Selecting potential summer phytoplankton eutrophication indicator species for the northern Baltic Sea

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Abstract. The composition, abundance, and biomass of aquatic flora, including phytoplankton, belong to the key biological indicators according to the EU Water Framework Directive. The changes in physico-chemical conditions lead directly or indirectly to impacts on biological quality elements. In order to identify which phytoplankton taxa may be indicative of ambient nutrient concentrations, we analysed the seasonal biomass pattern of selected dominant species and simultaneously measured hydrographical and chemical parameters. High frequency data were collected on the transect of the central Gulf of Finland in summer periods (from June to August) of 1997–2004. The relationships between abiotic and biotic variables were studied by linear correlation, regression, and multivariate BIO-ENV analyses. Among 14 selected taxa we found only 3 species (the diatoms *Skeletonema costatum*, *Cyclotella choctawhatcheeana*, and *Cylindrotheca closterium*) that responded regularly to enhanced nutrient concentrations having higher biomasses in coastal areas and following a similar temporal pattern. We suggest that some species (e.g. *Heterocapsa triquetra*, *Eutreptiella gymnastica*) are opportunistic and short-term changes in their biomass are not related to eutrophication levels.

Key words: phytoplankton, nutrients, eutrophication, Gulf of Finland, indicator species.

INTRODUCTION

Planktonic algae significantly contribute to the overall biomass in marine ecosystems and algal blooms at sea are naturally occurring phenomena. How-ever, these mass occurrences of microscopic algae have become more frequent and intense due to the eutrophication of the Baltic Sea (HELCOM, 2003). Eutrophication is a problem in many marine coastal areas (Vollenweider et al., 1992; Nixon, 1995; Cloern, 2001), including the Baltic Sea (Larsson et al., 1985; Elmgren, 1989; Rosenberg et al., 1990). It is caused by increased nitrogen and

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phosphorus input from the densely populated and intensively cultivated catchment area and from the atmosphere, resulting in an increase in phytoplankton biomass, primary production, and turbidity in the euphotic zone and indirectly in oxygen deficit in deep water layers (Wasmund & Uhlig, 2003).

The Gulf of Finland is an eutrophied shallow elongated basin in the north-eastern part of the Baltic Sea. Generally phytoplankton growth and biomass in the Gulf of Finland are nitrogen-limited (Granéli et al., 1990; Kivi et al., 1993; Lignell et al., 2003), except for the filamentous cyanobacteria that fix atmospheric nitrogen. The growth of filamentous cyanobacteria in the Baltic Sea is mainly temperature, trace element, or phosphorus limited (Lehtimäki et al., 1997; Stal et al., 1999; Rydin et al., 2002; Lignell et al., 2003), phosphorus being the main nutrient setting limits to bloom intensity. Nutriclines in the Gulf of Finland commonly lie in the thermocline, the phosphacline being shallower than the nitracline (Laanemets et al., 2004). Upwelling therefore leads to phosphorus enrichment and low dissolved inorganic nitrogen and dissolved inorganic phosphorus ratios (DIN:DIP ratios) in the euphotic layer (Lehtimäki et al., 1997).

According to the Water Framework Directive, a recent EU legislation, phytoplankton is one of the biological quality elements for the classification of ecological status of surface waters (lakes, rivers, coastal and transitional waters). The ecological status in coastal waters is characterized by using the taxonomic composition, abundance, and biomass of phytoplankton and the frequency of phytoplankton blooms. Therefore it is important to identify single phytoplankton taxa that are the most suitable indicators for assessing the ecological status and eutrophication of coastal waters.

As far as we know there are very few published relationships between the trends in nutrient concentrations and the biomass of total phytoplankton or single taxa. The impact of nutrient enrichment on the phytoplankton community structure has been observed by Lagus et al. (2004) and Vuorio et al. (2005). Gasiùnaite et al. (2005) tried to delineate a set of phytoplankton community indicators that are independent of season and salinity, but indicative of trophic status of different coastal areas.

The main aim of the present study was to identify the phytoplankton taxa whose wet weight biomass shows a good relationship with enhanced nutrient concentrations and therefore may prove indicative for the assessment of eutrophication.

