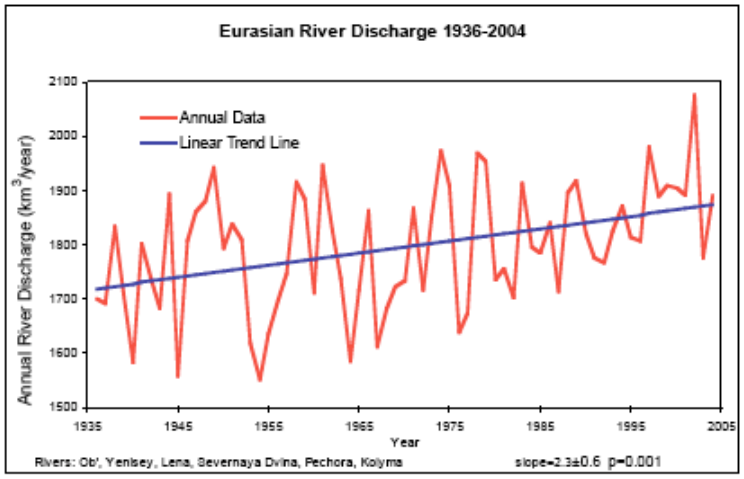






- 2011 (2nd lowest sea ice extent on record; 12% decline per decade

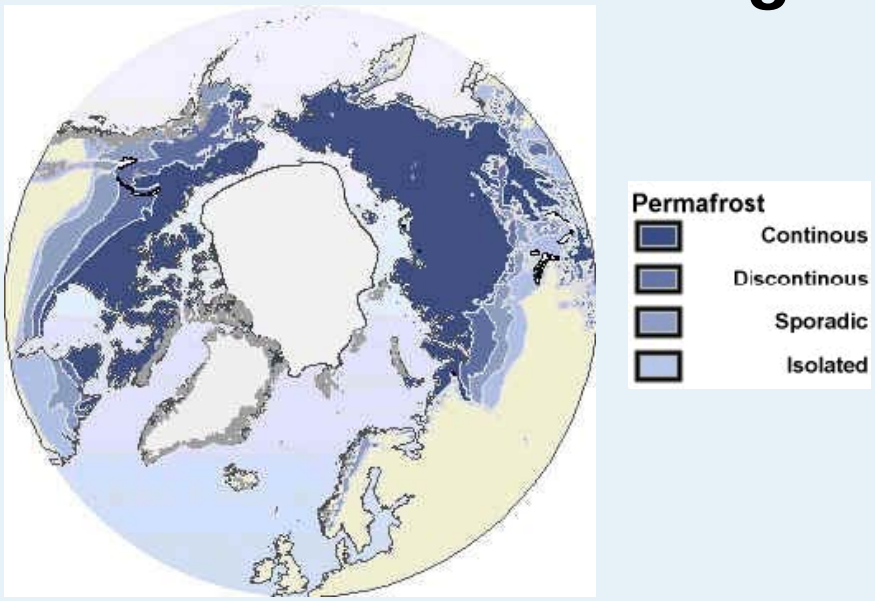
Increased freshwater input to Arctic Ocean through river flow and Pacific water input via Bering Strait



[Peterson et al. 2002, Shiklomanov et al. 2006]

- 60% freshwater to Arctic Ocean from rivers and local precipitation
- 40% freshwater to Arctic Ocean from Pacific water inflow through Bering Strait, using 32.5 for Pacific water salinity and and 34.8 for Atlantic water salinity
- data collected in 2000s indicate increased freshwater input through Bering Strait

Permafrost in northern hemisphere melting and releasing stored organic carbon and greenhouse gases




Dawson City, Yukon

- less sea and land ice, more shoreline erosion
- released methane and carbon dioxide as positive feedback to global warming
- infrastructure costs (bridges, pipelines, buildings) damaged by thawing permafrost
- movement of coastal villages upland

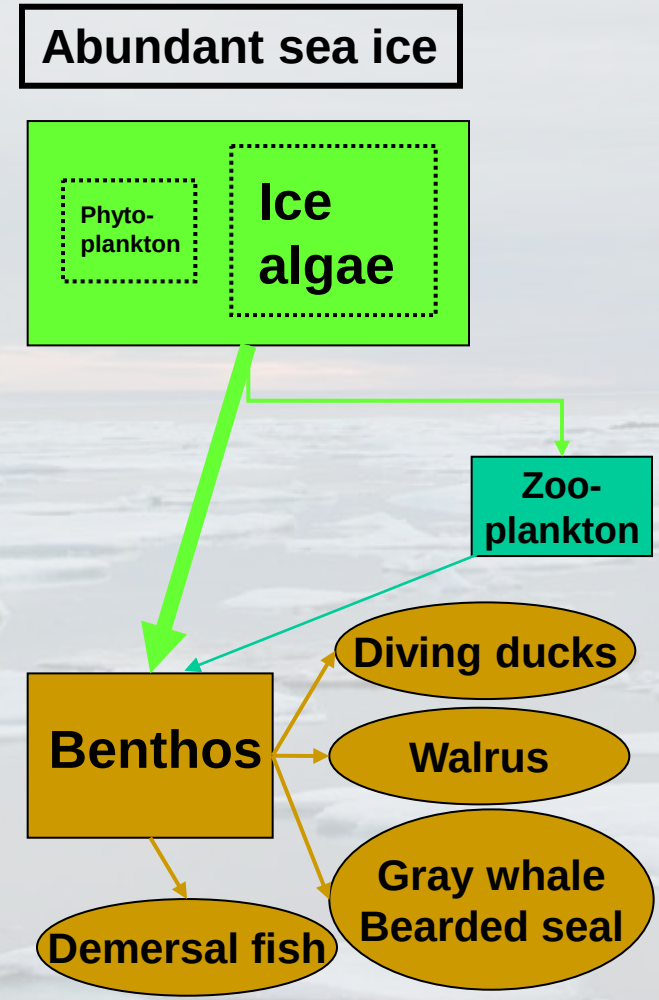
Observed Changes in the Pacific Arctic Region

a few examples

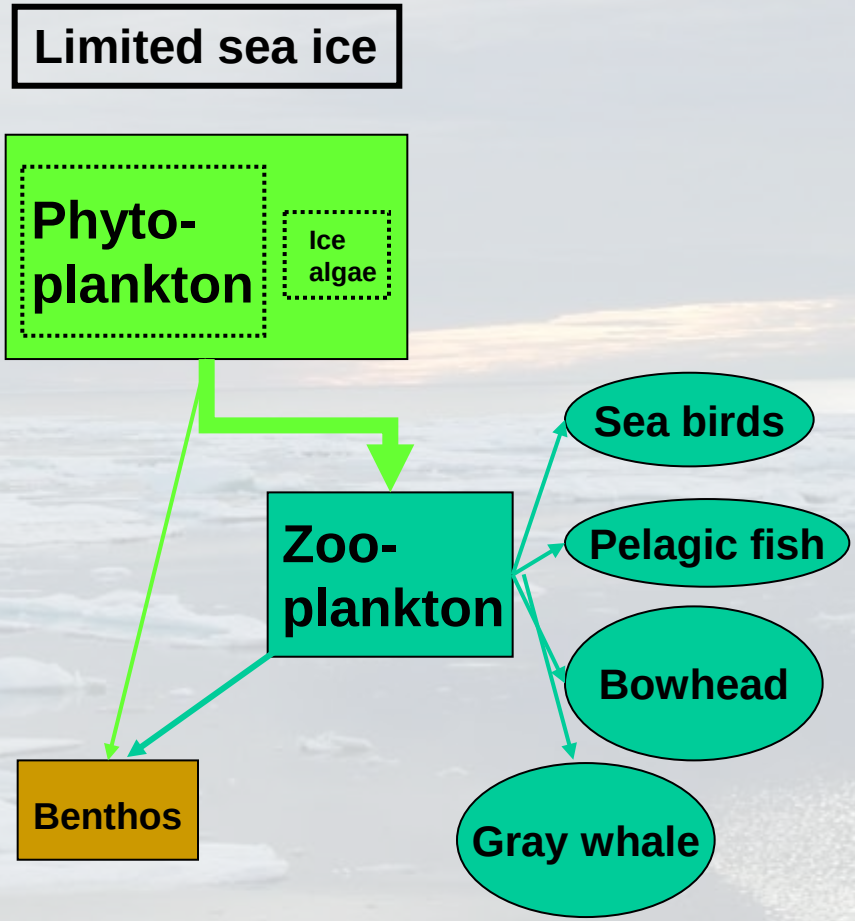
- Pacific zooplankton in Beaufort Sea
- Commercially fished ‘Bering species’ & snow crab in the western Beaufort Sea
- Seabird declines with drop in clam biomass [eiders] & access to ice-associated cod [guillemots]
- Gray whale feeding-focus shift from N. Bering to Chukchi
- Walrus hauling out on land in unprecedented numbers
- Polar bears reported drowned at sea, scavenging & denning on land

So how does light and Ice Cover Influence Ecosystem Structure?

