Biological monitoring programme for the Rhine river 2006 / 2007, part A

Summary report on the quality components phytoplankton, macrophytes / phytobenthos, macrozoobenthos, fish

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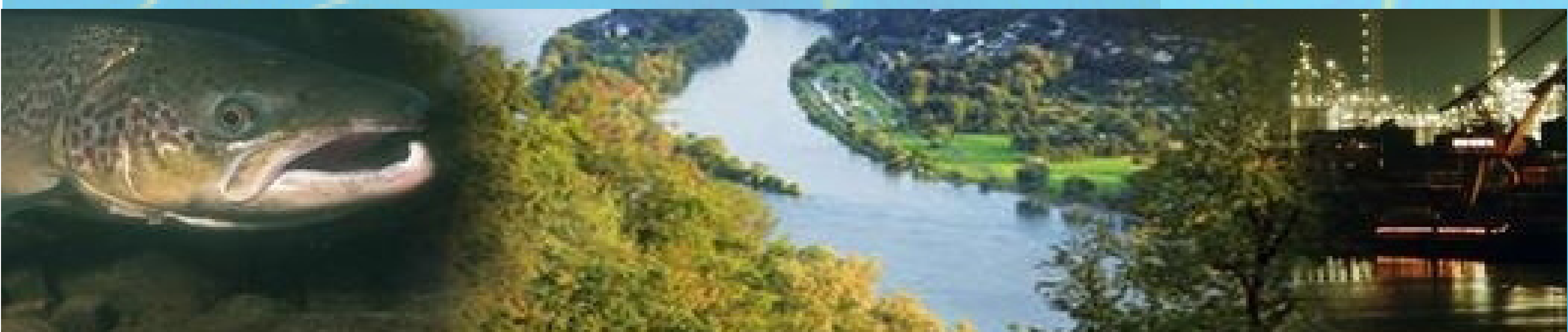

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Biological monitoring programme for the Rhine river 2006 / 2007, part A

Summary report on the quality components phytoplankton, macrophytes / phytobenthos, macrozoobenthos, fish

Biological monitoring programme for the Rhine river 2006 / 2007, part I: Summary report on the quality components phytoplankton, macrophytes / phytobenthos, macrozoobenthos, fish

Survey over the parts of the report

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Survey Part I

Summary

During 2006 to 2007, and within the “Rhine 2020” programme, the biological quality components were analysed on the basis of comparable criteria along the entire Rhine, taking into account the guidelines of the EU Water Framework Directive. Apart from conducting an inventory, the Biological Monitoring Programme for the Rhine aims at detecting modifications of the biocoenosis and gives an overall assessment of the ecological state of the different sections of the Rhine.

Due to today’s good quality of Rhine water, and the already implemented measures targeted at improving river patency and at enhancing structural variety, the biocoenoses of the Rhine have distinctly recovered: Many species have returned; as far as the fish fauna is concerned, the species composition is almost complete. However, concentrations of certain nutrients/substances distinctly increase along the longitudinal axis of the Rhine and there are too few varied habitats, so that many typical species are lacking, their species number is very low or their presence is restricted to local areas:
Based on results for phytoplankton and phytobenthos, the High Rhine is assessed to be of „very good“ quality, for the macrozoobenthos the result is „good“. These assessments reflect good water quality, while this section (just as the Alp Rhine) has deficits which are due to the impounded sections and lacking access or river patency for the fish fauna. The southern part of the Upper Rhine between Basle and Iffezheim is equally impounded. From the northern Upper Rhine to the coast (including Lake IJssel) the Rhine is unobstructed and fish benefit from the freely flowing river. However, structures and connections to backwaters are lacking.
In the navigable part of the Rhine from Basle to the coast, the phytoplankton indicates „good“ ecological quality, in the Lower Rhine and the Delta Rhine the ecological quality is locally “moderate”. From the Upper Rhine and downstream, phytobenthos indicates deterioration towards a “moderate” state. The same section of the Rhine shows deteriorating stocks of macrophytes from largely well furnished stocks on the Upper and Middle Rhine to poor species forms and poor species growth in the Lower and Delta Rhine (including Lake IJssel). This reflects the structural deficiency of the lower sections of the Rhine. The lacking structures equally have their effect on the heavily simplified macrozoobenthos with its many invasive species which, from the Upper Rhine to the coast (including Lake IJssel) is assessed to be “moderate” to “poor”. Only the state of the Wadden Sea is in “good”. As far as the component „macrophytes“ is concerned, the Wadden Sea is assessed to be „bad“, as the typical sea grass is largely lacking. According to phytoplankton data, the state of the Wadden Sea is moderate; in coastal waters water quality varies considerably from one year to the next and is assessed between „very good“ and „poor“.

1. Introduction

This summary report combines the results of the biological monitoring along the Rhine according to the programme „Rhine 2020" and the assessment of the "ecological state" according to the EC Water Framework Directive (WFD). The data on the biological quality components phytoplankton, macrophytes, phytobenthos, macrozoobenthos and fish were globally viewed for the main stream of the Rhine.

1.1 Biological monitoring programme for the Rhine

The „Biological monitoring programme for the Rhine" (ICPR 2006) determines the details on the monitoring locations in the main stream of the Rhine, on methods and assessment for each biological quality component. In the EU Member States it closely follows the requirements set out in the WFD.

The main objectives of the biological monitoring programme for the Rhine are

(1) an as complete and representative inventory of biological quality components (species survey – species list) in the Rhine between Lake Constance and the estuary, taking into account the natural structure of the Rhine; individual results for the Alp Rhine and for the great lakes (Lake Constance, Lake IJssel) complete these observations;

(2) the determination of modifications of the stock of species by comparing current with existing historical and recent data (inventories in the main stream of the Rhine from the outlet of Lake Constance to the North Sea estuary in 1990, 1995 and 2000);

(3) the determination of eventual considerable modifications of the dominant species proportions;

(4) the integration of monitoring results regarding fish migration at individual locations in the Rhine (Iffezheim and Gambsheim fish passages, fish passages in tributaries (mouth of the rivers Sieg and Agger, mouth of the Moselle, etc.);

(5) a first general assessment of the ecological status of the sections of the Rhine.

1.2 Determination of the „ecological status" based on the biological quality components according to the WFD

With a view to developing programmes of measures and management plans for river basin districts, the EC Water Framework Directive (EC-WFD) requires the assessment of the ecological status or ecological potential of water bodies. The components of the biocoenosis used for this assessment are phytoplankton, macrophytes, phytobenthos, macrozoobenthos and fish fauna (see 1.3).
The objective of the WFD is to determine the actual state, on the basis of which measures are implemented in order to achieve a good ecological status of the water body by 2015. The target for heavily modified water bodies is to achieve a good ecological potential. The development of the required assessment procedures in the EU-Member States is accompanied by the EU inter-calibration procedure which is to grant the comparability of the assessment results (see 2.4).
The Rhine bordering countries have classified almost the entire longitudinal course of the Rhine as heavily modified water body.

