

Report on the Field Activities of the Czech Research Group in the Central Part of the Svalbard Archipelago (Isfjorden, Billefjorden, Petuniabukta) During the Summer of 2010

This research was conducted under the auspices of the “Biological and climate diversity of the central part of the Svalbard Arctic archipelago” project, sponsored by the Ministry of Education, Youth & Sport of the Czech Republic, INGO - LA 341 (2007 - 2010). This is an interdisciplinary (biology and climatology) research project. It is a member of the Network for ARCtic Climate and Biological DIVersity Studies (ARCDIV), an international multidisciplinary research initiative; organized under the auspices of the International Polar Year (IPY 2007 - 2008). From June 18 to September, 2010 seventeen researchers from four Czech institutions (University of South Bohemia in České Budějovice - Josef Elster, Oleg Ditrich, Tomáš Tyml, Alexandr Pospěch, Daria Tashyreva, and Alexandra Bernardová; Institute of Botany, Academy of Sciences of the Czech Republic - Jitka Klimešová, Alena Bartošová, Tomáš Hájek, Jana Kvíderová, Otakar Strunecký, and Martina Pichrtová; Masaryk University in Brno - Kamil Láska, Jan Gloser, Peter Vaczi and Denisa Witoszová; plus Comenius Prague - Miloslav Dvořáček) conducted the field research (**Fig. 1** and **2**).



Fig. 1. Research group at the beginning of the season.



Fig. 2. Research group at the end of the season.

In a manner similar to the 2009 season, the Czech research activities covered the following disciplines:

1. Climatology
2. Botany (phycology, lichenology, phanerology, and plant eco-physiology)
3. Zoology (parasitology)
4. Photography, and Education

The fieldwork conducted in 2010 was focused on various topics, e.g.: the seasonal dynamics of the photosynthetic and N₂-fixation activities of the cyanobacterium *Nostoc commune* s.l. in a wet hummock tundra, under both natural and controlled conditions (Open Top Chambers); the seasonal developments, photosynthetic activity, and production of the dormant stages in the green filamentous algae *Zygnema* sp. and filamentous cyanobacteria, Oscillatoriales, *Phormidium* sp.; lichen mapping; life histories of selected vascular plant species; marine diversity of littoral biocenoses, including host-parasite relationships; the seasonal servicing of the automatic climatic stations; and temporary microclimatic measurements of the energy balance in the ice-free coastal area beyond Petuniabukta; etc.

Climatology

Throughout the 2010 Svalbard expedition, the meteorological measurements and climate research activities were carried out in the ice-free coastal zone of Petuniabukta (North-Western branch of Billefjorden) from June 22 through July 2, 2010. The main objective of the fieldwork activities was the maintenance and technical servicing of the meteorological stations, as well as the permanent study plots located in their vicinity (**Fig. 3**). Moreover, a temporary microclimate station for the measurement of the surface energy balance was operated in the coastal zone of Petuniabukta for two months. In the middle of September 2010, the microclimatic station was dismantled due to the potential of damage and failures of the highly sensitive instruments from the extreme weather conditions expected during winter.



Fig. 3. Location of the automatic weather stations along the northern coast of Petuniabukta.

Currently, six automatic weather stations (AWS) are operational along the northern coast of Petuniabukta at the following locations:

- AWS1 - an old marine terrace, at an altitude of 15 m a.s.l. (operational since 2008)
- AWS2 - an old marine terrace, at an altitude of 25 m a.s.l. (operational since 2008)
- AWS3 - at the head of Hørbye Glacier, at 67 m a.s.l (operational since 2008)
- AWS4 - on a mountain ridge of Mumien Peak, at 475 m a.s.l. (operational since 2008)
- AWS5 - a hummock tundra / thufur field, altitude 8 m a.s.l. (operational since 2009)
- AWS6 - on Pyramiden Peak, at 935 m a.s.l. (operational since 2009)



Fig. 4. Automatic weather station (AWS1), at the altitude of 15 m a.s.l.

Each AWS was equipped with an identical set of sensors to measure the air temperature and relative humidity at the height of 200 cm, as well as the soil temperature and volumetric water content (VWC) at depths of both 5 and 15 cm. Additionally, an extended monitoring program was carried out at AWS1 (**Fig. 4.**). It consisted of sensors for the measurement of: global and reflected shortwave radiation (used for the calculation of albedo), photosynthetically active radiation, wind speed and direction, air pressure, surface temperature of the tundra vegetation, as well as the soil temperature profile from ground level to a depth of 150 cm. In June 2010, new soil temperature sensors (platinum resistance thermometers) were installed at depths of 15, 30, 50, and 75 cm.

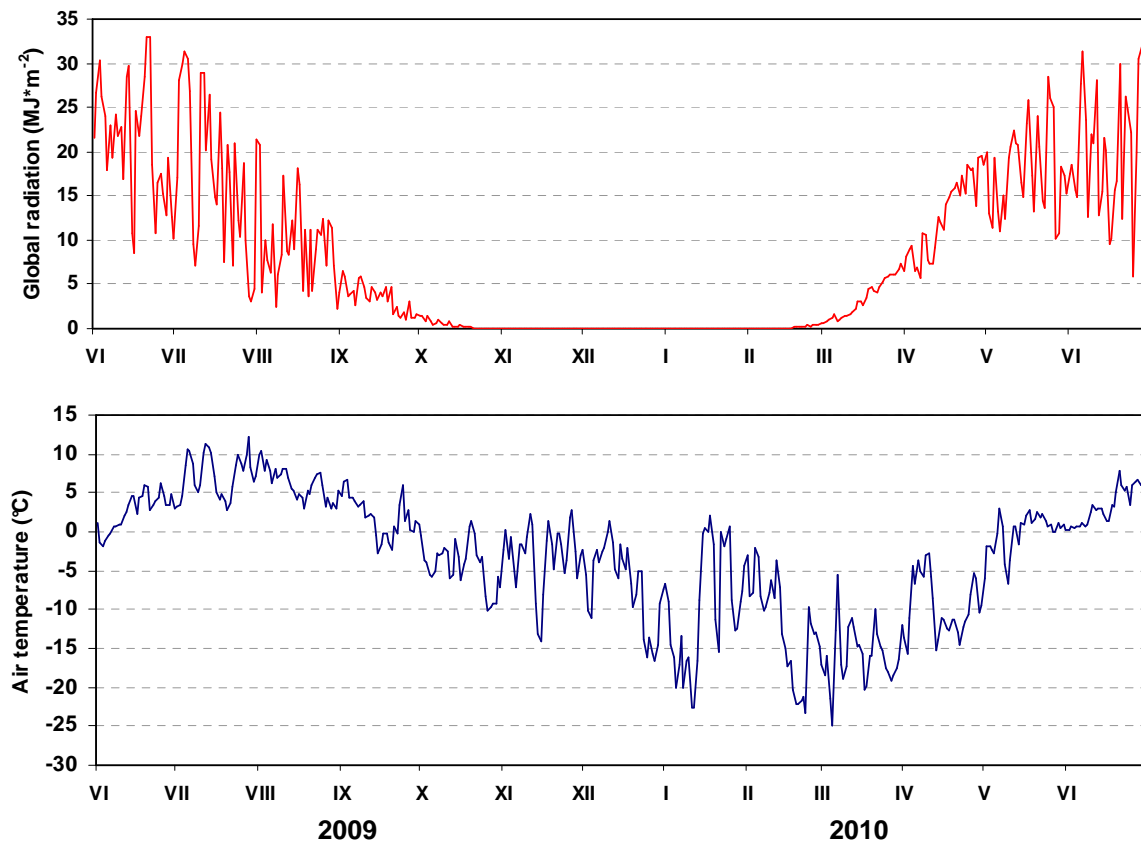


Fig. 5. Variation of the daily sums for global solar radiation and daily mean air temperature at Petuniabukta (AWS1) in the period July 2009 to June 2010.

The further analysis of climatic conditions at Petuniabukta was based on the evaluation of several meteorological data sets acquired from July 1, 2009 through June 29, 2010. During the period investigated, the mean air temperature at AWS1 was -3.6°C (Fig. 5). The absolute temperature minimum (-27.8°C) was recorded on March 5, 2010 at AWS1; the absolute temperature maximum (16.2°C) was recorded on July 28, 2009. In comparison to the previous years (2008/2009), the absolute minimum temperature occurrence was found to have occurred 3 months earlier (January 12, 2009).

For the entire period investigated, the mean global shortwave radiation was $95.1 \text{ W}\cdot\text{m}^{-2}$. However, the daily maximum global radiation intensity reached $369 \text{ W}\cdot\text{m}^{-2}$ on June 28, 2010 (Fig. 5). The mean surface temperature of the tundra vegetation (-4.0°C) corresponded to the length of the permanent snow cover existing for 8 months in the coastal zone of Petuniabukta (Fig. 6). In contrast, the maximum surface temperature rose to 26.5°C during the short summer period (July 11, 2009).

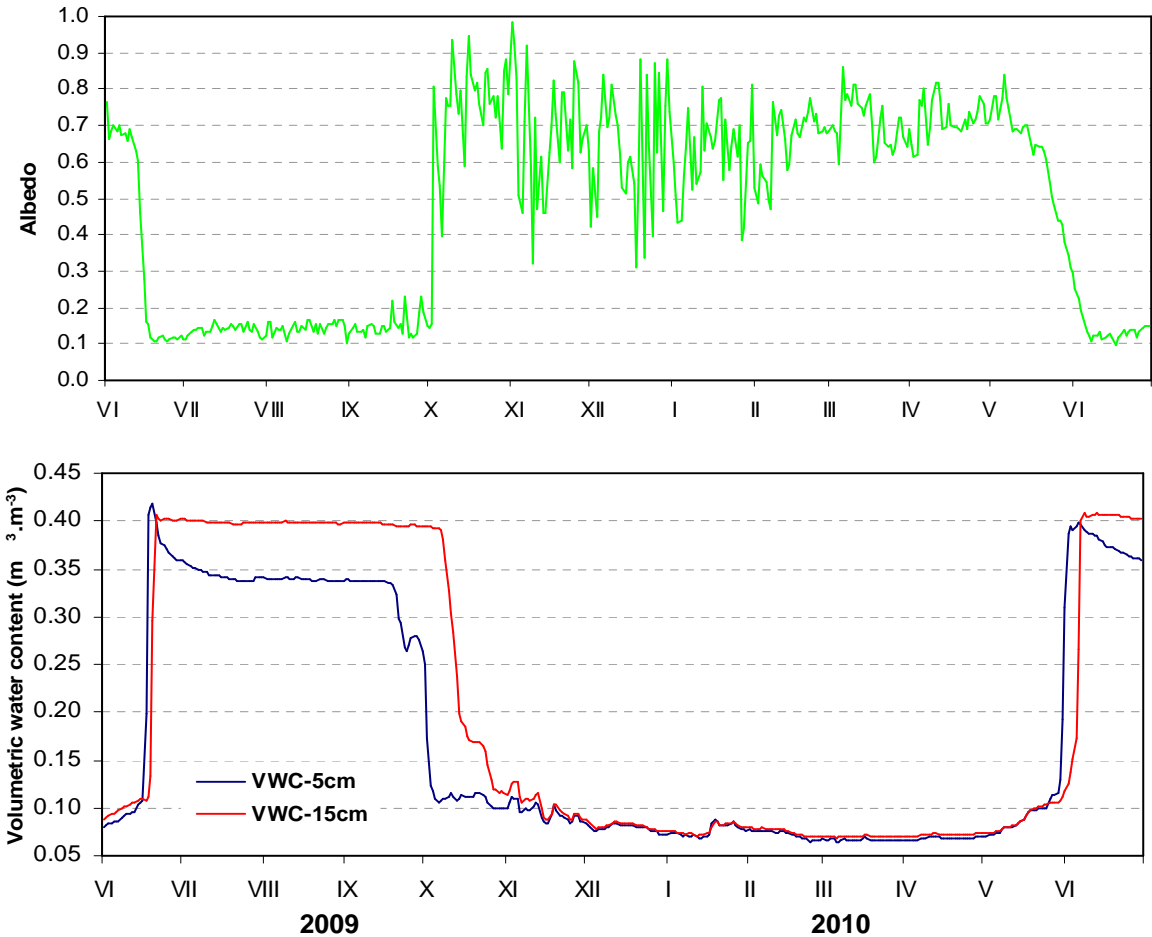


Fig. 6. Variation of daily mean albedo, and the volumetric water content (AWS1) at Petuniabukta, during the period July 2009 to June 2010.

