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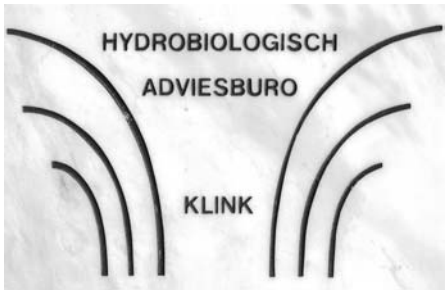

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1. Sampling Stations

In the Seine-Aval between river kilometer 203 and 324 a total of 125 samples has been taken from the intertidal, subtidal and the deep bottom. In the side channels upstream Rouan 9 samples have been taken. The River Eure was investigated op 4 stations. Finely a streamlet flowing into the Seine-Aval at km 215 was sampled on two locations. In table 1 an overview is given of the river kilometers and the samples taken from several depths (deep, subtidal, intertidal) and the sampled substrates. In total 140 samples have been taken and processed.

Table 1. Overview of the sampling program

River	km	Deep	Subtidal	Intertidal	Stones	Gravel	Sand	Silt	Wood	A.Sub.	Veg.	Other
S. Aval	203	6			3	2	1					
S. Aval	204		2	1			2		1			
S. Aval	205	3	4	4	5	6						
S. Aval	207		1	1						2		
Stream	215			2			1	1				
Eure	216	1		2				2			1	
Eure	217	1					1					
S. Aval	221	5	6	2	6	2	2	1	2			
S. Aval	223	1					1					
Side Ch.	226	1					1					
S. Aval	227	3	1			3			1			
Side Ch.	229		1	3				3	1			
Side Ch.	230			4				1	1		2	
S. Aval	230	2		1	1		1	1				
S. Aval	247	3					2	1				
S. Aval	249	1	3	1		2		2				1
S. Aval	250	5	2	1	3		4		1			
S. Aval	253		1									1
S. Aval	258	4			1		2			1		
S. Aval	260	5	1	5	2	2	4	1				2
S. Aval	265	1								1		
S. Aval	278	5			1		1	1		2		
S. Aval	288	3	4	3	5	3	1	1				
S. Aval	292	1			1							
S. Aval	294	3					2	1				
S. Aval	302	3	3	5	4			7				
S. Aval	305	2								2		
S. Aval	319	2			2							
S. Aval	320	4			1	2	1					
S. Aval	322		2		1	1						
S. Aval	324	3	2	4	5			4				
Total		**68**	**33**	**39**	**41**	**23**	**27**	**27**	**7**	**8**	**3**	**4**

The majority of the samples (68) are taken from the deep river bed, while the subtidal and intertidal were sampled 33 and 39 times respectively. The deep riverbed in the Seine-Aval consists of a number of different substrates. The most upstream part from the Dam of Poses to app. km. 240 the bed consists of rocks and gravel. From km. 240 to km. 255 sand dominates the material on the riverbed. From km. 255 to 268 limestone is the prevailing bed material with local sandbars. From km. 268 to km. 324 rocks and gravel predominant again and local sandbars are abundant (after Lesueur, 1999 p. 21 PsS-A 3 Peter plaatje overnemen met onze monsterpunten er in?).

The sampled substrates are thought to be representative for the substrates available in the river. The coarse substrates (stones and gravel) prevail over sand and silt. Wood is rare in the Seine-Aval as in all other western European rivers. Centuries ago the river forest were taken down and the snags in the water were removed in favour of navigation. Additionally artificial substrate (see elsewhere) was sampled. In only 3 occasions we found poor vegetations on the borders of a side channel and along the Eure. Other substrates were a steel ropes, a steel dams and an inlet sieve from the Shell facilities in Rouan.

2. Methods

2.1. Sampling methods (Bram)

2.2. Handling of the samples in the laboratory

The samples have been conserved in ethanol and transported to the Klink lab. in Wageningen (Netherlands). The samples were sieved over a mesh size of 500 µm and the residual on the sieve was converted to a scaled bucket of 12 litres and the amount of water added depends on the amount of material in the sample. The more material the more water is added and the volume amounts to entire litres. With a can of 1 litre the sample is stirred and portions of 1 litre are converted to a white photo-developing-tray with backlight. The macroinvertebrates were sorted out by naked eye. Of every group the total number in the sample was calculated and a maximum of 100 individuals was sorted out for later identification. After the identification the total number in the sample were recalculated. The macroinvertebrates were identified to species level (if possible). The list of identification literature is given in the chapter Literature.

3. Sampling stations (Peter)

4. Results

4.1. Longitudinal distribution of the macroinvertebrates

To get a first impression of the data, a cluster analysis (TWINSPAN) was executed. The factor with the major influence on the clustering was the river kilometer. Three distinct clusters showed up, representing the fauna on km. 203-230, km 247-288 and km 292-324. In the tables below the invertebrates will be presented by taxonomic group and representing all depths and substrates investigated.

