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Supplementary material and methods

In situ chlorophyll *a*

Firstly, the filters were transferred to plastic centrifuge tubes, then 8–11 ml 90% acetone was added. The filters were treated with an ultrasonic device in an ice-bath for less than a minute, and then further extracted in the refrigerator for 2 h. After refrigerated centrifugation for another 10 minutes the chlorophyll/acetone extract was measured in a dark laboratory room. The fluorometer was calibrated with a spectrophotometer using a *Sigma* chl *a* standard. Individual in situ chl *a* values were integrated for the 100 m water column and finally one mean chl *a* m^{-2} was calculated for every cruise.

Protistian plankton composition

Samples were stored cool in dark brown glass bottles and preserved with hexamine neutralized formaldehyde (0.5-1% final concentration) until further analyses. Cells were allowed to settle for at least 48 h before being identified and counted with an inverted microscope at 100×, 200× and 400× magnification. Some species, such as very small flagellates, were identified only to genera. Phytoplankton species were grouped into the following functional groups: diatoms, autotrophic and heterotrophic nanoflagellates, autotrophic and heterotrophic dinoflagellates, coccolithophores and *Phaeocystis* spp. The *Phaeocystis* spp. mainly consist of *Phaeocystis pouchetii* (>90%), however, we were not able to differentiate *P. pouchetii* from *P. globosa* in all samples.

Supplementary concluding remarks and outlook

Our annual sampling highlights the situation in summer in the Arctic. Future research should include investigations of all seasons using automatic platforms. This is why we use sediment traps and also have included ocean colour remote sensing, which allows for estimating the pigment development at greater spatial and temporal scales. However, at high latitudes ocean colour satellite data have sparse coverage due to the presence of sea ice, clouds and low sun elevation. We are working on adapting our own PhytoDOAS algorithm (Bracher et al. 2009; Sadeghi et al. 2012) to retrieve phytoplankton groups from hyperspectral, biomass and the estimation of phytoplankton production from multispectral ocean colour satellite data to the Arctic region. We use the in situ data of the Plankton Ecology and Biogeochemistry in a Changing Arctic Ocean research group as input and for validation of these adaptations. Because of the limitation of hyperspectral satellite data

with their large footprints, this information on phytoplankton composition will be combined with standard multispectral ocean colour data and applied to all available satellite measurements (e.g., SCIAMACHY, GOME-2, OMI, TROPOMI, SeaWiFS, MODIS, MERIS, OLCI, VIIRS). Still, additional measurements during other seasons are essential to explore shifts in species in time and space.

Our goal is to continue our long-term sampling to evaluate and detect further changes in the biota of the different water masses of Fram Strait. In addition, we seek a more mechanistic understanding of biological changes in the Arctic pelagic ecosystem. In a further step, we are planning onboard incubation experiments to follow alterations at the base of the food web. Additional field campaigns during other seasons in international multi-ship efforts would be fruitful.

