HYDROBIOLOGISCH ADVIESBURO KLINK

Macroinvertebrates of the Seine Basin

Alexander Klink

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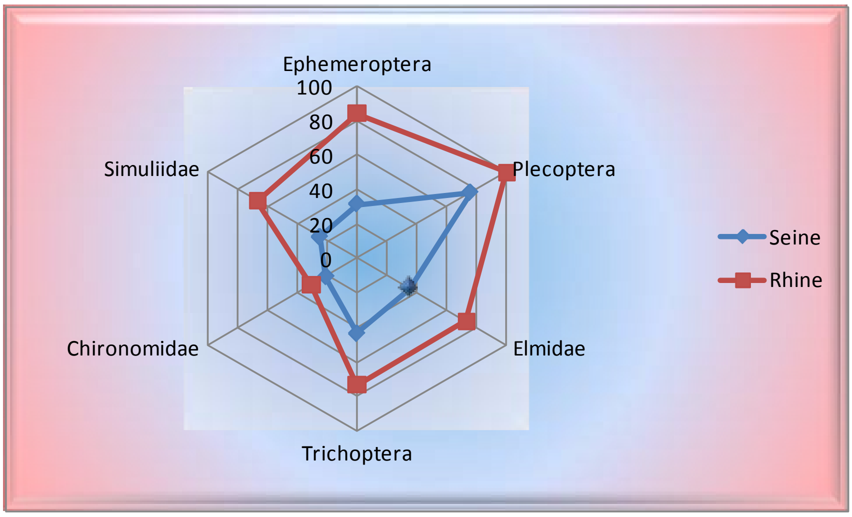
1. Abstract

This report is financed by the Rouen based **Groupement d’Intérêt Public SEINE AVAL** and contains an analysis of macro invertebrate communities in the large rivers in the Seine basin, the Seine Aval and the western streams running to the Seine Aval. The latter samples have been taken by DIREN in 2001-2006. The Seine Aval was examined in 2006 and the basin was sampled in summer 2008 and spring 2009.

Despite the fact that the basin (79,000 km^2) consists of 78% cropland and 20% urbanized surface, the biodiversity is staggering. With relative small effort we collected 571 species and 71% of the potential invertebrate fauna ever found in rivers in this eco region. The most endangered group are the stoneflies of which 76 % is not recovered. In graph 0 we can see the loss of the natural biodiversity (centre of the plot) and the present situation of the Seine and Dutch Rhine (after Klink, 2006).



Graph 0. Loss of the natural biodiversity in the Seine and Dutch Rhine

The present situation in the Seine is deduced from the 20 stations we have investigated. The present situation in the Rhine results from data over the past decades from over 1000 samples. Note that the Plecoptera in the Rhine are extinct (100% loss) and that the Ephemeroptera, Elmidae, Trichoptera and Simuliidae are pushed near extinction.

We tested six different assessment tools and concluded that the best available tool seems to be the “native” Index Biologique Global Normalisé (IBGN). With this tool we assessed the main tributaries as follows:

Table 0. Ecological quality of the Seine basin assessed by IBGN

Navigable	Yonne	Serein	Armançon	Marne	Saulx	Oise	Aisne	Seine	Grand Morin	Loing	Essonne	Eure	Epte
-													
+													

Blue = high; green = good, yellow = moderate and orange = poor

The fact that rivers are suitable for large vessels makes them unsuitable for a good ecological state. In the Lower Seine also considerable pollution was found around Rouen. Of the 10 western streams 3 were considered ecologically moderate (Commerce, Robec and Cailly) and the others good.

From paleo ecological and historical research we have to conclude that the present ecological state of the Seine Aval is bad, but that the recolonization potential from the upstream basin is large. With the elimination of pollution, habitat restoration and river bed adaptations there will be plenty of opportunity for the reestablishment of the original species composition.

Invasive alien species may pose a problem for the native invertebrate community. The most navigable stretches are already infested up to 19% in the Lower Marne. Navigation is the prime vector for these aliens and the planned “Canal Seine North Europe” will add considerable to this problem. This research shows that maintaining the

native diversity is of the utmost importance to keep the aliens on the leash.

Finally, the ecological assessment of surface waters should be based on present biodiversity compared to the natural biodiversity. In this respect information is needed on species level. Therefore the present assessment tools should be adapted and complemented with information on traits and a new presentation tool is needed to show not only the present status, but also the factors hampering the ecological rehabilitation.

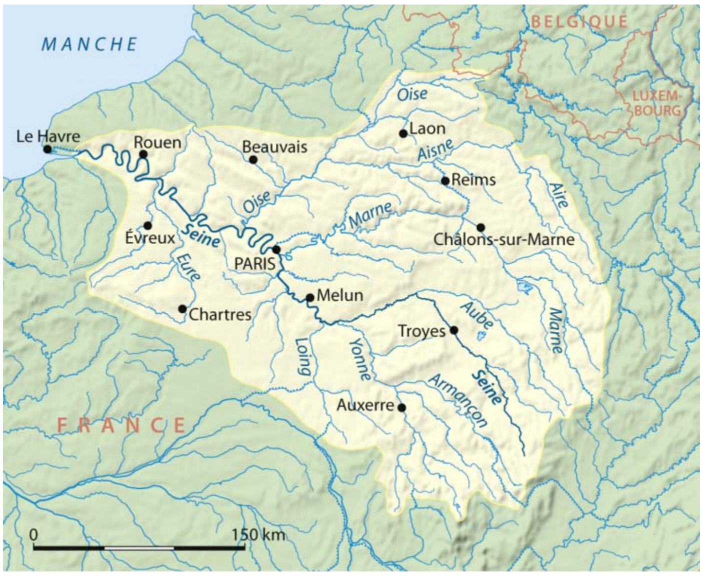
2. Introduction

The European Water framework Directive (WFD) will pose a serious challenge on all stakeholders in the various river basins in Europe. The reason for this research was the collection of basic ecological data on the rivers composing the Seine basin. These data should be put to use for the ecological assessment of the Seine basin. Similarly more information should become available if the Seine tributaries retain species that could return to the now impoverished Seine-Aval if chemical and a-biotic conditions would ameliorate. This information would only make sense if we knew what lives in a more natural freshwater estuary. So part of the job was to find out more about nature-like estuarine communities of invertebrates. Since alien invasions are of global concern this aspect has been plugged in as well. Additionally the DIREN conducted a monitoring program on the small streams entering the Seine-Aval and these samples were identified and taken also into consideration. Finally some thought is given on the research strategy and essential elements in a protocol to investigate experimental sites. This research is commissioned by GIP Seine-Aval (contract: Etude GIP 2008 benthos 1). We are very grateful for this opportunity, since it has led us to the real time experience of what we have learned in the past 25 years from paleo ecological research of old river deposits in the Netherlands. We would extend our acknowledgment to the following persons: Regien Klink and Bram Bij de Vaate for the contribution to the fieldwork and the former also for the excellent meals that kept us going. The sorting crew consisting of Lisanne and Arne Klink, Merel, Bart and Koen Möller and Maarten Kok did a splendid job. Peter Paalvast needs credits for the interpretation of the administrative part of this investigation. Riet Onderstal is acknowledged for the construction of the driftnets, which performed outstanding. Céline Dégremont deserves credits for the coordination of the project on behalf on GIP Seine-Aval.

3. The Seine basin and the sampling stations

3.1. The Seine Basin

The area of the Seine basin comprises almost 79,000 km^2 of which 78% is cropland, 20% is urban and 2% forest. The population density is 210 inhabitants/km^2. No irrigation of the cropland is taken place (http://earthtrends.wri.org/text/water-resources/map-334.html, 2010-1). The basin is mostly located on sedimentary rock (97,5 %) consisting of limestone and chalk, dating back from Oligocene, Eocene and Cretaceous (Ledoux et al., 2007). The upstream parts of the major tributaries have lateral navigation channels. This makes the courses of the rivers near natural in areal view (Photo 1) and most banks possess riparian strips of alluvial forests (Photo 2).

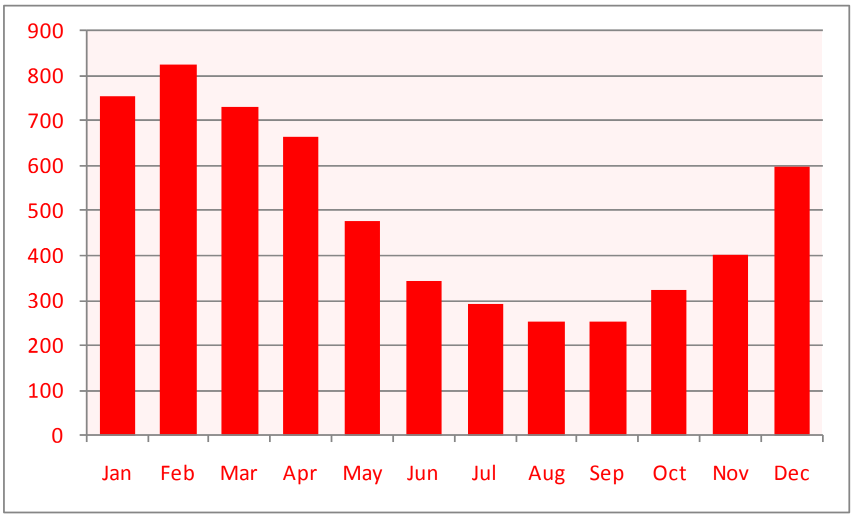


Map 1. Seine basin
(http://nl.wikipedia.org/wiki/Bestand:Seine_bassin_versant.png, 2010-1)

Table 1. Characteristics of the investigated rivers (http://nl.wikipedia.org/wiki/Seine, 2010-1)

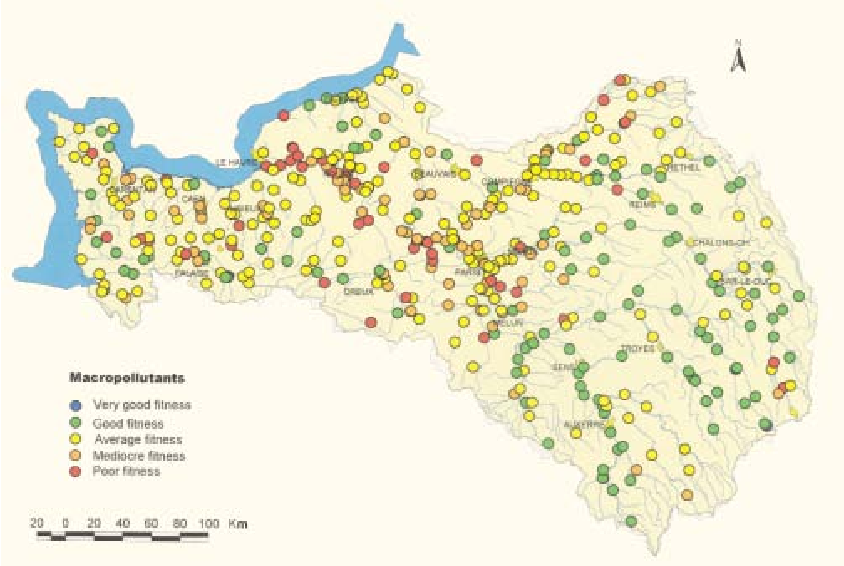
River	Length (km)	Area (km2)	Discharge (m3/s)	Source	Δ H (m)	H/km (‰)	Water quality
l'Aisne	353	7920	65,4	rain	208	0,59	good
l'Eure	228	5935	26,2	rain	137	0,60	mediocre
le Seine	776	78650	563	rain	471	0,61	good
la Marne	525	12680	110	rain	370	0,70	good
l'Oise	341	16667	110	rain	285	0,84	poor
l'Aube	248	4660	41	rain	257	1,04	good
l'Epte	113	1490	9,8	rain	129	1,14	mediocre
le Grand Morin	120	1190	7,61	rain	141	1,18	good
l'Essonne	90	1870	8,4	rain	117	1,30	average
le Loing	166	4150	19	rain	225	1,36	average
l'Armançon	202	2990	29,7	rain	314	1,55	average
Le Saulx	127	2100	25,7	rain	208	1,64	good
le Serein	186	1120	7,74	rain	367	1,97	average
l'Ource	100	736	8,6	rain	215	2,15	good
l'Yonne	292	10700	93	rain	675	2,31	good

Besides the small and the large rivers we can distinguish the lowland rivers and the rivers in hilly regions. True lowland rivers are the Aisne, Oise, Eure, Seine and Marne (gradient < 0,85‰). They lie to a great extend in the northern part of the Seine basin. The other rivers drain the better part of the Southern part and have an average gradient from source to mouth > 1‰. From this group only the Epte runs in the western part of the basin. Another characteristic of the Seine basin is that it is exclusively fed by rainwater, largely trapped in the calcareous aquifers. As a consequence, high discharges are typical for winter, whereas in summertime the discharges are low. At Paris, the Seine has a typical winter discharge of three times the discharge in summer



Graph 1. Mean monthly discharge (m^3/s) of the Seine at Paris (Seine, Wikipédia)

According to the Seine-Normandy Water Agency (AESN 2002) the chemical water quality is good in the major tributaries in their up- and midstream sections. A major exception forms the Oise with bad quality upstream and average quality downstream.



Map 2. Waterquality in the Seine-Normandy basin (AESN, 2002)

Photo 1. Areal view of the Aisne near Guignicourt (Google Earth)

Crucial for retaining of nutrients, metals and pesticides from the cropland are the riparian strips of woodland that are present along most of the rivers. Advocated by Naiman et al. (2005) in their book named Riparia that is completely dedicated to the ecological function of these corridors and the poster session of Wasson and Souchon (2008) on the mitigating function of natural corridors to human impacts on river basins. On Photo 2 a fair example of young riparian forest is given along the Seine upstream.

Photo 2. The Seine near Châtres with alluvial forest (A. Bij de Vaate)

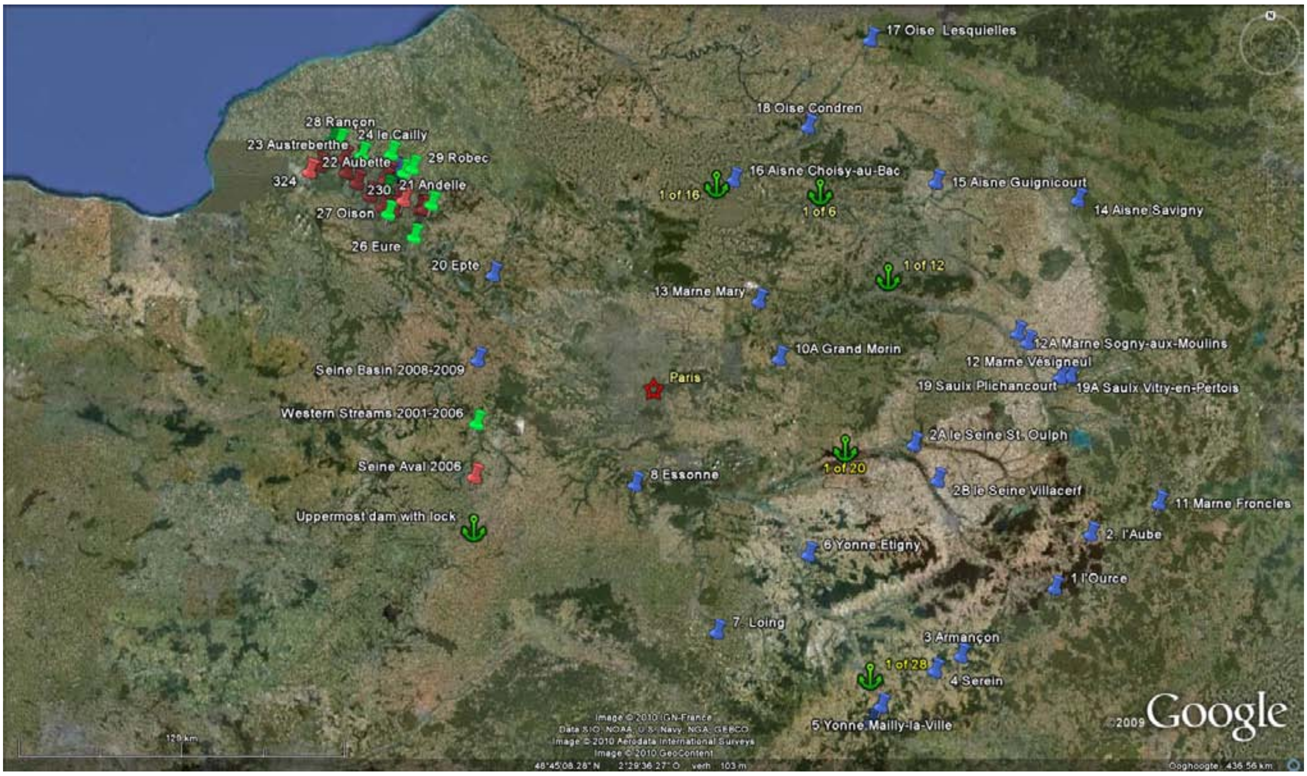
The rivers themselves have numerous small dams, often not much higher than 1-2 m (Photo 3). These dams provide the necessary depth for the navigation channels and serve as artificial riffles that add oxygen to the water.

Photo 3. Example of a small dam upstream in the Marne at Froncles

Further downstream all major tributaries are navigable for large vessels and a total 78 dams and locks have been spotted on Google earth (Seine 20, Yonne 28, Loing 2, Marne 14, Oise 7 and Aisne 7). Furthermore three storage reservoirs on diverted river courses have been constructed in the upper Seine, Aube and upper Marne. These adaptations have been greatly affecting the fish communities in the Seine basin (Boët et al., 1999). Due to the intensifying of the land use and growing population density, the Nitrate concentration of the Seine (at Ivry) has risen from 3 to 16 mg NO_3/l from 1887 to 1986. The Chloride concentration has been tripled in the same period (Meybeck, 1998).

