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Species diversity of phytoplankton in Estonian streams

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Abstract — This article provides an overview of the species composition, habitats, and diversity of phytoplankton in Estonian streams during 1991-2001. A checklist is presented containing 443 taxa with their occurrence and habitats. Diatoms were the most numerous group, followed by green algae and cyanobacteria, and nanoplanktonic flagellates were ubiquitous. The phytoplankton of Estonian streams was frequently supplemented with suspended epiphytic and epilithic diatoms. The number of taxa per litre varied in the range from 7 to 56 (median 19) and showed a weak upward trend with increasing trophic degree of stream water. The phytoplankton compound quotient (PCQ) ranged from 0.7 to 22.5 and correlated weakly with trophic degree, BOD_5 concentration and stream order.

Estonian streams / indices / phytoplankton / species diversity

Résumé — Diversité spécifique du phytoplancton des cours d'eau estoniens. L'étude de la composition, de l'habitat et de la diversité des espèces du phytoplancton dans les cours d'eau en Estonie s'est effectuée de 1991 à 2001. Le tableau 1 présente 443 taxons d'algues et leur habitat. Le groupe d'algues le plus représenté est celui des diatomées, suivi par les algues vertes et les cyanobactéries. Les flagellés nanoplanctoniques peuvent être considérés comme des taxons constants dans les cours d'eau estoniens. Le plus souvent ce sont les diatomées épiphytes et épilithes qui viennent enrichir le phytoplancton des cours d'eau. Le nombre de taxons pour un échantillon quantitatif varie de 7 à 56 (moyenne 19) et tend à être plus élevé avec l'augmentation du degré trophique du cours d'eau. Le quotient de composition de phytoplancton (PCQ) varie de 0,7 à 22,5 et n'est qu'en faible corrélation avec le degré trophique, la concentration de DBO_5 et le type de cours d'eau.

Cours d'eau estoniens / diversité spécifique / indices / phytoplancton

INTRODUCTION

Biodiversity studies became a focus of research in Estonia following the country joining the global Convention on Biological Diversity (CBD), Rio de Janeiro, 1992. Investigations of the flora and fauna, with the aim of establishing the number of species present and compiling checklists, have been a high priority (Kull, 1999). The goal of the International Biodiversity Observation Year (IBOY, 2001-2002) was to collect information on biodiversity in different ecosystems for

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the preservation of the structural diversity of natural habitats and for the promotion of sustainable use of biological resources. Studies of species diversity in different waterbodies contribute to the elaboration of the protection strategy of natural habitats in the framework of the Natura 2000 Project and play an important role in the evaluation of biological water quality in accordance with the EU Water Framework Directive (WFD).

Extensive research on the phytoplankton in Estonian running waters started with the project "Biota of the Estonian Rivers" at the Institute of Zoology and Botany in 1991. A monitoring project was launched in 1994 and data on the abundance and biomass of phytoplankton for 1991-1997 have been published (Piirsoo, 2001a, b). The goal of the present paper is to provide an overview of the species composition, habitats and diversity of phytoplankton in Estonian streams during 1991-2001, and also to clarify the suitability of some indices, based on phytopankton characteristics, for the evaluation of water quality.

MATERIALS AND METHODS

The Study Area

The river network in Estonia is relatively dense (average 0.72 km/km^2), with over 7,000 rivers, brooks, and ditches; the official register (EJOKN, 1986) listing 1,755 of them. Estonian running waters are divided into six drainage basins (Järvekülg, 2001).

Bedrock topography and Quaternary deposits play a very important role in the development of river valleys. Silurian and Ordovician outcrops, rich in carbonate rocks and limestone, are located in the northern part of Estonia while Devonian sandstones, siltstones, clay and marl deposits dominate in South Estonia (Viiding & Raukas, 1995). The thickness of river deposits is markedly different in North and South Estonian valleys. Channel deposits prevail in the stream valleys of North Estonia and their thickness is usually 1-2 m in the lower reaches. Overbank deposits, including fen peat, dominate in South Estonian valleys and their thickness increases up to 10-15 m towards the lower courses of the rivers (Miidel, 2001). Sediments, generated as a consequence of human activity mainly in the form of wastes, are increasing from year to year. Numerous streams rise from forests and peat bogs. The macroalgae *Cladophora glomerata,* and *Vaucheria* spp. as well as *Ulothrix zonata, Spirogyra* sp., *Chantransia chalybea* and *Batrachospermum moniliforme* occur most frequently in Estonian running waters (Trei, 2001).

Estonian streams are short and have a small catchment area – most of the investigated running waters (70 %) belong to second – or third-order streams, and only five rivers (Pärnu, Navesti, Halliste, Emajõgi, and Narva) are regarded as fifth-order streams. The catchment area of the overwhelming majority (90 %) of the studied running waters is smaller than 1,000 m^2. The stream gradient and flow velocity are highly variable, but rivers with a moderate stream gradient (1.0-2.0 m km^{-1}), flow velocity (0.25-0.5 m s^{-1}) and weakly alkaline water (pH 7.3-8.0) occupy the first place among the investigated streams. Residence time in longer Estonian rivers varies from 4 to 8 days in midsummer (Hang & Loopmann, 1995). Water temperature in the investigated streams in midsummer revealed significant differences (7.7-24.9 °C). Nitrogen and phosphorus compounds are abundant in many streams.

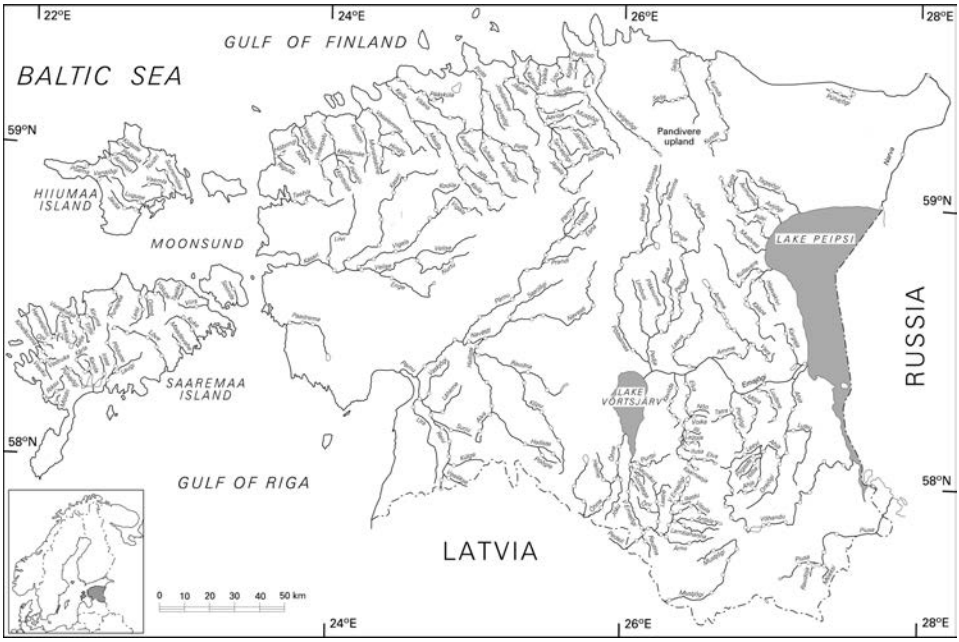

Fig. 1. The map and location of stations of phytoplankton sampling in the Estonian streams in 1991-2001.