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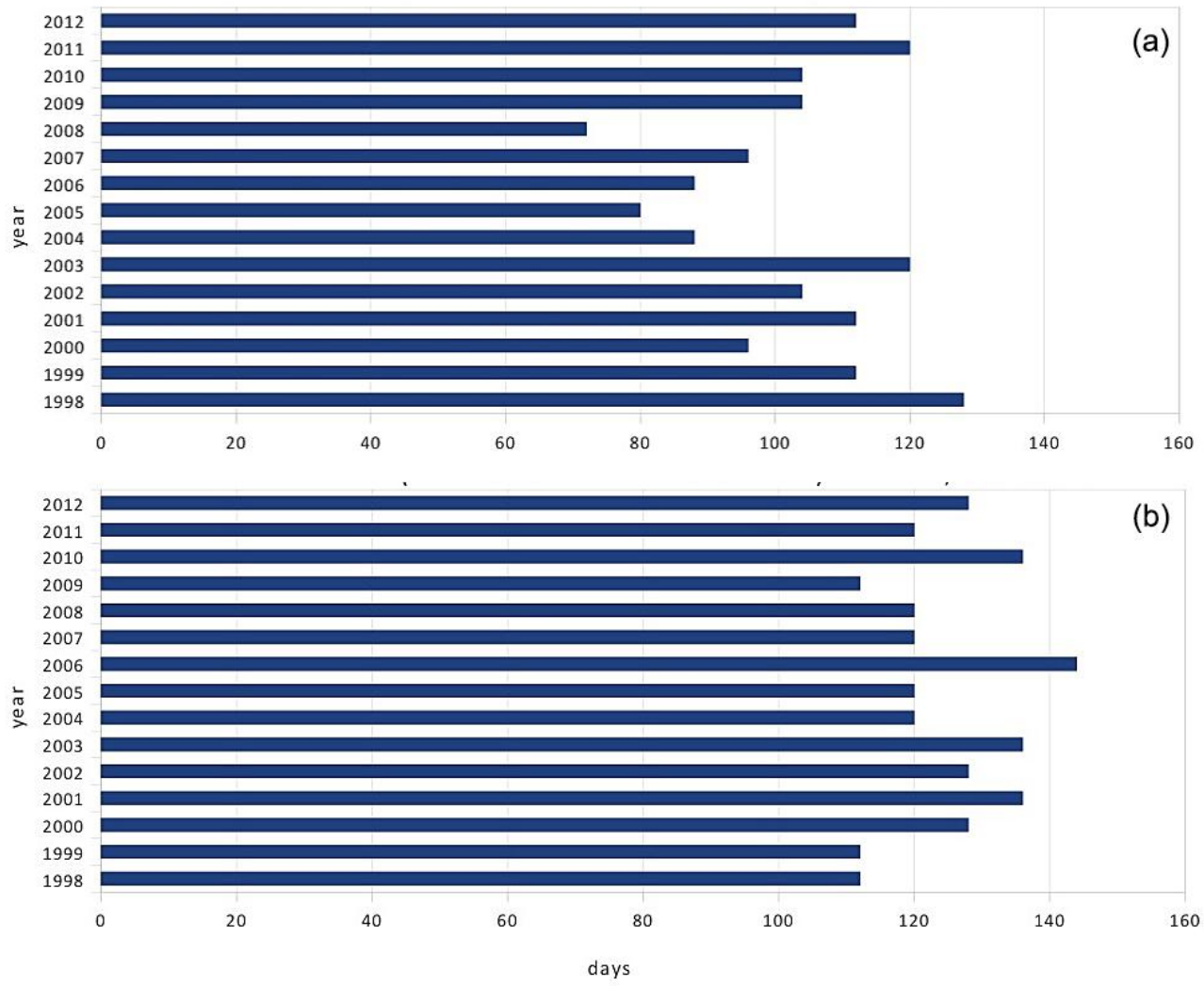
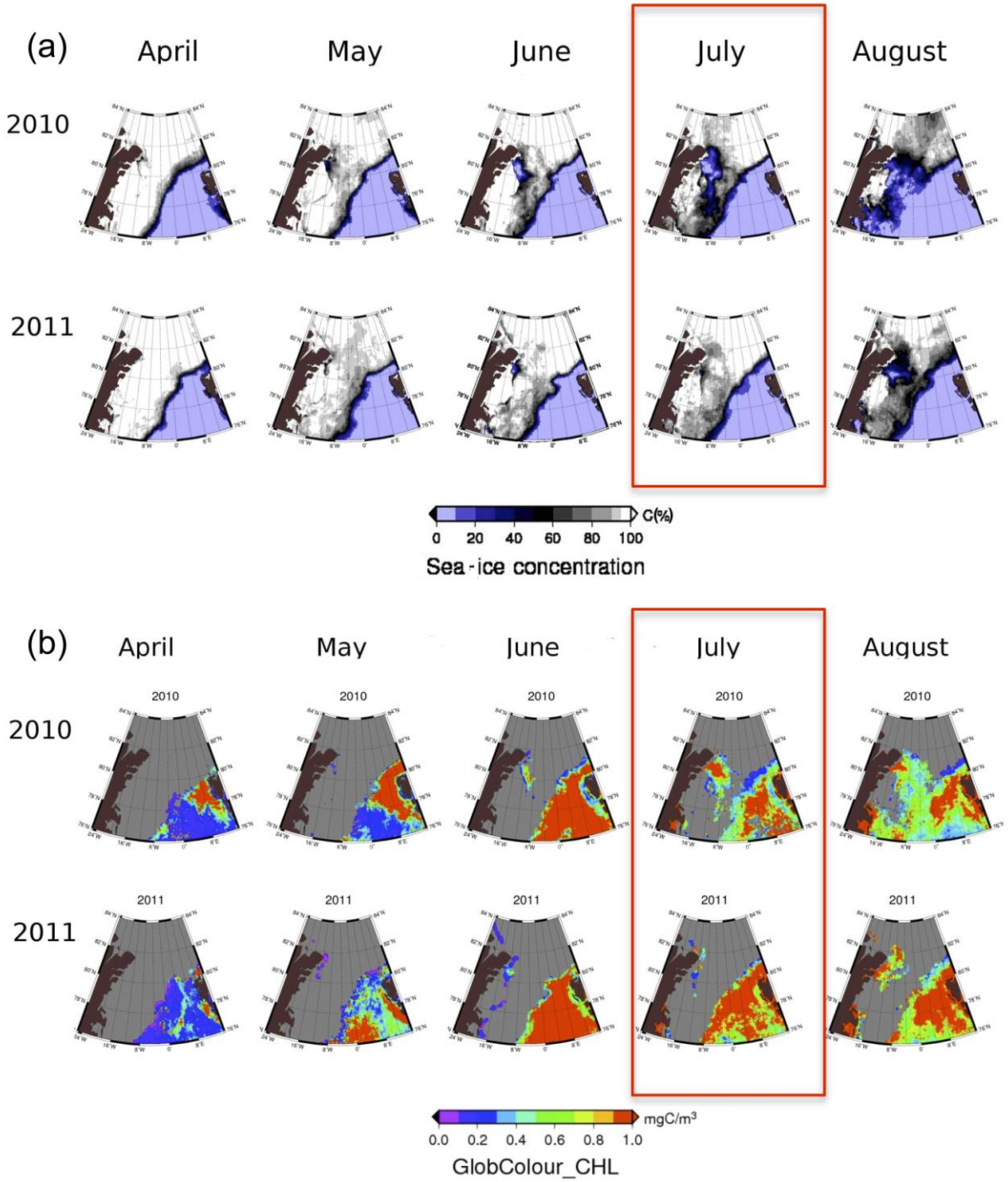
