Käapa Põhikool

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Variability of the phytoplankton functional composition in the lakes and streams in Võru county

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List of contents

1. Introduction

Aim of this research project was to learn about one of the most important component of aquatic ecosystems: planktic phototrophic microalgae, collectively known as *phytoplankton*.

As primary producers, phytoplankton form the basis of aquatic food chains. Because they are microscopic, then this is part of biodiversity less known for common observers of nature.

More specifically, this research was trying to answer the following questions: to the phytoplankton communities in not so distant lakes and rivers in Võru county (southern Estonia) look alike or not, and if not, then what are the main differences; and what may cause the differences.

To answer these questions, water samples were collected from fourteen water bodies, and the functional properties of phytoplankton community in the samples was investigated under light microscope. To describe functional diversity and composition, size and shape of the individual organisms was recorded. Both of these characteristics are important ecologically, determining how much of the biomass is edible for higher trophic levels.

Studied waterbodies included 12 lakes and 2 streams, and sampling was conducted during the phytoplankton spring blooms (in the end of April). Spring bloom was chosen because this is the time of year when most of the phytoplankton biomass is produced and consumed.

Kääpa School belongs to GLOBE schools, and the students measure the hydrological parameters in local lakes and rivers. Current study was part of these activities. The measurements done by different students will be combined in the end, to create new insights and links between these parameters.

2. Literature overview

2.1 Who or what is phytoplankton?

Phytoplankton consists of drifting aquatic organisms, who inhabit mostly the upper part of the water column that has light in it (Lee, 2008).Most phytoplankton organisms are photoautotrophic, using sunlight as an energy source when producing organic material.

Phytoplankton makes most of the primary production and is the base of the food web in aquatic ecosystems (Reynolds jt. 2002). Global total biomass of phototrophic phytoplankton in any moment of time is less than 1% of total photosynthesizing biomass on Earth, however, phytoplankton is still responsible for nearly half of the annual global primary production (Falkowski jt. 2004).This is possible because phytoplankton inhabits aquatic environment, and entire biomass is photosynthesizing (in contrast to trees, for example, where only small part – leaves – are photosynthesizing).

Phytoplankton is taxonomically very diverse (Lee, 2008), including many *phylogenetically* distant organisms from bacteria to eukaryotes. Some of the member of phytoplankton have flagella, and can swim around, some can also prey on other organisms (be both autotrophic and heterotrophic).

The main common characteristic of phytoplankton organisms is the need to remain in the upper layer of water column (where there is light), and not to become eaten (Reynolds, 2006). These two goals contradict eachother – because for not to be eaten, it is good to be large, but when large, it is difficult to remain floating. This kind of contradiction is called "trade-off" (Litchman jt. 2010).

Trade-offs are the reason why nature is so diverse – no single species can have all the good properties at the same time. Co-existence is possible, because each species is best in one thing.

2.2 Most important phytoplankton groups

There are many groups of algae, but only few are very widely spread. In the marine ecosystems, three groups dominate: diatoms, dinoflagellates and cyanobacteria. In freshwater, also green algae and golden algae are abundant (Lee 2008).

2.2.1 Diatoms

Special feature of diatoms (*Bacillariophyceae*)is their cell wall that is made of silica (biogenic *glass*), and looks like a box with a lid (Lee, 2008). Diatoms are the most common algae in all aquatic ecosystems, making up about half of the total phytoplankton globally (Graham ja Wilcox, 2000). All diatoms are non-motile (no flagellum), and after bloom, most of them sink to the bottom of the water body. To remain floating, they need waves and turbulence. Because they use the silica to make their cell walls – something that they simply take from water, and don't have to produce themselves, they are able to grow very fast. But they usually also need lot of nutrients (inorganic phosphorus and nitrogen). Therefore, diatoms are mostly seen during spring bloom – when there is plenty of nutrients, and more waves, and water is cold (Reynolds 2006). In the aquatic food webs, especially in oceans, diatoms are most important food source for zooplankton (for example for *copepods*). Diatoms can grow as single cells as well as chains or colonies.

2.2.2 Dinoflagellates

Dinoflagellates (*Dinophyceae*) are the second most common phytoplankton group in the world (Graham ja Wilcox, 2000). They have a organic cell wall, and they have two flagella, which makes them able to swim and move around. Dinoflagellates grow slowly, compared to diatoms. But they do better when the nutrient levels are low, and when the water is still (no waves). They are more abundant in summer, after the spring blooms.