In the period from July 1, 2009 to June 29, 2010, the volumetric water content (VWC) ranged from $0.06 \text{ m}^3\cdot\text{m}^{-3}$ to $0.42 \text{ m}^3\cdot\text{m}^{-3}$ at a depth of 5 cm; and ranged from $0.07 \text{ m}^3\cdot\text{m}^{-3}$ to $0.41 \text{ m}^3\cdot\text{m}^{-3}$ at a depth of 15 cm. Furthermore, it clearly was established that snow cover accumulation strongly influenced the changes in VWC, especially at the 5 cm depth (Fig. 6). In the winter period, VWC at depths of 5 and 15 cm dropped to similar levels, and only varied from $0.06 \text{ m}^3\cdot\text{m}^{-3}$ to $0.07 \text{ m}^3\cdot\text{m}^{-3}$ (AWS1). During the summer period, the volumetric water

content can reach up to $0.42 \text{ m}^3 \cdot \text{m}^{-3}$ at the 5 cm depth due to melt water from the nearest snow patches. We found that the mean soil temperatures during the period investigated ranged from -3.7°C at the depth of 5 cm; to -2.9°C at 75 cm.

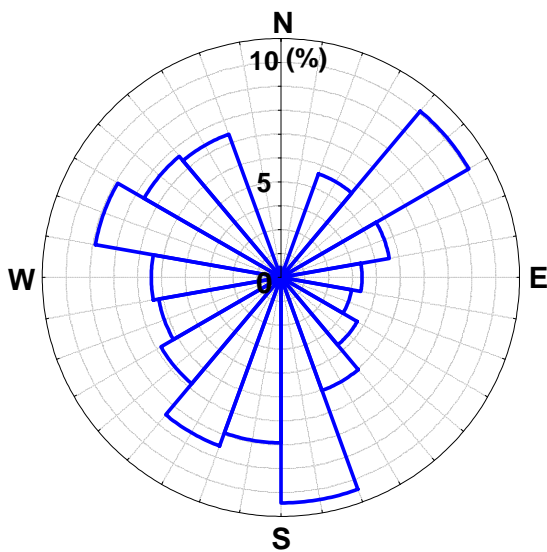


Fig. 7. The predominant wind direction was from the S-SSE in Petuniabukta, in the period July 2009 to June 2010.

The analysis of the prevailing winds was based on data from the period July 7, 2009 through June 29, 2010. However, there were some gaps in the data caused by snow and ice accumulation (rime) on the anemometers. The predominant wind direction was from the S-SSE, which distinctly corresponded to the local orography and the longitudinal axis of Petuniabukta (**Fig. 7**). The second most common prevailing wind direction occurred from the NE sector, which could be correlated with the location of the Ragnarbreen Glacier in the Ragnardalen Valley, where local (e.g. katabatic) winds exist. The mean wind speed recorded at AWS1 was $3.9 \text{ m}\cdot\text{s}^{-1}$. Furthermore, it was found that the strongest winds blow from the NE sector, although rarely does it exceed $20 \text{ m}\cdot\text{s}^{-1}$.

During the summer period (June 24 - September 16, 2010), the total precipitation measured along the northern coast of Petuniabukta exceeded 14 mm. Most of the precipitation fell in a liquid state as drizzle. The maximum amount of precipitation reached 7 mm, as recorded from August 12 to 14, 2010.

Botany

Phylogenetic and molecular diversity of cyanobacteria

For the 2010 season in Svalbard, the major portion of the research (researcher Otakar Strunecký) was funded by the EEA research fund (<http://www.eea-researchfund.cz/>). Cyanobacterial samples were collected at Petuniabukta, Longyearbyen, and the vicinity of Ny-Ålesund.

The cyanobacterial research encompasses three topics:

1. Biogeography of *Phormidium* s.l. (Oscillatoriales)
2. Searches for possible non-indigenous species
3. Taxonomy of other groups belonging to Oscillatoriales

Ad 1. During 2009, we had collected, isolated, and sequenced 14 genetically-distinct strains. Preliminary results showed that these strains grouped into two clusters of *Phormidium* sequences of different geographic or/and habitat origin (**Fig. 8**). In addition, another two genetically-distinct strains were collected from under the bird cliffs. These results outlined the necessity of gathering other strains of cyanobacteria from more diverse habitats than the streams and periodic pools. In the 2010 season, more than 80 samples were collected, with approximately 50 strains of *Phormidium*. To obtain a more

detailed view of the diversity of Oscillatoriales, *Phormidium* samples were again sampled from most of the shallow wetland habitats (e.g. soil crust - **Fig. 9**) in Petuniabukta and the adjacent parts of Billefjorden. In similar habitats, Oscillatoriales were also collected in the vicinity of Ny-Ålesund and Longyearbyen.

Ad 2. Special attention was given to specimens collected from habitats strongly influenced by anthropogenic activities. Here, could be found *Phormidium autumnale* genotypes, which had been transported to Svalbard from various parts of the world. Strains had been isolated from the Russian settlement of Pyramiden in Petuniabukta. Additionally, several samples were collected and isolated in the area of the campsite, as well as in the vicinity of the Longyearbyen airport, as well as within of settlement of Ny-Ålesund. "

Ad 3. The taxonomy of other groups of Oscillatoriales such as *Phormidesmis*, *Phormidium prystleyi*, and *Leptolyngbya* was included into the field research of the 2010 season. However, the precise conclusions on taxonomy of the collected specimens must wait the completion of genetic analysis in the laboratory.



Fig. 8. Example of *Phormidium autumnale* specimen from Petuniabukta.



Fig. 9. Cyanobacteria soil crust in Petuniabukta.

Seasonal dynamics of photosynthetic and N₂-fixation activities of cyanobacterium *Nostoc commune* s.l. in a wet hummock tundra

The wet hummock tundra in Petuniabukta (Billefjorden, Central Svalbard, High Arctic) is a diverse and productive habitat (**Fig. 10**) that serves as an important source of food for herbivores in the local terrestrial ecosystem. The cyanobacterium *Nostoc commune* s.l. produces a high biomass in wet hummock tundra microhabitats, forming macroscopic colonies of filaments embedded in extracellular polysaccharides (**Fig. 11**). In the Arctic, cyanobacteria play a key role in nitrogen cycling due to their nitrogenase activity, allowing for the fixation of N₂, which also affects the ecosystem's primary production and carbon cycle. Moisture and irradiance represent the most important ecological factors influencing the physiological activities of cyanobacteria. We tested how the *Nostoc* colonies respond to seasonal fluctuations of light intensity and water availability (cycles of desiccation and rewetting) *in situ* during the Arctic summer, June to September 2010. We monitored their photosynthetic activity (chlorophyll fluorescence) and nitrogenase activity (acetylene reduction assay). The effects of slow desiccation, followed by rewetting, was studied in the

fully hydrated field-grown colonies under different irradiances ($\cong 50, 200, \text{ and } 900 \mu\text{mol of PAR m}^{-2} \text{ s}^{-1}$) on a table in front of the field station at ambient temperatures. Direct sunshine, represented by the highest irradiance level, strongly inhibited not only the photochemical processes in photosystem II (**Fig. 12** and **13**), but also the nitrogenase activity (**Fig. 14**) of both the rehydrated and control (non-desiccated) colonies. In summary, direct sunshine leads to desiccation, as well as to light-induced stress in the *Nostoc* colonies, resulting in an attenuation of the biological nitrogen fixation in the Arctic wet hummock tundra ecosystem.



Fig. 10. Hummock wet tundra, with experimental site.



Fig. 11. Dry and wet colonies of *Nostoc commune* s.l..

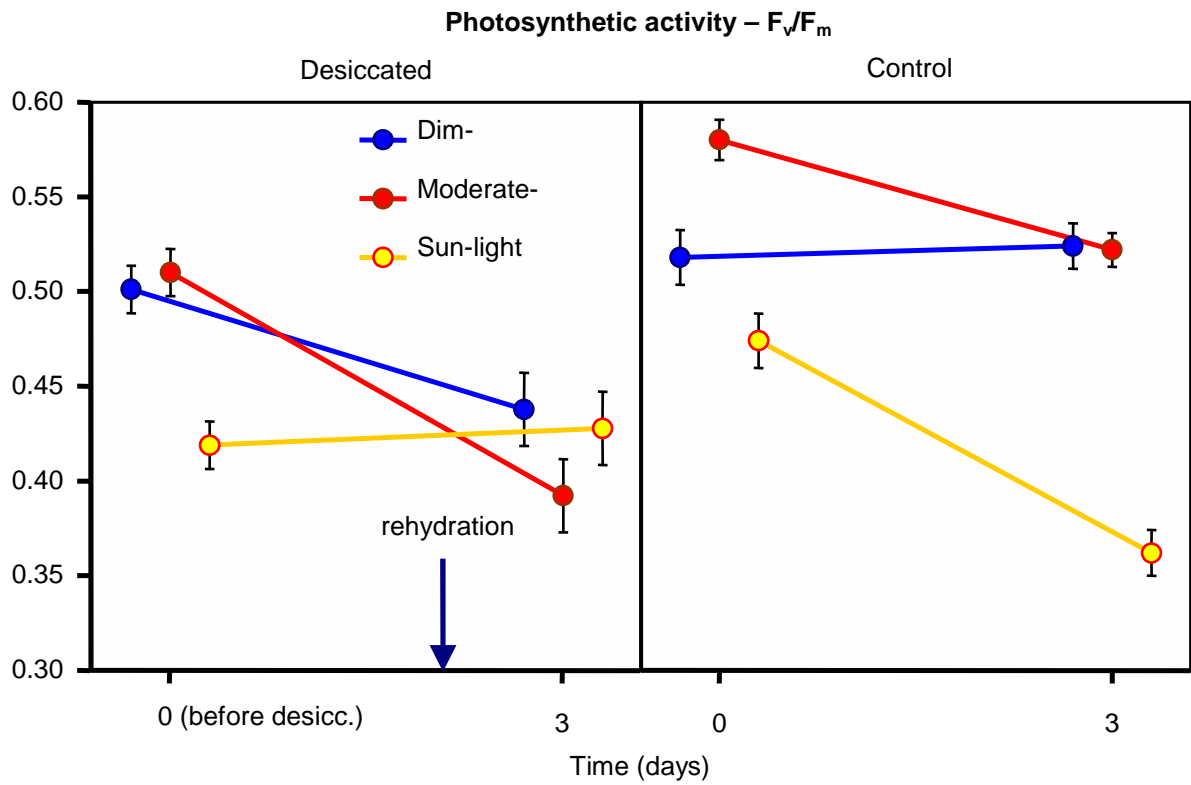


Fig. 12. Maximum quantum yield of colonies studied.

