

Summer phytoplankton in the Gulf of Finland – seasonal patterns and recommendations for monitoring design

EU Water Framework Directive (WFD) lists the phytoplankton quality elements, to be monitored and used in the assessment of the coastal and transitional waters:

- Phytoplankton composition and abundance of phytoplankton taxa
- Average phytoplankton biomass and water transparency
- Frequency and intensity of phytoplankton blooms

Classification systems for the ecological status should evaluate how the structure of the biological communities and the overall ecosystem functioning are altered in response to anthropogenic pressures, focusing mainly to nutrient loading. Declining ecological quality of coastal and transitional waters is characterised by slight ('good status') or moderate ('moderate status') disturbance in the composition of phytoplankton abundance and taxa, slight or moderate changes in the biomass compared to the high status, and slight or moderate increase in the frequency and duration of phytoplankton blooms.

As the plankton communities have high natural spatial and temporal variability, the changes observed in the eutrophication related indicators should not be interpreted to be entirely results of anthropogenic nutrient loading. The Gulf of Finland, like the Baltic Sea as a whole, is sensitive to the effects of climate and to a set of hydrodynamical processes of different scale.

Aims of the present study

Most Baltic monitoring stations are sampled more frequently during summer. A few monitored stations have weekly to biweekly samples, however, the monitoring programs typically have had less frequency – about monthly. Another problem has been spatially uneven station grid especially in the northern parts of the Baltic. Alg@line, using ships-of-opportunity (SOOP), has its main emphases on the high-frequency plankton monitoring. Taking into account spatial and temporal dimensions it should give more adequate information on plankton communities and dynamics than traditional monitoring. In addition, the continuously measured hydrographical parameters on board SOOP and simultaneous nutrient analyses give high frequency information of the water masses. Intensive monitoring on the cross-section of the central Gulf of Finland (Fig. 1) since 1997 has provided a uniform dataset. To evaluate seasonal (from June to September) pattern of phytoplankton succession, 1070 samples were statistically analyzed by selecting 13 taxa using wet weight biomass values. We aimed (1) to reveal between-years differences and “normal” seasonal pattern, (2) to find out spatial differences with suggestions of optimum distance between sampling locations, and (3) to evaluate the intensity of shifts in community structure with recommendations for regional optimum sampling frequency.

