The Biology of the Rhine

Summary Report on the Rhine Measurement Programme Biology 2018 / 2019 and National Assessments according to the WFD

IKSR
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Internationale Kommission zum Schutz des Rheins

Commission Internationale pour la Protection du Rhin

Internationale Commissie ter Bescherming van de Rijn

Report No. 280

Imprint

Publisher:
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Summary Report on the Rhine Measurement Programme Biology 2018 / 2019 and National Assessments according to the WFD

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Content

Summary

Within the "Rhine 2020" programme, an investigation of suspended algae (phytoplankton), water plants (macrophytes) and aquatic invertebrates (macro zoobenthos), the fish fauna, water plants and diatoms living on the river bottom (benthic diatoms as part of the phytobenthos) as well as the fish fauna was made along the entire course of the Rhine during 2018 and 2019. The "Rhine Measurement Programme Biology" the method of which has been coordinated on an international level 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 until including Delta Rhine) are classified as "heavily modified". The development target for these water bodies is not the good ecological state as for "natural" water bodies, but the good ecological potential. The coastal waters and the Wadden Sea are classified as natural water bodies.

Since the beginning of the 1990s, and due to today's good Rhine water quality, and the already implemented measures targeted at improving river continuity and at enhancing structural variety, the biocoenoses of the Rhine have distinctly improved: In some sections of the Rhine, the return of characteristic riverine species of invertebrate fauna can be observed. 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 Rhine water is today clearer than it used to be. Due to improved light conditions, aquatic 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 phytophilic fish species.

Nevertheless, many valuable spawning and juvenile fish habitats are still inaccessible due to existing migration obstacles. The implementation of measures to increase structural diversity in the riparian area, creating new habitats for Rhine-typical animals and plants, is also proceeding sluggishly, as it is both economically and socially challenging. Rising water temperatures as well as low water pose challenges for species typical of the Rhine. In addition, with the ongoing immigration of alien species (neobiota), mainly via navigation channels, there is a constant reconstruction of biotic communities. This mainly affects invertebrates, but since 2006 it has also affected fish, leading to a dramatic decline in native 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 round goby in particular has become well established from the Upper Rhine, but there are signs that its massive reproduction phase in heavily populated areas is coming to an end. It is also possible that there will be significant changes in the food chain in the next few years that will lead to a regulation of the goby populations. The impact of the displacement of this invasive species on native species has been proven. 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.* The neophytic diatom *Achnanthidium delmontii* is now also found in considerable quantities in the Upper Rhine section.

Among others, 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 within 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.). 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 riverbank habitats, the connection of lateral water bodies and measures aimed at improving river continuity 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 mitigating the adverse ecological effects of the faunal interchange and to stabilise the species diversity in the Rhine ecosystem.

To further improve the biotic communities of the Rhine, measures to restore structural diversity and water quality have to be continued.

1. Introduction

The synthesis report presents the results of the biological inventories within the 3rd monitoring cycle (2018/2019) within the framework of the third internationally coordinated management plan for the international river basin district (IRBD) Rhine as (IKSR 2021a) well as the results of the national assessments carried out by the individual states and compares them with the results of the 2nd cycle in 2012/2013. The monitoring programme combines the biological investigations into 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 elements phytoplankton, macrophytes/phytobenthos, macro zoobenthos and fish fauna are used for an overall assessment of the main stream of the Rhine. Figure 1 gives an overview of the six main Rhine sections as well as sub-catchments in the Rhine system. The work is carried out in continuation of the tradition of biological monitoring reports within the "Rhine Action Programme" of the International Commission for the Protection of the Rhine (ICPR) which, during 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 2018/2019 (ICPR 2017a) and in the comprehensive reports on the different biological groups (ICPR 2020 a- d, ICPR 2021b).

In addition to the results of the screening programme, the national ecological assessments of the individual quality elements according to the WFD for the third internationally coordinated management plan for the IRBD Rhine (draft version of 15 April 2021) are presented in Tables and Maps (Annexes) and compared with the assessments of 2015. Furthermore, a map in Annex 10 shows the overall assessment of the ecological status or potential according to the WFD for the third management plan (draft version of 15 April 2021).

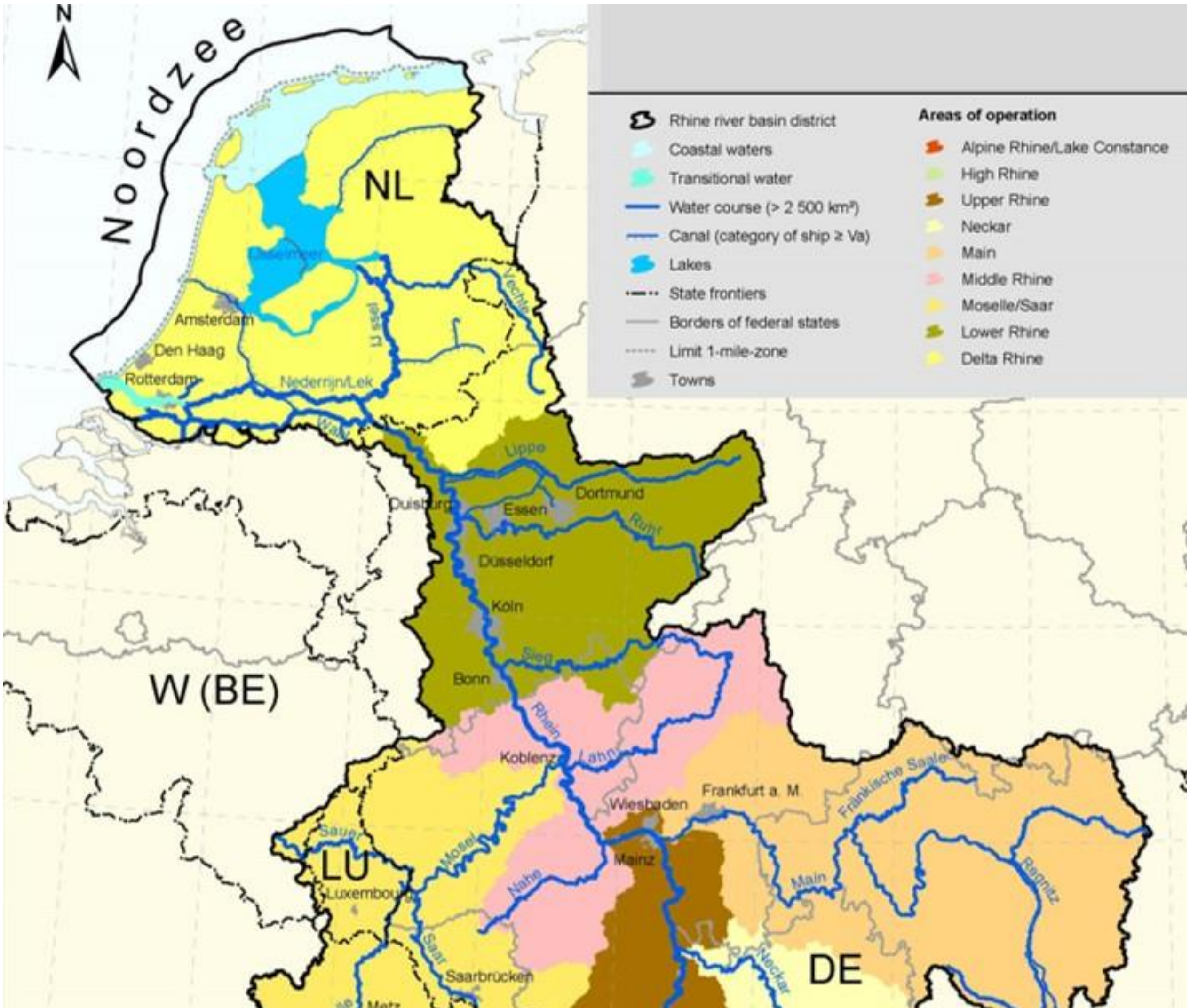


Figure 1: Sections of the Rhine and sub-basins in the Rhine system. (AR: Alpine Rhine; HR: High Rhine; OR: Upper Rhine; MR: Middle Rhine; NR: Lower Rhine; DR: Delta Rhine)

2. Phytoplankton

Suspended algae
see ICPR 2020a

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, affects water quality and may serve as an early warning system for coastal waters.

What does the biocoenosis of the Rhine look like?
The species-rich phytoplankton group plays an important part in the food web of large rivers. 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). In the process, if zooplankton concentrations are very high or populations of filter feeders are large, significant amounts of phytoplankton can be removed 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 basis for the further food web and thus for higher organisms, such as fish.

In 2018, the by far predominating share of the biomass consisted of benthic diatoms (class: Bacillariophyceae). During spring, they accounted for well over 90% of the total phytoplankton biovolume at the monitoring sites Koblenz (Middle Rhine) and Bimmen (Lower Rhine). Among them, the centric diatoms *Skeletonema subsalsum*, *Aulacoseira normanii* and *Skeletonema potamos* were particularly strongly represented during the algal peak at the end of May in Bimmen. Further upstream in Breisach (Upper Rhine), apart from diatoms, cryptomonads (Cryptophyceae), especially the species *Rhodomonas lacustris,* accounted for larger shares of the total phytoplankton biomass.

The taxonomic composition of the phytoplankton during the summer algal bloom could be observed in a more differentiated way at the Koblenz monitoring site. Here, a strongly pronounced diatom bloom was initially evident, 80% of which was formed by the centric diatom *Skeletonema potamos* on 8 August 2018. This species is considered to be heat-loving, is typically found in larger rivers and often represents a larger biomass share here. It is assumed that in future, it will benefit from temperature increases in the course of climate change (DULEBA et al. 2014). However, when measured on 15 August 2018, the biomass of *Skeletonema potamos* at the Koblenz monitoring site had already decreased to about two percent of the value on 8 August 2018. The diatom *Cyclotella meneghiniana*, which is also typical of the river, now dominated the much smaller phytoplankton biomass. Again, one week later, on 22 August 2018, green algae of the genus *Coelastrum polychordum* dominated the phytoplankton community and formed a second, completely differently composed phytoplankton bloom.

The striking phytoplankton dynamics at the Koblenz monitoring site are confirmed by the monthly phytoplankton counts at the other monitoring sites. The green alga *Coelastrum polychordum*, which formed a plankton bloom at the Koblenz monitoring station on 22 August 2018, is a typical species of the large pre-alpine lakes. It fits in with this that it was detectable in high numbers as far upstream as the mouth of the Aare. At the Breisach monitoring site, *Coelastrum polychordum* already accounted for almost 60% of the algal biomass on 21 August 2018. In Mainz, this species was even represented with more than 90% of the total phytoplankton biomass on 20 August 2018. Further downstream, at the Bimmen monitoring site, the green algal bloom had obviously not yet reached its full extent at this point. *Coelastrum polychordum* was already present in larger numbers, but, as in Koblenz a week earlier, the diatoms still dominated.

Overall, the results on phytoplankton in the Rhine and its tributaries indicate on the one hand further decreasing algal biomasses in spring and thus an improvement of the trophic status. On the other hand, the conspicuous summer algal blooms demonstrate that the trophic potential for high algal biomasses is present in the Rhine as well as in its tributaries (in 2018 in the Moselle and Lahn) and can be used by different phytoplankton species.

To interpret the phytoplankton, zooplankton was also examined at selected sites. The number and biomass of zooplankton organisms were low in 2018. Rotatoria ("rotifers") are typical zooplankton organisms in flowing waters. However, during the entire monitoring campaign, a maximum of 9 individuals/l was detected on the Rhine, at the monitoring sites Koblenz and Bimmen. This very low number was surprising because during the low water phase there were strong phytoplankton blooms, which provided plenty of food for rotifers. It is possible, however, that these phytoplankton blooms were too short, so that the rotatoria with their longer generation times could not react to them.

Other typical zooplankton organisms in the Rhine are the larvae (so-called "veliger larvae") of the zebra mussels *Dreissena polymorpha* and *Dreissena rostriformis bugensis*. In 2018, however, the number of veliger larvae was also relatively low. This low number is possibly due to a decline in the immigrant *Dreissena polymorpha* (zebra mussel), which has been displaced in the Rhine by the somewhat larger *Dreissena rostriformis bugensis* (quagga mussel).

Evaluation of the Rhine
From the **High Rhine** until the **Upper Rhine** upstream the mouth of R. Neckar the state of the phytoplankton is "very good" (see Annex 1). The southern Upper Rhine is only assessed by the German side. From downstream the mouth of the Neckar the condition is "good" until upstream the mouth of the Main and then changes to a "moderate" condition of the **Middle Rhine** and **Lower Rhine**. Compared to 2015, the ecological assessment of the component has shown a negative change between the mouth of the river Main and Duisburg on the Lower Rhine. Thus, these sections of the Rhine deteriorated from good 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. Lake IJssel and the Wadden Sea show a moderate potential and a "moderate" status respectively, which represents a deterioration of the previously "good" status of the Wadden Sea. Coastal waters consistently achieve "good" ecological status due to the improvement of the Wadden coastal area.

Comparison with the results of previous studies shows that current hydrological conditions and weather conditions override the long-term trend and promote seasonal algal blooms. During a spring with high runoff, as in 2009 and a corresponding trend also in 2018, phytoplankton development is low. The influence of the weather was particularly evident during the summer low-water phase in 2018. Here, the phytoplankton benefited from extended flow times, higher water temperatures and reduced mussel activity. This allowed the phytoplankton in Koblenz and Bimmen to grow to high concentrations (Figures 2 and 3). Consequently, despite the significantly decreased total P concentration (Figure 4), the potential for algal blooms in the Rhine is still present.

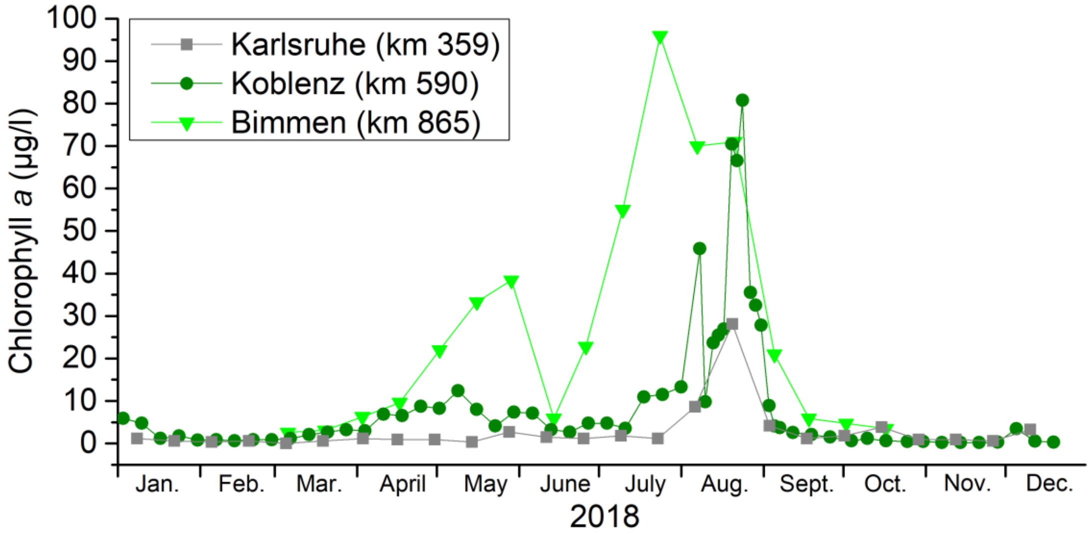


Figure 2: Seasonal course of chlorophyll concentration at the Karlsruhe, Koblenz and Bimmen monitoring sites.

Overall, the exceptional, weather-related phytoplankton dynamics in 2018 make it clear that permanent monitoring of phytoplankton with relatively narrow temporal sampling grids is urgently needed to make management successes visible and to document long-term environmental changes.

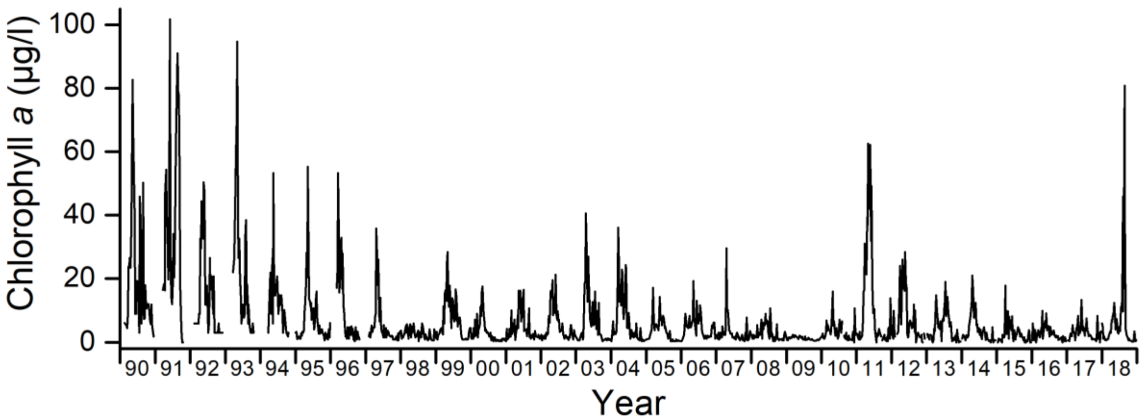


Figure 3: Development of the chlorophyll-a concentration at the Koblenz monitoring station since 1990. Data: Bundesanstalt für Gewässerkunde (BfG).

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 0.10 mg/l in 2018 (Figure 4). 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, for a long time, no values at such a level were determined. 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 tributaries, and, above all, increased filtration by the invasive zebra mussel (*Dreissena* sp.) (WEITERE & ARNDT 20024, HARDENBICKER et al. 2014, ICPR 2015c). However, current hydrological and weather conditions may override the long-term trend and promote seasonal algal blooms, as in summer 2018.

