BOREAL ENVIRONMENT RESEARCH 9: 25–35
Helsinki 27 February 2004

ISSN 1239-6095

Macroflora in the watercourses of Saaremaa Island (Estonia)

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Trei, T. & Pall, P. 2004: Macroflora in the watercourses of Saaremaa Island (Estonia). *Boreal Env. Res.* 9: 25–35.

The study focused on 40 reaches of 29 short narrow shallow watercourses on Saaremaa Island. The floristic list covers 68 taxa of vascular plants, including 14 species of true or obligate water plants, 18 taxa of amphibious plants, and 36 taxa of terrestrial plants. The article presents differences in the frequency of vascular plants between the watercourses of Saaremaa and mainland Estonia. Three taxa of macroalgae were new to Estonia. *Ranunculus aquatilis*, *Berula erecta*, and *Alisma plantago-aquatica* preferred a higher content of nitrogen compounds. However, *Lemna minor*, *Veronica anagallis-aquatica*, and *Agrostis stolonifera* var. *prorepens* preferred a higher content of phosphorous compounds. *Cladophora rivularis* preferred both higher nitrogen and phosphorous compounds in water. *Potamogeton natans* and *Equisetum fluviatile* preferred softer sediments, and *Ulothrix zonata* preferred relatively low pH values.

Introduction

The aim of this paper was to give a survey of the floristic composition of the macroflora in the watercourses of Saaremaa Island, to provide some comparison with respective data for mainland Estonia, and to study the possible relationships of macroflora species with environmental variables. The paper deals with vascular plants, mosses, and macroalgae occurring in the watercourses of Saaremaa Island and at one site on Muhumaa Island. Until now this topic has not been investigated thoroughly although notes on several species of vascular plants occurring in the above areas can be found in the volumes of the collection on the Estonian flora (“Eesti NSV Floora” I–XI, 1953–1984).

The present study is part of the project “Biota of the Estonian Rivers”, which was carried out in 1987–1997 by a group of river biologists at the Institute of Zoology and Botany of the Estonian Agricultural University under the supervision of Arvi Järvekülg, D.Sc. The data gathered during the project, including the data on the streams of the islands Saaremaa and Muhumaa, are available in the monograph *Estonian Rivers* (Järvekülg 2001). The book also contains data about the macroflora in mainland Estonia (Trei 2001).

Site description

The watercourses of Saaremaa Island (Fig. 1) are short, narrow, shallow rivulets or brooks. According to Horton-Strahler’s stream order system (Gordon *et al.* 1994) they belong to the first and second orders while only two downstream reaches of the river Põduste can be identified as third-order reaches. Although most studied watercourses have been dredged and straightened, they are characterized by permanent natural feeding.

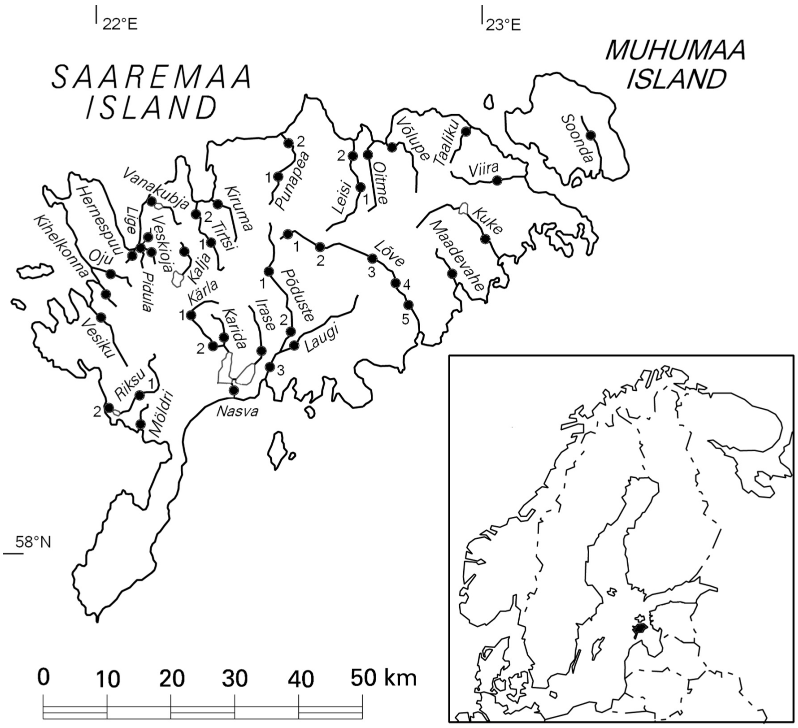

Fig. 1. The study area. The sampling sites are indicated by filled circles.