MATERIAL AND METHODS

Data collection and study area

The data used in the present study were collected with automated equipment on board the passenger ferries *Wasa Queen* (in 1997–1999), *Finnjet* (in 2000–2003), and *Romantika* (2004), which moved between Tallinn and Helsinki each day in the summer period (June to August) of the years 1997–2004. Locations of the sampling points along the transect between Tallinn and Helsinki are shown in Fig. 1.
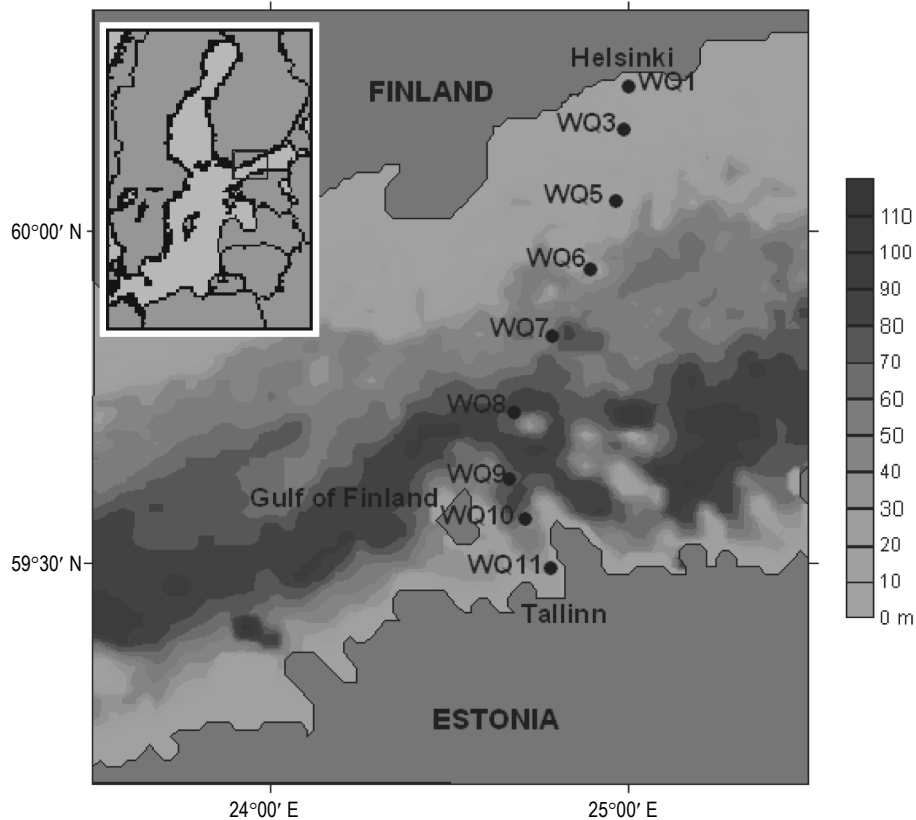
Fig. 1. Map of the study area in the Gulf of Finland, Baltic Sea. Sampling points along the transect between Tallinn and Helsinki (WQ1–WQ11) are indicated.

The water was pumped constantly through the sensors from a fixed depth (ca 5 m) on board a moving ship. The in vivo chlorophyll *a* fluorescence, temperature, and salinity were recorded quasi-continuously with spatial resolution of 150 m using an Aanderaa thermosalinograph and a Turner Design fluorometer. The measurement locations were determined with a GPS navigator. Physical and chemical measurements were repeated every 0.5–3 days in the same sea area depending on the schedule of the ferry.

The water samples for the analysis of phytoplankton species composition were obtained using an automated sampler (ISCO) and were taken at nine stations once a week along the transect (Fig. 1) and kept refrigerated (4 °C) in the dark before analysis. The water samples were analysed in an on-shore laboratory for chlorophyll *a* and nutrient concentrations as well as phytoplankton species composition and biomass.

The detection limit for total phosphorus (TP) and PO_4-P (DIP) was 0.06 µmol L^{-1}, for NO_3+NO_2-N (DIN) 0.07 µmol L^{-1}, and for total nitrogen (TN) 3.57 µmol L^{-1}.

Phytoplankton samples (100–200 mL) for quantitative phytoplankton analysis were preserved with acid Lugol solutions to a final concentration of 0.2–0.5% and analysed using the inverted microscope technique (Utermöhl, 1958). Inverted microscopes Olympus IM, Olympus IMT-2, and Leitz Fluovert using 200–400 × magnifications were used for counting. Depending on the density of the sample derived from chlorophyll concentrations, a 10 or 25 mL chamber was used for sedimentation and all cells on one diameter of the chamber bottom were counted. Since 2003, a counting program (PhytoWin, Software Kahma Ky) was used. Earlier samples were partly recalculated for biomass by feeding data into the program. Cell volumes contained in the program were used in biomass calculations; however, some new volumes were added after original measurements. Altogether 1008 phytoplankton samples were used in this work.

