Selection of potential phytoplankton indicator species for monitoring Baltic coastal waters

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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

How these needs are fulfilled?

- Only few time series document clear trends of change in biomass of total phytoplankton or single taxa coincident with trends of increasing nutrient concentrations
- General figures on phytoplankton biomass in the Baltic Sea (especially its eastern part) are hardly available
- Coastal areas are primarily subjected to eutrophication, however, former monitoring programs have been focusing on open sea areas and assuming a uniform horizontal biomass distribution

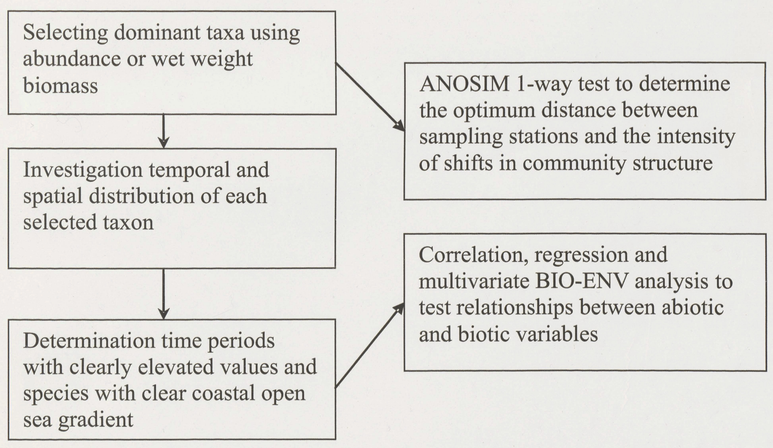
Aims of the present study

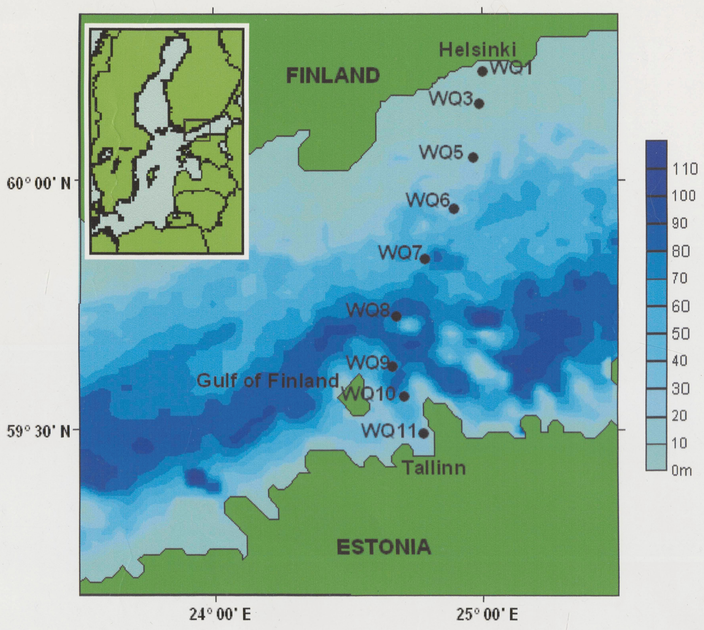
1) To reveal seasonal and spatial patterns for selected dominant phytoplankton species,
2) to evaluate the relationships of selected taxa to external nutrient levels,
3) to identify appropriate monitoring time periods for the species which may prove indicative for the assessment of eutrophication and to find out spatial differences with suggestions of optimum distance between sampling locations

