Lower trophic level prey in the Pacific Arctic

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Seasonal cycle of marine production now and in the future

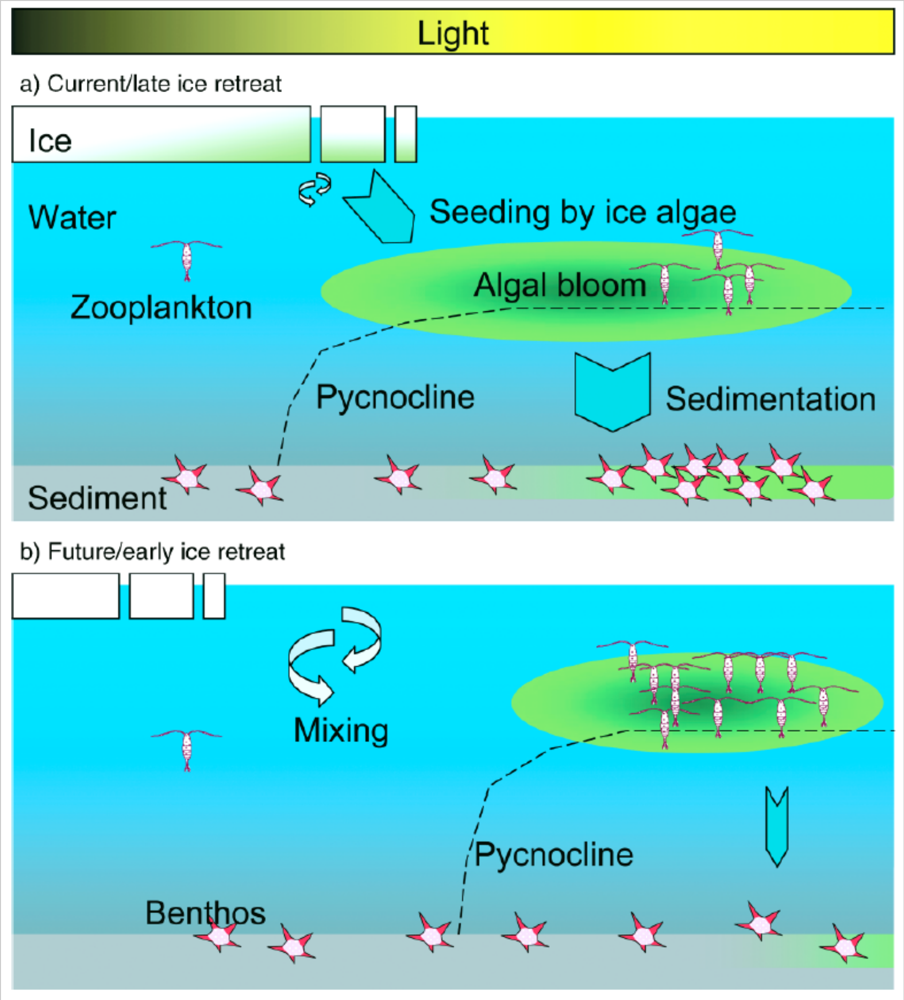


FIG. 4. Schematic representation of seasonal cycle of marine production in current/late ice retreat (a) and future/early ice retreat conditions (b). Early ice retreat allows for stronger wind mixing and causes later formation of the seasonal pycnocline. The delayed phytoplankton bloom is consumed by zooplankton, while, under current conditions on several Arctic shelves, it largely sinks directly to the sea floor, sustaining high benthic biomass.

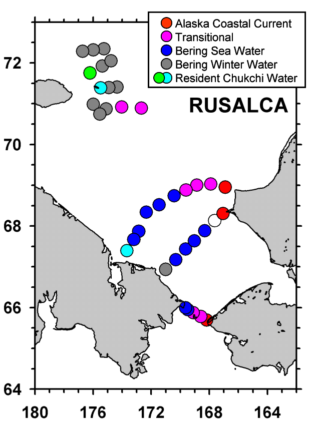
Bluhm and Gradinger 2008, Ecological Applications 18(2): S77-S96

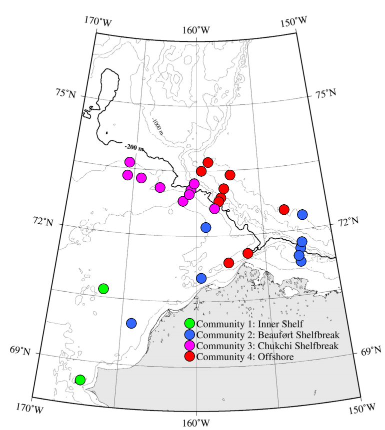
1. Disciplinary History and State of Knowledge-Zooplankton

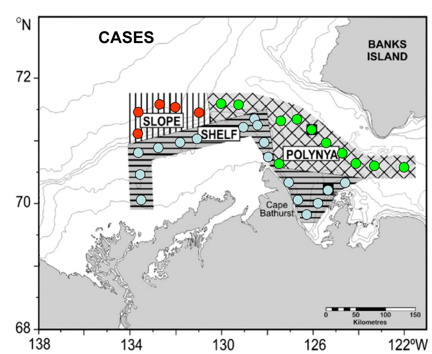
- Work in this region has been conducted mostly during spring/summer/fall but some work during winter
- Sampling conducted from icebreakers and ice camps; some moorings (acoustics)
- Most work has quantified composition, abundance, and distribution of zooplankton, particularly the large copepods *Calanus* spp. We now recognize that smaller copepods also are important (e.g., *Pseudocalanus* spp.) as well as non-copepods (e.g., gelatinous zooplankton)
- Much less work on rate processes
  - Quite a bit of egg production work (Plourde, Ashjian/Campbell, Hopcroft/Kosobokova)
  - Some grazing experiments (e.g., Campbell et al.)
  - Some development rate (?)
  - Growth/development very difficult to measure because of the slow rates in the cold environment
- Increasingly, molecular techniques are used to identify species and populations

1. Disciplinary History and State of Knowledge-zooplankton-cont.

- We have a pretty good understanding of distributions of species/types in the Chukchi Sea and how these distributions are associated with water masses and circulation
- We understand that species/populations from the northern Bering Sea (Pacific species) are advected into the Chukchi Sea and are seen there
- We understand how the Chukchi Sea is at present benthically dominated because the micro- and meso- zooplankton biomass cannot consume all of the primary production







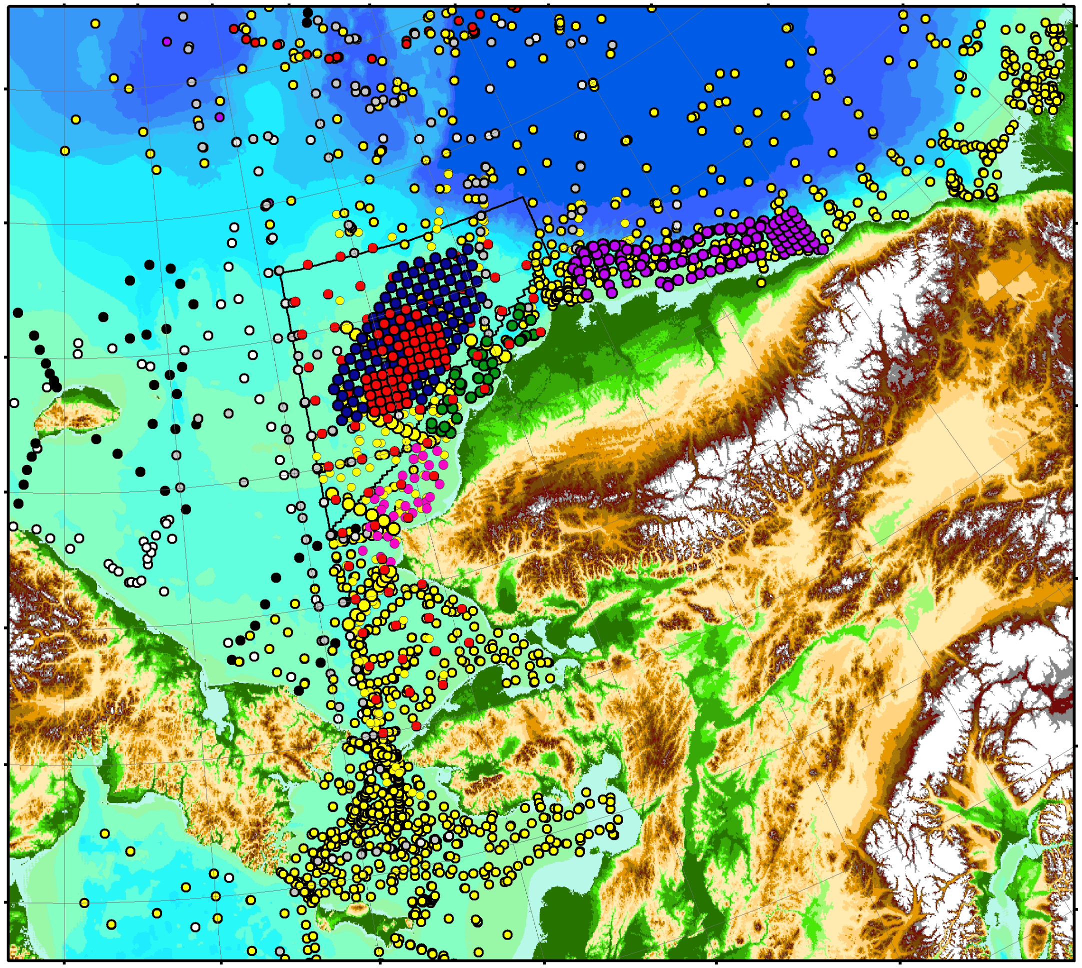
1. Disciplinary History and State of Knowledge- zooplankton-cont.

- We have some understanding of phenologies of copepod species particularly in the basin
- We hypothesize that zooplankton will respond to increased temperatures with increased vital rates but we have not demonstrated this
- Our information is skewed towards that collected during spring-early fall, when the region is accessible by ship (usually icebreaker)

2. Key observations, data sets, time frame-zooplankton

- Most observations conducted during spring-summer
- Exceptions:
  - Ice Camps in the Basin: US and Russian ice islands (1960s on), SHEBA (1997-1998), CASES (2003-2004), Other Canadian?
  - 2011 Winter Cruise
- A series of ”recent” (2000s+) comprehensive projects in spring/summer/fall including: SBI, RUSALCA, SNACS/ BOWFEST, CSESP, Japanese and Chinese cruises to the Chukchi, Beaufort Gyre Work, CHAOZ, BASIS, Beaufish (Arctic-EIS, Transboundary), C3O, NOAA Ocean Exploration in Arctic Basin
- Historical Data Sets including: OCSEAP, Johnson’s work in the early 1950s, BERPAC, ISHTAR, WEBSEC, various Russian studies… more than 80 years of observations

2. Key observations, data sets, time frame-zooplankton



Russ's Data Collection

3. Examples of change-zooplankton

- Examples are difficult to find because we have few/no long term studies
- The SOAR is an opportunity to look for changes in the available data sets