Statistical analyses

Fourteen dominant taxa in the Gulf of Finland were selected for statistical analysis by using wet weight biomass values. Biomass variables of Oscillatoriales (mainly from the genera *Pseudanabaena* and *Planktolyngbya*, summed up), *Anabaena* spp., *Aphanizomenon* sp., *Nodularia spumigena* Mertens, *Hemiselmis virescens* Droop, *Plagioselmis prolonga* Butcher, *Prorocentrum minimum* Schiller, *Heterocapsa triquetra* Stein, *Cyclotella choctawhatcheeana* Prasad, *Skeletonema costatum* Greville, *Cylindrotheca closterium* Reimann and J. Lewin, *Eutreptiella gymnastica* Throndsen, *Pyramimonas* spp., and *Monoraphidium contortum* Komárková-Legnerová were used. All species except *Hemiselmis virescens* and *Plagioselmis prolonga* were analysed separately.

First, temporal distribution of the wet weight biomass for each selected taxon was investigated to determine time periods with clearly elevated values. The investigated species are steadily present in the summer phytoplankton community, but become massive only in certain periods. Therefore the weeks with clearly elevated biomass values were used for further analysis. For the selected weeks, biomass variables for each taxon that formed less than 90 percentile, i.e. the values that were smaller in 90% of all observations, were excluded from further analysis (Table 1).

Phytoplankton biomasses were related to TP, TN, DIN, DIP, DIN : DIP ratio, temperature, and salinity. Some earlier studies in the Gulf of Finland have revealed that the time lag between a nutrient pulse and the response of phytoplankton is a few days (Rantajärvi et al., 1998). Therefore DIN and DIP were taken with one-week delay compared with the biotic variables for statistical analyses. Other abiotic variables used in analysis were of the same spatial and temporal coverage as the phytoplankton biomass.

Table 1. The values of 90 percentile for all biomass variables of each taxon. The biomass variables that formed less than 90 percentile were excluded from further analysis

Taxon	The value of 90 percentile, μmol L^{-1}
Oscillatoriales	154
Anabaena spp.	106
Aphanizomenon sp.	711.2
Nodularia spumigena	245.9
Hemiselmis virescens + Plagioselmis prolonga	61.6
Prorocentrum minimum	0
Heterocapsa triquetra	163
Cyclotella choctawhatcheeana	6.4
Skeletonema costatum	54.4
Cylindrotheca closterium	7
Eutreptiella gymnastica	66.4
Pyramimonas spp.	55
Monoraphidium contortum	30

The relationships between abiotic and biotic variables were tested by correlation and regression analyses and a *p*-value of <0.001 was accepted as significant. Multivariate BIO-ENV analyses were performed using the software package PRIMER, version 5 developed at the Plymouth Marine Laboratory (Clarke & Warwick, 2001).

RESULTS

Hydrometeorological and hydrophysical conditions

The seasonal average water temperature during the investigation period fluctuated between 14.2 and 17.4 °C (Fig. 2). Usually, the temperature minimums were recorded at the beginning of the investigation period and maximums at the end of July or in August.
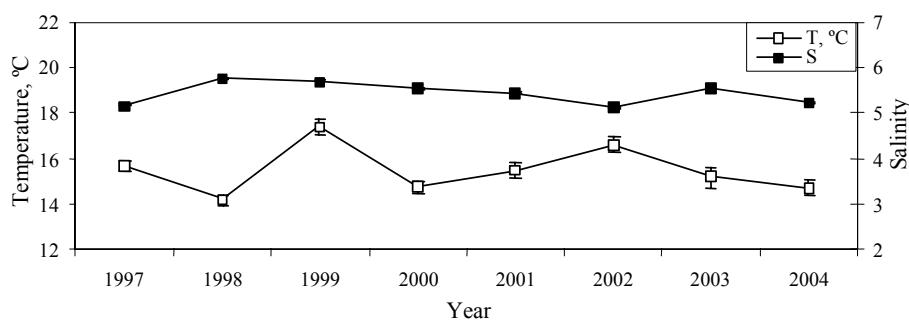

Fig. 2. Seasonal (June to August) average temperatures and salinity at a depth of ~5 m along the sampling transect in 1997–2004. The error bars denote the standard error.

