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MACROPHYTE VEGETATION AT THE RIVER KYRÖNJOKI ESTUARY IN 1982

Jarmo J. Meriläinen[1)]

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This study presents maps of a large area of macrophyte vegetation in the upper part of the River Kyrönjoki estuary, in the southern Bothnian Bay (63° 20' N). The vegetation maps are based on colour slides taken on August 17, 1982 from a height of 900 m. The more scanty vegetation of the lower estuary was also described. The study is part of a large scale investigation into the conditions prevailing at the estuary, on the basis of which it should be possible to observe the natural succession, as well as the possible biological effects caused by the extensive works in the course of the river. More than two-thirds of the total area mapped (17.97 km^2) were covered with aquatic plants, open water accounted for a quarter and shore vegetation 6 % of the total. Phragmites australis, Scirpus lacustris, Nuphar lutea and Nymphaea candida were the most important species of the area. The previously documented deleterious influence of the acid waters on aquatic animals in the limnic zone was not pronounced on the vegetation. However, the distribution of some species was possibly restricted by the acidity, e.g. the Potamogeton perfoliatus zone, important in the outer estuary, was totally absent from the limnic zone. The plant biomass of the upper estuary, 0.4 kg dry mass per square meter (about 6 400 tons for the whole area) was very high compared with the few values hitherto reported from the Bothnian Bay and its inlets.

Index words: Macrophyte research, vegetation maps, remote sensing

1. INTRODUCTION

The watercourse of the River Kyrönjoki has been the site of hydraulic engineering work for a quater of a century. Dredging of the tributary streams, construction of reservoirs and banking of the lower reaches of the river have all been used to reduce the flooding characteristic of this area. Further construction works are presently under consideration. In order to assay the environmental effects of watercource construction, extensive investigations were commenced in summer 1980 in both the river and its estuary. The Finnish Game and Fisheries Research Institute has undertaken investigations of fish, eel, crayfish and fishing economy aspects. Other aquatic animals and vegetation, as well as heavy metals and sedimentation in the estuarine region, have been investigated by the National Board of Waters and the University of Jyväskylä. The greater part of these basic investigations is approaching completion.

This study presents vegetation maps of the upper part of the estuary of the River Kyrönjoki based on information obtained by aerial

[1)] Jarmo J. Meriläinen, Water District Office of Vaasa, National Board of Waters, P.O. Box 262, SF-65101 Vaasa 10. Present address: Institute for Environmental Research, University of Jyväskylä, Yliopistonkatu 9, SF-40100 Jyväskylä 10, Finland.

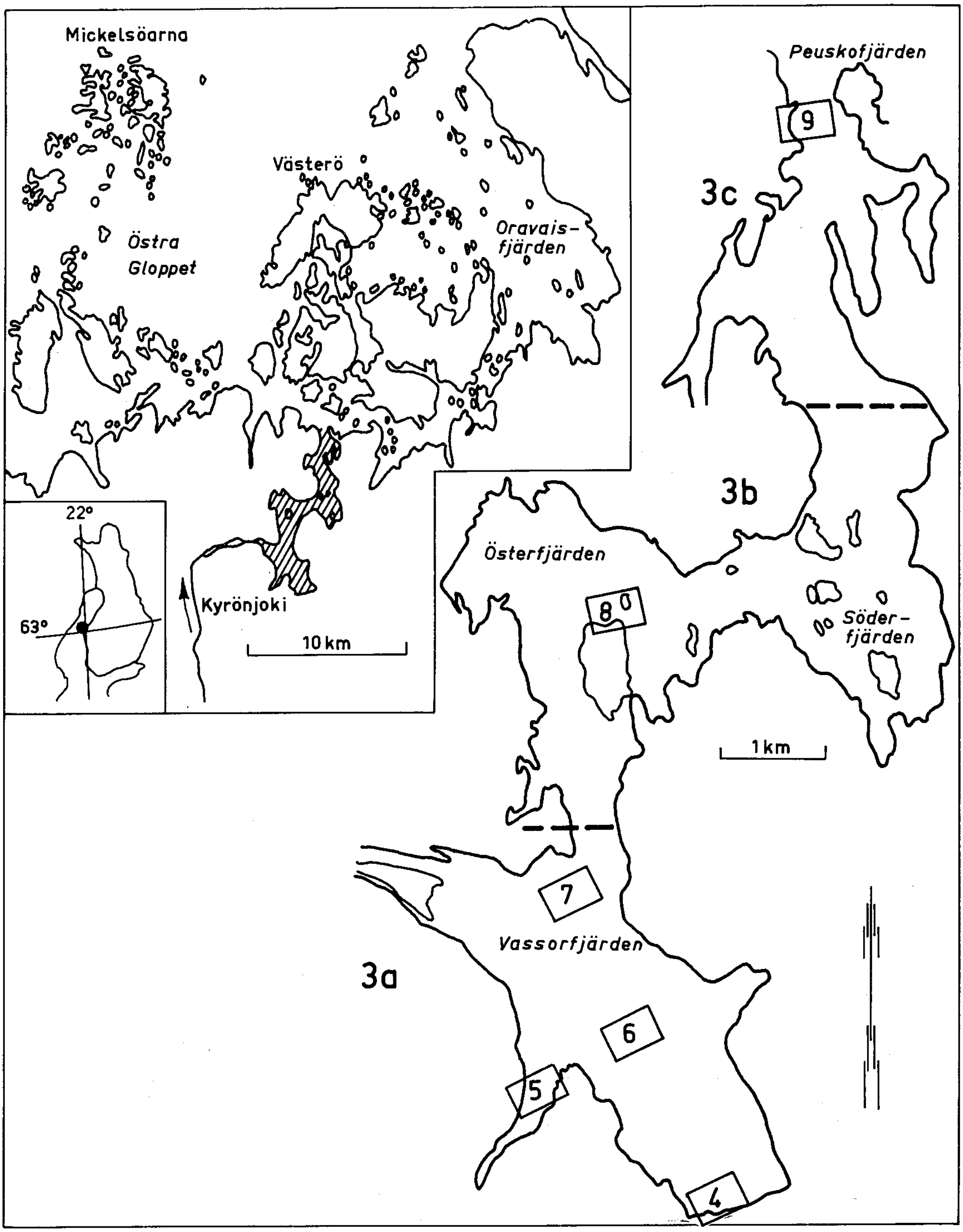

Fig. 1. The Kyrönjoki estuary and the part mapped out (magnified illustration on the right). The numbers refer to general (Fig. 3a, b, c) and more detailed maps (Fig. 4—9).

photography. The vegetation of the outer reaches of the estuarine region is also described. The plant biomass of the mapped area, about 20 km², was also estimated for the benefit of the mass balance study of the estuary. No previous information concerning vegetation in this estuary is available. Palomäki (1963) investigated the effect of the rising of land on the vegetation of the nearby archipelago. Segerstråle (1948) described the flora of small, eutrophic bay opening into the outer part of the estuary.

Vegetation of the estuaries emptying into the Gulf of Bothnia has not been extensively described, although the estuary of the River Kokemäenjoki has been mapped on two occasions (Säntti 1954, Aulio 1979). This estuary is probably the only one in the Gulf of Bothnia in which the effects of land upheaval on aquatic vegetation have been documented. A map of the small Ängerå estuary was recently published (Dahlberg 1982). Other investigations of estuarine flora in the Gulf of Bothnia have been presented by Häyren (1909), Kiimalainen (1958), Malvari (1961) and Kautsky et al. (1981). Works concentrating on shore vegetation has been presented e.g. by Siira (1970).