The results of this summary report will be integrated into the management plan for the International River Basin District Rhine (part A).

1.3 Indication of the ecological status on the basis of the individual quality components

Phytoplankton (species composition, biomass) indicates the nutrient pollution of a water body.
Phytobenthos (above all benthic diatoms = Bacillariophyta) react to changes in water quality with characteristic shifts of the species composition and the species frequency and indicates nutrient and salt pollution, saprobity and the state of acidity in the water body.
Aquatic **macrophytes** (aquatic plants) may equally be used to assess the nutrient pollution of flowing waters; however, they also distinctly react to interferences with the flow regime (potamalisation, impoundment) and reflect the structural conditions given in the water body (substrate diversity and dynamics, degree of cover establishment of the river bank and the river bottom).
Through species composition, dominance relationships and the presence of invasive species, the **macrozoobenthos** (invertebrates living on the river bottom) serves as an indicator for water quality and structural conditions in the water body.
Species composition, abundance and age structure of **fish** indicate structures of large areas, patency, modifications of discharge (e.g. impoundment, water intake, diversion) and thermal pollution.

1.4 Characterisation of the sections of the Rhine[1]

Due to hydrological and geo-morphological conditions, there are very different habitats in the Rhine. Therefore, along the 1320 km course of the river from the Swiss Alps to the outlet into the North Sea it is subdivided as follows:
The most important of the 13 identified source rivers of the Rhine are the **Vorderrhein** and the **Hinterrhein**. At an altitude of 2340 m, the Vorderrhein flows out of Lake Tomasee, the Hinterrhein begins at the Rheinwaldhorngletscher on the San Bernhardino. In certain locations, Vorder- and Hinterrhein flow through deep and narrow canyons (e.g. Via Mala). They are typical alpine mountain brooks with rocky subsoil, low temperature, high flow velocity, well oxygenised and with low nutrient content. Already in its source area, the Rhine undergoes to morphological and hydrological modifications due to water training measures (retention basins, water diversion canals).
At an altitude of 650 m and after 70 km of river course, Vorder- and Hinterrhein join to form the **Alp Rhine**. This section of the Rhine is hardly 100 km long and is followed by a 10 km wide trough valley of the former glaciers to Lake Constance. The river bottom consists of mighty aggradations which were used for gravel extraction during the last century. This led to erosion and lowered the groundwater table. Where it flows into Lake Constance (inland delta), the Alp Rhine also deposits detritus. River training measures carried out during the last century aimed at water protection, straightened the course of the Alp Rhine and cut it off its alluvial areas and side waters.
With its 535 km^2 **Lake Constance** is the third largest lake in Middle Europe. If its water volume is considered (48 km^3), it is even the second biggest. Its watershed is 11 500 km^2, its average depth is 90 m (maximum depth 254 m). 62 % of the water transported through the tributaries and into Lake Constance comes from the Alp Rhine. Lake Constance consists of two parts which differ in many characteristics: The considerably bigger and deeper Lake Obersee and the shallow Lake Untersee. The habitat of Lake Constance consists of bank and shallow water reaches (litoral and sublitoral zone), a benthic deep water zone (profundal zone) and the free water zone (pelagial zone). As

[1] See also „(Abschnitts)Typologie für den natürlichen Rheinstrom“ – ICPR report no. 147, www.iksr.org – only available in German, French and Dutch

Lake Constance is a standing water body, its biocoenosis considerably differs from that of the flowing Rhine. Man made activities (waste water discharges, uses of lake water, fishery, atmospheric substance inputs, etc.) have impacted the ecology of Lake Constance in many ways.
At Stein, the Rhine leaves Lake Untersee. Originally, the river section which, as far as Basle is called **High Rhine**, was characterized by a strong slope, sections with coarse substrate and rocky bottom, waterfalls and rapids (Falls of the Rhine near Schaffhausen, Laufen near Laufenburg). For purposes of power generation, 11 hydropower plants and some supporting weirs were built since the end of the last century and strongly modified the character of the High Rhine. In particular, in the backwaters of hydropower plants in the river large sections of the High Rhine have developed into a slowly flowing water body with a sandy, muddy sediment cover. The navigable part of the High Rhine begins at the bridges over the Rhine at Rheinfelden. Individual nature near, rapid and turbulently flowing sections with various gravel substrate mosaics still exist between Lake Constance and the mouth of the river Thur as well as upstream the mouth of R. Aare.

As late as the beginning of the 19th century, the **southern Upper Rhine** (Basle – Karlsruhe) was still a natural wild river, a river split up into many branches in a floodplain up to 6 km wide, where it changed its course with every flood. With Tulla's training of the Upper Rhine (1817-1874) landscape management and conservation restricted the Rhine to a closed river bed. In particular downstream of Basle this resulted in a twentyfold increase of river bed erosion, resulting in a deeper river and a groundwater table which sank below the root zone of the trees.

In order to produce energy and to improve navigation, the Great Alsace Canal was built between 1927 and 1959 parallel to the so-called **Old bed of the Rhine.** This old bed of the Rhine, where navigation is impossible, is the last freely flowing section of the southern Upper Rhine. In order to support the groundwater table, the planned continuation of the Canal was replaced by the so-called loop solution where the canal loops again flow into the old river bed. In the rest of the Rhine sections the water table is supported by sills. Downstream of Strasbourg until Iffezheim, the last barrage in the Rhine, the Rhine is completely restricted to a canal. The river bottom of the southern Upper Rhine consists of coarse-grained material, around the Isteiner Schwelle (old bed of the Rhine) it is also rocky. Fine sediments tend to deposit in the impoundments. In the river sections of the old Rhine the banks are comparatively nature near, in the other sections they are solidified by rockfill and concrete.

In the **northern Upper Rhine** (Karlsruhe – Bingen) the slope becomes less steep. Originally, and depending on morphological circumstances, the river began to form 2-7 km of meanders often changing their course. Since the last century, the course of the Rhine has been fixed by groynes. Cutting off several loops of the Rhine considerably shortened its course. Today's northern Upper Rhine is characterized by numerous (partly dredged) dead river branches which are only partly connected to the Rhine and flooded (during flood events). Due to the reduced slope of the section between Oppenheim and Bingen (Rheingau) sedimentation processes prevail and form a series of oblong islands.

