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RESEARCH ARTICLE

Spring-summer transition in the Curonian lagoon (SE Baltic Sea) phytoplankton community

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Abstract

1 - The Curonian lagoon is a shallow, mostly freshwater estuary. In the northern part it is connected to the south-eastern Baltic Sea, while the main inflow is dominated by the freshwater discharges from the Nemunas river and directed towards the sea. Phytoplankton development in the lagoon generally follows a pattern typical of eutrophic fresh waters: in the spring diatoms dominate, while during summer filamentous cyanobacteria prevail.

2 - Hydrological summer in the temperate waters starts when the thermocline is steady. However, the Curonian lagoon is very shallow, with a mean depth of 3.8 m, and no thermocline could be observed. Moreover, the exact timing of the shift between the spring and summer succession stages does not synchronise with calendar seasons and cannot be defined in calendar days. Therefore, the aim of this study was to describe spring and summer phytoplankton communities and delineate conditions when the shift between spring and summer seasons occurs in the eutrophic Curonian lagoon. This study was based on the structure of spring and summer phytoplankton communities according to the taxa, size and morphological features.

3 - Two main seasonal phytoplankton communities (spring and summer) were described as well as the timing of the transition between them in the temperate Curonian lagoon. Phytoplankton communities diverged into two groups according to the taxa and morphological features, and into three groups according to the size structure. The first "spring" group derived from all examined features contains mainly coccoid Centrales, with cells of 10-20 µm. The second (second and third according to the size structure) "summer" group was dominated by filamentous Cyanobacteria. Structure and taxonomical composition differences of two "summer" groups as well as mechanisms responsible for the seasonal shift were discussed.

4 - The shift from spring to summer communities was found to be decided by the cumulative sum of daily water temperatures and occurs when the sum of cumulative degrees is between 587 and 627.

Keywords: phytoplankton, Curonian lagoon, seasonal succession

Introduction

Phytoplankton seasonal succession and changes in physical and chemical water parameters are well-known phenomena in temperate waters, where two seasonal phytoplankton peaks (spring and summer) are often observed. In eutrophic fresh waters, spring communities are expected to be dominated by diatoms, while during summer filamentous cyanobacteria prevail (e.g. Sommer et al., 1986; Kangro et al., 2005). In brackish waters, besides the dominance of diatoms in the spring and cyanobacteria in the summer, the dinophytes could also dominate in the phytoplankton community (Wasmund et al., 2000). Phytoplankton development in the Curonian lagoon generally follows the fresh water pattern (Olenina, Olenin, 2002; Pilkaitytė, Razinkovas, 2006).

Hydrological summer in the waters (mostly dimictic lakes) starts when the thermocline is steady (Wetzel, 2001). However, the Curonian lagoon is very shallow, with a mean depth of

3.8 m, and no thermocline could be observed (Pustelnikovas, 1998). Moreover, the exact timing of the shift between spring and summer succession stages does not synchronise with calendar seasons and cannot be defined in calendar days.

There are three main nutrients needed for the phytoplankton to grow: nitrogen, phosphorus and silica. However, due to the different algae composition and their requirements, nutrients are consumed at different times and in different ratios (Pilkaitytė, Razinkovas, 2006). It is known that in boreal waters nutrient concentrations are highest in the winter-early spring, just before vegetation starts to develop, and later the nutrient concentration starts to decline. In shallow water bodies, due to other factors (e.g. wind, climate, the morphology of the water body), nutrient concentrations, especially phosphorus and silica, could be even higher during summer (e.g. Conley, Malone, 1992; Pilkaitytė, Razinkovas, 2006).

The aim of this study was to describe spring and summer phytoplankton communities and to delineate conditions when the shift between spring and summer seasons occurs in the shallow eutrophic Curonian lagoon. This study was based on the structure of the spring and summer phytoplankton communities according to taxa, size and morphological features.