2. THE AREA INVESTIGATED

The River Kyrönjoki drains into the southern Bothnian Bay initially as a shallow and narrow estuary for about ten kilometres to Peuskofjärden, to the east and west of which lie the bays Kvimofjärden and Pudimofjärden, respectively (Fig. 1). The eastern fork is connected by the narrow channel to the Oravaisfjärden bay. The Pudimofjärden bay opens into the wider brackish water area Östra Gloppet which, together with the Oravaisfjärden bay, belongs to the outermost zone of the estuary (Fig. 2).

Spruce forest is the major land vegetation on the shores of the estuary. The dominant tree species at the edge of the forest is common alder. Sea buckthorn and mountain ash are also found in the outer archipelago. The mountain ash is the pioneer of tree progression in the area, being the first tree species to appear on islets rising out of the sea (Palomäki 1963).

The mean flow of the River Kyrönjoki is 43 $m^3 s^{-1}$. However, due to efficient draining and the low percentage of lakes (0.9 %) of the land coverage of the drainage basin, the variations in flow rate are very high (1—400 $m^3 s^{-1}$). The estuary is loaded by intensive agriculture practiced along the course of the river as well as by municipal effluents. During the period 1970—1972 the river carried to the estuary an annual total of 190 tons of phosphorus, 2 100 tons of nitrogen and 26 000 tons of organic carbon (Wartiovaara 1975). Since the completion of the water purification plant in Seinäjoki town in 1979 the loading of phosphorus has to some extent decreased. The nutrient-rich river water is rather well aerated and markedly browned by humus (Table 1). The lower reaches of the river and the upper estuary are affected by acidity.

The acidity originates in sulphureous Litorina clays deposited during the previous phase of the Baltic Basin (about 6000—1500 BC). Sulphuric acid is produced by oxidation of the sulphureous compounds of the soil. The very acidic (pH 3.5) runoff waters of these areas acidify the poorly buffered river water even in very low concentrations. Runoff waters from embanked cultivations are removed by pumping. Acidic water entering the southern end of the Vassorfjärden bay from the pumping station can often be seen as a completely clear, transparent zone in the otherwise dark

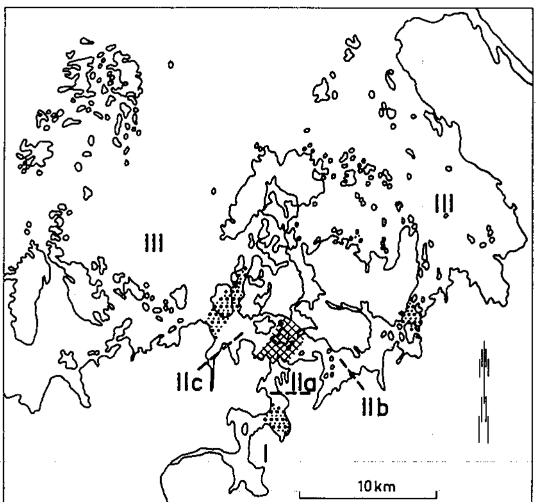

Fig. 2. The estuarine zones. 1 = the limnic, 11= the transition and 111 = the brackish water zone (Meriläinen 1984).

Table 1. Some parametres of water quality in the lower reaches of the river Kyrönjoki recorded between the years 1962—1979 (National Board of Waters, unpubl.).

	Min.	Max.	Mean	Median	Stand. dev.
Oxygen saturation (%)	66	97	84	86	8
Conductivity mS m^{-1}	7.5	37.4	15.6	14.0	5.1
Colour mg l^{-1} Pt	90	430	201	190	57
pH	4.2	7.3	..	5.5	..
Alkalinity mmol l^{-1}	0.00	0.51	0.16	0.10	0.17
Suspended solids mg l^{-1}	2	180	21	15	24
Total P $\mu g\ l^{-1}$	10	310	123	100	91
Total N $\mu g\ l^{-1}$	500	2 700	1 520	1 400	468
Ca mg l^{-1}	1.4	14.0	7.7	7.4	2.7
Mg mg l^{-1}	2.1	9.0	4.6	4.1	1.6
Mn mg l^{-1}	0.0	1.5	0.4	0.3	0.3
Fe mg l^{-1}	0.3	6.6	2.2	2.0	1.0

brown water of the bay. In the area around the river mout acidity (pH 4—5) is intermittent, lasting from several days to two weeks at a time. The acidity has considerable adverse effects on fishing in the estuary, either killing the fish or preventing their entry into the mouth area and even the outer regions of the estuary (Sevola 1978). The high metal content of the acid water (Matti Verta, personal communication) probably increases its toxicity.

The area mapped in this work belongs mainly to the limnic zone, although the outer area belongs to the transition zone (Fig. 2), in which the salinity of the surface water may occasionally reach 1.5 ‰. In the remainder of the transition zone the salinity remains below 3 and in the brackish water slightly below 4 ‰. The flow velocity in the upper estuary (the mapped area) is on average 5 cm s^{-1} and the theoretical retention time is 6 days. In the flood season, however, the water changes in less than one day. In the vegetation zone of the upper estuary the major sediment is soft mud (Meriläinen 1984). Tightly packed, minerogenic bottoms are encountered in the outermost regions of the estuary.

3. METHODS

The upper reaches of the estuary (Fig. 1), which were almost totally covered by vegetation, were photographed for mapping from a height of 900 m on colour positive film on 17.8.1983. For the general map about 200 pictures were developed to a scale of 1:5 200. With this map it was possible to identify shore vegetation, aquatic vegetation and the area covered by open water. The aquatic vegetation could further be devided into growths of common reed (Phragmites australis),, bulrush (Scirpus lacustris), water-lilies (Nymphaeaceae) and mixed vegetation (mosaics). The zones were delineated more precisely using slides (1:400—1:2 000), from which the more detailed maps were drawn.

In order to assist the interpretation of the aerial pictures, the extent and species composition of the growths were investigated in the field (26.7.—16.8.1982) to produce maps at a scale of 1:20 000. The studies were also made as analyses of line transects from the shoreline to the open water area where there were no more macrophytes. Using sampling areas of 2 x 2 m, all plants on every square were identified and the cover percentage of each taxa were estimeted. Mean water depth and sediment quality, if this information was not available on the basis of previous work (Meriläinen 1984), were also observed at each square.

In the case of the most important plant species the vegetation was investigated for growth depth, density and biomass. Growth depht was measured from the prevailing sea level (observation station at the Mickelsörarna island group) and was corrected to the mean sea level. Slanting of the water level due to the pressure of water entering the estuary was not taken into account. Densities of bulrush and reed growths were calculated for areas of 0.108 m^2 and those of water-lilies for areas of 1.0 m^2 in several locations (n=9—22). The biomass of these species (excluding those parts of the plants below the surface of the bottom) was estimated on the basis of growth density and the mean dry mass of a single stalk (drying at 80°C for at least 12 hours). The total biomass of the most important species in the whole mapped area was estimated on the basis of vegetation areas calculated from the aerial pictures and the mean biomass of the vegetation per unit area.

In addition to observations made in this work, observations made during the benthic fauna and sediment investigations of 1980 and 1981 are also available for the shore and aquatic vegetation of the outer region of the estuary, although the observations are rather sparse for the outer archipelago. Information concerning aquatic vegetation collected in conjunction with investigations of young fish populations in the estuarine area by the Finnish Game and Fisheries Research Institute was also available in this work.