In the **Middle Rhine** (Bingen – Bonn) and when the river leaves the Rheingau and enters the region of the Rhine Slate Mountains at the Bingener Pforte it abruptly changes from a slowly flowing river with a high degree of fine sediment to a rapidly flowing river of the uplands with rocky river bottom. In this section, morphological changes are limited to rock blasting and securing banks with rockfills. When regulating the mean water level, several groynes were built and transverse dams connected several islands to the river bank.

Due to a similar slope the **Lower Rhine** (Bonn – Bimmen) presents similar features as the northern Upper Rhine. However, due to higher water levels during floods the river meanders are considerably larger. Since the Middle Ages, the width of Lower Rhine has been restricted by dikes, banks have been stabilized, side branches have been obstructed and islands have been connected to the banks. Since the last century, the mean water table has been regulated by groynes. Further characteristic features are the dredged alluvial areas which are partly connected to the Rhine. The river bottom of the Lower Rhine consists of gravelly to sandy material.

At the German-Dutch border near Lobith, the **Delta Rhine** splits into two main branches flowing west. The southern main arm consisting of the sections Waal – Merwede – Noord – Nieuwe Maas is the largest and most important river line of the delta and transports 2/3 of the Rhine water. The kilometre marking of the Rhine follows this main branch. The northern branch – Nederrijn – later on Lek – flows into the Noord respectively the Nieuwe Maas. The (Geldersche) IJssel branches off the Nederrijn and flows north. The lower reaches of the different branches of these rivers are connected with the Maas by several natural as well as artificial water courses and form the Rhine-Maas-Delta.
The water of the Rhine flows into the North Sea at 3 different locations: Via the Haringvliet (by Nieuwe Merwede and Hollands Diep), via the Nieuwe Waterweg (Noord / Nieuwe Maas) and **Lake IJssel** (through the IJssel), an inland lake of 1100 km² created when a former sea bay, the Zuiderzee was cut off the sea by a dike in 1932.
Originally, there were still more river branches in the estuary with even more interconnections. The coastline was divided into numerous islands. With the 8th century, man began to dike islands, becoming more and more efficient, to drain marshes and to desalt them and to construct inland dikes and closure embankments with sluices. The banks of the Delta Rhine are stabilized by groynes and rock fills, the river bottom consists of sand or silt.

As far as the implementation of the EC-WFD is concerned, areas near the coast and the Wadden Sea are part of the International River Basin District Rhine.

2. Monitoring programme

2.1 Responsibility

The biological monitoring programme for the Rhine was carried out on behalf of the following authorities:

Austria:
- Lebensministerium, Wien
- Institut für Umwelt und Lebensmittelsicherheit des Landes Vorarlberg, Bregenz

Liechtenstein: Amt für Umweltschutz, Vaduz

Switzerland: Bundesamt für Umwelt (BAFU), Bern

Lake Constance: International Commission for the Protection of Lake Constance (IGKB)

Germany:
- Baden-Württemberg: Landesanstalt für Umwelt, Messungen und Naturschutz (LUBW), Karlsruhe
- Rheinland-Pfalz: Landesamt für Umwelt, Wasserwirtschaft und Gewerbeaufsicht (LUWG), Mainz
- Hessen: Hessisches Landesamt für Umwelt und Geologie (HLUG), Wiesbaden
- Nordrhein-Westfalen: Landesamt für Natur, Umwelt und Verbraucherschutz NRW (LANUV), Recklinghausen
- State level: Bundesanstalt für Gewässerkunde (BfG), Koblenz

France:
- Agence de l´Eau Rhin-Meuse, Metz
- DIREN Alsace, Straßburg
- Office National de l'Eau et des Milieux Aquatiques (ONEMA), Marly

Netherlands: RWS Waterdienst, Lelystad

2.2 Data basis

Within the biological monitoring programme for the Rhine, comprehensive biological surveys were carried out during 2006 and 2007 according to comparable criteria.
The surveys continued the biological surveys within the "Rhine Action Programmes" of the International Commission for the Protection of the Rhine (ICPR) along the Rhine from Lake Constance to the sea carried out every five years during 1985 to 2000. Qualitative and quantitative reference values for fish, benthic invertebrates (macrozoobenthos) and plankton (phytoplankton and zooplankton) are available for this period. Due to obligations under the Water Framework Directive (WFD) the component phytobenthos / macrophytes has been added (see 1.3). Data available fort he Vorderrhein, Hinterrhein and the Alp Rhine have also been interpreted. In Lake Constance and Lake IJssel samples were taken within separate programmes. Within the implementation of the WFD, coastal waters and the Wadden Sea have been analysed. As the salt water biocoenosis strongly differs from that of inland waters, these Dutch data have been interpreted separately and the results have been integrated into the reports.

2.3 Sampling locations

Table 1 (see annex) indicates, at which sampling locations and sections in the main stream of the Rhine which biological quality components were analysed in what years. Partly, sampling locations preliminarily determined in the "Biological monitoring programme for the Rhine" (ICPR 2006) were substituted by comparable other locations. Partly, data from additional monitoring locations in the Rhine bordering stations were additionally evaluated.

2.4 Methods

Sampling methods have been described within the IPCR (2006) and partly respect additional national obligations (see individual reports part II, A to E, always chapter 2). All Member States, the federal states or the regions have determined the criteria for the evaluation of the ecological state according to WFD annex V for each type of water body and for each relevant quality component. These national **assessment methods** are described in chapter 4 of all individual reports. As comparisons within the ICPR have shown, they are coherent for the main stream of the Rhine. The detailed comparison of methods for sampling and assessment of the tributaries is the issue of inter-calibration on a European level and has not yet been completely accomplished.

The Rhine bordering states have accomplished the national assessments in the beginning of 2009 so that it has been possible to compile the assessment results for the main stream of the Rhine.

3. Results of the individual reports on the biological quality components

In the following, a summary assessment of the coordinated analysis results for each biological quality component of the individual sections of the Rhine is being described. The assessment thus concerns sections of the Rhine.

The assessment for each water body of the river Rhine and for each biological component is available in the relevant maps of the management plan for the International River Basin District Rhine, part A. Work on the management plan will be achieved by 22 December 2009 and published on www.iksr.org.