Northern Bering & Chukchi Seas



Southeastern Bering Sea

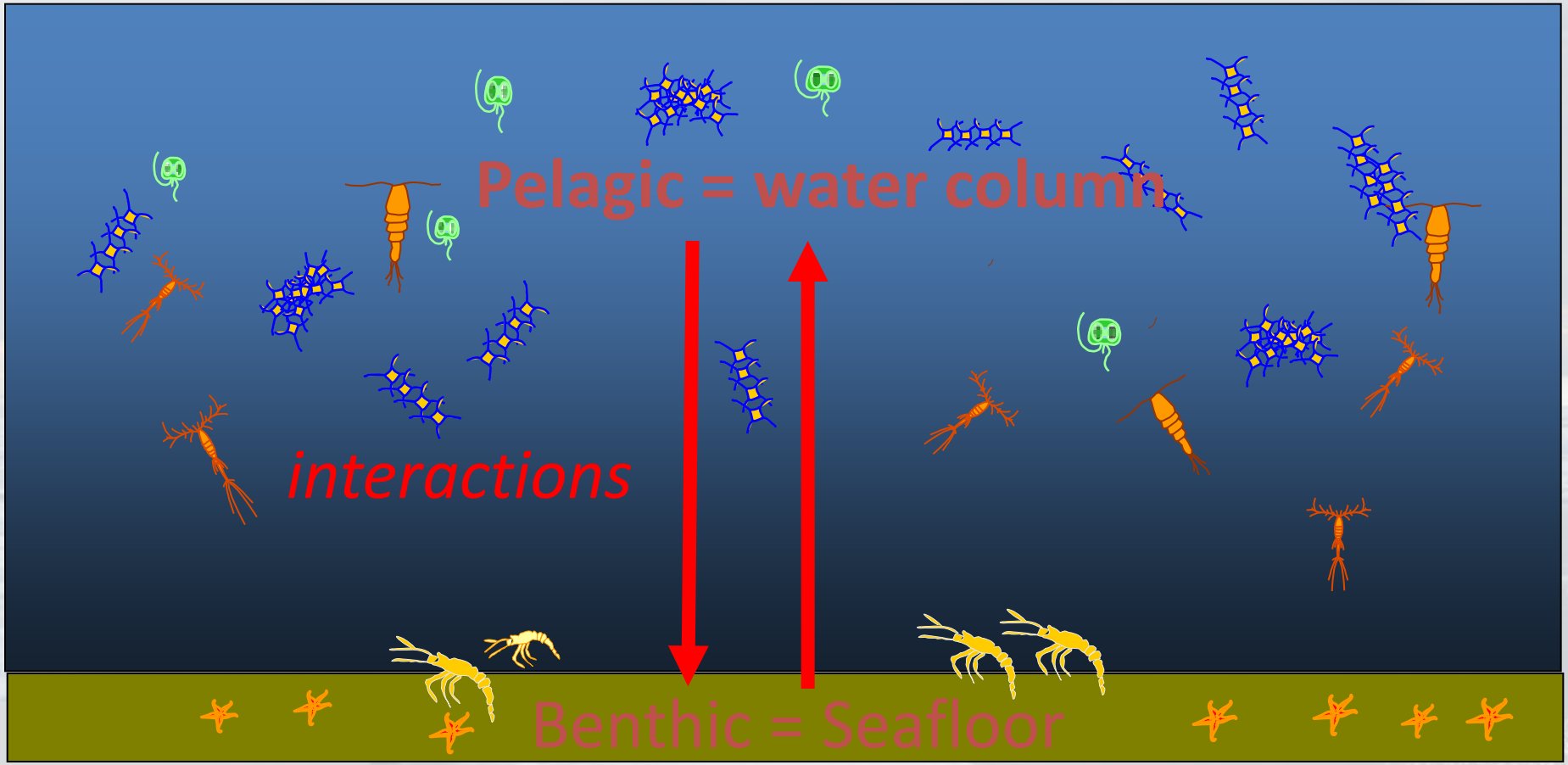


[Courtesy Katrin Iken; modified after Grebmeier and Barry 1991, Carroll and Carroll 2003]

BENTHIC DOMINATED

PELAGIC DOMINATED

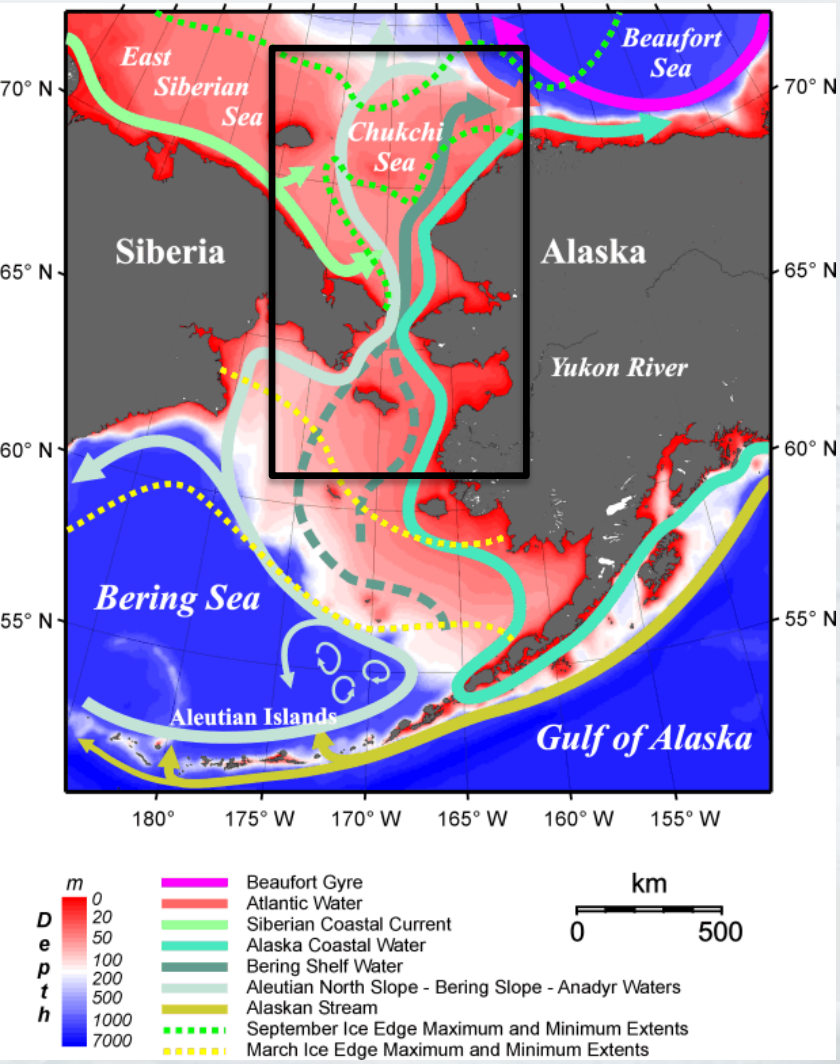
Pelagic and benthic interactions



[courtesy Christian Wexels Riser]

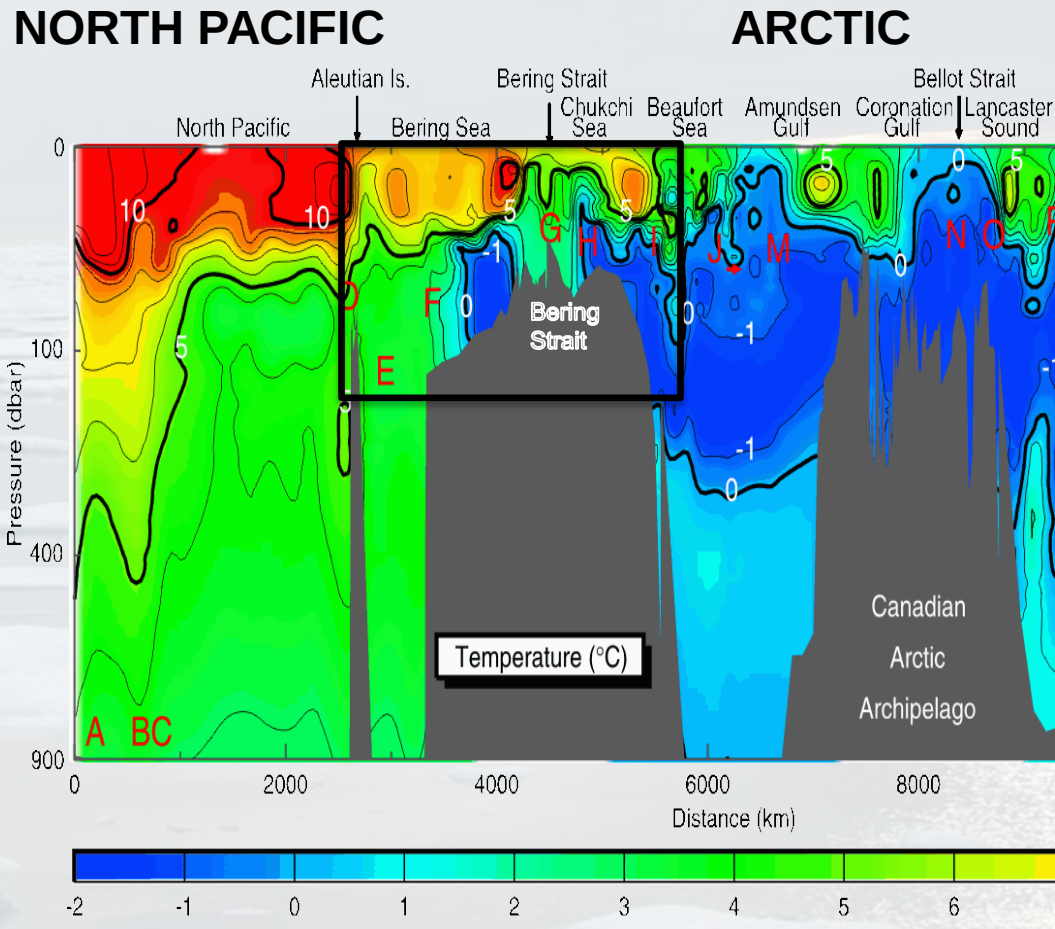
Pelagic and benthic interactions are frequently referred to as pelagic-benthic coupling