The average water salinity at the sampling sites ranged between 5.1 and 5.8 for the investigation period (Fig. 2). The mean water salinity increased slowly along the study transect from the Finnish coast to the Estonian coast (from 5.1 to 5.8).

Variation of nutrient concentrations

The average DIN and DIP concentrations remained low during the whole period of the study (Fig. 3). The measured concentrations ranged between 0.03 and 0.59 μmol L^{-1} of DIP and from 0.06 to 0.74 μmol L^{-1} of DIN. Respectively larger values of DIN and DIP were measured near the Finnish coast at stations WQ1 and WQ3. The DIN : DIP ratio remained mainly below the Redfield molar ratio (N : P = 16 : 1) and was very low (average value 2.28) during the study period.
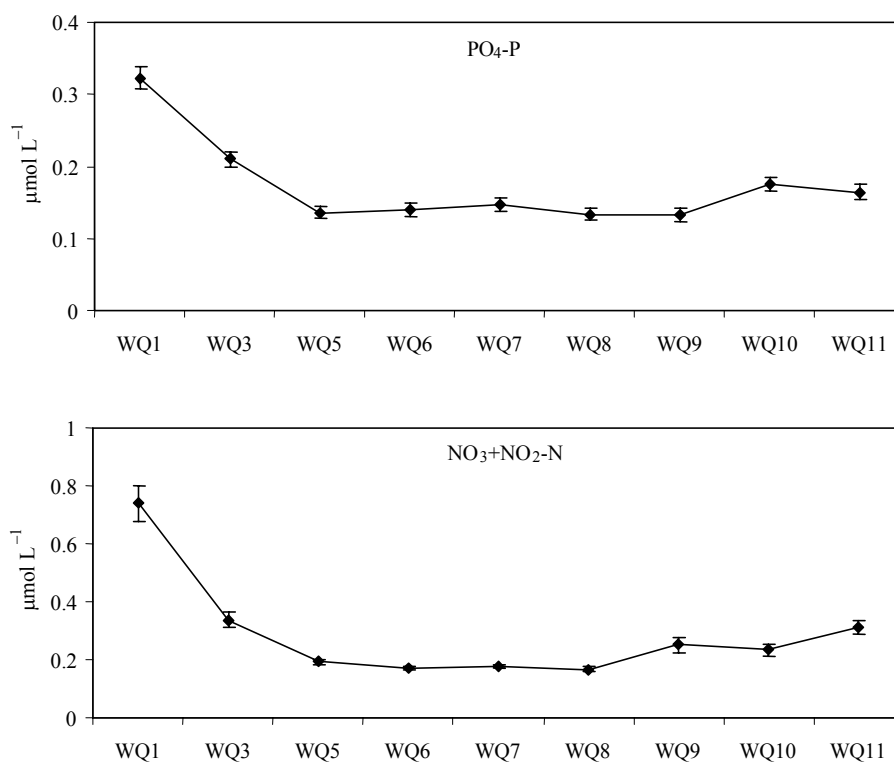
Fig. 3. Average concentrations and standard error of inorganic phosphorus (PO$_4$-P) and nitrogen (NO$_3$+NO$_2$-N) measured during the investigation period along the Helsinki–Tallinn ferry route at the sampling sites in 1997–2004.
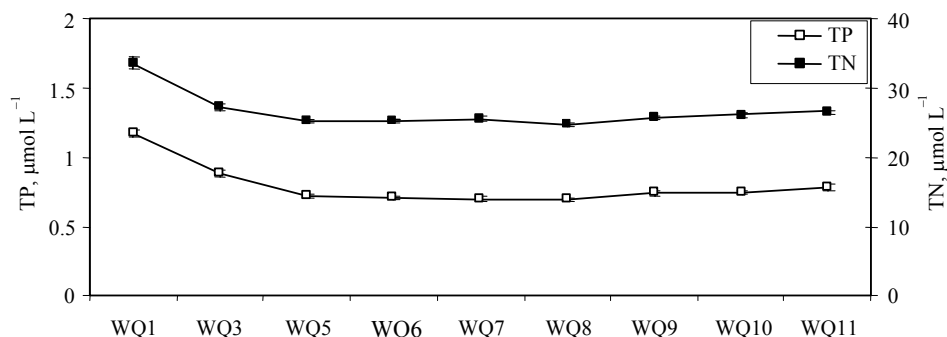
Fig. 4. Average concentrations and standard error of total phosphorus (TP) and total nitrogen (TN) measured during the investigation period along the Helsinki–Tallinn ferry route at the sampling sites in 1997–2004.