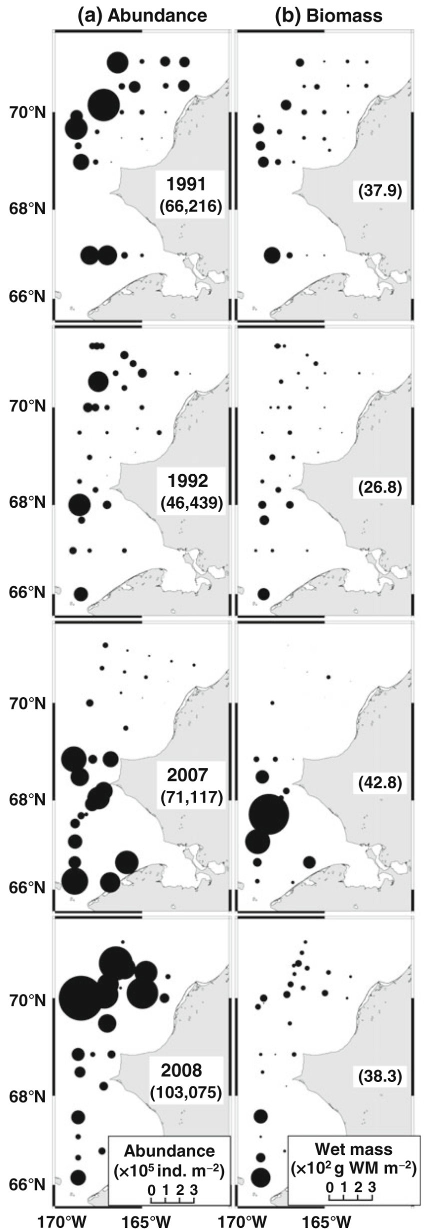


Fig. 4 Geographic distribution of the zooplankton abundance (**a**) and biomass (**b**) in the Chukchi Sea during July–August of 1991, 1992, 2007, and 2008. Values in the *parentheses* indicate mean values of each year

3. Examples of change

- Examples are difficult to find because we have few/no long term studies
- *Danger in mistaking interannual variability for long-term change*
- The SOAR is an opportunity to look for changes in the available data sets

[from Matsuno et al. 2011]

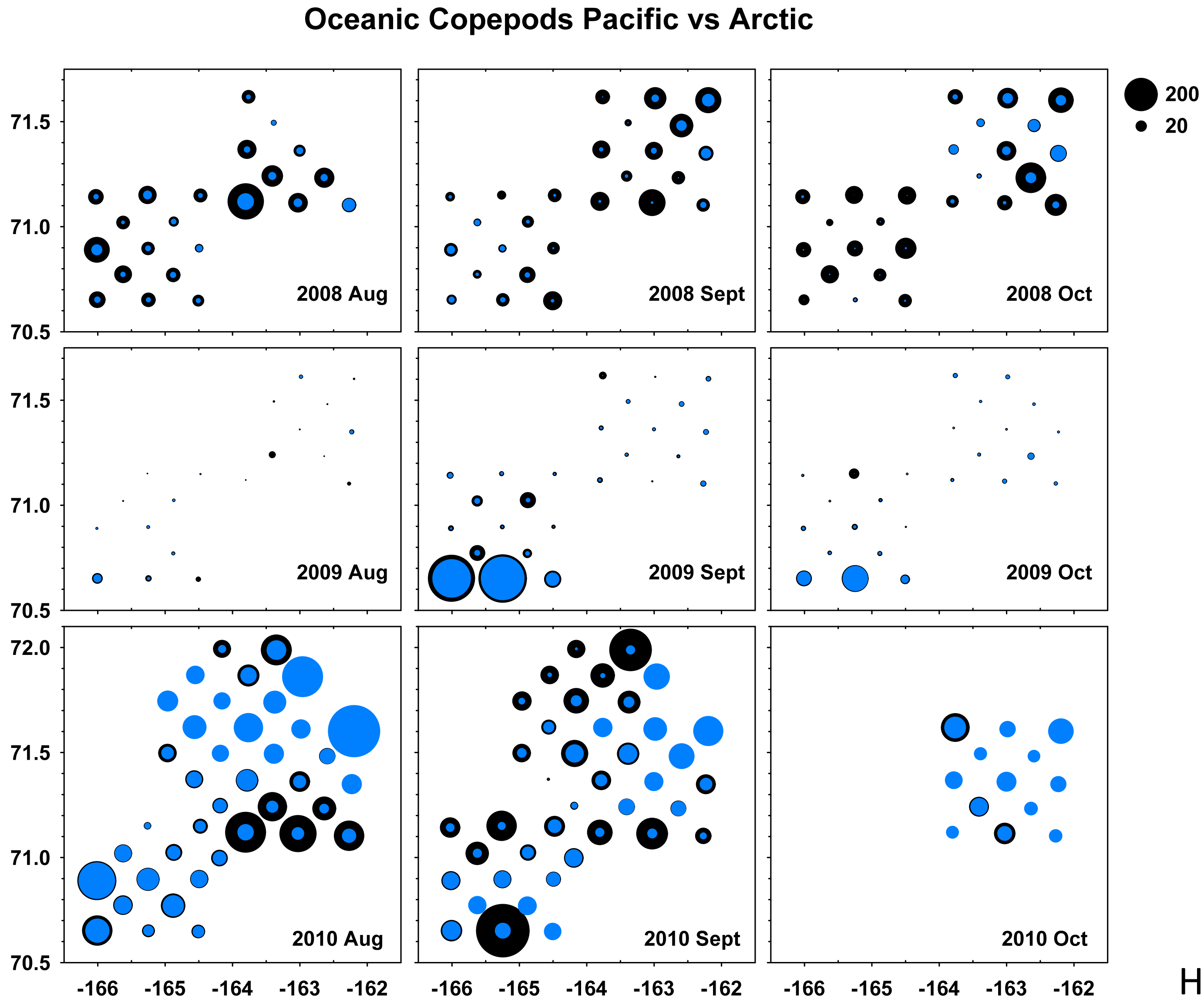
3. Examples of change

Seasonal and Interannual variability in NE Chukchi

2008

2009

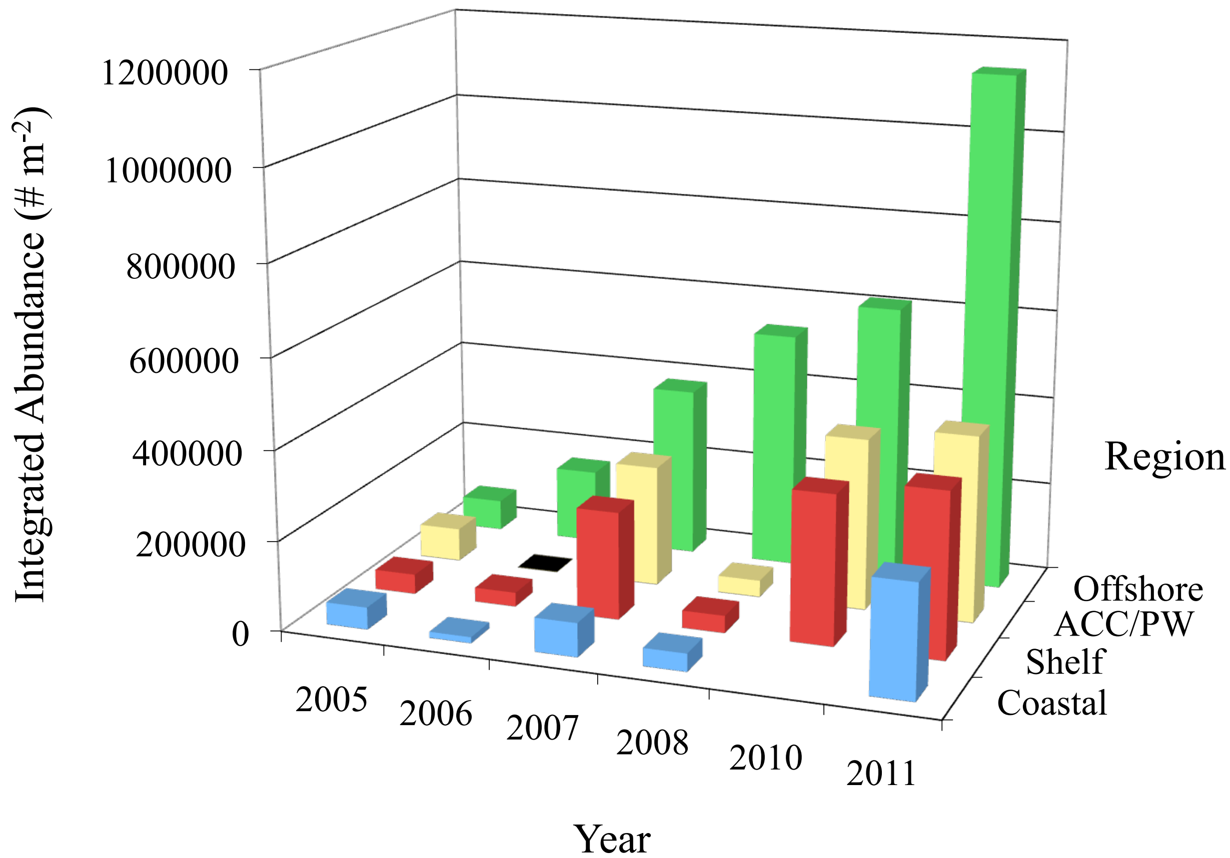
2010



Hopcroft

3. Examples of change

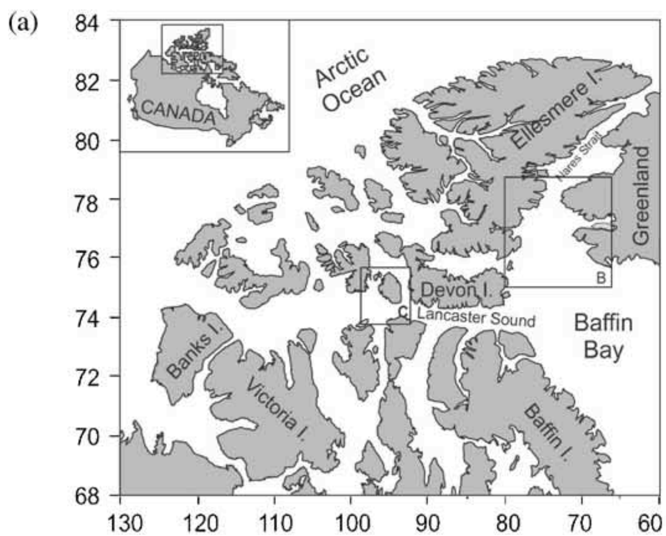
Interannual Variability in Total Zooplankton Abundance Near Barrow