Table 2. Longitudinal distribution of the triclads (Tricladida)

Tricladida	203-230	247-288	292-324
Dendrocoelum lacteum	+	++	
Dugesia lugubris/polychroa	++	++	
Dugesia tigrina	++	++	+
Total number of taxa	**3**	**3**	**1**

Frequency: + 0-10%; ++ >10-25%; +++ > 25%

Three triclad taxa were encountered in the upper 2 sections of the Seine-Aval. *Dugesia tigrina* was also present in the downstream samples. *Dendrocoelum lacteum* and the two *Dugesia* taxa are very common on solid substrates in lager standing and flowing waters.

Table 3. Longitudinal distribution of the bristle worms (Polychaeta)

Polychaeta	203-230	247-288	292-324
Hypania invalida	+++	+++	

Hypania invalida is an invasive species from the Danube who was able to expand its distribution range dramatically, after the opening of the Danube-Main-Rhine Canal in September 1992 (Bij de Vaate, 2003). *Hypania* is very common in the upper two sections. In the downstream section no specimens were found.

Foto 1. *Hypania invalida*

Table 4. Longitudinal distribution of the oligochaetes (Oligochaeta)

Oligochaeta	**203-230**	**247-288**	**292-324**
Aulodrilus pluriseta	+		
Limnodrilus udekemianus	+		
Nais pardalis	+		
Peloscolex multisetosus	+		
Enchytraeidae	++	++	
Lumbricidae	+	+	
Ophidonais serpentina	+	+	
Stylaria lacustris	+	++	
Chaetogaster diaphanus		+	
Eiseniella tetraedra		+	
Tubifex ignotus		+	
Haplotaxis gordioides		+	+
Peloscolex velutinus			+
Stylodrilus heringianus			+
Nais elinguis	+		+
Branchiura sowerbyi	+	++	++
Limnodrilus claparedeianus	+++	+++	+++
Limnodrilus hoffmeisteri	+++	++	++
Lumbriculidae	+	+++	+
Potamothrix moldaviensis	++	++	+
Psammoryctides barbatus	+++	+++	++
Total number of taxa	**15**	**14**	**10**

A total of 21 taxa of oligochaetes are collected in the Seine-Aval. According to Fomenko (1980) *Nais pardali*s and *Potamothrix moldaviensis* belong to mesorheophilic species, while the *Psammoryctides barbatus* and *Tubifex ignotus* are limnophilic species. The other species are typical limnophilic. Most of these species are abundant in the Lower Rhine also. This however is not the case for Tubifex *ignotus*, *Haplotaxis gordioides* and *Peloscolex velutinus* which are rare species.

Table 5. Longitudinal distribution of the leeches (Hirudinea)

Hirudinea	203-230	247-288	292-324
Cystobranchus respirans	+		
Erpobdella octoculata	+++	+++	
Erpobdella testacea	+	++	
Glossiphonia concolor	++	+++	
Glossiphonia heteroclita	++	+	
Helobdella stagnalis	+	++	
Hemiclepsis marginata	+	+	
Trocheta riparia	+	+	
Piscicola geometra		+	
Glossiphonia complanata	+++	+++	++
Total number of taxa	**10**	**10**	**1**

Nine different leeches have been collected. The leeches in the upper sections hardly differentiate. In the downstream section is almost deprived and only *Glossiphonia complanata* is encountered. The only rheophilic leech is *Cystobranchus respirans*, an ectoparasite on cyprinids and salmonids. *Trocheta riparia* is semi-aquatic (Nesemann, 1997).

Table 6. Longitudinal distribution of the molluscs (Mollusca)

Mollusca	203-230	247-288	292-324
Acroloxus lacustris	+		
Ancylus fluviatilis	+		
Corbicula fluminalis	++		
Galba truncatula	++		
Gyraulus albus	+		
Lithoglyphus naticoides	+		
Pisidium amnicum	+		
Pisidium casertanum plicatum	+		
Pisidium henslowanum	+		
Pisidium pulchellum	+		
Pisidium supinum	+		
Sphaerium rivicola	+		
Succineidae	+		
Physa fontinalis	+	+	
Pisidium casertanum	+	+	
Pisidium nitidum	++	+	
Pisidium subtruncatum	+	+	
Potamopyrgus antipodarum	++	+	
Sphaerium corneum	++	+++	
Sphaerium solidum	+	+	
Valvata piscinalis	++	+	
Viviparus viviparus	+	+	
Physella acuta		+	
Radix peregra		+	
Valvata cristata		+	
Bithynia tentaculata	+++	+++	++
Corbicula fluminea	++	+++	+
Dreissena polymorpha	+	+++	++
Radix ovata	++	++	+
Total number of taxa	**26**	**16**	**4**

