Present state of knowledge on possible consequences of changes of the discharge pattern and water temperature on the Rhine ecosystem and possible perspectives for action

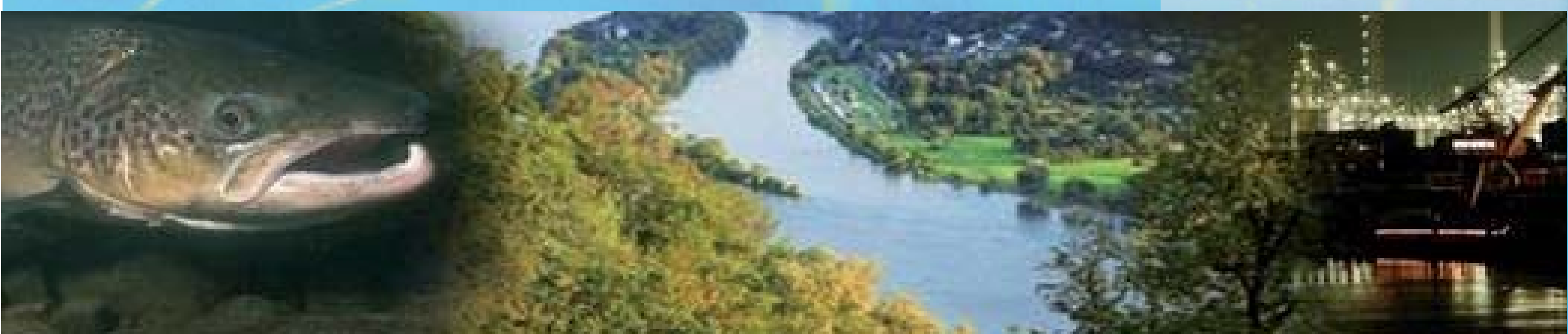
IKSR
CIPR
ICBR

Internationale Kommission zum Schutz des Rheins

Commission Internationale pour la Protection du Rhin

Internationale Commissie ter Bescherming van de Rijn

Report No. 204



Imprint

Publisher:
International Commission for the Protection of the Rhine (ICPR)
Kaiserin-Augusta-Anlagen 15, D 56068 Koblenz
P.O. box 20 02 53, D 56002 Koblenz
Telefone +49-(0)261-94252-0, Fax +49-(0)261-94252-52
E-mail: sekretariat@iksr.de
www.iksr.org

ISBN-Nr 3-941994-32-8

Present state of knowledge on possible consequences of changes of the discharge pattern and water temperature on the Rhine ecosystem and possible perspectives for action

Table of Contents

Introduction

Based on available literature, the ICPR working group Ecology has structured and summarized the effects of climate change on the aquatic and amphibian habitats in the Rhine catchment.

The most important impacts of climate change on the discharge and temperature regime of the Rhine and its tributaries, such as presented in the bibliographic study[1] *and in the "Study of Scenarios"*[2] *of the ICPR expert group KLIMA were starting points for this work. As far as the temperature development is concerned, only the results of the bibliographic study are available; more recent data are expected for 2013.*
These two reports clearly indicate the signals of climate change to be expected. However, indications concern bandwidths to be expected for the near and far future, which, when it comes to ecological statements, can only be exploited to a limited extent. Statements on extreme discharges, in particular on extreme flood discharges could not be predicted or only be predicted with considerable uncertainties.

Based on known signals of climate change, the Working Group Ecology has evaluated existing literature on the possible impacts of climate change on the ecosystems of the Rhine and its tributaries. The report adopts the plan of the groups of habitat types applied in the atlas on the "Habitat Patch Connectivity along the Rhine" and the biological quality components according to the WFD.[3]

In this report, the Working Group Ecology describes the general correlations and particularly the impact to be expected on the four biological quality components: phytoplankton, macrophytes/phytobenthos, marcrozoobenthos and fish fauna; a separate chapter concerns new invasive species.
Additionally, a short chapter concerns semi-aquatic and terrestrial habitats.
It is particularly important to determine "sensitivity guidance values" which, when they are reached, indicate a certain level, to which the asset of protection is concerned[4]*.*
According to the mandate of the Working Group Ecology, particular focus is placed on elaborating a joint view of the effects of temperature changes on the biocoenosis.

Furthermore, possible strategies for action aimed at mitigating the expected detrimental effects of climate change are indicated. It shows that, as a matter of principle, strengthening the functionality of ecosystems by protecting, interconnecting and extending habitats and thus enhancing biodiversity should be approved and enhanced with a view to impacts of climate change. The approaching implementation of the "Habitat Patch Connectivity" along the Rhine is thus an increasingly important contribution to mitigating the effects of climate change.

Interaction with measures induced by climate change taken by users and possibilities of optimizing the data base complete the report.

[1] ICPR 2009a
[2] ICPR 2011
[3] ICPR 2006
[4] Assets of protection which, in connection with questions of water management might be impacted by climate change are: Flood protection, water quality, different uses of water bodies such as drinking water supply, hydropower generation, navigation and availability of cooling water. From an ecological point of view, assets of protection are populations of animal and plant species, habitat types and the functionality of entire ecosystems.

1. Possible impact of climate change on aquatic and amphibian habitats in the Rhine catchment.

For most organisms in aquatic ecosystems, climate change is an additional factor of stress to those already resulting from the various anthropogenic interests.[5] This is particularly true for the densely settled and heavily industrialized Rhine catchment with its intensive agriculture.

In general, when environment conditions change,
- rare species,
- species with small to medium sized habitats,
- endemic species, existing in a certain, spatially clearly delimited region,
- species only tolerating small variations of environmental factors, so-called stenoecious or stenotopic species will particularly be at risk.

Apart from moors, wood xerothermic vegetation and heathlands, source areas, banks of waters and coastal habitats range among the habitats reacting particularly sensitive to climate change.[6]

Figure 1: Short-grass meadows in the Taubergießen nature protection area (Photo: Regierungspräsidium Freiburg)

The vulnerability (damage risk) of an ecosystem depends on the degree of climate change in a given region as well as on the adaptability of the ecosystem and its species. The ecosystems in the following regions in the Rhine catchment are most vulnerable:
- In the Upper Rhine Valley, conditions for organisms are likely to change due to a rise in temperature, more frequent floods and heavy rainfall as well as a shift of precipitation from summer to winter.
- In the Alps, climate change is expected to be particularly distinct and will concern a large number of endemic animal and plant species which are partly living in particular micro-climatic sites and hardly have any alternative habitats.

The midlands with a cooler and more humid climate are least vulnerable;[7] but even for these areas, estimates are more negative for wetlands and smaller water bodies and for individual species requiring a cool, humid climate (see below).

Direct and indirect alterations brought about by climate change impacting abiotic factors and (groups of) organisms were compiled within the KLIWA project[8]. Due to the number of factors and uses in large catchments, the interactions in the lower sections of rivers are more complex, than in their upper and middle sections. A large part of the main stream of the Rhine belongs to the category "lower river section". Often, it is not possible to derive a distinct reaction in one direction or the other (intensification/weakening), as opposite appearances are frequently observed during investigations. Direct effects of

---

[5] several in Rabitsch et al. 2010
[6] Rabitsch et al. 2010
[7] Zebisch et al. 2005
[8] KLIWA 2010, http://fliessgewaesserbiologie.kliwa.de

climate change, such as a rise in temperature become less important than other factors (e.g. substance concentration) or anthropogenic uses. Contrary to what applies to the upper and middle river sections, the lack of oxygen is an important factor, particularly in impounded river sections.

Figure 2 illustrates the parameters concerned in this type of water body.