4. RESULTS

Aquatic vegetation covered two thirds of the total area (17.97 km^2) in the upper reaches of the estuary. One quarter of the area was open water and shore vegetation accounted for only 6 % of the area (Table 2). In the inner areas (Figs 3 a and 3 b) the proportion of vegetation cover was considerable greater than at the end of the mapped area (Fig 3 c), where only about 50 % of the water surface was covered.

4.1 Shore vegetation

The small amount of shore vegetation in the mapped area was mainly concentrated in the southern reaches of the estuary, particularly in the Vassorfjärden bay (Fig. 3 a). Even these areas were in places so shallow that many aquatic plants, such as Phragmites australis, Eleocharis palustris and E. mamillata and Hippuris vulgaris, grew in the sedgecovered area in some considerable abundance. In drier areas the dominating plant species were grasses, particularly Deschampsia cespitosa, Calamagrostis stricta and Agrostis stolonifera. Single specimens of C. stricta were found in the sedge-covered area, slightly below the water surface, but more abundant growths (Fig. 4) were observed above the surface (+8 — +40 cm). The higher sedge growth (+5 — 15 cm) was comprised of Carex curta and C. acuta and the lower mainly of C. rostrata. C. rostrata grew mainly submerged below the water surface (-5 — -24 cm), at which depth Calla palustris was also present in some places rather abundantly and almost to the exclusion of other species (Fig. 4).

In the river mouth the sedge growth grew in association with characteristic shallow-water aquatic plants, such as Hippuris vulgaris, Polygonum amphibium, Callitriche spp., Elatine triandra, Eleocharis palustris and E. mamillata. The sedge was largely surrounded by Phragmites growing in association with Phalaris arundinacea, Calla palustris, Lysimachia vulgaris and L. thyrsiflora. Characteristic of the sedgy shores of both the Vassorfjärden bay and the river mouth were patches, of area about 0.5 m^2, totally without vegetation or supporting only the growth of Warnstorfia pseudostraminea.

In the outer part of the mapped area (Fig. 3 c) the shore vegetation was limited to a ribbon-like zone of only a few metres in width. Sedges were present only in small amounts. The shore vegetation composed mainly of Phalaris arundinacea, Agrostis stolonifera and Calamagrostis stricta, and higher up towards the edge of the forest of large herbs, e.g. Filipendula ulmaria, Lysimachia thyrsiflora, Cicuta virosa and Valeriana sambucifolia.

Only in the most outlying parts of the transition zone (Kvimofjärden and Pudimofjärden) were examples of true marine shore species observed, such as Juncus gerardii and Triglochin maritima. Festuca rubra and Calamagrostis stricta were still fairly abundant on the most sheltered shores of the Kvimofjärden bay, but their occurence was much reduced on the open shores of the Pudimofjärden bay and beyond, in the outer archipelago. In the outer archipelago the most outstanding species of shoreline vegetation were large grasses, Phalaris arundinacea and Deschampsia bottnica. Species such as Juncus gerardii, Triglochin maritima, Parnassia palustris and Agrostis stolonifera were also abundant. Leymus arenarius (L.) Hochst. was found on the barren gravelly shores of the outer archipelago.

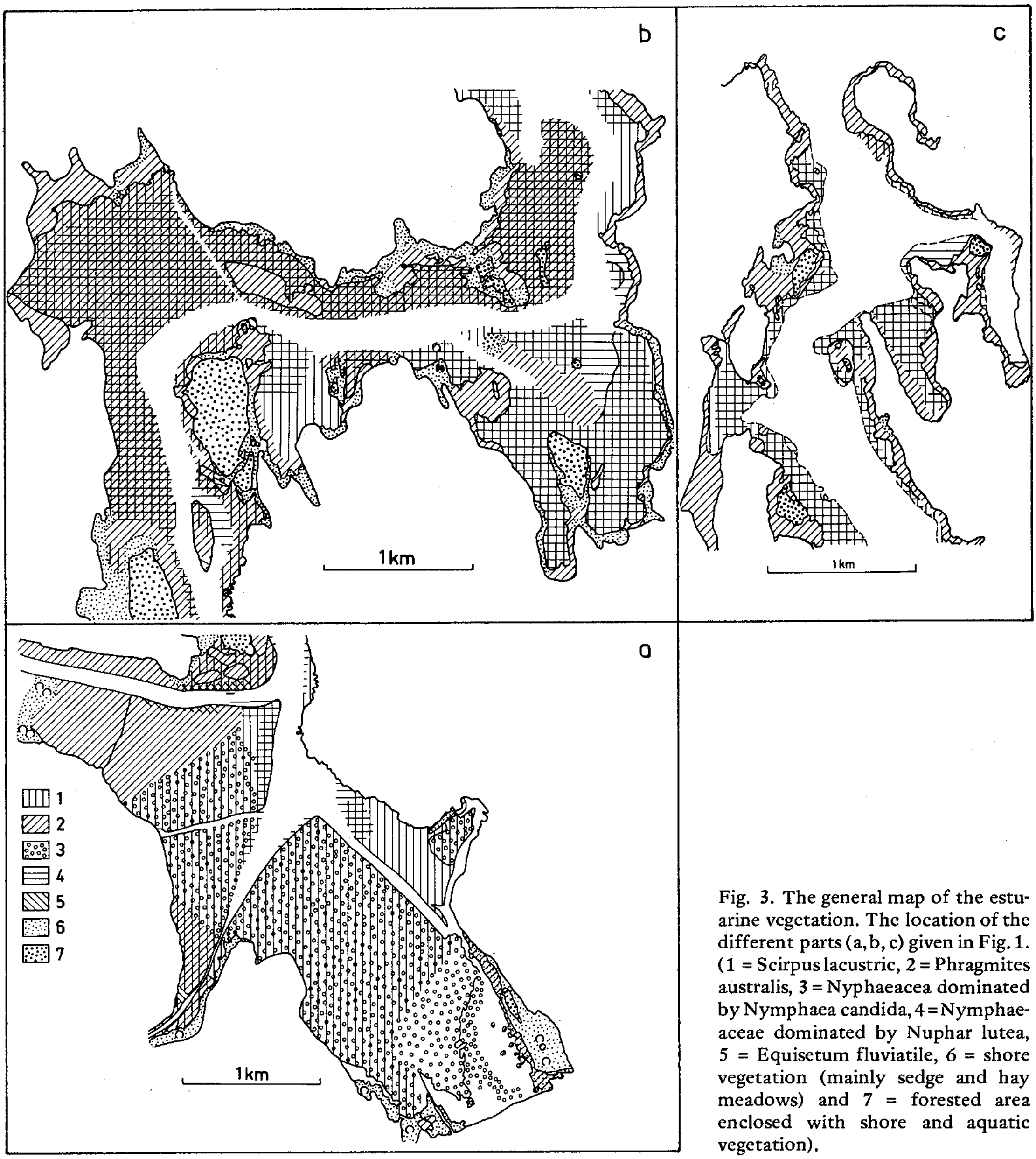

Fig. 3. The general map of the estuarine vegetation. The location of the different parts (a, b, c) given in Fig. 1. (1 = Scirpus lacustric, 2 = Phragmites australis, 3 = Nyphaeacea dominated by Nymphaea candida, 4 = Nymphaeaceae dominated by Nuphar lutea, 5 = Equisetum fluviatile, 6 = shore vegetation (mainly sedge and hay meadows) and 7 = forested area enclosed with shore and aquatic vegetation).