The average concentrations of TP stayed between 0.39 and 1.80 µmol L^{-1} (median 0.69 µmol L^{-1}) and TN between 21.24 and 57.58 µmol L^{-1} (median 25.71 µmol L^{-1}) during the investigation period (Fig. 4). The average concentrations of TP and TN were somewhat larger at stations WQ1 (1.17 µmol L^{-1} TP; 33.64 µmol L^{-1} TN) and WQ3 (0.89 µmol L^{-1} TP; 27.28 µmol L^{-1} TN) than at the other stations.

Dynamics of phytoplankton

The short duration of the study (8 years) precludes any assessment of long-term changes in the biomass of phytoplankton species. Still, 8-year monitoring data provide important information for the assessment of inter-seasonal variability of phytoplankton. The total biomass of phytoplankton varied between different years, but the general pattern can be distinguished for each species.

The maximum biomass values of *Skeletonema costatum* and *Monoraphidium contortum* were observed mainly in June. The biomass of *Aphanizomenon* sp. was highest in June–July, that of *Anabaena* spp., *Nodularia spumigena*, *Eutreptiella gymnastica*, and *Pyramimonas* spp. in July. Oscillatoriales, *Hemiselmis virescens*, *Plagioselmis prolonga*, and *Heterocapsa triquetra* reached their biomass peak generally in July–August. *Cyclotella choctawhatcheeana* and *Cylindrotheca closterium* showed the highest biomass in August. The dinophyte *Prorocentrum minimum* appeared among the dominant species only at the end of August 1999 and 2003. The biomass of *H. triquetra*, *C. choctawhatcheeana*, *S. costatum*, *C. closterium*, and *E. gymnastica* was usually higher at the stations situated near the coast (mainly in Finnish coastal waters) than in the central Gulf of Finland.

The relationships between abiotic and biotic variables are shown in Table 2. The biomass of *Aphanizomenon* sp., *Anabaena* spp., *Nodularia spumigena*, and

Table 2. Coefficients of Pearson correlation (*r*) and coefficients of Spearman correlation (BIO-ENV) between phytoplankton biomass and abiotic variables. Values with $p < 0.001$ are given in bold

	Analysis	Temperature	Salinity	TP	PO$_4$-P	TN	NO$_3$+NO$_2$-N	DIN:DIP
Oscillatoriales Weeks 28–35 n = 575	*r*	**0.24**	-0.17	**0.38**	0.02	0.11	-0.01	-0.04
	BIO-ENV	0.013	0.013	**0.069**	0.000	**0.057**	0.037	**0.05**
Anabaena spp. Weeks 27–30 n = 287	*r*	-0.06	**-0.21**	0.01	-0.15	0.02	-0.08	-0.05
	BIO-ENV	0.031	**0.136**	0.025	**0.08**	0.039	**0.11**	0.055
Aphanizomenon sp. Weeks 25–31 n = 501	*r*	0.03	-0.11	-0.08	**-0.21**	0.03	-0.07	-0.04
	BIO-ENV	0.088	-0.01	0.048	**0.138**	-0.006	**0.062**	0.065
Nodularia spumigena Weeks 27–31 n = 359	*r*	**0.23**	-0.05	**-0.22**	**-0.19**	0.05	-0.07	-0.05
	BIO-ENV	**0.087**	0.025	**0.063**	0.09	0.026	**0.066**	0.073
Hemiselmis virescens + *Plagioselmis prolonga* Weeks 27–34 n = 576	*r*	**0.21**	-0.05	**-0.21**	**-0.22**	0.09	-0.04	0.06
	BIO-ENV	-0.019	0.024	**0.039**	0.009	**0.054**	0.006	-0.018
Prorocentrum minimum Weeks 34–35 n = 144	*r*	-0.04	-0.05	0.24	0.08	0.00	-0.16	-0.10
	BIO-ENV	0.01	-0.073	**0.075**	0.002	-0.082	**0.061**	-0.016
Heterocapsa triquetra Weeks 28–35 n = 575	*r*	**-0.19**	0.00	**0.23**	**0.23**	0.03	**0.26**	0.03
	BIO-ENV	0.02	**0.088**	0.026	0.028	0.039	**0.071**	**0.108**