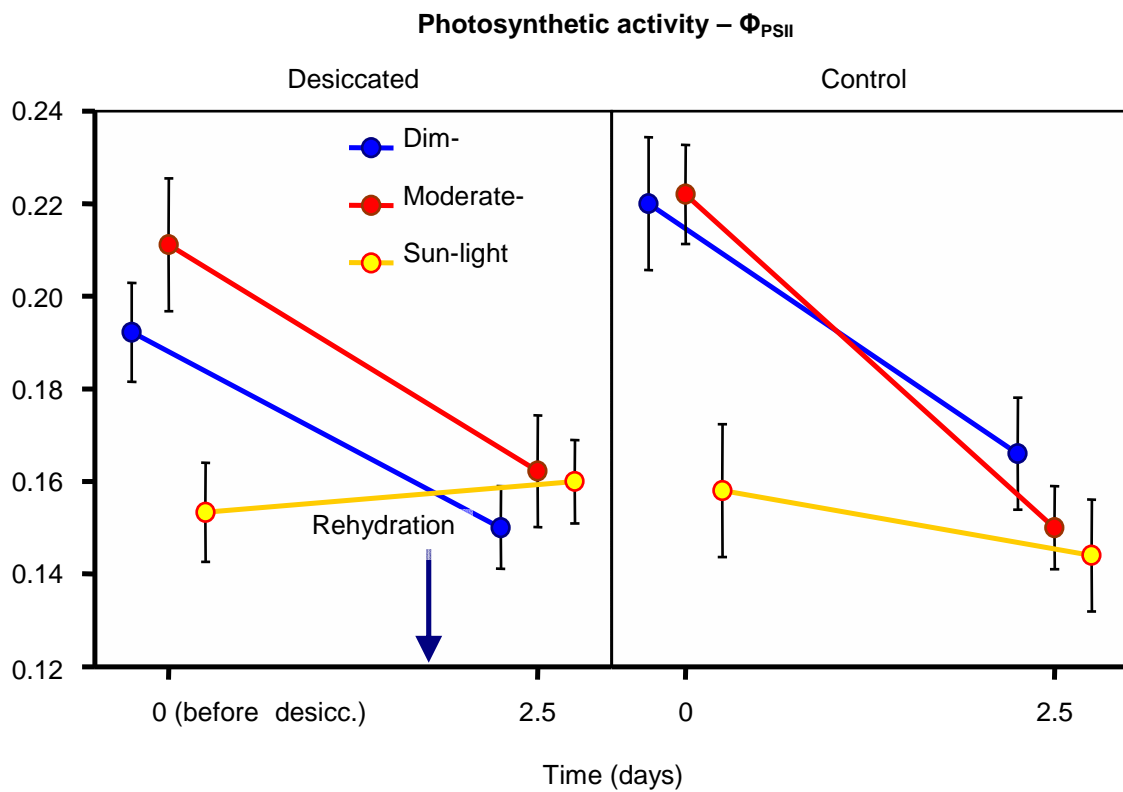


Fig. 13. Actual quantum yield of colonies studied.

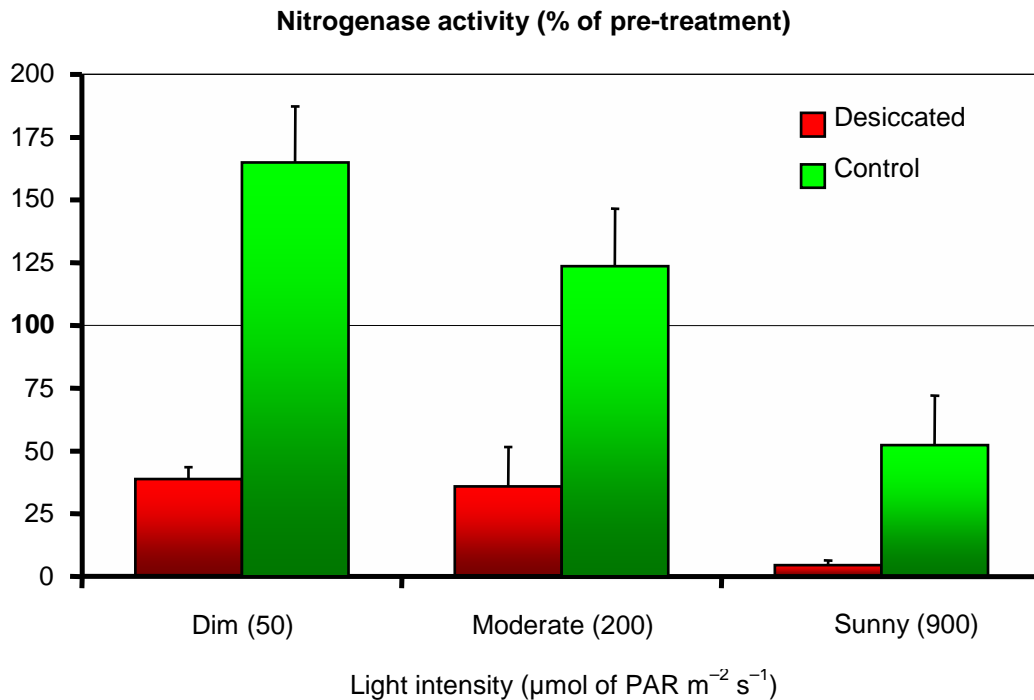


Fig. 14. Nitrogenase activity of colonies studied.

Field temperature and water content (humidity) manipulation (OTC - Open Top Chambers) and response of cyanobacterium *Nostoc commune* s.l.

As shown above, the wet hummock tundra is a diverse and productive habitat. Here, cyanobacterium *Nostoc commune* s.l. produces a high biomass. Moisture and temperature represent the most important ecological factors influencing the cyanobacterial physiological activities. Since summer 2009, we have monitored the *Nostoc commune* s.l. colonies' responses to changes in temperature and moisture in OTC and control boxes (CB). In OTC and CB, both the photochemical performance (chlorophyll fluorescence parameters - F_v/F_m , Φ_{PSII} , qP , and NPQ) and nitrogenase activity, together with the temperature and water content (humidity) are monitored. One year, the microclimate data showed that the OTC manipulation significantly changed the microclimatic conditions (**Fig. 15**). There are remarkable differences in mean summer temperatures and moisture between the top and the base of the thufurs. There are also differences between OTC and CB through the duration of a summer season. However, one year's measurements did not show any statistically significant changes in either the fluorescence parameters nor nitrogenase activity of the monitored *Nostoc commune* s.l. colonies (**Fig. 16**).

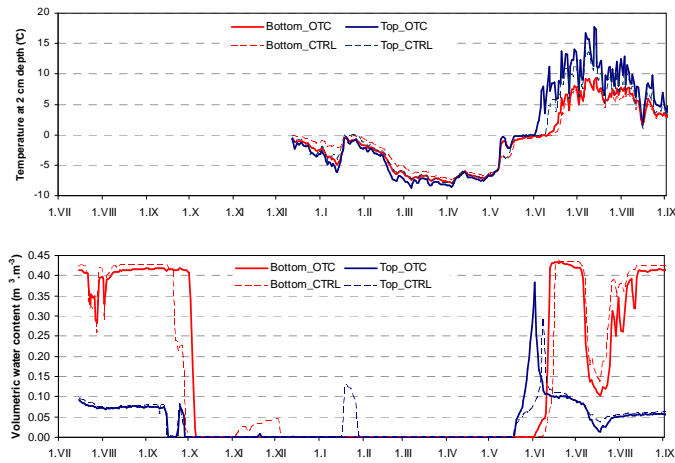


Fig. 15. The year's (7.1.2009 - 9.1.2010) changes of temperature and water content in the wet thufur tundra (OTC and CB – Cabe).

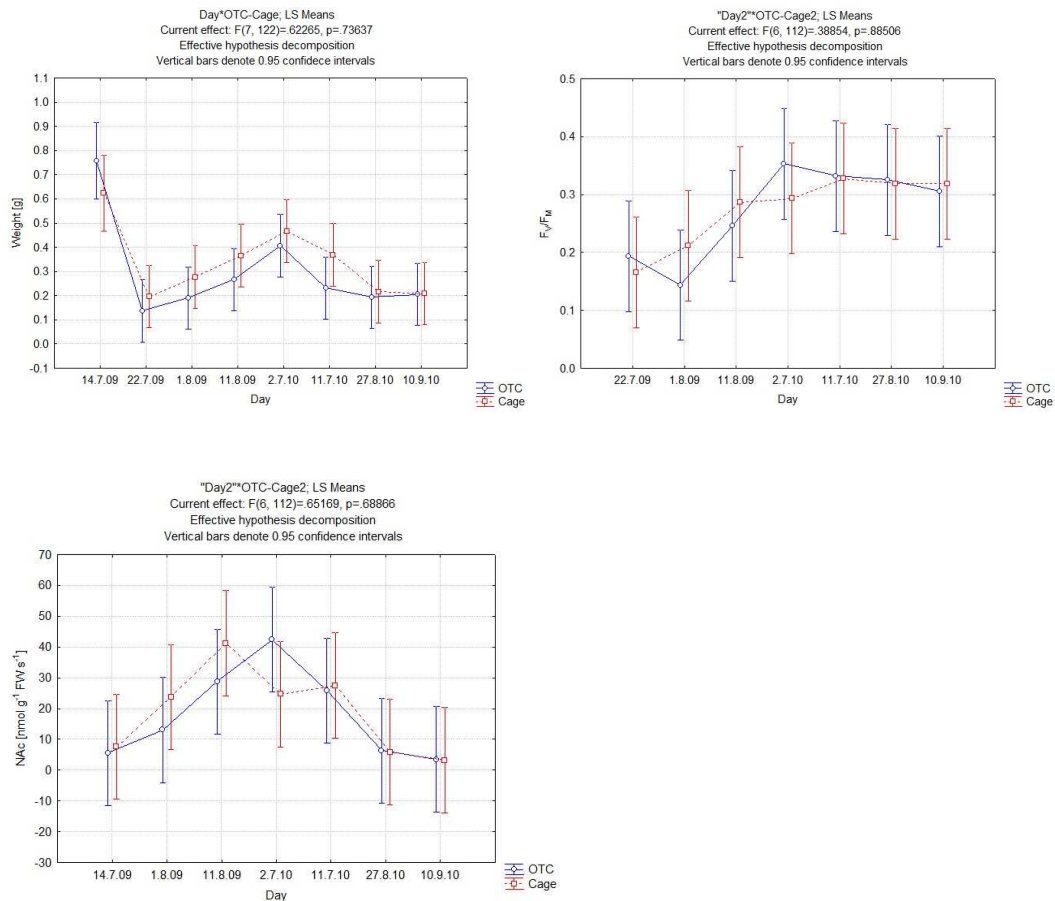


Fig. 16. The year's (7.14.2009 - 9.10.2010) changes of weight, maximum quantum yield, and nitrogenase activity of *Nostoc commune* s.l. colonies, in wet thufur tundra (OTC and Cabe/Cage).

