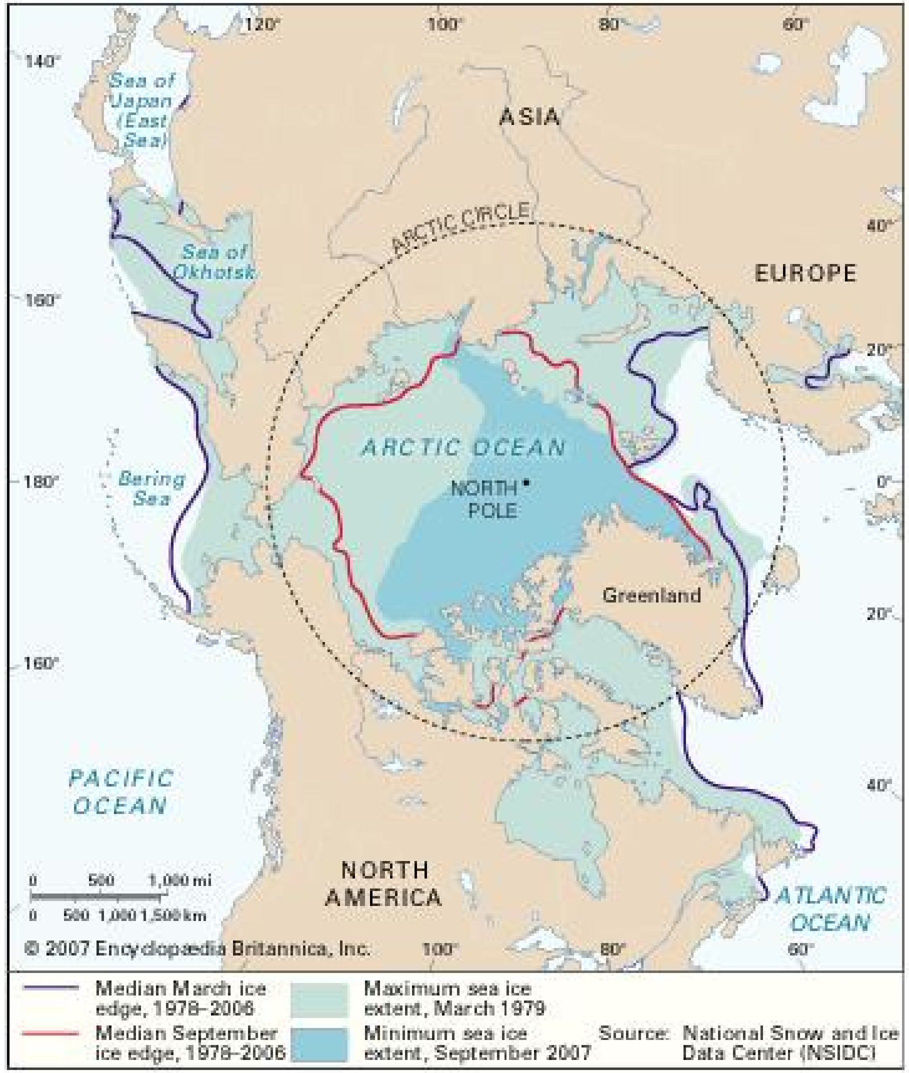
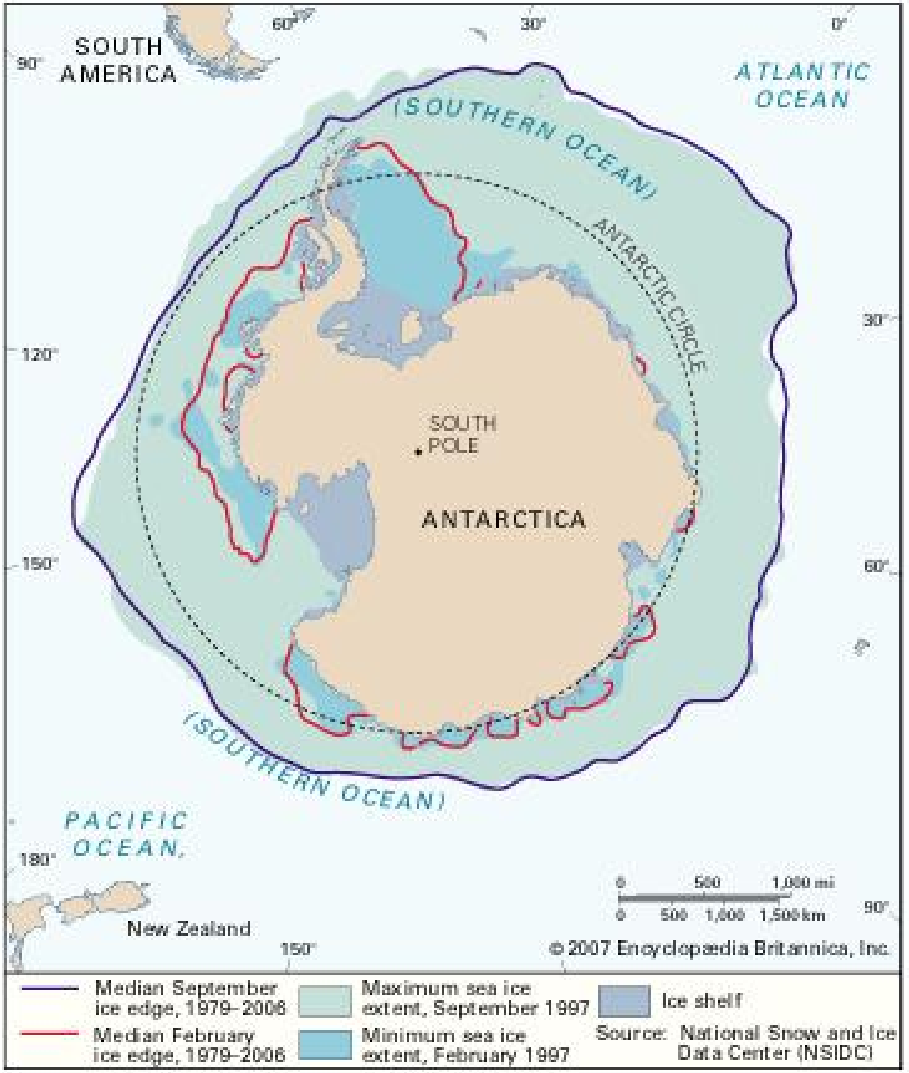
Ecology of polar oceans

Linda Nedbalová

Arctic Ocean and Southern Ocean



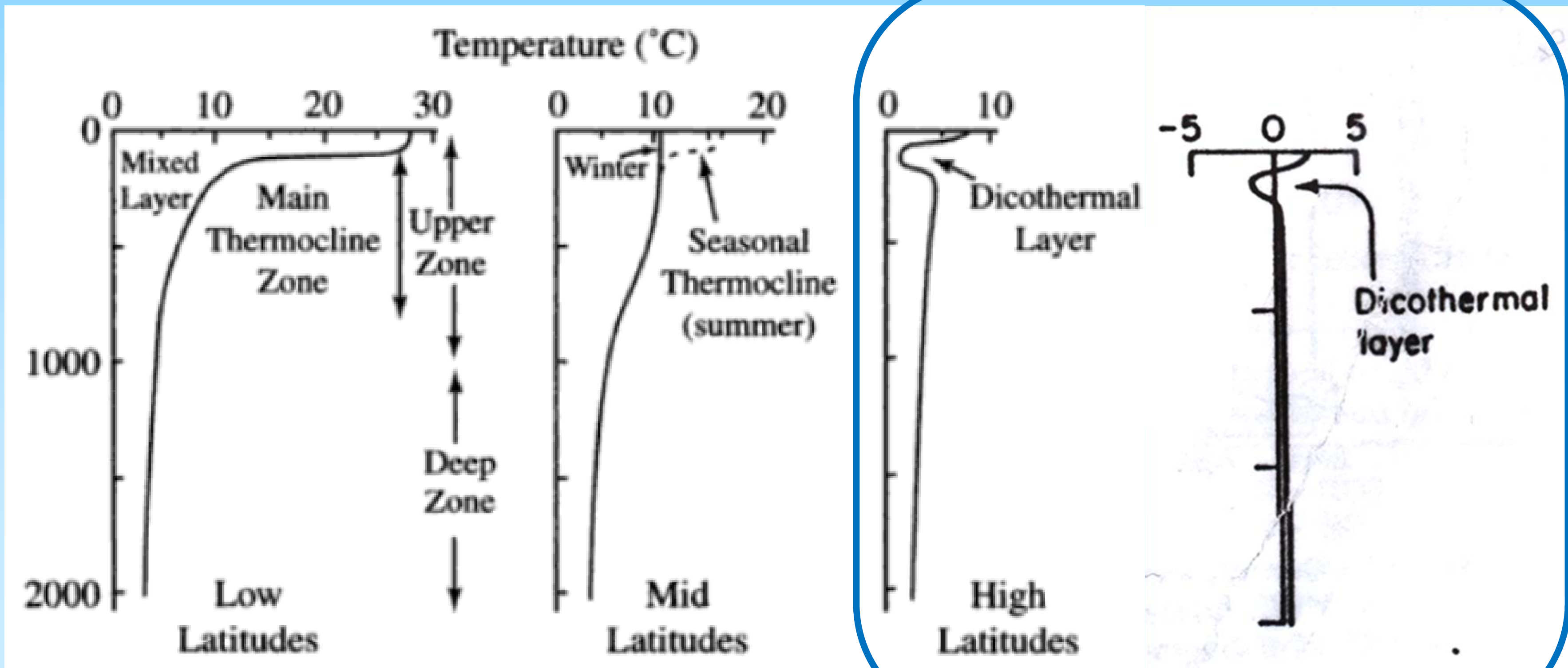


Sea ice extent in the Arctic and Antarctic regions

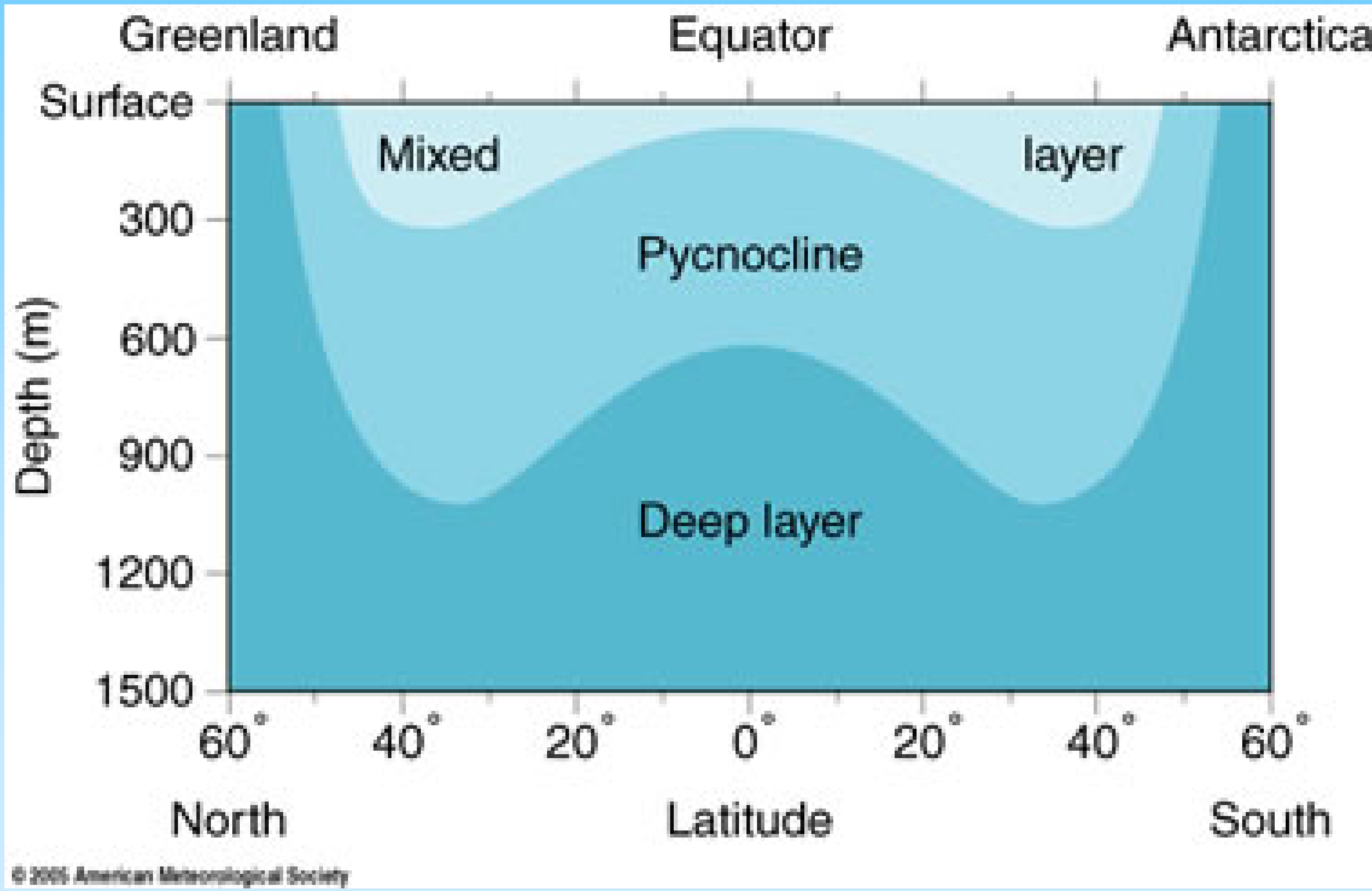
Temperature: vertical profile

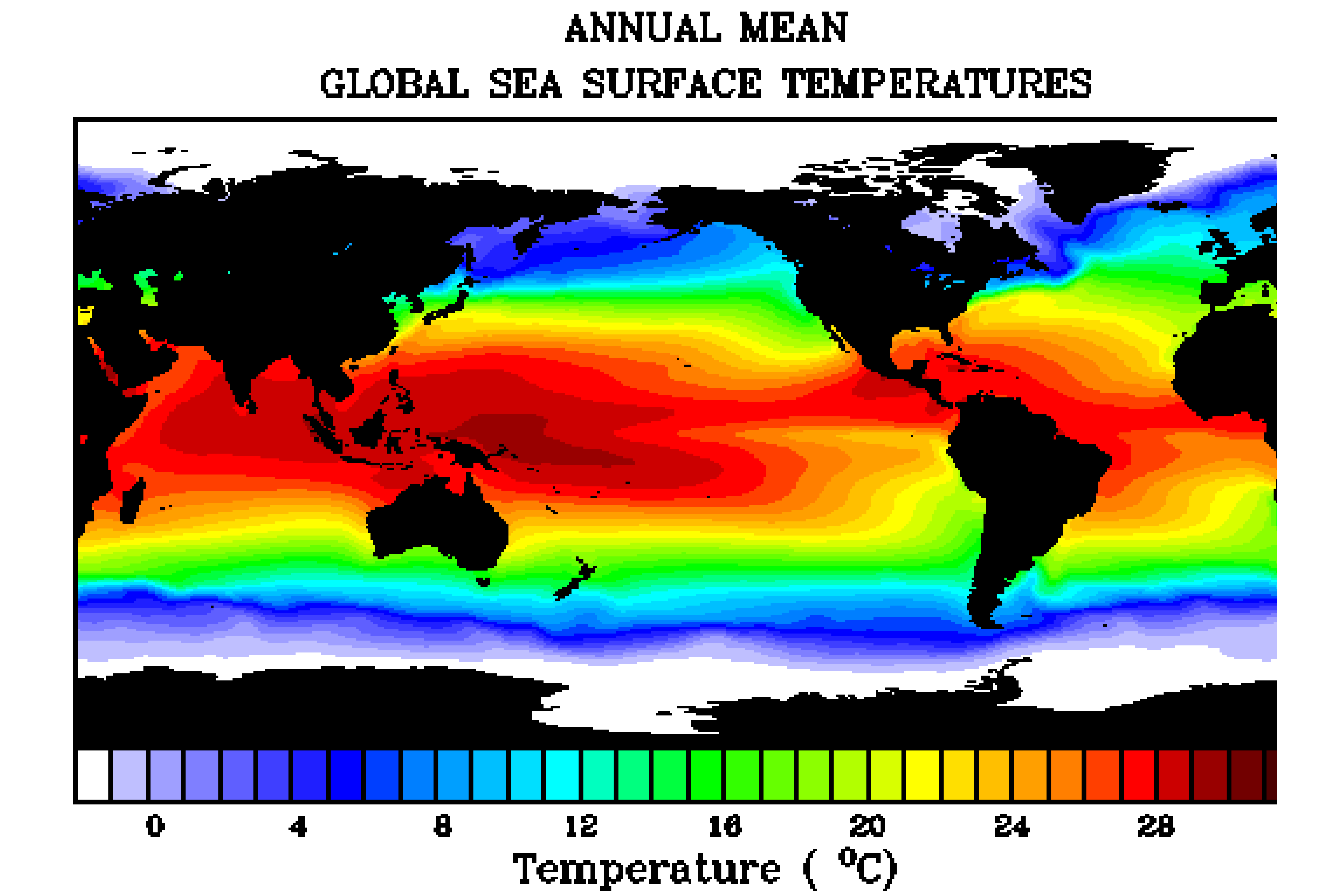
Solar radiation is absorbed by surface layers of oceans, causing **thermal stratification**.

