The Biology of the Rhine

Summary Report
on the Rhine Measurement Programme
Biology 2012/2013 and
National Assessments According
to the WFD

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The Biology of the Rhine

Summary Report on the Rhine Measurement Programme Biology 2012/2013

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Content

Summary

Within the “Rhine 2020” programme, an investigation of suspended algae (phytoplankton), water plants (macrophytes) and diatoms living on the river bottom (benthic diatoms as part of the phytobenthos), aquatic invertebrates (macrozoobenthos) as well as the fish fauna was made along the entire course of the Rhine during 2012 and 2013. The “Rhine Measurement Programme Biology”, whose methods have been internationally coordinated, is a regular inventory of the biology of the Rhine aimed at documenting and evaluating changes of the biocoenosis. Apart from the lower part of the Alpine Rhine, all water bodies of the Rhine as far as Basel (High Rhine) are classified as natural, those downstream of Basel (Upper Rhine to Delta Rhine) are classified as “heavily modified”. The development target for these water bodies is not the good ecological state but the good ecological potential. The coastal waters and the Wadden Sea are classified as natural water bodies.

Due to today’s good quality of Rhine water, and the already implemented measures targeted at improving river continuity and at enhancing structural variety, the biocoenoses of the Rhine have distinctly recovered since the beginning of the 1990ies: Among the invertebrates, many original Rhine species have returned; the species composition of the fish fauna is almost complete, even though this does not apply to all river sections and to the original dominant species proportions. Measures aimed at reducing the phosphorous content of the water body have resulted in a distinct attenuation of peaks of phytoplankton development so that the water of the Rhine is today clearer than it used to be. Due to an improved “light climate”, aquatic water plant communities typical of rivers and floodplains could again establish in sections of oxbow lakes and protected groynes of the Rhine and thus improve the habitat offer for phytophile fish species.

In parallel to these positive trends, the constant spreading of invasive species mainly via navigation canals leads to a permanent change in the biocoenosis above all of invertebrates, but, since 2006, also of the fish species. The main immigration corridor is the Main-Danube-Canal, by which different small crustaceans and molluscs as well as the first goby species have spread from the Danube. The resulting constant change of today’s Rhine fauna is reflected in considerable variations of concurrent species populations or of species in a predator-prey relationship. Invasive species are also found among the water plants and algae of the Rhine system. But few species occurring in the Rhine are considered to be strongly spreading, such as the Nuttall’s waterweed *Elodea nuttallii.*

Fish and invertebrates, thus the biological quality components which are most concerned by these migration processes, are decisive for the ecological evaluation. The present ecological evaluation of the Rhine ecosystem represents a snapshot, within which the fast biological interactions due to the faunal interchange with reactions of the biocoenosis to programmes of measures have mixed inseparably (see Table 1 and 2 in Chapter 7). Partly, methodical aspects lead to a modified evaluation (deriving the ecological potential, improved inventory techniques, etc., see Table 2 in Chapter 7). However, the long-term trends of the last 20 years also indicate distinct, sustainable ecological improvements. For example, along large stretches of the Rhine, the phytoplankton is again in a good to very good state. This implies ecosystem feedback effects which benefit to macrophytes but also to parts of the fauna (particularly fish). The reduction of the nutrient pollution of the Rhine has led to more a natural biocoenosis of benthic diatoms and of the phytoplankton (see Chapter 7 and Table 1). Structural improvements of river bank habitats, the connection of lateral water bodies, measures aimed at improving river continuity and the reduction of thermal inputs support the indigenous fauna under pressure and are thus heading in the right direction. It will not be possible to drive back established invasive species, but the variety of these measures contributes to mitigate

the adverse ecological effects of the faunal interchange and to stabilise the species diversity in the Rhine ecosystem.

1. Introduction

The synthesis report at hand represents the results of the biological inventories within the second monitoring cycle (2012/2013) of the management plan for the international river basin district Rhine and compares them with the results of the first cycle in 2006/2007. The monitoring programme combines the biological assessment of the river according to the programme “Rhine 2020” with the requirements of the European Water Framework Directive (WFD) (evaluation of the ecological state or potential). The data on the biological quality components phytoplankton, macrophytes/phytobenthos, macrozoobenthos and fish fauna were used for an overall assessment of the main stream of the Rhine. The work is carried out in continuation of the traditional biological monitoring reports within the “Rhine Action Programme” of the International Commission for the Protection of the Rhine (ICPR) which, from 1990 to 2000, were issued every 5 years. Already at that time they included qualitative and quantitative reference values for fish, benthic invertebrates (macroinvertebrates) and plankton (phytoplankton and zooplankton). Due to the requirements of the WFD, the reports now also include the component macrophytes/phytobenthos. Methodical details on the analysis programme and on assessment methods of the member states are given in the Rhine Monitoring Programme Biology (2012/2013 (ICPR 2011a) and in the comprehensive reports on the different biological groups (ICPR 2015a-e).

In addition to the results of the analysis programme, the national ecological evaluations for the 2nd management plan are presented in tables and maps (annex) and compared to evaluations of 2009.

2. Phytoplankton

Suspended algae
see ICPR 2015a

What does the phytoplankton tell about the pollution situation?
The development of a phytoplankton biocoenosis requires a sufficiently long residence time in a water body. Therefore, this quality component achieves high densities in impounded tributaries and in the lower sections of the Rhine. Species composition and biomass permit conclusions on the nutrient pollution of a water body. Phytoplankton (in particular the components chlorophyll-a and *Phaeocystis*) is of particular importance for coastal and transitional waters, as it is a reliable eutrophication indicator and may serve as an early warning system for coastal waters.

What does the biocoenosis of the Rhine look like?
In the food web of large rivers, the species-rich phytoplankton group plays an important part. It may be taken in by zooplankton as well as by active filter feeders among the benthos organisms (e.g. mussels, in particular the zebra mussel *Dreissena polymorpha*, the basket clam *Corbicula fluminea* or Corophium volutator of the genus *Chelicorophium* occurring in high densities). If concentrations of zooplankton are very high or in presence of big populations of mussels/Corophium volutator, a considerable amount of phytoplankton may be eliminated from the water column. The juvenile stages of many fish species depend on planktic organisms (zooplankton) which again depend on the phytoplankton biomass. Thus, planktic primary production is an important basic food resource for the further food web and thus for higher organisms, such as fish.

During the measurement cycle 2012, about 450 planktic living algae taxa were identified in the Rhine. The by far predominant proportion of the biomass consisted of benthic diatoms (class: Bacillariophyceae). In particular during maximum phytoplankton occurrence in the springtime they amount to distinctly more than 90 % of the total biological volume of the phytoplankton. During measurements in the end of May, in Bimmen, the proportion of benthic diatoms in the total volume amounted to exactly 90 %. In the course of the year, the proportion of benthic diatoms diminishes but remains above 50 % in most measurements. In the summer, cryptomonads (Cryptophyceae) represented a higher proportion of up to 24 %. At the measurement stations Koblenz and Bimmen, the proportion of green algae (chlorphyceae) equally rose during the summer. During the plankton bloom in summer in Bimmen, golden algae (chrysophyceae) represented a proportion of up to 37 % of the total phytoplankton volume. Blue algae (cyanobacteria, cyanophyceae) only occurred in concentrations worth mentioning in autumn at the measurement stations Mainz and Koblenz.

Above all, the centric diatoms with high proportions of varying importance of the species *Stephanodiscus hantzschii* and *Melosira varians* and the oblong, colonial diatom *Diatoma vulgaris* were the dominating taxa of diatoms during the spring blossom. Additionally, in the lower sections of the Rhine, *Actinocyclus normanii* and *Cyclotella meneghiniana* were detected. Later during the year, the centric diatom genus *Skeletonema* (*S. Subsalva* and *S. potamos*) dominated. Among the cryptophoceae, the genus *Cryptomonas* by far represented the greatest biomass, followed by the genus *Rhodomonas*. Among the green algae which only represented a low proportion of the biomass, the genus *Chlamydomonas* dominated in spring, later during the year the genus *Willea* partly took over. Among the blue algae, which only occurred in the fall, the genus *Oscillatoria* dominated.

Ecological evaluation of the Rhine
From the **High Rhine** to the **Upper Rhine** (Figure 1) upstream the mouth of R. Neckar the state of the phytoplankton is “very good” (see Annex 1 and 5). In the following

section up to the **Lower Rhine** at Duisburg the state is good, then it turns to moderate. In the **Delta Rhine**, the phytoplankton was assessed in the coastal and transitional waters, in canals and standing water bodies, but not in the big rivers. In this section, as in the Wadden Sea, the good state predominates. However, this good state is not as stable on the Wadden coast and in the Wadden Sea as along the Dutch coast. In the eastern part of the Wadden Sea the state is worse than in the western part.

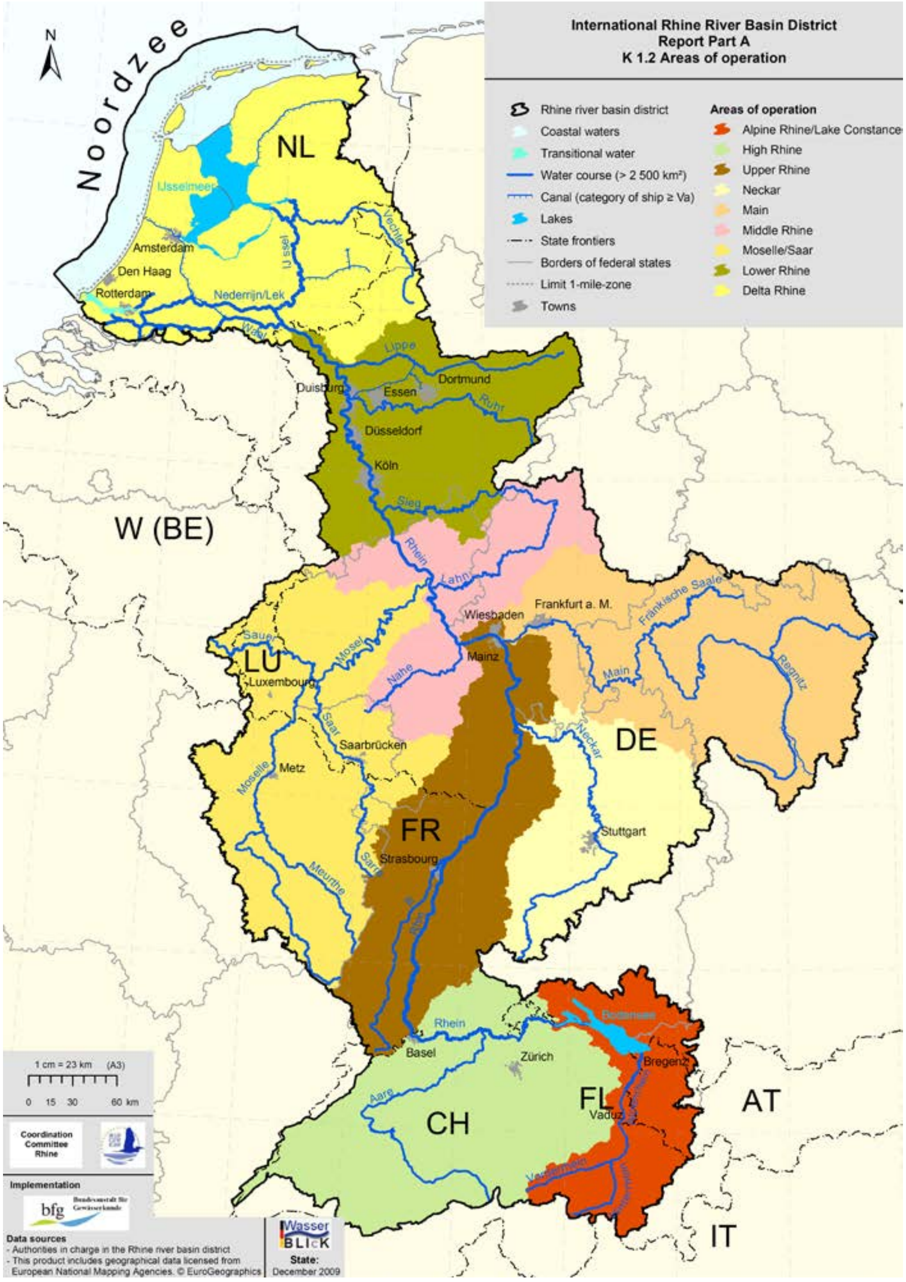


Figure 1: Sections of the Rhine and sub-basins in the Rhine system

A **comparison with the measurement series of 2000 and 2006/2007** shows that in 2012, the phytoplankton biomass was slightly above that of the afore mentioned analysis years. In 2012, concentrations of chlorophyll-a comparable to the total pigment concentrations of 2006/2007 were detected at Koblenz and Bimmen. Since the total pigment concentration also includes phaeophytin, it may be assumed, that, on the whole, chlorophyll-a concentrations were lower during the 2006/2007 measurement campaign. In 2000, the maximum values of the chlorophyll-a concentrations were also slightly lower than in 2012. This does however not mean that there is a trend towards increasing phytoplankton biomass. It may rather be deduced that the phytoplankton development during a vegetation period may differ from one year to the next (Figure 2). Partly, this interannual variability considerably overlaps the positive long-term trend and is mainly determined by the discharge. During a spring with high discharge, phytoplankton will little develop while periods with low discharge and sunny periods will lead to high and long lasting phytoplankton peaks.

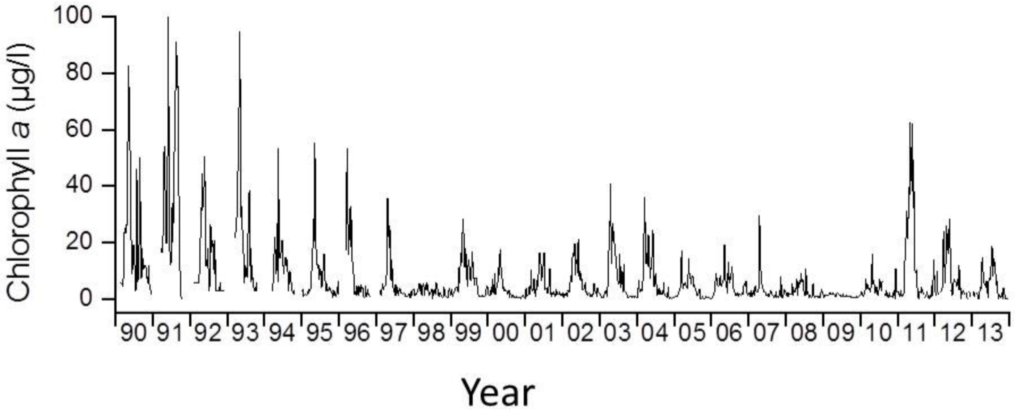


Figure 2: Development of the chlorophyll-a concentration at the Koblenz monitoring station since 1990. Data: Bundesanstalt für Gewässerkunde (BfG)

The ecological assessment of the component shows positive changes corresponding to the ongoing decrease of phosphorous content of the Rhine water. The section of the Upper Rhine between the R. Lauter and the mouth of R. Neckar e.g. improved from a good to a very good state.

What are the long-term trends?

The analysis of long-term trends of the phytoplankton in the Rhine shows that the phytoplankton biomass is distinctly decreasing. This corresponds to the decreasing concentrations of total P (Friedrich & Pohlmann 2009, Hardenbicker et al. 2014). From 0.56 mg/l in 1978, the mean annual total P concentration at the Koblenz monitoring station decreased to 0.12 mg/l in 2012 (Figure 3). While, in the beginning of the 1990s, maximum phytoplankton values of 80 to 100 µg/l chlorophyll a values were measured at this monitoring station, no values at such a level have been determined since. However, it is probable that the decreasing amounts of phytoplankton in the Rhine are not only due to reduced P discharges, but are also a result of reduced discharge from Lake Constance and, above all, increased filtration by the invasive zebra mussel (*Dreissena sp.*), the basket clam (*Corbicula sp.*) and the crayfish *Chelicorophium* (Weitere & Arndt 2002, Hardenbicker et al. 2014).

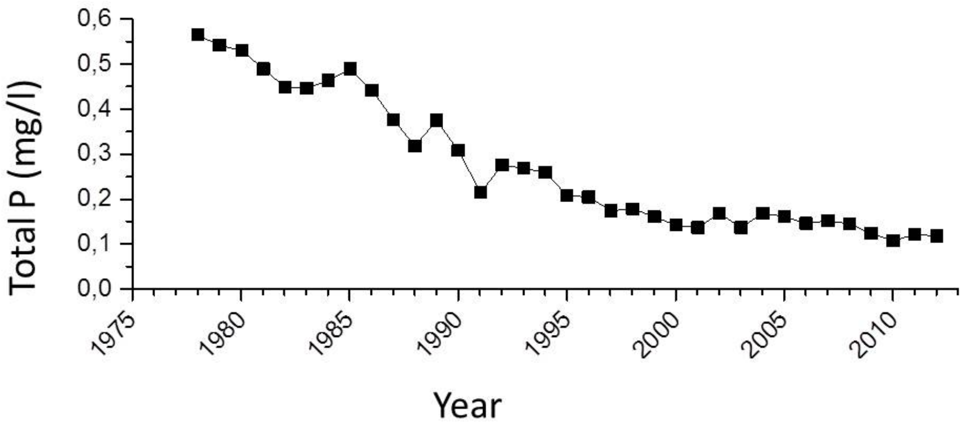


Figure 3: Development of total phosphorous concentrations (mean annual values) at the Koblenz monitoring station between 1978 and 2012. Data: Bundesanstalt für Gewässerkunde BfG

Centric diatoms (diatoms) such as *Stephanodiscus hantzschii* today constitute the by far greatest proportion of phytoplankton; cryptomonads (Cryptophyceae) and green algae (Chlorophyceae) figure among the further important groups of algae. Compared to former assessments, the long lasting trend of the floristic composition of the biocoenosis gives evidence of a distinct reduction of the proportion of green algae. This trend is explained by reduced phosphate contents in the Rhine (Friedrich & Pohlmann 2009).