Green alga *Zygnema* in Svalbard - seasonal development, photosynthetic activity and production of dormant stages

Zygnema (Zygnematophyceae, Streptophyta) is a filamentous green alga that grows in shallow pools or on the surface of wet soils where it can form massive mats. The genus has a cosmopolitan distribution, including the Polar Regions. On Svalbard, it is quite abundant in meltwater streams and pools, and therefore it is one of the most important primary producers of this region. The aim of our study was to investigate how the populations develop throughout the season, with respect of their cells' morphology and photosynthetic activity, measured by the chlorophyll fluorescence method. Our investigation lasted for almost three months (mid-June to mid-September). Soon after the snow melt, the study sites turned green, as mats of *Zygnema* quickly overgrew the newly developed pools. Altogether, 4 sites were chosen, and in each of them we marked out 20 sub-sites using glass rings. Chlorophyll fluorescence measurements, as well as microscopic observations of the biomass were carried out nine times during the investigation period, under various weather conditions. Each time, samples of the biomass were taken, and fixed with 3% formaldehyde, for subsequent morphological evaluation. In addition, the water (soil) temperature and irradiance also were measured. Towards the end of the growing season, some of the sites became completely desiccated, as meltwater was no longer available. In addition, freezing during the nighttime occurred repeatedly, starting from the end of August. After this, the biomass changed its appearance from mucilaginous bundles into crust-like films (**Fig. 17a,b**). The highest value measured for the maximum quantum yield (Fv/Fm) was 0.55 for population No. 1, 0.58 for No. 2, 0.65 for No. 3, and 0.6 for No. 4. However, this value was measured after keeping the biomass in darkness for 8 hours. Under natural conditions, where the irradiance reached to $1500 \mu\text{mol m}^{-2} \text{s}^{-1}$, the quantum yield was always much lower; showing that such conditions are rather stressful for the alga, and that it takes them quite a long time to recover. Interestingly, the cells of *Zygnema* retained their viability and photosynthetic activity even at the end of the season - when the biomass was partly desiccated, and had already undergone several diurnal freezing-thawing events (**Fig. 18**). The morphology and its changes during the season are currently being evaluated, and will supplement the fluorescence data with information about the possible occurrence of specialized dormant stages at the end of the summer season.

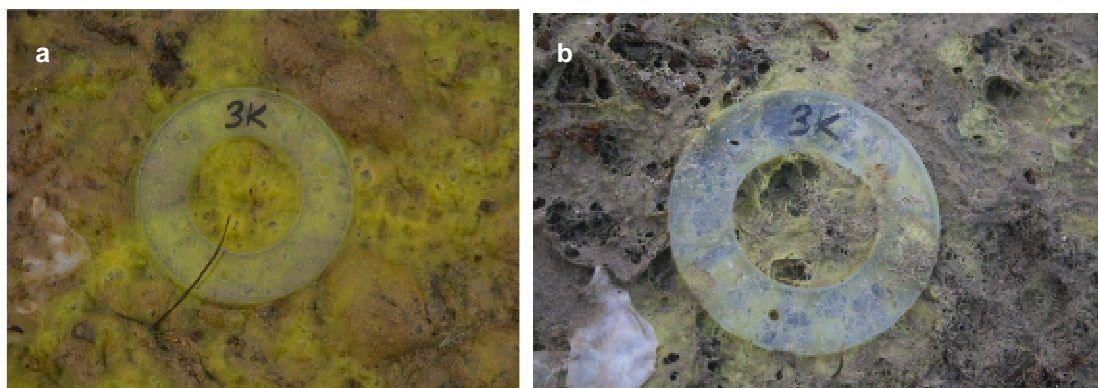


Fig. 17. Sampling site 3 on (a) July 4th, and (b) September 13th.

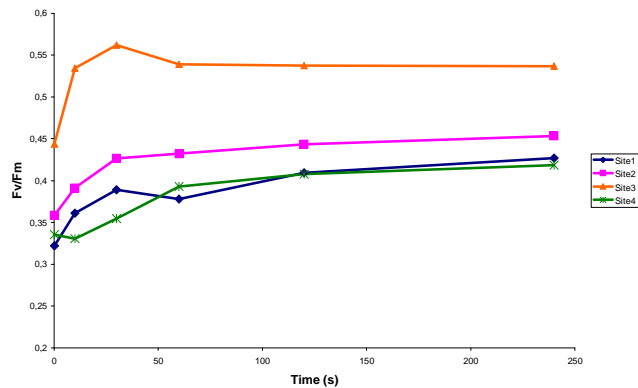


Fig. 18. Graph showing measured values of the fluorescence parameter F_v/F_m on September 8th. The X-axis shows the time since the biomass had been collected (and put into darkness).

Seasonal development of cyanobacterial *Phormidium*-dominated biofilms

Phormidium belongs to the non-akinetete-forming filamentous cyanobacteria (Oscillatoriales), which are very common in both Polar Regions. In the Arctic, *Phormidium* occupies various types of wetlands including seepages, shallow pools, streams, as well as wet soils and rocks. They are one of the most abundant photosynthetic organisms, and often accumulate a great biomass in the form of thick biofilms and crusts. Very well-known are the numerous stresses that High Arctic habitats are characterized by. During the year, they undergo numerous freezing-thawing and desiccation-rehydration events, as well as having to grow under significantly different levels of temperature and irradiance. *Phormidium* flourish in this environment without having any resting cells such as akinetes, with their enhanced stress resistance. Therefore, this genus should have other adaptations displayed in its morphology. Most probably, these adaptations would become evident at the end of the vegetative season, due to their preparations for overwintering. The aim of this study was to observe the seasonal changes in photosynthetic activity and the morphology of cells in the natural populations of *Phormidium*-dominated cyanobacteria. We made the assumption that the seasonal alteration of such abiotic factors such as temperature, irradiance, and water availability could have an effect on both the cell's morphology and physiological state. We had expected that cells of cyanobacteria would undergo modifications at the end of vegetative season, due to their transition to a more resistant state at that time. For our studies, we chose 3 sites represented by meltwater streams (2 sites) and shallow pools (1 site) in close proximity to the Czech Arctic Research Station (West Spitsbergen). On each of the 3 sites, we placed 20 glass rings (**Fig. 19**) to mark the areas for repeated examinations. During the vegetation period (from the middle of June to the middle of September), we estimated the photosynthetic activity of the cyanobacterial populations with the help of the chlorophyll fluorescence method. The study consisted of four measurements of fluorescence at the beginning of the vegetative season (end of June), and four measurements in September. At the same time, we collected some of the biomass and fixed it with a 3% solution of formaldehyde for microscopic examination. Also recorded, were the presence of water at the sites, the temperature of the air and biomass, as well as the rate of irradiance. We observed that the sites were flooded with meltwater at the beginning of vegetative season (in June), and then underwent several drying-rewetting and freezing-melting episodes at the end of the season (early September). However, there was no clear trend in the development of the cells according to their present state (partially dry, frozen).

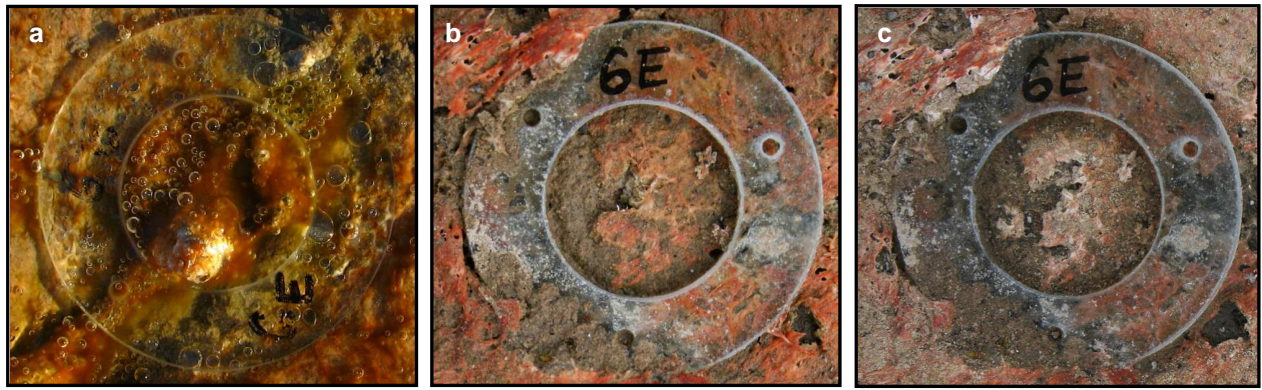


Fig. 19. *Phormidium* populations (Site 6) on (a) June 30th, (b) September 4th, and (c) September 15th.

We found that the morphology of the cells and filaments were quite uniform in early summer (second half of June); most of the filaments possessed very thin sheaths and had a slight granulation. A proportion of those filaments, without granulation, were enclosed in a moderately thick sheath and others were broken into short fragments. There were no evident differences between the circles at one locality. At the end of vegetative season there was a great variability within a small area, probably due to the heterogeneity of microhabitats (vertical distribution of water and nutrient availability, illumination, etc.). Therefore, it would be useful to observe the vertical structure of the crusts. It was quite difficult to quantify different kinds of cells and filaments, since there were a great number of various different qualitative and quantitative features such as: the presence and thickness of the sheaths, length and width of cells and filaments, degree of granulation, etc. However, the general trend is consists of the following: a huge number of the filaments are broken into hormogonia. Most of the unbroken filaments were enclosed in much thicker sheaths, when comparing to those in June. In some portions of the crust, most of the filaments possessed a very prominent granulation, and these granulated cells were the only viable cells in these portions (**Fig. 20**). Filaments with granulated cells are of particular interest for us, since we have observed very similar types of cells under laboratory conditions. Mature cultures of *Phormidium* isolated from cold regions and cultivated for several months on both agar and liquid media contained such filaments.

The interpretation of the fluorescence data was complicated, and we found that the (Fv/Fm) parameter selected does not reflect very well the seasonal changes in photosynthetic activity. This is due to the presence of phycobiliproteins, light-harvesting pigments, which have a strong fluorescence but do not drive the photosynthesis. Towards the end of the vegetative season, the Fv/Fm increases with a simultaneous decrease in Fo fluorescence. Most probably, it indicates a lowering of the phycobiliprotein content. It is well known that cyanobacteria can use their phycobilisomes as a source of nitrogen under conditions of nitrogen depletion. Thus, these measurements enabled us to assume that populations experiencing a lack of nitrogen at the end of vegetative season might be a trigger for dormancy. In order to prove the decrease in phycobiliprotein content, we need to analyze the content of nitrogen in early summer and late autumn samples, as well as to perform electron microscopy. Photosynthetic assessments can also be performed using several different protocols (photochemical quenching). In addition, it will be useful to combine these measurements with fluorescent staining and microscopy (SYTOX Green, CTC) in order to learn the physiological state of individual cells. Furthermore, it is important to focus on laboratory experiments and test for which kinds of cells are responsible for survival of the stressful conditions, since we are able to obtain hormogonia, young log-phase, as well as older cells.

