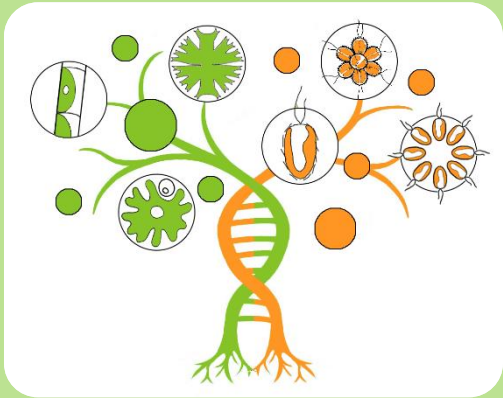
Speciation in protists

Spatial and ecological divergence processes cause rapid species diversification in a freshwater chrysophyte



Škaloud P. [1], *Škaloudová M.* [1], *Doskočilová P.* [1], *Kim J.I.* [2], *Shin W.* [2], *Dvořák, P.* [3]

[1]*Charles University, Czech Republic*

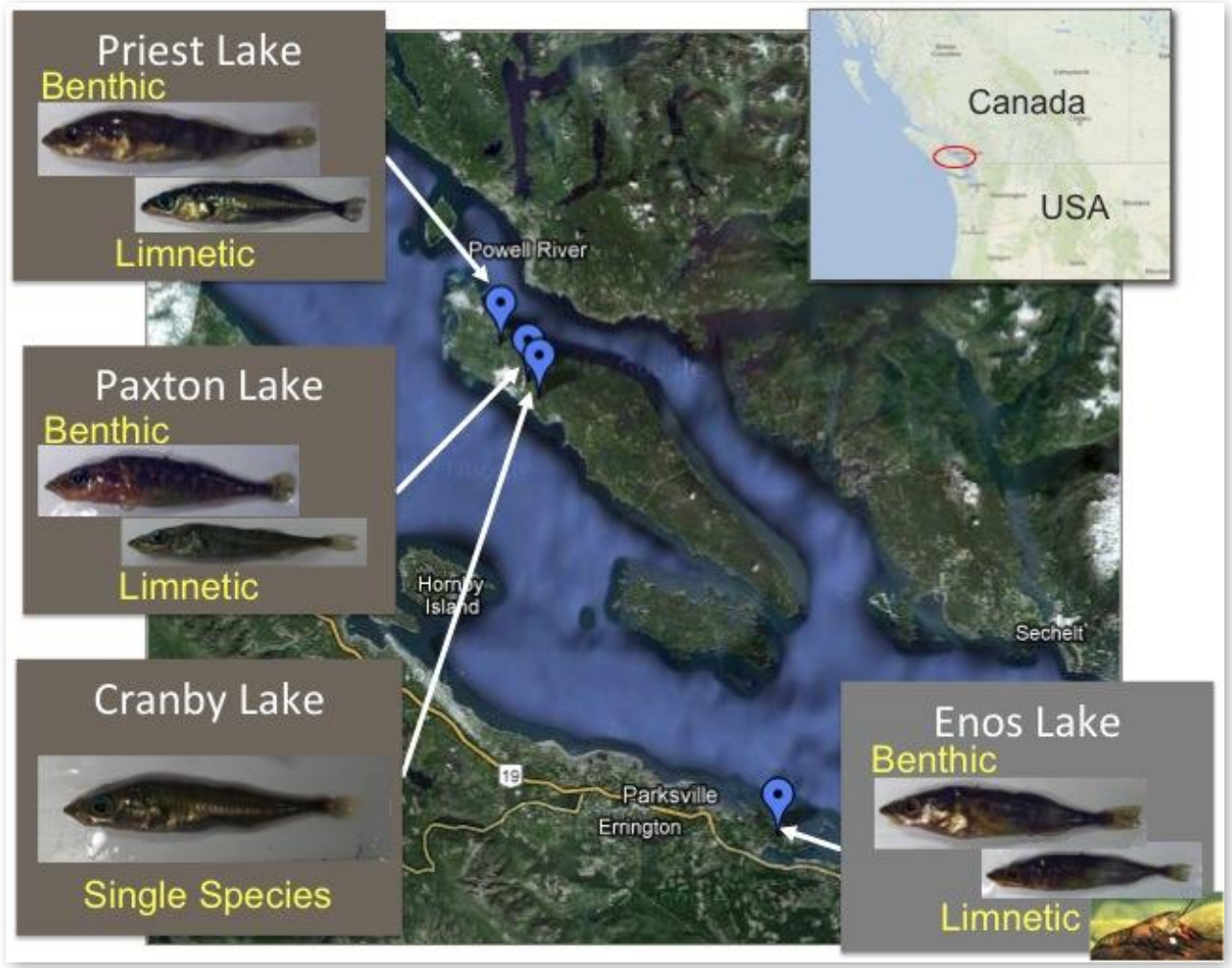
[2]*Chungnam National University, Korea*

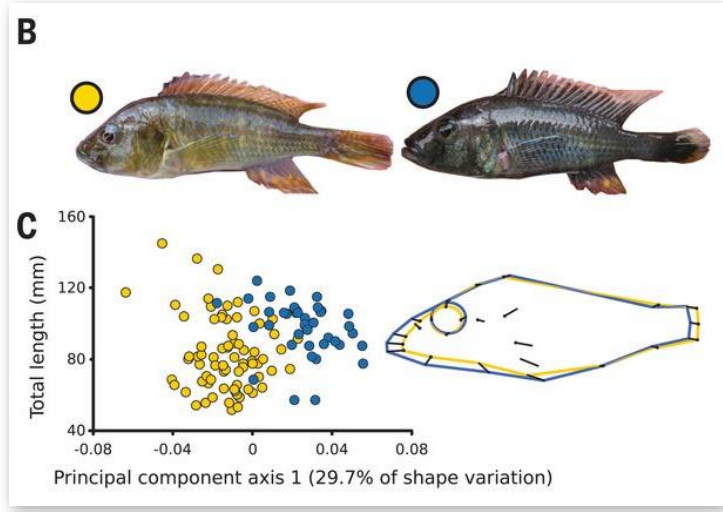
[3]*Palacký University, Czech Republic*

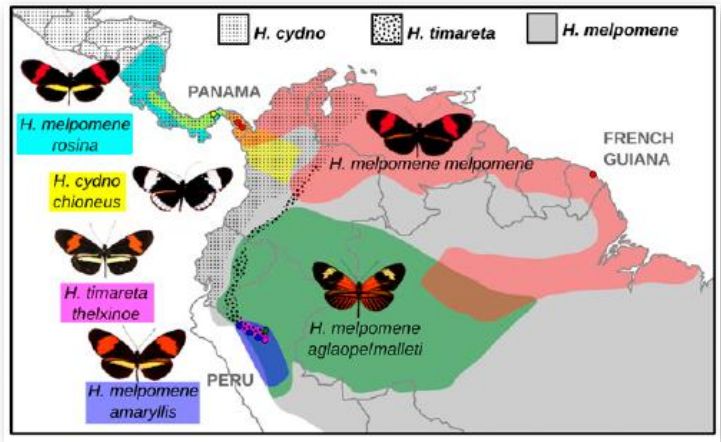
http://botany.natur.cuni.cz/skaloud

Speciation mechanisms

- Despite the growing number of published papers focusing to speciation, only a very small fraction is dealing with protists.