2.2.3 Green algae

Green algae (*Clorophyceae*) are mostly living in fresh water (Graham ja Wilcox, 2000). They differ from diatoms and dinoflagellates firstly by their color (photosynthetic pigments). In other aspects, they are quite diverse: there are species that make colonies, or live as single cells, who are able to swim (have flagellum) or are not. They are most common in summer, in the warm water. They are also sometimes seen as indicators of pollution, because they like high nutrient levels (Reynolds 2006).

2.2.4 Golden algae

Also golden algae (*Chrysophyceae*)are mostly living in freshwater, and they are the least abundant group of all these that are described here. Golden algae can live as single cells or colonies, and also include motile and non-motile species. Like diatoms, some golden algae use silica to build parts of they body, for example scales or long spines, that should protect them from zooplankton (Graham ja Wilcox, 2000).

2.3 Functional diversity

Functional diversity is one way to measure and describe biodiversity. Traditionally, the most typical way to measure diversity is with species richness: the more species you have, the more diverse is the community. More complicated, but ecologically important, is to look at *evenness:* if all species are equally abundant, or are some species dominating. Community, where one species dominates, is considered less diverse than the community, where all species are present equally, when the number of species is the same (Mulder jt. 2004).
Then it also possible to measure not how many species you have in the community, but also how closely they are related (Faith, 1992) – this is called *phylogenetic* diversity.
Functional diversity is little bit similar to phylogenetic diversity, but in this case, we measure how different species are ecologically. Ecological difference arises from the things that species do in the community (Petchey and Gaston, 2006). For example, one can measure the length of all species, and describe the community with the range of lengths that were represented by the species in the community.

It is also important to separate the two terms: *diversity* and *composition*. Diversity will tell, how diverse the community is, how many and how different species are. Composition will tell specifically, what species are there. Functional composition of phytoplankton will determine the primary production, and the quality of phytoplankton as food for higher trophic levels (Reynolds, 2006). Diversity is usually though to affect the productivity of the ecosystem, and how resilient it is to disturbance (when something bad happens, then there is a better chance in the diverse community that some species can survive).

2.3.1 Measuring the functional diversity

To study the functional diversity, and compare the results of different studies, is important that the definition and measurement would be same for all researchers (Chiarucci jt. 2011). Several ways have been suggested how to include the functional difference into the calculation (Petchey ja Gaston, 2002), for example mean pairwise functional difference (Ricotta, 2006), or number of functional groups (Kruk jt 2010). Most measures require the use of *functional traits.*

2.3.2 Phytoplankton functional traits

Functional trait is a property of an organism, which can be measured for all individuals. This can be for example body size, and shape. Shape can be measured for example as the ratio between the length and width of organism. Functional properties can also be presence or absence of something, for example – ability to swim – it is also possible to tell for each phytoplankton species, if it is able to swim or not.

For phytoplankton, the major group that organism belongs to, can also be used as a functional trait, to some extent, because of the ecological differences between large groups, which were described in the paragraph 2.2.

3. Material and methods

The samples for this analysis were collected on April 30, 2017, from 14 lakes and streams in Võru county (Table 1).

Table 1. Metadata of studied lakes

Name of the water body	**Coordinates**	**Sample volume**	**Zooplankton community: Dominating group, overall abundance**
Võhandu river	57.87, 27.12	15 L	Copepods, low abundance
Iskna river	57.83, 27.13	15 L	Rotifers, abundant
Lake Kärnjärv	58.04, 26.42	10 L	Cladocerans, medium abundant
Lake Paidra	57.92, 27.19	20 L	Rotifers, medium abundant
Lake Tsolgo Pikkjärv	57.92, 27.13	30 L	Mixed

Lake TsolgoMustjärv	57.92, 27.12	15 L	Copepdos, low abundance
Lake Nohipalu Valgjärv	57.94, 27.35	20 L	Rotifers, abundant
Lake Meenikunno	57.94, 27.33	30 L	No zooplankton
Small lake in the swamp	57.95, 27.33	25 L	Copepods, low abundant
Lake Nohipalu Mustjärv	57.94, 27.34	20 L	Cladocerans, abundant
Lake Lasva	57.86, 27.17	30 L	Copepods, abundant
Lake Nõnova kivikarjäär	57.82, 27.12	20 L	Rotifers, medium abundance
Pond "Kerstinipommiauk"	57.83, 27.12	15 L	No zooplankton
Lake Tamula	57.84, 26.98	40 L	No zooplankton

All samples were collected during one day, using plankton net with 20 micron mesh (photo 1). Sample volumes were from 10...40 L, depending on the water transparency. Samples were collected with a bucket, from the bridge, or from shore.