3.1 Phytoplankton

Centric diatoms form the by far largest part of the plankton biomass – in some places more than 90 %; other important groups of algae are cryptomonads and chlorophyta. Other groups are only of temporary or local importance. The zooplankton, which has been analysed in the Middle and Lower Rhine, increases downstream. With respect to quantity, the protazoa and rotifera, at times also freely swimming mussel larvae play an important role. Crustaceans are of minor importance. Their grazing impact on phytoplankton is considered to be minor and is largely due to stocks of big mussels. Compared to analysis six years ago, nutrient concentrations of the Rhine slightly decrease and the phytoplankton production in the entire main stream of the Rhine largely remains the same.
According to the present state of knowledge, the state of the plankton in Lake Constance is assessed to be good in Lake Obersee and Lake Untersee.
The High Rhine is assessed to be good at Öhningen; in this section, it is still considerably determined by the plankton of Lake Constance. Downstream, at Reckingen, the ecological state of the river is „very good“. This also applies to the upper reaches of the Upper Rhine between Weil and Karlsruhe. Based on phytoplankton, the lower Upper Rhine and the Middle Rhine are classified as „good“, while the lower Lower Rhine at the German-Dutch border is of “moderate” quality. This downstream quality classification reflects the increasing nutrient concentration in the downstream regions. Additionally, with decreasing flow velocity, longer water retention time in the Lower Rhine is in favour of phytoplankton development which already distinctly increases in the Middle Rhine and reaches its peak at Kleve. In the Delta Rhine, the chlorophyll-a-values in Lake IJssel are comparable to those in the Lower Rhine, while lower values were monitored at Maassluis. Along the coast and in the Wadden Sea, chlorophyll-a concentrations considerable vary from one monitoring year to the next (very good state to poor state).

Part II – A presents the monitoring results for phytoplankton in detail.

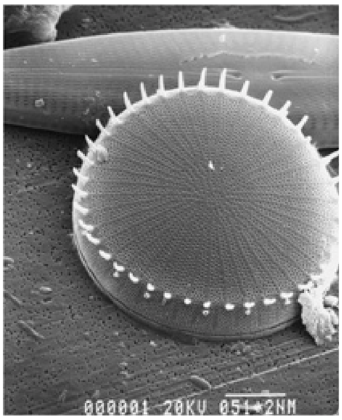

Fig. 1: Phytoplankton: Centric diatom *Stephanodiscus parvus*, scanning electron microscope photo. Photo: V. Burkhardt-Gehbauer, IFS Langenargen

3.2 Macrophytes

All in all, 36 aquatic macrophytes have been detected in the Rhine. Among them, 23 higher plant species (particularly often *Potamogeton pectinatus, Myriophyllum spicatum)*, 8 bryophytes and 5 stoneworts.
The total coverage of macrophytes and species number as well as number of forms of growth tend to decrease downstream the Rhine. Higher aquatic species (seed plants and fern) are found in all sections of the river Rhine. Taxonomic groups sensitive to stronger eutrophication are limited to the upper reaches until the Middle Rhine (submersed pond weeds) or have only been detected in the High Rhine and Lake IJssel (stoneworts).
In the High Rhine, all three sampling stations are rich in species and forms of growth (10-14 species). In the Upper Rhine, the upper reaches as far as Rhine kilometre 317 and the lowermost section around km 542 are equally rich in species and growth forms (4 to 10 species). The species number in the sections in between is low and the forms of growth in these sections are poor, in some sections macrophytes are even completely absent. In the Middle Rhine, only one monitoring station was examined which proved to be rich in both species and forms of growth. In the Lower Rhine, all four monitoring stations are poor in species and forms of growth with a maximum of 3 species and have low coverage. In the Delta Rhine, a monitoring station with a high number of forms of growth was assessed as „good" on a national level, while another location was assessed to be "poor" due to its low number of growth forms and little coverage. In spite of the occurrence of stoneworts indicating good water quality, Lake IJssel too was assessed to be poor because of little coverage and a low number of growth forms. Due to the largely absent sea grass, the state of the Wadden Sea was also assessed to be "poor".
Part II – B of this report presents the monitoring results for macrophytes in detail.

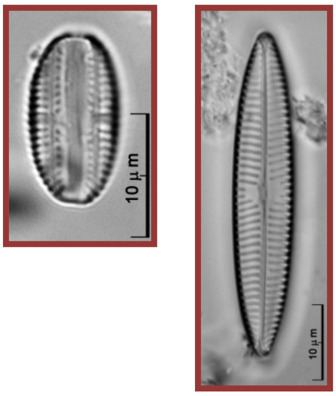

Fig. 2 (left): Water buttercup *Ranunculus fluitans* Photo: K. van de Weyer.
Fig. 3 (right): Diatoms *Amphora pediculus* and *Navicula tripunctata*. Photo: M. Werum

Phytobenthos (benthic diatoms)

Of the 269 diatom taxa detected in the Rhine, *Amphora pediculus, Achnanthes minutissima, Navicula cryptotenella, Nitzschia dissipata* and *Cocconeis placentula* are most wide spread. The species mentioned also develop the most numerous incidence of individuals and are often found as mass forms.
Varying species composition and frequency indicate a distinctly degrading ecological state from upstream to downstream. Trophic level and saprobity are low in the High Rhine and increase further downstream. From the High to the Middle Rhine, the salt pollution is negligible; in the Low Rhine, a low but continuous salt pollution is registered.
The analysed locations on the High Rhine are of very good ecological quality. While the sections of the Upper Rhine analysed downstream to Mannheim are largely assessed to be “good”, the middle and lower part of the Upper Rhine is largely characterized to be “moderate”. The quality of the Middle Rhine is moderate and tends towards the good status. The ecological quality of the Lower Rhine is characterised to be good to moderate. In the Delta Rhine, the good status is prevailing; on the way towards the North Sea, a deterioration of the ecological quality is to be observed.
Part II – C of this report presents the monitoring results for phytobenthos in detail.

3.4 Macrozoobenthos (benthic invertebrates)

All in all, more than 560 species or higher taxa were detected along the Rhine. Above all molluscs, oligochaeta, crustaceans, insects, freshwater spunges and bryozoa make up the aspect. Abundance varies from one section of the Rhine to the next; depending on the position in the transverse profile and seasonal aspects there are between 0 and 10 000 individuals/m².