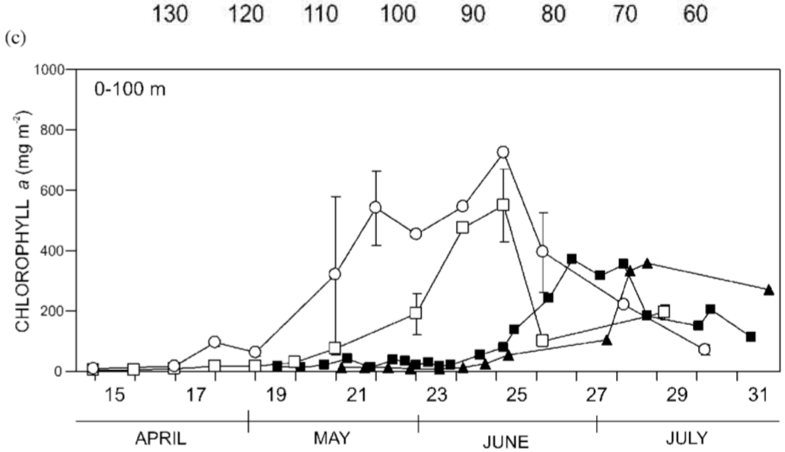


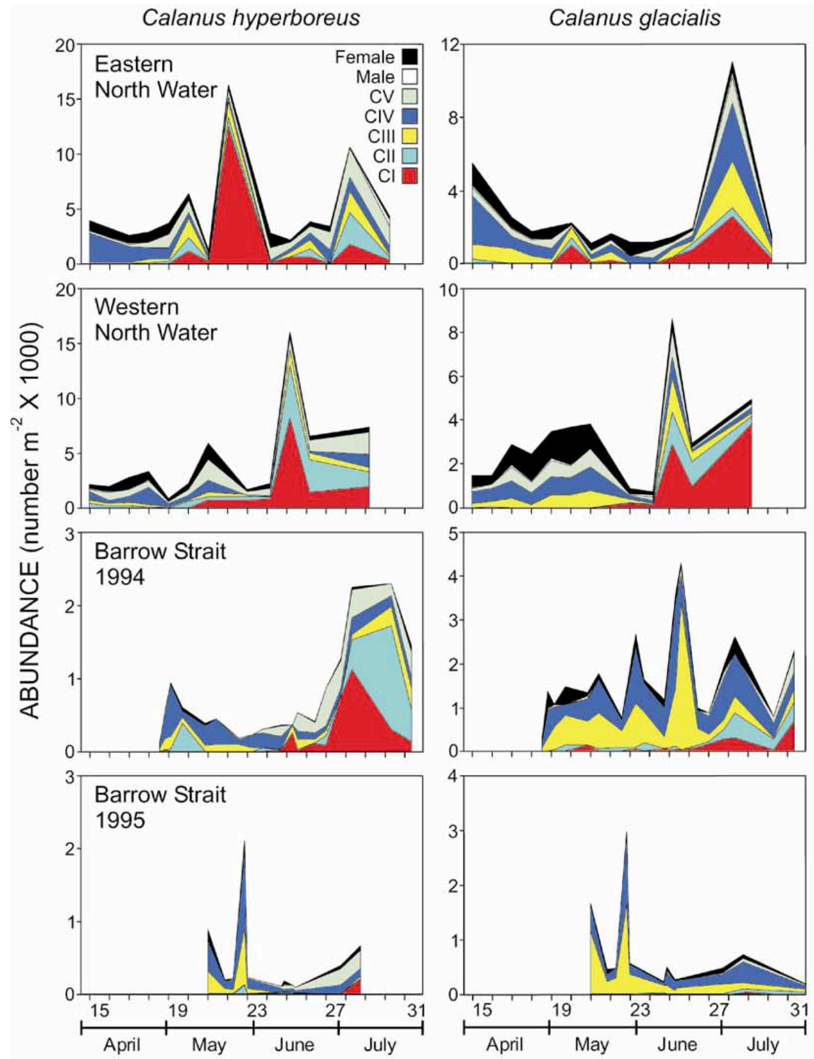
Ashjian and Campbell

3. Examples of change

Calanus reproduction is earlier in North Water Polynya than in Barrow Strait, corresponding to earlier phytoplankton bloom







Ringuette et al. 2002

4. Stressors-zooplankton

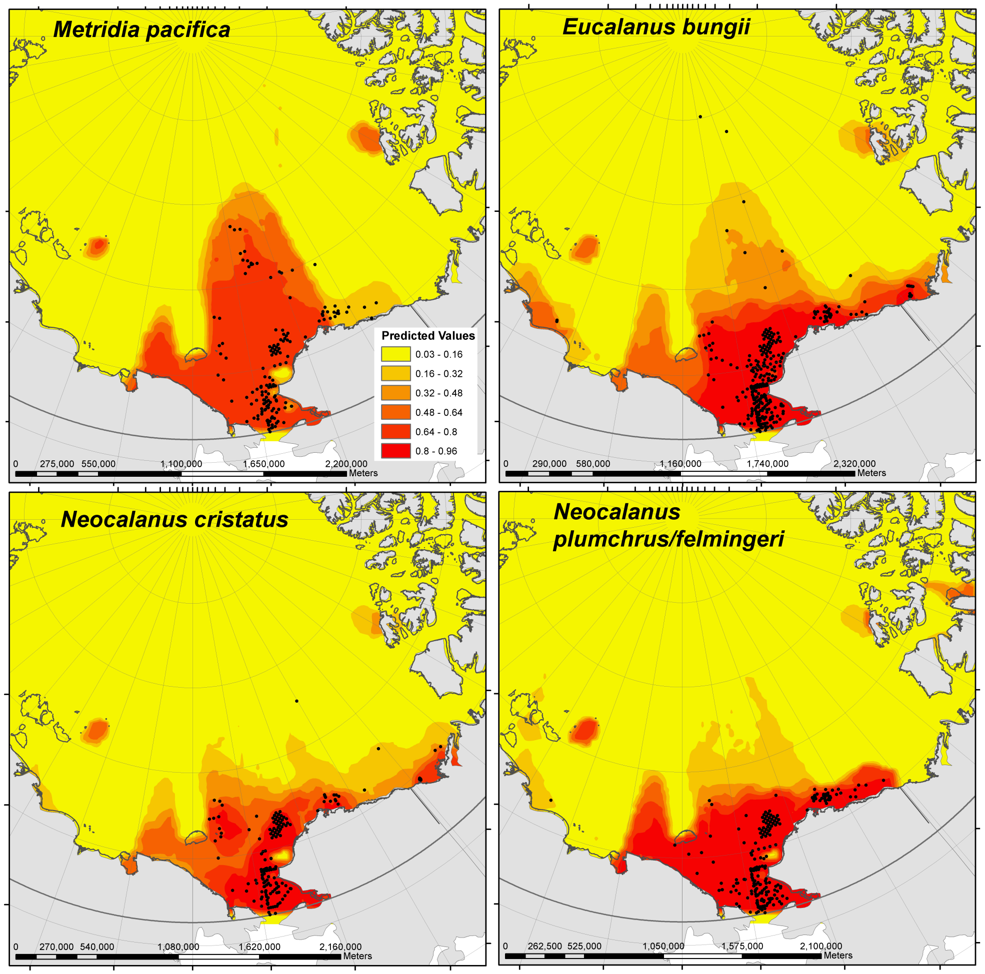
- Changes in sea ice
  - Thickness and snow cover
  - Timing of formation/melt
  - Extent
- Warmer water temperatures
- Changes in circulation
- Changes in transport from the northern Bering Sea into the Chukchi and beyond
- Increased/decreased predation (e.g., jellyfish)
- Changes in primary production and availability of food
- Changes in size of phytoplankton (smaller phytoplankton cells in basin, Liu et al. 2009)
- Increased length of growing season
- Changing seasonality: alterations in timing, magnitude, duration of production cycles

5. Capability to Forecast-zooplankton

- Our capability to forecast changes in the ecosystem is still hampered by:
  - Poor understanding of characteristics in winter
  - Poor understanding of rate processes
- Nonetheless, we do have some models (conceptual, numerical) with which we are addressing some of our questions. The models are not perfect and require a number of unsubstantiated assumptions

5. Capability to Forecast-zooplankton

Modeled probability of finding Pacific expatriates



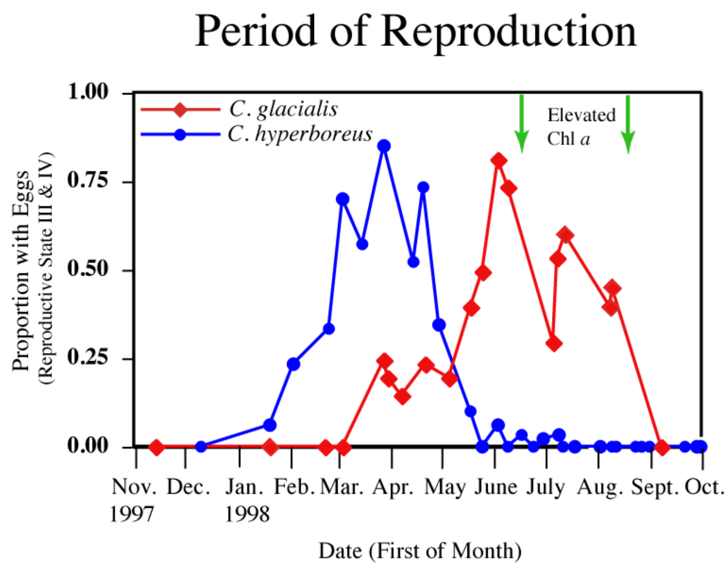
GIS Modeling based on environmental parameters (water mass) not currents

6. Example Questions-zooplankton

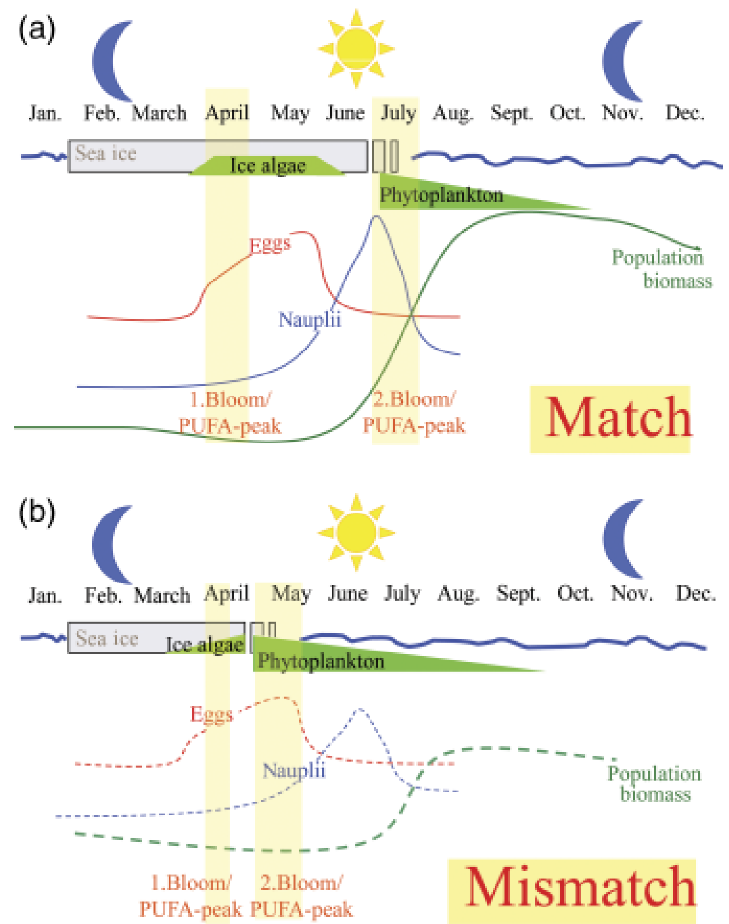
- Will climate change move the Chukchi Sea ecosystem from a benthically dominated system to a pelagically dominated system?
- Do we currently have enough knowledge and understanding of the present ecosystem structure and function to develop a conceptual model for what a progression (benthos to pelagic domination) would look like?
- How will proposed anthropogenic development of the Arctic (energy development, transportation, etc.) affect a transition between these two states (benthic v. pelagic)?

6. Example Questions-zooplankton

Will changes in the timing of primary production with reduced ice cover result in a mismatch between copepod (and other) phenologies and availability of algal food?



