Is Arctic zooplankton sleeping in the winter?

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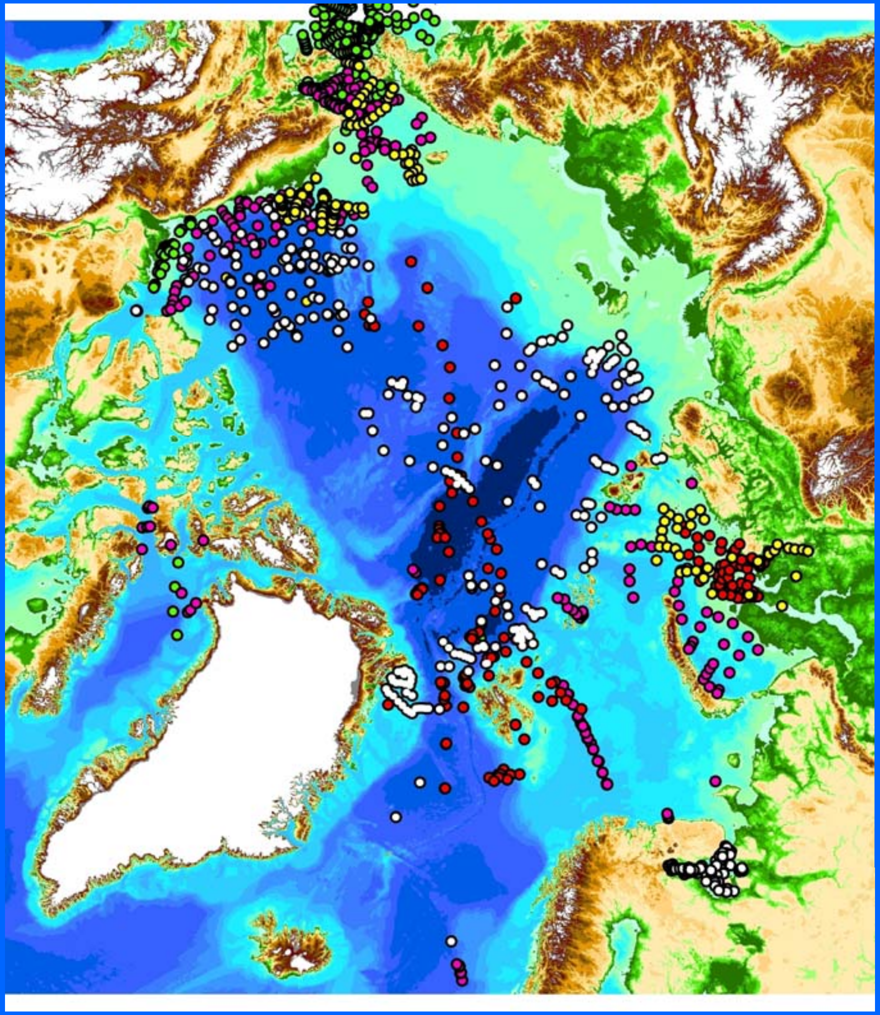
Arctic winter

Traditional perception:
Arctic zooplankton spend the winter season with little activity, using up energy stored during the previous productive season

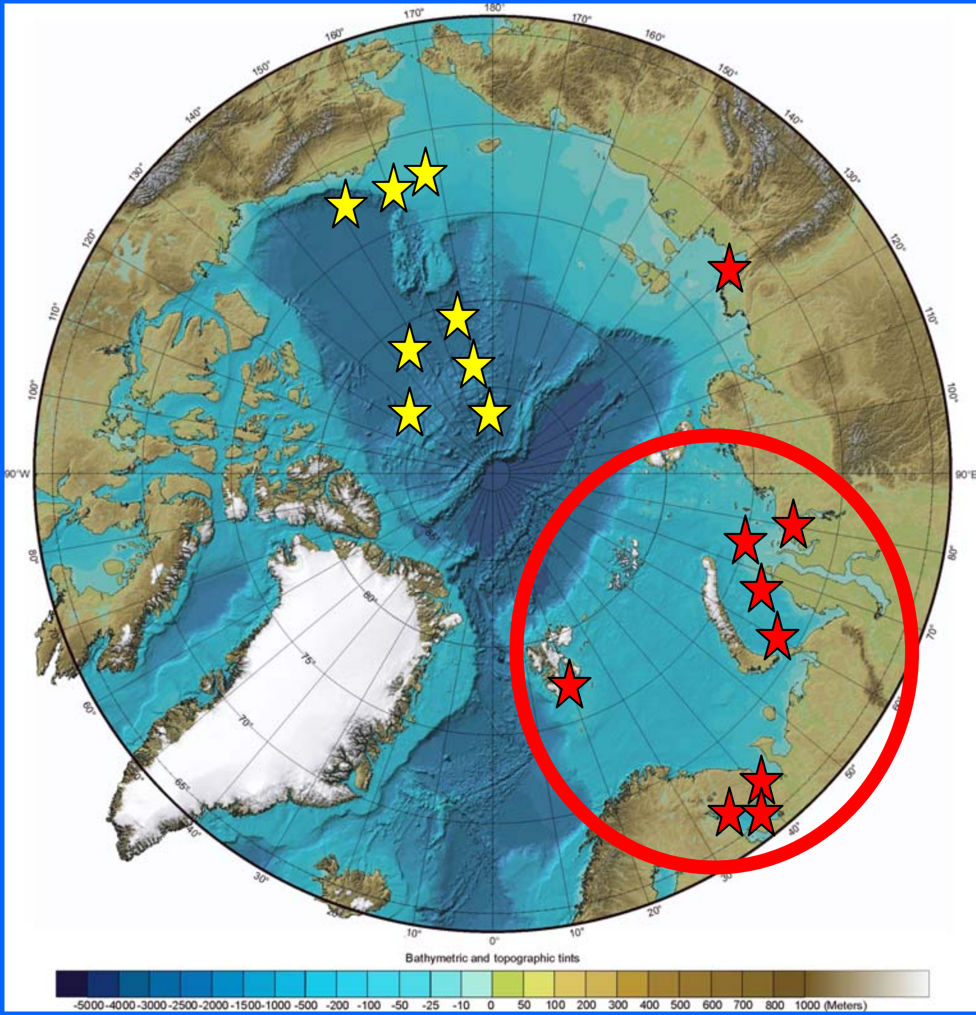
Based almost exceptionally on observations during the ice-free period