Fig. 4: Larvae of the mayfly *Epeorus alpicola*. Photo: B. Eiseler

In the Vorder- and Hinterrhein and in the Alp Rhine rheophile insect species, that is larvae of mayflies, stone flies and caddis flies typical for the system of the Alp Rhine are dominant. Species diversity is high and species composition increases downstream. None of the immigrated new species have so far been able to settle in the lower reaches of the Alp Rhine. The status can be said to be good. Only the swell-sunk waves due to hydropower plants in the Alp Rhine considerably impact the benthic biocoenosis.
Lake Constance being a still water has its own fauna composition distinctly different from that of the Rhine. Its status has not been assessed.
The High Rhine belongs to the most species rich sections of the Rhine. In particular in the freely flowing aspects it is characterised by a macrozoobenthos community near to the natural state. Increasingly, introduced fauna species are found. The status can be said to be good.
Downstream of Basle, the natural longitudinal segmentation of the Rhine is impacted by anthropogenic interferences. In the navigable and trained Rhine (Upper, Middle, Lower and Delta Rhine) the benthic fauna is largely uniform and is – apart from invasive species - dominated by common and frequent colonizers of bigger rivers and streams with little demands to their habitats (ubiquists). Elements of the original fauna are partly found in connected oxbow lakes and loops of the original course of the Rhine. The status of this section of the Rhine can be characterized as moderate to poor; in some sections along the Lower Rhine it is even bad. As far as the macrozoobenthos is concerned, the situation in the coastal waters indicates a moderate status, while the status in the Wadden Sea is characterised to be good.

The macrozoobenthos in the Rhine is closely connected to the pollution of the river water. In the beginning of the 20th century, about 165 species, among them 100 insect species were detected. With increasing wastewater pollution of the Rhine and its sinking oxygen content this number drastically diminished, in particular between the middle of the 1950s and the beginning of the seventies. Thus, in 1971, only 5 insect species were detected. Improved oxygen content due to the construction of industrial and municipal wastewater treatment plants made many characteristic river species which were said to be extinct or heavily reduced return from the mid 1970s on. However, many species are still absent. Partly, the areas they have retired to are so far away that a natural return seems unlikely.

Fig. 5: Asian clam *Corbicula fluminea*. Photo: K. Grabow

The invasive species, which, since 1992, have above all been introduced into the Rhine via the Main-Danube Canals settle in the main stream and the tributaries, often in great biomasses and, attached to ship even spread upstream – often the indigenous fauna pays the toll. Partly, anthropogenic influence such as increased water temperature, hydraulic engineering measures and substances present in the water favour their development. The dominance and constancy (= relative frequency or distribution of a species compared to other species and related to a specific habitat) of invasive species partly leads to a considerable restructuring of the biocoenosis. Original Rhine species (e.g. *Hydropsyche* sp.) or old invasive species (e.g. *Gammarus tigrinus)* have been crowded out and replaced.

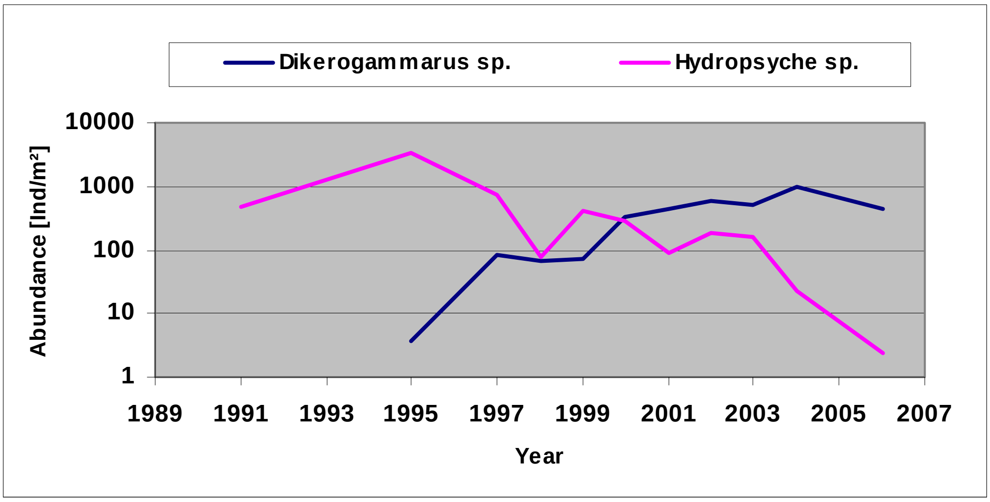

Fig. 6: Abundance of the predatory *Dikerogammarus sp*. introduced from the Black Sea and of the indigenous caddisfly *Hydropsyche sp*. in the Middle Rhine.

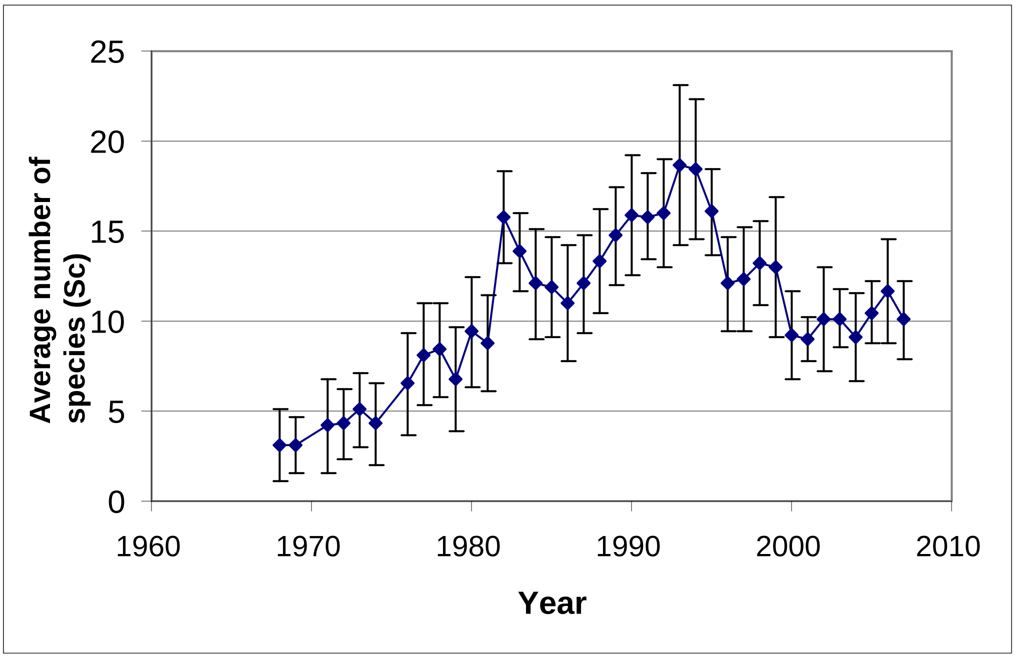

Fig. 7: Average number of species 1968 – 2006 along the Lower Rhine.
Increasing number of species until the beginning of the 90s due to rising oxygen content and decreasing pollution followed by increased spreading of invasive species at the expense of species typical for the Rhine.