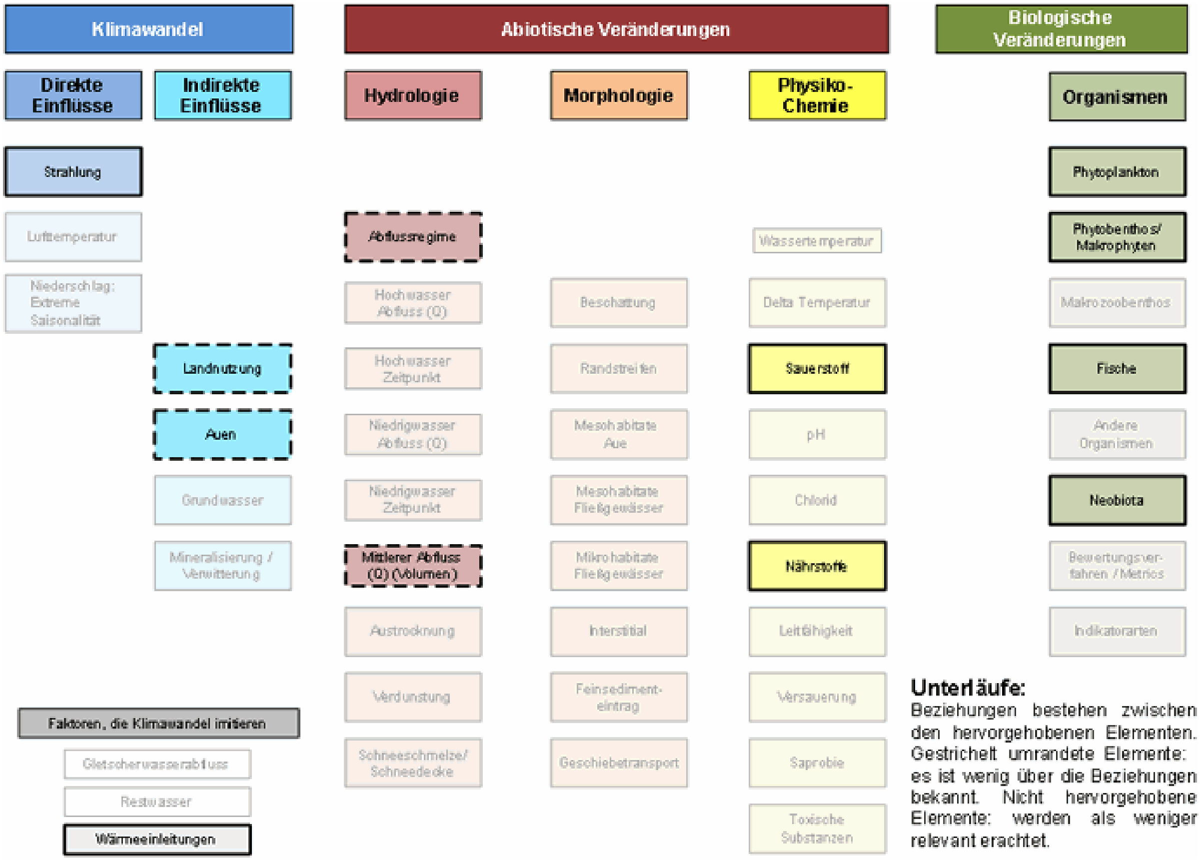


Figure 2: Abiotic factors and groups of organisms in a lower river section likely to be impacted by climate change.
There are relationships between the elements highlighted. Elements with dotted boundaries: little is known about the relationships. Elements not highlighted: considered as less relevant. Source: http://fliessgewaesserbiologie.kliwa.de

1.1 General interactions

Floods and low water which man considers as major disturbances and catastrophic events are natural, characteristic and important for the river ecosystem. The dynamics of water levels always gives new possibilities for organisms to settle in and along the water body and to spread; many species have developed specific survival strategies. However, there are few investigations into effects of extreme water levels with shorter return times on organisms as were witnessed in the near past, and which might have greater consequences. As the biocoenosis in great rivers require 1 to 2 years to regenerate, an increasing number of floods and low water levels over a longer period might in the medium and long term lead to a change of settlement structures in the river.[9]
A longer or even permanent increase in water temperature will have to be assessed differently, as it controls many vital processes in organisms (see below).

Storm, high runoff and floods

During high runoff, floods and storms with consecutive erosion and channel erosion, greater amounts of organic substances, salts and pollutants are washed into water bodies. Downstream of sewage plants and given sufficiently high temperatures, this may lead to a rise in biotic decomposition and thus to oxygen depletion in the water body.[10]
Early in springtime and if snow melt starts early, considerable sediment and nutrient quantities may be washed from agricultural lands into waters before crops start to grow. This increases bedload discharge and impacts all sessile organisms and life stages (marcrophytes, phytobenthos, macrozoobenthos, fish spawn). Additionally, fine matter might cause clogging of habitats in the interstices of pebbles on the riverbed leading to a lack of oxygen.
An eventual positive effect of higher runoff would occur in places where the connection between the river and the floodplain offers possibilities to extend the aquatic and semi-aquatic habitat into the floodplain (for a short time), where water-dependant habitats, such as swamps, reeds and herbaceous vegetation, greenland and floodplain forests would benefit from the hydrological dynamics and the spreading of plant seeds. During more frequent smaller and medium-sized floods, an ecological flooding of flood retention areas would be possible more often.

Low flow

During low flow, more areas along the river banks dry out, thus creating new terrestrial habitats and residual waters cut off from the river, if permitted by the bank structure. At the same time, the volume and surface of the water filled habitat is reduced.
Bird species such as the little ringed plover or the common sandpiper breed in riparian gravel areas exempt of vegetation which also serve as nutrient-rich habitat for ground beetles and spiders. Freely moving aquatic organisms follow the receding water level, while sessile organisms must outlast the draught, e.g. by forming resistant stages. The number of species and their abundance (individuals m^{-2}) will increase in the remaining water body in the middle of the river channel. As the flow velocity in the middle of the river channel is mostly above that in the habitats which have now dried out near the river banks, numerous organisms are threatened by drift.

[9] Koop et al. 2007
[10] Koop et al. 2007

Figure 3: Basket clam (Corbicula) shells on the banks of the Rhine near Oberwesel on 24 August 2003 (photo: W. Wiechmann, BfG)

If the entire river and stagnant water dries out, organisms will lose their habitats and die. As far as chemical pollution is concerned, low flow may lead to a higher concentration of chemicals which may harm sensitive organisms. Additionally, low flow may lead to a concentration of pathogenic agents, particularly in situations where temperatures and oxygen depletion increase in the smaller water volume (see below).

Water temperature

For animals and plants temperature is one of the most important environmental factors, as it e.g. controls reproduction, growth, development and migration. Cold-blooded (poikilothermic) organisms such as fish and macroinvertebrates which are unable to regulate their temperature but always adjust it to their environment are particularly affected.
Higher water temperatures might change the species composition and structure of dominance along the rivers. Oligostenothermic species, i.e. species depending on low temperatures are particularly affected. Their habitats could move northwards or to water regions in greater altitude. Eurythermal species able to cope with great variations in temperature and species preferring warm temperatures, among others a large number of new invasive species which so far more or less settled in areas near the river outlets would be favoured and could settle further upstream in the rivers. Above all, this concerns macrozoobenthos species and fish species, but also macrophytes.
Additionally, high temperatures lead to increased metabolism. A temperature rise of 10°C generally doubles the energy consumption for basal metabolism (Q10-rule). If there is not enough food, the immunological system will thus be weakened. Additionally, the spreading of pathogens, parasites etc. is being favoured.[11]
Vegetable biological components (phytoplankton, macrophytes and phytobenthos) are particularly concerned in the lower sections of great rivers, but also as a consequence of the effects of more intensive radiation.

Temperature as guidance value for sensitivity

Average as well as maximum temperatures are relevant. Preferences with respect to water temperature are particularly well documented for fish. Among others, a distinction is made between the following parameters:
The critical temperature (CTMax or CTMin) is achieved, when fish are no longer able to escape from the area of the lethal temperature range. A distinct change of behaviour brought about by temperature changes is to be observed in the lower/upper critical range. There is, for example, a temperature of avoidance, a temperature of errantry and a temperature of disturbance. In the optimal range, fish feed and do not show any sign of abnormal behaviour due to temperature. The preferred temperature is the range of temperature in which fish stay within a temperature gradient.[12]

[11] KOOP et al. 2007, RABITSCH et al. 2010
[12] KÜTTEL et al. 2002, see table 1 of the annex

According to the EU directive[13], the temperature of salmonid waters (= waters, in which cold water fish / salmon and trout varieties live) may not lie above 21.5°C, that of cyprinid waters (waters, in which warm water fish /carp varieties live) may not lie above 28°C. In waters where fish species reproduce requiring cold water for reproduction, the water temperature may not exceed 10 °C during spawning periods. These temperature limits may be exceeded during 2 % of the time.
Apart from maximum temperatures, the duration of warm spells is particularly decisive for the survival of water organisms. Thus, during the summer of 2003, when temperatures of the main stream of the Rhine exceeded 25 °C on 41 days, massive death of mussels and eel was observed. However, in 2006, after 31 days of warm spell, there was no such massive death.[14]
The outlets of lakes which warm up to a greater degree than rivers may be particularly affected by high water temperatures. During the extreme heat period in the summer of 2003, a massive death of approx. 50,000 greylings (20.9 tons of fish) was observed in the section of the Rhine immediately downstream of Lake Constance. On 12 August 2003, 25.9°C were measured at a depth of 4 meters at Stein am Rhein, near the banks temperatures even rose above 27°C.[15]

Oxygen as sensitivity guidance value

Normally, the oxygen concentration of water is at least 6 to 9 mg/l.
In waters with organic pollution, oxygen depletion may considerably rise, particularly when temperatures are high. An oxygen concentration below 5 mg/l in cyprinid waters, and below 6 mg/l in salmon is considered to be the critical limit for the fish fauna of the waters concerned.[16] Even if temperatures are low, most fish species cannot survive an oxygen concentration < 3 mg/l.[17]

