Biological Implications of Arctic Change

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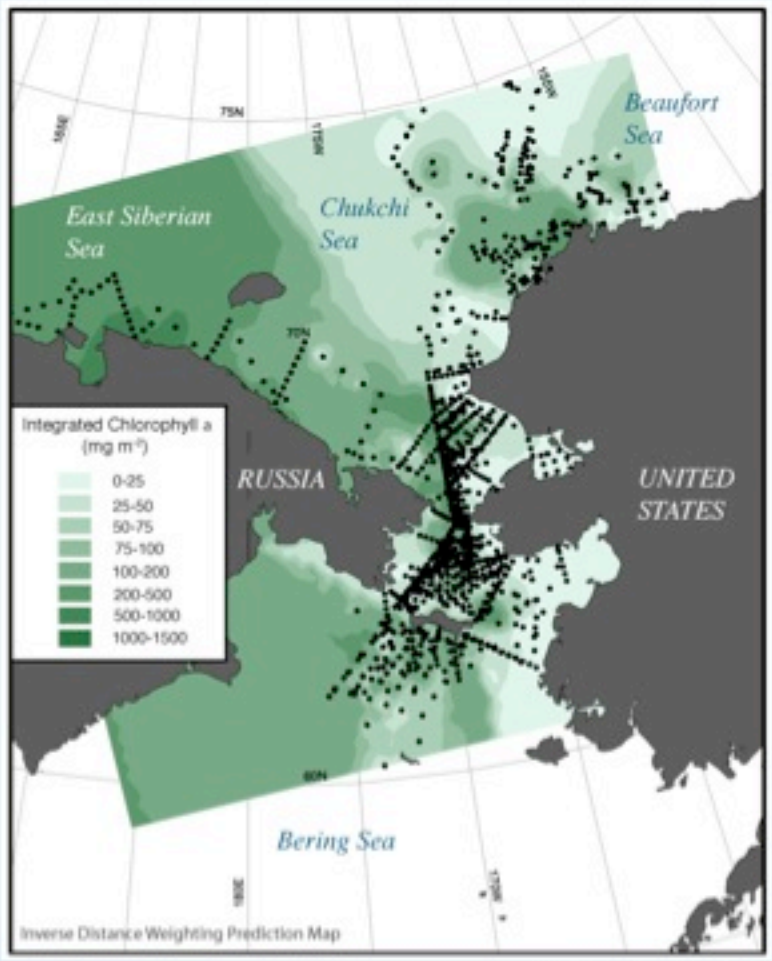
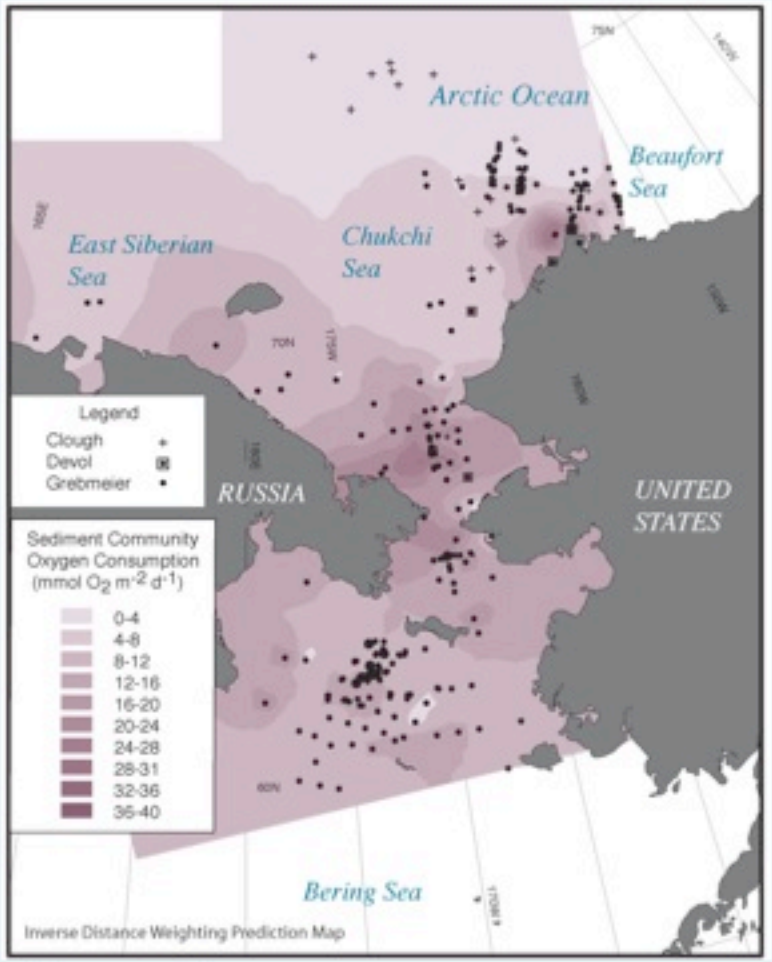
10 December 2008, 7 pm

CARE (Connecting Arctic/Antarctic Researchers and Educators) webinar

Pelagic-benthic coupling





[Grebmeier et al. , 2006, Prog. Oceanogr., 71]

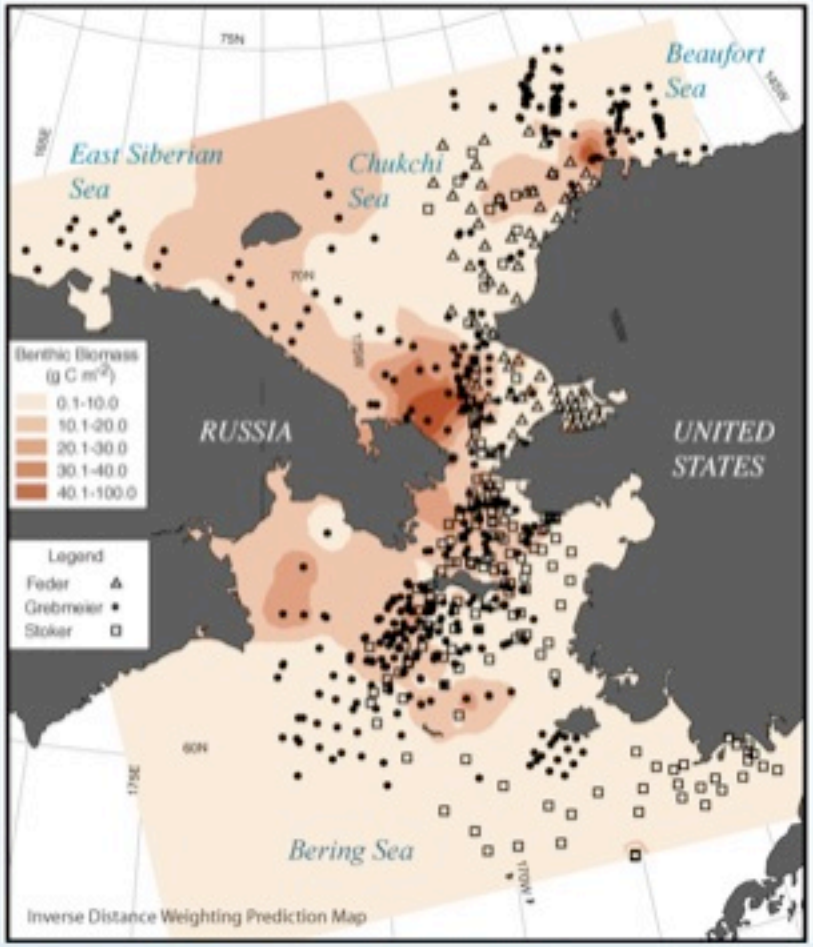
Integrated chlorophyll (mg m^{-2}; 1975-2004)

- regular patterns of high plant production resulting from inflow high nutrient Pacific water