Samples of phytoplankton were collected during complex hydrobiological expeditions to 503 reaches of 164 Estonian rivers, brooks, and ditches in the midsummers of 1991-2001 (Fig. 1). Sixty-eight streams were studied twice or three times. The number of samples per stream depended on stream length and ranged from 3 to 11 for the main rivers and from 1 to 3 for the tributaries. A total of 594 quantitative samples of 100-200 ml were taken from the main flows of streams at a depth of 0.1 m. In addition, 570 qualitative samples were collected by filtering 50 l of water through a phytoplankton net with a 50 µm mesh size. All samples were preserved in an acid Lugol solution. Species were identified using the light microscopes Labovert, Ergaval, and Amplival (magnifications 10×32, 16×40 and 16×100). For the identification of diatoms, frustules were cleaned with concentrated HCl and H_2SO_4. Altogether 378 diatom slides were prepared and mounted in Hyrax (refractive index 1.65).

The following literature and web sources were used to identify algae and to determine their habitats: Kossinskaja (1960), Palamar-Mordvintseva (1982), Komárek & Fott (1983), Krammer & Lange-Bertalot (1986, 1988, 1991a, b), Anagnostidis & Komárek (1988), Komárek & Anagnostidis (1989, 1999), Tikkanen & Willén (1992), Snoeijs (1993), Snoeijs & Vilbaste (1994), Snoeijs & Potapova (1995), Snoeijs & Kasperovičienè (1996), Cox (1996), Blomqvist & Herlitz, (1998), Snoeijs & Balashova (1998) and Baltic Sea Phytoplankton Sheets*. *Scenedesmus* species were identified after Uherkovich & Kiss (1995). The nomenclature of diatoms was updated using Round *et al*. (1990) as well as the Omnidia software (version 3). The diversity of suspended algae in the lower stream reaches was estimated using the Shannon-Weaver index (*H´*, natural logarithm ln was used)

(Shannon & Weaver, 1949), and the Nygaard phytoplankton compound quotient (1949), modified by Ott & Laugaste (1996) and widely used to estimate the trophic status of small Estonian lakes (PCQ) (Ott & Kõiv, 1999):

$$PCQ = \frac{*Cyan + Chl + Cent + Eugl + Cryp}{Zygn + Chr + 1}$$

* number of taxa in phytoplankton samples: Cyan – Cyanobacteria; Chl – Chlorococcales; Cent –Centrales; Eugl – Euglenophyta; Cryp – Cryptophyta; Zygn – Zygnematales; Chr – Chrysophyta.

The Sørensen index was calculated to assess the similarity of the phytoplankton community in different drainage basins, as well as in the same rivers in different years. Differences in the mean values of phytoplankton characteristics were tested by the non-parametric Kruskal-Wallis ANOVA median test; $P < 0.05$ was accepted as significant.

Stream order after Horton-Strahler (Gordon *et al*., 1994) was calculated using maps on a scale of 1: 400,000. Morphometric measurements, as well as hydrological and hydrochemical variables were determined simultaneously. The BOD5 value was obtained from the difference between the two measurements of dissolved oxygen before and after the incubation period (5 days at 20 °C in dark) with an accuracy of 0.1 unit. In order to determine the trophic degree, the concentrations of tot-N in river water were estimated using a scale elaborated by Forsberg & Ryding (1980). The concentrations of tot-P were estimated using the following original scale (Järvekülg, 1993): oligotrophic $\leq$ 10 mg m^{-3}, mesotrophic 11-50 mg m^{-3}, eutrophic 51-100 mg m^{-3} , and hypertrophic $>$100 mg m^{-3}. The trophic degree was determined by the content of the biogenous element that had a lower concentration. Calcareous and siliceous streams were determined according to the bedrock map of Estonia, based on the data of the Institute of Geology and Board of Geology (Arold, 1993).

RESULTS

Floristic composition

A total of 443 algal taxa in 163 genera were identified in Estonian streams (Tab. 1). Species richness was the highest in the genera *Scenedesmus, Navicula, Nitszchia, Cosmarium*, and *Cymbella*. The number of single- and few-species (2-5) genera was very high, making up more than 90% of the total number of genera.

The majority of taxa belong to the class Diatomophyceae, with 188 representatives from 58 genera (42 % of the total number of taxa). *Cocconeis pediculus* and *Nitzschia acicularis* were observed in more than 80 % of stream reaches, and they can be regarded as ubiquitous in Estonian streams. *Achnanthes minutissima*, *Synedra ulna*, *Cocconeis placentula*, *Meridion circulare*, *Melosira varians*, and *Rhoicosphenia abbreviata* occurred in more than 50 % of the stream reaches, and can be considered as frequent diatoms. The class Chlorophyceae, with 88 taxa, had

* http://www2.fimr/algaline/sheets

Tab. 1. Checklist of phytoplankton in Estonian streams in 1991-2001. Occurrence scale: vr- very rare (the species occurred less than in 1 % of the streams); r - rare (occurred in 1-20 % of the streams); c - common (occurred in 21-50 % of the streams); vc - very common (occurred in more than 51 % of the streams). Algal habitat: Pl- planktonic; Eh - epiphytic (attached to plants); El - epilithic (associated with rock surface); Ep - epipelic (unattached, motile in and on sediments); Es - epipsammic (attached to sand grains); + species for which information is lacking.

Taxon	*Occurrence*	*Habitat*
CYANOBACTERIA (CYANOPHYTA)		
Cyanophyceae		
Anabaena lemmermannii P. Richter	vr	Pl
A. planctonica Brunnth	vr	Pl
A. spiroides Klebahn	vr	Pl
A. variabilis Kützing *ex* Bornet *et* Flahault	r	Pl, Ep
Aphanizomenon flos-aquae (Linné) Ralfs *ex* Bornet *et* Flahault	r	Pl
A. gracile Lemmermann	vr	Pl
A. skujae Komárková-Legnerová *et* Cronberg	vr	Pl
Aphanocapsa delicatissima W. *et* G. S. West	r	Pl
A. grevillei (Berkeley) Rabenhorst	vr	El, Ep
A. holsatica (Lemmermann) Cronberg *et* Komárek	vr	Pl
A. reinboldii (Richter) Komárek *et* Anagnostidis	r	Es
Aphanothece clathrata W. *et* G. S. West	r	Pl
A. minutissima (W. West) Komárková-Legnerová *et* Cronberg	vr	Pl
A. stagnina (Sprengel) A. Braun	vr	Pl, Eh
Arthrospira jenneri Stizenberger *ex* Gomont	vr	Pl, Ep
Chroococcus dispersus (Keissler) Lemmerman	vr	Pl
C. distans (G. M. Smith) Komárková-Legnerová *et* Cronberg	vr	Pl
C. limneticus Lemmermann	r	Pl
C. minutus (Kützing) Nägeli	r	Pl, Eh
C. turgidus (Kützing) Nägeli	r	El, Ep
Coelosphaerium kuetzingianum Nägeli	r	Pl
Cyanodictyon imperfectum Cronberg *et* Weibull	vr	Pl
C. planctonicum Meyer	vr	Pl
Gomphosphaeria aponina Kützing	vr	Pl, Eh
Heterolebleinia kuetzingii (Schmidle) Anagnostidis *et* Komárek	r	Ep
Komvophoron sp.	vr	Pl
Lebleinia epiphytica (Hieronymos) Anagnostidis et Komárek	vr	Eh
Limnothrix planctonica (Woloszynska) Meffert	r	Pl
L. redekei (van Goor) Meffert	vr	Pl
L. sp. (l = 1.5 :m; L = 4-5 :m)	vr	
Lyngbya aestuarii (Mertens) Liebmann *ex* Gomont	r	Pl, Ep
Merismopedia glauca (Ehrenberg) Kützing	r	Eh, Pl
M. tenuissima Lemmermann	c	Pl
Microcystis aeruginosa (Kützing) Kützing	r	Pl
M. botrytis Teiling	vr	Pl
M. flos-aquae (Wittrock) Kirchner	vr	Pl
M. natans Lemmermann *ex* Skuja	vr	Pl
M. wesenbergii (Komárek) Komárek	r	Pl
Nodularia harveyana (Thwaites) Thuret *ex* Bornet *et* Flahault	vr	Pl, Ep
N. spumigena Mertens *ex* Bornet *et* Flahault	vr	Pl, Ep
Nostoc microscopicum Carm.*ex* Bornet *et* Flahault	vr	Ep
Oscillatoria brevis (Kützing) Gomont	vr	Pl, El, Ep
O. cf. *chalybea* (Mertens) Gomont	vr	Pl, El, Ep
O. cf. *irrigua* (Kützing) Gomont	vr	Pl, El
O. limosa C. Agardh *ex* Gomont	r	Pl
O. princeps Vaucher *ex* Gomont	vr	Pl, Ep