3.2. Sampling stations

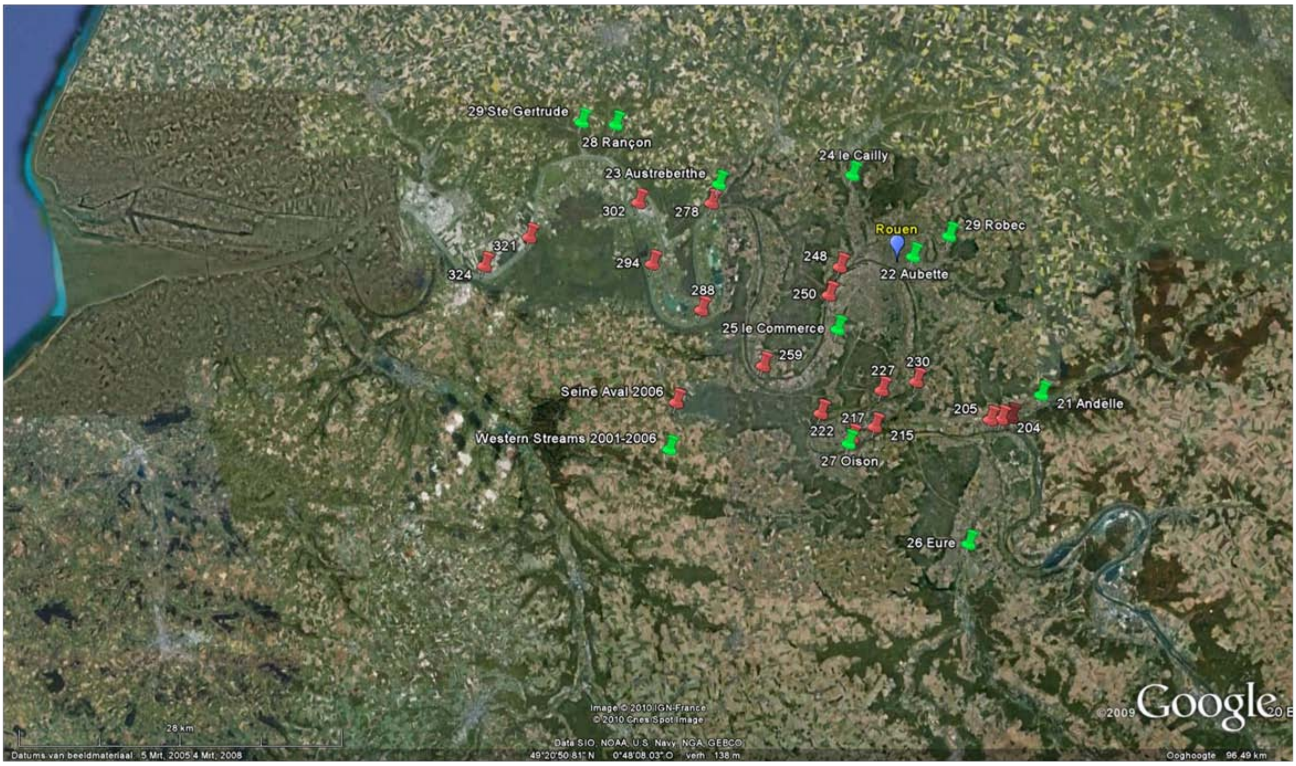
The sampling stations were selected mainly on the expectation that the fauna might be relatively undisturbed. We sought in Google earth for river stretches that were not dammed or otherwise disturbed. Also the whole Seine basin should be covered, meaning that all large tributaries should be included. We had to set a limit to 20 sampling stations for the first year (2008). Of these a selection of 10 stations should be resampled in 2009. This selection depended on the results of the 2008 species quality and diversity. Four sites fell off because they were locked by a dam (Yonne 6, Loing 7, Marne 13 and Aisne 16). The Oise at station 18 is hardly flowing and the littoral zone is silting up, resulting in a deteriorated invertebrate community. Four other stations were dropped for the reason that they are relatively small and contain few species characteristic also of large rivers. These stations are the Grand Morin (10a), Ource (1), Marne (11) and the Epte (20). The streams flowing into the intertidal Seine-Aval have been sampled by the DIREN from 2001 to 2006 on a yearly basis for most of the streams. In 2006 (Bij de Vaate et al., 2007) app. 140 samples were taken in the freshwater section of the Seine-Aval from the dam at Poses (km 203) to Vieux-Port (km. 324). In Map 3 the location of the stations in the entire Seine basin are projected and in Map 4 the stations in the Seine-Aval region are depicted.



Map 3. Sampling stations in the entire Seine basin, including the most upstream locks with dam (green anchor)

Table 2a. Seine Basin 2008-2009

Basin	River	Town	N	E	2008	2009
1	l'Ource	Grancey	49°01'41.93"	04°35'20.38"	24-Jul	
2	l'Aube	Bayel	48°11'53.88"	04°46'49.33"	23-Jul	6-May
2A	le Seine	St. Oulph	48°29'00.69"	03°58'21.21"	23-Jul	
2B	le Seine	Villacerf	48°11'53.88"	04°46'49.33"		6-May
3	Armançon	Pacy	47°46'43.53"	04°5'41.40"	24-Jul	7-May
4	Serein	Annay	47°43'37.94"	03°57'30.98"	24-Jul	7-May
5	l'Yonne	Mailly-la-Ville	47°36'16.12"	03°40'45.66"	24-Jul	
5A	l'Yonne	Châtel-Censoir	47°32'57.13"	03°37'43.14"		7-May
6	l'Yonne	Etigny	48°08'02.58"	03°17'39.51"	25-Jul	
7	le Loing	Montbouy	47°51'37.44"	02°49'16.10"	25-Jul	
8	l'Essonne	Gironville	48°22'13.41"	02°22'56.25"	25-Jul	
10a	Grand Morin	Boissy-le-Châtel	48°48'50.29"	03°07'57.90"	26-Jul	
11	la Marne	Froncles	48°18'05.18"	05°08'47.90	23-Jul	
12	la Marne	Vésigneul-sur-Marne	48°52'09.16"	04°27'15.21"	22-Jul	
12A	la Marne	Sogny-aux-Moulins	48°54'06.91"	04°24'06.34"		5-May
13	la Marne	Mary-sur-Marne	48°11'53.88"	04°46'49.33"	26-Jul	
14	l'Aisne	Savigny-sur-Aisne	49°21'55.99"	04°44'15.49"	22-Jul	4-May
15	l'Aisne	Guignicourt	49°25'48.82"	03°58'11.03"	20-Jul	4-May
16	l'Aisne	Choisy-au-Bac	49°25'58.11"	02°52'51.02"	21-Jul	
17	l'Oise	Lesquielles	49°55'39.39"	03°37'01.71"	21-Jul	8-May
18	l'Oise	Condren	49°37'19.46"	03°16'51.73"	21-Jul	
19	le Saulx	Plichancourt	48°45'06.14"	04°40'54.32"	22-Jul	
19A	le Saulx	Vitry-en-Pertois	48°44'45.34"	04°37'33.83"		5-May
20	l'Epte	Gasny	49° 05'14.21"	01°36'26.20"	28-Jul	



Map 4. Sampling stations in the Seine-Aval (red) and selected streams by the DIREN (green)

Table 2b. Seine Aval 2006

Seine Aval	River	Town	N	E	2006
pk 203	Seine Aval	Pitres	49°18'41.89"	01°13'50.30"	19-Jun
pk 204	Seine Aval	Pitres/Le Manoir	49°18'36.83"	01°13'07.62"	19-Jun
pk 205	Seine Aval	Le Manoir	49°18'35.23"	01°12'19.86"	19-Jun
pk 215	Seine Aval	Martot	49°18'15.83"	01° 04'04.36"	20-Jun
pk 217	Seine Aval	Caudebec-les-Elbeuf	49°17'44.74"	01° 02'25.70"	20-Jun
pk 222	Seine Aval	Orival	49°18'51.35"	01° 00'18.18"	19-Jun
pk 227	Seine Aval	Oissel	49°19'57.90"	01° 04'34.07"	19-Jun
pk 230	Seine Aval	Le Hamel	49°20'22.45"	01° 07'03.58"	20-Jun
pk 248	Seine Aval	Dieppedalle	49°25'43.40"	01° 01'33.91"	16-Jun
pk 250	Seine Aval	Petit-Couronne	49°24'24.49"	01° 00'46.99"	16-Jun
pk 259	Seine Aval	La Bouille	49°21'06.01"	00°56'04.14"	18-Jun
pk 278	Seine Aval	Duclair	49°28'41.36"	00°52'21.58"	17-Jun
pk 288	Seine Aval	Yville-sur-Seine	49°23'41.85"	00°51'39.29"	17-Jun
pk 294	Seine Aval	Jumièges	49°25'50.01"	00°48'07.73"	17-Jun
pk 302	Seine Aval	Le Trait	49°28'42.55"	00°47'07.16"	17-Jun
pk 321	Seine Aval	St-Maurice-d-Etelan	49°27'03.62"	00°39'18.49"	18-Jun
pk 324	Seine Aval	Vieux Port	49°25'41.88"	00°36'06.12"	17-Jun

Table 2c. Western streams sampled by DIREN (2001-2006)

Streams	River	Town	N	E	2001	2002	2003	2004	2005	2006
21	Andelle	Pont St. Pierre	49°19'44.78"	01°15'59.70		11-Jun	28-May	23-Jul	12-Jul	20-Jun
22	Aubette	Rouen	49°26'12.69"	01°06'48.41"		7-Aug	6-Jun	2-Sep	12-Jul	20-Jun
23	Austreberthe	Duclair	49°29'34.67"	00°52'52.46"		28-May	14-May	1-Sep	11-Jul	23-Jun
24	Cailly	Canteleu	49°30'00.57"	01°02'26.13				5-Aug	13-May	21-Jun
25	Commerce	Petit-Couronne	49°22'48.76"	01°01'23.83"		7-Nov		17-Aug	17-Aug	6-Sep
26	Eure	Louviers	49°12'47.60"	01°10'45.63"				28-Jul	11-Aug	9-Aug
27	Oison	Caudebec-les-Elbeuf	49°17'28.73"	01°02'11.69"	1-Aug	5-Aug	28-May	2-Sep	20-Jul	20-Jun
28	Rancon	Rançon	49°32'19.93"	00°45'27.01"		5-Aug	12-Jun	1-Sep	11-Jul	21-Jun
29	Robec	Rouen	49°27'10.32"	01°09'22.92"		7-Aug	6-Aug	2-Sep	12-Jul	20-Jun
30	Ste Gertrude	Ste. Gertrude	49°32'26.16"	00°43'00.76"		5-Aug	7-Aug	1-Sep	11-Jul	21-Jun

4. Methods

4.1. Sampling methods

The samples taken by hydrobiologisch Adviesburo Klink consisted of three subsamples in each station. One subsample was taken from the riverbed with a hand net (mesh 0,5 mm, width 30 cm, height 20 cm see Photo 4), covering 5 m with a sampled area of 1.5 m^2.

Photo 4. Handnet (photo A. bij de Vaate)

The second subsample consisted of solid substrates like wood or stones and vegetation. Wood and stones were brushed off and vegetation was collected with the handnet. In the case of wood and stones the surface was measured and the covering surface of the sampled vegetation was noted. All the collected material was pooled to one sample. A third subsample consisted mainly of exuviae collected by the handnet (2008) or by driftnet (2009, Photo 4). The purpose of this sample was mainly to get a good impression of the chironomid species composition of the river stretch. The chironomid larvae collected in the former samples are, in contrast to exuviae in many cases not identifiable to species level. The driftnet hung in the current during the whole sampling time (app. 1.5 hour).

Photo 5. Driftnet used to collect exuviae (diameter opening 60 cm)

4.2. 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 macro invertebrates 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.

4.3. Identification

Most samples are fully identified to species level (if possible). Exception is made for the 2008 stations that were rejected for the 2009 investigation. Of these samples only the Ephemeroptera, Plecoptera, Odonata, Elmidae and Trichoptera were identified on behalf of the biological assessment. For the Chironomidae a combination of larval and exuvial taxonomy was used to obtain the most detailed taxonomic level. The list of identification literature is given in the Literature section.

Photo 6. The Mayfly Ephemera danica

5. Results

5.1. Biodiversity of macro invertebrates in the Seine basin

The biodiversity in the Seine basin and western streams, according to only this research amounts to a total number of 571 taxa. In Table 2 the numbers par group are specified.

Table 3. Biodiversity of the macro-invertebrates in the dataset

Group	Number
Oligochaeta	36
Hirudinea	21
Mollusca	50
Hydrachnidia	38
Crustacea	17
Ephemeroptera	37
Plecoptera	6
Coleoptera	54
Trichoptera	64
Chironomidae	192
Simuliidae	12
Other Diptera	27
Minor groups	17
Total taxa	571

Of these species app. 460 have been found in the large rivers. The remaining species are exclusive for the western streams. The number of 460 is surprisingly almost identical to the 498 species that have been known to life in the Dutch Rhine in the period around 1725 – 1900 (Klink, 2006). Around 2000 the diversity in the Rhine has dropped to 330 species and with the recent invaders this number will be declining further.

In the following 10 tables you will be given an overview of the Mayflies, Stoneflies, Elmid beetles, Caddisflies, Midges (4 tables) Blackflies and Watermites in the Seine basin. The primary meaning of these tables is to give inside information for the specialists who know the meaning of the Latin names. The “normal” readers however will also get the hang of these tables once they realize that each name stands for a unique living contribution to the river ecosystem and food web. These tables will also tell a pertinent tale of the immense changes that occur during the journey downstream.

The tables are constructed after a first cluster analysis by TWINSPAN (Hill, 1979) on the whole dataset. This analysis showed that five distinct types of running water can be identified. The first group are the western streams (excl. Eure). The second group consists of the small rivers (Ource, Loing, Essone and Grand Morin). The next group are the large rivers condensed to the Yonne (including Armançon and Serein), Seine (including Aube), Marne (including Saulx) and Oise (including Aisne). The next groups are formed by Eure and Seine Aval. From these tables also the recolonization potential can be deduced. This potential is formed by the species present in the larger rivers. The species exclusively present in the streams and small rivers can be excluded since they form no intricate part of the large river fauna. Finally must be added that the data from the Seine-Aval consist also the most upstream part between the Pose dam and Rouen. This short stretch from km 203 to 230 (called Zone T1[a] in Bij de Vaate et al., 2007) contains a relative diverse species composition compared to freshwater downstream section from km 230 to km 324. These species form in fact the most ready available recolonization potential for the lower part of the Seine-Aval.

After each table we compare the species which we have encountered with the total of species known from ecoregion 13 and biotope 4 according to the Limnofauna Europapaea (Illies, 1978). Ecoregion 13 comprises the basins of the Meuse, Seine Loire, Garonne and Rhone up to the altitude of 500 m asl. Biotope 4 are rivers and large streams. This comparison will at least give us an impression about the present biodiversity in the research area. In Table 2 we start with the Mayflies, a group of primitive insects that are highly vulnerable in respect of water pollution.

Photo 7. The Mayfly Heptagenia longicauda

Table 4. Distribution and species composition of the Mayflies (Ephemeroptera) in the Seine basin

Distribution of the Mayflies (Ephemeroptera) in the Seine basin (37 species)	streams west of Rouen	small rivers	Yonne	Seine Amont	Marne	Oise	Eure	Seine Aval
Baetis buceratus	+	++	+++	++	+++	+++	+++	
Baetis fuscatus		++	+++	++	+++	+++		
Baetis liebenauae	+++	++	+++			++	+++	
Baetis lutheri		++		++				
Baetis rhodani	+++	++	+++	++	+++	++	+++	
Baetis scambus	+	++		++	+++			
Baetis vernus	+++	+++	++	++	+++	+++	+++	
Caenis beskidensis	+			++				
Caenis horaria		++	++			++		
Caenis luctuosa		+++	+++		++	++		
Caenis macrura		++	+++	+++	+++	+++	+++	+++
Caenis pseudorivulorum					++	++		
Centroptilum luteolum		+++	+++	+++	+++	+++	+++	
Cloeon dipterum		++	++	++		++	+++	
Cloeon simile			++					
Ecdyonurus aurantiacus						++		
Ecdyonurus dispar			+++		++			
Ecdyonurus gr. venosus		++	+++	++		++		
Ecdyonurus insignis			+++					
Ecdyonurus torrentis			+++					
Ecdyonurus venosus			++					
Ephemera danica	++	+++	+++	+++	+++	+++		
Ephemera glaucops				++		++		
Ephemera vulgata			++					
Ephoron virgo			+++		+++	++		
Heptagenia flava					+++	+++		
Heptagenia longicauda					++	++		
Heptagenia sulphurea	++		+++	++	+++	+++	+++	++
Kageronia fuscogrisea						++		
Oligoneuriella rhenana					+++			
Paraleptophlebia submarginata					++	+++		
Potamanthus luteus			++		+++	+++		
Procloeon bifidum			+++		++	++	+++	
Procloeon pennulatum		++	+++	++	+++	+++		
Serratella ignita	+++	+++	+++	+++	+++	+++	+++	++
Siphlonurus aestivalis						++		
Torleya major				++	++			
Number of species	9	16	24	17	22	26	10	3

A total of 37 species have been identified in this research.

In an orderly manor the species composition changes from the streams and small rivers to rivers with a high gradient (Yonne, Armançon and Serein) to typical lowland rivers as the Oise, Eure and the freshwater estuary of the Seine Aval. In the Oise basin (including Aisne) the most species have been encountered among which *Heptagenia longicauda*, a rare species of lowland rivers. *Siphlonurus aestivalis*, is a typical species inhabiting banks and temporary pools that fall dry in spring.

Photo 8. Temporary pool along the Aisne (nr. 14) containing many larvae of Siphlonurus aestivalis in May 2009

In the Seine Aval only three species are found and only *Caenis macrura* was collected downstream Rouen. The Eure might be an important supplier for the more sensitive species in the Seine Aval.

According to the Limnofauna Europaea (Illies, 1978) a total of 54 species has ever been collected from the rivers (Biotope 4) in the Seine Basin (Ecoregion 13). Species which are considered extinct are *Palingenia longicauda* and *Prosopistoma foliaceum*. Among the other missing species belong *Isonychia ignota*, *Rhitrogena germanica*, *Ecdyonurus affinis*, *E. lateralis*, *E. macani*, *Heptagenia coerulans,*

Ephemerella notata, Neoephemera maxima, Brachicercus harisella, Thraulus bellis, Leptophlebia marginata, Paraleptophlebia werneri Habrophlebia fusca. Ephemera lineata and Siphlonurus lacustris. At the moment we cannot be sure if these species have been disappeared from the Seine basin. After all only 20 sampling stations have been investigated. For the mayflies as a group the Seine basin is still a very important ecosystem.