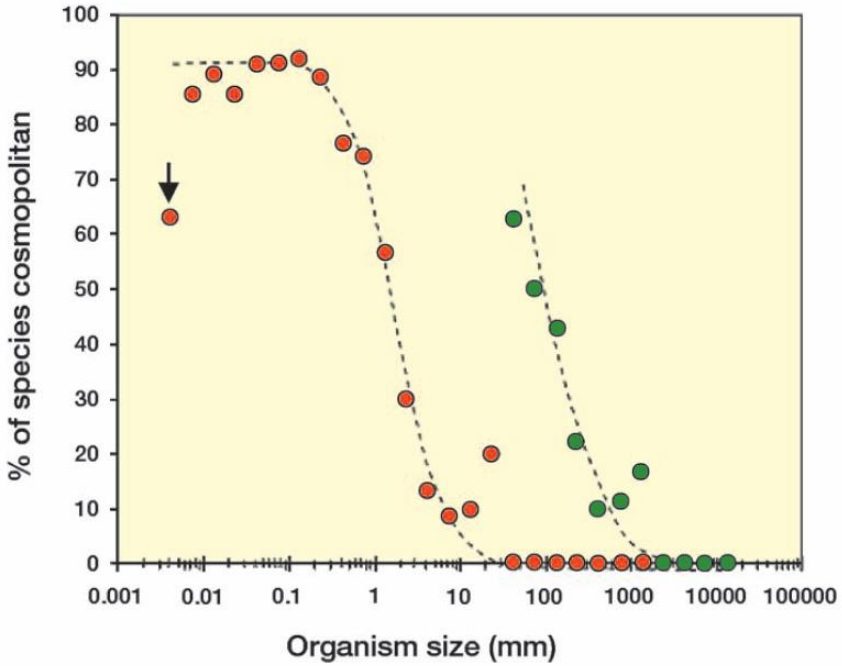


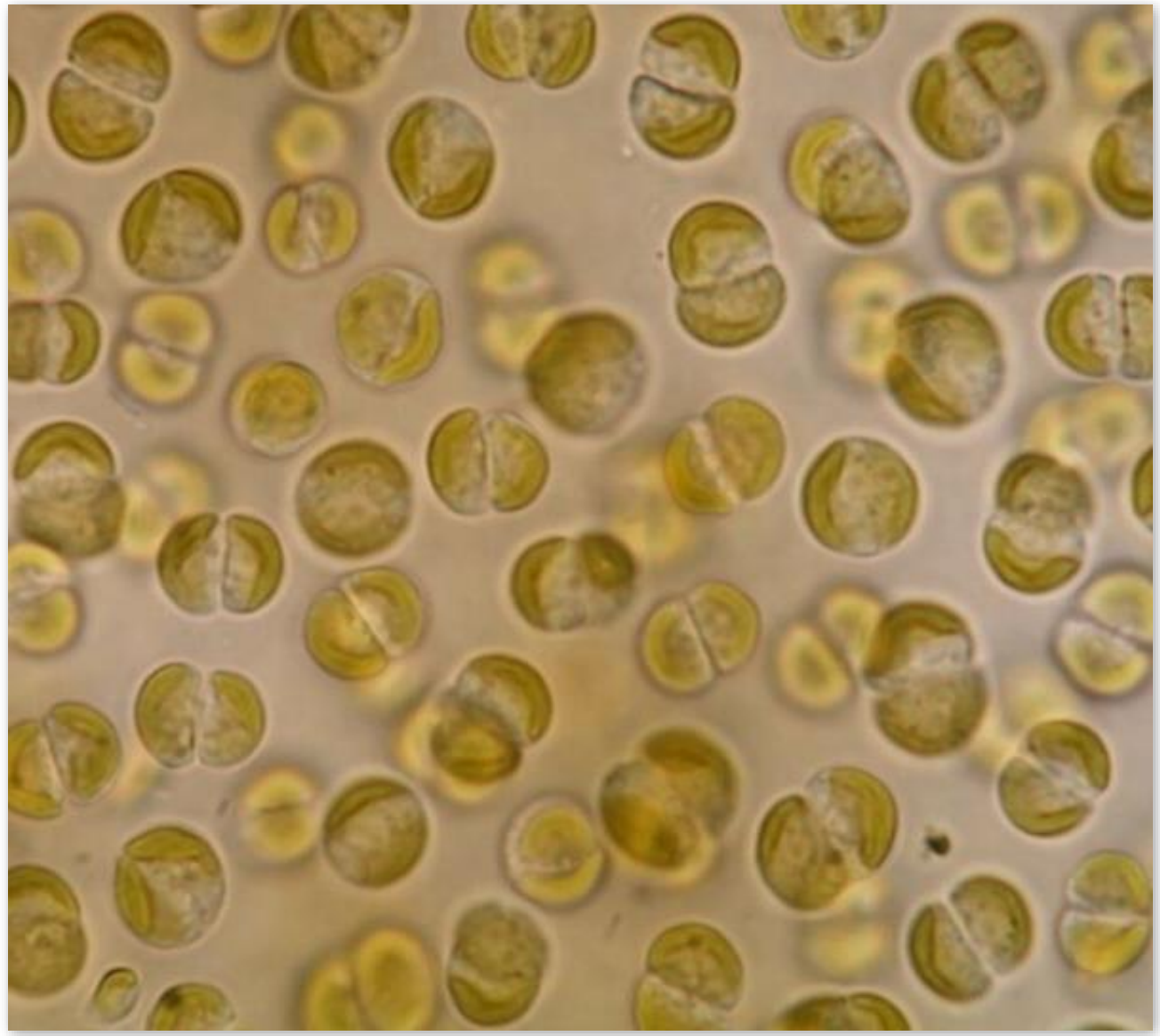


Specificity of protist organisms

- Enormous population sizes
- Unlimited dispersal & gene flow

- Lack of population differentiation
- Very low speciation rate



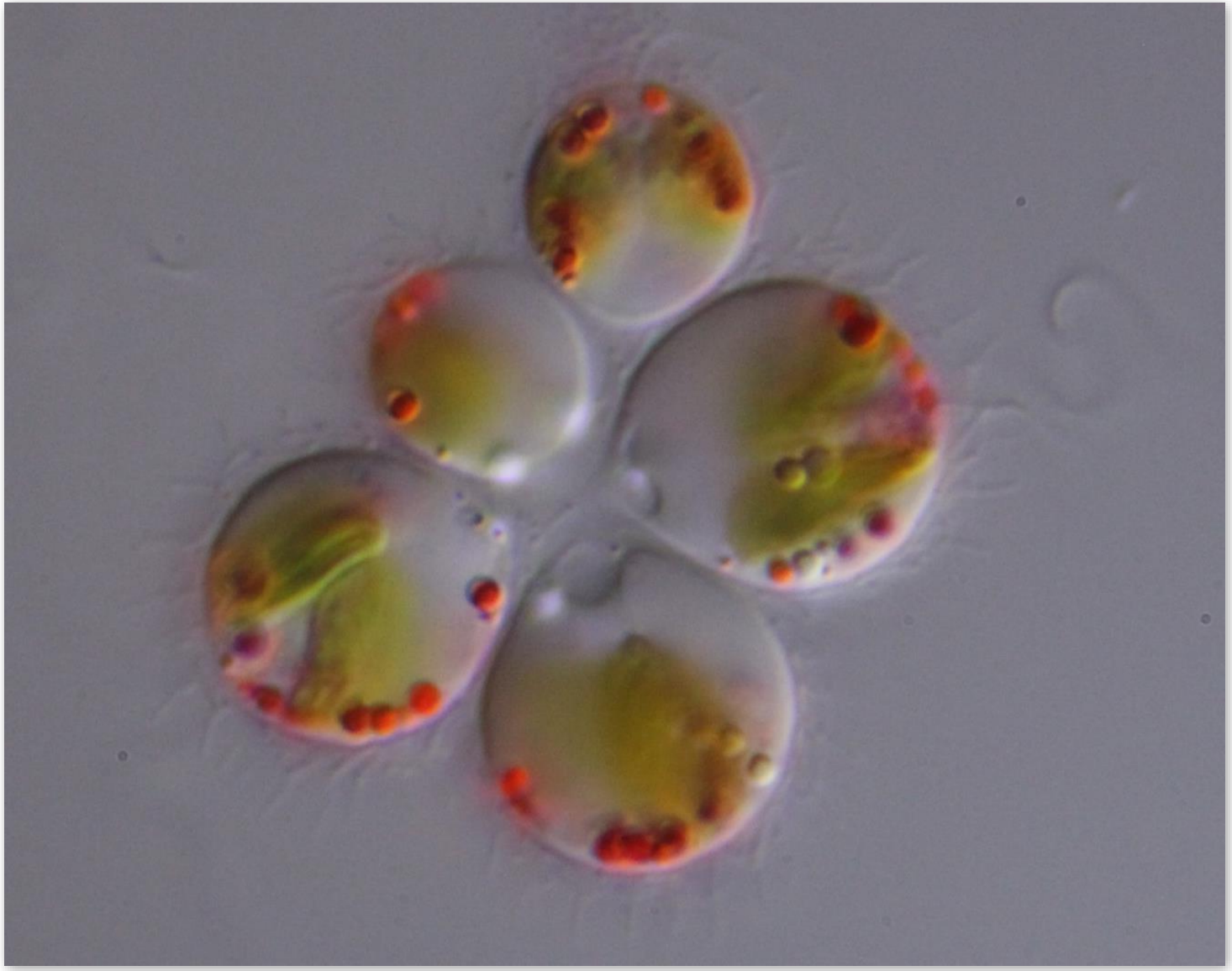


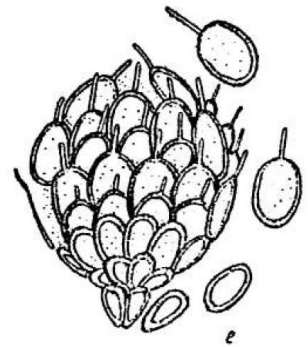
Finlay & Fenchel (1999). *Protist* **150**: 229-233

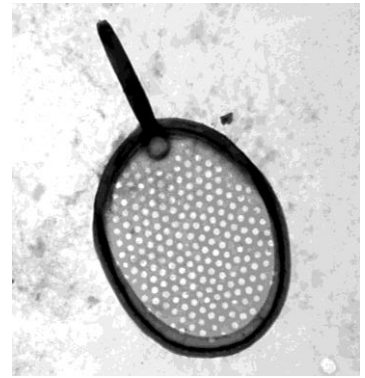
Main goals

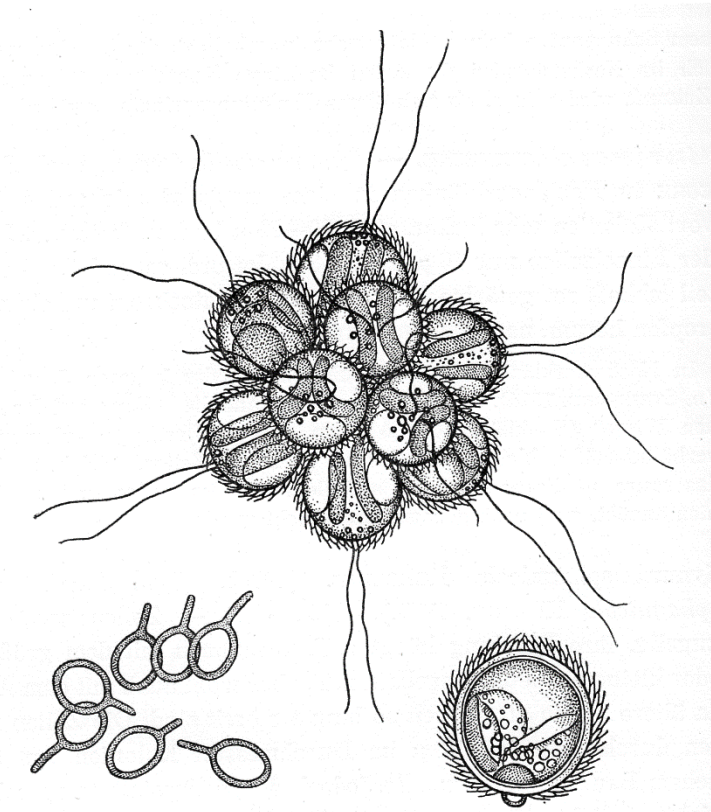
- Which are the main factors structuring the extant diversity in a protist species?
- Are the speciation mechanisms in protists different from those proposed for macroorganisms?

Synura sphagnicola (Chrysophyceae)