3. Macrophytes

Aquatic vascular plants, mosses, stoneworts
see ICPR 2015b

What do aquatic plants indicate with respect to pollution?
Aquatic macrophytes can be used to assess the pollution of running waters. Being plant organisms, they are above all very good trophic indicators. But they also distinctly react to other anthropogenic changes of running waters. By this means, interferences with the discharge regime, e.g. impoundments may be indicated. The occurrence of macrophyte vegetation also permits conclusions concerning structural conditions of the water body, e.g. concerning the diversity and dynamics of the substrate or the degree of constructions (see Table 1 in Chapter 7).

What does the biocoenosis of the Rhine look like?
In 2012/2013, 44 aquatic macrophyte species were detected at 49 monitoring stations in the main stream of the Rhine: 27 higher plants, 13 mosses and 4 stoneworts. *Potamogeton pectinatus* (fennel pondweed, 25) was most common, followed by *Myriophyllum spicatum* (Spiked water-milfoil, 20) and *Fontinalis antipyretica* (common water moss, 16). Nuttall's waterweed (*Elodea nuttallii*, Figure 4) is an invasive species which has rapidly spread in Middle Europe since the middle of the last century. In 2012/2013, it was detected in the Upper, Middle and Delta Rhine, but no longer in the High Rhine. However, such mass developments have so far only been observed in some backwaters of the Rhine (e.g. in the Ruhr impoundments). From a floristic point of view, the detection of *Potamogeton gramineus* (Upper Rhine) and *P. friesii* (Middle Rhine) are remarkable. Both species are rare in the Rhine bordering countries concerned and are highly endangered according to the corresponding red lists.

Figure 4: Nuttall's waterweed (*Elodea nuttallii*). Photo: Klaus van de Weyer.

Ecological "assessment" of the Rhine
Within the Rhine Monitoring Programme Biology, the partial component "macrophytes" was considered independently from the other two partial components "benthic diatoms" and "remaining phytobenthos". So far, a reference for aquatic water plant communities of the Rhine only exists for the Netherlands so that an evaluation of the ecological state of the components macrophytes / phythobenthos according to the WFD is only possible for the Netherlands (see Chapter 4). The evaluating statements for the other states are based on an **initial expertise** of individual monitoring stations taking into account the number of species and growth forms, the occurrence of quality indicators and the degree of vegetation cover (see Annex 6).
At three out of four sampling stations in the **High Rhine,** only one species was determined. The aquatic vegetation cover was mostly less than 2 %. This low number of

species and the low vegetation cover are due to methodical reasons and unfavourable discharge conditions (s. Table 2 in Chapter 7). In 2006/2007, with 10 to 14 species, this section of the Rhine belonged to the most species-rich ones.
Most sampling stations along the Upper and Middle Rhine show a cover of more than 2 %. The macrophyte stocks of the **Upper Rhine** are heterogeneous; some have considerable deficits, others are well developed. The 3 sampling stations on the **Middle Rhine** are rich in species and growth forms. During the investigation period, the sampling stations Bacharach (Middle Rhine, km 542) and Langenaue (Upper Rhine, km 490) gave evidence of the most developed macrophyte stocks in the entire course of the Rhine with 17 resp. 14 species and 7 growth forms each (Figure 5). In the **Lower Rhine**, the macrophytes gave evidence of strong deficits. Per sampling station, only 1 to 2 species and a low percentage of cover were detected. In the **Delta Rhine**, at most sampling stations in the Waal, no aquatic macrophytes were detected in 2006/2007 and 2013. However, more species were detected at sampling stations in the Dordtse Biesbosch, the Oude Maas and Lake IJssel.

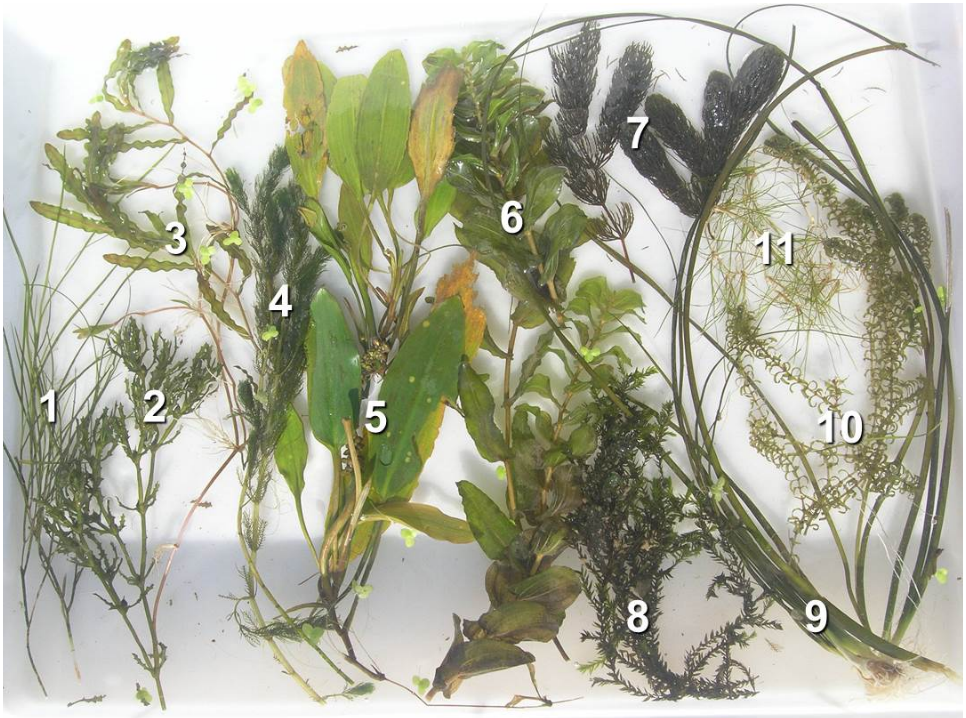


Figure 5: Aquatic plants collected in the Middle Rhine between Rheindiebach and Bacherach: 1) *Potamogeton pectinatus* (fennel pondweed), 2) *Najas marina* (spiny naiad), 3) *Potamogeton crispus* (curled pondweed), 4) *Myriophyllum spicatum* (spiked water-milfoil), 5) *Potamogeton nodosus* (branched bur-reed), 6) *Potamogeton perfoliatus* (perfoliate pondweed), 7) *Ceratophyllum demersum* (hornwort), 8) *Fontinalis antipyretica* (common water moss), 9) *Butomus umbellatus* (Flowering rush), 10) *Elodea nuttallii* (Nuttall's waterweed), 11) *Zannichellia palustris* (horned pondweed). Photo: LUWG Mainz

A **comparison with the data of 2006/2007** shows that today certain species, among them 3 stoneworts, are no longer detected. Twenty species, among them 5 mosses and the various-leaved pondweed *Potamogeton gramineus,* rarely occurring in the Rhine area, were detected for the first time. These changes may have methodical reasons (assessment, see Table 2 in Chapter 7), but they may also indicate specific spreading trends of species. In Germany, the latter may be assumed for the broom fork moss *Octodiceras fontanum* as well as for some pond weeds (*Potamogeton* spp.).
On the whole, the comparison of the present results with the inventory of macrophytes in 2006/2007 indicates great heterogenity in space and time in the Rhine (see Figure 6). There are three reasons for this:

(1) The difficulties of a representative assessment (partly, dives are required)

(2) Varying discharge conditions during the monitoring years
(3) Local variations in the frequency of advantageous riverbank structures (e.g. protected groynes with sand-pebble substrate, Figure 7).

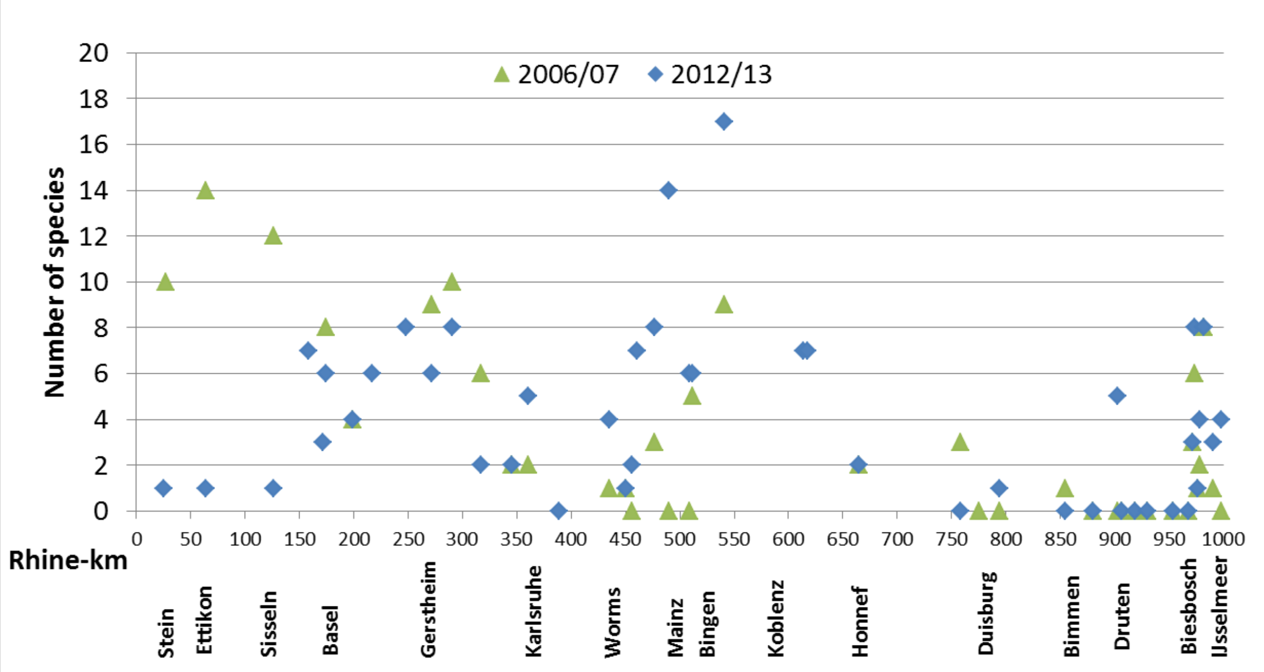


Figure 6: Number of aquatic macrophyte species at the sampling stations in the main stream of the Rhine and the Rhine delta during the investigations in 2006/2007 and 2012/2013

Figure 7: Habitat groyne in the Rhine. Photo: LUWG Mainz

What are the long-term trends?
Since the systematic analysis of the aquatic plants within the Rhine Monitoring Programme started only in 2006/2007, a review is only possible to a limited extent. However, the local mapping of some sections of the Middle and the Upper Rhine and of the floodplains of the Rhine indicates an increase in the number of species and the frequency of macrophytes in this period. This trend can be explained by a decrease in phytoplankton biomass in the Rhine. There is a competitive relationship between aquatic plants and phytoplankton governed by light and nutrients. The less phytoplankton

develops in springtime, the better the depth of visibility. This means that, during the growth period of the aquatic plants, sunlight will penetrate deeper into the water body and thus favour the development of larger stocks. In 2009, aquatic plants developed particularly well (Fischer et al. 2010). It was the year with the lowest chlorophyll-a-concentrations since decades (s. Figure 2).
Discharge conditions and in particular floods are factors influencing the durability and extent of such developments. Furthermore, appropriate riverbank structures are required for new settlements. These conditions may be found in sections of the Upper and the Middle Rhine. Also, the proximity with the species-rich floodplain waters of the Upper Rhine plays an important part in the recolonization of these sections of the Rhine.

4. Phytobenthos

Here: benthic diatoms, bottom-living diatoms

see ICPR 2015c

When evaluating the biological component “macrophytes / phytobenthos”, most Rhine bordering countries only refer to the benthic diatoms (bottom-living diatoms). The determination of the rest of the benthic algae flora is difficult from a taxonomical point of view, as there are no comprehensive identification guides. However, in Baden-Württemberg (DE-BW) and in North Rhine-Westphalia the evaluation takes into account benthic diatoms as well as the remaining phytobenthos. In the Netherlands, phytobenthos and macrophytes are evaluated together. The coastal and transitional waters are evaluated on the basis of seaweeds and common salt marshes (quality and quantity).

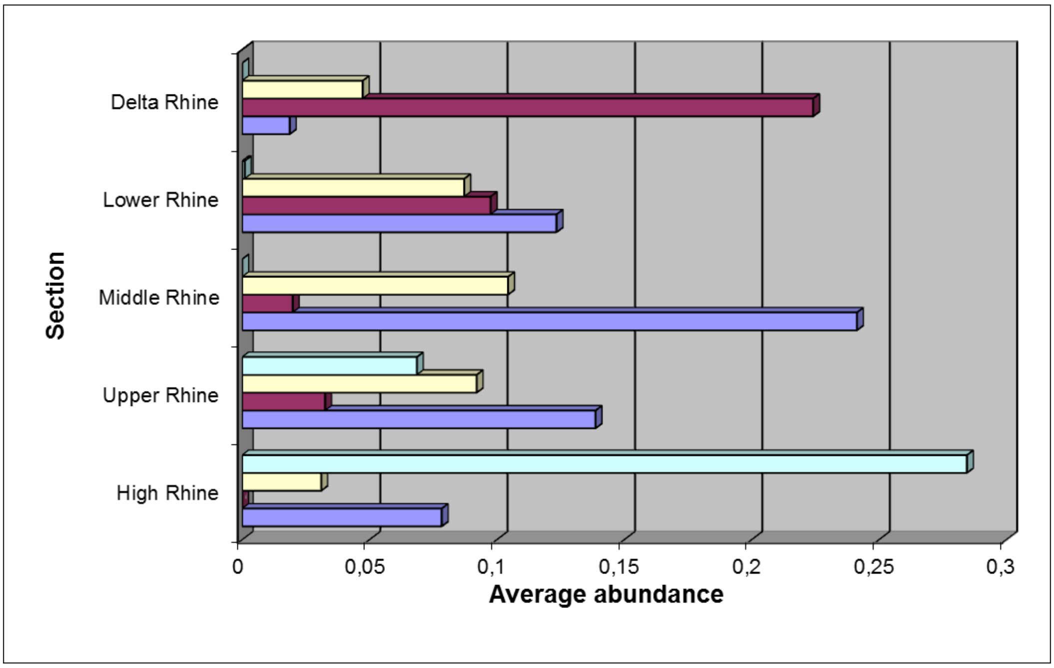
What do diatoms indicate with respect to pollution?

Diatoms are microscopically small single-celled algae. In particular, they develop in running waters, where they form a biofilm on surfaces below the water surface. Due to their great species diversity, their widespread occurrence and their sensitivity concerning the physical-chemical characteristics of their habitat, they are excellent bio-indicators. They in particular permit an evaluation of the nutrient pollution (trophic level), of acidification, salinity and organic pollution (saprobic level) of their habitat (Van Dam et al. 1994, Rott et al. 1997). Due to their short generation time of about three months, the biocoenosis can rapidly react to changes. Since sampling is done in the late summer, the result of the evaluation reflects the situation during the warmer period at lower discharge.

What does the biocoenosis of the Rhine look like?

During 2012/2013, 306 species of benthic diatoms were detected at the 47 analysed sites. This corresponds to a considerable diversity of species even for a large river such as the Rhine. However, many species only occur at a few sampling stations, while a comparatively low number of species (25) occurs at over 50 % of the sampled sites. Figure 8 shows the frequency of distribution of the four most widespread benthic diatom species in the Rhine (photos in Figure 9).

The biocoenosis of benthic diatoms occurring in the course of the Rhine have characteristic, indicative characteristics (guilds). Their succession reflects diminishing flow velocity and simultaneously increasing nutrient contents and organic substances: The species composition of the High Rhine is typical of running waters with few nutrients and organic substances. From the Upper Rhine to the delta, species typical of nutrient-rich habitats represent a considerable proportion. In addition, planktonic and halophile (salt-loving) species occur in the Rhine delta.



Achnanthidium pyrenaicum (Hustedt) Kobayasi
Melosira varians Agardh
Nitzschia dissipata (Kützing) Grunow ssp.*dissipata*
Amphora pediculus (Kützing) Grunow

Figure 8: Average abundance[1] of four aspect-forming species of benthic diatoms in the sections of the Rhine

Achnanthidium pyrenaicum is a pollution-senstive species with great abundance in the High Rhine (Figure 8). The widespread *Amphora pediculus* particularly abundant in the Middle Rhine is considered as euryoecious and ubiquitus which means that the species prefers moderately nutrient-rich waters and tolerates different habitat conditions. It is a pioneer species in habitats with strong biofilm grazing (e.g. by invertebrates or fish).
Nitzschia dissipata: Like most representatives of this genus, the species belongs to the "mobile" guild, capable of moving rapidly and adapted to habitats with turbulent flows and high nutrient concentration.
Melosira varians is a benthic Tychoplankton species which means that it is typical of eutrophic (nutrient-rich) standing waters and represents a large proportion in the samples from the lower river section. A portrait of the four most common species is given in Figure 9.

With respect to the trophic level (nutrient availability), the High Rhine and the first sampling stations on the Upper Rhine indicate a mesotrophic habitat (Figure 10). Further downstream the Rhine becomes increasingly enriched in nutrients, and meso-eutrophic and eutrophic taxa become more abundant. Downstream from the monitoring station Wyhl (no. 9) eutrophic species become more frequent; downstream of the monitoring station Biblis (no. 21) eutrophic species are dominant and represent more than 50 %.