Taxon	*Occurrence*	*Habitat*
Phormidium tenue (C. Agardh *ex* Gomont) Anagnostidis *et* Komárek	r	Pl, Ep
Planktolyngbya circumcreta (G. S. West) Anagnostidis *et* Komárek	vr	Pl
P. contorta (Lemmermann) Anagnostidis *et* Komárek	vr	Pl, Ep
P. subtilis (W. West) Anagnostidis *et* Komárek	r	Pl, Eh, Ep
Planktothrix agardhii (Gomont) Anagnostidis *et* Komárek	c	Pl, Ep
P. rubescens (Gomont) Anagnostidis *et* Komárek	vr	Pl, Eh
Pseudanabaena limnetica (Lemmermann) Komárek	c	Pl
P. mutica (Naumann *et* Huber-Pestalozzi) Bourrelly	vr	Pl
Rhabdoderma lineare Schmidle *et* Lauterborn	vr	Pl
Schizothrix sp.	vr	
Snowella lacustris (Chodat) Komárek *et* Hindák	r	Pl
S. litoralis (Häyren) Komárek *et* Hindák	vr	Pl
S. cf. *septentrionalis* Komárek *et* Hindák	vr	Pl
Spirulina major Kützing *ex* Gomont	vr	Pl, Ep
Trichodesmium cf. *lacustre* Klebahn	vr	Pl
Woronichinia compacta (Lemmermann) Komárek *et* Hindák	r	Pl
W. naegeliana (Unger) Elenkin	vr	Pl
CRYPTOPHYTA		
Crytophyceae		
Campylomonas cf. *reflexa* (Skuja) Hill	r	Pl
Cryptomonas cf. *anas* Javornicky	vr	Pl
C. cf. *curvata* Ehrenberg	r	Pl
C. cf. *erosa* Ehrenberg	c	Pl, Ep
C. cf. *obovata* Skuja	r	Pl
C. cf. *ovata* Ehrenberg	r	Pl, Ep
Flagellata spp. < 7µm	vc	
Rhodomonas lacustris Pascher *et* Ruttner	vc	Pl
DINOPHYTA (PYRRHOPHYTA)		
Dinophyceae		
Ceratium cornutum (Ehrenberg) Claparède *et* Lachmann	vr	Pl
C. furcoides (Levander) Langhans	vr	Pl
C. hirundinella (O. F. Müller) Schrank	r	Pl
Gymnodinium cf. *helveticum* Penard	vr	Pl
G. simplex (Lohmann) Kofoid *et* Swezy	vr	l
G. sp.	vr	Pl
Peridinium cinctum (O. F. Müller) Ehrenberg	vr	Pl
P. umbonatum Stein	c	Pl
P. cf. *willei* Huitfeld-Kaas	r	Pl
Protoperidinium brevipes (Paulsen) Balech	r	Pl
CHRYSOPHYTA		
Chrysophyceae		
Bitrichia chodatii (Reverdin) Hollande	vr	Pl
Dinobryon bavaricum Imhof	vr	Pl
D. cylindricum Imhof	vr	Pl
D. divergens Imhof	r	Pl
D. sertularia Ehrenberg	c	Pl
Uroglena sp.	vr	Pl
Synurophyceae		
Mallomonas akrokomos Ruttner	vr	Pl
M. cf. *caudata* Ivanov	r	Pl
M. cf. *tonsurata* Teiling	vr	Pl
Synura cf. *uvella* Stein	c	Pl

Taxon	*Occurrence*	*Habitat*
Diatomophyceae (Bacillariophyceae)		
EUPODISCALES (CENTRALES)		
Actinocyclus normanii (Gregory) Hustedt	r	Pl, Eh
Aulacoseira ambigua (Grunow) Simonsen	r	Pl, Eh
A. granulata (Ehrenberg) Simonsen	r	Pl
A. var. *angustissima* (O. Müller) Simonsen	vr	Pl
A. islandica (O. Müller) Simonsen	vr	Pl
A. valida (Grunow) Krammer	vr	Pl
Cyclostephanos dubius (Fricke) Round	vr	Pl
Cyclotella bodanica Grunow	r	Pl
C. meneghiniana Kützing	c	Pl
C. radiosa (Grunow) Lemmermann	r	Pl
C. stelligera Cleve *et* Grunow	vr	Pl
Ellerbeckia arenaria (Moore) Crawford	vr	Pl, El
Melosira varians C. Agardh	vc	Pl, Eh, El
Rhizosolenia longiseta Zacharias	r	Pl
Stephanodiscus binderanus (Kützing) Krieger	vr	Pl
S. hantzschii Grunow	r	Pl
S. neoastrea Håkansson *et* Hickel	vr	Pl
S. cf. *rotula* (Kützing) Hendey	vr	Pl
BACILLARIALES (PENNALES)		
Achnanthes exigua Grunow	vr	Eh
A. lemmermanni Hustedt	r	Es
A. minutissima Kützing	vc	Eh
Amphipleura pellucida (Kützing) Kützing	r	Eh, Ep
Amphora copulata (Kützing) Schoeman *et* Archibald	r	El, Ep
A. ovalis (Kützing) Kützing	c	El, Ep
A. pediculus (Kützing) Grunow	c	El, Ep
A. robusta Gregory	vr	Ep
Aneumastus tusculus (Ehrenberg) Mann *et* Stickle	vr	Ep
Anomoeoneis sphaerophora (Ehrenberg) Pfitzer	r	Pl
Asterionella formosa Hassall	r	Pl
Caloneis amphisbaena (Bory) Cleve	r	Ep
C. bacillum (Grunow) Cleve	r	Ep
C. schumanniana (Grunow) Cleve	vr	Ep
C. silicula (Ehrenberg) Cleve	vr	Ep
Campylodiscus clypeus Ehrenberg	r	Ep
C. echeneis Ehrenberg	r	Ep
C. hibernicus Ehrenberg	r	Pl, Ep
Cocconeis neodiminuta Krammer	vr	Es
C. pediculus Ehrenberg	vc	Eh
C. placentula Ehrenberg	vc	Eh, El
C. placentula var. *euglypta* (Ehrenberg) Grunow	r	Eh, El
C. scutellum Ehrenberg	vr	Eh
Craticula cuspidata (Kützing) Mann	r	Ep
Ctenophora pulchella (Ralfs ex Kützing) Williams et Round	r	Eh
Cylindrotheca closterium (Ehrenberg) Reimann et Lewin	vr	Ep, Pl
Cymatopleura elliptica (Brébisson)W. Smith	r	Ep
C. solea (Brébisson) W. Smith	c	Ep
Cymbella affinis Kützing	vr	El, Eh
C. amphicephala Nägeli	r	Eh, El, Ep
C. aspera (Ehrenberg) Cleve	vr	Eh, El, Ep
C. cistula (Ehrenberg) Kirchner	r	Eh, El
C. cuspidata Kützing	vr	Eh, El, Ep
C. cf. *delicatula* Kützing	vr	El