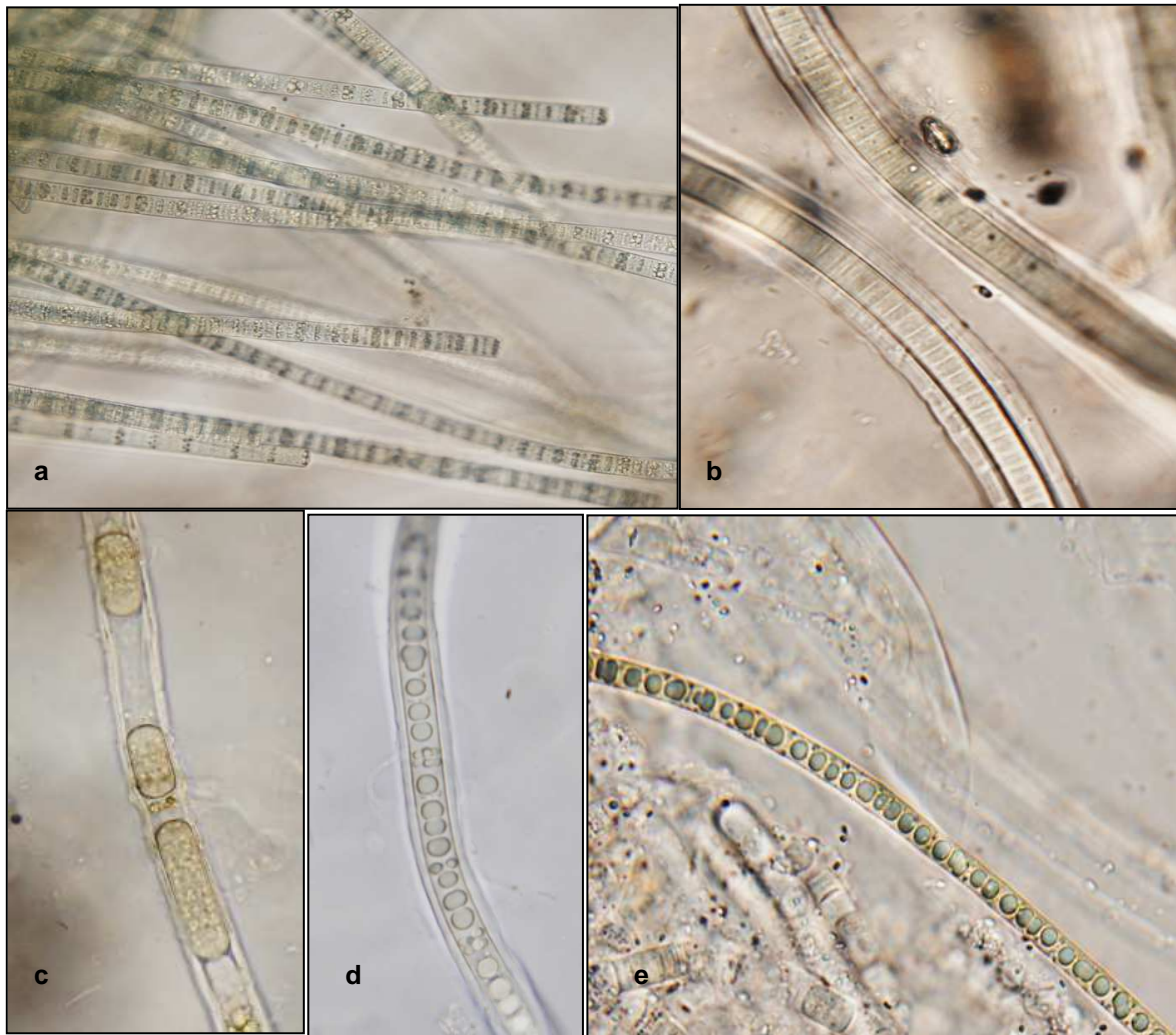


Fig. 20. Morphology of filaments (a) at the end of June, (b,c,d) in the middle of September, and (e) in a mature *Phormidium* culture isolated from the Arctic.

Lichens ecophysiology

Our fieldwork in June and July 2010 was mainly focused on the epipetric lichen communities growing along the west side of Petuniabukta from Mimerbukta to Horbyadalen, as well as in different altitudinal zones from the seashore to the summits of Pyramiden and Mumien. Samples of coriaceous species were collected with small pieces of rock (on which they were growing) for the determination and measurement of their structural and physiological characteristics in the laboratory. The evaluation of the samples has yet to be completed, but some preliminary observations can be presented. The biodiversity and abundance of the epipetric lichen flora decreased along the studied transect from the east oriented slopes of the Pyramiden Peak to the slopes of Svenbrehogta. A comparative study was performed in a longitudinal direction on similarly exposed boulders of sandstone, at elevations from about 50 to 100 m above sea level. A very sharp decrease of both the abundance and number of species was also found along the vertical dimension (from the seashore to the top of Pyramiden Peak), particularly above an elevation of about 500 m a.s.l. The monumental, freely exposed rock cascades around the summit above 850 m a.s.l., were almost without any lichens, despite relatively favourable climatic conditions (frequent fogs during summer, no snow cover during the winter, and no long periods of extreme frost). One of the possible causes of the absence of

the lichen could be the rather rapid weathering of the very porous, relatively young sandstone rock materials of the summit cascade (**Fig. 21**). The detrimental effect of sandstone weathering on lichen persistence was also quite visible upon lower-situated rock walls (about 400 m a.s.l.) at the eastern slopes of Pyramiden Peak (**Fig. 22**). On the other hand, the firmer red sandstones in the Ferdinandbreen Valley, probably from the carboniferous geologic era, were well colonized by lichens, including some endolithic species (**Fig. 23**). The microclimatic variables along the two transects mentioned were permanently monitored (year round) using sets of sensors and dataloggers (for details see the climatology report). The samples of lichens collected, as well as the different types of rocks bearing epipetric lichens were used for laboratory measurements of the spectral reflectance, in both their wet and dry state. The measurements were done with a UNISPEC reflectometric set (PP Systems, USA) equipped with a MMS1/NIR enhanced (300-1100 nm) detector with an internal light source (halogen lamp) and bifurcated foreoptics with a special clip for its orientation at a 60° angle to the sample plane. To calculate the spectral reflectance, scans of the reflected radiation from the samples were divided by scans of a 99% reflective standard. The following reflectance indices were derived from the spectral reflectance curves (R denotes the reflectance, and the subscripts refer to the specific spectral wavelengths):

- normalized difference vegetation index, $NDVI = (R_{900} - R_{680}) / (R_{900} + R_{680})$.
- structural independent pigment index, $SIPI = (R_{800} - R_{445}) / (R_{800} - R_{680})$.
- water index, $WI = R_{900} / R_{970}$

The measured structural characteristics of the samples (water saturation deficit, chlorophyll content) were determined. Detection of the structural and physiological status of all of the tested lichen species, using spectral reflectance analysis, was sufficiently reliable within a broad range of intrathalline water deficiency; and even with a high content of photoprotective metabolites in the upper cortex. The NDVI index was sufficiently suitable for an assessment of vitality and chlorophyll content of the lichen photobionts. The reflectance signal in the near-infrared region (at 970 nm) was found to be the most reliable water status indicator for the lichen species tested. The spectral reflectance of the different types of rocks, as well as the reflectance of dead lichen thalli, had relatively contrasting features in the red and near-infrared regions. These differences could be used for the detection of those areas not covered by lichen, and therefore, for vital lichen cover densities at the field sites, by using suitable imaging sensors for sampling on larger scales.



Fig. 21. Porous sedimentary rock, with many fossil fragments, at the top of the Pyramiden Peak. Some microscopic lichens could be found only in the most protected crevices.



Fig. 22. Very firm quartzitic intrusions are always more densely colonized by epipetric lichens than was the surrounding sandstone rock, which is more susceptible to erosion.



Fig. 23. Colony of predominantly endophytic lichens, growing on large boulders in the Ferdinandbreen Valley.

Palaeoecology

The study was focused on the analysis of macro-fossils, pollen, as well as other micro and macro objects found in the samples (tardigrades, foraminifers, etc.) (**Fig. 24**). Investigations of the lacustrine sediments from the tundra lakes or other waterlogged sediments provide data for a reconstruction of the vegetation's response to past local events. The uniqueness of the Arctic sediment records are even greater due the fact that this area had been protected from human impacts until very recently. The palaeoecological research is related to last year's work. It was focused on terrain prospecting, the collecting of plants and seeds for the reference collection, and making peat cores for analysis. The cores were dug down with a spade until the gravel terrace (or impenetrable permafrost) was reached. A profile was directly sampled from the core-side and then placed into plastic bags. The volume of each sample was approximately 300 ml. A list of recent vegetation found around each sampling location was recorded. This sampling was intended to obtain additional cores, in order to create more reliable results, as well as for use as reference comparisons. Prospecting for new suitable materials was done at Mathiesondalen, which is totally different from the rest of Petuniabukta, geologically. Unfortunately, the sediments were mixed due to periglacial events. Additionally, two cores of lacustrine sediments were obtained near Skottehytta (the Polish research station). The basal core sediment from the lowest terrace obtained the previous year was radiocarbon AMS dated to $5881 \pm 57\text{BP}$ (cal.). That data corresponds to the results of the Polish geomorphologists, as well as being in accord with the radiocarbon dating of the geological materials; the upper terraces could be correlated with a younger glacial episode at 9 - 8ka BP (Stankowski 1989). The study intended to reconstruct the changing biotic conditions of three small periodic lakes located within the system of raised marine terraces at Ebbadalen, Billefjorden area on Svalbard (where the hydrologic, hydrochemical, and sedimentologic conditions already have been investigated by researchers from Adam

Mickiewicz University in Poznań, Poland). The existing results from the analysis of the macrofossils and pollen show a continual vegetation record, with minimal changes since the terrace was uplifted. In the samples prepared for pollen analysis, eggs and exuvies of Tardigrada were found. Arctic conditions are very suitable for preserving remains of tardigrades in the sediments, and it opens up a new possibility of how to improve our results. At "Walton's marshes" in Adolfbukta, a 72 cm deep core was obtained last year. Radiocarbon dating revealed the age at the base to be 9016 \pm 123 BC. Another core, over 50 cm deep, from a nearby lower terrace was obtained to compare the fossil record from the vicinity, and to have proper materials for an outline of the sea level changes during the past. Walton's sampling area from 1929 was reconstructed, as well.



Fig. 24. Egg of *Macrobiotus hufelandi*.

Life histories of two arctic co-occurring hemiparasitic plants: *Pedicularis hirsuta* and *Pedicularis dasyantha*

Hemiparasitic plants are a type of plant which parasitize by means of special root organs onto the roots of other plants (instead of building their own root system). Via these connections they obtain their water and nutrients. This is a very useful strategy in the nutrient-poor Arctic plant communities; however, here root connections is endangered by frost heave. On Svalbard, we found two hemiparasitic plants to be widespread: *Pedicularis dasyantha* and *Pedicularis hirsuta*. Both species are very similar in habit, and similar community habitats were dominated by *Dryas octopetala*. The aim of the field study was to find possible differences between the two species in both their habitat demands and their life history. Per species, about 100 individuals were sampled; the cover and identification of the surrounding vegetation assessed, and the growth parameters of the plants measured. Plants of *P. dasyantha* were generally bigger; they have longer leaves, taller inflorescences, and fewer shoots than do plants of *P. hirsuta*. The size of the plants in both species is largest under the shelter of large stones. *P. dasyantha* occurs on drier places, nearly always close to *Dryas octopetala*; whereas *P. hirsuta* occurs in wetter places, usually found together with *Salix polaris*. However, both hemiparasitic species do not accompany their potential hosts at the most extreme (dry or wet) locations. Both species have preformed buds (Fig. 25) for the next year, which are protected by the base of the current year's green leaves. Both species are perennial, and can flower more than three times per lifetime. In both species, the average age was about three and a half

years, and the oldest individuals were about seven years old. Although, the overall size of the plants increases throughout their lives, the size of individual shoots diminishes as their number increases; this effect is especially prominent in *P. dasyantha*, which shows a larger size requirement for flowering. Small shoots, necrotic root systems, and sterility are typical for old plants; and also are probable reasons for their mortality.



Fig. 25. (a) generative and (b) vegetative apical meristem of *Pedicularis dasyantha*.