During the last 15 years, the total number of species has been comparably constant in the navigable part of the Rhine. However, since 1995, the average number of species per sampling location is regressing. Presumably, the invasive species as a factor of biological stress are partly responsible. In addition, the absence of suitable habitats in the river itself prevents the return and spreading of a benthos fauna typical for the Rhine. If at all, many of the insect species detected in the Rhine around 1900, such as the typical Rhine mayfly *Oligoneuriella rhenana* are only detected in the Rhine tributaries, as they do not find any suitable habitats in the main stream.
Part II – D of this report presents the monitoring results for macrozoobenthos in detail.

3.5 Fish

The species composition in the Rhine is almost complete. Including the 3 trout variants and introduced species, 67 fish species have been detected. Thus, all historically identified species except for the Atlantic sturgeon have returned. Since the last inventory in 2000, the round goby, a non indigenous fish species has settled. Another newcomer in the list of species is the European sea bass which, from time to time migrates from the North Sea into the mouths of rivers. After the inventories of 2000, the species great sturgeon, lake trout and silver carp have no longer been detected. Comparatively undemanding species (roach, bream, chub, perch, bleak, and ruffe) are dominant. The predatory asp has distinctly increased and spread to further areas.
Most fish species are found in the Upper Rhine and the Delta Rhine including Lake IJssel, where some marine species as well as brackish water species are detected. The least species are in found in the Alp Rhine. The reasons for this are partly natural. However, neither the course of the river, nor developments since the middle of the 1990s give evidence of a distinct development tendency of the number of species.
Compared to the freely flowing reaches, the many impounded reaches of the Rhine and in most tributaries present considerable deficits for the habitat of the fish fauna. In the

Alp Rhine, construction measures, the modified flow regime due to the use of hydro power for power generation (swell-sunk) and the cutting off of tributaries and of the lower reach are limiting factors for the fish fauna. Habitats for rheophile species are absent in the impounded Alp Rhine, the High Rhine and the southern Upper Rhine. On the whole, frequency and biomass are comparably low. In the High Rhine, the reduced stock of grayling and common nase represent the insufficient quality of habitats for rheophile species.
For species spawning on gravel and in herbaceous areas or which spend parts of their life cycle (juvenile stage) in oxbow lakes and stillwaters rich in plants, habitats (lateral connected alluvial waters and side channels, flooded areas, structures in the mainstream) are still absent. The consequence is that the number of individuals, in particular of phytophilous and stagnophilous species (among others rudd, pike, tench, Crucian carp, weatherfish) and bitterlings depending on big mussels is low.
In the river section Iffezheim - Gambsheim the consequence of the restoration of the up- and downstream river patency is that formerly absent anadromous migratory fish (salmon, sea trout, sea and river lamprey, occasionally allis shad) have returned.
Today, Rhine water quality is no limiting factor for the fish fauna. However, locally higher water temperatures, fine sediment discharges and inputs may put a stress on fish.

Migratory fish
Those water systems, for which river patency has been restored, nearly all show a positive trend in the number of salmonids returning from the sea and in the number of naturally reproducing salmon. Today, the main reproduction areas are to be found in the river systems of Wupper-Dhünn, Sieg, Ahr (presumably), Saynbach and in the Bruche (Ill river system). In 2007/2008, considerable natural reproduction was for the first time documented for the R. Wisper (Middle Rhine). It may be assumed for certain river systems on the Lower and Middle Rhine (R. Sieg, Saynbach, ev. Ahr and Wisper) that between 5 and 20 % of the returning adults during 2007 and 2008 result from natural reproduction of wild salmon.
Presumably, sea trout reproduce in the same habitats as salmon and profit from measures aimed at improving access to and quality of these habitats. Redds of sea lamprey have, among others, been found in the R. Ill system, in the R. Wieslauter, Murg, Wisper, Saynbach, Nette and in the river systems of Sieg and Wupper-Dhünn. It is highly probable that, on the High Rhine, the species also reproduces in the main stream (as far as the barrage Strasbourg). There is no proof of a reproduction or of juvenile allis shad; due to the low number of individuals the species does not seem to settle. Since 2008 and within a EU-LIFE-project, vast stocking exercises are carried out in the Upper Rhine (Hesse), in the Lower Rhine and in the Sieg (NRW) and allis shad will also profit from past and on-going measures towards restoring river patency and improving the habitats in these waters just as the other migratory fish do, so that, on the medium term, a sustainable re-introduction of the species into the Rhine system can be expected.
The stock of eel has considerably diminished. Since the beginning of the 1980s, the influx of glass eel to the European coasts has sunk to a few per cent of the longstanding mean value. There are many reasons for this considerable decrease: Loss of habitats due to river training, reduced upstream migration due to transverse constructions, loss of downstream migrating silver eel at hydropower plants and parasites (*Anguillicola crassus*), fishing of glass eel, yellow eel, silver eel, etc. Additionally, modifications of the marine habitat which are presumably caused by climate change may have a negative impact on the population of the European eel.
Part II – E of this report presents the monitoring results for the fish fauna in detail.

Fig. 8: Sea lamprey. Photo: U. Weibel

4. Outlook

In order to monitor the ecological state of the Rhine and to document the success of the measures planned, a continuous surveillance of the biological quality components continues to be essential.
The cycle of the biological monitoring programme for the Rhine (so far: every 5 years) will be harmonised as follows with the investigations required in the Water Framework Directive (every 6 years): In future, an extensive report comparable to the present one will be presented every 6 years. These reports will include all data on the biological quality components inventoried every year or every 3 years, all depending on national or WFD requirements. As runoff and meteorological conditions distinctly vary from one year to the next, the authorities of the countries or Länder/regions in the Rhine watershed should present data for biological quality components inventoried in one and the same year (i. e. 2012). This would grant better comparability.

5. Literature

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Annex

Table 1: Sampling locations in the main stream of the Rhine and sampled biological quality components