1.2 Phytoplankton

Improved living conditions for phytoplankton - lower flow velocity, higher nutrient contents and higher temperatures during a longer period of the year - generally lead to a lower ecological quality of a water body.
In particular, in standing waters stronger phytoplankton growth leads to oxygen supersaturation, followed by oxygen depleting degradation processes during which filter feeders - that is "plankton feeders" such as basket clams belonging to the genus *Corbicula* and zebra mussels of the genus *Dreissena* - reduce their activities. This again leads to increased plankton growth.[18]
Modelling results mostly predict an increase of chlorophyll concentrations caused by lower discharge, a rise in temperature and eutrophication processes.[19]
However, an experiment also indicated that a rise in temperature may detrimentally impact the phytoplankton biomass, the average cell size and the share of microplankton diatoms, which is expected to lead to a lower transfer of energy in the food chain from primary producers to fish.[20]

During dry spells such as in the summer of 2003 and the resulting rise in water temperature, a strong increase of phytoplankton and of macrophytes was among others

[13] Directive 2006/44/EC of 6 September 2006 on the quality of fresh waters needing protection or improvement in order to support fish life
[14] Koop et al. 2007
[15] BUWAL 2004
[16] see Directive 2006/44/EC of 6 September 2006 on the quality of fresh waters needing protection or improvement in order to support fish life
[17] from Koop et al. 2007: Casselmann & Harvey 1975
[18] ICPR 2009e
[19] from KLIWA 2010: Zebisch et al. 2005; Wagenschein 2006, Stadthagen 2007, Ducharne et al. 2007, Quiel et al. 2008
[20] from KLIWA 2010: Sommer & Lengfellner 2008

observed in the Rhine[21] along with a strong reproduction of diatoms. Apart from weedage of waters there is also a risk of a strong increase of blue algae (cyanobacteria).[22]
Besides the impact of algal formation on oxygenation conditions of waters (see above), strong algal growth may result in "biogenic decalcification". As observed on the High Rhine in 2003, lime secretion of algae leads to a milky colour of the water body and foam appears. At given pH values, ammonium is increasingly converted into ammonia which is toxic for fish.[23]
The water quality simulation model QSim (*Quality Simulation*) developed by the BfG allows for a simulation of plankton development, in particular of algae, as well as the simulation of water quality and of the load of organic suspended matter; it is expected that future development will enable a more realistic forecasting for the Rhine.[24]

Figure 4: Different aspects of water in which cyanobacteria spread. (Source: M. Leitão, Guide pratique des Cyanobactéries planctoniques du Grand Ouest de la France)

[21] Bundesanstalt für Gewässerkunde 2006
[22] ICPR 2004
[23] BUWAL 2004
[24] from KLIWA 2010: KIRCHESCH & SCHÖL 1999

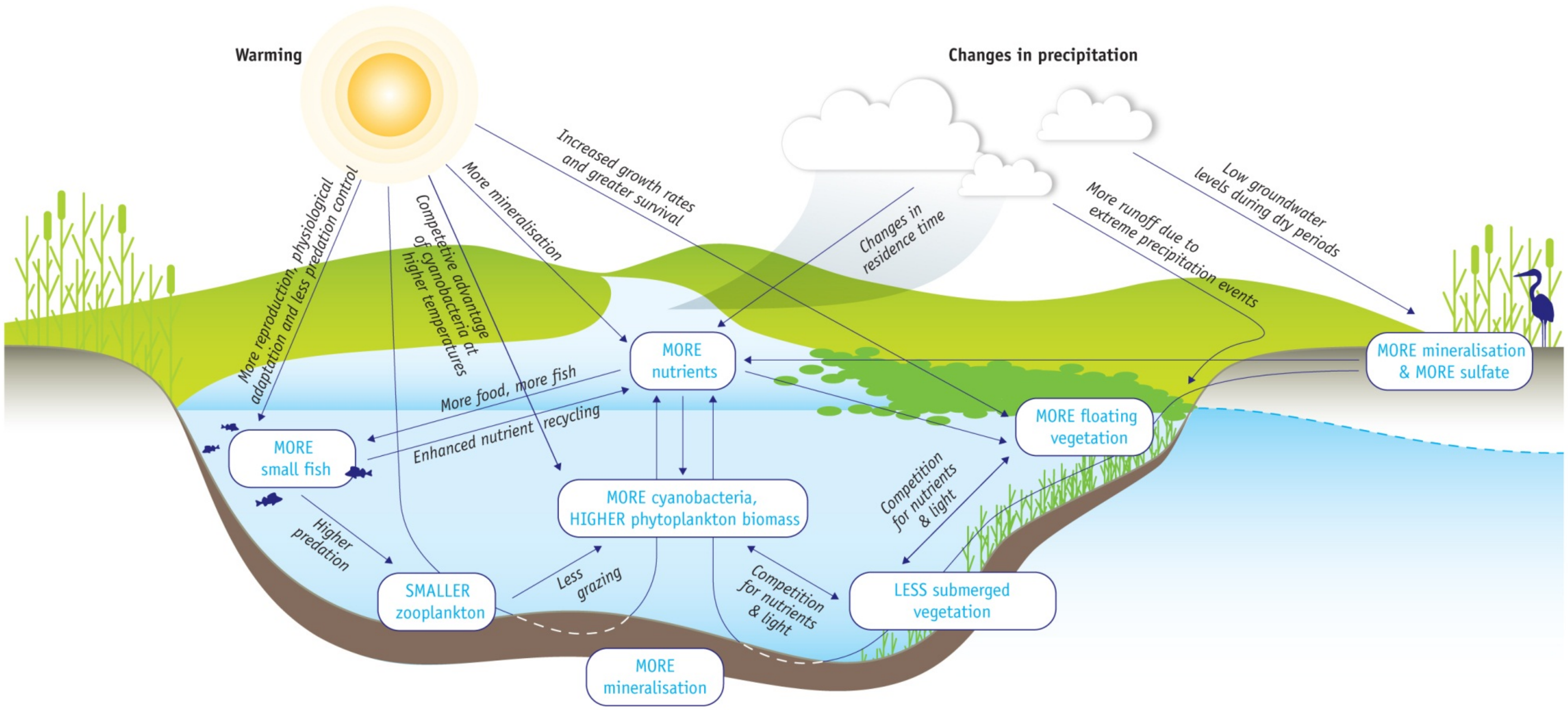


Figure 5: Most important effects of climate change.
Conceptual representation of the most important effects of climate change on eutrophication and its results. Source: STOWA 2011, according to Moss et al. 2011 (International Society for Limnology).

1.3 Macrophytes and Phytobenthos

Runoff and the resulting bedload discharge considerably impact macrophyte growth. Floods particularly move sediments, an appearance detrimentally impacts phytobenthos and marcophytes. Individual macrophyte species (e.g. river water crowfoot, *Ranunculus fluitans*) may benefit from increased eutrophication due to diffuse nutrient inputs, e.g. during storms leading to considerable weedage of water bodies. This often impairs ecological quality. In particular, high temperatures and strong radiation may lead to a rapid development of the phytobenthos and macrophyte biomass and their just as rapid crash is equally possible. This dying off and decomposition of organic material then results in a fall of interstitial oxygen contents, that is, a fall of the oxygen content in the gap system of the river bottom ("biogenic clogging"; see "fish fauna").[25]
A rise in temperature would above all detrimentally impact oligostenothermic plant species in small rivers rich in fine sediment, in sources and mountain lakes; rare species might experience a regress. Examples are blinks (*Montia fontana*), golden saxifrage (*Chrysosplenium oppositifolium*) and alpine pondweed (*Potamogeton alpinus*).[26]

1.4 Macrozoobenthos

Largely, climate change detrimentally impacts the macrozoobenthos. An investigation into tributaries of the Middle Rhine (Wisper, Gründelbach, Nette, Saynbach, Ahr) showed that the impounding effect of Rhine floods reduces flow velocity in the downstream sections while reduced drag force increases sedimentation. These interferences lead to a lower number of macroinvertebrate species than in areas further upstream and to a different structure of dominant species. The share of rheophile species drops. During the weeks following a flood of the Rhine, the share of rheophile species will then again rise in the tributary and a coenosis will develop, which will be distinctly different from that of the Rhine.[27] If floods of the Rhine occur more frequently, this restoration phase may be shortened and sustainably impoverish the coenosis.
A drying out of substratum during low water periods may drive back the normally dominating species. Most macroinvertebrates do not have any problem in following a change of water level at a rate of less than 40 to 50 cm h^{-1} and only extreme events will affect the biocoenosis.
Also, massive migration of macroinvertebrates towards the outlets of tributaries have been observed; they thus avoid the effects of concentration and higher water temperatures during low water periods.[28]

In particular, a rise in temperature will affect the macrozoobenthos in brooks, smaller rivers and the source region in mountain areas, among them many oligostenothermic species. The result will be a longitudinal shift of biocoenosis along the river and oligostenothermic species will be at risk of a "peak trap", since they do not have any possibility of escaping further upstream (see fish fauna).[29]
Examples are:
- several Bythinella species (*Bythinella spp.*)
- the freshwater bivalve *Pisidium personatum,*
- several dragonfly species, such as sombre goldenring (*Cordulegaster bidentata*), azure hawker (*Aeshna caerulea*), subarctic hawker (*Aeshna subarctica elisabethae*) and Alpine emerald (*Somatochlora alpestris*);
- numerous stone fly species (Plecoptera)
- numerous Trichoptera, e.g. *Agapetus fuscipes*. [30]