Table 2. Extent of different zones (km^2) in the upper estuary mapped out in Fig. 3 a, b and c.

	Area in Fig. and its percentage (%)			
	3 a	3 b	3 c	Total
Total area	6.59 (100)	7.75 (100)	3.63 (100)	17.97 (100)
Open water	1.23 (19)	1.35 (18)	1.88 (52)	4.46 (25)
Aquatic vegetation	4.87 (74)	5.74 (74)	1.72 (47)	12.33 (69)
Shore vegetation	0.49 (7)	0.66 (8)	0.03 (1)	1.88 (6)

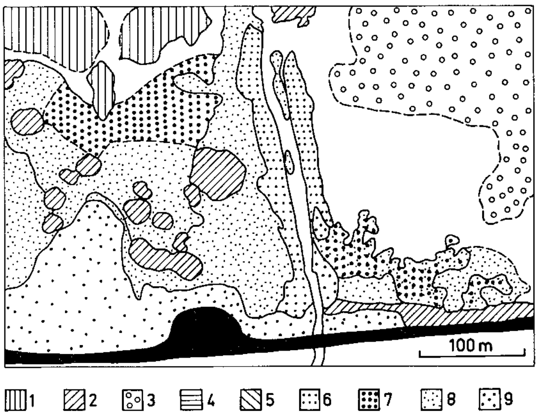

Fig. 4. Vegetation from the southern part of the limnic zone affected by very acid run-off waters (see Fig. 1). The blackened area represents the coastal road number 8. (1 = Scirpus lacustris, 2 = Phragmites australis, 3 = Nymphaea candida, 4 = Nuphar lutea, 5 = Equisetum fluviatile, 6 = Calamagrostis stricta, 7 = Calla palustris, 8 = shore vegetation (mainly sedge and hay meadows) and 9 = stand of forest).

4.2 Aquatic vegetation

4.21 Aquatic vegetation in the mapped area

Of the 22 species of aquatic vascular plants recorded in the area (Table 3) the most abundant were Phragmites australis, Scirpus lacustris, Nymphaea candida and Nuphar lutea (Fig. 3). Equisetum fluviatile (Fig. 3 a, b), Sparganium erectum, S. emersum and Drepanocladus moss were also rather common. Sparganium erectum occurred particularly in the Nymphaea-Scirpus vegetation of the Vassorfjärden bay and S. emersum as small patches throughout the area. Drepanocladus spp. thrived in the shallow waters of the Vassorfjärden, Söderfjärden and Österfjärden bays at a depth of 20—80 cm, including the very acidic areas at the southern end of the Vassorfjärden bay.

Phragmites australis comprised the uppermost zone of the aquatic vegetation. Wide, almost pure growths were observed in the upper part (Fig. 3 a) a coverage of 0.97 km^2 corresponded to about 20 % of the aquatic growth surface, while the corresponding figures for the central and lower parts of the area (Figs 3 b and 3 c) were 1.24 km^2 (20 %) and 0.86 km^2 (49 %) respectively. The largest growths extended from just above the waterline to a depth of about 0.5 m, although smaller growths were also encountered in even deeper water (Table 4). Thus, Phragmites thrived in associations with both shore- (Fig. 4) and aquatic vegetation (Fig. 5, 3 b) and also, as a mixed associations of small areas, in deeper waters (e.g. Fig. 7). The mean abundance of the growths was 166 ind. per square metre (±102 (S.D.), n=22) and the mean biomass was 1.16 kg m^{-2}.

Scirpus lacustris, along with Phragmites australis was the most abundant helophyte in the area, and thrived at greater depths than Phragmites (Table 4). In deep water (80—120 cm), Scirpus grew in circular growths (Fig. 6) but in shallower water the growth was in dense, widespread zones (Figs. 5 and 9) or in small-area mosaic growths in association with Phragmites, Nuphar lutea and Nymphaea candida (Fig. 5,7 and 8). The circular growth patches were particularly characteristic of large bays (Vassorfjärden, Österfjärden and Söderfjärden). The mean diameter of the circular growths was 18.6 m (± 10.6 m, n = 102), the greatest measured diameter being 42 m. The growth formed a kind of atoll: the outer ring of vegetation was considerably denser (395 ± 56 ind. m^{-2}, n = 8) than the central area (139 ± 78, n = 12). The biomass of the growth of mean size was 344 kg (1.26 kg m^{-2}). The Scirpus biomass of the photographed area was 1660 tons, i.e. 0.10 kg m^{-2}.

Nymphaea candida and Nuphar lutea occurred to some extent in the same areas, although Nuphar thrived at a greater depth (Table 4) and was also much more abundant in the outermost parts of the region (e.g. Figs. 8 and 9). Nymphaea was the more abundant only in the shallow upper reaches of the bays. It was particularly abundant in the Vassorfjärden bay (Fig. 6), in which a coverage of 100 % was recorded over wide areas. The density of the Nymphaea-Nuphar growths was 21 ± 13 ind. m^{-2} (n = 9) and the biomass 0.07 kg m^{-2}. Over the whole area the biomass was 499 tons, i.e. 0.03 kg m^{-2}.

The greatest recorded differences in aquatic vegetation in the mapped area were in the outer region the increase in Phragmites and the concurrent decrease in the proportion of Scirpus-Nymphaeaceae growths and the occurrence of the submergedleaved zone of Potamogeton perfoliatus, missing in the upper reaches of the surveyed area, in the last third of the region. The first P. perfoliatus growths in the Söderfjärden bay were small and isolated, but in the final part of the channel the zone was quite definitive, extending from a depth of about 0.5 m to just under 2 metres (Table 4).

Table 3. Vascular plants (excluding trees) found in the limnic (I) and transition zone (II, see Fig. 2) of the estuary. Aquatic flora according to Linkola's (1932) classification marked with an asterisk.