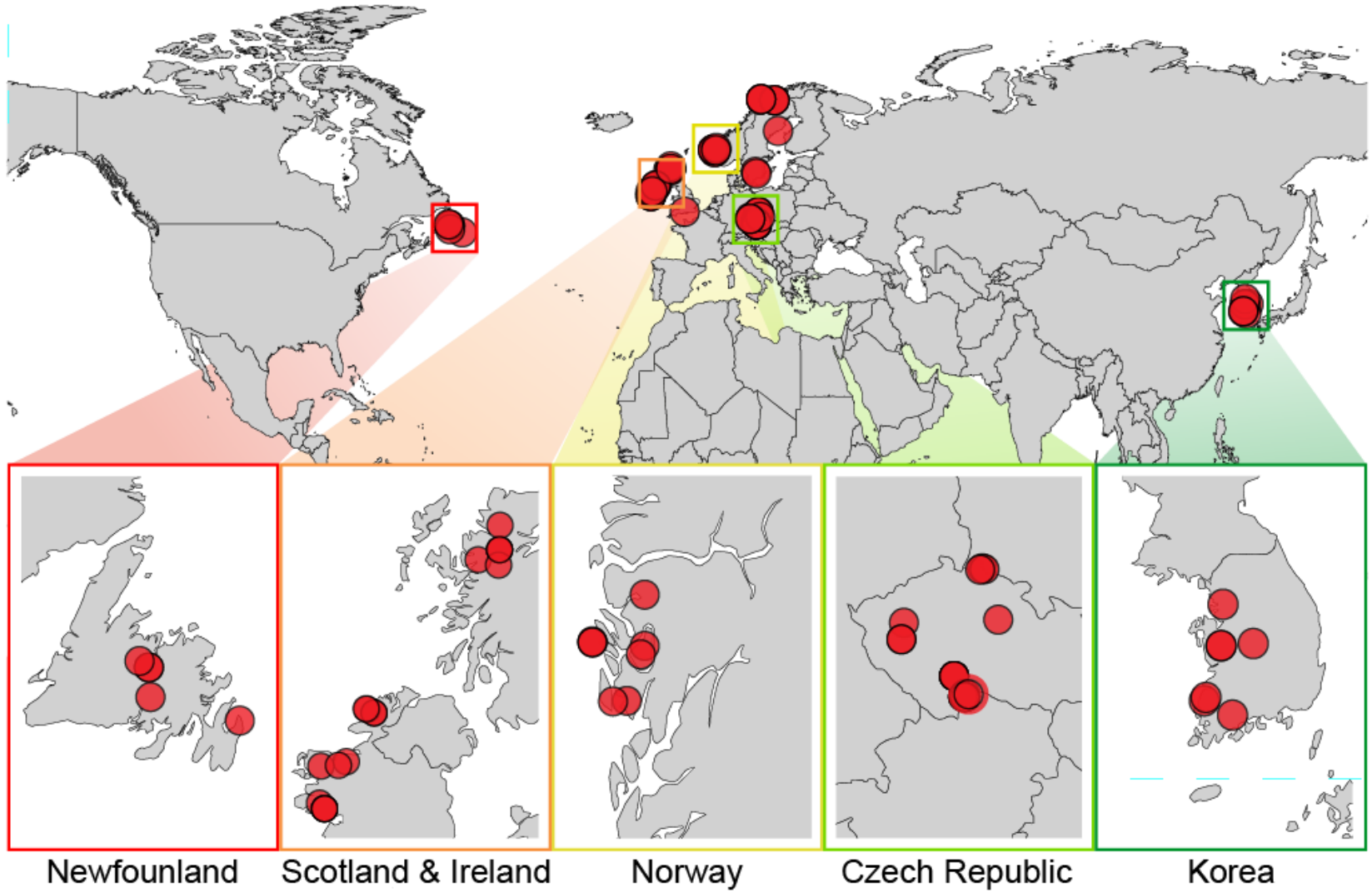






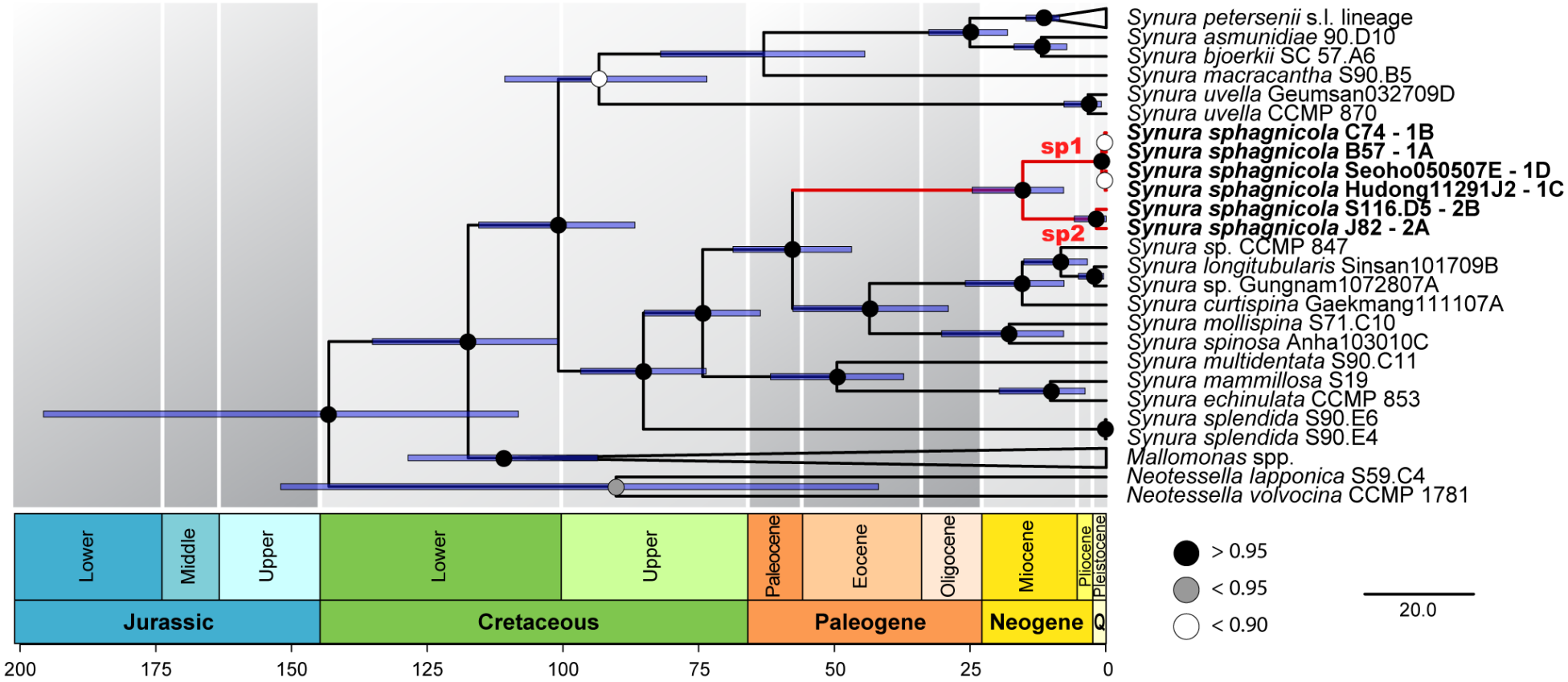
Sampling

- A total of 71 newly established strains
  - ITS, cox, psaA ,SSU, rbcL sequences
  - Geographic coordinates
  - Environmental data (19 bioclimatic variables, 7 habitat variables)
  - Morphological analyses (morphometry of silica scales)



Phylogenetic relationships and timing of divergence

- All strains form a single, monophyletic lineage
- The lineage was split into two distinct clades at about 15 - 18 Mya

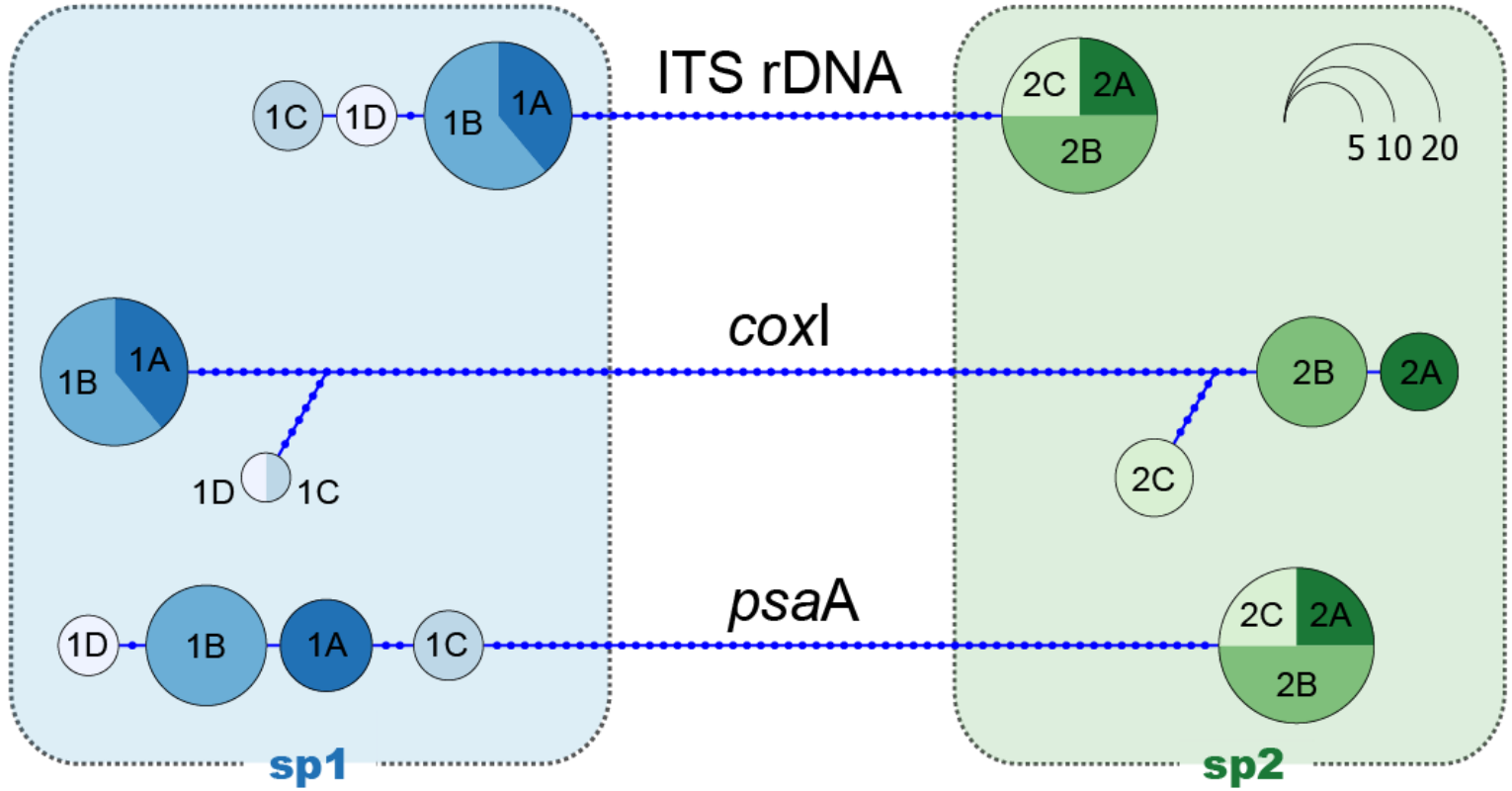


Time-calibrated phylogeny for the Synurales based on concatenated *SSU rDNA* and *rbcL* sequences

Škaloud, P., Škaloudová, M., Doskočilová, P., Kim, J.I., Shin, W. & Dvořák, P. (2019): Speciation in protists: Spatial and ecological divergence processes cause rapid species diversification in a freshwater chrysophyte. *Molecular Ecology* 28: 1084-1095.