Campbell and Ashjian



- Reproduction in Arctic species is timed to coincide with the availability of food (phytoplankton or ice algae) or so that their young start to feed coincident with the availability of food.
- The idea that earlier ice melt will result in mismatch between these events is being explored in modeling, but field observations are needed

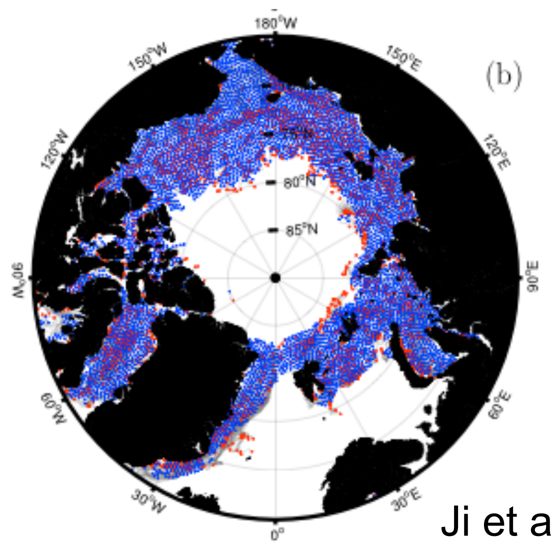
Søreide et al. 2010

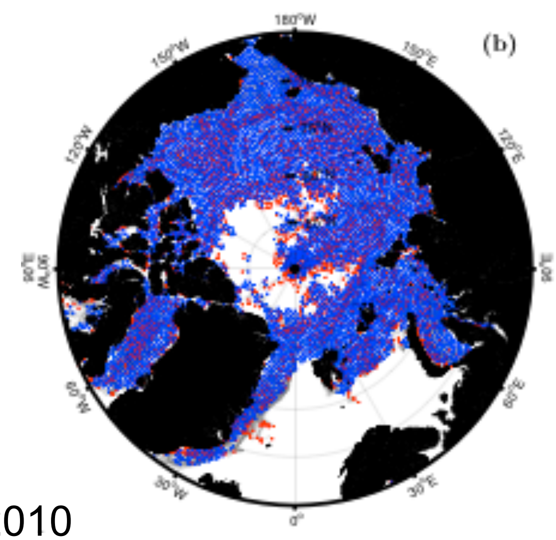
6. Example Questions-zooplankton (and: 5. Capability to Forecast-zooplankton)

How will the changing environment under climate change impact life histories?

Locations where *C. glacialis* can develop to diapause stage now

Locations where *C. glacialis* can develop to diapause stage with 2°C warming





Ji et al., 2010

1. Discipline history & state of knowledge benthos

Benthic Biomass hotspots in high latitudes

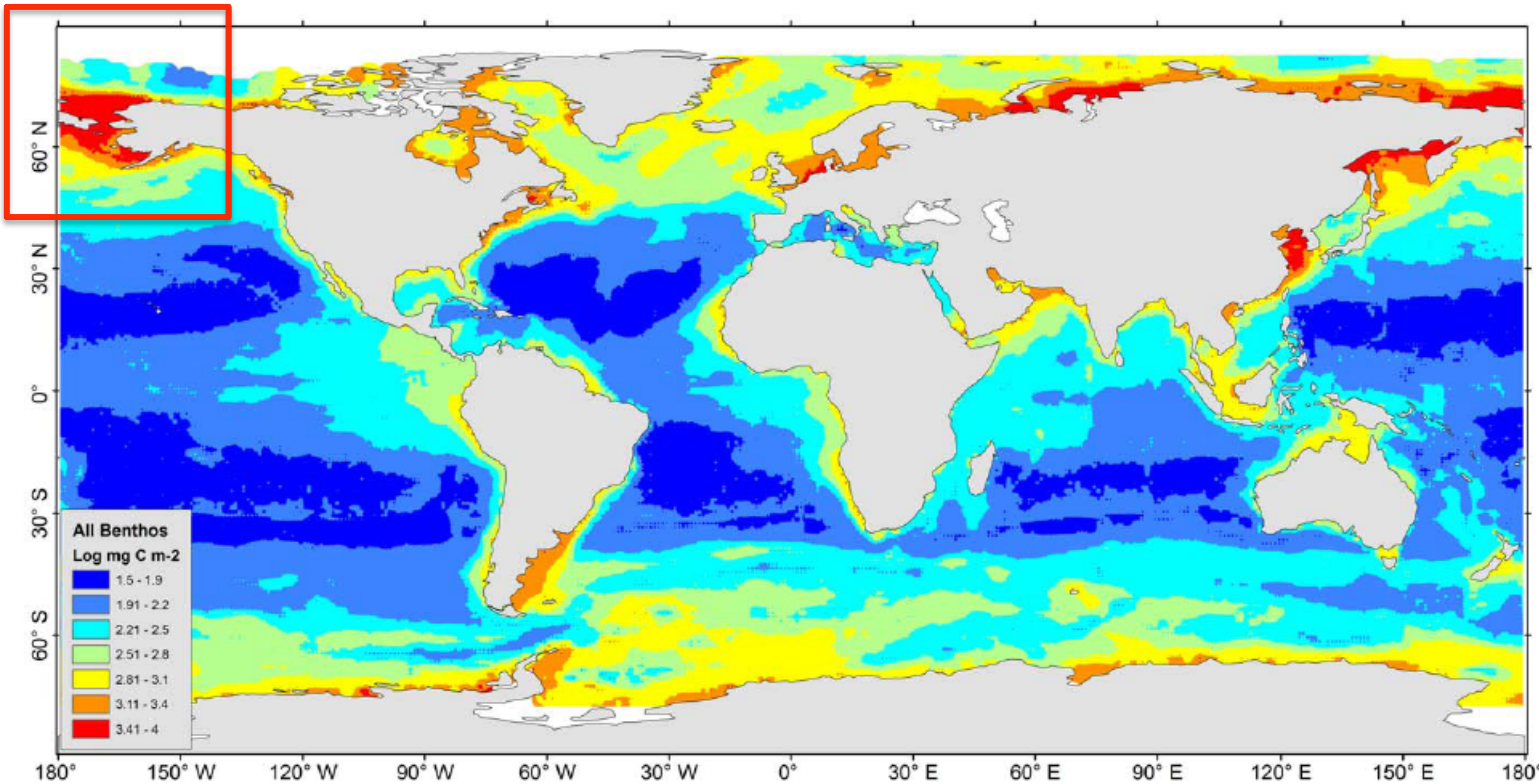
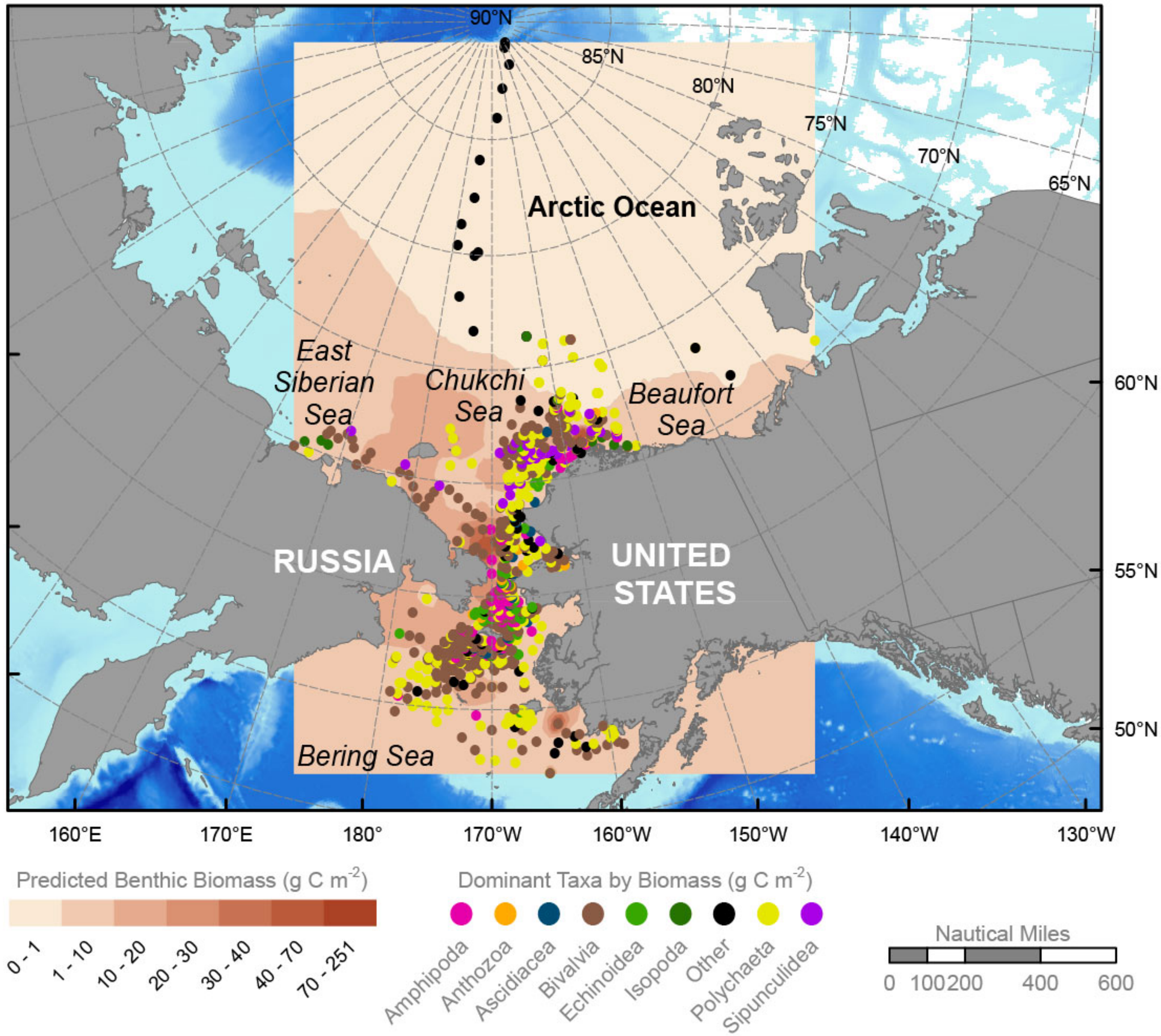


Figure 7. Distribution of seafloor biomass predictions. The total biomass was combined from predictions of bacteria, meiofauna, macrofauna, and megafauna biomass (Figure S5a, b, c, d). Map was smoothed using Inverse Distance Weighting interpolation to 0.1 degree resolution and displayed in logarithm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