The two longest streams of Saaremaa are the river Lõve (length 31 km, width 1.5–10 m, depth 0.2–0.8 m, catchment area 159 km^2) and the river Põduste (length 30 km, width 4–10 m, depth 0.4–0.8 m, catchment area 206 km^2). Three studied streams were 20–25 km long, their width varied between 2.5–8 m, depth 0.2–1.0 m (mainly 0.4–0.6 m) and catchment area varied between 49–96 km^2. Eleven rivulets were 10–19 km long (width 2–5 m, depth 0.2–0.5 m, catchment areas mostly 20–50 km^2, max 132 km^2). The length of 13 brooks and ditches was less than 10 km; their width was 2–5 m, depth 0.1–0.6 m, and catchment area 10–30 km^2 (Loopmann 1979, Arukaevu 1986, Järvekülg 2001).

In the watercourses of Saaremaa, gravel and shingle with sand and clay are the prevailing bottom substrata. There also occur sand and clay silted to various degrees. Silty bottom can be found at some sites. These substrata are suitable for the anchoring of vascular plants which take up nutrients from sediments and water. Rarely, some charophytes can be encountered among vascular plants. Hard bottoms, such as stones and cobbles, occurring in places, and even limestone, found in one reach, represent the localities for mosses and algae, which obtain nutrients from water.

Flow velocity was usually low (< 0.1–0.25 m s^{-1}) or moderate (0.25–0.5 m s^{-1}). Table 1 presents the descriptive statistics of hydrochemical variables for the reaches of the studied streams (measured once during the fieldwork). Water temperature in midsummer was much lower in the spring-fed upper courses than in the lower courses and especially in the lake outlets. The content of dissolved oxygen in water was recorded mostly in the range 7.0–10.0 mg l^{-1} with a few higher and lower values. Water was weakly alkaline, the value of pH was mostly 7.4–7.9, sometimes higher. The content of total nitrogen and that of nitrate were relatively low and varied only within a limited range in comparison with the respective data from the rivers of mainland Estonia. The content of ammonia and phosphorus were usually low, although several exceptions were reported.

Material and methods

Fieldwork was carried out in July 1994 on 40 reaches of 29 watercourses (Fig. 1). At each site a reach of 50–100 m was used for analysis. The study of the macroflora comprised floristic composition, abundance, and domination of species. Total coverage (%) was estimated as well. In the case of stones on a streambed, the dominants were provisionally determined and samples were collected for further identification of mosses and macroalgae in the laboratory. The abundance of vascular plants as well as mosses and algae, occurring on stones, was evaluated at each site using the following five-step scale: 0 = species absent, 1 = species occurring as single specimens, 2 = species forming small assemblages, 3 = species forming large assemblages, 4 = dominating species (the most abundant species forming separate patches/communities). In one river reach several communities were found, usually monodominant or rarely with 2–(3) dominants.

The frequency of occurrence was calculated (the proportion of the sites where the species occurred in the total number of studied sites). The flora of the river bank was not included.

The guides by Mäemets (1984) and Leht (1999) were used for the identification of vascular plants, and the guide by Ingerpuu and Vellak (1998) was used for bryophytes. The taxonomic nomenclature of vascular plants is based on *Flora Europaea* vols. 1–5 (1964–1980). The following literature sources were used to identify algae: van den Hoek 1963, Gollerbakh and Krasavina 1983, Moshkova and Gollerbakh 1986, Topachevskij and Masjuk 1984, Vinogradova *et al*. 1980.

The identification of species presented some problems, the most serious of which was related to the genus *Sparganium*. On the territory of Estonia, there occurred mainly vegetative plants of this genus in July. Submerged vegetative plants of *Sparganium erectum s. lat*., mainly *S. microcarpum* Neuman (Čelak) and *Sparganium emersum* Rehmann were very similar and could not be differentiated on the basis of the morphological characteristics. We reached this conclusion after studying the submerged specimens of these two species, which were attached to emergent plants with long (up to 1 m) offshoots winding in bottom sediments. In order to avoid errors, the submerged plants and the vegetative plants of *Sparganium* with leaves floating on water surface were recorded as *Sparganium* spp. Species were identified only in case the reproductive organs were present. Probably, most plants in the flowing waters of Saaremaa, identified as *Sparganium* spp. belong to the species *Sparganium emersum*.

Simultaneously with macroflora studies the working group determined several environmental parameters. Arvi Järvekülg measured water temperature, pH, and flow velocity; Rein Järvekülg described bottom sediments; Malle Viik was responsible for the measurement of the content of nutrients in water. The content of phosphorous and nitrogen compounds (N_{tot}, NO_3-N, NO_2-N, NH_4-N, P_{tot}, and PO_4-P) was determined from unfiltered water according to Grasshoff *et al.* (1983). The content of organic nitrogen (N_{org}) was calculated from total nitrogen (N_{tot}) minus inorganic nitrogen (NO_3-N + NO_2-N + NH_4-N) and the content of organic phosphorus (P_{org}) from total phosphorus (P_{tot}) minus inorganic phosphorus (PO_4-P), respectively.