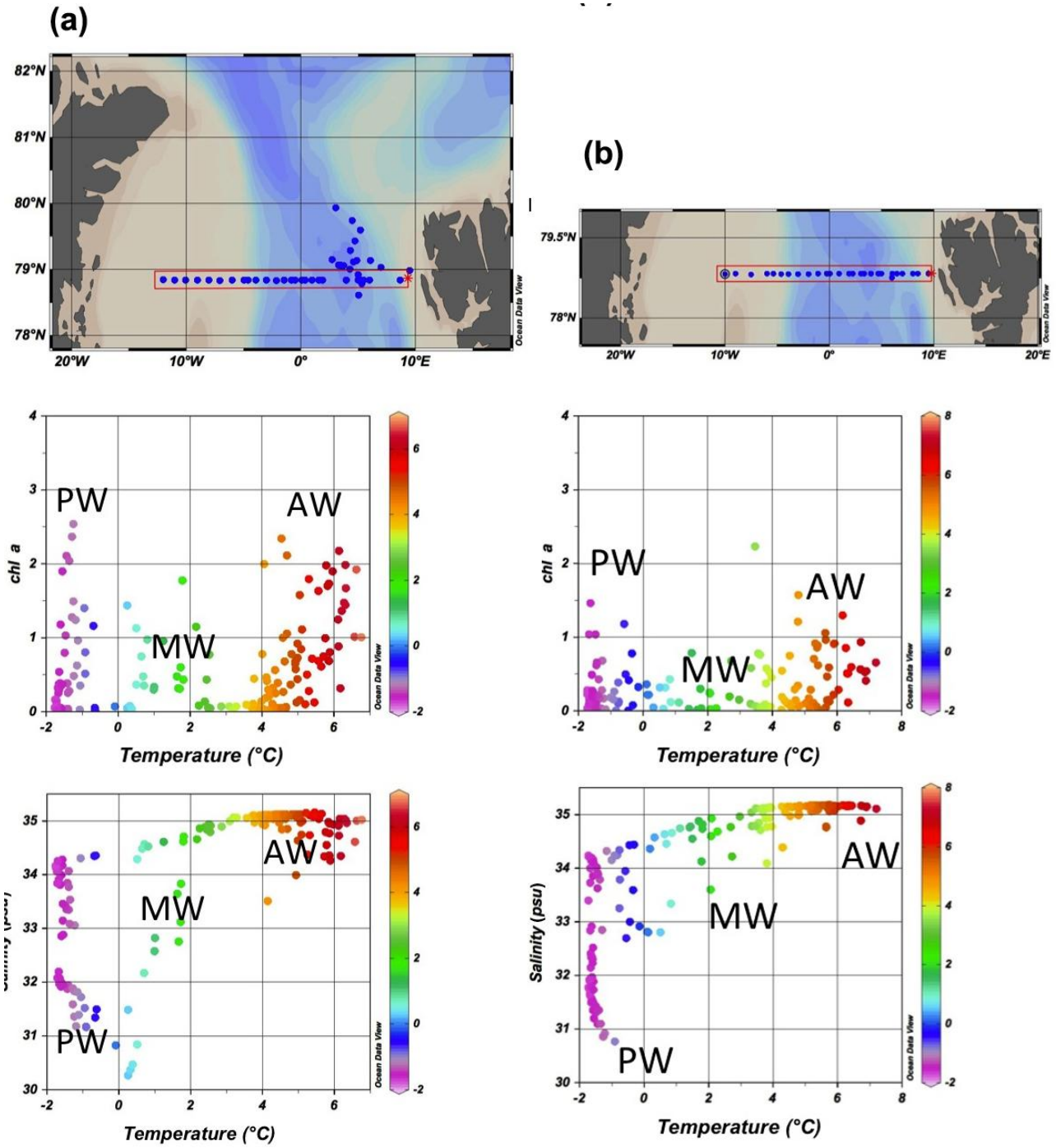