---

[25] Ibisch 2004
[26] MKUNLV 2010
[27] from KLIWA 2010: Beckmann 2002
[28] KLIWA 2010
[29] from KLIWA 2010: Cordellier 2009, Lorenz & Graf 2008; several in WWF 2009
[30] several in Rabitsch et al. 2010

When important grazers such as *A. fuscipes* regress in small brooks, a secondary effect would be an increased biofilm and an algae layer on stones (see macrophytes /phytobenthos).
A rise in temperature would particularly endanger a great number of endemic species of the Chalk Alps.
During extreme hot temperatures such as in the summer of 2003, a mussel death must be reckoned with.[31]
Species like Chironomidae, Gammaridae or species preferring warm temperatures, such as *Physella acuta* as well as numerous invasive species are partly a competitive interference to native species (see "invasive species"). It is expected that an increase of these species will entail a deterioration of the ecological state according to WFD.[32]

A rise in winter water temperature could e.g. cause a premature end of the dormant stage or changed development periods.[33]
Some species also show increased voltinism, i.e. they reproduce more often and there are several generations per year.[34]

1.5 Fish fauna

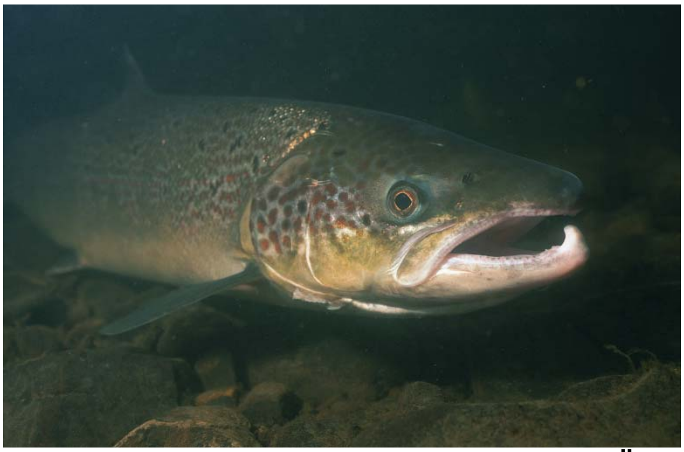


Figure 6: Male salmon (photo: Ulrich Haufe, LÖBF)

Input and bedload

Due to the input of fine soil, e.g. during a storm, the interstitial space may clogg, spacing in the river gravel bed where fish spawning in the gravel bed (such as salmon and trout) deposit their spawn and where juvenile fish lives may be filled up by sediments, and the oxygen remaining in the gravel interstice may be reduced.[35] Diffuse inputs may additionally detrimentally affect water quality and harm the spawn and juvenile fish.
Bedload dynamics is a natural process in the river, permanently restructuring the river bed and supplying it with oxygen. However, point of time and frequency are decisive; these factors may be altered by climate change.

As the melting of the glaciers and of permafrost in the Alps uncovers detritus, it is expected that many mountain rivers will in future carry more gravel and sand. This leads to a stronger bedload movement. If this occurs in winter during reproduction periods and

[31] from KLIWA 2010: LUBW 2004
[32] Daufresne et al. 2007, Groß 2003, LUBW 2004 and Schöll 2007 in KLIWA 2010
[33] Mehlig & Rosenbaum-Mertens 2008, Fischer 2003, Ladewig 2004 in KLIWA 2010
[34] from KLIWA 2010: Braune et al. 2008
[35] MKULNV 2010, Ibisch 2004

when river trout spawning in the gravel hatch, spawn as well as juvenile fish may be harmed.[36]

Low flow

Generally speaking, low flow is unfavourable to fish migration. During too long periods of low flow migratory fish may not have sufficient time to reach the spawning waters which might result in emergency spawning in suboptimal habitats. Furthermore, the risk of mortality due to fishing and predation rises.
Locally, between 4 and 22 % (at maximum 75 %) of fish biodiversity is at risk of vanishing until 2070.[37]
In particular when occurring together with high water temperatures, dry spells may cause increased fish mortality and illness (see below).

Figure 7: Low flow of the Rhine in 2009 (photo: Marc Braun)

Water temperature

Compared to the relatively temperature-tolerant cyprinids, salmonids are little temperature-tolerant (see annexed Table 1).
Values such as the critical maximum temperature and the optimal range (see above) differ according to the stage of life; for eggs and juvenile fish the optimal range will mostly be narrower than for adult fish, while particular temperature requirements are observed with respect to spawning fish. For fish development, the successive number of days with a certain water temperature is decisive.[38]
Furthermore, there is a regional adaptation of fish populations belonging to one species. For trout, (*Salmo trutta*, several subspecies in the Rhine area) a risk due to high water temperatures and low water levels is only predicted for Southern Europe, including the Alps.[39] Due to higher temperatures, spawn, embryos and juvenile fish of brown trout in the Alp region (eventually also in the midlands) will possibly be able to better survive winters - but this is only true up to a certain temperature. Locally adapted brown trout populations might prove to be comparatively tolerant with respect to higher temperatures and thus secure the survival of the species. Mostly, such tolerance is not caused by physiological factors but is due to an adaptation in the course of the life cycle, as e.g. a shift of the spawning point of time.
If milder winters would lead to an earlier start of the spawning period, small fish feeding on zooplankton would exist for a longer period of time in the feeding chain[40].

---

[36] ongoing project SEDRIVER, http://www.wsl.ch/fe/gebirgshydrologie/wildbaeche/projekte/sedriver/
[37] from KLIWA 2010: Xenopolous et al. 2005
[38] Tisson & Souchon 2010
[39] Eurolimpacs 2009, Notter & Staub 2009; also see fig. 2
[40] Stowa 2011

As trouts are important predators of macroinvertebrates, their regression would impact the entire food web.[41]

Longitudinal spreading of fish communities

In the midlands and in the Alps, temperature dependence of life processes results in a distinct longitudinal spreading of fish communities from the source to the mouth of the river. The regions are designated as trout region, greyling region, barbel region and bream region. This segmentation is a result of the constant rise in water temperature and the diminishing slope of the river from the source to its mouth. Thus, in general, salmonids are largely present in the upper river sections, while cyprinids remain in the lower sections.

A rise in water temperature extends the habitat for warm water fish species such as barbel, bream, bleak, stone loach and chub. They are able to spread upstream and might thus even profit from climate change.

Salmonids, however, are adapted to cooler waters and would be driven back or try to migrate to higher ranges in order to avoid critical temperatures.[42] A model for an alpine water body (R. Mur, Danube region) e.g. forecasts a shift of the salmonid region by up to 27 km further upstream towards the source if water temperature rose by about 1°C. Modelling for the Upper Rhine resulted in regressing brown trout and, in parallel, an increase in chub.[43] In the upper section of the R. Rhône, the rise in water temperature (downstream Lake Geneva) by 1.5 °C during the last 30 years has had a stronger effect on the fish fauna than the temperature rise by 3.0°C in the lower river section. In this lower section, thermophile species were already predominant. Some rheophile cyprinid species have retracted to higher regions.[44]

However, a migration to higher regions is only possible, if the upstream river sections are accessible and dispose of an adequate structure. Since, in mountainous regions, most Rhine tributaries are strongly fragmented by transverse structures and the predicted shift of fish communities to higher regions will in most cases thus not be possible, higher water temperatures would result in a regression or even in local dying out of some species (see table 1 of the annex). Additionally, many species of the middle and lower section (hyporhitral and epipotamal) are not adapted to the high flow velocity of the upper river sections, making it uncertain whether the "gap" in species composition will be filled and fish populations can remain stable in the upper river sections.

The immigration of similar species will lead to more homogenized populations in the summer-cool to slightly warm middle and lower river sections (hyporhithral and epipotamal)[45].

Among the source populations, species diversity will increase due to migration of species from further downstream river sections, while typical species for the source region might locally die out, among others due to increased concurrence, as they do not have the possibility to escape further upstream and might be affected by a (temporary) drying out of the sources.