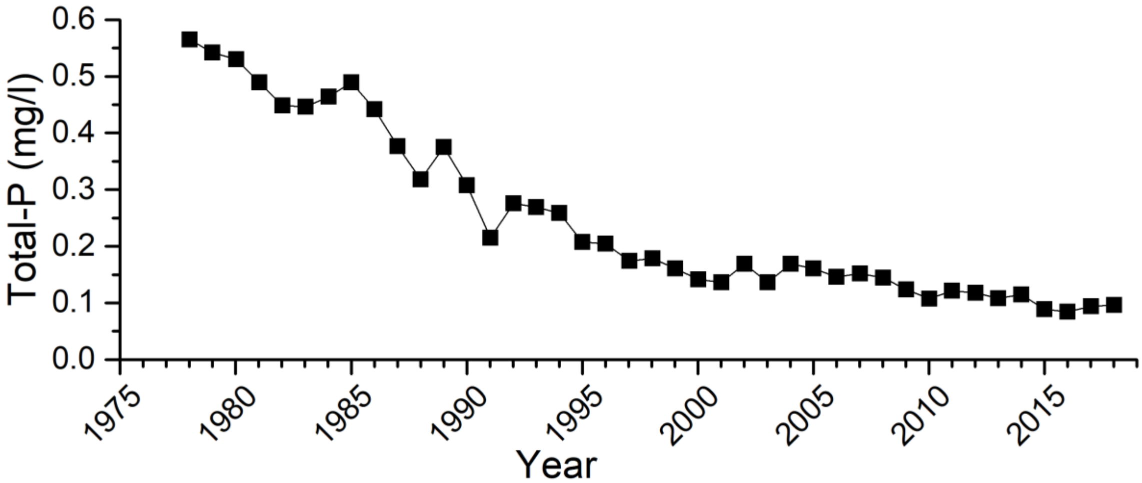


Figure 4: Development of total phosphorous concentrations (mean annual values) at the Koblenz monitoring station between 1978 and 2018. Data: Bundesanstalt für Gewässerkunde (BfG)

Long-term future monitoring will show whether the exceptionally high phytoplankton biomasses in summer 2018 were an isolated case in an extremely dry and warm year or whether climate development will promote such algal blooms in the future and thus counteract efforts to improve the trophic status of the Rhine.

3. Macrophytes

Aquatic vascular plants, mosses, stoneworts
see ICPR 2020b

What do aquatic plants indicate with respect to pollution?
Aquatic macrophytes are very good trophic indicators. But being plant organisms, they also distinctly react to other changes of running waters caused by man. By this means, interferences with the discharge regime, e. g. impoundments may be indicated. The degree 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 2018/2019, 55 aquatic macrophyte species were detected at 50 monitoring stations in the main stream of the Rhine: 33 higher plants, 18 mosses and 4 stonewort. In 2012/2013, 44 aquatic macrophytes were detected. The increase in the number of species is to be seen in connection with the higher number of monitoring sites. *Potamogeton pectinatus* (fennel pondweed, 32) was most common, followed by *Myriophyllum spicatum* (Spiked Watermilfoil, 29) and *Fontinalis antipyretica* (common water moss, 26). Nuttall's waterweed (*Elodea nuttallii*, Figure 5) 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. In 2006/2007 and 2018/2019, *Elodea nuttallii* was detected in all sections apart from the Alpine Rhine and the Lower Rhine, at several survey sites each.

Figure 5: Nuttall's waterweed (*Elodea nuttallii*). Photo: Klaus van de Weyer.

Evaluation of the Rhine
Within the Rhine Monitoring Programme Biology, the partial component Macrophytes has been considered independently from the two other partial components "benthic diatoms" and "other phytobenthos". Total macrophyte cover is a criterion used in the Dutch river assessment procedure (VAN DER MOLEN et al. 2012). In the LANUV NRW (2017) method, the total cover of aquatic macrophytes is also considered. In the other countries evaluative conclusions are based on **initial expert assessment** of single monitoring stations considering the number of species and growth forms, the occurrence of quality indicators and the degree of vegetation cover (see Annex 6).

In the **Alpine Rhine**, which was investigated for the first time in 2018/2019 at a sampling site, a high total cover of aquatic macrophytes was recorded. The macrophyte population was "well developed".
In 2018/2019, the study sites in the **High Rhine** were characterised by low or medium cover of aquatic vegetation (< 2% and 2-5%, respectively), which is rich in growth forms compared to 2012/2013. In 2012/2013, all survey sites in the High Rhine showed only a low cover of aquatic vegetation (below 2%). Two study sites each were classified as having "slight deficits" and "significant deficits".
In the **Upper and Middle Rhine**, most study sites showed cover values of below 2%, in 2012/2013 mostly cover values of above 2% were recorded. In both reporting periods, however, there were also individual study sites that had medium or high cover of aquatic vegetation (3 sites with 5-25% and one site with over 25%).
In the **Upper Rhine**, the stock of macrophytes is heterogenous; some show "considerable deficits", others are "well developed". The 3 sample sites in the **Middle Rhine** cover the range from "well developed", with "slight deficits" to "clear deficits" and are rich in species as well as growth forms.
In the **Lower Rhine**, aquatic macrophytes were completely absent at all study sites in 2018/2019, which classifies them with "very strong deficits". In 2012/2013, macrophytes with very low cover were present at least at some study sites.
In the **Delta Rhine**, no aquatic plants were detected at all but one site in 2012/2013. In 2018/2019, the vegetation cover was very heterogeneous; some survey sites show "very strong deficits", others are "well developed". In addition to sites without vegetation, there were also sites with low, medium and strong vegetation.
The sampling sites Bacharach (Middle Rhine, km 541), Speyer (Upper Rhine, km 389) and Oude Maas (Delta Rhine, km 957-985) show the best developed macrophyte populations in the entire course of the Rhine during the study period with 14 and 16 species, respectively.

The **comparison with data from 2012/2013** shows that some species can no longer be detected, 18 species were detected for the first time. Comparison is made difficult by the fact that the number of monitoring sites has increased significantly - from 36 monitoring sites in 2012/2013 to 50 in 2018/2019. In the **High Rhine**, an increase in the number of aquatic macrophyte species was observed in 2018/2019. In the **Upper Rhine**, the trend is not clear. In addition to declines, there have also been increases. This is also true for the **Middle Rhine**. No aquatic macrophytes were detected in the **Lower Rhine** in 2018/2019, in 2012/2013 there were only two species in this section. Possible reasons for the lack of macrophytes on the Lower Rhine are the structural poverty with anthropogenically shaped river morphology and the higher turbidity, which may be caused by increasing navigation, among other things. Comparatively high chlorophyll concentrations also occur on the Lower Rhine, which can additionally lead to limited light availability.
An increase was recorded in the **Delta Rhine**. It should be noted here that several monitoring sites were sampled within the study sections. These changes can be due to methodical reasons, but they may also be a sign of concrete proliferation trends of species. This is to be assumed for the fountain pocket-moss *Octodiceras fontanum* and for some pondweeds (*Potamogeton* spp.) in Germany.
On the whole, the comparison of the present results with the inventory of macrophytes of 2012/2013 indicates a high spatiotemporal heterogeneity in the Rhine (see Figure 6). There are three reasons:

(1) Difficulties of a representative coverage (partly diving is required);
(2) Differing discharge situations from one monitoring year to the other;
(3) Local differences in the frequency of advantageous riverbank structures (partly protected groyne fields with sand-gravel substrates, Figure 7).

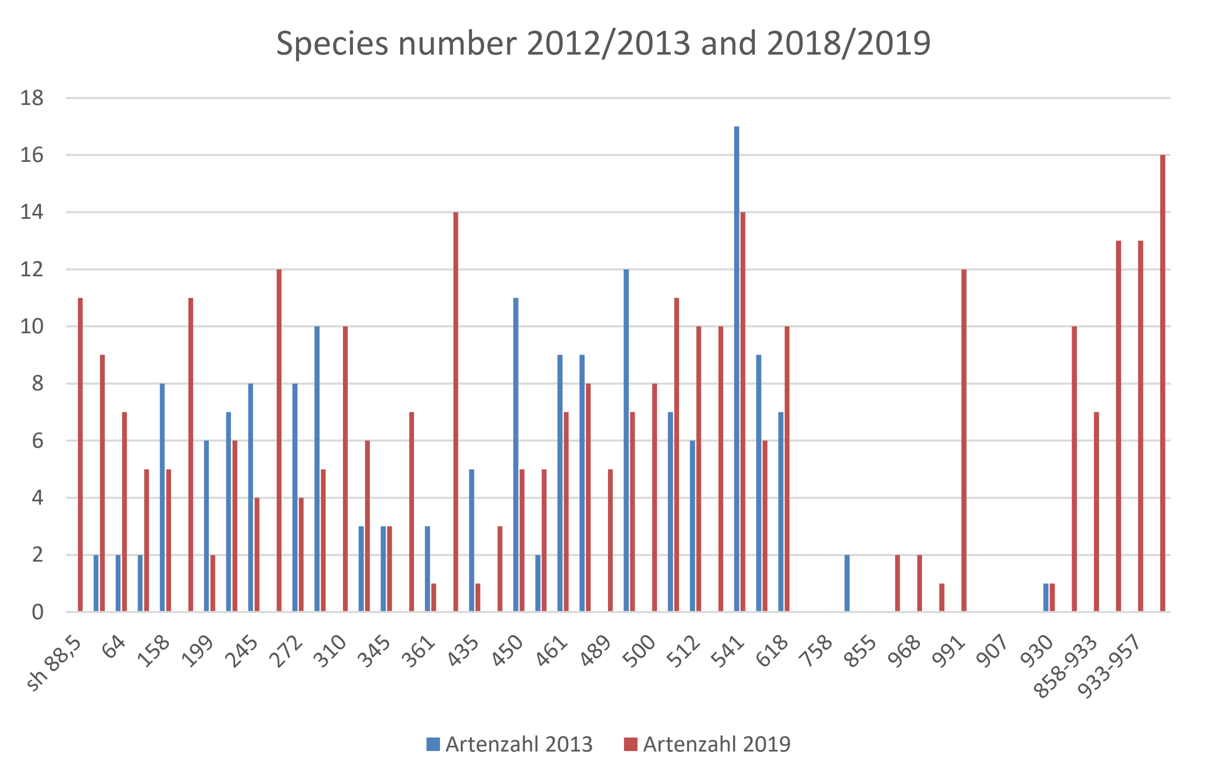


Figure 6: Species number of aquatic macrophyte species along the main stream of the Rhine with indication of Rhine-km during the analysis periods 2012/2013 and 2018/2019. (AR: sh 88,5; HR: 64-158; OR: 199-512; MR: 541-618; NR: 758-855; DR: 968-933/957)

Figure 7: Habitat groyne field Rhine. Photo: LfU Mainz.

What are the long-term trends?
The development of aquatic plants in the Rhine has been systematically studied since the Rhine monitoring programme 2006/2007. Local mapping of some sections of the Middle and of the Upper Rhine and of alluvial areas along the Rhine show an increase in the number of species and frequency of macrophytes during the period concerned. This trend can only be explained by the reduced development of phytoplankton biomass in the Rhine. Aquatic plants and phytoplankton show a competitive behaviour governed by light and nutrients. If less phytoplankton can develop during the springtime, transparency increases. During the growth period of aquatic plants sunlight now penetrates deeper into the water and thus favours the development of larger stocks.
Discharge and particularly floods are also decisive for how sustainable and ample these developments are. Furthermore, suitable riverbank structures for new establishments are required. These conditions are given in certain sections of the Upper and the Middle Rhine. Another important factor for the recolonisation of these sections of the Rhine is the proximity to species-rich alluvial waters of the Upper Rhine. The Lower Rhine and the Delta Rhine show structural deficits which make the emergence of macrophytes difficult (lack of areas with calm currents, wave action, strong water level fluctuations).
In the large stillwaters along the Rhine, such as in Lake Constance, Lake IJssel and Markermeer as well as in the Randmeren, improved water quality has a positive effect on macrophyte populations. Extensive macrophyte vegetation in turn promotes the increase of aquatic plant-eating bird species (ICPR 2020i).

4. Phytobenthos

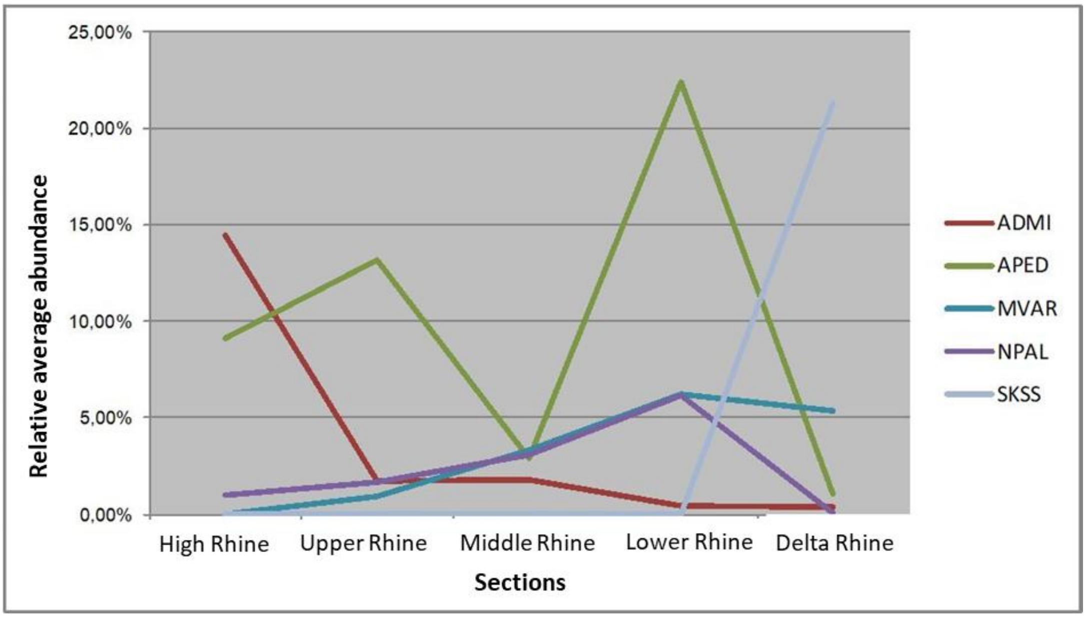
Here: benthic diatoms, bottom living diatoms
see ICPR 2020c

Most Rhine bordering countries only use the benthic diatoms (bottom-dwelling diatoms) for the assessment of the biological component "macrophytes / phytobenthos". In Baden-Württemberg not only benthic diatoms, but also the rest of the phytobenthos is covered by the assessment. In the Netherlands, phytobenthos and macrophytes are assessed together. The coastal and transitional waters are assessed based on seaweeds and common salt marsh grass (quality and quantity).

What do diatoms indicate with respect to pollution?
Diatoms are microscopic small single-celled algae. They particularly develop in running waters, where they constitute 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 enable an assessment of the nutrient pollution (trophic level), of acidification, salt pollution and of the organic pollution (saprobia) of their habitat (VAN DAM et al. 1994, ROTT et al. 1997). Since diatoms have short generation times, the community can react quickly to changes. Sampling took place from May to October, so that the assessment result reflects the material situation during the warmer period. In this context, the considerable scatter of the sampling data, as well as the low water period in summer 2018 must be considered.

What does the biocoenosis of the Rhine look like?
Between August 2015 and October 2018, 340 species of benthic diatoms were detected at the 41 analysed sites. This corresponds to a considerable species diversity even for a big river such as the Rhine. However, many species only occur at few sampling sites, while a comparatively low number of species (25) occurs at over 50% of the sampled sites thus dominating the biocoenosis at the individual site. Figure 8 illustrates the frequency of distribution of the five most widespread diatom species in the Rhine (photos in Figure 9).

The diatom biocoenosis occurring in the course of the Rhine (see Figure 1) have characteristic indicative features (guilds). Their sequence reflects the reduction of flow velocity and at the same time a rise in the nutrient supply and of organic substances:
The species composition of the **High Rhine** is typical of flowing waters with few nutrients and organic substances. Downstream, the species composition changes successively.
From the **Upper Rhine until the delta**, species typical of nutrient-rich habitats represent a considerable share. In addition, planktonic and halophile (salt-loving) species occur in the **Rhine delta**.



ADMI: *Achnanthidium minutissimum* (Kützing) Czarnecki sensu lato; APED: *Amphora pediculus* (Kützing) Grunow; MVAR: *Melosira Varians* (Agardh); NPAL: *Nitzschia palea* (Kützing) W.Smith; SKSS: *Skeletonema subsalsum* (Cleve-Euler) Bethge.

Figure 8: Average abundance of five aspect-forming species of benthic diatoms in the sections of the Rhine.

- *Achnanthidium minutissimum* sensu lato is a pollution-sensitive species, which occurs in the High Rhine in a high density of individuals and only sporadically in other sections of the Rhine (Figure 8).
- *Amphora pediculus* was recorded in all sections of the Rhine but occurs in greater abundance on the Lower Rhine. The low abundance in the Middle Rhine is a special feature compared to the 2012/2013 inventory. It is considered euryecious and ubiquitous, i.e., 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).
- *Melosira varians* and *Nitzschia palea* increase in average abundance in the downstream direction. *Melosira varians* is a benthic tychoplankton species which means that it is typical of eutrophic (nutrient-rich) standing waters and represents a large share in the samples from the lower river section. The gradual increase in the average abundance of the very pollution-insensitive taxon *Nitzschia palea* can be linked to the organic influx and thus the gradual increase in organic and trophic load in the Rhine. Its disappearance from the Rhine delta is probably due to the highly lenitic conditions, which are rather unfavourable for the taxon, rather than to an improvement in water quality.
- *Skeletonema subsalsum* is typical for the Rhine delta. The special, very lenitic conditions of this section favour strong sedimentation and explain the very abundant occurrence of this plankton species in the benthos.

Four of the five most common species are portrayed in Figure 9.

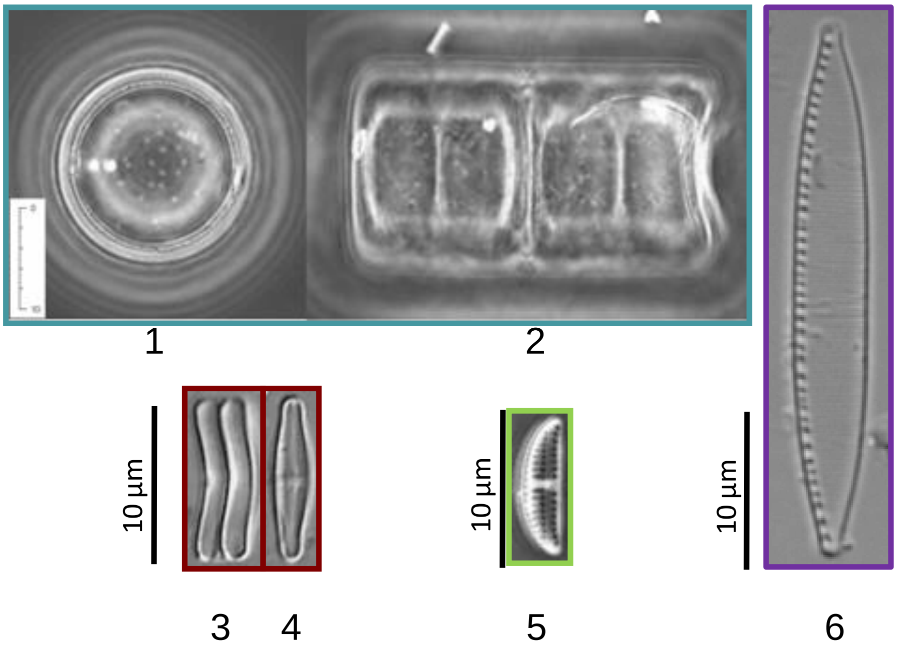


Figure 9: The four aspect-forming species of benthic diatoms of the Rhine. 1-2: *Melosira varians* top view (1) and side view (2); 3- 4: *Achanthidium minutissimum* sensu lato in lateral view (3) and top view (4); 5*: Amphora pediculus;* 6: *Nitzschia palea;* photos D. Heudre.