Seasonal water mass structure in the Pacific sector



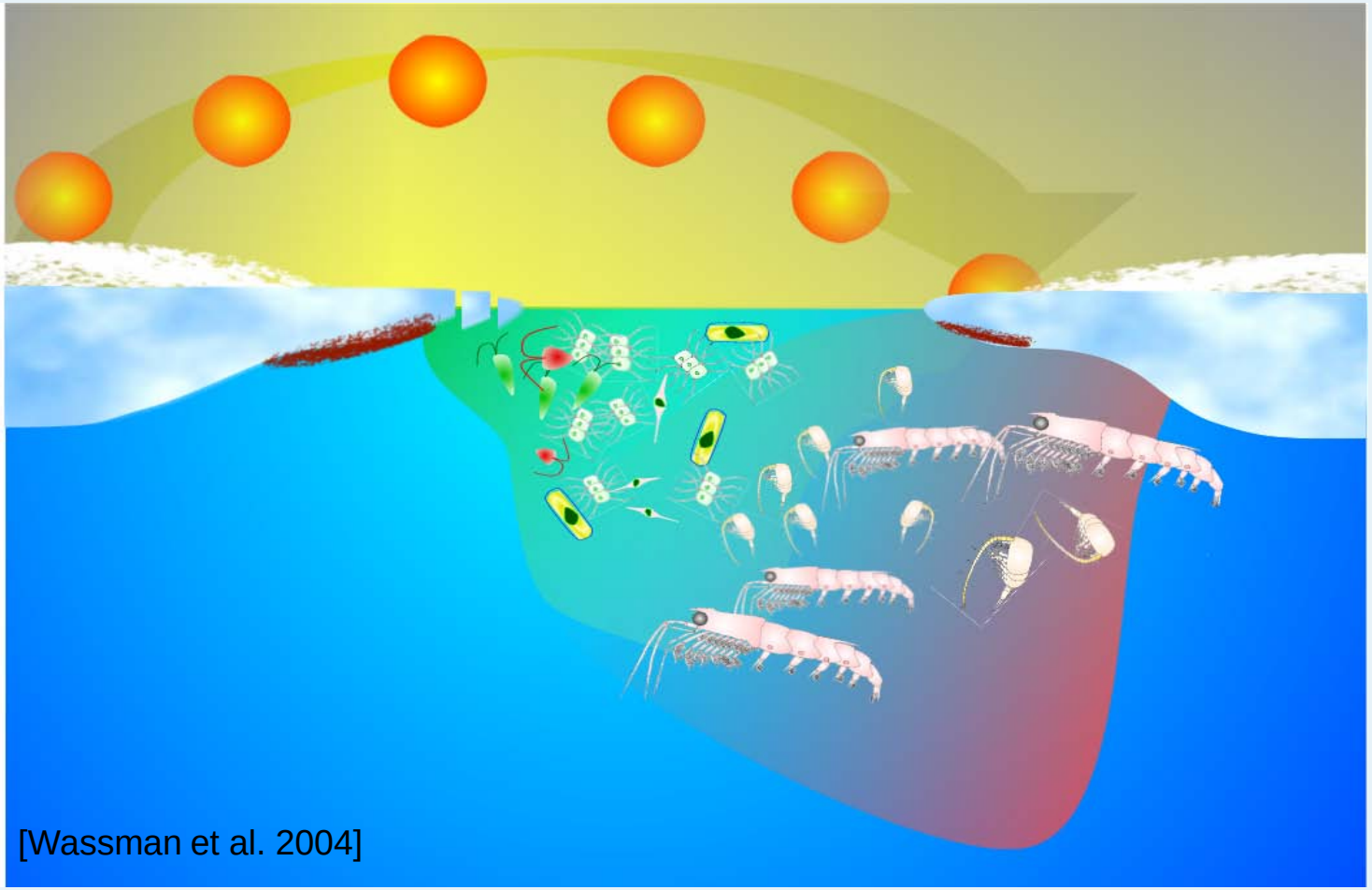
[Tom Weingartner and Seth Danielson]

C3O Seawater Temperature "Slice" in July 2008

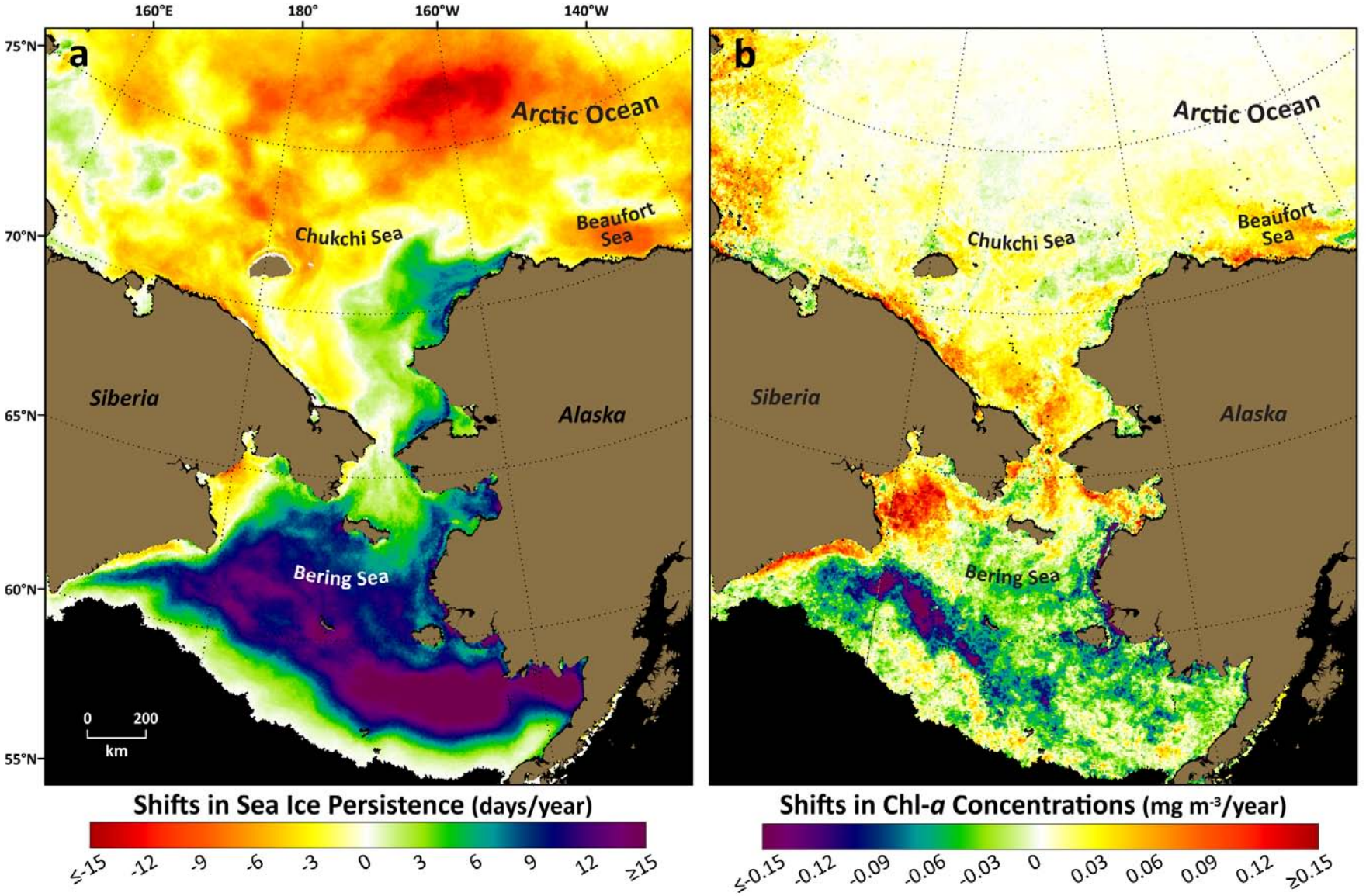


[Eddy Carmack/IOS]

Timing and location of ice algae growth depends on ice cover and light, zooplankton growth influences food reaching underlying sediments



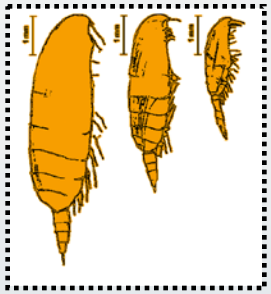
Shifts in sea ice persistence and Chl-a concentration from 2003-2009



Based on SSM/I Sea Ice Concentrations and the GlobColour (SeaWiFS, MODIS, MERIS) satellite time series, courtesy Karen Frey