[41] Eurolimpacs 2009
[42] RABITSCH et al. 2010
[43] PONT 2003
[44] KHALANSKI et al. 2008
[45] from KLIWA 2010: BUISSON & GRENOUILLET 2009

Figure 8: Possible spreading of the brown trout in Switzerland in 2050 according to a BAFU model, presuming a 5.5°C temperature rise. In this scenario, the optimal region for the brown trout would be reduced by 44 % compared to today (according to other scenarios, the reduction would at least amount to 6 %). This would mean that, in the Swiss midlands, the brown trout would practically not occur. Blue: River sections apt for the brown trout. Pink: River sections too warm for the brown trout. Source: NOTTER & STAUB 2009

Just as salmon, the **smelt** is a migratory fish with an adipose fin requiring cool water with a comparatively high oxygen content. In some lakes, where the smelt occurs, among others in Lake IJssel, the climate change and organic pollution (eutrophication) have altered oxygenation conditions. High temperatures may lead to such short term but lethal low oxygen contents for the smelt. This is also the reason for why the populations of Coregonus species and burbots have considerably regressed. This reduction of the population is not compensated by species better adapted to higher temperatures and lower oxygen concentrations so that the general stock of fish is regressing parallel to the loss of species preferring cold temperatures. These observations are not valid for rivers where the oxygen supply is better due to running waters.[46]

Fish migration

A certain adaptability of migratory fish to the greater variation of precipitation and runoff may be expected, as they are known to profit from favourable runoff conditions for their migration and to wait for less favourable phases to pass.

Storm-water flow in smaller catchments and higher runoff in all rivers may locally and for a short time even result in more favourable conditions for fish migration.

River sections where water temperatures are too high may turn out to be a thermal barrier for migrating fish species (e.g. salmon, sea trout, allice shad) on their way from the sea to their spawning waters. They are obliged to cross the large cyprinid waters (in particular the main stream of the Rhine, the Moselle, Main) in order to reach the cooler reproduction waters (metarhithral to epipotamal). During transponder investigations in the Rhine it was found that adult salmon migrating upstream stop migrating at a water temperature around 25°C. This must be interpreted as a sign of stress; due to the interruption of migration, the period of time the returning fish has before spawning is impaired.[47] High temperatures as in the hot summer of 2003 when water temperatures in the Rhine rose to 27°C and even beyond, and nearly 28°C were measured in the tributaries (e.g. R. Sieg) for some 6 weeks during July and August caused an interruption of the migration of adult salmonids which, so far, only lasted for a short lapse of time. In future, an increased water temperature of the Rhine and its tributaries combined with anthropogenic effects (thermal discharges) could be a limiting factor for the salmon populations in the Rhine.[48]

[46] see KANGUR et al., different publications; LAMMENS (RWS), orally
[47] ICPR 2009b; BREUKELAAR (RWS), orally
[48] ICPR 2009b

Illness

High temperatures below the lethal range lead to an increased risk of mortality due to stress and infections, in particular for individuals caught by accident and put back into the river.[49]
Higher temperatures have a negative effect on the immunological system of salmon which become more predisposed for illnesses. It is expected that the Proliferative Kidney Disease, PKD which, at water temperatures above 15°C is lethal for brown trout, will increasingly appear.[50]
Similarly, the Enteric Redmouth Disease, a bacteriological illness affecting European eel is obviously being enhanced by stress due to warm temperatures and to their frequent collisions in a reduced volume of water.[51]

1.6 Invasive species

For several years and enhanced by navigation and anthropogenic uses, a considerable shift of biocoenosis caused by invasive species has been observed in the Rhine, so that biological interactions partly overlap the abiotic effects of climate change.
Mostly, when invasive species spread and immigrate, climate change is not the most important factor; for certain species it may facilitate their settlement and strongly influence their abundance.[52]
Many invasive species are tolerant to eutrophication, salinization and, in particular, higher temperatures and thus indirectly profit from climate change.
Mild winters enhance the reproduction and spreading of most invasive species preferring warm temperatures, while longer winter periods with water temperatures below 5 °C have a limiting effect.

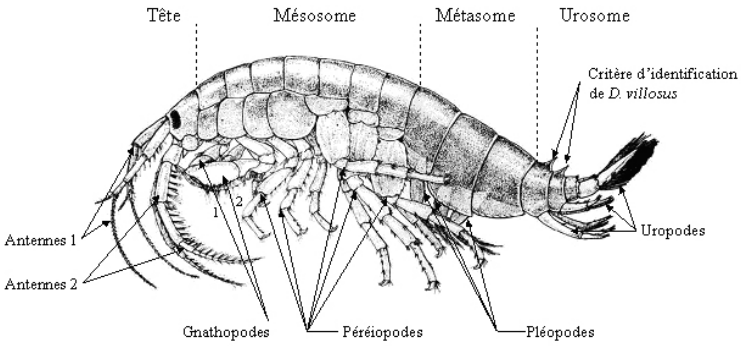


Figure 9: Invasive species *Dikerogammarus villosus* (source: Université de Lorraine)

Macrophytes

The Nuttall's waterweed, *Elodea nuttallii,* is an invasive plant, tolerant towards great changes in temperature. In Middle Europe, it has been detected since the middle of the last century and has spread very rapidly. It grows at temperatures starting with 4°C and may even, for a short time, continue to grow at water temperatures above 28°C. Thus, if water temperatures rise, this species might profit from climate change. During the past years, *E. nuttallii* has driven back the invasive Canadian waterweed (*Elodea canadensis*), which only tolerates temperatures up to 25°C. Plankton algae are also concerned by the strong concurrence of *E. nuttallii*.
The American floating marshpennywort *(Hydrocotyle ranunculoides*) prefers standing or slowly flowing and eutrophic waters, its physiological optimum ranging between 25°C and 30°C. So far, in the Rhine catchment, this species has only been detected in the R. Erft.

[49] ICPR 2009b
[50] from KLIWA 2010: WAHLI et al. 2002, STERUD et al. 2007; BURKHARDT-HOLM 2009
[51] ICPR 2004, KOOP et al. 2007
[52] STOWA 2011

When stands are dense and due to its floating and emergent leaves, this species exerts considerable competitive stress on other submerse species and may even crowd out native species.[53]
The thermophilic water fern (*Azolla filiculoides*) is also expected to spread.[54]

Macrozoobenthos

At present, the golden freshwater clam (*Corbicula fluminea*) originating from Southeast Asia is the dominant mass species in the waterways. It is sensitive to low water temperatures, which is probably the reason for why its eastward spreading is limited, while masses are e.g. found downstream of warm water discharge points. With such massive spreading, basket clams might drive back native freshwater snails. When maximum water temperatures rise up to 30 °C, the survival time of *C. fluminea* is reduced from over one month to few days and a mass die-off may be observed, such as was the case in the Rhine in 2003.[55]
Further species, which will presumably profit from higher water temperatures are the killer shrimp (*Dikerogammarus villosus*) and *Dugesia tigrina.*
The invasive New Zealand mudsnail (*Potamopyrgus antipodarum*) profits from low water levels, as it is a grazer searching for food in the soft substrate.

Fish fauna

The bighead goby (*Neogobio kessleri*) is considered to be a native species of the Danube, from where it has spread via the Main-Danube-Canal to the Rhine catchment. The species is tolerant to water temperatures from 25°C to 30°C. As it is a predator feeding on invertebrates, it is a concurrence to native fish species. Additionally, it is a predator of spawn and could thus detrimentally impact the re-colonization programmes of salmon and other fish species.
The behaviour of the round goby (*Neogobio melanostomus*, among others indigenous in the Black See) is comparable. Additionally, due to its search for food at night it might crowd out native species. A comparable impact is to be expected of the monkey goby (*Neogobius fluviatilis*), even though this species tolerating temperatures between 4°C and 20°C is likely to benefit less from climate change.
Compared to the indigenous brown trout (*Salmo trutta fario*), the rainbow trout (*Oncorhynchus mykiss*) which was introduced for commercial reasons and has been established for a long time is more tolerant with respect to higher water temperatures (10°C to 24°C) and lower oxygen content and might thus also benefit from climate change.[56]

[53] HUSSNER et al. 2010; several in KLIWA 2010
[54] MKULNV 2010
[55] KOOP et al. 2007
[56] BUWAL 2002

2. Possible impact of climate change on semi-aquatic and terrestrial habitats in the Rhine catchment

- Swamps, reeds and herbaceous vegetation (habitat type group 3)
- Greenland (habitat type group 4)
- Low moisture habitats (habitat type group 5)
- Floodplain forests / other forests of the former floodplain (habitat type groups 6 and 7)

During longer dry spells in summer, desiccation, evaporation and sinking groundwater levels may lead to increased humus and peat mineralization in humid biotopes, such as reeds, herbaceous vegetation, moist and wet meadows and floodplain forests, which will result in increased nutrient release and eutrophication. On the other hand, in dry biotopes less nutrients will be available, thus leading to oligotrophication. Both processes may result in a shift of the species composition which may be accompanied by the loss of rare species.
Numerous species in semi-aquatic habitats depend on very moist soils and / or a certain vegetation. If conditions change, they are at risk of dying out.[57]
Mediterranean species tolerating longer dry spells, among them eventually invasive species might e.g. settle and spread in low moisture habitats. Many thermophilic species (e.g. some orchids, bird species or winged insects) indigenous to the Rhine catchment but living at the northern limit of their distribution area will be likely to benefit from the rising temperatures and eventually also return to habitats lost. In this process, the Rhine valley between the Upper Rhine and the Delta Rhine plays a particular role as migration corridor from south to north.
In the greenlands, an earlier start of mowing and grazing is to be reckoned with, which will impact the different kinds of greenland.