Phylogenetic relationships and timing of divergence

- A fine molecular diversity was revealed within the clades sp1 and sp2
- Seven haplotypes recovered: 1A, 1B, 1C, 1D, 2A, 2B, 2C

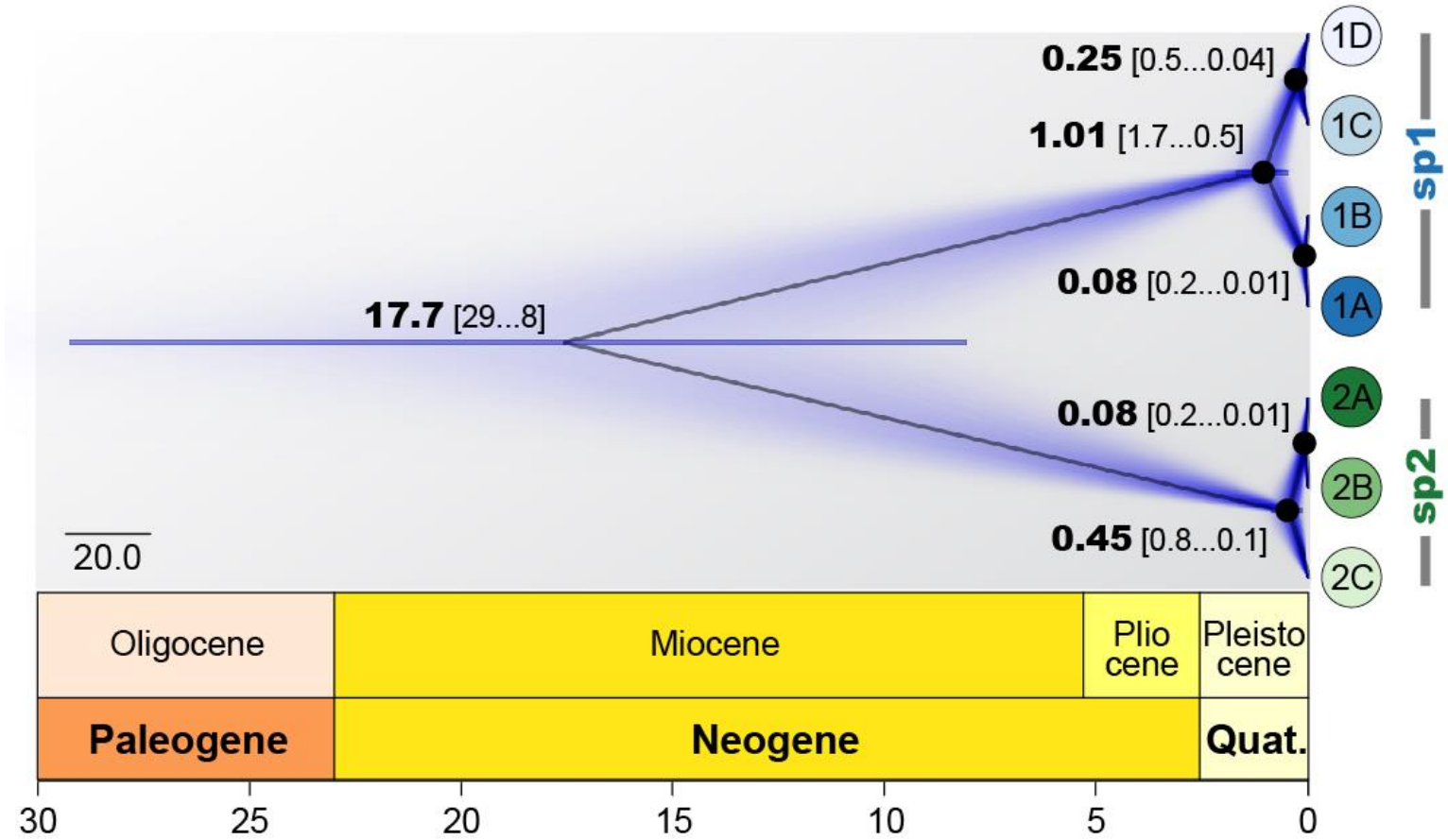


Statistical parsimony networks of four sp1 and three sp2 haplotypes based on the analysis of three loci sequences. Circle sizes are proportional to haplotype frequency. Lines between haplotypes are single mutational steps; small dots indicate missing haplotypes.

Škaloud, P., Škaloudová, M., Doskočilová, P., Kim, J.I., Shin, W. & Dvořák, P. (2019): Speciation in protists: Spatial and ecological divergence processes cause rapid species diversification in a freshwater chrysophyte. *Molecular Ecology* 28: 1084-1095.

Phylogenetic relationships and timing of divergence

- Recent radiation of haplotypes in the Pleistocene

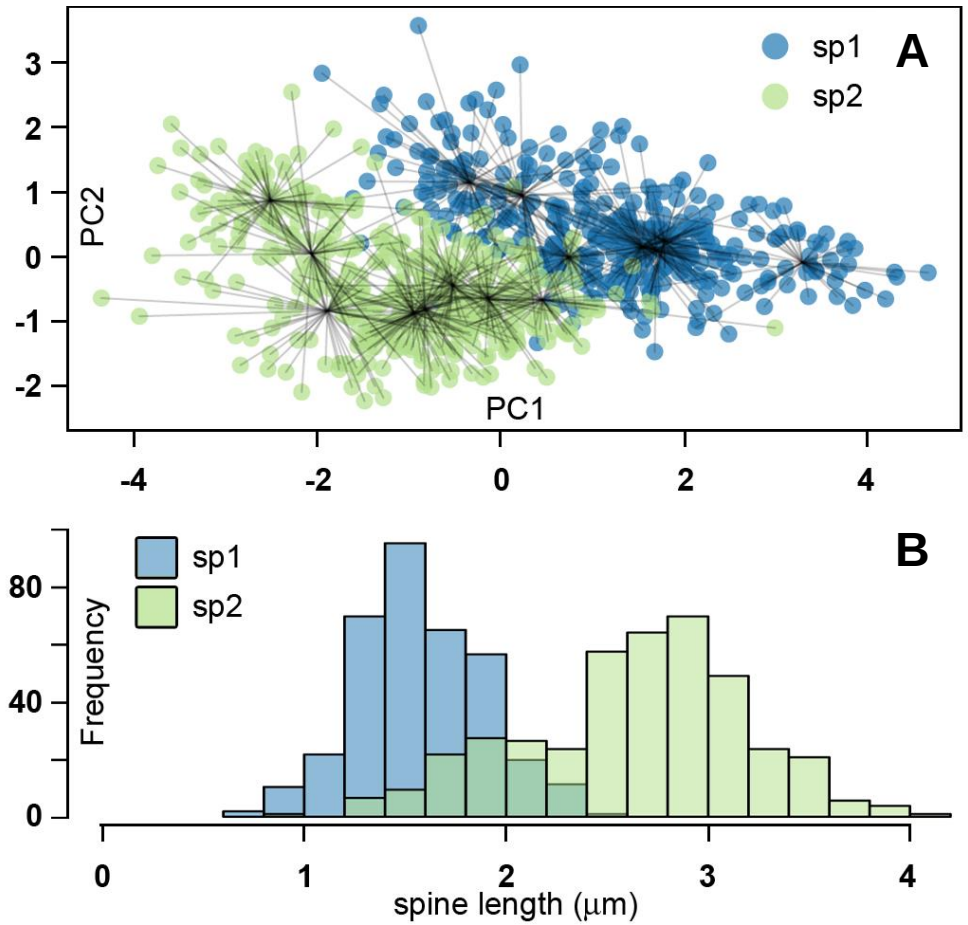


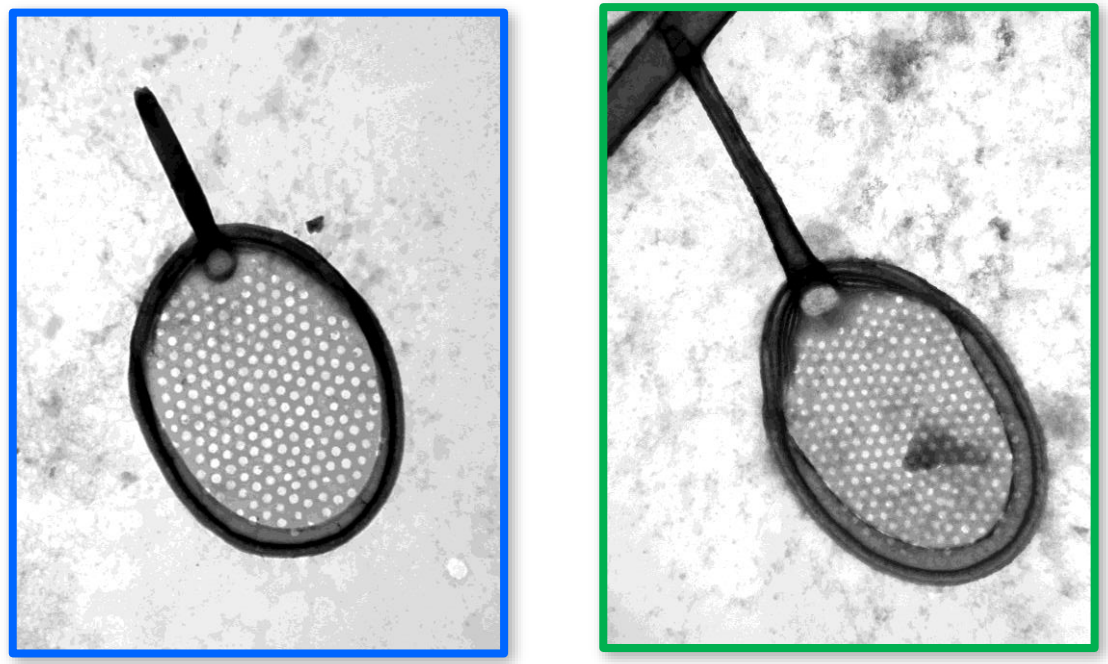
Time-calibrated coalescence species tree with the visualisation of the most probable topologies.

Škaloud, P., Škaloudová, M., Doskočilová, P., Kim, J.I., Shin, W. & Dvořák, P. (2019): Speciation in protists: Spatial and ecological divergence processes cause rapid species diversification in a freshwater chrysophyte. *Molecular Ecology* 28: 1084-1095.

Morphological analyses

- Sp1 and sp2 clades are morphologically well differentiated, with the spine length selected as the best discriminating character.
- Haplotypes morphologically indistinguishable.





A: PCA ordination of 810 silica scales showing the morphological distinction of the lineages sp1 and sp2. The scales clustered based on their affiliation to 15 investigated strains.