Methods

The Curonian lagoon is a shallow, mostly freshwater estuary. In the northern part it is connected to the south-eastern Baltic Sea, while the main inflow is dominated by freshwater discharges from the Nemunas river directed towards the sea; therefore the southern and central parts of the lagoon contain fresh water (Pustelnikovas, 1994).

Phytoplankton samples were collected from the upper surface layer from two stations: 1) in the Klaipėda strait (55°42’13 N; 21°06’55 E) in year 1998 and 2) in the central part of the Curonian lagoon (55°20’46 N; 21°11’17 E) in years 2000 – 2002 (Figure 1), every second - fourth week from late March up to late September. In addition the water temperature and nutrients, such as NO_3, PO_4, SiO_2, were measured (Pilkaitytė, Razinkovas, 2006). The samples were collected when water salinity was below 0.5 PSU.

Rough taxonomic phytoplankton species composition (except picoplankton species) and phytoplankton density were estimated after fixation with Lugol solution and sedimentation under inverted microscope. Hierarchical clustering analysis was performed according to: 1) main phytoplankton taxa (Chlorophyta, Cyanophyta, Bacillariophyceae, Other), 2) phytoplankton cell size (< 2, 2-5, 5-10, 10-20, 20-50, and > 50 μm), and 3) phytoplankton morphology (single coccoid cells, flagellates, solitary cells with spines or other processes, filaments or cells in chains, naked colonies (coenobia) without mucilage, and small colonies with mucilage). In this case Bray-Curtis similarity (group average linking) was applied using the PRIMER 5 (Plymouth Routines In Multivariate Ecological Research) software following the recommendations of Clarke and Warwick (1994) and references therein.

Daily water temperature data and monthly nutrient concentrations (1984-2002) were obtained from the National monitoring programme performed by the Marine Research Centre, Lithuanian Ministry of Environment. The cumulative sum of water temperature was calculated for each sampling day, starting from the beginning of calendar year.

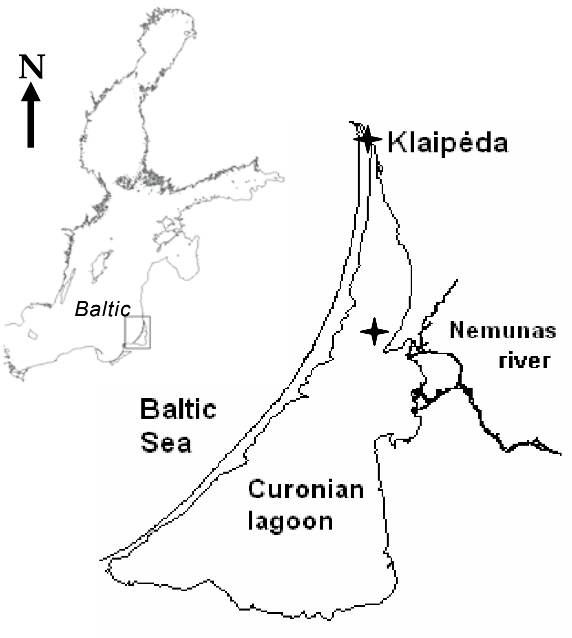

Figure 1. Sampling site locations in the Curonian lagoon.

Results

According to the taxonomic composition, two groups of phytoplankton communities diverged at a similarity threshold of approximately 66 % (Figure 2). The first "spring" group included samples where the diatoms dominated. Green algae accounted on average for 22 % of the total density. Some green algae species, such as Scenedesmaceae and Ankistrodesmaceae, or unidentified flagellates accounted for over 10 % of the total abundance in some phytoplankton samples (e.g. 98/03/31, 00/04/26, 01/04/25, 01/05/07). Most of the samples in this group were taken from the end of March to the end of May. Some samples taken in July and August (in the figure they are marked with stars) were pooled together with the "spring" samples.

