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Zonation of the macrozoobenthos in the Kyrönjoki estuary in the Bothnian Bay, Finland

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This study gives an account of the quantitative and qualitative distribution of the macrozoobenthos in the Kyrönjoki estuary, in the southern Bothnian Bay (63° 20′ N). The quantitative material, sampled with an Ekman-Birge grab, consisted of 150 samples from six different subareas including 25 sampling stations. Each station was sampled in June and August 1980. Additional samples were taken using different qualitative methods. The study is a part of a large-scale investigation on the conditions prevailing at the estuary before extensive construction work is done on the river.

Altogether 116 animal taxa (excluding water mites) were recorded, a large proportion of which were limnobionts. The differences in quantity between the months were not statistically significant, while the regional variation was significant. The innermost, limnic zone had a deteriorated fauna and low biomass (0.1 g/m^2 ODW) consisting mainly of oligochaetes, especially *Limnodrilus hoffmeisteri.* The transition zone was heterogenic and further divided into three subzones where the mean biomass was 0.3–0.8 g/m^2. *Potamothrix hammoniensis* was the most important species, though midge larvae, especially *Tanytarsus* spp., were abundant, too. Some brackish water and relict species (e.g. *Pontoporeia affinis*) inhabited the outermost and deepest parts of the zone. *Pontoporeia, Macoma baltica* and *Saduria entomon* were the most important species in the brackish water zone. The mean biomass, 2.5 g/m^2, was high compared with those reported from the northern Bothnian Bay. In addition to salinity, acidity seemed to be one of the most decisive factors leading to faunal zonation. The impact and importance of some other environmental factors on species distribution is also discussed.

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1. Introduction

In the present paper faunal zonation was established from a comprehensive quantitative and qualitative sampling of the macrozoobenthos at the Kyrönjoki estuary in the northernmost basin of the Baltic Sea, the Bothnian Bay.

Limnobionts, such as oligochaetes and midge larvae, usually reach high quantities in oligohaline waters. High abundances of midge larvae have been reported in many zoobenthic studies of the Finnish coastal waters and inlets (e.g. Segerstråle 1933, Tulkki 1960, 1964, Bagge et al. 1965, Laakso 1965, Särkkä 1969, Leppäkoski 1975). However, the composition of the midge fauna remained relatively unknown until Bagge et al. (1980) studied the insect fauna of the archipelago of Loviisa, in the Gulf of Finland. Some notes on the midge larvae are available from the Bothnian Sea (Rosenberg et al. 1975), but information on the Bothnian Bay is lacking at present.

Studies on estuarine zoobenthos, as a whole, in the Gulf of Bothnia are few. However, there is one extensively studied estuary which has just become the subject of a book (Müller 1982). In the northern basin, the Bothnian Bay, only one of the estuaries has already been biologically described (Kautsky et al. 1981). The estuary lies on the northern part of the bay. This study attempts to fill the gap in our knowledge of the southern end.

The Kyrönjoki estuary is heavily loaded with organic matter and nutrients originating from intensively cultivated fields and densely populated areas along the riverside. Between the years 1970–1972 the mean annual discharge of phosphorus, nitrogen and organic carbon was 190, 2 100 and 26 000 tons (Wartiovaara 1975). Since the start-up of the sewage purification plant of the town of Seinäjoki the phosphorus load has been somewhat lower. Acidity, occurring especially during flood periods, has been the main problem in the lower reaches and the mouth area of the river (Sevola 1978, 1979). Acidity originates in sulphureous Litorina clays deposited during the previous phase of the Baltic Basin (about 6000–1500 BC).

At present the river is being subjected to rather extensive construction activities, the purpose of which is to control floods, as well as to permit regulation for power plants. In order to examine the possible effects of the construction work on estuarine life, a large-scale investigation was started in the summer of 1980. The Finnish Game and Fisheries Research Institute is responsible for the fish and fishing studies. The transportation and deposition of organic and inorganic matter, heavy metals in sediment and water, macrovegetation and zoobenthos are being investigated by the National Board of Waters and the University of Jyväskylä. Earlier data on biological conditions in the area are not available.

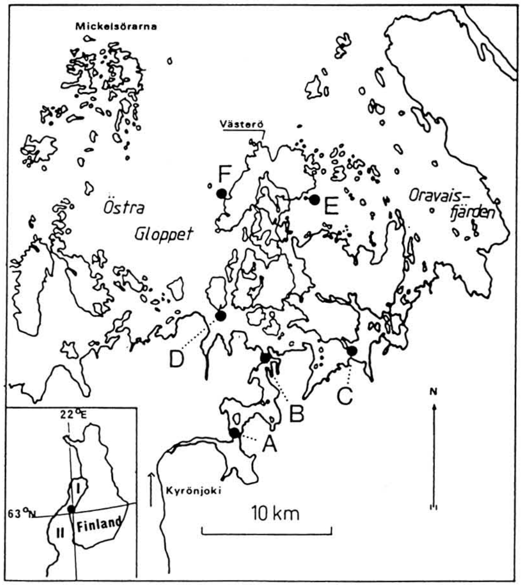

Fig. 1. The Kyrönjoki estuary and location of the quantitatively studied subareas (A–F). I = the Bothnian Bay and II = the Bothnian Sea.

2. Study area

The river Kyrönjoki, discharging into the southern part of the Bothnian Bay, has a runoff area of 4900 km^2 and a mean flow of 43 m^3/s. A shallow channel, about 3 m deep, extends from the river mouth about 10 km to the north, whence it turns to the west and east (Fig. 1). The eastern branch, Kvimofjärden, is a shallow (2–3 m), sheltered area, which is connected to the bay of Oravaisfjärden through a narrow sound. The deeper (7–10 m) western branch, Pudimofjärden, spreads out into the region of Östra Gloppet.

The water in the mouth area is rich in humus and nutrients and the oxygen concentration is fairly high throughout the year (Table 1). The lower reaches flow through the sulphureous soil developed during the Litorina Phase. Oxidized sulphate dissolves abundantly during the spring and autumn floods. These very acid flood waters reduce pH-values in the lower reaches of the river: acid conditions (pH below 5) at the river mouth may last for several days, even a week or two. Acidity causes great problems for the local fishery: e.g. in the spring of 1977 acid water killed and drove away fish from the mouth area and adversely affected fishing over some 300 km^2 in the estuary (Sevola 1978).

The estuarine currents were measured by the Vaasa District Office of the National Board of Waters (the data is partly available as mimeographs). Under the ice cover the river water spreads out from the mouth area, in a surface layer of 2–3 m, both to the east, Kvimofjärden, and to the west, Pudimofjärden, becoming thinner further away in the region of Östra Gloppet and Oravaisfjärden. In this district the Coriolis force turns currents to the north, and the river water can be observed in the surface waters near the west coast of the Island of Västerö.

In the open season, from about the second half of May to about the end of November, the mixing is stronger and the stratification is not so clear as it is under the ice. During the summer months when the river flow is at its minimum (NQ = 1 m^3/s) turbid river water is discernible in Kvimofjärden and in the surface waters in Pudimofjärden (Table 2). The main current, especially during floods, is directed through the deep Pudimofjärden to the region of Östra Gloppet. Estuarine currents are also influenced by the fluctuation of the sea level (-50 ... +100 cm). In this non-tidal estuary fluctuation is caused by changes in atmospheric pressure and winds. During the sea level rise, the brackish water thrusts into the estuary.

On hydrographical grounds three zones can be distinguished in the estuary (Fig. 2). I. The limnic zone or the river water zone; II the transition or β-oligohaline zone where the river water is always visible in the surface layer; and III the brackish water or α-oligohaline zone where the river water is visible only occasionally in the inner parts at the time of the ice cover and floods.