Photo 1. Taking the sample with plankton net, from lake Tsolgo Pikkjärv (K. Rätt is on the right).

Concentrated samples were delivered to lab in dark thermos box. In the lab, samples were thoroughly shaken, and 3 drops of water were used to make a microscope slide. Under microscope, up to 100 individuals were photographed, with 400x magnification (Nikon E200 upright microsope (40x objective), ja Nikon Fi1/L2 microscope camera).

Functional properties measured from each organism were size, shape and taxonomic group it belongs to. Shape and size was described by measuring the length and width of each photographed individual (Photo 2).

Measuremets were done on the computer screen, and with the photo of micrometer scale, the on screen measurements were converted to actual dimensions of organisms.

Under the stereomicroscope (10-15x magnification) zooplankton community was descrbied: whether it was low, medium or very abundant, and which group (copepods, cladoceransorrotifers) dominated.

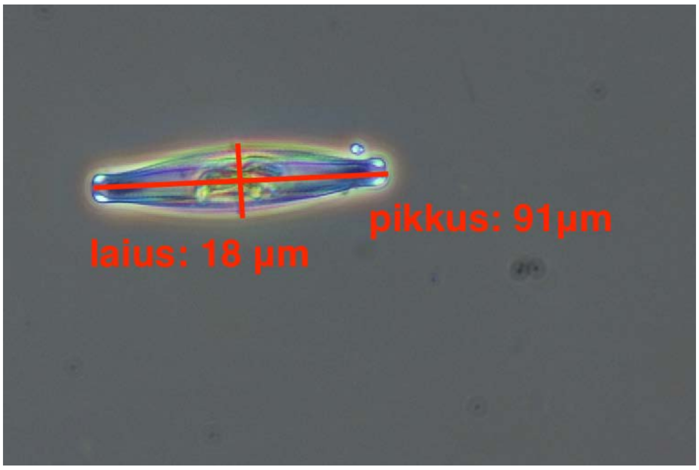

Photo 2. Example of measurements:length (“pikkus”) (91 µm) and width(“laius”) (18 µm). This is a diatom.

Results were visualized in the freely available statistical program R (R Core Team, 2017). Scatterplot were used to show the size and shape distribution of organiosms in different water bodies, histograms were used to describe the frequency of different taxonomic groups.

4. Results

Main results are shown in Figure 2 and 3. In the 3 out 14 water bodies, phytoplankton was missing, and no results are shown for these water bodies in Figures 2 & 3.