Zooplankton collections obtained during:

Summer



Winter



Goal

To understand the zooplankton community maintenance in the shelf Arctic seas during the winter season

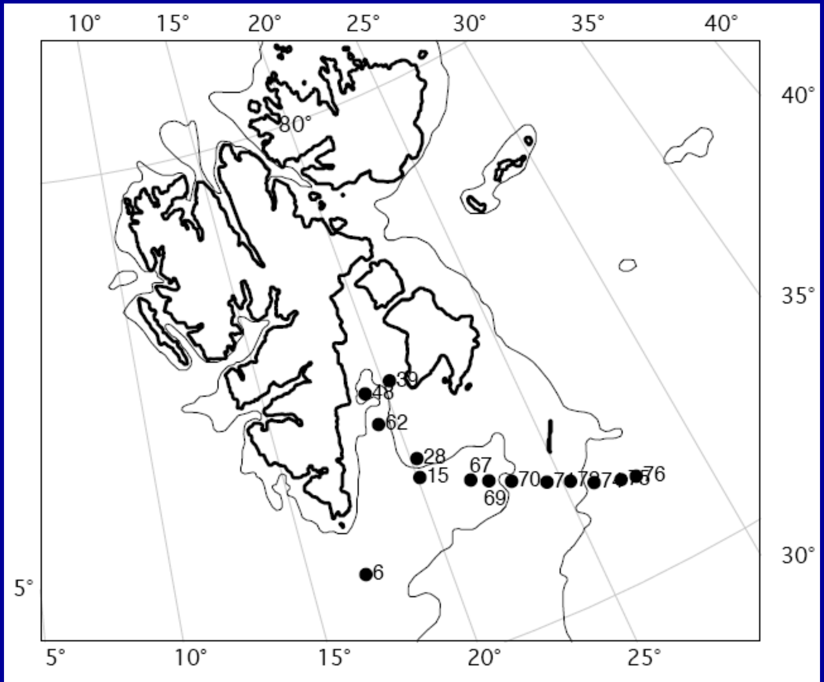
Approach:

- inventory of metazoan invertebrates in the studied areas during the winter season;
- Analysis of developmental stage/size structure of populations of key and more rare species during the winter;
- Analysis of the reproductive state of zooplankton populations;
- in situ and experimental observations on egg production of key species

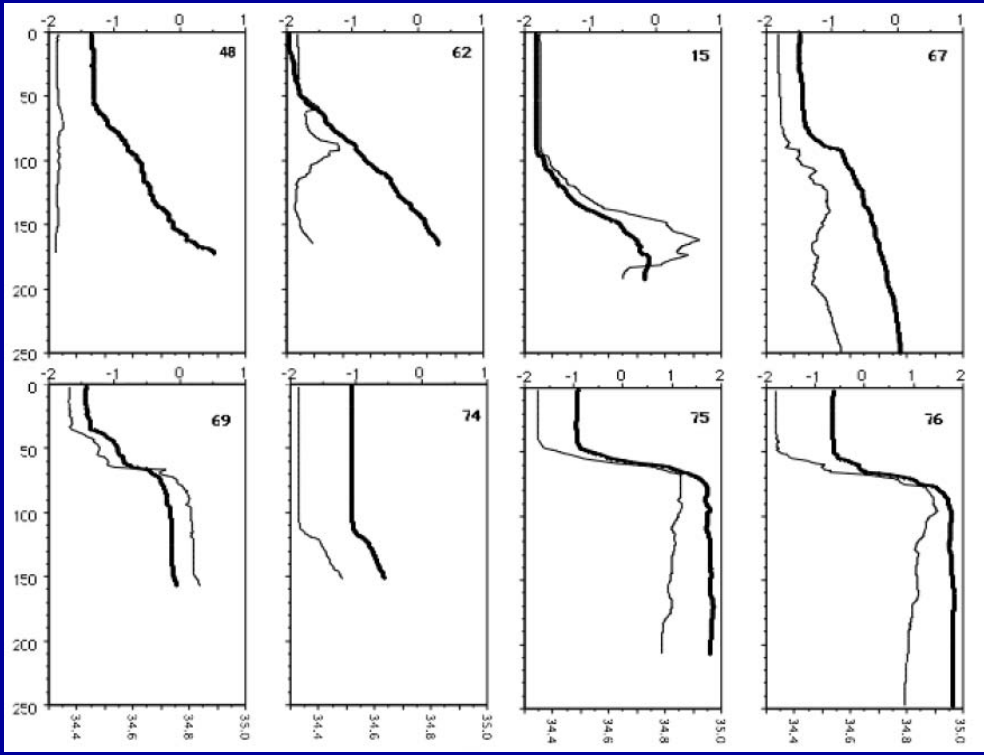
Study area 1: Barents Sea, Storfjord (Svalbard):