Sediment community oxygen consumption (mmol O_2 m^{-2} d^{-1}) from 1984-2004

- an indicator of carbon supply to the benthos

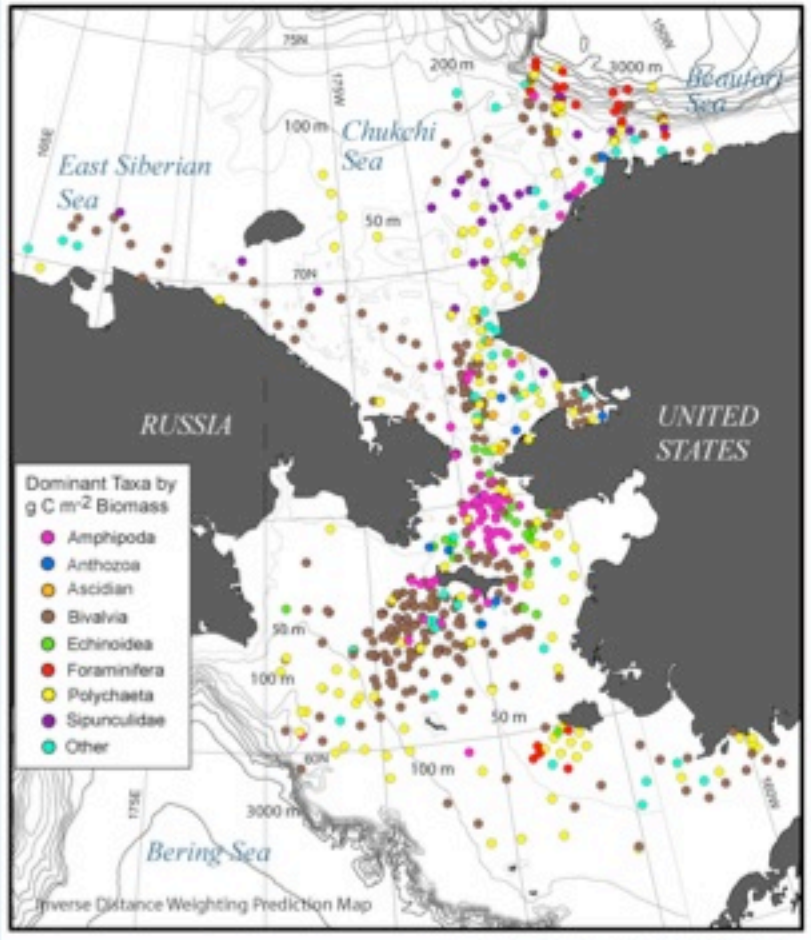
Pelagic-benthic coupling



[Grebmeier et al. , 2006, Prog. Oceanogr., 71]

Macrofaunal biomass (g C m^{-2}) from 1977-2004

- "foot prints" of carbon deposition and benthic biomass on the shallow continental

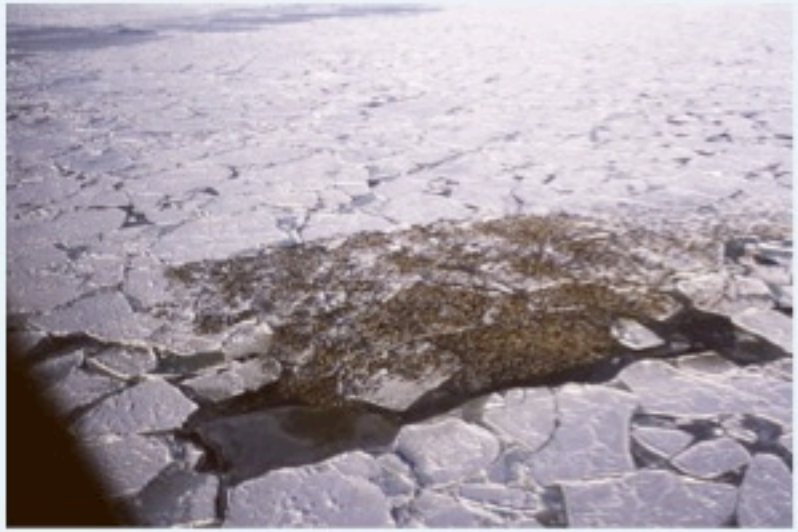


[Grebmeier et al. in prep.]]

Dominant benthic taxa by biomass (g C m^{-2}) from 1977-2004

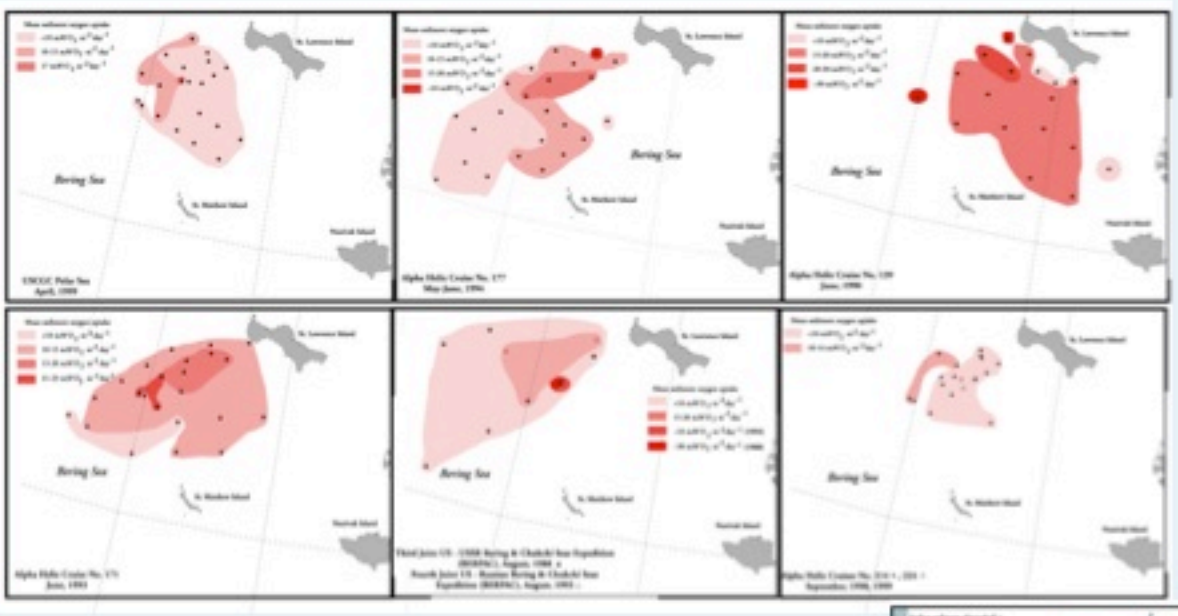
- variations by food supply, sediment grain size and predator-prey interactions

Threatened spectacled eiders keyed to ice and clams-Northern Bering Sea time series



- Threatened spectacled eider feeds on clams
- shallow system, high cascade potential
- ocean acidification with increasing CO_2 in seawater potential to dissolve clam shells