Taxon	*Occurrence*	*Habitat*
C. ehrenbergii Kützing	r	Eh, El, Ep
C. helvetica Kützing	r	Eh, El
C. lanceolata (Ehrenberg) Van Heurck	r	Eh, El
C. microcephala Grunow	vr	Ep
C. pusilla Grunow	r	Ep, El
C. tumida (Brébisson) Van Heurck	vr	Eh
C. sp.	r	
Diatoma hyemalis (Roth) Heiberg	r	Eh
D. mesodon (Ehrenberg) Kützing	r	Eh
D. moniliformis Kützing	r	Eh
D. tenuis C. Agardh	r	Pl, Eh
D. vulgaris Bory	c	Eh
Diploneis elliptica (Kützing) Cleve	r	Ep
D. oblongella (Naegeli) Cleve-Euler	vr	Ep
D. ovalis (Hilse) Cleve	r	Ep
Encyonema caespitosum Kützing	r	El
E. prostratum (Berkeley) Kützing	r	El
E. silesiacum (Bleisch) Mann	c	Eh, El
Entomoneis ornata (Bailey) Reimer	vr	Ep
Epithemia adnata (Kützing) Brébisson	vr	Eh
E. sorex Kützing	vr	Eh
E. turgida (Ehrenberg) Kützing	r	Eh
Eunotia arcus Ehrenberg	vr	Eh
E. bilunaris (Ehrenberg) Souza	r	Eh
E. exigua (BrJbisson) Rabenhorst	vr	Eh
E. pectinalis (Kützing) Rabenhorst	vr	Eh
E. praerupta Ehrenberg	vr	Eh
Fallacia pygmaea (Kützing) Stickle *et* Mann	r	Ep
Fragilaria bidens Heiberg	vr	Ep
F. capucina Desmazières	c	Pl
F. crotonensis Kitton	r	Pl
F. cf. *famelica* (Kützing) Lange-Bertalot	r	Ep
F. parasitica (W.Smith) Grunow	vr	Eh
Fragilariforma virescens (Ralfs) Williams *et* Round	r	Ep
Frustulia saxonica Rabenhorst	r	Ep
F. vulgaris (Thwaites) De Toni	vr	Pl, El
Gomphonema acuminatum Ehrenberg	r	Eh
G. angustatum (Kützing) Rabenhorst	vr	Eh, El
G. olivaceum (Hornemann) Brébisson	r	Eh, El
G. parvulum (Kützing) Kützing	c	Eh, El
G. truncatum Ehrenberg	r	Eh, El
Gyrosigma acuminatum (Kützing) Rabenhorst	r	Ep
G. attenuatum (Kützing) Rabenhorst	c	Ep
G. scalproides (Rabenhorst) Cleve	vr	Ep
Hantzschia amphioxys (Ehrenberg) Grunow	r	Ep, El
Hippodonta capitata (Ehrenberg) Lange-Bertalot, Metzeltin *et* Witkowski	c	Ep
H. hungarica (Grunow) Lange-Bertalot, Metzeltin *et* Witkowski	vr	Ep
Karayevia clevei (Grunow) Round *et* Buktiyarova	vr	Es
Lemnicola hungarica (Grunow) Round et Basson	r	Eh
Luticola mutica (Kützing) Mann	r	El
Martyana martyi (Héribaud) Round	r	Es
Meridion circulare (Greville) Agardh	vc	Eh, El
Navicula bipustulata Mann	vr	Ep
N. capitatoradiata Germain ex Gasse	r	Ep
N. cari Ehrenberg	vr	Ep

Taxon	*Occurrence*	*Habitat*
N. cf. *cincta* (Ehrenberg) Ralfs	vr	Ep
N. cryptocephala Kützing	c	Ep
N. cryptotenella Lange-Bertalot	r	Ep
N. digitoradiata (Gregory) Ralfs	vr	Ep
N. gregaria Donkin	r	El, Ep
N. integra (W. Smith) Ralfs	vr	Ep
N. lanceolata (Agardh) Ehrenberg	c	El
N. laterostrata Hustedt	r	Ep
N. menisculus Schumann	r	Ep
N. oblonga (Kützing) Kützing	vr	Ep
N. peregrina (Ehrenberg) Kützing	r	Ep
N. perminuta Grunow	r	El
N. pseudolanceolata Lange-Bertalot	vr	Ep
N. radiosa Kützing	r	El
N. reinhardtii (Grunow) Grunow	r	Ep
N. rhynchocephala Kützing	c	Ep
N. tripunctata (O.F.Müller) Bory	c	El
Neidium affine (Ehrenberg) Pfitzer	vr	Ep
N. ampliatum (Ehrenberg) Krammer	r	Ep
N. binodis (Ehrenberg) Hustedt	vr	Ep
Nitzschia acicularis (Kützing) W. Smith	vc	Pl, Ep
N. dissipata (Kützing) Grunow	r	Ep
N. dubia W. Smith	vr	Ep
N. frustulum (Kützing) Grunow	r	El
N. linearis (Agardh) W. Smith	r	Ep
N. microcephala Grunow	vr	Ep
N. palea (Kützing) W. Smith	r	Ep, Eh
N. paleacea (Grunow) Grunow	c	El
N. perminuta (Grunow) M. Peragallo	r	El
N. recta Hantzsch	r	Ep
N. salinicola Aleem *et* Hustedt	vr	Ep
N. sigma (Kützing) W. Smith	r	Ep
N. sigmoidea (Nitzsch) W. Smith	c	Ep
N. vermicularis (Kützing) Hantzsch	r	Ep
Parlibellus crucicula (W. Smith) Witkowski *et al.*	vr	Ep
P. protractus (Grunow) Witkowski *et al*.	vr	Ep
Pinnularia interrupta W. Smith	vr	Ep
P. maior (Kützing) Rabenhorst	r	Ep
P. microstauron (Ehrenberg) Cleve	r	Ep
P. subcapitata Gregory	vr	Ep
P. viridis (Nitzsch) Ehrenberg	r	Ep
P. sp.	vr	Ep
Placoneis clementis (Grunow) Cox	vr	Ep
P. placentula (Ehrenberg) Heinzerling	r	Ep
Planothidium delicatulum (Kützing) Round *et* Bukhtiyarova	c	El, Es
P. lanceolatum (Brébisson) Round et Bukhtiyarova	c	El, Es
Pleurosigma elongatum W. Smith	vr	Ep
Pseudostaurosira brevistriata (Grunow) Williams *et* Round	vr	Pl
Rhoicosphenia abbreviata (C. Agardh) Lange-Bertalot	vc	Eh, El
Rhopolodia gibba (Ehrenberg) O. Müller	vr	El, Ep
R. musculus (Kützing) O. Müller	vr	El, Ep
Sellaphora bacillum (Ehrenberg) Mann	r	Ep
S. pupula (Kützing) Mereschkowsky	r	Ep
Stauroneis acuta W. Smith	vr	Ep
S. anceps Ehrenberg	r	Ep