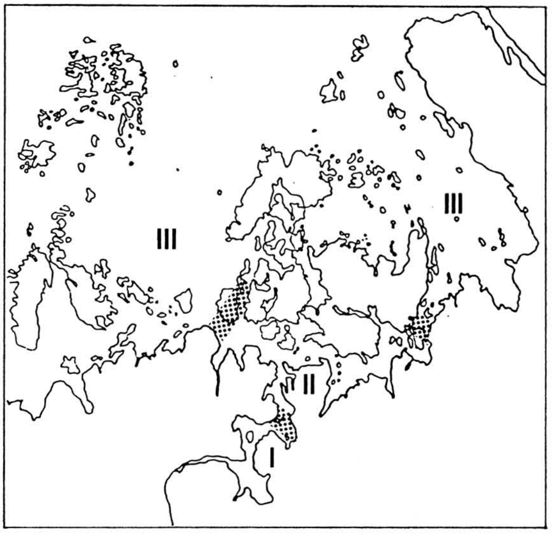

Fig. 2. The three estuarine zones, I. the limnic, II. the transition and III. the brackish water zone.

3. Material and methods

The quantitative sampling sites, subareas A–F (Fig. 1), were chosen on the basis of knowledge of the estuarine currents and water mixing, so that they would be representative of different parts of the estuary. However, hard beds with gravel and stones, which were common in outer parts of the estuary, especially in the archipelago of Mickelsörarna, could be sampled only by qualitative methods.

The quantitative samples were taken with an Ekman-Birge grab in June (4–17.VI) and August (19–26.VIII) 1980. Each sample consisted of two hauls of the grab, which has an area of 270 cm^2. Three samples were taken from each station on each occasion, the total number of samples being 150 and the corresponding area 8.1 m^2 (Table 3). The samples were sieved through a sieve of 0.6 mm mesh and the sieving residue was preserved in a buffered (Hexamine) 4 % formaldehyde solution. Although the use of a sieve of 1.0 mm is recommended for Baltic macrofauna (Dybern et al. 1976), the smaller mesh size is used for special purposes in macrozoobenthic studies, as, for example, at estuaries in the Gulf of Bothnia, where the bottom fauna is composed mainly of small animals like oligochaetes and midge larvae (cf. Särkkä 1969, Rosenberg et al. 1975).

The qualitative material was collected from 28 localities in August 1980 and June 1981 (Fig. 3). In shallow areas to a depth of about 2 m, samples were taken with a handnet, which has a triangular aluminium frame, each side of which is 25 cm long, and a bag 60 cm in depth. Deeper areas were

Table 1. Some parameters of water quality recorded at the river mouth (A in Fig. 1, minimum and maximum values for depths 1–3 m, 8.I–20.XI 1980), at the mouth of the channel (B, values for depths 1 and 5–6 m, 8.I–6.VIII 1980) according to the Vaasa District Office of the National Board of Waters and in the brackish water area (mean values for surface and near bottom waters), according to Sevola (1978).

	River mouth (A)			Mouth of channel (B)					Brackish water	
		1–3 m			1 m		5–6 m		surface	bottom
	N	min	max	N	min	max	min	max	mean	mean
O_2 saturation %	19	70	89	8	75	90	66	90	-	-
Suspended solids mg/l	19	5	94	9	5	53	1	6	-	-
Conductivity (25° C) mS/m	20	14	27	10	21	330	520	680	700	700
pH	21	4.6	6.4	10	4.8	7.1	6.8	7.2	-	-
Colour mg Pt/l	21	90	280	10	85	230	20	70	10	10
Total N µg/l	17	1500	2700	7	740	2200	150	630	200	110
Total P µg/l	17	50	210	7	19	85	12	27	13	11
Total Fe µg/l	19	1200	4300	9	420	2400	90	320	-	-

Table 2. Salinity (o/oo) and colour (mg Pt/l) of surface and near bottom water in different parts of the estuary (A–F, the Mickelsörarna archipelago and the Oravaisfjärden bay in Fig. 1) in July (2.VII.1980) according to the Vaasa District Office of the National Board of Waters.

	A		B		C		D		E		F		Mickelsörarna		Oravaisfjärden	
	1 m	3 m	1 m	5 m	1 m	3 m	1 m	10 m	1 m	10 m	1 m	20 m	1 m	15 m	1 m	15 m
Salinity	0.06	0.07	1.15	2.80	1.80	1.80	2.70	3.50	3.35	3.45	3.50	3.85	3.55	3.40	3.40	3.75
Colour	280	240	140	60	50	40	60	25	20	25	20	20	20	20	20	20

Table 3. Geographic location of the subareas (A-F) sampled quantitatively. Range of sampling depths, number of samples and area sampled (m^2) in each site.

Subarea	Coordinates (Grid 27° E)	Depth range	Number of samples	Area sampled
A	70204:2470	1-3	18	0.972
B	70256:2500	1-5	24	1.296
C	70260:2570	1-3	18	0.972
D	70300:2470	1-10	30	1.620
E	70380:2544	1-10	30	1.620
F	70384:2484	1-20	30	1.620
Total			150	8.100

sampled with a modified Ockelman sledge and a so-called triangular dredge, these being trailed slowly by a motorboat. The samples were sieved through sieves of 0.6 and 1.0 mm mesh. The latter apparatus was used for deep water samples.

All the water mites were not identified in this study, although they were caught abundantly by qualitative methods. Some of the insect larvae were identified only as far as their genera. The notation "type", which here is frequently used for larvae, means either that the imago of the particular larva is not known, or the type comprises two or more species which are not identifiable in the larval stage. The midge larvae were identified mainly on the basis of Chernovskii's (1949) and Moller Pillot's (1979) guides. The nomenclature of the Diptera is according to Hackman (1980) and that of the other species according to Limnofauna Europaea (Illies 1978).

Biomass was given as organic dry weight (ODW). The biomass values were obtained from length-weight relationships. The animals were dried at 70° C for about twenty-four hours, this being doubled for larger molluscs. The ODW was determined after the animals had been incinerated in a muffle oven at 500° C for 3 hours. The biomasses of *Caenis horaria*, caddis flies and midges were obtained from the Pääjärvi Project (Paasivirta, unpubl.) Numerous factors may bias the biomass estimates, e.g. both the length measurements made on the animals (especially oligochaetes), and the fact that biomass variations due to the reproductive cycle of hololimnic animals are not taken into consideration, can lead to errors in determination. Other sources of error have been discussed in detail by Lappalainen & Kangas (1975).

In order to classify estuarine sediments, the organic matter (ignition loss of dry matter) and water content, as well as the mean particle size of the inorganic fraction, were measured from the uppermost 5 cm of the sediment. One sample per station was taken in June with a Kajak-Hakala one-core sampler (Hakala 1971) of area 15 cm^2. The frozen sample was dried and incinerated as recommended by Dybern et al. (1976).

For particle size measurements the dried sample was sieved on a sieve shaker (Oy Santasalo, Helsinki, Finland) which moves the sieve set in a horizontal, elliptical manner. A set of eight steel wire square mesh sieves (0.040, 0.075, 0.125, 0.250, 0.5, 1.0, 2.0 and 4.0 mm) was used to separate the different fractions. The standard sieving time was 15 minutes, after which the content of each sieve was weighed to the nearest 0.1 g. A cumulative distribution curve of particle size was drawn for each sample. The point where the curve exeeded the 50 % limit determined the mean particle size of the sample. The fractions were named according to the Wenthworth classification (e.g. Green 1968).