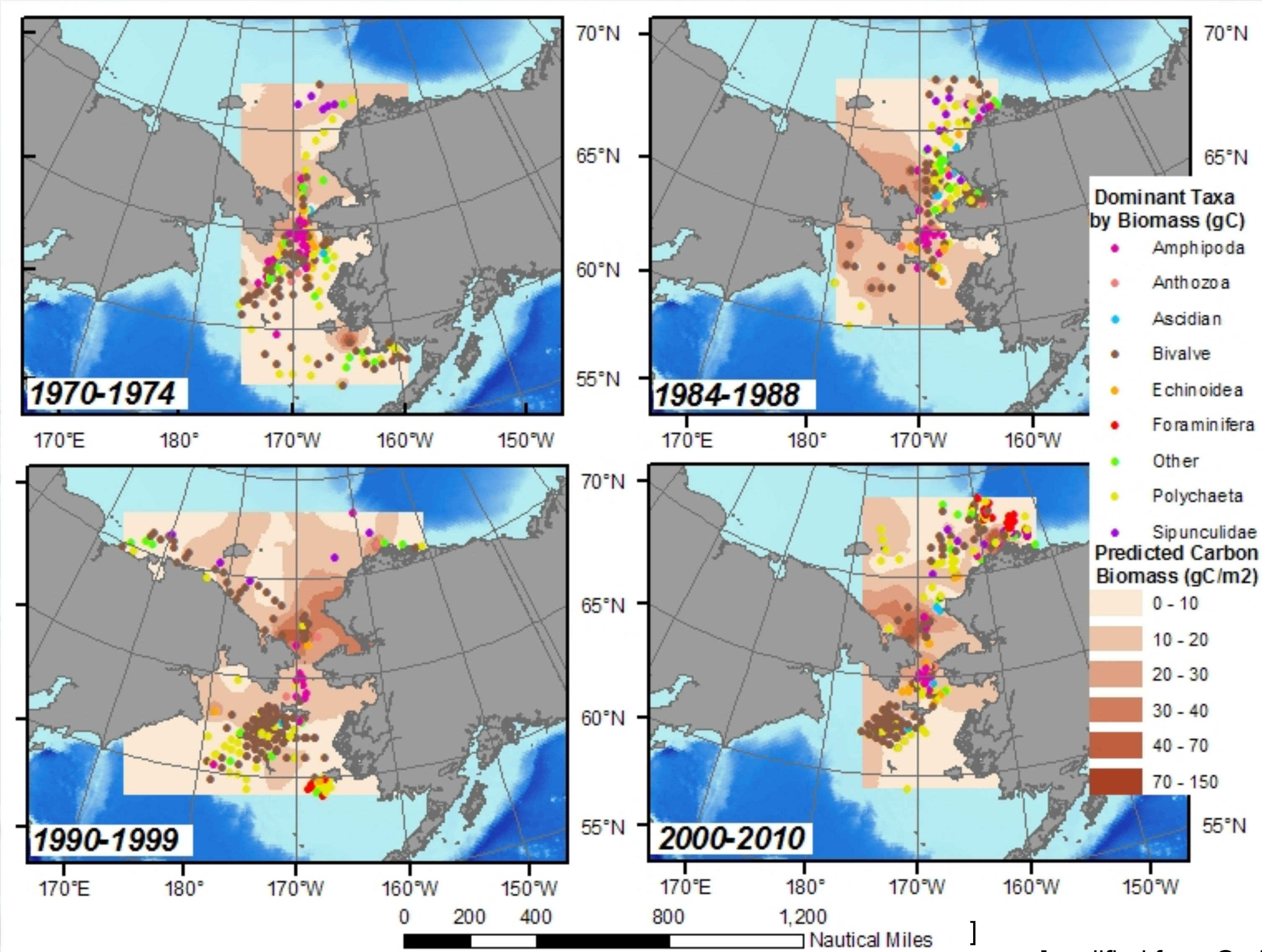
Wei et al. (with Grebmeier and Bluhm) 2010 PLoS ONE 5(12): e15323

Dominant benthic macroinfauna & biomass in the Pacific Arctic region



Bluhm and Grebmeier 2011-Arctic Report Card

Dominant infaunal taxa includes bivalves, amphipods, polychaetes and sipunculids



[modified from Grebmeier 2012]

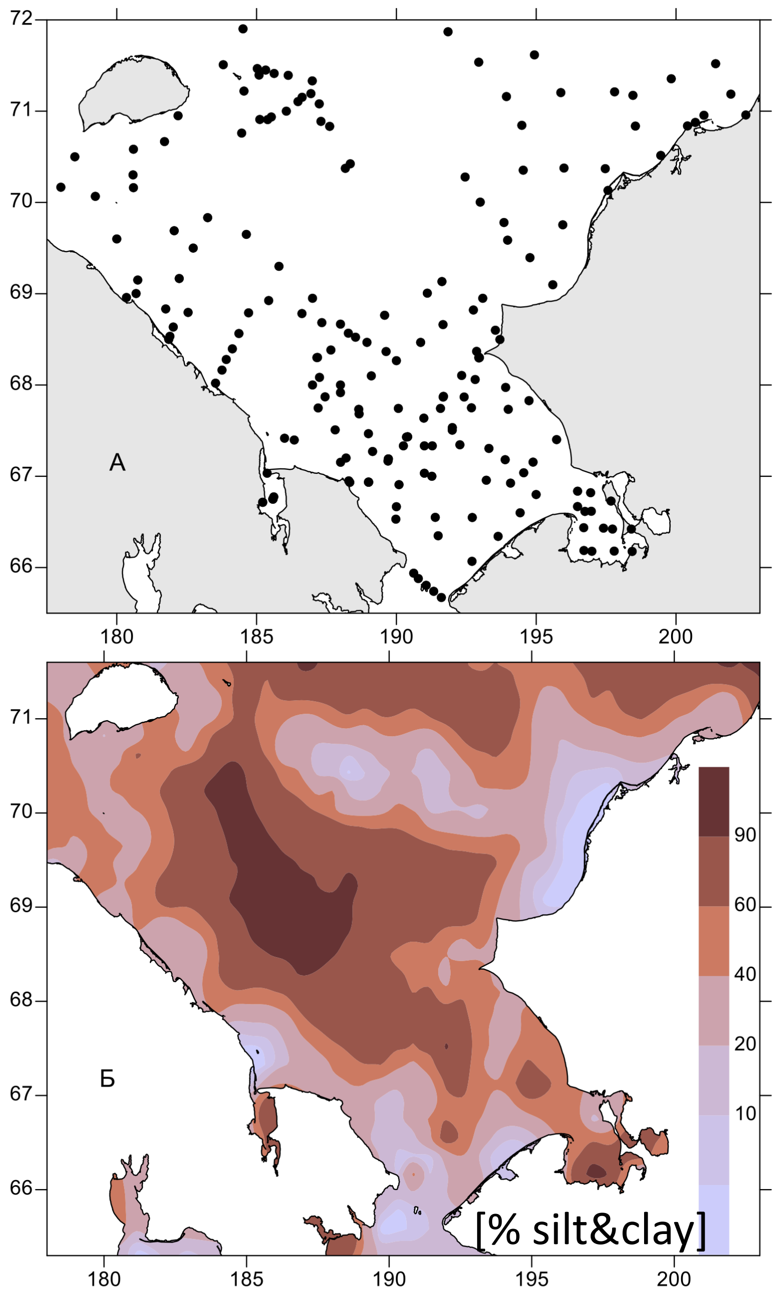


Рис. 1. Расположение бентосных станций в Чукотском море в период с 1986 по 2006 г. (А) и доля алевропелита в донных осадках (с дополнениями и изменениями по Кошелевой, Яшину, 1999).

Russian benthic infauna from the Zoological Institute, Russian Academy of Sciences, St. Petersburg, Russia

Courtesy Boris Sirenko, Stanislov Denisenko (2010)

BIORESOURCES OF KEY SPECIES, MAIN TAXONOMIC AND TROPHIC GROUPS OF ZOOBENTHOS IN THE CHUKCHI SEA 1986-2006

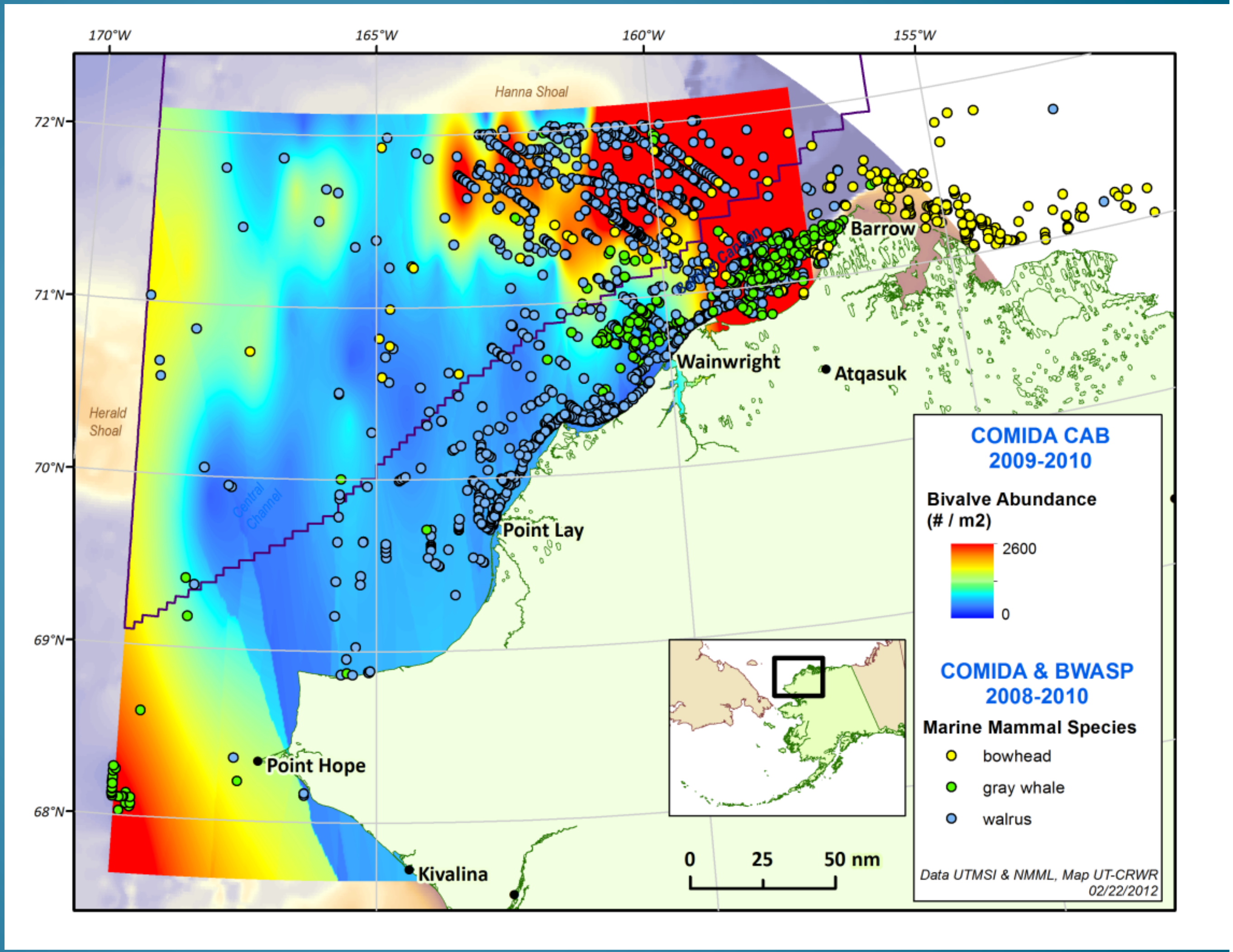
The paper describes total stock and spatial biomass distribution of the key species, main taxonomic and trophic groups of zoobenthos in the Chukchi Sea. Determined key species, according to rank of theirs stock value, are following: *Macoma calcarea, Ennucula tenuis, Astarte borealis, Golfingia margaritacea, Nuculana radiate, Yoldia hyperborea, Maldane sarsi, Psolus peroni.* The influence of bottom sediments and water masses on zoobenthos bioresources is discussed. A hypothesis explaining phenomenon of very high biomass in the southern Chukchi Sea is presented and discussed. On the base of relation between stocks of filtrating feeders and deposit feeders the examined sea area is classified as eutrophic marine system.