Growth and life-history characteristics of selected vascular plants

There is an assumption that the species *Braya purpurascens* is unable to complete its life cycle in the same season when it is flowering. Last year, a transect was established, along which all specimens of this species were recorded. This year, the phenological status of all of these specimens was repeatedly evaluated at the end of the vegetation season. The main finding was that the species is able to set seeds in the year of flowering. Herbivorous birds destroyed some of the specimens. Additionally, a study transect was established last year, and divided into five parts according to both dominant and co-dominant species, as well as the geomorphology: *Carex subspathacea* (thufurs; 13 - 15 m a.s.l.), *Cassiope tetragona* (terraces; 15 - 66 m n. m.); *Saxifraga oppositifolia* + *Dryas octopetala* (upper terrace, exposed to the wind; 66 - 87 m n.m.); *Dryas octopetala* + *Salix polaris* (scree slope, consisting of debris with slope up to 35°; 87 - 153 m n.m.), *Salix polaris* (scree slope, consisting of debris with slope greater than 35°; 153 - 222 m n.m.). 10 specimens of *Salix polaris* and 15 of *Dryas octopetala* were collected from each area (if the species occurred there), and these samples will be subjected to tree-ring analysis.

Measurements of daily courses of primary photosynthetic processes in three species of vascular plants (*Silene acaulis*, *Dryas octopetala*, and *Salix polaris*) and lichen (*Peltigera* sp.)

Within the Svalbard 2010 expedition, plant physiologists carried out comparative measurements of daily courses of primary photosynthetic processes in three species of vascular plants. We extended the long-term study topic of last season (July 2009) to analysis of daily courses of poikilohydric lichens. The measuring instruments were installed in the vicinity of the Petunia hut, located in the Petunia Bay. A fluorometric device, using the method of repeated saturation with light pulses was applied, to measure daily courses of the photosynthetic processes. The pulses were applied in the actual physiological state of a plant, *i.e.* in the light-adapted state, reflecting the actual amount of incident photosynthetically active radiation. In this way, the quantum yield of photosynthetic processes in photosystem II (effective quantum yield: Φ_{PSII}) was measured. For the measurement we used handy

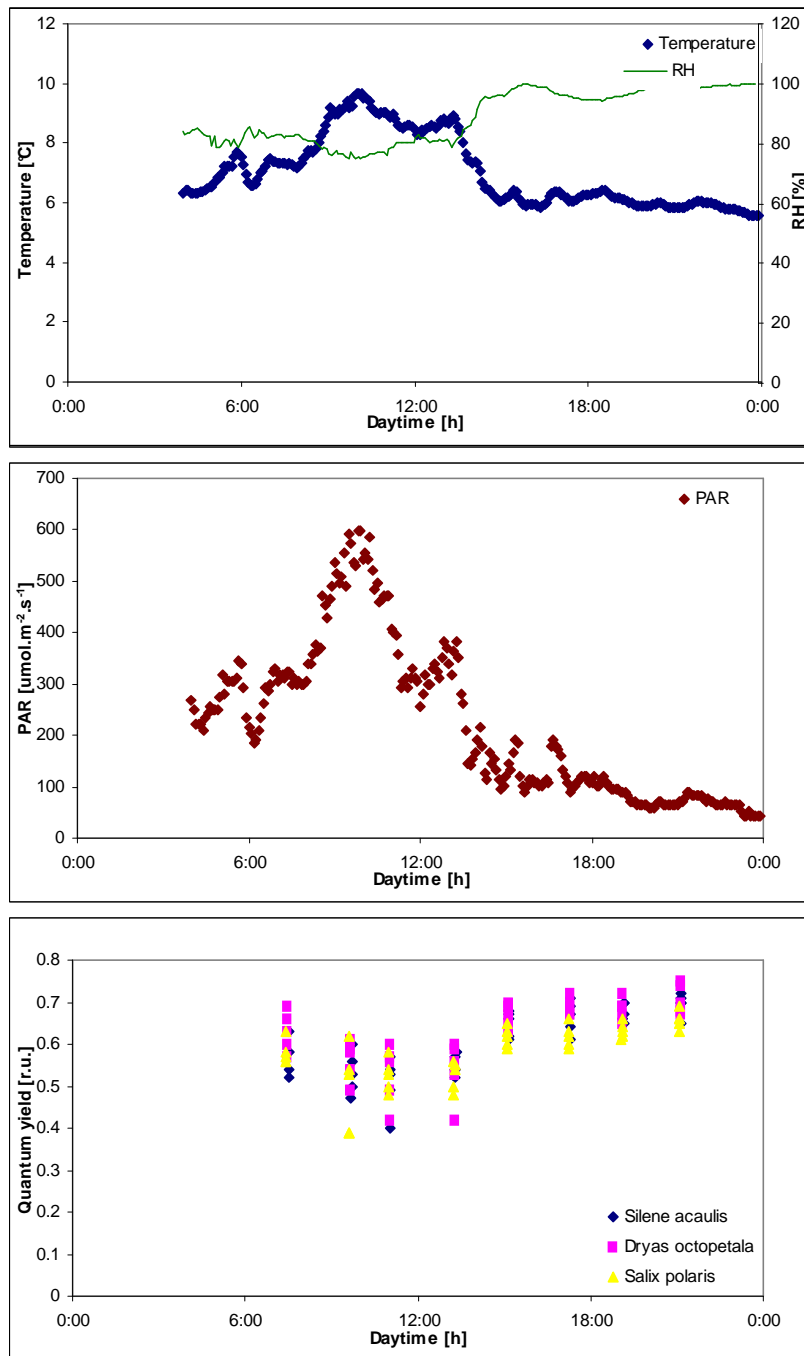


Fig. 26. Selected typical partly cloudy day daily course of air temperature, relative air humidity, photosynthetically active radiation (PAR) and corresponding effective quantum yield for three plant species (*Silene acaulis*, *Dryas octopetala*, *Salix polaris*).

fully overcast day with precipitations, (b) partly cloudy day, and (c) fully sunny day (**Fig. 26**). From a microclimate point of view, the data on leaf temperature for the three different species are interesting. The leaf temperature reached a minimum of 2.4°C and a maximum of 25.1°C. For lichens, the daily photosynthetic activity is strongly affected by air humidity and temperature – the key limiting factors for poikilohydric organisms (**Fig. 27**). From the data analysis of daily courses of microclimatic conditions and effective quantum yield in *Silene*, *Dryas* and *Salix* seems to be the effect of changing temperature and air humidity on photosynthetic processes more important than level of incident light even for higher plants.

fluorometric system Fluorpen FL-100 (Photon Systems Instruments, Czech Republic). The three selected species were dominant in the vegetation cover of the tundra at Petuniabukta: *Silene acaulis*, *Dryas octopetala*, and *Salix polaris*. Additionally, we measure lichen species from the genus *Peltigera*. Simultaneously with the fluorometric parameters of the three plant species, ecophysiological data on (1) leaf temperature, (2) air temperature in 30cm over the ground, (3) relative air humidity, and (4) incident photosynthetically active radiation (PAR - EMS-12 radiometer, EMS Brno, Czech Republic) were taken by dataloggers (Minikin, Edgebox, EMS Brno, Czech Republic). Handy measurement allowed taking 4 daily courses of Φ PSII in the period July 18th to July 28th, 2010. All the data obtained were processed recently. Preliminary data analysis has shown that within the

above-specified period, diurnals of photosynthesis were recorded for three basic weather types: (a)

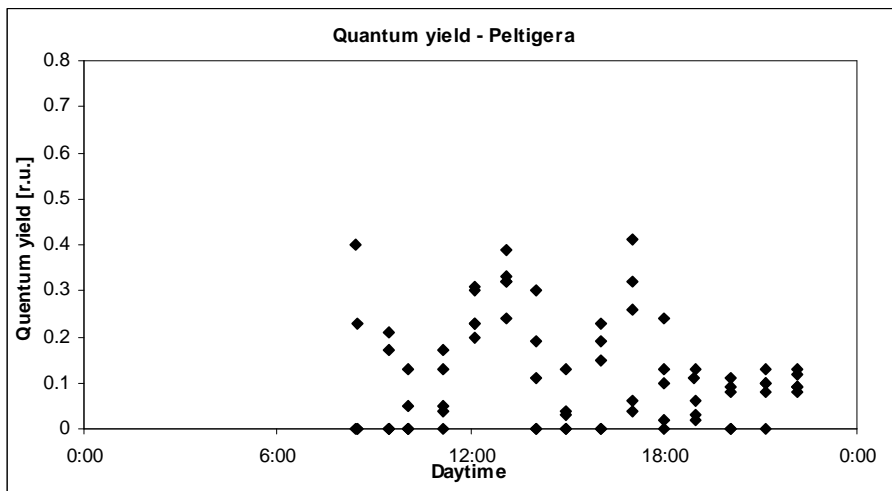
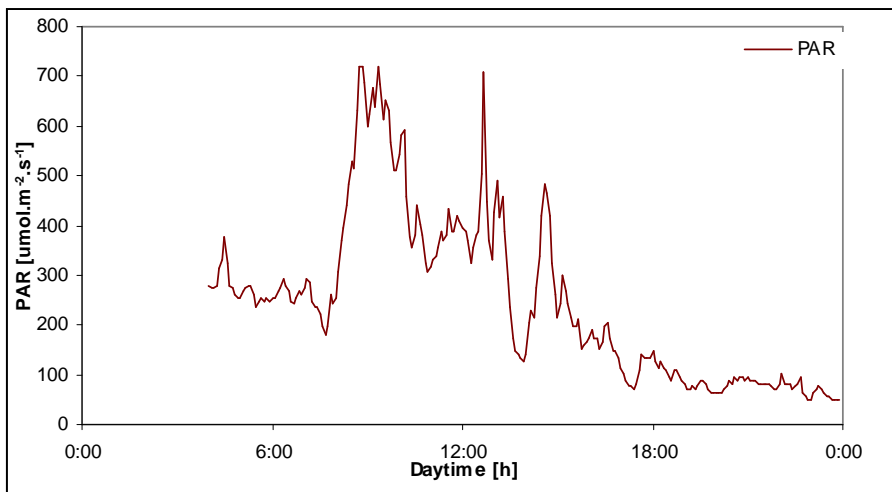
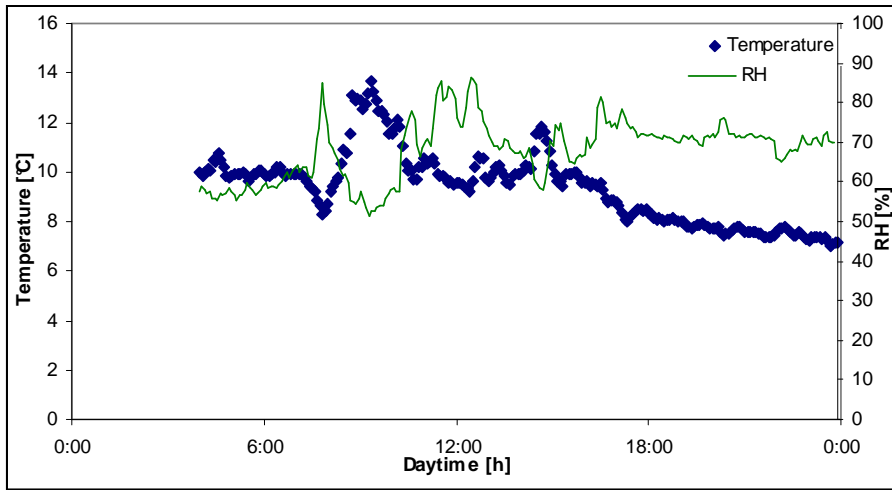


Fig. 27. Selected typical overcast day daily course of air temperature, relative air humidity, photosynthetically active radiation (PAR) and corresponding effective quantum yield for lichen species (*Peltigera* sp.).