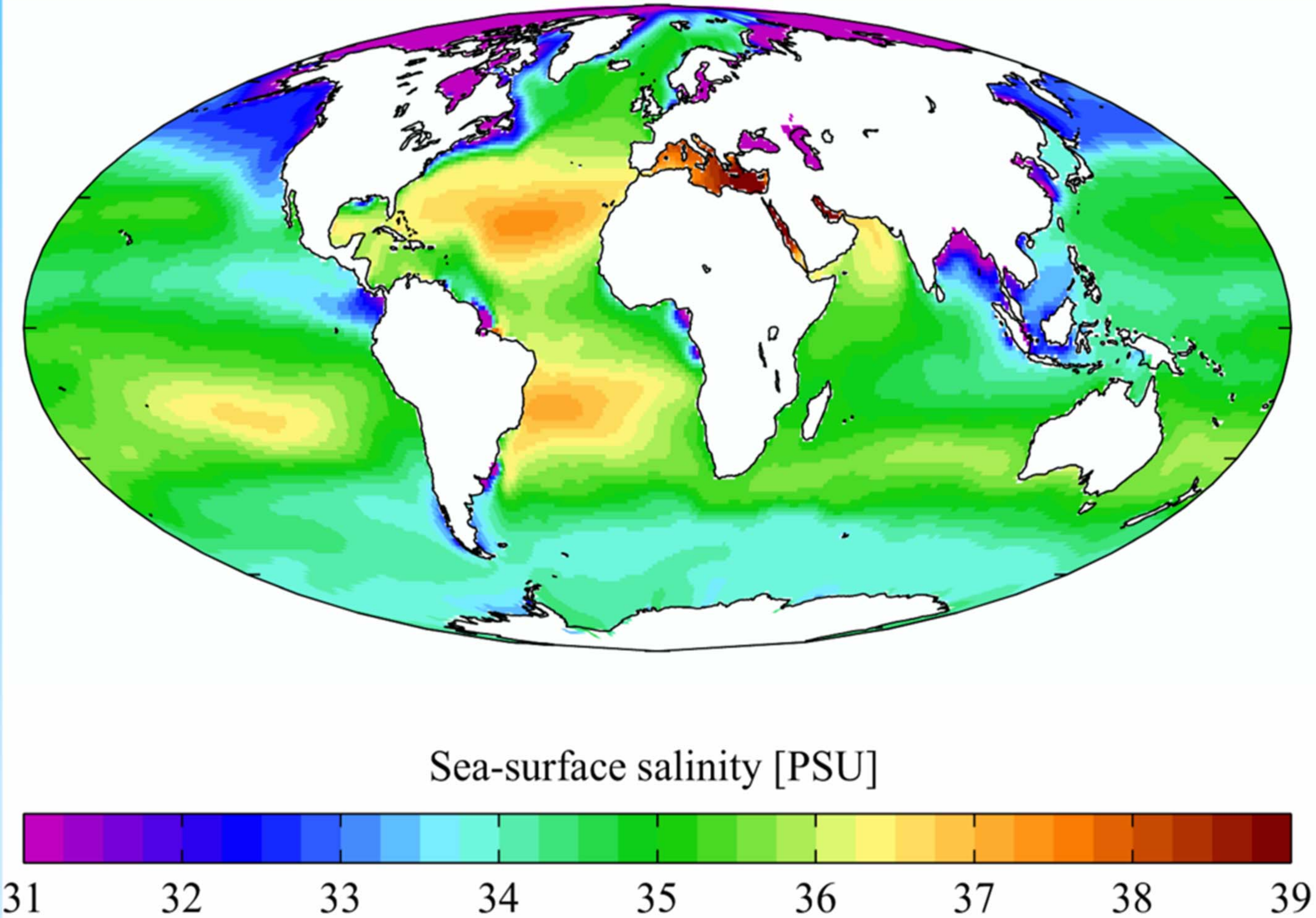
Thermocline – transition to colder denser bottom water, abrupt change of temperature.



Temperature: vertical profile

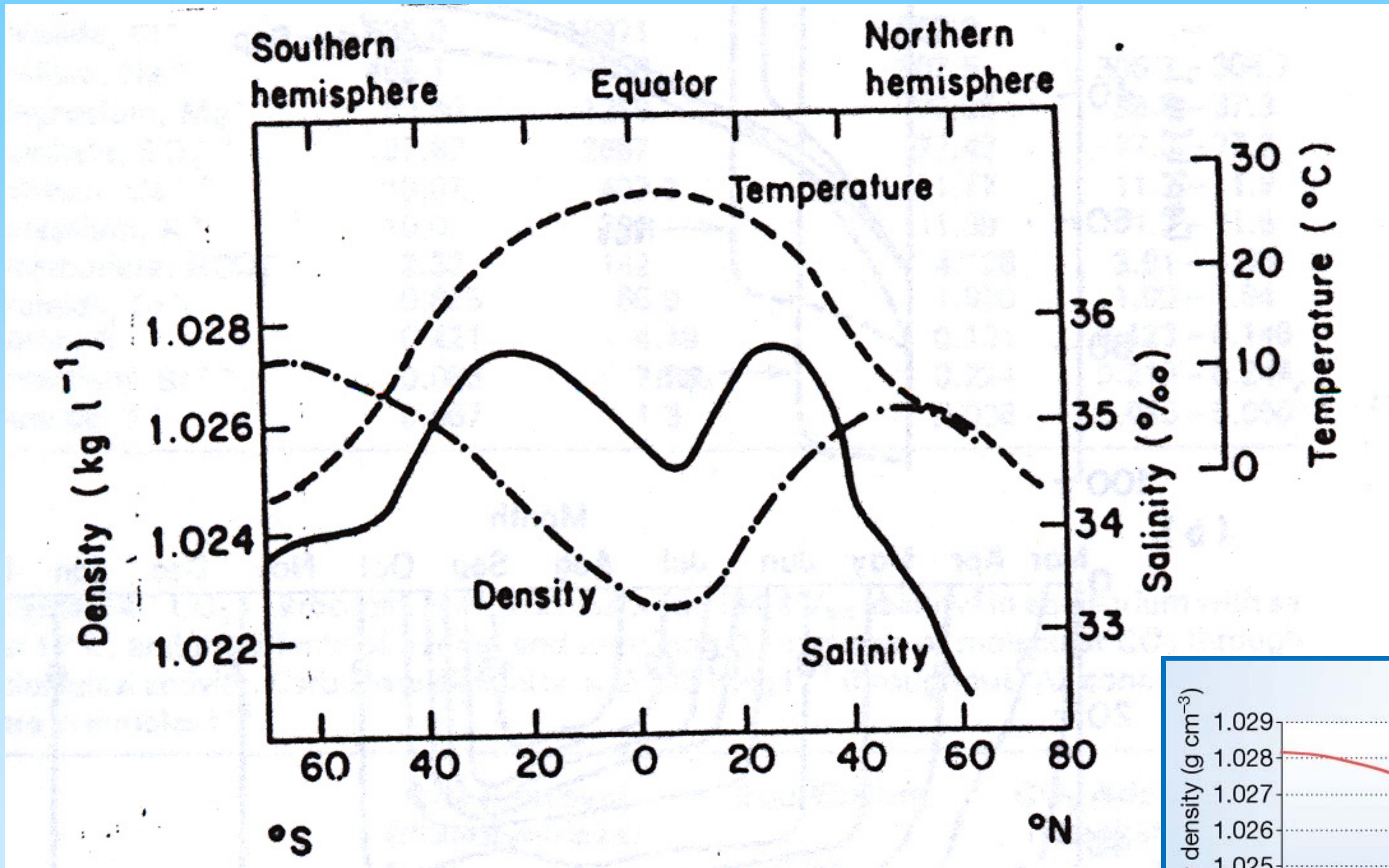


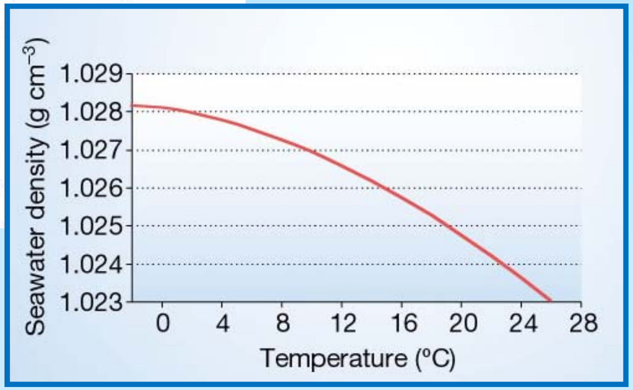

ANNUAL MEAN
GLOBAL SEA SURFACE TEMPERATURES
0
4
8
12
16
20
24
28
Temperature (°C)


Sea-surface salinity [PSU]
31
32
33
34
35
36
37
38
39

Temperature and **salinity** are related.

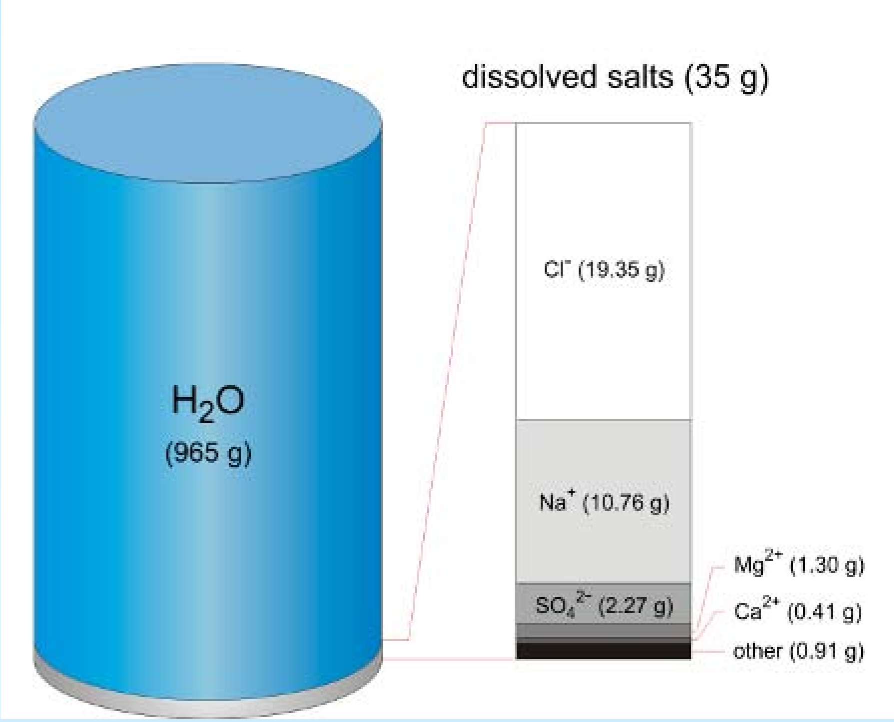
Highest salinity in subtropical regions, the lowest in polar regions.





Chemismus mořské vody je velice stabilní, 97.7 % z celkových rozpuštěných minerálních látek připadá na látky, které charakterizují **salinitu**. Zbývající podíl připadá na **dusík a fosfor.** pH **7.8 až 8.4**.

Chemical composition of 1 kg seawater with a salinity of 35 ‰



Constituent	Concentration mg-at l^{-1}	Concentration mg l^{-1}	Salinity ratio mg l^{-1} (‰)$^{-1}$	Salinity ratio Range
Chloride, Cl^-	535.0	18971	552.8	–
Sodium, Na^+	459.1	10555	307.5	306.1 – 308.7
Magnesium, Mg^{++}	52.86	1268	36.95	36.8 – 37.3
Sulphate, SO_4^{--}	27.67	2657	77.42	77.2 – 77.8
Calcium, Ca^{++}	10.07	403.9	11.77	11.7 – 11.9
Potassium, K^+	10.0	391	11.39	11.2 – 11.6
Bicarbonate, HCO_3^-	2.33	142	4.138	3.91 – 4.38
Bromide, Br^-	0.825	65.9	1.920	1.90 – 1.94
Boron, B	0.421	4.48	0.131	0.123 – 0.146
Strontium, Sr^{++}	0.088	7.70	0.224	0.210 – 0.244
Fluoride, F^-	0.067	1.3	0.038	0.035 – 0.050

Table 2.4 CO_2 – carbonate system in sea water (34.5‰ salinity) in equilibrium with air at 15°C, and the effects of adding and removing 0.1 mmoles of molecular CO_2 through biological activity. Carbonate alkalinity = 2.325 meq l^{-1} throughout. All concentrations are in mmoles l^{-1}.

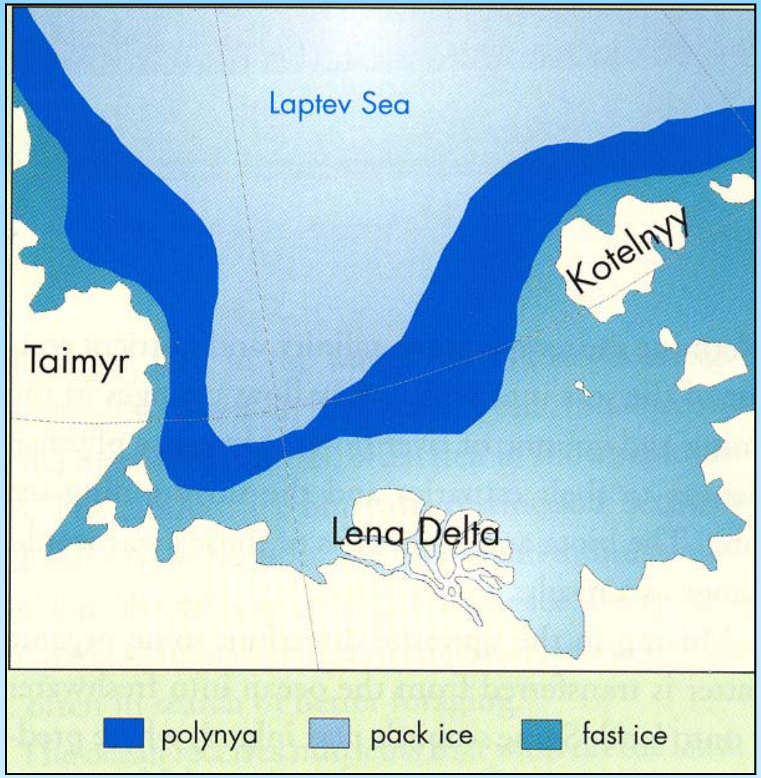
Components	CO_2 Removal (Photosynthesis) New values	CO_2 Removal (Photosynthesis) Δ C	Equilibrium Initial values	CO_2 Addition (Respiration) Δ C	CO_2 Addition (Respiration) New values
Total CO_2 (ΣCO_2)	2.039	− 0.100	2.139	+ 0.100	2.239
[CO_2 + H_2CO_3]	0.0068 (0.33%)	− 0.0056	0.0124 (0.58%)	+ 0.0136	0.0260 (1.16%)
[HCO_3^-]	1.7394 (85.31%)	− 0.1888	1.9282 (90.14%)	+ 0.1728	2.1010 (93.84%)
[CO_3^{--}]	0.2928 (14.36%)	+ 0.0944	0.1984 (9.28%)	− 0.0864	0.1120 (5.00%)
pH	8.46		8.24		7.96

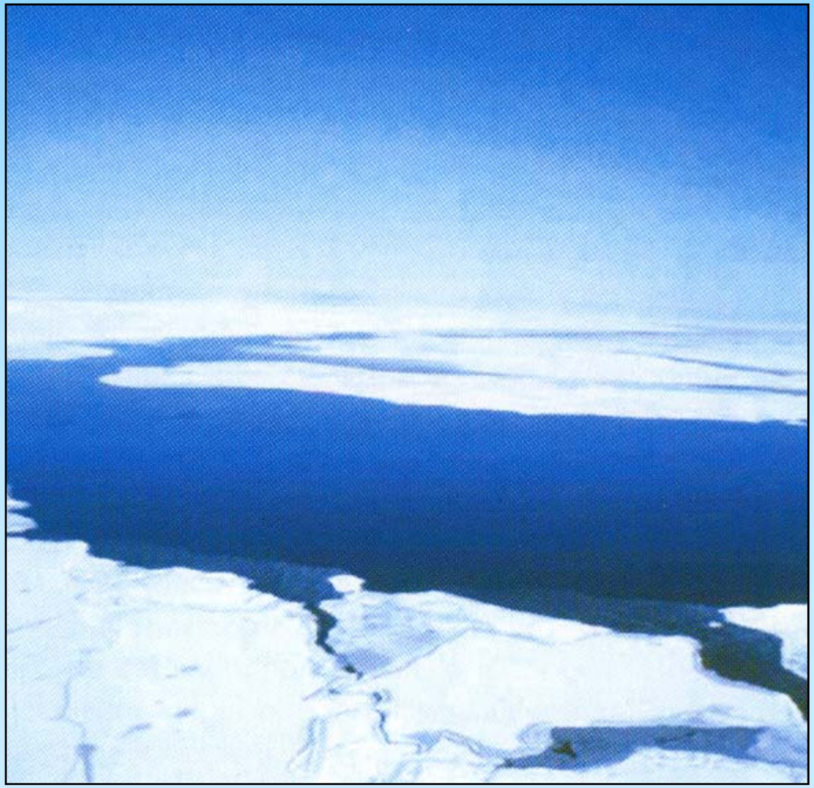
Table 2.5 Concentrations of selected minor constituents in sea water (source as for Table 2.2).