In terms of trophicity (nutrient supply) (i.e., the sensitivity of species compositions to nitrates and phosphorus), it can be seen that species compositions quickly become eunitrophilic, but then gradually evolve towards mesonitrophilic dominance (Figure 10a and 10b).

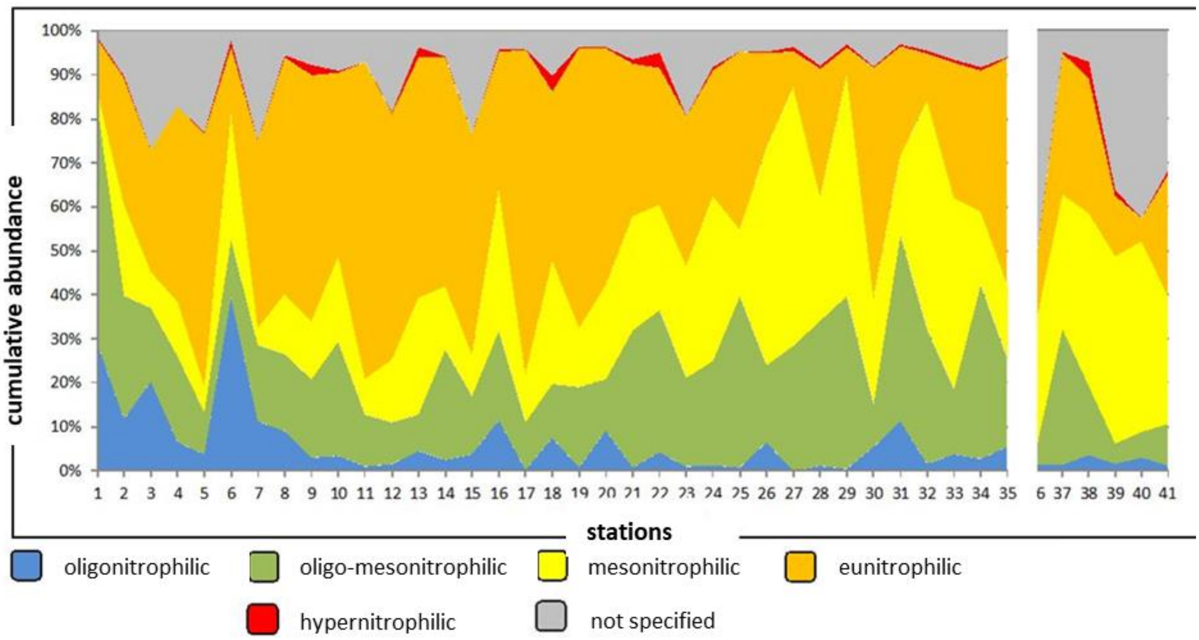


Figure 10a: Cumulative abundance of species distributed according to nitrate sensitivity (Carayon *et al.* 2019) (monitoring sites per Rhine section: 1-5 (High Rhine); 6-28 (Upper Rhine); 29-32 (Middle Rhine); 33-35 (Lower Rhine); 36-41 (Delta Rhine)).

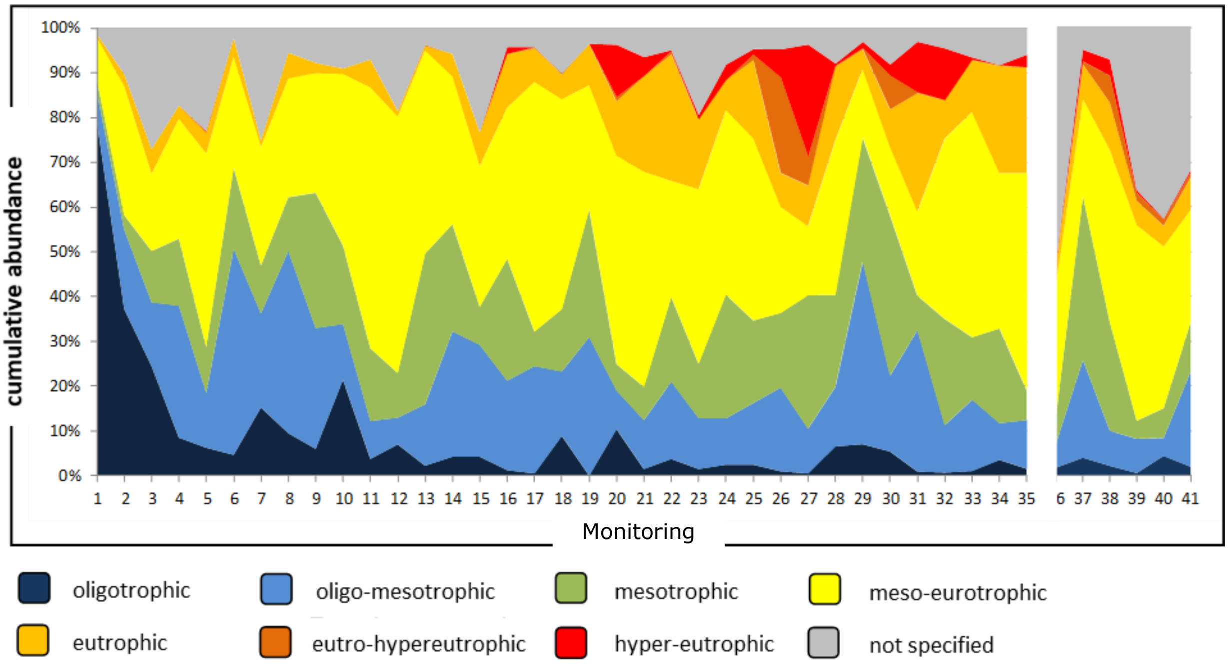


Figure 10b: Cumulative abundance of species distributed according to phosphorus sensitivity (CARAYON *et al.* 2019) (Monitoring sites per Rhine section: 1-5 (High Rhine); 6-28 (Upper Rhine); 29-32 (Middle Rhine); 33-35 (Lower Rhine); 36-41 (Delta Rhine)).

Evaluation of the Rhine
As Annex 2 and Annex 7 show, **Lake Constance** is rated "good" in all parts in 2018/2019 - as it was in 2012/2013 - as is the **High Rhine** up to upstream the Aare. For macrophytes and phytobenthos, the **southern Upper Rhine** up to Breisach is rated "good" by the German side and "moderate" by the French side. The southern Upper Rhine from Breisach to Strasbourg is rated "moderate" by the German side and "good" by the French side. Without exception, the further course of the Rhine (**northern Upper Rhine, Middle Rhine**) until the German-Dutch border is classified as "moderate" with two "good" sections in the **Upper Rhine** (mouth of Lauter to mouth of Neckar) and in the **Middle Rhine**. The section in the Lower Rhine (mouth of Wupper to mouth of Ruhr) has improved from "bad" to "moderate" compared to 2015. In the **Delta Rhine**, numerous water bodies have achieved the good state with respect to the quality component macrophytes/phytobenthos: Boven Rijn and Waal, Nieuwe Waterweg, Hartel-, Caland- and Beerkanaal and Lake IJssel. The **Wadden Sea** was rated "poor". The **coastal waters** are of a different type, where the assessment based on seagrass and common salt marshes is not applicable.

In the **Rhine monitoring programme Biology 2018/2019**, 41 monitoring sites were sampled, i.e., 6 less than in 2012/2013. However, the total number of species was now 11% higher at 340 taxa. The most common species are *Nitzschia dissipata*, *Amphora pediculus* and *Navicula cryptotenella*, which were recorded at almost all monitoring sites. In addition, *Cocconeis placentula* sensu lato, *Navicula antonii*, *Nitzschia fonticola*, *Achnanthidium minutissimum* sensu lato, *Navicula tripunctata* and *Cocconeis pediculus* play dominant roles.

What are the long-term trends?
The benthic diatoms have been studied in the Rhine monitoring programme since 2006/2007. A nice succession of diatom communities can be observed with decreasing flow velocity and simultaneous increase in nutrient supply from the upper to the lower

reaches of the Rhine. Most of the course of the Rhine is thus characterised by taxa favouring medium mineralisation and by a dominance of taxa characteristic of high and moderate oxygenation. As far as nutrient pollution of the environment is concerned, this is a very classic case of large rivers: Nitrate accumulation is rapid, and phosphorus is a limiting element with a gradual increase from upstream to downstream.
Comparable to the phytoplankton situation - the reduction of the nutrient pollution of the Rhine has resulted in a more natural biocoenosis.

5. Macro zoobenthos

Invertebrate fauna of the bottom of the water body
see ICPR 2020d

What does the invertebrate fauna tell about the pollution situation?
The species diversity and dominant species proportions of the macro zoobenthos is an indicator of water quality, and of the quantity and quality of habitat structures in a water body. The increasing 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 macrozoobenthic species were detected in the Rhine between the Alps and the North Sea. Above all molluscs (Mollusca), oligochaeta, crustaceans, insects, freshwater sponges and bryozoa make up the aspect.
The **Anterior and Posterior Rhine** as well as the **Alpine Rhine** present a high macrozoobenthic variety. Rheophile insect species such as i.e. of ephemera, stone flies and trichoptera typical for the system of the Alpine Rhine dominate. High population densities are also reached by amphipoda. Larvae of net-winged midges, which were found in high abundance in the Anterior Rhine, are also remarkable. None of the other immigrated new species have so far been able to settle in the lower reaches of the Alpine Rhine.
In **Lake Constance**, typical species of stagnant waters or ubiquitous species can be found, such as the killer shrimp, the common bithynia, the New Zealand mud snail, the Helobdella stagnalis, various mayflies, caddisflies and species of amphipods. Invasive species, such as the killer shrimp and the basket clam, reach high individual densities. In 2016, the quagga mussel was detected, which is spreading rapidly and displacing the zebra mussel.
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 parts and despite immigrated fauna species still nature near. In the navigable and trained Rhine downstream of Basel (Upper Rhine, Middle Rhine, Lower Rhine and Delta Rhine), the benthic fauna is largely uniform and dominated by common and frequent colonisers of bigger rivers and streams with little demands on their habitats (ubiquists). Alien invasive species account for 60 % of the total population. Elements of the original fauna are partly found in connected oxbow lakes and loops of the original course of the Rhine.
The navigable **southern Upper Rhine** is characterised by alien invasive species. Due to their relative structural richness, the **Old Rhine/ Rest Rhine** and the **loops of the Rest Rhine** are comparatively well populated; dragonfly larvae of the common clubtail have been recorded.
The biocoenosis of the **northern Upper Rhine** is similar in dominance and constancy to that of the southern Upper Rhine. Some special features are large mussels (e.g. the painter's mussel (*Unio pictorum*)), the big-ear radix (*Radix auricularia*), the gravel snail *(Lithoglyphus naticoides*), the mayfly *(Ephoron virgo*) from downstream of the mouth of the Neckar, and the river nerite *(Theodoxus fluviatilis*), which spreads upstream and downstream from the mouth of the Main.
In the **Middle Rhine** the proportion of alien invasive species is decreasing and that of some ancestral Rhine species is increasing. Apparently, this is also due re-colonizing of indigenous species from refuges in the tributaries.
In the further course of the **Lower Rhine**, widespread species can also be found. Sessile species such as bryozoans and freshwater sponges, which contribute to the self-purification of the river as filter feeders are also characteristic.
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.

Evaluation of the Rhine

As Annex 3 and Annex 8 show, the **Alpine Rhine** is species-rich and the macro zoobenthos shows a "good" ecological potential. The share of invasive species rises in the **High Rhine** until Basel, so that the assessment only results in a "moderate" state. The ecological potential of the macro zoobenthos is "moderate" in the entire **Upper Rhine** up to Bingen. The southern Upper Rhine is only assessed by the German side. In the **Middle Rhine** up to the **Lower Rhine** near Duisburg, the "good" ecological potential is achieved. From Duisburg to the Dutch border, the potential is classified as "moderate", which is an improvement from previously "poor" potential compared to 2015. The Rhine arms Boven Rijn and Waal were assessed as "moderate", but other water bodies in the **Delta Rhine** as "good".

The development of the macro zoobenthos in the second section of the Upper Rhine between Breisach and Strasbourg (assessment only from the German side) as well as in the northern Upper Rhine between the mouth of the Lauter and the mouth of the Neckar is a striking **change compared to the second monitoring cycle** (from "unsatisfactory" to "moderate" potential). The macro zoobenthic component also improves on the Lower Rhine: from Leverkusen to Duisburg by two classes (from "unsatisfactory" to "good" potential) and from Duisburg up to and including the arms of the Rhine Boven Rijn and Waal in the Delta Rhine by one class ("unsatisfactory" to "moderate" potential). The Wadden Sea and the Dutch coast also show an improvement from "moderate" to "good" potential.

Three reasons might be given for these changes:

(1) The 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 Main (Fig. 11 and 12)[1]. In 2018, an almost complete settlement of the Rhine is observed. Since 2012, a recovery of some Rhine-typical species such as the caddisfly species *Hydropsyche* sp. and *Psychomyia pusilla* has been noticeable.

(2) Reduced abundance of 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 of this is the successive displacement of the zebra mussel (*Dreissena polymorpha*) by the quagga mussel (*Dreissena rostriformis bugensis*) (SCHÖLL et al. 2012).

(3) Mass occurrence of alien goby species: The decline in invasive alien species may also be due to this. Alien goby species originate from the Ponto-Caspian region and are thus natural predators of many benthic invasive species that are also originally native to this area. Recent studies show that the round goby represents at least a quarter of the total fish population between the southern Upper Rhine and the Lower Rhine. In relation to individual water bodies or sampling sites, up to over 90% of the fish detected belong to the gobies.

[1] 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 research (GERGS et al. 2014). This does however not have any effect on the species status and its ecological role in the Rhine ecosystem.

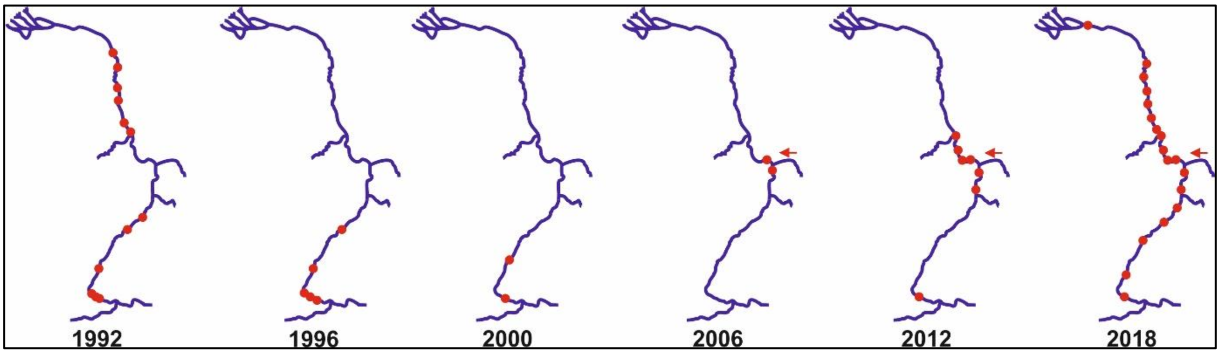


Figure 11: Spreading of the river nerite *Theodoxus fluviatilis* in the navigable Rhine (Westermann et al. 2007, complemented)**, without taking into account the occurrence in side waters**

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

The movement of alien species through coastal ports and canals by navigation is a widely described phenomenon. The potential of inland vessels as a vector for the spread of alien species had not been investigated in detail so far. Recent investigations (SCHWARTZ & SCHÖLL 2018) showed that all hulls of the investigated inland vessels were covered with vegetation but varied in vegetation thickness and number of species (Figure 13). The evidence of a barnacle colony *(Balanus improvisus*) that reached the port of Duisburg in the Rhine is remarkable. Furthermore, most ships used ballast water, which can promote the introduction and spread of invasive alien species. On canals, the proportion of ships with ballast water is significantly higher (75%) than on the other waterways (54%), which is related to the reduction of the ship's height above the water level when passing below low bridges.

Figure 13: Fouling of various inland vessels (A) Faint vegetation covered with green algae. (B) Patchy vegetation with the barnacle *Balanus improvisus*. (C) Micro fouling covering the entire area with scattered mussels and insect larvae. (D) Fouling of mussels *(Dreissena rostriformis bugensis*) in sea chest. (E) Fouling of *D. rostriformis bugensis* and sponges in ballast water pumping hole. (F) Extensive cover of *D. rostriformis bugensis* , associated with other species (SCHWARTZ & SCHÖLL 2018).

What are the long-term trends?
After the rapid increase in the species diversity of the macrozoobenthic following the improvement of the Rhine water quality in the 1980s and the 1990s a reverse trend is being observed since about the year 2006 (Figure 14). In particular, the fauna of water insects was much more diverse between 1995 and 2000 than it is today. This trend is being explained with the immigration of invasive species. At present it is difficult to predict how stable this trend is. Since 2012, however, there has been a slight increase in mean species numbers, which is also accompanied by the recovery of some Rhine-typical species such as the caddisfly species *Hydropsyche* sp. and *Psychomyia pusilla*.
Compared to migratory fish (see Chapter 6), 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. To revitalise the biotic communities of the Rhine, further measures have to be taken to improve the structure as well as the water quality. In addition, suitable measures must be taken to reduce the introduction of alien invasive species.

