Climate swings and ecosystem effects

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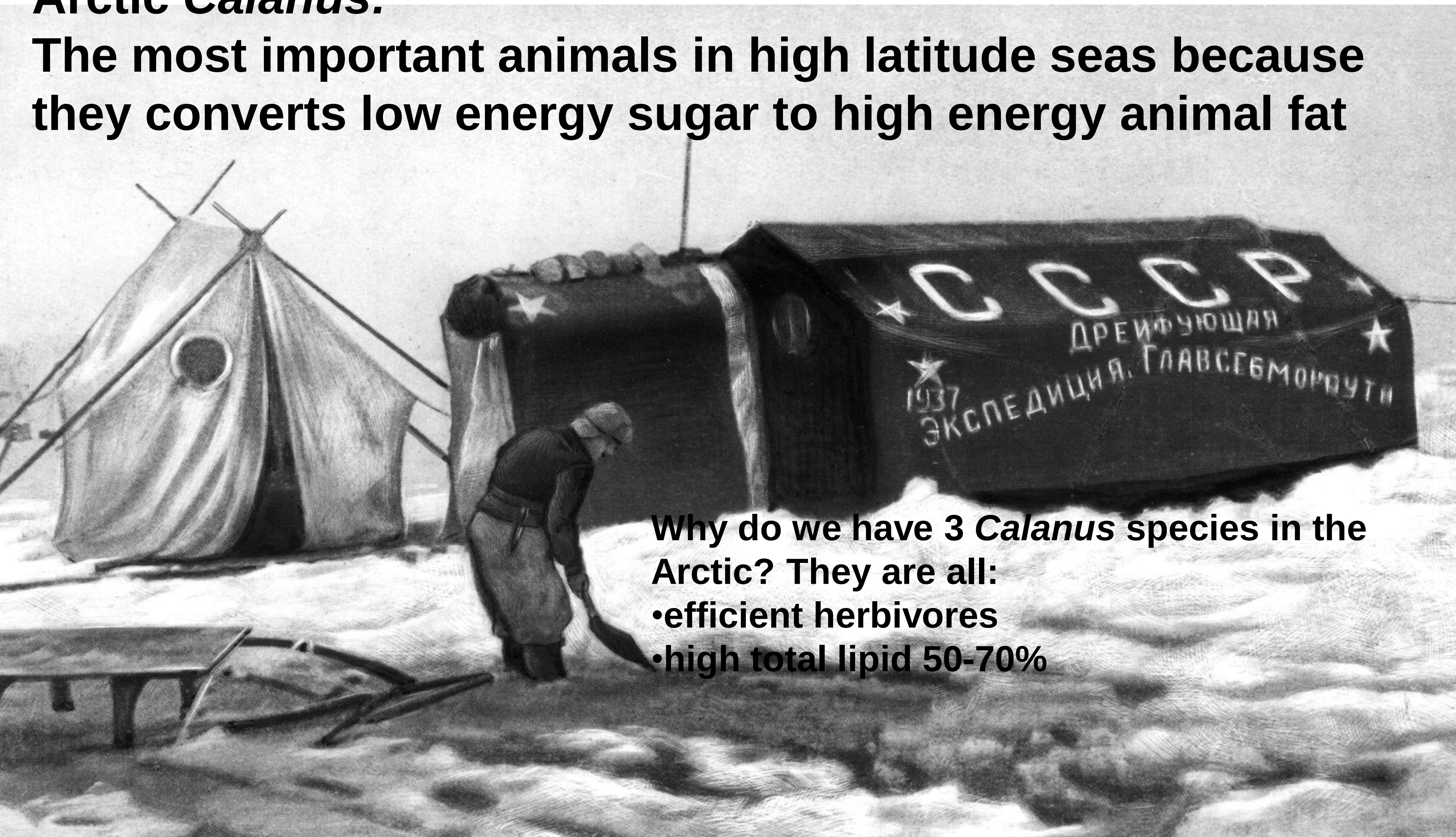
The effect of climate variability on marine biological systems, the *Calanus* complex

Arctic *Calanus*:

The most important animals in high latitude seas because they converts low energy sugar to high energy animal fat



Why do we have 3 *Calanus* species in the Arctic? They are all:

- **efficient herbivores**
- **high total lipid 50-70%**

Diatoms and *Calanus*

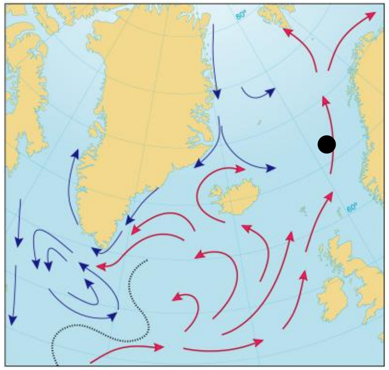
The Cenozoic record of diatoms and the appearance of the copepod super families with myelin-sheathed nerve fibres and short lived, none feeding males (*Calanus*) appeared 65 MYA

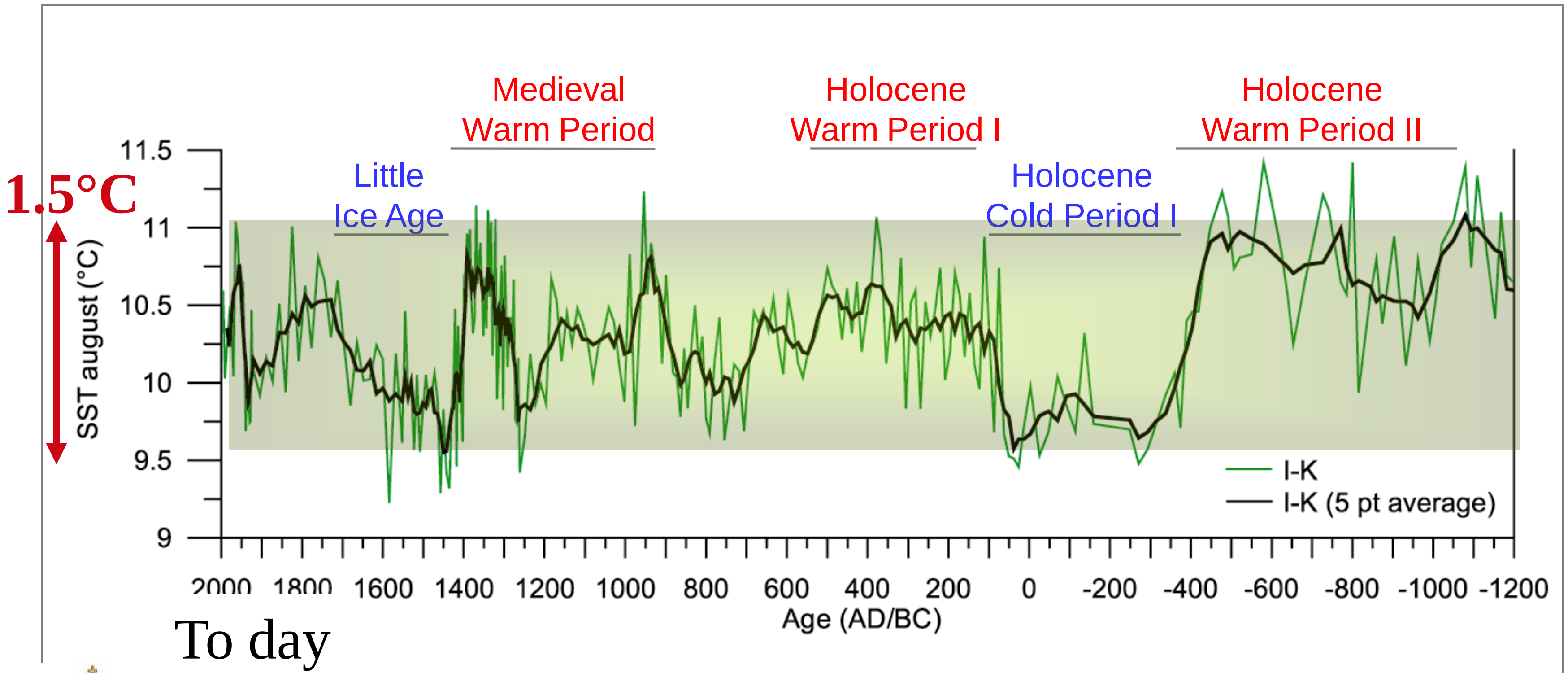
coincides with

Expansion of the polar ice cap, cooling of the ocean, increased wind, thermohaline circulation, turbulent mixing, seasonality of production

i.e. Strongly pulsed primary production

The Norwegian Atlantic Currents – natural variability over the last 3000 years (from Nalan Koc)