Element	Mean concentration ($\mu g\ l^{-1}$)	Typical range of concentration ($\mu g\ l^{-1}$)
Silicon	2000	0 – 4900
Nitrogen (combined)	280	0 – 560
Phosphorus	30	0 – 90
Aluminium	6	0 – 10
Iron	3.1	0.1 – 62
Zinc	7.3	1 – 48.4
Iodine	53	48 – 80
Copper	1.3	0.5 – 27
Manganese	1.2	0.2 – 8.6
Cobalt	0.15	0.005 – 4.1

POLYNYAS – persisting areas of open water

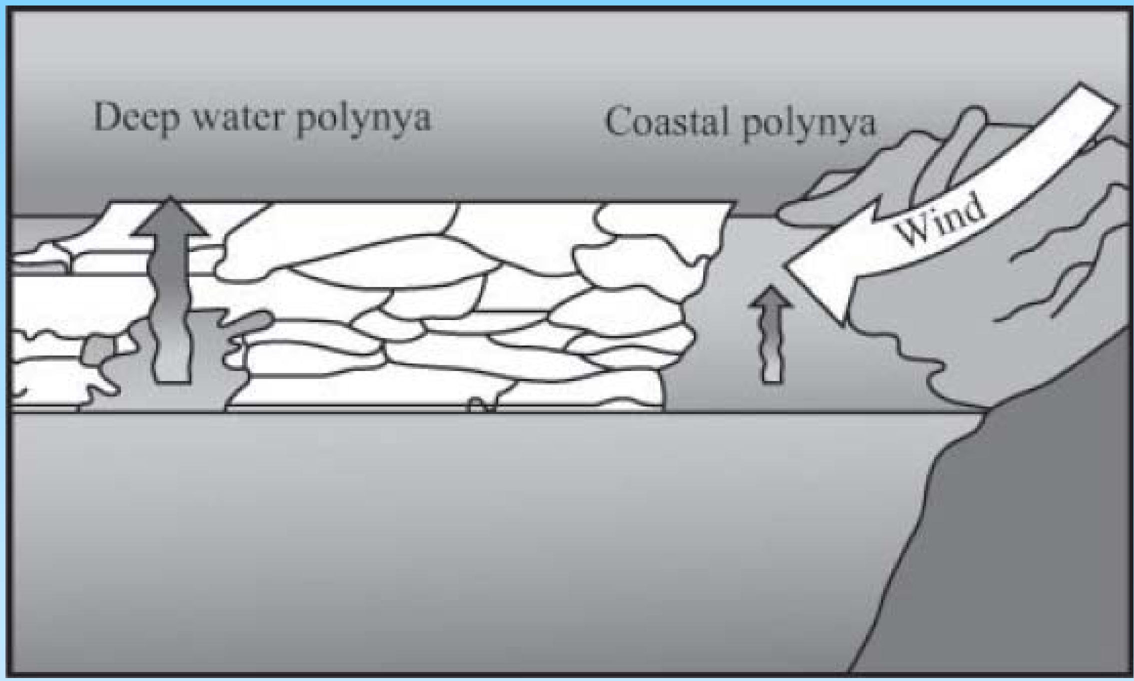
- can persist throughout the whole winter
- may occur in the same region over a number of years
- recurring polynyas
- vary greatly in size from a few square kilometres to huge areas





POLYNYAS – origin and importance

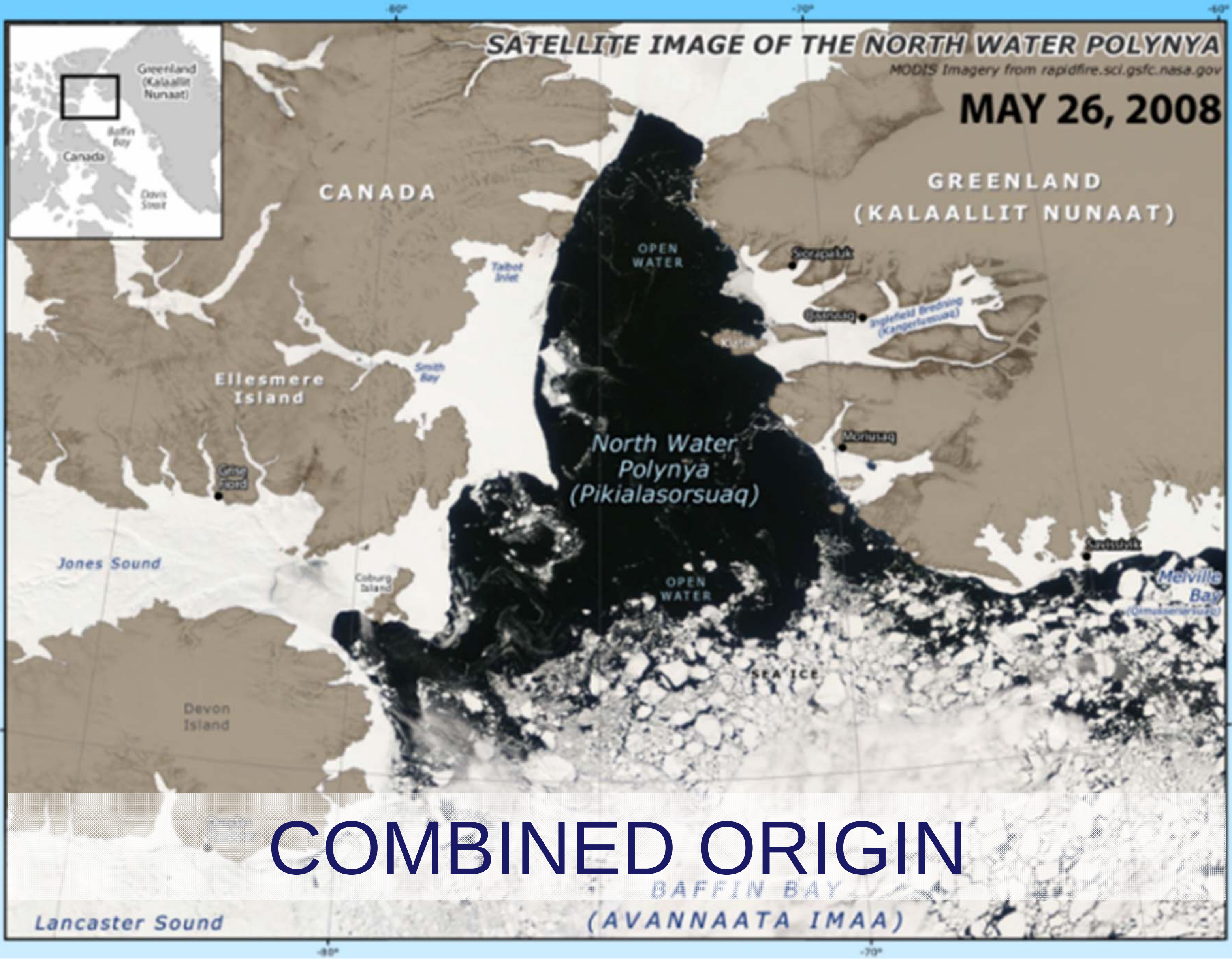
- upwelling of warmer water (sensible-heat or open ocean),
- mechanical divergence of the pack ice (latent-heat or coastal)



- pathways for heat losses to the atmosphere
- provide open water to birds and sea mammals in winter
- ice edge with enhanced productivity
- important for seasonal hunting of indigenous people

North Water (NOW) polynya

80 000 km^2 in northern Baffin Bay, largest Arctic polynya

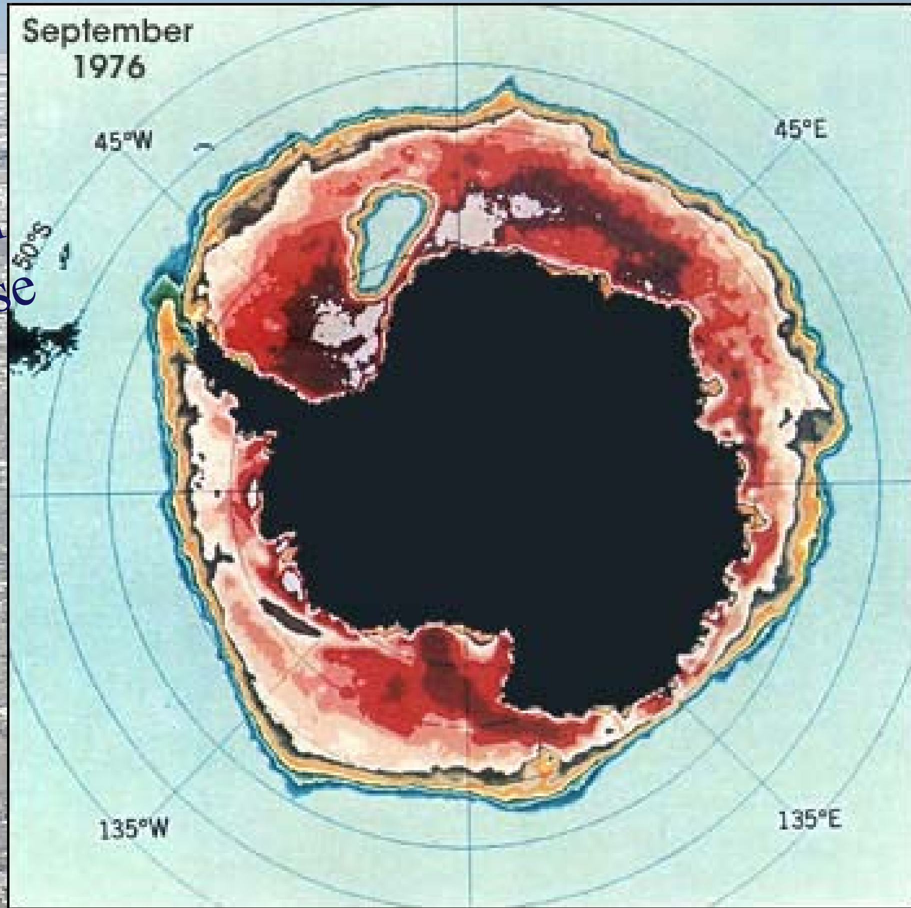


COMBINED ORIGIN

Weddell Sea polynya

200 000 km^2, 1974-1976

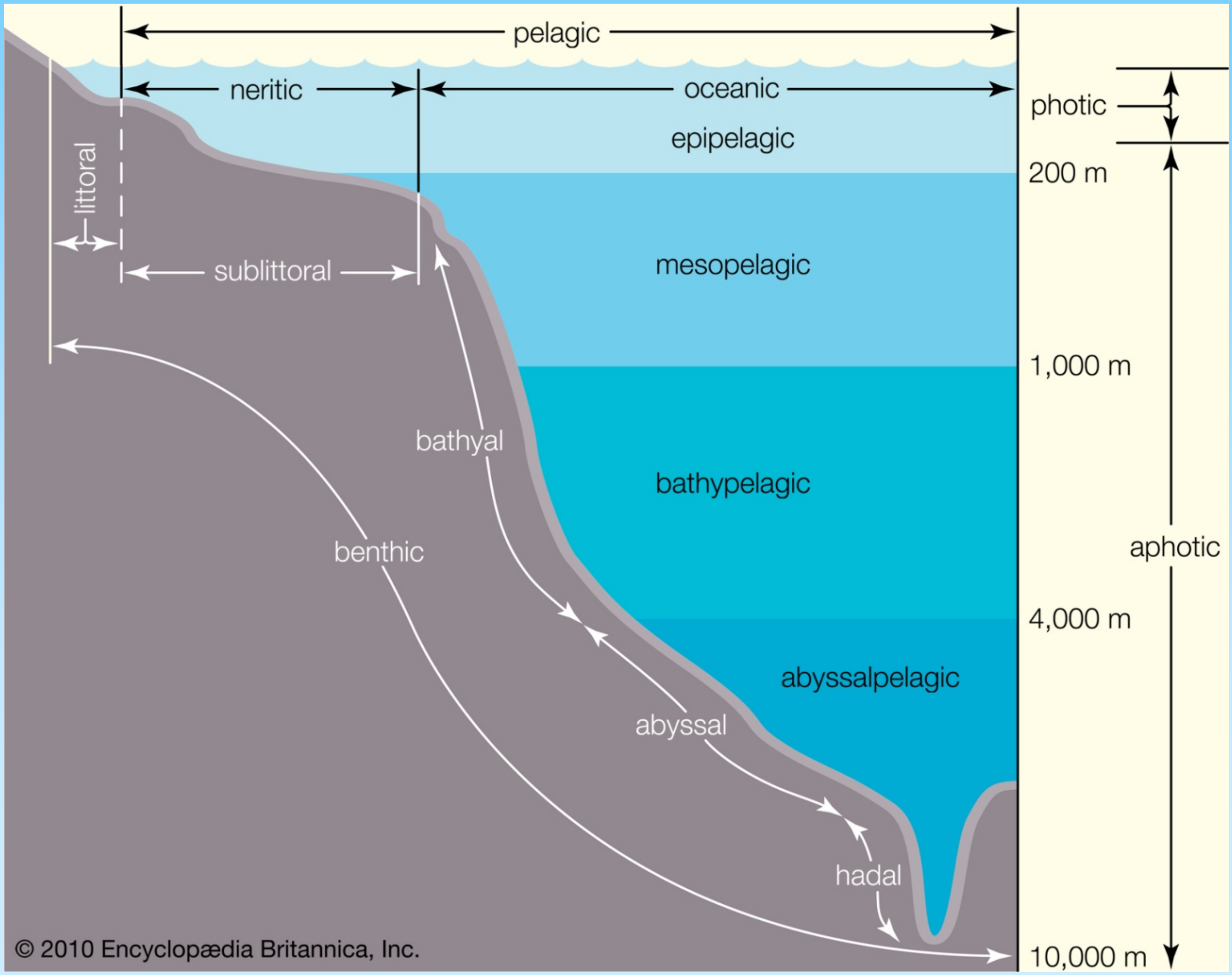
thought to have been associated with the underlying sea mount, Maud Rise
- ocean currents push the denser subsurface waters against an underwater mountain



OPEN OCEAN

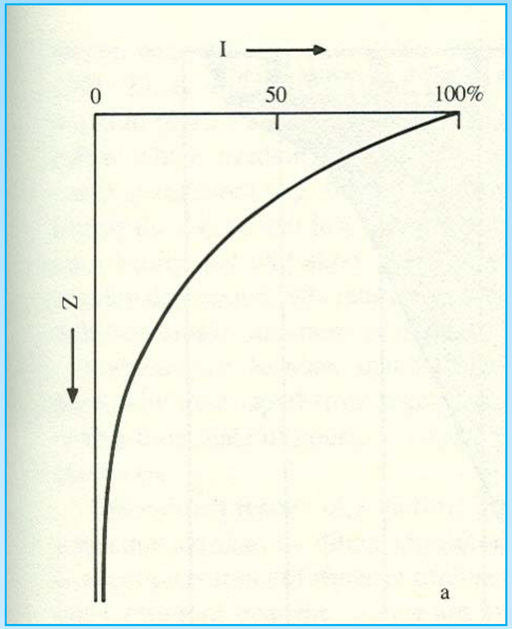
Ocean ecosystem can be divided into two main systems:

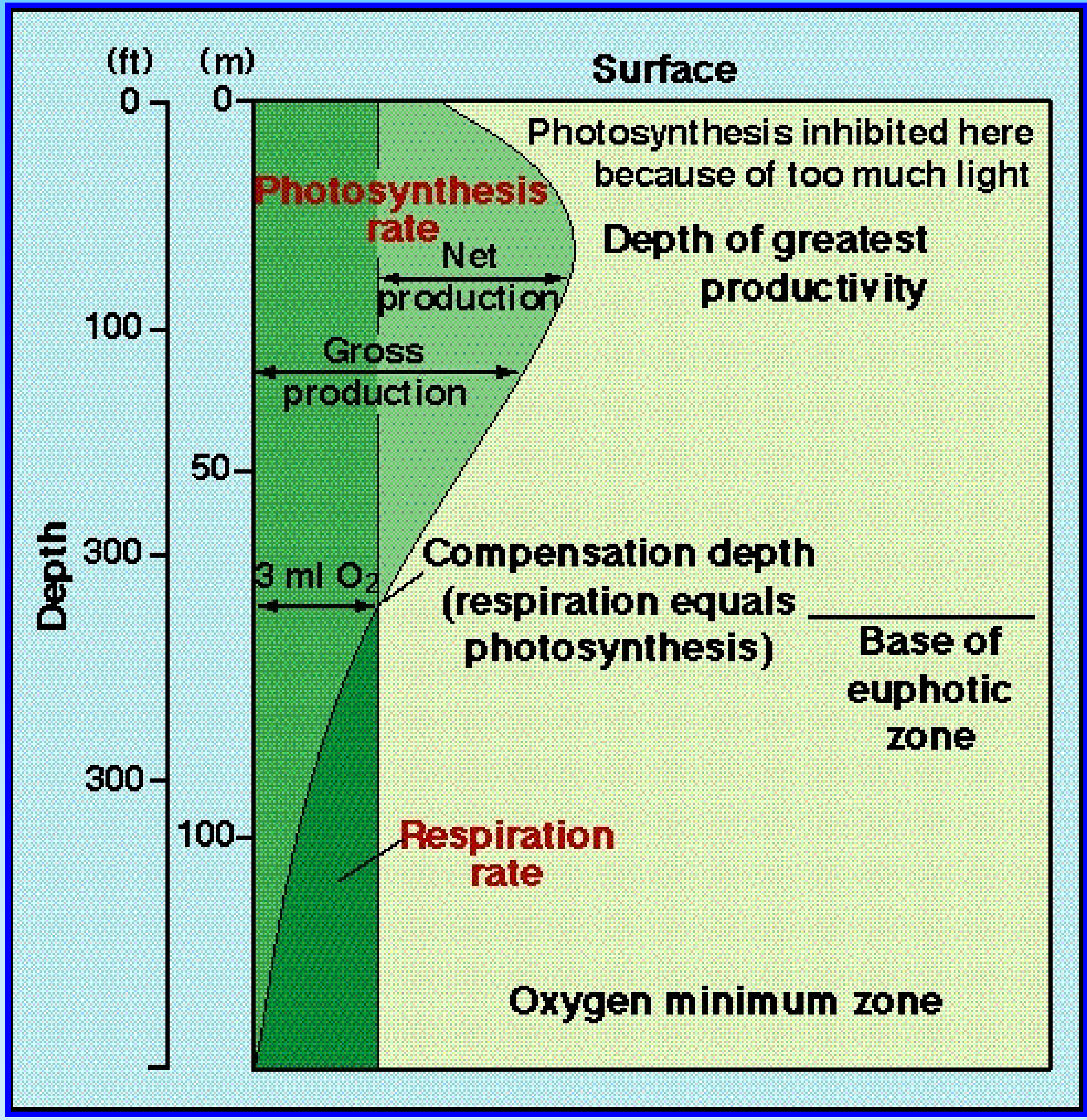
1) **Open ocean** – up to 90% of the world ocean surface, epipelagic, mesopelagic, bathypelagic, abyssopelagic zones
2) **Littoral zone** – warmer, enriched in nutrients, three main types – estuaries, steep littoral zone, sandy and stony beaches.