Section of the Rhine	River km		Monitoring location / monitoring section	Responsibility	Biological quality component				
	from	to			Phyto-plankton	Macro-phytes	Phytoben-thos (benth. diatoms)	Makrozoo-benthos	Fish
Vorder- and Hinterrhein			Hinterrhein Bonaduz / Plazas	CH				2006	
Vorder- and Hinterrhein			Vorderrhein upstream Ilanz	CH				2006	
Vorder- and Hinterrhein			Vorderrhein upstream Reichenau	CH				2006	
Alp Rhine			Reichenau-Plessur	CH					2006
Alp Rhine			Oldis-Mastrils	CH					2006
Alp Rhine			Landquart-Ellhorn	CH					2006
Alp Rhine			Ellhorn-Buchs	CH / FL					2006
Alp Rhine			Buchs-Ill	CH / FL					2006
Alp Rhine			Diepoldsau - Mündung Bodensee	CH / A					2006
Alp Rhine			Alp Rhine near Haldenstein	CH				2006	
Alp Rhine			Mastrilser Auen	CH				2006	
Alp Rhine			Triesen	FL / CH				2006	
Alp Rhine			Bangs	A / CH				2006	
Alp Rhine			Fussach	A / CH				2006	
Lake Constance		0,0	Lake Constance	A / CH / D				2006	
High Rhine		23,0	Öhningen (outlet Lake Untersee)	D-BW	2006				
High Rhine	26,0	29,0	Stein am Rhein/Wagenhausen	CH / D-BW		2006	2007		
High Rhine		30,0	Hemishofen	CH / D				2006	2006
High Rhine		56,3	Rheinau (Stau)	CH / D-BW				2006	
High Rhine		56,3	Rheinau	CH					2006
High Rhine		57,0	Jestetten	D-BW			2007		
High Rhine		64,0	Ellikon/Rüdlingen (Thurmündung)	CH / D-BW		2006		2006	2006
High Rhine		71,0	Tössegg	CH				2006	2006
High Rhine		82,0	Hohentengen	D-BW					2006
High Rhine		90,1	Reckingen	CH	2006				
High Rhine		98,2	Rietheim, "Alt Rhi"	CH / D				2006	2006
High Rhine		100,0	Waldshut (mouth R. Aare)	CH	2006			2006	2006
High Rhine	120,0	126,0	Laufenburg/Sisseln	CH / D-BW		2006	2007	2006	2006
High Rhine	153,0	153,3	downstream Rheinfelden	D-BW			2007		2006
High Rhine		158,0	Pratteln/ Schweizerhalle	CH				2006	2006
High Rhine		158,4	upstream Pratteln, discharge ARA Rhine	CH / D-BW				2006	
High Rhine		168,2	Basel	CH / D-BfG				2006	
High Rhine		170,0	Basel	CH					2006
Upper Rhine		170,0	Basel	D-BfG				2006	
Upper Rhine		171,5	Basel	D-BfG				2006	
Upper Rhine	171,0	173,0	Basel /Weil	D-BW	2006				
Upper Rhine	174,0	174,0	Märkt (Old bed of the Rhine)	D-BW		2006			
Upper Rhine		174,5	Märkt (Old bed of the Rhine)	D-BW				2006	
Upper Rhine		183,0	Kembs	F	2006		2006	2006	
Upper Rhine		192,0	Old bed of the Rhine near Hombourg	F					2006
Upper Rhine	199,0	199,0	Neuenburg, Old bed of the Rhine	D		2006	2006	2006	
Upper Rhine		218,0	Breisach, Old bed of the Rhine	D-BfG				2006	
Upper Rhine		220,0	Breisach	D-BfG				2006	
Upper Rhine		225,0	Breisach/Vogelgrün, Old bed of the Rhine	CH/ D-BW	2006				
Upper Rhine		227,0	Biesheim (north of Neuf-Brisach)	F					2006
Upper Rhine	236,1	239,0	Breisach/Vogelgruen (Jechtingen)	D-BW					2006
Upper Rhine		249,0	Schoenau (Le Schaftheu)	F					2006
Upper Rhine		252,0	Old bed of the Rhine Sundhouse (near Mulhouse)	F					2006
Upper Rhine		258,0	Rhinau	F	2006		2006, 2007	2006	2006
Upper Rhine		272,0	Schwanau	D-BW		2006	2006		
Upper Rhine		272,5	Ottenheim (loop old bed of the Rhine)	D-BW				2006	
Upper Rhine		291,0	Kehl/Marlen (loop old bed of the Rhine)	D		2006	2006	2006	
Upper Rhine		310,0	Gambsheim	F	2006		2006, 2007	2006	2006
Upper Rhine	313,0	316,0	Grauelsbaum	D-BfG				2006	
Upper Rhine	317,0	318,0	Grauelsbaum	D-BW		2006	2006	2006	
Upper Rhine	319,5	323,0	Rastatt/Iffezheim (Greffern)	D-BW					2006
Upper Rhine		341,0	Rastatt-Plittersdorf upstream Murg-Mündung	D-BW					2006
Upper Rhine		345,0	Steinmauern	D-BW		2006	2006		
Upper Rhine		350,0	Lauterbourg / Karlsruhe	D / F	2006			2006	
Upper Rhine		354,0	Neuburg, frontier	D-RP				2006	
Upper Rhine	360,0	363,0	Karlsruhe	D-BfG				2006	
Upper Rhine	361,0	361,5	Karlsruhe	D-BW	2006	2006	2006	2006	
Upper Rhine		372,0	Leimersheim	D-RP				2006	
Upper Rhine		418,0	Alzey	D-BfG				2006	
Upper Rhine		419,0	Rheingönheim	D-RP				2006	
Upper Rhine	426,0	435,3	Mannheim	D-BW		2006	2006		2006
Upper Rhine		435,5	Frankenthal-Petersau	D-BfG				2006	
Upper Rhine		435,7	Kirchgartshausen	D-BW				2006	
Upper Rhine		443,0	Ibersheim	D-HE			2006		
Upper Rhine		443,3	Worms	D-RP	2006				
Upper Rhine		448,0	Worms	D-BfG, D-RP				2006	
Upper Rhine	450,0	450,0	Rheindürkheim (upstream)	D-HE		2006			
Upper Rhine	456,0	457,0	Biblis	D-HE		2006		2006	
Upper Rhine		462,0	Eich ferry (between Worms and Oppenheim)	D-RP			2008		
Upper Rhine		465,0	Biebesheim	D-HE			2006		
Upper Rhine	468,0	474,0	Stockstadt	D-HE				2006	
Upper Rhine	477,0	477,0	Schusterwörth	D-HE		2006			
Upper Rhine	479,0	479,0	Oppenheim	D-HE			2008		
Upper Rhine		479,5	Oppenheim	D-BfG				2006	
Upper Rhine		488,0	Astheim	D-HE			2006		
Upper Rhine	490,0	490,0	Langenaue	D-HE		2006			
Upper Rhine	492,0	496,0	Ginsheim	D-BfG, D-HE				2006	
Upper Rhine		497,0	Mouth of the R. Main near Bischofsheim	D-RP	2006				
Upper Rhine	496,0	504,0	Mainz	D-RP, D-HE	2006		2006	2006	
Upper Rhine	509,0	509,0	Eltville	D-HE		2006	2006		
Upper Rhine	509,0	511,0	Mainz to Eltville	D-BfG, D-HE				2006	
Upper Rhine	512,0	512,7	Heidenfahrt	D-RP		2006	2006, 2008		