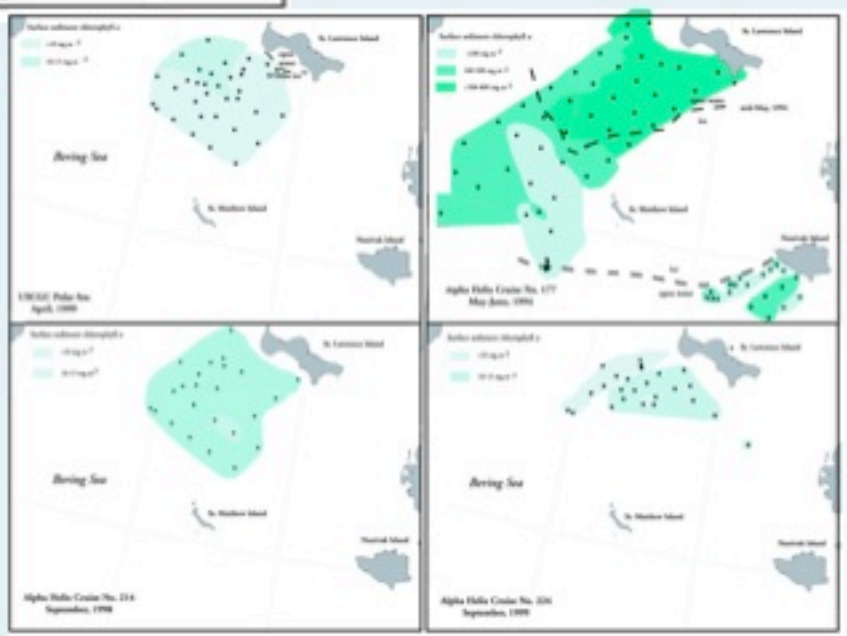
Highest organic carbon deposition to benthos in May-June after spring bloom



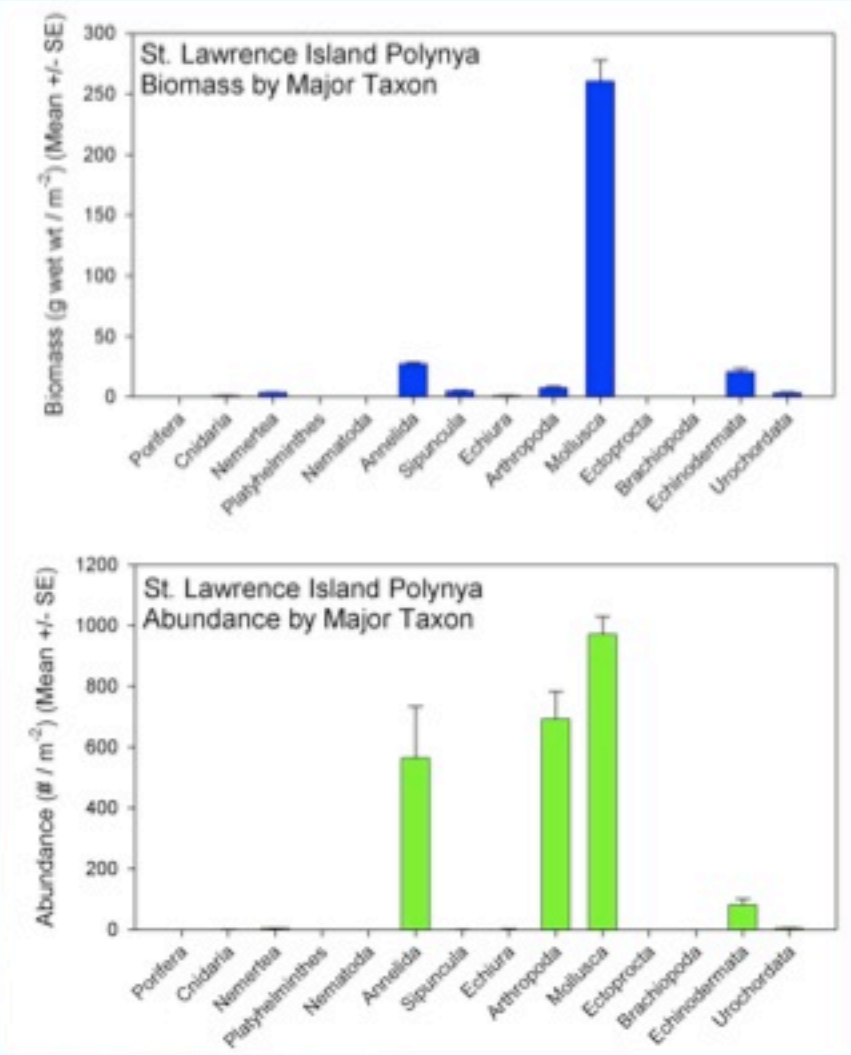
• **Sediment community oxygen consumption (mmol O_2 m^{-2} d^{-1})**

[Cooper et al., MEPS 2002]

• **Integrated water column chlorophyll (mg m^{-2})**



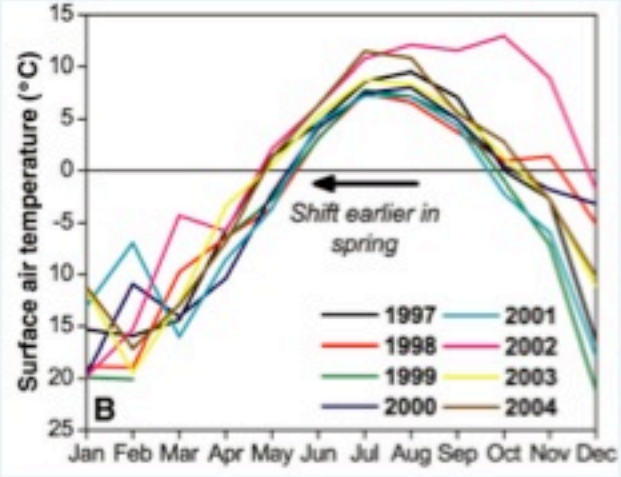
Benthic infaunal data from 1973-2004



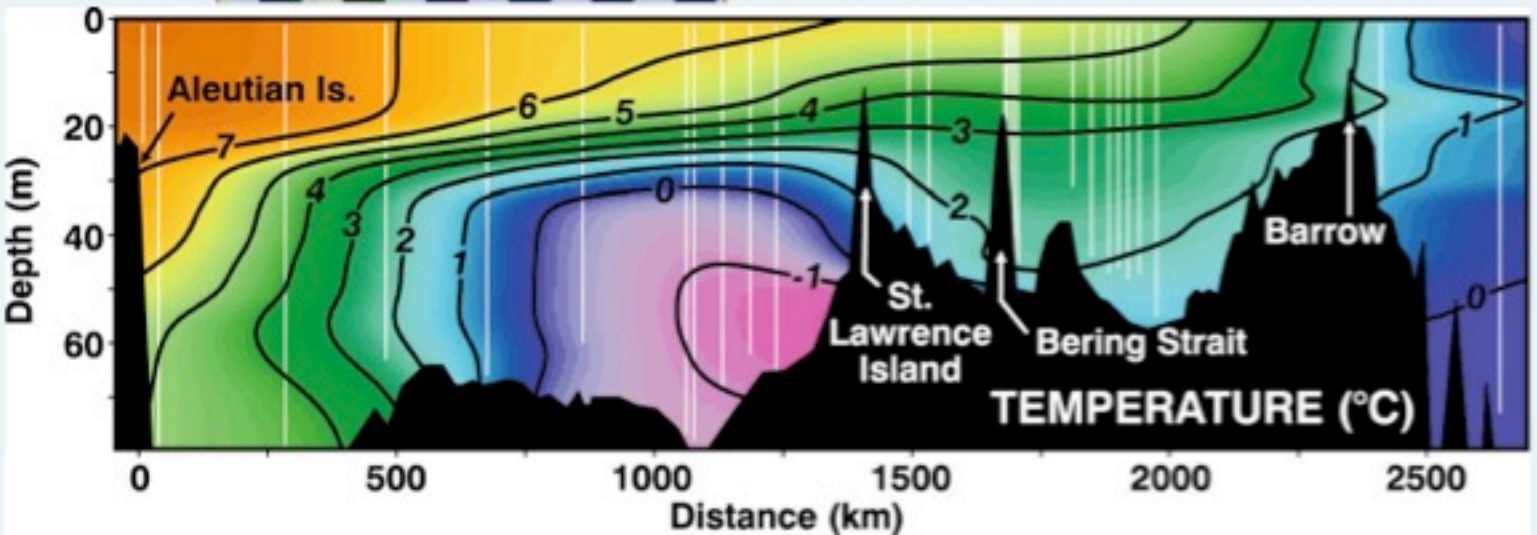
[modified from Grebmeier and Barry 2007]