Taxon	*Occurrence*	*Habitat*
S. phoenicentron (Nitzsch) Ehrenberg	r	Ep
S. smithii Grunow	r	Ep
S. tackei (Hustedt) Krammer *et* Lange-Bertalot	r	Ep
Staurosira construens (Ehrenberg) Williams et Round	r	Es
S. construens var. *binodis* (Ehrenberg) Hamilton	r	Es
S. construens var. *venter* (Ehrenberg) Hamilton	r	Es
Staurosirella leptostauron (Ehrenberg) Williams *et* Round	r	Ep
S. pinnata (Ehrenberg) Williams *et* Round	c	El, Es
Surirella angusta Kützing	r	Ep
S. biseriata Brébisson	r	Eh, Ep
S. brebissonii Krammer *et* Lange-Bertalot	r	El, Ep
S. elegans Ehrenberg	r	Ep
S. linearis W. Smith	r	Ep
S. minuta Brébisson	r	El, Ep
S. ovalis Brébisson	r	Ep
S. robusta Ehrenberg	r	Ep
Synedra acus Kützing	r	Pl, Eh
S. capitata Ehrenberg	vr	Pl, Eh
S. ulna (Nitzsch) Ehrenberg	vc	Pl, Eh
Tabellaria fenestrata (Lyngbye) Kützing	r	Pl
T. flocculosa (Roth) Kützing	r	Eh, El
Tabularia fasciculata (Agardh) Williams et Round	vr	Eh
T. tabulata (Agardh) Snoeijs	r	Eh
Tryblionella gracilis W. Smith	vr	Ep
T. hungarica (Grunow) Mann	r	Ep
T. levidensis W. Smith	vr	Ep
Tribophyceae (Xanthophyceae)		
Characiopsis longipes (Rabenhorst) Borzi	vr	Eh, El
Goniochloris fallax Fott	vr	Pl
G. pulchra Pascher	vr	+
G. cf. *smithii* (Bourrelly) Fott	vr	Pl
Ophiocytium capitatum Wolle	vr	Pl
Pseudogoniochloris cf. *tripus* (Pascher) Krienitz, Hegewald, Reymond *et* Peschke	vr	Pl
cf. *Tetraëdriella gigas* (Pascher) Dedusenko-Stscheg.	vr	Pl
EUGLENOPHYTA		
Euglenophyceae		
Euglena acus Ehrenberg	r	Pl
E. cf. *charkowiensis* Swirenko	vr	Pl
E. clara Skuja	vr	Pl
E. gracilis Klebs	r	Pl
E. cf. *hemichromata* Skuja	r	Pl
E. intermedia (Klebs) Schmitz	vr	Pl
E. oxyuris Schmarda	r	Pl
E. proxima Dangeard	r	Pl
E. subehrenbergii Skuja	vr	Pl
E. tripteris (Dujardin) Klebs	r	Pl
E. viridis Ehrenberg	c	Pl
Eutreptiella sp.	c	
Phacus caudatus Hübner	r	Pl
P. curvicauda Swirenko	r	Pl
P. longicauda (Ehrenberg) Dujardin	r	Pl
P. pleuronectes (O.F. Müller) Dujardin	c	Pl
P. pyrum (Ehrenberg) Stein	r	Pl
P. suecicum Lemmermann	r	Pl

Taxon	*Occurrence*	*Habitat*
P. tortus (Lemmermann) Skvortzow	r	Pl
Strombomonas cf. *deflamdrei* (Roll) Deflandre	vr	Pl
S. cf. *verrucosa* (Daday) Deflandre	vr	Pl
Trachelomonas cf. *abrupta* Swirenko *em.* Deflandre	vr	Pl
T. hispida (Perty) Stein *em*. Deflandre	r	Pl
T. intermedia Dangeard	vr	Pl
T. planctonica Swirenko	c	Pl
T. varians Deflandre	r	Pl
T. volvocina Ehrenberg	c	Pl
CHLOROPHYTA		
Prasinophyceae (Micromonadophyceae)		
Pyramimonas sp.	c	Pl
Conjugatophyceae		
Closterium acerosum (Schrank) Ehrenberg *ex* Ralfs	r	Pl, Eh
C. aciculare T. West	vr	Pl
C. acutum Brébisson *ex* Ralfs	r	Pl, Eh
C. cynthia De Notaris	vr	Pl, Eh
C. dianae Ehrenberg *ex* Ralfs	r	Pl, Eh
C. ehrenbergii Meneghini *ex* Ralfs	c	Pl, Eh
C. gracile Brébisson *ex* Ralfs	r	Pl, Eh
C. kuetzingii Brébisson	r	Pl, Eh
C. cf. *moniliferum* (Bory) Ehrenberg *ex* Ralfs	r	Pl, Eh
C. cf. *parvulum* Nägeli	r	Pl, Eh
C. strigosum Brébisson	r	Pl, Eh
C. tumidum Johns.	r	Pl, Eh
Cosmarium abbreviatum Raciborski	vr	Pl, Eh
C. bioculatum Brébisson *ex* Ralfs	r	Pl, Eh
C. blyttii Wille	r	Pl, Eh
C. botrytis Meneghini *ex* Ralfs	r	Pl, Eh
C. formosulum Hoff	r	Pl, Eh
C. granatum Brébisson *ex* Ralfs	r	Pl, Eh
C. cf. *humile* (Gay) Nordstedt	r	Pl, Eh
C. cf. *laeve* Rabenhorst	r	Pl, Eh
C. margaritatum (Lundell) Roy *et* Bisset	vr	Pl, Eh
C. cf. *meneghinii* Brébisson *ex* Ralfs	vr	Pl, Eh
C. punctulatum Brébisson	vr	Pl, Eh
C. pygmaeum Reinsch	vr	Pl
C. subspeciosum Nordstedt	r	Pl, Eh
C. turpinii Brébisson	vr	Pl, Eh
Desmidium aptogonum Brébisson	vr	Pl, Eh
Euastrum cf. *insulare* (Wittrock) Roy	vr	Pl, Eh
Micrasterias crux-melitensis (Ehrenberg) Hassall *ex* Ralfs	vr	Pl, Eh
Raphidiastrum cf. *avicula* (Brébisson ex Ralfs) Palamar-Mordvintseva	vr	Pl, Eh
Spirogyra sp.	c	Eh, El
Staurastrum cf. *chaetoceros* (Schröder) G. M. Smith	vr	Pl, Eh
S. cf. *longipes* (Nordstedt) Teiling	r	Pl, Eh
S. cf. *planctonicum* Teiling	vr	Pl, Eh
S. sp.	vr	
Staurodesmus dejectus (Brébisson *ex* Ralfs) Teiling	vr	+
Zygnema sp.	r	Eh, El
Chlorophyceae		
Actinastrum hantzschii Lagerheim	r	Pl
Ankistrodesmus falcatus (Corda) Ralfs	r	Pl
A. fusiformis Corda	r	Pl