	I	II a	II b	II c
Isoetes lacustris L*	—	—	+	—
Equisetum arvense L.	—	—	—	+
E. fluviatile L.*	+	+	—	—
Nymphaea candida C. Presl*	+	+	+	+
Nuphar lutea (L.) Sibth. & Sm.*	+	+	+	+
Ceratophyllum demersum L.*	—	—	—	+
Caltha palustris L.	—	+	—	—
Ranunculus baudotii Gordon*	—	—	+	—
R. repens L.	—	+	—	—
R. reptans L.*	—	—	—	+
Sedum telephium L.	+	—	—	—
S. acre L.	+	—	—	—
Filipendula ulmaria (L.) Maxim.	—	+	+	+
Potentilla palustris (L.) Scop.	+	—	—	—
P. argentea L.	—	+	—	—
P. anserina spp. egedii (Wormsk.) Hiit.	—	—	—	+
Alchemilla spp.	+	—	—	—
Vicia cracca L.	—	—	—	+
Hippuris vulgaris L.*	+	—	—	—
Cicuta virosa L.	—	+	—	—
Peucedanum palustre (L.) Moench	+	—	—	—
Elatine hydropiper L.*	—	—	+	—
E. triandra Schkuhr*	+	—	—	—
Subularia aquatica L.*	—	—	—	+
Lysimachia vulgaris L.	+	—	—	—
L. thyrsiflora L.*	+	+	—	+
Polygonum amphibium L.*	+	—	—	—
Galium palustre L.	+	+	—	—
Valeriana sambucifolia Milkan fil.	—	+	—	+
Melampyrum pratense L.	—	—	—	+
Plantago major (s.lat.) L.	—	—	—	+
Utricularia vulgaris L.*	+	—	—	—
U. intermedia Hayne*	+	—	—	—
U. minor L.*	+	—	—	—
Callitriche spp.*	+	+	+	+
Bidens spp.	+	—	—	—
Cirsium spp.	—	—	+	—
Sagittaria sp.*	+	—	—	+
Alisma plantago-aquatica L.	—	—	+	—
Triglochin palustre L.	—	—	—	+
Triglochin maritima L.	—	—	+	+
Potamogeton filiformis Pers.*	—	—	—	+
P. pectinatus L.*	—	—	—	+
P. natans L.*	—	+	+	—
P. perfoliatus L.*	—	+	+	+
Juncus gerardii Loisel.	—	—	+	+
J. effusus L.	+	—	—	—
J. filiformis L.	+	—	—	—
J. spp.	+	—	—	—
Scirpus maritimus L.*	—	—	+	—
S. lacustris L.*	+	+	+	+
Eleocharis palustris (L.) Roem. & Schult.*	+	+	—	+
E. mamillata H. Lindb.*	+	+	—	—
E. acicularis (L.) Roem. & Schult. *	—	—	—	+
Carex acuta L.	+	+	+	+
C. vesicaria L.	+	—	—	—
C. rostrata Stokes	+	+	—	—
C. curta Good.	+	—	—	—
Phragmites australis (Cav.) Trin. & Steudel*	+	+	+	+
Festuca rubra (s.lat.) L.	—	—	+	+
Deschampsia cespitosa (L.) Beauv.	+	+	—	—
D. bottnica (Wahlenb.) Trin.	—	—	+	+
Calamagrostis stricta (Timm) Koeler	+	—	+	—
C. spp.	+	—	—	—
Agrostis stolonifera L.	+	+	—	+
A. capillaris L.	+	—	—	—
Phalaris arundinacea L.	+	+	+	+
Calla palustris L.	+	—	—	—
Sparganium gramineum Georgi*	+	—	—	—
S. emersum Rehman*	+	+	—	—
S. erectum L.*	+	—	—	—
Typha latifolia L.	+	+	+	—

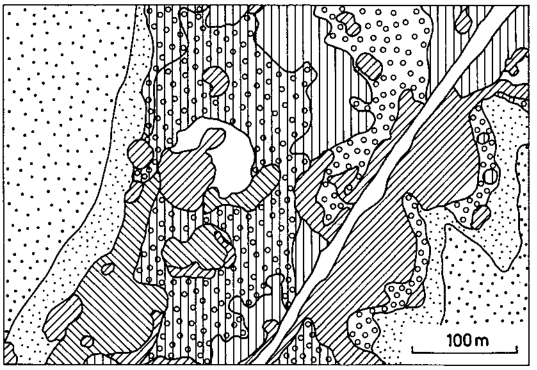

Fig. 5. Vegetation from the mouth area of a dried inlet (see Fig. 1). Symbols as in Fig. 4.

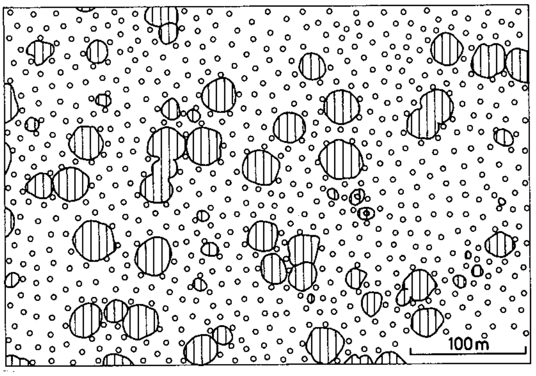

Fig. 6. A detailed map of the vast zone of Scirpus-Nymphaea in the southern bay, Vassorfjärden (see Fig. 1). Symbols as in Fig. 4.

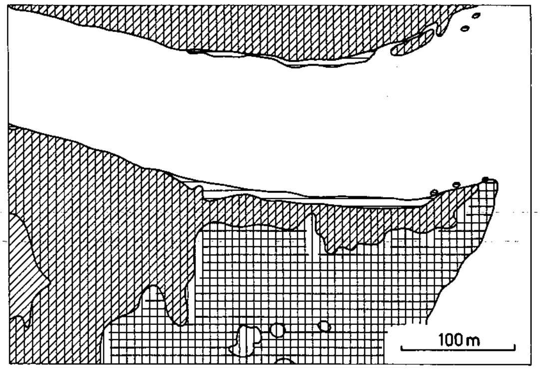

Fig. 7. Vegetation in the river mouth (see Fig. 1). Symbols as in Fig. 4.

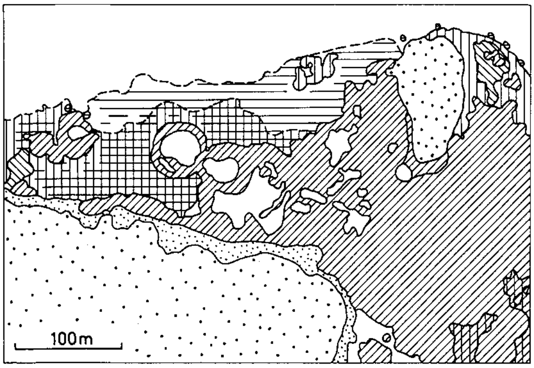

Fig. 8. Vegetation in the outer parts of the limnic zone (see Fig. 1). Symbols as in Fig. 4.

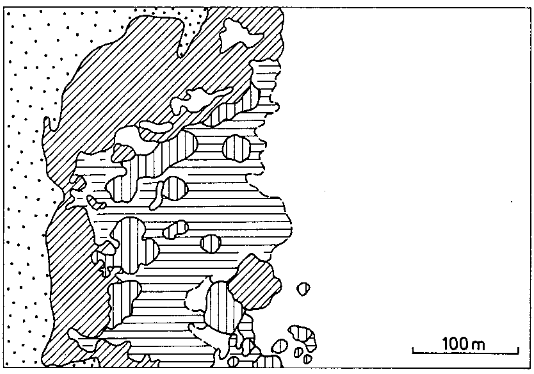

Fig. 9. Vegetation in the outer part of the mapped area in the transition zone of the estuary. Note that the submerged zone of Potamogeton perfoliatus was not drawn in the map. Symbols as in Fig. 4.

4.22 Aquatic vegetation in the outer transition zone and the brackish water zone

The changes occurring in the aquatic vegetation of the final reaches of the estuarine channel were even more extensive in the outer transition zone. Growths of Potamogeton perfoliatus became more widespread and extended to greater depths (Table 4). Scirpus beds and growths of Nuphar decreased, becoming confined to sheltered bays. Phragmites continued to comprise the uppermost, almost unbroken zone of aquatic vegetation.

Scirpus maritima was also observed in some places in the reed growths of the Kvimofjärden bay, at the eastern edge of the transition zone. Typha latifolia, which was comparatively rare throughout the estuarine channel, being present in the form of a widespread growth only at one site (Björnholmen, 70204:24745, Grid 27° E), was rather common in the Kvimofjärden bay. Isoetes lacustris was frequently recorded in the Kvimofjärden bay but was not observed at all in the Pudimofjärden bay. Many isoetids and submerged-leaved, which were not observed in the inner parts of the estuary, were found in the shallow waters near the shore of the Pudimofjärden bay both within the reed growths and also independently. Species recorded included Eleocharis acicularis, Subularia aquatica and Ranunculus reptans as generally occurring species, along with more occasional examples of Potamogeton pectinatus, P. filiformis and Ceratophyllum demersum.