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Table 2. *Continued*

	Analysis	Temperature	Salinity	TP	PO$_4$-P	TN	NO$_3$+NO$_2$-N	DIN:DIP
Cyclotella choctawhatcheeana Weeks 31–35 n = 360	r	0.10	**–0.34**	**0.34**	0.16	**0.19**	**0.18**	–0.03
	BIO-ENV	–0.015	**0.073**	**0.162**	0.09	**0.064**	0.05	–0.022
Skeletonema costatum Weeks 22–26 n = 288	r	–0.12	–0.16	0.14	0.03	**0.31**	**0.31**	**0.22**
	BIO-ENV	**0.105**	0.02	**0.099**	0.052	**0.111**	0.028	0.043
Cylindrotheca closterium Weeks 32–35 n = 288	r	0.06	–0.12	**0.44**	**0.21**	0.04	–0.01	–0.06
	BIO-ENV	–0.004	0.08	**0.203**	0.013	–0.026	**0.084**	0.021
Eutreptiella gymnastica Weeks 25–28 n = 288	r	0.04	0.01	0.01	0.01	0.00	0.00	0.00
	BIO-ENV	–0.01	**0.025**	**0.061**	0.018	–0.001	**0.039**	0.003
Pyramimonas spp. Weeks 27–35 n = 359	r	0.13	**–0.20**	–0.13	–0.06	**0.19**	–0.02	0.07
	BIO-ENV	–0.023	**0.112**	0.045	–0.011	**0.085**	0.028	0.016
Monoraphidium contortum Weeks 22–26 n = 288	r	**–0.20**	**–0.32**	0.02	0.04	–0.16	–0.04	–0.01
	BIO-ENV	**0.04**	**0.108**	**0.126**	0.017	0.098	–0.047	–0.021

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Cryptophyceae did not give any significant positive correlation with nutrients. Oscillatoriales, Cryptophyceae, and *N. spumigena* gave a positive correlation with temperature and *Anabaena* spp. a negative correlation with salinity. Oscillatoriales also gave positive results with TP. Multivariate BIO-ENV analysis that linked the biomass data to all the studied abiotical variables showed DIP and DIN to be the nutrient variables that best grouped with the biomass variables of *Anabaena* spp. and *Aphanizomenon* sp. *Nodularia spumigena* grouped best with TP, DIN, and temperature.

The biomass of the dinophyte *Prorocentrum minimum* did not show any correlation with abiotic variables. Still, multivariate BIO-ENV analysis gave the best match with TP and DIN. Correlation analysis showed a positive correlation between another dinophyte, *Heterocapsa triquetra*, and nutrients DIP, TP, and DIN and its negative correlation with temperature.

The diatoms *Cyclotella choctawhatcheeana*, *Cylindrotheca closterium*, and *Skeletonema costatum* showed a strong relationship with nutrients. The biomass of *C. choctawhatcheeana* and *C. closterium* gave a significant positive correlation with TP and *S. costatum* with TN and DIN. In addition, *C. choctawhatcheeana* correlated negatively with salinity.

Multivariate BIO-ENV analysis showed a positive correlation between the euglenophyte *Eutreptiella gymnastica* and TP, DIN, and salinity. The biomass of *Pyramimonas* spp. showed a positive correlation and *Monoraphidium contortum* a negative correlation with TN. *Monoraphidium contortum* correlated negatively with salinity and temperature and *Pyramimonas* spp. with salinity.

DISCUSSION

Solar radiation and nutrient availability are the dominant physical factors controlling phytoplankton production in the sea. The most common use of the term eutrophication is related to inputs of mineral nutrients, primarily nitrogen and phosphorus, to coastal waters. The Gulf of Finland is the sub-basin of the Baltic Sea that is most seriously affected by the effects and consequences of eutrophication. Analysing long-term physical, chemical, and biological data (1980–2002), Lundberg et al. (2005) brought out clear differences between coastal and offshore areas. During the 1990s the nutrient discharges from the catchment area of the Gulf of Finland decreased by 40% and the reductions were especially clear for the southern, i.e. Estonian coastal waters (Pitkänen et al., 2001). Thus, differences in phytoplankton dominance on both coastal open sea gradients and between Finnish and Estonian coastal stations might be expected. We distinguished some species (*H. triquetra*, *S. costatum*, *C. choctawhatcheeana*, *C. closterium*, and *E. gymnastica*) that had usually higher biomasses at the stations close to the coast, mainly in Finnish coastal waters.