A total of 29 species has been collected in de Seine-Aval. The molluscs differentiate clearly in the three sections. De uppermost section inhabits many rheophilic species (*Ancylus fluviatilis*, *Pisidium amnicum*, *P. henslowanum*, *P. supinum*, *Sphaerium rivicola* and *Sphaerium solidum*). In the middle section *Sphaerium solidum* is the only rheophilic left. In the lower section only four mollusc species can cope with the environment. *Galba truncatula* is a characteristic inhabitant of the intertidal mud. Both *Corbicula* species are invasive and originate from the far East. They were brought to America by Chinese immigrants and reached Europe by ballast water in American ships in the second part of the 20th century (Bram graag aanpassen en literatuur). *Dreissena polymorpha* is a much older invader, originating from the Ponto-Caspian region it reached the Netherlands as early as 1926 (Kinzelbach,1992). Striking is the absence of *Unionidae* in even the Benne-Hamon samples, while sub fossil shells are scattered everywhere along the shores and on the bottom of the river. Also many shells of *Theodoxus fluviatilis* have been seen, but none with the snail in it.

Photo 2. *Corbicula fluminalis*

Table 7. Longitudinal distribution of the crustaceans (Crustacea)

Crustacea	**203-230**	**247-288**	**292-324**
Crangonyx pseudogracilis	+		
Dikerogammarus villosus	+		
Echinogammarus berilloni	+		
Orchestia	+		
Asellus aquaticus	+++	+++	
Orconectes limosus	+	+	
Proasellus coxalis		+	
Proasellus meridianus	+++	+++	+
Gammarus salinus	++	+++	+++
Total number of taxa	**8**	**5**	**2**

A total of 9 species has been collected. In the upstream section *Crangonyx pseudogracilis* and *Dikerogamarus villosus* are invasive species. The former originates from America and the latter is a Ponto-caspian invader. In the Netherlands both species are a menace to the indigenous gammerids (*Gammarus pulex* and *G. fossarum*). *Orconectes limosus*, also an American species has been collected in both upstream sections. The most wide spread crustacean in the Seine-Aval is *Gammarus salinus*. In the Rhine-Meuse estuary this species is confined to brackish waters in the estuary and along the coast with freshwater influence (Pinkster and Platvoet, 1986). In the Seine-Aval the species is common even in the upstream section. In the downstream section *G. salinus* is the dominating inhabitant of solid substrates.

Photo 3. *Dikerogammarus villosus* mature male

Table 8. Longitudinal distribution of the mayflies (Ephemeroptera)

Ephemeroptera	**203-230**	**247-288**	**292-324**
Ephemerella ignita	+		
Heptagenia sulphurea	+		
Caenis macrura	+	+	
Total number of taxa	**3**	**1**	

No more than three species of mayflies has been collected. *Ephemerella ignita* is a characteristic inhabitant of smaller rivers and streams. *Heptagenia sulphurea* and *Caenis macrura* are true potamal species. Of *Heptagenia sulphurea* only one specimen has been found. The other species are more wide spread, but still not common. Typical burying mayflies like *Ephemera*, *Ephoron* and *Palingenia* seem to be lacking in the Seine-Aval.

Photo 4. *Ephemerella ignita*

Table 9. Longitudinal distribution of the stoneflies (Plecoptera)

Plecoptera	203-230	247-288	292-324
Leuctra fusca	+		

Leuctra fusca inhabits streams and small rivers. The occurrence in the Seine-Aval might be a result of drift from upstream. On km. 203 one specimen has been collected.

Table 10. Longitudinal distribution of the water bugs (Heteroptera)

Heteroptera	203-230	247-288	292-324
Aphelocheirus aestivalis	+		
Micronecta minutissima	+		
Sigara striata		+	
Total number of taxa	**2**	**1**	

Only three water bugs have been found. Of these only *Aphelocheirus aestivalis* is a true inhabitant of large rivers. This species is very sensitive to low oxygen content since it breaths through diffusion of oxygen from the surrounding water.

Table 11. Longitudinal distribution of the water beetles (Coleoptera)

Coleoptera	203-230	247-288	292-324
Haliplus fluviatilis	+		
Elmis	+	+	
Limnius		+	
Esolus	+	+	+
Total number of taxa	**3**	**3**	**1**

Also water beetles are almost absent in the Seine-Aval. The reason is the lack of suitable habitats like small shallow ponds with lush vegetation. The larvae of *Elmis*, *Limnius* and *Esolus* are indicators of a good oxygen content since these larvae (like *Aphelocheirus*) do not breath air but get oxygen by diffusion from the water.