Further out to sea, in the brackish water zone, the vegetation of the barren gravelly and stony beds was rather sparse. Cladopho-

Table 4. Bathymetric distribution (± cm) of the zones of the most important aquatic plants in the estuarine area. Distance from the river mouth (km) given in parentheses.

	Vassorfjärden (2)	River mouth	Nabben (10)	Kvimofjärden (15)	Pudimofjärden (15)
Phragmites australis	+10 ... —120	+10 ... —50	0 ... —115	—20 ... —95	—10 ... —140
Scirpus lacustris	—25 ... —130	—50 ... —80	—20 ... —150	—100 ... —140	—
Nuphar lutea	—20 ... —140	—30 ... —120	—30 ... —130	—35 ... —135	—40 ... —150
Nymphaea candida	—20 ... —120	—	—	—80 ... —100	—
Sparganium erectum	—90 ... —110	—50 ... —80	—	—	—
Sparganium emersum	—80 ... —100	—30 ... —50	—80 ... —100	—	—
Potamogeton perfoliatus	—	—	—50 ... —190	—40 ... —255	—30 ... —310
Isoetes lacustris	—	—	—	—50 ... —115	—
Scirpus maritimus	—	—	—	—30 ... —65	—
Eleocharis acicularis	—	—	—	—	—25 ... —80
Subularia aquatica	—	—	—	—	—60 ... —80

ra-algae were generally found on stones immediately below the water surface. Scirpus tabernaemontani C.C. Gmelin and Eleocharis uniglumis (Link) Schultes grew in fair abundance in some sheltered bays. In somewhat deeper water Potamogeton pectinatus and Ranunculus baudotii, already observed further up the estuary, were also recorded. Chara-algae extended on hard silt and sand bottoms from a depth of about 1.5 m as an unbroken growth to 3 or 4 metres. Chara-algae were also observed in small, recently isolated pools in the outer archipelago, in association with e.g. Sparganium minimum Wallr., Potamogeton obtusifolius Mert. & Koch and P. berchtoldii Fieber.

5. DISCUSSION

The shape of the estuary is determined by the topography of the coast. The rapid rising of the shoreline of the Bothnian Bay by as much as 8—9 mm a^{-1} (Flóden and Winterhalter 1981) causes continuous change in the shape of the estuary. The wide, shallow and sheltered bays and the nutrient-rich water of the river provide an inviting environment for aquatic plants, while the new, low-lying onshore land supports an abundant meadow vegetation. The shore vegetation in the estuarine area has been to some extent checked by e.g. road-building and clearing of land for agricultural cultivation. This can be seen clearly in the southern part of the Vassorfjärden bay, where cultivations are protected by a coastal road which has been banked almost to the shoreline. Since this survey the resting place in the coastal road has been enlarged and the shore vegetation of the area (Fig. 4) has been partly covered.

The vegetation at the estuary of the River Kokemäenjoki, situated about 200 km south of the estuary of the River Kyrönjoki estuary, was very similar to that described in the present work. The dominant species were Phragmites australis, Scirpus lacustris and water-lilies (Säntti 1954, Aulio 1979). However, Typha was much more abundant in the estuary of the River Kokemäenjoki. Apparently this species has colonized the estuary only in recent decades, as it was not included in the map produced by Säntti (1954), although mention was made of small amounts of Typha at the edges of Scirpus growths as well as by Häyrén (1909) already at the beginning of the century. Although the mean discharge of the River Kokemäenjoki is about five times greater than that of the River Kyrönjoki, the unbroken aquatic vegetation zone of the River Kokemäenjoki estuary is slightly less than half (about 6 km^2, according to the map prepared by Aulio) of the corresponding area of the estuary studied. The abundance of the aquatic vegetation in the upper estuary mapped in this work is well demonstrated by the amount of nutrients taken up during the growth season. For example phosphorus content of the most frequently occurring species in the area is roughly about 0.2—0.4 % of the dry mass (see e.g. Bernatowicz 1969, Puustinen and Lindqvist 1982). The total amount taken up is thus about 17 tons. This corresponds to about 10 % of the phosphorus annually entering the estuary with the river flow.

Dahlberg (1982) described very different aquatic vegetation in the river Ängerå estuary at the north end of the Bothnian Sea (63° 35' N). In this small, open estuary the Phragmites zone was totally absent. The most abundant species in the small area of aquatic vegetation were Equisetum fluviatile, Scirpus lacustris, Eleocharis palustris and E. acicularis, while in deeper waters the dominant species were Potamogeton perfoliatus and Myriophyllum alterniflorum (DC.).

Plant biomass data reported for the northern part of the Bothnian Bay are rather low. In the estuary of the River Lule älv the vegetation biomass composed of submergedleaved, isoetids and algae was 7—11.5 g m^{-2} over an estuarine area of 190 km^2. Even the highest recorded mean biomass, in the 0.5—1.0 m zone, was only 64 g m^{-2} (Kautsky et al. 1981). In the shallow, sheltered bay (Kalalahti, 65° 47' N) to the north of the estuary the biomass, consisting mainly of Subularia aquatica and Potamogeton perfoliatus, was about 30 g m^{-2} (Sjöberg and Danell 1981). The biomass estimated in the present work, 0.4 kg m^{-2} for the upper estuary, almost reaches the levels recorded in the bladderwrack zone of the Baltic Proper (0.6 kg m^{-2}) by Jansson and Kautsky (1977).

Growth and vegetation are determined by physical-chemical and biological environmental features, such as light, sediment structure, nutrients and nutrient availability. Many mutually dependent factors are also dependent on the topography of the area. It is not possible here to investigate the effects of environmental factors separately, but a few cases can be considered in more detail.

The innermost, limnic, zone of the estuary (Fig. 2) is a rather extreme environment for many animal species. This is illustrated by mass deaths of fish (Sevola 1978, 1979), the sparse nature of the benthic fauna (Meriläinen 1984) and the failure of spawning in the Vassorfjärden bay, which is in many respects an ideal environment for spawning and fry development (Hudd et al., unpubl.). The main detrimental factor is probably the acidity of the water, although high metal concentrations may also play a part.

It would appear that the acidity of the water does not have the same inhibitory effect on the total amount of aquatic vegetation, as the vegetation is very abundant even in the most acidic waters, such as those of the Vassorfjärden bay. The acidity may, however, have limited the distribution of different species occurring in the estuary.

The pH of the sediment is usually slightly higher than that of the free water. For example in lake waters made acidic by pulping effluents the mean difference may be as much as 0.8—1.2 units of pH (Eloranta 1970). As the pH of the water in the southern part of the Vassorfjärden bay is usually below 4.5 and on occasion even below 4.0, it is probable that the sediment is also too acidic for many aquatic plants. Water-lilies and common reed thrive well in relatively acidic environments. Misra (1938) reported a lower tolerance limit of 5.3 (measured from the sediment) for these species, whereas the lower limits for Potamogeton perfoliatus and Isoetes lacustris were 5.5 and 6.0, respectively. Is is possible that the zoning of vegetation in the southern part of the Vassorfjärden bay (Fig. 3 a) results from the effects of acid water entering and spreading into the southern end of the bay from the stream.