Arctic, Subarctic and Bering Sea: dominant copepods

All sketches drawn at same magnification; all scale bars represent 1mm



Arctic Copepods

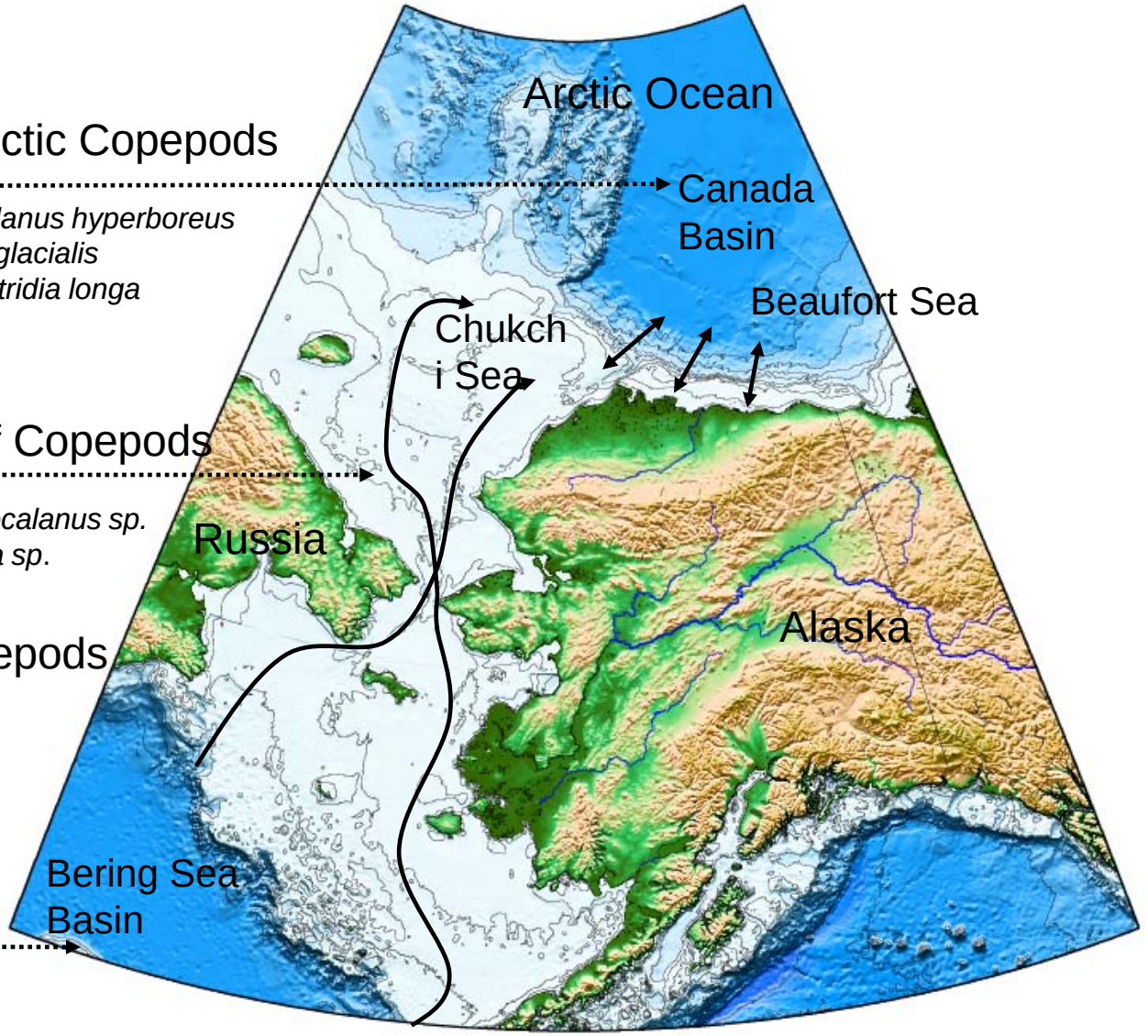
Calanus hyperboreus
C. glacialis
Metridia longa

Shelf Copepods

Pseudocalanus sp.
Oithona sp.

Bering Sea Copepods

Neocalanus cristatus
N. flemingeri
Calanus marshallae



[courtesy Sharon Smith]

Discipline history & state of knowledge benthos

Benthic Biomass hotspots in high latitudes

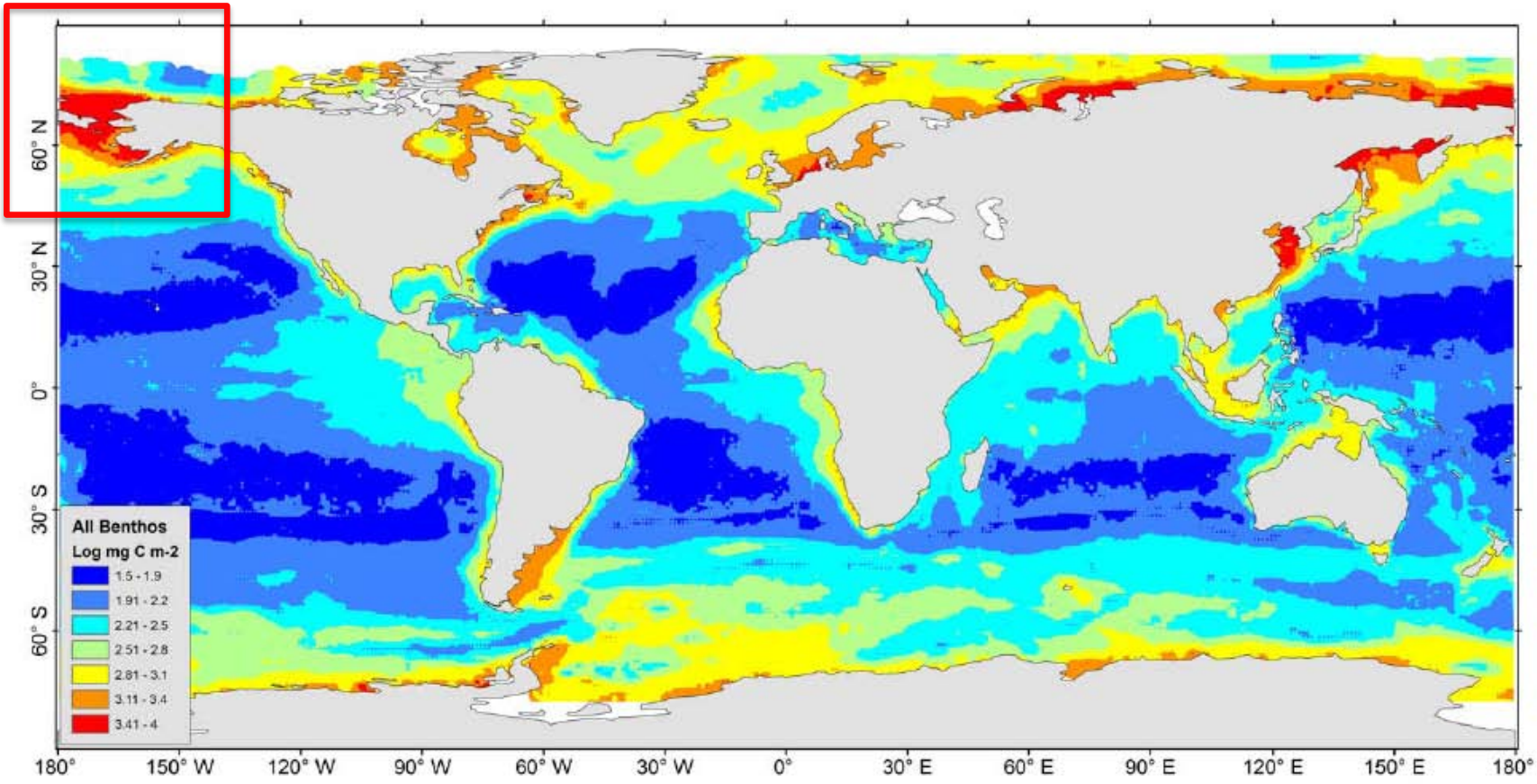
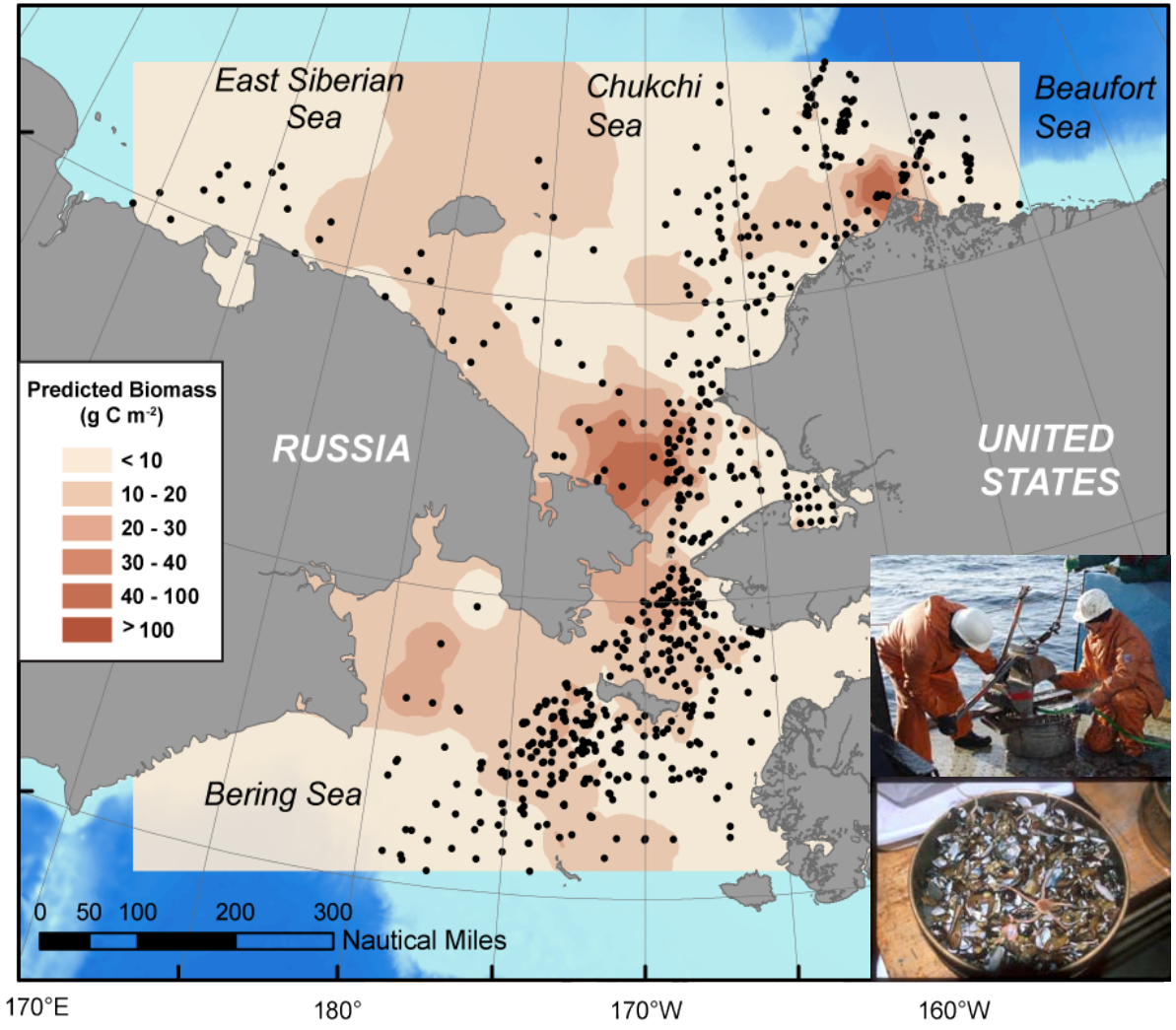