Table 12. Longitudinal distribution of the caddis flies (Trichoptera)

Trichoptera	203-230	247-288	292-324
Ecnomus tenellus	+		
Hydroptila	+		
Lepidostoma hirtum	+		
Hydropsyche contubernalis	+++		
Neureclepsis bimaculata	+++	+	
Total number of taxa	**5**	**1**	

A total of only six species of caddis flies has been collected. Almost exclusively from the upstream section. *Lepidostoma hirtum* is a rare and sensitive species from streams and rivers. Only on km 203 the larvae have been found. In the upstream section the potamal species *Hydropsyche contubernalis* and *Neureclepsis bimaculata* are very abundant on solid substrates.

Photo 5. *Hydropsyche contubernalis*

Table 13. Longitudinal distribution of the midges (Chironomidae)

Chironomidae	203-230	247-288	292-324
Tanypus kraatzi	+		
Tanypus punctipennis	+		
Potthastia longimanus	+		
Prodiamesa olivacea	+		
Bryophaenoicladius gr. muscicola	+		
Paratrichocladius rufiventris	+		
Tvetenia calvescens	+		
Chironomus acutiventris	+		
Chironomus bernensis	+		
Chironomus nudiventris	++		
Chironomus plumosus agg.	+		
Cladopelma laccophila gr	+		
Cryptochironomus defectus	+		
Dicrotendipes lobiger	+		
Endochironomus albipennis	+		
Harnischia	++		
Microchironomus tener	+		
Microtendipes chloris gr	+		
Phaenopsectra	+		
Polypedilum convictum	+		
Polypedilum cultellatum	+		
Polypedilum sordens	+		
Paratanytarsus dissimilis	+		
Cricotopus bicinctus	+++	++	
Cricotopus intersectus	+++	++	
Cricotopus sylvestris	+++	++	
Nanocladius bicolor agg.	++	++	
Rheocricotopus chalybeatus	+++	++	
Cryptochironomus supplicans	+	+	
Cryptochironomus	+	+	
Glyptotendipes pallens	+++	+++	
Glyptotendipes paripes	+++	+++	
Parachironomus arcuatus gr	++	+	
Parachironomus spec. Kampen	+	+	
Paratendipes albimanus	++	+	
Polypedilum nubeculosum	++	+	
Xenochironomus xenolabis	++	+	
Micropsectra atrofasciata	+	+	
Paratanytarsus dissimilis agg	+	+	
Rheotanytarsus	+	+	
Clinotanypus nervosus		+	
Pseudosmittia		+	
Tanytarsus		+	
Thalassosmittia thalassophila		+	+
Procladius	+	+	+
Limnophyes	+++	++	+
Dicrotendipes nervosus	+++	+++	+++
Parachironomus longiforceps	++	++	+
Polypedilum scalaenum	+++	+++	++
Cladotanytarsus mancus gr	+++	++	+
total number of taxa	**47**	**27**	**7**

By far the most divers group of invertebrates are the midges. A total of 52 taxa have been collected. Again, most taxa live in the upper section,

and the species richness declines very rapidly downstream. In the lower section only 7 taxa remain. Rheophilic species are *Paratrichocladius rufiventris* (solid substrates), **Tvetenia calvescens** (solid substrates), *Chironomus acitiventris* (sand), *Harnischia* (sand), *Microchironomus tener* (sand) **Polypedilum convictum** (solid substrates), **P. cultellatum** (wood), *Rheocricotopus chalybeatus* (solid substrates), *Microspectra atrofasciata* (all substrates), *Rheotanytarsus* (solid substrates) and *Polypedilum scalaenum* (shifting sand). In bold are the critical species, which also live in foothill streams. By far the majority of these species is confined to the upper section. An exception is *Polypedilum scalaenum* which is one of the few species that also inhabits the sand in the lower section of the Seine-Aval. Semi-aquatic taxa are *Bryophaenocladius* gr. *muscicola*, *Pseudosmittia*, *Thalassosmittia thalassophila* en *Limnophyes*. *Parachironomus* spec. *Kampen* and *P. longistyla* are confined to colonies of *Bryozoa* and *Xenochironomus xenolabis* inhabits freshwater sponges. One of the most pollutant tolerant species is *Dicrotendipes nervosus*. It was among the first midges that recolonized the Lower Rhine in the late 1970's after a period that the river was dead .

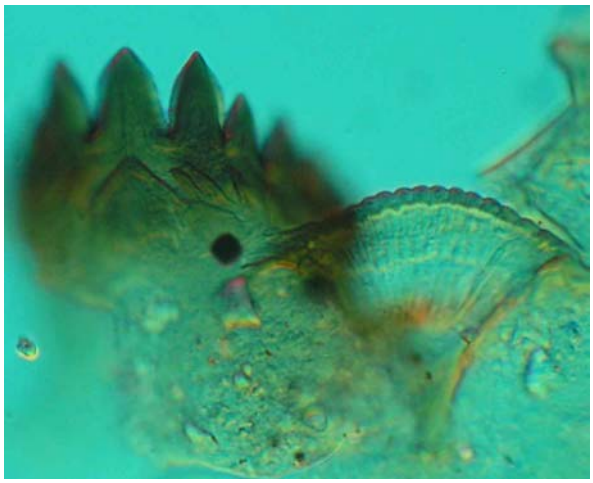

Photo 6. Detail of head of a *Dicrotendipes nervosus* larva

The conclusion of this paragraph must be that the invertebrates exhibit a strict differentiation between the three sections. The upper section is the most divers with rheophilic potamal and rhitral species. The middle section is deprived from rheophilic species and only trivial species find a biotope. The downstream section is even worse. The invertebrate fauna is dominated by the oligochaete Limnodrilus claparedeianus, the amphipod *Gammarus salinus* and the midge *Dicrotendipes nervosus*.