Figure 10: Alluvial landscape near Bingen (photo: Klaus Wendling)

[57] MKUNLV 2010

3. Possible perspectives for action aimed at mitigating the detrimental impact of climate change on the Rhine ecosystem

Even though the issue of climate change is not explicitly included in the text of the EU WFD, the EU Water Directors stated in their „Common Implementation Strategy" that this issue can be integrated into several fields of action within the cyclic implementation of the WFD. Issues mentioned are the typing of water bodies, the analysis of *pressures and impacts*, the economic analysis, monitoring and programmes of measure as well as target values.[58] Based on available knowledge, programmes of measure are to be subjected to a climate check. It is to be checked, which measures enhance or weaken adaptability, which measures can be considered as *no-regret* or *win-win* solutions and which measures might prove to be more or less *robust* towards climate change regarding their effectiveness to achieve the WFD targets. As of 2015, management plans are to be *climate proofed.*[59]

The ecological and morphological quality targets of the WFD seem to be particularly apt to enhance the resilience of waters towards changing climate conditions.

According to some assessments, there is an increased risk that, due to the expected effects of climate change by 2050, water bodies which are today in the interface between the target state and the "moderate status" will fail to achieve the "good status". This risk is assessed to be less for those water bodies which, according to present criteria are in a "good status". It is expected that the effects of the expected rise in temperature on the quality of water and water bodies will be less, the less important the organic and trophic pollution of a water body (surface water, groundwater) is and the less surface waters are morphologically impacted.[60]

Thus, these impairments must be minimized in order to reduce the vulnerability of species, biocoenosis and ecosystems along the Rhine from "high" to "moderate".

The following perspectives for action are largely taken from already existing national adaptation strategies and international reports on climate change.

3.1 Enhancing ecosystems by protecting habitats and creating a habitat network connectivity

It is expected that climate change will modify the spreading of ecosystems and their species. Therefore, the protection of habitats continues to be of particular importance. If existing protection areas are maintained and extended, new ones are designated and habitats are improved, species already at risk and those which could be at risk due to climate change will be strengthened.

Protection concepts for protected and closed areas should be flexible and adaptable to new circumstances. Given the extinction of individual species or the regression of species so far not at risk, it should e.g. be possible to eventually adapt the catalogue of target species. The reference state (among others the species community) should eventually be checked.

Alien species and in particular invasive species should be observed and investigated into (see 4). However, prevention and control are particularly limited in shipping lanes (Wiesner et al. 2010, LUWG 2011).

Process protection becomes more important when considered against the background of changing environmental conditions. This includes permitting natural succession and regeneration and allowing for free species migration (see below).

---

[58] European Commission 2009, see also Reese 2011

[59] Report to the EU Water Directors: "Best practices and approaches for a climate check of the first Programmes of Measures" (11/2008)

[60] "moderate" and "strong" statement found in Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft Austria (2010)

It is well known that a varied habitat patchwork enhances biodiversity. Examples along the Rhine and its tributaries are:

- freely flowing sections, in particular those with redds for rheophile fish species;
- nature near reshaped river banks;
- oxbow lakes, bypasses and other backwaters connected to the main stream,
- brackish water sections (more nature-near transition from freshwater to salt water)

and all replacement habitats for habitats which disappeared due to river training and their qualitative improvement.

If possible, floodplains and alluvial water bodies should be reconnected to the river. Floodplains should be extensively managed as greenland or forest and not be used for cropping. These are examples of win-win-measures which not only serve purposes of biodiversity, habitat patch connectivity and the good status of waters, but also contribute to flood protection: due to flood retention on the surface and, as a matter of precaution, by reducing the damage potential and the damage risks in inundation areas.
Wherever possible, the natural dynamics of the river should again be enabled.[61]
Examples of programmes in the Rhine catchment, which take up these aspects are:

- "Flussrevitalisierungen" in Switzerland[62]
- „Trame verte et bleue“ in France[63]
- "Integriertes Rheinprogramm" in Baden-Württemberg/Germany[64]
- „Aktion Blau“ / „Aktion Blau Plus“ in Rhineland-Palatinate
- „Lebendige Gewässer“ in North Rhine Westphalia
- "More Room for the River" in the Netherlands[65]
- the "Masterplan Migratory Fish Rhine" of the ICPR in the entire Rhine catchment.[66]

Potential climate refuge areas may be identified and connected to existing areas of fish species at risk.[67]
A habitat patch connectivity will enable species, which experience that, due to rising temperatures their habitats move further north or into the mountains to migrate to areas with a more favourable climate.
This means that the planned implementation of the "Habitat patch connectivity along the Rhine"[68] giving a detailed description of the afore mentioned aspects for the main stream of the Rhine and its alluvial areas is gaining in importance, as it contributes to reducing the effects of climate change.

3.2 Mitigating the effects of higher water temperatures

If backwaters are connected to the main stream, fish living in the Rhine will locally have the possibility of withdrawing to cooler branches and lateral water bodies (e.g. disposing of more shadow). Additionally, river channel widening will enable an exchange between river water and groundwater. When water temperatures are high, such cold groundwater springs also serve as withdrawal areas for fish. In order to limit the rise in water temperature, shading shrubs should be planted or allowed to spread on the banks of small and medium-sized backwaters. However, given the width of large parts of the main channel of the Rhine and its major tributaries, this measure does not have much effect for these waters.

[61] Parteneriat für Umwelt und Klima 2011, Luxemburg
[62] see BAFU / EAWAG 2010
[63] see www.legrenelle-environnement.fr/-Trame-verte-et-bleue-.html
[64] see www.rp.baden-wuerttemberg.de/servlet/PB/menu/1188090/index.html
[65] see www.ruimtevoorderivier.nl/
[66] see ICPR 2009c
[67] Freyhof 2009 in Rabitsch et al. 2010
[68] ICPR 2006

Additional anthropogenic increase of water temperature due to thermal discharges should be limited to a minimum and must not prevent achieving the good ecological status or the good ecological potential. According to the EU directive[69], the temperature of salmonid waters (= waters, in which cold water fish / salmon and trout varieties live) may not lie above 21.5°C, that of cyprinid waters (waters, in which warm water fish /carp varieties live) may not lie above 28°C. In waters in which fish species reproduce requiring cold water for reproduction, the water temperature may not exceed 10 °C during spawning periods. These temperature limit values may be exceeded during 2 % of the time.
As, after the introduction of the Water Framework Directive, the Freshwater Fish Directive will no longer be applicable beyond 2013, it will be necessary to draft new rules for thermal discharge. Germany plans to draft new rules based on the settings of the recently adopted Regulations for Surface Waters (Oberflächengewässerverordnung (OGewV)). These would then take into account the requirements of species or species communities in certain types of rivers and during the entire lifecycle.
In individual cases, modern control mechanisms will enable to grant the respect of seasonal guidance values with an ecologically optimal effect and least possible economic losses. Should a guidance value be at risk of being exceeded, the operation of thermal power stations may be reduced or other measures aimed at reducing thermal discharge may be taken.[70] For hot spells, the exchange of information on measures taken to reduce thermal discharges and the international networking of actors concerned should be improved.

With respect to fish stocking it should be checked, whether the river section chosen is apt for the targeted species, taking into account temperature conditions even in cases, where the species formerly occurred in these sections.[71]

3.3 Mitigating soil erosion and sediment discharges due to storms and floods

The renaturation of river banks and more extensive agriculture along the river bank, e.g. by preferring greenland (permanent pastures and meadows) to cropland may reduce soil erosion and sediment discharge, particularly during storms and floods (see 2.1).
Also, reduced soil sealing may greatly contribute to this mitigation and is at the same time a flood prevention measure (*win-win*).[72]

---

[69] Directive 2006/44/EC of 6 September 2006 on the quality of fresh waters needing protection or improvement in order to support fish life Not applicable after 31.12.2013 (WFD, Art. 22)
[70] HOFFMANN et al. 2011
[71] FIBER-Newsletter 03/2010, http://www.fischereiberatung.ch/newsletter/News_10_03/index?clear_lang=1#klima
[72] Parteneriat für Umwelt und Klima 2011, Luxemburg

4. Interactions with measures users take due to climate change

For the sectors along the Rhine using water - among others energy production, industry, navigation and agriculture - climate change is expected to bring about changes which will indirectly affect the ecology of the Rhine.
Such effects may be caused by activities aimed at reducing CO2 emissions or at compensating effects of climate change.

Energy cropping

Energy cropping means intensive use of agricultural land. In reactivated floodplains it may lead to a loss of species variety and habitats and to increased input of nutrients and fine sediments into the waters. Additionally, most energy crops draw more water from the soil than other crops.