Zoology

Parasitological research





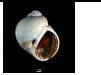










The parasitological portion of the project continued with studies of the littoral biocenoses and host - parasite relationships:

- 1.) Study of the host-parasite interactions between flukes of the genus *Gymnophallus* and the intermediate host *Mya truncata*. Study of the life cycle of this fluke (we have obtained permission to dissect 3 specimens of *Somateria mollissima* - the potential definitive host; 3 other birds were accidentally captured in the fishnets).
- 2.) Study of other helminthes found in fish and selected invertebrate hosts.
- 3.) Isolation of amphizoic amoebae from the tissues of marine animals, as well as from environmental samples.
- 4.) Examination of the tissues and organs of selected vertebrate and invertebrate hosts with the objective of histological studies of parasites from the groups Myxozoa, Microsporidia, Ciliata, and Amoebae.














Materials for parasitological examination:

The fish and birds were parasitologically dissected, with special attention paid to flukes and tapeworms. Tissue samples from selected organs were sampled for histological examinations. The invertebrate hosts were dissected, using the compression method, and the parasites were fixed for both morphological and molecular studies. The numbers of animals dissected in 2010 can be found in **Tab. 1** and **2**.

Tab. 1. Invertebrates dissected.

host species		N° dissected
<i>Mya truncata</i>		226
<i>Hiatella arctica</i>		101
<i>Serripes groenlandica</i>		8
<i>Littorina saxatilis</i>		56
<i>Euspira pallida</i>		13
<i>Buccinum</i> sp.		108
<i>Dendronotus robusta</i>		14
<i>Gammarus</i> sp.		168
<i>Hyas</i> sp.		58
<i>Pagurus pubescens</i>		13
<i>Sclerocrangon</i> sp.		2
<i>Strongylocentrotus droebachiensis</i>		2
<i>Marthasterias glacialis</i>		2
<i>Urticina felina</i>		2
<i>Mertensia ovum</i>		24

Tab. 2. Vertebrates dissected.

Host species		N° dissected
<i>Myoxocephalus scorpius</i>		145
<i>Gymnocanthus tricuspis</i>		73
<i>Triglops murrayi</i>		4
<i>Lumpenus lampretaeformis</i>		28
<i>Clupea harengus</i>		18
<i>Hippoglossoides platessoides</i>		12
<i>Polachius virens</i>		3
<i>Boreogadus saida</i>		2
<i>Salmo salar</i>		1
<i>Somateria mollissima</i>		2
<i>Anser brachyrhynchus</i>		1
<i>Cephus grylle</i>		1
<i>Fulmarus glacialis</i>		1

Selected results:

Parasitic flatworms

Acoel flatworms of the genus *Proporus* (Fig. 28) were found in *Mya truncata*. Although this flatworm has long been considered as a commensal, our results revealed its parasitic nature. We have found it in more than 72% of the *Mya truncata*, and in no other species of bivalve. The histological sections proved their presence in the inner organs (hepatopancreas) and the reaction of the tissues (Fig. 29).

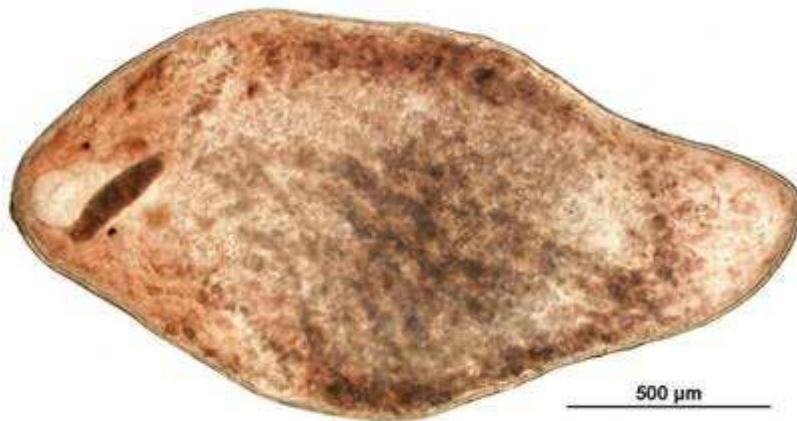


Fig. 28. *Proporus* sp. isolated from *Mya truncata*.

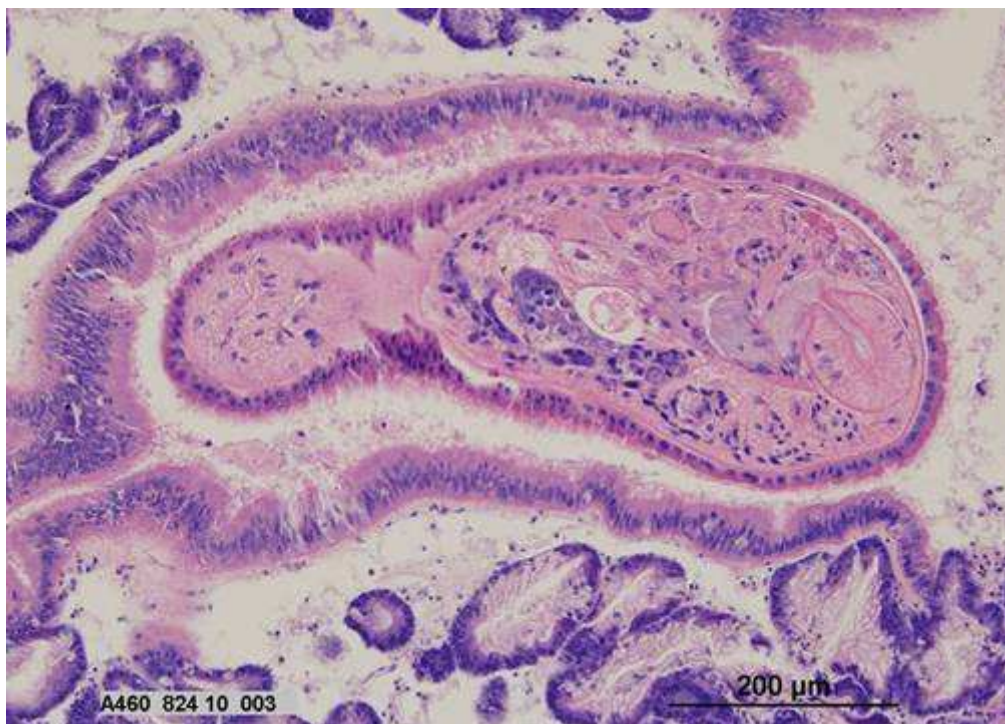


Fig. 29. Hepatopancreas of *Mya truncata* with *Proporus* sp.

Manipulation of *Mya truncata* by the fluke *Gymnophallus* sp.

Bivalve mollusks *Mya truncata* and *Hiatella arctica* retract into the bottom sediments in order to avoid predator attack. However, some of the molluscs stay exposed on the sediment surface. (**Fig 30**).

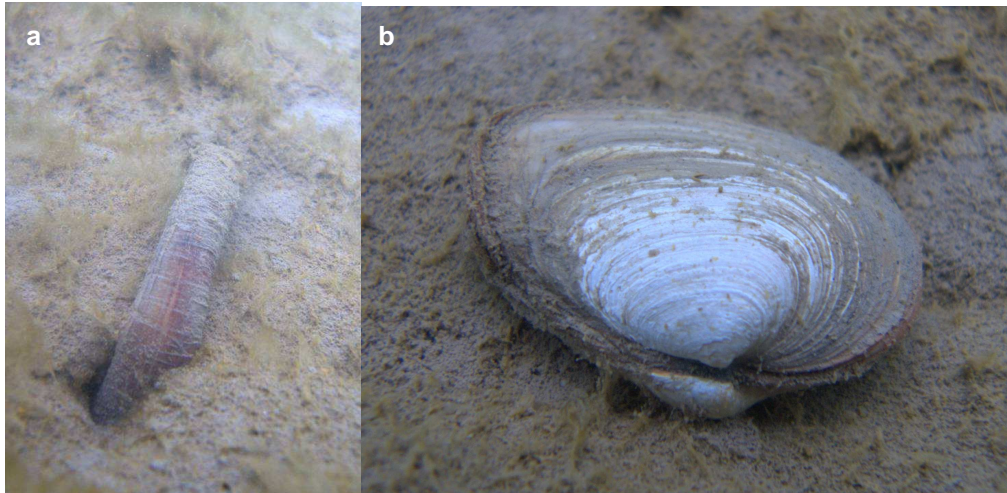


Fig. 30. *Mya truncata*, (a) hidden in the sediment, and (b) exposed on the surface.

During the parasitological examinations of bivalves, targeted at the larval stages of flukes, specifically *Gymnophallus* sp., we noticed significant differences in the prevalence of hidden and exposed hosts (**Tab. 3**).

Tab. 3. Differences in the prevalence of *Gymnophallus* sp., in hidden and exposed bivalves.

N° of molluscs dissected/ positive for <i>Gymnophallus</i> sp.	hidden	exposed
<i>Mya truncata</i>	87/41	78/77
<i>Hiatella arctica</i>	39/4	16/4

Very probably, this parasite manipulates the behavior of its intermediate hosts in order to increase the probability of their predation by the definitive hosts, which are probably the eiders (*Somateria mollissima*). This strategy probably works in spite of the fact that the exposed bivalves are the prey of other predators, as well (snails *Buccinum* spp., and sea stars *Marthasterias glacialis*).

Parasites of birds

In order to find the definitive host of *Gymnophalus* sp. from the bivalves we intend to dissect common eiders (*Somateria mollissima*), and describe their adult flukes. The capturing of the eiders was an unexpected problem as fulmars (*Fulmarus glacialis*) spoiled the bird nets above the seashore, because largely they were caught, unintentionally. In the end, we dissected only 2 eiders instead of the 3 permitted. However, the gymnophalid flukes found in their intestines were not adult. Small juvenile flukes were hidden in the crypts of the colon (**Fig. 31**).