Taxon	*Occurrence*	*Habitat*
A. spiralis (Turner) Lemmermann	vr	Pl
Ankyra lanceolata (Koršikov) Fott	vr	Pl
Asterococcus limneticus (Cienkowski) Scherffel	vr	Pl
Botryococcus braunii Kützing	vr	Pl
Carteria sp.	r	
Chlamydomonas sp. (L=9µm; l= 5µm)	r	
C. sp. (L= 12µm; l= 4µm)	r	
C. sp. (L= 20µm; l=12 µm)	r	
Chlorogonium maximum Skuja	vr	Pl
C. minimum Playfair	vr	Pl
C. sp.	r	
Cladophora sp.	r	El
Closteriopsis cf. *longissima* Lemmermann	vr	Pl
Coelastrum astroideum De Notaris	r	Pl
C. cambricum Archer	vr	Pl
C. microporum Nägeli	c	Pl
C. reticulatum (Dangeard) Senn	vr	Pl
Crucigenia quadrata Morren	c	Pl
C. tetrapedia (Kirchner) W. et G.S. West	r	Pl
Crucigeniella apiculata (Lemmermann) Komárek	vr	Pl
C. crucifera (Wolle) Komárek	r	Pl
Dictyosphaerium ehrenbergianum Nägeli	r	Pl
D. pulchellum Wood	r	Pl
Draparnaldia sp.	vr	El
Elakatothrix gelatinosa Wille	r	Pl
E. genevensis (Reverdin) Hindák	r	Pl
Eudorina elegans Ehrenberg	r	Pl
Eutetramorus cf. *fotti* (Hindák) Komárek	vr	Pl
Franceia armata (Lemmermann) Koršikov	vr	Pl
F. droescheri (Lemmermann) G.M. Smith	r	Pl
Fusola viridis Snow	vr	Pl
Golenkinia radiata Chodat	r	Pl
Gonium pectorale O.F. Müller	r	Pl
G. sociale (Dujardin) Warming	r	Pl
Kirchneriella lunaris (Kirchner) Möbius	r	Pl
Koliella cf. *longiseta* (Vischer) Hindák	r	Pl
K. cf. *spirotaenia* (G. S. West) Hindák	vr	Pl
Korschikoviella limnetica (Lemmermann) Silva	vr	Pl
Lagerheimia genevensis Chodat	r	Pl
L. longiseta (Lemmermann) Wille	vr	Pl
L. quadriseta (Lemmermann) G.M. Smith	vr	Pl
L. subsalina Lemmermann	vr	Pl
Micractinium quadrisetum (Lemmermann) G.M. Smith	vr	Pl
M. pusillum Fresenius	r	Pl
Monoraphidium contortum (Thuret) Komárková-Legnerová	vc	Pl
M. convolutum (Corda) Komárková-Legnerová	r	Pl
M. griffithii (Berkeley) Komárková-Legnerová	c	Pl
M. minutum (Nägeli) Komárková-Legnerová	r	Pl
Oedogonium sp.	vr	
Oocystis borgei Snow	r	Pl
O. lacustris Chodat	r	Pl
Pandorina morum (O.F. Müller) Bory	c	Pl
Pediastrum biradiatum Meyen	vr	Pl
P. boryanum (Turpin) Meneghini	r	Pl
P. duplex Meyen	r	Pl

Taxon	*Occurrence*	*Habitat*
P. integrum Nägeli	vr	Pl
P. kawraiskyi Schmidle	vr	Pl
P. simplex Schmidle	r	Pl
P. tetras (Ehrenberg) Ralfs	r	Pl
Phacotus cf. *angustus* Pascher	r	Pl
Polyedriopsis spinulosa (Schmidle) Schmidle	vr	Pl
Radiococcus nimbatus (De Wildeman) Schmidle	vr	Pl
Scenedesmus acuminatus (Lagerheim) Chodat	c	Pl
S. acutus Meyen	c	Pl
S. var. *globosus* Hortobágyi	vr	Pl
S. arcuatus (Lemmermann) Lemmermann	r	Pl
S. armatus Chodat	r	Pl
S. bicaudatus Dedusenko	vr	Pl
S. brasiliensis Bohlin	vr	Pl
S. denticulatus Lagerheim	r	Pl
S. ecornis (Ralfs) Chodat	vc	Pl
S. intermedius Chodat	r	Pl
S. opoliensis P. Richter	r	Pl
S. quadricauda (Turpin) Brébisson	vc	Pl
S. serratus (Corda) Bohlin	vr	Pl
S. spinosus Chodat	c	Pl
S. subspicatus Chodat	c	Pl
Schroederia setigera (Schröder) Lemmermann	r	Pl
Selenastrum bibraianum Reinsch	vr	Pl
Tetradesmus wisconsiensis G.M. Smith	r	Pl
Tetraëdron caudatum (Corda) Hansgirg	r	Pl
T. incus (Teiling) G.M. Smith	r	Pl
T. minimum (A. Braun) Hansgirg	c	Pl
T. triangulare Korschikov	r	Pl
Tetrastrum staurogeniaeforme (Schröder) Lemmermann	r	Pl
Treubaria triappendiculata Bernard	vr	Pl
Ulothrix cf. *zonata* (Web. *et* Mohr.) Kützing	r	Eh, El
Volvox aureus Ehrenberg	r	Pl

the second highest number of species, but only three, *Monoraphidium contortum*, *Scenedesmus ecornis* and *S. quadricauda* were recorded in more than half of the stream reaches. In a few reaches, *Scenedesmus acuminatus, Pyramimonas* sp., *Pandorina morum* and *Chlamydomonas* sp. dominated the phytoplankton biomass. The number of Cyanobacteria was also relatively high (63 taxa, 14 %), but only *Planktothrix agardhii* and *Oscillatoria limosa* were common, with frequencies of 22 % and 18 % respectively. The abundance of cyanobacteria usually increased downstream of standing waterbodies. Thirty seven species of Zygnematales were recorded, with *Closterium ehrenbergii* the most common desmid with a frequency of 45 %. In some shallow river reaches filamentous *Spirogyra* sp. was washed into the water column from the bottom. The Euglenophyceae (27 taxa, 6 %) and Dinophyceae (10 taxa, 2 %) were only occasionally present. Among the euglenoids and dinoflagellates, *Euglena viridis* and *Peridinium umbonatum* were the most common species. Cryptophyceae, Tribophyceae, Chrysophyceae, Synurophyceae and Prasinophyceae (collectively 26 taxa, 6 %) were rarely encountered.

Species of the genera *Rhodomonas* and *Cryptomonas* were common in the water column: the frequencies of *Rhodomonas* cf. *lacustris, Cryptomonas* cf.

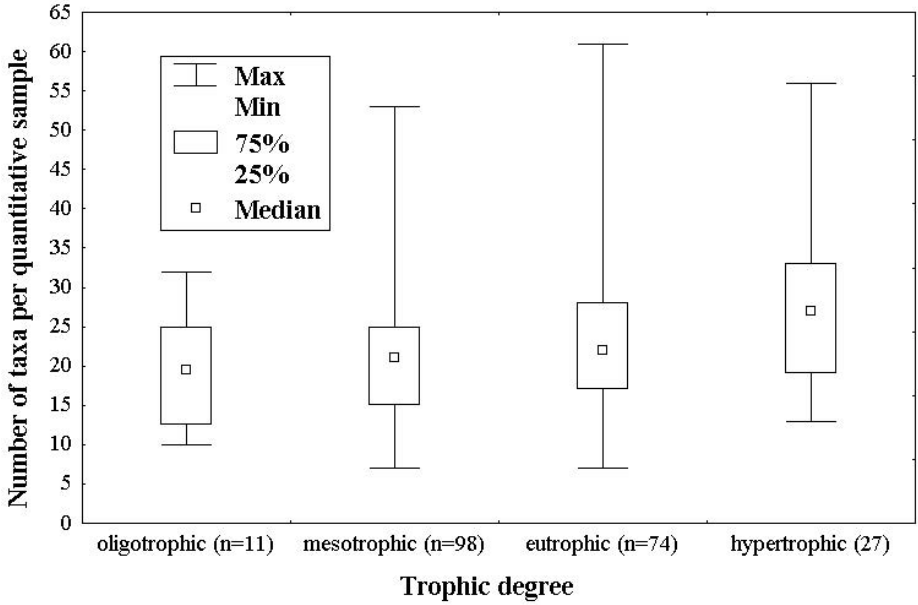

Fig. 2. The number of algal taxa per litre in the Estonian streams with a different trophic degree. The box around the median represents 50 % of the values of the number of taxa. The number of stream reaches is indicated in parentheses.

erosa and *C.* cf. *obovata* were 75 %, 43 %, and 16 %, respectively. In a few stream reaches, *Cryptomonas* cf. *ovata* and *C.* cf. *rostratiformis* dominated the phytoplankton biomass.