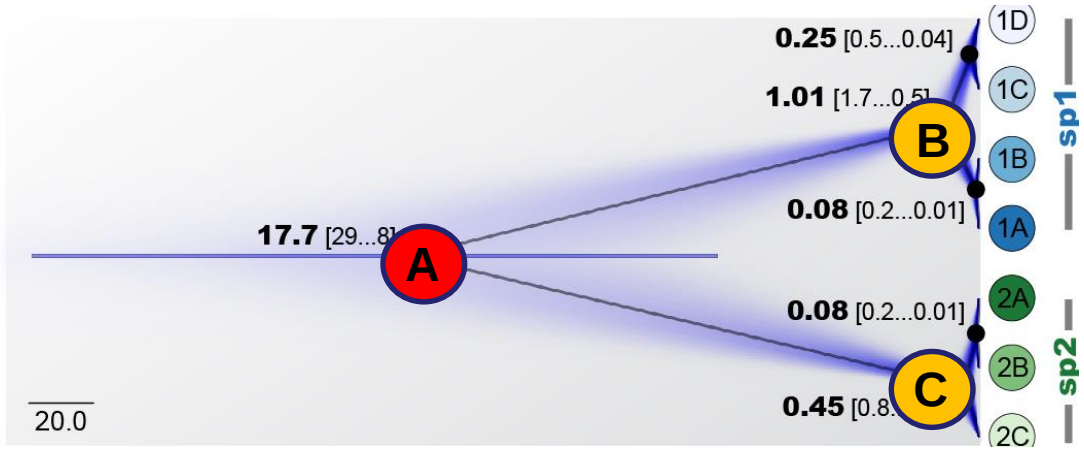
B: The distribution of spine lengths in sp1 and sp2 lineages.

Škaloud, P., Škaloudová, M., Doskočilová, P., Kim, J.I., Shin, W. & Dvořák, P. (2019): Speciation in protists: Spatial and ecological divergence processes cause rapid species diversification in a freshwater chrysophyte. *Molecular Ecology* 28: 1084-1095.

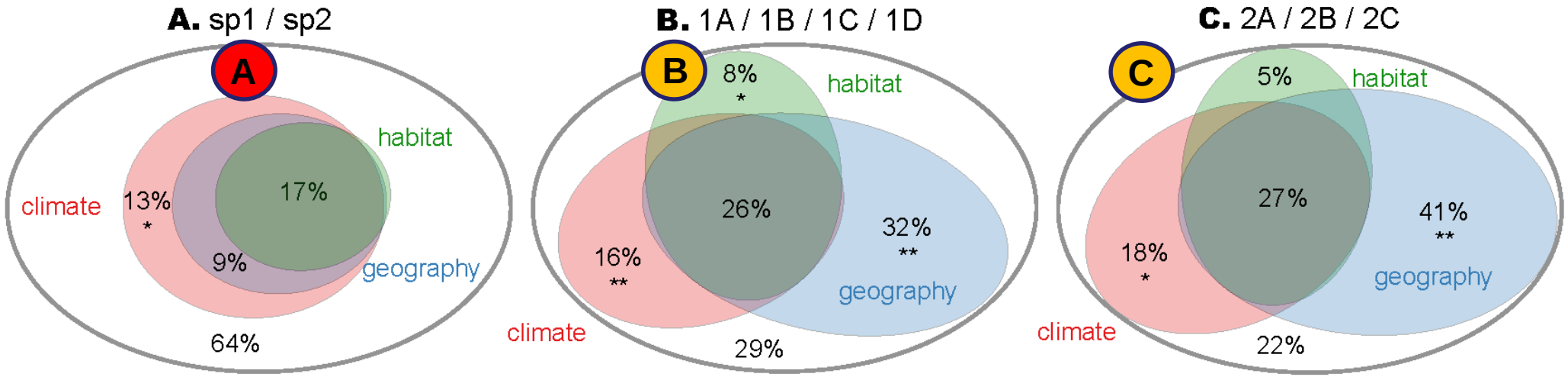
Explaining patterns in molecular diversity

- The haplotypes are ecologically and biogeographically much more differentiated than the old clades, presumably because of their persistent differentiation after the allopatric speciation events.

- The patterns of variation partitioning of sp1 and sp2 lineages are very similar



Venn's diagrams showing the relative effects of climate, habitat and geographical distance on the variance in *Synura* diversity:



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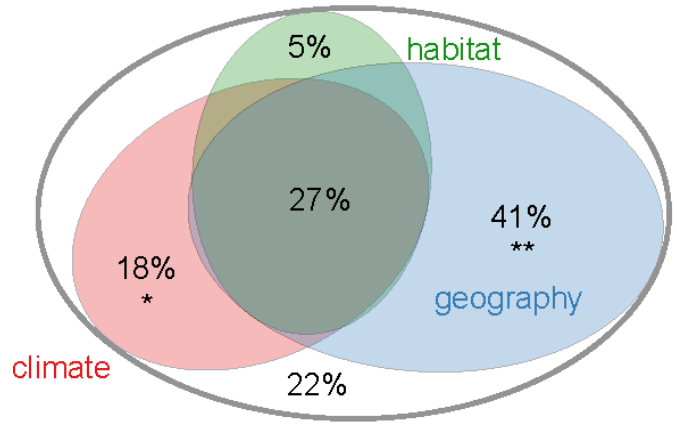
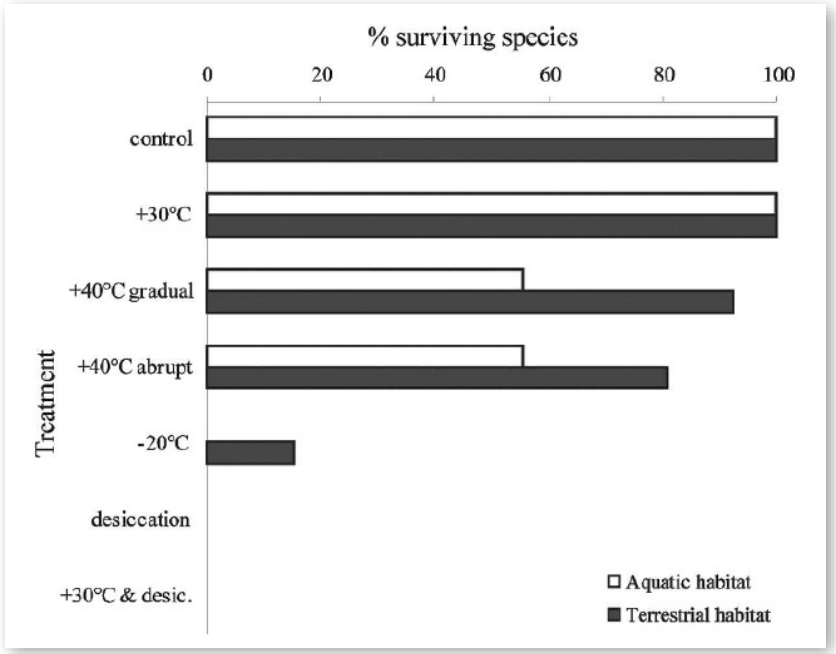
Protist speciation

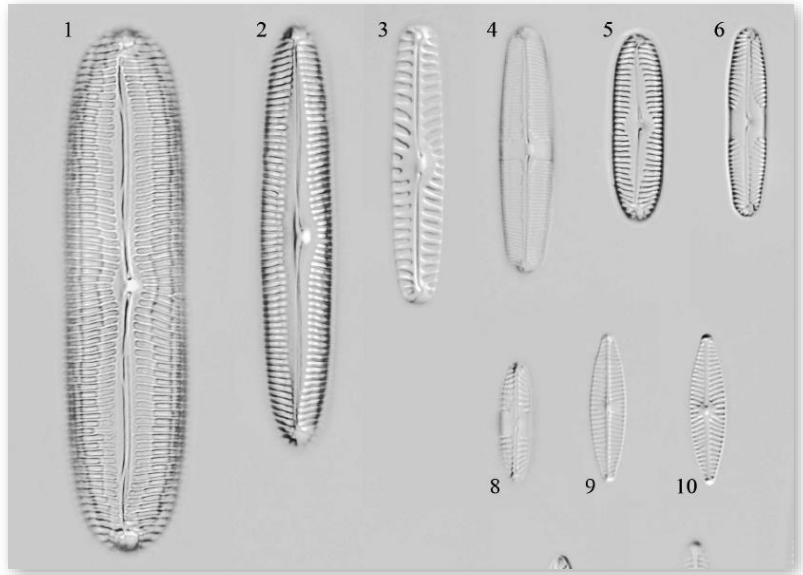
- Both allopatric and divergent ecological speciation may occur in protists.

- How can populations be resistant to gene flow under the continuous influx of immigrant cells?



1. Unfavourable conditions during the long-distance transport





Souffreau et al. (2010). *Phycologia* **49**: 309-324

Škaloud, P., Škaloudová, M., Doskočilová, P., Kim, J.I., Shin, W. & Dvořák, P. (2019): Speciation in protists: Spatial and ecological divergence processes cause rapid species diversification in a freshwater chrysophyte. *Molecular Ecology* 28: 1084-1095.

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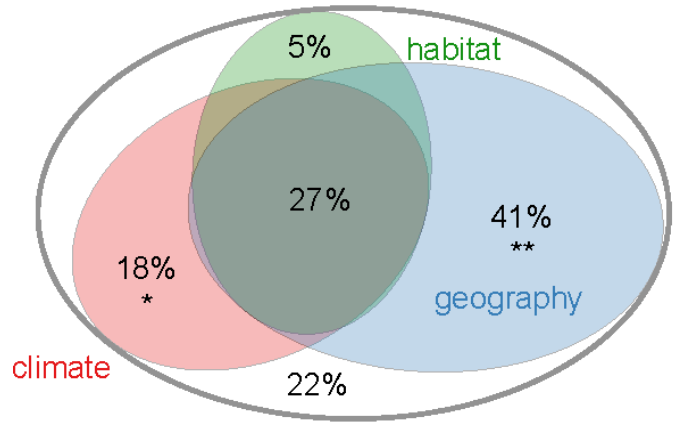
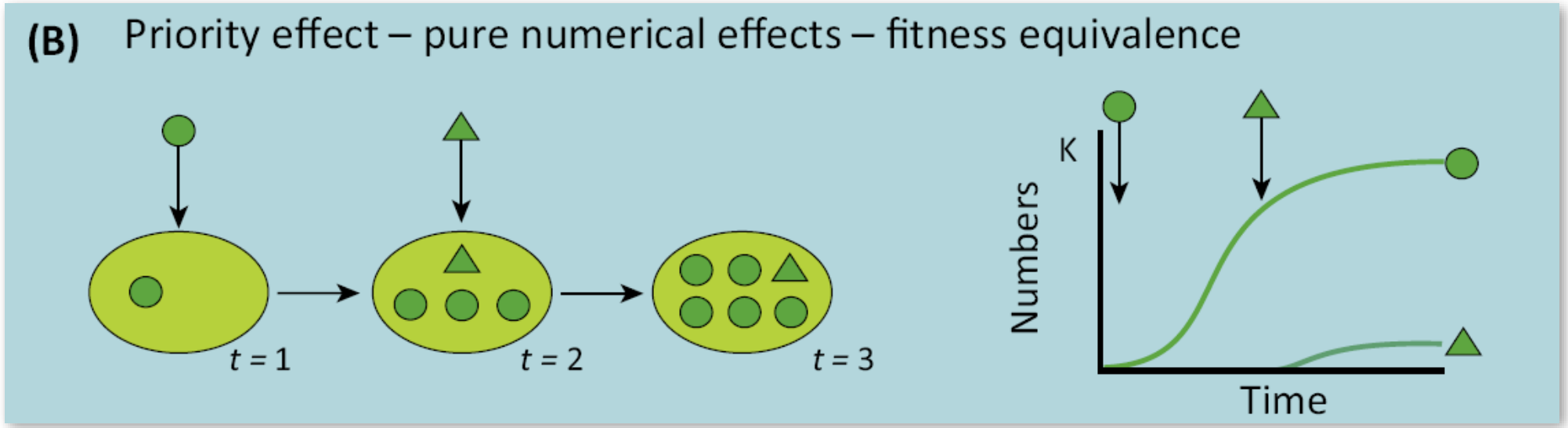