Vertical profile of light and productivity

- productivity changes with depth as result of decreasing light intensity






Ocean Light Zones
Euphotic Zone
Disphotic Zone
Aphotic Zone
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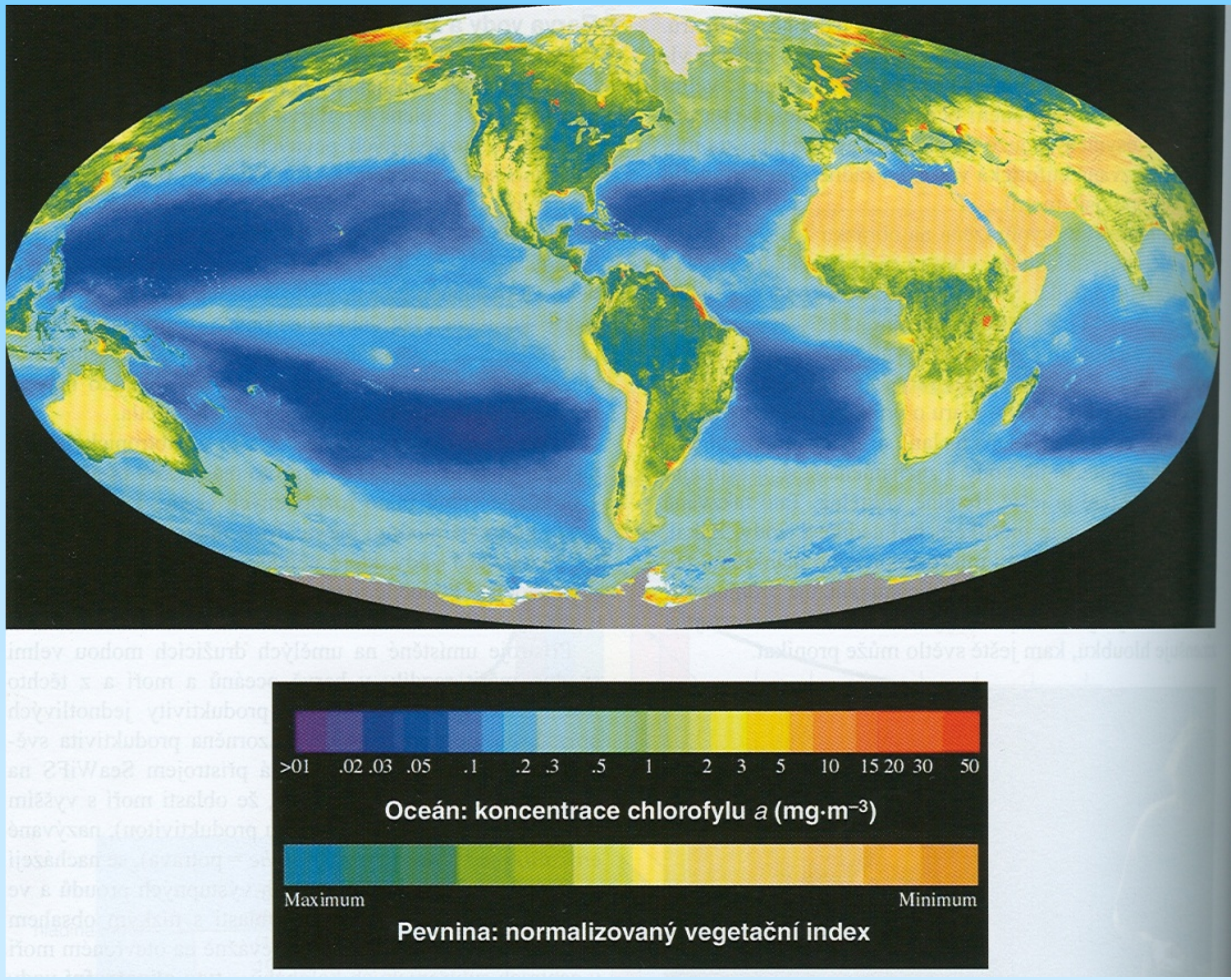
Primary producers of polar oceans

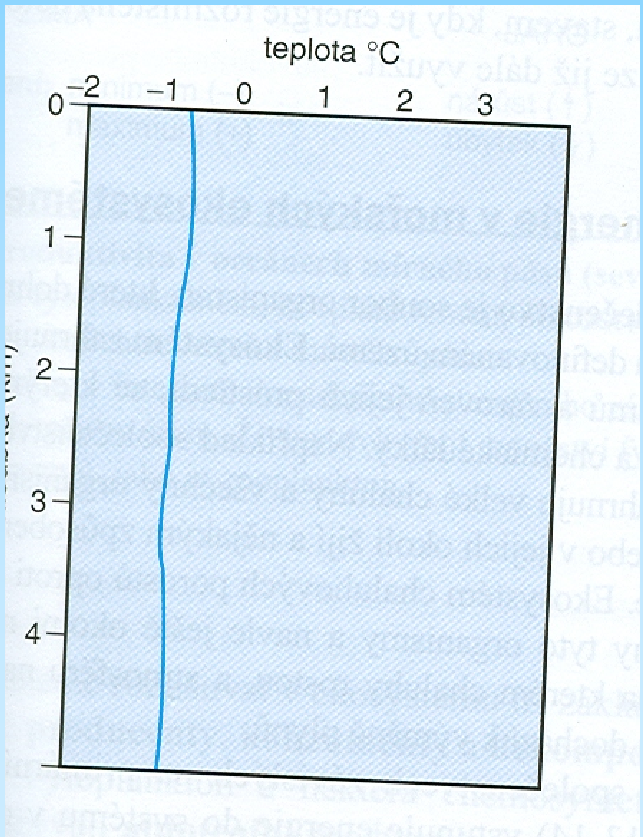
Phytoplankton composed mainly by **diatoms, haptophytes (coccolithophores), dinoflagellates and cyanobacteria**.

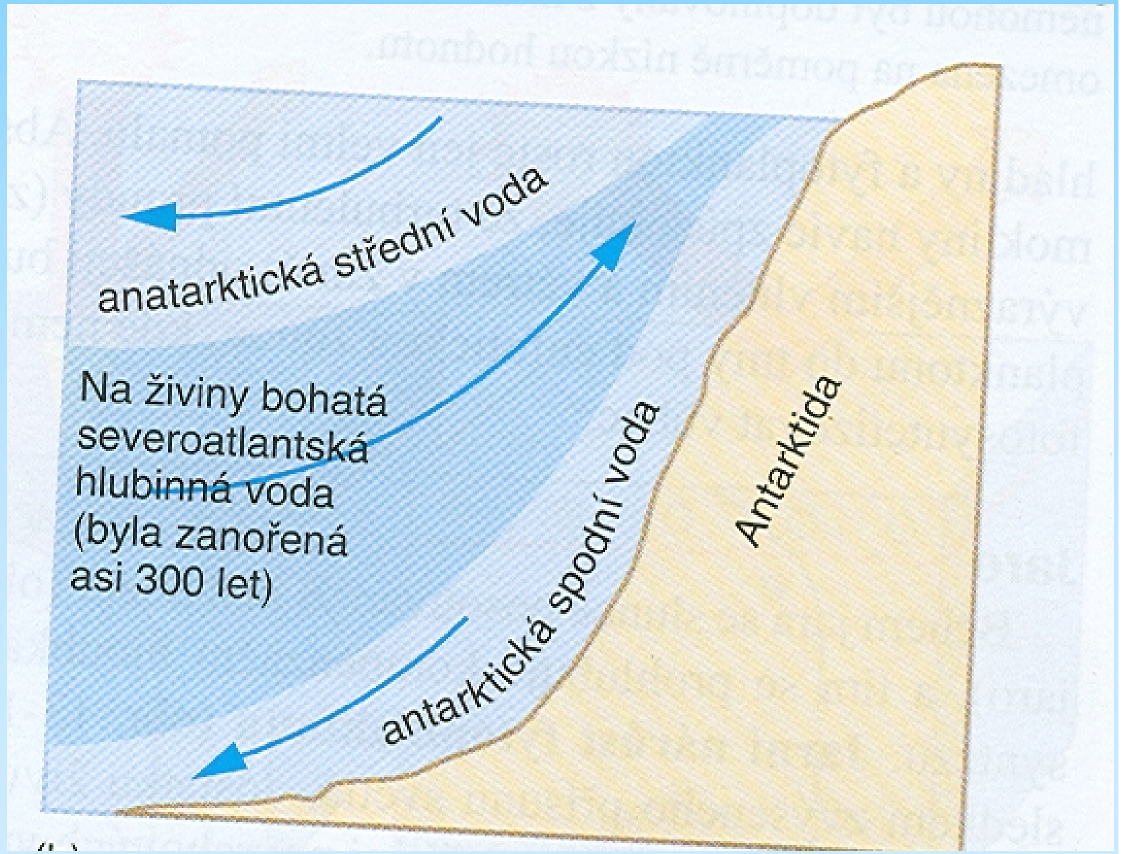
Polar oceans belong to the **most productive** marine ecosystems.

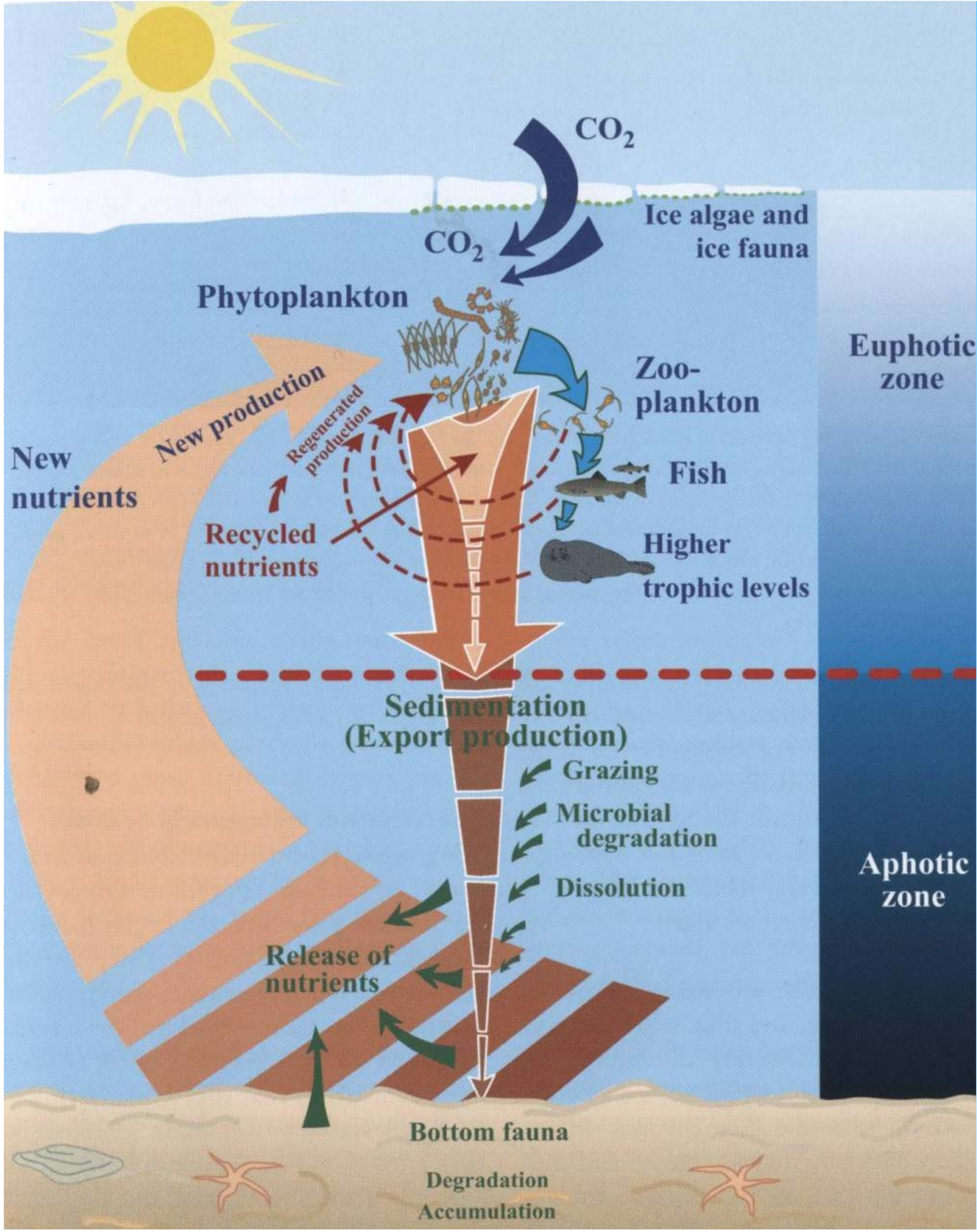


Productivity of polar oceans

- Southern Ocean – productivity higher than in the Arctic
- upwellings of nutrient-rich deep water
- isothermic temperature profile does not prevent mixing







Polar ocean

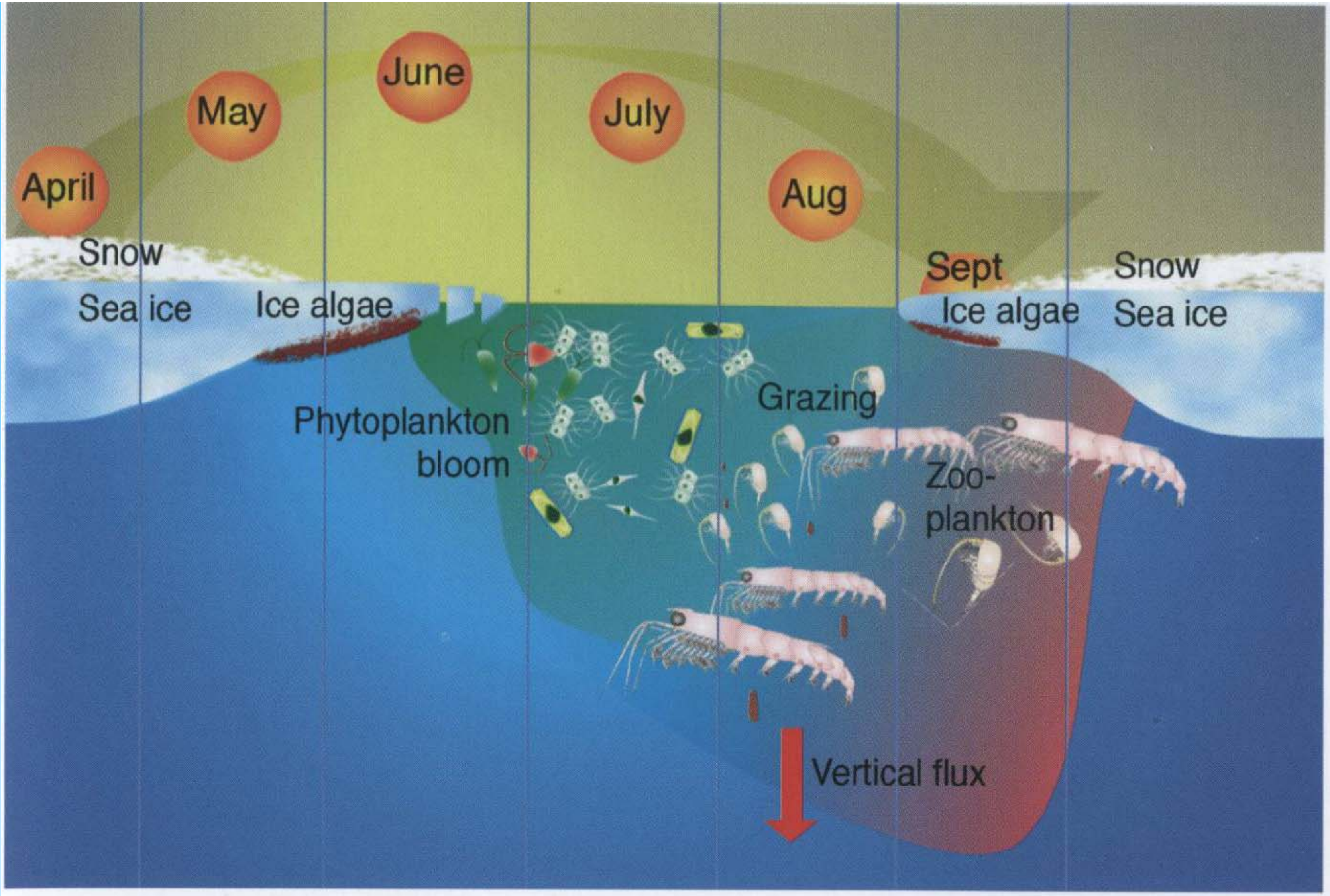
food chain and nutrient cycling

Plankton: size classification

Table 6.1 Classification of polar plankton based on size and taxonomy.

Size fraction	Femto-	Pico-	Nano-	Micro-	Meso-	Macro-	Mega-
Taxonomic group	<0.2 μm	0.2–2 μm	2–20 μm	20–200 μm	0.2–20 mm	2–20 cm	>20 cm
Viruses	*						
Heterotrophic bacteria	*	*					
Cyanobacteria		*					
Dinoflagellates			F	*	F		
Diatoms (including colonies)			F	*	F		
Prymensiophytes			*	*	*		
Prasinophytes		F	*				
Heterotrophic flagellates, amoeba		*	*	F			
Ciliates			*	*	F		
Copepods				* Juveniles	* Adults		
Euphausiids				*	* Juveniles	* Adults	
Amphipods					*	*	
Jellyfish					*	*	*
Salps						*	*
Chaetognaths					*		

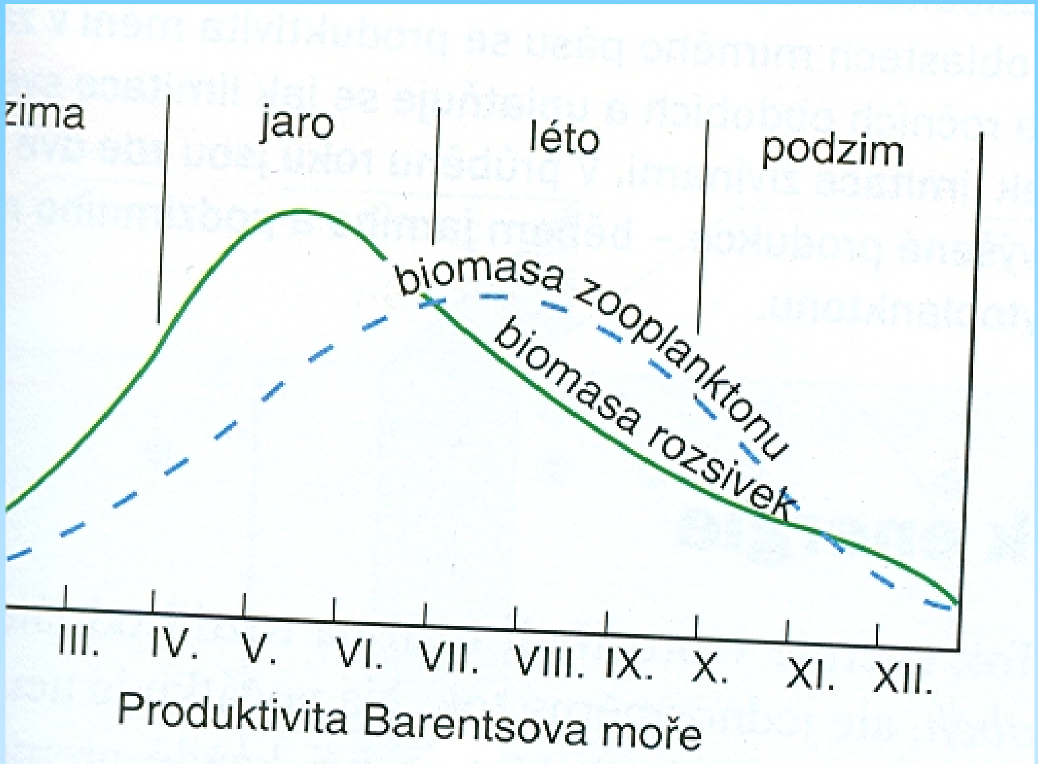
* Indicates that the species are only or mostly in those size class ranges; F indicates that a few species are found in those size classes.