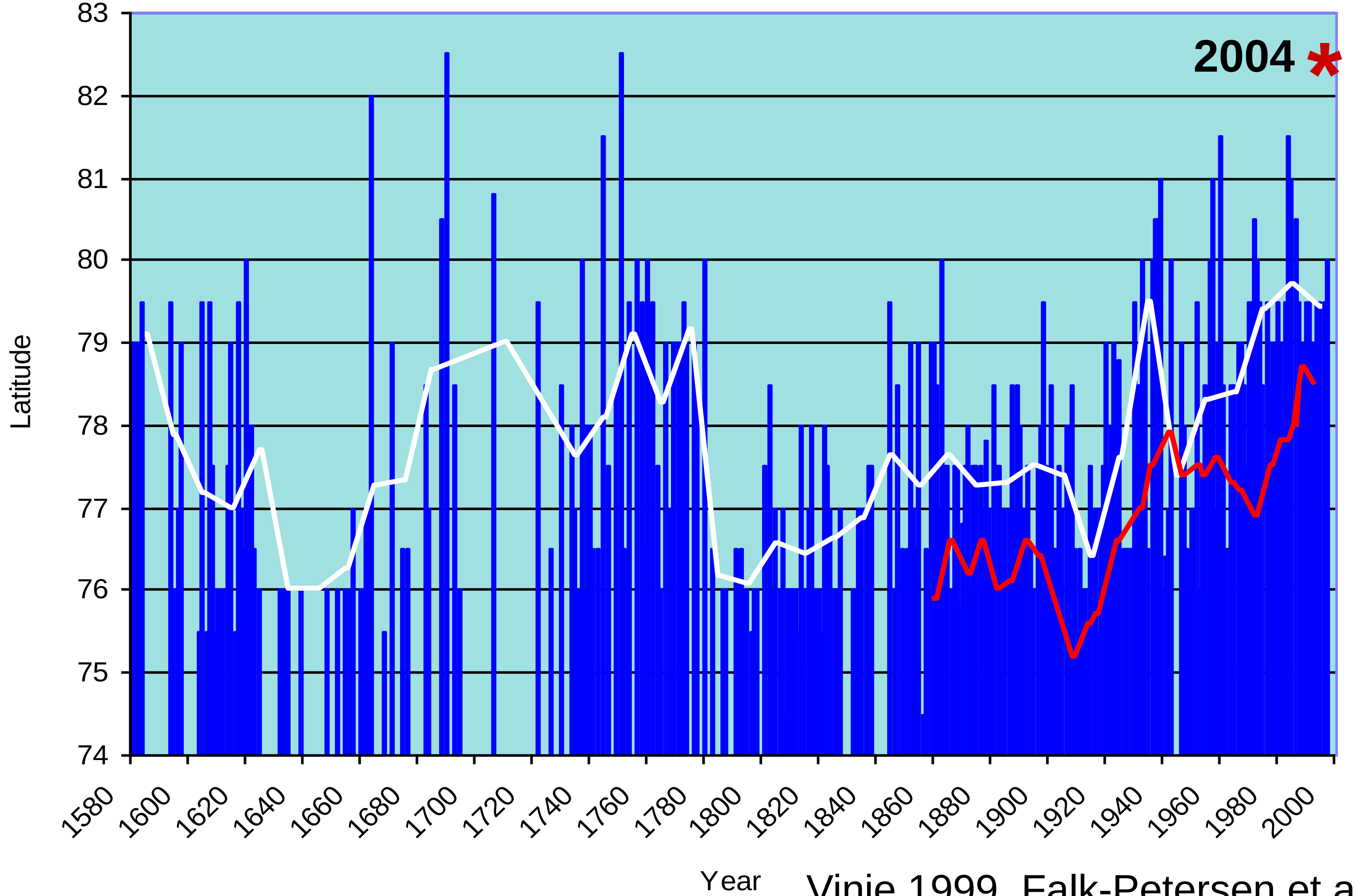




Little ice edge - 1.5 ^{o} C colder in 10-years

NORSK·POLARINSTITUTT

Record northerly (82°N) location of the ice edge in autumn 2004, not observed since 1751



Vinje 1999, Falk-Petersen et al. 2007

Environmental variability (ice cover) exists on all time scales: days, decades, centennial and geological scales

Effect on:

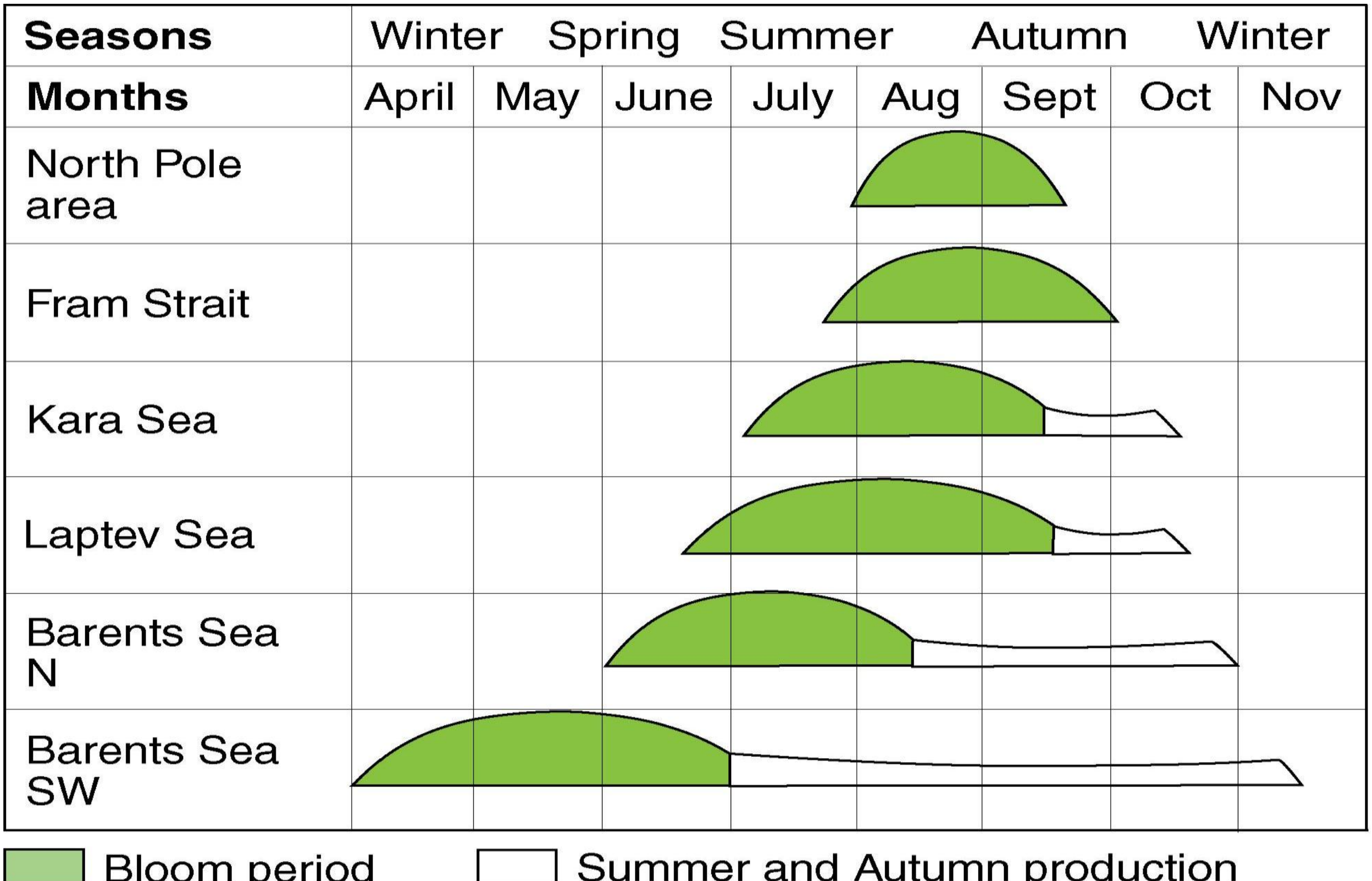
- **Light**
- **The total primary production**
- **The timing of the Arctic bloom**
- **Geographical area of the production**

The pulsed Arctic bloom is important for :

- **Accumulating large lipid reserves**
- **Lifecycles strategy**
- **Development biology**

The concept of Arctic plankton blooms

(blooms occurs at the retreating ice edge and in leads as the ice melts)



Falk-Petersen et al 2007 Modified after Zenkevich 1963

The Arctic *Calanus*

The genus *Calanus* is engineered to:

1) feed on pulses of energy
2) convert low energy sugars to a high energy lipids
3) store energy in strongly pulsed systems

(This is further support by the development of specialized biosynthetic pathways for wax ester formation)

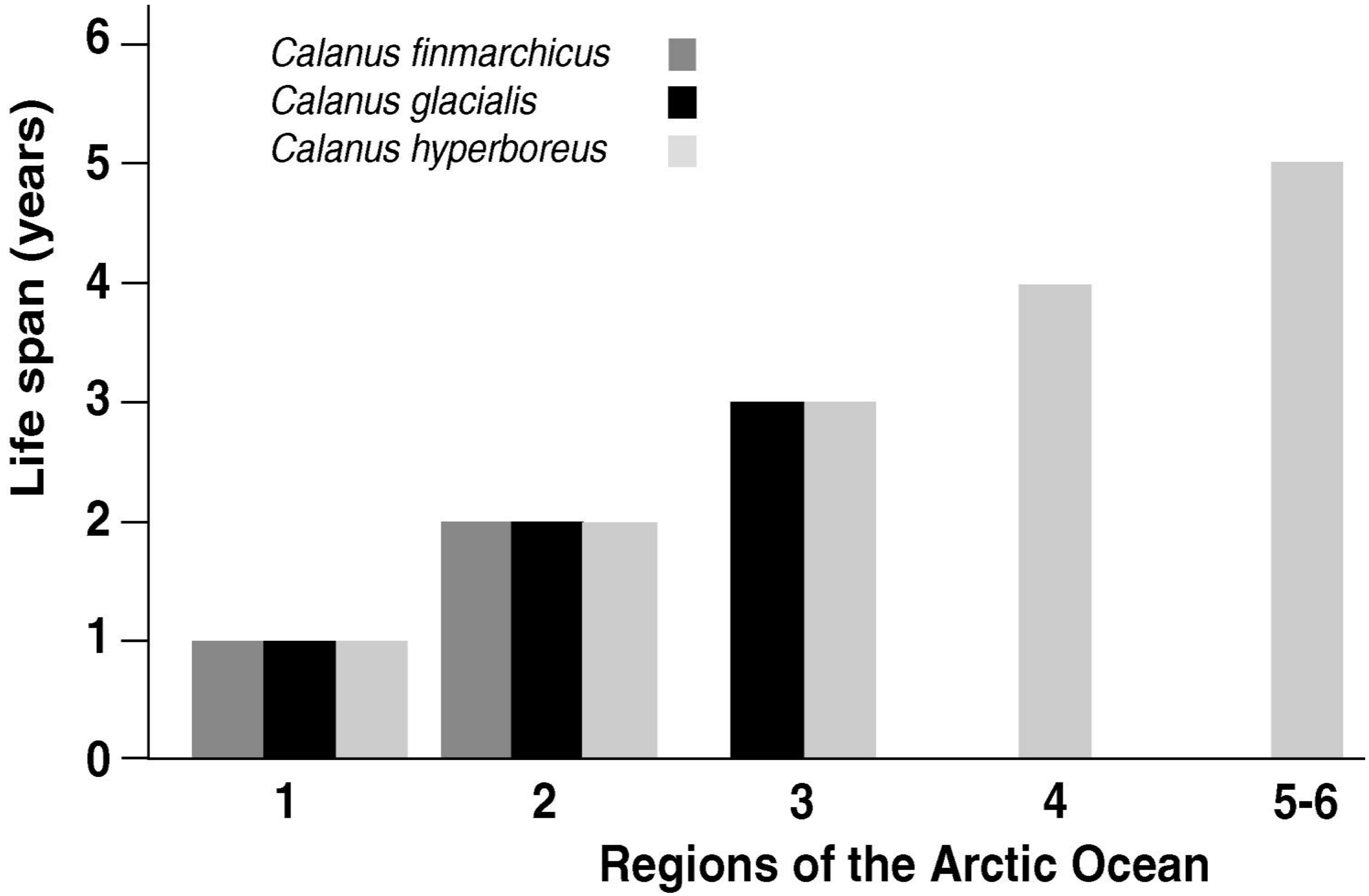
but

Why three species?