Among the selected cyanobacterial taxa only non-N_2-fixing Oscillatoriales gave a positive relationship with TP. Oscillatoriales showed also a significant positive

correlation with temperature and a negative correlation with salinity indicating its freshwater origin and preference for warm water. Based on recent plankton data and considering the relationship between plankton and trophic level, Finni et al. (2001b) attribute the dominance of oscillatorean cyanobacteria (*Planktothrix agardhii*, *Pseudanabaena limnetica*, *Planktolyngbya*) to considerably eutrophic or hypereutrophic conditions. On the other hand, Nixdorf et al. (2003) also state that the dominance of Oscillatoriales in lakes is a result of the human-induced eutrophication process, but analysing phytoplankton data from shallow hypertrophic lakes they concluded that turbid mixed layers with highly light deficient conditions seem to be the key factors favouring the dominance of some oscillatorean genera like *Pseudanabaena*. Some earlier investigations also suggest that Oscillatoriales are able to outcompete N_2-fixing cyanobacteria under declining photosynthetically active radiation (Wiedner et al., 2002; Mischke, 2003).

Occurrence of cyanobacterial surface accumulations was first reported in the Baltic Sea in the 19th century (Finni et al., 2001a) and these are natural phenomena (Kahru et al., 1994; Bianchi et al., 2000; Finni et al., 2001a). Generally phyto-plankton biomass is nitrogen-limited in the Gulf of Finland (Granéli et al., 1990; Kivi et al., 1993; Lignell et al., 2003), except the diazotrophic cyanobacteria, which are able to fix gaseous nitrogen. In our study the biomass of these species (*Anabaena* spp., *Aphanizomenon* sp., and *Nodularia spumigena*) showed a positive relationship neither with dissolved nutrients nor total nitrogen or phosphorus. Therefore only the blooming of blue-green algae may not, by itself, be a sign of high trophic conditions, as stated also by Gasiùnaite et al., 2005.

The cryptophytes *Hemiselmis virescens* and *Plagioselmis prolonga* gave a negative relationship with TP and DIP and a positive relationship with temperature. It seems that they are not indicative for the assessment of eutrophication level.

Many of the common dinoflagellates may potentially be mixotrophic species, partly independent of ambient nutrient conditions (Jacobson & Andersen, 1994; Gasiùnaite et al., 2005). The abundance of *Prorocentrum minimum* in the Baltic Sea has been generally not related to salinity or temperature (Hajdu et al., 2004). It could be a dominant species at both high and low salinity (over 15 and 4.8), and its temperature range is broad (from 2.7 to 26.4 °C). However, dense populations of *P. minimum* usually occur from July to October at temperatures above 10 °C and our study period (June to August) may be too limited for final conclusions. Still, multivariate BIO-ENV analysis showed a positive relationship between the dino-phyte *P. minimum* and TP and DIN. A positive correlation between the successes of *P. minimum* in the Baltic Sea and high concentrations of TP and TN was previously observed by Hajdu et al. (2004) and Pertola et al. (2004). However, the mass occurrence of *P. minimum* in the northern Baltic areas is probably related to the intrusion of water masses from the southern basins under favourable meteorological and hydrodynamic conditions.

The dinophyte *Heterocapsa triquetra* showed a strong relationship with TP, DIP, and DIN. This species is often causing red tides (discoloured water) and is probably favoured by frequent mixing with more continuous supply of nutrients,

for example by a stimulating effect of water movements caused by ferries (Lindholm & Nummelin, 1999). The same authors relate the development of red tide to high phosphorus levels and a low TN : TP ratio with earlier indications of success of *H. triquetra* in quite eutrophic conditions (e.g. Niemi & Hällfors, 1974). However, Olli & Seppälä (2001) demonstrated apparent vertical movements of *H. triquetra* (diurnal surface and nocturnal deep aggregations) in a mesocosm experiment, which make the species greatly independent of the availability of the nutrient supply in the mixed surface layer.