- Dominant bivalve families: Nuculanidae, Nuculidae, and Tellinidae

Potential restructuring of northern Bering Sea ecosystem with sea ice retreat

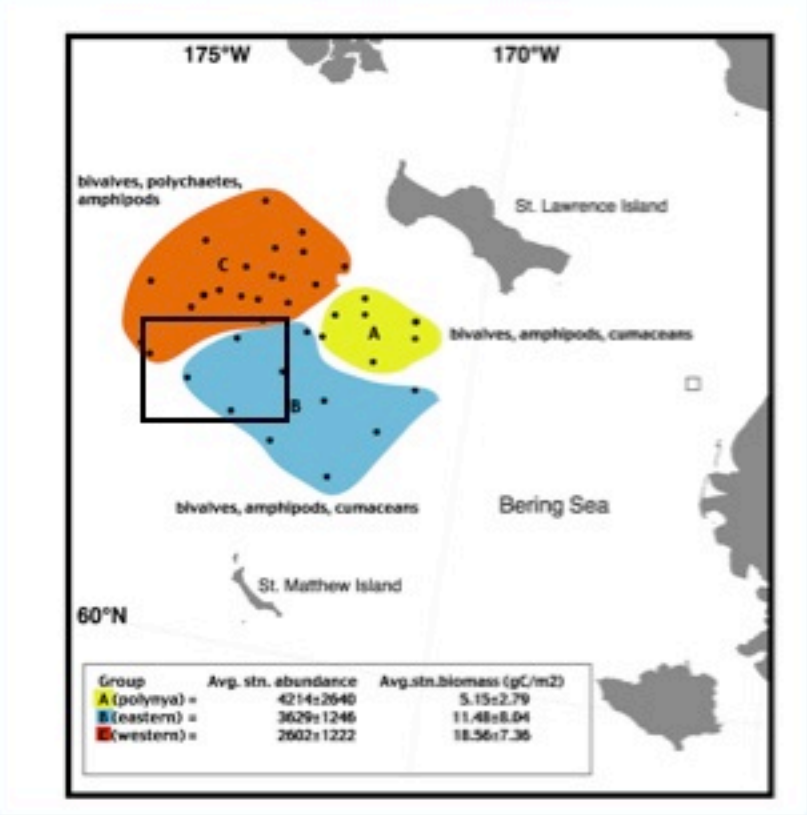


[Grebmeier et al. 2006, Science 311]

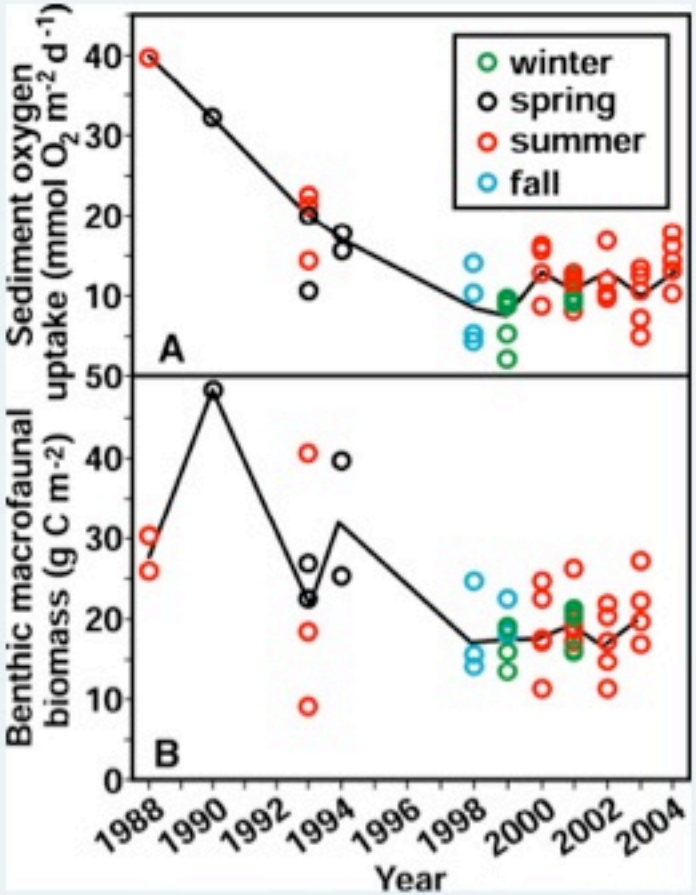


Reduced carbon supply (lower sediment oxygen uptake) means less food (less biomass) for spectacled eiders and walrus

BSEO-S sites embedded in Group C, orange



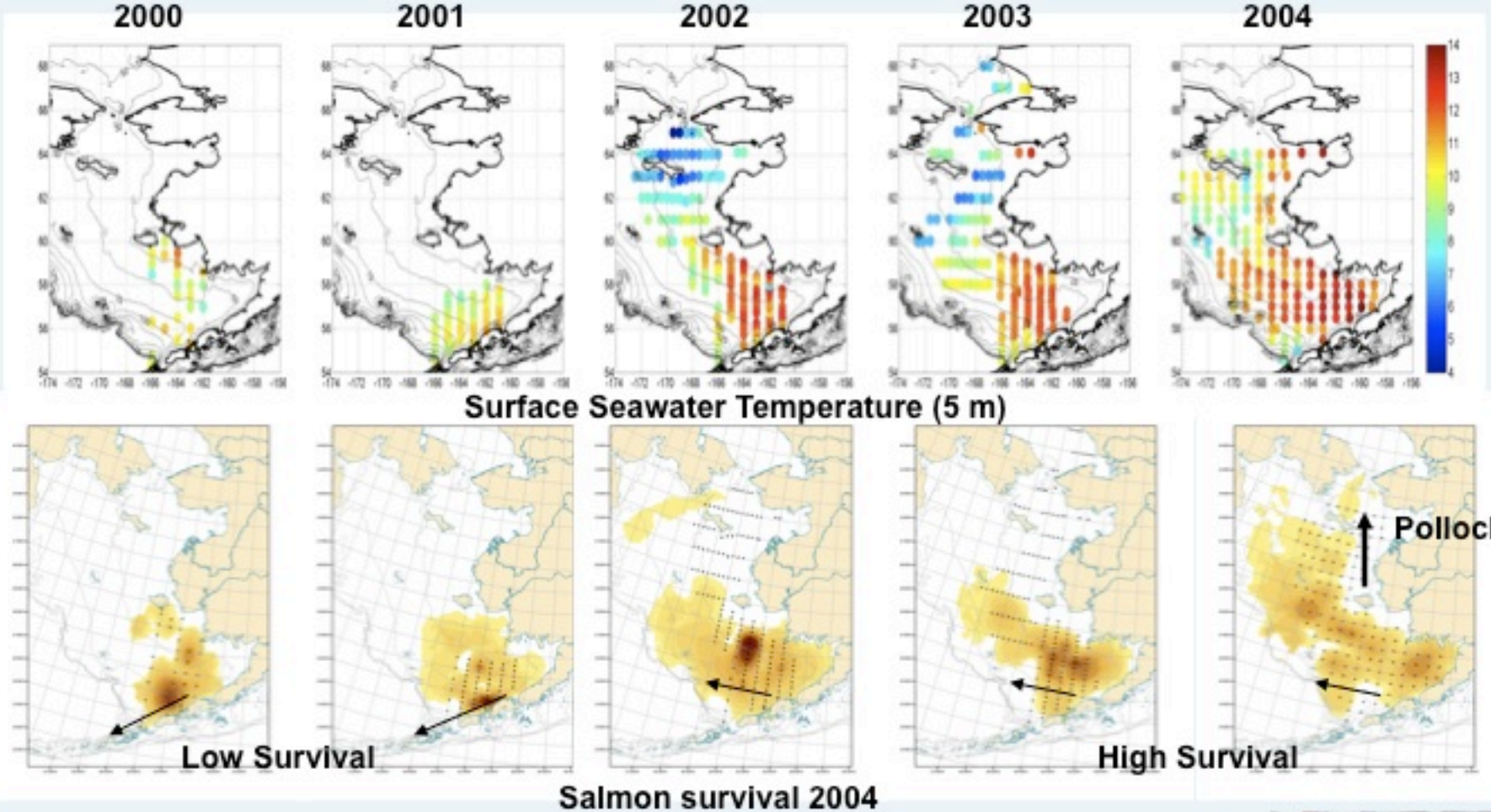
[Simpkins et al. 2003, Polar Biology 26]