Table 5. Distribution and species composition of the Stoneflies (Plecoptera) in the Seine basin

Distribution of the Stoneflies (Plecoptera) in the Seine basin (6 taxa)	streams west of Rouen	small rivers	Yonne	Seine Amont	Marne	Oise	Eure	Seine Aval
Nemouridae	+		++		++			
Leuctra fusca	++	++	+++	+++	++			
Leuctra geniculata		++	+++	++	+++	+++		
Isoperla diffiformis				++				
Isoperla grammatica				+++				
Siphonoperla torrentium						++		
Number of species	2	2	3	4	3	2		

Stoneflies are relatively rare in the Seine basin. The main reason will by the low gradient and high temperature, since stoneflies are very sensitive to low oxygen levels. In only one stream (Andelle) stoneflies have been found in larger (> 10) numbers. In the Oison and Rançon only a single specimen of *Leuctra fusca* has been caught. The stoneflies (especially *Leuctra fusca* and *L. geniculata*) are most abundant in the upper reaches of the Yonne, Seine and Marne. The three *Isoperla* species have exclusively been found in the Aube and *Siphonoperla torrentium* lives in the upper Aisne. According to the expectation no stoneflies have been collected in the Eure and Epte. In contrast with the mayflies, the stonefly diversity has suffered very badly. The rivers of the Seine watershed were home to a total of 25 species. Of this number we were able to retrieve no more than 7 taxa. In 1948, Geijskes already noted that the immense decline of the Plecoptera fauna in the large Dutch rivers had been started in the 19th century with water pollution and habitat destruction as main causes. The last stoneflies from the Dutch Rhine have been collected over half a century ago (Collection Dept. Entomology Agr. Univ. Wageningen NL). The missing species are: *Brachyptera braueri, Taeniopteryx araneoides, T. nebulosa, Amphinemoura sulcicollis Protonemoura intricata, P. meijeri, Leuctra digitata, L. hippopus, L. inermis, L. major, L. nigra, Capnia bifrons, C. nigra, Isoperla grammatical, I. obscura, Perlodes microcephala, Marthamea vitripennis, Xanthoperla apicalis and Perla burmeisteriana*.

Table 6. Distribution and species composition of the Elmid beetles (Elmidae) in the Seine basin

Distribution of Beetles (Elmidae) in the Seine basin (15 species)	streams west of Rouen	small rivers	Yonne	Seine Amont	Marne	Oise	Eure	Seine Aval
Riolus subviolaceus	+++	++	++	++	+++	+++		
Stenelmis canaliculata	+	++	+++	+++	+++	+++		
Riolus cupreus	+	++	+++	+++	+++	+++		
Oulimnius tuberculatus	++	+++	+++	+++	+++	+++	+++	
Elmis obscura	+						+++	
Macronychus quadrituberculatus		++	+++	++	+++	+++	+++	
Limnius opacus			+++					
Riolus cf. illiesi			++					
Normandia nitens			++	++	+++			
Elmis maugetii			+++	++		+++		
Limnius muelleri			+++	++	+++	++		
Potamophilus acuminatus			++	+++	+++	++		
Elmis aenea	+++	+++	+++	+++	+++	+++	+++	++
Limnius volckmari	+++	+++	+++	++	+++	++	+++	++
Esolus parallellepipedus	++	+++	+++	+++	+++	+++	+++	++
Number of species	8	8	14	12	11	11	6	3

Elmidae are sensitive for low oxygen levels since they do not (like other water beetles) breathe air, but depend on diffusion of dissolved oxygen to their layer of fur (plastron). Despite that fact all rivers contained representatives of this group. Even in the Seine Aval three species have been found. Of these *Esolus paralellepipedus* was collected in the whole freshwater stretch of the Seine Aval. Except *Limnius opacus* (Armançon, Yonne and Serein) and *Riolus cf. illiesi* (Armançon), no other species seem to prefer high gradient rivers. The occurrence of *Macronychus quadrituberculatus* and *Potamophilus acuminatus* coincides with the presence of wood in which they eat mines. In all the stations in the large rivers wood is present (often in small quantities however) and was sampled. The 15 collected species are a reasonable proportion of the total of 23 species mentioned for rivers (biotope 4) in Eco-region 13. Species that have not been found are: *Elmis rioloides, Esolus pygmaeus, Limnius intermedius, Oulimnius major, O. rivularis, O. troglodytes, Dupophilus brevis* and *Stenelmis consobrina*.

Table 7. Distribution and species composition of the Caddisflies (Trichoptera) in the Seine basin

Distribution of the Caddisflies (Trichoptera) in the Seine basin (58 species)	streams west of Rouen	small rivers	Yonne	Seine	Marne	Oise	Eure	Seine Aval
Adicella reducta	++							
Drusus annulatus	++							
Limnephilus rhombicus/politus	++							
Odontocerum albicorne	++							
Lasiocephala basalis	+							
Limnephilus bipunctatus	+							
Limnephilus rhombicus	+							
Limnephilus subcentralis	+							
Melampophylax mucoreus	+							
Potamophylax latipennis	++	++						
Chaetopteryx villosa	++	++						
Limnephilus lunatus	++		++		++			
Potamophylax cingulatus	++		++		++			
Silo nigricornis	++			++				
Tinodes spec.	+							
Halesus radiatus	++	++	++		++	++		
Potamophiylax rotundipennis	++					++		
Rhyacophila dorsalis	+++	++	+++	+++	+++	++		
Lype phaeopa	+	+++	+++	+++	+++	+++		
Ithytrichia lamellaris	+			++	+++	+++		
Hydropsyche siltalai	++	++	+++	++	+++		+++	
Sericostoma personatum	++	++					+++	
Hydropsyche pellucidula	++	+++	+++	+++	+++	+++	+++	
Athripsodes albifrons	+		+++	++	+++	++	+++	
Cheumatopsyche lepida	+	++	+++	++	+++	++	+++	
Agapetus fuscipes	+++			++			+++	
Tinodes waeneri	+	++	+++		++	++		
Hydropsyche angustipennis	+	++			++	++		
Notidobia ciliaris		++	++					
Plectrocnemia geniculata		++	+++	++				
Anabolia nervosa		++	+++		+++			
Hydropsyche exocellata		++	++		++			
Mystacides nigra		++			++			
Oecetis notata		++	++		++	+++		
Polycentropus flavomaculatus		+++	+++	++	+++	+++		
Psychomyia pusilla		++	+++	+++	+++	+++		
Goera pilosa		++	+++		+++	++	+++	
Athripsodes cinereus		++	+++	++	+++	+++	+++	
Mystacides azurea		++	+++	+++	+++		+++	
Cyrnus trimaculatus		+++	+++		+++	+++		
Brachycentrus subnubilus		++			+++	++		
Molanna angustata		++				++		
Chimarra marginata			++					
Oxyethira spec.			++					
Athripsodes bilineatus			++					
Ceraclea dissimilis			++	++	++	++		
Hydropsyche incognita			+++			++		
Metalype fragilis				++				
Setodes agentipunctellus				++				
Ylodes spec.					++			
Setodes "viridis"?					+++	++		
Ceraclea annulicornis						++	+++	
Hydroptila spec.	+++	+++	+++	+++	+++	+++	+++	++
Lepidostoma hirtum	+	++	+++	++	+++		+++	++
Neureclipsis bimaculata		++	++		++	+++	+++	++
Ecnomus tenellus		++	++		++	++		++
Hydropsyche contubernalis			++	++	++	+++	+++	++
Number of species	31	29	31	20	31	26	15	5

Of the 58 encountered species 9 are exclusively collected in the streams and 2 in the small rivers (Ource, Loing, Essone and Grand Morin). Only a very limited number occurs in all streams and rivers. Of the 5 species in the Seine-Aval only *Neureclipsis bimaculata* have been found downstream Rouen. Characteristic river species exclusively found in the Yonne basin are *Athripsodes bilineatus* (Armançon 1 ind.) and *Chimarra marginata* (Yonne, 1 ind.). In the Aube, *Metalype fragilis* (2 ind.) and *Setodes argentipunctelles* (more abundant) were collected. An unidentified juvenile larvae of *Ylodes* was found in the Saulx.

When we compare the 58 collected species with the total number of 97 river species in Eco-region 13 we have to conclude that they also are severely endangered. The following species have been missed in this research: *Rhyacophila nubila, R. pascoe, Glossosoma boltoni, Agapetus laniger, Agraylea multipunctata* (trivial species), *Allotrichia pallicornis, Orthotrichia angustella, O. costalis, Hydropsyche ornatula, H. saxonica, Polycentropus irroratus, Oligoplectrum maculatum, Micrasema setiferum, Limnephilus germanus, L. hirsutus, L. sericeus, Grammotaulius nitidus, G. signatipennis, Anabolia furcata, Phacopteryx brevipennis, Halesus digitatus, Micropterna sequax, Allogamus ligonifer, Annitella obscurata, Silo pallipes, S. piceus, Athripsodes commutatus, A. leucophaeus, Ceraclea alboguttata, C. nigronervosa, C. riparia, Ylodes ochreelus, Y. simulans, Oecetis testacea* (trivial species), *O. tripunctata, Setodes punctatus, Leptocerus interruptus, L, lusitanicus* and *Molanna albicans*.

Table 8. Distribution and species composition of the Midges (Chironomidae) in the Seine basin I: Tanypodinae (* no data)

Distribution of Midges 1 (Tanypodinae) in the Seine basin (21 taxa)	streams west of Rouen	small rivers*	Yonne	Seine Amont	Marne	Oise	Eure	Seine Aval
Macropelopia nebulosa	+++							
Conchapelopia melanops	++							
Thienemannimyia spec? Langton	+		++					
Conchapelopia Pe1 Langton	++			++	++			
Apsectrotanypus trifascipennis	++			++	++	++		
Conchapelopia pallidula	++		+++	+++	++	+++		
Procladius spec.	++		+++	+++	+++	+++	+++	++
Ablabesmyia longistyla			+++	++	+++	+++	+++	
Ablabesmyia monilis			+++	++	+++	+++		
Tanypus kraatzi			++					
Conchapelopia viator			++	++				
Hayesomyia tripunctata			++	++		++		
Nilotanypus dubius			+++	++	+++	+++		
Rheopelopia ornata			++	++		+++		
Tanypus punctipennis			+++	++		+++		
Telopelopia fascigera			++			++		
Thienemannimyia vitellina			+++			+++		
Clinotanypus nervosus			++					++
Rheopelopia maculipennis				++				
Thienemannimyia carnea				++				
Thienemannimyia pseudocarnea							+++	
Number of taxa	7		14	13	7	11	3	2
* only identified to family level								

Of the subfamily of Tanypodinae 21 taxa have been identified. A number of them cannot be identified in the larval stage and their names are based on the collected empty pupa skins (exuviae). *Macropelopia nebulosa* and *Conchapelopia melanops* have only been found in the western streams. Trivial species of stagnant and slow flowing waters are *Clinotanypus nervosus, Tanypus kraatzi* and *T. punctipennis.* The other species are more or less confined to flowing waters. Typical inhabitants of rivers are *Hayesomyia tripunctata, Nilotanypus dubius, Rheopelopia ornata* and *Telopelopia fascigera* (Fittkau and Murray, 1986). In the Limnofauna Europaea (Illies, 1978) only two missing species fit the criteria of biotope 4 and Eco-region 13. One of them is the trivial *Psectrotanypus varius*. The other is *Trissopelopia longimanus*. This species however may also be found in small seepage area's (Klink, 1980; Vallenduuk and Moller Pillot, 2007). The conclusion must be that in the 70's of last century very few data were available form the Chironomidae in the rivers of this regeion The exuviae described by Langton (1991) as *Thienemannimyia spec?* and *Conchapelopia Pe 1* belong to species as jet unknown. The Eure, Seine Aval and to a lesser extend, the Marne are less favourable for the true rheophilic Tanypodinae.

Table 9. Distribution and species composition of the Midges (Chironomidae) in the Seine basin II (Orthocladiinae)

Distribution of Midges 2 (Orthocladiinae) in the Seine basin (55 taxa)	streams west of Rouen	small rivers*	Yonne	Seine Amont	Marne	Oise	Eure	Seine Aval
Paratrissocladius excerptus	++							
Eukiefferiella brevicalcar	+							
Metriocnemus hygropetricus agg.	+							
Rheocricotopus glabricollis	+		++					
Brillia modesta	++		++	++				
Paracricotopus niger	++		+++	++				
Cricotopus triannulatus	+			+++				
Eukiefferiella claripennis	++			++				
Metriocnemus hirticollis agg.	+			++				
Tvetenia discoloripes	+++		+++			++		
Brillia flavifrons	+		+++	+++	+++	++		
Nanocladius rectinervis	++		+++	++	++	++		
Eukiefferiella ilkeyensis	+++		+++	+++	+++	++		
Paracladius conversus	+		+++	++	++	+++		
Parametriocnemus stylatus	+		+++	++	++	+++		
Orthocladius (O) rubicundus	+		+++	+++	+++	+++		
Cricotopus trifascia	++		+++	+++	+++	+++	+++	
Rheocricotopus fuscipes	+++		++	+++	++	++	+++	
Synorthocladius semivirens	++		+++	+++	+++	+++	+++	
Eukiefferiella clypeata			++					
Eukiefferiella coerulescens			++	++				
Thienemanniella flaviforceps			++	++				
Thienemanniella majuscula			+++	++				
Orthocladius (O) oblidens			+++	++	+++	++		
Cardiocladius fuscus			+++	++	++	+++		
Cricotopus annulator			+++	+++	+++	+++		
Cricotopus tristis			+++	++		+++		
Cricotopus vierriensis			+++	++	+++	++		
Eukiefferiella gracei			+++	+++	++	++		
Tvetenia verralli			++	+++		+++		
Nanocladius balticus			++			++		
Eurycnemus crassipes				++				
Euorthocladius frigidus				++				
Orthocladius (Eudactylocladius) spec.				++				
Parorthocladius nigritus				+++				
Rheocricotopus atripes				++				
Epoicocladius flavens				++		++		
Orthocladius (Euorthocladius) thienemanni				+++	+++	++		
Orthocladius (O) Pe1				++		++		
Corynoneura lobata					++			
Psectrocladius sordidellus gr.					++			
Thienemanniella clavicornis					++			
Orthocladius majus					+++	+++		
Orthocladius (Euorthocladius) rivicola						++		
Parakiefferiella Pe1						+++		
Cricotopus bicinctus	+++		+++	+++	+++	+++	+++	+++
Cricotopus sylvestris	+++		+++	+++	++	+++	+++	+++
Paratrichocladius rufiventris	++		+++	+++	+++	+++		++
Tvetenia calvescens	+++		+++	+++	+++	+++	+++	++
Limnophyes spec.	+							+++
Nanocladius bicolor	+							+++
Rheocricotopus chalybeatus			+++	+++	+++	+++	+++	+++
Cricotopus intersectus								+++
Pseudosmittia								++
Thalassosmittia thalassophila								++
Number of taxa	25		30	37	24	29	7	10

Of the Orthocladiinae 55 taxa have been collected. Only three of them seem to be confined to small streams. *Paratrissocladius excerptus* has been collected in the Andelle and Aubette. *Eukiefferiella brevicalcar* in the Austreberthe (1 ind.) and *Metriocnemus hydropetricus agg*. in the Aubette. The group from *Brillia flavifrons* to *Orthocladius (O) rubicundus* has been found in the streams and rivers except Eure and Seine Aval. *Cricotopus trifascia, Rheocricotopus fuscipes* and *Synorthocladius semivirens* have been collected on all sites but the

Seine Aval. Trivial species like *Cricotopus bicinctus*, *C. sylvestris*, *Paratrichocladius rufiventris* and *Tvetenia calvescens* occur everywhere. Species confined to a single river are: *Eukiefferiella clypeata* (upper Yonne), *Eurycnemus crassipes* (Aube), *Euorthocladius frigidus* (Aube), *Orthocladius (Eudactyloladius) spec.* (Aube), *Parorthocladius nigritus* (Aube and Upper Seine and *Rheocricotopus atripes* (upper Seine). *Corynoneura lobata* (Saulx), *Thienemanniella clavicornis* (Saulx), *Orthocladius (Euorthocladius) rivicola* (Aisne), *Parakiefferiella Pe1* (Oise, Aisne). The Eure with only 7 taxa shown no typical species, but in the Seine Aval three “own” taxa have been collected. *Cricotopus intersectus* is a trivial species of standing and slow flowing eutrophic waters. *Pseudosmittia* species are terrestrial and may occur in the intertidal belt. *Thalassosmittia thalassophila* is the only species confined to the freshwater intertidal of large rivers (Bij de Vaate et al., 2007). Species that could be considered missing according to the Limnofauna Europaea are: *Cardiocladius capucinus, Cricotopus albiforceps, C. festivellus, C. flavocinctus, C. pilitarsis, C. relucens, C. tremulus, C. tricinctus* and *Eukiefferiella similis*. In this respect the Orthocladiinae fauna of the Seine basin seems rather unaffected.