The level of water trophy for a river reach was estimated by the content of N_{tot} and P_{tot}. The scale of Forsberg and Ryding (1980) (oligotrophic < 400 mg m^{-3}, mesotrophic 400–600 mg m^{-3}, eutrophic 600–1500 mg m^{-3}, hypertrophic > 1500 mg m^{-3}) was used for N_{tot}. The content of P_{tot} was estimated according to the following scale: oligotrophic < 10 mg m^{-3}, mesotrophic 11–50 mg m^{-3}, eutrophic 51–100 mg m^{-3}, hypertrophic > 100 mg m^{-3} (Järvekülg 1993). The degree of trophy was determined from the content of the nutrient whose concentration was lower.

Table 1. Descriptive statistics of the hydrochemical variables in the water of the streams of Saaremaa Island in midsummer 1994.

Variable	Min.	Max.	Mean	Median
Temperature (°C)	8.9	25.2	17.1	17.25
O_2 (mg l^{-1})	3.3	11.0	8.4	8.65
pH	7.4	8.5	7.7	7.7
N_{tot} (mg m^{-3})	290	1890	947	918
N_{org} (mg m^{-3})	149	1593	735	651
NO_3-N (mg m^{-3})	1	842	181	96
NO_2-N (mg m^{-3})	0.5	11	3	2
NH_4-N (mg m^{-3})	0.1	286	28	17
P_{tot} (mg m^{-3})	10	130	42	37
P_{org} (mg m^{-3})	1	66	25	22
PO_4-P (mg m^{-3})	1	82	16	13

For this study the indices for the estimation of relative hardness of stream bottom were calculated by attaching different values to different substrates: mud = 1, clay = 3, sand = 5, gravel = 7, stones = 9, and pure limestone = 11. The calculations took into account whether a bottom substrate was dominating, present (relative importance 25%), or rare (relative importance 10%). For example, if bottom sediments were dominated by sand and gravel, the index was calculated as $(5 + 7)/2 = 6$. In the case of sandy bottom with a few stones the index was calculated as $0.9 \times 5 + 0.1 \times 9 = 5.4$.

The values of the environmental parameters (nutrient content, trophy, pH, index of bottom hardness) for reaches with different abundance of macroflora species were compared for testing the possible relationship between the distribution of a particular species and environmental parameter. Where the result from the non-parametric Kruskal-Wallis test was statistically significant ($p < 0.05$), the parameter was considered to exert an effect on species distribution. Stream width, depth, and flow velocity were not analysed, as their values often varied within a single reach.

Table 2. The list of vascular plants in the watercourses of Saaremaa Island with a frequency of $\geq 10\%$.

Species	Frequency (%) on Saaremaa	Frequency (%) on mainland	Domination (%) on Saaremaa
Obligate water plants			
Lemna minor	12.5	20.5	2.5
Lemna trisulca	25	12.4	
Nuphar lutea	12.5	46.2	
Potamogeton alpinus	17.5	9.1	10
Potamogeton natans	15	8.8	15
Ranunculus aquatilis	12.5		
Amphibious plants			
Alisma plantago-aquatica	45	29.3	
Berula erecta	20	14.6	7.5
Equisetum fluviatile	25	38.4	
Glyceria fluitans	17.5	5.6	2.5
Hippuris vulgaris	17.5	14.6	2.5
Mentha aquatica	42.5	15.4	5
Myosotis scorpioides	25	28.8	
Schoenoplectus lacustris	32.5	32.8	7.5
Sparganium erectum s. lat.	37.5	39.9	17.5
Sparganium spp.	32.5	35.4	5
Veronica anagallis-aquatica	22.5	22.9	2.5
Terrestrial plants			
Agrostis stolonifera var. *prorepens*	25	12.4	2.5
Caltha palustris	35	8.6	
Carex acuta	27.5	24.2	5
Carex spp.	12.5		
Eleocharis palustris	10	0.3	7.5
Epilobium hirsutum	22.5	5.3	
Galium palustre	12.5	–	2.5
Iris pseudacorus	27.5	10.9	
Juncus articulatus var. *hylandri*	15	–	
Lysimachia thyrsiflora	20	22.7	2.5
Phalaris arundinacea	32.5	24	5
Phragmites australis	47.5	19.9	22.5
Rumex spp.	17.5		
Solanum dulcamara	10	11.4	2.5
Typha latifolia	30	15.2	2.5

Results

Floristic composition

The floristic list contains altogether 68 taxa of vascular plants. The frequency of 32 species was ≥ 10% (Table 2); the frequency of 36 taxa was < 10% (Table 3). Figure 2 shows the distribution maps of 7 more frequently predominant species of vascular plants. Table 2 presents the comparison of frequency data with the data from watercourses of mainland Estonia (Trei 2001) as well as the data about the domination of species in the flowing waters of Saaremaa. It is evident that some species with a similar frequency occur in both areas while the frequency of other species is highly different. Moreover, a number of species frequent in the watercourses of the mainland, such as *Acorus calamus, Butomus umbellatus, Catabrosa aquatica, Elodea canadensis, Glyceria maxima, Potamogeton perfoliatus, Ranunculus trichophyllus, Rorippa amphibia*, and *Spirodela polyrhiza* were not found in the flowing waters of Saaremaa. *Sagittaria sagittifolia* is considered common on the mainland but is very rare on the islands (Leht 1999). We found it at two sites in Saaremaa.