[1] See glossary

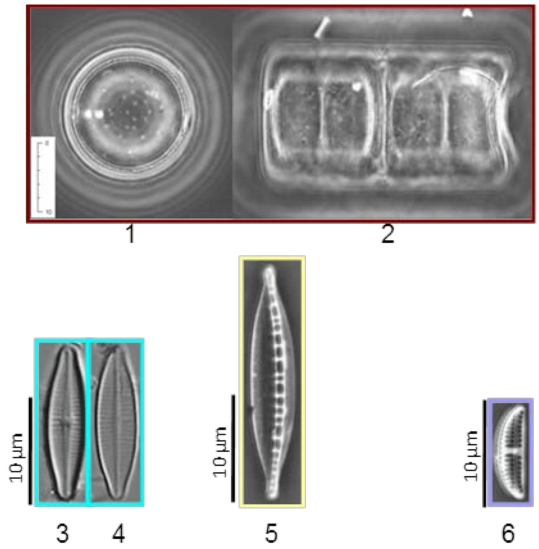


Figure 9: The four aspect-forming species of benthic diatoms of the Rhine. 1-2: *Melosira varians* top view (1) and side view (2); 3-4: *Achnanthidium pyrenaicum*; 5: *Nitzschia dissipata*; 6: *Amphora pediculus;* photos D. Heudre.

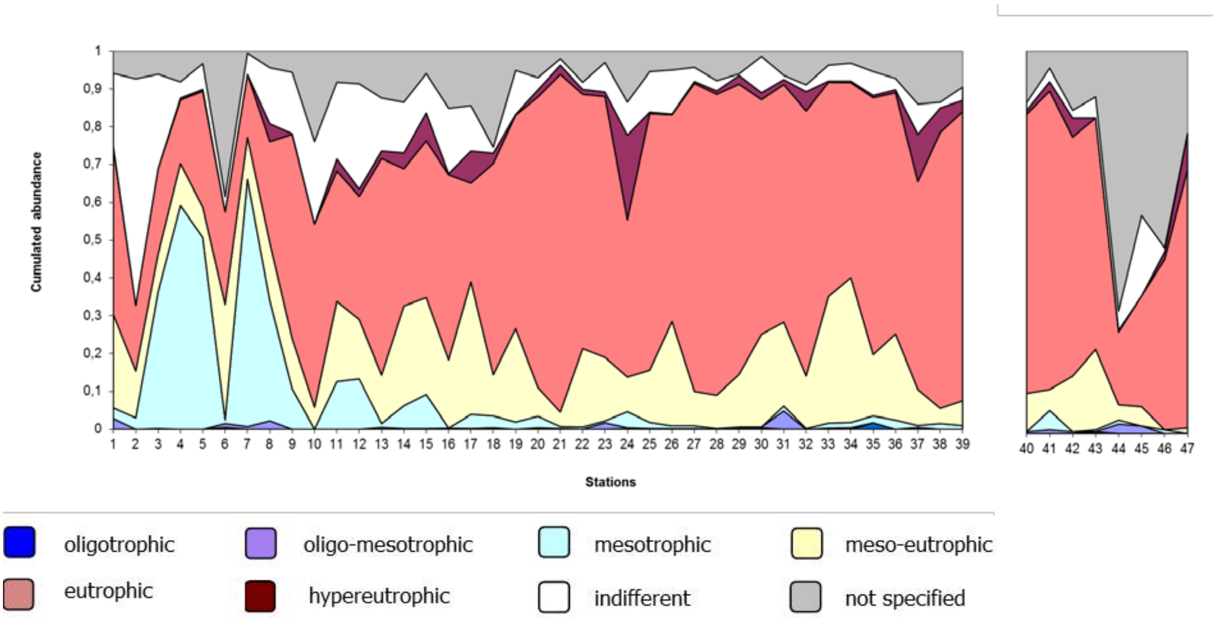


Figure 10: Cumulated species abundance, distribution based on nutrient sensitivity (Van Dam et al. 1994). High Rhine: Stations 1 - 5; Upper Rhine: 6 - 28; Middle Rhine: 29 - 32; Lower Rhine: 33 - 36; Delta Rhine: 37 – 39; IJssel: 40 – 45; Noordzeekanaal: 46; Hollandsche IJssel: 47.

Ecological evaluation of the Rhine

As shown in Annex 2 and Annex 7, all parts of **Lake Constance** were evaluated to be "good" in 2012, just as the entire **High Rhine and the southern Upper Rhine** to the Iffezheim impoundment. Without exception, the further course of the Rhine (**northern Upper Rhine, Middle Rhine**) up to the German-Dutch border is evaluated as moderate with one "poor" section in the **Lower Rhine** (mouth of R. Wupper to mouth of R. Ruhr). Numerous water bodies of the Delta Rhine have achieved the good state / good ecological potential as far as the quality component macrophytes / phytobenthos is concerned: Boven Rijn / Waal, IJssel, the Randmeren, Ketelmeer, Vossemeer, Zwartemeer and all big canals. Nederrijn / Lek, Merwede, Afgedamde Maas, Noord, Dortdtsche Kil and the Markermeer were evaluated as moderate, the Hollandsche IJssel as poor. The **mainland coast of the Wadden Sea** was evaluated as moderate, the **Wadden Sea** as poor. The **Dutch coast** belongs to a different type, for which the evaluation on the basis of seaweeds and common salt marshes is not applicable.

Within the **Rhine Monitoring Programme Biology 2012/2013,** 47 monitoring stations, that is 11 more than in 2006/2007, were sampled. Accordingly, the total number of species amounted to 306 taxa, which is 14 % more than before. However, in both monitoring cycles aspect forming species are similar. The two most common species (*Amphora pediculus* and *Nitzschia dissipata* ssp. *Dissipata)* maintained their ranking. This also applies to their steadiness (probability of occurrence at a monitoring station). In addition, *Achnanthes minutissima* var. *minutissima* and *Navicula cryptotenella* play dominant roles. However, in 2012/2013, *Melosira varians,* belonging to the dominant algae in plankton, was more common.

With a resulting good status, the ecological evaluation deducted from the results has remained comparatively stable for the main stream of the Rhine up to the northern Upper Rhine. The following sections up to the transition of the Lower Rhine into the Delta Rhine were mostly evaluated as moderate. In the Delta Rhine, the water bodies Waal and Lake IJssel have improved from moderate to good. This also applies to the Niewe Waterweg which has improved from moderate to good.

What are the long-term trends?

As benthic diatoms were first investigated and evaluated by the Rhine Monitoring Programme 2006/2007, no statement can be made with respect to the long-term trend of this group. It is however undeniable that - comparable to the phytoplankton situation - the reduction of the nutrient pollution of the Rhine has resulted in a more natural biocoenosis.

5. Macrozoobenthos

Invertebrate fauna at the river bed
see ICPR 2015d

What does the invertebrate fauna tell about the pollution situation?
The species diversity and dominant species proportions of the macrozoobenthos is an indicator of water quality, and of the quantity and quality of habitat structures in a water body. The settlement of thermophilic invasive species also permits to draw conclusions on thermal pollution.

What does the biocoenosis of the Rhine look like?
All in all, more than 500 macrozoobenthos species were detected in the Rhine between the Alps and the North Sea. Above all molluscs (Mollusca), oligochaeta, crustaceans, insects, freshwater spunges and bryozoa make up the aspect. The **Anterior and Posterior Rhine** as well as the **Alpine Rhine** present a high macrozoobenthos variety. Rheophile insect species such as larvae of ephemera, stone flies and trichoptera, which are typical of the system of the Alpine Rhine, dominate. None of the other immigrated new species have so far been able to settle in the lower reaches of the Alpine Rhine. The **High Rhine** combines biocoenosis components from a large variety of types of water bodies - from mountain and upland rivers to the great lake of the Pre-Alps and to the potamal. The fauna is species-rich and, in spite of immigrated fauna species, in parts still close to natural. In the navigable and trained Rhine downstream of Basel (Upper, Middle, Lower and Delta Rhine), the benthic fauna is largely uniform and is – apart from invasive species - dominated by common and frequent colonisers of bigger rivers and streams with little demands on their habitats (ubiquists). Elements of the original fauna are partly found in connected oxbow lakes and loops of the original course of the Rhine. In the **northern Upper Rhine** downstream of Mainz and in the **Middle Rhine,** the proportion of invasive species is diminishing while that of traditional Rhine species is increasing. Apparently, this is also due to re-colonization by indigenous species from refuges in the tributaries. In the further course of the **Lower Rhine** up to Cologne, these positive trends decrease again. In the lowlands, the river changes its character. Sandy substrate increases. In the **Delta Rhine**, these substrates are above all colonized by chironomidae, oligochaetes and mussels while, on hard substrates, a biocoenosis similar to that of the Lower Rhine is found. In the Delta Rhine near the coast the fauna is composed of brackish and marine water species.

Ecological evaluation of the Rhine
As is shown in Annex 3 and Annex 8, the alpine sections of the Rhine up to upstream the mouth of R. Aare (**Alpine Rhine** and **parts of the High Rhine**) are species-rich and in a good ecological state. The proportion of invasive species rises in the further **High Rhine** up to Basel, so that the evaluation only results in a moderate state. For the navigable part of the Rhine downstream of Basel the environmental target is to achieve a good ecological potential. As far as Breisach in the southern Upper Rhine it is moderate. From there on up to Strasbourg and from Karlsruhe to the mouth of R. Neckar it is evaluated to be poor, while the sections from Strasbourg to Karlsruhe and from downstream the mouth of R. Neckar to Mainz are again moderate (s. Annex 8). In the course of the **northern Upper Rhine** the situation continues to improve and from the Rheingau on and in the **Middle Rhine**, even the good ecological potential is achieved. In the **Lower Rhine** up to Cologne, the potential has been classified as moderate, from there on to the Dutch border as poor. The Rhine arms Boven Rijn / Waal, Nederrijn / Lek and IJssel were evaluated as poor, most other water bodies in the Delta were evaluated as better: the

Markermeer, the Wadden Sea and the Ducht coast as moderate, Lake IJssel, the Nieuwe Waterweg and the Wadden coast as good.

A positive **change compared to the first monitoring cycle** is the development in the northern Upper Rhine downstream the mouth of R. Neckar up to the end of the first section of the Lower Rhine at Leverkusen. In this section, the macrozoobenthos component improved by one class (from a poor state to a moderate potential), while the improvement between Mainz and Bad Honnef (last section of the Upper Rhine and Middle Rhine) even amounted to two classes (from a poor state to a good potential). This improvement may have three reasons:

(1) The spreading trends of original Rhine species of great ecological value: Since 2006 it is observed that the river nerite (*Theodoxus fluviatilis*) is starting to re-colonize the Rhine from the R. Main (Fig. 11 and 12)[2]. At the time being, its focal point of colonization in the Rhine is located between Karlsruhe and Koblenz. Downstream of Mainz it is developing large populations. Furthermore, the Middle Rhine is being inoculated by some insect species typical for the Rhine from R. Nahe, where they had found a refuge.

(2) Less frequent invasive species: This is in particular very distinct in parts of the Middle Rhine. Recently imported invasive species are a concurrence for "older" invasive species in the Rhine, a trend which particularly concerns strongly related species and/or species, which fundamental niches largely overlap. An example for this phenomenon is the successive displacement of the Zebra mussel (*Dreissena polymorpha*) by the Quagga mussel (*Dreissena rostriformis bugensis*) (Schöll et al. 2012) or that of the Caspian mud shrimp *Chelicorophium curvispinum* by the related *C. robustum* (Fischer 2013). Since thermophile species such as the Asian clam (*Corbicula fluminea*) are proved to be sensitive to cold temperatures, the cold winters 2009/2010 and 2012/2013 and ceased thermal discharges will probably have resulted in a decrease of the species (Schöll 2013) (see Table 2 in Chapter 7).

(3) Improvements for methodical reasons: For the first time, the procedure of evaluating the potential has been applied to heavily modified Rhine water bodies. During the 1st monitoring cycle, these water bodies had still been considered as natural water bodies and their evaluation was thus too strict. (see Table 2 in Chapter 7).

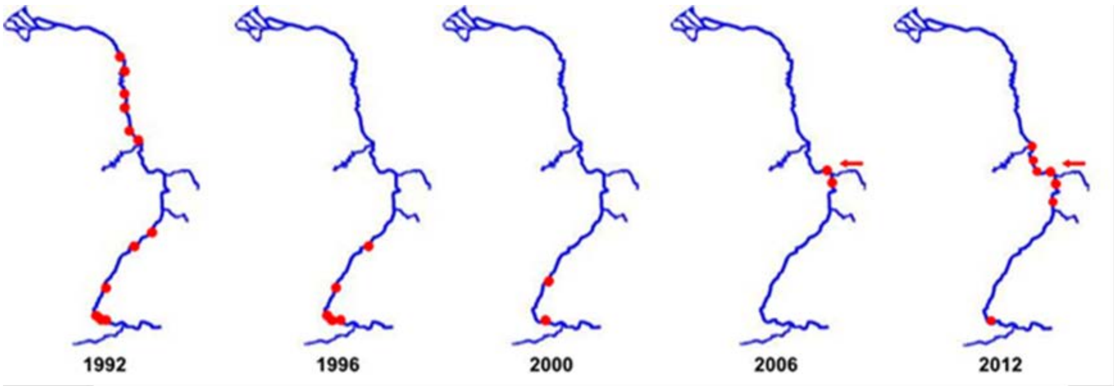


Figure 11: Spreading of the river nerite *Theodoxus fluviatilis* in the navigable Rhine (Westermann et al. 2007, complemented), without taking into account the occurrence in side waters

[2] The population of *Theodoxus fluviatilis* spreading in the Rhine since 2006 originates from a genetic cohort indigenous in the Danube area ("cryptic invader"). This is the result of recent scientific investigations (Gergs et al. 2014). This does, however, not have any effect on the species status and its ecological role in the Rhine ecosystem.

Figure 12: *Theodoxus fluviatilis*. Photo: LUWG Mainz

The only deterioration compared to the 1st monitoring cycle (from a moderate ecological state to a poor ecological potential) is registered in a water body in the northern Upper Rhine. The classification of the state cannot yet be considered to be stable.

What are the long-term trends?
After the rapid increase in the species diversity of the macrozoobenthos following the improvement of the Rhine water quality in the 1980s and the 1990s, a reverse trend is being observed since about the year 2000 (Figure 13). In particular, the fauna of water insects was much more diverse between 1995 and 2000 than it is today. This trend could possibly be explained with the immigration of invasive species. At present it is difficult to predict how stable this trend is. During the measurement cycle at hand it has at least been possible to slow it down in certain sections (Rheingau, Mittelrhein).

Compared to migratory fish (see below), positive trends registered in the group of invertebrates are rarely due to precise individual measures. It is rather the sum of all measures which may also have been taken a longer time ago, which support a development in the right direction.

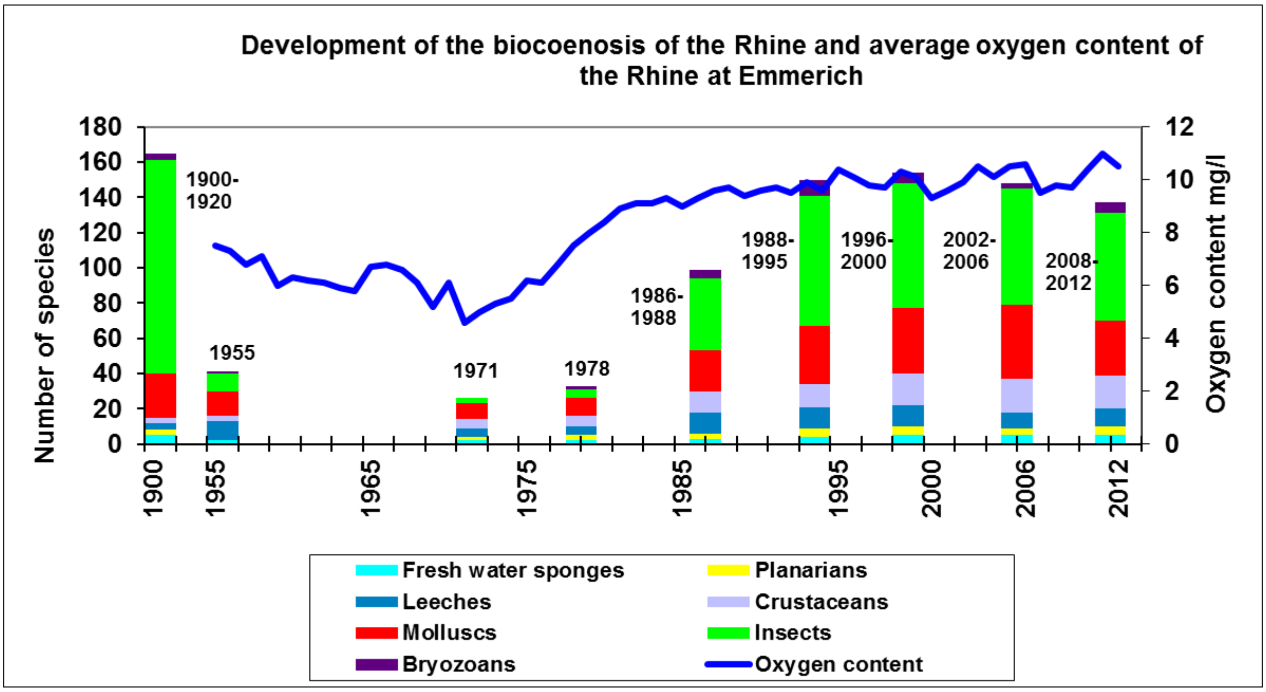


Figure 13: Historical development of the biocoenosis of the Rhine between Basel and the German-Dutch border related to the average oxygen content of the Rhine at Bimmen (selected fauna groups)

6. Fish fauna

see ICPR 2015e

What does the fish fauna tell about the pollution situation?
The species composition, abundance and age structure of fish reflect the large-scale occurrence of habitat structures of importance for different life stages and river continuity. Discharge modifications (impoundments, water intake, diversion) and thermal pollution also impact the species composition.