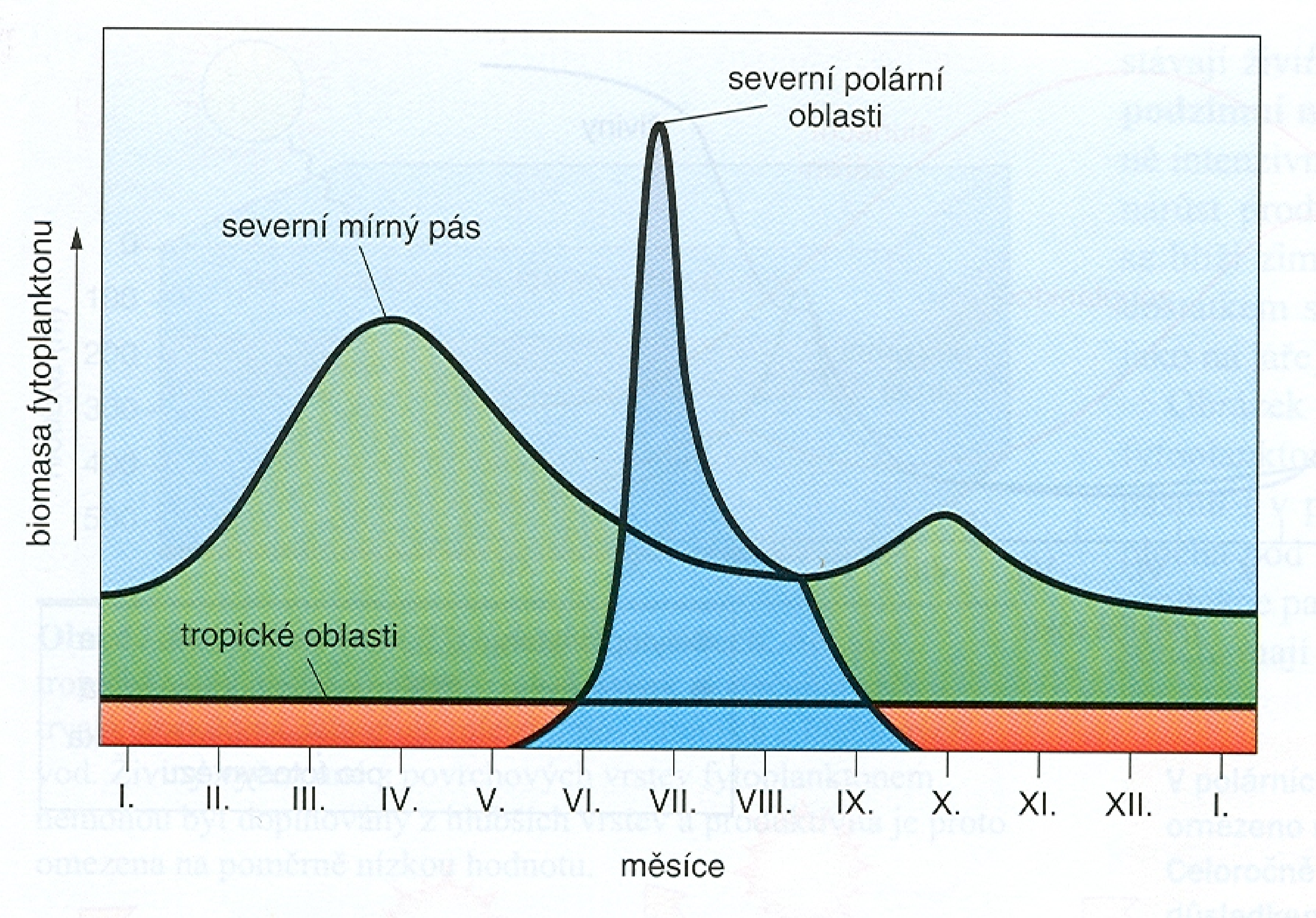
The sun appears over the horizon in April and supplies light to support the growth of ice algae and phytoplankton. When the sun is at its highest in June, production peaks and the zooplankton thrive on this superabundance of food. The production gradually declines during the season as the phyto-plankton use up the nutrients in the water, and when the sun once more sinks below the horizon the plankton hibernate until the next growing season. From Alexander Keck & Paul Wassmann (1993), modified by Frøydis Strand, NFH, UiT

Polar seas - plankton

phytoplankton maximum in May, **zooplankton** in June, high biomass till the onset of polar night

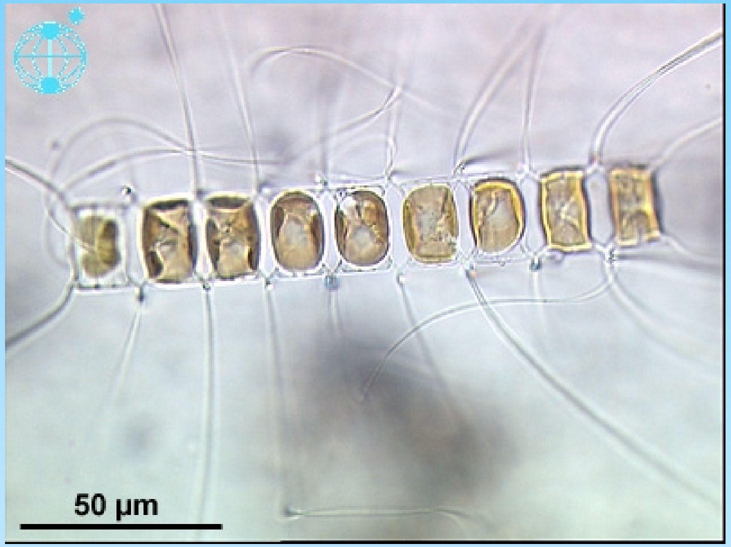


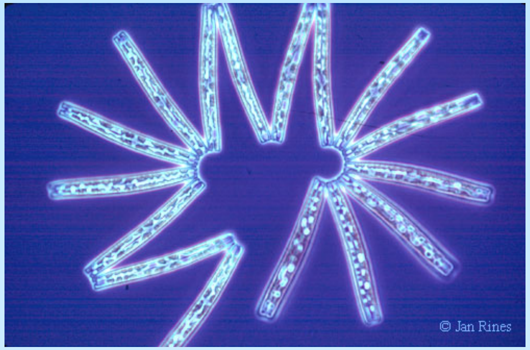
Seasonal development of phytoplankton production

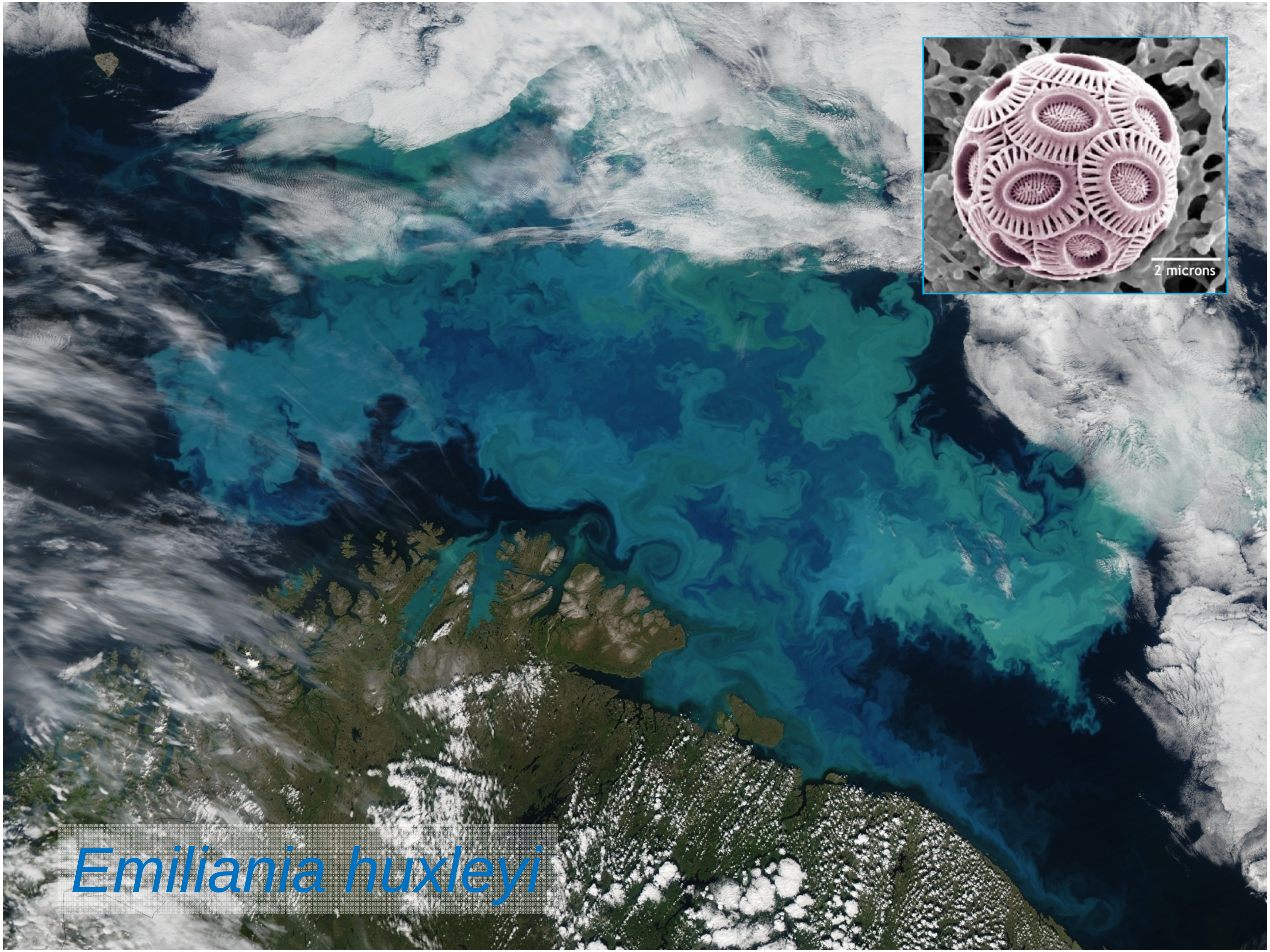


Phytoplankton of the Arctic Ocean

- dominance of diatoms (Bacillariophyceae), coccolithophores (Coccolithophyceae)

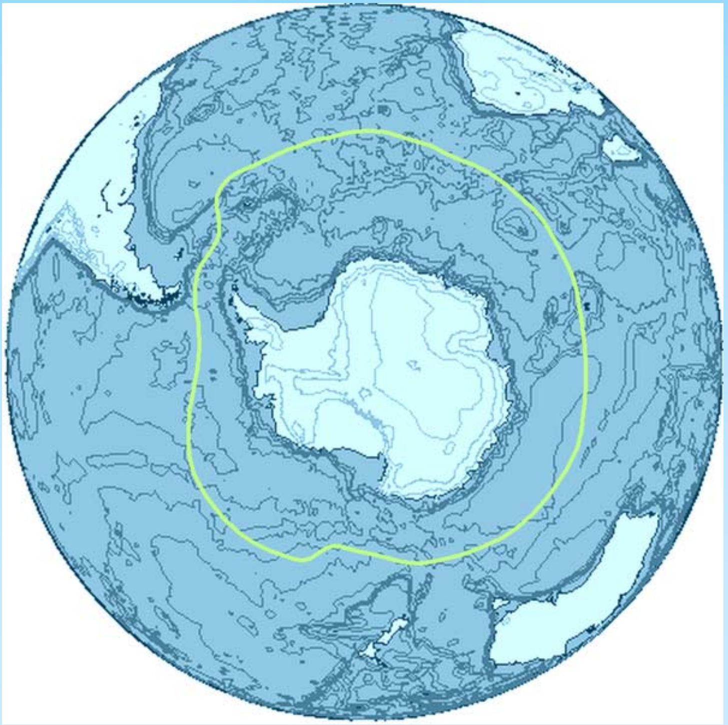




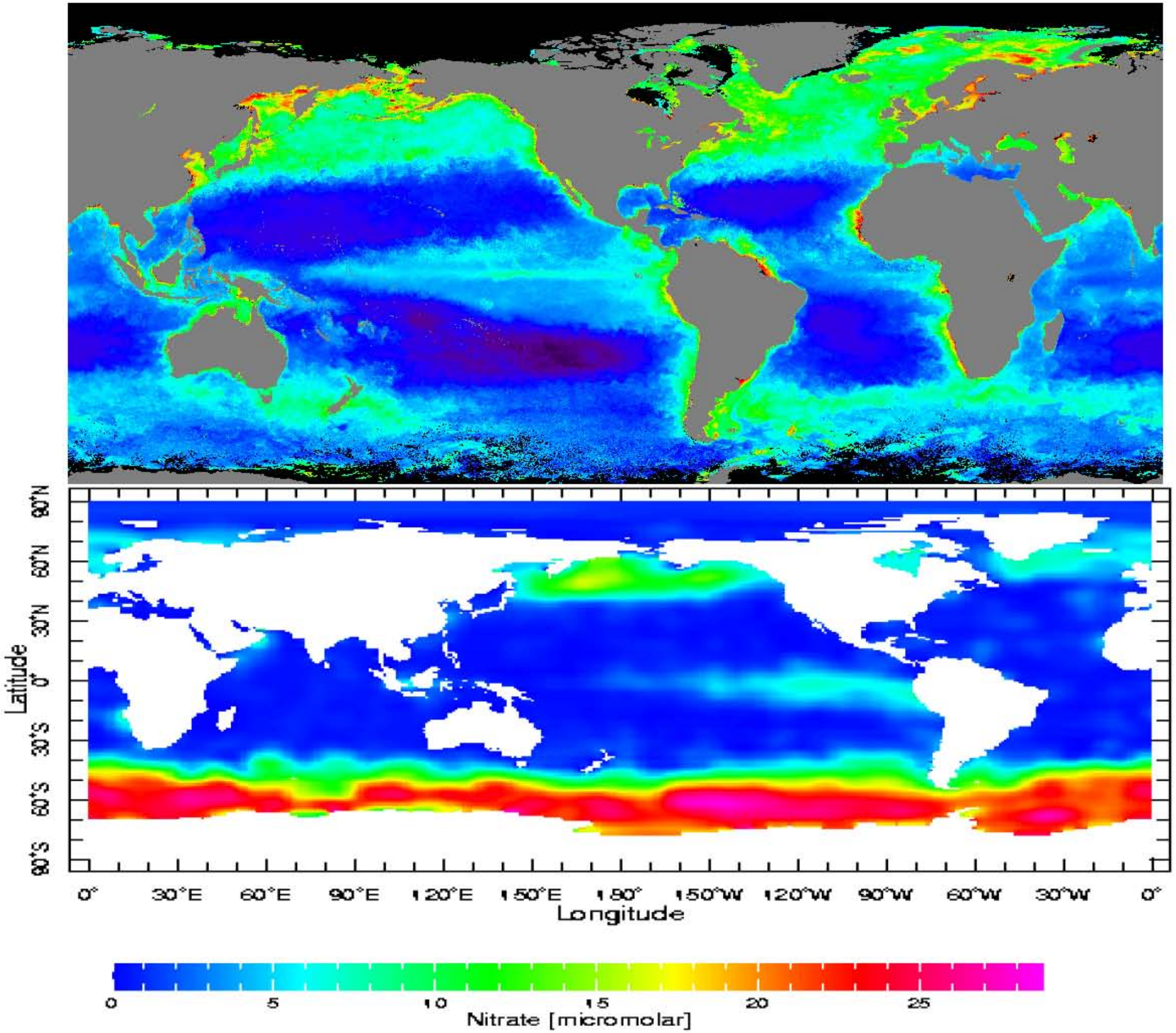

2 microns
Emiliania huxleyi

Southern Ocean

- 20 % of the global ocean surface – role in climate regulation
- relatively higher nutrient concentrations, but HNLC regions
- dominance of diatoms