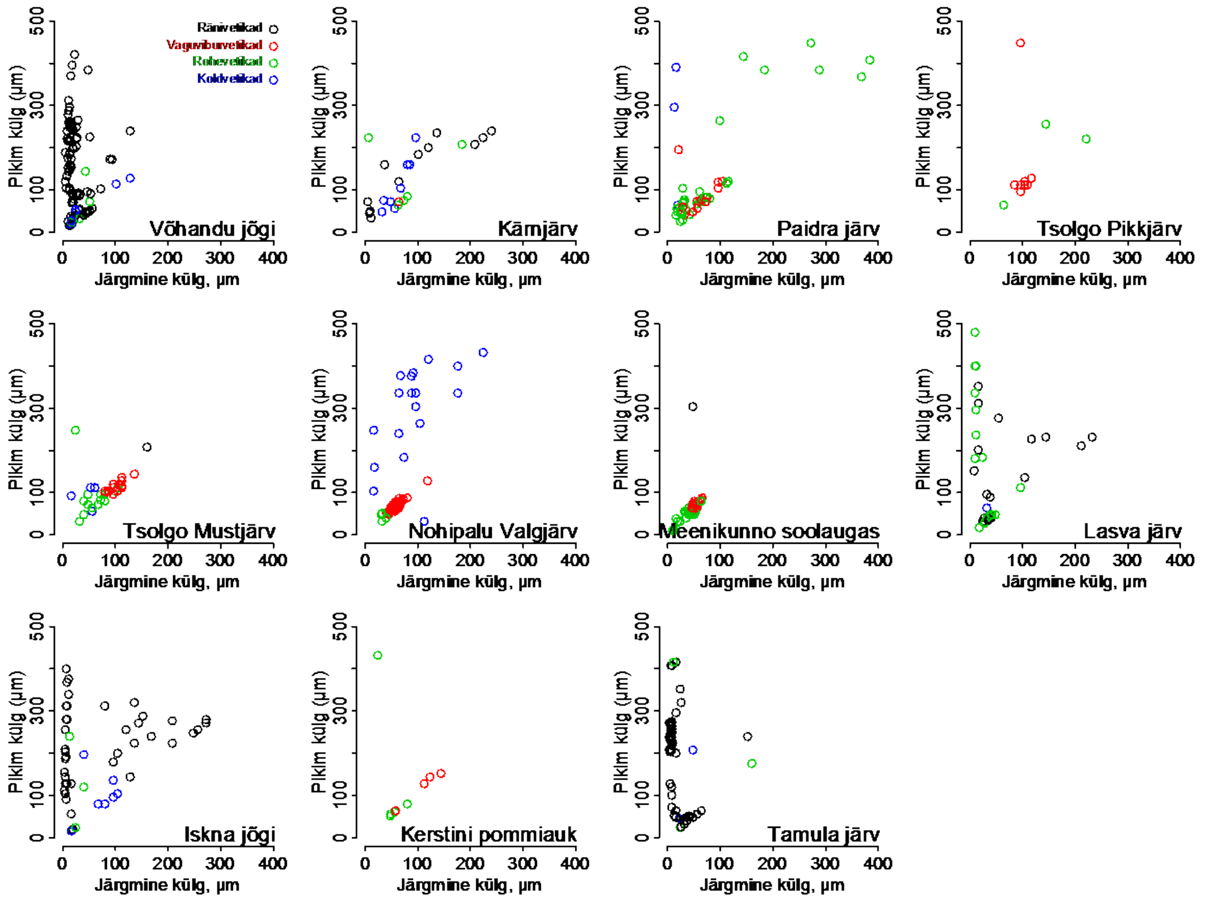

Figure 2. Size and shape of individuals, described by the scatterplots of length (y-axis) vs width (x-axis) of individual organisms. Color denotes the large taxonomic group: black- diatoms, red – dinoflagellates, green- green algae, blue - golden algae.

From Figure 2 it can be concluded, that three types of communities existed: i) all points aligned on the diagonal (Lake Kärnjärv, Lake Pikkjärv, Lake Tsolgo Mustjärv, Lake Meenikunno soolaugas, pond Kerstini pommiauk); ii) all points aligned close to y-axis (Võhandu river, Lake Lasva, Lake Tamula); and iii) points scattered between the diagonal and y-axis (Lake Paidra, Lake Nohipalu Valgjärv, Iskna river).Differences were also in the dominating phytoplankton group (Figure 3). In three places, diatoms dominated, dinoflagellates dominated in one place, and in the rest of the samples, communities were mixed.Only two samples contained all four main groups. Zooplankton community was also variable, as already described in Table 1. Couple of water bodies had no zooplankton, Lake Nohipalu Mustjärv was sticking out for particularly abundant cladoceran population.