Potamogeton perfoliatus has been reported slightly to favour organically polluted waters (Kurimo 1970) but to avoid acidic waters (e.g. Renkonen 1935, Maristo 1941). The innermost boundary of the occurrence of this species was the same as that of the molluscs, which are also known to be sensitive to acidity (Meriläinen 1984). The boundary separates the strongly acidified limnic zone from the transition zone, which is diluted by water from the open sea (see Fig. 2).

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Vaasa, December 1983

Jarmo Meriläinen

LOPPUTIIVISTELMÄ

Tutkimuksessa kartoitettiin Kyrönjoen suiston yläosan laaja kasvillisuusalue. Kasvillisuuskartat perustuvat 900 m korkeudelta 17. VIII 1982 otettuihin värikuviin. Myös ulomman suiston niukempaa kasvillisuutta kuvattiin. Tutkimus on osa suiston nykytilaa selvittävistä töistä, joiden perusteella voidaan seurata suiston muuttumista ja mahdollisia laajamittaisen jokirakentamisen biologisia vaikutuksia.

Kartoitetun alueen kokonaisalasta (17.97 km^2) runsas kaksi kolmannesta oli vesikasvillisuuden peitossa, neljännes oli avointa vesialuetta, 6 % rantakasvillisuutta. Alueen tärkeimmät lajit olivat järviruoko, järvikaisla, ulpukka ja lumme. Limnisen vyöhykkeen happamuus, joka aikaisemmin on kuvattu tuhoisaksi alueen vesieläimille, ei vaikuttanut suuresti kasvillisuuteen. Mahdollisesti happamuus kuitenkin rajoitti joidenkin lajien esiintymistä, esim. ulompana suistossa laaja ahvenvitavyöhyke puuttui kokonaan limniseltä vyöhykkeeltä. Suiston yläosan kasvibiomassa, 0.4 kg kuivamassaa m^{-2} (n. 6 400 t koko alueelle), oli hyvin suuri verrattuna harvoihin Perämereltä ja sen suistoista ilmoitettuihin lukuihin.

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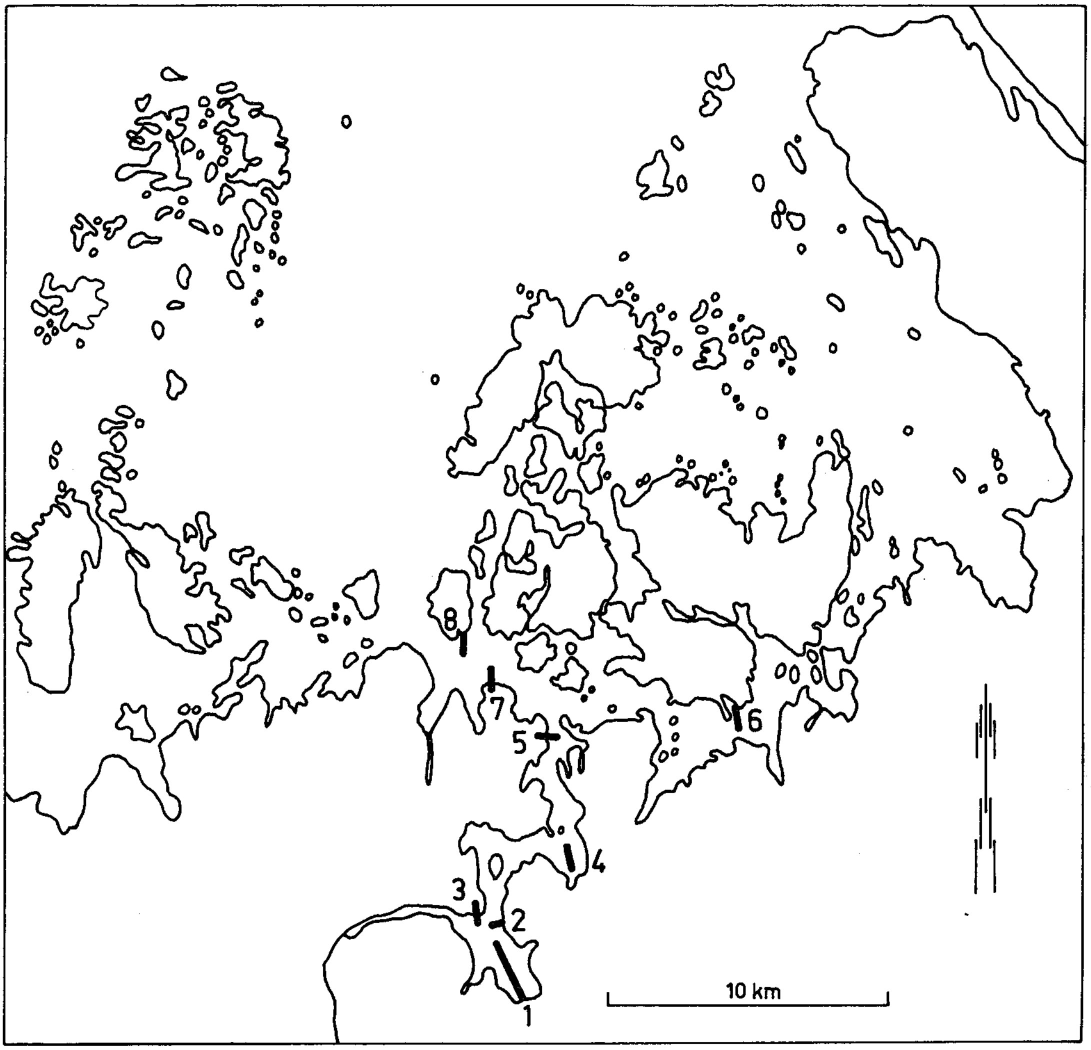
Appendix 1. Location of the macrophyte transects (1—8).



Appendix 2. Percentage cover of macrophytes on the studied squares (2x2 m) along the transects (1—8, see append. 1), mean height of each square from the sea level (± cm) and sediment type (Gr = gravel, Sa = sand, Si = silt, mSi = mixed silt, mM = mixed mud and M = mud). Coverage of dense helophyte growths given on the basis of the area (not the true projection) of the growth.

Transect 1	A	B	C	D	E	F	G	H	I	J
	+5	+5	—10	—20	—25	—25	—80	—90	—90	—100
	..	..	M	M	M	M	M	M	M	M
Carex acuta	70	+	—	—	—	—	—	—	—	—
Agrostis stolonifera	20	—	—	—	—	—	—	—	—	—
Potentilla palustris	2	—	—	—	—	—	—	—	—	—
Peucedanum palustre	+	—	—	—	—	—	—	—	—	—
Galium palustre	+	—	—	—	—	—	—	—	—	—
Juncus effusus	+	—	—	—	—	—	—	—	—	—
Phragmites australis	—	40	—	—	—	—	—	—	—	—
Deschampsia cespitosa	—	60	—	—	—	—	—	—	—	—
Carex curta	—	+	—	—	—	—	—	—	—	—
Lysimachia vulgaris	—	+	—	—	—	—	—	—	—	—
Bidens spp.	—	+	—	—	—	—	—	—	—	—
Warnstorfia pseudostraminea	—	—	30	—	—	—	—	—	—	—
Calla palustris	—	—	30	—	—	—	—	—	—	—
Sparganium erectum	—	—	+	—	—	2	—	—	—	—
Carex rostrata	—	—	10	—	—	—	—	—	—	—
Hippuris vugaris	—	—	1	—	—	—	—	—	—	—
Juncus spp.	—	—	+	—	—	—	—	—	—	—
Utricularia spp.	—	—	+	—	—	+	+	—	—	—
Eleocharis mamillata	—	—	+	—	—	—	—	—	—	—
Nymphaea candida	—	—	—	60	100	90	95	80	—	—
Drepanocladus spp.	—	—	—	1	5	+	—	—	—	—
Sparganium spp.	—	—	—	—	+	—	—	—	—	—
Scirpus lacustris	—	—	—	—	—	1	5	40	2	+
Callitriche spp.	—	—	—	—	—	+	—	—	—	—
Sparganium graminea	—	—	—	—	—	+	—	—	—	—
Nuphar lutea	—	—	—	—	—	—	—	—	40	40