Material and methods

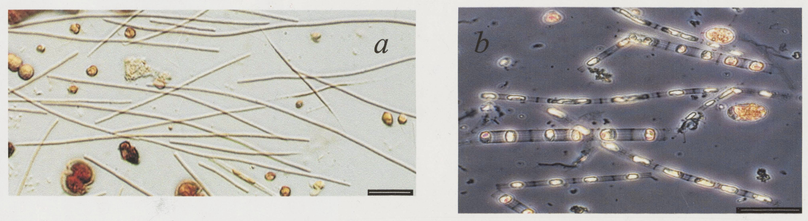
- Weekly or biweekly monitoring since 1997 (June to September) on the cross-section of the central Gulf of Finland (NE Baltic Sea) with similar climatic and hydrographic conditions, but different nutrient level
- 1224 quantitative phytoplankton samples
- Continuously measured hydrographical parameters on board the ships of opportunity and simultaneous nutrient analyses

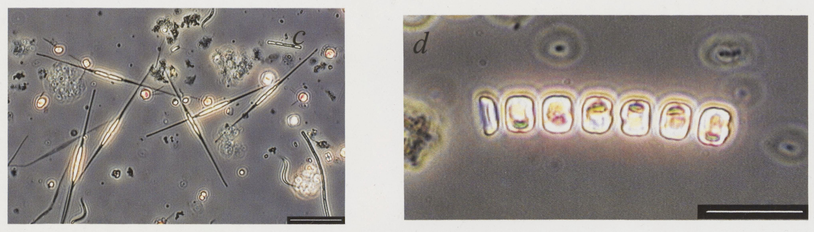
Data treatment





Map of the study area in the Gulf of Finland, Baltic Sea

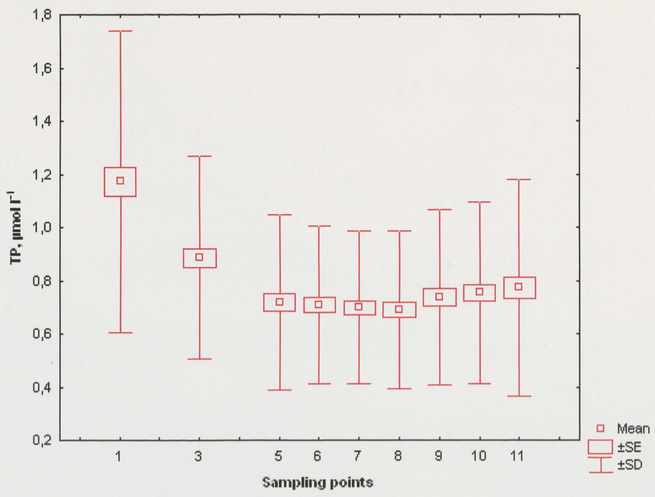


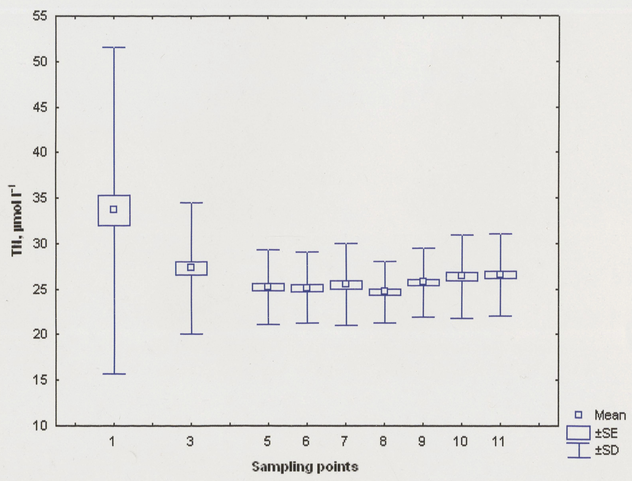


Potential indicator species –Oscillatorialean cyanobacteria (a), the diatoms Skeletonema costatum (b), Cylindrotheca closterium (c) and Cyclotella choctawhatcheeana (d). Scale bars – 15 µm *(a,d) and* 30 µm *(b,c)*

Pearson (r) and Spearman rank correlation coefficients (BIO-ENV) between phytoplankton biomass and abiotic variables. Values with p<0.001 are marked with bold; n= number of samples