[Grebmeier et al. 2006, Science 311]

- **trend lines through station means**

Less sea ice, warmer water, and northward migration of salmon and predatory pollock

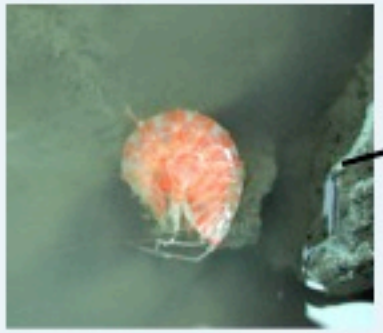


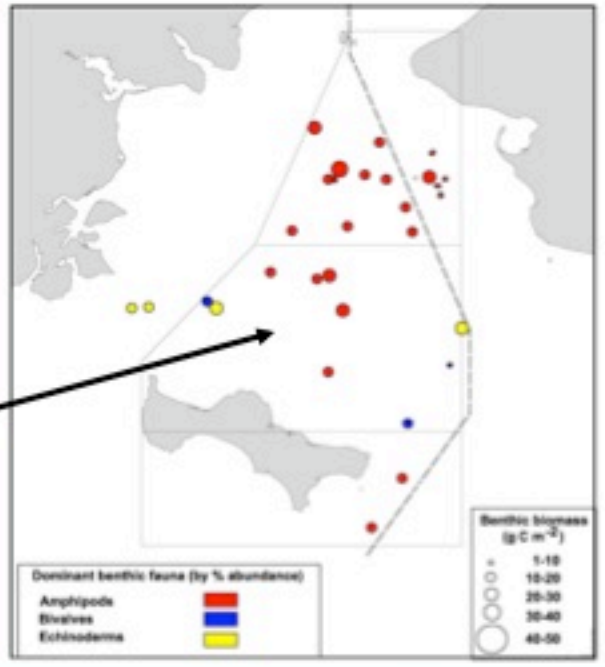
Salmon

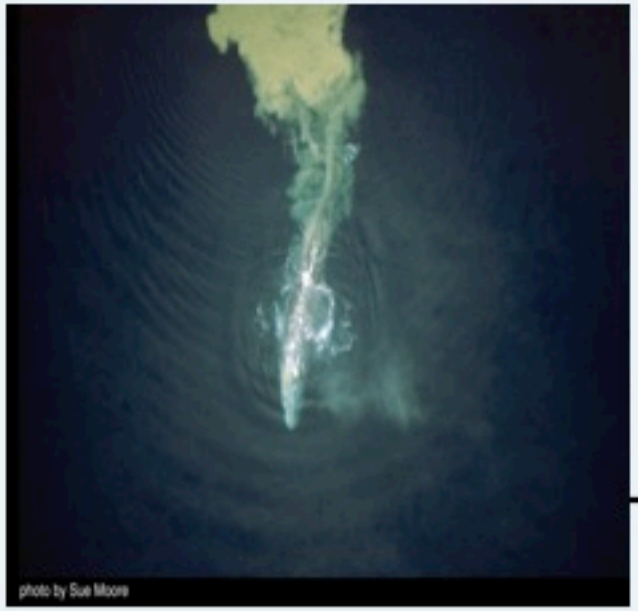
Pollock

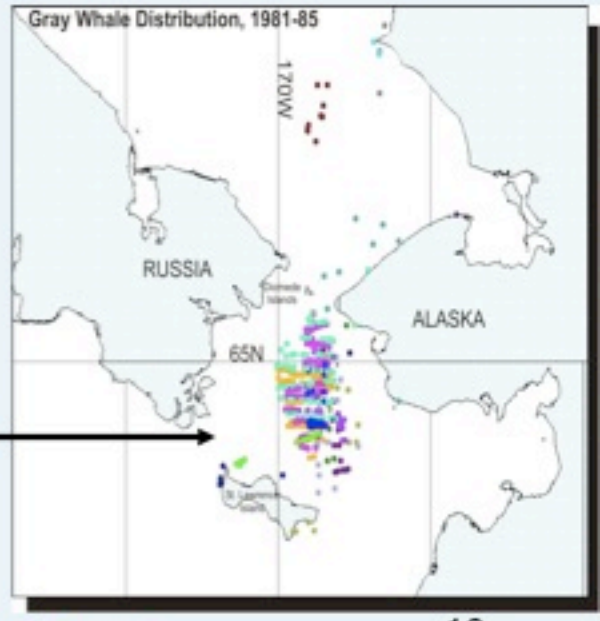
Chirikov Basin, Northern Bering Sea in the 1980s

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





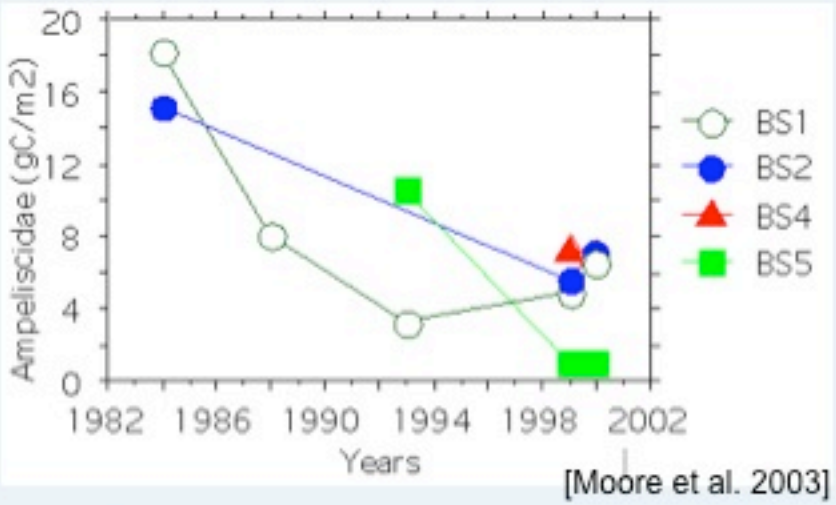




Gray whale sightings

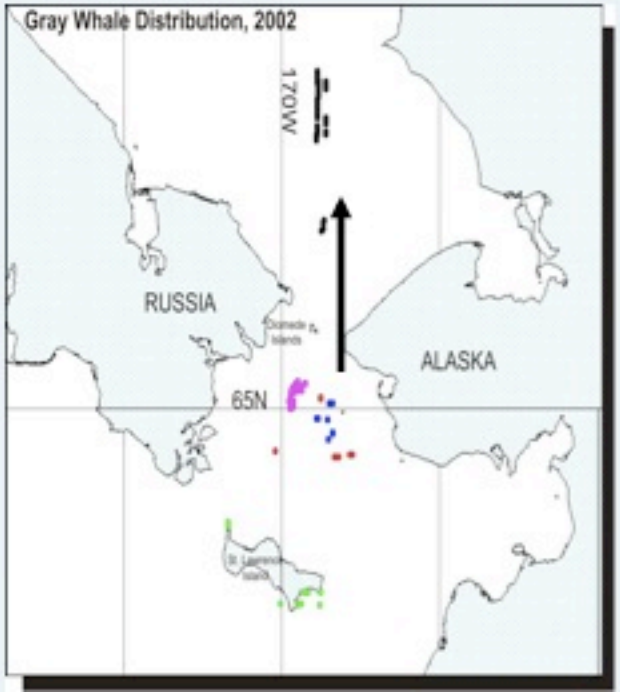
Drop in Benthic Productivity in 1990s coincident with sea ice reduction