The second group was dominated mostly by the cyanobacteria – Aphanizomenon flos-aquae, Limnothrix redekei, Planktothrix agardhii, Anabaena spp., and green algae Planktonema lauterbornii (Figure 2). The samples belonging to the second "summer" group were taken from the middle of May up to the late autumn (beginning of October).

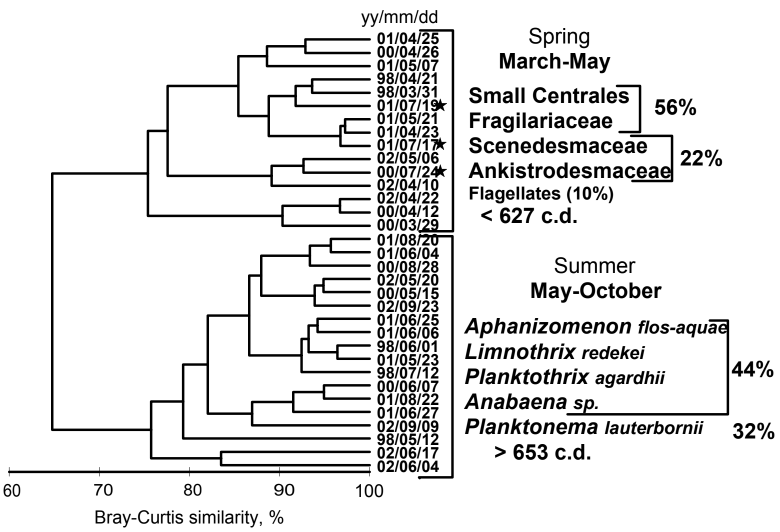

Figure 2. Hierarchical clustering dendrogram (group average linking using Bray-Curtis similarity) of the phytoplankton communities. Stars indicate samples collected during summer. On the right – dominant phytoplankton species / higher taxa in the groups and relative abundance in the samples. c.d. – cumulative water temperature degrees.

Phytoplankton communities distinguished according to the examined morphological features diverged into two groups at a similarity threshold of approximately 50 % (Figure 3). The first group included samples mostly composed of single coccoid shape phytoplankton cells. In some samples single coccoid cells with filaments (98/05/12), or single coccoid cells with flagellates (02/04/10, 02/05/06), or even single coccoid cells, small colonies with mucilage and filaments together (00/08/28) were dominant. In one sample (00/07/24) only flagellates were dominant. Samples of the "spring" group were taken in March-May, except for four samples, which were taken in July-August (in the figure they are marked with stars).

The second – "summer" group was composed mostly of filament shaped species (Figure 3). However, there were some samples where the both filaments and small colonies were dominant (02/06/04, 02/06/17).

According to the phytoplankton cell sizes, three groups of phytoplankton communities diverged, at a similarity threshold of approximately 65 % (Figure 4). The first group included samples where 10-20 µm sized phytoplankton species were dominant, or those algae together with other size groups were most abundant. Samples of this group were taken in the late spring – from the end of April till the middle of May, except for two samples, which were taken in July (in the figure they are marked with stars).

Extremely large (>50 µm) pennate diatom species dominated in one sample (02/04/22), which also was taken in the same period, but was placed in a separate group.

The rest of the samples, which in Figure 4 are identified as "summer" group, were mainly taken during the summer. There could be distinguished two groups – one group, where algae of 5-10 µm size ("summer I" group) dominated, and the second group, where phytoplankton species of 2-5 µm size ("summer II" group) dominated. The "summer I" group contained only those algae communities that where taken during summer, while the "summer II" group comprised some samples that where taken in the early spring – until middle of April (in the figure they are marked with triangles).