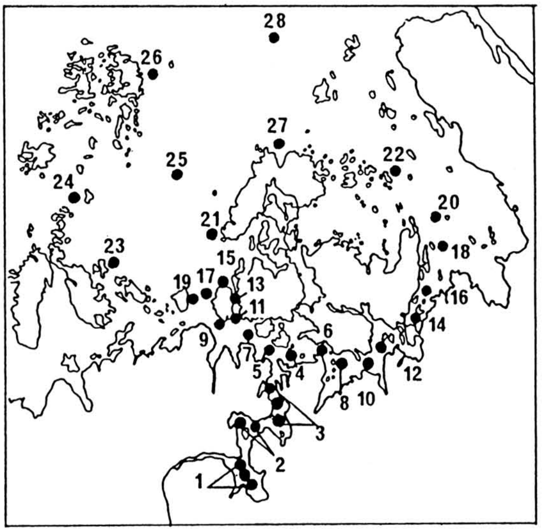

Fig. 3. Location of the stations sampled by qualitative methods.

Because there is no generally accepted practice of classifying sediments on the basis of the parameters measured, the following procedure was used. Organogenic sediments (organic content >5 %) were divided into two parts: mixed mud and mud (organic content 5-10 % and >10, respectively). Minerogenic sediments (organic content <5 %) were classified according to their organic content (as mixed, when the organic content was 2-5 %) and the Wenthworth classification. Finally, the sediment was loosely packed ("loose") or tightly packed ("packed") when the water content was ≥70 % or ≤30 %, respectively.

Statistical analyses were performed with the SPSS system for the UNIVAC 1100 computer at the Computing Centre of the University of Jyväskylä.

4. Results

4.1. Sediment

The sediment was aerobic at every station of the estuary, and the odour of H_2S was not detected. The sediment was organogenic in subareas A, B and C, being mainly loose mud or loose mixed mud, while minerogenic sediments prevailed in the outer parts (Table 4).

The erosion caused by the river flow during floods was clearly visible at depths of 2 and 3 m at the river mouth (St. A2, A3). The brown mud layer above the blackish blue sulphidic clay was thin (1-3 cm) and the organic content low compared with the corresponding properties at 1 m (A1), where the currents are suppressed. Eroded bottoms in other subareas were caused by wave action and confined to the upper littoral zones. Bare rocks and stony beds were common even in the deep water area (about 20 m) of the outer archipelago, especially in the eastern and southern parts of the Mickelsörarna Islands.

Table 4. Organic matter and water (%) content and mean particle size (μm) of the uppermost five centimetres of the sediment and sediment type at the stations of the estuary studied. The particle size of organogenic sediments is given in parenthesis since the method used is applicable to the minerogenic fraction. The number in the station codes indicates the depth.

Station	Organic content	Water content	Particle size	Sediment type
A1	23.9	85	(75)	loose mud
A2	9.7	86	(125)	loose mixed mud
A3	6.5	70	(125)	loose mixed mud
B1	7.9	70	(250)	loose mixed mud
B2	14.4	86	(125)	loose mud
B3	30.6	95	(125)	loose mud
B5	23.1	95	(40)	loose mud
C1	5.8	59	(40)	mixed mud
C2	15.0	85	(75)	loose mud
C3	21.6	90	(125)	loose mud
D1	1.2	34	40	silt
D2	2.4	43	40	mixed silt
D3	3.1	58	40	mixed silt
D5	10.0	74	(40)	loose mud
D10	13.3	81	(40)	loose mud
E1	0.3	24	125	packed fine sand
E2	1.0	30	75	packed very fine sand
E3	0.8	29	75	packed very fine sand
E5	3.5	59	40	mixed silt
E10	10.6	82	(40)	loose mud
F1	0.4	22	250	packed medium sand
F2	0.4	22	125	packed fine sand
F3	0.1	21	125	packed fine sand
F5	1.2	30	125	packed fine sand
F20	5.7	70	(75)	loose mixed mud

4.2. Fauna

Species composition

Altogether 116 macrozoobenthos taxa were recorded (Table 5). The figure excludes water mites (Hydrachnellae), which were caught abundantly by qualitative methods, especially from shallow localities in the transition and brackish water zone. Only one species, *Limnochares aquatica* (L.), was found in the limnic zone, while the total number of water mite species found at the estuary is about 20 (Bagge & Meriläinen, unpubl.). In addition to those in Table 5, *Anodonta* (Lamellibranchiata, Unionidae) was reported from Pudimofjärden in the transition zone (Hudd, pers. comm.).

In the study area there occured 13 species which have been reported as living in Finland only in brackish water viz. *Prostoma obscurum, Theodoxus fluviatilis, Potamopyrgus jenkinsi, Macoma baltica, Paranais litoralis, Nais elinguis, Mysis mixta, Neomysis integer, Saduria* (= *Mesidotea*) *entomon, Jaera praehirsuta, Corophium volutator, Gammarus salinus* and *G. zaddachi. Prostoma* (three specimens) was found only at St. 22 (Fig. 3) at depths of 30-60 m. Only one specimen of *Mysis mixta* was found, this being at St. 28 at a depth of about 40 m, also on a soft bottom. *Jaera praehirsuta* was fairly common on stony beds at St. 23 and 24 at depths of 2-5 m. *Theodoxus fluviatilis* was abundant on stony littoral areas (1-5 m) in the outer archipelago; the innermost findings were from St. 15 and 22. The horizontal distribution of *Macoma* and *Potamopyrgus* was the same (Fig. 4), both being absent from the transition zone. The distribution of the two relics, *M. relicta* and *Pontoporeia*, was in accordance with that of *Neomysis* and *Saduria.* These also all occured in the deeper parts of the transition zone.

Gammarus spp. and *Corophium* were also living in the transition zone (Pudimofjärden). Of the identified (mature) *Gammarus* specimens only two were *G. salinus*; both were found in subarea F. The relict crustacean, *Pallasea quadrispinosa*, was recorded in August at St. E2 and E3 (about 30 ind./m^2).

The limnic element consisted of 100 taxa, only 35 of which were found in the limnic zone. It is also noteworthy that many groups, such as molluscs, leeches, mayflies and bottom-living beetles, were totally absent from this zone. In addition to this, there was another sparsely populated area: the small-sized basin in the transition zone, St. B5. *Chaoborus flavicans* larvae, together with some chironomid larvae, were the only inhabitants at this station.

Table 5. Macrozoobenthos taxa found in the zones illustrated in Fig. 2 (I = the limnic, II = transition and III = brackish water zone). Taxa marked with an asterisk were found only in qualitative samples.