Figure 7. Distribution of seafloor biomass predictions. The total biomass was combined from predictions of bacteria, meiofauna, macrofauna, and megafauna biomass (Figure S5a, b, c, d). Map was smoothed using Inverse Distance Weighting interpolation to 0.1 degree resolution and displayed in logarithm scale (base of 10).
doi:10.1371/journal.pone.0015323.g007

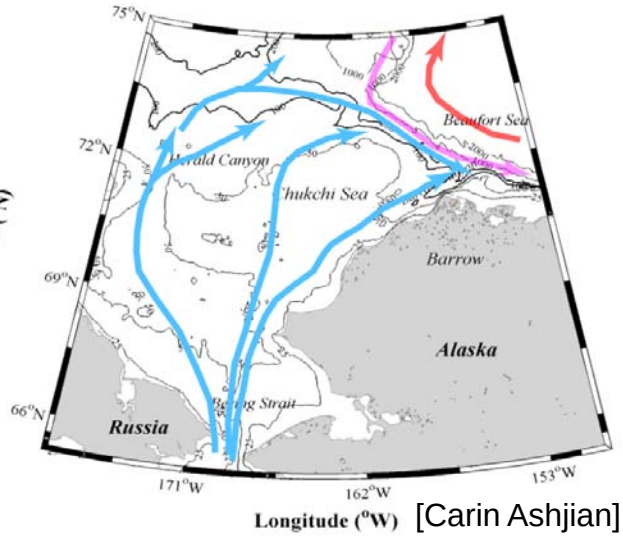
Wei et al. (with Grebmeier and Bluhm) 2010 PLoS ONE 5(12): e15323

Rich benthic communities on the western side of the Bering/Chukchi Sea system 1970-2010



[updated from Grebmeier et al. 2006]

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



[Carin Ashjian]

Ice Associated and Seasonally Migrant Species = Pelagic sentinels?

Is a change in bowhead & gray whale numbers & phenology (timing of migration) since the 1980s…

- Reflecting a shift in prey composition? Gray whales consume benthic amphipods and pelagic euphausiids
- Resulting in competition for prey near Barrow?
- Influencing Inuit hunting?

[courtesy Sue Moore]

Benthic Foragers: respond to changes in sea ice

Gray whales = shifts in distribution reflects sea-ice related prey decline

(amphipods: time and space) & over-wintering opportunity feed euphausiids;

staying longer north to feed

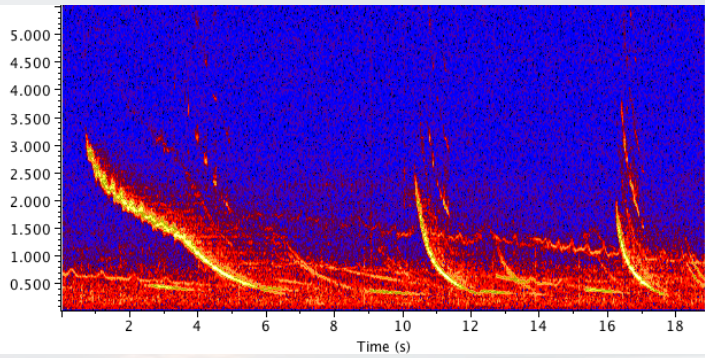
[courtesy Kate Stafford]

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

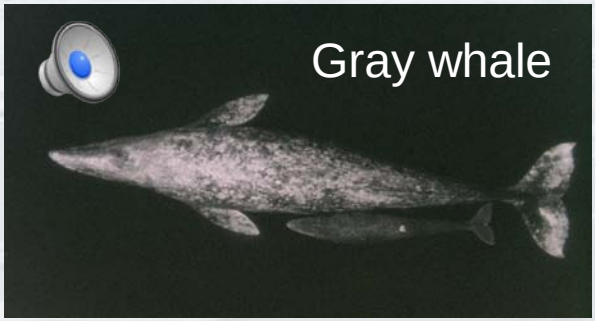
Nine Sentinel Species in Western Arctic

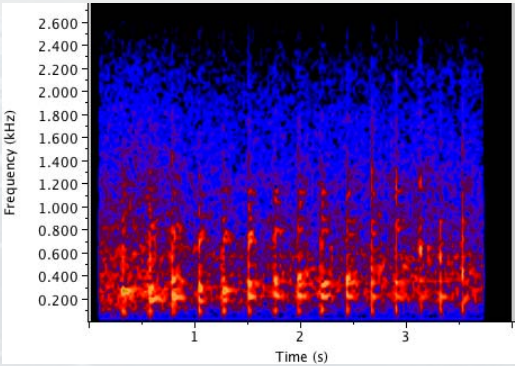
Each species reflects a different aspect of the Arctic ecosystem