Seven taxa of mosses and 18 taxa of macroalgae were identified on stones (Table 4). *Fontinalis antipyretica* and *Amblystegium riparium* were the most frequent species of mosses. *Vaucheria* spp., *Cladophora glomerata*, and *Ulothrix zonata* were the most frequent macroalgae. In places these three taxa occurred on water surface as loose assemblages of filamentous macroalgae, sometimes also accompanied with *Cladophora rivularis*.

Habitat requirements

We tested the possible effect of several environmental variables on the distribution of macrophytes. For this, we considered species with a frequency of ≥ 10%. Table 5 represents the results of the Kruskal-Wallis' test for the establishment of the relationship between the species abundance and the environmental parameters. The table includes the species with at least a single significant ($p < 0.05$) result. Water trophy and

Table 3. The list of vascular plants in the watercourses of Saaremaa Island with a frequency < 10%.

Taxa found in (Percentage of studied sites)	three reaches (7.5%)	two reaches (5.0%)	one reach (2.5%)
Obligate water plants			
	Potamogeton filiformis	*Potamogeton pectinatus*	*Callitriche* spp. *Myriophyllum spicatum* *Oenanthe aquatica* *Potamogeton berchtoldii* *P. friesii* *P. gramineus*
Amphibious plants			
	Cardamine amara	*Polygonum amphibium*	*Schoenoplectus tabernaemontanii*
	Sium latifolium	*Sagittaria sagittifolia*	*Veronica beccabunga* *Veronica* spp.
Terrestrial plants			
	Equisetum palustre *Lysimachia vulgaris* *Mentha* × *verticillata* *Menyanthes trifoliata* *Ranunculus lingua* *Valeriana officinalis*	*Epilobium* spp. *Glyceria* spp. *Ranunculus flammula* *Ranunculus* spp. *Rumex aquaticus* *Scirpus sylvaticus*	*Carex vesicaria* *Eleocharis* spp. *Glyceria plicata* *Juncus articulatus* *Ranunculus auricomus* *R. repens* *R. sceleratus* *Salix lapponum* *Teucrium scordium*