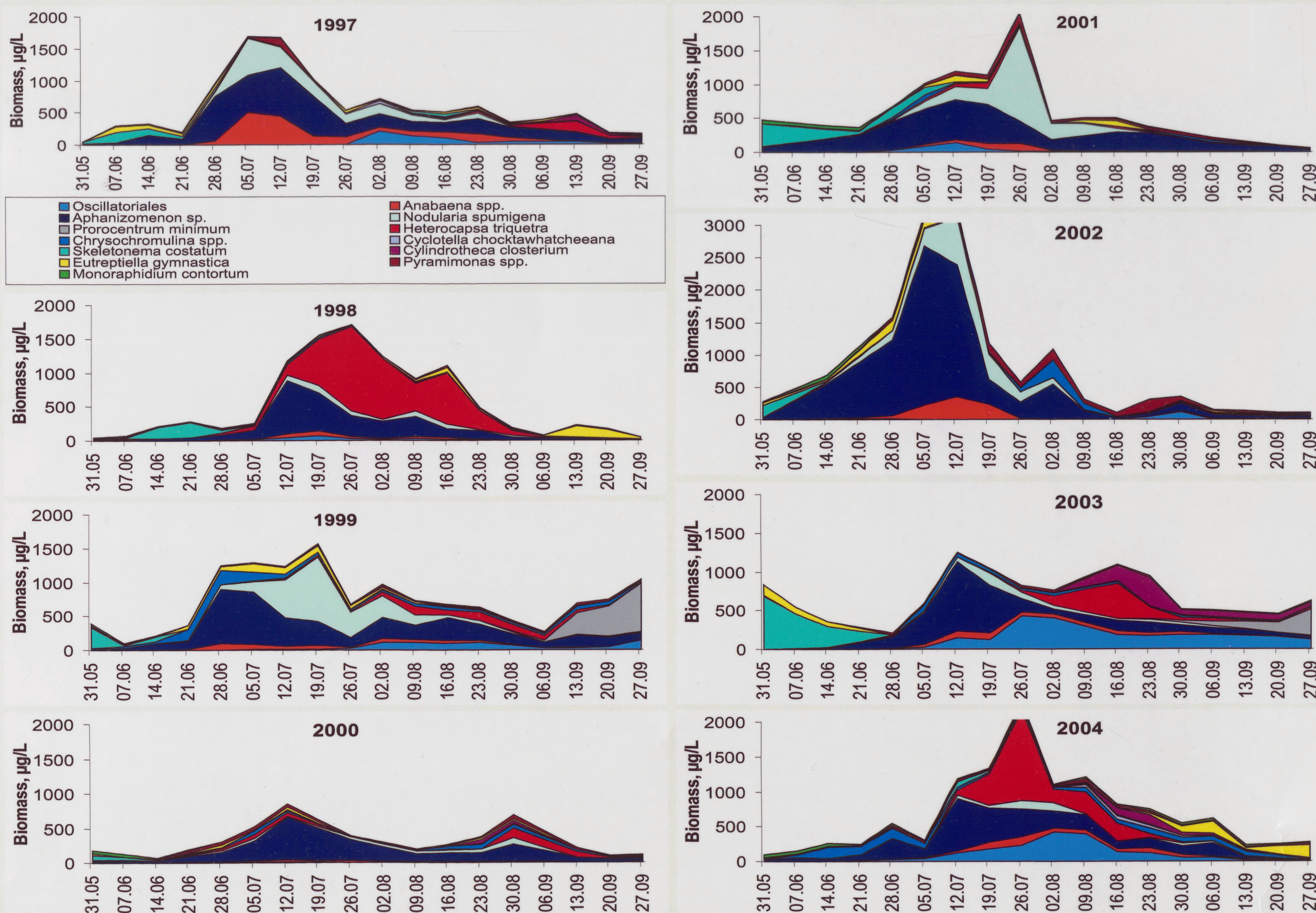
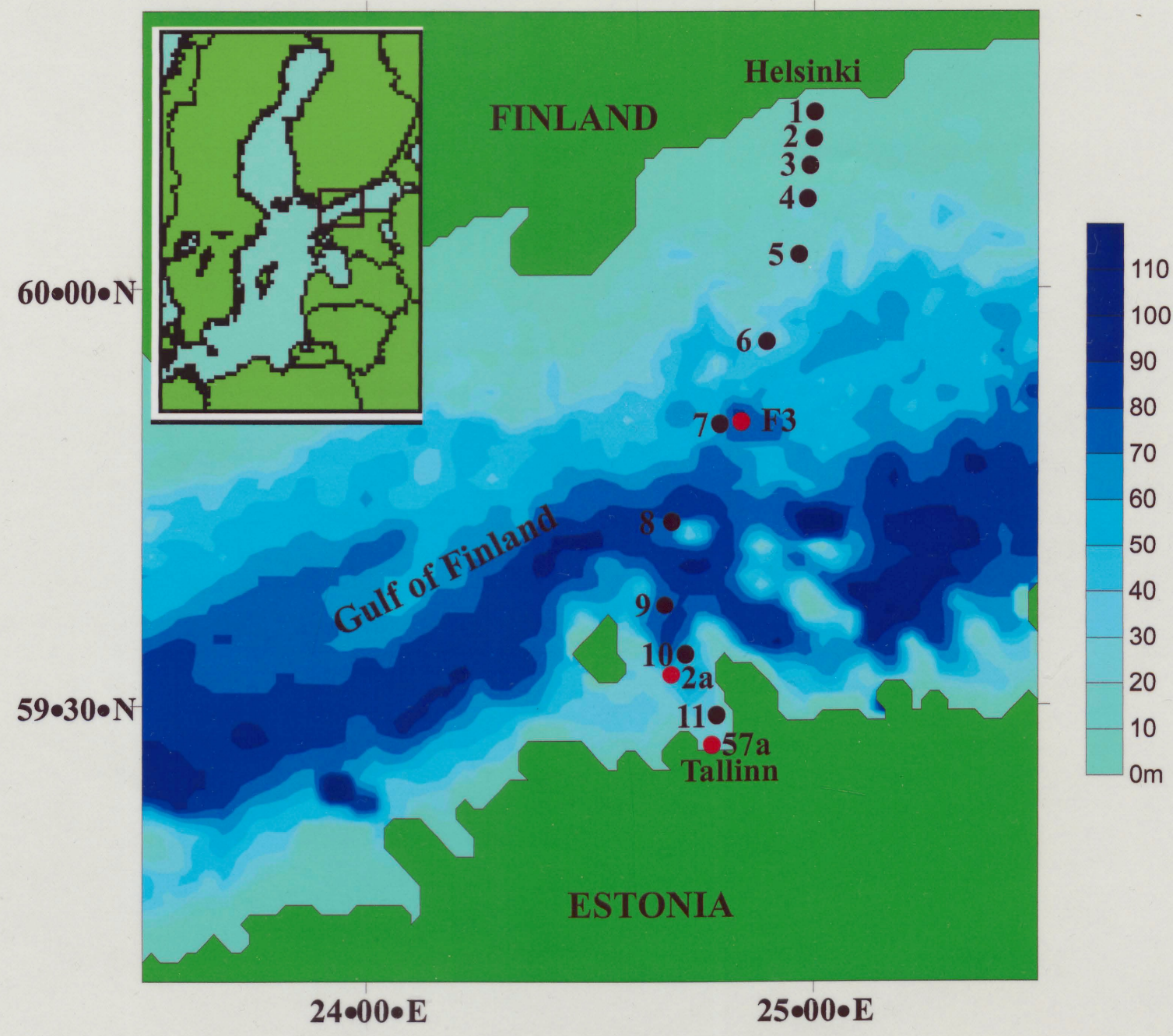