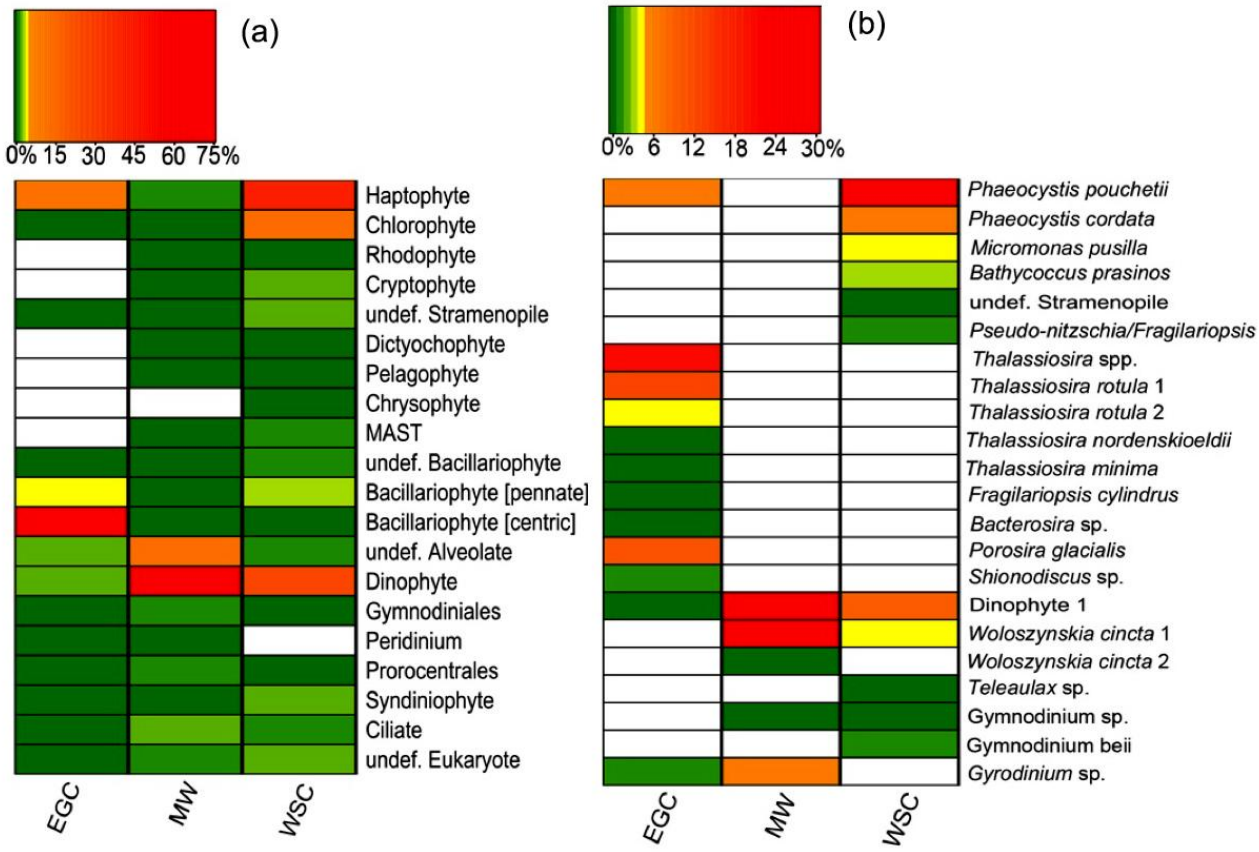
Supplementary Fig. S1. Time-series of bloom duration of eight-day means of satellite-retrieved GlobColour chlorophyll *a* averaged for the Fram Strait area. (a) East Greenland Current, 76°N-84°N, 15°W-0°, and (b) West Spitsbergen Current 76°N-84°N, 0°-15°E. To estimate the timing of the phytoplankton blooms, fine temporal resolution of the satellite data is required. As the daily data maps sometimes show no data, eight-day maps were chosen. These maps contain data for every eight-day file from the beginning of April to the end of August from 1998 to 2012. The threshold for the onset of the bloom was set to 1 mg chl *a* m^{-3}, as by Wu et al. (2007). For each year, the earliest eight-day map in which more than 5% of the pixels with data reached the threshold was assumed to be the onset of the spring bloom. Similarly, the ending of the bloom was determined as the latest eight-day period having more than 5% of the pixels with data reaching the threshold. The exact date assigned to the onset/ending of the bloom was the fourth day of the respective eight-day file. From this information the bloom duration was calculated.