Hydropower

The construction of new transverse structures with hydropower stations will reduce river continuity and the number of freely flowing river sections. This means a particular stress for target species waters and programme waters for migratory fish and Cyclostomata which should be avoided, if possible.[73]

Flood protection

Increased technical flood protection should only be practised locally in settlement areas. From the point of view of nature protection, wherever possible, a flood protection taking into account the ecological functionality of the riparian structures and the floodplains (by flooding polders or relocating dikes) should be preferred to technical flood protection.

5. Possibilities of optimizing the data basis for biological surveillance monitoring according to WFD taking into account the effects of climate change to be expected

Navigation

As low flow situations are already occurring more often in the Rhine, navigation shows first trends to use smaller ships, in particular for transporting goods. The positive effect would be reduced lapping of waves and thus less effects on the riparian flora and fauna. A deepening of the river channel which would enable navigation even during periods of low flow will detrimentally impact the riverbed as habitat for e.g. macrozoobenthos organisms.
In a river, shallows and scours naturally develop with the current, where juvenile fish, e.g. smolt migrating downstream and young allice shad as well as upstream migrating glass eel may spend some time. During upstream spawning migration, e.g. salmon, sea trout and allice shad will search for cooler scours particularly during low water periods (in particular when occurring combined with high water temperatures) to rest. Wherever possible, it should be avoided to level and (partly) fill these structures, so as to preserve habitats and possible areas to withdraw to.

[73] ICPR 2009b

Good ecological status / good ecological potential

However, the effects of climate change must not only be taken into account with respect to measures, but also with respect to management targets. Based on the natural reference state, a "good ecological status" has been defined for each type of water body, for heavily modified waters the "good ecological potential" has been defined. If the "good ecological status" is not achieved in an unpolluted (reference) water or if, due to changed climate conditions, the achievement of the target status would require disproportionate efforts, it may be necessary to adapt these targets with great care in order to avoid reducing the ecological quality strived for.[74]
The species composition and structure of dominance along rivers may change when water temperatures rise, and move river zones further north or to higher altitudes. This is true of indigenous species and of individual invasive species which partly massively spread - above all in the navigable river sections - as a consequence of climate change. In certain places, invasive species account for more than 90% of the biomass of the Rhine. As far as "younger" invasive species from warmer regions (Black Sea, South America and Asia) are concerned, it is believed that, with increasing water temperatures, their possibilities of spreading will be further enhanced.[75]
On the long term, this dynamic development may call into question the validity of reference states for the biological quality component macrozoobenthos and eventually also for fish and macrophytes. Certain states in the Rhine catchment have already assessed the settlement potential and the ecological, economic and hygienic effects of invasive species.[76]

Climate monitoring

Due to diverse uses of great rivers and their catchment areas it is particularly difficult to differentiate between the interactions of changes driven by climate change and those driven by anthropogenic factors (navigation, discharge of cooling water, ...). A good example is the development of invasive species in waterways. Furthermore, many biological processes are also determined by the runoff pattern. This is particularly true of the development of phytoplankton and the growth of the stands of water plants in rivers.[77] Due to the biological rearrangement processes observed not only in the species composition of invertebrates but equally in the fish fauna of the Rhine, it is extremely difficult to consider individual indicator organisms. Alterations brought about by climate change will possibly only show on the long term and based on biocoenotic indications directly or indirectly impacted by the temperature or runoff regime or by the level of nutrient contents. Currently, research is done in this field.[78] It is not yet possible to make a statement on whether the results of this research will be transferable and genuinely operational within the framework of Rhine monitoring programmes. Therefore, a solid data basis comparable to that of the existing ICPR biological monitoring programme[79] is of great importance for the future development of instruments for climate monitoring.

[74] Reese 2011
[75] Regierungspräsidium Freiburg 2009
[76] BUWAL 2002, Switzerland; Partenariat für Umwelt und Klima 2011, Luxemburg
[77] KLIWA 2010
[78] e.g. Marten 2011
[79] see ICPR 2009d

6. References

- BAFU (BUNDESAMT FÜR UMWELT) (2010): Strategie der Schweiz zur Anpassung an die Klimaänderung - Zwischenbericht zuhanden des Bundesrats.
- BAFU / EAWAG 2010: River revitalization: Synergien zwischen Hochwasserschutz und Ökologie. Informationstagung des Projekts «Integrales Flussgebietsmanagement», 25. November 2010, Kulturhalle 12, Bern. www.rivermanagement.ch .
- BUNDESANSTALT FÜR GEWÄSSERKUNDE (2006): Niedrigwasserperiode 2003 in Deutschland: Ursachen - Wirkungen - Folgen. Mitteilung Nr. 27. 211.
- BUNDESMINISTERIUM FÜR LAND- UND FORSTWIRTSCHAFT, UMWELT UND WASSERWIRTSCHAFT (2010): Anpassungsstrategien an den Klimawandel für Österreichs Wasserwirtschaft. www.klimawandelanpassung.at .
- BUNDESMINISTERIUM FÜR LAND- UND FORSTWIRTSCHAFT, UMWELT UND WASSERWIRTSCHAFT (2010): Anpassungsstrategien an den Klimawandel für Österreichs Wasserwirtschaft – Kurzfassung. Vienne.
- BUNZEL-DRÜKE, Margret (2011): Wie reagieren Fische und Rundmäuler auf den Klimawandel? Natur in NRW 4/11, p. 27 – 32.
- BUWAL (2002): Einwanderung von Fischarten in die Schweiz – Rheineinzugsgebiet. Mitteilungen zur Fischerei, Nr. 72, Bern.
- BUWAL (2004): Auswirkungen des Hitzesommers 2003 auf die Gewässer. Schriftenreihe Umwelt Nr. 369, Bern. http://www.bafu.admin.ch/publikationen/publikation/00533/index.html?lang=de
- Euro-Limpacs-Projekt (2009): Definition of indicators for Climate Change effects on freshwater ecosystems. http://www.climate-and-freshwater.info.
- EUROPEAM PARLIAMENT AND EUROPEAN COUNCIL (2006): Directive 2006/44/EC of 6 September 2006 on the quality of fresh waters needing protection or improvement in order to support fish life (codified version). Official Journal of the European Union
- EUROPEAN COMMISSION (2009): River Basin Management in a changing climate. Technical Report 2009-040, Guidance document No. 24, Common Implementation Strategy for the Water Framework Directive (2000/60/EC).
- HOFFMANN, A.; KAUERMANN, G.; WINDMANN, M.; TISCHBIERECK, J.; LEONHARD, V. (2011): Temperaturmanagement in der Wupper. Natur in NRW 1/11, p. 34-40.
- HUSSNER, A., WEYER, K. VAN DE, GROSS, E., HILT, S. (2010): Eine Übersicht über die aquatischen Neophyten in Deutschland – Etablierung, Auswirkungen und Managementperspektiven. Handbuch Angewandte Limnologie – 27. Erg. Lfg. 4/10: 1-27.
- IBISCH, Ralf B. (2004): Biogene Steuerung ökologischer Systemeigenschaften des hyporheischen Interstitials der Lahn (Hessen). Forst-, Geo- und Hydrowissenschaften, Wasserwesen, Institut für Hydrobiologie, Dresden.
- ICPR (2004): Wärmebelastung der Gewässer im Sommer 2003. Zusammenfassung der nationalen Situationsberichte. 70. Plenary Assembly 8 and 9 July 2004 - Bern. ICPR report no. 142d:
- ICPR (2006): Biotopverbund am Rhein. Report & atlas. www.iksr.org – Brochures.
- IKSR (2009a): Analysis of the state of knowledge on climate changes so far and on the impact of climate change on the water regime in the Rhine watershed. ICPR report no. 174, www.iksr.org.
- ICPR (2009b): Comprehensive fish-ecological analysis including an assessment of the effectiveness of on-going and planned measures in the Rhine watershed with respect to the reintroduction of migratory fish. ICPR report no. 167 (extensive version).