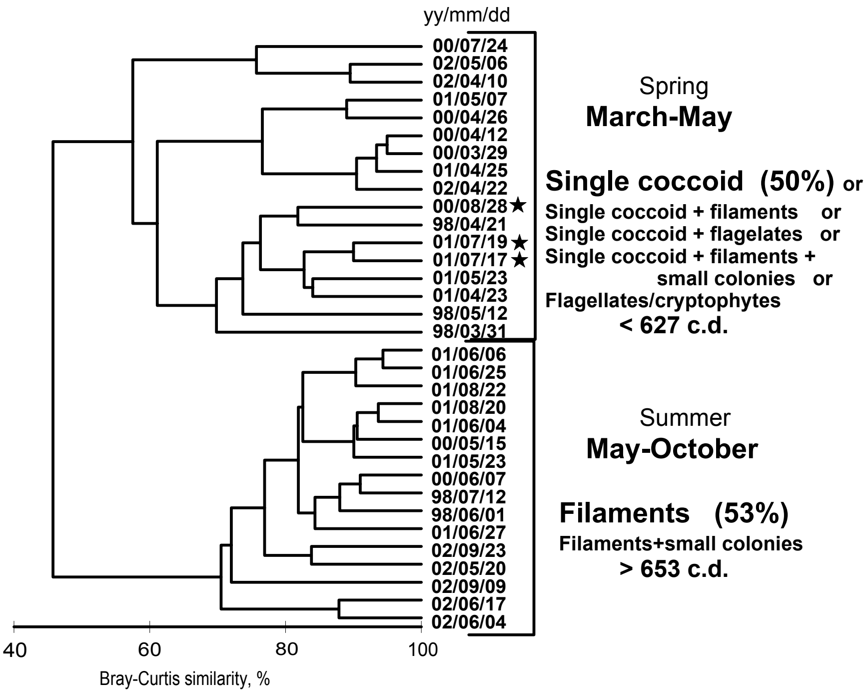

Figure 3. Hierarchical clustering dendrogram (group average linking using Bray-Curtis similarity) of the phytoplankton morphological groups. Stars indicate samples collected during summer. On the right – dominant morphological groups of phytoplankton in the groups and relative abundance in the samples. c.d. – cumulative water temperature degrees.

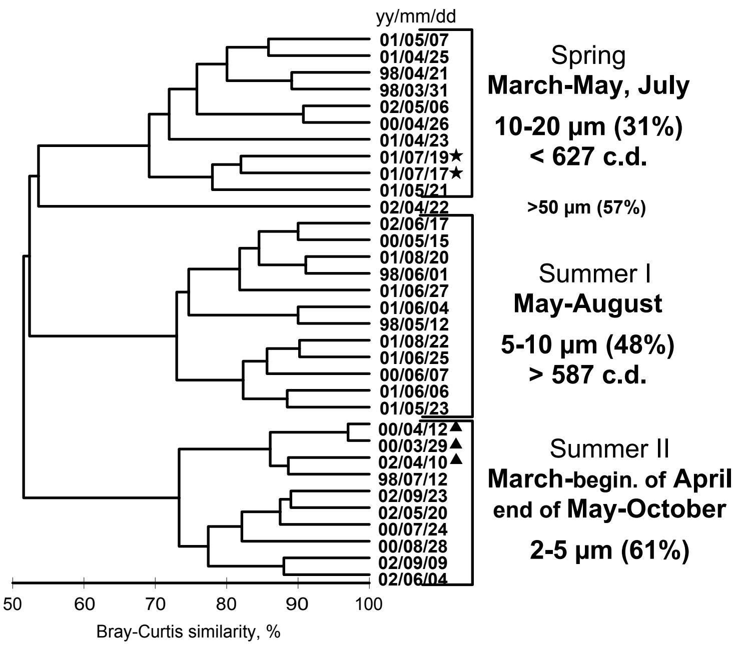

Figure 4. Hierarchical clustering dendrogram (group average linking using Bray-Curtis similarity) of the phytoplankton size structure. Stars indicate samples collected during summer, triangles – samples collected during spring. On the right – dominant size groups of phytoplankton in the groups and relative abundance in the samples. c.d. – cumulative water temperature degrees.