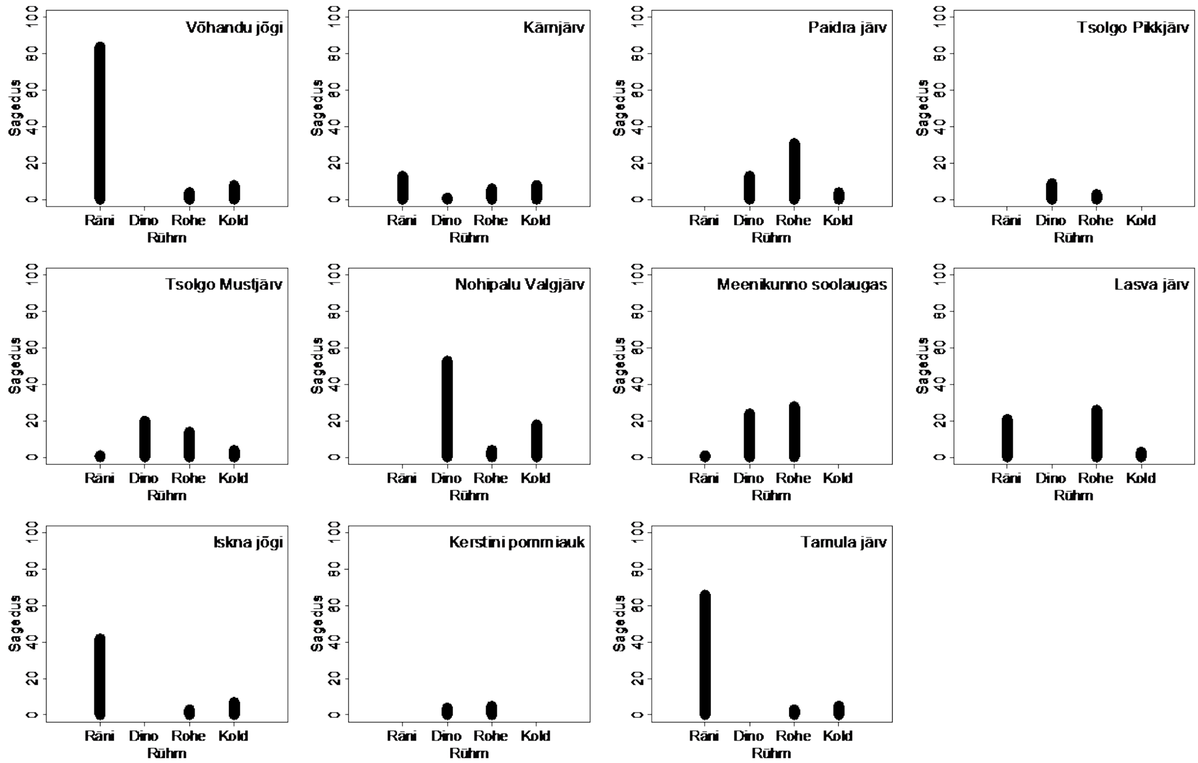

Figure 3. Frequency of main phytoplankton groups in the samples: “Räni” – diatoms, “Dino” – dinoflagellates, “Rohe”- green algae, “Kold” – golden algae.

5. Discussion

This study was aiming to answer the question: is phytoplankton community notably different across lakes and streams in Võru county. Figures 2 and 3 illustrated the variability in the communities across lakes, and the short answer to the first question was: yes, they are different.

Figure 2 describes the size and shape variation. To understand the patterns in Figure 2, it is useful to remember the meaning of X and Y axes. Every point in Figure 2 denotes one individual organism. The points aligning close to Y axis indicate elongated organisms, and the higher the value on Y axis, the longer it was. Points aligning close to diagonal belong to round or square shaped organisms (because the length and width had a similar value).

Based on visual inspection, three types of communities were common. In some places, the organisms were mostly round or square shaped(Lake Kärnjärv, Lake Tsolgo Pikkjärv, Lake Tsolgo Mustjärv, Lake Meenikunno soolaugas and pond Kerstini pommiauk). Second type the communities where elongated organisms dominated(Võhandu river, Lake Lasva and Lake Tamula).In remaining places, community was more diverse, based on shape and size (Lake Paidra, Lake Nohipalu Valgjärv and Iskna river).
The area covered by points in each panel of Figure 2 is on itself a measure of functional diversity: the larger the area that is covered by points, the more diverse was the community. So based on size and shape, diversity was highest in Lake Paidra, and relatively diverse in Iskna river, Lake Nohipalu Valgjärv and Lake Lasva. Functionally poorest were Lake Meenikunno soolaugas, pond Kerstini pommiauk and Lake Tsolgo Mustjärv. In the latter three places, communities consisted of small round organisms.

In figure 2,another interesting rule emerges: very large organisms were mostly elongated(i.e. close to Y-axis, couple of examples of these organisms are also shown inPhoto 3).