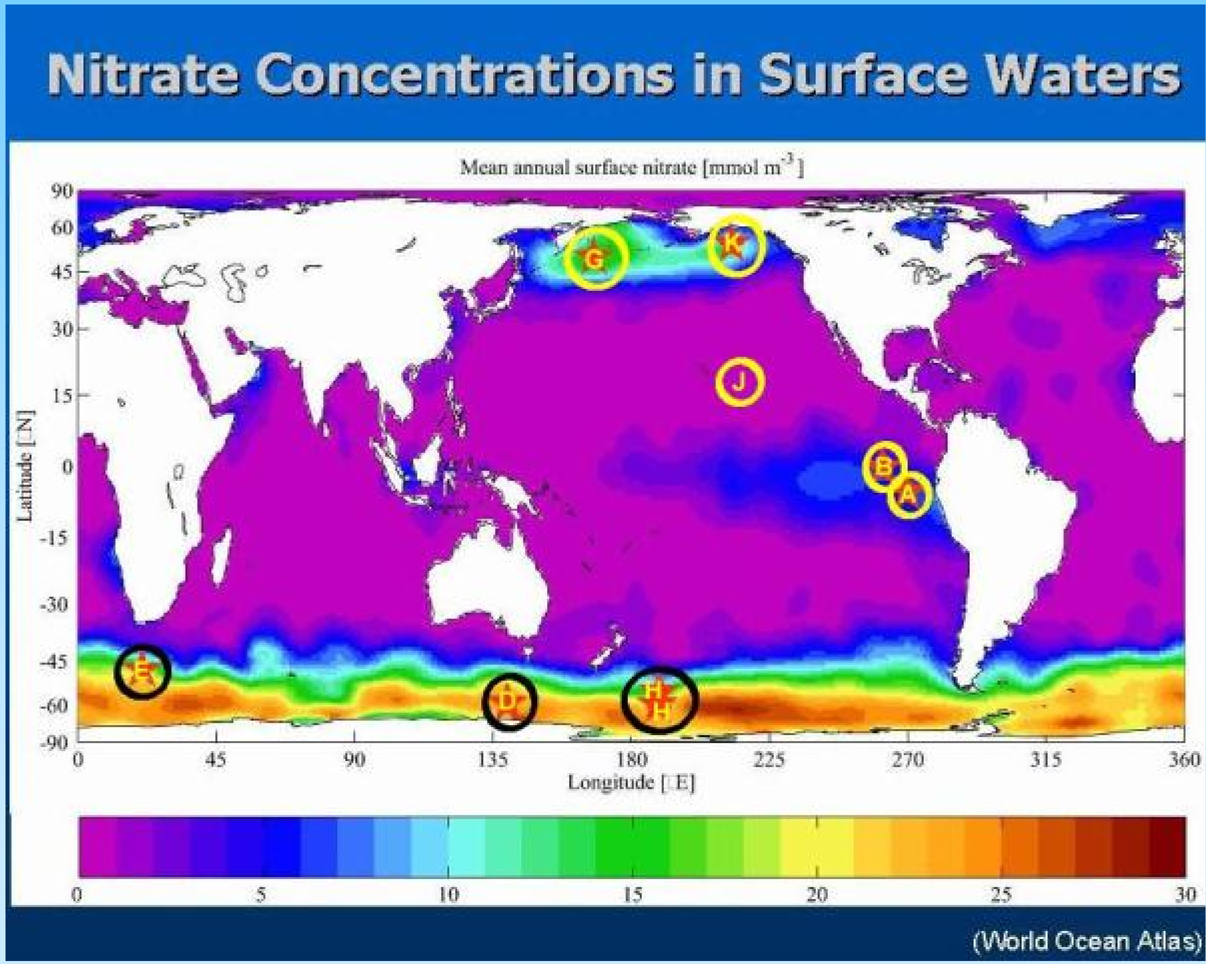
High Nutrient Low Chlorophyll Ecosystems




Iron as limiting nutrient:
mesoscale enrichment experiments

Iron as limiting nutrient

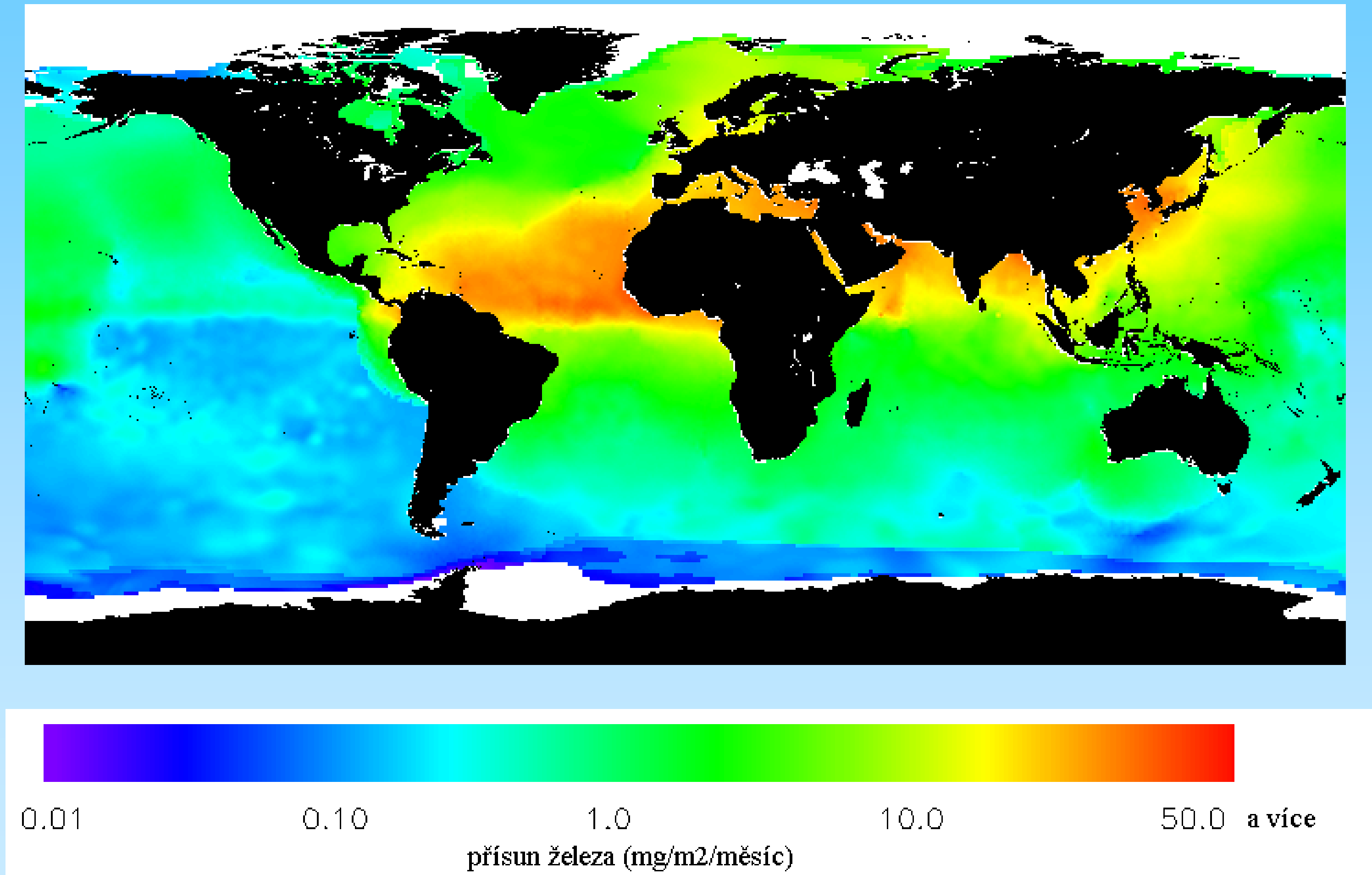
• mesoscale enrichment experiments



•A: IronEx I
•B: IronEx II
•D: SOIREE
•E: EisenEx
•G: SEEDS
•H: SOFeX
•J: Planktos
•K: SERIES

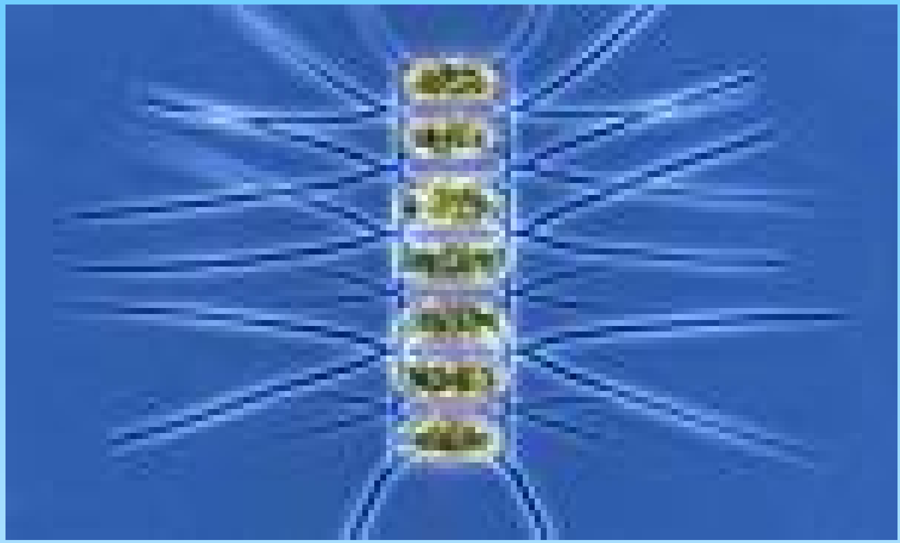
• up to 40x increase in phytoplankton biomass

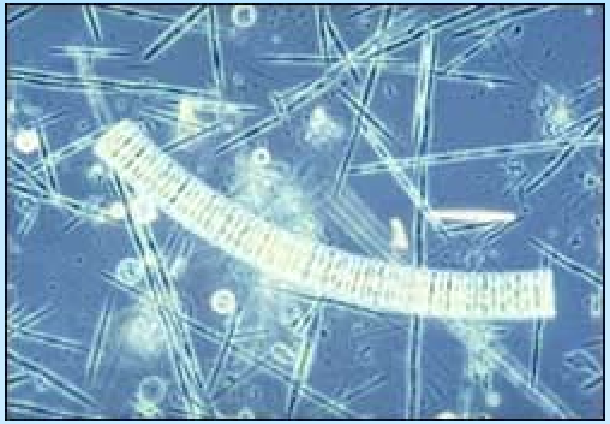
Iron as limiting nutrient



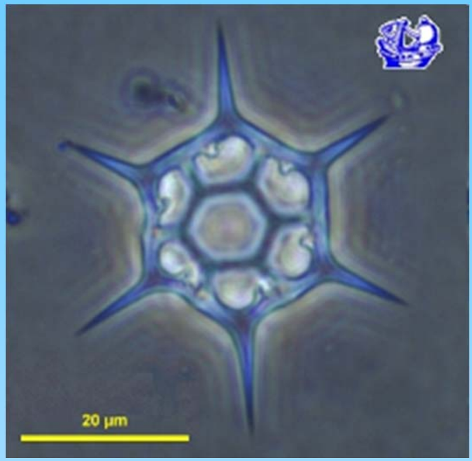
Gao et al. 2001

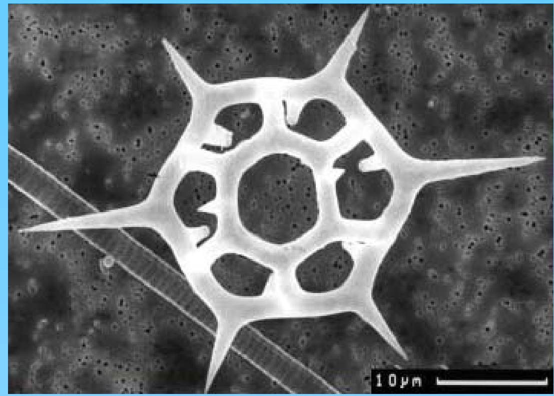
Phytoplankton of the Southern Ocean

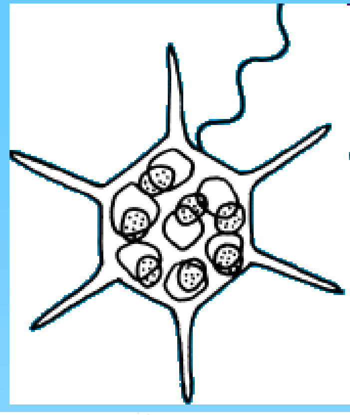




Dictyochophyceae







silicoflagellates -
Dictyocha
cold seas,
involved in global
cycle of silicon

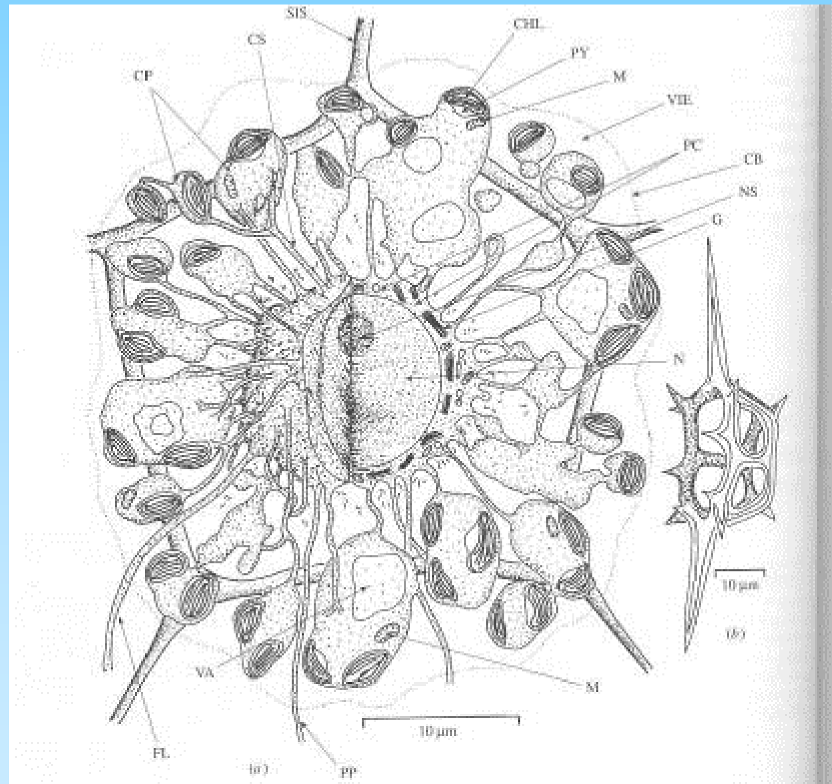
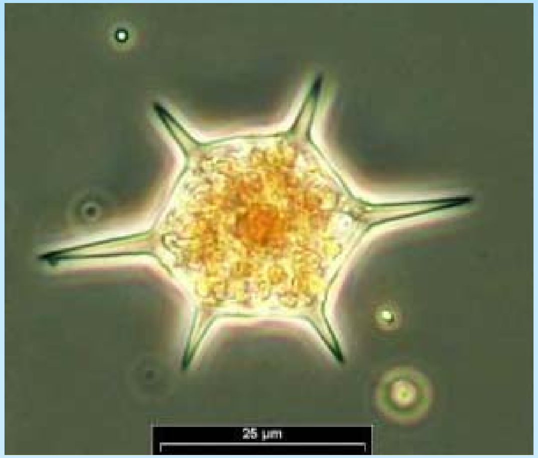
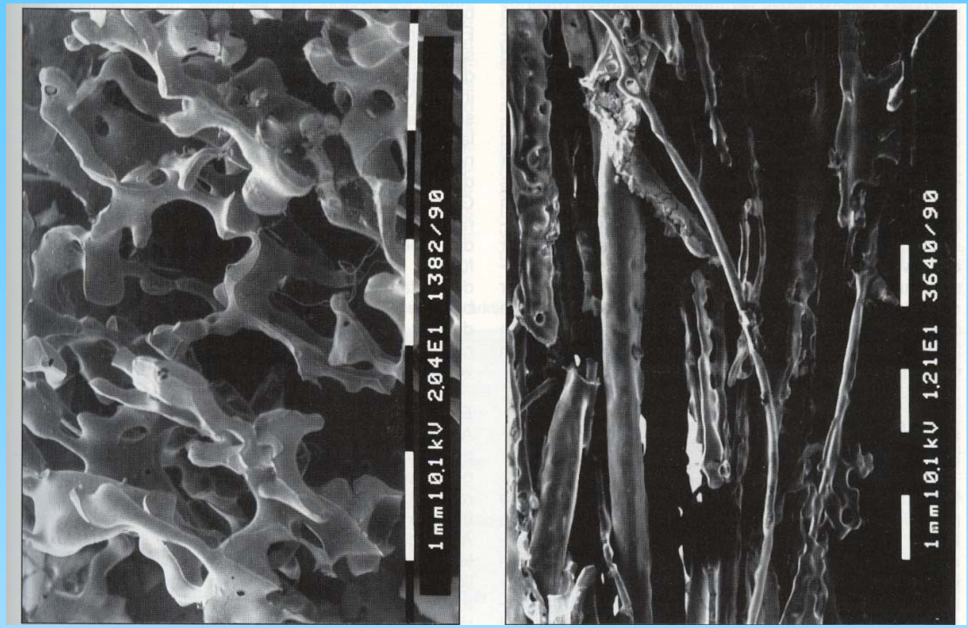


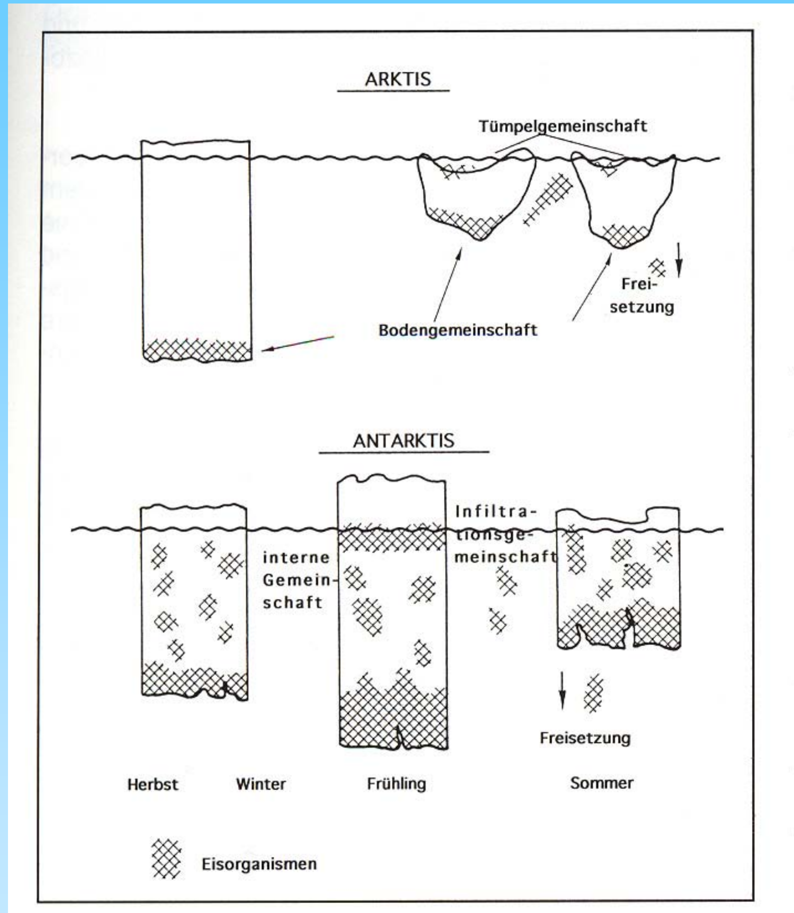
Figure 11.1. *Dictyocha*. (*a*) The radially organized living cell. (*b*) Siliceous skeleton. CB = boundary of cell envelope; CHL = chloroplast; CP = cytoplasmic process; CS = connecting strand; FL = flagellum; G = golgi body; M = mitochondrion; N = nucleus; NS = nucleolus; PC = perinuclear cytoplasm (= peri- karyon); PP = pseudopodium; PY = pyrenoid; SI siliceous skeleton; VA = vacuole; VIE = the ex sive viscous envelope around the cell, without ous structure. (*a* based on [1812, 1811]; *b* on [300].)