4.2. Seine-Aval as a freshwater intertidal habitat

The freshwater tidal section of the Seine-Aval is limited upstream by the dam of Poses (km. 202) and downstream by the salt intrusion up to Vieux Port at km 325. Thus a stretch of 123 km is potentially a

freshwater intertidal habitat for macroinvertebrates. In Table 14 we summarized the semi-aquatic species present in the intertidal area.

Table 14. Longitudinal distribution of semi-aquatic species

Oligochaeta	**203-230**	**247-288**	**292-324**
Enchytraeidae	+++	+	
Lumbricidae	++	+	
Lumbriculidae	++	+	++
Hirudinea			
Trocheta riparia		+	
Mollusca			
Galba truncatula	+++		
Succineidae	+		
Crustacea			
Orchestia	+		
Chironomidae			
Bryophaenoicladius gr. muscicola	+		
Pseudosmittia		+	
Thalassosmittia thalassophila		+	++
Limnophyes	+++	+	++
Other Diptera			
Limoniidae	++		
Tipulidae	+		
Total number of taxa	**10**	**7**	**3**

A total of 13 semi-aquatic species has been collected in 31 samples in the intertidal area. Also 63 aquatic species have been collected. Of these species only *Trocheta riparia* and *Galba truncatula* seem to be more frequent in the intertidal than in the remaining river system. *Thalassosmittia thalassophila* is a good indicator because it actually (in the Netherlands) has not jet been found outside the intertidal. The remaining taxa are semi-aquatic and they can be found in wet soils or temporary waters outside the river basin.

Photo 7. Larvae and pupa of *Thalassosmittia thalassophila*

4.3. The macroinvertebrates of the Eure

In the Eure only three samples have been taken, one near each bank and one in the middle. The macroinvertebrates resemble those of the upper section, but far less divers. The recent invaders *Hypania invalida*, *Corbicula fluminalis* and *C. fluminea* have reached the Eure. Species exclusive for the upper section are the clams *Pisidium amnicum*, *P. casertanum*, *P. henslowanum* and *P. supinum*. The amphipod *Echinogammarus berelloni* and mayfly *Caenis macrura* have been collected, but caddis larvae are absent in the samples. Also the midges *Chironomus nudiventris*, *Cladopelma* gr. *laccophila* and *Polypedilum cultellatum* have only been collected in the upper section of the Seine-Aval.

5. Seine-Aval as habitat for macroinvertebrates

5.1. All collected invertebrates

In 140 samples we have collected little over 150 taxa. To learn the meaning of this number we need a reference. The scope of this research is not to look into historical data of the Seine, but we use the Rhine as a reference. Since the Seine and Rhine lie in the same fauna region one can expect the same invertebrate communities. Indeed all the species we have found during this research are known to the Rhine as well.

The reference of the Rhine has been constructed by three different sources (Klink, 1989):

- Paleoecological research (5000 BP – present)
- Literature research (1752 – present)
- Recent research (1975 – present)

From a political reason we took as reference (aim for the future) the state of the Rhine in 1725 and the current state was set at 2000. In table 15 the comparison is made between the Rhine in 1725 - 2000 and the current data of the Seine-Aval.

Table 15. The macroinvertebrates of Seine-Aval in comparison with the Rhine in 1725-2000

	Lower Rhine		Seine-Aval
Group	**1725**	**2000**	**2006**
Tricladida	3	4	3
Oligochaeta	51	52	22
Polychaeta	0	1	1
Hirudinea	13	14	10
Mollusca	42	47	32
Hydrachnellae	26	26	0
Crustacea	9	17	9
Ephemeroptera	44	7	3
Plecoptera	16	0	1
Odonata	9	4	2
Heteroptera	8	3	3
Coleoptera	26	7	5
Neuroptera	2	2	0
Lepidoptera	4	4	0
Trichoptera	60	16	5
Chironomidae	179	124	54
Simuliidae	6	2	0
Total	**498**	**330**	**150**

Explanation: Groups in italics leave no, or not enough, remnants in river sediments and/or are poorly documented in (old) literature. For these groups the current diversity is used for the state in 1725 + or – the recent invaders and known extinct species. For the other groups paleoecological data and/or data from literature give a consistent picture of the changes.