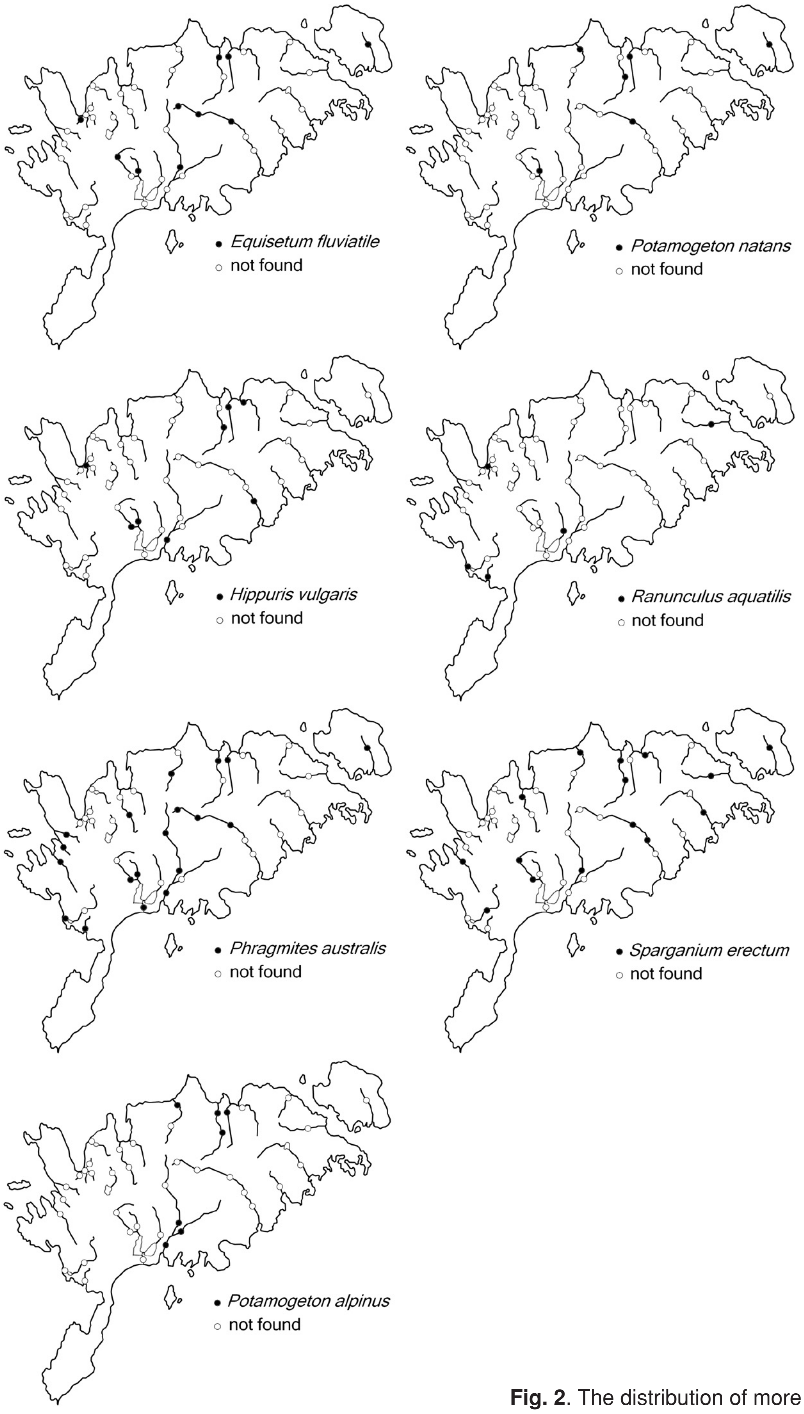

Fig. 2. The distribution of more common macroflora species.

nutrient content more often exerted an effect on species distribution. Our results were of little significance in the case of most tested environmental parameters for the distribution of the majority of vascular plants. Several relationships, although statistically significant, were difficult to explain. However, some of them deserve to be mentioned. *Alisma plantago-aquatica* and *Ranunculus aquatilis* occurred more often in reaches with a relatively higher concentration of N_{tot} and N_{org}. *Alisma* *plantago-aquatica* was absent from oligotrophic reaches. *Agrostis stolonifera* var. *prorepens* and *Veronica anagallis-aquatica* (Fig. 3) were found at sites with a higher content of P_{tot} and P_{org}. *Myosotis scorpioides* and *Epilobium hirsutum* preferred reaches with a relatively high content of PO_4-P. The former occurred at sites with a lower content of NH_4-N. *Berula erecta* was found more often in reaches with a lower content of N_{org}, but the abundance of *Berula* increased with increasing N_{org} content (Fig. 3). *Lemna minor* showed a strong preference for the higher content of phosphorous compounds: PO_4-P, P_{org}, and P_{tot} (Fig. 3). The species was absent from oligotrophic reaches. A softer bottom was clearly preferred by *Potamogeton natans* (Fig. 3), *Equisetum fluviatile* and *Amblystegium riparium* (Fig. 3).

We were unable to detect any significant dependence of the distribution of mosses or algae on nutrients. The only exception was *Cladophora rivularis*, which occurred more frequently in the reaches with a relatively higher content of N_{tot} and N_{org}, P_{tot}, and PO_4-P (Fig. 3). The species was not found in oligotrophic water. Although

Table 4. The list of mosses and macroalgae in the watercourses of Saaremaa Island.

Taxa	Frequency (%)	Reaches
Mosses		
Marchantiopsida		
Chiloscyphus polyanthos	2.5	Oju
Pellia endiviifolia	2.5	Riksu 1
Bryopsida		
Amblystegium riparium	25	dominating in 4 reaches
Amblystegium tenax	7.5	Riksu 1, Oju, Punapea 2
Amblystegium varium	2.5	Oju
Cratoneuron filicinum	5	Taaliku, Maadevahe
Fontinalis antipyretica	47.5	dominating or co-dominating to algae or to *Ambl. riparium*
Algae		
Bangiophyceae		
Batrachospermum moniliforme	7.5	Kärla 2, Irase, Riksu 1
Batrachospermum spp.	10	Oju, Kiruma, Võlupe, Lõve 4
Chantransia chalybea	5	Tirtsi 1, Kiruma
Tribophyceae		
Vaucheria fontinalis f. *polysperma**	2.5	Taaliku
Vaucheria spp.	35	Dominating in 7 reaches
Charophyceae		
Chara fragilis	2.5	Lige, (dominating)
Chara spp.	10	Riksu 2, Hernespuu, Lige, Kalja
Chlorophyceae		
*Chaetophora incrassata***	5	Irase, Oju
*Cladophora globulina****	2.5	Irase
Cladophora glomerata	35	Dominating in four reaches
Cladophora rivularis	17.5	Nasva, Möldri, Oitme, Viira, Kuke, Lõve 3, Lõve 4
Enteromorpha spp.	2.5	Nasva
Microspora spp.	10	Tirtsi 1, Kiruma, Taaliku, Lõve 4
Stigeoclonium spp.	2.5	Oitme
Tetraspora spp.	2.5	Kärla 1
Ulothrix zonata	25	Dominating in 4 reaches
Ulothrix spp.	5	Punapea 2, Leisi 1
Conjugatophyceae		
Spirogyra spp.	15	Nasva, Irase, Oju, Vanakubja, Tirtsi 1, Leisi 1

* *Vaucheria fontinalis* f. *polysperma* is the only finding in the waters of Estonia; the species was identified owing to the presence of the generative organs.