What does the biocoenosis of the Rhine look like?
All in all, today there are 64 fish species (including cyclostomata such as river and sea lamprey) in the Rhine, which represents a considerable diversity. Apart from the European sturgeon, all historically proven species are again detected. In many places, results of electro fishing are dominated by the invasive goby species, above all the round goby (Figure 14) which above all prefer the riprap of the river banks. Furthermore, mostly ecologically euryoecious species such as roach, bream, chub, perch and bleak are found.
The greatest number of fish species is found in the Upper Rhine and the Delta Rhine. On the one hand, this result is due to the high density of sampling stations, on the other hand it is due to the special make-up of biocoenosis in these sections. In the Upper Rhine, the alluvial areas of the Rhine rich in water plants contribute to this result, in the Delta Rhine the brackish water habitats and Lake IJssel. In particular along the Upper Rhine and the Middle Rhine (above all in the oxbow lakes and the groynes of the main stream) the vegetation of macrophoytes has considerably increased. This development furthers the reproduction of rheophile species. Juvenile fish habitats are thus available for many further species.

Figure 14: Goby egg batch. Photo: LUWG Mainz

25 species have been inventoried in the **High Rhine**. Spirlin, chub, roach and bream were predominant. Nase, bullhead and eel frequently occur. According to a special investigation aimed at inventorying the stocks of juvenile fish, the proportion of invasive species (stone moroko, goldfish, bighead goby, sunfish and pike-perch) remains at comparatively low 14 %. 31 species are detected in the **southern Upper Rhine**. The dominance of invasive goby species begins already here. More than half of the individuals caught are round gobies and bighead gobies, which are followed by less demanding species such as chub, roach, three-spined stickleback, stone loach and bleak. In the undersluices pockets there are no habitats for rheophile species such as the nase which rarely occurs. In spite of potentially available habitats, particularly in the old bed of the Rhine, anadromous migratory fish are extremely rare in this section, as the ecological continuity of the Rhine has not yet been restored at the Strasbourg impoundment

(inauguration of the fish passage planned for end 2015), at Gerstheim (construction planned for 2016-2017), Rhinau, Marckolsheim and in the Grand Canal d'Alsace.
The return of the bitterling to the Rhine is encouraging. This species is above all continuously spreading in the **northern Upper Rhine**. Even the formerly rare spined loach is again regularly found in the Upper Rhine. With 64 % frequency of occurrence among individuals caught, the round goby here reaches its highest dominance. It is followed by roach, bighead goby, bleak and eel. All in all, 28 species have been detected in this section of the Rhine. Flow velocity increases in the breakthrough valley of the **Middle Rhine**, offering good conditions for rheophile species. All in all, 21 species have been recorded, but half of the catches are again round gobies. The species composition of the other species is similar to that of the northern Upper Rhine, even though the eel occurs a bit more often in the Middle Rhine, where it represents 5 % of the individuals caught. In the **Lower Rhine**, 27 species were detected. Here, too, almost half of the catches were round gobies. Apart from that, the bleak dominates with 20 %. The sub-dominant fraction consists of the species nase and perch. Together, the **Delta Rhine and Lake IJssel** have the highest density of individuals and species of all Rhine sections. Here, the ruffe is by far the most frequent species, followed by roach, bream, perch, monkey goby and smelt. All in all, 44 species were registered.

Ecological evaluation of the Rhine
Each country has evaluated the state of the fish fauna in its section of the Rhine on the basis of a national method. In addition, the evaluation of transboundary river sections was coordinated bilaterally. The state of the Swiss **Anterior and Posterior Rhine** has not been evaluated. As shown in Annex 4 and 9, the potential of the fish fauna of the Austrian **Alpine Rhine** can be evaluated as poor. This is above all due to lacking longitudinal river continuity and to the hydropeaking of hydro power plants. From the point of view of fish ecology, the state of **Lake Constance** is good. The fish fauna of the impounded **High Rhine** has been evaluated as moderate. In the **southern Upper Rhine**, the fish fauna of the right bank was evaluated as moderate including a section between Breisach and Strasbourg validated as poor. On the left bank, these sections were evaluated as good. It has not been possible to achieve an agreement for this biological quality component. With one exception (poor), the **northern Upper Rhine** and **Middle Rhine** are evaluated as moderate. The potential of the **Lower Rhine** is moderate. Downstream the mouth of R. Ruhr up to and including the first water body in the **Delta Rhine** (Boven Rijn / Waal), the Rhine is evaluated as poor. Merwede, Nederrijn / Lek, Nieuwe Waterweg, Oude Maas, Spui, Vecht, Hollandse IJssel, IJssel and **Lake IJssel** have been evaluated as moderate. Markermeer, Ketelmeer, Vossemeer and the Randmeren have, among others, been evaluated as good, as far as the fish fauna is concerned. The Dordtse Biesbosch has been evaluated as poor. According to the Directive, no evaluation of the fish fauna is required for the **coastal waters** and the **Wadden Sea**.

The most distinct **change compared to the last ICPR inventory of the Rhine in 2006/2007** is the great spatial spreading of invasive goby species (ICPR 2013c). Compared to the earlier inventory this partly leads to considerable modifications of the dominant species proportions. At the sampling sites, the round goby alone on average represented 28 % of the individuals; on the Upper Rhine, the relative frequency locally reached more than 90 %. An ecological replacement of indigenous species is to be assumed. As an example, the stock of the regularly detected ruffe is particularly declining at locations where riprap-structures predominate. These offer ideal habitat structures for gobies, leading to their high density of stocks. It is assumed that the grazing pressure of the gobies contributes to reduce the eudominance of the benthic invasive species (e.g. *Chelicorophium, Dikerogammarus*) (see Chapter 2 and Table 2 in Chapter 7).
However, the development must be further observed. It is also possible that other predatory fish such as pike-perch, barbel, asp and perch adapt to these small fish species

as new food source. In future, that might lead to changes in the food web which, on the long run, will again lead to reduced goby stocks.

What are the long-term trends?

During the past 20 years, the fish fauna of the Rhine has considerably changed. Due to improved water quality, some species have again spread and the species numbers have increased. A comparison of the species numbers of the four ICPR inventory campaigns between 1995 and 2013 shows the notable development (Figure 15). Today, invasive fish species represent 16 % of the species distribution.

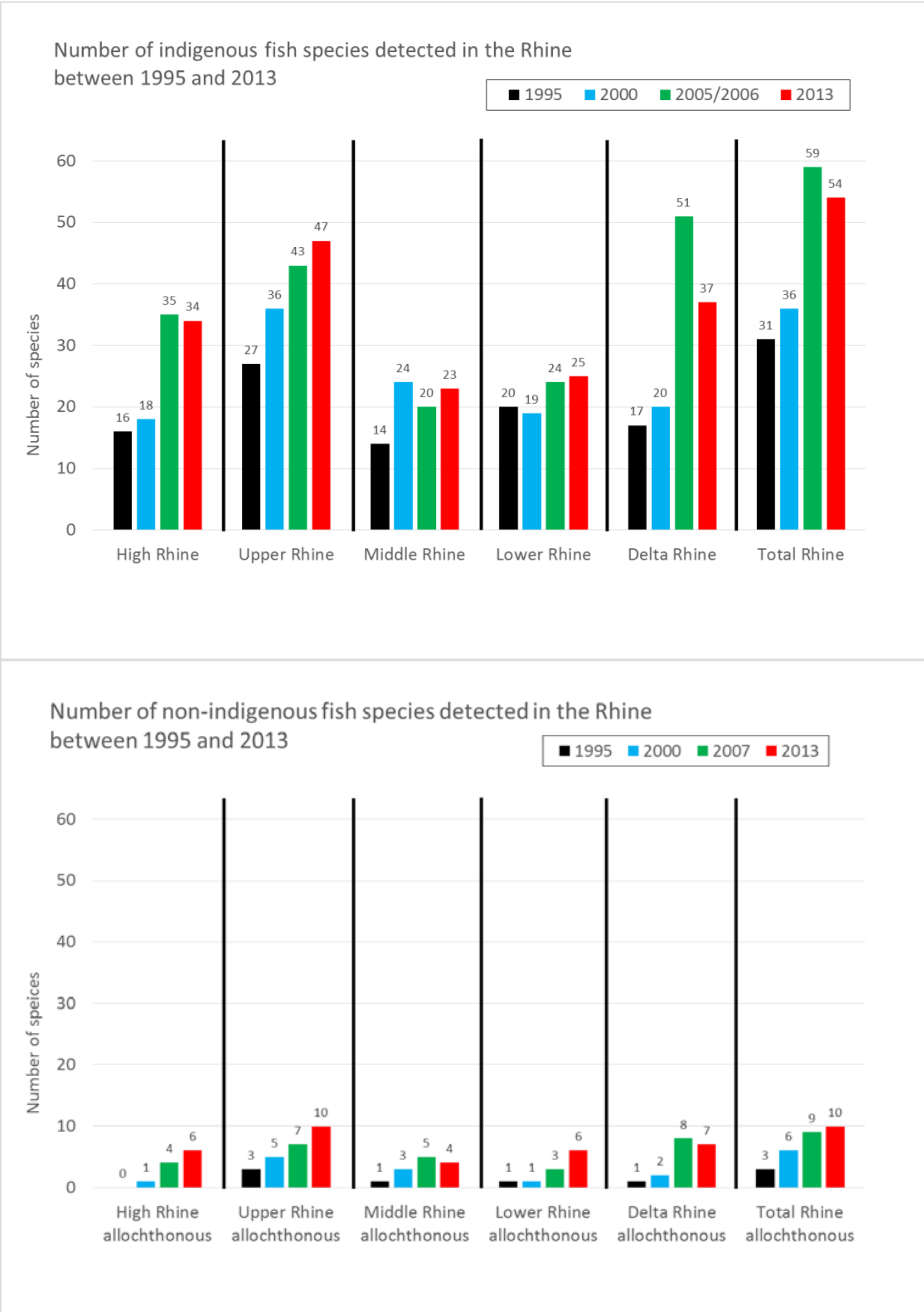


Figure 15: Number of indigenous (above) and invasive (below) fish species detected in the Rhine during 1995 to 2013

However, the species number cannot be the only criterion for an ecological improvement, as it also increases due to immigrating fish species, as was shown above. Also, within WFD monitoring, the intensity of investigation was increased and new registration techniques were introduced, such as automatic control stations at fish passages. Again and again these register rare species which would otherwise not be detected (see below and Table 2 in Chapter 7).

With respect to the **quantity** within fish populations, data from the Lower Rhine and the fyke-net Moselle/Koblenz show that fish densities have considerably decreased since the 1980s and are almost stable since 1993. This is a consequence of reduced nutrients and reduced organic pollution in the 1980s and early 1990s (see Chapter 7 and Table 1). This has reduced the food supply (e.g. plankton) in the Rhine. However, due to the varying activity of the different fish species according to the seasons and partly due to the sampling method, the density of sampled fish also varies within the sections of the Rhine and within one year. This leads to varying dominance, in particular of very frequent fish species such as roach, bream, barbel and chub. At present, the strong development of the round goby population superposes the natural variation of dominance.

Due to progress made with respect to the restoration of accessibility resp. the continuity of reproduction waters during the last 20 years, the situation of the stock of **long distance migratory fish** improved for a while: Increasing numbers of returners of **salmon** and **sea lamprey** and distinctly increasing numbers of proofs of reproduction in accessible water bodies gave evidence of the success of measures until 2007. However, between 2008 and 2013, less proofs concerning the great salmonids salmon and **sea trout** were registered (Figure 16 and 17). Apart from different sampling methods, the reasons might be found in the common migration corridor Rhine and/or in the coastal area: Fishery (illegal catches), high predation pressure on smolts by predatory fish and cormorants, high rates of smolt mortality in hydro power plants. Also, reduced survival rates in the marine part of the life cycle are being discussed. In the upper sections of the Rhine, the construction of a 5th turbine at the Iffezheim impoundment between April 2009 and October 2013 led to a reduction of the number of upstream migrating individuals of numerous fish species.
Since the end of the construction works, higher numbers of specimen are again reported for the fish passages at Iffezheim and Gambsheim.
At the time being, and due to the few specimen registered, it is not possible to state whether a comparable trend as that of big salmonids exists for the **river lamprey**. Due to the past stocking measures in Hesse and North Rhine-Westphalia, the number of returning **allice shad** should distinctly increase in the years to come. Counts at the Iffezheim fish passage confirm this assumption. A large number of upstream migrating allice shad (157) was first documented in Iffezheim in 2014 (Figure 16); on 10 July 2013, the first allice shad was registered in the Moselle (Koblenz control station) for 60 years (Figure 18) and 1, resp. 2 and 4 allice shad were recorded in the Delta Rhine in 2012, resp. 2013 and 2014. In addition, the detection of individual young allice shad in the Upper Rhine in 2013 and 2014 upstream of all stocking sites indicates a natural allice shad reproduction. Figure 16 also points out this positive development for the period January to September 2015.

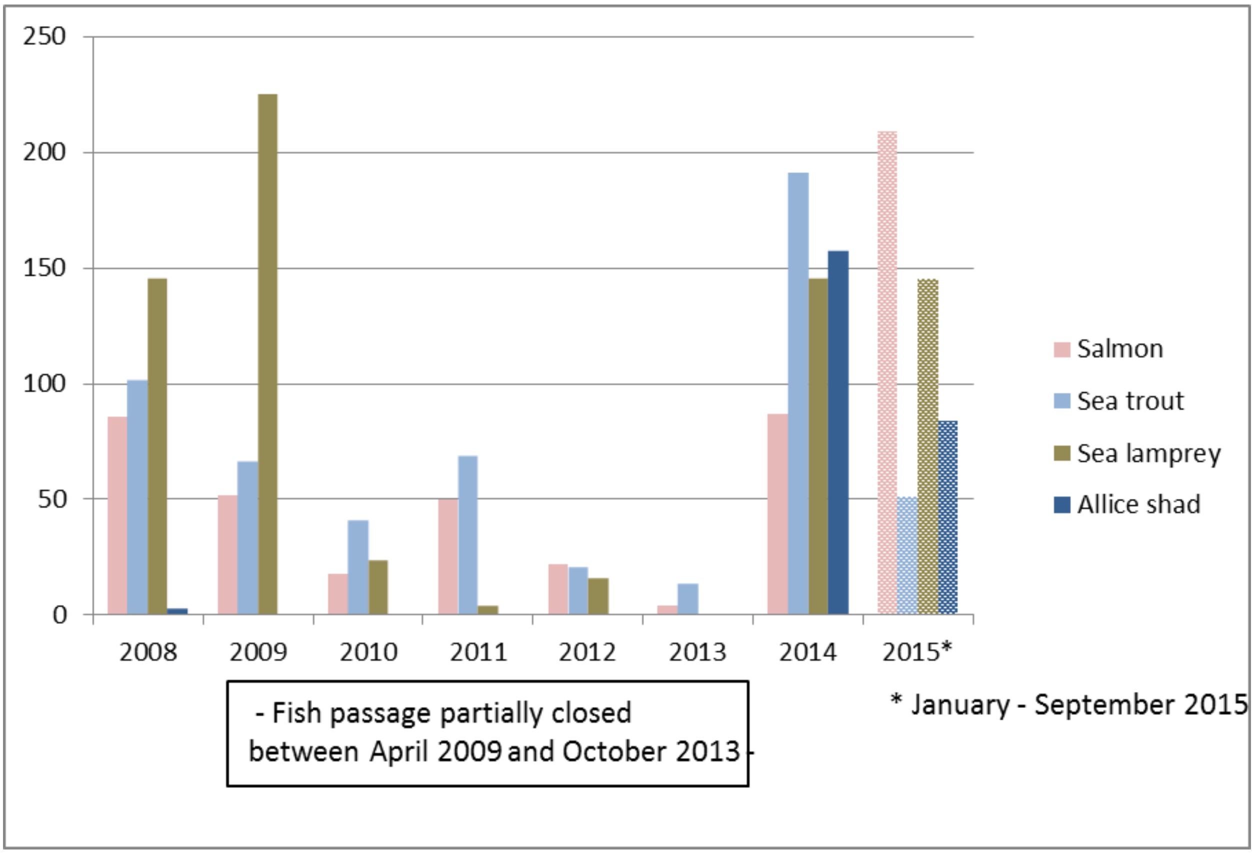
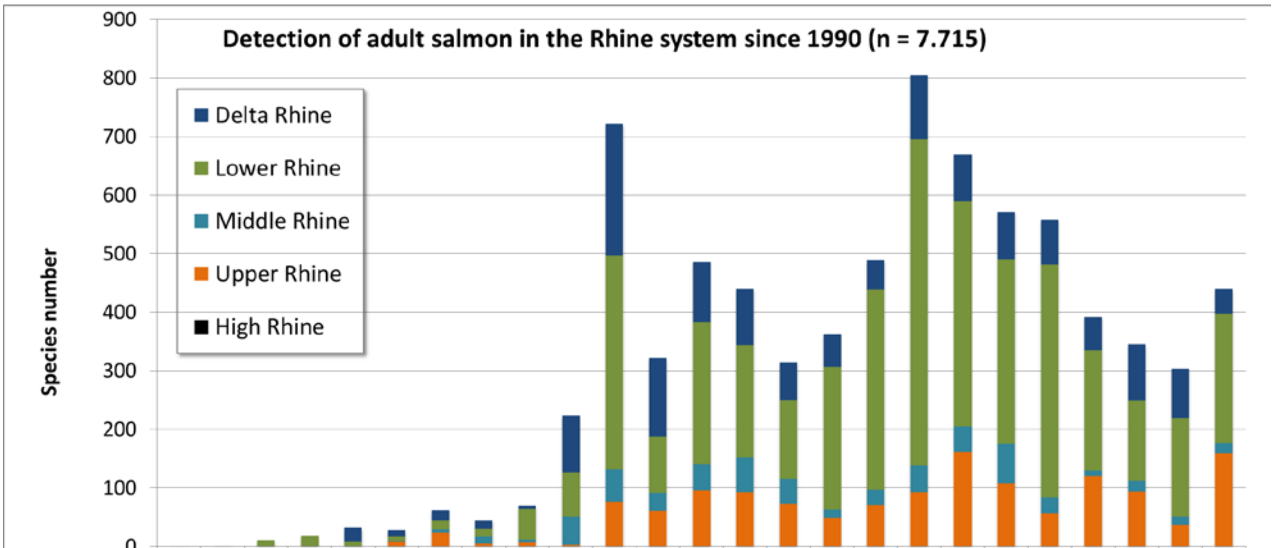


Figure 16: Results of fish counts of selected long distance migratory fish at the Iffezheim impoundment since 2008 (*2015: January to September)



Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Delta Rhine	0	0	0	0	23	11	17	15	5	97	225	134	103	97	65	56	50	110	80	82	76	57	96	84	42
Lower Rhine	1	2	10	18	9	7	16	13	52	76	365	96	242	191	135	244	342	556	385	314	398	205	137	169	221
Middle Rhine	0	0	1	0	0	1	5	12	5	48	56	31	45	59	42	14	27	46	44	68	27	10	18	15	18
Upper Rhine	0	0	0	0	0	9	24	5	7	3	76	61	96	93	73	49	70	93	161	108	57	120	92	36	159
High Rhine	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0

Figure 17: Salmon detected in the Rhine system since 1990
Limited operation of the Iffezheim fish passage between April 2009 and October 2013. Due to the end of fyke-net fishing in the Netherlands, less returning salmon have been detected since 2011.