March 8-25, 2003,
typical winter situation

Ice cover 0.4-1.8 m
Snow cover 20-30 cm
Air T° -27.5 to -1.8°C
Surface water T° -1.7 to -0.7°C
Chlorophyll 0.032-0.045 mg L^{-1}



Temperature, °C



Salinity

Stations in the fjord, affected by Polar water;
Stations in the open Barents Sea, with Atlantic water near the bottom

Zooplankton community characteristics:

- **Low biomass: 0.7 to 2.4 g DW m^{-2} (summer: 0.6 to 14 g DW m^{-2});**
- **Lower species number comparing to summer;**
- **Vertical distribution typical of winter season with low values in the upper layers and an increase at depth;**
- **Small copepods *Oithona, Pseudocalanus, Microsetella* dominated numbers (73-87%);**
- **Large copepods *Calanus, Metridia* and chaetognaths *Parasagitta* dominated biomass (65-83%),**

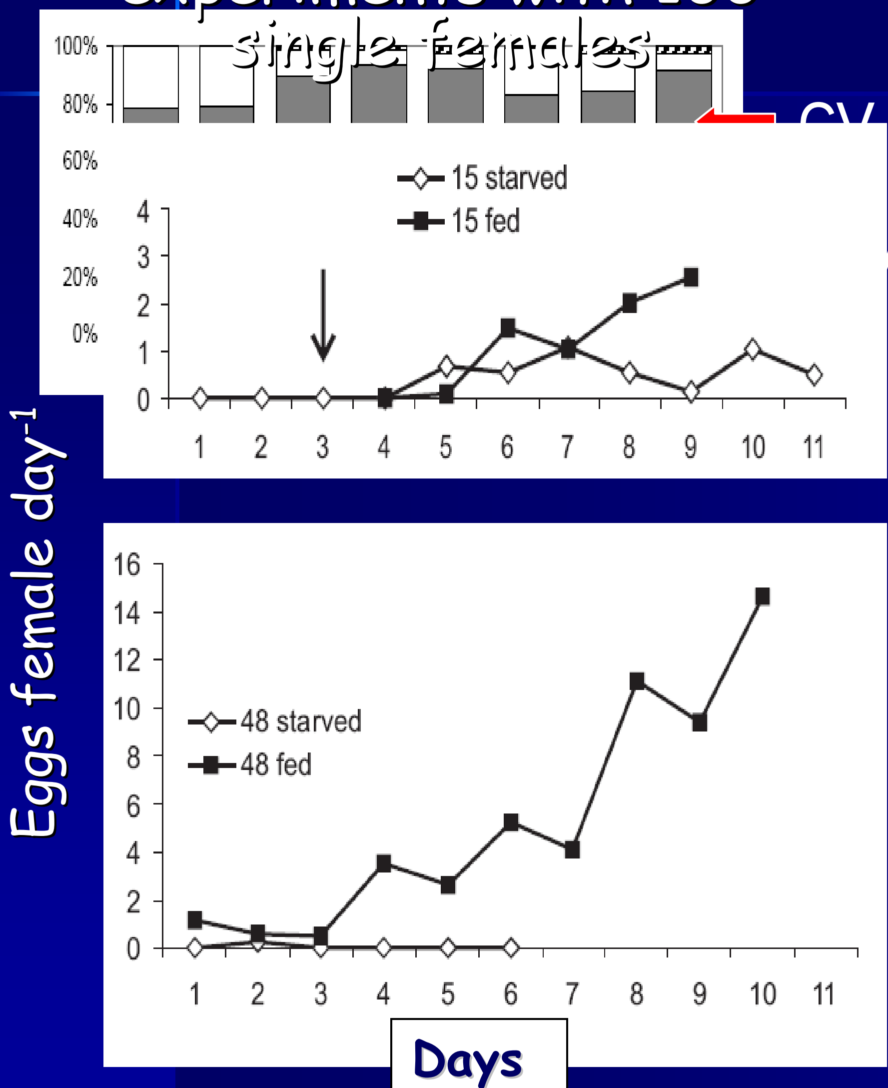
BUT

- **Several taxa showed signs of reproductive activity: quite a number had advanced state of gonad maturation, some laid eggs or had youngest developmental stages present in their populations**