	I	II	III
Nemertinea			
Prostoma obscurum (Schultze) *	-	-	+
Mollusca			
Theodoxus fluviatilis L. *	-	-	+
Valvata pulchella Studer *	-	+	-
V. piscinalis Müller	-	+	+
Potamopyrgus jenkinsi Smith	-	-	+
Bithynia tentaculata L.	-	+	+
Lymnaea peregra Müller	-	+	+
Gyraulus albus Müller *	-	+	+
Pisidium casertanum Poli	-	+	-
P. spp. *	-	+	-
Macoma baltica (L.)	-	-	+
Oligochaeta			
Stylodrilus heringianus Clap.	+	-	-
Limnodrilus claparedeanus Rat. *	+	-	-
L. hoffmeisteri Clap.	+	+	+
L. profundicola (Verr.)	-	+	+
L. udekemianus Clap.	+	-	-
Peloscolex ferox (Eisen)	+	-	-
Potamothrix hammoniensis (Mich.)	-	+	+
Psammoryctides barbatus (Grube)	+	+	+
Paranais litoralis (Müller)	-	+	+
Uncinais uncinata (Oerst.)	-	+	-
Nais communis Pig.	-	+	-
N. elinguis Müll.	-	+	+
N. simplex Pig.	-	+	-
Stylaria lacustris L.	-	+	-
Enchytraeidae	-	-	+
Hirudinea			
Glossiphonia complanata (L.)	-	+	-
Helobdella stagnalis (L.) *	-	+	-
Acari			
Hydrachnellae	+	+	+
Crustacea			
Mysis mixta Lilljeborg *	-	-	+
M. relicta Lovén	-	+	+
Neomysis integer (Leach)	-	+	+
Asellus aquaticus L.	+	+	+
Saduria entomon (L.)	-	+	+
Jaera praehirsuta Forsman *	-	-	+
Corophium volutator (Pallas)	-	+	+
Gammarus salinus Spooner	-	-	+
G. zaddachi Sexton	-	+	+
Pallasea quadrispinosa Sars	-	-	+
Pontoporeia affinis Lindstr.	-	+	+
Ephemeroptera			
Cloeon simile Etn. *	-	-	+
Caenis horaria L.	-	+	+
Odonata			
Coenagrion hastulatum (Charp.) *	+	+	-
Coleoptera			
Haliplus sp.	-	-	+
Hydrophilidae	-	+	-
Megaloptera			
Sialis sordida Klingst.	+	+	-
Trichoptera			
Neureclipsis bimaculata L. *	+	+	-
Polycentropus flavomaculatus Pictet *	-	-	+
Holocentropus dubius Rbr. *	+	-	-
H. picicornis Steph. *	+	-	-
Cyrnus flavidus McL.	+	+	-
C. trimaculatus Curtis *	-	+	+
Tinodes waeneri L. *	-	-	+
Agrypnia obsoleta Hagen *	+	-	-
A. picta Kol. *	-	-	+
A. varia Fabr. *	+	-	-
Phryganea bipunctata Retz.	+	+	+
P. grandis L.	+	-	+
Limnephilus spp. *	-	+	+
Athripsodes spp.	-	+	+
Ceraclea annulicornis Steph. *	-	-	+
Mystacides spp.	+	+	+
Oecetis lacustris Pictet	-	+	+
O. ochracea Curtis	-	+	+
Molanna albicans Zett. *	-	+	-
M. angustata Curtis	-	+	+
Lepidoptera			
Nymphula nymphaeata L.	-	+	-
Diptera			
Chaoborus flavicans (Meig.) *	-	+	-
Ablabesmyia longistyla Fittkau	+	+	-
A. monilis type	+	+	+
Clinotanypus nervosus (Meig.)	+	-	-
Macropelopia sp.	-	+	-
Procladius spp.	+	+	+
Thienemannimyia group	+	-	-
Potthastia gaedii (Meig.)	-	-	+
P. longimanus K. *	-	+	-
Corynoneura scutellata type	-	+	-
Cricotopus spp.	-	-	+
Nanocladius sp.	-	+	+
Orthocladius consobrinus (Holmgren)	-	-	+
O. thienemanni type	-	-	+
Parakiefferiella smolandica (Br.)	-	+	+
Psectrocladius psilopterus type	-	+	+
P. medius type	-	+	+
Chironomus plumosus type	+	+	+
C. thummi type	+	+	+
Cladopelma viridula (L.)	+	+	+
Cryptochironomus sp.	+	+	+
Demicryptochironomus vulneratus (Zett.)	+	+	+
Endochironomus albipennis (Meig.)	-	+	+
E. tendens (Fabr.) *	+	+	-
Glyptotendipes spp.	+	-	-
Limnochironomus nervosus (Staeg.)	-	+	+
L. pulsus (Walk.)	-	+	+
Harnischia curtilamellata (Malloch)	-	+	-
Microchironomus tener (K.)	-	+	-
Microtendipes spp.	-	+	+
Pagastiella orophila (Edw.)	-	+	-
Parachironomus spp. *	+	+	+
Paracladopelma camptolabis type	-	+	+
Paralauterborniella nigrohalteralis (Malloch)	-	+	-
Paratendipes sp. *	-	-	+
Phaenopsectra (Sergentia) sp. *	+	-	-
Polypedilum scalaenum type *	-	+	+
P. nubeculosum (Meig.)	-	+	+
P. pullum (Zett.)	+	+	+
Stenochironomus sp.	-	+	-
Stictochironomus sp.	-	+	+
Pseudochironomus prasinatus (Staeg.)	-	+	-
Cladotanytarsus spp.	-	+	+
Paratanytarsus spp.	-	-	+
Stempellina subglabripennis (Br.)	-	+	-
Stempellinella minor (Edw.)	-	+	+
Tanytarsus spp.	+	+	+
Ceratopogonidae	+	+	+
Brachycera	-	+	+
Bryozoa			
Paludicella articulata (Ehrenberg) *	-	-	+

Quantity

The differences in the total quantity of both biomass and abundance were not significant between the months, while the regional variation between the subareas was significant ($P \leq 0.001$, one-way ANOVA). In the following examination the subareas are described separately. All the cases of significance quoted below are based on the one-way analysis of variance unless otherwise stated.

Subarea A. The mean biomass was only 0.12 g/m^2. In contrast to the abundance (Table 6), the differences in biomass were not significant between the months, but in the bathymetric distribution they were significant ($P \leq 0.05$). The mean biomass at a depth of 3 m was 0.21 g/m^2, while it was only 0.08 g at 1-2 m.

Oligochaetes accounted for about 70 % of the total biomass. *Limnodrilus hoffmeisteri* was the most important species in the subarea. Its biomass (including immature specimens of *Limnodrilus*) comprised more than half (59 %) of the total biomass, and it was fairly evenly distributed between different depths (Fig. 5a). It is noteworthy that *Potamothrix hammoniensis*, one of the most numerous species at the estuary, was totally absent from this subarea. Of the midge larvae, only *Procladius* spp. were abundant, especially in August.

Subarea B. The total biomass (0.27 g/m^2) was more than double that of subarea A. The biomass varied between 0.29-0.44 g/m^2 at depths of 1-3 m, but at 5 m was only 0.03 g/m^2. The biomass had a high proportion of oligochaetes (80 %). The most important species, *Potamothrix hammoniensis*, accounted for about half of the total biomass (Table 7).

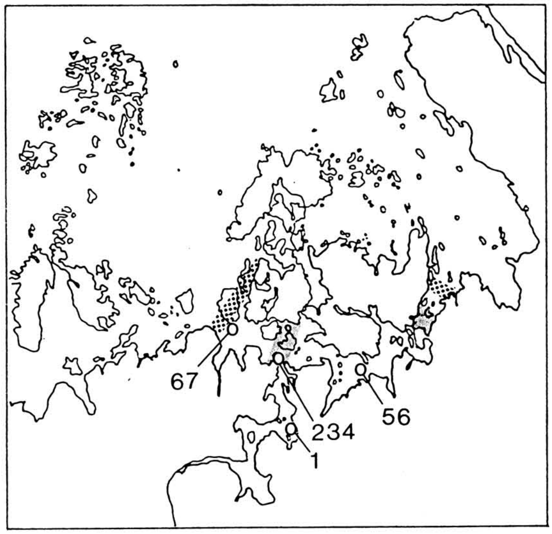

Fig. 4. The innermost limits of the distribution of *Macoma baltica* and *Potamopyrgus jenkinsi* (dotted area), *Saduria entomon, Mysis relicta, Neomysis integer* and *Pontoporeia affinis* (shaded area). The innermost findings of the freshwater molluscs (1 = *Pisidium casertanum*, 2 = *Bithynia tentaculata*, 3 = *Gyraulus albus*, 4 = *Lymnaea peregra*, 5 = *Valvata pulchella*, 6 = *V. piscinalis* and 7 = *Pisidium* spp.).

Limnodrilus (all mature specimens were *L. hoffmeisteri*) was most abundant at 1 m, while *Potamothrix* was living deeper, at 2-3 m (Fig. 5b). The sparse fauna at a depth of 5 m consisted of some chironomid larvae (*Procladius* spp., *Chironomus plumosus* type, *Cryptochironomus* sp. and

Table 6. Abundance (individuals/m^2, mean and confidence limits of 95 %), bathymetric distribution (range of occurrence, the depth of the maximum abundance and significance of differences in bathymetric distribution), the month of the maximum abundance (June or August) and biomass (ODW mg/m^2, mean and confidence limits of 95 %) for the most important taxa (≥ 10 individuals/m^2) in subarea A. (One-way ANOVA, significances: * = $P \geq 0.05$, ** = $P \geq 0.01$ and *** = $P \geq 0.001$.)