Figure 18: First allice shad in the Moselle for 60 years. Photo: BfG

The stocks of **houting** and **thwaite shad** continue to be small. After stocking measures in the Lower Rhine, the numbers of the formerly absent houting have distinctly increased and this species is again successfully reproducing in the lower sections of the Rhine and its delta. Stocking measures in the Rhine were stopped again as early as 2006 and since then, a self sustaining population has established (BORCHERDING 2014).
The reduced number of detected **sea lamprey** also seems to be caused by the construction in connection with the establishment of a 5th turbine in Iffezheim between 2009 and 2013 entailing limited monitoring.

In the Alpine Rhine / Lake Constance sub-basin, the **lake trout** (*Salmo trutta lacustris*) is the only long-distance migratory fish. All in all, compared to its historic distribution, the habitat of the Lake Constance lake trout has been heavily reduced. In Lake Constance with its water bodies “Obersee” (Upper Lake) and “Untersee” (Lower Lake) today presenting a good chemical and ecological status, open water constitutes the preferred habitat of the lake trout. It there grows up until it is mature to spawn and migrates into the tributaries to Lake Constance and into the Alpine Rhine and its tributaries to spawn. In the 1970s, the number of lake trout in Lake Constance continually sank in spite of stocking exercises. Looking back, the first lake trout programme of the “Lake Trout Working Group” was responsible for the survival of the lake trout in Lake Constance and that it may today again be used for commercial fishery. Saving the last spawning fish, the subsequent stocking measures and the gradual elimination of obstacles to migration in the spawning rivers figured among the decisive measures.

During the past decades, the stocks of the **European eel** have greatly diminished in almost its entire distribution area, including the Rhine and its tributaries. Since the beginning of the 1980s, only a few percent of the long-time average of glass eels migrating upstream into the rivers return. Among the known causes figure habitat modifications, parasite infections, the construction of hydro power plants for energy production, overfishing of the stock of glass and silver eel and sediment pollution. In almost all waters in the Rhine area where eels are reported, their migration is restricted by transverse constructions. This is in particular true of the downstream migration in the Delta Rhine, the southern Upper Rhine and in almost all tributaries. In particular, downstream migrating eels are caught in the turbines of power plants, in intake constructions, pumps, etc. Due to the length of their bodies, they may suffer from grievous, mostly lethal injuries; the cumulated mortality may be considered substantial if several transverse constructions follow one another.

7. Outcome - What has been achieved, what remains to be done?

As a result of the improvement of the Rhine **water quality** during the past 20 years, the array of fish species is again almost complete and many invertebrate species characteristic for rivers which were considered to be extinct or strongly depleted, are today again an inherent part of the Rhine fauna. To some extent, this can also be demonstrated for aquatic macrophytes. However, certain fish species in the Rhine and its tributaries (e.g. eel) are still contaminated by **pollutants** (dioxins, furanes, dl-PCB, mercury, occasionally also indicator PCB, hexachlorobenzene = HCB or perfluoroctanesulphonate (PFOS)) among others from contaminated areas (ICPR 2011b). The contamination of biota (fish) with pollutants in the Rhine catchment has been registered within a first joint coordinated analysis programme (ICPR 2014a). However, this analysis is primarily directed towards studies concerned with food legislation and cannot be transferred to ecosystem questions automatically. The effects of the **(mixed) toxicity** of pollutants detected in the Rhine on organisms in the river, in particular on the health of fish in different life stages, on fecundity / reproductivity, motility and potential correlations with fish diseases are little known so far.

Micro-pollutants are a new challenge for water protection. In today's normal mechanical-biological wastewater treatment plants, many micro-pollutants - such as plant protection agents, hormones or pharmaceuticals - are not or only partly treated and thus discharged into the water bodies. So far, there has not been sufficient research into the possible effects of these substances on water ecology. Different measures are implemented in order to reduce the discharge of micro-pollutants into water bodies. The ICPR has been mandated to draw a balance of the developments stated in 2018 and to use these findings for deciding on measures aimed at reducing the discharges of micro-pollutants by decisive discharge pathways (ICPR 2013d).

Contrary to inland waters, the **nitrogen pollution** is decisive for the ecology of the sea shore and is thus more critical than the phosphorous pollution. Therefore, efforts towards reducing the nitrogen pollution must be continued.

Climate change might in future lead to temperatures in excess of certain **critical threshold values** for fish (ICPR 2014b). Temperatures above 25 °C occurred during 7 of the last 12 years, while, during 1978-1989, they only occurred once (ICPR 2013e). However, the rise in water temperature is also critical in winter, e.g. when phases of dormancy in winter governed by temperature or the maturing of reproductive organs of fish are disturbed. In addition, if days with very low temperatures no longer occur, this might favour the permanent settlement of invasive thermophilic species (ICPR 2013a). In future, the anthropogenic **thermal pollution** of the Rhine, which has already diminished after certain nuclear power plants along the Rhine were turned off, should thus remain limited.

The present ecological evaluation of the Rhine ecosystem represents a snapshot, within which the dynamic biological interactions within the faunal interchange with reactions of the biocoenosis to programmes of measures have mixed inseparably (see Table 1 and 2). Partly, methodical aspects lead to a modified evaluation (deriving the ecological potential, improved inventory techniques, etc., see Table 2). However, the long-term trends of the last 20 years also indicate distinct, sustainable ecological improvements. The future implementation of different ecological measures could contribute to perpetuate this trend.

In order to **improve the habitats** for plants and animals in the Rhine, the main stream should be re-connected with the alluvial areas wherever possible, in order to open up side waters rich in aquatic plants and by-passes as habitats (improvement of the lateral continuity, see Table 1). In connection with flood protection measures, between 2000 and 2012, a surface of more than 100 km² was reactivated as floodplain and will be further extended during the years to come (Figure 19). Parallel constructions or filled up groynes may constitute shallow replacement habitats rich in structure, and protected from the lapping of waves. Such a diversification of river banks is favourable among others for juvenile fish, aquatic plants (marcophytes) and the macrozoobenthos. Removing superfluous bank stabilizations (e.g. at sloping banks) may be an effective measure to counterbalance the ecological consequences of the rapidly spreading invasive round goby, as this species above all profits from riprap banks (see Table 1).

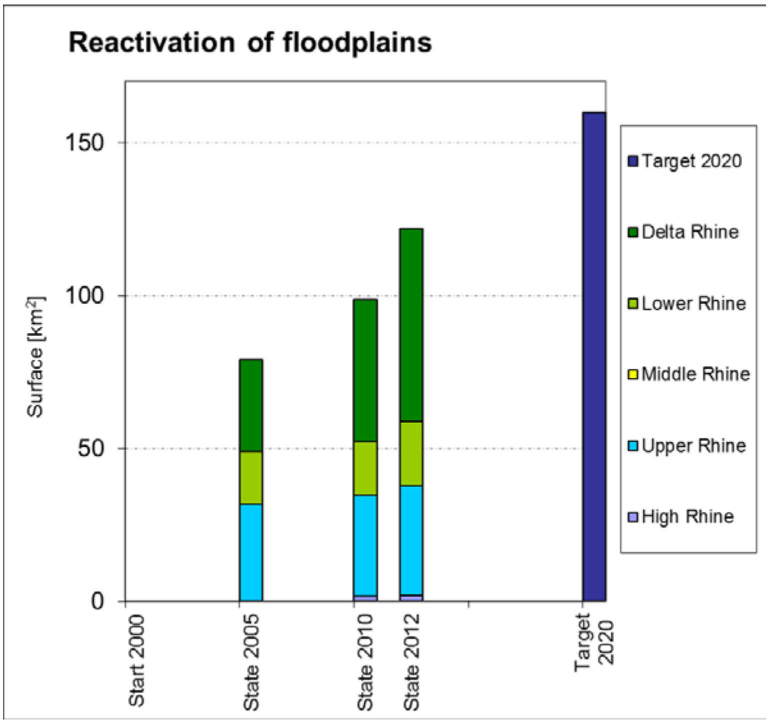


Figure 19: Reactivation of floodplains between 2000 and 2012

Within the framework of the Rhine 2020[3] programme, and in order to increase **habitat diversity**, 100 oxbow lakes and backwaters will be reconnected with the dynamics of the Rhine by 2020, and former hydraulic and biologically effective connections between the river and its floodplains will be restored. Along suitable sections of the Rhine, the structural diversity will be increased along 800 km at a minimum (see Table 1), taking into account aspects of security for navigation and people. Figure 20 gives a survey over measures implemented from 2000 to 2012 aimed at reconnecting oxbow lakes (left) and at improving the structure of the banks of the Rhine (right).

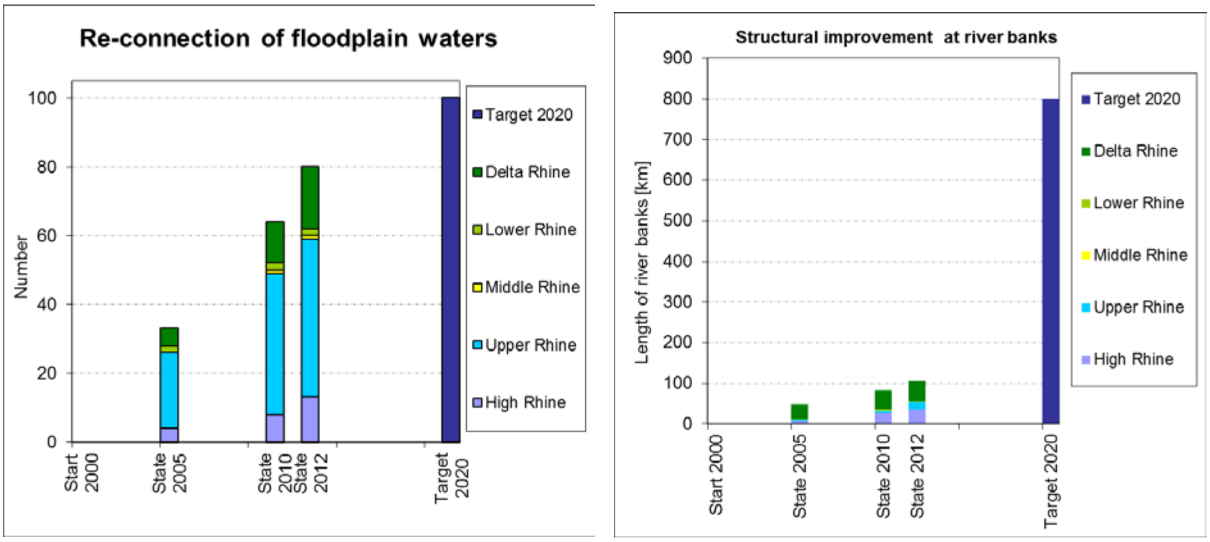


Figure 20: Number of floodplain waters reconnected with the Rhine (left) and length of river banks along the main stream of the Rhine, where measures aimed at structural improvement were implemented (right).

The programme "Rhine 2020" of the ICPR and the plans for the habitat patch connectivity for the Rhine (see brochure "The Rhine and its Catchment" presented at the conference of Rhine Ministers in 2013 and the brochure and atlas "Habitat Patch Connectivity along the Rhine" 2006 www.iksr.org) offer an important basis for the planning of measures.

In order to establish and secure the stocks of migratory fish presently being built up or regenerating, the **restoration of free migration** in the Rhine (Haringvliet, impoundments in the southern Upper Rhine) and its tributaries is essential and must be speeded up (see Table 1). In the so-called programme waters of the Rhine catchment, as many identified spawning and juvenile fish habitats as possible must again be made accessible and/or revitalised. Furthermore, in particular in migratory fish waters, there should not be any further development of small hydro power plants. The "Master Plan Migratory Fish Rhine" of the ICPR (ICPR 2009, ICPR 2013b) constitutes an important basis for planning measures. All in all, from 2000 to 2012, 480 measures aimed at improving river continuity in the programme waters have been implemented (see Figure 21). These measures are expected to have a positive effect on the entire aquatic fauna and flora.

[3] ICPR documents Rhine 2020

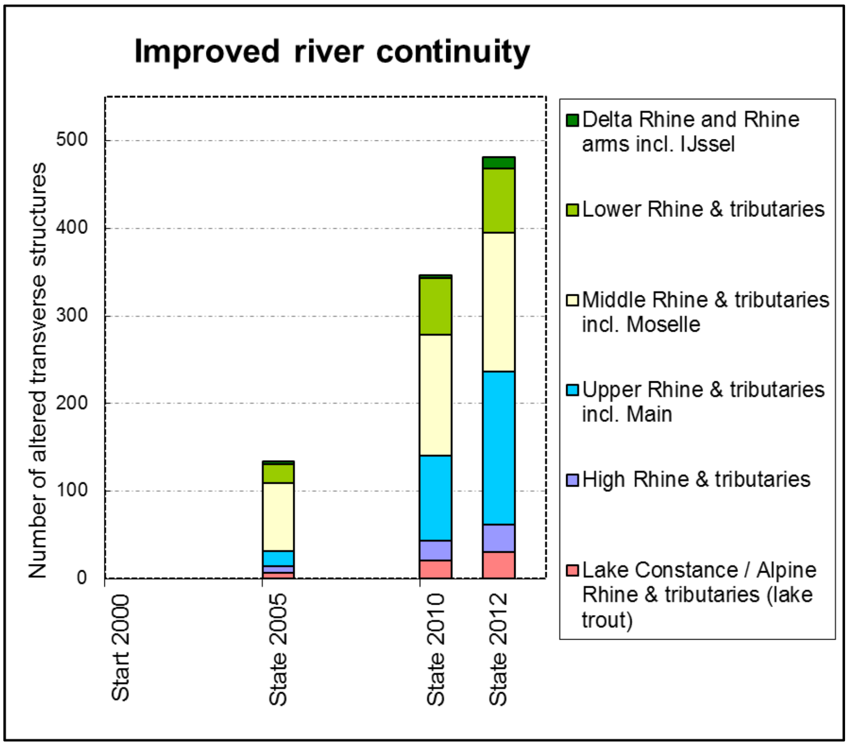


Figure 21: Improved river continuity of the Rhine and its tributaries, in particular of programme waters for migratory fish: Number of altered transverse structures. State June 2013

However, measures hindering the introduction of invasive species are difficult, as the pathways (e.g. hulls, ballast water, intended an unintended release, fishkeeping stores, etc.) are numerous and difficult to control. Furthermore, established invasive species can only be contained in individual cases and by targeted management. For several introduced species it is however known that, after an explosive reproduction, they settle at a lower level. When evaluating the introduction of new species it must be remembered that nature is not a static state, but a dynamic process which is liable to continuing changes. The restoration of the ecological continuity will foster the re-settlement of indigenous species in various habitats.

In future, the implementation of the different ecological measures and continued intensive, coordinated biological monitoring will make it possible to observe long-term trends and developments on the basis of robust data. This is in particular valuable with respect to climate change.