In the period between 1745 and 2000 the Lower Rhine has lost 184 taxa (37%) of its original macro invertebrate fauna. In the same time at least 16 taxa invaded. These taxa are predominantly molluscs (*Corbicula fluminalis, C. fluminea, Dreissena polymorpha, Lithoglyphus naticoides, Physella acuta, Potamopyrgus antipodarum* and *Viviparus viviparus*) and Crustaceans (*Atyaephyra desmaresti, Corophium curvispinum, Crangonyx pseudogracilis, Dikerogammarus villosus, Echinogammarus ischnus, Hemimysis anomala, Jaera istri, Limnomysis benedeni* and *Orconectes limosus*) (Kinzelbach, 1982; Bij de Vaate, 2003). But also the oligochaete *Branchiura sowerbyi*, the leech *Dendrocoelum romanodanubiale*, the bristle worm *Hypania invalida* are foreign additions to the fauna of the Rhine.

The degradation is most dramatic in the Ephemeroptera (decline 84%), Plecoptera (decline 100%) and Trichoptera (decline 75%). The cause of the faunal degradation is in the first place the water pollution, starting at the first industrial revolution in the mid 19th century. But also the training of the shores and the removal of submerged wood will have led to very serious habitat decline. When we compare the current state of the macroinvertebrates in the Rhine with those in the Seine-Aval, we see that less than half the taxa are collected in the Seine. This is at least partly due to a less extensive sampling program (In the Rhine about 1000 samples were processed against 140 in the Seine-Aval). An other reason is that the campaign lasted only 1 week in June. It is to be expected that more species will be collected when sampling is taken place in other seasons (esp. April and May). Despite these limitations we see the same picture in the Seine-Aval as in the present Lower Rhine. The Ephemeroptera, Plecoptera and Trichoptera are near extinction in the Seine. The limited amount of mollusc species is mainly

due to the absence of vegetation along the banks of the river. The same holds true for the water mites (Hydrachnellae) of which not even one specimen was collected during our research.

5.2. Freshwater intertidal invertebrates

Table 16. The intertidal macroinvertebrates of Lower Rhine and Seine-Aval

	Lower Rhine	Seine Aval
Hirudinea		
Trocheta pseudodina	+	
Trocheta bykowski	+	
Trocheta riparia		+
Mollusca		
Mercuria confusa	+	
Galba truncatula	+	+
Hydrachnellae		
Nilotonia borneri	+	
Piersichia limophila	+	
Coleoptera		
Dryops vienensis	+	
Chironomidae		
Thalassosmittia thalassophila	+	+
Einfeldia carbonaria	+	
Total	**9**	**3**

The information on freshwater tidal invertebrate communities is very scarce. The most information we gathered from the Rhine-Meuse estuary since we were involved in several nature development projects to restore the freshwater tidal ecosystem. Some useful information was extracted from Dutch research done before the estuary was closed off in 1972. This information leads to several conclusions:

- The intertidal fauna contains far less species than the fauna in permanent water.
- The bulk of the species is very common in freshwater or very common on land.
- The composition invertebrate fauna is unique since species of land and water meet each other in the freshwater intertidal.
- Only a very limited number of species is characteristic or depends on the intertidal.

We have only recovered 10 species that are more abundant in the freshwater tidal habitats than in the remaining river system. It has to be noticed that most of these species have been found after the Dutch estuary was closed in 1972 and only small areas of freshwater intertidal remained. Of these species only *Mercuria confusa* and *Thalassosmittia thalassophila* are confined to the freshwater tidal habitat. The water mite *Nilotonia borneri* was recently discovered in an intertidal reed

march and this still is the only known location in the Netherlands. The indicators of the intertidal in the Seine-Aval are even less developed.