- Ice seals: bearded, ringed, ribbon and spotted

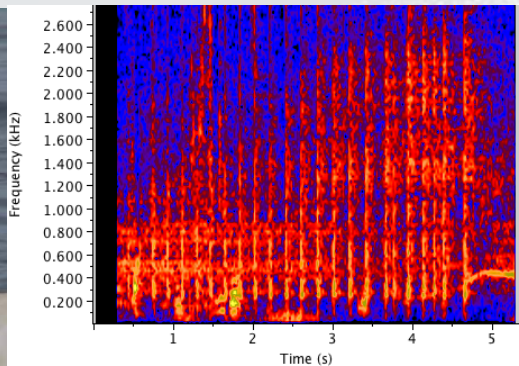


- Whales: bowhead, beluga and gray





- Polar bears and walruses

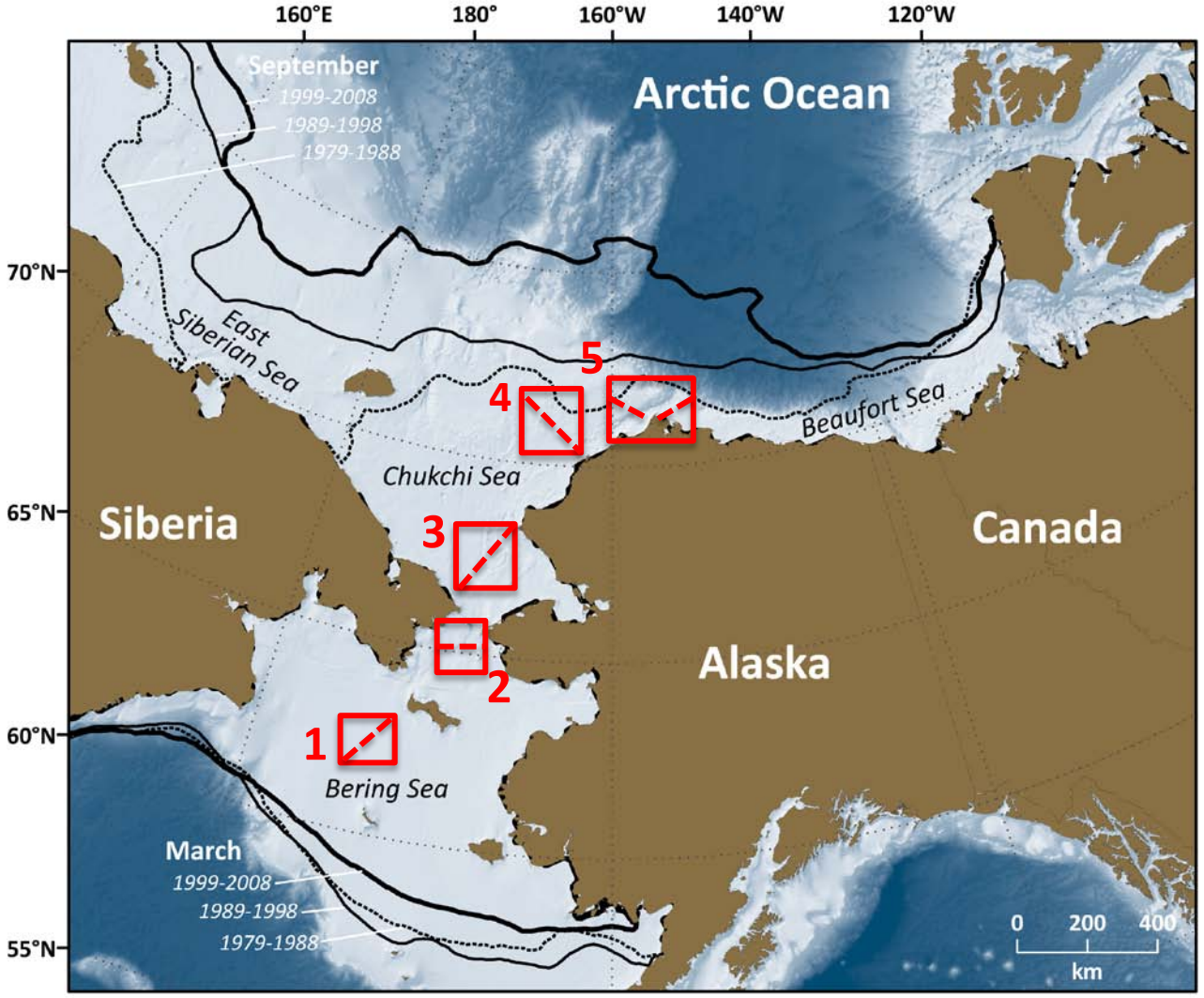


[Figures and sounds courtesy of K. Stafford; photos courtesy K. Frey and L. Cooper]

Local Alaskan Communities are concerned by unpredictability of ice conditions and its impact on subsistence hunting, lifestyle and the associated ecosystem

[photos courtesy Gay Sheffield, ADFG]

Distributed Biological Observatory (DBO) Sites

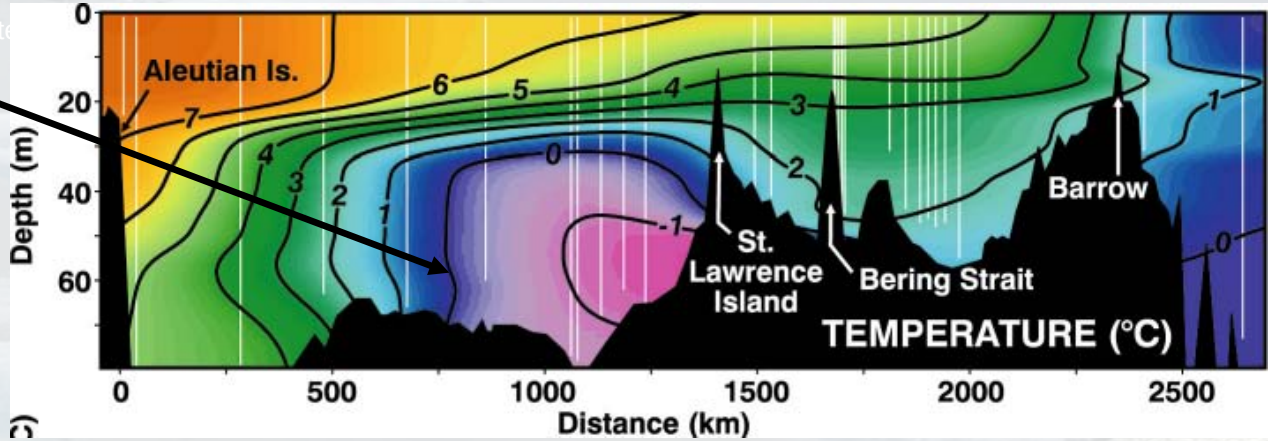


- **DBO sites (red boxes) are regional "hotspot" transect lines and stations located along a latitudinal gradient**
- **DBO sites are considered to exhibit high productivity, biodiversity, and overall rates of change**
- **DBO sites will serve as a change detection array for the identification and consistent monitoring of biophysical responses**
- **Sites occuppied by national and international entities with shared data plan**

Threatened spectacled eiders keyed to sea ice and specific bivalves (DBO1)

[courtesy Andrew Trites]

- 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

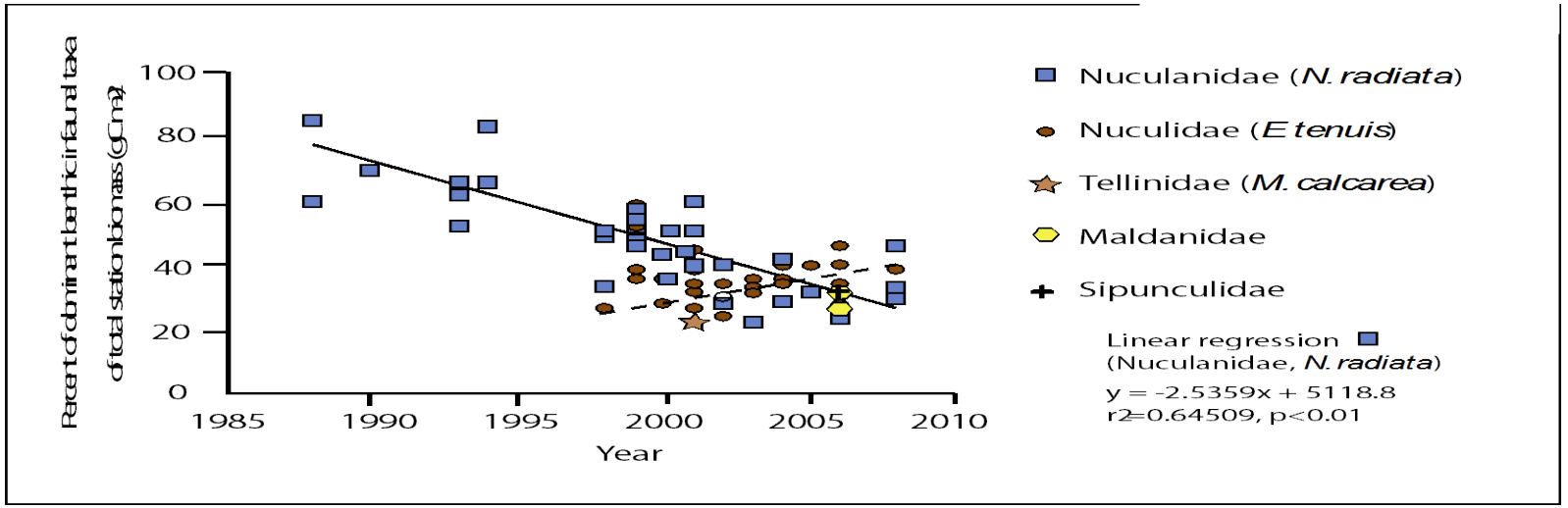


[Grebmeier et al. 2006, Science 311]

Examples of change-benthos

DBO1 area observe decline in dominant bivalve (*N. radiata*), with possible shift to smaller bivalve (*E. tenuis*)

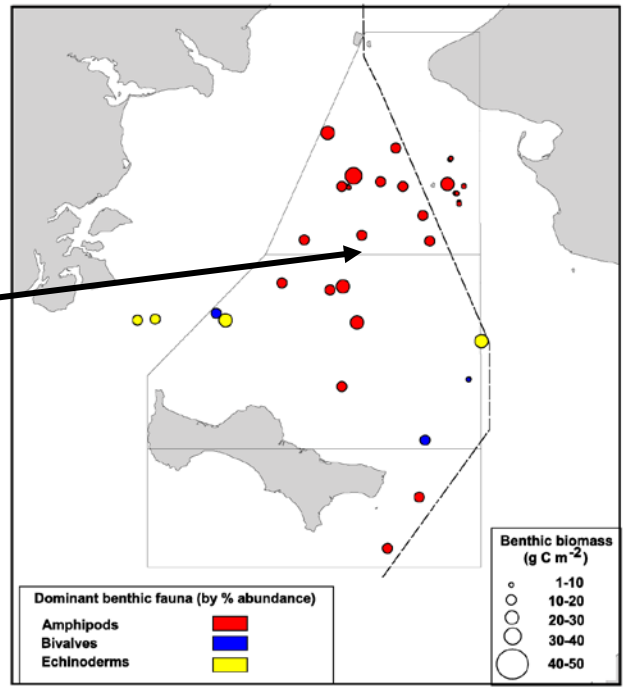
- **Observed decline in carbon supply to the benthos**
- **Negative impact on declining spectacled eider populations**



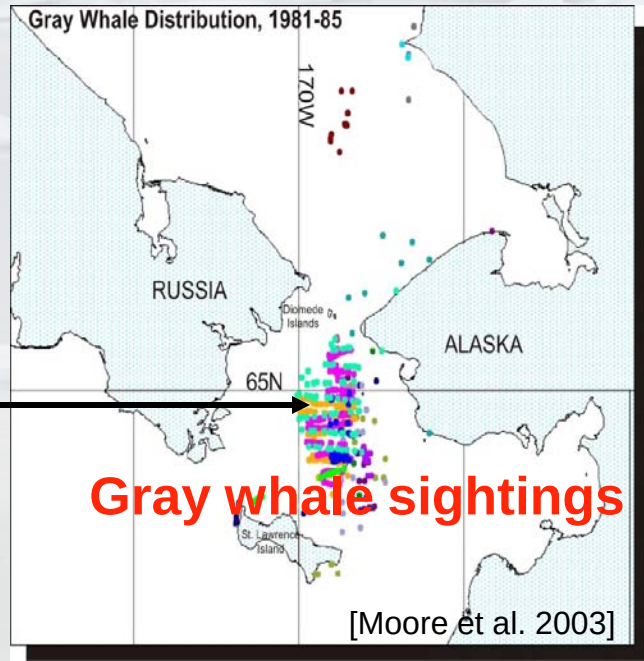
[Grebmeier 2012, Ann. Rev. Mar. Sci. 4]

Evidence for recent benthic change Chirikov Basin (DBO2)

- high amphipod populations in sediments in 1980's
- coincident large populations of migrating gray whales that feed on benthic amphipods



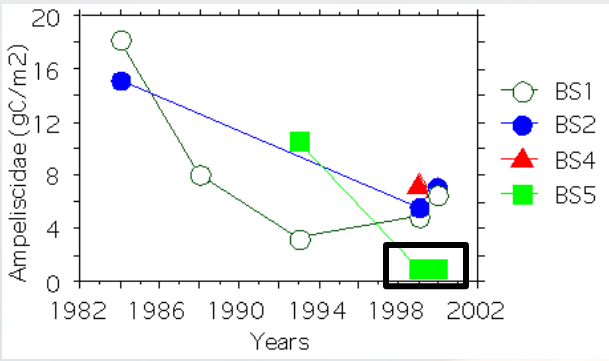
Movie of Gray whale normally viewed in this presentation can be viewed separately as a related resource.