		Tempe-rature	Salinity	TP	PO_4-P	TN	NO_3+ NO_2-N
Oscillatoriales	r	**0.24**	**-0.17**	**0.38**	0.02	0.11	-0.01
Weeks 28-35, n=575	BIO-ENV	0.013	0.013	**0.069**	0.000	**0.057**	0.037
Anabaena spp.	r	-0.06	**-0.21**	0.01	-0.15	0.02	-0.08
Weeks 27-30, n=288	BIO-ENV	0.031	**0.136**	0.025	**0.080**	0.039	**0.110**
Aphanizomenon sp.	r	0.03	-0.11	-0.08	**-0.21**	0.03	-0.07
Weeks 25-31, n=501	BIO-ENV	0.088	-0.010	0.048	**0.138**	-0.006	**0.062**
Nodularia spumigena	r	**0.23**	-0.05	**-0.22**	**-0.19**	0.05	-0.07
Weeks 27-31, n=359	BIO-ENV	**0.087**	0.025	**0.063**	0.090	0.026	**0.066**
Prorocentrum minimum	r	-0.04	-0.05	0.24	-0.08	0.00	-0.16
Weeks 34-35, n=144	BIO-ENV	0.010	-0.073	**0.075**	0.002	-0.082	**0.061**
Heterocapsa triquetra	r	**-0.19**	0.00	**0.23**	**0.23**	0.03	**0.26**
Weeks 28-35, n=575	BIO-ENV	0.020	**0.088**	0.026	0.028	0.039	**0.071**
Cyclotella choctawhatcheeana	r	0.10	**-0.34**	**0.34**	0.16	**0.19**	**0.18**
Weeks 31-35, n=360	BIO-ENV	-0.015	**0.073**	**0.162**	0.090	**0.064**	0.050
Skeletonema costatum	r	-0.12	-0.16	0.14	0.03	**0.31**	**0.31**
Weeks 22-26, n=288	BIO-ENV	**0.105**	0.020	**0.099**	0.052	**0.111**	0.028
Cylindrotheca closterium	r	0.06	-0.12	**0.44**	**0.21**	0.04	-0.01
Weeks 32-35, n=288	BIO-ENV	-0.004	0.080	**0.203**	0.013	-0.026	**0.084**
Eutreptiella gymnastica	r	0.19	-0.10	-0.10	-0.10	0.07	-0.03
Weeks 25-28, n=288	BIO-ENV	-0.010	**0.025**	**0.061**	0.018	-0.001	**0.039**
Pyramimonas spp.	r	**0.21**	**-0.19**	-0.02	-0.13	**0.21**	0.00
Weeks 27-35, n=597	BIO-ENV	**0.062**	**0.090**	0.014	0.052	**0.075**	0.021
Monoraphidium contortum	r	**-0.20**	**-0.32**	0.02	0.04	-0.16	-0.04





Mean concentrations (µmol l^{-1}), standard error (SE) and standard deviation (SD) of total phosphorus (TP; upper figure) and total nitrogen (TN; lower figure) measured during the investigation period at the sampling points (WQ1-WQ11)

Selection criteria for summer indicator phytoplankton species of eutrophic conditions

- Regular spatio-temporal pattern
- Clear relationships with total nutrient concentrations
- Relative independency on inorganic nutrient pulses and hydrologic perturbations
- Common at least on basin or regional level
- Easily identified at different taxonomic competence

Recommendations for monitoring design

- Phytoplankton biomass data more variable in the shallower northern part (Finnish coastal waters). Statistically significant differences found even in a distance of 3 km
- 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 open waters.
- Eutrophication assessments often based on the calculation of mean or median values over the assessment period (year, season)
  monitoring data should be distributed approximately equidistantly over the considered period
- 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 (July in the northern Baltic Sea) the recommended frequency is 3-4 times a month
- Suggested indicator species have their maximum in the end of July or in August-September when changes in community structure are less remarkable and biweekly sampling could be enough