Table 1: Ecological measures in the main stream of the Rhine

Measures in the main stream of the Rhine						
Measure	**Effect on biological quality component**					**Where observed**
	Macrozoobenthos	**Fish fauna**	**Phytoplankton**	**Phytobenthos**	**Macrophytes**	
Reduction of nutrient pollution		**(+)** more natural biocoenosis, less biomass	**(+)** more natural biocoenosis, less biomass	**(+)** more natural biocoenosis	**(+)** enhancement of stocks by little shading of the water bottom (less phytoplankton)	Entire stream of the Rhine (see ICPR report no. 224, 226, 228)
Removed riverbank structures (in particular riprap structures)/reduced degree of bank constructions	**(+)** increased species diversity	**(+)** reduction of invasive gobies			**(+)** increased species diversity	Entire stream of the Rhine (see ICPR report no. 223)
Parallel constructions or filled up groynes as shallow replacement habitats rich in structure, and protected from the lapping of waves.	**(+)**	**(+)** in particular enhancement of juvenile fish	**(+)**	**(+)**	**(+)** important emitter origin for macrophytes, from there re-colonization of areas presenting deficits	Middle Rhine, Lower Rhine, Delta Rhine (see ICPR reports no. 225, 228)
Improved reconnection of tributaries, alluvial waters and backwaters / lateral river continuity	**(+)** recolonization by indigenous species from refuges in the tributaries	**(+)** enhancement of species spawning on plants and gravel; favouring the reproduction of rheophile species (rudd, pike, tench); juvenile fish habitat for other species			**(+)** spreading of seed	Entire stream of the Rhine (see ICPR report no. 223, and Chapter 7 in the 2nd Management Plan for the Rhine)
Construction or optimization of structures for up- and downstream fish migration		**(+)** Long distance migratory fish reach spawning waters; middle-distance migratory fish may change habitat (according to their life-cycle); linking of local population shares => enhanced fitness			**(+)** spreading of seed with upstream migrating fish (zoochory)	Delta Rhine, Upper Rhine, High Rhine and Rhine tributaries (see Annex 7 in the 2nd Management Plan for the Rhine)

Table 2: Changes in the ecological evaluation due to biological interaction or changed methods

Changes in the ecological evaluation due to biological interaction and changed methods						
Change	**observed on biological quality component (cause, comments)**					**Where observed**
	Macrozoobenthos	**Fish fauna**	**Phytoplankton**	**Phytobenthos**	**Macrophytes**	
Change in the abundance of non-indigenous species	**(+)** severe winter 2009/2010 and 2012/2013 and discontinuation of some thermal discharges into the Rhine	**(+)** Increase due to immigration (gobies)				Rhine: *Corbicula fluminea* (Schöll et al. 2013)
	(+) Concurrence if closely related species immigrate due to overlapping of habitat niche					Middle Rhine *D. polymorpha* / *D. rostriformis* (Schöll et al. 2012), *C. curvispinum* / *C. robustum* (Fischer 2013)
	(+) increased grazing pressure of gobies (non-indigenous species)					northern Upper Rhine, Middle Rhine: Schöll et al. 2013
more species detected; detection of rare species which would otherwise not be found	**(+)** increased intensity of investigation (dredging vessel)	**(+)** increased intensity of investigation within WFD monitoring, new recording techniques, more monitoring stations			**(+)** spreading trends of individual species	Entire stream of the Rhine (see ICPR report no. 228)
Less species detected	**(+)** since 2006, some non-indigenous species are no longer detectable				**(+)** methodical reasons, unfavourable discharge conditions (floods)	High Rhine (see ICPR report no. 225)
Less phytoplankton biomass			**(+)** filtration activities of immigrated mussels, favourable discharge conditions for macrophytes			Middle Rhine, Lower Rhine
In DE, the introduction of the evaluation of the potential (biologically derived evaluation of the potential) leads to more favourable evaluation results of individual biological components	**(+)**	**(+)**				Upper Rhine, Middle Rhine, Lower Rhine

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Glossary

Abundance: Population density; number of individuals of a species per surface unit; for diatoms: the percentage proportion of a species compared with the total number of individuals counted at each sampling site

Adult: mature, full grown, designates the life stage after sexual maturity

Anadromous: migrating from the sea into inland waters to spawn

Benthos: All living organisms occurring in the bottom zone of a water body

Benthic: bottom-living

Bioindicator: indicative species; organism reacting to changes of environmental impacts

Groyne: construction comparable to a dike in transverse direction to the river

Chironomidae: Midge flies

Diatoms: diatoms

Dominance: Dominant occurrence of a species in a biocoenosis

Euryoecious: Occurring in different habitats

Eutrophic: nutrient rich with high phosphorous content and thus high organic production

Fauna: All animal species in an area

Flora: All plant species in an area

GUild: Group of species; biocoenosis

Habitat: characteristic living area of a plant, an animal or another organism

Halophilic: Organisms living in an environment with increased salt concentration

Invasive species: Species spreading in an area where it is not indigenous

Invertebrates: Multicellular animals without a spine

Lethal: mortal

Makrophytes: aquatic plants visible to the naked eye

Makrozoobenthos: organisms of the water bottom visible to the naked eye

Mesotrophic: moderately nutrient-rich

Mortality: death rate

Invasive species: non-indigenous species

Invasive plant: non-indigenous plant species

Neozoon / Neozoen: non-indigenous species

Oligochaetes: oligochaetes

Phythobenthos: lower aquatic plants (algae) living on the bottom of water bodies

Phytophilous: preferring plants; with respect to guilds of reproduction: Species spawning on plants

Phytoplankton: suspended algae; plant plankton

Pioneer species: species which, due to particular adaptation rapidly colonize new habitats

Plankton: Organisms floating freely in the water and which are unable to move against the current

Planktic: Concerning the phytoplankton

Potamal: Concerning the lower regions of a river

Refuge: Retreat area

Rheophile: Current-loving

Saprobic level: organic pollution

Smolt: stage of juvenile salmonids (salmon, sea trout) during downstream migration in which they are largely silver coloured

Taxon, Taxa: Unit of organisms within the biological systematics (e.g. species)

Taxonomy: Systematic of relationships of organisms

Taxonomic: concerning taxonomy

Thermophile: Warmth-loving

Trophic level: Nutrient pollution / nutrient offer

Tychoplankton: Organisms occurring in the plankton only occasionally and accidentally

Ubiquitous: occurring everywhere; widespread

Zooplankton: animal plankton

Appendices

<u>Remark</u>: The numbers of the maps correspond to those of the 2nd management plan for the IRBD Rhine.

<u>Annexes 1 to 4</u>:
In 2009, there was no biologically derived procedure to determine the ecological potential of heavily modified water bodies (HMBW) in Germany. In 2014, new procedures of evaluating the potential were used for the components macrozoobenthos and fish. The evaluation of the plant components (macrophythes, phythobenthos) only determines the state, not the potential.
In the Netherlands, the potential was indicated for all components and for the complete evaluation already in 2009. In this connection, there is no particular procedure, the standard for natural waters is always used; less strict targets are then set for HMBW. In France, only the global evaluation refers to the ecological potential.

Annex 1: Evaluation of the phytoplankton in the Rhine according to WFD for the management plan 2009 and for the management plan 2015

Annex 2: Evaluation of the biological quality component macrophytes / phytobenthos in the Rhine according to WFD for the management plan 2009 and for the management plan 2015

Annex 3: Evaluation of the macrozoobenthos in the Rhine according to WFD for the management plan 2009 and for the management plan 2015

Annex 4: Evaluation of the fish fauna in the Rhine according to WFD for the management plan 2009 and for the management plan 2015

Annex 5: Map Phytoplankton evaluation

Annex 6: Map Initial expertise of the partial component macrophytes

Annex 7: Map Evaluation of the phytobenthos/macrophytes

Annex 8: Map Macrozoobenthos evaluation

Annex 9: Map Evaluation of the fish fauna

Annex 10: Map evaluation of the ecological state / the ecological potential on the whole

Annex 1: Evaluation of the phytoplankton in the Rhine according to WFD for the management plan 2009 and for the management plan 2015

Evaluation of the phytoplankton in the Rhine according to WFD for the management plan 2009 and for the management plan 2015

State: December 2015

Assessment of quality component not required	./.	very good	1
No inventory or assessment of the component / insufficient data		good	2
		moderate	3
		poor	4
		bad	5

Water body	River km	ICPR survy monitoring - monitoring station in the water body	State / federal state	Category Management Plan 2009	Category Management Plan 2015	Management Plan 2009	Management Plan 2015
LAKE CONSTANCE							
BOD-OS Lake Constance - Upper Lake	No kilometre marking	Fischbach-Uttwil	DE-BW	natural	natural	2	2
BOD-USZ Lake Constance - Lower Lake		Zellersee	CH / St. Gallen	natural	natural	2	2
HIGH RHINE Lake Constance - Basel	**24-170**						
High Rhine 1 - Lake Constance to mouth R. Aare	24-102.7	Outlet Lower Lake Öhningen, Reckingen	CH / DE-BW	natural	natural		1
High Rhine 2 - mouth R. Aare to Basel	102.7/-170		CH / DE-BW	heavily modified	natural		1
UPPER RHINE Basel - Bingen	**170-529**						
Upper Rhine 1 - OR 1 - Rhine 1 - Old Rhine, Basel to Breisach	170-225	Weil am Rhein	CH / DE-BW	heavily modified	heavily modified		1
Upper Rhine 2 - OR 2 - Rhine 2 - Loop of the Rhine, Breisach to Strasbourg	225-292	Upstream Rhinau	DE-BW	heavily modified	heavily modified		1
Upper Rhine 3 - OR 3 - Rhine 3 - impounded section of the Rhine, Strasbourg to Iffezheim	292-352	Karlsruhe	DE-BW	heavily modified	heavily modified		1
Upper Rhine 4 - OR 4 - Rhine 4 - Iffezheim impoundment to upstream mouth R. Lauter	352-428		DE-BW	heavily modified	heavily modified		1
Upper Rhine 5 - OR 5 - Lauter to mouth R. Neckar	352-428		DE-BW	heavily modified	heavily modified	2	1
Upper Rhine 6 - OR 6 - Neckar to mouth R. Main	428 - 497	Worms	DE-RP	heavily modified	heavily modified	2	2
Upper Rhine 7 - OR 7 - Main to mouth R. Nahe	497 - 529	Mainz/Wiesbaden	DE-RP	heavily modified	heavily modified	2	2
MIDDLE RHINE Bingen - Bonn	**529-639**	Koblenz	DE-RP	heavily modified	heavily modified	2	2
LOWER RHINE Bonn - Kleve-Bimmen / Lobith	**639-865.5**						
Lower Rhine 1 NR 1 - Bad Honnef to Leverkusen	639-701	Cologne-Godorf	DE-NW	heavily modified	heavily modified	2	2
Lower Rhine 2 NR 2 - Leverkusen to Duisburg	701-764	Düsseldorf harbour	DE-NW	heavily modified	heavily modified	2	2
Lower Rhine 3 NR 3 - Duisburg to Wesel	764-811	Duisburg-Walsum / Orsoy	DE-NW	heavily modified	heavily modified	3	3
Lower Rhine 4 NR 4 - Wesel to Kleve	811-865	Niedermoermter / Rees	DE-NW	heavily modified	heavily modified	3	3
DELTA RHINE Lobith - Hoek van Holland	**865.5-1032.**						
Boven Rijn, Waal	880-930	Lobith	NL	heavily modified	heavily modified	./.	./.
Maas-Waalkanaal	n.a.		NL	artificial	artificial	2	2
Nederrijn/Lek	954-980		NL	heavily modified	heavily modified	./.	./.
Dordtse Biesbosch	972-982		NL	heavily modified	heavily modified	./.	./.
Beneden Merwede, Boven Merwede, Sliedrechtse Biesbosch, Waal, Afgedamde Maas-Noord	n.a.		NL	heavily modified	heavily modified	./.	./.
Oude Maas (upstream Hartelkanaal), Spui, Noord, Dordtsche Kil, Lek to Hagestein	977-998		NL	heavily modified	heavily modified	./.	./.
Hollandsche IJssel	n.a.		NL	heavily modified	heavily modified	./.	./.
Nieuwe Maas, Oude Maas (downstream Hartelkanaal)	n.a.		NL	heavily modified	heavily modified	2	3
Nieuwe Waterweg, Hartel-, Caland-, Beerkanaal	998-1013	Maassluis	NL	artificial	artificial	2	2
Amsterdam-Rijnkanaal Betuwepand	n.a.		NL	artificial	artificial	2	2
Amsterdam-Rijnkanaal Noordpand	n.a.		NL	artificial	artificial	2	2
Noordzeekanaal	n.a.		NL	artificial	artificial	2	2
Twentekanalen	n.a.		NL	artificial	artificial	2	2
Zwartemeer	n.a.		NL	heavily modified	heavily modified	3	2
Ketelmeer + Vossemeer	n.a.		NL	heavily modified	heavily modified	3	2
Markermeer	n.a.		NL	heavily modified	heavily modified	3	3
Randmeren-Oost	n.a.		NL	heavily modified	heavily modified	3	2
Randmeren-Zuid	n.a.		NL	heavily modified	heavily modified	3	2
Lake IJssel	n.a.	Vrouwezand	NL	heavily modified	heavily modified	3	3
Wadden Sea mainland coast (coastal waters)	n.a.		NL	heavily modified	heavily modified	3	2
Wadden Sea (coastal waters)	n.a.	Dantziggat, Doove Balg west	NL	natural	natural	3	2
Dutch coast (coastal waters)	n.a.	Noordwijk 2	NL	natural	natural	2	2
Wadden coast (coastal waters)	n.a.	Boomkensdiep	NL	natural	natural	2	3

Annex 2: Evaluation of the biological quality component macrophytes / phytobenthos in the Rhine according to WFD for the management plan 2009 and for the management plan 2015

Evaluation of the biological quality component macrophytes / phytobenthos in the Rhine according to WFD for the management plan 2009 and for the management plan 2015	./.	Evaluation of quality component not required	very good	1	*Ec. potential*
		No inventory or assessment of the component / insufficient data	good	2	2
	Macrophytes / Phytobenthos: In DE-BW these results refer to the entire biological component. In France, only diatoms were evaluated		moderate	3	3
			poor	4	4
State: December 2015			bad	5	5

Water body	**River km**	**ICPR survy monitoring - monitoring station in the water body**	**State / federal state**	**Management Plan 2009**	**Management Plan 2015**
ALPINE RHINE Reichenau - Lake Constance					
AR 3 Alpine Rhine, OWK AT 10109000		Fussach	AT/ Vorarlberg/CH (SG)	2	2
LAKE CONSTANCE					
BOD-OS Lake Constance - Upper Lake	No kilometre marking	Fischbach-Uttwil	DE-BW	2	2
BOD-USZ Lake Constance - Lower Lake		Zellersee	CH / St. Gallen	2	2
HIGH RHINE Lake Constance - Basel	**24-170**				
High Rhine 1 - Lake Constance to mouth R. Aare	24-102.7	Stein, Ellikon	CH / DE-BW	1	2
High Rhine 2 - mouth R. Aare to Basel	102.7/-170	Sisseln, Pratteln/Wyhlen	CH / DE-BW	1	2
UPPER RHINE Basel - Bingen	**170-529**				
Upper Rhine 1 - OR 1 - Rhine 1 - Old Rhine, Basel to Breisach	170-225	Weil am Rhein	DE-BW	1	3
			FR	2	2
		Coordination result			2
Upper Rhine 2 - OR 2 - Rhine 2 - Loop of the Rhine, Breisach to Strasbourg	225-292		DE-BW	2	3
		Upstream Rhinau	FR	2	2
		Coordination result			2
Upper Rhine 3 - OR 3 - Rhine 3 - impounded section of the Rhine, Strasbourg to Iffezheim	292-352		DE-BW	2	3
		Upstream Gambsheim	FR	3	2
		Coordination result			2
Upper Rhine 4 - OR 4 - Rhine 4 - Iffezheim impoundment to upstream mouth R. Lauter	352-428	Karlsruhe	DE-BW	2	3
		Upstream Lauterbourg/Karlsruhe	FR		3
		Coordination result			3
Upper Rhine 5 - OR 5 - Lauter to mouth R. Neckar	352-428		DE-BW	2	3
			DE-RP	2	3
Upper Rhine 6 - OR 6 - Neckar to mouth R. Main	428 - 497		DE-BW	3	3
			DE-HE		3
		Worms	DE-RP	3	3
Upper Rhine 7 - OR 7 - Main to mouth R. Nahe	497 - 529	Mainz/Wiesbaden	DE-HE		3
			DE-RP	3	3
MIDDLE RHINE Bingen - Bonn	**529-639**				
Middle Rhine (MR)	529-639		DE-HE		3
		Koblenz	DE-RP	3	3
LOWER RHINE Bonn - Kleve-Bimmen / Lobith	**639-865.5**				
Lower Rhine 1 NR 1 - Bad Honnef to Leverkusen	639-701	Cologne-Godorf	DE-NW	3	3
Lower Rhine 2 NR 2 - Leverkusen to Duisburg	701-764	Düsseldorf harbour	DE-NW	2	4
Lower Rhine 3 NR 3 - Duisburg to Wesel	764-811	Duisburg-Walsum / Orsoy	DE-NW	3	3
Lower Rhine 4 NR 4 - Wesel to Kleve	811-865	Niedermoermter / Rees	DE-NW	2	3
DELTA RHINE Lobith - Hoek van Holland	**865.5-1032.**				
Boven Rijn, Waal	880-930	Lobith	NL	2	2
Maas-Waalkanaal	n.a.		NL	./.	./.
Nederrijn/Lek	954-980		NL	2	3
Dordtse Biesbosch	972-982		NL	2	2
Beneden Merwede, Boven Merwede, Sliedrechtse Biesbosch, Waal, Afgedamde Maas-Noord	n.a.		NL	./.	./.
Oude Maas (upstream Hartelkanaal), Spui, Noord, Dordtsche Kil, Lek to Hagestein	977-998		NL	2	2
Hollandsche IJssel	n.a.		NL	./.	./.
Nieuwe Maas, Oude Maas (downstream Hartelkanaal)	n.a.		NL	./.	./.
Nieuwe Waterweg, Hartel-, Caland-, Beerkanaal	998-1013	Maassluis	NL	2	2
Amsterdam-Rijnkanaal Betuwepand	n.a.		NL	./.	./.
Amsterdam-Rijnkanaal Noordpand	n.a.		NL	./.	./.
Noordzeekanaal	n.a.		NL	./.	./.
Twentekanalen	n.a.		NL	./.	./.
Zwartemeer	n.a.		NL	./.	./.
Ketelmeer + Vossemeer	n.a.		NL	./.	./.
Markermeer	n.a.		NL	./.	./.
Randmeren-Oost	n.a.		NL	./.	./.
Randmeren-Zuid	n.a.		NL	./.	./.
Lake IJssel	n.a.	Vrouwezand	NL	2	2
Wadden Sea mainland coast (coastal waters)	n.a.		NL	5	3
Wadden Sea (coastal waters)	n.a.	Dantziggat, Doove Balg west	NL	4	4
Dutch coast (coastal waters)	n.a.	Noordwijk	NL		
Wadden coast (coastal waters)	n.a.	Boomkensdiep	NL	./.	./.