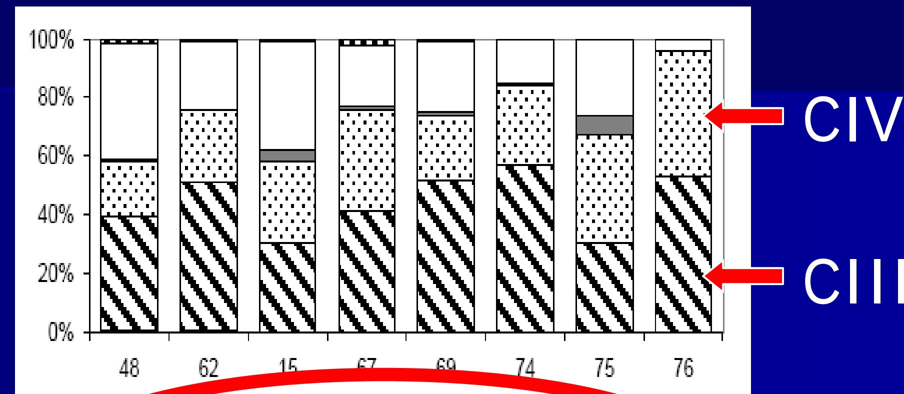
Key filter-feeders:

Calanus finmarchicus
(10-30% of biomass)

Egg production experiments with 100 single females



Calanus glacialis
(10-50% of biomass)



Few eggs present in the water column

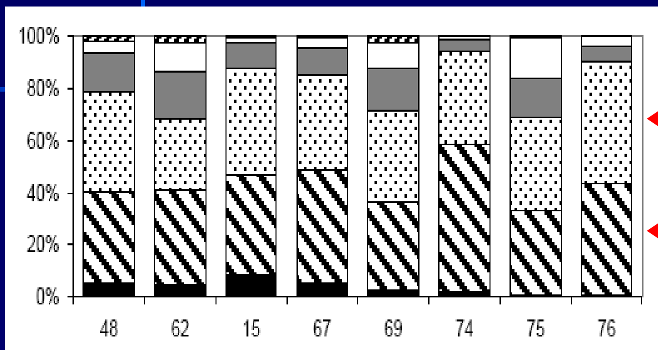
In situ (24-hs incubation):
6% females spawning
EPR: 2.2 eggs fem d^{-1}
Max clutch: 22 eggs fem^{-1}

2 weeks-long incubation:
Without food
EPR : 1.1 eggs fem d^{-1}
With food:
EPR: 15 egg fem d^{-1} after 15 d

Other key species:

Pseudocalanus spp.
(3-6% of biomass)

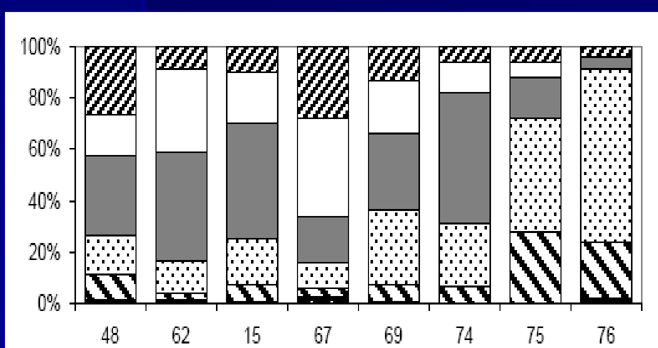
3-8% females are egg-brooding, 5-25% females have mature oocytes inside ovary, nauplii, CIs present



CIV

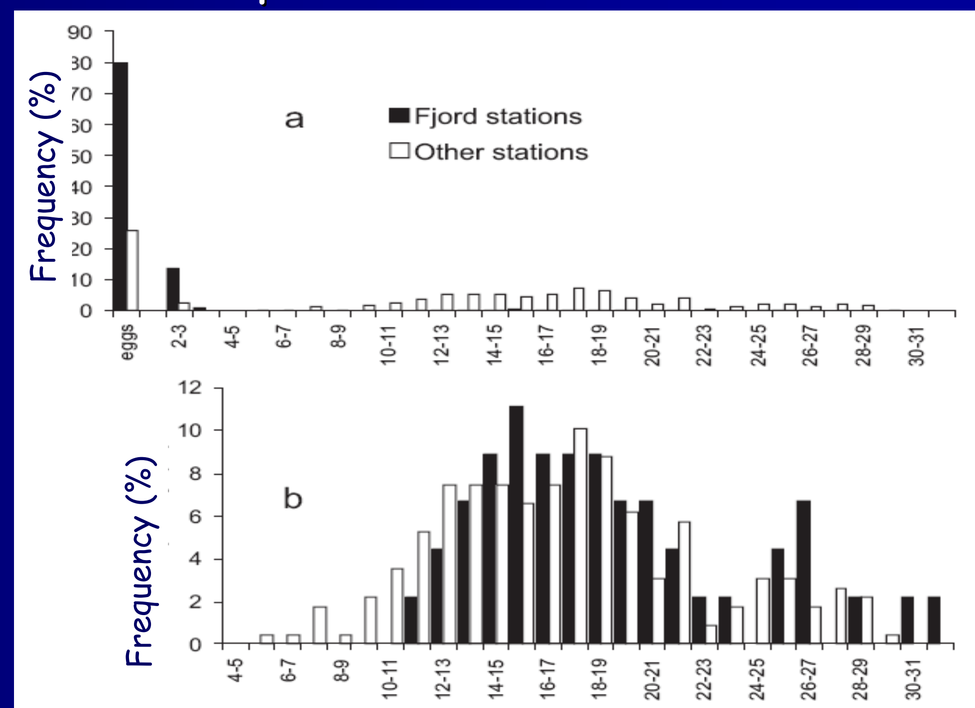
CIII

Metridia longa
(5-10% of biomass)