Table 10. Distribution and species composition of the Midges (Chironomidae) in the Seine basin III (Chironomini)

Distribution of Midges 3 (Chironomini) in the Seine basin (54 taxa)	streams west of Rouen	small rivers*	Yonne	Seine Amont	Marne	Oise	Eure	Seine Aval
Chironomus riparius agg.	+							
Demicryptochironomus vulneratus	+		+++		+++	+++		
Polypedilum albicorne	++		++	++				
Paracladopelma gr. laminata	++		++		+++	+++		
Paracladopelma nigritula	++					++		
Polypedilum laetum	++		++	++	++	++		
Paratendipes albimanus	++		+++	+++	+++	+++	+++	++
Phaenopsectra flavipes	+		+++	++	+++	+++		++
Polypedilum convictum	++		+++	+++	++	++	+++	++
Chironomini genus C Wiederholm			+++					
Chironomini gen? sp? Pe4 Langton			++					
Cryptochironomus albofasciatus			+++					
Cryptotendipes holsatus			++					
Cryptochironomus gr. obreptans			+++	++		++		
Microtendipes britteni			+++	+++		++		
Cryptochironomus denticulatus			+++	++	++	++		
Polypedilum acifer			++		++	++		
Polypedilum bicrenatum			++			++		
Harnischia fuscimana			++			++		
Microtendipes diffinis			+++	++	+++	+++		
Cryptotendipes Pe 1C			+++	++	+++	+++		
Stenochironomus gibbus			+++	+++	+++	+++		
Polypedilum pedestre			+++	+++	++	+++		
Cryptochironomus rostratus			+++	++	++	+++	+++	
Microtendipes chloris gr			++	++				++
Xenochironomus xenolabis			+++	++				++
Harnischia spec.			++	++	+++	++		++
Dicrotendipes nervosus			++		++	+++	+++	+++
Cryptochironomus supplicans			+++					++
Polypedilum scalaenum			++	++	++	+++		+++
Polypedilum cultellatum			+++	+++	++		+++	++
Polypedilum nubeculosum			+++	++	+++	+++	+++	++
Harnischia curtilamellata				++		+++		
Kiefferulus tendipediformis				++		+++		
Chironomus acutiventris				++	+++	++		
Chironomus bernensis				++	++	++		
Paralauterborniella nigrohalteralis				++	++	+++		
Endochironomus albipennis					++			++
Kloosia? spec?						++		
Paracladopelma near mikiana						++		
Stictochironomus maculipennis						++		
Stictochironomus pictulus						++		
Cladopelma gr. laccophila						++		
Cryptotendipes pseudotener						++		
Dicrotendipes notatus						++		
Glyptotendipes paripes						+++		+++
Parachironomus arcuatus						++		++
Chironomus nudiventris								++
Cryptochironomus defectus								++
Dicrotendipes lobiger								++
Polypedilum sordens								++
Glyptotendipes pallens								+++
Parachironomus longiforceps								+++
Parachironomus spec. Kampen								++
Number of taxa	9		30	24	22	36	6	21

Chironomini are foremost represented in stagnant and slow flowing waters. It is not surprising that in the western streams only one taxon (Chironomus riparius agg.) has been collected. This taxon is by no means characteristic for streams however. It also lives on mud bottoms in the potamal zone (Lehmann, 1971) as well as in rain polls, ditches and ponds (Moller Pillot, 2009). Although Chironomidae and especially Chironomini generally are considered ubiquists, only three species have been found in all categories (*Paratendipes albimanus, Polypedilum convictum* and *Phaenopsectra flavipes*, missing in the Eure). A typical species in the Yonne basin is *Chironomini gen. C* Wiederholm (Upper Yonne) as exuviae and a very aberrant larva that is possibly conspecific. This taxon is new to Europe according to

Wiederholm (1986) who states that one species is known from North America and congeneric exuviae have been collected in China and East Africa. *C. gen? sp? Pe4* Langton (Serein) is only known from a Spanish stream (Laville and Reiss, 1992). *Cryptochironomus albofasciatus* (Armançon and Upper Yonne) and *Cryptotendipes holsatus* (Upper Yonne) are more common species. In the Upper Seine and Marne basin no typical species have been encountered. In the Oise basin the most species (36) have been collected, among which *Kloosia? spec.?* exuviae (Aisne) is an undescribed species or even genus with a remote resemblance to *Kloosia pusilla*. Other typical taxa are *Paracladopelma near mikiana* (Aisne) Langton, *Stictochironomus maculipennis* (Aisne), *S. pictulus* (Aisne), the trivial *Cladopelma gr. laccophila* (Aisne) and *Dicotendipes notatus* (Oise) and *Cryptotendipes pseudotener* (Oise). The Eure seems to be underrepresented with only 6 taxa. The Seine Aval is rather divers with 21 species. Most species are trivial, but *Chironomus nudiventris* lives on silty sand in large rivers (Klink, 1994). *Parachironomus longiforceps* and *P. spec Kampen*. According to Moller Pillot (2009) are these taxa conspecific. The larvae are confined to large rivers where they live in colonies of Bryozoa on solid substrates in the littoral zone (Ertlova, 1974). According to the Limnofauna 10 species should be considered as missing: *Cladopelma krusemani*, *Dicrotendipes pulsus*, *Einfeldia pagana, Glyptotendipes foliicola* the trival pair *Endochironomus tendens* and *Microchironomus tener*, *Kloosia pusilla*, *Parachironomus biannulatus, Stictochironomus histrio* and *Robackia demeijere*i. According to the great similarity of the bottom dwelling Chironomidae in large lowland rivers in Europe (Chernovskij, 1949; Pankratova, 1983, Klink, 1989, Klink and Bij de Vaate, 1994; Moller Pillot, 2009; unpublished data from the Pripjat in Belarus) there are a number of other species to be expected in the Seine basin. Many from the Harnischia complex. The following species have been encountered in both western and eastern European lowland rivers:

Beckidia zabolotzkyi, Chernovskiia macrocera, Lipiniella arenicola, L. moderata, Paratendipes connectens 3 Lipina, P. nubilus, Saetheria reissi.

On top of the 54 taxa 17 should be added to amount a total of 71 Chironomini in the rivers of the Seine basin.

Table 11. Distribution and species composition of the Midges (Chironomidae) in the Seine basin IV (Tanytarsini and other subfamilies)

Distribution of Midges 4 (other subfamilies and Tanytarsini) in the Seine basin (27 taxa)	streams west of Rouen	small rivers*	Yonne	Seine Amont	Marne	Oise	Eure	Seine Aval
Paratanytarsus austriacus	+							
Micropsectra apposita	++			++	++			
Odontomesa fulva	++					++		
Rheotanytarsus photophilus	+		++	++		++		
Tanytarsus gr. brundini	+		+++	+++	++	++		
Potthastia gaedii	+		+++	+++	+++	+++		
Tanytarsus ejuncidus	+		+++	+++	+++	+++	+++	
Rheotanytarsus curtistylus	++						+++	
Prodiamesa olivacea	+++		+++	+++	++	+++	+++	++
Rheotanytarsus	++		+++	+++	+++	+++	+++	++
Tanytarsus spec.	++		++	++	++	+++		++
Potthastia longimanus	++		+++	+++	+++	++		++
Micropsectra atrofasciata	+++					++		++
Tanytarsus eminulus			++					
Rheotanytarsus reissi			++	++	+++			
Buchonomyia thienemanni			+++	++		+++		
Rheotanytarsus rhenanus			++	++	++	+++		
Cladotanytarsus gr. vanderwulpi			+++	++	+++	++		
Virgatanytarsus spec.			+++	+++	+++	+++		
Tanytarsus pallidicornis			+++	++	++		+++	
Cladotanytarsus gr. mancus			++		+++	+++		+++
Paratanytarsus dissimilis			++	++	+++	+++	+++	++
Tanytarsus heusdensis					++	++		
Cladotanytarsus spec?						+++		
Micropsectra notescens						++		
Stempellina bausei						++		
Stempellinella Pe 1 Langton						++		
Number of taxa	13		17	16	16	21	6	7

A total of 27 taxa belong to this group of the midges. Only one species is typical for the streams. *Paratanytarsus austriacus* indeed is a typical inhabitant of sources and small streams (Klink, 1983). From the typical species in the Oise, *Cladotanytarsus spec?* (Oise) are undescribed exuviae and *Stempellinella Pe1* (Aisne) is described by Langton, but the corresponding adult male is not yet known. The only species found in the Limnofauna that is missing is *Sympotthastia spinifera*.

Table 12. Distribution and species composition of the Black flies (Simuliidae) in the Seine basin

Distribution of Blackflies (Simuliidae) in the Seine basin (12 taxa)	streams west of Rouen	small rivers*	Yonne	Seine Amont	Marne	Oise	Eure	Seine Aval
Simulium angustitarse	+							
Simulium aureum	++							
Simulium cryophilum	+							
Simulium noelleri	+		++			++		
Wilhelmia equina	++		+++	+++	+++	+++	+++	
Boophthora erythrocephala	+		+++		+++	+++	+++	
Simulium ornatum species complex	+++		+++	++	+++	++	+++	
Simulium morsitans			++					
Wilhelmia lineata			+++		++		+++	
Simulium reptans			+++	++	++	++		
Simulium gr. angustipes				++				
Simulium posticatum					++			
Number of taxa	7		7	4	5	5	4	

Larvae of Black flies have a unique feature in the form of two rayed fans on their head with which they filter the passing water. For that reason this group is rheobiont and is absent in dammed rivers (except on the dam itself). They are not critical to water quality, but they need solid substrates in the current. Where this is available in the form of vegetation (usually River water-crowfoot *Ranunculus fluitans*) or wood it gives an impulse to the habitat diversity and therefore to the biodiversity.

Of the 12 collected taxa, 3 species are typical for the streams in the west (*Simulium angustitarse, S. aureum* and *S. cryophilum*) and indeed are known from small streams only (Bass, 1998). *Simulium noelleri*, *Wilhelmia equina* and *Simulium ornatum* complex (3 species) are not confined to either small of large flowing waters. From the 5 species only collected in the rivers only *S.* gr. *angustipes* (2 species) can also colonize smaller streams. The other species are confined to rivers. *S. posticatum* (Saulx) is an inhabitant of slow flowing weedy rivers (Bass, 1998). Only three missing species have been found (*Byssodon maculatum, Simulium austeni* and *S. galeratum*). *Byssodon maculatum* was a characteristic species in large lowland rivers from the Seine to the ultimate eastern part of the former USSR (River Kolima)(Rubsow, 1964). The species was very common in the Dutch Rhine before 1730 as appeared from paleoecological research of old floodplain deposits (Klink, 1989). It is uncertain of this species was ever seen alive in the Netherlands. The only note found on this species dates as far back as 1877 (Van der Wulp, 1877). The Simuliidae in the Rhine have long since diminished and became extinct in the 20th century. The main factor might well be the waves generated by the vessels. If there is one factor that Simuliidae can not cope with, it is constant changing of the force and direction of the current (Schroeder, 1980, 1888; Howell et al., 1981; Corrarino et al., 1983; Chance and Craig, 1986; Cleque-Gazeau et al., 1986; Klink, 1986). Other factors may be loss of habitat and pollution.

Table 13. Distribution and species composition of the Water Mites (Hydrachnidia) in the Seine basin

Distribution of Water mites (Hydrachnidia) in the Seine basin (34 taxa)	streams west of Rouen	small rivers*	Yonne	Seine Amont	Marne	Oise	Eure	Seine Aval
Hydryphantes spec.	+							
Lebertia (Lebertia) minutipalpis	+							
Lebertia (Pseudolebertia) salebrosa	+							
Sperchon squamosus	+							
Sperchon setiger	++							
Atractides (Megapus) nodipalpis	++							
Sperchon denticulatus	++		+++	++				
Sperchon compactilis	+			++				
Hygrobates nigromaculatus	+++		+++		++	+++		
Lebertia (Pilolebertia) inaequalis	++		++		++	++		
Sperchon clupeifer	++		+++	++	++	+++		
Atractides (Megapus) tuberosus	++		+++	++	++	++		
Lebertia (Pilolebertia) porosa	++		+++	++	++	++		
Hygrobates fluviatilis	+++		+++	++	++	+++		
Mideopsis orbicularis			+++	++				
Sperchonopsis verrucosa			+++	++				
Hygrobates trigonicus			++	++				
Torrenticola brevirostris			+++	++	++			
Torrenticola elliptica			+++	++	++			
Hygrobates calliger			+++	++	++	++		
Lebertia (Lebertia) fimbriata			+++	++	++	++		
Torrenticola amplexa			+++		++	++		
Protzia eximia				++				
Protzia invalvaris				++				
Sperchon papillosus				++				
Torrenticola stadleri				++				
Lebertia (Pilolebertia) insignis				++			+++	
Lebertia (Lebertia) rivulorum					++			
Mideopsis crassipes					++	++		
Neumania imitata					++	++		
Forelia variegator					++	++		
Lebertia (Pilolebertia) leioderma						++		
Neumania papillosa						++		
Albia stationis						++		
Number of taxa	14		15	18	15	15	1	

A modest number of only 34 taxa of Water mites is collected. This is mainly due to the stream velocity (Lebertia, Sperchon and Torrenticola species) and, where there is no flow, the lack of suitable habitat like emergent and submerged vegetation. More or less like the Mayflies the Water mites are grouped over the subsequent basins. In the streams 6 taxa are typical. Six species from *Hygrobates nigromaculatus* to *H. fluviatilis* could be considered euryoecious. Typical species for the Yonne are absent. In the Upper Seine basin *Protzia eximia, P. invalvaris, Sperchon papillosus* and *Torrenticola stadleri* (all Aube) are typical. In the Marne basin only *Lebertia rivulorum* (Saulx) is typical. Species only collected in the Oise basin are *Lebertia leioderma* (Oise), *Neumania papillosa* (Aisne) and *Albia stationes* (Aisne). In the Eure just 1 species (*Lebertia insignis*) is collected and in the Seine Aval not a single Water mite was collected. In the Limnofauna only *Albia stationes* is mentioned in biotope 4 of Eco-region 13. Almost all the other species are classified as stream inhabitants. A reason could be that the taxonomists on mites are few and mites, in most cases, are not identified in ecological assessment studies. At this stage we cannot comprehend what species are missing in the rivers of the Seine basin.

Table 14. Biodiversity of the selected groups of organisms in the Seine basin

Biodiversity of selected groups	streams west of Rouen	small rivers*	Yonne	Seine Amont	Marne	Oise	Eure	Seine Aval	all rivers
Ephemeroptera	9	16	24	17	22	26	10	3	37
Plecoptera	2	2	3	4	3	2			7
Elmidae	8	8	14	12	11	11	6	3	15
Trichoptera	31	29	31	20	31	26	15	5	49
Chironomidae	54		91	90	69	97	22	40	150
Simuliidae	7		7	4	5	5	4		9
Hydrachnidia	14		15	18	15	15	1		28
Total	125	55	185	165	156	182	58	51	295

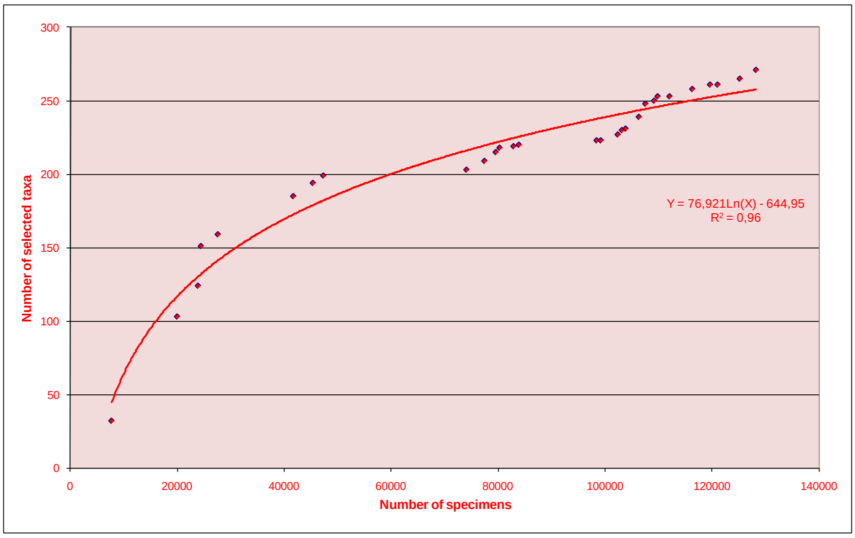
The total biodiversity in the rivers amounts to 295 species of the selected groups. The diversity in Yonne (7 samples), Upper Seine (5), Marne (7) and Oise (8) is comparable. The low diversity in the Eure is probably due to few (4) and small samples. The low diversity in the Seine Aval is very real since this stretch is heavily over-sampled with 150 samples. The diversity also shows that each basin has its own signature, making the total of 295 taxa in all rivers.

In Table 15 we can learn more about the ecological state of the Seine basin.

Table 15. River inhabiting species (Group 4 Limnofauna) in the (small and large) rivers of the Seine basin compared to those known from Eco-region 13.

Selected groups	Seine Basin	Region 13	% absent
Ephemeroptera	37	54	31
Plecoptera	6	25	76
Elmidae	15	23	35
Trichoptera	49	86	43
Chironomidae	150	189	21
Simuliidae	9	12	25
Hydrachnellae	28	-	-
Total	**294**	**389**	**24**

As we saw above, the Plecoptera are by far the most threatened group with 76% missing. Of the caddisflies almost half is missing. The Ephemeroptera and Elmidae miss about one third of their strength, the Simuliidae one quarter and the Chironomidae one fifth. In all 29% is missing. This does not necessarily mean that in these species are extinct in the Seine basin. It only means that we did not collect them for a jet unknown reason. The species could be present and we could easily miss them with the very small probe of 29 samples we took from the rivers in the Seine basin. In Graph 2 the classic relation is shown between the number of specimens sampled and the number of taxa (species) involved.



Graph 2. Relation between number of specimens and number of taxa in the rivers of the Seine basin (excl. Eure and Seine Aval)

As always, the graph levels off after every consecutive sample (or specimen). From the equation we can learn that we need about 825,000 specimens before we should reach the 403 species that would make the Seine basin ecologically complete. This would mean that on top of the 29 samples, we should take another 155 samples. In practice we would indeed have a list of 403 species in the selected groups, however many of them will not belong to the "missing species". Nevertheless the graph shows that we can expect to collect more "missing species" and if we keep in mind that the list in the Limnofauna was composed by many naturalists from about 1800 until 1970, we might draw the next conclusions:

- Despite the fact that only a fraction of the most vulnerable group of insects, the Stoneflies is collected, it is hopeful to see that with 20 sampling stations and 29 samples (composed of 1,5 m^2 of bottom and the same surface of submerged vegetation (if available), a modest amount of solid substrate and exuviae) we already collected 71% of the "target species"!
- A glimpse at Graph 2 shows that in 29 samples close to 130.000 specimens have been collected, meaning about 4400 ind. par sample. More specific: 1 m^2 of bottom is home to an average number of **1961** specimens (SDEV = 2379) and 1 m^2 of solid substrate inhabits **1959** (SDEV = 1427) specimens. These numbers indicate that the Seine basin is very much alive!