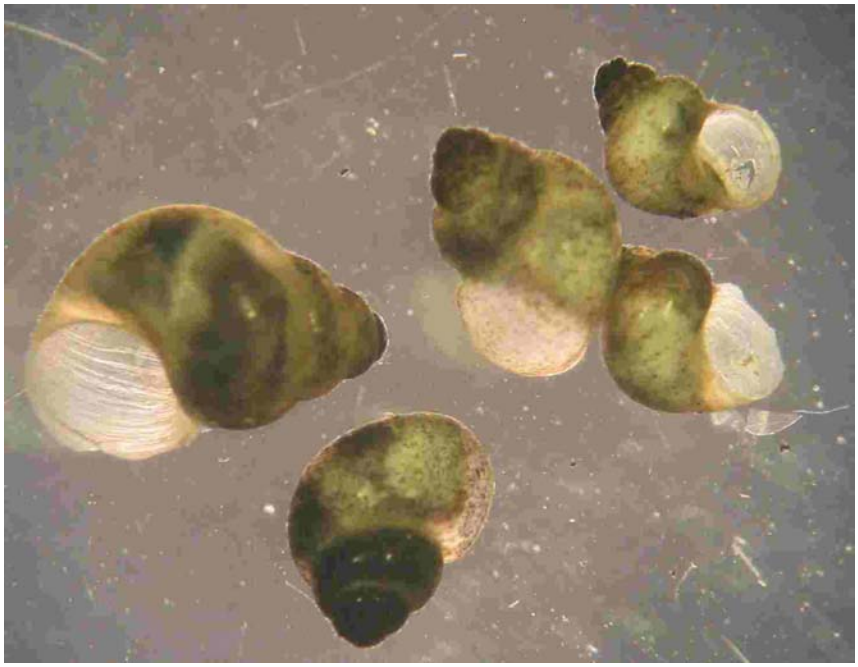

Photo 8. *Mercuria confusa*, the freshwater tidal snail

6. The problems of the Seine-Aval

The macroinvertebrates clearly point out that things are seriously wrong in the Seine-Aval. We will try to shed light on the causes of this unwanted situation. We tested the invertebrate samples with the European Water Framework Directive (Dutch concept version of April 2006), under the assumption that the Seine-Aval should be a natural water. In Table 17 the results are shown.

Table 17. Assessment with the Water Framework Directive (Dutch concept version 4-2006).

section	203-230	247-288	292-324
score	0,35	0,33	0,37
assessment	insufficient	insufficient	insufficient

Compared to a natural river the assessment of the Seine-Aval is insufficient with an average score of 0,33 on a scale from 0 to 1. At the moment it is not possible to test the Seine-Aval against a heavy modified river, since the tools are still in preparation. In contrast with the species diversity, the assessment does not discriminate between the three separate sections.

6.1. Water quality and recent invaders

The Seine-Aval flows through the industrial nuclei of Paris and Rouan. The direct consequences for the aquatic ecosystem can be seen in Figure 1, where the dissolved oxygen content in longitudinal direction is shown.

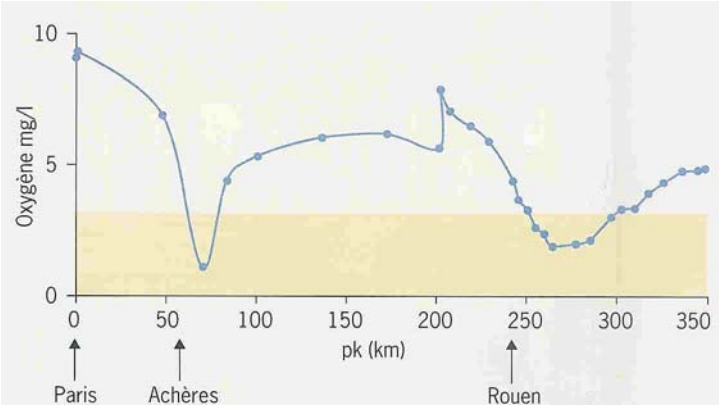

Figure 1. Longitudinal oxygen content in the Seine-Aval as average summer values in 1993-1999 (Billen and Poulin ny).

At the dam of Poses the oxygen content is high, but falls rapidly when approaching Rouan. Further downstream rehabilitation takes place and the oxygen content rises to app. 5 mg/l. It seems no coincidence that the macroinvertebrates in the upper section (km 203-220) coincide with the relative high oxygen content. The middle and lower sections lie in the hatched part of Figure 1, where the critical content of 4 mg O2/l (in the summer half year) is not met.

In comparison we see in Figure 2 the oxygen content (annual average) of the Lower Rhine and the dominant macroinvertebrates on stones in the IJssel (east branch of the Rhine).