Table 1 continued: Sampling locations in the main stream of the Rhine and sampled biological quality components

Section of the Rhine	River km		Monitoring location / monitoring section	Responsibility	Biological quality component				
	from	to			Phyto-plankton	Macro-phytes	Phytoben-thos (benth. diatoms)	Makrozoo-benthos	Fish
Middle Rhine		530,0	Nahe near Grolsheim	D-RP	2006				
Middle Rhine		533,0	Trechtingshausen	D-RP			2006	2006	
Middle Rhine	490,0	540,0	Mainz to Bingen	D-RP					2006
Middle Rhine	538,0	540,0	Lorch, upstream mouth of R. Wisper	D-HE				2006	
Middle Rhine		542,0	Bacharach	D-RP		2006	2006, 2008		
Middle Rhine		546,0	Kaub	D-BfG				2006	
Middle Rhine		546,0	Kaub, Kauber Wasser	D-RP				2006	
Middle Rhine		555,0	Loreley	D-BfG				2006	
Middle Rhine		586,0	Mouth R. Lahn near Lahnstein	D-RP	2006				
Middle Rhine		590,0	Koblenz, upstream R. Moselle	D-BfG	2006			2006	
Middle Rhine		590,0	Koblenz, upstream R. Moselle	D-RP					2006
Middle Rhine		592,0	Koblenz, mouth R. Moselle	D-BfG	2006				
Middle Rhine		592,0	Koblenz, mouth R. Moselle	D-BfG, D-RP				2006	
Middle Rhine		593,5	Koblenz, downstream mouth R. Moselle	D-BfG				2006	
Middle Rhine		620,0	Brohl	D-BfG					
Middle Rhine		640,0	Honnef	D-NRW			2007		
Lower Rhine	640,0	642,0	Bad Honnef	D-NRW	2006			2006	
Lower Rhine	643,5	644,0	Königswinter	D-NRW					2006
Lower Rhine		654,0	Bonn	D-BfG				2006	
Lower Rhine	651,7	658,5	Bonn	D-NRW					2006
Lower Rhine	663,0	665,0	Niederkassel	D-NRW		2008	2006, 2007		2006
Lower Rhine		680,0	Köln-Rodenkirchen	D-NRW			2007		
Lower Rhine		681,0	Cologne-Westhoven (upstream), right	D-NRW				2006	
Lower Rhine		696,0	Köln-Niehl	D-BfG				2006	
Lower Rhine	672,6	696,0	Köln-Niehl	D-NRW					2006
Lower Rhine		701,0	Cologne - Merkenich, left	D-NRW				2006	
Lower Rhine		703,0	Mouth R. Wupper (near Opladen)	D-NRW	2006				
Lower Rhine	702,0	703,7	Leverkusen	D-NRW					2006
Lower Rhine	709,8	715,9	Monheim	D-NRW					2006
Lower Rhine		723,0	Mouth R. Sieg	D-NRW	2006				
Lower Rhine		734,0	upstream Neuss - Grimlinghausen, left	D-NRW				2006	
Lower Rhine	725,0	740,0	Neuss-Zons (Steiger) to Düsseldorf	D-NRW			2007		
Lower Rhine		740,0	Düsseldorf	D-BfG				2006	
Lower Rhine		735,0	Düsseldorf-Flehe	D-NRW	2006				
Lower Rhine	722,2	756,3	Düsseldorf	D-NRW					2006
Lower Rhine	758,0	758,4	Meerbusch/Nierst	D-NRW		2008	2006, 2007		
Lower Rhine		764,0	Duisburg-Mündelheim, right opposite to Krefeld	D-NRW				2006	
Lower Rhine		765,0	Uerdingen	D-NRW				2006	
Lower Rhine		780,0	Ruhrmündung (Duisburg-Ruhrort)	D-NRW	2006				
Lower Rhine		781,0	Duisburg-Homberg	D-NRW			2007		
Lower Rhine		787,5	Homberg, left	D-NRW				2006	
Lower Rhine		792,0	Orsoy, left	D-NRW				2006	
Lower Rhine	775,0	795,5	Duisburg	D-NRW	2006	2008	2006, 2007	2006	2006
Lower Rhine		798,0	Mouth R. Emscher	D-BfG				2006	
Lower Rhine	805,0	812,9	Voerde	D-NRW					2006
Lower Rhine		815,0	Mouth R. Lippe near Wesel	D-NRW	2006				
Lower Rhine	820,8	821,3	Wesel	D-NRW					2006
Lower Rhine	829,0	846,0	Rees	D-NRW				2006	2006
Lower Rhine		850,0	Emmerich	D-BfG				2006	
Lower Rhine	854,0	855,0	Emmerich	D-NRW		2008	2006, 2007		2006
Delta Rhine		860,0	Spijksedijk	NL				2006	
Lower Rhine	862,5	865,0	Kleve - Bimmen/Lobith	D-NRW	2006		2007	2006	2006
Delta Rhine		885,0	Velp	NL				2006	
Delta Rhine	879,0	891,0	Nederrijn	NL					2004-2006
Delta Rhine		912,0	Remmerden/Rhenen	NL				2006	
Delta Rhine		945,0	Lek, Hagestein Boven Sluis (bei Vianen)	NL			2007		
Delta Rhine		951,0	Loevestein/Vuren	NL				2006	
Delta Rhine		885,0	Waal (Bovenwaal)	NL					2004-2007
Delta Rhine	966,0	976,0	Waal (Nieuwe Merwede)	NL		2008	2007	2006	2004-2006
Delta Rhine		982,0	Opperduit/Lekkerkerk	NL				2006	
Delta Rhine	990,0	991,0	Heinenoord	NL				2006	
Delta Rhine		990,0	Ketelmeer West	NL				2006	
Delta Rhine	982,0	992,0	Oude Maas	NL		2007	2007		2004-2006
Delta Rhine	990,0	1002,0	IJssel / Zwolle, Kampen	NL			2007	2006	2004-2006
Delta Rhine			IJsselmeer	NL	2006	2007	2007	2006	2006/2007
Delta Rhine		1017,0	Maassluis	NL	2006				
Delta Rhine			Egmond	NL				2006	
Delta Rhine			Dovebalg	NL				2006	
Delta Rhine			Piet Scheveplaat raai 601, station 10	NL				2006	
Delta Rhine			Waddenkust 4 km	NL				2006	
Delta Rhine			Waddenkust 8 km	NL				2006	

Remark: Kilometre marking of the Alp Rhine downstream of Reichenau follows the international training of the Rhine (IRR, international treaty Austria-Switzerland) and differs from the kilometre marking of the Rhine downstream of Lake Constance; it is therefore not included here.