5.2. Ecological assessment of the Seine basin

The ecological assessment has been performed with several different systems. The first one is the Indice Biologique Global Normalisé (AFNOR, 1992) based on the sensitiveness of invertebrate families to ecological degradation of flowing water in general. The second is the system of the Biological Monitoring Working Party (BMWP) in England

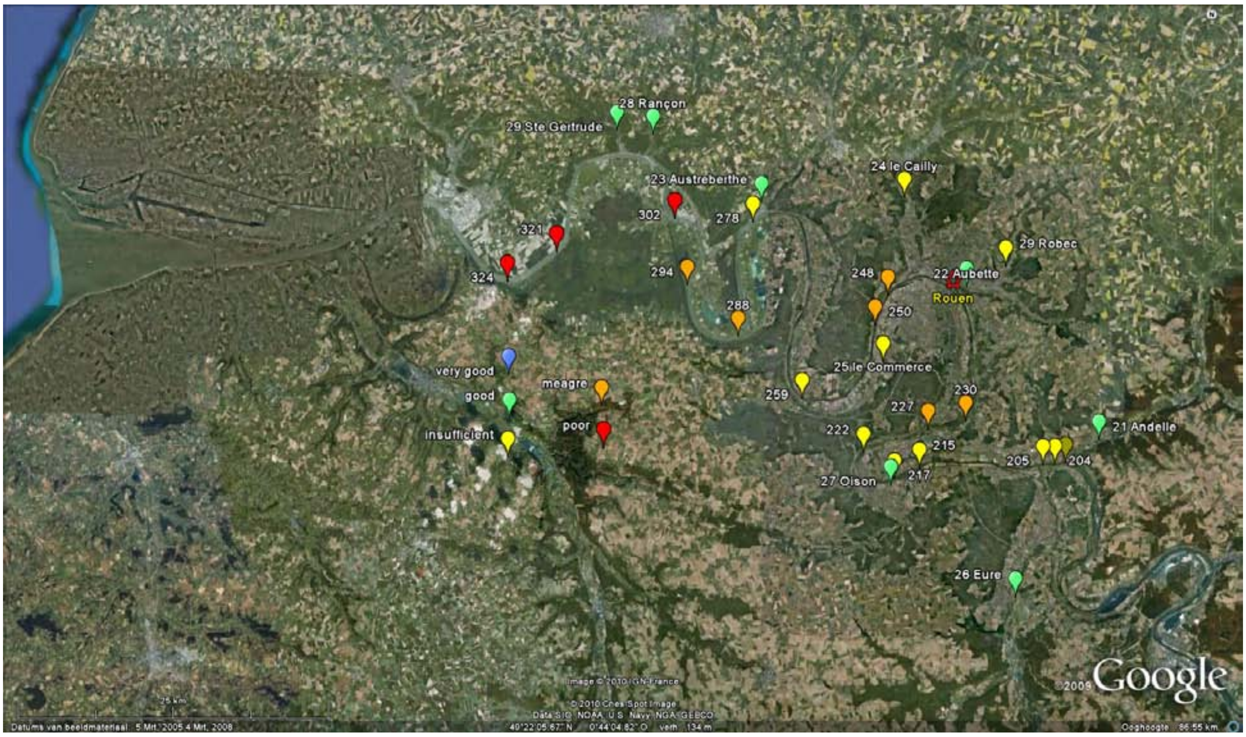
(Armitage et al., 1983). The next one is PERLODES, the official assessment tool in Germany and a European stream and river assessment program in which Austria, Czech Republic, Greece, Italy, Portugal, Sweden and the Netherlands have participated (ASTERICS, 2008). QBWat is the Dutch system for assessing flowing and standing waters by means of phytoplankton, benthic diatoms, macrophytes, macro invertebrates and fish (Pot, 2009). The BBI is the Belgium Biotic Index (de Pauw et al., 1999) and AQEM is the original German assessment system for streams only (also incorporated in ASTERICS, 2008).

Table 16. Ecological assessment of the investigated waters of the Seine Basin I: Western streams

Stream	Year	IBGN	BMWP	QBWat	Perlodes	AQEM	BBI
Andelle	2002	Green	Green	Blue	Blue	Green	Blue
Andelle	2003	Green	Green	Green	Green	Green	Blue
Andelle	2004	Green	Green	Green	Green	Yellow	Blue
Andelle	2005	Yellow	Yellow	Yellow	Green	Yellow	Green
Andelle	2006	Green	Blue	Green	Green	Yellow	Blue
Aubette	2002	Yellow	Yellow	Green	Green	Yellow	Green
Aubette	2003	Green	Yellow	Yellow	Yellow	Yellow	Blue
Aubette	2004	Yellow	Yellow	Yellow	Yellow	Orange	Blue
Aubette	2005	Yellow	Yellow	Yellow	Yellow	Orange	Green
Aubette	2006	Green	Yellow	Yellow	Yellow	Yellow	Blue
Austreberthe	2002	Yellow	Yellow	Yellow	Yellow	Orange	Blue
Austreberthe	2003	Green	Green	Yellow	Yellow	Orange	Green
Austreberthe	2004	Green	Green	Yellow	Orange	Orange	Blue
Austreberthe	2005	Yellow	Yellow	Green	Orange	Orange	Green
Austreberthe	2006	Green	Green	Yellow	Yellow	Orange	Blue
Cailly	2004	Yellow	Yellow	Yellow	Orange	Orange	Green
Cailly	2005	Yellow	Yellow	Yellow	Orange	Red	Yellow
Cailly	2006	Yellow	Yellow	Yellow	Orange	Orange	Green
Commerce	2002	Yellow	Yellow	Yellow	Orange	Red	Blue
Commerce	2003	Yellow	Yellow	Yellow	Red	Red	Green
Commerce	2004	Yellow	Yellow	Yellow	Red	Orange	Green
Commerce	2006	Yellow	Yellow	Yellow	Red	Orange	Green
Eure	2003	Yellow	Green	Yellow	Yellow	Red	Blue
Eure	2004	Yellow	Green	Yellow	Orange	Red	Green
Eure	2005	Green	Blue	Green	Yellow	Yellow	Blue
Eure	2006	Green	Green	Green	Orange	Orange	Blue
Oison	2001	Yellow	Yellow	Yellow	Green	Yellow	Green
Oison	2002	Yellow	Yellow	Green	Green	Green	Green
Oison	2003	Green	Yellow	Green	Yellow	Green	Green
Oison	2004	Yellow	Yellow	Yellow	Green	Yellow	Blue
Oison	2005	Yellow	Yellow	Green	Green	Green	Yellow
Oison	2006	Yellow	Yellow	Green	Yellow	Yellow	Green
Rançon	2002	Yellow	Yellow	Green	Green	Yellow	Blue
Rançon	2003	Green	Green	Yellow	Green	Yellow	Blue
Rançon	2004	Yellow	Green	Yellow	Green	Yellow	Blue
Rançon	2005	Green	Green	Yellow	Yellow	Orange	Blue
Rançon	2006	Green	Green	Yellow	Yellow	Yellow	Blue
Robec	2002	Yellow	Yellow	Yellow	Orange	Orange	Green
Robec	2003	Green	Green	Yellow	Yellow	Yellow	Blue
Robec	2004	Orange	Orange	Yellow	Orange	Orange	Yellow
Robec	2005	Green	Yellow	Yellow	Orange	Orange	Blue
Robec	2006	Yellow	Yellow	Yellow	Orange	Orange	Blue
Ste. Gertrude	2002	Green	Green	Yellow	Green	Yellow	Blue
Ste. Gertrude	2003	Green	Yellow	Green	Green	Yellow	Blue
Ste. Gertrude	2004	Green	Green	Yellow	Yellow	Orange	Blue
Ste. Gertrude	2005	Green	Green	Yellow	Yellow	Orange	Blue
Ste. Gertrude	2006	Green	Green	Green	Green	Yellow	Green

Blue = high; green = good; yellow = moderate; orange = poor and red = bad

At the first glance we see that all systems give a different assessment of the western streams. The IBGN and BMWP have a similar result though. The QBWat system gives an overall more negative judgement, with only a few streams that have a sufficient quality. The PERLODES and especially AQEM systems assess the situation the worst and according to the BBI index the quality is good or high. By looking at the specific data the BBI system overestimates the ecological quality. It is also clear that the PERLODES and AQEM systems are too negative. The QBWat system runs out of pace with the IBGN and BMWG in a number of occasions. This might be caused by the narrow specifics of the different stream types in the QBWat system. In the Netherlands (without mountainous regions) no less than 14 types of streams have been constructed and each type contains characteristic species, dominant positive and dominant negative species which all are weighted in the assessment. Choosing other stream types will influence the QBWat assessment, but at the moment it is not clear if the western streams can be compared to any kind of Dutch streams. Leaving IGBN and BMWP as candidates. Both systems follow the same philosophy. The identification is on family level and the more sensitive a family is the higher its score and also the greater the diversity (of families), the higher the score. The score is also not influenced by the type of running water. The typical fact occurs that both systems rank the families different, but in the end the result is almost identical. Both systems are biased for sample size. The larger the sample the higher the diversity and the score.



Map 5. Ecological assessment of the Seine-Aval and the western streams based on the IBGN

As far as the western streams are concerned, the ecological quality is good in the Andelle, Austreberthe, Eure (2005 and 2006), Rançon and Sainte Gertrude. In the Cailly and Commerce the ecological quality is moderate. In the Oison the level is just under the green border. In the Robec the results are strongly fluctuating for jet unknown reasons. The assessment of the Seine-Aval will be discussed later.

In the following we will apply the IBGN index for assessing the ecological quality of the rivers and will see where the other indices come out.

Table 17. Ecological assessment of the investigated waters of the Seine Basin II: Rivers

Nr.	River	Year	IBGN	BMWP	Perlodes	QBWat	BBI
1	Ource	2008					
2	Aube	2008					
2	Aube	2009					
2a	Seine	2008					
2b	Seine	2009					
3	Armacon	2008					
3	Armacon	2009					
4	Serein	2008					
4	Serein	2009					
5	Yonne	2008					
5a	Yonne	2009					
6	Yonne	2008					
7	Loing	2008					
8	Essonne	2008					
10	Gr. Morin	2008					
11	Marne	2008					
12	Marne	2008					
12a	Marne	2009					
13	Marne	2008					
14	Aisne	2008					
14	Aisne	2009					
15	Aisne	2008					
15	Aisne	2009					
16	Aisne	2008					
17	Oise	2008					
17	Oise	2009					
18	Oise	2008					
19	Saulx	2008					
19a	Saulx	2009					
20	Epte	2008					
KM	River						
203	Seine-Aval	2006					
205	Seine-Aval	2006					
221	Seine-Aval	2006					
227	Seine-Aval	2006					
250	Seine-Aval	2006					
260	Seine-Aval	2006					
278	Seine-Aval	2006					
288	Seine-Aval	2006					
302	Seine-Aval	2006					
324	Seine-Aval	2006					

Grey headings are waters navigable by large vessels

In contrast tot Table 16 the differences in the IBGN assessment and BMWP are considerable. In many cases the BMWP scores a class better than the IBGN. The PERLODES and QBWat scores are even lower (notice that QBWat cannot jet be used to access freshwater tidal rivers like the Seine-Aval). Again the BBI index scores highest of all. In general the more upstream the stations the higher the ranking. Navigable stretches of rivers have moderate scores on the IBGN for the reason that they are wide and deep and have no current under normal discharge. The lack of rheophilic species (families) therefore drops the score. The Seine-Aval between the Pose dam and Rouen scores moderate in the stretch heavily influenced by Rouen the score drops to bad. Than at Km 260 a small recovery is noticed. From Km 278 the score drops to bad as a result of the rising concentration of suspended

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solids (to 400 mg/l in Caudebec en Caux) and a growing discrepancy in low tidal currents of + 1,3 m/s and the current at high tide of -1,4 m/s (Klink, 2006).

Map 6. Overall assessment of the Seine basin, based in the IBGN and average scores par sampling station over the successive sampling dates

As already noted, the upstream sections score good or high. This is especially true for the Oise, Saulx, Marne, Yonne and tributaries. The Upper Seine and upper Aisne score good. The middle Aisne at Guignicourt scores even better. The small tributaries Essonne, Loing and Grand Morin have also a good score. In all cases the rivers have navigation locks the score drops to moderate. In Table 18 an impression will be given of the impact of navigation on selected invertebrate families used in the IBGN.

Table 18. Impact of navigation on selected invertebrate families

River	l'Yonne	Marne	Aisne	Marne 13	l'Yonne	Aisne 16
Station	5, 5A	11, 12, 12A	14, 15	13	6	16
	Free flowing			Navigable		
Philopotamidae	+					
Lepidostomatidae	+	+				
Rhyacophilidae	+	++				
Leuctridae	+++	++	+			
Ephemerellidae	+++	++	+			
Polymitarcidae	++	++	+			
Aphelocheiridae	++	+	+			
Potamanthidae	+	++	++			
Heptageniidae	+++	++	++	+		
Hydropsychidae	++	++	++	+		
Hydroptilidae	+	++	+++	++		
Leptoceridae	+	++	+	+		
Ephemeridae	+	+	++	+	+	
Baetidae	+++	+++	++	++	++	++
Limnephilidae	+	+				+
Caenidae	+	++	++	+	++	+
Psychomyidae	+	++	+	+	++	++
Polycentropodidae	+	+++	++	++	++	+++
Brachycentridae		+	+			
Goeridae		+			+	
Leptophlebiidae			+			
Siphlonuridae			+			
Families	18	19	17	9	6	5

Due to the adaptations in favour of navigation, half or more of the families have disappeared in the navigable stretches. This of course is expected when the current disappears. Stream velocity is the prime factor in governing the invertebrate community. Dolédec and Statzner (2008) reach the same conclusion with their trait study in large rivers that the influence of navigation is even worse than the effect of pollution on the invertebrate community.

5.3. Estimation of the actual recolonization potential for the freshwater estuary

The investigation of the macro invertebrates in the Seine Aval (Klink, 2006) showed that at the moment 150 species live in the Seine below the dam of Poses. Of these 150 species 127 have been collected between Poses and Rouen (Km 202 – 236). From Rouen to la Bouille (Km 236 – 260) the number of species dropped to 87 and between la Bouille and Vieux Port (Km 236 – 326) only 26 species have been found. The main causes, as mentioned above, are the water pollution and the unnatural channel morphology of the estuary, causing severe loss of habitat, unnatural currents and immensely high concentrations of silt. If these stressors would disappear it seems likely that a large number of species found in the major tributaries would recolonize the estuary. But before we can estimate to what extend the rehabilitation could take place, we have to know more about the invertebrate community in the estuary. For this reason literature has been collected of old observations of invertebrates in the Rhine estuary. The oldest historical data are from Van der Wulp (1877) and especially Albarda (1889). Combined with some “more recent” sources an image can be constructed of the Ephemeroptera, Plecoptera and Trichoptera fauna in the estuary over the last one and a half century, collected near Rotterdam only 32 km from the North Sea and with an open connection (Wolters-Noordhoff, 1990). Fortunately we also have two sediment cores at our disposal from the Nieuwe Merwede, a tidal arm in the Rhine estuary (Klink, 1989). The cores are not dated, but from the species composition we can deduct that their age must be over a century at least, since they contain remnants of the mayfly *Palingenia longicauda* who has become extinct in the Netherlands in first decade of the 20th century (Mol, 1981). Important additional data from these cores are the species composition of the Chironomidae, a group not well documented in the Dutch literature of the 19th and first half of the 20th century. In Table 19 we will reconstruct the estuarine community of these insect groups and that community will serve as the reference for the Seine-Aval. On top of that we will compare that reference community with the species we have so far collected in the Seine-Aval and in the whole Seine basin. From that comparison we will get a clear scope on the recolonization potential of the species that really have lived in the estuarine environment.

Table 19. Reconstruction of the estuarine community in the Rhine delta compared to the recent status of these species in the Seine basin.

Estuarine species from the Rhine Delta in the past and their present status in the Seine basin	Albarda, 1889	Geyskes, 1948	Everts, 1898	Fischer, 1943	de Meijere, 1935	van der Wulp, 1877	Klink, 1989	recent in Seine Basin	recent in Seine-Aval
Ephemeroptera									
Habrophlebia fusca	+								
Palingenia longicauna	+						+		
Ephoron virgo	+						+	+	
Potamantus luteus	+						+	+	
Ephemera sp.							+	+	
Ecdyonurus aurantiacus/dispar	+						+	+	
Paraleptophlebia submarginata	+							+	
Baetis fuscatus	+							+	
Heptagenia flava	+							+	
Heptagenia longicauda	+							+	
Heptagenia sulphurea	+							+	+
Plecoptera							+		
Taeniopteryx nebulosa	+	+							
Isogenus nubecula		+							
Isoperla obscura		+							
Xanthoperla apicalis		+							
Isoperla grammatica	+							+	
Odonata									
Calopteryx splendens								+	
Gomphus flavipes									
Coleoptera									
Potamophylus acuminatus			+					+	
Trichoptera									
Ceraclea nigronervosa				+					
Ceraclea riparia				+					
Hydropsyche bulgaromanorum				+					
Hydropsyche ornatula				+					
Orthotrichia spp.				+					
Phacopteris brevipennis				+					
Ceraclea dissimilis				+				+	
Hydropsyche angustipennis				+				+	
Ithytrichae lamellaris				+				+	
Oecetis notata				+				+	
Polycentropus flavomaculatus				+				+	
Psychomyia pusilla				+			+	+	
Brachycentrus subnubilus							+	+	
Cheumatopsyche lepida							+	+	
Lype phaeopa							+	+	
Hydropsyche conbtubernalis							+	+	+
Lepidostoma hirtum							+	+	+

Estuarine species from the Rhine Delta in the past and their present status in the Seine basin	Albarda, 1889	Geyskes, 1948	Everts, 1898	Fischer, 1943	de Meijere, 1935	van der Wulp, 1877	Klink, 1989	recent in Seine Basin	recent in Seine-Aval
Simuliidae									
Simulium aureum					+			+	
Byssodon maculatum							+		
Chironomidae									
Paratendipes nubilus						+	+		
Orthocladius (E) rivulorum							+		
Symposiocladius lignicola							+		
Beckidia sp.							+		
Chernovskiia macrocera							+		
Demeijerea rufipes							+		
Glyptotendipes gr. caulicola							+		
Lipiniella sp.							+		
Microchironomus tener							+		
Paratendipes connectens 3							+		
Robackia demeijerei							+		
Potthastia gaedii							+	+	
Prodiamesa olivacea							+	+	
Brillia flavifrons							+	+	
Brillia modesta							+	+	
Cardiocladius fuscus							+	+	
Cricotopus trifascia							+	+	
Eukiefferiella ilkleyensis							+	+	
Paracladius conversus							+	+	
Parametriocnemus stylatus							+	+	
Synorthocladius semivirens							+	+	
Cladopelma gr. laccophila							+	+	
Cryptotendipes sp.							+	+	
Demicryptochironomus vulneratus							+	+	
Paracladopelma gr. laminata							+	+	
Paralauterborniella nigrohalteralis							+	+	
Polypedilum laetum							+	+	
Stenochironomus sp.							+	+	
Stictochironomus sp.							+	+	
Xenochironomus xenolabis							+	+	
Stempellina sp.							+	+	
Tanytarsus gr. brundini							+	+	
Rheocricotopus chalybeatus							+	+	+
Harnischia sp.							+	+	+
Microtendipes gr. chloris							+	+	+
Polypedilum scalaenum							+	+	+
Cladotanytarsus gr. mancus							+	+	+
Parachironomus longiforceps							+		+
Total							74	50	9

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The reference of the estuarine community consists of 74 taxa. In reality there are much more species since we only took some groups of insects that have been collected in the past and that we are able to identify as subfossil remains in old river deposits. However of these 74 taxa only 9 are collected in the present Seine-Aval. Six of them are Chironomidae the one Mayfly *Heptagenia sulphurea*, and the caddisflies *Hydropsyche contubernalis* and *Lepidostoma hirtum* have been found in 2006 between Poses and Rouen. When we look at the whole basin of the Seine, we see that 50 of the 74 taxa are not rare (since we collected them in one or more of just 20 stations). This means that the recolonization potential for the Seine-Aval is very favourable.