Figure 2. Spatially averaged biomass ($\mu\text{g/L}$) dynamics of dominant phytoplankton species during summer period (June-September) along the ferry route between Tallinn and Helsinki in 1997–2004.

Andres Jaanus¹, Inga Lips¹, Seppo Kaitala² and Kaire Kaljurand¹

¹Tartu University, Estonian Marine Institute

²Finnish Institute of Marine Research



Scheme of sampling points. Black dots– Alg@line (SOOP) stations, red dots– traditional monitoring stations.

Interannual variability

To link species information to multivariate environmental patterns the BIO-ENV procedure was run using PRIMER statistical software. The idea was to explore if the taxonomic phytoplankton biomass data could be used to develop ecological quality indicators that would have low natural variability and could be sensitive to ecosystem change, particularly with respect of eutrophication.

In most cases, the interannual variability obscured the possible influence of environmental parameters. We could not find any analogue years on the ground of temporal biomass dynamics (Fig. 2). However, some species or other taxonomical units could be suggested as potential indicators of eutrophication (Table1). We took into consideration both the response to elevated nutrient concentrations and the stability of certain species in term of temporal determination.

Distance between sampling sites and monitoring frequency

Increasing the number of stations and observations to characterise given water bodies will improve the precision of decisions. Using ANOSIM 1-way test we tried to determine the optimum distance between sampling stations. The distances between SOOP stations vary from 3 to 13 km. If monitoring stations are located too close to each other there is a risk of redundant information. Our analysis resulted that the dissimilarities using square route transformed phytoplankton biomass data were larger in the shallower northern part of the route near Helsinki. Statistically significant differences were

found even in a distance of 3 km. However, in the open gulf and the southern deeper part at least neighbouring stations could be merged. Depending on the locations and the intensity of water exchange with open sea the distances between stations should not be less than 10-30 km for coastal and open waters.

Eutrophication assessments are often based on the calculation of mean or median values over the assessment period (year, season). It assumes that the monitoring data should be distributed approximately equidistantly over the considered period. Sampling frequency is determined by the variability, and it is recommended a minimum of monthly sampling with optional increased sampling frequency in seasons with main bloom events.

Table 1. Linkage of selected phytoplankton taxa to environmental and spatio-temporal variables. Data from the Alg@line ship route between Tallinn and Helsinki, June-September 1998–2004. Statistically significant relationships ($p < 0.001$) in bold. Taxa in bold suggested as indicators of eutrophication.

Name of taxa	Coastal	open sea gradient	Temporal determination	Temperature	Salinity	Nutrients
Oscillatoriales			July-August	high		low PO₄ , high TP, DIN
Anabaena spp.			July		low	low PO₄ , TP, DIN
Aphanizomenon sp. ('baltica')			June-July			
Nodularia spumigena			July	high		low DIN
Prorocentrum minimum			September-October		high	high PO ₄ , TN, DIN
Heterocapsa triquetra	coastal		July-August		>5 PSU	
Chrysoschromulina spp.					>5 PSU	high TP, DIN
Cyclotella choctawhatcheeana	coastal		August			high DIN , TP
Skeletonema costatum	coastal			low		
Cylindrotheca closterium	coastal		August-September		>5 PSU	high DIN
Eutreptiella					>5 PSU	
gymnastica						
Pyramimonas spp.			July	high		
Monoraphidium contortum			minimum in July			

The results of ANOSIM analyze indicate that in the Gulf of Finland and probably in the whole Northern Baltic Proper the most rapid changes in phytoplankton community structure occur in the end of June and in July (Fig. 3). Including chlorophyll *a* data, no remarkable changes were found in the first half of June either.

Chlorophyll *a* has been used almost 50 years to measure total phytoplankton biomass. The advantage of this parameter is the simplicity of analysis and cheapness. Though, chlorophyll is only a coarse measure of phytoplankton. The variation depends on the species composition, physiology of cells and light conditions in the water column. Some phytoplankton species we included in total biomass may be mixotrophic or miss chlorophyll *a*. Thus, chlorophyll *a* contains no information on species and necessarily cannot be an objective assessor of water quality.

We suggest that for surveillance and operative monitoring 7–8 observations could be a minimum for the period from June to September. In the period of most probable bloom events (in July in the Gulf of Finland) the recommended frequency is 3-4 times a month.