The number of taxa per litre varied between 7 and 56 (median 19) and showed a weak upward trend with increasing trophic degree of stream water. The highest variability in the number of taxa was observed in the eutrophic stream reaches (Fig. 2). There were no marked dissimilarities in the algae occurring between different drainage basins – the value of the Sørensen index varied from 0.4 to 0.6. A comparison of the similarity of phytoplankton occurring in streams after a five-year period showed that the Sørensen index varied from 0.4 to 0.5.

Algal communities and species diversity

The species composition of phytoplankton in Estonian streams was very heterogeneous. Euplanktonic species formed a major ecological group (196 species, 46 %) and their proportion increased in lakes, ponds, and mill weirs, which were rich in phytoplankton, as well as in the lower reaches of five long rivers (Võhandu, Pärnu, Põltsamaa, Piusa, and Navesti). The proportion of tichoplanktonic (epiphytic, epilithic, epipelic and epipsammic) forms was also appreciable (168 species, 38 %). Altogether 67 species (15 %) live in both planktonic and benthic habitats. The euplanktonic component consisted mostly of species from the classes Cryptophyceae, Dinophyceae, Chrysophyceae, Euglenophyceae, and Chlorophyceae. The tichoplanktonic component was comprised primarily of

epipelic (80 taxa), epiphytic (22 taxa), epilithic (11 taxa), and epipsammic diatoms (7 taxa). Eurytropic species, living either in the water column or attached to various substrata, belong principally to the class Cyanophyceae and the order Zygnematales. Although the species richness of epipelic diatoms was the highest in the benthic community, the phytoplankton of Estonian streams was also frequently supplemented with epiphytic and epilithic diatoms (e.g., *Achnanthes minutissima, Cocconeis pediculus, C. placentula, Meridion circulare*, and *Rhoicosphenia abbreviata*), and less often with epipelic and epipsammic diatoms (e.g., *Cymatopleura solea, Nitzschia sigmoidea, Navicula cryptocephala, N. rhynchocephala*). In the fifth-order rivers (Pärnu, Navesti, Halliste) the proportion of planktonic species in the lower course was usually higher than in the upper course.

The species richness of phytoplankton showed some regional differences – the highest median (23 taxa per stream reach) was observed in the rivers flowing into the lakes of Võrtsjärv and Peipsi; the lowest median (13) was noted in the streams of Hiiumaa Island. The Shannon-Weaver diversity index *(H')* varied on the scale from 0.2 to 3.2 (median 1.6) in different streams and did not correlate with environmental factors. The lowest value was recorded in the Purtsi River in 1991, where one taxon constituted 97 % of the total phytoplankton abundance. The highest value of the Shannon-Weaver index was calculated from the phytoplankton data of the Mustjõgi River (a tributary of the Jägala River), where the abundance of several taxa of the genera *Rhodomonas* and *Cryptomonas* was equally high. The phytoplankton compound quotient (PCQ) varied from 0.7 to 22.5 (median 4.5). The minimum PCQ value was calculated from the phytoplankton data of the Kalja brook in 1994, where desmids were present in relatively large

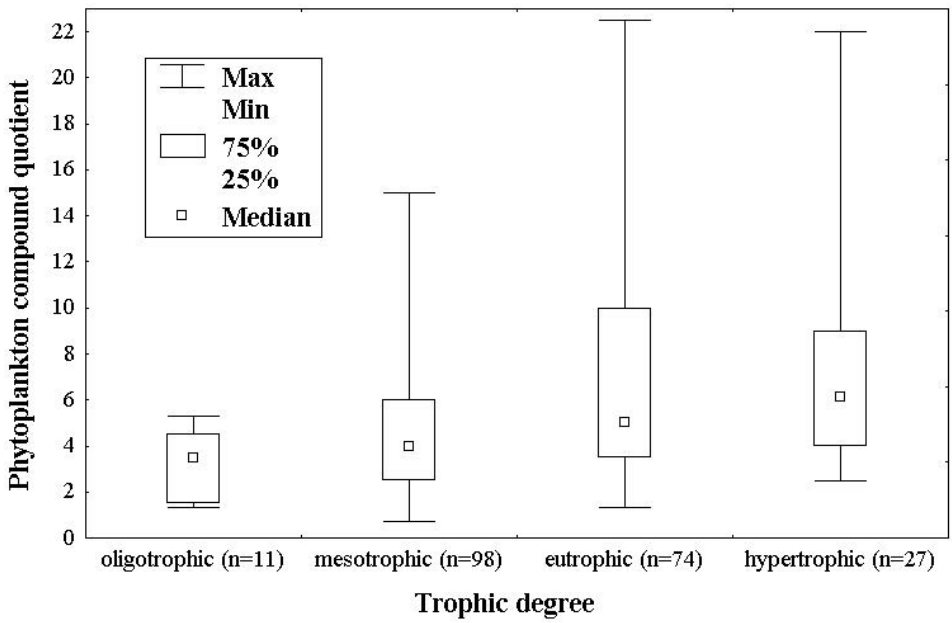

Fig. 3. Phytoplankton compound quotient (PCQ) for streams with a different trophic degree. The box around the median represents 50% of the values of the PCQ. The number of stream reaches is indicated in parentheses.

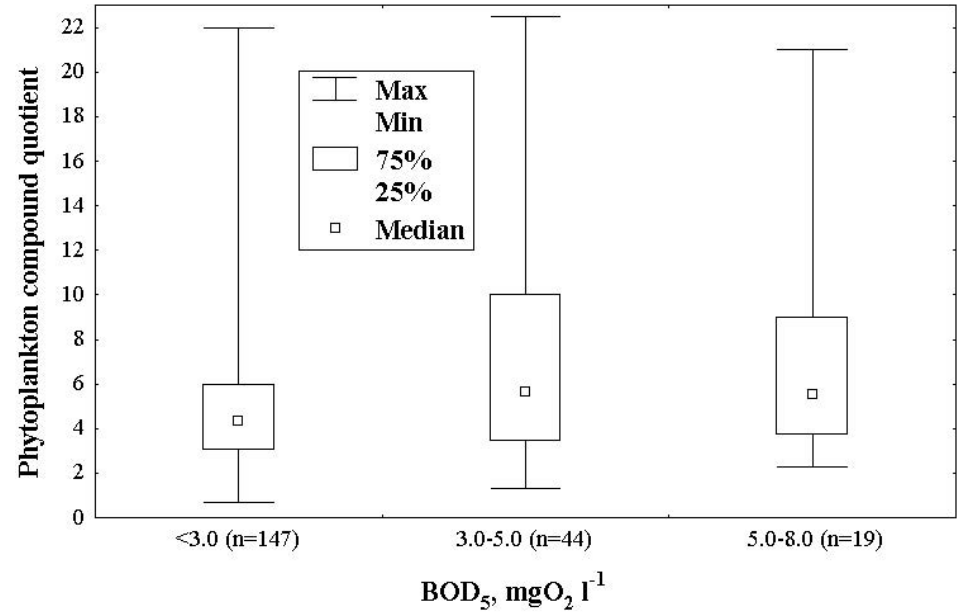

Fig. 4. Phytoplankton compound quotient (PCQ) for streams with a different BOD5 concentration. The box around the median represents 50 % of the values of the PCQ. The number of stream reaches is provided in parentheses.