2. Priority effect of resident species

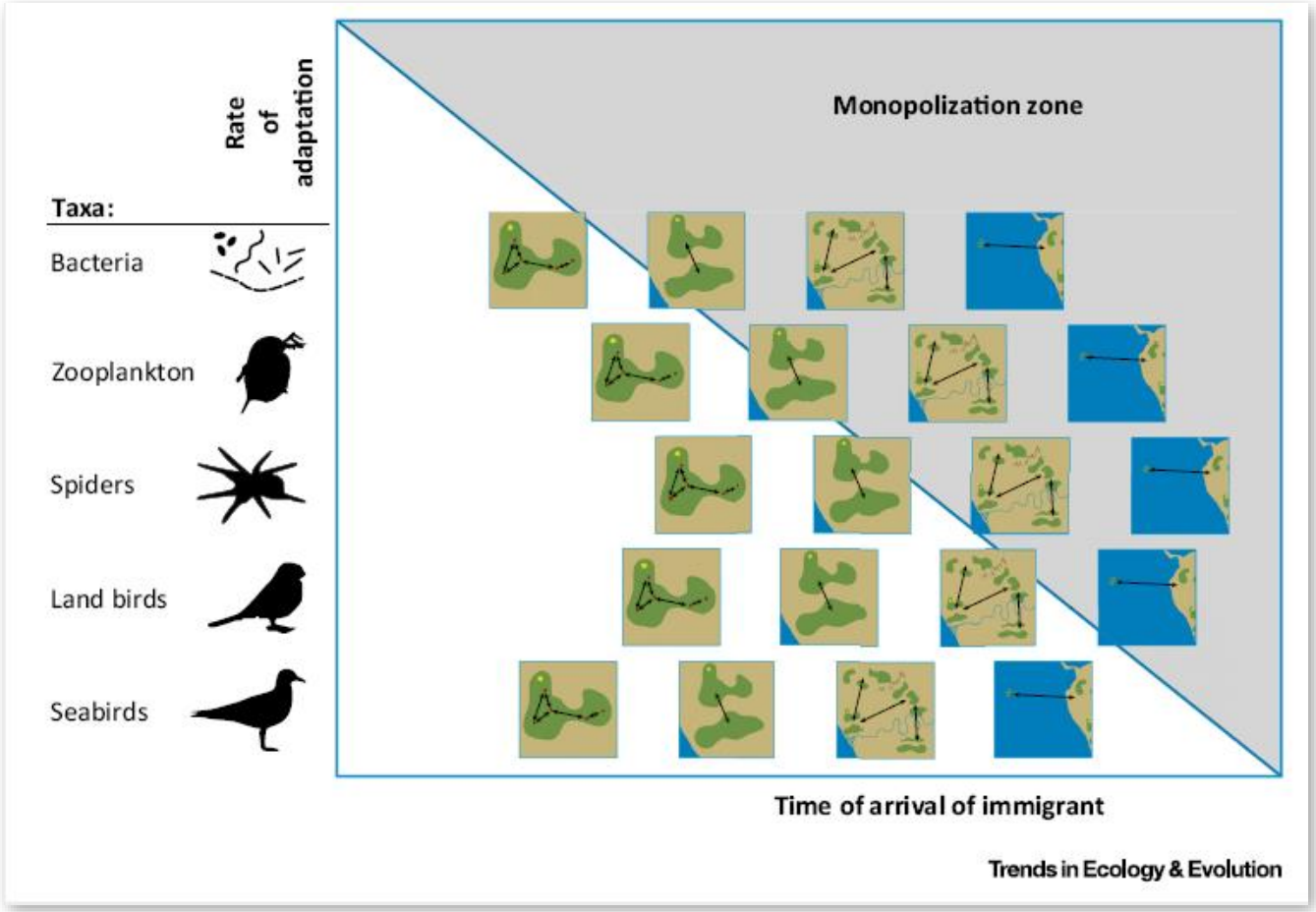


De Meester et al. (2016). *Trends Ecol Evol* **31**: 136-146

Škaloud, P., Škaloudová, M., Doskočilová, P., Kim, J.I., Shin, W. & Dvořák, P. (2019): Speciation in protists: Spatial and ecological divergence processes cause rapid species diversification in a freshwater chrysophyte. *Molecular Ecology* 28: 1084-1095.

Priority effect

- Priority effect (monopolization of resources) much probable for microorganisms.

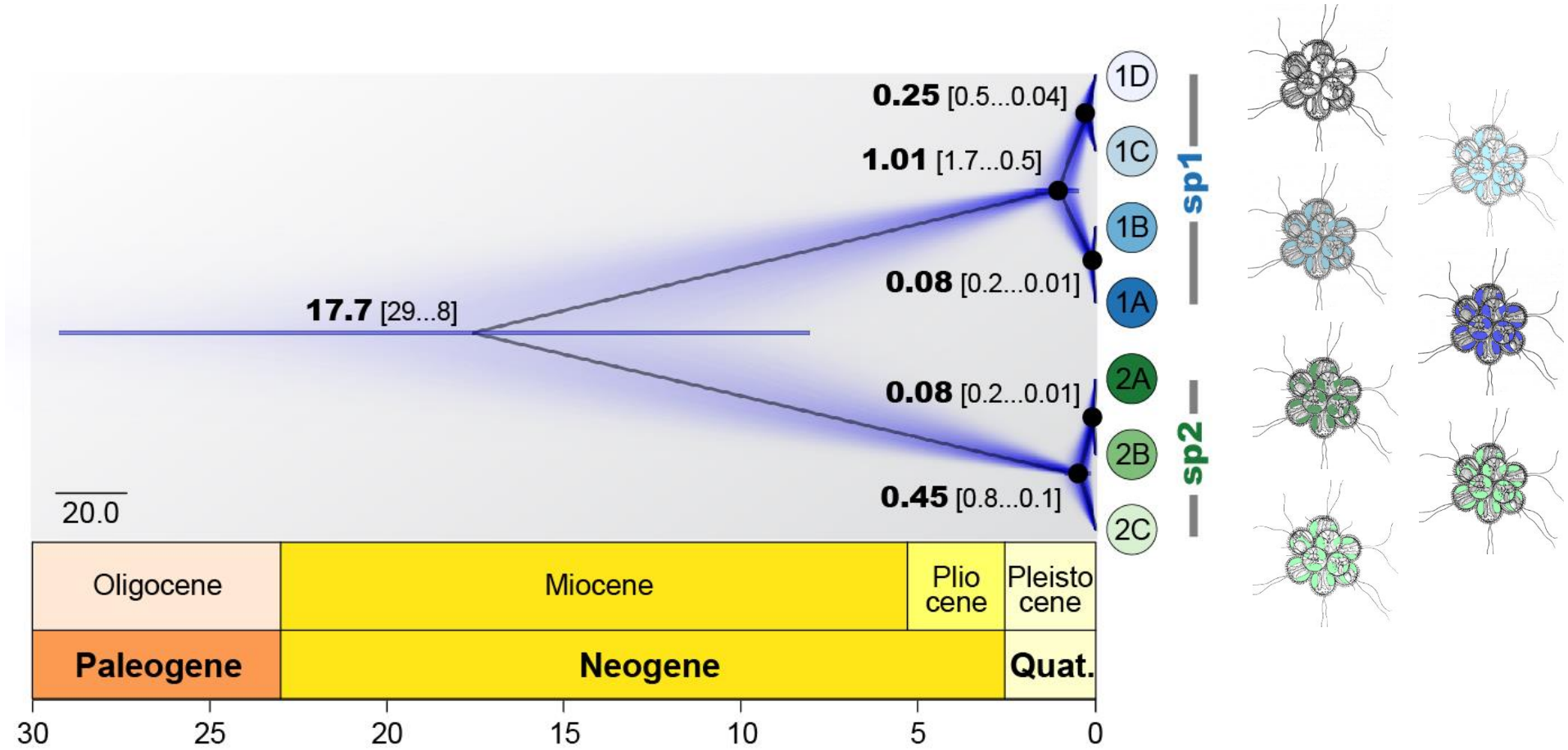


De Meester et al. (2016). *Trends Ecol Evol* **31**: 136-146

Škaloud, P., Škaloudová, M., Doskočilová, P., Kim, J.I., Shin, W. & Dvořák, P. (2019): Speciation in protists: Spatial and ecological divergence processes cause rapid species diversification in a freshwater chrysophyte. *Molecular Ecology* 28: 1084-1095.

Revisiting species concept of protists

- The haplotypes in fact represent young species diverging in late Pleistocene.
- The scarcity of morphological features in protists lead to ignoring recently diverged lineages and recognizing rather evolutionary old lineages as species units.