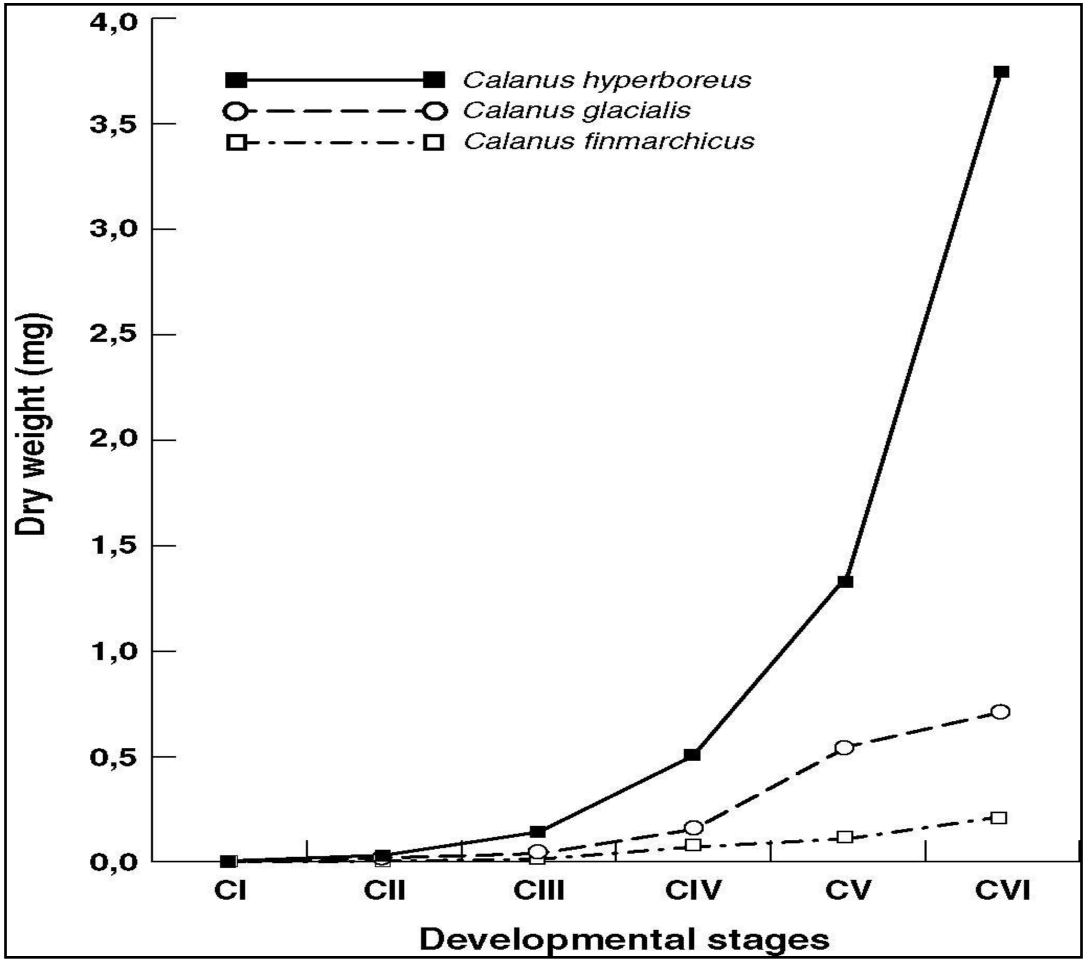
The Arctic climate variability has created three ecological niches for herbivores

Life cycle strategy

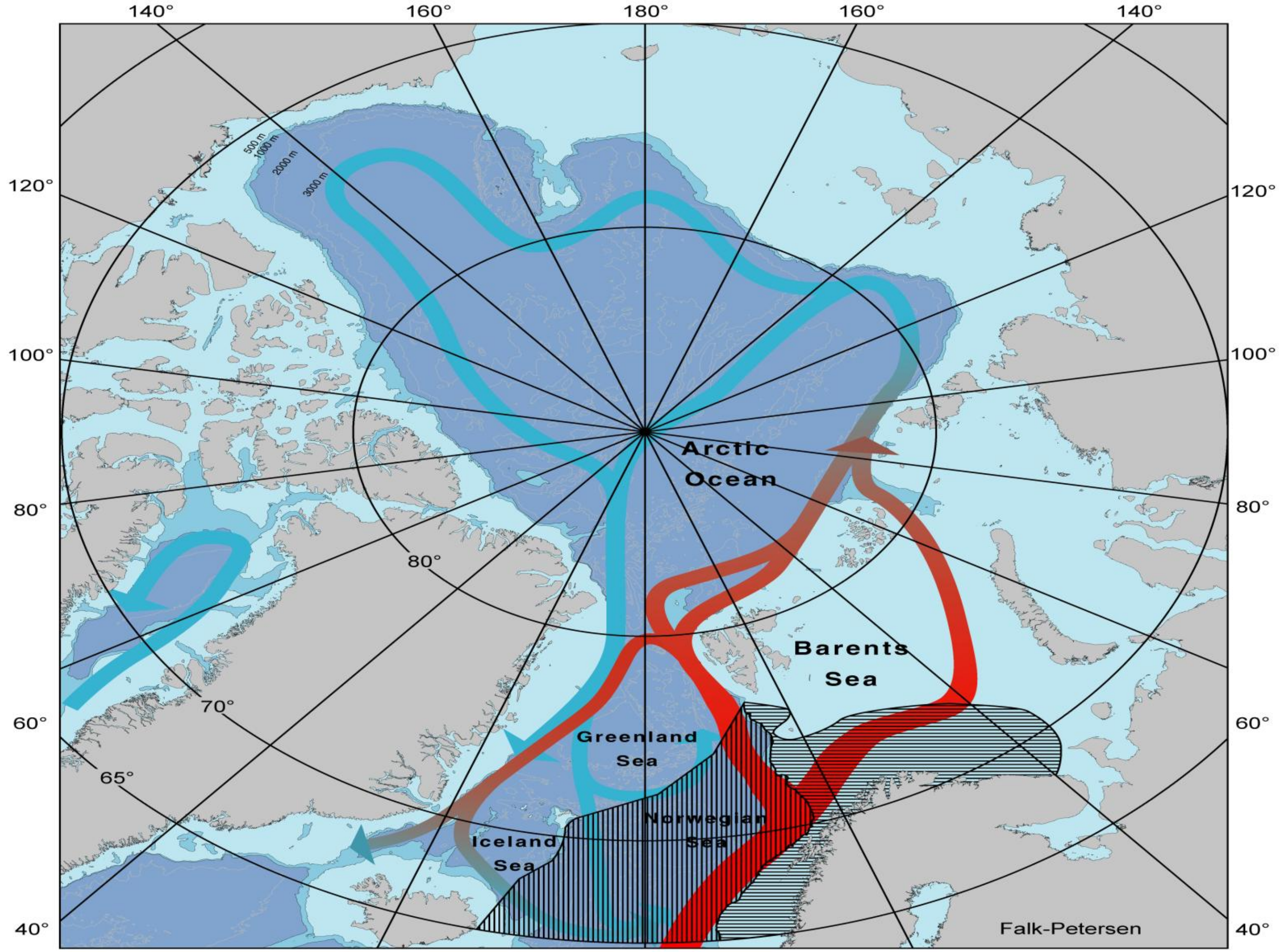
1. Life span



2. Growth of the different copepodite stages



The current system in the Arctic.
3. Core over wintering areas for C. finmarchicus, C. glacialis and C. hyperboreus



The three species are adapted to the timing of the bloom

- ***Calanus finmarchicus*** **is a deep-water species adapted to a regular yearly spring bloom => the Norwegian Sea.**
- ***Calanus glacialis*** **is a shelf species adapted to large variations in the timing and length of the annual bloom => northern Barents Sea, Siberian and American shelves.**
- ***Calanus hyperboreus*** **is a deepwater species adapted to large inter-annual variations in ice cover and algal blooms => central Arctic Ocean, Greenland Sea and Fram Strait.**

The Arctic *Calanus* herbivores has adapted to climate variability in the Arctic:

- **as genus by accumulate energy reserves (lipids). The Arctic *Calanus* species are herbivores designed to feed on the Arctic diatom blooms**

- **as species / populations by developing different life strategy. Timing of the bloom determines the life strategy of the individual species and biodiversity of the *Calanus* complex**

We hypotheses that:
the European Arctic ecosystem will switch between a *C. finmarchicus* and a *C.glacialis* / *C.hyperboreus* system dependent on the climate mode