Discussion

According to the PEG (Plankton Ecology Group) model, small fast-growing algae, such as Cryptophyceae and small centric diatoms, make up the spring bloom. In addition, large diatoms and small chlorococcales can make a large contribution in shallow lakes (Sommer et al., 1986). Generally, the early spring phytoplankton in the Curonian lagoon could be regarded as limited only by ambient physical conditions (Pilkaitytė, Razinkovas, 2006). Diatoms are well-adapted to stronger mixing (Lindenschmidt, Chorus, 1998; Petersen et al., 1998). That could be a reason for those algae to thrive in the phytoplankton community at this time (Razinkovas, Pilkaitytė, 2002). From the size structure clustering analyses, the "spring" group comprises the samples starting mainly from the end of April, where centric diatoms of 10 to 20 μm size were most abundant. Smaller diatom species of 5-10 μm dominated in the earlier period till the end of April. Therefore, those samples are pooled together with "summer" ones ("summer II" group, Figure 4) using the clustering procedure. However, there are lakes where filamentous diatoms are dominant until the end of May (Noges et al., 1998) in contrast to most common phytoplankton of coccoid shape (Figure 3, see also Sommer et al., 1986).

Between spring and summer, a quite short "clear water" phase is distinguished in the shallow eutrophic lakes (Sommer et al., 1986). This period is characterized by increased importance of top-down interactions (Kagami et al., 2002, Gasiūnaitė, Razinkovas, 2004). Low silica and phosphate concentrations (Figure 5), limiting respectively diatoms and green algae groups dominating the phytoplankton community in the Curonian lagoon at that time (Pilkaitytė, 2003), were observed in May. Communities found at that time were characterized by low phytoplankton abundance, and, according to different characteristics (Figures 2, 3, 4), belong already to summer.

Eutrophic waters are regarded as cyanobacteria-dominated water bodies during the summer (Sommer et al., 1986). Depletion of Si and N during this time, high water temperatures (>20° C) and stable weather conditions give advantage to cyanobacteria over other algae and they make a big contribution to the phytoplankton community in many eutrophic waters (Nixdorf, Hoef, 1993; Laamanen, Kuosa, 2005). The Curonian lagoon is no exception. Huge amounts of cyanobacteria are observed during the warm and calm summer time (Olenina, Olenin, 2002). At this period in the Curonian lagoon, as well as in other eutrophic water bodies, mostly filamentous species of 5-10 μm of cell size, such as Aphanizomenon and Anabaena, dominate (Figures 2, 3, 4 ("summer I"); Dokulil, Teubner, 2000; Wasmund et al., 2000; Kangro, Noges, 2003). Green algae Planktonema lauterbornii could dominate in the Curonian lagoon and in Lithuanian coastal waters (Figure 2; see also Wasmund et al., 2000). Their cell size falls into the 5-10 μm range and could make a contribution to the "summer I" group (Figure 4). Another filamentous cyanobacterium, Planktothrix, also could dominate in the phytoplankton community (Figures 2, 3; Dokulil, Teubner, 2000; Kangro, Noges, 2003), while its cell size is smaller – 2-5 μm. Therefore, the samples dominated by this species were pooled into the separate ("summer II") group (Figure 4).

During the summer, growth of diatoms is supposedly restricted by lower irradiance availability (Tilman et al., 1986; Litchman, 1998; Flöder et al., 2002), which is diminished by phytoplankton attenuation, and by stable conditions, as they require well-mixed conditions (Lindenschmidt, Chorus, 1998). However, the few samples belonging to the "spring" group (Figures 2, 3, 4) were taken in July and August. Diatoms of 10-20 μm size dominated in the phytoplankton community during that time. Stronger wind or water flow due to the heavy rain could mix water masses and could blow and/or disturb cyanobacteria blooming aggregates (Ibelings, Maberly, 1998; Pilkaitytė, Razinkovas, 2006). Under such conditions diatoms become dominant in the phytoplankton community instead of common cyanobacteria (Pilkaitytė, 2003). The high diatom abundance events, as in samples

01/07/17 and 01/07/19 during the summer, could be an example of this situation, as a few days before sampling southern – south-eastern winds dominated, blowing the cyanobacteria aggregates from the sampling site.