** *Chaetophora incrassata* has not been identified in the watercourses of mainland Estonia.

*** *Cladophora globulina* is the only finding in Estonian watercourses.

the pH values varied only within a limited range, *Ulothrix zonata* was found to prefer reaches with lower pH values (Fig. 3).

Attention was paid to nineteen reaches because of their vegetation-choked channels (coverage 70%–100%). Among them nine reaches were characterized by patches of loose filamentous algae on the water surface, and in three reaches there occurred, in addition, macro-assemblages of microalgae (diatoms and blue-green algae). These reaches differed significantly from the others in a slightly higher PO_4-P content. Among all the studied reaches the coverage and PO_4-P content yielded a significant correlation (non-parametric Spearman $R = 0.51$; $p < 0.001$).

Three reaches of the rivulets Oju, Taaliku, and Irase differed from the others in their high species diversity of mosses and algae. Three species of algae new to Estonia were found in these reaches. These rivulets were narrow (2–4 m) and shallow (0.2 m), with a current velocity of about 0.2–0.3 m s^{-1} and an extremely low nitrate content.

Discussion

Macrophytes occurring in the streams represent a mixed assemblage of true water plants, amphibious plants, and terrestrial plants that tolerate submergence (Sand-Jensen 1997). Water is the obligatory environment for true water plants; the two latter plant groups can grow in waterbodies, but they are also common in moist or swampy meadows, on shores of waterbodies, and in swamps. The distinction between these two groups is somewhat subjective, and it is sometimes not easy to judge to which group a particular plant belongs. Amphibious species form flowers and seeds mainly on land and grow vegetatively in water, but they can also disperse seeds and shoot fragments by hydrochory (Baattrup-Pedersen and Riis 1999 and references therein). Recently, Riis *et al.* (2001) suggested a criterion for distinguishing these two groups. Namely, amphibious plants, growing submerged in streams, develop aquatic forms, which are morphologically distinct from terrestrial forms. Terrestrial plants, occurring occasionally in waterbodies, never develop morphologically distinct water forms.

We generally accept the lists of obligate submerged plants, amphibious plants, and terrestrial plants by Riis *et al.* (2001). However, we hold a different standpoint concerning discrimination between a few species. In our opinion, *Hippuris vulgaris,* which has both a morphologically different submerged aquatic form and a terrestrial form, belongs to the group of amphibious plants but not to the group of obligate submerged plants

Table 5. The results of the Kruskal-Wallis' test between the abundance of species with a frequency of ≥ 10% and the environmental variables as statistic *H*. ns = not significant ($p > 0.05$); * = $p < 0.05$; ** = $p < 0.01$. Species without any significant result are not included.

Species	Hardness	Trophy	pH	N_{tot}	NO_3-N	NO_2-N	NH_4-N	N_{org}	P_{tot}	PO_4-P	P_{org}
Agrostis stolonifera	ns	ns	ns	ns	ns	ns	ns	ns	11.20*	ns	10.21*
Alisma plantago-aquatica	ns	7.18**	ns	4.58*	ns	ns	ns	5.62*	ns	ns	ns
Berula erecta	ns	ns	ns	ns	ns	ns	ns	9.87*	ns	ns	ns
Epilobium hirsutum	ns	ns	ns	ns	ns	ns	ns	ns	ns	9.06*	ns
Equisetum fluviatile	8.80*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Galium palustre	ns	11.74**	ns	ns	ns	ns	ns	7.94*	ns	ns	8.32*
Iris pseudacorus	ns	ns	ns	ns	ns	9.72*	ns	ns	ns	ns	ns
Lemna minor	ns	12.62**	ns	ns	ns	ns	ns	ns	8.72*	7.63*	7.59*
Myosotis scorpioides	ns	ns	ns	ns	ns	ns	4.52*	ns	ns	5.29*	ns
Potamogeton natans	9.91**	4.40*	ns	ns	ns	4.60*	ns	ns	ns	ns	ns
Ranunculus aquatilis	ns	ns	ns	9.21**	ns	ns	ns	11.28**	ns	ns	ns
Typha latifolia	ns	ns	ns	10.39*	ns	ns	ns	ns	ns	ns	ns
Veronica anagallis-aquatica	ns	ns	ns	ns	ns	ns	ns	ns	11.57*	ns	14.14**
Amblystegium riparium	9.86*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Cladophora rivularis	ns	10.20*	ns	9.77*	ns	ns	ns	8.87*	8.36*	10.35*	ns
Ulothrix zonata	ns	ns	12.21**	ns	ns	ns	ns	ns	ns	ns	ns
Vaucheria spp.	ns	ns	ns	ns	8.08*	ns	ns	ns	ns	ns	ns