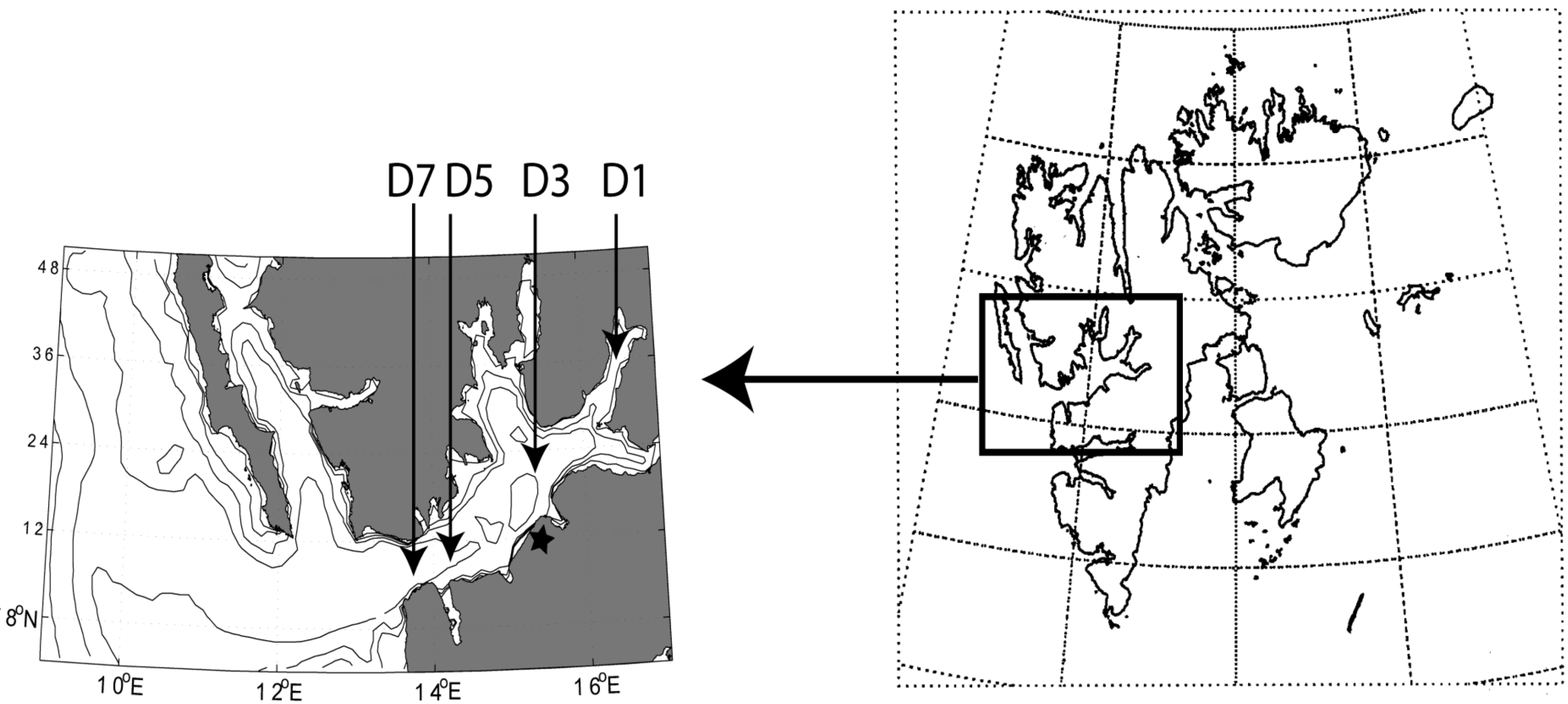
Energy level and size spectrum of *Calanus* as prey

- ***C. hyperboreus* is 2 times larger than *C. finmarchicus***

- ***Calanus hyperboreus* has 26 and *C. glacialis* 10 times as much energy as *C. finmarchicus*, per individual**

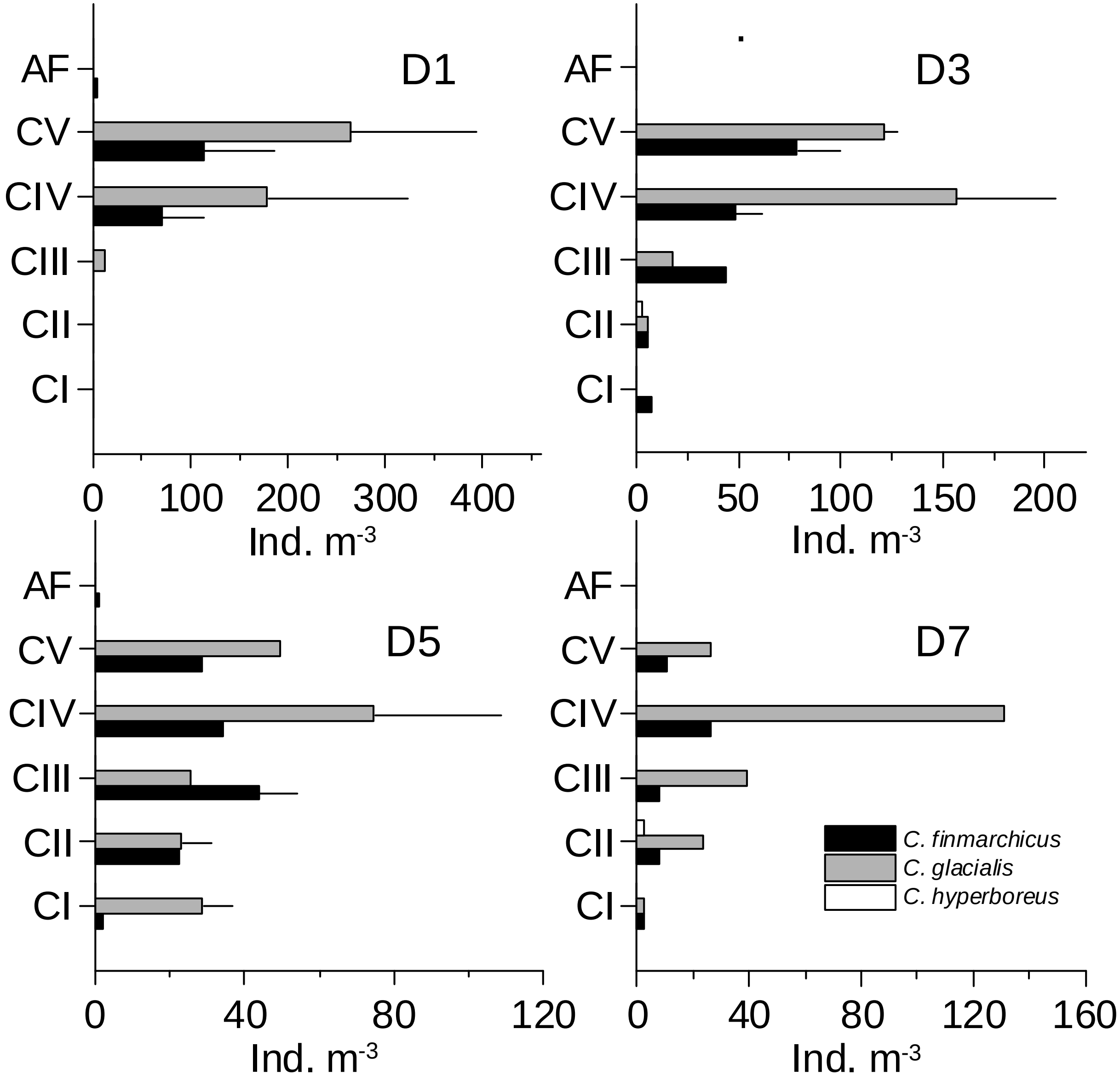
Climate swings and ecosystem effects on Little Auk

The sampling sites and the location of the little auk colony



Steen et al. 2007

Abundance of the three species *Calanus hyperboreus*, *C. glacialis* and *C. finmarchicus* at the four stations in Isfjorden.