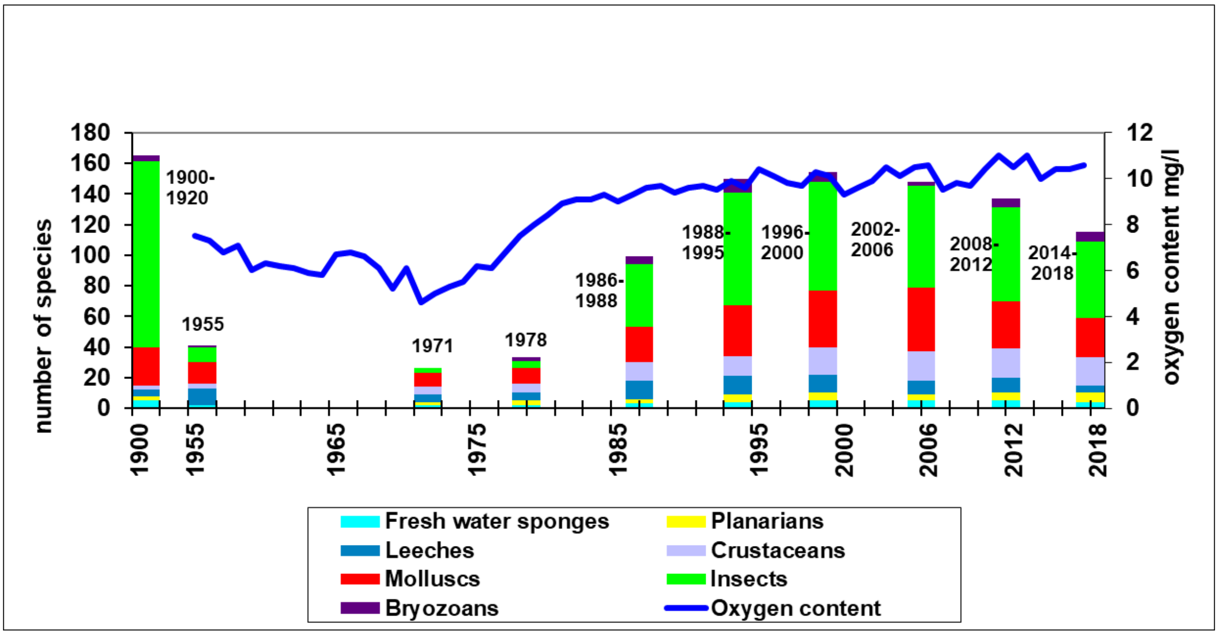


Figure 14: Historical development of the biocoenosis of the Rhine between Basel and the German-Dutch border related to the average oxygen content of the Rhine at Bimmen (selected fauna groups).

6. Fish fauna

Fish and lampreys (cyclostomes)
see ICPR 2021b

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 the river continuity.
Discharge modifications (impoundments, water intake, diversion) and thermal pollution also impact the species composition. Compared to the other biological quality elements, fish and lampreys are long-lived and mobile, so that the ecological status assessment based on fish fauna can provide an integrating statement over the entire water body and over a longer period of time.

What does the biocoenosis of the Rhine look like?
All in all, today there are 71 fish species (including cyclostomata such as river and sea lamprey) in the Rhine, which corresponds to a considerable diversity. Apart from European sturgeon, all historically proven species are again detected. In many places, results of electro fishing are dominated by invasive goby species, above all the round goby (Figure 15) which above all prefers the riprap of the riverbanks. Furthermore, mostly ecologically euryoecious species such as roach, bream, chub, perch and bleak are found.
With interruptions, a natural increase of fish species in the course of the Rhine due to the continuum of flowing waters is still discernible in the Middle Rhine and the Lower Rhine. The greatest number of fish species is naturally found in the Delta Rhine. This is also due to the large number of individual fishing points that have been combined to form larger areas, the fishing methods (in addition to electrofishing, also trap and net catches) and the special habitat types with the IJsselmeer and brackish water habitats, which enables an exchange of individuals. The interruption of the continuous increase of fish species in the Middle Rhine is due to the character of the cross valley, leading to a natural acceleration of runoff and a low number of floodplain and side waters in this narrow section of the Rhine. The exceptionally low number of fish species in the Lower Rhine, on the other hand, indicates high use-related pressures and an anthropogenically caused structural poverty, as also indicated by the almost complete absence of aquatic plants in the Lower Rhine.
In particular along the Upper Rhine and the Middle Rhine (above all in the oxbow lakes and groynes of the main stream) the macrophyte vegetation has considerably increased. This development furthers the reproduction of phytophilic species. Juvenile fish habitats are thus available for many further species.

Figure 15: Goby egg batch. Photo: LfU Mainz.

In the **Alpine Rhine**, 18 species were detected. The dominant species are the souffia, the only eudominant species, and the European bullhead. Brown trout and lake trout, the alien rainbow trout and the chub are frequently detected (Figure 16). A special study of the International Governmental Commission on the Alpine Rhine (IRKA) shows that the Alpine Rhine is a deficient section in terms of fish ecology, which is due to structural poverty and a strong hydropeaking regime (Eberstaller et al. 2013). The occurrence of the souffia, an extremely rare species considered to be very demanding, is probably due to groundwater-influenced and deep areas along the bank and its insensitive response to surge-sunk conditions.

Figure 16: The aspect-forming fish species of the Alpine Rhine. above: Lake trout, bottom left: Souffia; bottom right: Milner of the rainbow trout migrating between Lake Constance and the Alpine Rhine. Photos: Hydra.

29 species have been inventoried in the **High Rhine**. Barbel and chub dominate. Spirlin, round goby and bleak are also rather common. The 2017/2018 data obtained as part of the FOEN juvenile fish monitoring show relative abundances that deviate from this. Only the chub was classified as eudominant. Compared to 2011/12, juvenile grayling, ruffe, moderlieschen, asp and pike-perch were missing in the juvenile fish monitoring commissioned by the Swiss Federal Office for the Environment (FOEN). The juvenile numbers of chub, barbel, nase and dace have increased, as well as those of the round goby, which had only reached the High Rhine in a few specimens in 2012.
36 species are detected in the **southern Upper Rhine**. The dominance of the invasive round goby begins here already. It accounts for more than a third of the individuals caught. The Kessler goby, on the other hand, is in sharp decline. The roach is currently the second most common species, closely followed by the bleak and the chub. As a special feature, the single catch of a *Cobitis bilineata* near Kembs should be mentioned, which is otherwise only known for the High Rhine. In the undersluices pockets there are no habitats for rheophile species such as the nase which rarely occurs. Despite potentially available habitats, especially in the Old Rhine, anadromous migratory fish are extremely rare in this area, since ecological continuity has not yet been restored for the sections of the Rhine starting at the Rhinau barrage.
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 41% frequency of occurrence among individuals caught, the round goby here reaches its highest dominance. Roach and bleak follow. All in all, 29 species have been detected in this section of the Rhine.

Flow velocity increases in the cross valley of the **Middle Rhine**, offering good conditions for rheophile species. All in all, 35 species have been recorded, but again 38% of the catches are round gobies. The composition of the remaining species is similar to that in the northern Upper Rhine, with the nase accounting for 16% of the individuals caught and the eel also being somewhat more common in the Middle Rhine, where it accounts for 6%.
In the **Lower Rhine**, 22 species were detected. In this section of the Rhine, too, the round goby accounts for the largest share of catches, although it only has the status of a dominant species there. In addition, the bleak (19%), the ide (16%) and the roach (12%) are dominant. The sub-dominant fraction consists of the species perch, nase and eel.
Together, the **Delta Rhine and Lake IJssel** have the highest density of individuals and species of all Rhine sections. Here, the perch is by far the most common species, which can possibly only be attributed to an exceptionally good reproductive year for this species. This is followed by roach as the dominant species and round goby, ruffe, bream and silver bream as subdominant species. Compared to the last reporting period 2012/2013, the significant decrease in catch figures for ruffe and the increase in round gobies are particularly noticeable. The drop in the number of ruffes in particular, however, may also be related to the extended sampling range. All in all, 41 species were registered.

Evaluation of the Rhine
The majority of states have determined the status of the fish fauna in their sections of the Rhine on the basis of a national method. The assessment of transboundary water stretches was also coordinated bilaterally. In the Swiss **Anterior and Posterior Rhine**, the condition has not been assessed. As Annex 4 and 9 show the potential of the fish fauna in the Austrian **Alpine Rhine** can be described as "moderate". Compared to 2015, the ecological potential has thus improved by two classifications. Nevertheless, the Alpine Rhine is fully regulated except for a short section, its longitudinal continuity has not yet been restored and it is impacted by the hydroelectric power plants' hydropeaking. From the point of view of fish ecology, the state of **Lake Constance** is good. The fish fauna of the impounded **High Rhine** was assessed to be "moderate". In the **southern Upper Rhine**, the fish fauna was evaluated to be "moderate" by Germany/Baden-Württemberg and includes a "poor" section between Breisach and Strasbourg. These sections were not assessed by France, as in France the biological quality element Fish is not considered in the assessment of ecological potential in heavily modified water bodies. The assessment of the **northern Upper Rhine** as far as the mouth of the Main is equally "moderate". The further course of the northern Upper Rhine and the Middle Rhine are assessed to be "good", which means an improvement by one classification (from "moderate" potential). The potential of the **Lower Rhine** is "moderate". Downstream the mouth of the Ruhr until and including the first water body in the **Delta Rhine** (Boven Rijn / Waal), the Rhine is evaluated as "poor". Nieuwe Waterweg, Hartel-, Caland- and Beerkanaal as well as **Lake IJssel** are rated "moderate". According to the Directive, no evaluation of the fish fauna is required for the **coastal waters** and the **Wadden Sea**.

The most striking **change compared to the last survey in the Rhine in 2012/2013** is the strong spatial spread and population increase of the alien round goby. Compared to the previous survey, it leads to partly considerable shifts in the dominance ratios. Between the southern Upper Rhine and the Lower Rhine, the round goby accounted for an average of a quarter of the detections; locally, a relative abundance above 90% was recorded. Nevertheless, the relative abundances of the species are declining between the northern Upper Rhine and the Lower Rhine compared to the last campaign (ICPR 2015d). This is possibly a sign that the phase of mass reproduction is ending in the previously heavily populated areas. On the other hand, round gobies have spread even further into the High Rhine and Delta Rhine since the last survey in 2012/2013. Displacement effects on native species were demonstrated by HOLM et al. (2016) (Figure 17).

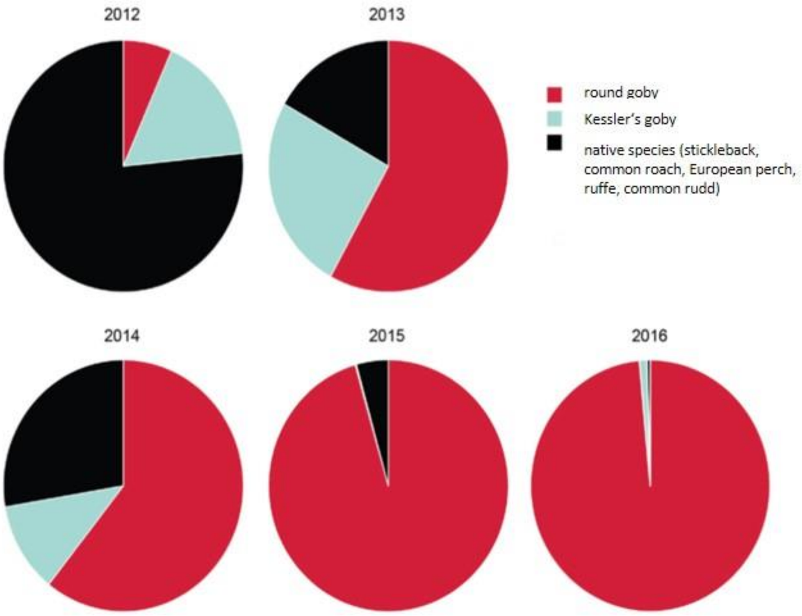
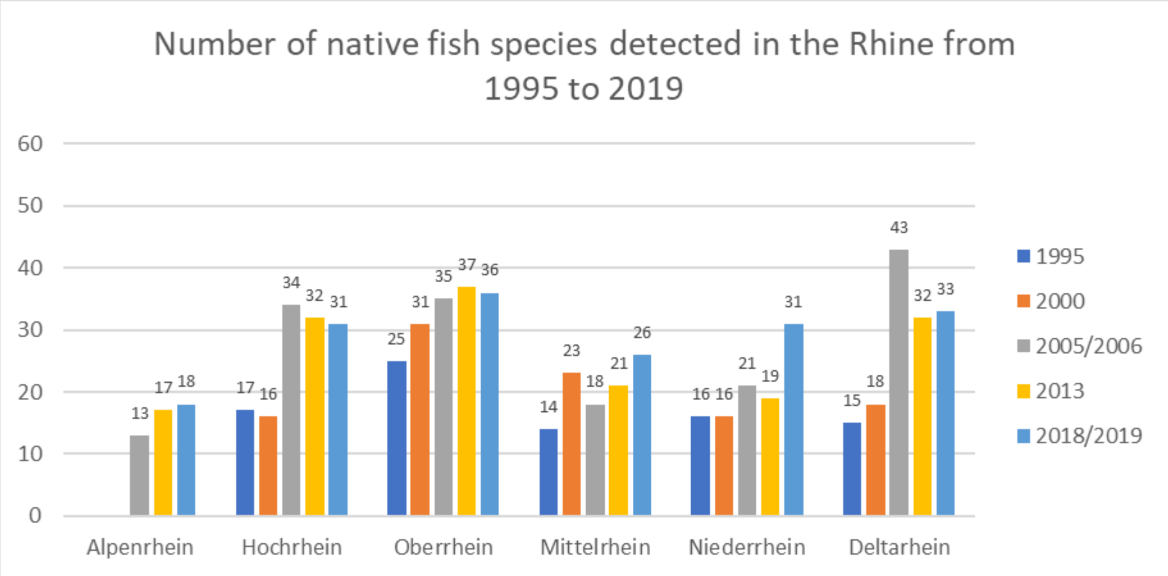


Figure 17: Displacement of the previous fish population and the Kessler goby by the mass reproduction of round gobies in the Kleinhünigen harbour near Basel (2012 to 2016). Source: HOLM et al. 2016.

Compared to the last survey in 2012/2013, the significant decrease in catches of ruffe and the increase in catches of round gobies (Figure 17) are particularly striking. During the same period, the scope of sample sites was expanded. The ruffe experiences population losses due to riprap on the banks, among other things. These represent ideal habitat structures for the round goby and enable high population densities.

On the other hand, all invasive gobies represent a new food source for fish-predating fish species such as pike, pike-perch, barbel, catfish, asp and bleak. Cannibalism and feeding pressure among each other seem to be common (REY & HESSELSCHWERDT 2020, in preparation). In future, that might lead to considerable changes in the food web which, on the long run, may again lead to a regulation of goby stocks. Especially in sections where the juveniles of Rhine fish species have to seek cover mainly in riprap structures, where the gobies find ideal living conditions, an influence on the fish species community of the Rhine can be assumed (NEHRING et al 2010, REY & HESSELSCHWERDT 2020, in preparation).

What are the long-term trends?
The Rhine fish fauna has undergone a major change over the last 25 years. Due to the improvement in water quality, some species have spread again, so that the species numbers have increased. The comparison of the species numbers of the five ICPR survey campaigns from 1995 to 2019 shows the remarkable development (Figure 18). Today, alien fish species make up about 22% of the species composition.



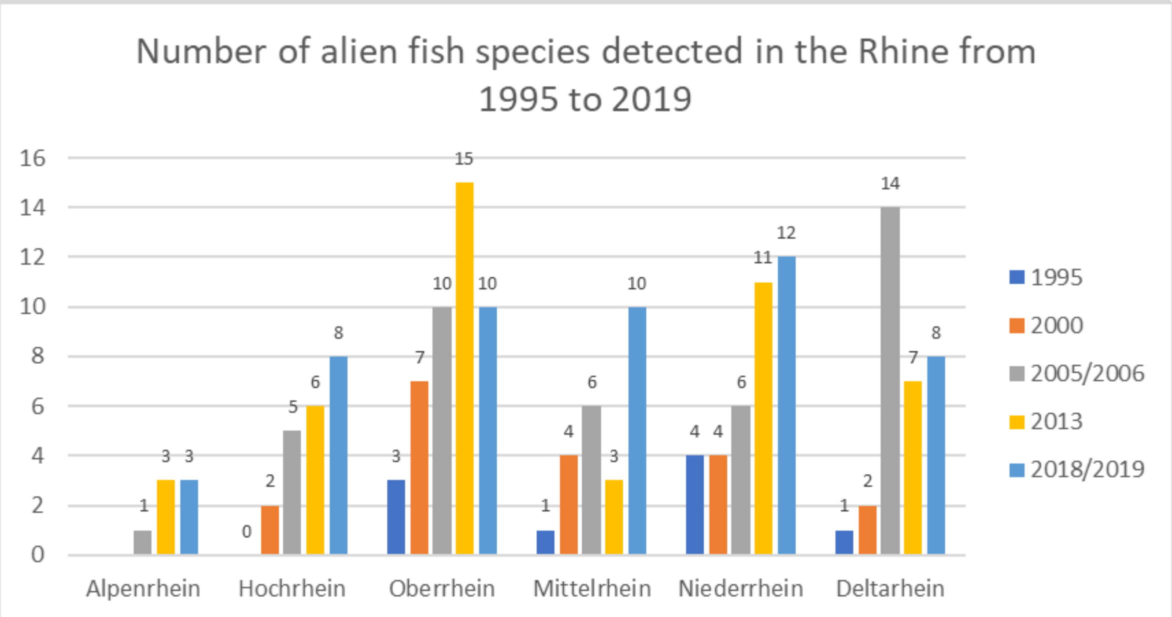


Figure 18: Number of native (top) and alien fish species (bottom) detected in the individual sections of the Rhine in the period 1995 to 2019.

However, the number of species cannot be considered the sole criterion for ecological improvement, since, as shown, it also increases due to immigrant fish species. In addition, the study intensities within the framework of WFD monitoring have been increased and novel recording techniques, such as automatic control stations at fishways, have been introduced. This repeatedly leads to the detection of rare species that would otherwise remain undiscovered (see below). The consideration of additional surveys has also led to a considerable gain in knowledge regarding the occurrence of various species (ICPR 2015d).