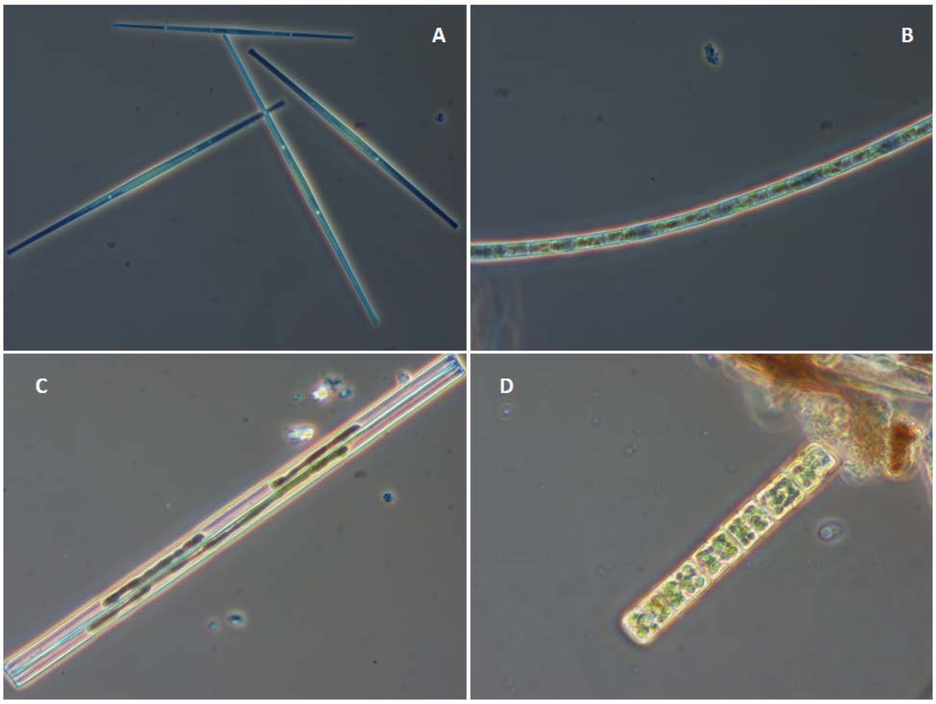

Photo 3. Examples of elongated organisms A, C & D are diatoms, B is green algae. A & C are single celled, B & D are filaments (consisting of several cells).

Round or squared organisms along the diagonal were usually small (not exceeding the 200 microns). Exceptions were some large green algae from Lakes Paidra and Kärnjärv(Photo 4, A &B), golden algae from Lake Nohipalu Valgjärv(Photo 4, C), and diatoms from lake Lasva (Photo 4, D):in all these examples, the organisms were colonial, not single celled. Therefore, there seems to be two “tricks” to being large: either be elongated, or make colonies.

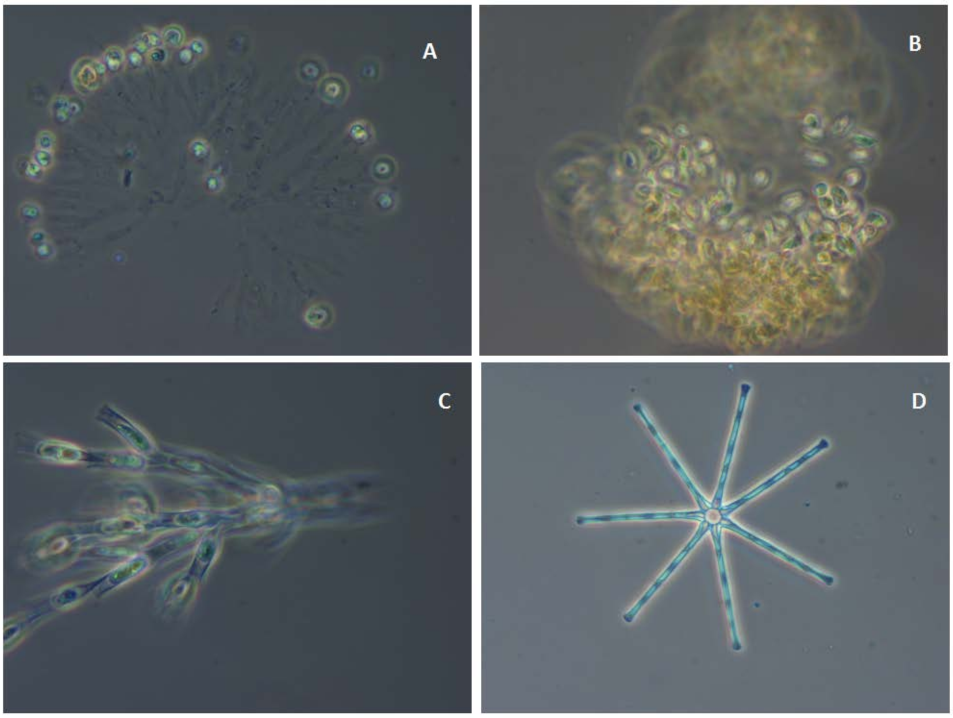

Photo 4. Examples of large colonies.