Mature females, eggs, nauplii, CIs

Parasagitta elegans
(14-18% of biomass)
Population size structure



Body length (mm)

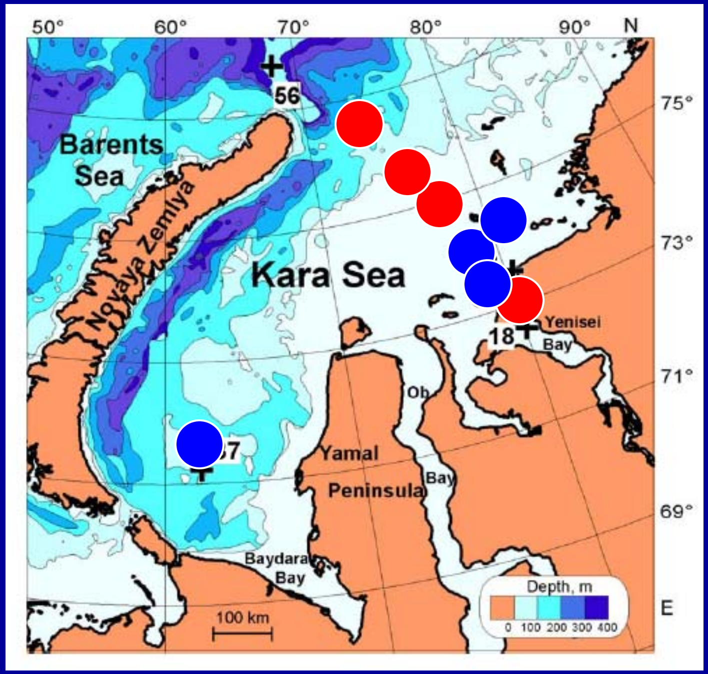
Storfjord and open Barents Sea. Reproductive activity observed in:

Taxa	Developmental stages	Trophic group
Calanus glacialis	eggs, spawning females	Filer-feeder (predominant herbivore)
Metridia longa	eggs, CI, mature females	Omnivore
Pseudocalanus minutus	egg-brooding females, nauplii, CI-II	Omnivore
Oithona similis	egg-brooding females, nauplii	Omnivore
Aetideidae gen sp.	CI	Omnivore
Euphausiacea	eggs	Omnivore
Themisto libellula	females with eggs and offspring in marsupium	Omnivore
Pteropoda: Limacina helicina, Clione limacina	larvae	Herbivore and carnivore
Paraeuchaeta glacialis	CI	Carnivore
Hydromedusae: Aglantha digitale, Aeginopsis laurentii, Plotocnide borealis	Very young stages	Carnivores
Ctenophora	Eggs, larvae	Carnivores
Parasagitta elegans	eggs, recently hatched juveniles <2 mm	Carnivores
Meroplankton	larvae of Polychaeta, Nudibranchia, Bivalvia, Gastropoda, Bryozoa, Ophiuroidea, Ascidia	

Study area 2: Kara Sea, February 2001 and March 2002

Ice thickness 2 m
Surface T° -1.7 to -0.5°C

Phytoplankton abundance:
0.4-9.1 10^3 cells L^{-1}
0.6-12.7 10^{-3} mg C L^{-1}



3 stas in the Yenisei Estuary;
5 stas in the open sea

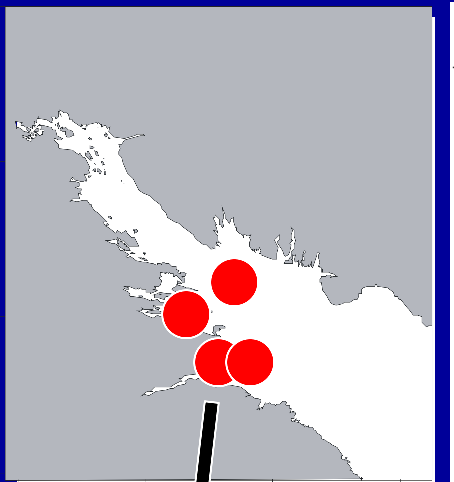
- Low biomass 0.15-0.96 g DW m^{-2} (5-10 times lower compared to summer values);
- Abundance in the estuary within the summer range (not significantly lower);
- **Several taxa have started reproduction and had youngest stages in their populations:** Pseudocalanus minutus, Oithona similis, Euphausiacea, Beroe, Aeginopsis, Plotocnide, Limacina, meroplankton (Bivalvia, Nudibranchia, Polychaeta)
- Most striking observation: an active reproduction of two brackish-water copepods in the Yenisei estuary:
- Drepanopus bungei,
- Pseudocalanus major

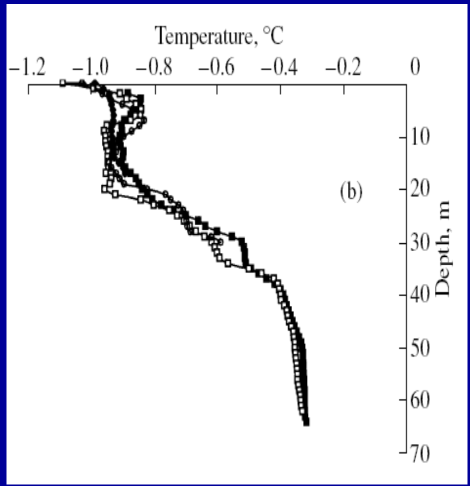
Reproductive state of brakish-water copepods Drepanopus bungei and Pseudocalanus major (egg-brooders) in Yenisei estruary