2. Key observations, datasets & time frame-benthos (just some examples)

- US, Russian and Canadian data sets, especially since the 1930s
- Infaunal and epifaunal community composition and structure
  - 1970s MMS OCSEAP
  - 1980s ISHTAR, BERPAC, MMS studies
  - 1990s MMS environmental studies, NSF/NOAA benthic studies in the Bering and Chukchi Seas
  - 2000s NSF studies Chirikov Basin, SBI , RUSALCA, CASES, CP-Shell-StatOil environmental studies, MMS/BOEM COMIDA CAB (Chukchi Sea) and ANIMIDA (Beaufort Sea), NPRB benthic studies, BEST/BSIERP, C30, others
  - 2010 CP-Shell-StatOil environmental studies, COMIDA Hanna Shoal, RUSALCA, C30, DBO
- Nearshore benthic studies (UAF, State AK, EPA)
- Beaufort sea snow crab surveys, benthic studies
- Arctic Basin: NOAA Ocean Exploration

BIVALVE ABUNDANCE & MAMMAL SIGHTINGS

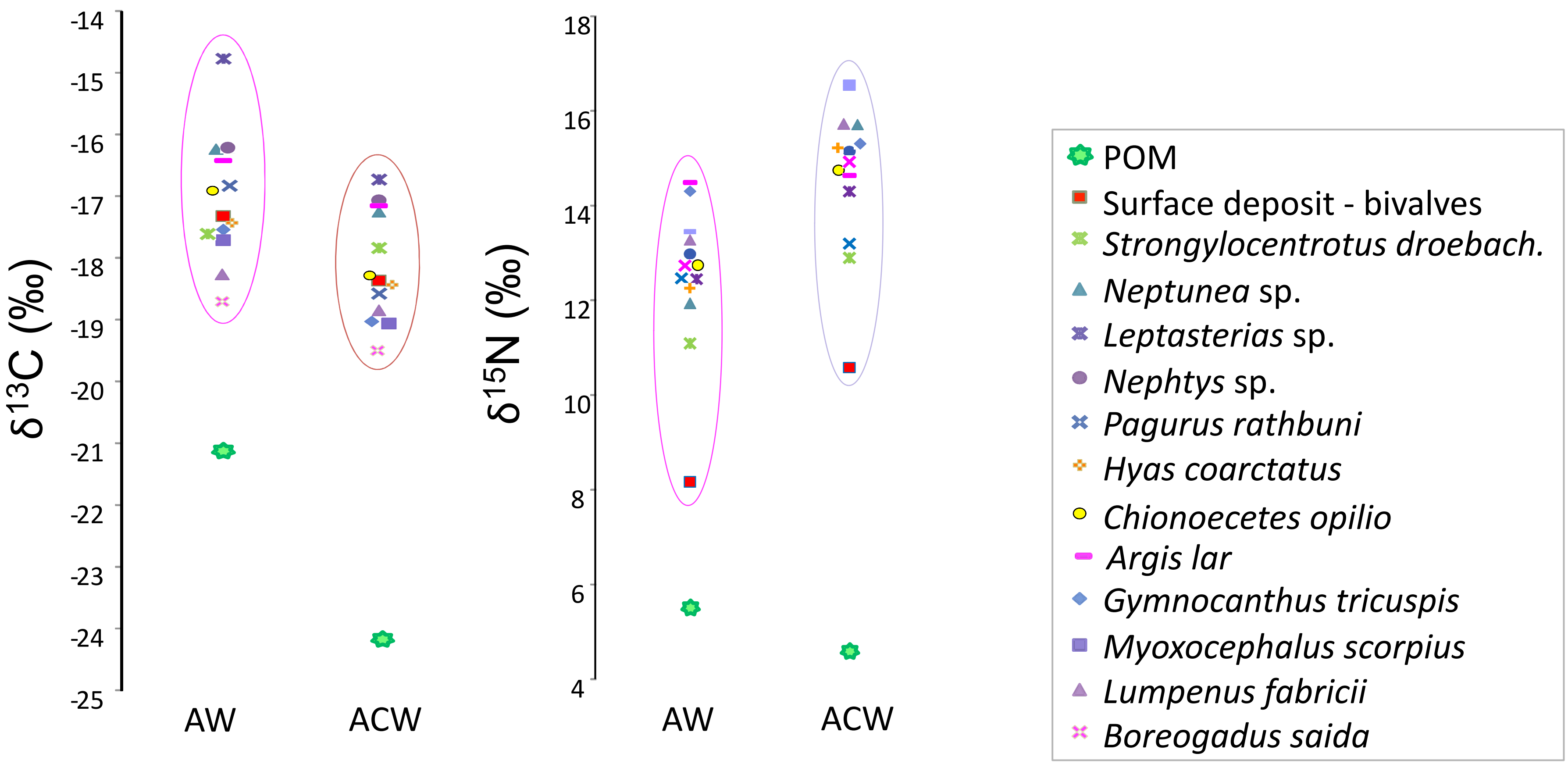
Marine mammal aerial studies funded by BOEM and NOAA/NMML. Data courtesy of Sue Moore, NMML.



Compiled by Schonberg & Dunton, 2012

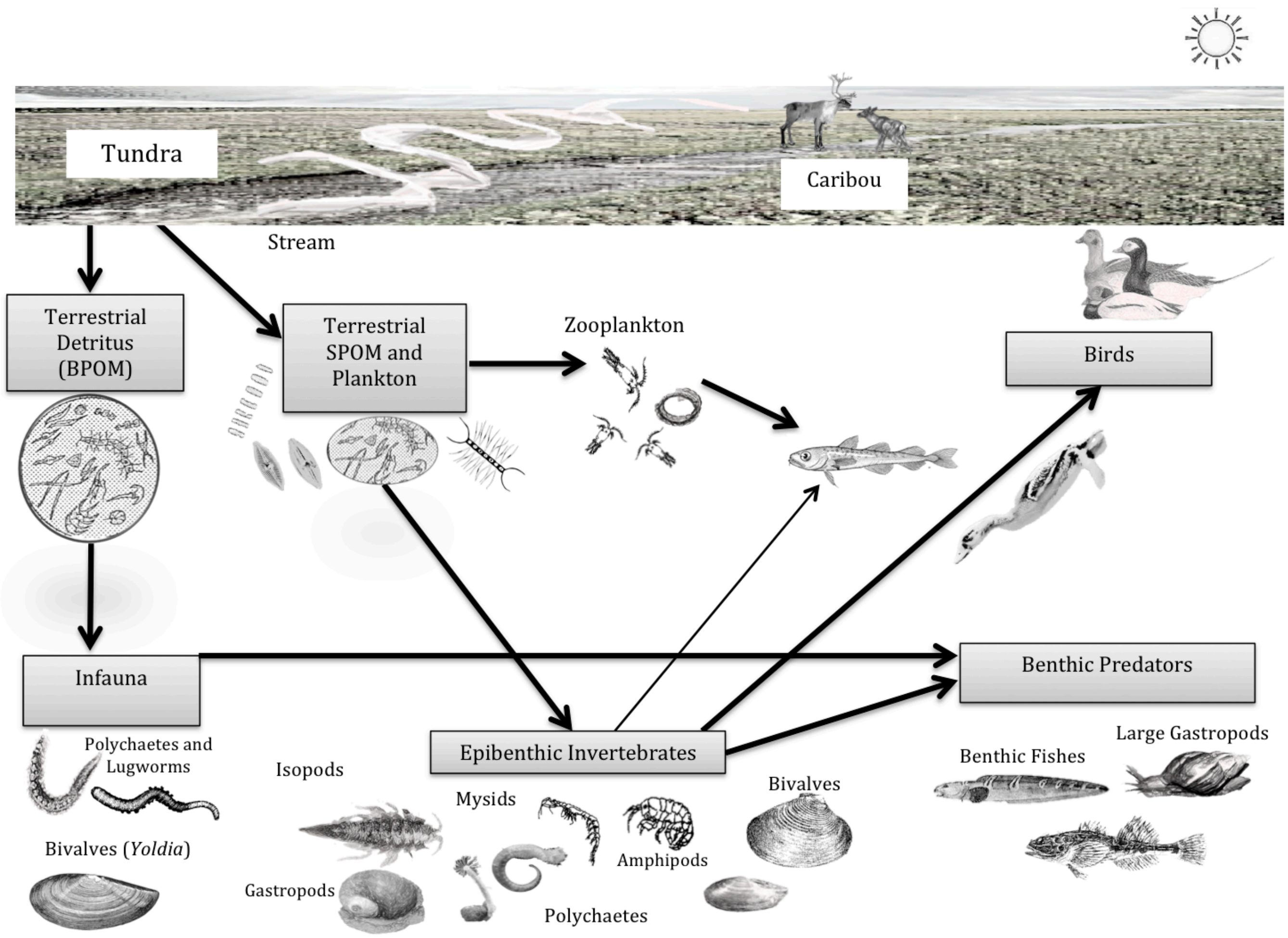
Benthic-pelagic coupling from a food web angle of epifauna and infauna: stable isotopic response to difference in C-signatures

- tighter coupling in more productive water mass (reflected in lower $\delta^{15}N$ ratios of same species consumers)



Iken, Bluhm, Dunton 2010 Deep-Sea Research II 57: 71-85

Benthic Trophic Links to Terrestrial Carbon Sources are Strong in Arctic Coastal and Estuarine Systems

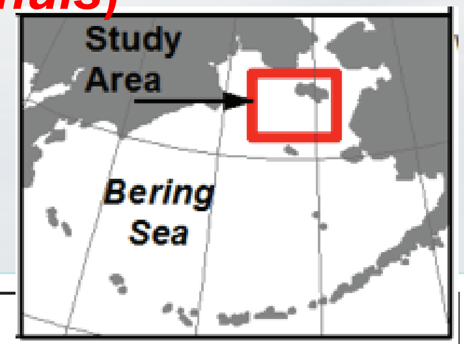


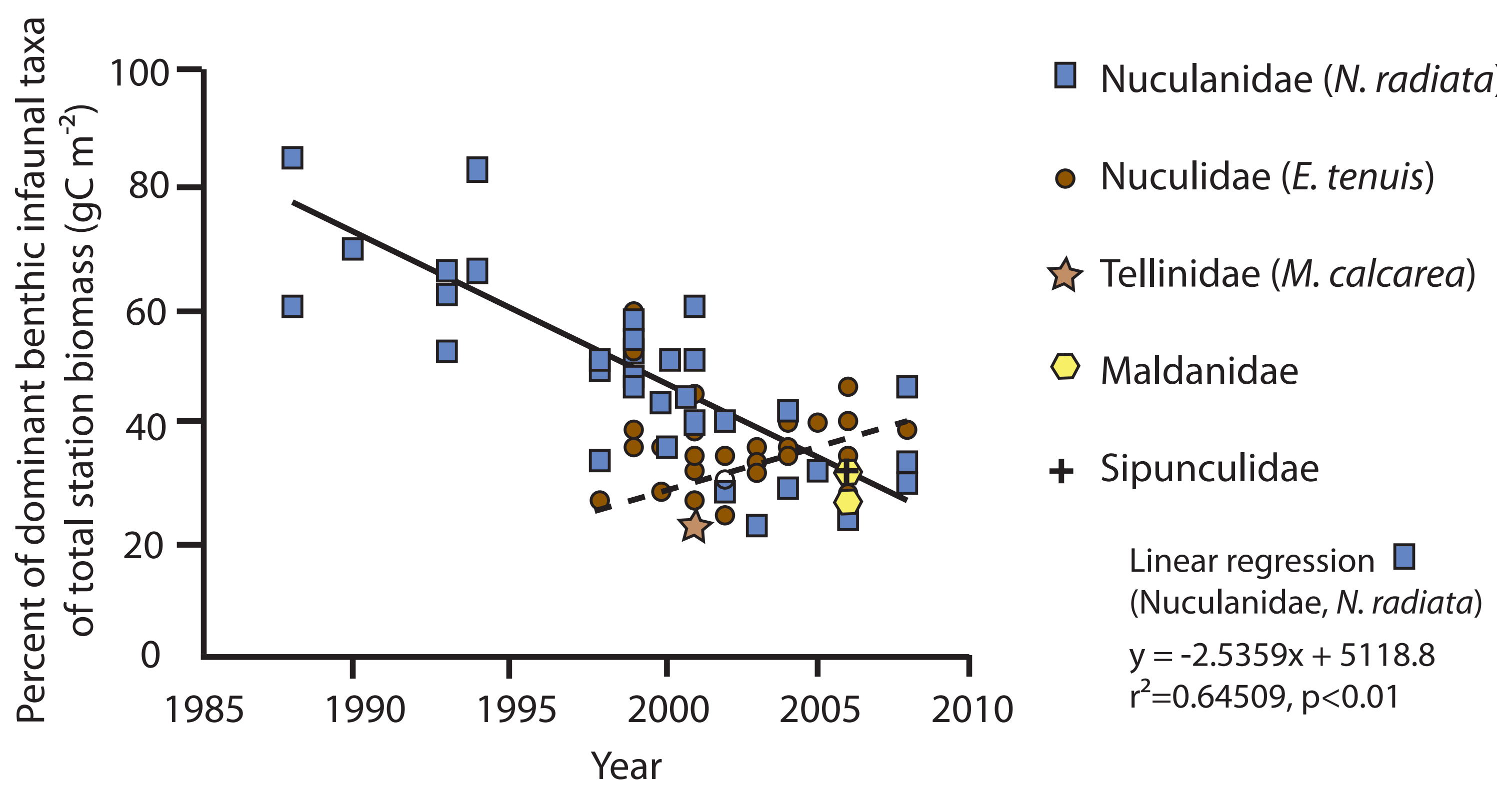
From Dunton, Schonberg and Cooper, 2012

3. 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]