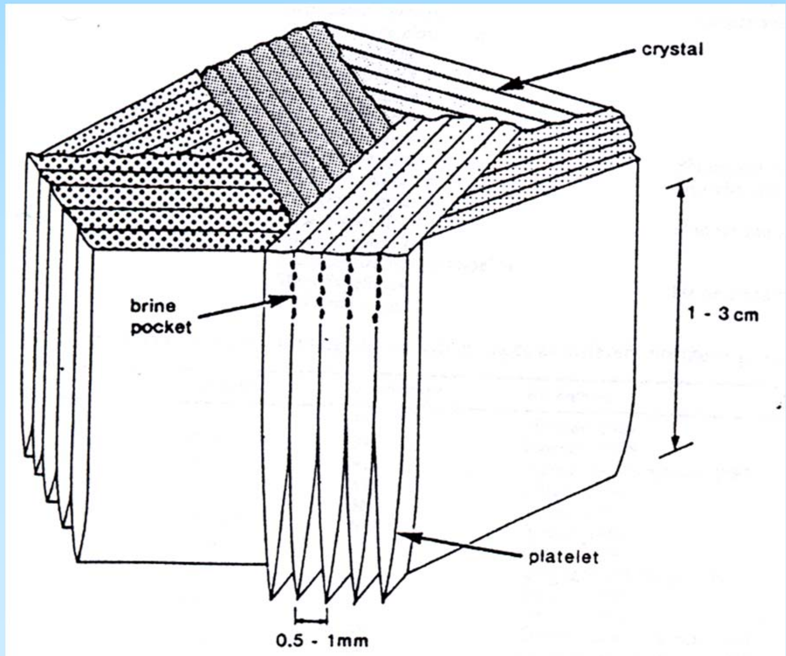


bioindication of cold periods in the past

Ice algae


1mm 10,1kU 204E1 1382/90
1mm 10,1kU 121E1 3640/90


ARKTIS
Tümpelgemeinschaft
Bodengemeinschaft
Frei-
setzung
ANTARKTIS
interne
Gemein-
schaft
Infiltra-
tionsge-
meinschaft
Freisetzung
Herbst
Winter
Frühling
Sommer
Eisorganismen

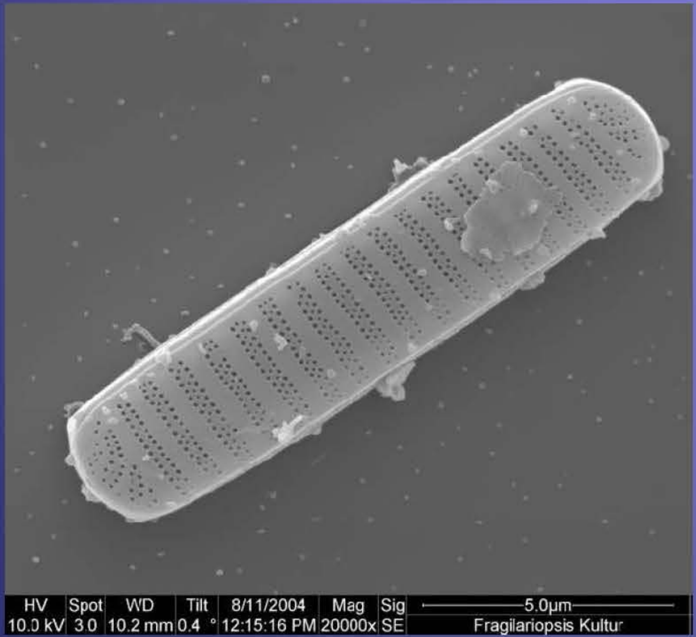

crystal
brine
pocket
1 - 3 cm
platelet
0.5 - 1mm



Fragilariopsis cylindrus

Phylum *Bacillariophyta*
Family *Bacillariaceae*

One of the most abundant diatoms, especially in the southern polar oceans, is *Fragilariopsis cylindrus* (Grunow) Krieger (Bacillariophyceae). The optimum growth temperature of *F. cylindrus* is +5°C (Fiala & Oriol, 1990)



Zooplankton of the Arctic Ocean

Calanus glacialis

- the most important species
- stores a large amount of fat (lipids), which can amount to as much as 70 % of its body mass
- primary food source for Arctic cod, marine birds and bowhead whales
- mature females feed on ice algae
- offsprings feed on phytoplankton
- developmental stages are perfectly synchronised with the two distinct algal bloomsc

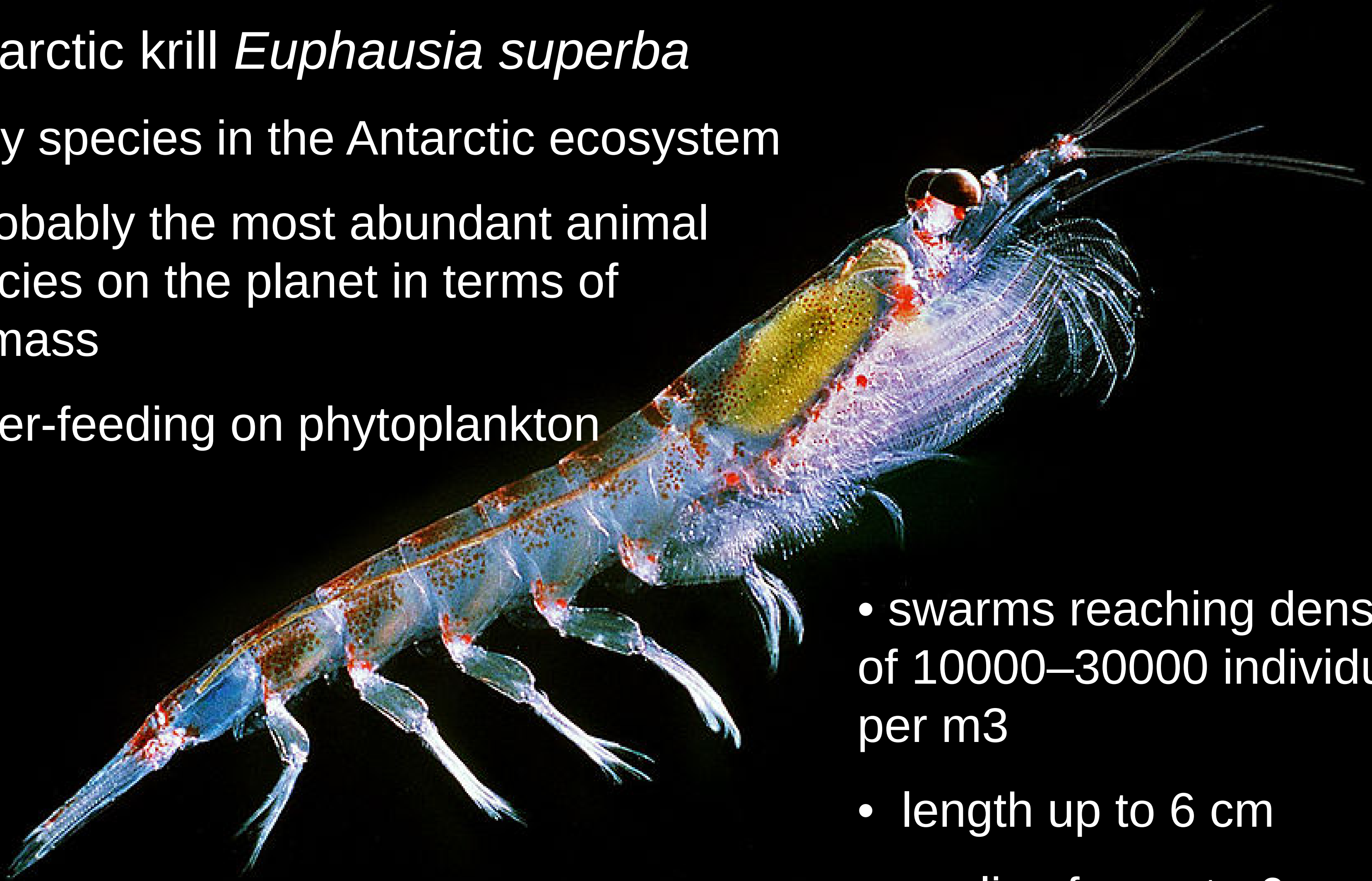
Zooplankton of the Southern Ocean

Antarctic krill *Euphausia superba*

• key species in the Antarctic ecosystem

• probably the most abundant animal species on the planet in terms of biomass

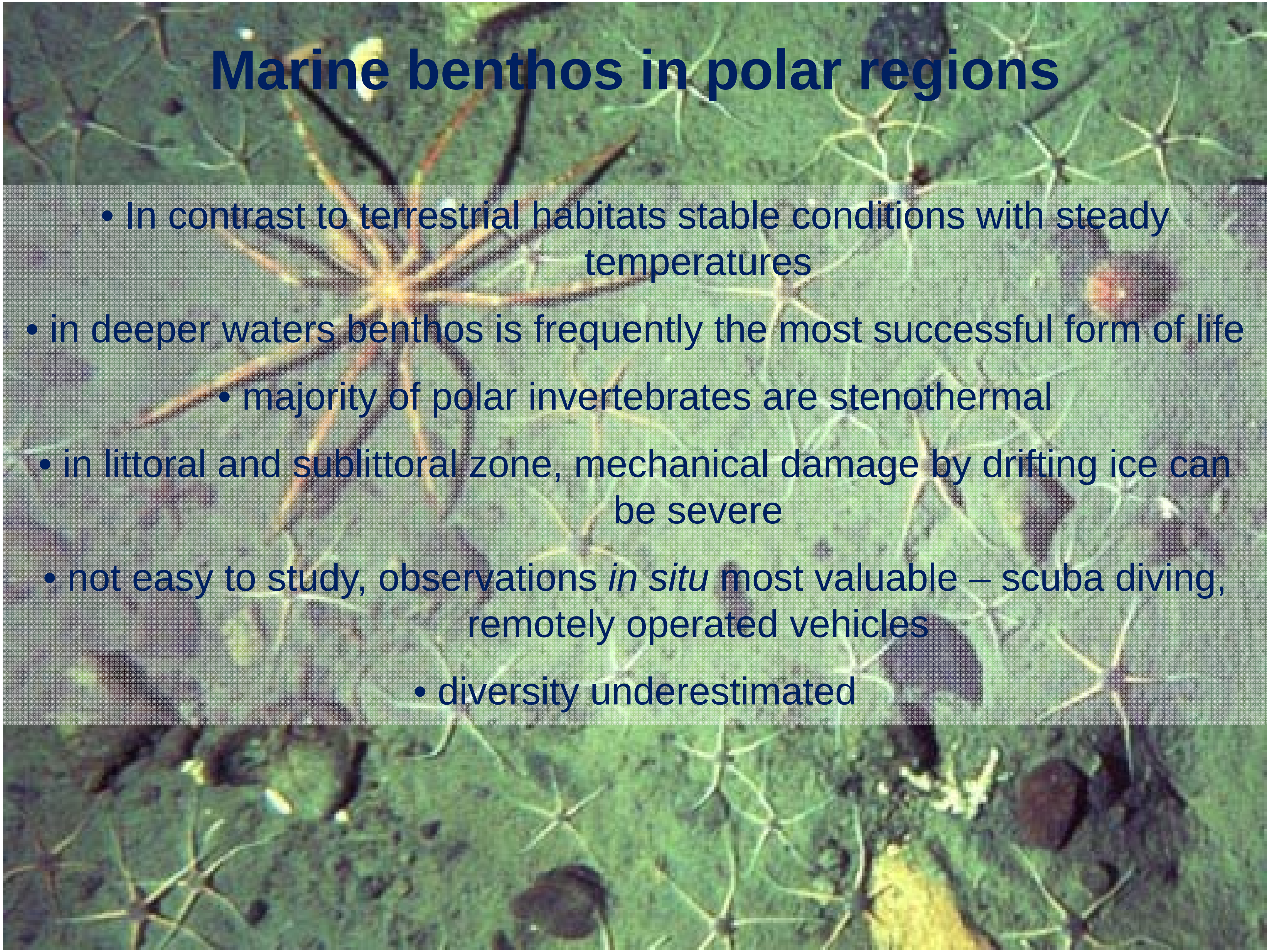
• filter-feeding on phytoplankton



• swarms reaching densities of 10000–30000 individuals per m3

• length up to 6 cm

• can live for up to 6 years



Marine benthos in polar regions

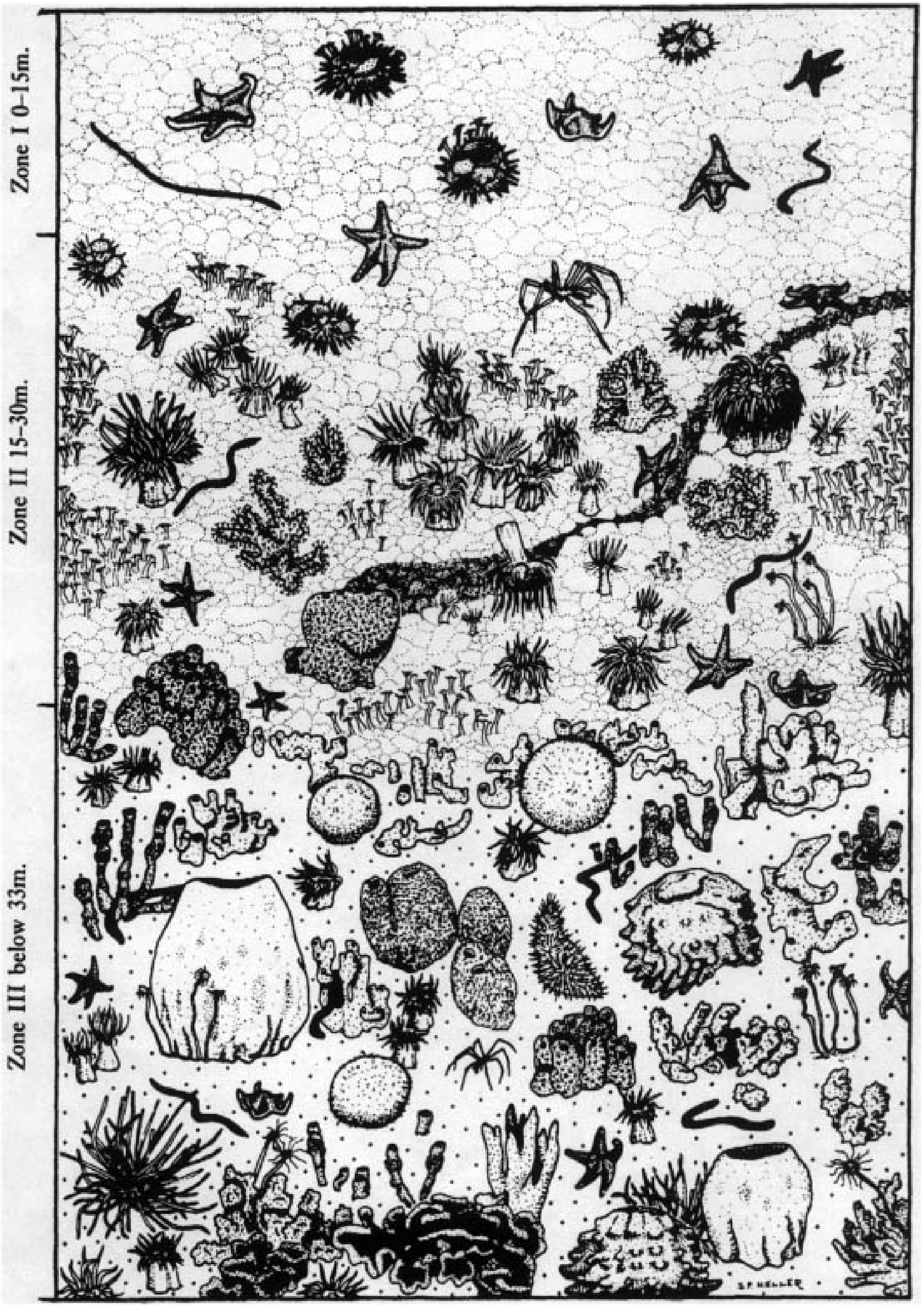
- In contrast to terrestrial habitats stable conditions with steady temperatures
- in deeper waters benthos is frequently the most successful form of life
- majority of polar invertebrates are stenothermal
- in littoral and sublittoral zone, mechanical damage by drifting ice can be severe
- not easy to study, observations *in situ* most valuable – scuba diving, remotely operated vehicles
- diversity underestimated

Littoral and sublittoral zones

- disturbance by scouring ice
- sublittoral benthos can only develop fully in polar regions out of reach of scouring sea ice, around 10 m below low tide level
- below these depths an extreme example of severe habitat transformation is caused by icebergs
- without significant mechanical distubŕbance – a productive ecosystem

Vertical zonation of fauna in the shallow-water benthic community of McMurdo Sound.

