Lake Database project

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Abstract

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Introduction

P1: The general question

Multicellularity is a major evolutionary transition that enabled life to grow larger and explore new ecological niches, resulting in a diverse biosphere we see today. The multiple, independent origins of multicellularity across the tree of the life indicate convergence of ecological opportunities for multicellular phenotypes. However, the majority of life remain unicellular. We therefore lack the understanding of how ecological factors differentially favour multicellular or single-celled organisms.

What still needs to be done in this field?

P2: pros and cons of multicellularity, why need ecological factors in explaining the rise and maintenance of multicellularity

As cells start forming groups. The group level (multicellular) unit interact with its environment differently. Generally speaking, multicellularity brings a size increase and an internal environment. Larger size can improve predator/grazer resistance, faster sedimentation rate for accessing nutrient in aquatic environment, or faster foraging of patchy resources in terrestrial environments. Benefits by internal environment includes buffer against stress, nutrient deficiency, efficient use of extracellular products, etc. A significant disadvantage in the initial evolution of multicellular phenotypes, however, is reduced growth (i.e., reduced per-cell division rate). This direct fitness cost poses a barrier in explaining the initial emergence of multicellularity. It is therefore crucial to examine whether there are any broad-scale ecological factors associated in multicellularity that not only maintains the multicellular phenotype but also enable their coexistence with unicelled organisms.

P3: Why it’s challenging?

Studying ecological factors in relation to multicellularity across a large scale is challenging in three major ways. First, there are nearly infinite dimensions of ecological factors that can select for traits, we therefore need a study system which ecological predictors and species’ traits are well established. Second, extensive data on ecological factors and species occurrence and traits over space and time are required for uncovering general patterns. Third, as species traits are also heavily influenced by their evolutionary history, therefore phylogenetic information among species are necessary to disentangling ecological factors from evolutionary ones.

P4: Study system: freshwater algae and the Swedish lake monitoring scheme

The Swedish long-term lake monitoring scheme provides a unique opportunity for addressing such challenges. It is a database span over 60 years and over 10,000 Swedish lakes. Data including lake physiochemical properties such as macronutrients nitrogen and phosphorus, temperature, dissolved oxygen, etc; together with freshwater green algae species occurrence and abundance were routinely collected. We therefore have a system with green algae species and their ecological correlates over spatial and temporal dimensions. Freshwater green algae are particularly well suited for this study as their growth response under the influence of nutrient and light are well documented. In addition, they have clear trait differences in their cellular constructions, as many species are single celled, and many others are colonies.

P5: How did I address this knowledge gap?

In this study, we compliment the freshwater green algae species in Sweden by adding trait information on multicellularity as well as the presence of extracellular matrix, also referred to as mucilage or mucus layer, through literature search. This phenotypic information was combined with phylogenetic relationships of 114 genus were obtained from 18S sequencing. Modelling the data using Hierarchical Modelling of Species Communities (HMSC), which integrates species’ phylogeny, traits and their influence under temporal and spatial ecological factors. We aim to answer three questions. 1, Do unicellular and multicellular freshwater green algae species differ in their ecological niche, if so, which ecological factors favour multicellularity? 2, Are their seasonal differences between unicellular and multicellular green algae? (more questions?)

Methods

**The environments and phenotypes of green algae in Swedish lakes**

Data on Swedish lakes’ physiochemical parameters and phytoplankton abundance (biovolume, mm3 l−1) from years 1964 to 2023 was downloaded from SLU Miljödata-MVM (http://www.slu.se/miljodata-MVM) on 18th January 2024. Subsequent literature searches were performed on each phytoplankton species in the database (N=332) to describte whether they are multicellular or unicellular, and whether there are ECM present (multicellular species were classified as having typical cell numbers larger or equal to four). References includes Swedish freshwater phytoplankton field guide ‘Växtplanktonflora’ (phytoplankton flora), the online algae database ‘Algaebase’ ([www.algaebase.org](http://www.algaebase.org)), and other primary publications where focal species were described. (Supplementary).

**Phylogeny construction**

“ In total, there were 332 species from 114 genera. Multicellularity and ECM presence were typically invariant within genera. Records for some species were sparse and we therefore summarized phenotypic information at the genus level and calculated the median concentration of ammonium, nitrite + nitrate and total phosphorus concentrations of lakes where each genus was found. Total phosphorus was included in analyses as it is a critical macronutrient that is often limiting for algal growth. Species with less than ten occurrence records were excluded from the dataset. The full dataset with references for cell number and ECM is presented in Supplementary Table 4.”

Literature search on species description with focus on multicellularity and presence of mucilage.

Merging physiochemical data on Swedish lakes and the phytoplankton flora

“Information on water chemistry and phytoplankton biovolumes (mm3 l−1) from all lakes in Sweden from years 1964 to 2019 was downloaded from SLU Miljödata-MVM (http://www.slu.se/miljodata-MVM) on 18 January 2019. For each species in the database, we performed literature searches to collect data on multicellularity (a species was considered multicellular when the typical cell number in a group was greater or equal to four) and the presence of ECM, sometimes referred to as mucus or mucilage. The primary reference for all species was ‘Växtplanktonflora’ (phytoplankton flora)76. The second main reference was ‘Algaebase’ (www.algaebase.org). When these sources did not have information about species, freshwater field guides in Europe or the original publication describing the species were used (Supplementary Table 476–112). In total, there were 332 species from 114 genera. Multicellularity and ECM presence were typically invariant within genera. Records for some species were sparse and we therefore summarized phenotypic information at the genus level and calculated the median concentration of ammonium, nitrite + nitrate and total phosphorus concentrations of lakes where each genus was found. Total phosphorus was included in analyses as it is a critical macronutrient that is often limiting for algal growth. Species with less than ten occurrence records were excluded from the dataset. The full dataset with references for cell number and ECM is presented in Supplementary Table 4”