- decline of amphipod biomass at time series sites
- possible amphipod decline as causal to gray whale mortalities
- shift gray whale feeding north of Bering Strait as ice receded



[Moore et al. 2003]

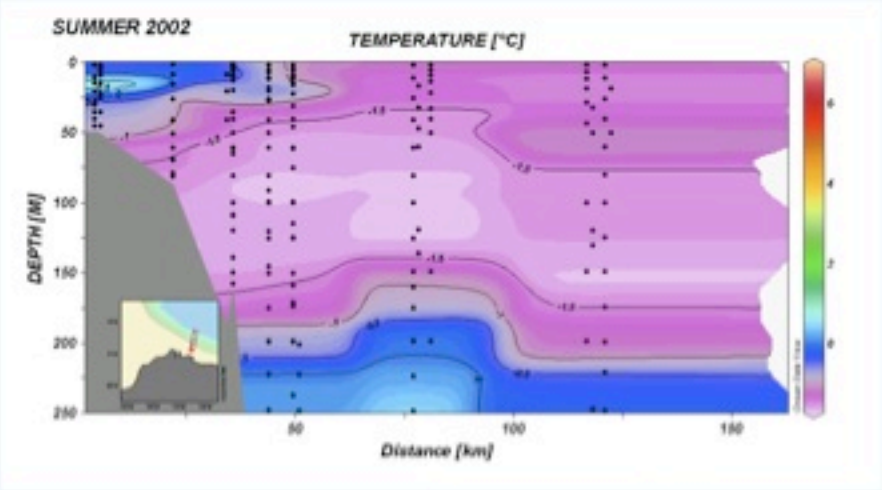
Gray whale

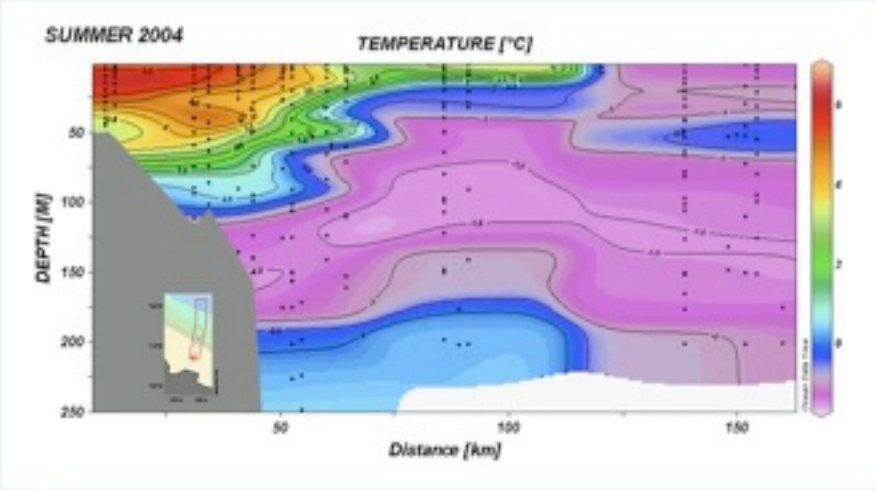


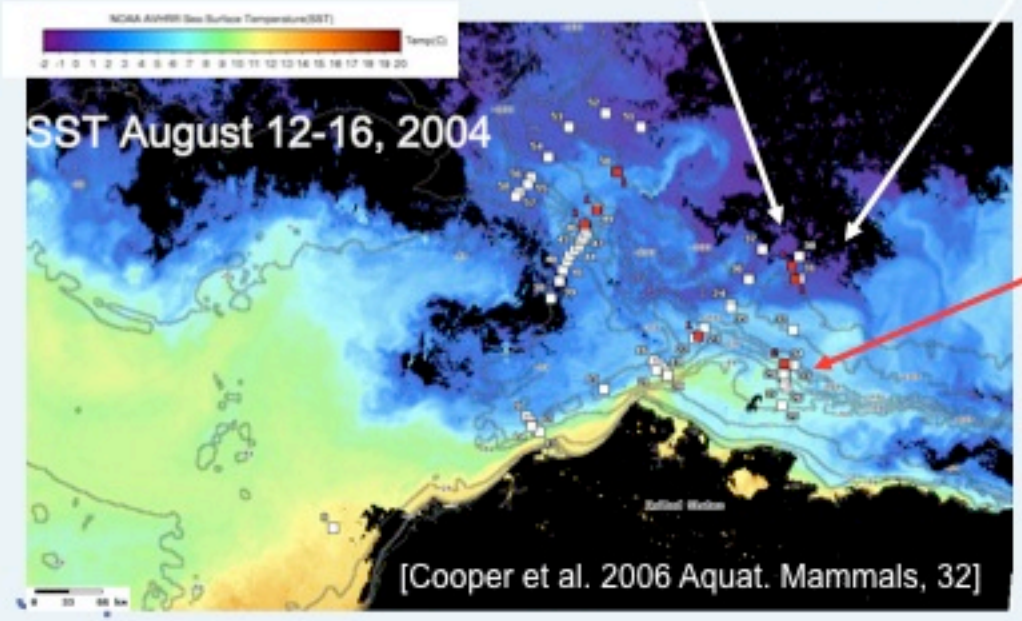
Key Environmental Factors Influencing Arctic Marine Food webs

- **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

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

SBI arctic change
ONR NSF
SHELF BASIN INTERACTIONS

No. 05-1120

In The Supreme Court of the United States

COMMONWEALTH OF MASSACHUSETTS, *et al.*,

Petitioners,

v.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY,

Respondent.

ON WRIT OF CERTIORARI TO THE UNITED STATES COURT OF APPEALS FOR THE DISTRICT OF COLUMBIA CIRCUIT

BRIEF OF AMICI CURIAE ALASKA INTER-TRIBAL COUNCIL, COUNCIL OF ATHABASCAN TRIBAL GOVERNMENTS, AND RESISTING ENVIRONMENTAL DESTRUCTION ON INDIGENOUS LANDS IN SUPPORT OF PETITIONERS

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Female walruses with calves use seasonal sea-ice as a platform from which to dive to the bottom while feeding.[73] These animals are not normally observed in deep water because of the absence of food in those areas and their inability to dive to depths greater than 200 meters.[74] Walrus calves are dependent on maternal care for two or more years before they are able to forage for themselves, so the presence of seasonal sea-ice appears to be critical to their survival.[75] As the sea ice disappears, adult walrus may be forced to abandon their calves to search for food.

In the summer of 2004, researchers in the Chukchi and Beaufort Seas observed nine abandoned walrus calves.[76] These observations coincided with a rapid melting of sea ice in that area.[77] It is likely that other walrus calves have been abandoned, and presumably many have drowned.[78]

If, as a result of environmental changes in the Arctic, sea-ice continues to decline in thickness and extent, or if as the researchers observed, seasonal sea-ice retreat occurs rapidly with the onset of summer, it is possible that female walruses will have difficulty nourishing themselves and caring for their young.[79] Separations of walrus may become more common and widespread. Since walruses have a low reproduction rate and a high investment in nurturing young, with single calves born only every two to three years, the Pacific walrus populations may soon decline.[80]

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[73] Lee W. Cooper et al., *Rapid Seasonal Sea-Ice Retreat in the Arctic Could Be Affecting Pacific Walrus Recruitment*, 32 Aquatic Mammals 98 (April 2006).

[74] *Id.*

[75] *Id.*

[76] *Id.*

[77] *Id.* at 100.

[78] *Id.* at 98.