Regarding the **quantity** within the fish populations, data from the Lower Rhine and from the Moselle/Koblenz fish trap show that fish densities have strongly decreased since the 1980s and have been approximately stable since 1993. This is a consequence of the decline of the roach, which had been abundant until then, and the reduction of nutrients and organic load in the 1980s to early 1990s (cf. Chapter 7 and Table 1). This has reduced the food supply (e.g. plankton) in the Rhine. However, the sampled fish densities also vary over the course of the Rhine sections and within a year due to the seasonally varying activity of the different fish species and partly due to the type of sampling. As a result, dominance ratios vary, especially for very common fish species such as roach, bream, chub, perch and bleak. Currently, the strong population development of the invasive round goby interferes with the natural dominance fluctuations. Since the last fish monitoring of the ICPR (ICPR 2015d), no further statements can be made about an again changing fish density in the Rhine.

Due to progress made with respect to the restoration of accessibility resp. the continuity of reproduction waters during the last 25 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 such proofs concerning the great salmonids salmon and **sea trout** were registered (Figures 19 and 20). Apart from changes in sampling methods, the causes may lie in the common migration corridor of the Rhine and / or the coastal area: Fishing, high predation pressure on smolts by predatory fish and cormorants, high mortality rates of smolts due to hydropower plants. Declining survival rates in the marine life stage are also 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.
During 2013 to 2020, the numbers of returnees have increased again, especially for **salmon**, **sea lamprey** and **sea trout**. This can certainly be explained by the completion of construction work on the Iffezheim and Gambsheim fish passes. The low numbers of returnees in 2018 are due to irregularities in monitoring (June) and work on the Iffezheim fish pass between August and November, as well as to the low water event on the Rhine between July and November 2018 (ICPR 2020e). In August, a fish kill occurred in the High Rhine at water temperatures of 27 °C (ICPR 2019b). 2019, when similarly low detections were made, was also characterised by prolonged drought. The connection of the tributaries to the Rhine turned out to be problematic, as the discharge is an important migration stimulus. The consequences are a lack of river continuity, only very low numbers of migratory fish ascending in many Rhine tributaries and the absence of downstream migration of eels ready to spawn (ICPR 2020f).
On 12 October 2019, the first salmon was discovered in the fish pass in Kembs (Old Rhine/Restrhine) on its way to Switzerland (Figure 21).
The new programme "Rhine 2040", which was adopted in February 2020 within the framework of the 16th Conference of Rhine Ministers, sets concrete goals for the restoration of the river continuity in the Rhine catchment (IKSR 2020g).

At the time being, and due to the few specimens 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 exercises in Hesse and North Rhine-Westphalia, the number of returning **allis shad** should distinctly increase in the years to come. Counts at the Iffezheim fish passage confirm this assumption. A high number of upstream migrating allis shad (157) was documented there for the first time in 2014 (Figure 19). In addition, the detection of individual young allis shad in the Upper Rhine in 2013 and 2014 upstream of all stocking sites indicate a natural allis shad reproduction. In 2015, a relatively large number of allis shad were still documented, before records were found at a much lower level. But these numbers are many times higher than the isolated records before 2014. Moreover, in the entire Rhine system as well as at the Iffezheim control station, a slight increase in allis shad can be observed again in the years from 2017 onwards, despite the low water in 2018 and 2019.

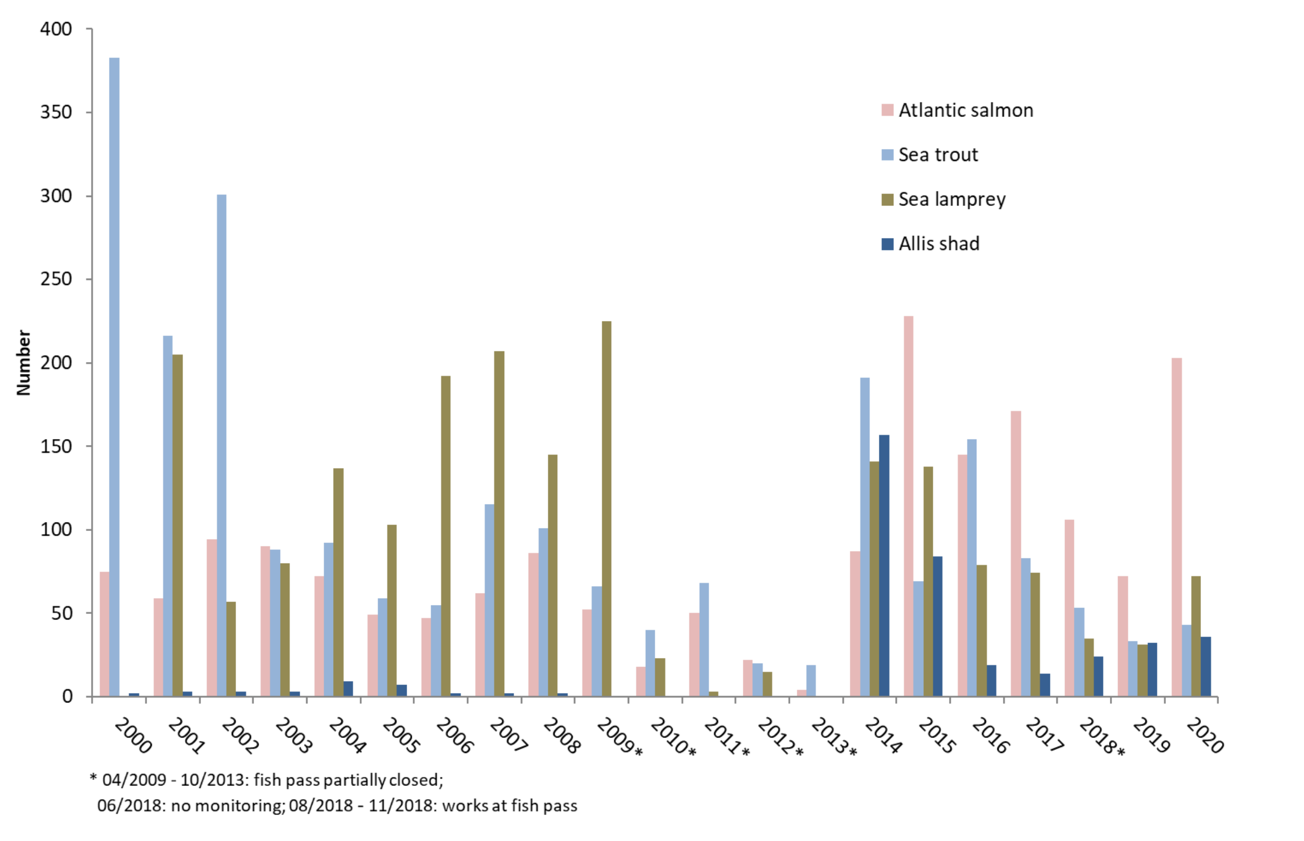
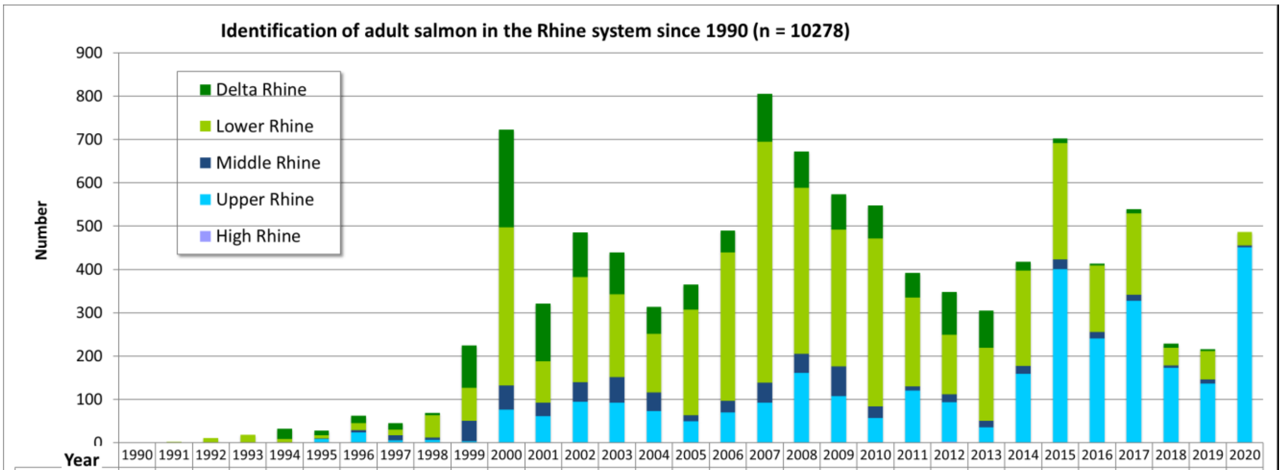


Figure 19: Results of fish counts of selected long distance migratory fish at the Iffezheim impoundment since 2000.



Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Delta Rhine	0	0	0	0	23	11	17	15	5	98	226	133	103	96	63
Lower Rhine	1	2	10	18	9	7	16	13	52	76	365	96	242	191	135
Middle Rhine	0	0	1	0	0	1	5	12	5	48	56	31	45	59	43
Upper Rhine	0	0	0	0	0	9	24	5	7	3	76	61	95	93	73
High Rhine	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Delta Rhine	58	51	110	83	82	76	57	99	86	21	10	4	10	10	4	0
Lower Rhine	244	342	556	384	316	388	205	137	168	220	269	153	187	41	66	32
Middle Rhine	14	27	46	44	68	27	10	18	15	18	22	15	14	5	9	4
Upper Rhine	49	70	93	161	108	57	120	92	36	159	401	241	328	173	137	451
High Rhine	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0

Figure 20: Salmon records in the Rhine system (Rhine incl. salmon programme waters) in the period 1990 to 2020. Remark: For methodological reasons, the figures are not comparable from one Rhine section to the next. The number per section of the Rhine represents the sum of several (on the Upper Rhine partly successive) monitoring stations and electro-fishing campaigns. In addition, collection methods can vary overtime: Restricted operation of the Iffezheim fish passage between April 2009 and October 2013. After fyke-net fishing stopped in the Netherlands in 2011, less returning salmon were identified. The ICPR addresses the measurement results and the resulting possibilities of interpretation.

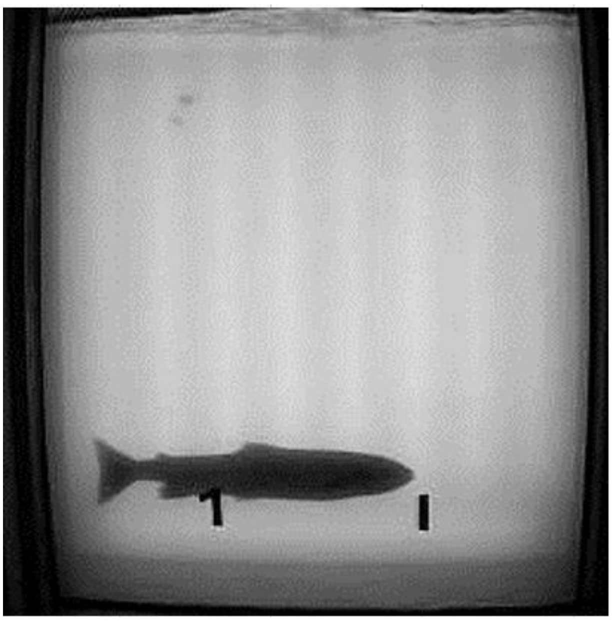


Figure 21: First salmon in the fish pass in Kembs on its way to Switzerland. Photo: EDF.

The reduced number of detected **sea lamprey** also seems to be caused by the construction measures in connection with the installation of a 5th turbine at Iffezheim between 2009 and 2013 and thus limited monitoring. The number of returnees continues to decline.

In the Alpine Rhine / Lake Constance sub-basin, the **sea 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, the free water constitutes the preferred habitat of the lake trout. Here it grows up until it is mature to spawn and migrates upstream to the tributaries to Lake Constance and to the Alpine Rhine and its tributaries to spawn. During the 1970ies, the yield of the lake trout continuously sank in Lake Constance despite stocking measures. 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 eel numbers migrating upstream into the rivers return. After an interim slight increase in 2013 and 2014, the numbers have fallen back to a low level (ICPR 2018a). Known causes include habitat changes, parasite infestation, the expansion of hydropower utilisation for electricity production, overfishing of glass eel and silver eel stocks, pollutant loads in sediments as well as feeding pressure by the cormorant, etc. The migration of the eel is impaired by transverse structures in almost all waters where it is widespread in the Rhine basin. This is especially true for the downstream migration in the Delta Rhine, in the southern Upper Rhine and in almost all Rhine tributaries. In particular, downstream migrating eel often get into the turbines of hydro power plants. 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. Balance - Factors influencing the ecology of the Rhine

As a result of the improvement of the Rhine **water quality** during the past 25 years, the array of fish species is again almost complete and in some sections of the Rhine, 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. The improvement of the water quality in the Rhine is illustrated, for example, by the decrease of the annual mean values of the total P concentration from 0.56 mg/l in 1978 to 0.10 mg/l in 2018 at the Koblenz monitoring station (cf. Figure 4).

However, certain fish species in the Rhine and its tributaries (e.g. eel) are still contaminated by **pollutants** (dioxins, furans, dl-PCB, mercury, occasionally also indicator PCB, hexachlorobenzene = HCB or perfluoroctanesulphonate (PFOS)) among others from contaminated areas (ICPR 2018b).
In 2014 and 2015, a first joint investigation programme on the contamination of biota (fish) with pollutants in the Rhine catchment was carried out (ICPR 2014). The evaluation of this pilot project was carried out by the Fraunhofer Institute in cooperation with the ICPR (ICPR 2018b). The aim was to obtain comparable data, as the investigations of the states had previously been very different, and a joint evaluation was hardly possible. For this pilot programme, selected fish species were analysed at 37 monitoring sites in the Rhine catchment. The EQS for mercury and polybrominated diphenyl ethers (PBDE) were exceeded almost everywhere. For perfluorooctane sulfonic acid (PFOS), hexachlorobenzene (HCB) as well as heptachlor and heptachlor epoxide, exceedances of the EQS were detected in some cases. Differences in the pollution situation were visible in the longitudinal course of the Rhine and between the fish species. In future, biota studies in the Rhine catchment will be carried out as harmonised and comparable as possible. According to the WFD, the EQS must be met by 2027. States are obliged to implement measures to this end.

Micro-pollutants are a new challenge for water protection. In the mechanical-biological wastewater treatment plants commonly used today, many micropollutants - such as pesticides, hormones, or drug residues - are not or only partially removed from the wastewater and thus enter surface waters. It is already clear that they have a negative impact on water quality and may be relevant both for ecology and for the production of drinking water.
According to the 2017 balance (ICPR 2017b), active pharmaceutical ingredients and their degradation and transformation products are detectable in the entire catchment area of the Rhine. Building on the balance, the ICPR made recommendations in 2019 on how to further reduce the inputs of micropollutants into water bodies. This also explicitly dealt with active pharmaceutical ingredients and X-ray contrast media (ICPR 2019a). By 2040, inputs of micropollutants into water bodies are to be reduced by at least 30% (ICPR 2020g).

Unlike in inland waters, the ecology of marine coasts is dominated by **nitrogen pollution** which is therefore more critical than phosphorus. Corresponding reduction efforts must therefore also be continued. By 2015, the nitrogen load could be reduced by 15-20% due to the continuous upgrading, optimisation and expansion of municipal and industrial wastewater treatment plants. A significant reduction in the input of nutrients from diffuse sources (with a focus on the agricultural sector, but also urban areas) has not yet been achieved (ICPR 2020h).

The issue of **(micro-)plastics** continues to be in the focus of public interest, especially because of marine litter. It is the subject of a large number of research projects. Since 2013, an annual exchange of information on this issue has taken place in the ICPR. This exchange of information and the studies available so far show that there are still considerable gaps in knowledge regarding the environmental behaviour and consequences of (micro)plastics and that the data situation needs to be improved.

In the course of **climate change**, certain **temperature thresholds critical** for fish, such as 25°C in general and 20-23°C for oligostenothermic species like brown trout and grayling, could be exceeded more frequently in the future. According to the simulations, the number of consecutive days when the water temperature will exceed 25°C will also increase; in the distant future, years without exceeding 25°C or even 28°C will be very rare.
There is evidence that, between 1978 and 2011, the **water temperature** in the Rhine has risen by about 1 °C to 1.5°C (ICPR 2013). Future scenarios assume a water temperature increase of about 1.5°C in the near future (by 2050) and of about 3.5°C in the far future (by 2100) (reference period: 2000-2010) (ICPR 2015a).
Furthermore, **low water levels** and the high water temperatures have an effect on living organisms in the water. In 2018, for example, the critical value of 25°C for many fish and invertebrate species living in the Rhine near Koblenz was exceeded on 31 consecutive days. In August, fish kills occurred in the High Rhine at water temperatures of 27°C (ICPR 2020e).
In 2015, the ICPR published the first ICPR Climate Change Adaptation Strategy for the Rhine catchment (ICPR 2015a). It contains a compilation of knowledge and forms a framework for action for adaptation options. Knowledge about the effects of climate change on biocoenoses and ecosystems associated with the river must be further developed through studies and monitoring. As far as possible, the anthropogenic **thermal load** of the Rhine should therefore continue to be 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.). However, the long-term trends of the last 25 years also indicate distinct, sustainable ecological improvements. The future implementation of various ecological measures could help to continue this trend, especially those foreseen in the "Rhine 2040" programme.

In order to **improve the habitats** for plants and animals in the Rhine, the main stream should, wherever possible, be reconnected with the floodplain in order to open up side waters and side channels rich in aquatic plants as habitats (improvement of lateral continuity, cf. Table 1). In connection with flood protection measures, more than 130 km^2 were reactivated as floodplains from 2000 to the end of 2018 (ICPR 2020h). The target of 160 km^2 set for 2020 has been steadily approached over the last few years (Figure 22).

Parallel structures or siltation groyne fields can form flow-calmed, wave-protected and structurally rich substitute biotopes in the river. Among others, juvenile fish, aquatic plants (macrophytes) and also the macro zoobenthos benefit from this bank diversification. The removal of superfluous bank protections (e.g. on sliding slopes) can be an effective measure to mitigate the ecological consequences of the rapidly spreading invasive round goby, as this fish species primarily benefits from the riprap structures (cf. Table 1).