In the water bodies Wadden Sea and Wadden Sea mainland coast, there is no evaluation of the phythobenthos, but of seaweeds and common salt marshes (evaluation of quality and quantity for both).

In 2012, the standards for macrophytes (and fish) were improved in the Netherlands, so that the ecological quality ratios partly greatly differ. In order to be able to compare the old standards with the new improved ones, data for 2012 were screened according to both standards. Subsequently, the good ecological potential was adapted so that evaluations of 2009 and 2012 may all the same be compared.

Annex 3: Evaluation of the macrozoobenthos in the Rhine according to WFD for the management plan 2009 and for the management plan 2015

Evaluation of the macrozoobenthos in the Rhine according to WFD for the management plan 2009 and for the management plan 2015							
					very good	1	*Ecol. potential*
					good	2	2
State: December 2015					moderate	3	3
Evaluation of quality component not required	./.				poor	4	4
No inventory or assessment of the component / insufficient data					bad	5	5

Water body	River km	ICPR survy monitoring - monitoring station in the water body	State / federal state	Category Management Plan 2009	Category Management Plan 2015	Management Plan 2009	Management Plan 2015
ALPINE RHINE Reichenau - Lake Constance							
AR 3 Alpine Rhine, OWK AT 10109000		Fussach	AT/ Vorarlberg /CH (SG)	heavily modified	heavily modified	3	2
LAKE CONSTANCE							
BOD-OS Lake Constance - Upper Lake	No kilometre marking	Fischbach-Uttwil	DE-BW	natural	natural		./.
BOD-USZ Lake Constance - Lower Lake		Zellersee	CH / St. Gallen	natural	natural		
HIGH RHINE Lake Constance - Basel	**24-170**						
High Rhine 1 Eschenzer Horn until upstream River Aare	24-102.7	upstream mouth Hemishofer B. - Rietheim	CH / DE-BW	natural	natural	2	2
High Rhine 2 downstream river Aare until R. Wiese inclusive	102.7/-170	Downstream mouth Aare - Basel	CH / DE-BW	heavily modified	natural	3	3
UPPER RHINE Basel - Bingen	**170-529**						
Upper Rhine 1 - OR 1 - Rhine 1 - Old Rhine, Basel to Breisach	170-225	Weil am Rhein	DE-BW	heavily modified	heavily modified	3	3
			FR	heavily modified	heavily modified	3	
		Coordination result		heavily modified	heavily modified		3
Upper Rhine 2 - OR 2 - Rhine 2 - Loop of the Rhine, Breisach to Strasbourg	225-292		DE-BW	heavily modified	heavily modified	4	4
		Upstream Rhinau	FR	heavily modified	heavily modified		4
		Coordination result		heavily modified	heavily modified		4
Upper Rhine 3 - OR 3 - Rhine 3 - impounded section of the Rhine, Strasbourg to Iffezheim	292-352		DE-BW	heavily modified	heavily modified	4	3
		Upstream Gambsheim	FR	heavily modified	heavily modified	4	5
		Coordination result		heavily modified	heavily modified		3
Upper Rhine 4 - OR 4 - Rhine 4 - Iffezheim impoundment to upstream mouth R. Lauter	352-428	Karlsruhe	DE-BW	heavily modified	heavily modified	4	3
		Upstream Lauterbourg/Karlsruhe	FR	heavily modified	heavily modified	4	4
		Coordination result		heavily modified	heavily modified	4	3
Upper Rhine 5 - OR 5 - Lauter to mouth R. Neckar	352-428		DE-BW	heavily modified	heavily modified	3	4
			DE-RP	heavily modified	heavily modified	3	4
Upper Rhine 6 - OR 6 - Neckar to mouth R. Main	428 - 497		DE-BW	heavily modified	heavily modified	4	3
			DE-HE	heavily modified	heavily modified	4	3
		Worms	DE-RP	heavily modified	heavily modified	4	3
Upper Rhine 7 - OR 7 - Main to mouth R. Nahe	497 - 529	Mainz/Wiesbaden	DE-HE	heavily modified	heavily modified	4	2
			DE-RP	heavily modified	heavily modified	3	2
MIDDLE RHINE Bingen - Bonn	**529-639**						
Middle Rhine (MR)	529-639		DE-HE	heavily modified	heavily modified	4	2
		Koblenz	DE-RP	heavily modified	heavily modified	4	2
LOWER RHINE Bonn - Kleve-Bimmen / Lobith	**639-865.5**						
Lower Rhine 1 NR 1 - Bad Honnef to Leverkusen	639-701	Cologne-Godorf	DE-NW	heavily modified	heavily modified	4	3
Lower Rhine 2 NR 2 - Leverkusen to Duisburg	701-764	Düsseldorf harbour	DE-NW	heavily modified	heavily modified	4	4
Lower Rhine 3 NR 3 - Duisburg to Wesel	764-811	Duisburg-Walsum / Orsoy	DE-NW	heavily modified	heavily modified	5	4
Lower Rhine 4 NR 4 - Wesel to Kleve	811-865	Niedermoermter / Rees	DE-NW	heavily modified	heavily modified	5	4
DELTA RHINE Lobith - Hoek van Holland	**65.5-1032**						
Boven Rijn, Waal	880-930	Lobith	NL	heavily modified	heavily modified	4	4
Maas-Waalkanaal	n.a.		NL	artificial	artificial	2	2
Nederrijn/Lek	954-980		NL	heavily modified	heavily modified	3	4
Dordtse Biesbosch, Nieuwe Merwede	972-982		NL	heavily modified	heavily modified	4	3
Beneden Merwede, Boven Merwede, Sliedrechtse Biesbosch, Waal, Afgedamde Maas-Noord	n.a.		NL	heavily modified	heavily modified	4	3
Oude Maas (upstream Hartelkanaal), Spui, Noord, Dordtsche Kil, Lek to Hagestein	977-998		NL	heavily modified	heavily modified	3	2
Hollandsche IJssel	n.a.		NL	heavily modified	heavily modified	4	4
Nieuwe Maas, Oude Maas (downstream Hartelkanaal)	n.a.		NL	heavily modified	heavily modified	2	2
Nieuwe Waterweg, Hartel-, Caland-, Beerkanaal	998-1013	Maassluis	NL	artificial	artificial	2	2
Amsterdam-Rijnkanaal Betuwepand	n.a.		NL	artificial	artificial	2	2
Amsterdam-Rijnkanaal Noordpand	n.a.		NL	artificial	artificial	2	2
Noordzeekanaal	n.a.		NL	artificial	artificial	2	3
IJssel	n.a.		NL	heavily modified	heavily modified	4	4
Twentekanalen	n.a.		NL	artificial	artificial	2	2
Zwartemeer	n.a.		NL	heavily modified	heavily modified	3	3
Ketelmeer + Vossemeer	n.a.		NL	heavily modified	heavily modified	3	3
Markermeer	n.a.		NL	heavily modified	heavily modified	2	3
Randmeren-Oost	n.a.		NL	heavily modified	heavily modified	3	2
Randmeren-Zuid	n.a.		NL	heavily modified	heavily modified	3	3
Lake IJssel	n.a.	Vrouwezand	NL	heavily modified	heavily modified	2	2
Wadden Sea mainland coast (coastal waters)	n.a.		NL	heavily modified	heavily modified	3	3
Wadden Sea (coastal waters)	n.a.	Dantziggat, Doove Balg west	NL	natural	natural	2	3
Dutch coast (coastal waters)	n.a.	Noordwijk	NL	natural	natural	2	3
Wadden coast (coastal waters)	n.a.	Boomkensdiep	NL	natural	natural	3	2

Annex 4: Evaluation of the fish fauna in the Rhine according to WFD for the management plan 2009 and for the management plan 2015

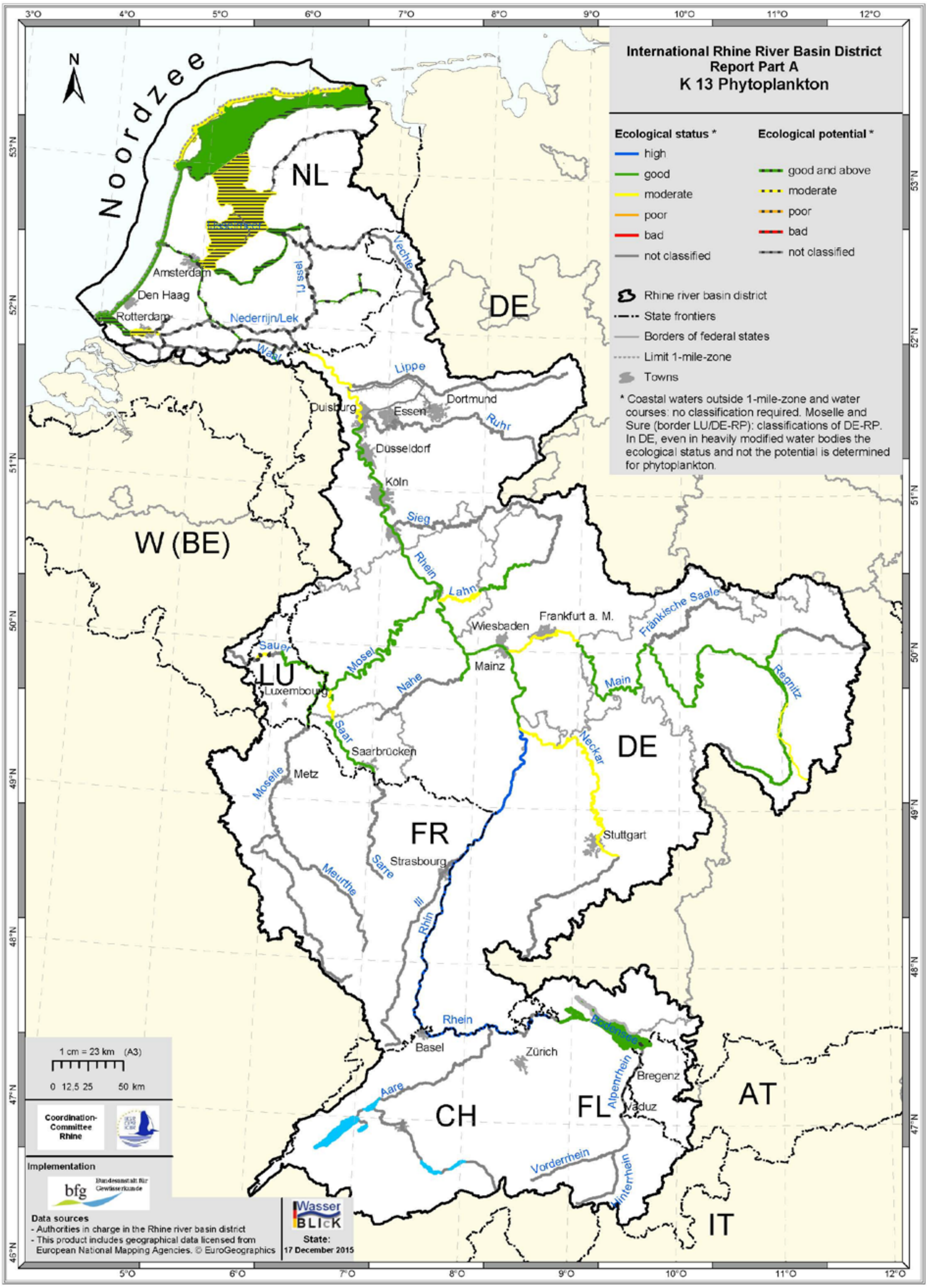
Evaluation of the fish fauna in the Rhine according to WFD for the management plan 2009 and for the management plan 2015	./.	Evaluation of quality component not required		very good	1	*Ecol. potential*
		No inventory or evaluation of the component / insufficient data		good	2	2
		Differing evaluation		moderate	3	3
	Fish: So far, the ecological potential has not been determined in the tributaries to the Lower Rhine in DE-NW. The deviation from the One-out-all-out-principle for the water bodies of the Upper Rhine 7 and for the Middle Rhine has been coordinated between DR-RP and DE-HE (for fish, the results obtained in DE-RP are more representative). The evaluation of the fish fauna on OR 1 to 4 differs for DE-BW and FR. It has not been possible to achieve an agreement for this biological quality component.			poor	4	4
State: December 2015				bad	5	5

Water body	River km	ICPR survy monitoring - monitoring station in the water body	State / federal state	Category Management Plan 2009	Category Management Plan 2015	Management Plan 2009	Management Plan 2015
ALPINE RHINE Reichenau - Lake Constance							
AR 3 Alpine Rhine, OWK AT 10109000		Fussach	AT/ Vorarlberg /CH (SG)	heavily modified	heavily modified	5	5
LAKE CONSTANCE							
BOD-OS Lake Constance - Upper Lake	No kilometre marking	Fischbach-Uttwil	DE-BW	natural	natural		2
BOD-USR Lake Constance - Lower Lake		Zellersee	DE-BW	natural	natural		
HIGH RHINE Lake Constance - Basel							
High Rhine 1 - Lake Constance to mouth R. Aare	24-102.7	Hohentengen, Kadelburg	CH / DE-BW	natural	natural	3	3
High Rhine 2 - mouth R. Aare to Basel	102.7/-170	Up- and downstream of Rheinfelden	DE-BW	heavily modified	natural	2	
UPPER RHINE Basel - Bingen							
Upper Rhine 1 - OR 1 - Rhine 1 - Old Rhine, Basel to Breisach	170-225	Weil am Rhein	DE-BW	heavily modified	heavily modified	3	3
			FR	heavily modified	heavily modified		2
		Differing evaluation		heavily modified	heavily modified		
Upper Rhine 2 - OR 2 - Rhine 2 - Loop of the Rhine, Breisach to Strasbourg	225-292		DE-BW	heavily modified	heavily modified	3	4
		Upstream Rhinau	FR	heavily modified	heavily modified		2
		Differing evaluation		heavily modified	heavily modified		
Upper Rhine 3 - OR 3 - Rhine 3 - impounded section of the Rhine, Strasbourg to Iffezheim	292-352		DE-BW	heavily modified	heavily modified	3	3
		Upstream Gambsheim	FR	heavily modified	heavily modified		2
		Differing evaluation		heavily modified	heavily modified		
Upper Rhine 4 - OR 4 - Rhine 4 - Iffezheim impoundment to upstream mouth R. Lauter	352-428	Karlsruhe	DE-BW	heavily modified	heavily modified	3	3
		Upstream Lauterbourg/Karlsruhe	FR	heavily modified	heavily modified		2
		Differing evaluation		heavily modified	heavily modified		
Upper Rhine 5 - OR 5 - Lauter to mouth R. Neckar	352-428		DE-BW	heavily modified	heavily modified	3	3
			DE-RP	heavily modified	heavily modified	3	3
Upper Rhine 6 - OR 6 - Neckar to mouth R. Main	428 - 497		DE-BW	heavily modified	heavily modified	4	3
			DE-HE	heavily modified	heavily modified		3
		Worms	DE-RP	heavily modified	heavily modified	4	3
Upper Rhine 7 - OR 7 - Main to mouth R. Nahe	497 - 529	Mainz/Wiesbaden	DE-HE	heavily modified	heavily modified	3	4
			DE-RP	heavily modified	heavily modified	3	3
MIDDLE RHINE Bingen - Bonn							
Middle Rhine (MR)	529-639		DE-HE	heavily modified	heavily modified	3	3
		Koblenz	DE-RP	heavily modified	heavily modified	3	3
LOWER RHINE Bonn - Kleve-Bimmen / Lobith							
Lower Rhine 1 NR 1 - Bad Honnef to Leverkusen	639-701	Cologne-Godorf	DE-NW	heavily modified	heavily modified	2	3
Lower Rhine 2 NR 2 - Leverkusen to Duisburg	701-764	Düsseldorf harbour	DE-NW	heavily modified	heavily modified	3	3
Lower Rhine 3 NR 3 - Duisburg to Wesel	764-811	Duisburg-Walsum / Orsoy	DE-NW	heavily modified	heavily modified	3	4
Lower Rhine 4 NR 4 - Wesel to Kleve	811-865	Niedermoermter / Rees	DE-NW	heavily modified	heavily modified	4	4
DELTA RHINE Lobith - Hoek van Holland							
Boven Rijn, Waal	880-930	Lobith	NL	heavily modified	heavily modified	4	4
Maas-Waalkanaal	n.a.		NL	artificial	artificial	2	2
Nederrijn/Lek	954-980		NL	heavily modified	heavily modified	4	3
Dordtse Biesbosch	972-982		NL	heavily modified	heavily modified	3	4
Beneden Merwede, Boven Merwede, Sliedrechtse Biesbosch, Waal, Afgedamde Maas-Noord	n.a.		NL	heavily modified	heavily modified	3	3
Oude Maas (upstream Hartelkanaal), Spui, Noord, Dordtsche Kil, Lek to Hagestein	977-998		NL	heavily modified	heavily modified	3	3
Hollandsche IJssel	n.a.		NL	heavily modified	heavily modified	3	3
Nieuwe Maas, Oude Maas (downstream Hartelkanaal)	n.a.		NL	heavily modified	heavily modified		3
Nieuwe Waterweg, Hartel-, Caland-, Beerkanaal	998-1013	Maassluis	NL	artificial	artificial		3
Amsterdam-Rijnkanaal Betuwepand	n.a.		NL	artificial	artificial	3	2
Amsterdam-Rijnkanaal Noordpand	n.a.		NL	artificial	artificial	3	2
Noordzeekanaal	n.a.		NL	artificial	artificial	2	2
IJssel	n.a.		NL	heavily modified	heavily modified	4	3
Twentekanalen	n.a.		NL	artificial	artificial	2	2
Zwartemeer	n.a.		NL	heavily modified	heavily modified	2	2
Ketelmeer + Vossemeer	n.a.		NL	heavily modified	heavily modified	2	2
Markermeer	n.a.		NL	heavily modified	heavily modified	2	2
Randmeren-Oost	n.a.		NL	heavily modified	heavily modified	2	2
Randmeren-Zuid	n.a.		NL	heavily modified	heavily modified	3	2
Lake IJssel	n.a.	Vrouwezand	NL	heavily modified	heavily modified	3	3
Wadden Sea mainland coast (coastal waters)	n.a.		NL	heavily modified	heavily modified	./.	./.
Wadden Sea (coastal waters)	n.a.	Dantziggat, Doove Balg west	NL	natural	natural	./.	./.
Dutch coast (coastal waters)	n.a.	Noordwijk	NL	natural	natural	./.	./.
Wadden coast (coastal waters)	n.a.	Boomkensdiep	NL	natural	natural	./.	./.