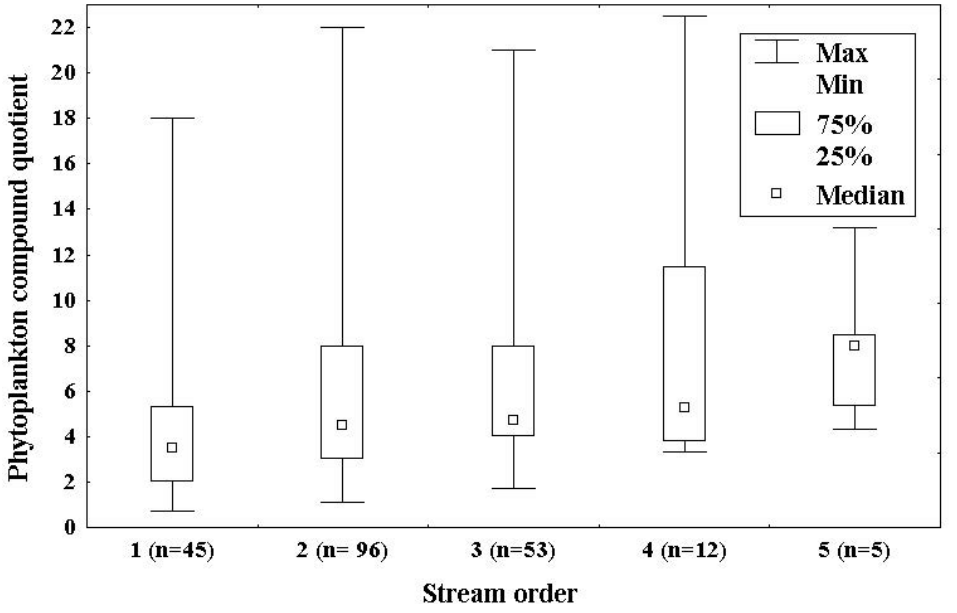

Fig. 5. Phytoplankton compound quotient (PCQ) for streams belonging to different orders. The box around the median represents 50 % of the values of the PCQ. The number of streams is given in parentheses.

numbers. The maximum value was registered in the Väike-Emajõgi River, where species richness of Chlorococcales was high in 1991. A high PCQ variability was observed in eutrophic and hypertrophic stream reaches (Fig. 3), as well as at remarkably different BOD5 values (< 3.0-8.0 mg O_2 l^{-1}) (Fig. 4). PCQ correlated weakly with the trophic degree (Spearman r = 0.33; $P < 0.001$), BOD5 concentration (Spearman r = 0.21; $P < 0.001$), and stream order (r = 0.27; $P < 0.001$) while in the latter case significant differences in PCQ were observed only between the first- and second-order streams, and between the first- and fifth-order streams (Fig. 5).

DISCUSSION

According to long-term studies (Piirsoo, 1997), the species richness of phytoplankton in Estonian streams is somewhat similar to that in Estonian coastal waters (392). However, it is much lower than that in the Estonian large lakes where, for example, 518 species of algae have been identified in Lake Võrtsjärv alone (Pork & Kõvask, 1973) and more than 1000 species in Lake Peipsi (Laugaste *et al*., 1999). Historical comparisons of phytoplankton richness in Estonian streams are difficult, as only scarce and scattered data are available from the middle of the 20th century (Mölder, 1943, 1944, 1945).

The taxonomic structure of the phytoplankton in Estonian streams is similar to that of northern floras, which are characterized by a large number of single- and few-species genera (Getzen, 1985). In most Estonian streams, the nutrient supply (phosporus and nitrogen) is sufficient and has no direct limiting effect on phytoplankton (Järvekülg, 1993). The streams are small and characterized by a short residence time of water, which varied only from 4 to 8 days in large rivers (Hang & Loopmann, 1995). The stream banks are often lined with trees and shrubs. It appears, therefore, that the most important factors that control species diversity in Estonian streams are the short residence time of water and light deficiency.

Phytoplankton of small rivers can be classified as suspended algae consisting of benthic, limnoplanktonic, and true potamoplanktonic species (Reynolds, 1996). The species composition of phytoplankton in the Estonian streams is very heterogenous. Small flagellates are common in summer, presumably as they are able to maintain a high degree of reproductivity in turbulent shallow river water (Reynolds, 1988). Some species of the genera *Cryptomonas* and *Chroomonas* are heterotrophic (Salonen & Hammar, 1986), which could explain their abundance in dark forest brooks and rivulets. There is a similarity between the taxonomic structures of phytoplankton in Estonian rivers and that of streams in Canada (Hudon, 2000), Finland (Holopainen *et al*.,1988), Lithuania (Kostkevičiené, 1997, 2001), and Moldova (Šalar', 1984), where tiny flagellates, partly of the genera *Rhodomonas* and *Cryptomonas*, were also abundant during summer. The species richness of phytoplankton in Estonian streams is considerably lower than in large rivers such as the Danube, for example, where 260 genera and 1,097 taxa of algae were recorded (Hindák & Makovinská, 1999). True phytoplankton (potamoplankton) develop in large lowland rivers, where the long residence time of water and the low flow rate allow sufficient time for algal growth and reproduction (Reynolds, 1988). The prevalence of diatoms is common in rivers, and can be attributed to their suspension due to mixing caused by the water flow (Descy, 1987). Centric

diatoms and green algae dominate the summer phytoplankton in large lowland rivers (Descy, *op. cit*; Dokulil, 1991; Hötzel & Croome, 1996; Kiss, 1986, 1987; Yang *et al*., 1997; Noppe & Prygiel, 1999; Leland *et al*., 2001). In shallow streams, pennate diatoms are washed into the water column from the bottom. The occurrence of centric diatoms was low in Estonian streams, and the phytoplankton was enriched by a large number of tichoplanktonic diatoms, e.g. *Cocconeis placentula, C. pediculus, Achnanthes minutissima, Synedra ulna, Nitzschia acicularis*, and *Meridion circulare*.

The occurrence of green algae in running waters has been reported in many studies (Kumsare, 1967; Schmidt *et al*., 1994; Kiss & Schmidt, 1998). Species of the genera *Scenedesmus* and *Monoraphidium* are common. In Estonian streams, *Monoraphidium contortum, Scenedesmus ecornis*, and *S. quadricauda* were frequent. The frequency of other green algae increased downstream of lakes, ponds, and mill weirs.

Cyanobacteria are only occasionally present in Estonian streams and their occurrence seems to be related to the influence of lakes or ponds rich in phytoplankton. In a few cases excessive growth of *Planktothrix agardhii* occurred in stream reaches affected by pollution, or there were open banks and high water temperatures (Piirsoo, 2001a).

The mean values of the Shannon-Weaver diversity index for phytoplankton in Estonian streams are similar to that for rivers of the Russian Far East (1.57-2.41) (Medvedeva, 2001) but lower than for the benthic diatom communities in Estonian streams (0.96-5.07) (Vilbaste, 2001). The mean value of the PCQ index (3.4-8.8) for Estonian small lakes (Ott & Kõiv, 1999) is higher than the value for Estonian streams. According to the classification of the PCQ values (Ott & Laugaste, 1996), the streams vary from oligo- to hypertrophic, but mesotrophic stream reaches are the most widespread in Estonia. The assessment the trophic state of the Estonian rivers from the concentration of tot-N and tot-P in the summer low-water period yielded the same result. According to this method, 51 per cent of studied river reaches were mesotrophic (Järvekülg, 2001). The PCQ index seems to be sensitive to environmental factors and can, therefore, serve as a suitable tool, besides the other phytoplankton characteristics (abundance, biomass, and species richness), for describing biological water quality in Estonian streams.

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