We have to meet a number of conditions however to get the species in the estuary and let them develop healthy populations. To this end we combined the 74 taxa with the environmental traits in the traits database of Tachet et al. (2002). This leads us to Table 20.

Table 20. Traits of the potential invertebrate fauna and present conditions in the Seine Aval.

Traits of the potential fauna River kilometer	Number of Species	Avarage Preference	T1A 202-238	T1B 238-260	T2 260-324
Var. 12 Transversal distribution					
river channel	21	4,0			
banks, connected side-arms	20	3,3			
ponds, pools, disconnected side-arms	2	3,0			
marshes, peat bogs	1	4,0			
temporary waters	0				
lakes	6	3,5			
groundwaters	0				
Var. 13 Longitudinal distribution					
crenon	2	3,0			
epirithron	10	3,3			
metarithron	14	3,7			
hyporithron	23	3,9			
epipotamon	21	4,1			
metapotamon	9	3,7			
estuary	0				
outside river system	4	4,0			
Var. 14 Altitude					
lowlands	31	3,0			
piedmont level	0				
alpine level	0				
Var. 15 Substrate					
flags/boulders/cobbles/pebbles	26	4,1			
gravel	6	3,2			
sand	3	4,0			
silt	1	4,0			
macrophytes	18	3,7			
microphytes	0				
wood	13	3,4			
organic detritus/litter	4	3,5			
mud	1	3,0			
Var. 16 Current velocity					
null	2	3,0			
slow	13	3,0			
medium	18	3,0			
fast	1	3,0			
Var. 17 Trophic status					
oligotrophic	7	3,0			
mesotrophic	17	3,0			
eutrophic	2	3,0			
Var. 18 Salinity					
fresh water	37	3,0			
brackish water	0				
Var. 19 Temperature					
psychrophilic	0				
thermophilic	0				
eurythermic	28	3,0			
Var. 20 Saprobity					
xenosaprobic	0				
oligosaprobic	10	3,0			
b-mesosaprobic	25	3,0			
a-mesosaprobic	0				
polysaprobic	0				

Number of species are the number of species in Table 20 (Chironomidae excluded) that correspond with the traits in Tachet et al. (2002). Average preference of a species for a certain trait is a measure of the affinity to the trait (3-5 indicating high affinity). T1A is the upstream part of the Seine Aval from the dam of Poses to km 238 (Sotteville les-Rouen).T1B is the region Rouen and downstream. T2 is the downstream part of the Seine Aval from La Bouille to Vieux Port. The green colour means the variable is present and red absent at the river stretch.

The variables 1-11 are omitted since these are physical and biological characteristics of the species. Variables 12-20 show the species demands to the environment. From the species in Table 20 (Chironomidae excluded since they are lumped as subfamilies in Tachet et al. (2002) 37 taxa remain, since all species are lumped to generic level in de traits database. Only three of these species are recently encountered in the Seine Aval (Klink, 2006). We now will analyse the reaction of these species to the separate variables:

- Variable 12: Transverse distribution shows that most species live in the channel, on banks and connected side arms. In the upper Seine Aval banks and side-arms are well developed. In the T1B and T2 section the banks consist largely of stones (T1B and T2) and mud (T2). Ponds, pools and disconnected side arms are only present in T1A.
- Variable 13: Longitudinal distribution shows that some species have a higher affinity for the upstream sections (*Ecdyonurus* and *Isoperla* species). The focus of most species however lies in the lower part of the rivers (e.g. *Heptagenia* and *Potamophilus acuminatus*).
- Variable 14: Altitude shows clearly that the species involved are confined to the lowlands.
- Variable 15: Substrate is of the utmost importance to the invertebrates. The majority of the species of confined to solid substrates (29). *Gomphus flavipes* is confined to silt and *Ephoron virgo* and *Ephemera* spp. live in sand and gravel . Natural solid substrates as wood, macrophytes and pebbles are only present in T1A. The only solid substrates in T1B and T2 are the stones on the banks.
- Variable 16: Current velocity also is a very important factor. In tidal systems there is a continuous inward and outward flow corresponding with high and low tide In the T1B and T2 sections of the Seine Aval the current is very strong due to the embankment of the river. In section T1A the tidal currents are more natural and the side channels also provide stagnant water.
- Variable 17: Trophic status of the Seine Aval is eutrophic. *Orthotrichia*(caddisfly) is the only taxon with an exclusive high affinity to eutrophic conditions. All other species have high affinities to oligo and mesotrophic conditions.
- Variable 18: Salinity in this reach of the estuary is low and all the potential species are confined to fresh water.
- Variable 19: Temperature preference of all potential species is euthermic.
- Varable 20: Saprobity affinity of most taxa is ß-mesosaprobic. The Mayfly *Paraleptophlebia submarginata*, all Stoneflies and the caddisfly *Ithytrichia* have an exclusive high affinity for oligosaprobic conditions.

Based on the Trophic status 23 out of 24 potential species can be excluded from the present river. Based on Saprobity 7 out of 32 species can be excluded from the Seine Aval. When we keep in mind that the habitat diversity in the upstream part of the Seine

Aval is near natural, although wood is still scarce, we should expect many potential species to recolonize when the trophic conditions ameliorate. For the downstream sections T1A and T2 the situation is much worse. The main problems hampering ecological rehabilitation are:

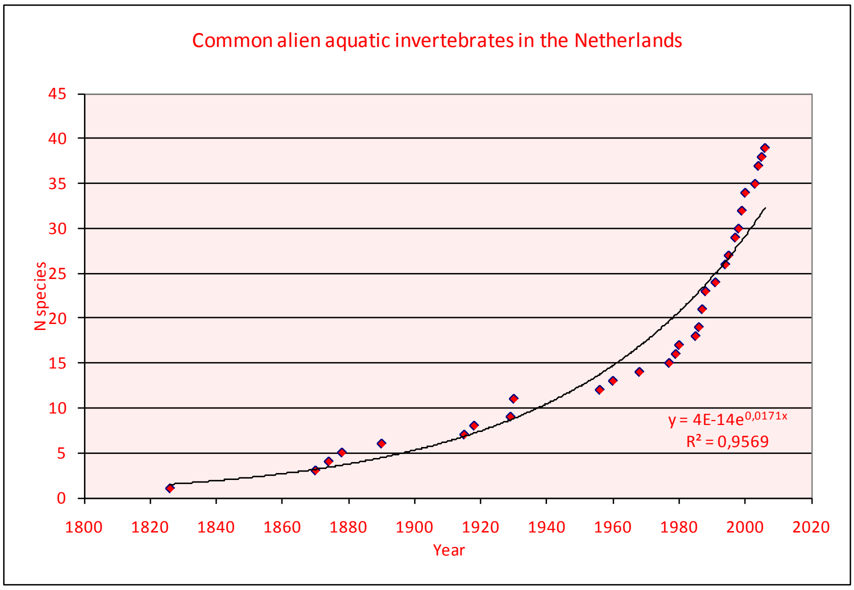
- Severe pollution from the Rouen area
- Lack of habitat diversity
- Stress of strong tidal currents
- High silt concentrations in the water and silting up of the banks

It is obvious that ecological rehabilitation, of this much larger part of the freshwater estuary, means that the river should get more space to deposit the silt on the intertidal flats once more. Reclaimed tidal flats should be connected to the river again and ways should be found to combine nature development in the estuary with the shipping traffic and other economic and urban activities.

The least of our problems would be to get the potential species back into the estuary. When the conditions are favourable they will get there drifting during high discharge or flying in their reproduction swarms.

5.4. Impact of invasive alien species on the indigenous community

An increasing number of books are recently published on behalf of species invasions (Elton, 1958; Williamson, 1996; Sandlund et al., 2001; Weber, 2003; Van Driesche and Van Driesche, 2004; Sax et al., 2005 and Nentwig, 2006). In the Netherlands 39 alien species in the freshwater environment are common nowadays (http://www.werkgroepexoten.nl, 2010-1). Here we are considering alien species as those species that have been immigrated after 1900. Species that entered before that can be considered as native or as an intricate part of the ecosystem. An example is the zebra mussel (*Dreissena polymorpha*) that spread out over western Europe in the first part of the 19th century. In Figure 1 we can distinguish two different periods in colonisation. In the first period (1820 – 1980) there is a slow and linear rise of alien species. In the second period (1980 present) the rise is much steeper.



Graph 3. "The sky is the limit" or the exponential rise of the alien freshwater invertebrates in the Netherlands

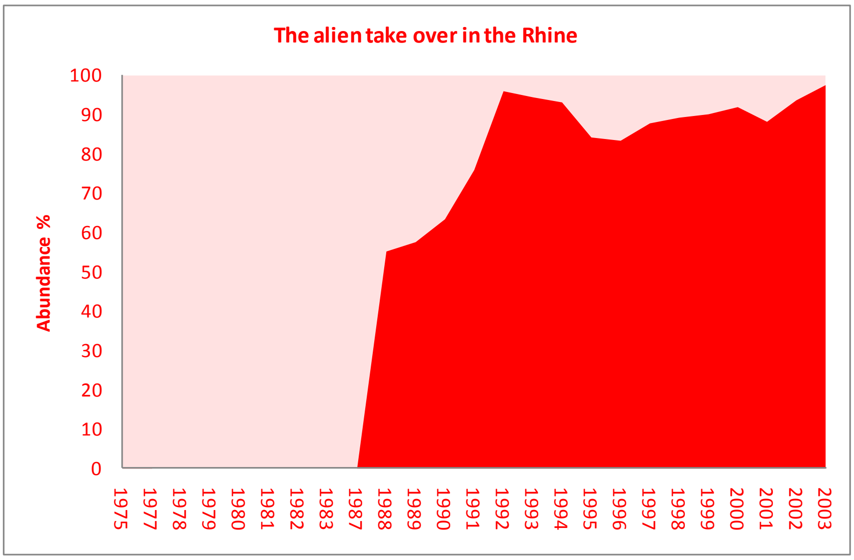
Most of the invaders from before 1994 originated from other continents (*Orconectes limosus, Corbicula* spp., *Quistadrilus multisetosus, Crangonyx preudogracilis, Gammarus tigrinus* all N. America. *Corbicula* originates from China was brought to N. America by Chinese immigrants (Bij de Vaate, 1991). At least the first containers in Rotterdam were shipping from North America. Exceptions of aliens colonizing the Rhine prior to 1994 are *Chelicorophium curvispinum* and *Chaetogammarus ischnus*(also shrimps) who are native in the Ponto-Caspian region and have made their way to the Rhine through the "Mittellandkanal" and "Ems-Dortmundkanal" (Bij de Vaate, 2003; Eggers and Martens, 2001 resp.). In 1994, two years after the reopening of the "Ludwig Kanal" between the Danube and Main (major tributary of the Rhine), the killer shrimp (*Dikerogammarus villosus*) arrived in the Netherlands (Bij de Vaate and Klink, 1995).

Photo 9. Killer shrimp (*Dikerogammarus villosus*) mature male

Through this canal, the traffic of 200.000 T/y, was accommodated in 1850 without noticeable alien dispersal. After a few decades the canal was abandoned in favour of railway traffic. After the reopening in 1992, a total of 5.2 M tons of goods passed through the canal in 1999. By the eastern expansion of the EU a further increase to 18 M tons is feasible (Galil et al., 2007).

With the killer shrimp a whole new Ponto-Caspian cohort of aliens colonized the Rhine. Among them, the freshwater Polychaeta *Hypania invalida* (Klink and Bij de Vaate, 1996), the triclad *Dendrocoelum romanodanubiale* (Bij de Vaate and Swarte, 2001), the leach *Caspiobdella fadejewi* (Bij de Vaate et al., 2002), the water mite *Caspihalacarus hyrcanus danubialis* (Klink, 2002a) and the crustaceans *Astacus leptodactylus, Chelicorophium robustum, Dikerogammarus haemobaphes, Echinogammarus trichiatus, Jaera istri, Hemimysis anomala* and *Limnomysis benedeni* (Ketelaars, 2004).

The start of the alien take over is, in the Netherlands ironically, not documented in detail since the monitoring of invertebrates in the Rhine was aborted in 1984 – 1986. In that time *Gammarus tigrinus* had already arrived in the Rhine, but was still a rare inhabitant (Klink and Moller Pillot, 1982). In 1988 *G. tigrinus* starts to expend. After the first find of *Chelicorophium curvispinum* in 1987 (Van den Brink et al., 1989) their density exploded from 1990 onwards. Den Hartog et al. (1992) speculate on the reason for the success of *C. curvispinum* (and *Corbicula* spp.) and draw a conclusion that the alien outbreak follows the Sandoz incident at November 1986, leaving the Rhine almost devoid of predators and competitors.

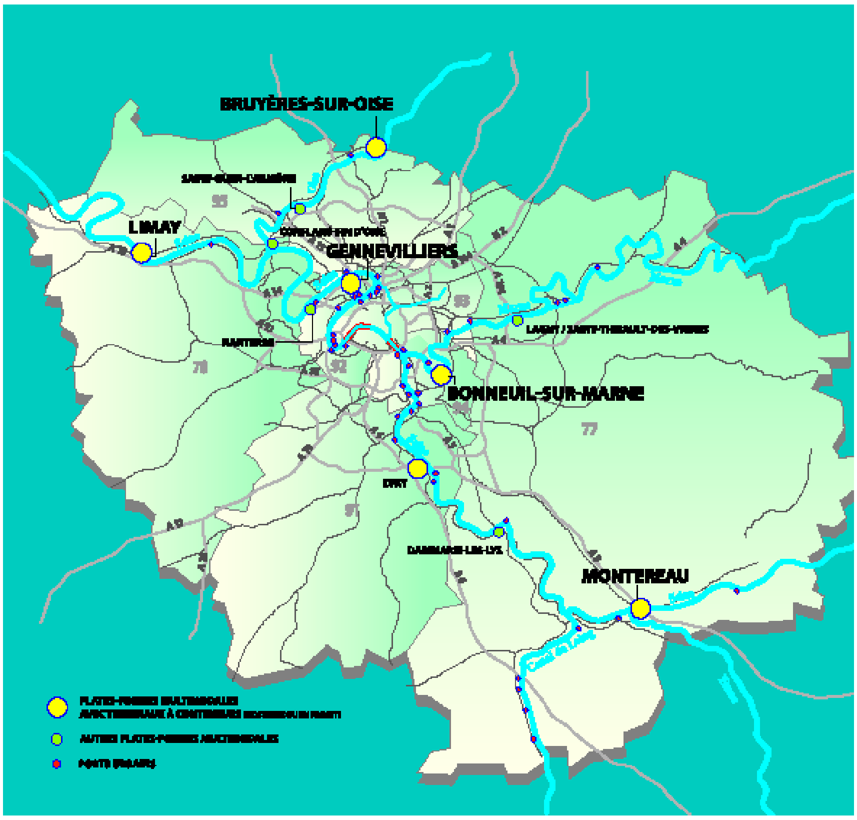


Graph 4. The alien take over in the Rhine (Van Urk, 1981; Bij de Vaate, 2002 and unpublished data Waterdienst Lelystad Nl)

There indeed is little doubt on the assumption that the less diverse, the more susceptible an ecosystem is for alien take over (Sandlund et al., 1999; Bauer and Schmidlin, 2007; Hufbauer and Torchin, 2007). Van Driesche and Van Driesche (2000) express it as follows: “Continual simplification of a natural system simplifies well-integrated systems into simple disorganized ones. In many cases followed by an invasion that otherwise would not have happened.” Context are the invasions of the zebra mussel (*Dreissena polymorpha*) in the Laurentian Lakes and large dammed US rivers leading to the extinction of the native unionid and pearly mussels.

The present Rhine at the German border is “alienated” in average for more than 90% since 1992. Surprisingly the Dutch Meuse River at the Belgian border shows an average alienation of “only” 4 % during 1992 – 2003. This discrepancy might well be caused by the difference in annual freight passing both borders. In the Rhine 154 Mton passed in 2006, and at the Meuse just 4 Mton (http://statline.cbs.nl/, 2010-1). A second important aspect is the poor water quality in the Meuse at the Belgian border. We come to speculate on that point later.

The Seine basin is connected also to other watersheds through canals with Scheldt (Oise), Meuse (Aisne, Marne), Rhine (Marne), Rhône (Marne, Yonne) and Loire (Seine). These canals provide an excellent vector for the colonization of the mentioned invaders (Bauer and Schmidlin, 2007).



Map 7. Ports in the Seine basin (Ile-de-France, 2009).

In the Seine basin the container traffic is a booming business. In 2000 30,000 TEU were transported against 145,000 in 2006. The total traffic in the Seine basin amounts 22 Mton annually (http://www.lognews.info/Repondre-a-la-hausse-de-trafic.html, 2010-1). In comparison to the Rhine (154 Mton) the traffic is modest, however compared to the Meuse at the Belgium – Dutch border (4Mton) the traffic in the Seine basin could have a profound effect on the infestation with aliens. In Map 7 (from an advertisement to invest in the freight on the rivers "Fret Fluviaux") the large yellow dots depict the container terminals.

In the near future the navigation (and alien rise) will get a further boost when the Canal Seine North Europe will be opened in 2015. This gigantic canal with a length of 106 km, will connect the Seine to the Scheldt. Paris will than have a second link to the sea and it is not realistic to expect that the ballast water from see ships will already be devoid of aliens by that time.

The infestation rate of the Seine basin is presented in Table 21. The Alien Infestation Rate (AIR) is the proportion of alien individuals in the total individuals in the sample expressed as percentage.