Supplementary Fig. S2. Sea-ice concentration and chlorophyll concentration of satellite GlobColour chlorophyll *a*, which is the MERIS–MODIS–SeaWiFS monthly mean data within the Fram Strait area: 76°N-84°N, 25°W-15°E for the years (a) 2010 and (b) 2011; red rectangles mark cruise periods. Daily sea-ice concentration (SIC) maps were provided by the Physical Analysis of Remote Sensing Images Group of the University of Bremen (Spreen et al. 2008). SIC data were retrieved from the Advanced Microwave Scanning Radiometer–Earth Observing System (AMSR-E) data with a spatial resolution of 6.25 km. Satellite chl *a* level-3 data were taken from the GlobColour archive (http://hermes.acri.fr).



Supplementary Fig. S3. Section across Fram Strait during (a) ARK XXV/2, 2-23 July 2010 and (b) ARK XXVI/1, June 26 June – 10 July 2011 with the RV *Polarstern*, showing the relationship between chlorophyll a (chl *a*) concentrations (fluorometric measurements) and temperatures (°C) as well as the temperature/salinity relationships. The two latter show the separation of the section into three main water masses cold Polar Water (PW), mixed water (MW) and warm northern Atlantic Water (AW).



Supplementary Fig. S4. Heatmaps constructed on the basis of the relative sequence abundances (%) resulting from 454-pyrosequencing. (a) presented at the higher taxonomic level, including all sequences; (b) presented on lower taxonomic level including sequences that grouped in abundant operational taxonomic units (OTUs; >1% of total sequence number). Blank boxes represent the absence of (a) single groups and (b) abundant OTUs, respectively. For the East Greenland Current (EGC) we sequenced station 237 in 15 m depth, for the mixed water (MW) station 231 in 5 m depth and for the West Spitsbergen Current (WSC) station 124 in 15 m depth. All samples were taken in summer 2010.

Supplementary Table S1. Overview of the long-term data sets in the Fram Strait area.

Period	Parameter	Area covered	Method
1991–2012	chlorophyll *a*	cruises see Fig. 4 (RVs *Polarstern*, *Maria S. Merian*, *Lance*) 76°N - 84°N 15°W - 15°E	fluorometric and spectrophotometric method, water column upper 100 m
1998–2011	protists > 3 µm	at 8 stations close to 79°N, 4°E	counting with inverted microscope, water column upper 100 m
1998–2012	monthly mean chlorophyll *a*	76°N - 84°N 15°W - 15°E	Satellite, merged SeaWIFs, MODIS, MERIS chl *a* data from GlobColour product
1998–2012	phytoplankton bloom duration	76°N - 84°N 15°W - 15°E	Satellite, merged SeaWIFs, MODIS, MERIS chl *a* data from GlobColour product

Supplementary Table S2. Overview of the measured parameters shown in this article for the two RV *Polarstern* cruises in 2010 and 2011.

Cruise/ period	Parameter	Area covered and stations	Method
ARK XXV/2 2 - 23 July 2010	temperature, salinity, nutrients, phytoplankton pigments	23-28 stations along 7.6 - 7.9 °N 10°W - 10°E	CTD[a] probe, autoanalyser, HPLC[b], water column upper 100 m
	protists, all sizes	16 stations (ARISA[c]), 3 stations (454-pyrosequencing) along 78°N in chlorophyll *a* maximum	ARISA, 454-pyrosequencing
	bacteria, biogeochemistry	20 stations along 78.8°N 10°W - 10°E in water surface	Cell numbers, HNA[d]
ARK XXVI/1 26 June – 10 July 2011	temperature, salinity, nutrients, phytoplankton pigments	14-25 stations along 78.8°N 10°W - 10°E	CTD probe, autoanalyser, HPLC, water column upper 100 m
	bacteria, biogeochemistry	17 stations along 78.8°N 10°W - 10°E in chlorophyll *a* maximum	Cell numbers, HNA
	zooplankton copepods, amphipods	3 stations at 78.83°N, 5.34°W 78.83°N, 0.04°E 78.83°N, 8.02°E	multinet ø 0.25 m², 150 µm ø 0.5 m², 1000 µm five depth ranges (0 m - 50 m - 200 m - 500/600 m and 500/600 - 1000 m)

[a] Conductivity, temperature and depth. [b] High-performance liquid chromatography. [c] Automated ribosomal intergenic spacer analysis. [d] High-nucleic-acid cells.

Supplementary Table S3. Summary of nutrient concentrations for phosphate (PO_{4-}, µmol P), silicate (Si OH_4, µmol Si) nitrate and nitrite (NOx , µmol N; the nitrite concentrations were in almost all cases zero) for the two *Polarstern* cruises in 2010 and 2011. Mean concentrations and standard deviations (SD) across the entire Fram Strait are given for the upper 20 m and 20-100 m water column.

Cruise/ period	Depth	PO_4 (µmol P)	Si (µmol Si)	NOx (µmol N)
ARK-XXV/2 2 - 23 July 2010	0 - 20 m	0.16	2.07	1.54
	SD	0.15	0.77	2.02
	20 - ca. 100 m	0.49	3.41	6.77
	SD	0.19	1.31	3.62
ARK-XXVI/1 26 June – 10 July 2011	0 - 20 m	0.45	3.24	3.61
	SD	0.23	1.2	2
	20 - ca. 100 m	0.51	3.13	5.24
	SD	0.13	1.29	2.23