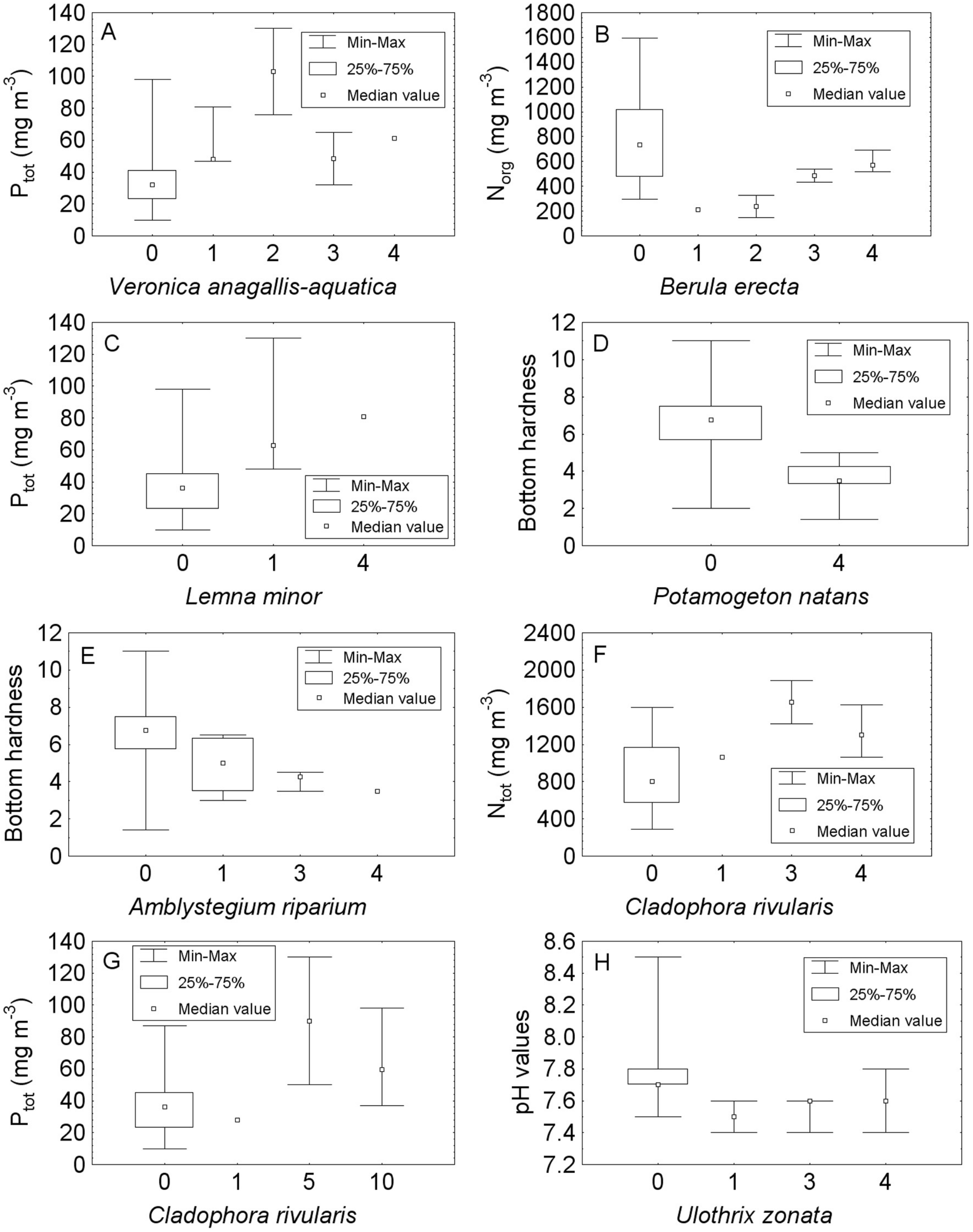

Fig. 3. The relationship between the abundance of species and the environmental variables: (**A**) *Veronica anagallis-aquatica* and P_{tot}, (**B**) *Berula erecta* and N_{org}, (**C**) *Lemna minor* and P_{tot}, (**D**) *Potamogeton natans* and bottom hardness, (**E**) *Amblystegium riparium* and bottom hardness, (**F**) *Cladophora rivularis* and N_{tot}, (**G**) *Cladophora rivularis* and P_{tot}, (**H**) *Ulothrix zonata* and pH. Abundance was estimated as follows: 0 = species absent, 1 = species occurring as single specimens, 2 = species forming small assemblages, 3 = species forming large assemblages, 4 = dominating species.

as the above authors suggest. On the contrary, *Hydrocharis morsus-ranae* should be treated under the group of obligate submerged plants as it does not develop any terrestrial form. The species *Alisma plantago-aquatica* and *Cardamine amara* of the group of terrestrial plants (Riis *et al.* 2001) are actually amphibious plants with distinct water forms as well as land forms.