[Moore et al. 2003]

And changes have already been observed..
One example is *Chirikov Basin:*
Drop in Benthic productivity
1980s to 1990s

Time-series sites



- decline of ampeliscid amphipod biomass at 4 time series stations (Moore et al. 2003)

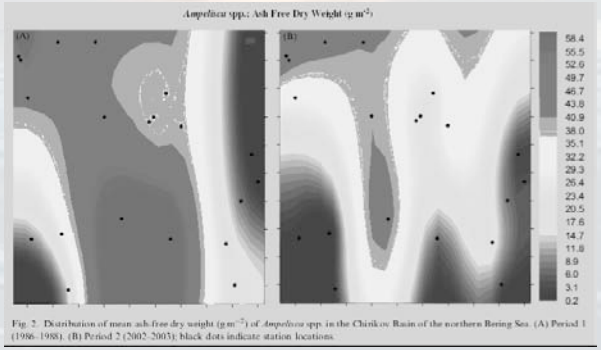
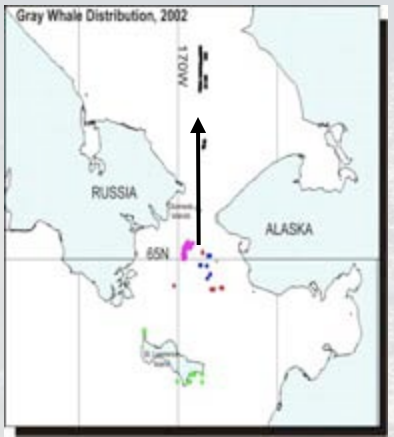


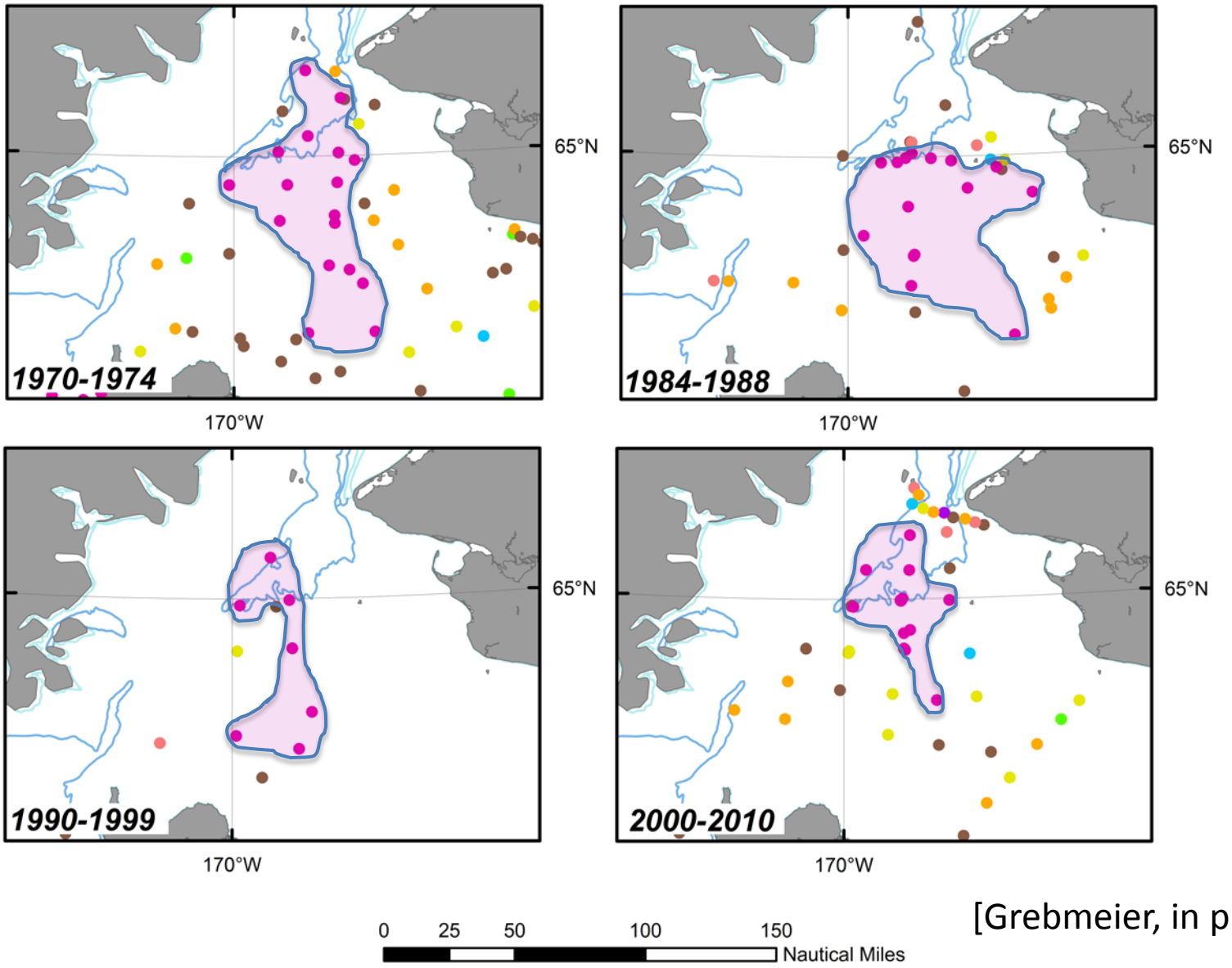
Fig. 2. Distribution of mean ash-free dry weight (g m^{-2}) of *Ampelisca* spp. in the Chirikov Basin of the northern Bering Sea. (A) Period 1 (1986–1988). (B) Period 2 (2002–2003); black dots indicate station locations.

- Highsmith and Coyle (1992) found a 30% reduction in benthic amphipod production from 1986-88 and continued into the 2000s (Coyle et al. 2007)



- Shift: gray whales north of Bering Strait, prefer feeding in ice-free areas

“Footprint” of ampeliscid amphipod prey contracting spatially



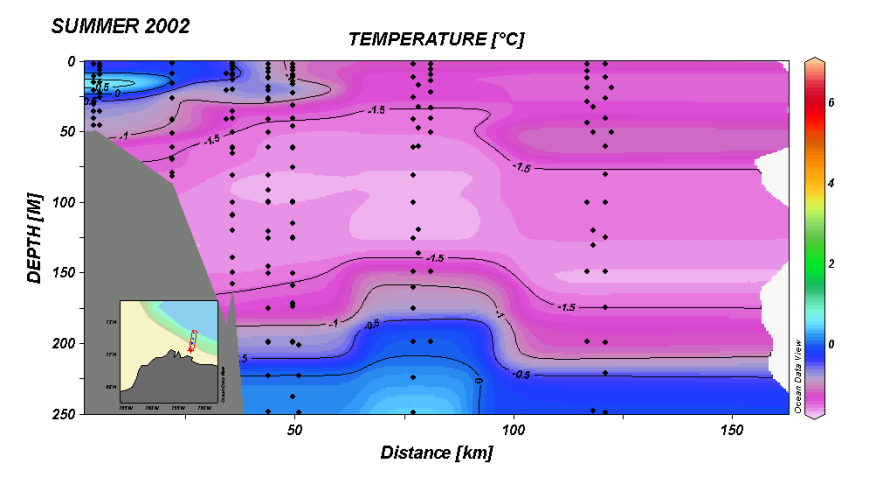
[Grebmeier, in prep.]