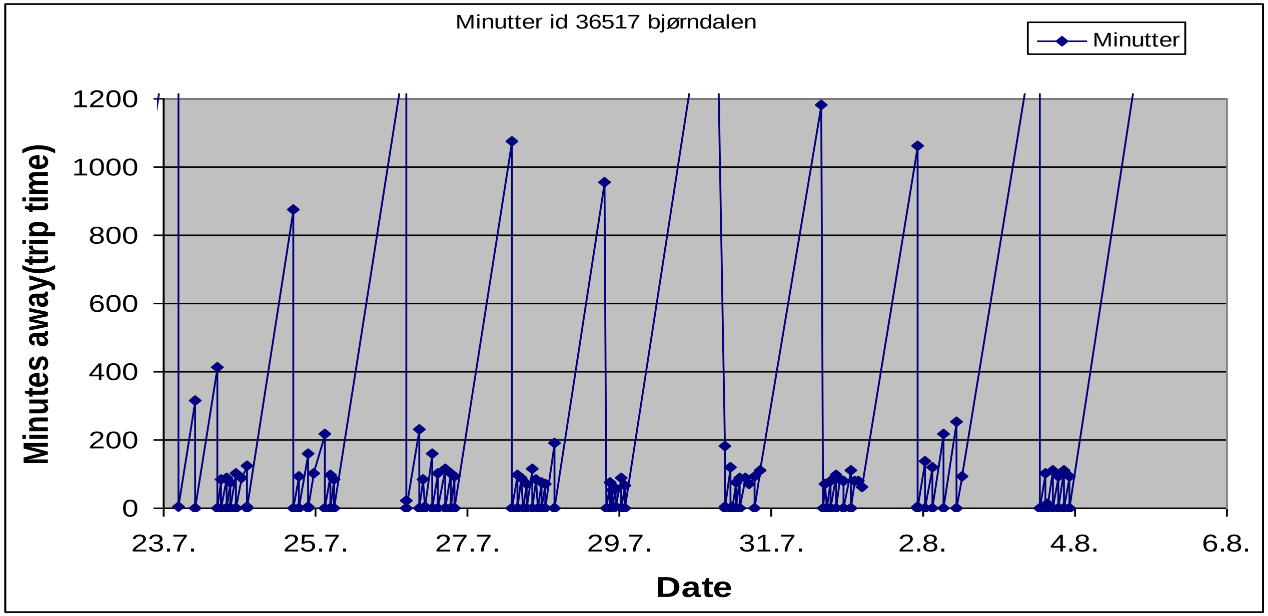


Steen et al. 2007,
27th of July 2005

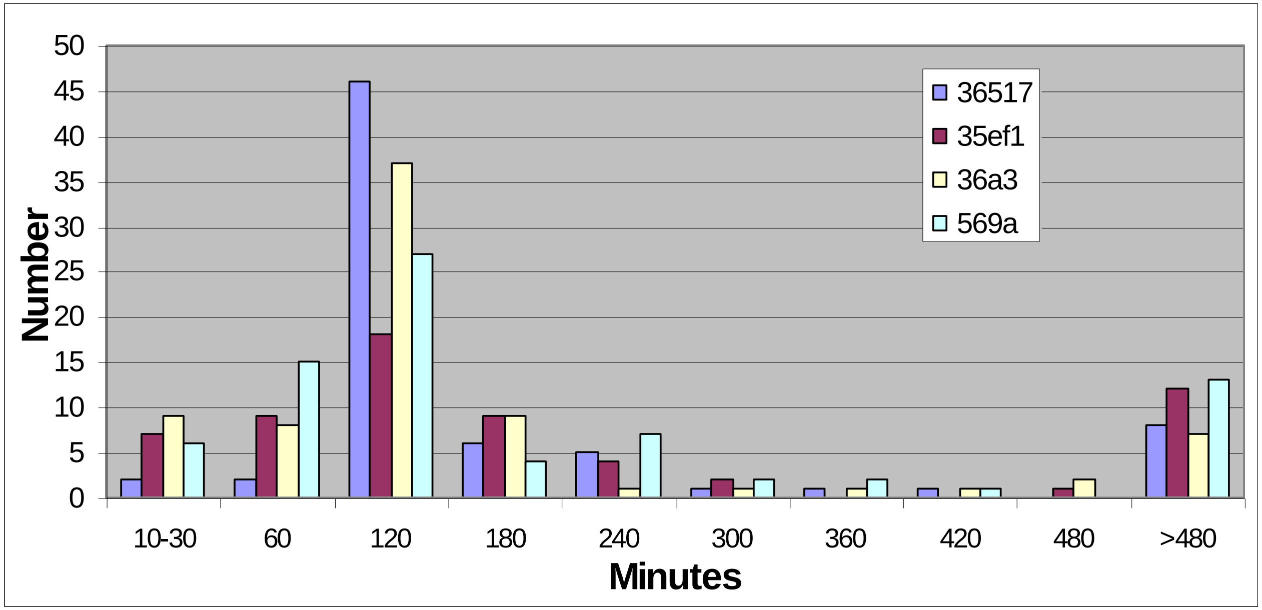
Frequency of occurrence of prey species in gular pouch
Two diets groups: on containing less than 25% *C. hyperboreus* (19) and those containing more (5).
Bold, prey items that occur in 10% or more

	Diets with less than 25% *C. hyperboreus*		Diets with less than 25% *C. hyperboreus*	
Species	**Mean**	**SE**	**Mean**	**SE**
Calanus finmarchicus CV	0.051	0.018	0.004	0.004
Calanus glacialis CIV	0.006	0.002	0.007	0.007
Calanus glacialis CV	**0.571**	0.056	**0.144**	0.019
Calanus glacialis female	0.018	0.002	0.008	0.004
Calanus hyperboreus CIV	0.003	0.002	0.018	0.008
Calanus hyperboreus CV	0.014	0.008	**0.407**	0.035
Calanus hyperboreus female	0.007	0.003	**0.286**	0.052
Themisto abyssorum	**0.176**	0.048	0.029	0.021

Steen et al. 2007



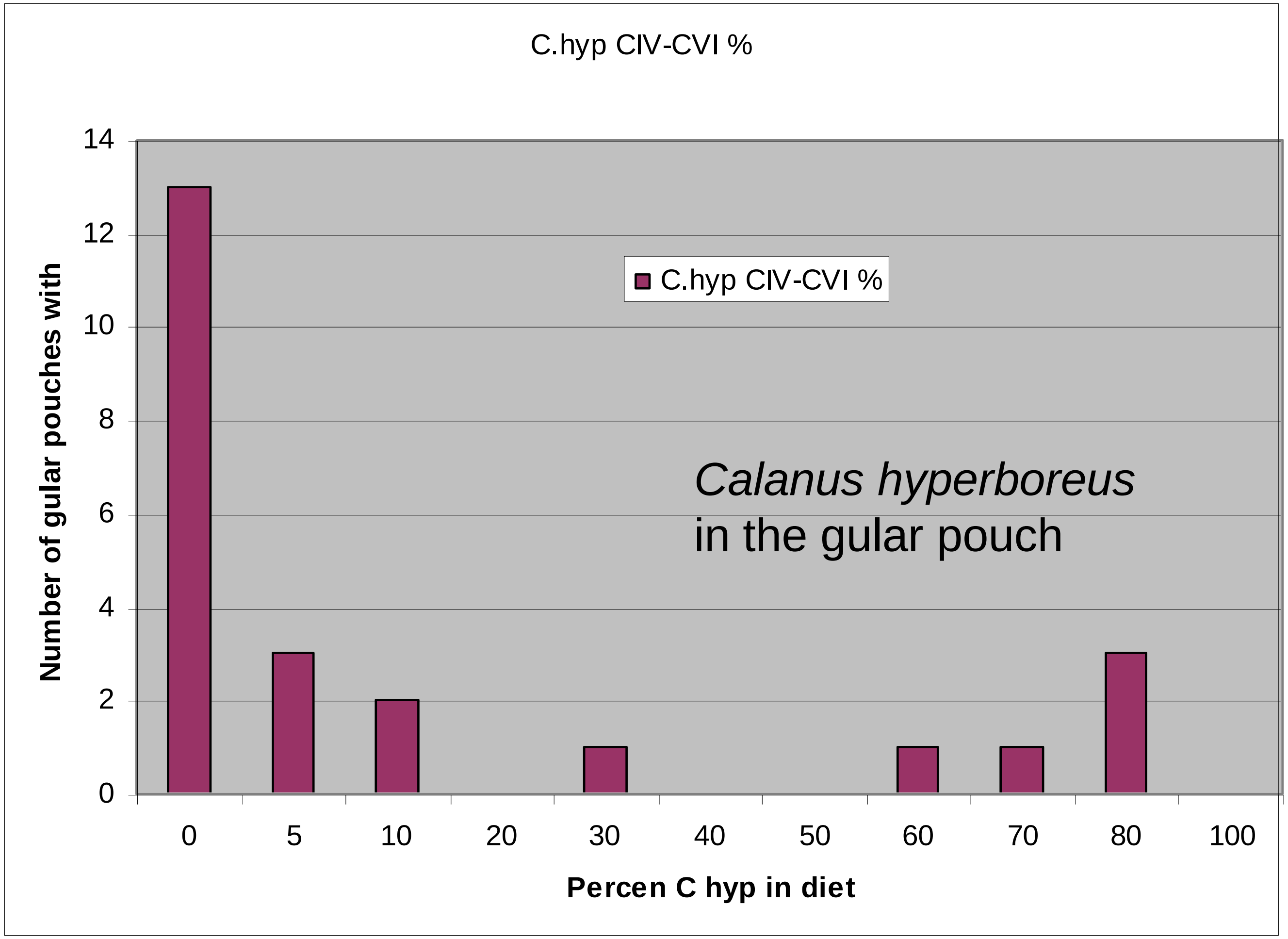
An example of trips of 1 bird. Hatch d 11 July



Duration of foraging trips, 4 birds

Steen et al. 2007

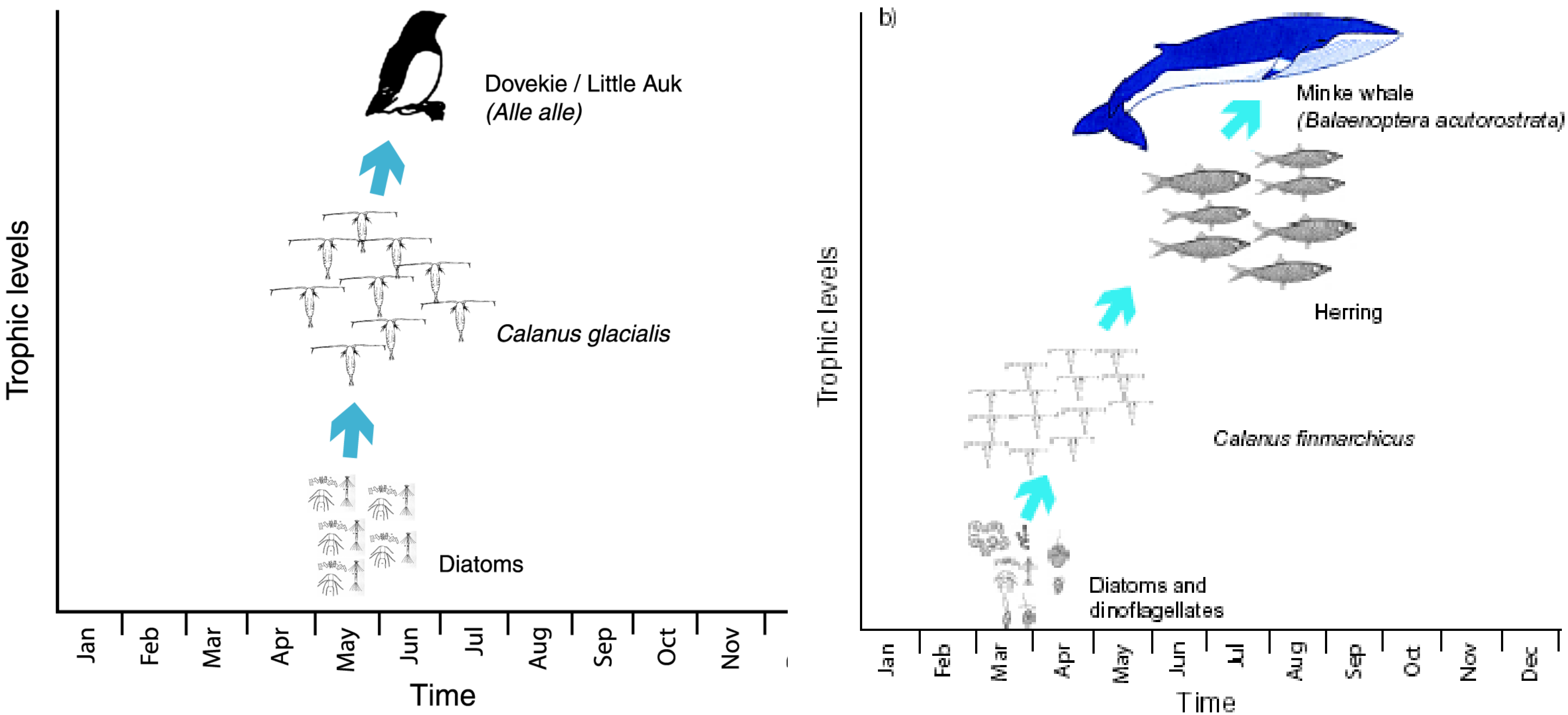
Ratio of long to short trips 1: 5.2
5 of 24 contained large C. hyperboreus
During the long trips (12 hrs) they can reach the shelf
By chance?