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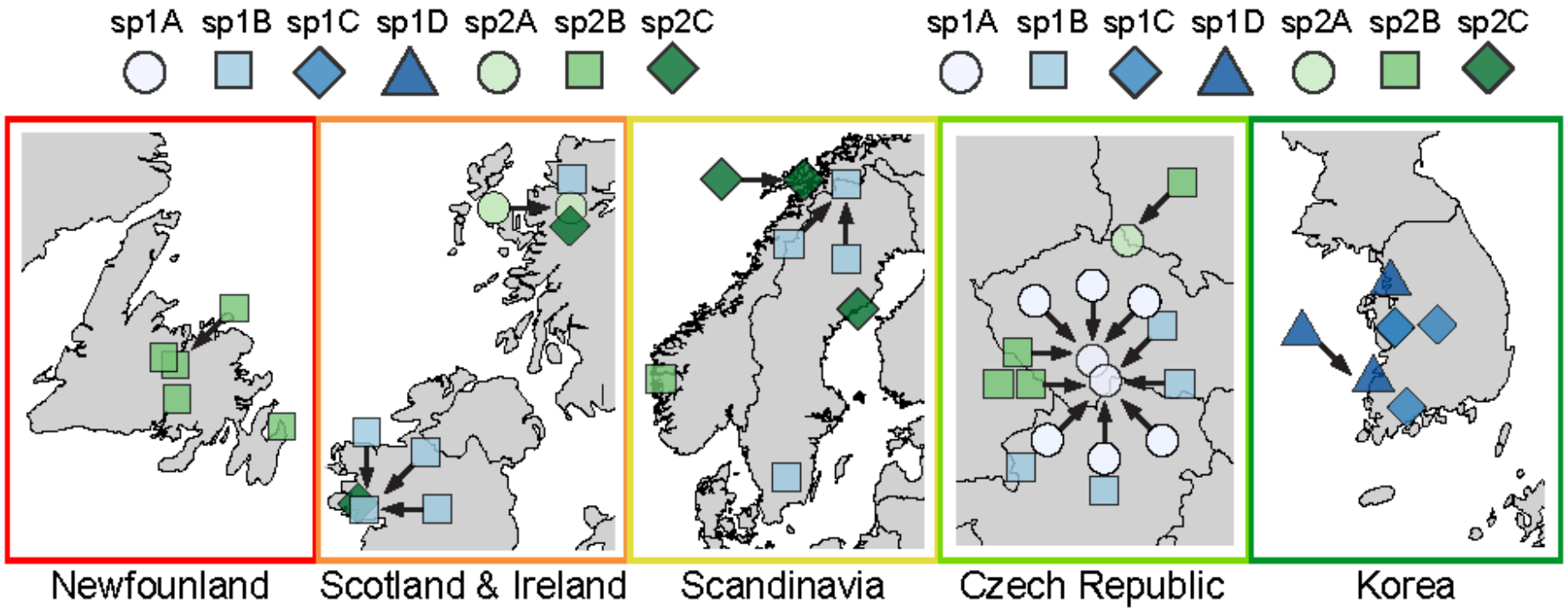

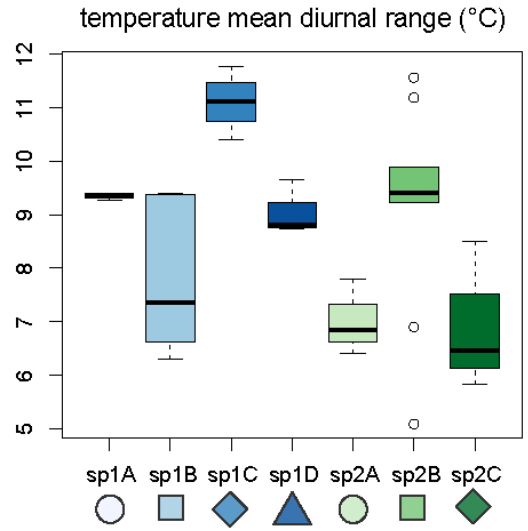

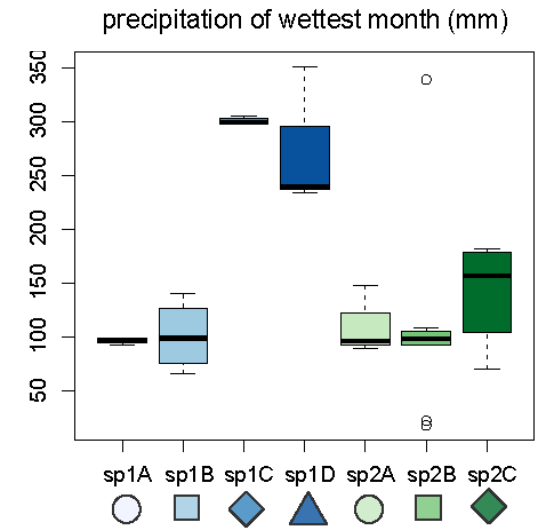

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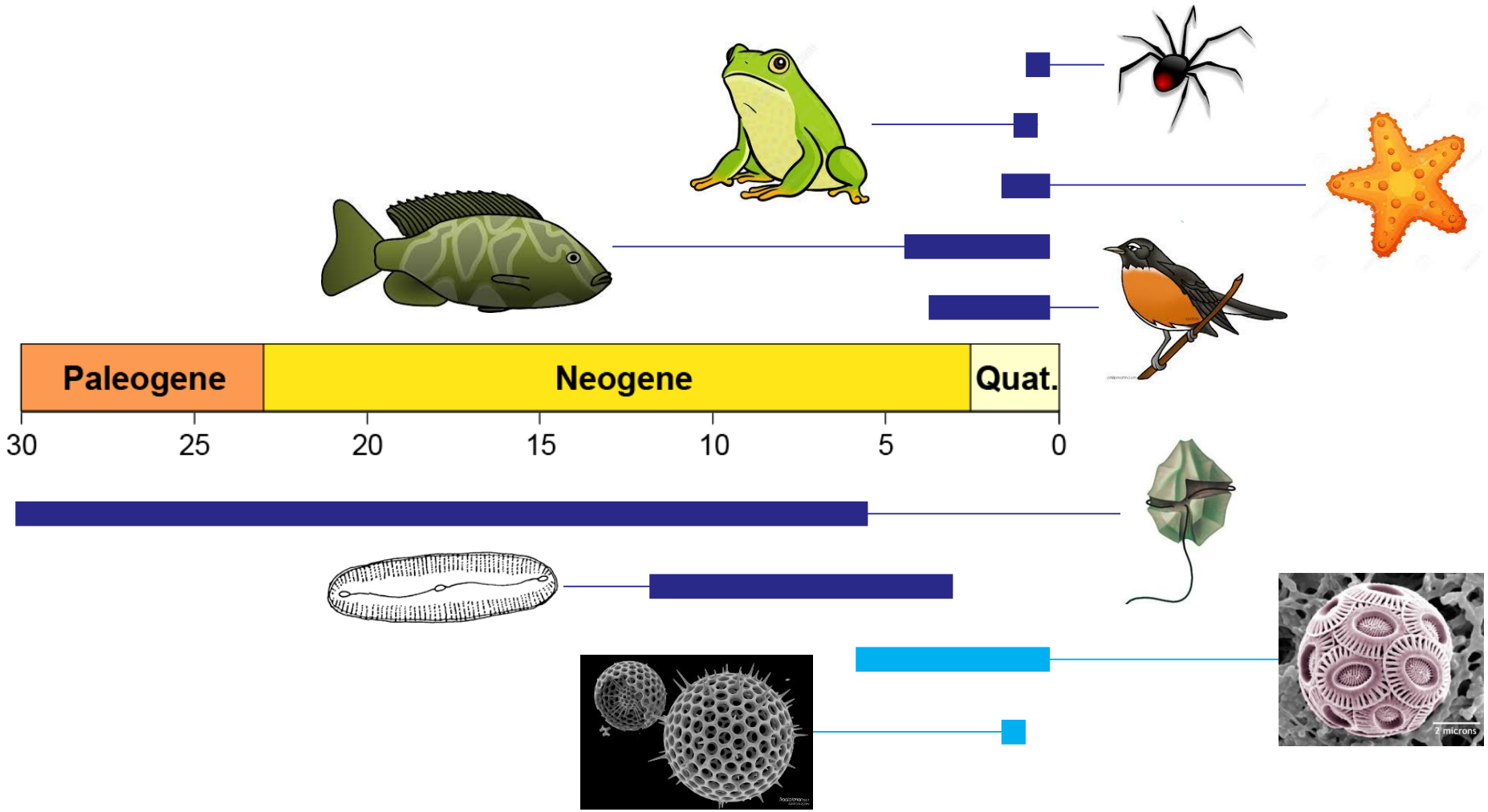
Revisiting species concept of protists

- In contrast to macroorganisms, the estimated divergence times of sister protist species are usually much older.



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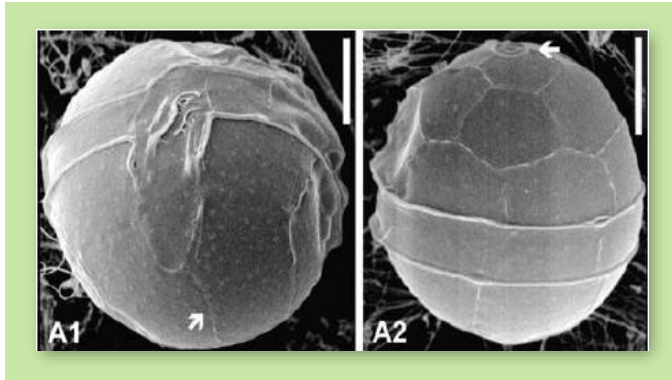
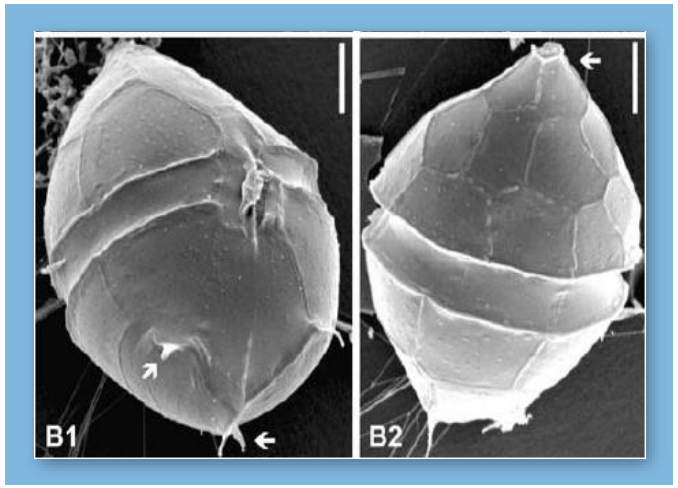
Revisiting species concept of protists

- It is highly probable that numerous protist species originated during the Quaternary