A few mobile animals, but no sessile forms, are found in Zone I; the sessile animals in Zone II are mostly coelenterates and those in Zone III are predominantly sponges



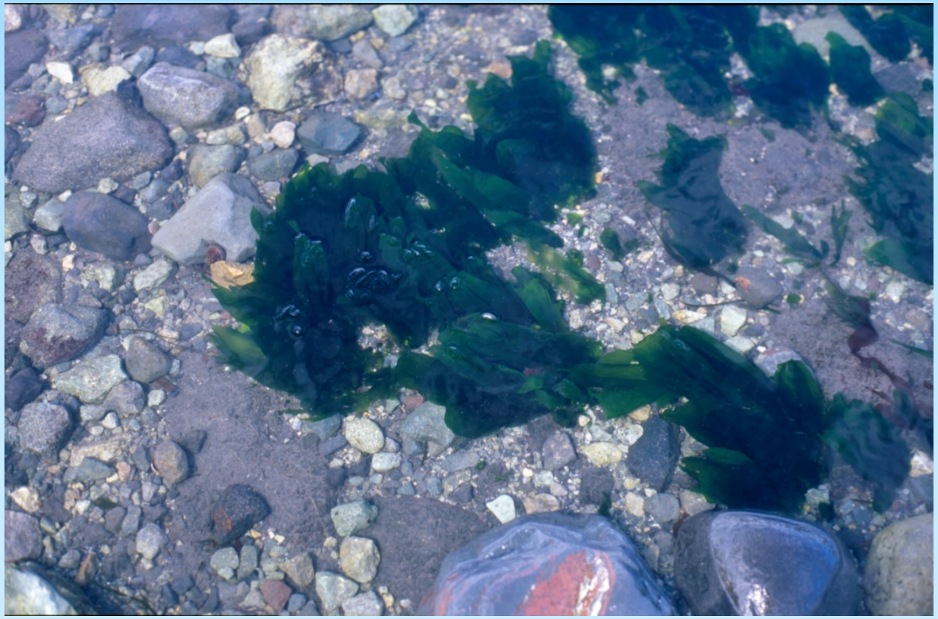
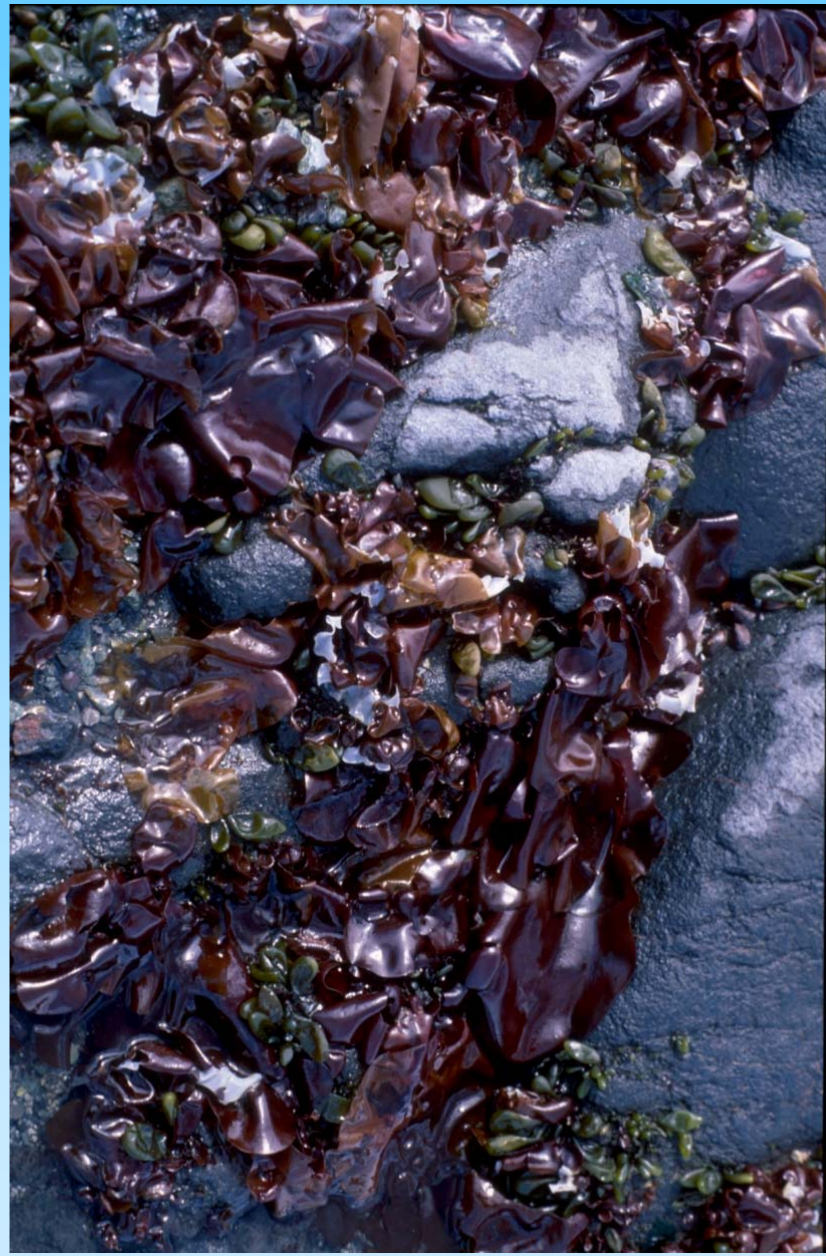
D.G. Lillie with siliceous sponges (the one he is holding was probably Rosella villosa) from the Ross Sea; Terra Nova expedition 1911-13. From Huxley (1913) Scott's Last Expedition, Smith, Elder & Co., London. Supplied by Scott Polar Research Institute.

Benthic macroalgae: maximal depth ?

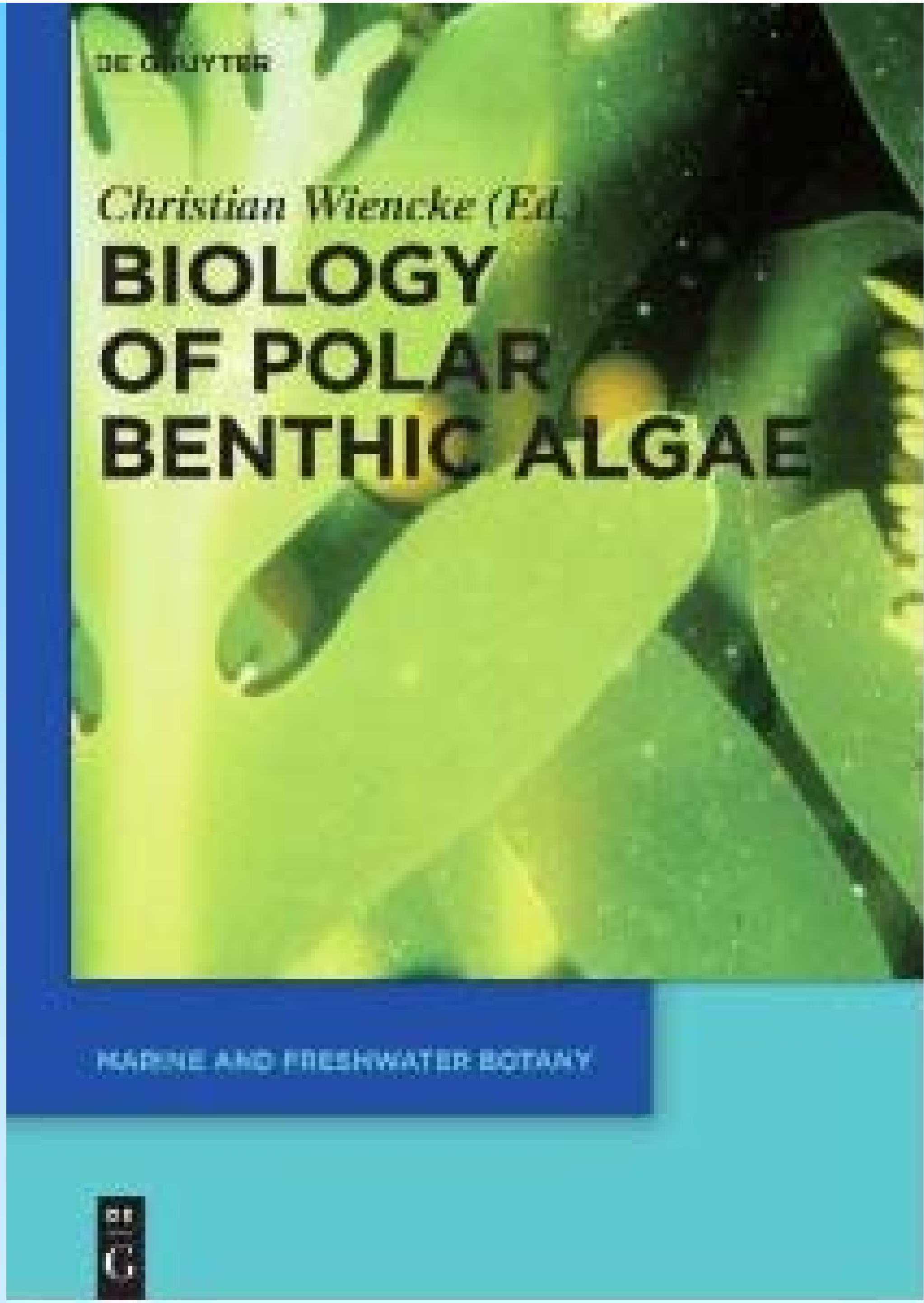
- below 40 m growth is sparse
- there are records of macroalgae from depths > 100 m
- photosynthetic growth was considered as possible at irradiances around 1 umol/m^2/s
- deep water red algae seem to survive at 0.05 umol/m^2/s

The most southern occurrence of benthic macroalgal assemblages was described from Ross Sea (**77°30´ S**.), where sea ice is 2 meters thick and persist 10 months per year.

Characteristic **vertical zonation** – 3 dominant species of red algae prefer different depths>
Iridaea cordata around 3,5 m,
Phyllophora antarctica 12 m
Leptophytum coulmanicum 18 m

The largest seaweeds can be found around Subantarctic islands – thalli of ***Macrocystis pyrifera*** can measure up to 40 m and have a significant impact on the whole littoral zone, because they act as a natural breakwater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BIOLOGY
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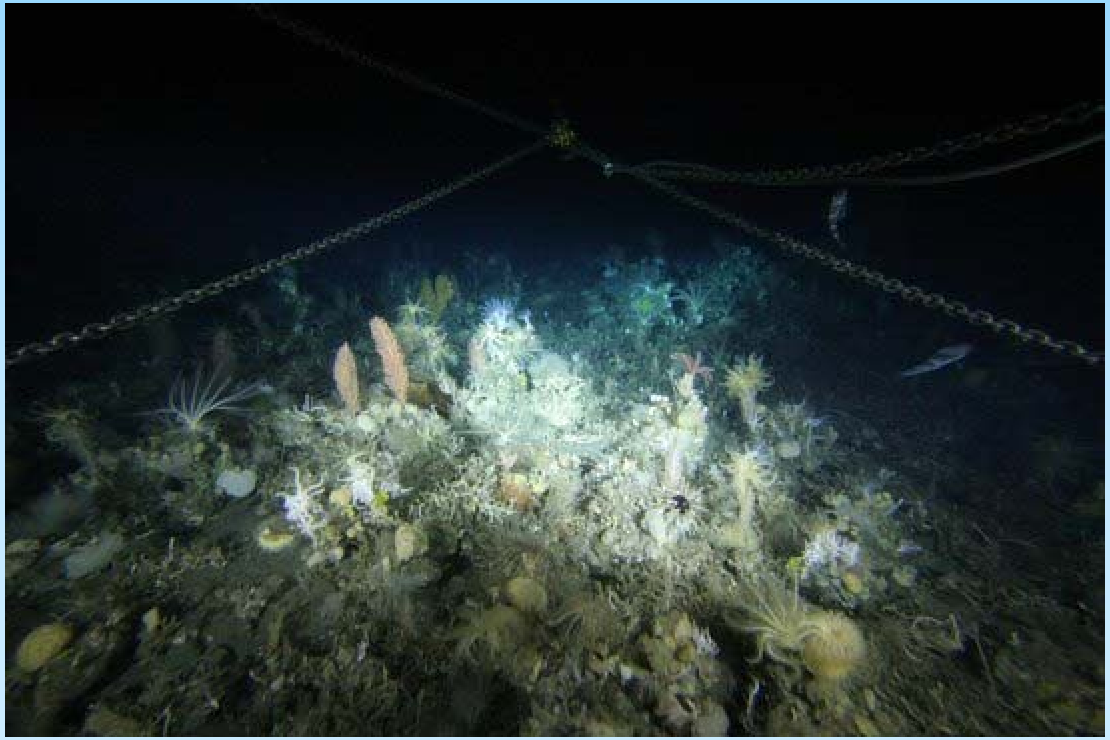
BENTHIC ALGAE
MARINE AND FRESHWATER BOTANY

Benthos of deep waters

• viewed as a region of low biodiversity.

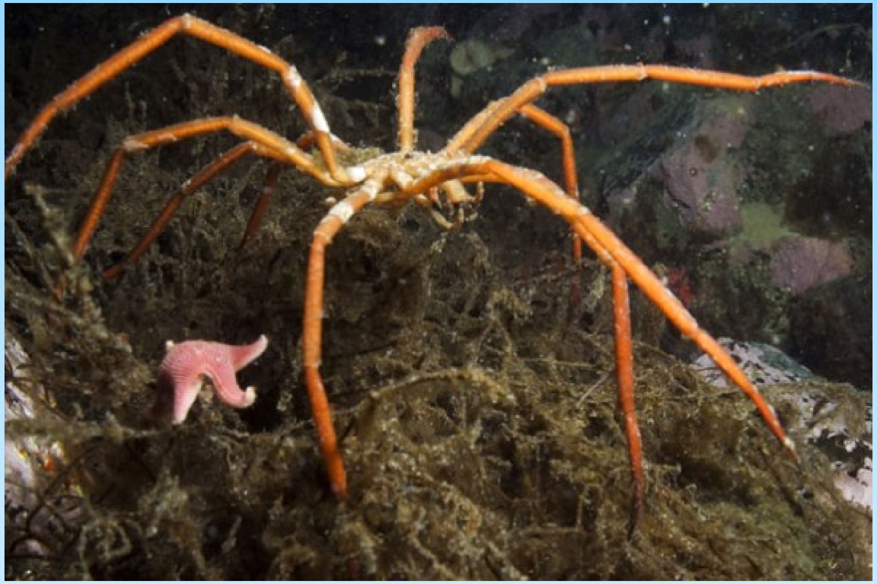
• however, three coordinated expeditions in the deep Weddell Sea (748-6348m) have shown this not to be true

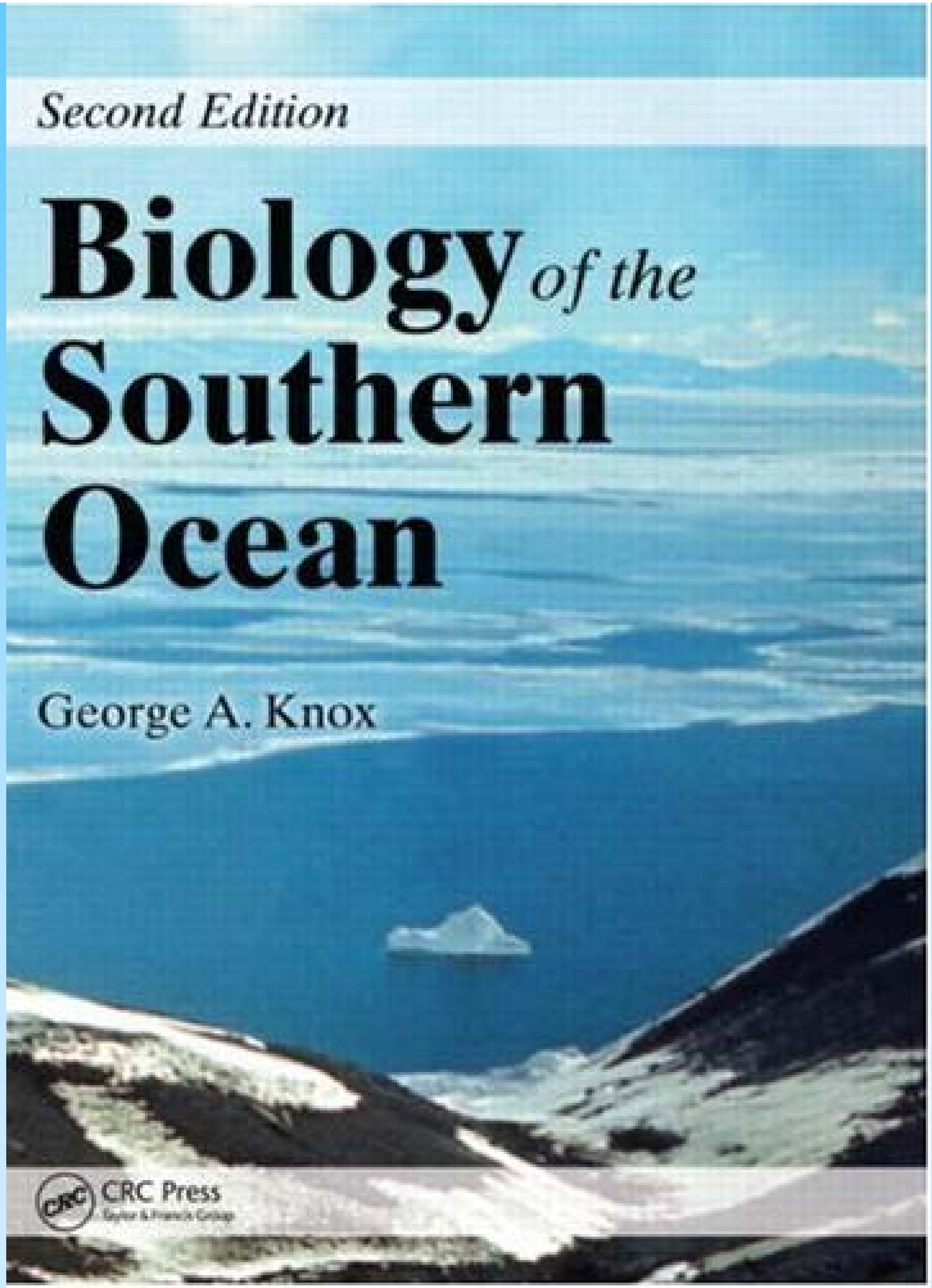
• among the 13000 specimens were: 200 polychaete species (81 new), 160 species of gastropods and bivalves, 76 species of sponge (17 new), 674 isopods (585 new), 57 nematode species, and 158 species of foraminifera



Gigantism

• slow, seasonal growth and delayed maturation
• low water temperatures certainly slow metabolic rates to the extent that growth rates are slow enough to enable organisms to live longer

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