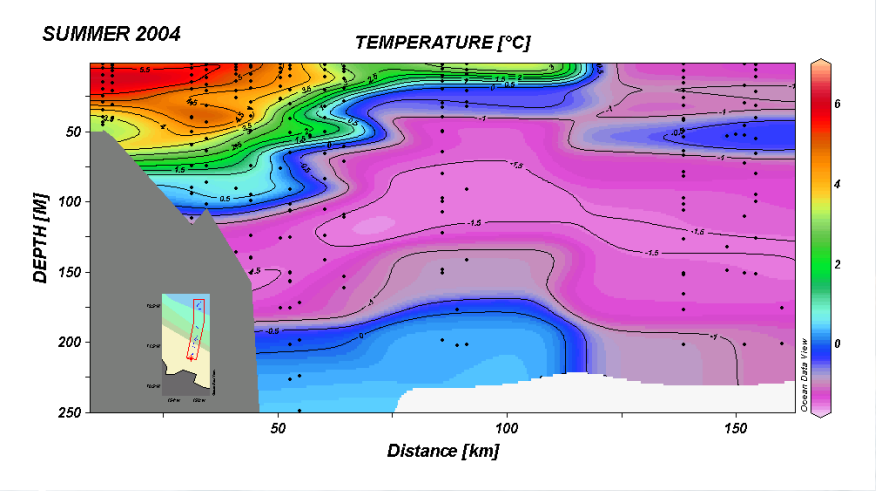
DBO5 (Barrow Canyon, BC)
High benthic biomass and diversity at head of Barrow Canyon

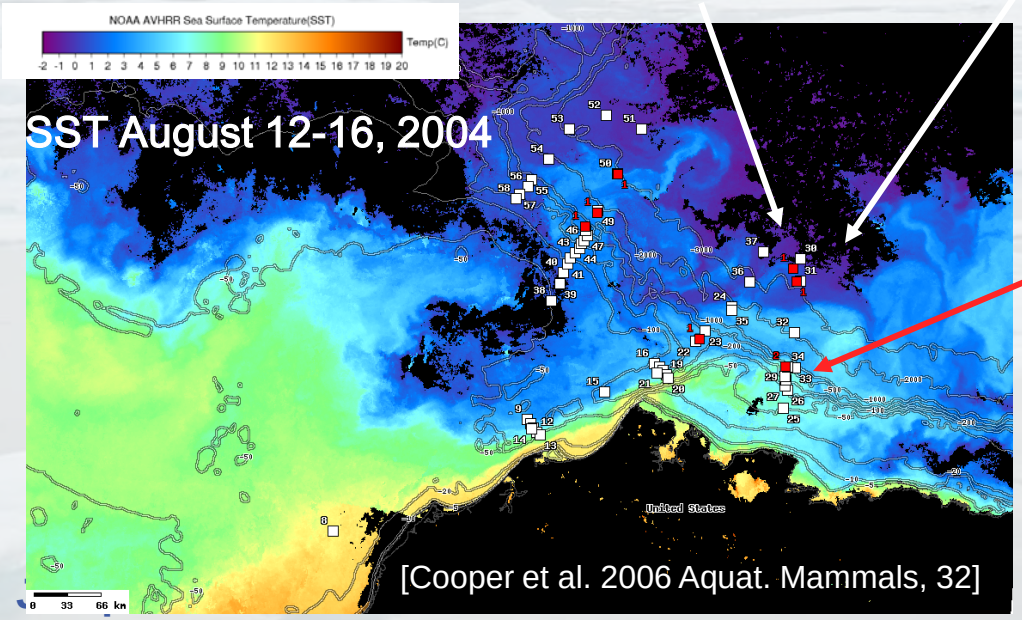
Movie of Barrow Canyon Biodiversity on the Seafloor normally viewed in this presentation can be viewed separately as a related resource.

- also upper Barrow Canyon “hotspot” for infaunal mussels, highest overall biomass for total Chukchi Sea due to large amount of organic carbon in bottom waters

Increased seawater temperature from 2002 to 2004 coincided with high sea ice retreat; abandoned baby walruses observed in 2004







Red squares: abandoned walrus pups with rapid ice retreat

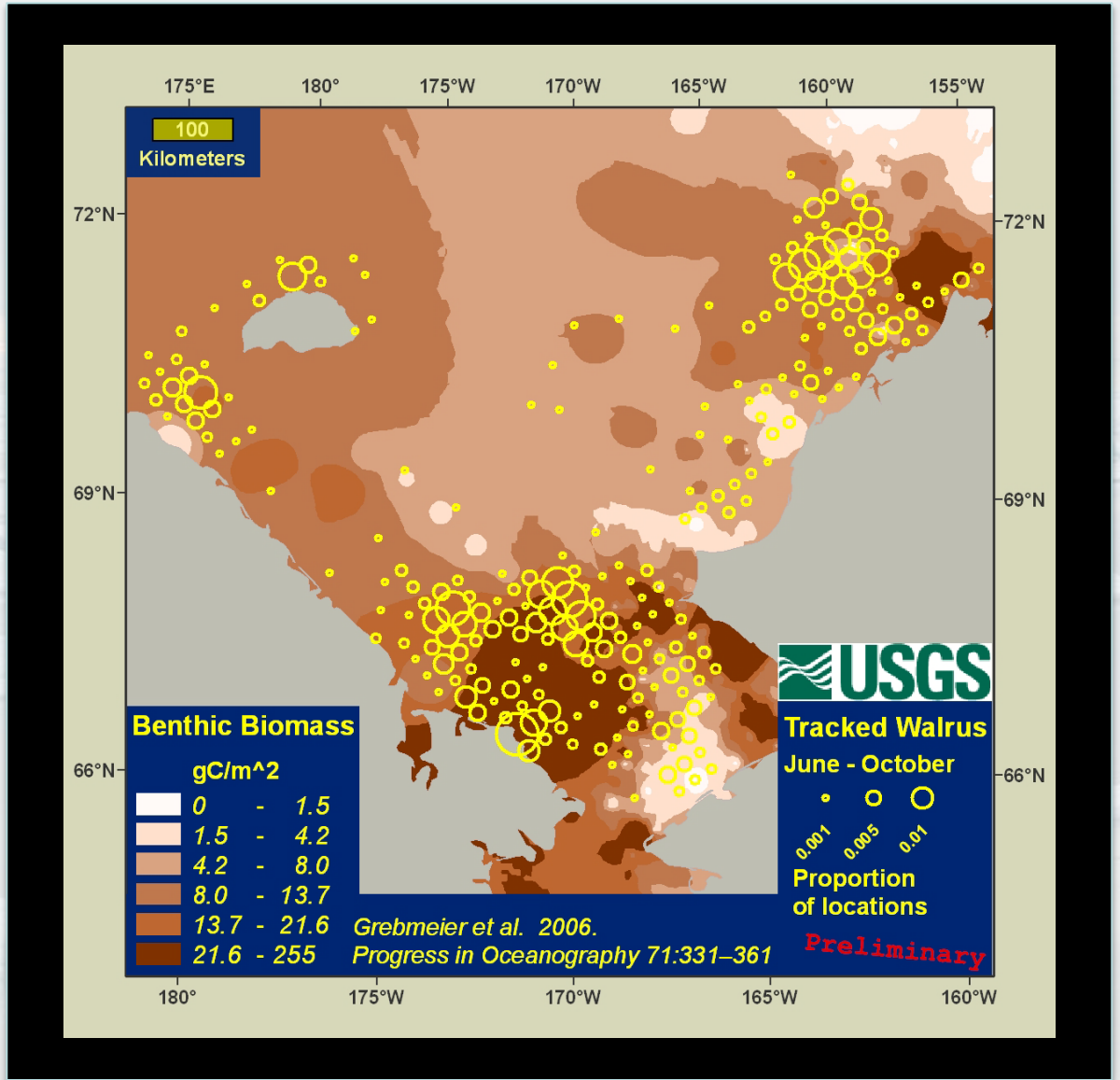
Calf strandings predicted by B. Kelly, 1998

Loss of Feeding/Resting Platform in Chukchi Sea

- USGS* tagged walrus in 2007-10 <usgs.web>
- Walrus swim to small ice floes & land as ice retreats
- Massive haul-outs in 2007, 2009, and 2010 = stampedes *& shift to 'central-place' foragers?*
- 2009 calf mortalities near Icy Cape (X, Fischbach et al. 2009) and Pt. Lay (X, 2010, 2011)

*Chad Jay & team

Walrus location and benthic infaunal prey biomass (Jay and Fischbach unpubl.)



- walrus feeding in areas of ice and rich underlying benthic infauna
- issue of higher energy expenditure if have to haul-out on land

SUNDAY 04.12.2009 baltimoresun.com / maryland closeup

MARYLAND closeup OPINION&COMMENTARY

Pre-cruise visit to Savoonga, January

Good Morning America, ABC News, June

Post-cruise visit to J.C. Parks Elementary School, Indian Head, Maryland (for PolarTREC teacher Deanna Wheeler) On-going plans include sister school relationship between Savoonga and J.C. Parks

French-German language IPY presentation during Healy 09-01 to French-German Foundation for Youth, Cité de Sciences, Paris

Baltimore Sun, April 12 2009

See MARBELLA, page 5

Selected outreach activities Healy 09-01 cruise

Summary and Direction

- With **decreasing sea ice**, increasing heat and freshwater transport into the Arctic, decreasing ice algal production, and more open water production will change marine carbon cycle and biodiversity

- **Coastal erosion of** land carbon changes carbon cycle, dilutes rich marine food for coastal organisms

- **Northward movement** of subarctic-arctic frontal zone and associated biological expansion, e.g. prey water column and benthic species, fisheries, migratory animals, invasive species

- **Ecosystem reorganization and system change**, potentially resulting in system wide impacts

- **Pacific Arctic Sector**, a crossroads for local, national and international stakeholders

Thank you. Any questions?

Acknowledgements: Many thanks to Betty Carvellas, Lee Cooper, Marisa Guarinello, Linton Beaven, Chad Jay, Sue Moore, Lisa Wilt, Kathryn Osborne, Markus Janout, Rebecca Pirtle-Levy, Jim Lovvorn, Adam Humphrey, Sherry Cui, Eddy Carmack, Christian Johnson, Stephanie Soquez, and many more.

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[photo courtesy Karen Frey]