	Abundance		Bathymetric distribution			Monthly	Biomass	
	mean	conf.lim.	range	max	signif.	maximum	mean	conf.lim.
Limnodrilus hoffmeisteri	92	52-131	1-3	3	*	(VI)	69	35-103
L. (immature)	14	1-28	1-3	2	-	VIII*		
Peloscolex ferox	21	4-37	1-3	3	**	(VI)	5	0-10
Psammoryctides barbatus	10	1-16	3	3	-	(VIII)	5	0-12
Procladius spp.	207	117-297	1-3	3	-	VIII***	18	12-24
Chironomus plumosus t.	13	0-29	1	1	*	(VIII)	<1	••
Tanytarsus spp.	16	0-35	1-3	1	-	VIII*	<1	••
Total	399	268-531	1-3	3	-	VIII***	117	67-168

Table. 7. Subarea B as in Table 6.

	Abundance		Bathymetric distribution			Monthly	Biomass	
	mean	conf.lim.	range	max	signif.	maximum	mean	conf.lim.
Limnodrilus hoffmeisteri	80	11-150	1-2	1	***	(VI)	} 89	9-170
L. (immature)	22	0-44	1	1	***	(VI)		
Potamothrix hammoniensis	403	170-635	1-3	3	**	(VI)	132	50-214
Procladius spp.	99	72-125	1-5	3	-	VI**	24	14-33
Chironomus plumosus t.	17	5-29	2-5	3-5	-	VIII*	6	1-11
Cryptochironomus sp.	32	15-49	1-5	1	**	(VI)	21	4-37
Tanytarsus spp.	22	4-40	1-5	2	-	VIII**	<1	••
Total	706	469-943	1-5	3	*	(VI)	271	161-382

Tanytarsus sp.) and larvae of semipelagic *Chaoborus flavicans*.

Subarea C. Though the number of individuals in the subarea was higher, the total biomass (0.29 g/m^2, Table 8) was nearly equal to that of subarea B. Neither the differences in biomass between the depths, nor those between the months, were significant. There was a marked difference in the community structure compared to the previous subareas. The proportion of oligochaetes in the biomass (*Limnodrilus* and *Potamothrix*) was only 23 %, while the main proportion consisted of midge larvae. The bathymetric distribution curves of *Potamothrix* and *Limnodrilus hoffmeisteri* (Fig. 5c) were similar to those of subarea B.

The four midge larvae (*Tanytarsus* spp., *Procladius* spp., *Endochironomus albipennis* and *Cryptochironomus*) accounted for more than half (56 %) of the total biomass. *Tanytarsus* spp., which were particularly abundant in August (mean 2230 ind/m^2), included *T. bathophilus, lestagei* and *occultus* types identified in the pupal stage.

Subarea D. The total biomass (0.83 g/m^2) was nearly three times higher than in subareas B and C. The bathymetric variation in biomass was not significant. In August the biomass was significantly ($P \leq 0.05$) higher (0.93 g/m^2) than in June (0.71 g/m^2). The proportion of oligochaetes in the biomass was high, being about half of the total, and the most important species, as in subarea B, was *Potamothrix hammoniensis*.

Pontoporeia affinis occured throughout the entire depth range, but had its highest density in deeper waters. At depths of 5-10 m its biomass (0.30-0.41 g/m^2) accounted for about 50 %, and together with *Potamothrix*, nearly 100 %, of the total biomass.

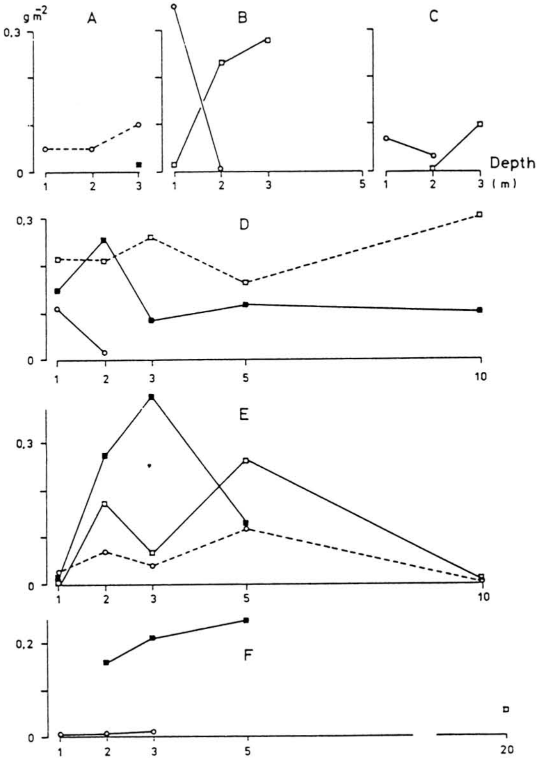

Fig. 5. The bathymetric distribution of *Potamothrix hammoniensis* (open squares), *Psammoryctides barbatus* (black squares) and *Limnodrilus* (circles) in different subareas of the estuary (A-F). *Limnodrilus* was mainly *L. hoffmeisteri* in the innermost parts (A-D) and *L. profundicola* in the outermost parts (E-F, see also text). The dashed line indicates that the differences in biomass between the depths were not significant (one-way ANOVA).

Table 8. Subarea C as in Table 6.

	Abundance		Bathymetric distribution			Monthly	Biomass	
	mean	conf.lim.	range	max	signif.	maximum	mean	conf.lim.
Pisidium casertanum	48	13-84	1-3	1	*	VIII*	6	3-16
Limnodrilus hoffmeisteri	39	15-63	1-2	1	**	(VI)	34	15-52
L. (immature)	11	0-29	1	1	-	(VI)		
Potamothrix hammoniensis	61	3-120	2-3	3	**	(VI)	33	1-64
Procladius spp.	187	140-234	1-3	2	-	VIII*	44	27-62
Parakiefferiella smolandica	32	11-53	1-3	3	-	VIII*	<1	••
Chironomus plumosus t.	11	0-25	3	3	-	(VIII)	<1	••
C. thummi t.	10	0-22	1	1	*	(VIII)	<1	••
Cryptochironomus sp.	66	43-88	1-3	2	-	(VIII)	24	12-37
Endochironomus albipennis	135	0-375	1-2	1	-	(VIII)	41	0-119
Paralauterborniella nigrohalteralis	36	16-56	1-3	1	-	(VI)	<1	••
Polypedilum nubeculosum	14	0-30	1	1	*	(VIII)	2	0-3
P. pullum	16	0-32	1-3	1	-	VIII*	<1	••
Pseudochironomus prasinatus	20	3-36	1-3	1	**	(VI)	4	0-9
Tanytarsus spp.	1275	689-1861	1-3	3	-	VIII***	52	22-82
Total	2016	1254-2777	1-3	1	-	VIII***	289	163-414

Table 9. Subarea D as in Table 6.