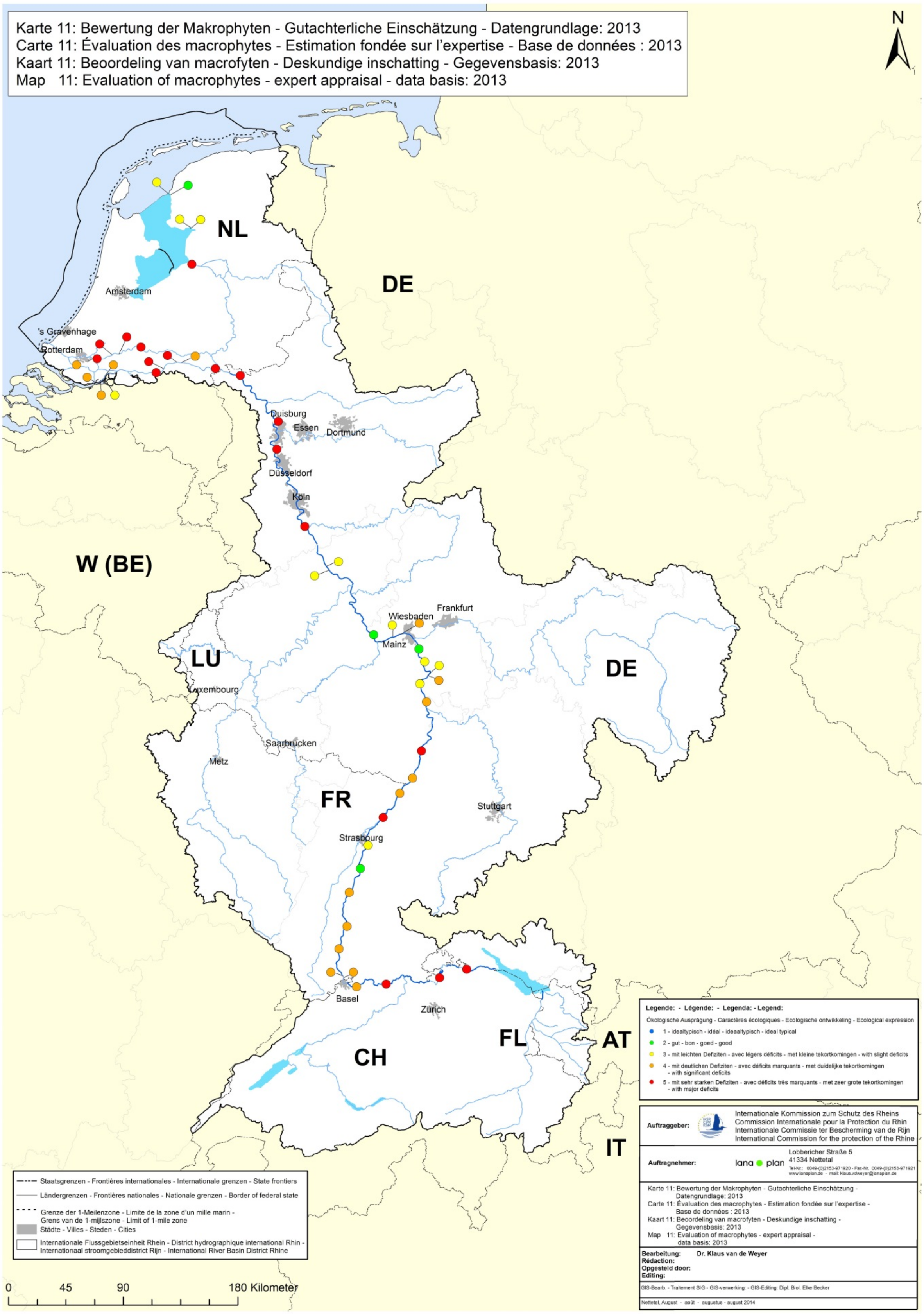
NL: The evaluations of 2009 differ from the original ones, as they were re-calculated according to an improved standard. They have been included here in order to enable a good comparison with 2014.

Annex 5: Map Phytoplankton evaluation

Map 13 of the 2nd Management Plan for the Rhine

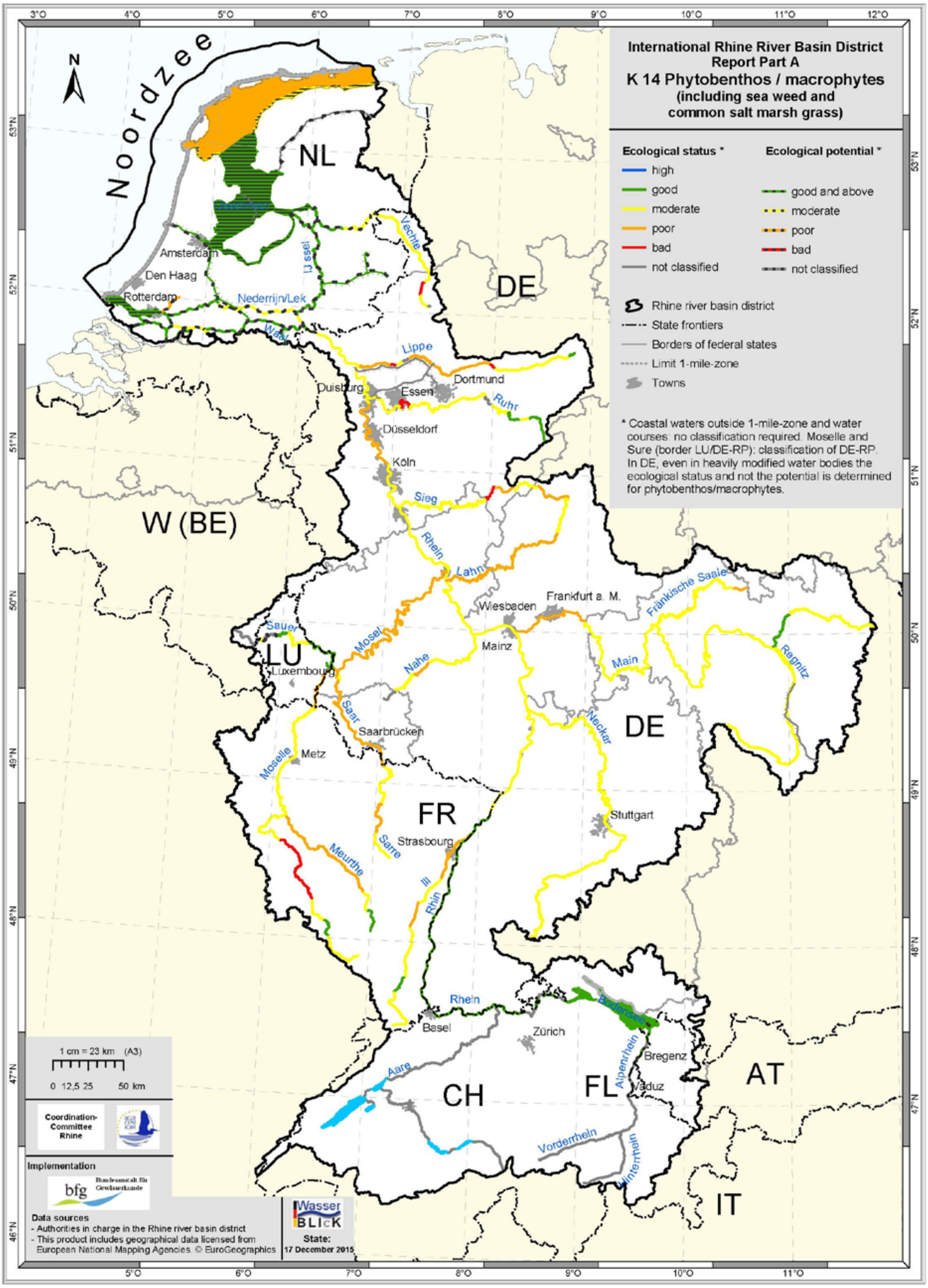


Annex 6: Map Initial expertise of the partial component macrophytes (data basis 2013)



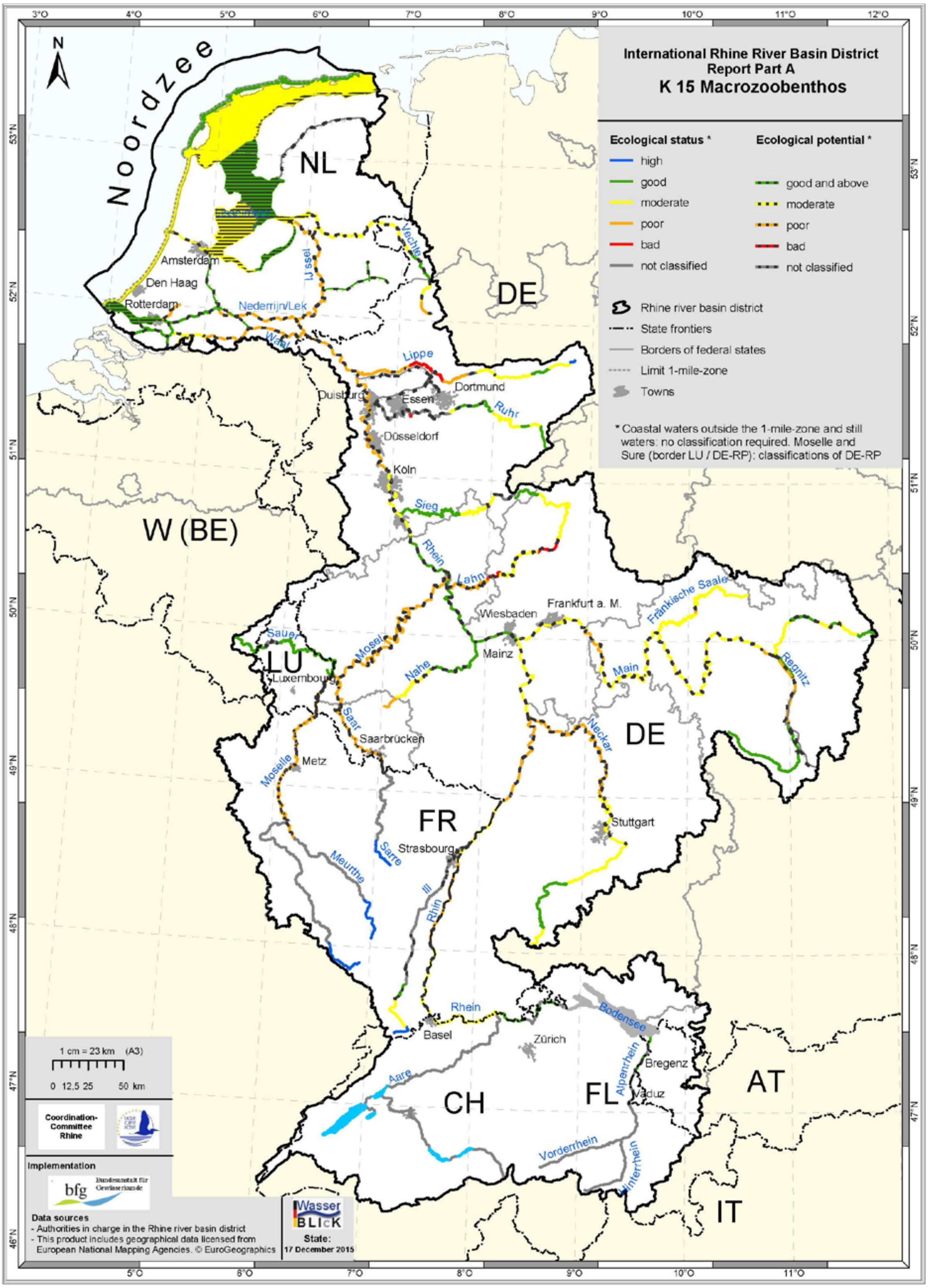
Annex 7: Map Evaluation of the phytobenthos/macrophytes

Map 14 of the 2nd Management Plan for the Rhine



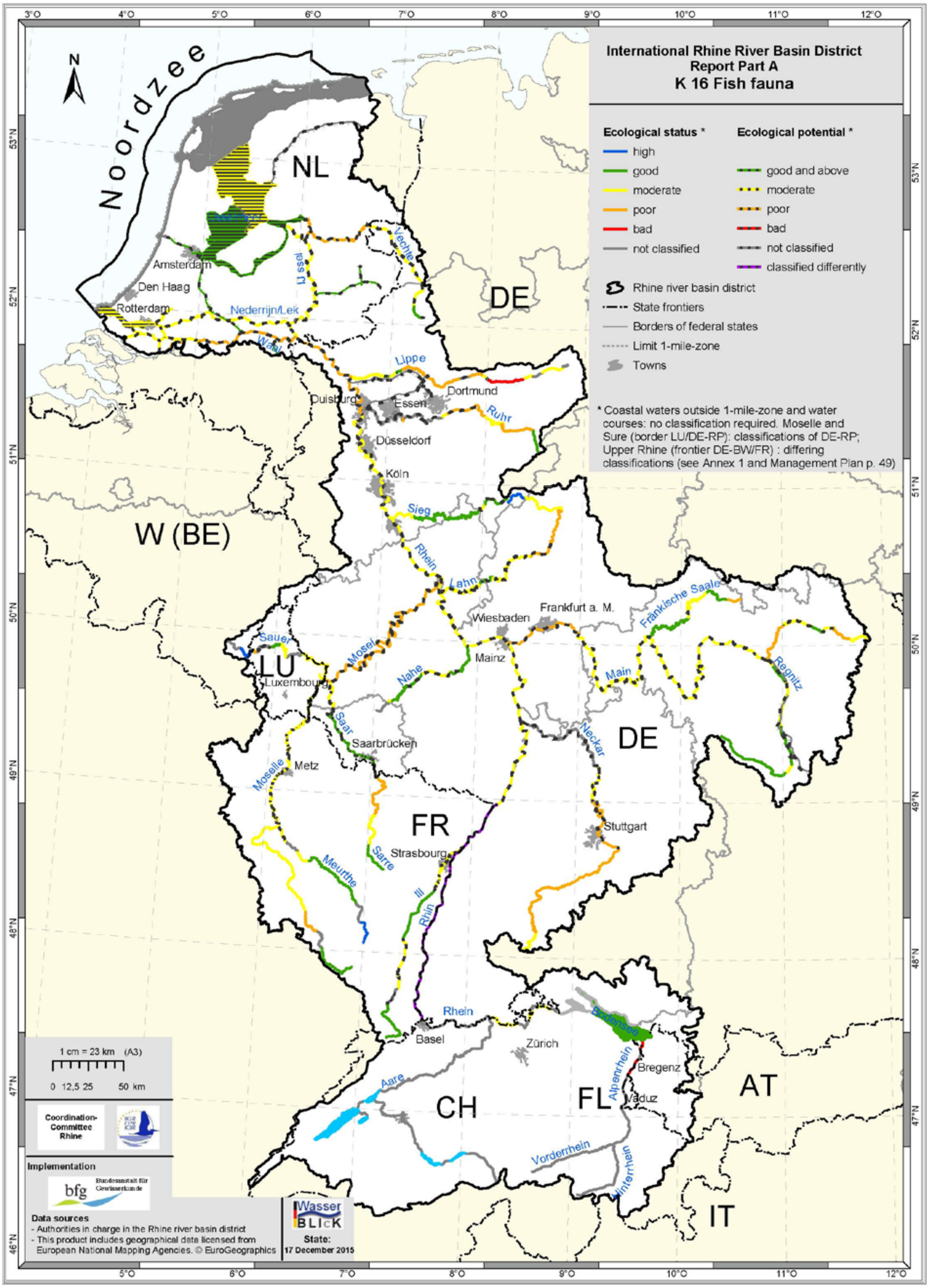
Annex 8: Map Macrozoobenthos evaluation

Map 15 of the 2nd Management Plan for the Rhine



Annex 9: Map Evaluation of the fish fauna

Map 16 of the 2nd Management Plan for the Rhine



Annex 10: Map Evaluation of the ecological state / the ecological potential on the whole

Map 17 of the 2nd Management Plan for the Rhine