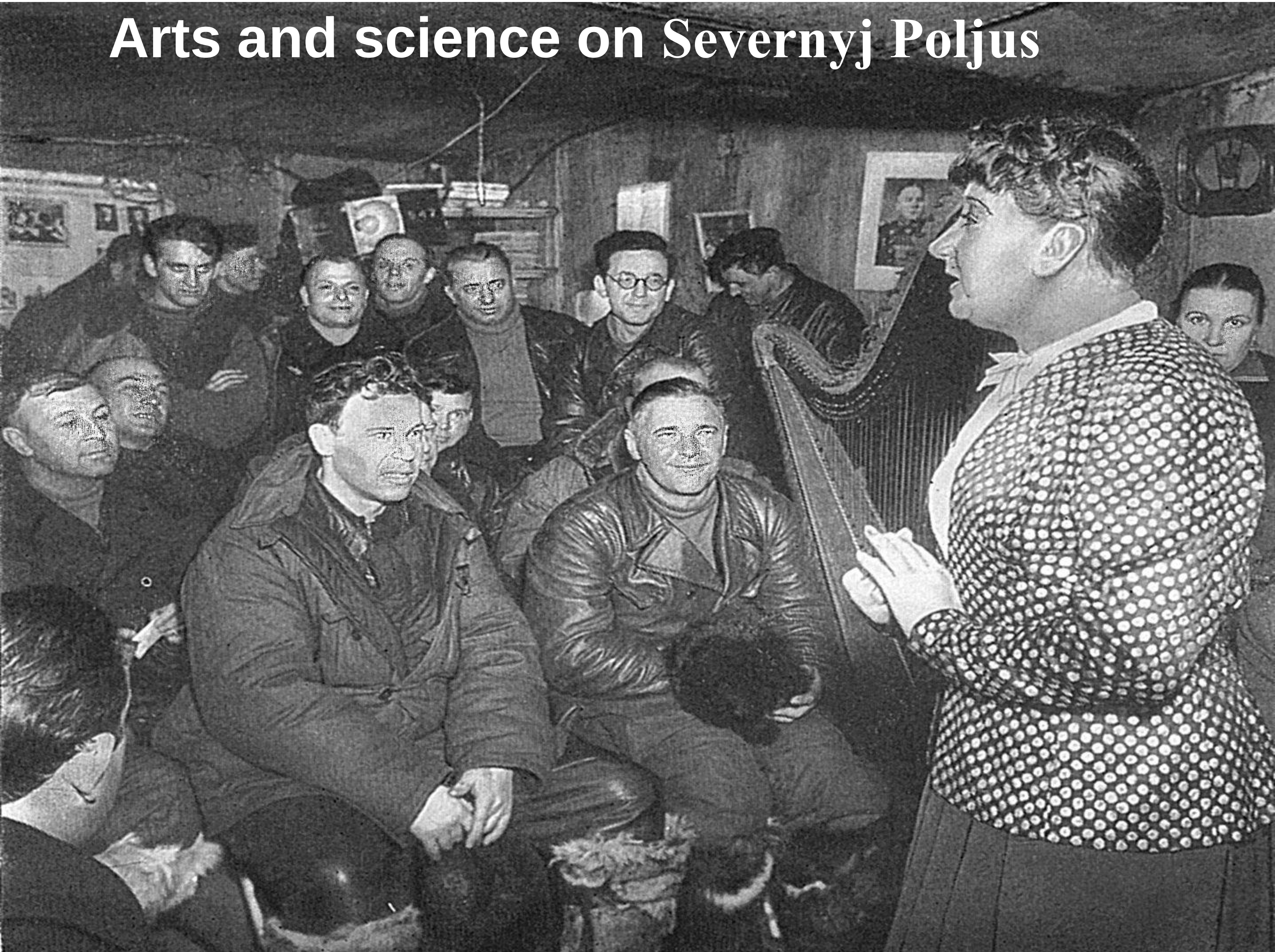
Conclusion

- **We show for the first time bimodal foraging trip for an alcid species**
- **Food for chicks close to colony**
- **Lack of suitable prey items close to colony to meet energy needs for the parents**
- **Flexible foraging strategy evolved to a highly variable environment**