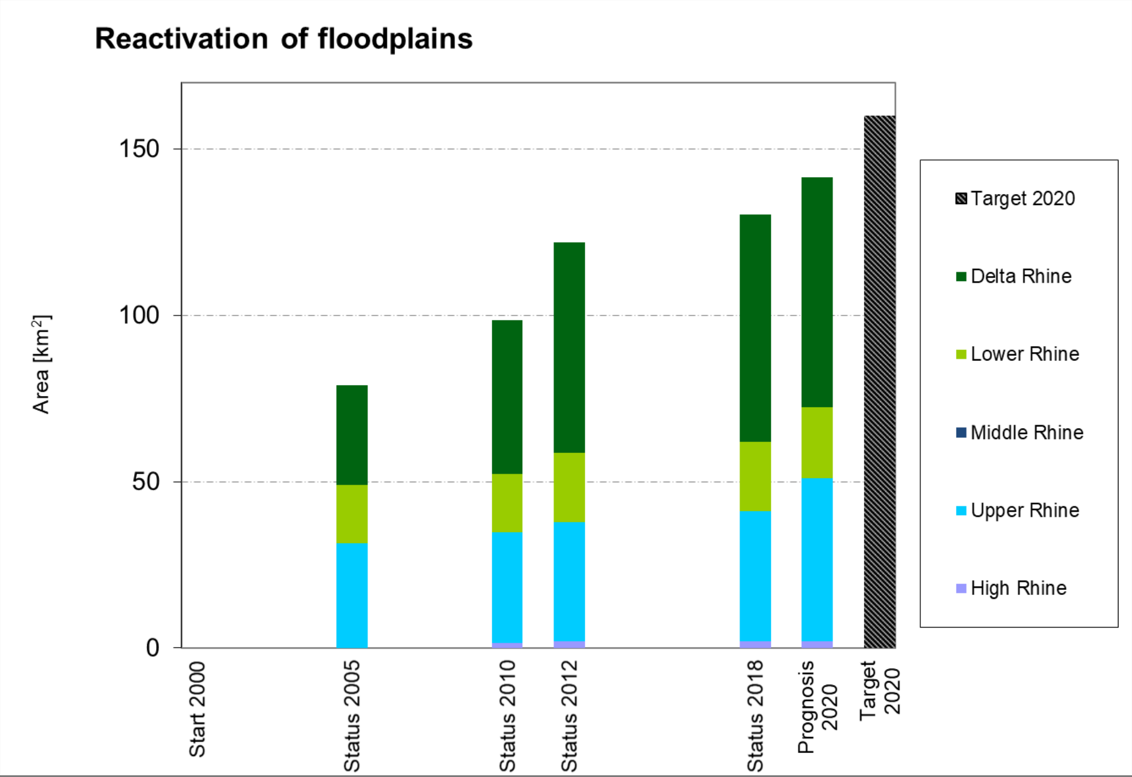
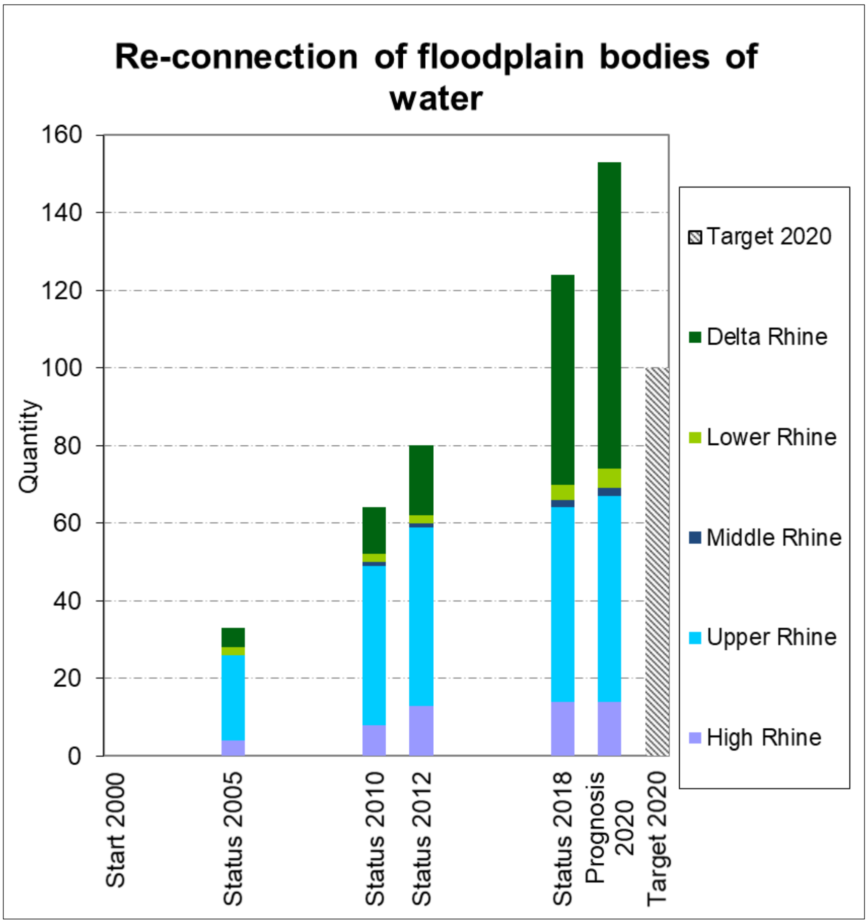


Figure 22: Reactivation of floodplains between 2000 and 2018 (see ICPR 2020h)

In order to increase **habitat diversity**, a total of 124 floodplain waters were reconnected to the main stream of the Rhine by the end of 2018 (ICPR 2020h). The target set for 2020 to reconnect 100 oxbow lakes and side waters with the Rhine has been largely exceeded by the end of 2018. Since the beginning of the programme "Rhine 2020", the number of again flowed tributaries has been continuously increased.
In the riparian area, measures to increase structural diversity were implemented on a total of 166 km by the end of 2018 (ICPR 2020h). The originally set, ambitious goal of improving structural diversity along 800 km of the Rhine and its branches by 2020 is thus clearly missed. The implementation of corresponding measures is made difficult in many places by the diverse uses along the main stream of the Rhine.
Figure 23 gives a survey over measures implemented during 2000 to end 2018 aimed at reconnecting oxbow lakes (above) and at improving the structure of the banks of the Rhine (below).



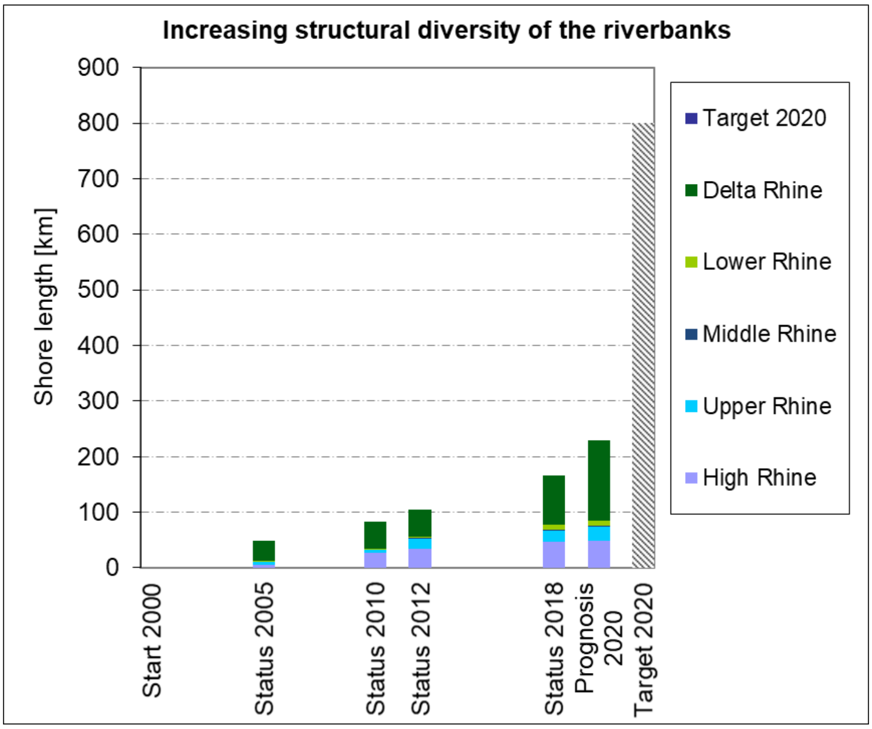


Figure 23: Number of floodplain bodies of waters reconnected with the Rhine (above) and length of riverbanks along the main stream of the Rhine, where measures aimed at structural improvement were implemented by 2018 (below), see ICPR (2020h).

An important basis for the planning of measures is the new ICPR programme "Rhine 2040" continuing the programme "Rhine 2020" and aiming at restoring the formerly existing network of Rhine-typical biotopes, the biotope network. The progress achieved in this process was most recently described by positive exemplary projects for each section of the Rhine for the period 2005 to 2013 (ICPR 2015b). The results of the next success monitoring, which for the first time was also carried out based on satellite data, are expected to be published by the end of 2021.

For the establishment and protection of the anadromous migratory fish stocks, which are in the process of development or recovery, the **restoration of the longitudinal continuity of the Rhine** (barrages Rhinau, Marckolsheim and Vogelgrün) and its tributaries is essential and must be further promoted (cf. Table 1).
However, some milestones for the restoration of the continuity of the main stream of the Rhine have already been reached. At the end of 2018, the Haringvliet Dam south of Rotterdam was partially opened. For the salmon migrating from the North Sea into the rivers Meuse and Rhine, the path is open again when there is sufficient runoff. In addition, the construction of four fish passes at the major barrages of the Upper Rhine in Iffezheim (2000), Gambsheim (2006), Strasbourg (2016) and Gerstheim (2019) has now made it possible for fish to migrate as far as downstream of Rhinau.
Important bases for the planning of measures are the "Master Plan Migratory Fish Rhine" of the ICPR, which was updated in 2018 due to new developments and findings (ICPR 2018a), as well as the programme "Rhine 2040" (ICPR 2020g).
In total, almost 600 migration obstacles in the Rhine and in the tributaries important for the reintroduction of migratory fish were removed or equipped with fish passes in the period from 2000 to the end of 2018 (cf. Figure 24). The goal of reopening the Rhine from the North Sea to Switzerland for fish migration has gradually come closer but has not yet been achieved. Many valuable spawning and juvenile fish habitats are still inaccessible due to existing migration obstacles.

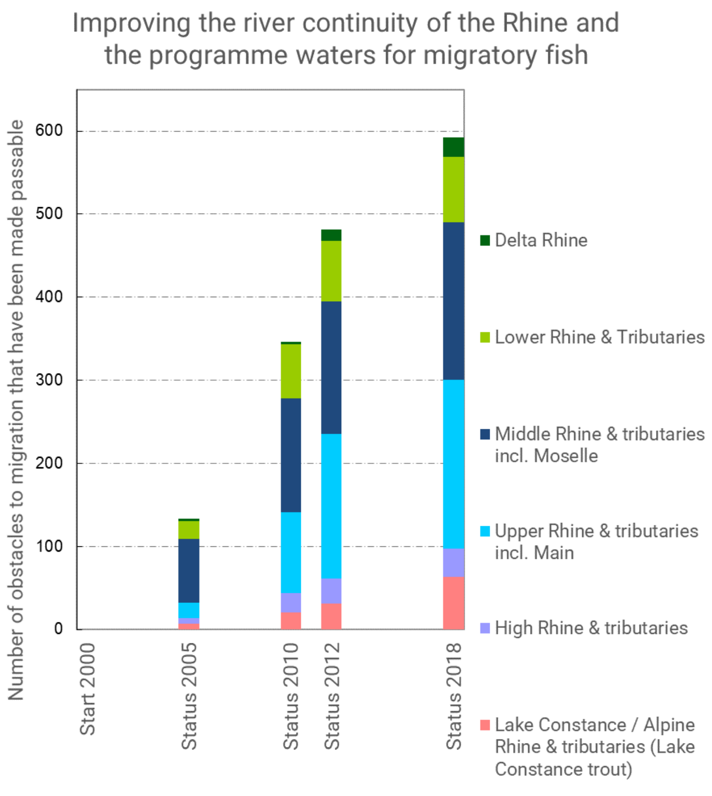


Figure 24: Restoration of the river continuity of the Rhine and of programme waters for migratory fish: Number of migration obstacles made passable. State 2018, cf. ICPR (2020h).

In contrast, measures against the introduction of **invasive alien species** are difficult, as the input pathways (e.g. hulls, ballast water, intentional and unintentional release, aquarium trade, etc.) are diverse and difficult to control. Also, already established invasive alien species can only be contained in individual cases through targeted management. For many introduced species, however, it is known that they settle down to a lower level after explosive reproduction. When assessing the immigration of new species, one must not forget that nature is not a static state, but a dynamic process that is subject to continuous change. The restoration of ecological continuity will favour the recolonisation of diverse habitats by native species.
In future, the implementation of the different ecological measures and continued intensive, coordinated biological monitoring will make it possible to observe long-standing trends and developments based on robust data. The EU's invasive alien species regulation - Regulation (EU) No. 1143/2014 of the European Parliament and of the Council of 22 October 2014 - creates a legal framework for this. This is in particular valuable with respect to climate change.

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

Measure	Effect on biological quality component					Where observed
	Macro zoobenthos	Fish fauna	Phytoplankton	Phytobenthos	Macrophytes	
Reduction of nutrient pollution	(+) more natural community	(+) more natural community, less biomass	(+) more natural community, less biomass	(+) more natural community	(+) enhancement of stocks by less shading of the water bottom (less phytoplankton)	Entire main stream of the Rhine (see ICPR report no. 273, 275, 279[2])
Removal of bank protections (especially bank reinforcement with armourstone) / reduction of the degree of obstruction of riverbanks	(+) Increase species diversity; reduce alien (especially sessile) species	(+) reduction of invasive gobies			(+) Increase biodiversity	Entire main stream of the Rhine (see ICPR report no. 223)
Parallel constructions or filled up groynes as shallow replacement habitats rich in structure, protected from the lapping of waves.	(+)	(+) in particular enhancement of juvenile fish	(+)	(+)	(+) Increase biodiversity	Middle Rhine, Lower Rhine, Delta Rhine (see ICPR reports no. 274, 279)
Improved reconnection of tributaries, alluvial waters and backwaters / lateral river continuity, reconnecting alluvial areas	(+) Recolonisation by native species from refugia in tributaries	(+) enhancement of species spawning on plants and gravel; favouring the reproduction of phytophilic species (rudd, pike, tench); juvenile fish habitat for other species			(+) Seed dispersal	Entire main stream of the Rhine (see ICPR report no. 223, and Chapter 7 in the 2nd Management Plan for the Rhine 2022-2027)
Construction or optimization of structures for up- and downstream fish migration	(+) concerns only upstream migration facilities	(+) 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 Management Plan for the Rhine 2022-2027)

[2] *ICPR technical report no. 279, in preparation*

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Glossary

Abundance: Population density; number of individuals of a species per unit area; for diatoms: the percentage share of a species in the total number of individuals counted at the respective sampling site

Anadromous: migrating from marine waters into freshwater in order to spawn

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

Benthic: living on the bottom of a water body

Bioindicator: Indicator species; Living being that indicates changes in environmental conditions

Groyne: a dam-like structure built at right angle to the bank of a river

Chironomidae: Non-biting midge

Diatoms: Diatoms

Dominance: Predomination of a species in a biocoenosis

Euryecious: occurring in different habitats

Eutrophic: nutrient-rich with a high phosphate 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 place of a plant, an animal or another organism

Halophilic: Organisms living in environments with elevated salt concentrations

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

Invertebrates: Invertebrates; multicellular animals without vertebral column

Lethal: fatal

Macrophytes: aquatic plants visible to the naked eye

Macro zoobenthos: All invertebrate organisms of the water bottom detectable with the naked eye

Mesotrophic: moderately nutrient-rich

Mortality: death rate

Neobiota: alien, non-native species

Neophyte: alien plant species

Neozoon /Neozoa: invasive animal species(es)

Nitrophilous: nitrogen-loving

Oligochaetes: Earthworms

Phytobenthos: lower aquatic plants (algae) living at the bottom of the water body

Phytophilic: Preferring plants; for reproduction guilds: Species spawning on plants

Phytoplankton: Suspended algae; Plant plankton

Pioneer species: Species that quickly colonise newly created habitats through special adaptations

Plankton Organisms floating freely in the water, which are not able to move against the current

Planktic: pertaining to the phytoplankton

Potamal: concerning the lower course of a watercourse

Rheophilic: current-loving

Saprobic: organic load

Smolt: predominantly silvery stage of young salmonids (salmon, sea trout) during migration into the sea

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

Taxonomy: Systematics of the kinship relationships of living organisms

Taxonomic: relating to taxonomy

Thermophilic: Heat loving

Trophic level: Nutrient load / supply

Tychoplankton: organisms found only intermittently and incidentally in the plankton

Ubiquitous: occurring everywhere; widespread

Zooplankton: animal plankton

Annexes

Note:
The numbering of the maps corresponds to that of the third management plan for the IFGE Rhine (draft version of 15 April 2021, Part A).

To Annexes 1 to 4:
In 2009, no biologically derived procedure for determining the ecological potential of heavily modified water bodies (HMBW) was yet available in Germany. In 2014, new potential assessment procedures were used for the macrozoobenthos and fish components. When assessing the plant components (macrophytes, phytobenthos), only the status and not the potential is determined.
In the Netherlands, the potential was already indicated in 2009 for all components and for the overall assessment. There is no special procedure for this, but the yardstick of natural waters is always used; less stringent targets are then set for HMBW. In France, the ecological potential is only used for the overall assessment.