	Abundance		Bathymetric distribution			Monthly	Biomass	
	mean	conf.lim.	range	max	signif.	maximum	mean	conf.lim.
Uncinais uncinata	11	2-20	1-2	1	**	(VIII)	<1	••
Limnodrilus hoffmeisteri	21	3-39	1-2	1	***	(VIII)	25	6-45
L. (immature)	29	3-55	1-2	1	***	(VIII)		
Potamothrix hammoniensis	694	537-851	1-10	1	**	(VIII)	231	189-273
Psammoryctides barbatus	168	124-212	1-10	2	**	(VIII)	141	99-182
Pontoporeia affinis	641	409-873	1-10	10	**	(VIII)	182	101-263
Procladius spp.	116	75-156	1-10	2	-	VI***	14	10-18
Parakiefferiella smolandica	30	12-47	1-3	2	**	(VIII)	<1	••
Chironomus plumosus t.	263	82-444	1-5	3	**	VIII*	128	52-203
C. thummi t.	70	0-146	1-3	1	**	(VIII)	7	3-11
Cryptochironomus sp.	30	14-45	1-10	1	*	(VIII)	11	5-16
Polypedilum nubeculosum	218	24-412	1-5	1	**	VIII*	20	5-34
P. pullum	19	1-37	1-3	1	**	(VIII)	<1	••
Cladotanytarsus spp.	116	30-202	1-3	1	**	VIII*	3	1-5
Stempellinella minor	57	17-96	1-3	1	*	VIII**	<1	••
Tanytarsus spp.	504	87-922	1-5	1	**	VIII*	17	3-32
Ceratopogonidae	22	10-33	1-3	1	***	(VIII)	2	1-3
Total	3093	2082-4103	1-10	1	*	VIII**	827	719-934

In the shallow water area, in addition to *Potamothrix*, *Limnodrilus* (nearly all mature specimens were *L. hoffmeisteri*), *Psammoryctides barbatus*, and *Chironomus plumosus* type were the most important taxa. The main proportion of *Limnodrilus* biomass was confined to a depth of 1 m, while *Potamothrix* and *Psammoryctides* were abundant at all depths (Fig. 5d). At a depth of 3 m *Chironomus plumosus* type accounted for about half (0.47 g/m^2) of the total biomass.

Subarea E. The mean biomass (2.53 g/m^2) was appreciably higher than that of the previous subareas. The bathymetric variation in biomass was significant ($P \leq 0.05$). At a depth of 1 m the biomass (0.47 g/m^2) was much lower than at the greater depths (2-10 m), where it ranged from

Table 10. Subarea E as in Table 6.

	Abundance		Bathymetric distribution			Monthly	Biomass	
	mean	conf.lim.	range	max	signif.	maximum	mean	conf.lim.
Potamopyrgus jenkinsi	64	17-112	1-2	2	**	VI*	81	25-138
Macoma baltica	4	1-7	1-5	5	*	-	176	26-326
Limnodrilus profundicola	48	12-84	1-5	5	*	VI*	51	24-79
L. (immature)	133	70-195	1-10	5	-	VI*		
Potamothrix hammoniensis	258	135-381	1-10	5	***	(VIII)	103	51-154
Psammoryctides barbatus	246	126-367	1-5	3	***	(VIII)	158	83-233
Saduria entomon	52	28-76	1-10	2	*	(VI)	795	232-1357
Corophium volutator	215	108-322	1-10	3	***	(VIII)	35	22-49
Gammarus zaddachi	26	1-51	1-2	2	*	(VI)	29	0-59
G. (immature)	78	0-157	2-3	2	***	(VI)		
Pontoporeia affinis	4574	3217-5930	1-10	10	***	VI*	798	518-1077
Procladius spp.	123	65-182	1-10	2	-	VI***	7	4-9
Cricotopus spp.	16	1-32	1-3	2	-	VI*	1	0-2
Parakiefferiella smolandica	27	6-47	1-5	5	-	VI*	<1	••
Psectrocladius medius t.	14	2-25	1-5	1	-	VI*	<1	••
Chironomus plumosus t.	361	25-697	1-5	5	**	VIII*	63	17-109
Cryptochironomus sp.	19	11-26	1-5	1	***	-	2	1-3
Limnochironomus nervosus	126	0-267	1-5	2	-	VI*	6	0-13
Microtendipes spp.	40	0-92	2-3	2	-	(VIII)	6	0-15
Polypedilum nubeculosum	517	272-762	1-10	2	***	VI*	85	29-141
Stictochironomus sp.	54	12-97	1-3	2	-	VIII**	5	1-9
Cladotanytarsus spp.	158	50-266	1-5	1	***	(VIII)	5	1-8
Paratanytarsus spp.	76	12-140	1-5	2	***	(VI)	5	1-9
Tanytarsus spp.	551	260-841	1-5	2	***	(VI)	16	8-24
Ceratopogonidae	15	4-27	1-5	5	**	VI*	2	1-3
Total	7873	6338-9408	1-10	5	***	VI*	2528	1807-3248

Table 11. Subarea F as in Table 6.

	Abundance		Bathymetric distribution			Monthly	Biomass	
	mean	conf.lim.	range	max	signif.	maximum	mean	conf.lim.
Potamopyrgus jenkinsi	19	0-39	2-5	3	-	(VIII)	31	0-64
Macoma baltica	102	61-144	1-20	5	***	VI*	1797	987-2606
Paranais litoralis	12	0-26	1-2	2	-	(VIII)	<1	••
Potamothrix hammoniensis	23	3-44	20	20	***	(VI)	11	1-22
Psammoryctides barbatus	157	99-216	2-5	5	***	(VIII)	124	76-172
Saduria entomon	35	21-49	1-5	5	-	VI*	652	348-956
Corophium volutator	112	47-177	2-5	3	**	(VIII)	12	7-17
Gammarus zaddachi	16	4-27	2-5	2	*	(VIII)	11	3-20
Pontoporeia affinis	298	170-425	1-20	3	***	(VIII)	98	37-160
Orthocladius thienemanni t.	34	5-63	2-3	2	**	(VIII)	4	1-8
Psectrocladius psilopterus t.	11	1-21	2-3	3	-	VIII*	<1	••
Chironomus thummi t.	31	0-64	2-5	5	*	VIII*	5	1-9
Cryptochironomus sp.	14	5-23	1-3	1	**	(VI)	6	1-11
Microtendipes spp.	17	1-33	2-5	5	*	VIII*	<1	••
Paracladopelma camptolabis t.	10	2-18	1-2	2	*	VI*	2	1-3
Stictochironomus sp.	169	109-228	1-5	3	***	(VIII)	29	19-39
Cladotanytarsus spp.	56	25-87	1-5	3	**	VI*	2	1-2
Total	1152	817-1487	1-20	3	***	(VIII)	2794	1762-3826

2.58 (at 2 m) to 3.38 g/m^2 (at 3 m). *Potamopyrgus* (0.17 g/m^2), together with *Macoma* and *Pontoporeia*, accounted for nearly two-thirds of the total biomass at 1 m.

Pontoporeia and *Saduria* (both 0.80 g/m^2) were the most important species and made up 62 % of the total biomass. In deeper waters, 5-10 m, *Pontoporeia* was much more abundant (about 8200 ind./m^2 and 1.42 g/m^2) than at depths of 3 m (3560 and 0.92) and 1-2 m (850-2150 and 0.08-0.16, respectively). The main proportion (76 %) of the total biomass in the deep water area consisted of *Pontoporeia* and *Saduria*. Other species with high densities were *Psammoryctides, Potamothrix, Polypedilum nubeculosum, Chironomus plumosus* type and *Limnodrilus*. All mature *Limnodrilus* individuals in quantitative samples were *L. profundicola*. It is notable that, contrary to the previous subareas, *Limnodrilus* was quite evenly distributed throughout the whole depth range (Fig. 5e).

Subarea F. The mean biomass (2.79 g/m^2) did not differ significantly from the mean in subarea E. The biomass had its maximum at depths of 5 and 3 m (6.25 and 4.68 g/m^2) and its minimum at 1 and 20 m (0.74 and 0.70 g/m^2). This variation was significant ($P \leq 0.001$).

The most important species was *Macoma baltica*. It comprised almost two-thirds, and together with *Saduria*, almost 90 %, of the total biomass in the subarea (Table 11). The highest biomasses of *Macoma* were at depths of 3-5 m (mean 3.76 g/m^2). At a depth of 20 m its biomass (0.63 g/m^2) accounted for nearly 90 % of the total.