In temperate and boreal coastal areas diatoms generally prevail during the first phase of the succession (spring bloom) and they are generally adapted to more turbulent environments characterized by high nutrient concentrations (Margalef, 1978). The biomasses of the diatoms *Cyclotella choctawhatcheeana*, *Cylindrotheca closterium*, and *Skeletonema costatum* were well related to the nutrients and the highest values of biomasses were observed at the sampling points situated near the coast (WQ1 and WQ3). The strongest relationship with TP was shown by *C. choctawhatcheeana* and *C. closterium* and with TN and DIN by *S. costatum*. On the contrary to our study a nutrient enrichment experiment conducted by Lagus et al. (2004) revealed that *S. costatum* is P-limited. In spite of this difference it seems that *C. choctawhatcheeana*, *C. closterium*, and *S. costatum* may be reliable indicators of eutrophication.

The biomass of the euglenophyte *Eutreptiella gymnastica* was positively related with TP and DIN. Olli et al. (1996) characterize this species as having a particular combination of environmental adaptations like a high growth potential in environments of elevated nutrient levels and flexible behaviour (vertical migrations, cyst formation). In our material, *E. gymnastica* reached bloom-like concentrations almost throughout the investigation period and showed a rather irregular pattern of spatio-temporal distribution. It is true that the absolute maximum biomass values were recorded in coastal sites, but the clearly opportunistic character of such short-term peaks does not allow relating *E. gymnastica* blooms to the background biogenic level unambiguously.

The biomass of the prasinophyte *Pyramimonas* spp. was positively related with TN and negatively with salinity. More information about *Pyramimonas* spp. will be needed for drawing any conclusions.

Kononen (1988) and Kuosa (1988) observed the chlorophyte *Monoraphidium contortum* to be abundant at relatively low salinities (3 to 4), high phosphorus concentrations, and low N : P ratios. Multivariate BIO-ENV analysis showed that the abiotic variables that best grouped with the biomass of *M. contortum* were TP, TN, salinity, and temperature. However, correlation analysis did not show any positive relation between *M. contortum* and enhanced nutrients.

In conclusion, the biomass of the non-N-fixing cyanophyta Oscillatoriales can be expected to increase with enhanced phosphorous concentrations. However, their biomass may be influenced by light conditions and enhanced nutrients and therefore, further investigations on eutrophication gradients are needed. The same is true about *Heterocapsa triquetra*, which may be greatly independent of the

availability of nutrients in the mixed surface layers owing to its high mobility. The diatoms *Skeletonema costatum*, *Cyclotella choctawhatcheeana*, and *Cylindrotheca closterium* had a strong positive relationship with nutrients and their biomasses were usually higher at stations near the coast. Thus, these species are suggested as potential and reliable indicators in terms of eutrophication. Still the gradient of the nutrients used in our work might have been too restrictive and more data are needed from sea areas with different trophic and hydrological conditions.

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Potentsiaalsed eutrofeerumise indikaatorliigid Läänemere põhjaosa suvises fütoplanktonis

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Veetaimestiku, sh fütoplanktoni liigilist koosseisu, arvukust ja biomassi peetakse pinnavee bioloogilisteks kvaliteedinäitajateks vastavalt Euroopa Liidu veepoliitika raamdirektiivile. Muutused vee füüsikalis-keemilistes tingimustes avaldavad otseselt või kaudselt mõju bioloogilistele kvaliteedielementidele. Leidmaks, milline fütoplanktoni liik võib osutuda indikatiivseks veekeskkonnas sisalduvate toitainete suhtes, on analüüsitud 14 dominantliigi biomasside sesoonseid mustreid ja veekeskkonna hüdrograafilisi ning keemilisi parameetreid. Kasutatud andmed on kogutud intensiivse seire käigus Soome lahe keskosast suveperioodil aastatel 1997–2004. Biootiliste ja abiootiliste tegurite vahelise seose uurimiseks on kasutatud regressioon- ning korrelatsioonanalüüse ja mitmemõõtmelist BIO-ENV-analüüsi. 14 dominantliigi hulgast reageerivad suurenenud toitainete sisaldusele korrapäraselt vaid kolme liigi biomassid (ränivetikad *Skeletonema costatum*, *Cyclotella choctawhatcheeana* ja *Cylindrotheca closterium*). Lisaks on nimetatud liikide biomassid suuremad rannalähedastes jaamades ja joonistub välja ka biomasside üldine ajaline muster. Vaadeldud liikidest on mõned (nt *Heterocapsa triquetra*, *Eutreptiella gymnastica*) lühiajaliste muutuste suhtes pigem oportunistid ja autorid ei seostaks neid konkreetse mereala troofsustasemega.