Annex 1: Assessment of the phytoplankton in the Rhine according to the WFD for the management plans 2009, 2015 and 2021*(draft version of 15 April 2021*)

Annex 2: Assessment of the biological quality element macrophytes / phytobenthos in the Rhine according to the WFD for the management plans 2009, 2015 and 2021 *(draft version of 15 April 2021*)

Annex 3: Assessment of the macro zoobenthos in the Rhine according to the WFD for the management plans 2009, 2015 and 2021 *(draft version of 15 April 2021*)

Annex 4: Assessment of the fish fauna in the Rhine according to the WFD for the management plans 2009, 2015 and 2021 *(draft version of 15 April 2021*)

Annex 5: Map Assessment of phytoplankton in the Rhine according to WFD for the management plan 2021 *(draft version of 15 April 2021*)

Annex 6: Map Initial expert assessment of the macrophyte sub-component

Annex 7: Map Assessment of phytobenthos / macrophytes in the Rhine according to WFD for the management plan 2021 *(draft version of 15 April 2021*)

Annex 8: Map Assessment of the macro zoobenthos in the Rhine according to the WFD for the management plan 2021 *(draft version of 15 April 2021*)

Annex 9: Map Assessment of the fish fauna in the Rhine according to the WFD for the management plan 2021 *(draft version of 15 April 2021*)

Annex 10: Map Assessment of the overall ecological status / ecological potential in the Rhine according to the WFD for the management plan 2021 *(draft version of 15 April 2021*)

Annex 1: Assessment of the phytoplankton in the Rhine according to the WFD for the management plans 2009, 2015 and the management plan 2021 *(draft version of 15 April 2021)*

Assessment of phytoplankton in the Rhine according to WFD for Management Plan 2009, Management Plan 2015 and Management Plan 2021 (draft)						very good	1	
						good	2	
State: April 2021						moderate	3	
Assessment of quality component not required	./.					poor	4	
No inventory or assessment of the component / insufficient data						bad	5	

Water body	**River-km**	**ICPR surveillance monitoring station in the water body**	**State / federal state**	**Category Management Plan 2009**	**Category Management Plan 2015**	**Management Plan 2009**	**Management Plan 2015**	**Management Plan 2021 (draft)**
LAKE CONSTANCE								
BOD-OS Lake Constance-Obersee	No kilometre milage	Fischbach-Uttwil	DE-BW	Natural	Natural	2	2	2
BOD-USZ Lake Constance-Untersee		Zellersee	CH / St. Gallen	Natural	Natural	2	2	2
HIGH RHINE Lake Constance - Basel	**24-170**							
High Rhine 1 - Lake Constance to the mouth of the River Aare	24-102.7	Lower lake outlet Öhningen, Reckingen	CH/ DE-BW	Natural	Natural		1	1
High Rhine 2 - mouth of the Aare to Basel	102.7-170		CH/ DE-BW	heavily modified	Natural		1	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	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	1
Upper Rhine 3 - OR 3 - Rhine 3 - regulated section of the Rhine, Strasbourg to Iffezheim	292-352	Karlsruhe	DE-BW	heavily modified	heavily modified		1	1
Upper Rhine 4 - OR 4 - Rhine 4 - loop of the Rhine Iffezheim barrage to upstream mouth of River Lauter	352-428		DE-BW	heavily modified	heavily modified		1	1
Upper Rhine 5 - OR 5 - mouth R. Lauter to mouth R. Neckar	352-428		DE-BW	heavily modified	heavily modified	2	1	1
Upper Rhine 6 - OR 6 - mouth R. Neckar to mouth R. Main	428- 497	Worms	DE-RP	heavily modified	heavily modified	2	2	2
Upper Rhine 7 - OR 7 - mouth R. Main to mouth	497- 529	Mainz/Wiesbaden	DE-RP	heavily modified	heavily modified	2	2	3
MIDDLE RHINE Bingen - Bonn	**529-639**	Koblenz	DE-RP	heavily modified	heavily modified	2	2	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	heavily modified	heavily modified	2	2	3
Lower Rhine 2 - NR 2 - Leverkusen to Duisburg	701-764	Düsseldorf harbour	DE-NW	heavily modified	heavily modified	2	2	3
Lower Rhine 3 - NR 3 - Duisburg to Wesel	764-811	Duisburg-Walsum / Orsoy	DE-NW	heavily modified	heavily modified	3	3	3
Lower Rhine 4 - NR 4 - Wesel to Kleve	811-865	Niedermoermter / Rees	DE-NW	heavily modified	heavily modified	3	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	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	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	3
Dutch coast (coastal waters)	n.a.	Noordwijk 2	NL	Natural	Natural	2	2	2
Coast Wadden Sea (coastal waters)	n.a.	Boomkensdiep	NL	Natural	Natural	2	3	2

Annex 2: Assessment of the biological quality element macrophytes / phytobenthos in the Rhine according to the WFD for the management plans 2009, 2015 and the management plan 2021 *(draft version of 15 April 2021)*

Assessment of the biological component macrophytes/phytobenthos in the Rhine according to WFD for Management Plan 2009, Management Plan 2015 and Management Plan 2021 (draft)

State: April 2021

./.	Assessment of quality component not required	very good	1	*Ecol. potential*
	No inventory or assessment of the component / insufficient data	good	2	2
Macrophytes / Phytobenthos: In DE-BW, this result refers to the complete biocomponent. In France, only diatoms were assessed.		moderate	3	3
		poor	4	4
		bad	5	5

Water body	River-km	ICPR overview monitoring point in the water body	State / federal state	Management Plan 2009	Management Plan 2015	Management Plan 2021 (draft)
ALPINE RHINE - Reichenau - Bodensee						
AR 3 Alpine Rhine, OWK AT 10109000		Fussach	AT/ Vorarlberg/CH (SG)	2	2	2
LAKE CONSTANCE						
BOD-OS Lake Constance-Obersee	No kilometer milage	Fischbach-Uttwil	DE-BW	2	2	2
BOD-USZ Lake Constance-Untersee		Zellersee	CH / St. Gallen	2	2	2
HIGH RHINE Lake Constance - Basel	**24-170**					
High Rhine 1 - Lake Constance to the mouth of the River Aare	24-102.7	Stein, Ellikon	CH/ DE-BW	1	2	2
High Rhine 2 - mouth of the Aare to Basel	102.7-170	Sisseln, Pratteln/Wyhlen	CH/ DE-BW	1	2	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	1	3	2
			FR	2	2	3
			Result of coordination		2	
Upper Rhine 2 - OR 2 - Rhine 2 - loop of the Rhine, Breisach to Strasbourg	225-292		DE-BW	2	3	3
		Upstream Rhinau	FR	2	2	2
			Result of coordination		2	
Upper Rhine 3 - OR 3 - Rhine 3 - regulated section of the Rhine, Strasbourg to Iffezheim	292-352		DE-BW	2	3	3
		upstream of Gambsheim	FR	3	2	3
			Result of coordination		2	
Upper Rhine 4 - OR 4 - Rhine 4 - loop of the Rhine Iffezheim barrage to upstream mouth of River Lauter	352-428	Karlsruhe	DE-BW	2	3	3
		upstream Lauterbourg/Karlsruhe	FR		3	3
			Result of coordination		3	
Upper Rhine 5 - OR 5 - mouth R. Lauter to mouth R. Neckar	352-428		DE-BW	2	3	3
			DE-RP	2	3	2
Upper Rhine 6 - OR 6 - mouth R. Neckar to mouth R. Main	428- 497		DE-BW	3	3	3
			DE-HE		3	3
		Worms	DE-RP	3	3	3
Upper Rhine 7 - OR 7 - mouth R. Main to mouth R. Nahe	497- 529	Mainz/Wiesbaden	DE-HE		3	3
			DE-RP	3	3	3
MIDDLE RHINE Bingen - Bonn	**529-639**					
Middle Rhine (MR)	529-639		DE-HE		3	3
		Koblenz	DE-RP	3	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	3
Lower Rhine 2 - NR 2 - Leverkusen to Duisburg	701-764	Düsseldorf harbour	DE-NW	2	4	3
Lower Rhine 3 - NR 3 - Duisburg to Wesel	764-811	Duisburg-Walsum / Orsoy	DE-NW	3	3	3
Lower Rhine 4 - NR 4 - Wesel to Kleve	811-865	Niedermoermter / Rees	DE-NW	2	3	3
DELTA RHINE Lobith - Hoek van Holland	**865.5 -1032**					
Boven Rijn, Waal	880-930	Lobith	NL	2	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	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	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	4
Dutch coast (coastal waters)	n.a.	Noordwijk	NL			
Coast Wadden Sea (coastal waters)	n.a.	Boomkensdiep	NL	./.	./.	./.

In the water bodies Wadden Sea and Wadden Sea mainland coast, no phytobenthos is assessed, but seagrass and common salt marshes (both on quality and quantity).

The benchmarks for macrophytes (and fish) in the Netherlands were improved in 2012, resulting in EQR values that sometimes deviate considerably. In order to be able to compare the old with the improved yardsticks, the data from 2012 were checked against both yardsticks. The Good Ecological Potential was then adjusted so that the assessments from 2009 and 2012 can nevertheless be compared well with each other.

Annex 3: Assessment of the macro zoobenthos in the Rhine according to the WFD for the management plans 2009, 2015 and the management plan 2021 *(draft version of 15 April 2021)*

Assessment of the macrozoobenthos in the Rhine according to the WFD for the Management Plan 2009, Management Plan 2015 and Management Plan 2021 (draft)					very good	1	*Ecol. potential*	
					good	2	2	
State: April 2021					moderate	3	3	
Assessment 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 surveillance monitoring station in the water body**	**State / federal state**	**Category Management Plan 2009**	**Category Management Plan 2015**	**Management Plan 2009**	**Management Plan 2015**	**Management Plan 2021 (draft)**
ALPINE RHINE - Reichenau - Bodensee								
AR 3 Alpine Rhine, OWK AT 10109000		Fussach	AT/ Vorarlberg/CH (SG)	heavily modified	heavily modified	3	2	2
LAKE CONSTANCE								
BOD-OS Lake Constance-Obersee	No kilometre milage	Fischbach-Uttwil	DE-BW	Natural	Natural		./.	
BOD-USZ Lake Constance-Untersee		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	above mouth Hemishofer B. - Rietheim	CH/ DE-BW	Natural	Natural	2	2	3
High Rhine 2 downstream river Aare until R. Wiese inclusive	102.7-170	below Mdg. Aare - Basel	CH/ DE-BW	heavily modified	Natural	3	3	3
UPPER RHINEBasel - 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	3
			FR	heavily modified	heavily modified	3		
		Result of coordination		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	3
		Upstream Rhinau	FR	heavily modified	heavily modified		4	
		Result of coordination		heavily modified	heavily modified		4	
Upper Rhine 3 - OR 3 - Rhine 3 - regulated section of the Rhine, Strasbourg to Iffezheim	292-352		DE-BW	heavily modified	heavily modified	4	3	3
		upstream of Gambsheim	FR	heavily modified	heavily modified	4	5	
		Result of coordination		heavily modified	heavily modified		3	
Upper Rhine 4 - OR 4 - Rhine 4 - loop of the Rhine Iffezheim barrage to upstream mouth of River Lauter	352-428	Karlsruhe	DE-BW	heavily modified	heavily modified	4	3	3
		upstream Lauterbourg/Karlsruhe	FR	heavily modified	heavily modified	4	4	
		Result of coordination		heavily modified	heavily modified	4	3	
Upper Rhine 5 - OR 5 - mouth R. Lauter to mouth R. Neckar	352-428		DE-BW	heavily modified	heavily modified	3	4	3
			DE-RP	heavily modified	heavily modified	3	4	3
Upper Rhine 6 - OR 6 - mouth R. Neckar to mouth R. Main	428- 497		DE-BW	heavily modified	heavily modified	4	3	3
			DE-HE	heavily modified	heavily modified	4	3	3
		Worms	DE-RP	heavily modified	heavily modified	4	3	3
Upper Rhine 7 - OR 7 - mouth R. Main to mouth R. Nahe	497- 529	Mainz/Wiesbaden	DE-HE	heavily modified	heavily modified	4	2	3
			DE-RP	heavily modified	heavily modified	3	2	3
MIDDLE RHINE Bingen - Bonn	**529-639**							
Middle Rhine (MR)	529-639		DE-HE	heavily modified	heavily modified	4	2	2
		Koblenz	DE-RP	heavily modified	heavily modified	4	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	4	3	2
Lower Rhine 2 - NR 2 - Leverkusen to Duisburg	701-764	Düsseldorf harbour	DE-NW	heavily modified	heavily modified	4	4	2
Lower Rhine 3 - NR 3 - Duisburg to Wesel	764-811	Duisburg-Walsum / Orsoy	DE-NW	heavily modified	heavily modified	5	4	3
Lower Rhine 4 - NR 4 - Wesel to Kleve	811-865	Niedermoermter / Rees	DE-NW	heavily modified	heavily modified	5	4	3
DELTA RHINE Lobith - Hoek van Holland	**865.5 -1032**							
Boven Rijn, Waal	880-930	Lobith	NL	heavily modified	heavily modified	4	4	3
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	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	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	2
Dutch coast (coastal waters)	n.a.	Noordwijk	NL	Natural	Natural	2	3	2
Coast Wadden Sea (coastal waters)	n.a.	Boomkensdiep	NL	Natural	Natural	3	2	2

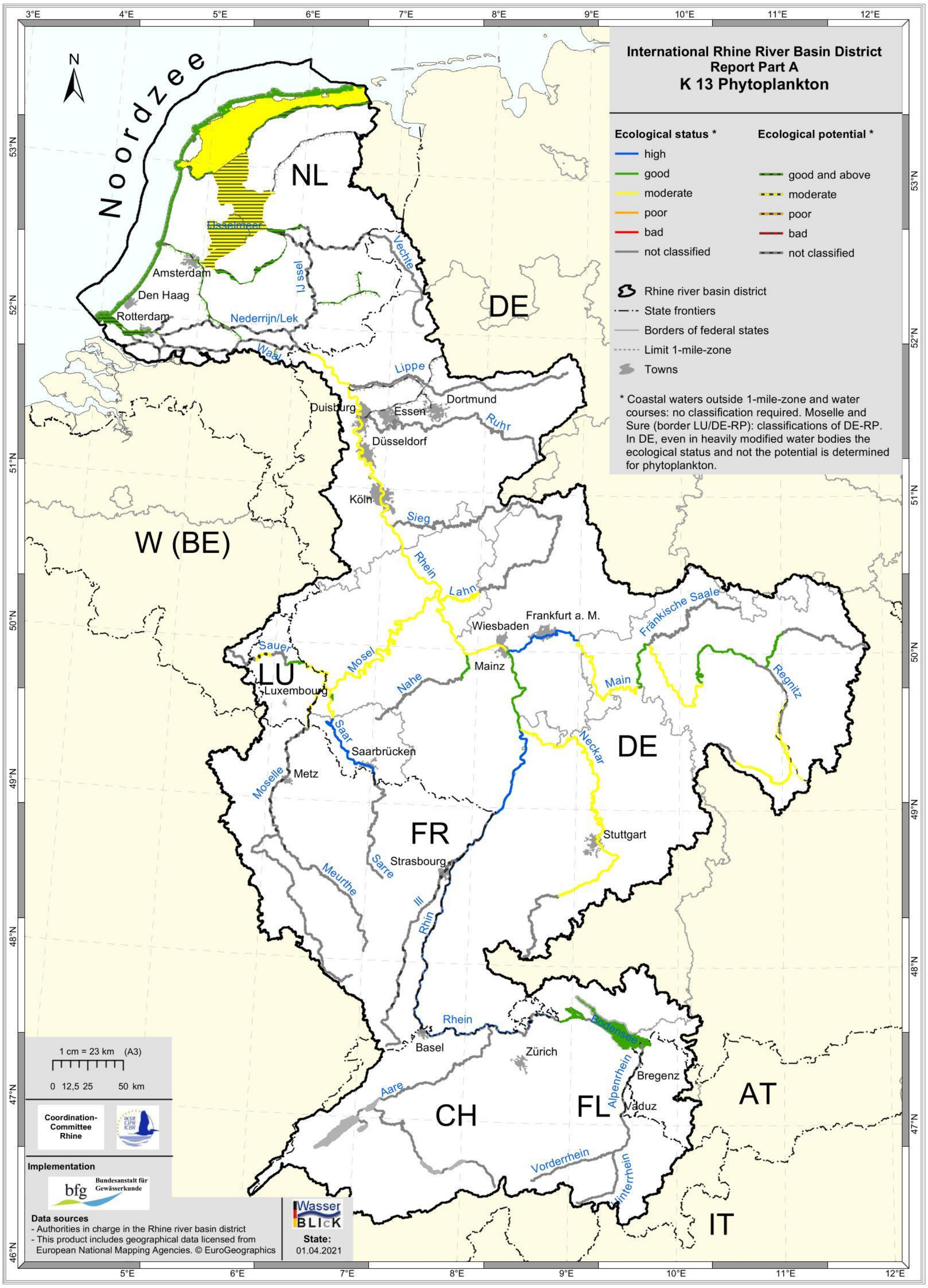
Annex 4: Assessment of the fish fauna in the Rhine according to the WFD for the management plans 2009, 2015 and the management plan 2021 *(draft version of 15 April 2021)*

Assessment of the fish fauna of in the Rhine according to the WFD for the Management Plan 2009, Management Plan 2015 and Management Plan 2021 (draft)	./.	Assessment of quality component not required	very good	1	*Ecol. potential*	
		No inventory or assessment of the component / insufficient data	good	2	2	
		different assessment	moderate	3	3	
	Fish: In the tributaries in DE-NW no ecological potential has yet been determined. The deviation from the one-out-all-out principle for the water bodies Upper Rhine 7 and Middle Rhine is coordinated between DE-RP and DE-HE (the results for fish in DE-RP are more representative).		poor	4	4	
State: April 2021			bad	5	5	