Table 21. Alien infestation rate (AIR) in the Seine basin

Rate of alien infestation	Hypania invalida	Caspiobdella fadejewi	Corbicula fluminalis	Corbicula fluminea	Cheliorophium curvispinum	Crangonyx pseudogracilis	Dikerogammarus villosus	Orconectes limosus	Total
Streams W of Rouen									
Andelle	-	-	-	-	-	-	-	-	-
Aubette	-	-	-	-	-	-	-	-	-
Austreberthe	-	-	-	-	-	-	-	-	-
Cailly	-	-	-	-	-	-	-	-	-
Commerce	-	-	-	-	-	-	-	-	-
Eure	-	0,6	-	-	-	-	-	-	-
Oison	-	-	-	-	-	-	-	-	-
Rancon	-	-	-	-	-	-	-	-	-
Robec	-	-	-	-	-	-	-	-	-
Ste Gertrude	-	-	-	-	-	-	-	-	-
Rivers									
Ource	-	-	-	-	-	-	-	-	-
Aube	-	-	-	-	-	-	-	-	-
Seine 2A+2B	-	-	-	0,2	-	-	-	-	0,2
Armacon	-	-	0,0	0,0	-	-	-	-	0,0
Serein	-	-	-	-	-	-	-	-	0,0
Yonne 5	-	-	-	0,2	-	-	-	-	0,2
Yonne 6	-	-	-	3,3	-	0,2	4,5	-	8,0
Loing	-	-	-	0,0	-	-	0,2	0,0	0,3
Essone	-	-	-	-	-	-	-	-	-
Grand Morin	-	-	-	-	-	-	-	-	-
Marne 11	-	-	-	-	-	-	-	-	-
Marne 12	-	-	-	0,9	-	-	4,6	-	5,5
Marne 12A	-	-	-	0,2	-	-	0,7	-	0,9
Marne 13	1,8	-	-	1,3	-	-	16,0	-	19,0
Aisne 14	-	0,2	-	-	-	-	-	-	0,2
Aisne 15	-	-	-	0,2	-	-	0,0	-	0,2
Aisne 16	0,5	0,2	-	1,0	0,4	0,0	0,9	-	3,1
Oise 17	-	0,1	-	-	-	-	0,0	-	0,1
Oise 18	-	-	-	-	-	-	0,1	0,1	0,3
Saulx 19	-	-	0,0	0,7	-	-	-	-	0,7
Saulx 19A	-	-	0,0	0,1	-	-	-	-	0,1
Epte	-	-	-	-	-	-	-	-	-
Eure mouth	0,9	-	0,2	0,7	-	-	-	-	1,9
Seine Aval pk 203	0,4	-	0,1	-	-	0,0	0,1	-	0,6
Seine Aval pk 205	0,6	-	0,1	0,1	-	-	0,2	-	0,9
Seine Aval pk 221	1,3	-	0,1	0,2	-	-	-	0,0	1,6
Seine Aval pk 227	0,2	-	0,0	0,5	-	-	-	-	0,7
Seine Aval pk 250	0,7	-	-	4,1	-	-	-	0,0	4,8
Seine Aval pk 260	0,3	-	-	4,5	-	-	-	-	4,8
Seine Aval pk 278	1,2	-	-	0,1	-	-	-	-	1,4
Seine Aval pk 288	-	-	-	0,1	-	-	-	-	0,1
Seine Aval pk 302	-	-	-	0,0	-	-	-	-	0,0
Seine Aval pk 324	-	-	-	-	-	-	-	-	-
Navigable stretches in black									

In the Seine basin only 7 aliens have been met. Of these only three have abundance higher than 1% of the total community. The small western streams are devoid of aliens, except the mouth of the Eure. In the Seine-Aval the Polychaeta *Hypania invalida* and the *Corbicula* clams are widely distributed, in low densities however. The killer shrimp, *Dikerogammarus villosus* has only been met in the least polluted part of the Seine-Aval between Poses and Rouen. Surprisingly the distribution of *Chelicorophium curvispinum* is limited to the navigable Aisne, whereas this species reached densities of several 100,000 ind/m^2 in the Rhine several years after their initial colonization (Van den Brink et al., 1992).

Compared to the 90% infestation in the Rhine and 4% in the Meuse, the Upper Seine basin scores an intermediate position with an alien hotspot in the navigable Marne. However also the non navigable Marne at 12 is strongly infested. In Marne and Yonne it mainly concerns the killer shrimp (*Dikerogammarus villosus*), the high competitive invader dominant in the present Rhine (van Riel, 2007). Other bad news is that aliens have been collected in the upstream sections of all the main tributaries. They probably are spread through the small channels by small vessels like the recreational shipping and can enter the river were the canals meet the river. As shown in Figure 4 also transport over land occurs. This engine fouled by zebra mussels also contained living species of the killer shrimp, *Dikerogammarus villosus* and *Echinogammarus trichiatus* after 6 days out of the water (Martens and Grabov, 2008).

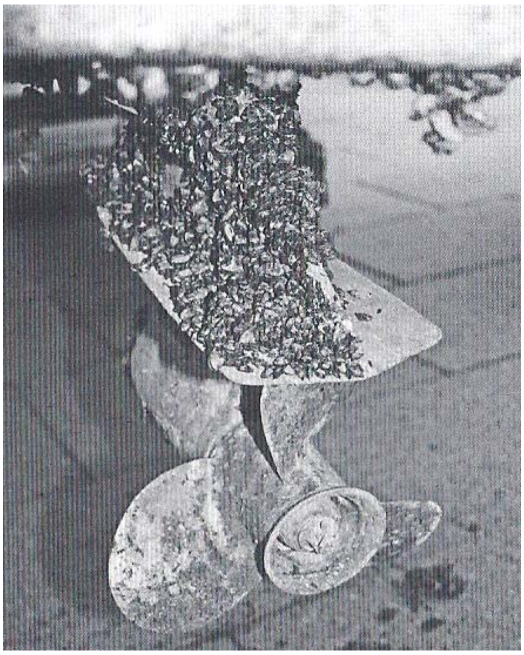


Photo 10. Example of aliens transported over land (Martens and Grabov, 2008)

5.5. Factors that might affect alien infestations

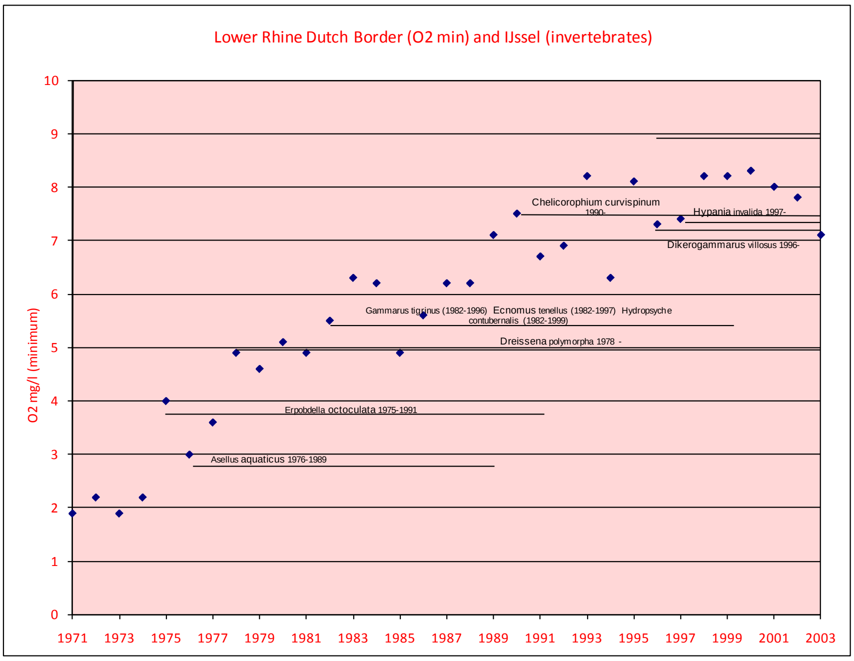
In the preceding paragraph some factors were named that could play a role in the success of alien invasions. These factors are:

- water quality
- shipping and connectivity
- native diversity

In this paragraph we will try to prow a little deeper into these factors and focus with prime interest on the killer shrimp, with *Chelicorophium curvispinum* by far the largest threat to the native fauna.

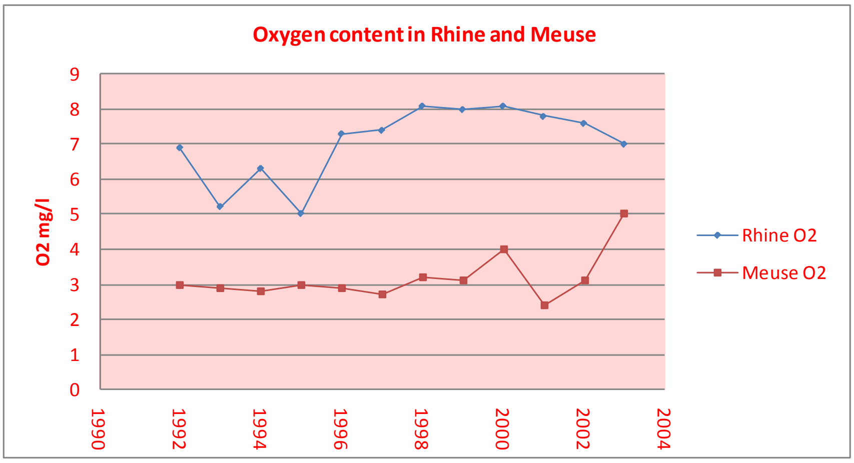
5.5.1. Water quality

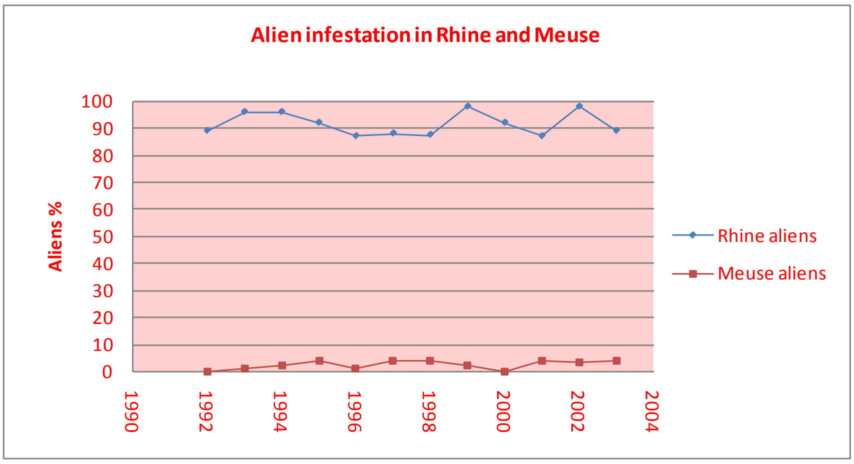
According to the IBGN and the other ecological assessments we have to conclude that the Seine Basin has a fair to good water quality on the sampling stations upstream Paris. This is a conformation of the chemical assessment of the Agence de l'Eau Seine-Normandie where most upstream stations are considered good and in the navigable section the quality is average or better. The water quality is dramatically increased in the last 40 years. The Marne has changed from passable to excellent form 1989 to 2000 thanks to the wastewater treatment plant in St. Ozier in 1995. Only nitrate is worsening as a typical result of rising oxygen concentrations where all the available ammonia is converted to nitrate (AESN, 2002). As we noted above, the low infestation rate in the Meuse at the Dutch border might be an effect of the bad water quality. To learn more we can again take the Rhine as an example of what happened in the cause of the historic events.



Graph 5. Oxygen content (minimum) 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 minimum oxygen content has increased to app. 5,5 mg/l, which led to the alien domination of *Gammarus tigrinus* and the native caddis flies *Ecnomus tenellus* and *Hydropsyche contubernalis*. These three species lasted until 1996 (*Gammarus tigrinus*), 1997 (*Ecnomus tenellus*) and 1999 (*Hydropsyche contubernalis*). Their extinction coincided with the invasion of the killer shrimp, *Dikerogammarus villosus* and not with the immense densities of *Chelicorophium curvispinum*, earlier in the 90's. As the water quality is concerned it seems that *D. villosus* develops optimally at minimal oxygen levels higher than 5 mg/l. In Graph 6a and b we can see the effect of lower oxygen levels on AIR.





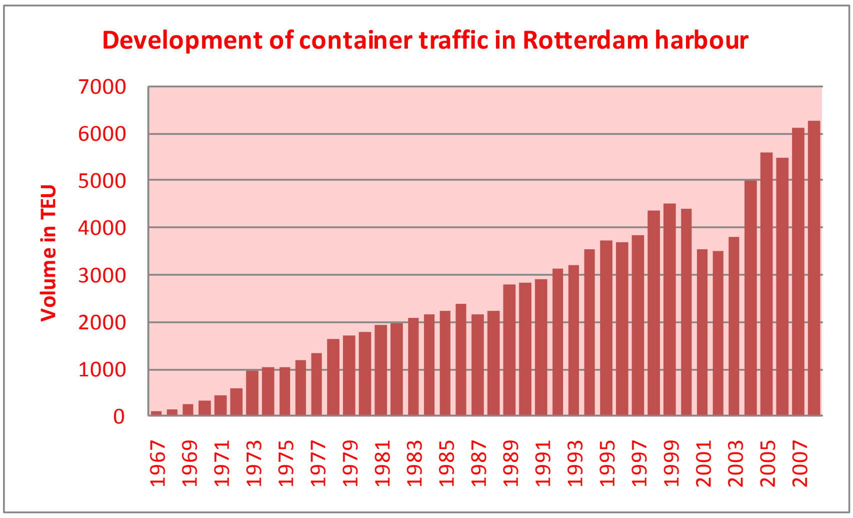
Graph 6a. Oxygen (minimum) levels in the Rhine and Meuse at the Dutch border. Graph 6b. Alien abundance at the same stations

In Graph 6a and b the message is clear. From 1997 the killer shrimp appears in the Meuse, but is not able to eat its way through the native population and the numbers remain modest (4% max.). The minimal oxygen content, not reaching 5 mg/l is probably too low for most aliens. The high dissolved Cadmium concentrations in the Meuse could keep the shrimps on the leash as well. Knowledge about the relation between aliens and water quality might prove essential in the case that the polluted part of the Seine Aval is ameliorating and thus might become suitable for these aliens.

5.5.2. Shipping and connectivity

Shipping is an ideal way for an alien to get dispersed. Infamous is the invasion of the zebra mussel in North America (Nalepa and Schlösser, 1993). The fact that the invaders from the Danube entered the Rhine is clear evidence. The aliens first had to be helped upstream in the Danube, before they could let themselves drift downstream in the Main and Rhine.

When we compare the explosion of the aliens species in the Netherlands from 1980 onwards (Graph 4) with the development of the container traffic at Rotterdam harbour (Graph 7). We see that the growth of the traffic is linear instead of exponential. The effect of navigation on the alien development seems like facilitating their presence in the receiving countries rather than a continuing stream of alien individuals. As shown (Graph 6), a minimum of 5-6 mg O2/l seems to be required for an explosive alien development.



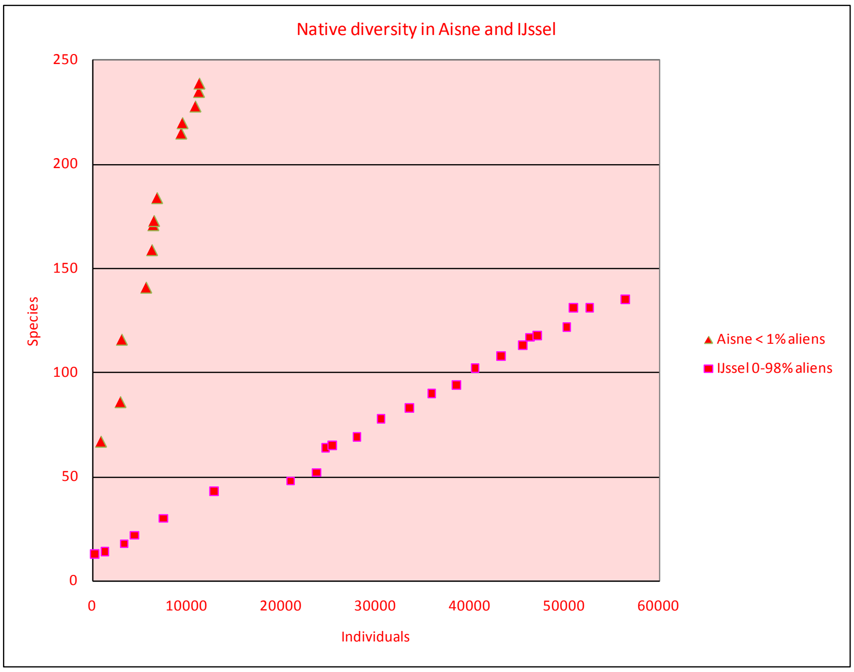
Graph 7. Development of the largest container terminal in the Rotterdam harbour (http://www.ect.nl/public/static/HistoryECT.htm, 2010-1). Units (TEU) are Twenty feet Equivalent Units of 20*8*8 foot.

The killer shrimp in the Netherlands has become so widespread that it is no longer dependant on navigation and it will spread itself in the surface waters that receive water (in summer) from the Rhine and Meuse (73% of the Dutch surface water is fed by the Rhine (Oecologische Kring, 1983)). Only polluted waters, acidic and isolated waters without recreational shipping might be saved from this killer. In the Seine basin with booming container traffic, the invaders might have colonised all navigable river sections. Possibly due to recreation they are able to penetrate the upstream sections as well. Fortunately they do not seem to cause much damage yet.

5.5.3. Native diversity

As mentioned above, native diversity is one of the factors mentioned to be of influence on the alien success (Sandlund et al., 1999; Van Driesche and Van Driesche, 2000; Bauer and Schmidlin, 2007; Hufbauer and Torchin, 2007). The philosophy behind this is:

The greater the diversity the smaller the available niche space (Den Hartog et al., 1992). However we have not found any convincing figures to proof this right for the present invaders.



Graph 8. Native diversity in the Aisne (natural course) and in the IJssel in the Netherlands (accommodates large vessels). Percentages are alien infestation rates (AIR).