The Arctic food chain depends on *Calanus* species at the base



Arts and science on Severnyj Poljus

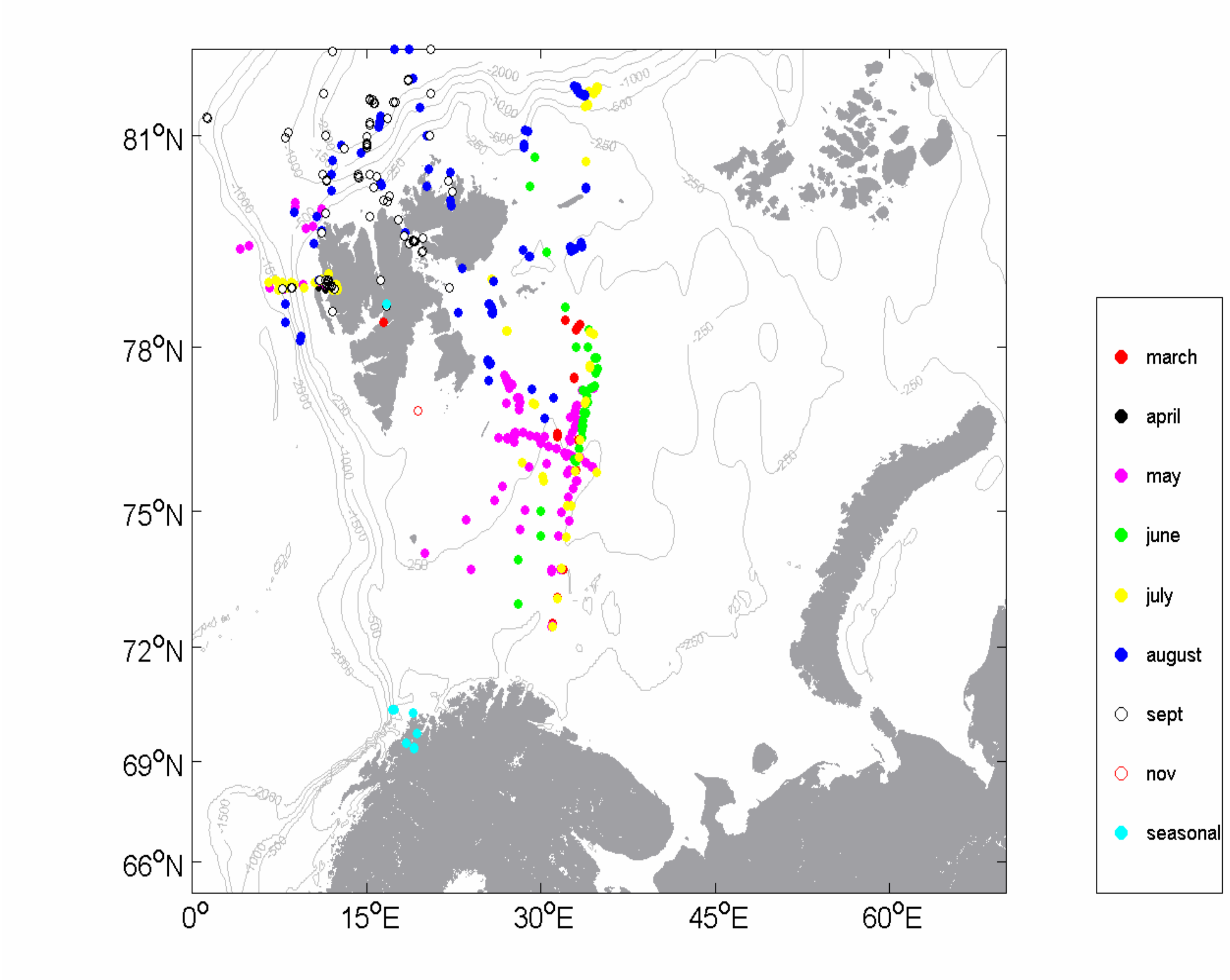


Long term Arctic zooplankton studies

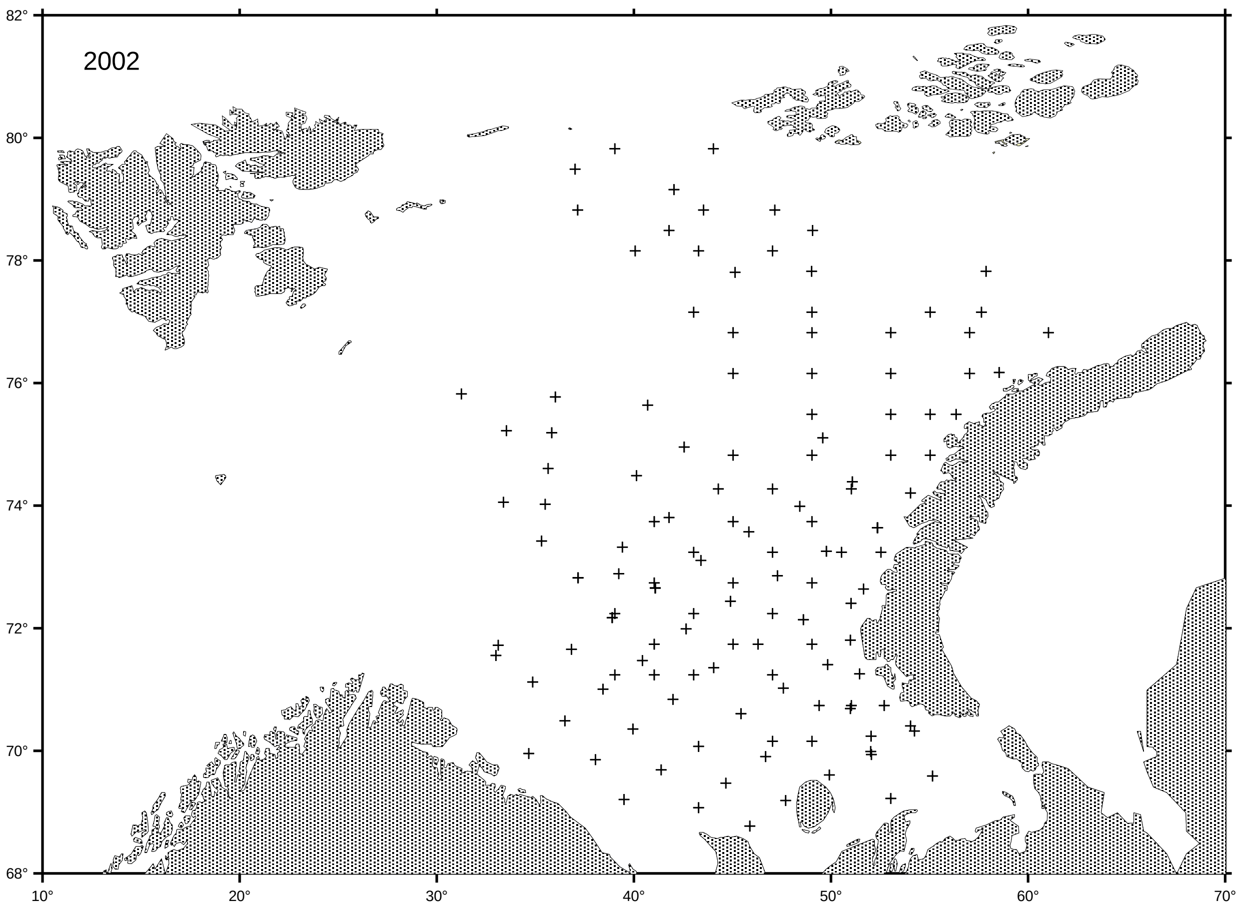
Table 1. Contributing institutions and the number and status of available data. Number of samples available exceeds the number of stations as several stations are sampled with a depth resolution. Contact persons at the different institutions are also given.

Institutions	Number of stations	Status	Format	Supporting data	Contact person
NPI	451	Analysed	Database	Temperature, Salinity	S. Falk-Petersen
UNIS	65	Analysed	Database with NP	Temperature, Salinity	K. Eiane
APN	16	Partly analysed	Excel	Temperature, Salinity	G. Pedersen
NCFS/Shirshov	109	Analysed	Excel	Temperature, Salinity, pigments, carbon	M. Reigstad
MMBI	278	Analysed	Unknown spreadsheet	Temperature, Salinity	Need new contact after S. Timofeev
PINRO	1486	250 analysed to species, stage, abundance	Excel	Temperature, Salinity	Emma Orlova

The seasonal distribution of sampling in the different regions.



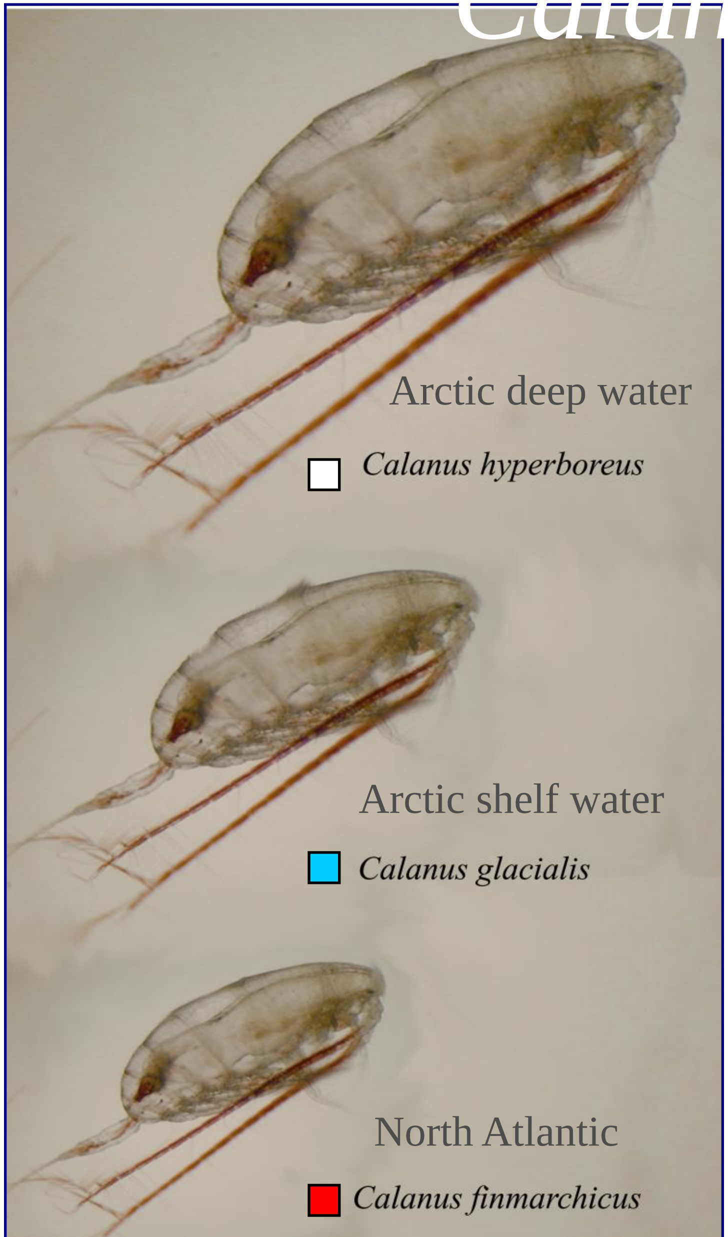
Distribution of stations covered by PINRO, from 2002.

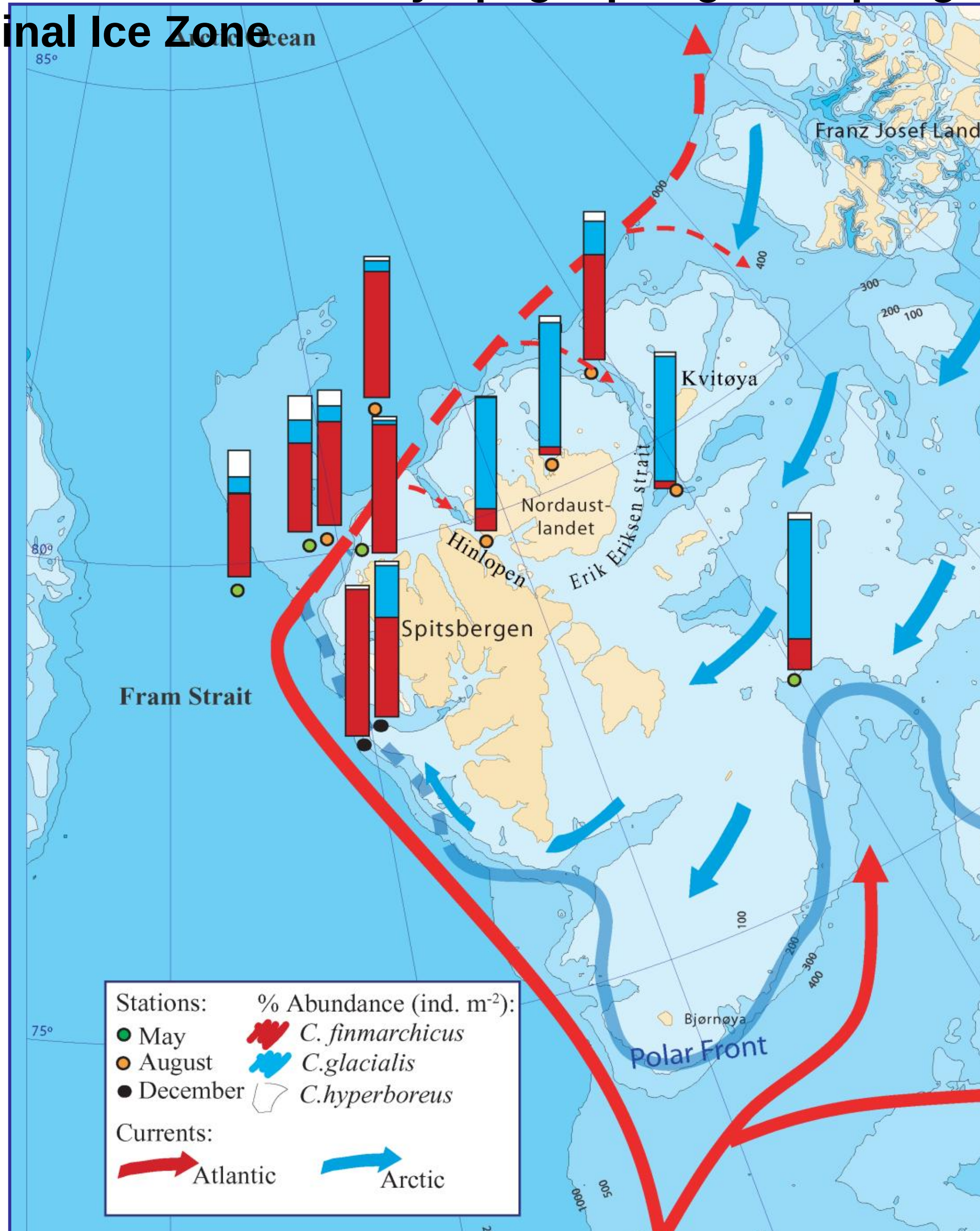


The SINMOD model
Coupled physical – biological model.