In addition to variability in size and shape, the dominating taxonomic group varied across lakes and streams. Highest taxonomic richness was in Lakes Kärnjärv and Tsolgo Mustjärv (all 4 groups present). In most lakes, 3 groups were present. Green algae was the only group that was found in all samples. It also looked like the diatoms and dinoflagellates were avoding each other: where the diatoms were more abundant, dinoflagellates were missing (e.g. Võhandu and Iskna rivers, Lake Tamula), and vice versa (e.g. Lake Paidra, Lake Tsolgo Pikkjärv, Lake Nohipalu Vagjärv, Lake Meenikunno soolaugas).Since diatoms and dinoflagellates prefer different environments, this pattern is actually half-expected. Lakes, where dinoflagellates dominated, was the spring bloom probably already over, and not enough nutrients anymore for diaotms (Reynolds 2006).

In addition to relative abundances of large groups, figure 3 also describes another aspect of diversity that was mentioned in the introduction section: the evenness. Even if the number of groups present was the same (mostly 3), the diversity can be considered as higher in the places, where all groups were present more or less equally (for example LakeKärnjärv). But when one group clearly dominates, like the diatoms in Võhandu river, then the diversity is low, even if same number (3) of large groups was technically present.

To understand the reasons for the differences in phytoplankton composition, the type of water body (lake or river), and characteristics of zooplankton community, were considered.
The type of water body was not important in this case, because the river communities were similar to several lake communities. However, the sample was also biased (only 2 rivers, but 12 lakes).
Zooplankton community was highly variable, both in terms of abundance and dominating group.
From the three main groups, rotifers are physically the smallest, and do not eat the phytoplankton.
Cladocerans are larger, and they feed on small-sized phytoplankton (<200 μm). They are filtering the water and are able to clean the water from algae (Reynolds 2006). Copepods are the largest of the three, and they usually select and catch their food, preferring larger (but still not too large) items. They usually cannot control the abundance of phytoplankton, especially the smaller organisms.
Based on the general properties of the zooplankton groups, following rules are expected: a) when rotifers domninate, phytoplankton community should be unaffected, so it can be anything;b) if the cladocerans were abundant, smaller phytoplankton should be missing, nothing or large algae left; and c) when copepods were abundant, there should have been abundantly large phytoplankton available, as a prerequisite for copepod population.

These patterns also held to some extent.
Where rotifers were abundant, the phytoplankton was usually abundant and diverse (Iskna river, Lake Paidra, Lake Nohipalu Valgjärv).
Cladocerans were medium abundant in Lake Kärnjärv, and very abundant in Lake Nohipalu Mustjärv. Latter could explain the absence of algae in Lake Nohipalu Mustjärv – they were probably all cleared away by cladocerans. However, in Lake Kärnjärv, the abundance of small phytoplankton was unexpectedly high. And the high number and dominance of small phytoplankton in pond Kerstini pommiauk and Lake Meenikunno soolaugas can be explained by the total absence of zooplankton. Copepods were abundant only in Lake Lasva, and there were also larger phytoplankton organisms available. But since there were also other places with large cells, but without copepods, it is not possible to draw any conclusions about the link between copepods and algae based on this study.

6. Summary

This study analysed the phytoplankton functional composition in lakes and streams in Võru county, and answered following research questions:

1) Does the phytoplankton community vary across nearby lakes and streams?
2) If yes, then what are the differences and what could be driving the differences?

Results of the analysis confirmed, that phytoplankton communities indeed vary notably in their functional composition. Three types of communities typically existed: 1) communities made of long cells and organisms; 2) communities made of small roundish organisms, and 3) mixed types. The type of water body (river or lake) did not explaint he differences, but some expected links were identified with zooplankton communities: for example, abundant communities of small round phytoplankton species were usually there, where the cladocerans were missing. Functionally most diverse was the phytoplankton in Lake Paidra, relatively diverse in Iskna river, Lake Nohipalu Valgjärv and Lake Lasva. Functionally poorest were Lake Meenikunno soolaugas, pond Kerstini pommiauk and Lake Tsolgo Mustjärv.

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