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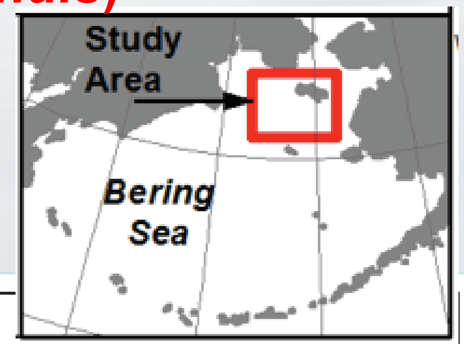
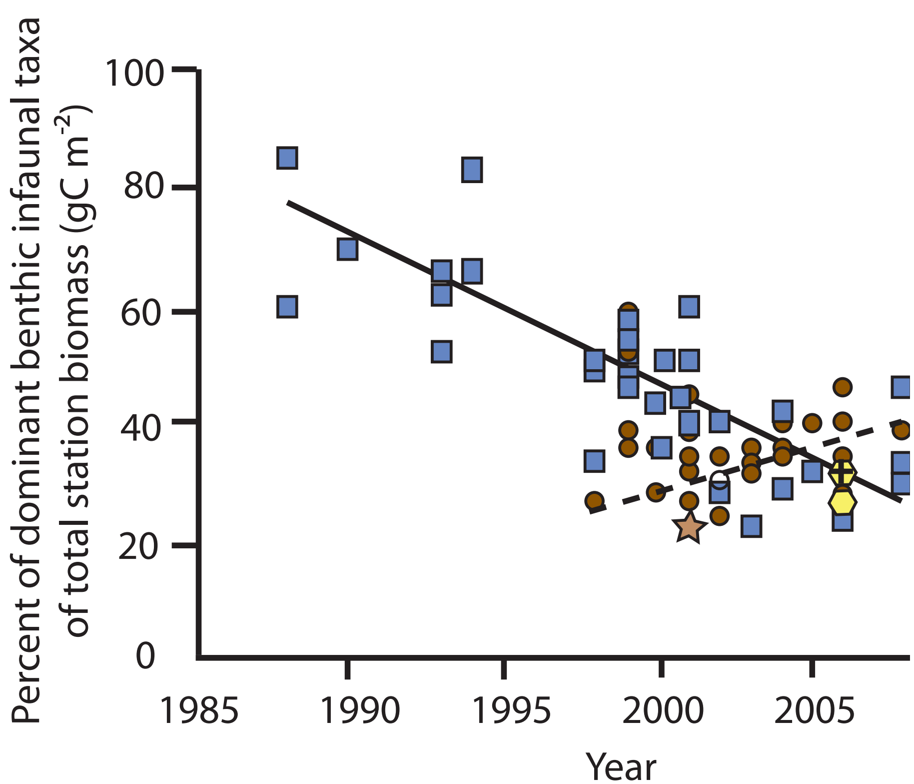
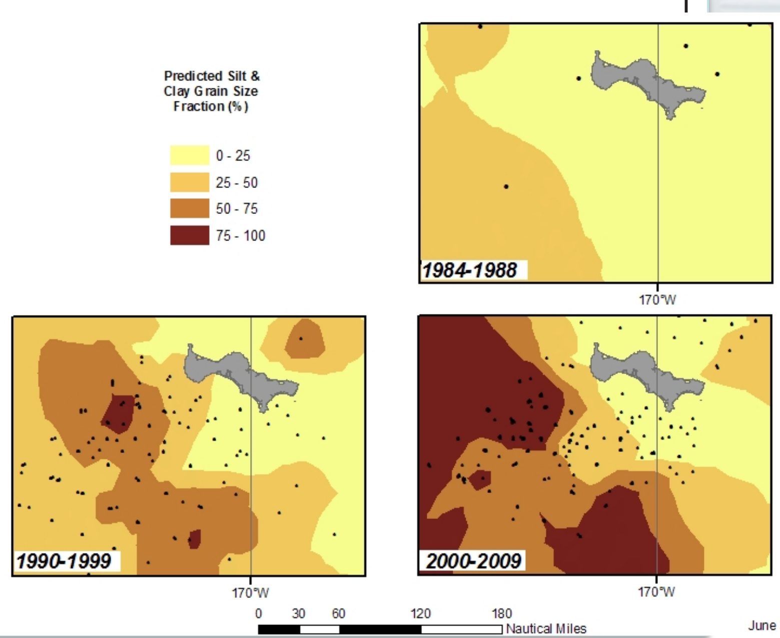
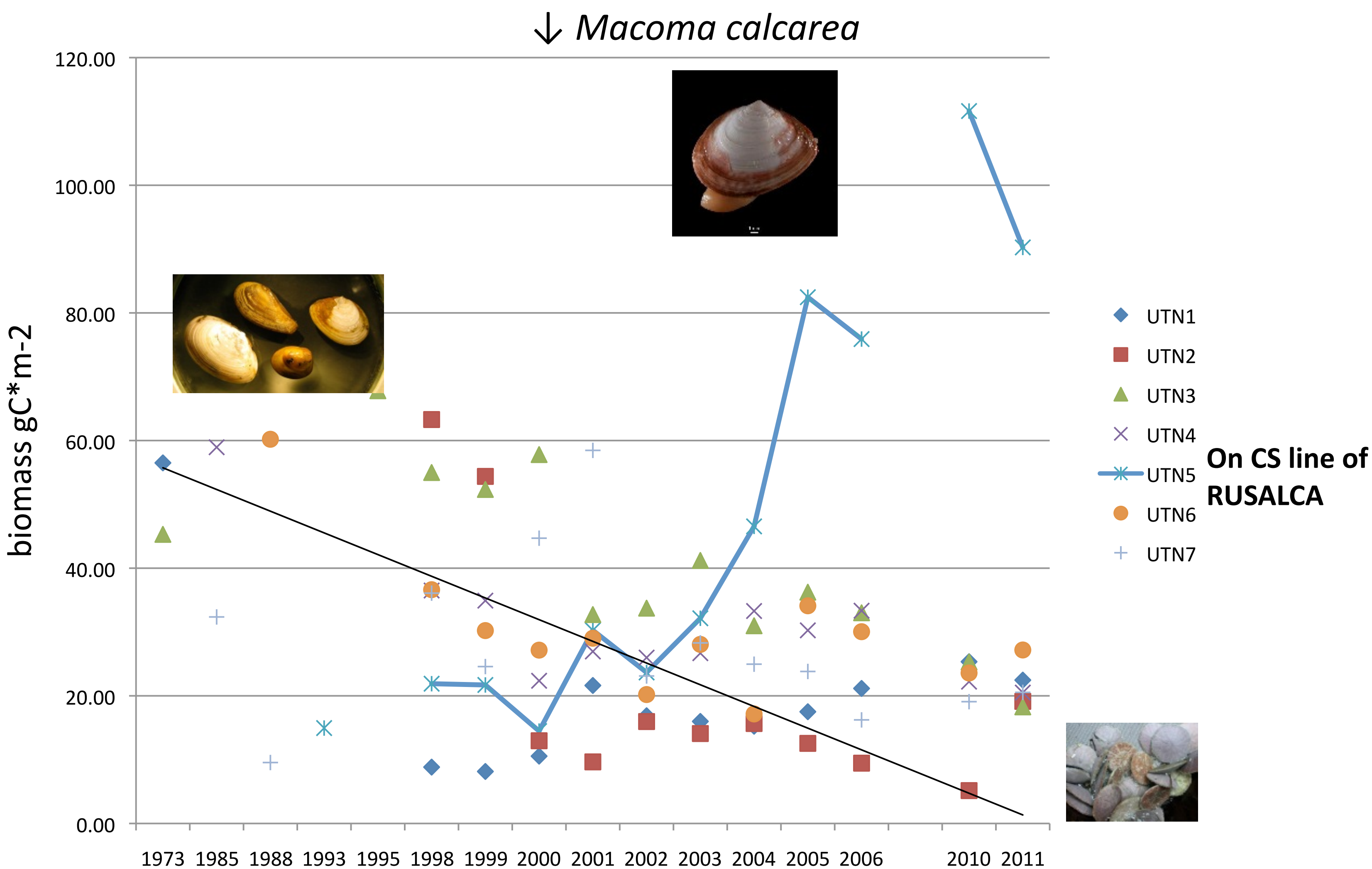