Of the oligochaete species only *Psammoryctides barbatus* was abundant in the littoral sites, *Potamothrix* being confined to deeper locations (Fig. 5f). It is also interesting to note that the mean biomass of *Pontoporeia* was only 10 % of the corresponding value in subarea E.

Characterisation of the three zones

The three zones established in the estuary on the basis of hydrography (Fig. 2), were characterised also by differences in the quantity and quality of macrozoobenthos (Table 12). Differences in biomass, diversity and species composition between the zones were obvious.

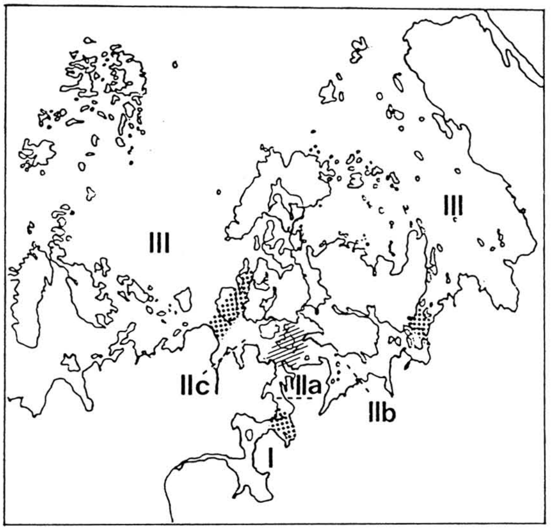

Fig. 6. The zones and subzones of the estuary, separated on the basis of hydrography and macrozoobenthos. The main features are described in Table 12.

The limnic zone was characterised by a very impoverished fauna (p. 93). The number of hololimnic species (species living in water throughout their life span) was particularly low, even though they made up the main proportion of the total biomass (Table 6). The transition zone was heterogenic and could be further divided into three subzones: IIa. the lower part of the channel; IIb. the shallow eastern part; and IIc. the deeper western area (Fig. 6). Although some brackish water and relict species occurred in IIc, the proportion of these in the total biomass, as well as the total biomass, was low compared with the corresponding values in the brackish water zone (Table 12).

Gastropods, *Theodoxus fluviatilis, Lymnaea peregra* and *Bithynia tentaculata* with some caddis fly larvae (e.g. *Tinodes waeneri, Ceraclea annulicornis, Limnephilus* spp. and *Athripsodes* spp.) were the most abundant bottom animals in exposed stony littorals of the outer archipelago. *Potamopyrgus*, together with some midge larvae (esp. *Cladotanytarsus, Paratanytarsus* and *Tanytarsus* species) were most abundant on sand and gravel among large stones.

Table 12. The main features of the three zones illustrated in Fig. 2 (I = the limnic, II = transition and III = brackish water zone). The mean biomass of macrofauna (ODW, g/m^2) and abundance ($ind./m^2$), arithmetical mean of Shannon diversity based on abundances and ln-values (minimum and maximum value per station), the species with highest biomass proportion and number of species of molluscs (M), relict (R) and brackish water spcies (B) in each zone and subzone. The subzones of zone II are indicated in Fig. 6 and described in text.

Zone	Mean biomass	Mean abundance	Shannon diversity	Species with highest biomass	Number of species M	R	B
I	0.1	400	1.03 (0.23-1.77)	*Limnodrilus hoffmeisteri*	–	–	–
II	0.5	2000	1.35 (0.49-2.35)	*Potamothrix hammoniensis*	8	2	5
a	0.3	700	1.06 (0.49-1.65)	*Potamothrix*	1	–	–
b	0.3	2000	1.38 (0.67-1.87)	*Tanytarsus* spp.	5	–	1
c	0.8	3100	1.62 (0.77-2.35)	*Potamothrix*	7	2	5
III	2.7	4500	1.67 (0.21-2.48)	*Pontoporeia affinis* *Macoma baltica* *Saduria entomon*	7	3	13

5. Discussion

5.1. The estuary compared with other parts of the northern Baltic Sea

The number of species of marine or brackish water origin, as well as of some macrozoobenthos groups, is diminished in the Bothnian Bay (Table 13). The distribution of marine and brackish water species in the Gulf of Bothnia is quite well-known (Segerstråle 1956, 1960, Haahtela 1964, Lassig 1965a, 1965b, Laakso 1969, Särkkä 1969, Bagge & Ilus 1973, Haahtela 1974, Rosenberg et al. 1975, Kangas 1976, Kautsky et al. 1981). Equivalent knowledge of the fresh water fauna is still inadequate.

The fresh water gastropod, *Valvata pulchella*, has not been previously found living in brackish water. On the grounds of its occurrence at the estuary, it can be classified as a β-oligohaline fresh water species (cf. Koli 1961). The local occurrence of the relict crustacean, *Pallasea quadrispinosa*, at St. E2 and E3 where the salinity was about 3.5 o/oo, is interesting. The species has been reported once before from the Bothnian Bay (Segerstråle 1956), but it has later been excluded from the fauna of the Bothnian Bay (Segerstråle 1960, Haahtela 1964). The species inhabits larger lakes and rivers, through which it can drift into the sea (Segerstråle 1956). However, *Pallasea* has not been found in the river Kyrönjoki (Koskenniemi, pers. comm.). It is also improbable that the species lives in small turbid, acid streams (the rivers Oravaistenjoki and Vöyrinjoki) discharging into the estuary.

Table 13. Number of marine and brackish water species and number of taxa of some macrozoobenthos groups at the Kokemäenjoki estuary in the Bothnian Sea, 61° 30′ (Särkkä 1969), Kyrönjoki, 63° 20′ (this study) and Luleå estuary, 65° 30′ N (Kautsky et al. 1981) in the Bothnian Bay.

	Kokemäen-joki	Kyrön-joki	Luleå
Marine and brackish water species	30	13	6
Priapulida	1	–	–
Nemertinea	1	1	1
Gastropoda	6	7	6
Lamellibranchiata	11	4	3
Polychaeta	2	–	–
Tubificidae	7	7	2
Naididae	4	6	3
Hirudinea	–	2	1
Mysidacea	3	3	..
Isopoda	5	3	2
Amphipoda	7	5	3
Trichoptera	8	20	..
Chironomidae	..	46	..

The tubificid species found tolerate low salinities in coastal and estuarine waters (Laakso 1969). The most common species in the estuary (*Potamothrix hammoniensis, Psammoryctides barbatus, L. hoffmeisteri* and *L. profundicola*) are common in the whole coastal area of the Gulf of Bothnia (Särkkä 1969, Bagge & Ilus 1973, Rosenberg et al. 1975). *Tubifex costatus*, the brackish water species which was not recorded in the estuary, has been reported by Nyman (1981) from the coastal area of Monäs (63° 29′N), a few kilometres north of St. 28, where it was the most numerous oligochaete at a salinity of about 4 o/oo.

The mayflies and caddisflies found in the estuary, as well as *Coenagrion hastulatum* (Odonata) and *Sialis sordida* (Neuroptera), are limnobionts that have been reported living in oligohaline coastal and estuarine waters in the northern parts of the Baltic Sea (Saaristo 1966, Carlsson 1979, Lingdell & Müller 1979, Bagge et al. 1980, Danielsson & Müller 1982, Kaiser & Müller 1982). According to the list of Finnish Trichoptera (Nybom 1960) *Cyrnus trimaculatus* and *Molanna albicans* are new species to the biogeographical province in question (OA). Of the midge taxa found in the transition and brackish water zone (see Fig. 2), about three-quarters have been previously reported from brackish water in the northern Baltic (Palmén 1955, 1959, 1960, 1962, Lindeberg 1963, Palmén & Aho 1966, Bagge & Tulkki 1967, Paasivirta 1972, Rosenberg et al. 1975, Bagge et al. 1980).