The summer blooms usually peak for a rather short period (one week). As it appeared from the BIO-ENV analysis, none of the most common bloom forming species (*Aphanizomenon* sp., *Nodularia spumigena*, *Heterocapsa triquetra*) had reliable correlations with enhanced nutrient concentrations and may not be reliable indicators in terms of eutrophication. The species we suggested for that purpose (*Oscillatoriales*, *Cyclotella choctawhatcheeana*, *Cylindrotheca closterium*) have their maximum in the end of July or in August-September when the changes in community structure are less remarkable and biweekly sampling could be enough.

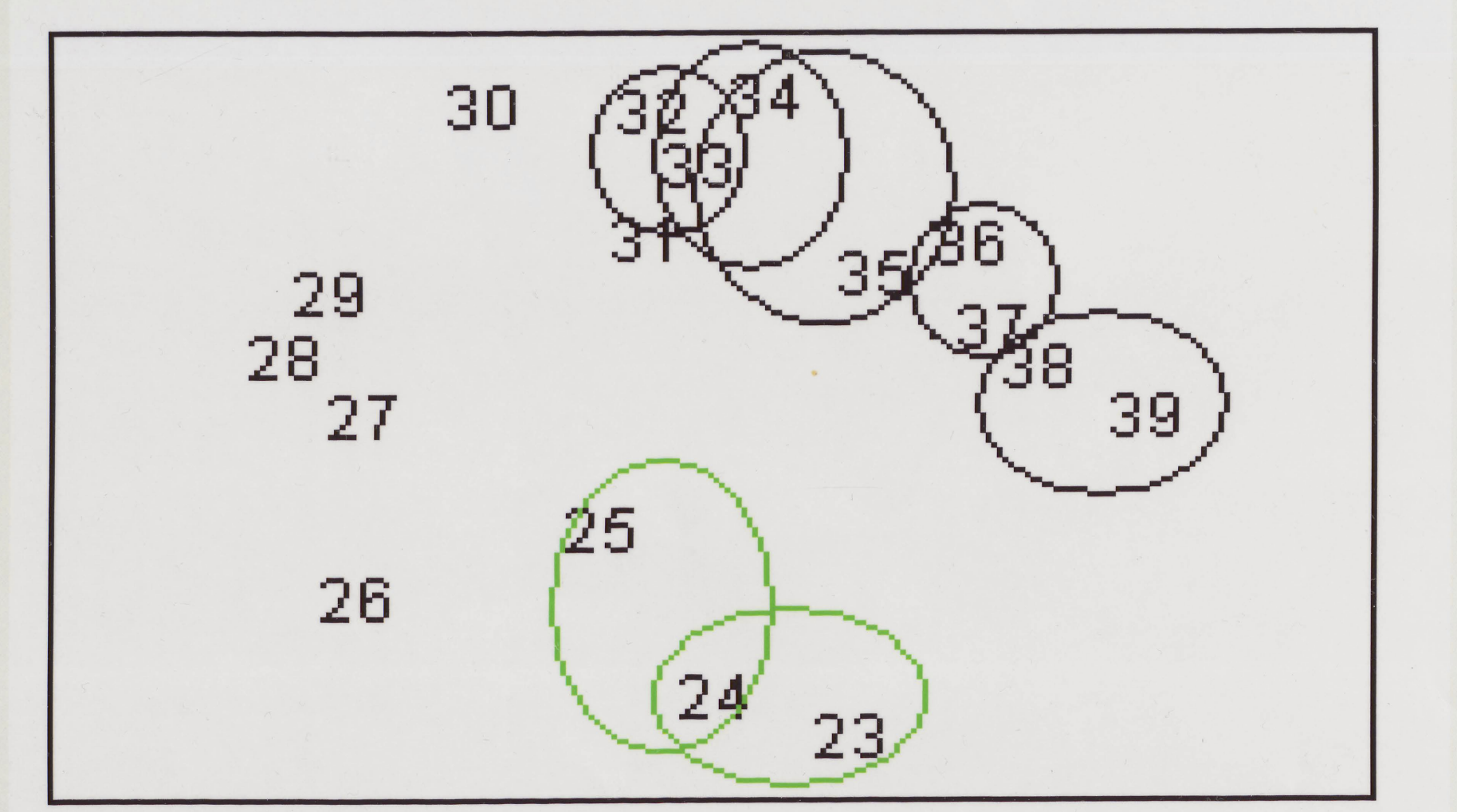


Figure 3. MDS of square root-transformed (June to September) phytoplankton biomass data of weekly resolution from the ferry route between Tallinn and Helsinki. Time period 1998–2004. Black circles merge consecutive weeks with insignificant differences based on community structure, green circles indicate no differences according to chlorophyll *a* concentrations.