The list of 68 vascular plants registered in the study area (Tables 2 and 3) contains 14 taxa of true or obligate water plants, 18 amphibious plants, and 37 terrestrial plants. We propose using the term "obligate water plants" instead of the term "obligate submerged plants" (Riis *et al.* 2001) because the former group comprises, besides submerged plants, also free-floating and floating-leaved plants.

In the shallow watercourses of Saaremaa, amphibious plants usually grow as land forms that do not develop morphologically distinct water forms as they often do in the watercourses of the mainland. Only *Hippuris vulgaris, Sparganium* spp. (probably *Sparganium emersum*) and sometimes *Veronica anagallis-aquatica* occurred as submerged water forms.

It is generally accepted that aquatics have an extensive geographical distribution and a wide range of most environmental factors. However, clarification of the importance of individual factors requires more detailed special research. Water flow is the most significant environmental factor in running waters, which determines grain size and sediment composition, as well as channel type and development of the flood plain (Janauer 2001). Already Butcher (1933) pointed to the importance of the stability of the bed and the destructive action of floods for water plants. Sedimentation and erosion constantly create new conditions on bottom, which may change quickly after a high-water period and as a result of the activity of ice. As water flow often varied within the studied reaches, it was too complicated to test it reliably; however, we tested bottom hardness which is related to flow. *Potamogeton natans* and *Equisetum fluviatile*, which preferred a softer bottom, are known as the species of standing waters. *Amblystegium riparium* also yielded a statistically significant relationship with bottom hardness (Table 5) and preferred a softer bottom (Fig. 3). As this species is usually attached to stones, it can be expected to occur more often on single stones situated on softer bottoms.

Relationships with water nutrients should be discussed cautiously. Several authors (Barko *et al.* 1991, Demars and Harper 1998, Ali *et al.* 1999, Fernándes *et al.* 1999, Clarke 2002) point to the important role of sediment nutrients. According to Sand-Jensen and Borum (1991), nutrient concentrations in sediment may be several orders of magnitude higher compared with the corresponding concentrations in the water column. Sediments are the main source of nutrients for helophytes. For submerged macrophytes the uptake of nutrients is more complicated and can obviously depend on water nutrient content. Recent manipulative experiments with four submerged species in Danish streams demonstrated that in nutrient-rich streams the mineral nutrient demand could be satisfied by leaf uptake alone (Madsen and Cedergreen 2002). According to our results, *Lemna minor* can be definitely referred to phosphorus-preferring species. For the other species conclusive sequences can be developed only on the basis of experimental studies. It was surprising that mosses and algae, being stone-attached species and hence depending more on water nutrient content, yield so few significant relationships with nutrients. The explanation is that the nutrient content in the water of the studied reaches varied to a limited extent.

A complex of habitat requirements determines the distribution of plants in flowing waters. In the watercourses of Saaremaa, macrophyte distribution is mainly regulated by light availability. One could often reveal the effects of the marginal shade of trees and bushes as macrophytes were absent in shady places. In two entirely shaded reaches the macroflora was absent from the whole reach. Unfortunately, our data about the shadiness of the reaches were unfit for statistical analysis.

Conclusions

The species diversity of the macroflora in the watercourses of Saaremaa Island is relatively high. Altogether 68 taxa of vascular plants, 7 taxa of mosses, and 18 taxa of macroalgae were identified. Three taxa of macroalgae were new to Estonia. Considerable differences in floristic composition and frequency were established between the watercourses of Saaremaa Island and mainland Estonia. Water nutrient content and hardness of bottom sediments affects the distribution of some species.

Acknowledgements: The investigation was supported by the Estonian Ministry of the Environment and by the Estonian Science Foundation. We appreciate the help of our colleague Dr. Heljo Krall in the determination of some vascular plants and the assistance of our colleagues Dr. Nele Ingerpuu, and Dr. Kai Vellak in the identification of mosses. We are grateful to our colleagues Arvi Järvekülg, Rein Järvekülg, and Malle Viik for the permission to use their data of pH values, descriptions of bottom sediments, and data on the content of nutrients. We thank Dr. Enn Veldi for providing linguistic assistance. The manuscript profited from comments by the anonymous reviewer.

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Received 19 March 2002, accepted 18 June 2003