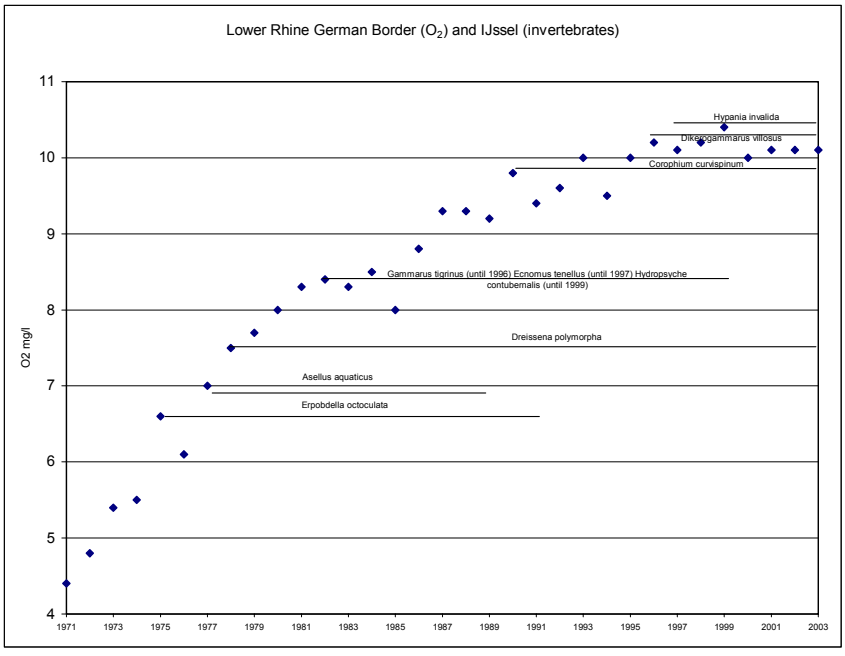

Figure 2. Oxygen content in the Rhine (1971 – 2003) and dominant taxa on stones in the subsequent periods (after Heymen and Van der Weijden, 1991; Bij de Vaate, 2003).

At 1972 the Rhine was black and hardly any invertebrates were encountered except for *Tubificidae* in the mud and Leeches on the stones (personal perception). From 1975 systematic research has been conducted on the stones in the IJssel. *Erpobdella octoculata* was already present and lasted until 1991. *Asellus aquaticus* arrived in 1976

and vanished after 1989. The zebra mussel (*Dreissena polymorpha*) settled in 1978 and is still present. Starting in 1982, a dramatic change took place in the community on the stones. The year average oxygen content has increased to 8 mg/l (app. 6,5 mg/l as average for April – September) which led to the domination of *Gammarus tigrinus* (invader from America) and the indigenous caddis flies *Ecnomus tenellus* and *Hydropsyche contubernalis*. This stage is similar to that of the upper section of the Seine-Aval, where these caddis flies are also present. The middle and lower section (deprived of caddis flies) are in a stage comparable to the Rhine before the 1980's. These three species lasted until 1996 (*Gammarus tigrinus*), 1997 (*Ecnomus tenellus*) and after 1999 also *Hydropsyche contubernalis* disappeared. The second large change occurred in 1990-1997 after the arrival of *Corophium curvispinum*, *Dikerogammarus villosus*, *Hypania invalida* and other ponto-caspian invaders. These species make up for more than 90% of the total community on stones and the indigenous species-richness is deteriorating rapidly. Although *Dikerogammarus villosus* (upper section) and *Hypania invalida* (upper and middle section) are present in the Seine-Aval, they do not seem to suppress the native fauna yet. This however might well be the case when the water quality improves. In the Rhine there is no evidence that indigenous species can cope with these invaders. The macro invertebrate fauna in the Rhine will therefore never meet the objective, the situation in 1725.

6.2. Physical restraints

6.2.1. Currents

As a consequence of the embankment of the Seine-Aval, the water at flood will no longer be divided over the marchlands, but is pushed inwards. At low tide the water will rush downstream. With the peaks in the flow also a lot of suspended material will be transported. The macroinvertebrates are sensitive to the disturbance of their habitat. In other words, as the current grows more intense less species will be able to hold on to their habitat and will drift away with the current. Also habitat (mud and sand) will be flushed away. In Table 17 the current velocities in the different sections of the studied area are shown.

Table 17. Maximum velocities at flood and low tide in the studied area (Le Hir, ny)

Section	**203-230**	**247-288**	**292-324**
Flood	0,0	-0,5 - -1,0	-1,0 - -1,4
Low tide	0,5	0,5 - 1,0	1,0 - 1,3

Considerable differences occur in current velocities in the three sections. With flood the upper section does not flow because of the Poses dam. At low tide the water flows downstream with just 50 cm/s. The peak in suspended solids amounts to 125 mg/l in Rouan (km. 241,8) (Dupont ny). In the middle section the incoming water flows at 0,5 -1 m/s, as fast as the outgoing flow at low tide. The concentration of suspended solids rises to 170 mg/l in Val des Leux (km. 265,5) The most harsh conditions occur in the lower section where the water has an amplitude of 1,4 m/s upstream to 1,3 m/s downstream in each cycle. The suspended solids at Caudebec en Caux peak over 400 mg/l. Considering that the water quality in the lower section is as bad as in the middle section, it seems that the physical conditions in the lower section are limiting for a considerable amount of macroinvertebrates.

6.2.2. Embankments

The second physical restriction is also caused by the embankments. They prevent the development of intertidal marches and are responsible for habitat loss of hundreds of square kilometres. This is also the reason that so few characteristic intertidal species have been collected.

6.2.3. Erosion and sedimentation

The side channels in the section with the islands in the Seine-Aval suffer from rapid sedimentation. The water is so turbid that submerged vegetation cannot develop. In time these channels will be filled up and riverine forest will develop if they are not kept open artificially.

Sedimentation is severe on the shores of the lower section as well. Thick layers of mud prevent any establishment of plant or animal.

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