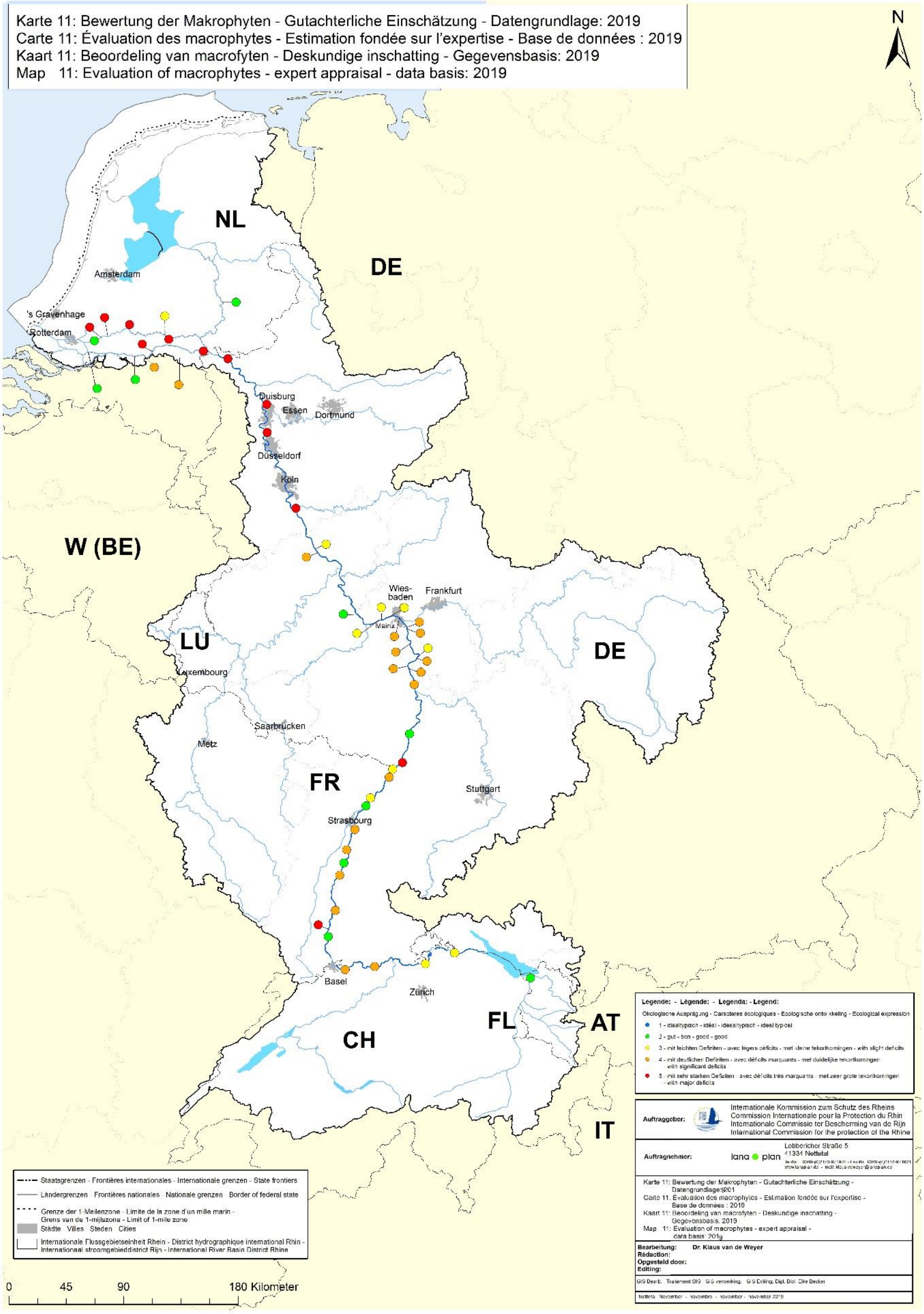
Water body	River-km	ICPR surveillance monitoring station in the water body	State / federal state	Category Management Plan 2009	Category Management Plan 2015	Management Plan 2009	Management Plan 2015	Management Plan 2021 (draft)
ALPINE RHINE - Reichenau - Bodensee								
AR 3 Alpine Rhine, OWK AT 10109000		Fussach	AT/ Vorarlberg/C	heavily modified	heavily modified	5	5	3
LAKE CONSTANCE								
BOD-OS Lake Constance-Obersee	No kilometre milage	Fischbach-Uttwil	DE-BW	Natural	Natural		2	2
BOD-USR Lake Constance-Untersee		Zellersee	DE-BW	Natural	Natural			2
HIGH RHINE Lake Constance - Basel								
High Rhine 1- Lake Constance-Aare estuary	24-102.7	Hohentengen, Kadelburg	CH/ DE-BW	Natural	Natural	3	3	3
High Rhine 2- mouth of the Aare to Basel	102.7-170	above and below Rheinfelden	DE-BW	heavily modified	Natural	2		3
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	3
			FR	heavily modified	heavily modified		2	
		different assessment		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	4
		Upstream Rhinau	FR	heavily modified	heavily modified		2	
		different assessment		heavily modified	heavily modified			
Upper Rhine 3 - OR 3 - Rhine 3 - regulated section of the Rhine, Strasbourg to Iffezheim	292-352		DE-BW	heavily modified	heavily modified	3	3	3
		upstream of Gambsheim	FR	heavily modified	heavily modified		2	
		different assessment		heavily modified	heavily modified			
Upper Rhine 4 - OR 4 - Rhine 4 - loop of the Rhine Iffezheim barrage to upstream mouth of River Lauter	352-428	Karlsruhe	DE-BW	heavily modified	heavily modified	3	3	3
		upstream Lauterbourg/Karlsruhe	FR	heavily modified	heavily modified		2	
		different assessment		heavily modified	heavily modified			
Upper Rhine 5 - OR 5 - mouth R. Lauter to mouth R. Neckar	352-428		DE-BW	heavily modified	heavily modified	3	3	3
			DE-RP	heavily modified	heavily modified	3	3	3
Upper Rhine 6 - OR 6 - mouth R. Neckar to mouth R. Main	428- 497		DE-BW	heavily modified	heavily modified	4	3	3
			DE-HE	heavily modified	heavily modified		3	3
		Worms	DE-RP	heavily modified	heavily modified	4	3	3
Upper Rhine 7 - OR 7 - mouth R. Main to mouth R. Nahe	497- 529	Mainz/Wiesbaden	DE-HE	heavily modified	heavily modified	3	4	2
			DE-RP	heavily modified	heavily modified	3	3	2
MIDDLE RHINE Bingen - Bonn								
Middle Rhine (MR)	529-639		DE-HE	heavily modified	heavily modified	3	3	2
		Koblenz	DE-RP	heavily modified	heavily modified	3	3	2
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	3
Lower Rhine 2 - NR 2 - Leverkusen to Duisburg	701-764	Düsseldorf harbour	DE-NW	heavily modified	heavily modified	3	3	3
Lower Rhine 3 - NR 3 - Duisburg to Wesel	764-811	Duisburg-Walsum / Orsoy	DE-NW	heavily modified	heavily modified	3	4	4
Lower Rhine 4 - NR 4 - Wesel to Kleve	811-865	Niedermoermter / Rees	DE-NW	heavily modified	heavily modified	4	4	4
DELTA RHINE Lobith - Hoek van Holland								
Boven Rijn, Waal	880-930	Lobith	NL	heavily modified	heavily modified	4	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	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	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	./.	./.	./.
Coast Wadden Sea (coastal waters)	n.a.	Boomkensdiep	NL	Natural	Natural	./.	./.	./.

NL: The 2009 assessments differ from the original assessments because they have been recalculated using an improved yardstick. They have been included here to allow a good comparison with 2014.

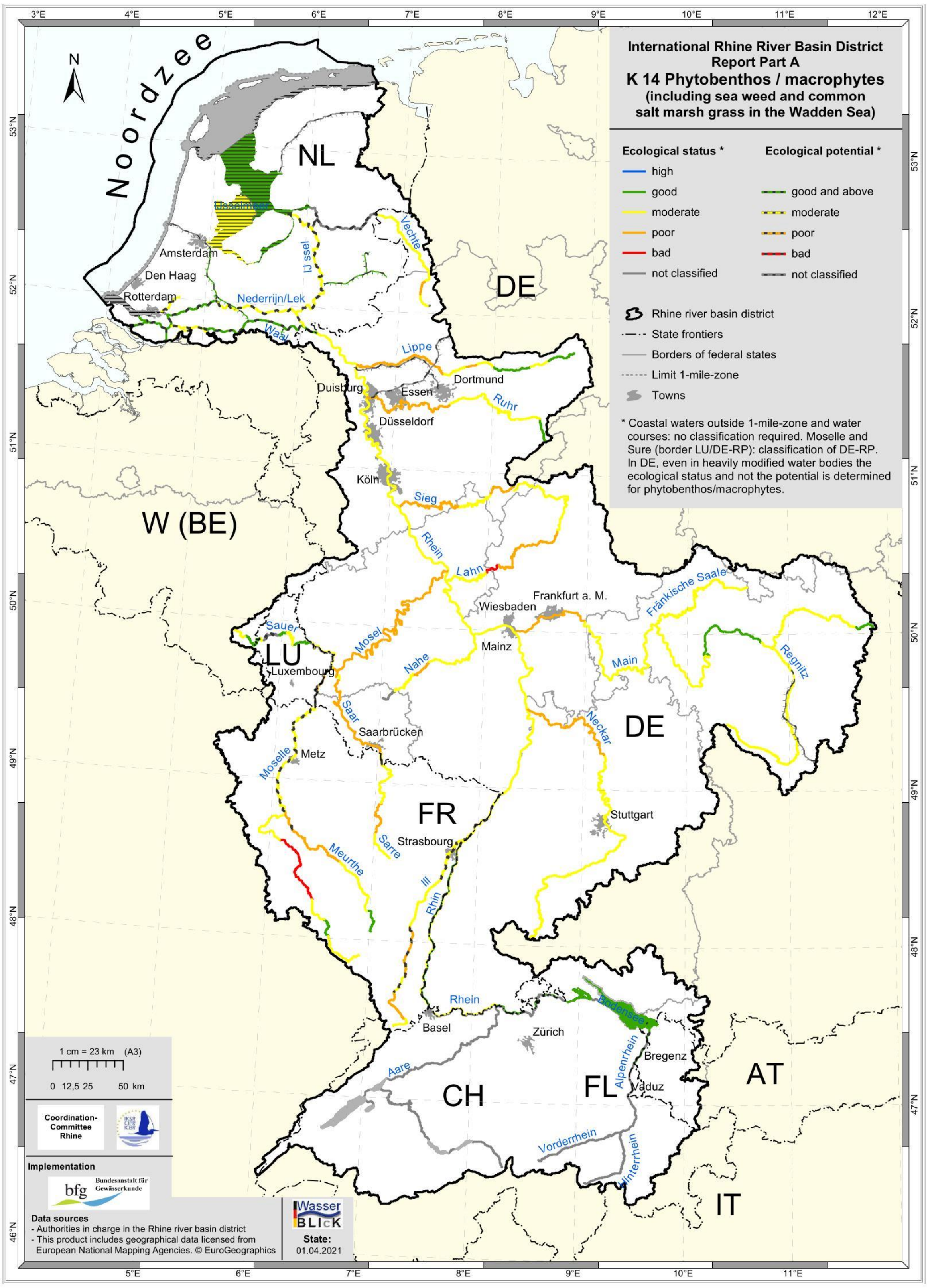
Annex 5: Map Assessment of phytoplankton
Map 13 from the 3rd management plan Rhine *(draft version of 15 April 2021)*



Annex 6: Map Initial expert assessment of the macrophyte subcomponent (data basis 2019)

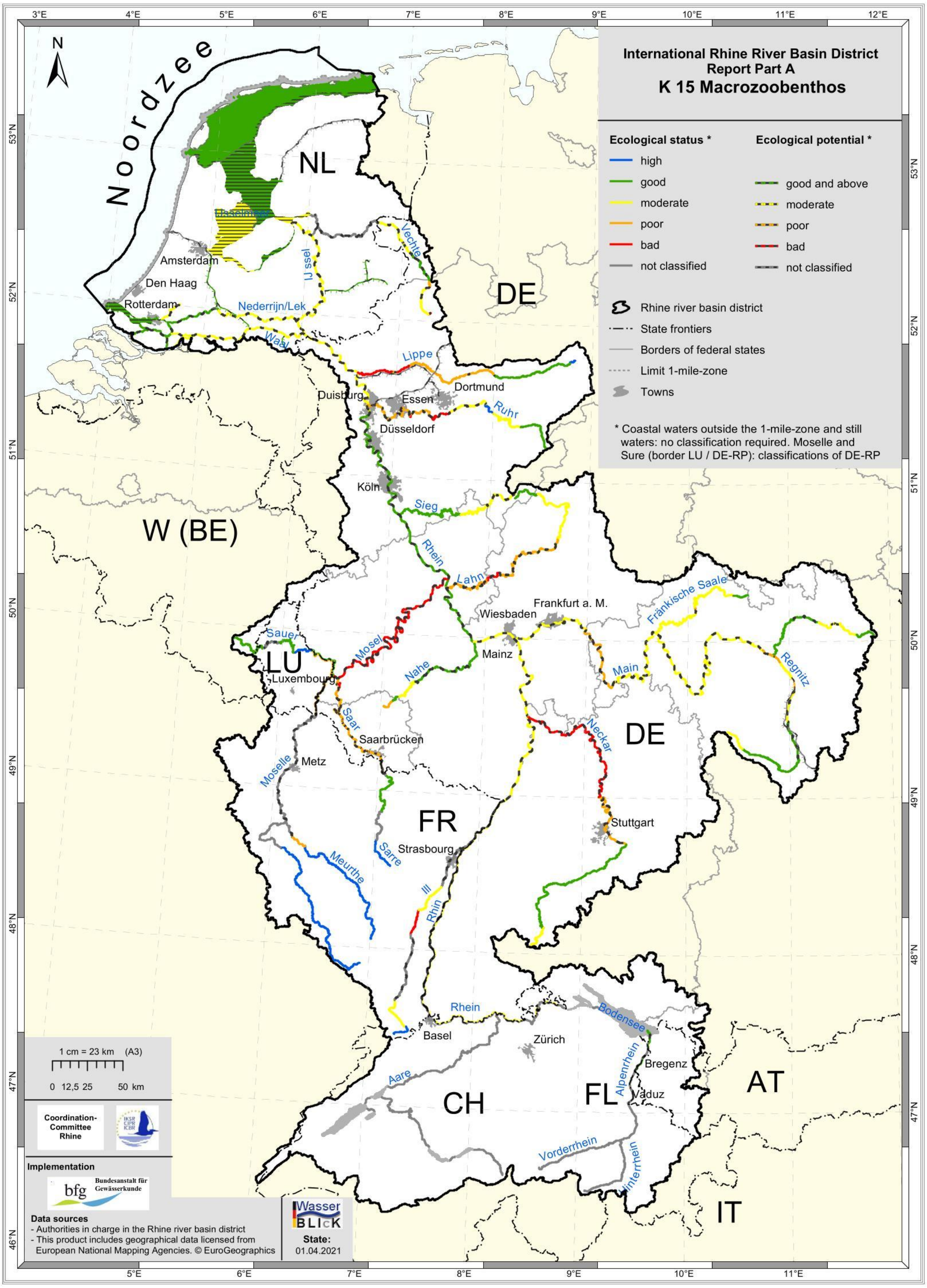


Annex 7: Map Assessment of phytobenthos / macrophytes
Map 14 from the 3rd management plan Rhine *(draft version of 15 April 2021)*

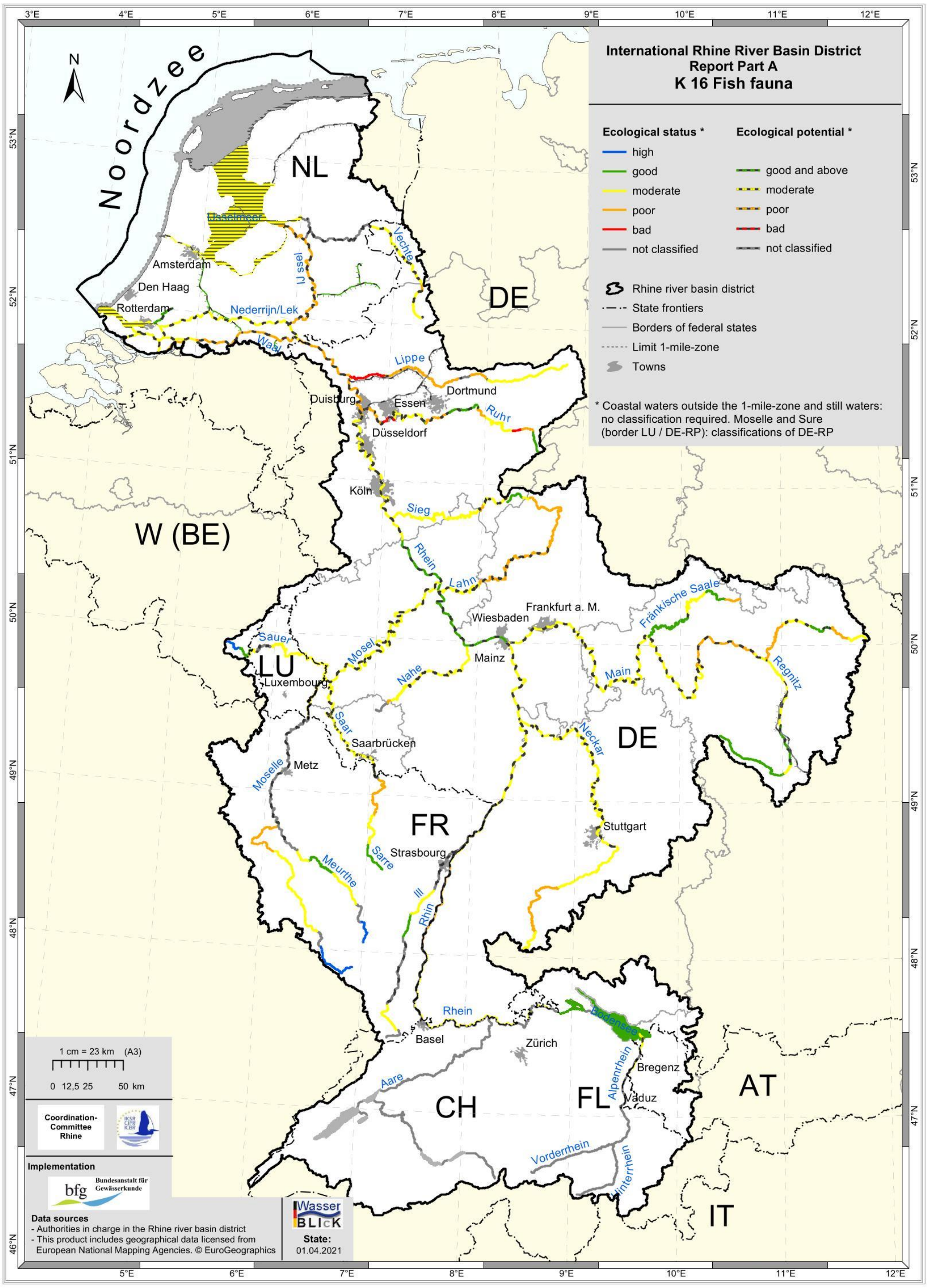


Annex 8: Map Assessment of the macro zoobenthos

Map 15 from the 3rd management plan Rhine *(draft version of 15 April 2021)*



Annex 9: Map Assessment of fish fauna
Map 16 from the 3rd management plan Rhine *(draft version of 15 April 2021)*



Annex 10: Map Overall assessment of Ecological Status / Ecological Potential
Map 17 from the 3rd management plan Rhine *(draft version of 15 April 2021)*