	Drepanopus bungei		Pseudocalanus major	
Females	Ind.	%	Ind.	%
Large oocytes in ovaries	48	42	10	38
Developing oocytes in ovaries	6	6	4	16
Egg brooding	6	5	6	21
Remains of egg sac	7	6		
Carrying spermatophore	14	12		
Total	114		27	
Eggs, ind m^{-2}			356	
Eggs, ind m^{-3}			18.1	

Study area 3: White Sea, April 2001 and 2003

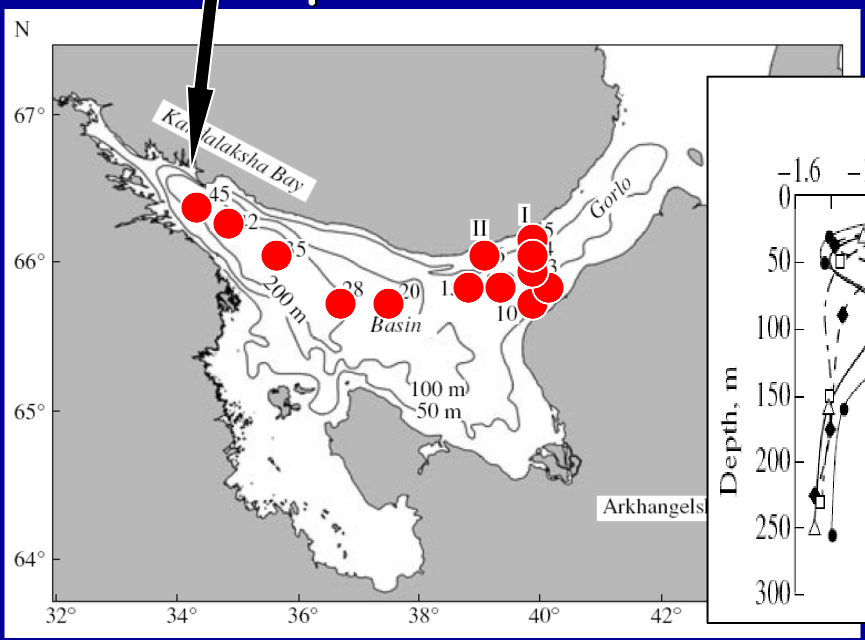
6-9 April 2002: 4 stations

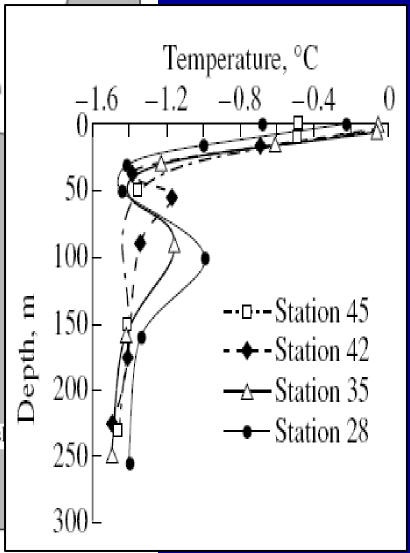




Sea-ice thickness 32-52 cm;
ice covered with 5 cm of snow;
Surface T°-1.1 to -1.0°C;
Surface salinity 26.0-27.2;
Phytoplankton biomass (surface):
6-21 10^{-3} mg C L^{-1}

18-23 April 2003: 13 stations





Sea-ice thickness 30-70 cm;
Surface T°-0.7 to -0.2°C;
Surface salinity 27.0-27.6;
Phytoplankton biomass (surface):
0.7 10^{-3} mg C L^{-1}

Kandalaksha Bay, 6-9 April 2002

Following taxa were reproducing or had youngest developmental stages:

Copepods: *Calanus glacialis* – eggs, mature females;

Metridia longa – CI, mature females;

Pseudocalanus minutus – mature females, eggs, nauplii;

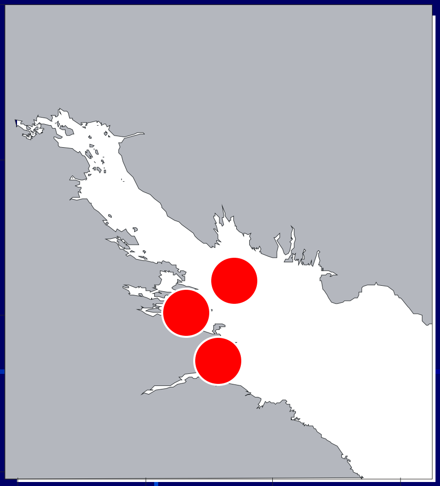
Neoscolecithrix farrani – nauplii, CI;

Hydromedusae: *Aeginopsis laurentii* – larvae;

Aglantha digitale – larvae;

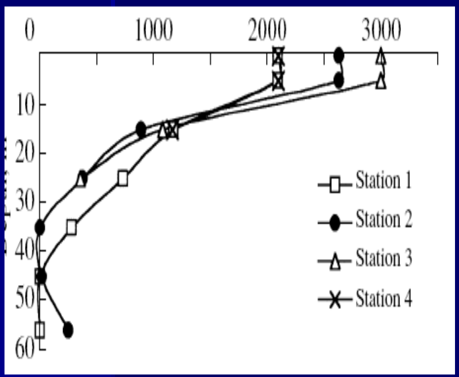
Ctenophores: *Beroe cucumis*, *Pleurobrachia pileus* – eggs, larvae;