- Fining sediments over time →



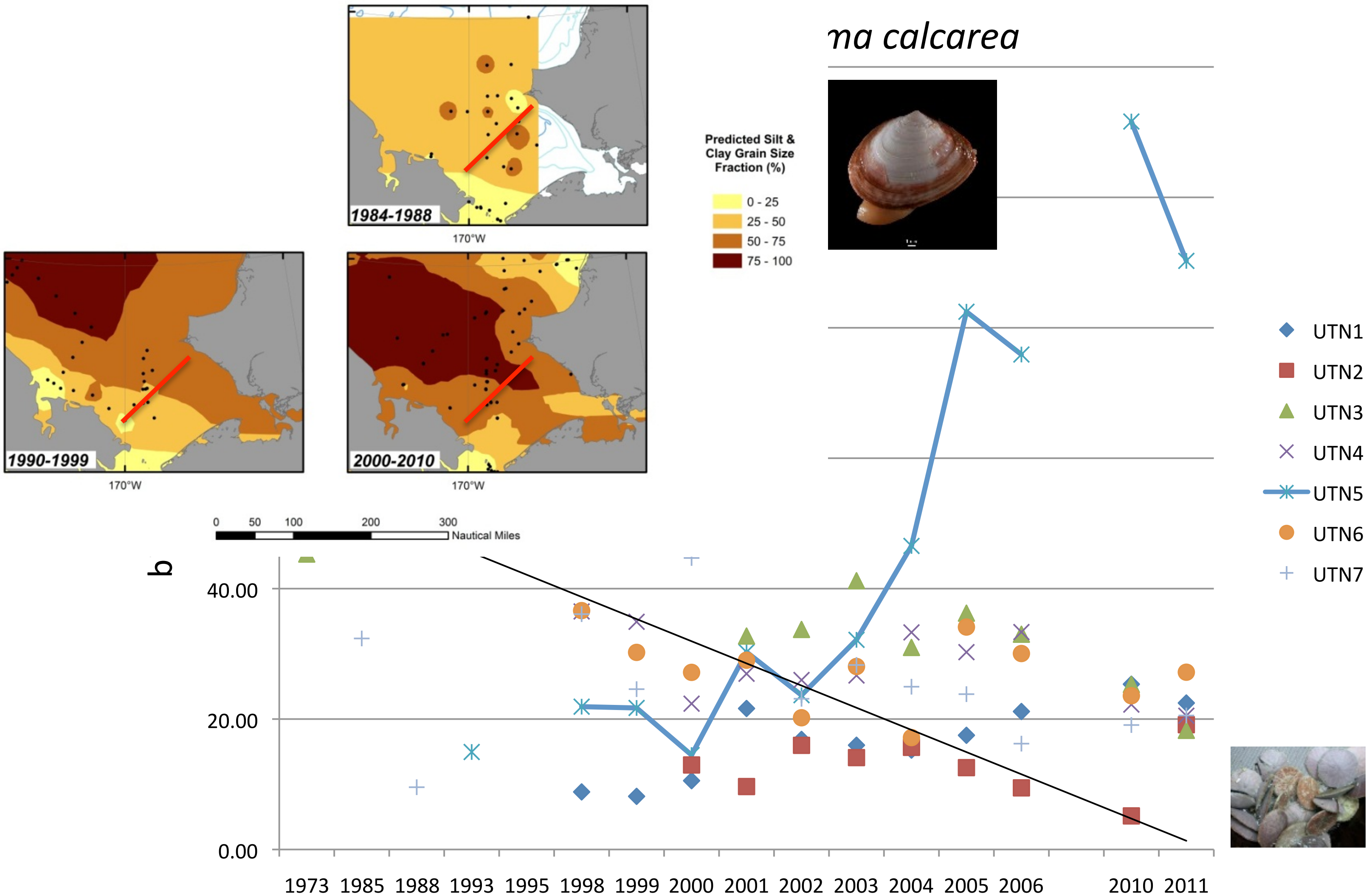
DBO3-SE Chukchi Sea



[Updated and modified from Grebmeier et al. 2006; Grebmeier et al. 2012 in prep.]

DBO3-SE Chukchi Sea

Southern Chukchi

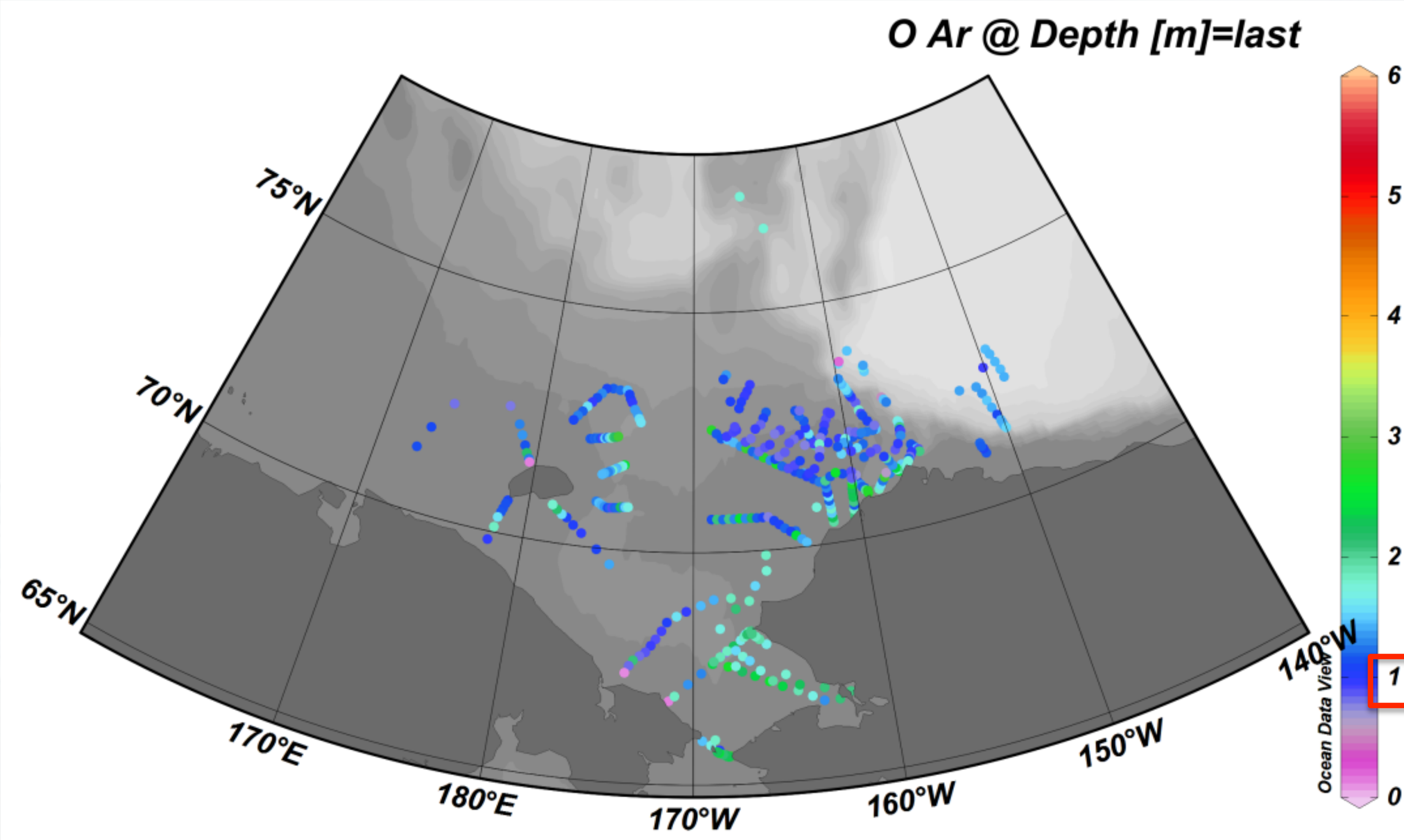


[Updated and modified from Grebmeier et al. 2006; Grebmeier et al. 2012 in prep.]

4. Identify stressors/physical forcing mechanisms- benthos

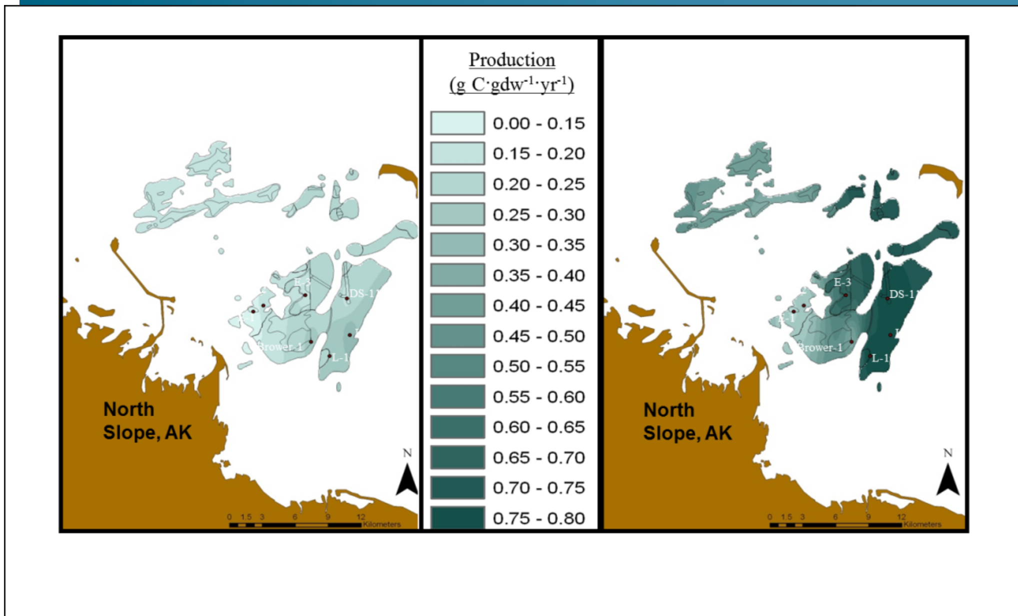
- Changing sea ice conditions and connection to upper water column production (sea ice and ice edge bloom)
- Warming water enhancing zooplankton production and enhanced intrusion Pacific species seasonally, potential increasing grazing that reduces export production
- Change in surface sediment patterns via hydrographic forcing changes have direct impact on benthic population structure
- Changing temperature and food supply to benthos is intimately connected to the the timing of reproductive events in the benthos that release meroplankton or demersal young annually, with consequences on benthic community composition and structure
- Ocean acidification has potential for negative impacts on calcium & aragonite producing infauna, such as bivalves, snails, and corals

Ocean Acidification vulnerability



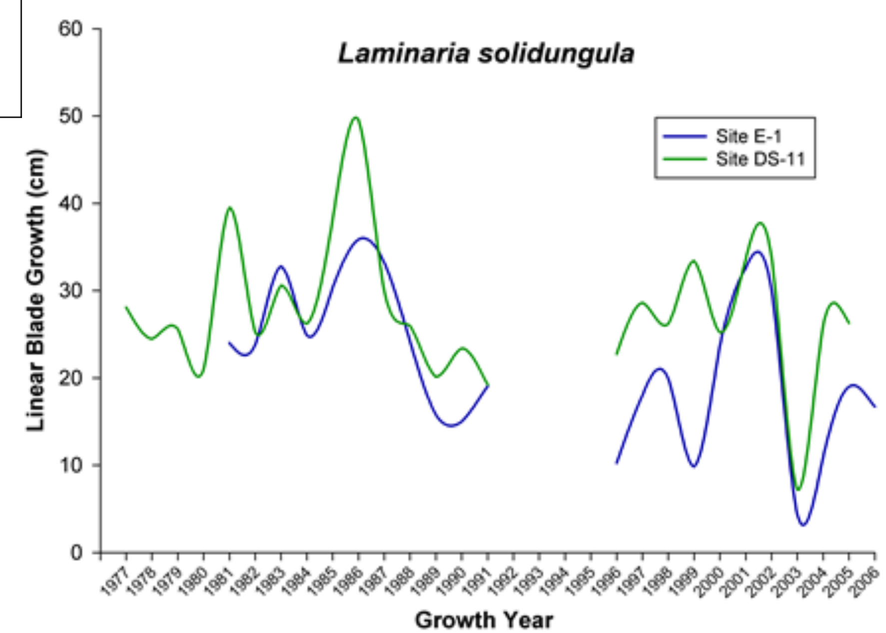
Bates, Orchowska, Garley, Mathis *et al.*, 2011

Examples of Change over Annual and Decadal Scales



Benthic primary production reflects overlying water transparency which is a product of sediment re-suspension.

Benthic kelp production in the Beaufort Sea reflects stressors of decreased ice extent, increased coastal erosion, changing meteorological forcing functions in predominant wind speed s and direction.



From Dunton et al.

5. Capability to forecast benthos

- Benthic parameters not normally included in most ecosystem modeling for Pacific sector, yet

- Benthos (fauna and sediment parameters) can be integrators of overlying water column processes, so patterns and areas of change can provide “first responder” information to change within areas of high pelagic-benthic coupling

- Need standard, time series, interdisciplinary focal measurements for modeling validation

6. Example questions for discussion-benthos

- How will lower trophic biodiversity change under variable physical forcing with climate warming?

- Will potential changes in faunal abundances, composition and distributions over both space and time influence carbon cycling and higher trophic level populations?

- How will benthic hotspots change over time and space with changes in hydrographic forcing and sediment dynamics, and can these hotspots provide a framework to assess ecosystem response and change?

- How can we assess the impact of key stressors on benthic faunal systems and can we develop models to forecast ecosystem response?

Thank you.

Any questions?