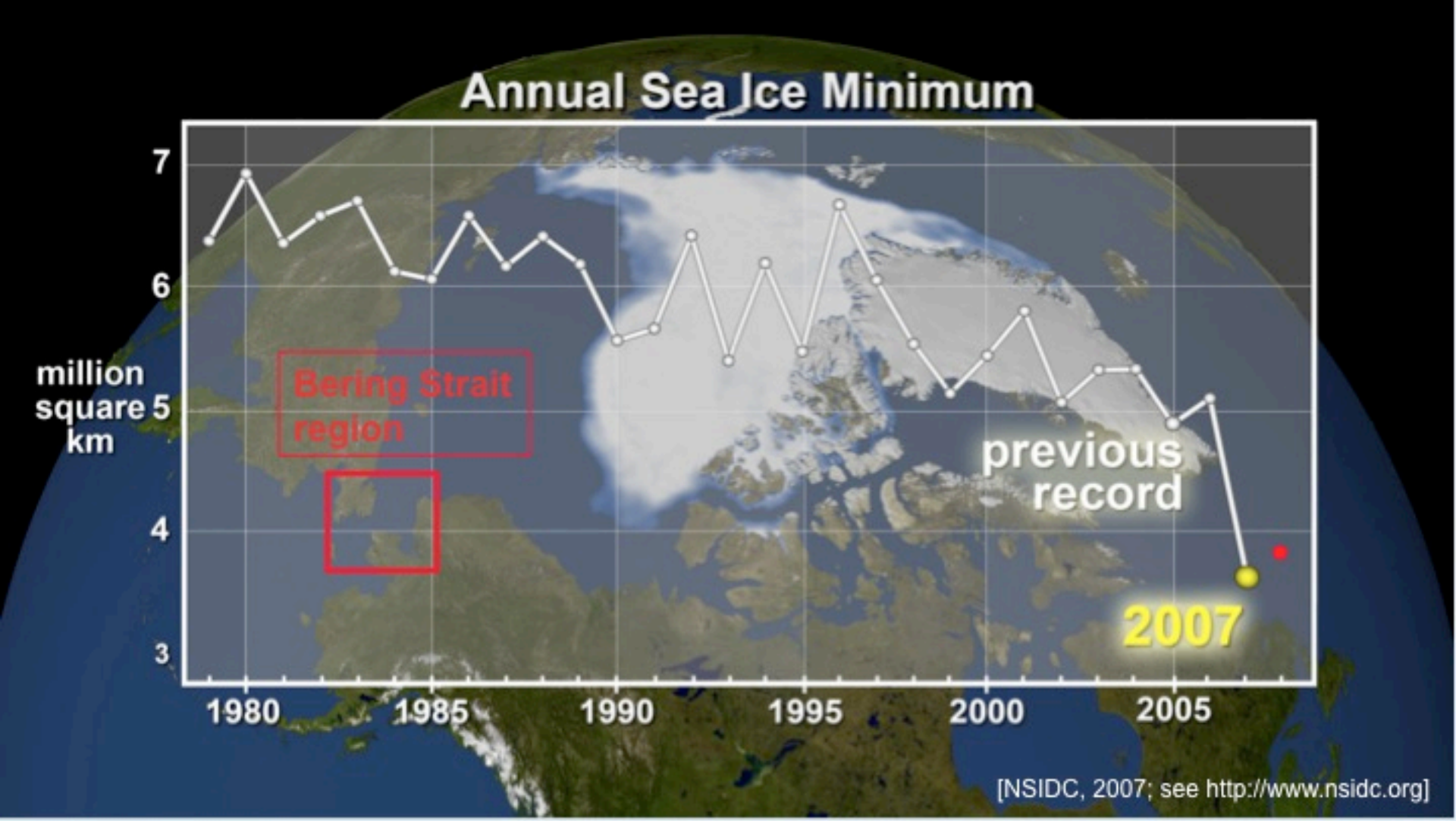
[79] *Id.* at 101.

[80] *Id.*

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 transition 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

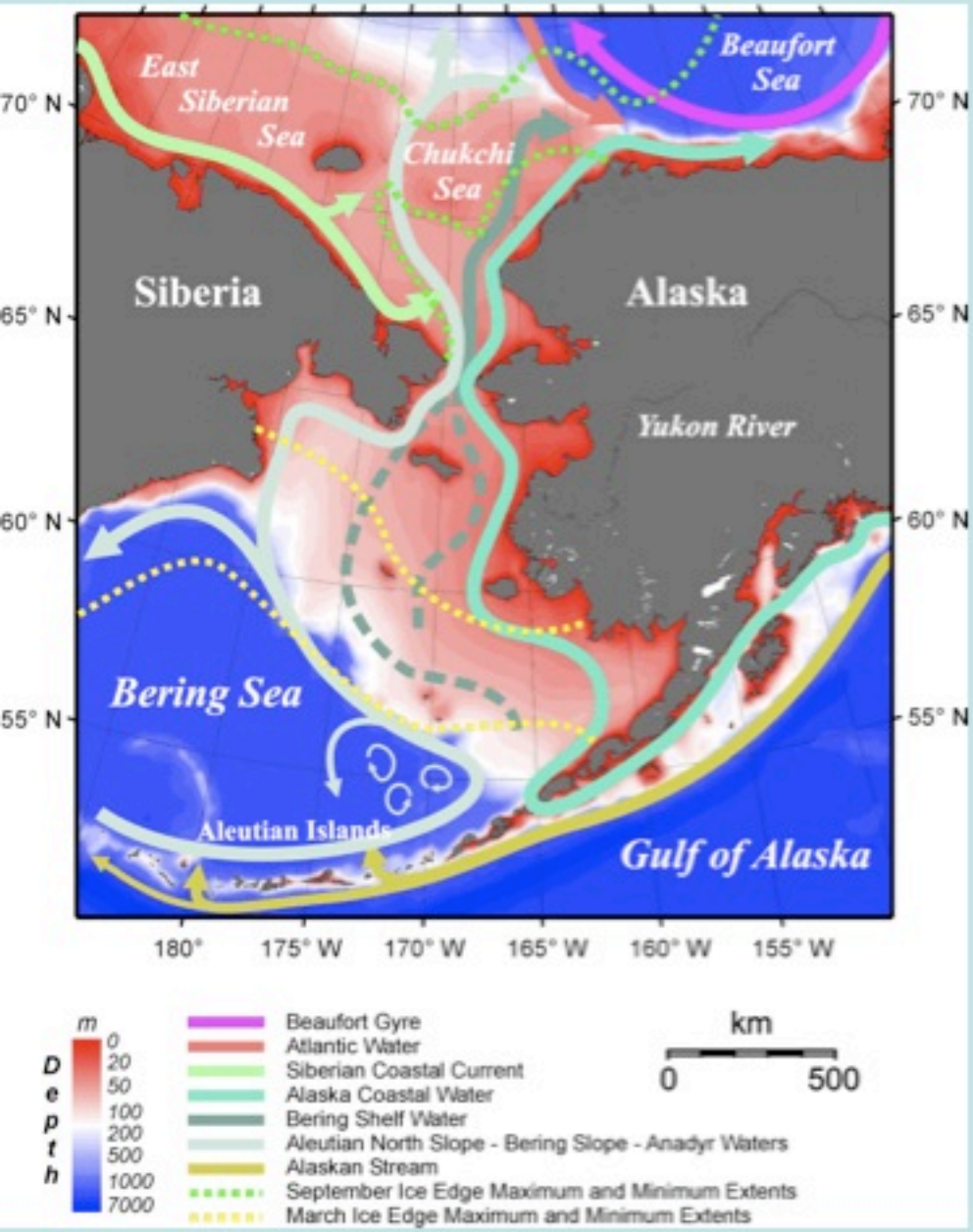
Support from U.S. National Oceanic and Atmospheric Administration, National Science Foundation, Office of Naval Research, North Pacific Research Board