Graph 8 is constructed from the cumulative number of individuals and species every time a new sample is added. As in Graph 2, eventually the line will level off to horizontal when all the species have been collected. Different aspects can be seen in the graph:

At first we see the shape of the different lines (curves). The Aisne in its natural course is rocketing upwards and in 13 samples we collected just over 10,000 specimens belonging to 239 species. The alien infestation rate amounts less than 1%. The next example is from the IJssel, a Dutch affluent of the Rhine with the longest time series of invertebrates, started in 1975 by Van Urk (1981) and continued by the Waterdienst. Just as the Lower Rhine, the IJssel has been “corrected” to accommodate the shipping and to prevent flooding of the adjacent land. The river is not dammed, but is narrow and deep. The present series comprise the period 1975 – 2003. In 1975 the Dutch Rhine system was heavily polluted (see for oxygen content Graph 5) and hardly any specimens (and species) were collected on the littoral stones. Interesting is the fact that with the rehabilitation of the water quality, the number of species gradually increased. The alien infestation rate was zero at the start of the investigation and in 2003 respectively 98% of the invertebrates on the station are alien. From this graph we can learn the following:

- The native diversity is immensely higher in natural like situations (Aisne) compared to altered rivers.
- Another fact is that the biodiversity is dropping and that the original species composition dramatically changes when dams and or cargo-shipping are in effect (Trotzky and Gregory, 1974; Ward, 1976; Armitage, 1977; Donald and Much, 1980; Sedell et al., 1989; Sedell et al., 1990; Saltveit et al., 1994; Ward and Stanford, 1995; Stanford et al., 1996; Sparks et al., 1998; Stevens et al., 1998;Statzner et al., 2001; Vinson, 2001; Cortes et al., 2002; Sheldon et al., 2002; Lessard and Hayes, 2003; Dolédec and Statzner, 2008).
- A collateral effect is that cargo-shipping enhances the alien colonization through ballast water, typical intercontinental (e.g. Grogorovich et al., 2003) or by fouling on local to international scale (e.g. Martens and Grabov, 2008; Photo 10).

What can not be seen in the graph is what has happened to the species that have colonized the literal zone **after** the aliens have settled. From data of the Waterdienst we could construct Table 22, the losers in the Rhine at the Dutch border. Several groups are involved. The greatest are the Chironomidae with 12 species. Other groups are Hirudinea (1), Mollusca (5), Crustacea (3), Trichoptera (3) and regretfully also the only Heptagenid mayfly in the Dutch Rhine

Table 22. List of native species that have colonized the Rhine since 1975 and have lost from the aliens.

Losers	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Rheocricotopus chalybeatus																
Proasellus coxalis																
Tvetenia verralli																
Bithynia tentaculata																
Ceraclea dissimilis																
Hydropsyche contubernalis																
Micropsectra atrofasciata																
Parachironomus frequens																
Gammarus pulex																
Pisidium supinum																
Rheopelopia																
Erpobdella octoculata																
Cryptochironomus																
Pisidium henslowanum																
Valvata piscinalis																
Cricotopus sylvestris gr.																
Cricotopus triannulatus																
Cricotopus vierriensis																
Synorthocladius semivirens																
Parachironomus arcuatus gr.																
Aselus aquaticus																
Microtendipes chloris gr.																
Physa fontinalis																
Heptagenia sulphurea																
Hydropsyche bulgaromanorum																

From this paragraph we can learn the following aspects concerning alien invasions:

- Water quality was (and locally still is) an important limiting factor for the impact of invasive aliens
- Shipping and connectivity are the starting conditions for alien invasions, but may not be necessary for a further spread in the infested basin
- Native diversity indeed proofs to be a very important repellent against alien dominance.

5.6. Protocol for the evaluation of experimental sites

In the context of the Water Framework Directive (WFD), experimental sites will be implemented in the Seine-Aval to mitigate the ecological damage that has already been done to the system (pers. comm. with GIP S-A). From this investigation in the Seine basin it seems obvious to write a protocol that provides ecological information about the sites and their surroundings. It also seems logic to provide information on the level of species, since this is the only true biological unit. However, since taxonomic knowledge seems to be slipping away from our society (there are exceptions though), it might not longer be feasible to identify to species level. There are numerous examples where the rank of family sets the standard (e.g. IBGN, BMWP, and BBI) for the biological assessment of streams and rivers. Relatively new seems to be the approach on biological traits bases on genus level (Usseglio-Polatera et al., 2000; Charvet et al., 2000, Statzner et al., 2001; Dolédec and Statzner et al., 2008). It is obvious that a lot of time can be saved or that many more samples can be taken when identification is put to a higher level. We will get to that at the discussion. Another aspect in the protocol should be the sampling of all available habitats and making a field list of all the relevant environmental factors.

A short list for a protocol should contain at least the following aspects:

1. Sampling strategy (minimum sampling with maximum information, mesh size, sampling gear, ship etc.). With the 2006 study in the Seine Aval, the present study and additional experience with field work for the last 30 years, we should be able to work out a sampling strategy. Important is that all available habitats are sampled and that, if possible, at least 1000 individuals are collected par sampling site, divided over several samples. The Seine basin is divided in the navigable and non-navigable stretches. In the navigable parts the bottom has to be sampled with a grab of some sort. In the Seine Aval the Hamon Grab (Benne Hamon) seemed the only appropriate grab for the chalkbed . For the gravel bottom in the T1A section the pyramid dredge

was the only device that worked properly.

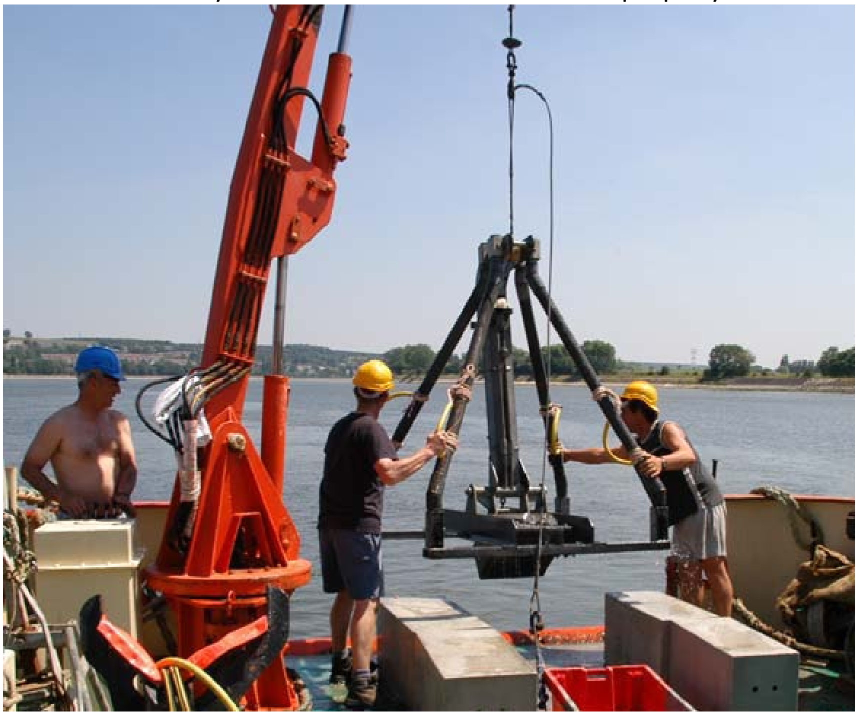


Photo 11 Hamond Grab (Benne Hamon) op operation in the Seine Aval (Photo A. bij de Vaate)

Photo 12 Pyramid dredge (Photo A. bij de Vaate)

In the non-navigable section and in the littoral zone of the deep rivers a hand net can be used with the standard mesh size of 500 µm and opening of 30 cm wide (see photo 4). Solid substrates are brushed and the material is converted to the hand net for sieving prior to conservation. All material should be converted to 70% ethanol and stored cool. The drift sampling can be left out of the protocol since these samples were only taken as an additional reconnaissance of the river fauna.

Given the requisite that at least 1000 ind. should be collected on all the habitats in one sampling site, The sampling effort as shown in Table 23 should be sufficient

Table 23. Sampling gear and effort for the sampling of one sampling site.

Biotope	navigable river	non-navigable river
riverbed chalk	5 Hamon grabs	5 m handnet
riverbed stones	5 Hamon grabs	5 m handnet kick
riverbed gravel	15 m trangular dredge	5 m handnet kick
littoral wood	brush 0,5 m2	brush 0,5 m2
littoral stones/ bricks	0,5 m2	0,5 m2
littoral vegetation	handnet 0,5 m2	handnet 0,5 m2

Description of the sampling stations. For the evaluation of the experimental sites it is of great importance that changes on the site are monitored as well as changes in the species composition. On the sites we monitor on a regular basis, the natural development and the annual discharge characteristics seem to be largely decisive for the changes in species composition. This also holds true for the development of the habitats. For instance when riparian forest develops on the banks, this will have consequences for the available macrophytes in the river and on the banks. Also wood as a substrate will become available to the aquatic invertebrates. A peak discharge, on the other hand may lead to severe erosion and can flush away habitats that have developed in the preceding years. In this respect the sampling site can be described according to a lot of parameters, but photographs, discharge characteristics and description of the habitats are prime indicators.

Photo 13 Newly dug side channel along the Dutch Rhine (1994)

Photo 14 Same location 16 years later

2. Sorting strategy (mesh size and amount of specimens and selection of groups).

   In the Netherlands there is a nationwide consensus on how to sort the samples. In detail there are differences, but all laboratories sieve their samples over a mesh width of 500 µm. All groups are sorted out and conserved for identification in ethanol 70% except Hydrachnidia , that are conserved in a mixture of acetic acid, water and glycerine (2:3:5).

3. Identification strategy (e.g. species or families).

   In order to find out if experimental sites develop favourably, identification should by at the lowest possible taxonomic level. Especially Chironomidae react instantaneous to changes in their environment and they contain numerous excellent indicators that can only be detected by species identification.

4. Biological assessment and evaluation of the experimental sites.

   We have made an assessment of the sampling stations by means of the IGBN. The IGBN is an index based on the diversity on the faunal composition on the family level. To assess experimental sites, we could look more specific at the aims the site is constructed for. When the site is planned to accommodate rheophilic species, than these species should be part in the assessment. When we are looking at a bigger picture e.g. rehabilitation of the whole river system. The list of species in this study and the missing species from Ecoregion 13, biotope 4 in the Limnofauna Europaea (Illies, 1978) might be a starting point in constructing an assessment system.

6. Discussion

6.1. Biodiversity of macro invertebrates in the Seine basin

A total of 571 taxa have been recovered from the Upper Seine, Seine-Aval and the western streams. Approximately 460 species are riverine species. According to geography the highest diversity is found in the upstream part of the basin in the large tributaries, not adapted to accommodate cargo-vessels. This is consistent with Dolédec and Statzner (2008) who discovered that most strategies and traits of the invertebrates alter when a section of a river is made navigable. Although only a limited amount of stations has been sampled a large percentage (71%) of the reference fauna has been collected. Also a geographic differentiation has been noticed, between the relatively high gradient southern tributaries (Yonne, Seine, and Aube) and the low gradient Marne and Oise basins in the north. The former is home to several *Ecdyonurus spp*, *Isoperla grammatica* and *I. diffiformis*, *Chimarra marginata*, *Athripsodes bilineatus*, *Metalype fragilis, Setodes argentipunctellus, Rheopelopia maculipennis, Thienemannimyia carnea, Eurycnemus crassipes, Parorthocladius nigritus, Chironomini genus C Wiederholm, Chironomini gen? sp? Pe4 Langton, Sperchonopsis verrucosa, Protzia spp*. and *Sperchon papillosus*. The Marne and Oise basin is differentiated by *Paraleptophlebia submarginata, Caenis pseudorivulorum, Heptagenia flava, H. longicauda, Setodes viridis, Orthocladius majus*, several Chironomini from standing and slow flowing waters, *Stempellina bausei, Stempellinella Pe1 Langton*, *Simulium posticatum, Mideopsis crassipes, Neumania imitata* and *Forelia variegator*. Of the identified invertebrates it is clear that Stoneflies are the most threatened group. Of the 26 species once living in these rivers, only 6 have been recovered, meaning that 73% is relatively rare, hidden of extinct. Of the caddis flies only 57% has been recovered. The other groups seem less vulnerable (recovery rate of the elmid beetles is 65%, mayflies 69%, black flies 75% and midges 79%. Of the water mites the reference status is unknown and no recovery rate can be established.

The western streams are differentiated by 113 taxa that have not been collected in the rivers. These species do not seem to contribute to the ecological rehabilitation of the main rivers.

6.2. Biological assessment of the Seine basin and research strategy

6.2.1. Biological assessment of the Seine basin

The assessment of the Seine basin has taken place by adopting several different assessment tools. Of these the IBGN seems the most suitable. Of the western streams the Andelle, Aubette, Austreberthe, Eure, Oison, Rançon and Sainte Gertrude have a good assessment and the Cailly, Commerce and Robec have an moderate assessment. The Seine-Aval has, at best, an moderate ecological quality. The situation gets worse near and downstream Rouen, augments a bit and turns bad in the most downstream section.

In the upstream part of the basin the quality is good in most tributes without cargo navigation. The most upstream stations in the Yonne, Marne and Oise as well as the stations in the Serein, Armançon, Saulx and Aisne (middle reach) get a “high” score. This seems to be too much credit since a lot of families in the highest biological class have not been found in these rivers. All the stations in the navigable parts score moderate. This also is the cause for the middle reach of the Oise and the Epte. Extrapolating the score for the basin upstream Paris we calculate that 22% of the total river length has an moderate biological quality, mainly due to navigational adaptations. A fraction of 42% has a good ecological quality and 36% scores high.

6.2.2. Biological assessment and research strategy

In this report we conducted two forms of biological assessment. The first and most direct one is the analysis of the biodiversity based on the species composition. The second one is the application of the IBGN index based on family composition and seemingly the best assessment tool among the tested ones.

Information only available in the biodiversity analyses is:

- Assessment of the true biodiversity

- Testing against the reference species composition in the same ecological region and biotope (29% of the species not found and vast majority of stoneflies missing)
- Testing of existing species against communities known from historical and paleo -ecological sources (reference for Seine-Aval).
- Establishment of the fact that aliens have entered the Seine basin and cause problems so far only in the navigable stretches
- Species within groups as the Chironomidae can be reliable indicators.
- Species can be linked to quality indices or traits to get a better understanding of the functioning of a certain community in a certain biotope

The major arguments not to work on species level seem the following:

- There are hardly, if any, educational facilities equipped in taxonomic training.
- Conducting identifications does not seem “hot”
- Managers cannot cope with Latin names
- Seemingly time consuming and thus expensive

When we keep in mind that € 200,000,000,000 is put in the implementation of the WFD it seems in place to get the best available data. It is good practice in the chemical laboratories to analyse the chemicals in the surface water to “species” level (e.g. 3,4-Benzpyrene) and not at a “family” level (Poly Aromatic Hydrocarbon). And indeed there is a good cause to do so. How else can you examine dose – effect relations or trace the polluter?

The same holds true for the biological practice. We need the best available data because the WFD has given ecology the highest priority.

It is here that we would advice to put effort in education facilities for biological analysts to perform proper species identification. A parallel strategy is the development of DNA kits to detect the presence and abundance of species in a sample routinely. The proven technology is available and all that needs to be done is the sequencing of appr. 1500 species and design oligonucleotide microarrays for each species. In our opinion it will take less than 10 years to get routine DNA identification operational at a profitable economic base.

Another effort is needed to construct a highly sensitive assessment application.

It might consist of three elements:

- Species identification for biodiversity information
- Functional composition at species level to get insight in the (mal)functioning of ecosystems and the reasons why
- A new assessment index for the presentation of the results

6.3. Recolonization potential

With the reconstruction of the macro invertebrate community on the freshwater tidal zone of the Rhine some 150 years ago, we indeed can establish that the present fauna in the Seine basin contains many species that are home in the estuary too. Earlier we noted (Klink, 2006) that there are only two species confined to the intertidal belt. One of them is the midge *Thalassosmittia thalassophila*, already found in the Seine-Aval. The other one is the mussel *Mercuria confusa*. Other inhabitants of the freshwater estuary are semi-terrestrial species that can be found outside the estuary as well, or true riverine species able to cope with the tidal currents. As already mentioned, the least concern will be to get the target species in the estuary. The main challenge will be to keep them there, meaning that the estuary has to undergo a major restoration.

6.4. Alien infestation

We touched on a lot of subjects in the paragraph on aliens. We demonstrated that the present Dutch Rhine has an alien infestation rate (AIR) of about 95% and the Dutch Meuse at the Belgian border hosts only 5% aliens. In this specific case it is clear that the aliens are quite intolerant to low oxygen levels and/or high heavy metal pollution. A second aspect is the fact that navigation alters the whole invertebrate community and the functional composition as well (Dolédec and Statzner, 2008). In our research we noticed that the biodiversity drops dramatically when a river accommodates cargo-ship traffic. We also established that the semi-natural upstream sections contain a very high native diversity and low AIR. From literature we learned that regulation of rivers leads to loss of diversity regardless the absence/presence of aliens.

From these facts we can construct the true cascade of events leading to the impoverished state of the present Rhine:

5000 BP -1700 AD: River is still at full width in its summer bed, but since 1100 AD the wide floodplain has dikes. There is still wood the riparian zone and also lots of woody debris lies in the river. These obstructions lead to meandering and the formation of oxbow lakes.

1700 – 1900: The snags are removed and at first local channel corrections are performed. With the ever increasing navigation (from tow paths upstream and with the flow downstream). Later on (From 1825) the channel corrections concerned the whole riverbed. Islands were connected to the shore, groynes were constructed and a second dike close to the riverbed was put in effect. Its function was mainly to prevent the river to move sideways and to collect clay after the dike was flooded (Van Urk and Smit, 1989).

1900 – 1985: The pollution starts to increase to such levels that seals, cormorants and terns could hardly reproduce any more. The pollution was at its peak in 1975. Since then a multi-billion investigation in sewage plants was rolled out and the ecological rehabilitation was well under way (Van Urk, 1981).

1985 – 2010: The rise of the aliens turns the rehabilitation into deterioration. What is gained so far is the construction of nature-like side-channels often in nature reserves. In these side channels the AIR fortunately is much lower (30 – 50%) than in the main channel (Klink, 2008). This is mainly due to the fact that the bottom of the main channel is almost devoid of invertebrates caused by the high powered tow-vessels (Klink, 2002b), while in the side channels a normal live in the sediment is possible.

The events in the Seine will deviate from those in the Rhine, since pollution and large scale training works on the rivers were on a more modest scale. From the collected data of the Seine basin this is likely what has happened:

“After the rivers were suitable for cargo-vessels, the native biodiversity dropped dramatically. Since ships are spreading aliens, the aliens could grab their chance in the impoverished navigable river sections. They can reach the upstream nature-like sections as well, but the native resistance is too strong in most places.”

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