Transect 2	A	B	C
	—20	—50	—100
	Gr+M	M	M
Sparganium emersum	+	+	—
Sagittaria	+	—	—
Phalaris arundinacea	+	—	—
Nuphar lutea	—	10	+

Transect 3	A	B	C	D	E
	+10	+5	+5	—5	—25
	Sa	Sa	Sa	M	M
Equisetum fluviatile	50	+	—	—	—
Phragmites australis	40	40	30	20	—
Carex rostrata	—	2	+	2	+
C. acuta	—	+	+	—	—
C. vesicaria	—	—	+	—	—
Callitriche spp.	—	—	+	+	—
Drepanocladus spp.	—	—	—	+	—
Eleocharis palustris	—	—	—	1	—
Hippuris vulgaris	—	—	—	+	—
Calla palustris	—	—	—	+	—

Lysimachia vulgaris	—	—	—	+	—
Scirpus lacustris	—	—	—	—	70
Nuphar lutea	—	—	—	—	10
Lysimachia thyrsiflora	—	—	—	+	—
Elatine triandra	—	—	—	+	+
Polygonum amphibium	—	—	—	—	+
Sparganium erectum	—	—	—	—	+
S. emersum	—	—	—	—	+

Transect 4	A 0 ..	B —30 M	C —60 Sa+M	D —70 M	E —70 M	F —110 M
Sparganium emersum	1	+	+	—	—	—
Eleocharis palustris	1	—	—	—	—	—
Callitriche spp.	+	—	—	—	—	—
Equisetum arvense	+	—	—	—	—	—
E. fluviatile	+	+	—	—	—	—
Juncus spp.	+	—	—	—	—	—
Nuphar lutea	—	20	20	2	+	50
Scirpus lacustris	—	+	40	+	—	—
Potamogeton natans	—	+	—	+	—	—
Drepanocladus spp.	—	+	30	50	+	—
Pharagmites australis	—	+	—	—	80	—

Transect 5	A +5 Gr	B 0 Sa	C —10 Sa	D —30 Si	E —60 mM	F —120 M	G —150 M
Agrostis stolonifera	50	—	—	—	—	—	—
Lysimachia thyrsiflora	15	—	—	—	—	—	—
Phalaris arundinacea	15	—	—	—	—	—	—
Phragmites australis	10	5	15	—	+	—	—
Galium palustre	3	—	—	—	—	—	—
Filipendula ulmaria	2	—	—	—	—	—	—
Galtha palustris	1	—	—	—	—	—	—
Carex acuta	+	—	—	—	—	—	—
Cicuta virosa	+	—	—	—	—	—	—
Valeriana sambucifolia	+	—	—	—	—	—	—
Potentilla argentea	+	—	—	—	—	—	—
Ranunculus repens	+	—	—	—	—	—	—
Scirpus lacustris	+	+	+	+	10	2	+
Eleocharis palustris	—	+	+	—	—	—	—
E. mamillata	—	+	—	—	—	—	—
Nuphar lutea	—	—	—	50	20	+	—
Potamogeton perfoliatus	—	—	—	+	20	20	5
Sparganium spp.	—	—	—	—	+	—	—
Sparganium emersum	—	—	—	—	+	+	—

Transect 6	A +5 ..	B —15 mSi	C —30 mSi	D —60 mM	E —80 mM	F —120 M
Festuca rubra	30	—	—	—	—	—
Calamagrostis stricta	30	—	—	—	—	—
Deschampsia bottnica	+	—	—	—	—	—
Filipendula ulmaria	+	—	—	—	—	—
Triglochin maritima	+	—	—	—	—	—

Juncus spp.	+	—	—	—	—	—
J. gerardii	+	—	—	—	—	—
Phragmites australis	—	50	50	50	1	—
Scirpus maritimus	—	20	+	+	—	—
Elatine hydropiper	—	+	—	—	—	—
Nymphaea candida	—	—	—	+	—	—
Nuphar lutea	—	—	—	+	10	+
Potamogeton perfoliatus	—	—	+	+	10	30
Isoetes lacustris	—	—	—	+	30	—

Transect 7	A	B	C	D	E	F	G	H	I
	+15	+10	0	—10	—30	—50	—90	—120	—190
	..	..	Sa	Sa	Sa+Si	Si	Si	mSi	mSi
Vicia cracca	5	—	—	—	—	—	—	—	—
Agrostis stolonifera	5	—	—	—	—	—	—	—	—
Melampyrum pratense	1	—	—	—	—	—	—	—	—
Valeriana sambucifolia	+	—	—	—	—	—	—	—	—
Triglochin maritima	+	—	—	—	—	—	—	—	—
Equisetum arvense	+	—	—	—	—	—	—	—	—
Carex acuta	—	5	—	—	—	—	—	—	—
Phragmites australis	—	5	5	—	10	10	—	—	—
Deschampsia bottnica	—	—	—	10	—	—	—	—	—
Subularia aquatica	—	—	—	—	—	+	—	—	—
Callitriche spp.	—	—	—	+	—	—	—	—	—
Eleocharis acicularis	—	—	—	—	50	10	—	—	—
Ranunculus reptans	—	—	—	—	2	—	—	—	—
Scirpus lacustris	—	—	—	—	2	+	50	+	—
Eleocharis palustris	—	—	—	+	2	—	—	—	—
Potamogeton perfoliatus	—	—	—	—	—	+	+	10	+
P. pectinatus	—	—	—	—	—	+	—	—	—
P. filiformis	—	—	—	—	—	+	—	—	—
Sagittaria sp.	—	—	—	—	—	+	—	—	—
Nuphar lutea	—	—	—	—	—	—	10	10	—

Transect 8	A	B	C	D	E	F	G	H
	+5	—5	—30	—60	—100	—100	—150	—260
	..	Sa	mSi	Si	Si	mSi	mSi	mSi
Phragmites australis	40	50	60	80	+	—	—	—
Phalaris arundinacea	10	—	—	—	—	—	—	—
Juncus gerardii	10	—	—	—	—	—	—	—
Alnus glutinosa	5	—	—	—	—	—	—	—
Deschampsia bottnica	5	—	—	—	—	—	—	—
Vicia cracca	1	—	—	—	—	—	—	—
Triglochin maritima	1	—	—	—	—	—	—	—
T. palustre	+	—	—	—	—	—	—	—
Ranunculus reptans	—	+	—	—	—	—	—	—
Eleocharis acicularis	—	+	5	+	—	—	—	—
Potamogeton perfoliatus	—	—	+	10	30	40	5	10
Subularia aquatica	—	—	—	2	—	—	—	—
Nuphar lutea	—	—	—	—	20	+	+	—