Decline in September ice extent from 1979 to 2007

- September rate of sea ice decline: 1979-2007
- 2007 is the maximum ice retreat on record, with 2008 the 2nd lowest
- ice-albedo feedback is a positive loop, resulting in loss sea ice and continued seawater warming

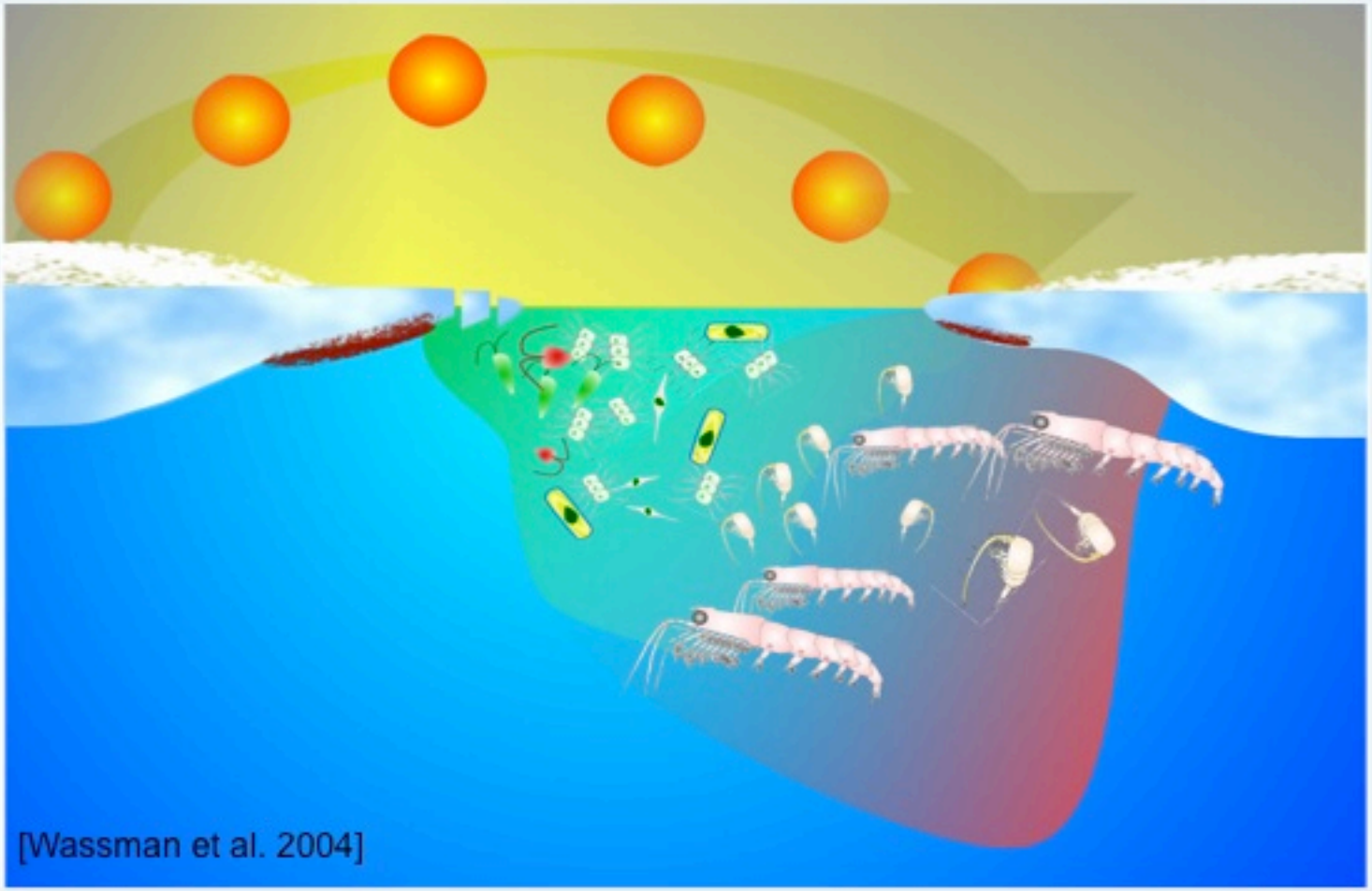
Introduction



[courtesy Tom Weingartner]

- highly productive ecosystem influenced by Pacific water input
- sea ice important for system
- timing annual production critical for water column production, carbon cycling, and pelagic-benthic coupling
- short food chains; lower trophic level impacts cascade efficiently to higher trophic organisms
- potential impacts of change have broad-reaching implications for long-term ecosystem structure

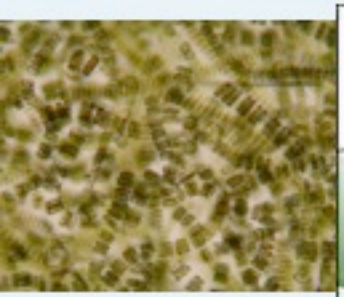
Timing and location of ice algae growth depends on ice cover and light, zooplankton growth influences food reaching underlying sediments



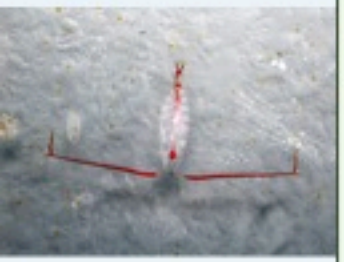
Arctic Marine Food Web







permanent ice cover
pond
snow algae
ice
pond
marginal ice zone
under-ice Fauna
copepods
gelatinous zooplankton
ice-edge bloom
benthos
sea floor
sedimentation



[Rolf Grandinger 2004]

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]

BENTHIC PROCESSES

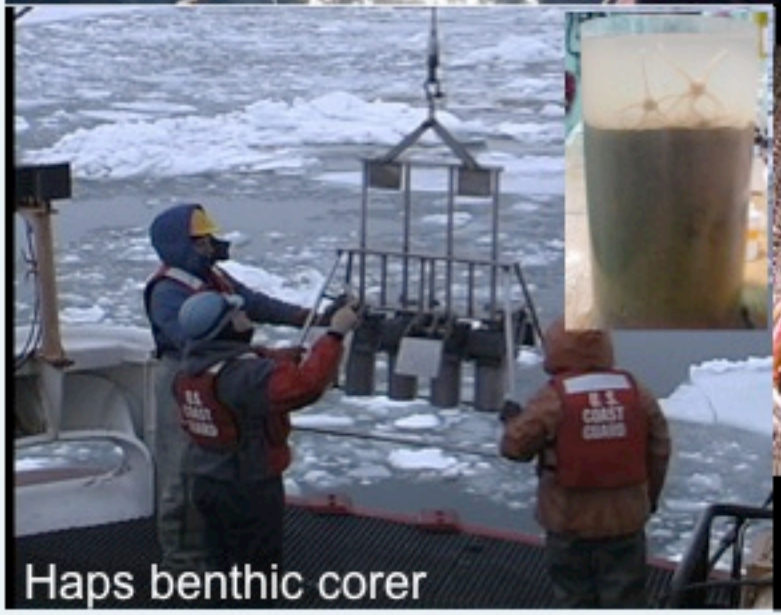
- Influenced by:
  - extent and duration of sea ice
  - water temperature and salinity
  - water column production and grazing
  - net carbon flux to the sediments
  - sediment grain size
  - predator-prey relationships

- Benthic fauna are excellent indicators of climate change since they reflect large scale changes in biological response

- Pelagic-benthic coupling can be studied via underlying sediment processes on various time scales
  - Sediment metabolism: days-to-weeks
  - Sediment tracers (e.g. chl a): weeks-to-years
  - Benthic faunal populations: months-to-years (integrators)


0.1 m² van Veen grab


Benthic sieving


Haps benthic corer


Benthic clams, worms, and brittle stars