Meroplankton (Bivalvia, Nudibranchia, Polychaeta)



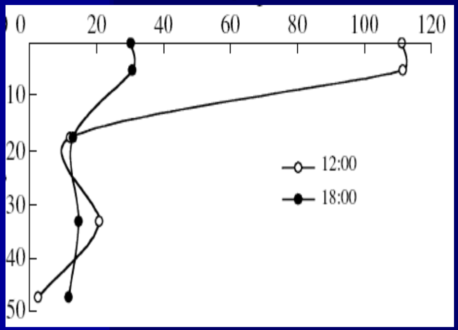
Total zooplankton
Abundance, ind m-3

Depth, m



Biomass, mg WW m-3

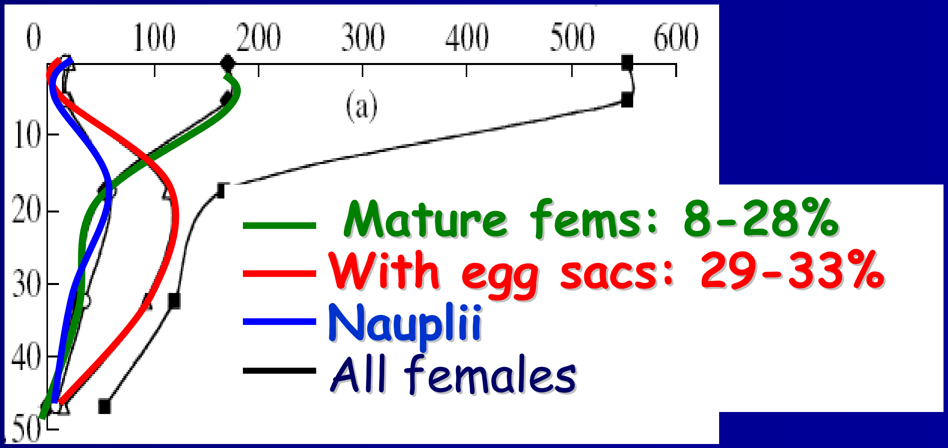
Depth, m



Pseudocalanus minutus

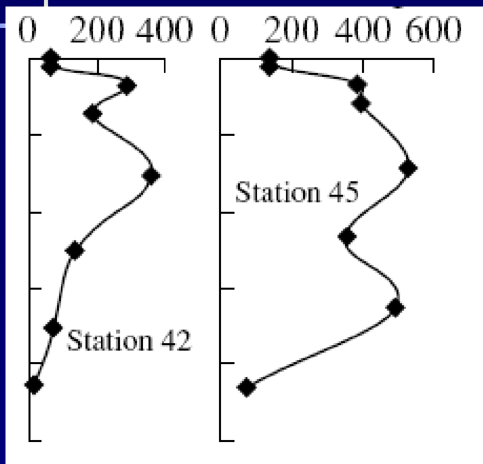
Abundance, ind m-3

Depth, m



Central deep (100-340 m) White Sea. 18-23 April, 2003

Total biomass, mg WW m^{-3}

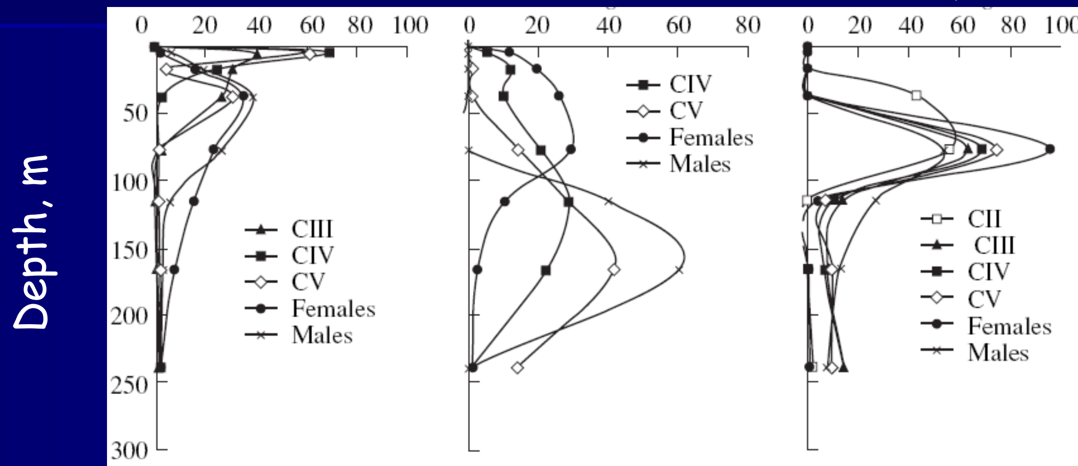


Pseudocalanus minutus

Metridia longa

Calanus glacialis

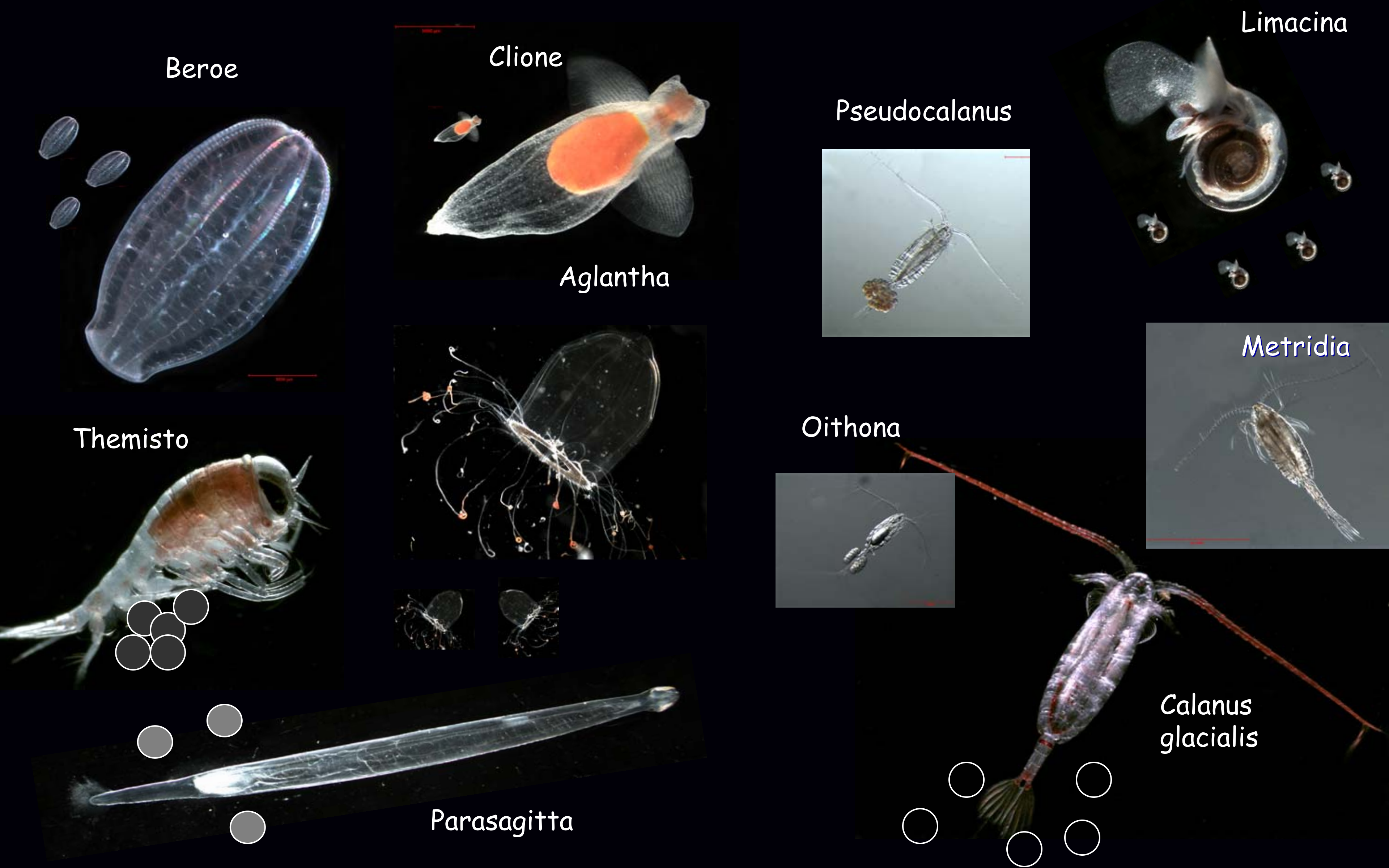
Abundance, ind m^{-3}



Calanus glacialis egg production rates (phytoplankton biomass 0.7 10^{-3} mg C L^{-1})

Date	No. fem	No. spawned	Clutch size range, egg fem^{-1}	Mean clutch size, Egg fem^{-1}	Mean EPR, egg fem^{-1} d^{-1}
20 Apr	13	6 (46%)	16-102	50.0 ± 32.2	19.4
21 Apr	18	7 (39%)	32-56	46.8 ± 9.3	13.1
23 Apr	36	2 (6%)	19	19	1.06

Reproductively active taxa



Summary & Conclusions

- Quite a portion of the zooplankton communities was to a certain extent "awake" in the three Arctic seas during the second half of the winter;
- Reproduction and advanced maturation took place in the arctic filter-feeder Calanus glacialis, copepods with opportunistic feeding strategies (Pseudocalanus major, Drepanopus, Metridia, Oithona similis), a number of carnivorous and benthic taxa with planktonic larvae;
- Early reproduction of filter-feeders Calanus glacialis was fueled by internal reserves stored by parents during previous summer, but females responded fast to addition of food with recognizable increase of egg laying activity;
- Some benthic taxa (and Pseudocalanus minutus?) seem to follow similar reproductive strategy;

Summary & Conclusions

- Reproduction of opportunistic feeders, and especially of brakish-water omnivores Pseudocalanus major and Drepanopus bungei in the Yenisei estuary seemed to be fueled by feeding on detritus particles;
- The nutritional base for reproduction of various carnivores (chaetognaths, hydromedusae, ctenophores and carnivorous copepods) could be provided by early offspring of other plankters and meroplankton;
- The zooplankton communities of the shelf Arctic seas seem to be prepared to exploit earlier phytoplankton blooms predicted to occur in the near future due to earlier ice melt

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