Nested into the 20 km model is the large 4 km grid area (black rectangle) which in turn provides boundary conditions for the main 4 km/800 m model (grey rectangle).

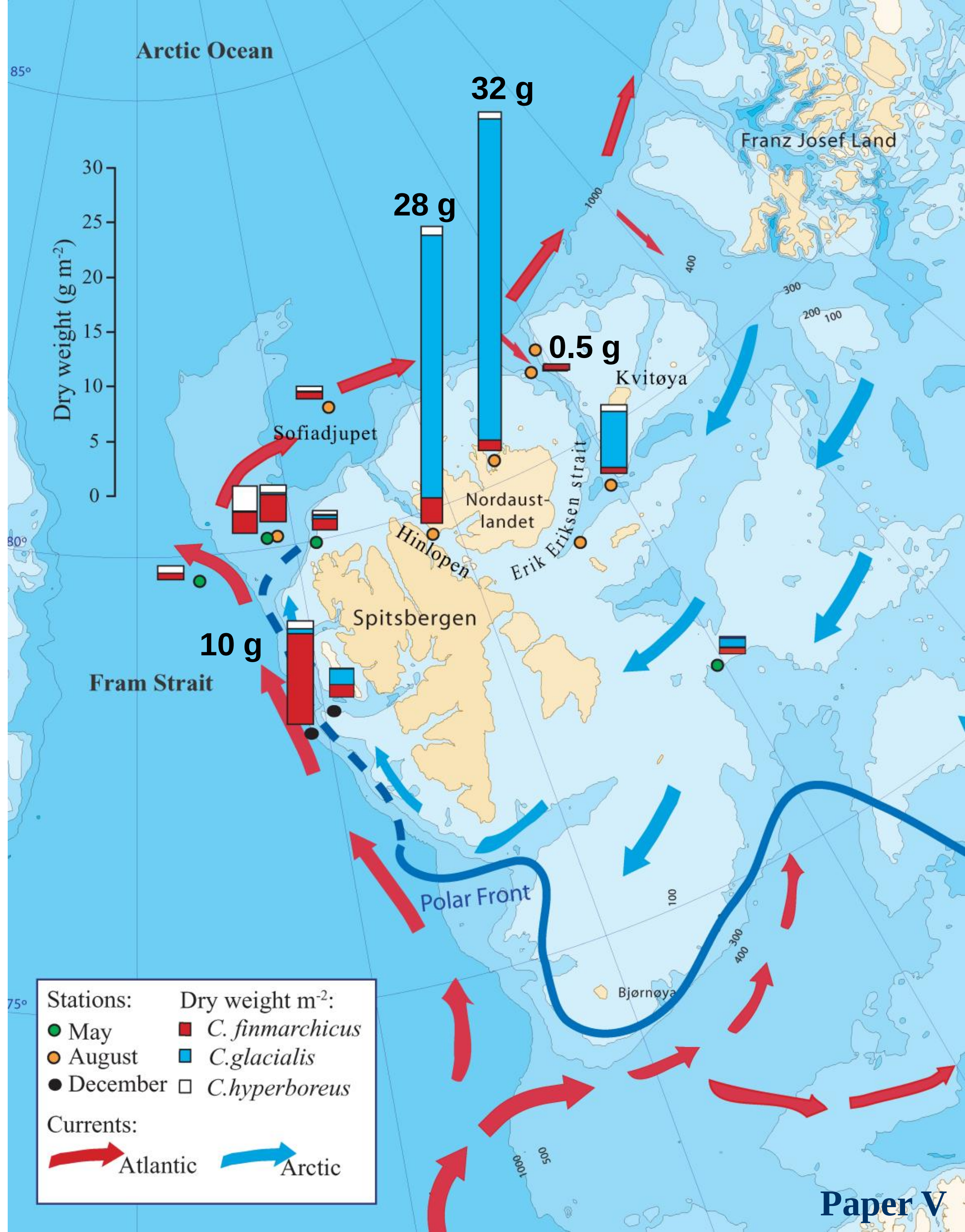
Zooplankton communities, food web structures and sympagic-pelagic coupling in the Svalbard-Barents Sea Marginal Ice Zone





BIOMASS

- (0.3 – 8.7 g DW m^{-2})
- (0.1 – 30.6 g DW m^{-2})
- (0.1 – 2.6 g DW m^{-2})



Paper V

The Ice Edge Programme

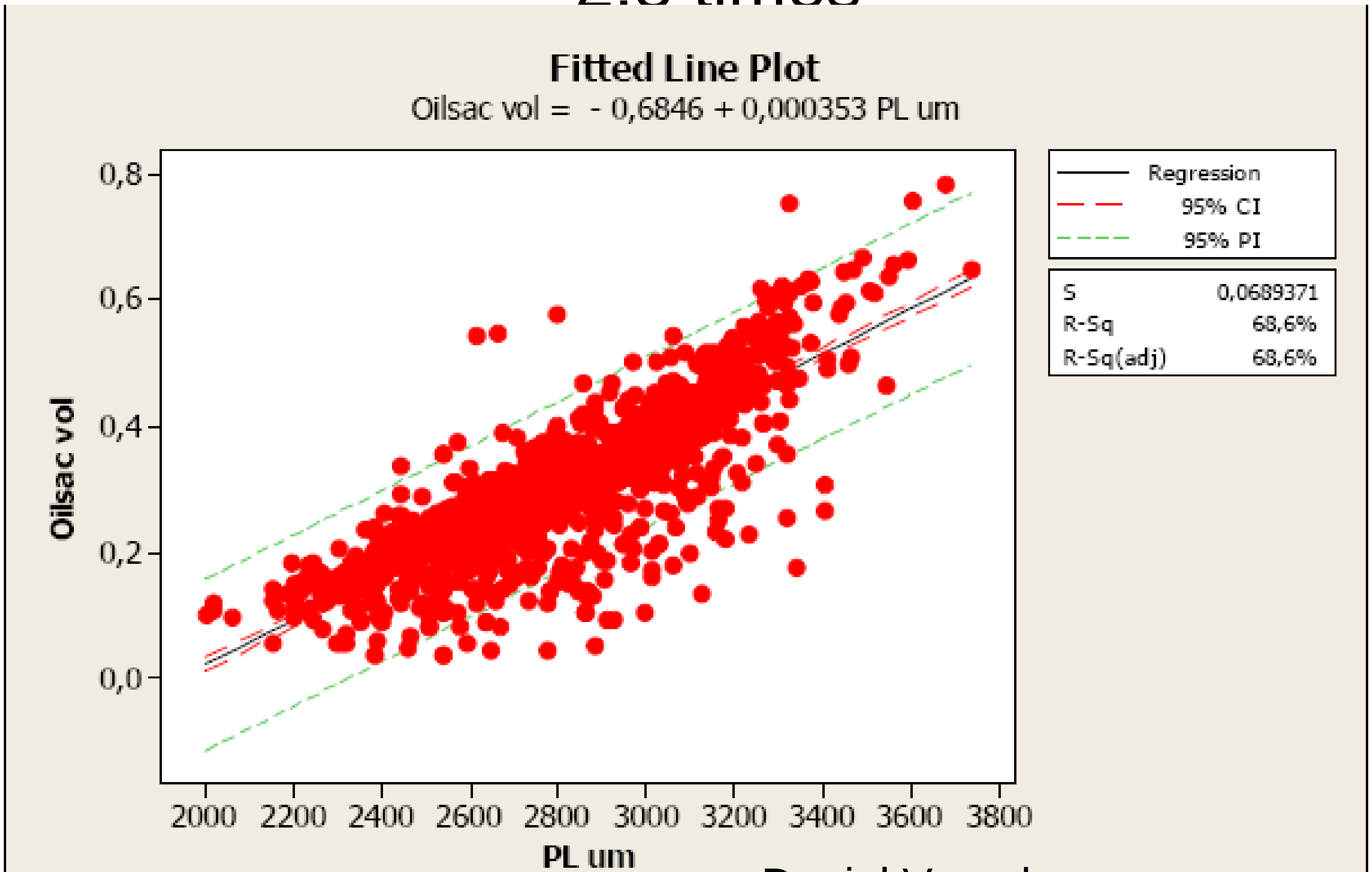
The Statoil Ice edge programme

- Ecological and ecotoxicological studies of ice amphipods
- Microbial degradation of carbon
- Arctic primary production
- Ecology of the key fish species *Leptoclinus maculates*
- Effect of oil on Arctic *Calanus* and Ice Amphipods

CLEOPATRA – Climate effects on planktonic food quality and trophic transfer in Arctic Marginal Ice Zones

- The effect of PAR and UV on the quality of the phytoplankton
- Timing of seasonal migration and spawning of C. glacialis

Increase in size of *Calanus* versus lipid sac volume (increas in prosome of .5 mm increases the oil volume 2.8 times



Daniel Vogedes