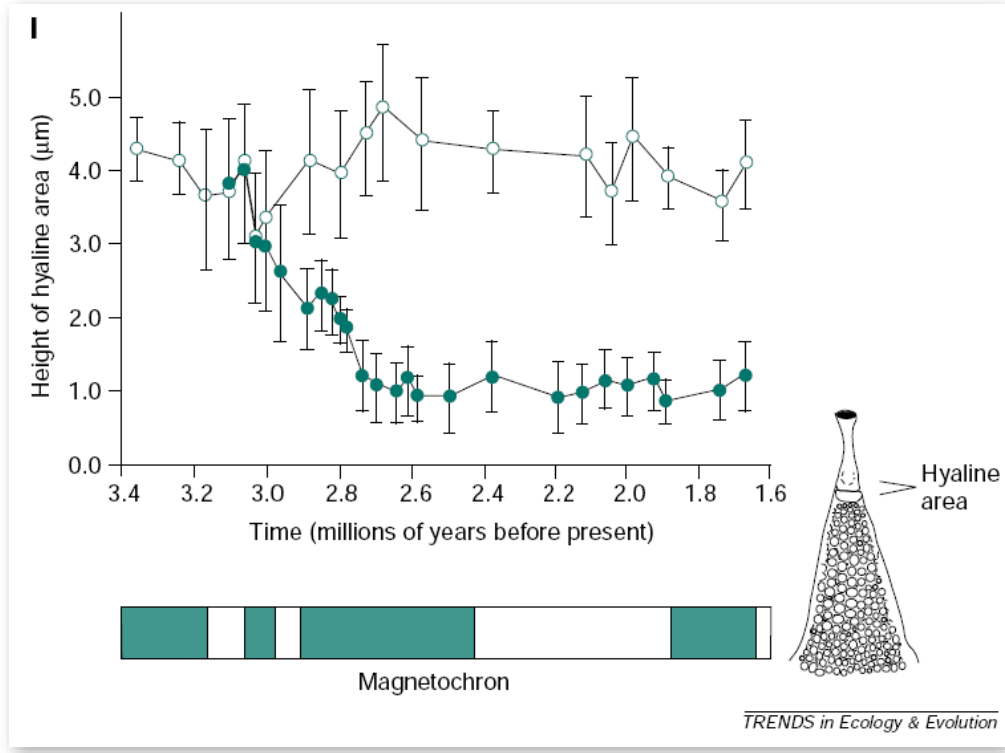
Scrippsiella hangoei - brackish



Peridinium aciculiferum - freshwater



Rhizosolenia praebergonii



Benton & Pearson (2001). *Trends Ecol. Evol.* **16**: 405-411

Logares et al. (2007). *Microb. Ecol.* **53**: 549-561

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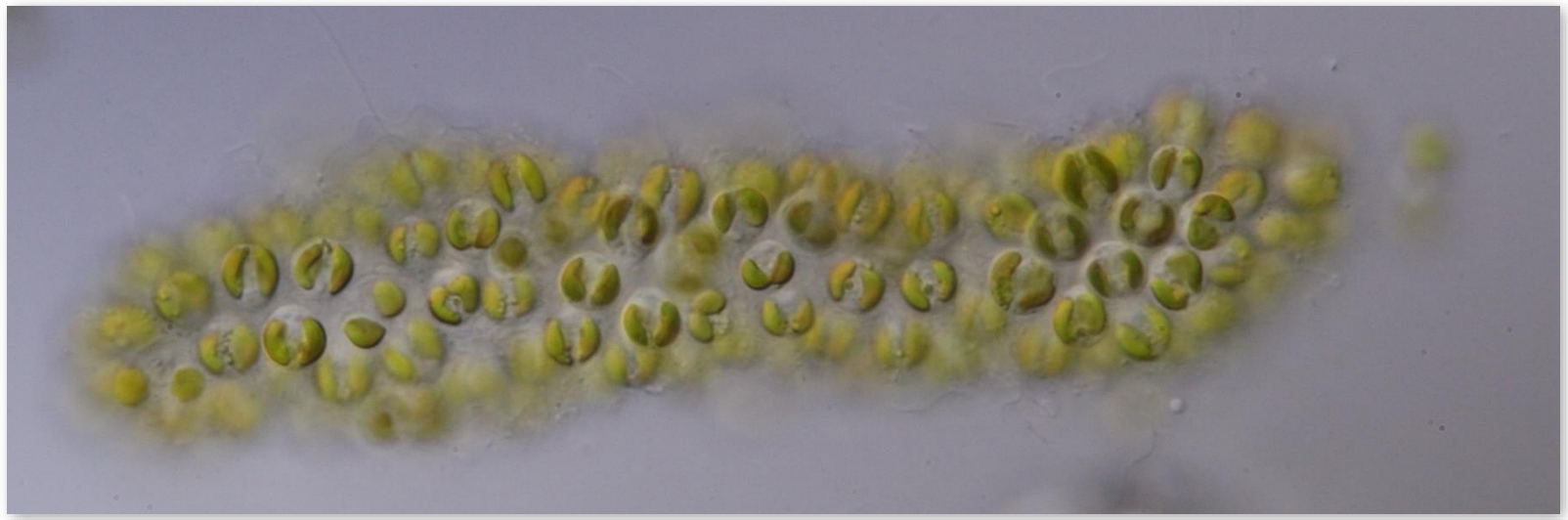
Conclusions

- We uncovered rapid species diversification in a freshwater microbial eukaryote that occurred during the late Pleistocene.
- Ecological and allopatric speciation seem to occur much more readily in microbia eukaryotes than was previously thought.
- Speciation times of microorganisms may be in some lineages equivalent to the estimated divergence times of plants and animals.



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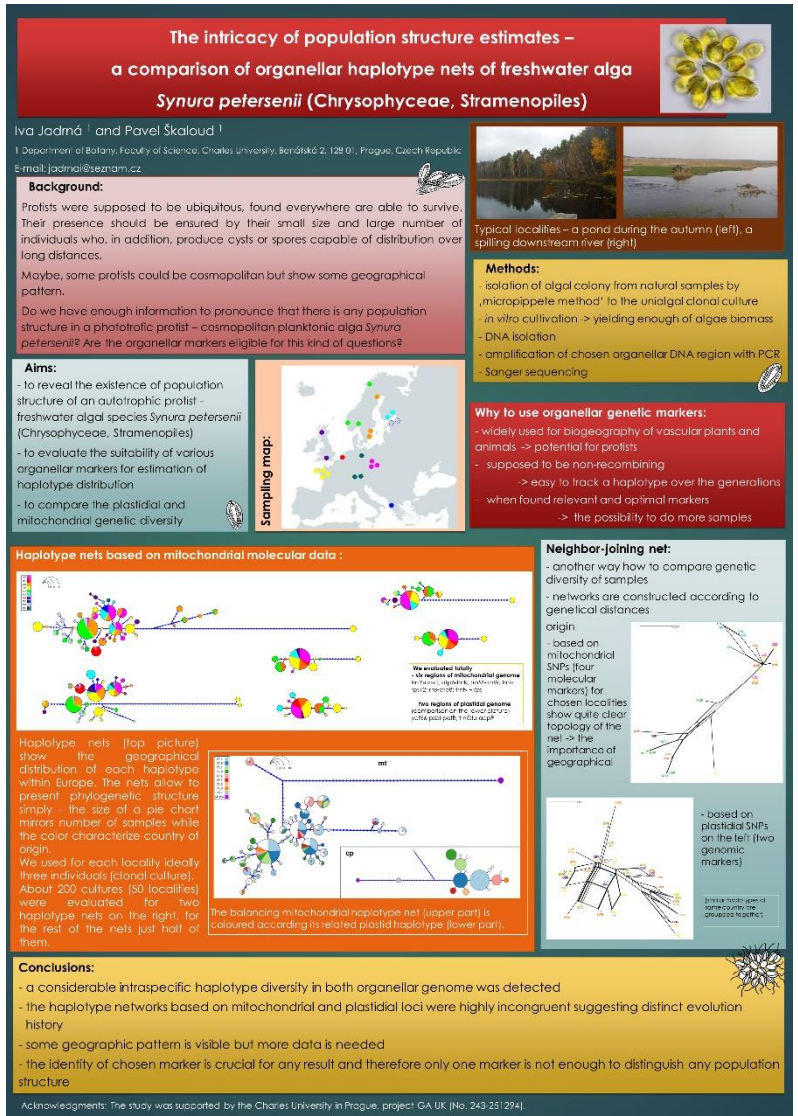
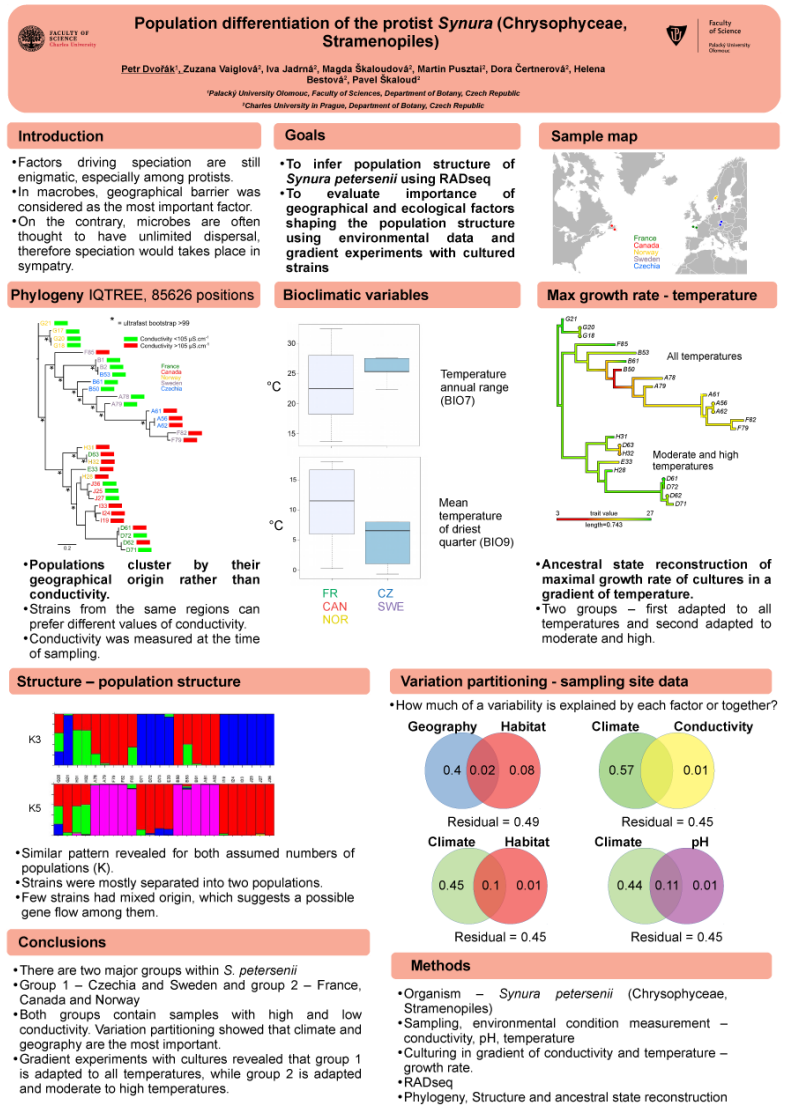
Future steps

- To recover the population structure and assess the importance of geographical and ecological factors in shaping the populations



organellar loci
15PO.1 Iva Jadrná

RAD-Seq
15PO.3 Petr Dvořák



Thank you for your attention!

This research was supported by the Czech Science Foundation No. 17-13254S