According to the three different phytoplankton features – taxa, morphology, and size, two main seasonal assemblages could be derived: spring and summer. It appeared that the shift between seasons falls into a very narrow range. The cumulative sum of the effective water temperatures that corresponded to the phytoplankton samples of the first "spring" group were below 627 cumulative degrees (Figures 2, 3, 4). The second or "summer" group of samples classified according to the taxa and size corresponded to at least 587 cumulative degrees (Figures 2, 4), while classified according to phytoplankton morphology – from 653 cumulative degrees up (Figure 3). Depending on the year, this shift in the Curonian lagoon could occur in May – June. In most cases this period coincides with a short decline in water temperature, following a long and sharp increase (Figure 5).

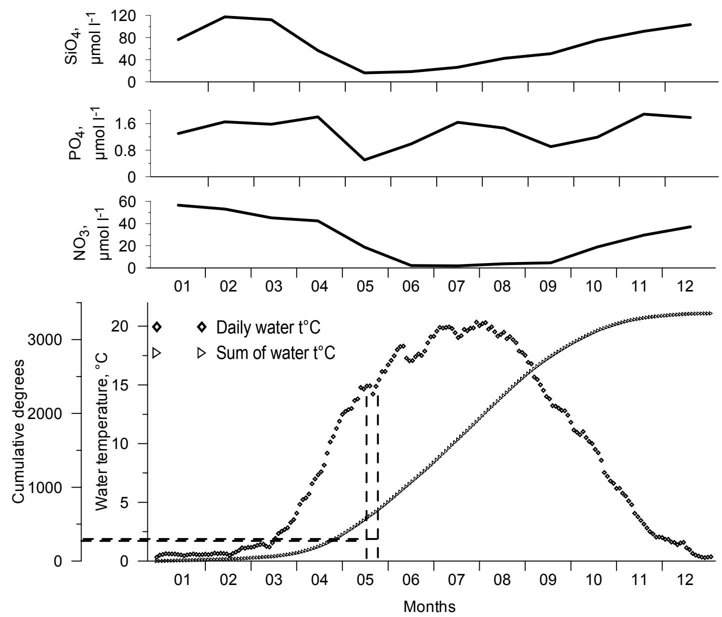

Figure 5. Daily water temperature averages and cumulative sum of effective water temperatures, and the nutrient (SiO4, PO4, NO3) concentrations in the central part of the Curonian Lagoon (unpub. MRC data 1984-2002).

Conclusions

The Curonian lagoon ecosystem is mainly dominated by algae communities of two morphological types (single coccoids and filaments) and correspondingly belonging to two systematical groups (diatoms and cyanobacteria).

In the "spring", phytoplankton is represented by various size groups, while large diatoms dominate. Algae of 5-10 µm size (Aphanizomenon, Anabaena, Planktonema) dominate during the "summer" season. However, algae of 2-5 µm size are abundant during both seasons: small Centrales during early spring and Planktothrix, flagellates and cryptophytes during summer.

In certain climatic conditions during the summer (strong winds and intensive mixing throughout the water column) diatoms of 10-20 µm size start to dominate the phytoplankton community instead of cyanobacteria.

According to all phytoplankton community structure characteristics, the "spring" community was observed at 627 cumulative degrees at the latest. According to taxa and size structure, the "summer" community was first observed when the sum of cumulative degrees reached 587, while the "summer" community defined according to the algae morphology was found at 653 cumulative degrees at the earliest. At that time phytoplankton abundance, silicate and phosphate concentrations are at their minimum values, and this period is characterised as the "clear water" phase.

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