Organically loaded coastal areas, as, for instance, many estuaries, usually have a sharp zonation of zoobenthos, e.g. the biomass reaches its maximum at some distance from the pollution centre, where food resources are nearly optimal and other environmental factors, such as oxygen, are favourable (see e.g. Leppäkoski 1975). This kind of maximum is made up of so-called progressive species. *Macoma baltica* is the most important of these species in the Bothnian Sea (Särkkä 1969, Leppäkoski 1975, Rosenberg et al. 1975, Danielsson & Müller 1982). In the Kyrönjoki estuary there was no maximum of this kind, but the biomass steadily grew seawards from the river mouth (Table 12). The lack of a biomass maximum can be explained by the fact that *Macoma* does not live in the low salinities of the transition zone (cf. Lassig 1965a), where it remains mainly below 3 o/oo.

At the Luleå estuary, in the northwestern corner of the Bothnian Bay, the mean biomass of macrozoobenthos in the littoral sites (0-7 m) was slightly higher on muddy bottoms (1.5 g/m^2, dry weight including shells) than on sandy bottoms (0.9 g/m^2, Kautsky et al. 1981). Because of the high proportion of gastropods the figures are barely more than 0.4 and 0.25 g/m^2 ODW, respectively. The biomass values reported by Kangas (1976) for the littoral (0-8 m) of the Krunnit area, in the northern Bothnian Bay, varied between 6.0-8.4 g/m^2 wet weight on sandy and stony bottoms. I assume that the values of the Krunnit area do not exceed 1.5 g/m^2 ODW. The littoral biomasses of the northern Bothnian Bay, cited above, are thus in good accordance with the corresponding values observed in the transition zone (β-oligohaline zone) of the Kyrönjoki estuary.

In the "semi-healthy" areas of the Nätraå estuary, in the northwestern part of the Bothnian Sea, the biomass of macrozoobenthos varied between 40-116 g/m^2 wet weight, (Rosenberg et al. 1975). These values, approx. 5-15 g/m^2 ODW, are somewhat higher than the biomasses in the brackish water zone of the Kyrönjoki estuary where the highest values remained below 7 g/m^2. The biomass at the deepest station (F20) was four to five times higher than the deep water value for the Bothnian Bay, 1 g/m^2 WW, reported by Elmgren (1978).

5.2. Influence of environmental factors on occurrence and abundance of different species

Physico-chemical and biological factors act as a multidimensional net which defines the species composition in space and time. It is widely known that, e.g. the zonation of marine and brackish water species is generally clearly discernible in the salinity gradient, but in most other cases the key-factors remain unknown, mainly because the number of environmental parameters measured are inadequate.

Tubificids and sediment structure

Sediment structure, in addition to microbial activity and its composition, has often been proposed as one of the main factors defining the distribution of burrowing sediment eaters like tubificids (e.g. Brinkhurst 1974). In the study area *Potamothrix hammoniensis* occurred abundantly both in organogenic and minerogenic sediments, while *Psammoryctides barbatus* was abundant mainly on minerogenic beds (Table 14). On minerogenic beds *Potamothrix* preferred a smaller particle size than *Psammoryctides*. On silt and mixed silt the biomass of *Potamothrix* was significantly higher compared to *Psammoryctides* (t-test, $P \leq 0.05$), while the situation was quite the opposite on coarser sediments, on very fine, and fine, sand ($P \leq 0.01$, $P \leq 0.001$, respectively). *Limnodrilus hoffmeisteri* preferred shallow localities where the sediment was mainly mixed mud. These results are in good accordance with the visual observations made by Bagge & Ilus (1973) on the coastal waters of the Gulf of Bothnia. As Nyman (1981) has reported, *L. profundicola* prefers a minerogenic substrate; it also seemed to be indifferent to particle size.

A view on the negative relationship between the abundances of Macoma and Pontoporeia

In addition to the different horizontal distribution of *Macoma* and *Pontoporeia*, e.g. in a salinity or pollution gradient, there are observations of another kind of negative relationship between the species (see e.g. Segerstråle 1978). This correlation has been explained by so-called predation theory. The theory suggests that *Pontoporeia* preys on newly settled *Macoma*. Ankar (1977) has doubted this. In his opinion competition for food and biotope selection should be considered. Observations from the estuary support both of these conceptions. *Macoma* was much more abundant in exposed, and *Pontoporeia* in sheltered, localities in the brackish water zone (cf. Table 10 and 11). In other words, deposit feeding *Pontoporeia* was abundant in localities, where sedimentation was quite undisturbed, while *Macoma*, able to feed on suspended matter, reached high densities in exposed areas. Predation may thus limit the distribution of *Macoma* only in areas with dense *Pontoporeia* populations.

Areas of deteriorated fauna

The bottom fauna of the limnic zone consisted mainly of hololimnic species, while only merolimnic animals were found in another poorly populated area, St. B5. This station is located in the innermost basin, where the deposition rate of allochthonous matter, carried down by the river flow, is high, especially during floods. Depletion of oxygen, a common phenomenon in deeper estuarine basins, has not been observed at this site. It may be assumed that species like tubificids living continuously in sediments, suffocate under the heavy rain of deposits. Only species with a capacity for rapid colonization (e.g. chironomids and semipelagic *Chaoborus*) can inhabit this kind of biotope.

An absence of fresh water molluscs, especially gastropods, from acid, soft waters rich in humus has often been reported (e.g. Boycott 1936, Hubendick 1947, Aho 1966). It is highly probable that the absence of molluscs from the limnic zone is closely correlated with acidity, even though synergism with heavy metals may be the most decisive factor. Preliminary studies (Verta, pers. comm.) have revealed high metal concentrations in acid run-off waters originating from the Litorina soils and discharging into the mouth area. For instance, an average copper-concentration of 69 μg/l water has been found in the southern bay of the river mouth. Tubificids, which were abundant at the river mouth, are known to be quite resistant to high metal concentrations (Wentzel et al. 1977, Chapman et al. 1980). However, they are rather sensitive to copper (Brkovic-Popovic & Popovic 1977). According to these authors the LD_{50} for *Tubifex tubifex* is 116–136 μg Cu/l at the average value for hardness, 7–9 mg $CaCO_3$/l, found at the river mouth. The observed mean, 69 μg, remains well below the calculated limit, but is quite high compared with, for example, the values below 50 μg Cu/l represented by EPA (ref. Conroy et al. 1976) as LD_{50} for rainbow trout in soft waters with $CaCO_3$ below 20 mg/l.

Table 14. Distribution of the most common tubificids on different substrates at the Kyrönjoki estuary (- = absent or very rare, + = present and ++ = abundant). mSa = medium sand, fSa = fine sand and vfSa = very fine sand.

	Minerogenic				Organogenic	
	mSa	fSa	vfSa	silt	mixed mud	mud
Potamothrix hammoniensis	-	-	+	++	+	++
Psammoryctides barbatus	-	+	++	+	+	+
Limnodrilus hoffmeisteri	-	-	-	+	++	+
L. profundicola	+	+	+	+	-	-

Certain insects are resistant to high concentrations of heavy metals. For example, Cherry et al. (1979) found chironomids in areas which had average concentrations of 400 μg Cu, 370 μg Zn and 120 μg Cd/l. Studies by Nehring (1976) and Anderson et al. (1980) have indicated that the resistance of insect larvae to high concentrations of heavy metals may not be a general response, but that there are rather sensitive species, too. For instance, according to Anderson et al. (1980) the LD_{50} for *Tanytarsus dissimilis* was as low as 16.3 μg Cu/l in test water with 47 mg $CaCO_3$/l.

At present the knowledge of heavy metal concentrations (e.g. sediment data) and the effects of these on different animals are insufficient for us to be able to draw conclusions on the importance of heavy metals in the study area. The studies being made at the National Board of Waters will help alleviate these problems.

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