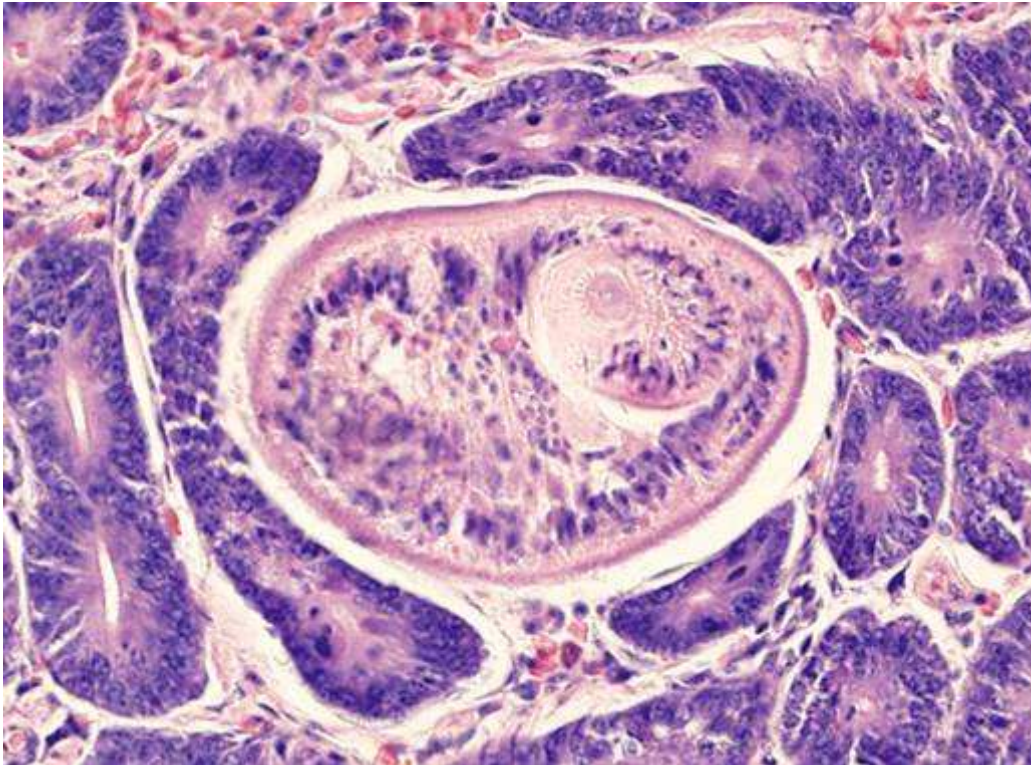
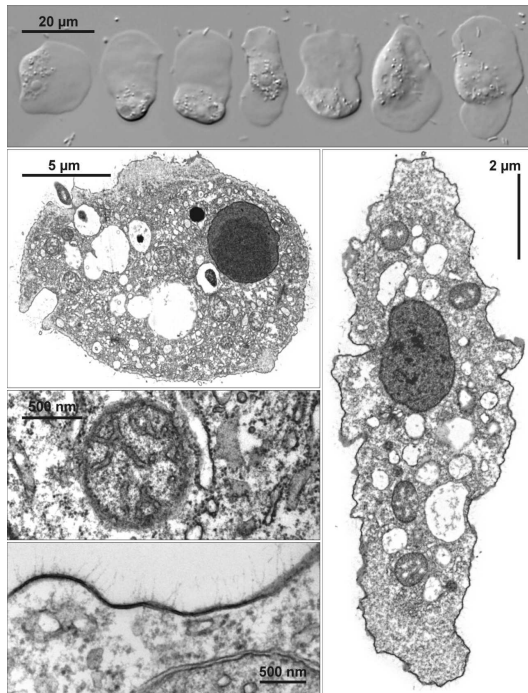


Fig. 31. Juvenile gymnophalid fluke, in the colon crypt of *Somateria mollissima*.

Besides the gymnophalid flukes, *Profilicollis botulus* (Acanthocephala) and *Tetrabothrium* sp. (Cestoda) were also found in the eider's intestines. Tetrabothriid cestodes were found in *Anser brachyrhynchus*, *Cepphus grylle*, and *Fulmarus glacialis*, as well.

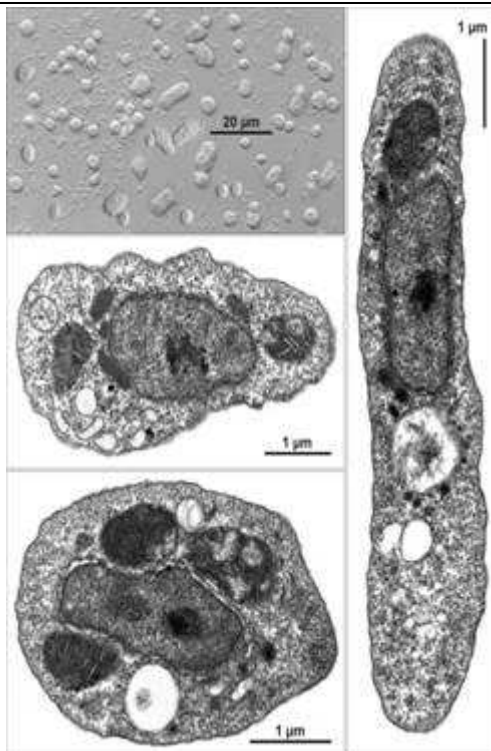
Morphological and phylogenetic studies of amphizoic amoebae

In 2010, from marine organisms 31 isolates were obtained, and 25 from fresh water environments. They were cultivated in cultures with bacteria, and their morphology was studied using both light microscopy and transmission electron microscopy. A phylogenetic study using SSU rDNA is planned in the near future. Some strains isolated in previous years are shown in following figures.



PET1V

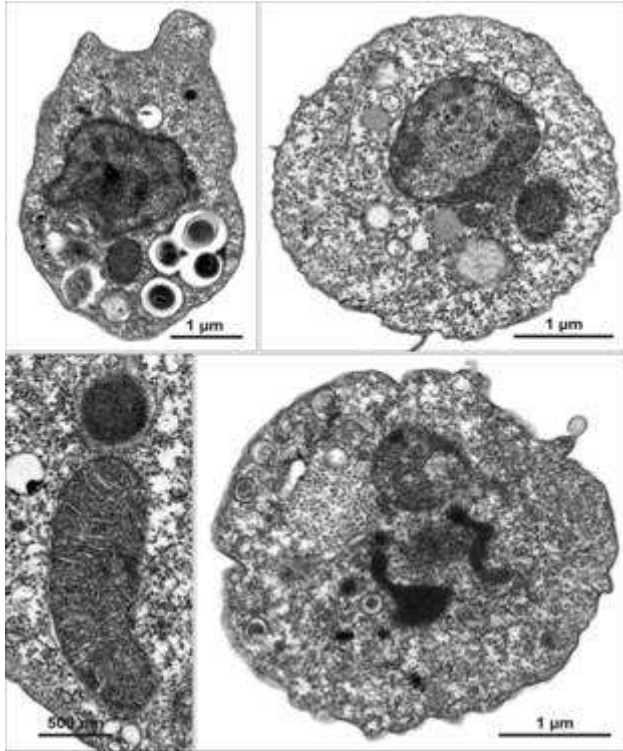
Lithoderma



SV6 -I

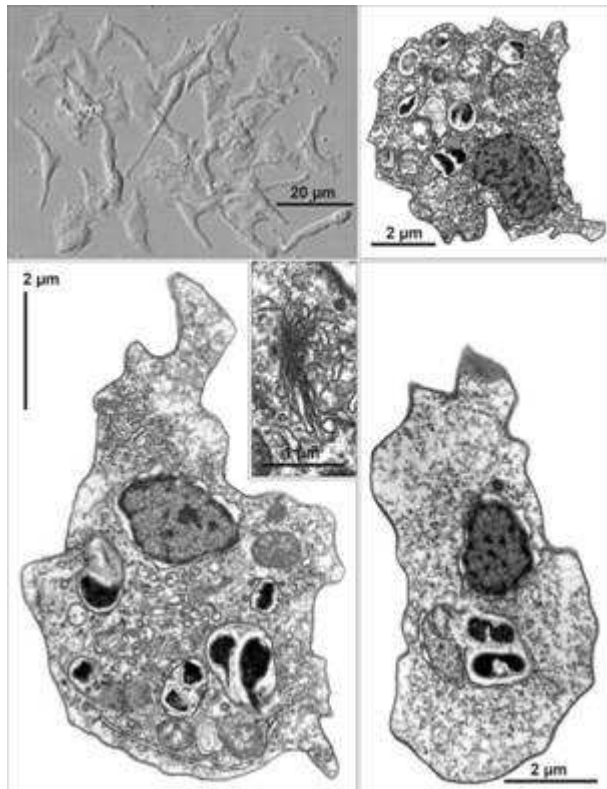
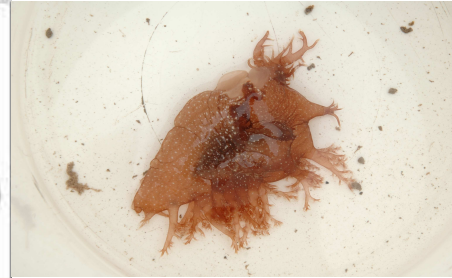
*Dendronotus
robusta*





SV6- II

*Dendronotus
robusta*



SV198

*Pagurus
pubescens*



Arctic photography

Intensive photo documentation of the wildlife and research activities was implemented during the 10-week period of Arctic Summer in the Billefjorden area. Professional photography equipment and advanced techniques were used in order to capture more than 60 000 photos.

Several different types of Czech Arctic Research were documented, as well as field equipment such as the meteorological stations, open-top chambers, and some of the experimental areas.



Various species of plants were captured, some of them during their period of blooming.



The marine invertebrates and fish were photographed in aquariums and in special glass chambers (in the case of smaller animals). A combination of natural light plus two flashes was usually used, with the emphasis on capturing the authentic colours of the living specimens.



Photos of the landscapes were taken under different weather conditions, as well as documenting the changes of the tip of the Nordernskiöld iceberg.



Special equipment was used for the high-magnification macrophotography of living animals directly in the field. Attention was paid to the capturing of different species of springtails (*collembola*) in diverse environments.



Various types of behaviours of both wild birds and mammals were documented, including adult animals with their offspring, birds in flight or hunting, as well as their feeding activities.



The effects of growing tourism were monitored, including the developments of an accidental fire in Brucebyen, which was recorded using a time-lapse technique. These photos were used for the police investigation.



The Russian coal-mining settlement at Pyramiden was abandoned in 1998; but retaken by the wildlife. Now, there is an effort to rebuild the town into a tourist centre. Therefore, 2010 may be the last chance to take photos of this town in ruins, with almost no human presence.



A wider selection of photographs has been published online at www.photographypospech.com ; and others are in preparation for species determinations, as well as for publication in magazines and other media.

List of research papers and presentations in 2010:

Redchenko, O., Košnar, J. and Gloser, J. 2010: A contribution to lichen biota of the central part of Spitsbergen, Svalbard Archipelago. *Polish Polar Research* 31(2): 159-168 (DOI 10.4202/ppres.2010.09).

Prach, K., Košnar, J., Klimešová, J. and Hais, M. 2010: High Arctic vegetation after 70 years: a repeated analysis from Svalbard. *Polar Biol.* 33: 635-639 (DOI 10.1007/s00300-009-0739-6).

Strunecký, O., Elster, J. and Komárek, J. 2010: Relationship in geographically separate *Phormidium* like cyanobacteria: Is there a link between north and south Polar Regions? *Polar Biol.* 33: 1419-1428, (DOI 10.1007/s00300-010/0834/8).

Kvíderová, J., Elster, J., Šimek, M. 2010: In situ response of *Nostoc commune* s.l. colonies to desiccation, in Central Svalbard, Norwegian High Arctic. *Fottea-Czech Phycology* (accepted).

Tashyreva, D. and Elster, J. 2010: Production of dormant stages and stress resistance of polar cyanobacteria. *Algae and Cyanobacteria in Extreme Environments*, J. Seckbach, (ed.). - *Kluwer Academic Publishers*, The Netherlands, (accepted).

Conference presentations in 2010:

Kvíderová, J., Elster, J. & Šimek, M. 2010: *In situ* response of the *Nostoc* sp. colonies to desiccation, Billefjorden, central Svalbard, High Arctic. 18th Symposium of the International Association for Cyanophyte Research. 15th - 20th August, České Budějovice, p.66.

Láska, K., Witoszová, D., Prošek, P. (2010): Climate Conditions of the Permafrost Active Layer Development in Petuniabukta, Billefjorden, Spitsbergen. In: Mertes, J.R., Christiansen, H.H., Etzelmüller, B. (eds.): *Thermal State of Frozen Ground in a Changing Climate During the IPY. Proceedings of the Third European Conference on Permafrost*. Longyearbyen, June 13-17, 2010. University Centre in Svalbard, Svalbard, p. 128-128.

Hájek, T., Kvíderová, J., Elster, J., Šimek, M. 2010: Seasonal dynamics of photosynthetic and N₂ fixation activity of cyanobacterium *Nostoc commune* s.l. in wet hummock tundra (Central Svalbard, High Arctic), MicroPerm Workshop, Potsdam, Germany, November 8 - 10, 2010, p. 20-21.