- ICPR (2009c): Master Plan Migratory Fish Rhine. ICPR report no. 179, www.iksr.org.
- ICPR (2009d): Biological monitoring programme for the Rhine river 2006 / 2007, part A: Summary report on the quality components phytoplankton, macrophytes / phytobenthos, macrozoobenthos, fish. ICPR report no. 168, www.iksr.org.
- ICPR (2009e): Biological Monitoring Programme for the Rhine river 2006/2007, part II-A – Phytoplankton in the Rhine (2006-2007) ICPR report no. 169, www.iksr.org.
- ICPR (2011): Study of scenarios for the discharge regime of the Rhine - State April 2011. ICPR report no. 188, www.iksr.org.
- KANGUR A., KANGUR P., KANGUR K. & MÖLS T. (2007) The role of temperature in the population dynamics of smelt *Osmerus eperlanus eperlanus m. spirinchus* Pallas in Lake Peipsi (Estonia/Russia). Hydrobiologia 584, 433–441.
- KANGUR K., KANGUR A., KANGUR P. & LAUGASTE R. (2005) Fish kill in Lake Peipsi in summer 2002 as a synergistic effect of cyanobacterial bloom, high temperature and low water level. Proceedings of the Estonian Academy of Sciences. Biology Ecology 54, 67–80
- KANGUR A., Kangur P., Kangur K. & Möls T. Long-term effects of concurrent eutrophication and environmental extremes on the fish community of Lake Peipsi (Estonia/Russia). Submitted to Fishery Management and Ecology.
- KHALANSKI, M., CARREL, G., DESAINT, B., FRUGET, J.-F., OLIVIER, J.-M., POIREL, A., SOUCHON, Y. (2008): Étude thermique globale du Rhône - Impacts hydrobiologiques des échauffements cumulés (*Global thermal study of the Rhone - Hydrobiological impact of cumulative warming* - *with english summary*). Hydroécologie Appliquée 16: 53-108.
- KLIWA (2010): Einfluss des Klimawandels auf die Fließgewässerqualität – Literaturauswertung und erste Vulnerabilitätseinschätzung. Bericht im Auftrag des KLIWA-Konsortiums. 59 S. + Anhang.
- KLIWA (2010): Kooperationsvorhaben „Klimaveränderung und Konsequenzen für die Wasserwirtschaft" (Kooperation zwischen dem Deutschen Wetterdienst (DWD), dem Ministerium für Umwelt, Naturschutz und Verkehr Baden-Württemberg, dem Bayerischen Staatsministerium für Umwelt und Gesundheit und dem Ministerium für Umwelt, Forsten und Verbraucherschutz Rheinland-Pfalz => „Fließgewässerbiologie und Klimawandel" http://fliessgewaesserbiologie.kliwa.de/.
- KOOP, J.H.E., BERGFELD, T., KELLER, M. (2007): Einfluss von extremen Niedrigwasser-Ereignissen und gleichzeitigen "Hitzeperioden" auf die Ökologie von Bundeswasserstraßen. Hydrologie und Wasserbewirtschaftung 51, Heft 5, S. 202-209
- KÜTTEL, S., Peter, A., Wüest, A. (2002): Temperaturpräferenzen und –limiten von Fischarten Schweizerischer Fliessgewässer. Rhône Revitalisierung, Publikation Nummer 1.
- LAWA (2007): Leitlinien für ein nachhaltiges Niedrigwassermanagement – Empfehlungen, 15 p.
- LAWA (2010): Strategiepapier „Auswirkungen des Klimawandels auf die Wasserwirtschaft" - Bestandsaufnahme und Handlungsempfehlungen. 36 p.
- LUWG (Hg.) (2011): Neubürger in Rhein und Mosel. – Infoblatt Gewässerschutz 01/11.
- MARTEN, M. (2011): Makrozoobenthos und Klimawandel – reichen unsere Monitoringsysteme aus? Erweiterte Zusammenfassung der Jahrestagung der Deutschen Gesellschaft für Limnologie, Bayreuth 2010. p. 375-380.
- MINISTERE DE L'ECOLOGIE, DES TRANSPORTS ET DU LOGEMENT (2011): Plan national d'adaptation de la France aux effets du changement climatique 2011 – 2015. www.developpement-durable.gouv.fr .

- Ministerie van Infrastructuur en Milieu, Ministerie van Economische Zaken, Landbouw en Innovatie (2010): Deltaprogramma / Nationaal waterplan 2009 - 2015. www.rijksoverheid.nl
- MKULNV (Ministerium für Klimaschutz, Umwelt, Landwirtschaft, Natur- und Verbraucherschutz NRW) (2010): Natur im Wandel: Auswirkungen des Klimawandels auf die biologische Vielfalt in Nordrhein-Westfalen. Düsseldorf. www.umwelt.nrw.de .
- Moss, B., Kosten, S., Meerhoff, M., Battarbee, R.W., Jeppesen, E., Mazzeo, N., Havens, K., Lacerot, G., Zhengwen, L., De Meester, L., Paerl, H. & Scheffer, M. (2011): Allied attack: climate change and nutrient pollution. Inland waters 1 (2011), pp. 101-105
- Notter, B., Staub, E. (2009) Lebensraum der Bachforelle um 2050. GWA Gas, Wasser, Abwasser. No. 1/2009: 39-44.
- Partenariat für Umwelt und Klima (2011): « Paquet Climat » (6 mai 2011), Synthesedokument der *groupe de pilotage* für eine nationale Nachhaltigskeitsstrategie, Luxemburg. www.developpement-durable-infrastructures.public.lu .
- Pont, D. (coordinator) (2003): Programme GICC – AQUABIO. Conséquences potentielles du changement climatique sur les biocénoses aquatiques et riveraines francaises - Rapport final. CNRS, Université de Lyon
- Rabitsch, W., Winter, M., Kühn, E., Kühn, I., Götzl, M., Essl, F. und Gruttke, H. (2010): Auswirkungen des rezenten Klimawandels auf die Fauna in Deutschland. BfN-Heft Nr. 98, Bonn.
- Reese, M. (2011): Die Anpassungen an den Klimawandel im Bewirtschaftungssystem der Wasserrahmenrichtlinie. Zeitschrift für Wasserrecht, Heft 2/2011, pp 61-82.
- Regierungspräsidium Freiburg (2009): Bewirtschaftungsplan Hochrhein (Baden-Württemberg) gemäß EG-WRRL. Freiburg.
- Sterud, E., Forseth, T., Ugedal, O. Poppe, T. T., Joergensen, A., Bruheim, T., Fjeldstad, H.-P., Mo, T. A. (2007): Severe mortality in wild Atlantic salmon *Salmo salar* due to proliferative kidney disease (PKD) caused by *Tetracapsuloides bryosalmonae* (Myxozoa). Disease of Aquatic Organisms, 77: 191-198.
- Stowa (Stichting toegepast onderzoek waterbeheer) 2011: Een frisse blik op warmer water. Over de invloed van klimaatverandering op de aquatische ecologie en hoe je de negatieve effecten kunt tegengaan. Stowa-Bericht Nr. 2011-20 im Auftrag von Rijkswaterstaat waterdienst. Amersfoort.
- Terra Incognita Stedenbouw en Landschapsarchitectuur im Auftrag des Ministerie van Infrastructuur, Milieu, Economische Zaken, Landbouw en Innovatie (2009): Handreikingen Ruimtelijke Kwaliteit Rijn / Waal / IJssel. www.ruimtevoorderivier.nl.
- Tissot, L., Souchon, Y. (2010): Synthèse des tolérances thermiques des principales espèces de poissons des rivières et fleuves de plaine de l'ouest européen (*Synthesis on thermal tolerances of the principal freshwater fish species of large Western Europe rivers*). Hydroécologie Appliqué, Band 17, S. 17-76.
- UNECE (2009): Guidance on water and adaptation to climate change.
- Wahli, T., Knuesel, R., Bernet, D., Segner, H., Pugovkin, D., Burkhardt-Holm, P., Escher, M., Schmidt-Posthaus, H. (2002): Proliferative kidney disease in Switzerland: current state of knowledge. Journal of Fish Disease, 25: 491-500.
- Wiesner, C.; Wolter, C., Rabitsch, W. & S. Nehring (2010): Gebietsfremde Fische in Deutschland und Österreich. BfN-Skripten 279, 192 p.
- WWF Deutschland (2009): Die mögliche Wirkung des Klimawandels auf Wassertemperaturen von Fließgewässern. Frankfurt am Main.
- Zebisch, M., Grothmann, T., Schröter, D., Haße, C., Fritsch, U., Cramer, W. (2005): Klimawandel in Deutschland – Vulnerabilität und Anpassungsstrategien

klimasensitiver Systeme. Kurzfassung. Potsdam-Institut für Klimafolgenforschung im Auftrag des Umweltbundesamtes (UBA), UFOPLAN 201 41 253.

Annex

Table 1 : Forecast impact of a rise in temperature on fish and Cyclostomata in the Rhine area and in other rivers in Middle Europe

Explanations: **EU Eel Regulation**: Council Regulation (EC) no. 1100/2007 of 18 September 2007 establishing measures for the recovery of the stock of European eel; **Habitats Directive** Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora; **CITES:** Convention on International Trade in Endangered Species of Wild Fauna and Flora

Fish species Scientific Name	Fish species English name	Prognosis	State of protection, origin	Remarks Tolerated temperatures / extreme values (and optimum)	Source
Abramis brama	Bream	Increase		Spawn 8-28°C (18-23°C) Larvae 17.5-19.5°C Juvenile 14-34°C Adult 8-28°C / 35°C (23-26°C) Spawning period 8-23°C / 28°C (12-20°C) Extension of the habitat in rivers of the midlands and the Alps	KÜTTEL et al. 2002, several in TISSON & SOUCHON 2010
Alburnus alburnus	Bleak	Regression		Regression predicted in French rivers at a temperature rise of 2°C	PONT & CRANE in PONT 2003
		Increase		May tolerate water temperatures > 20°C; strong rise in stock predicted Spawn 21-27°C Larvae 22.5°C Adult 20-38°C / 35°C (20-30°C) Spawning period 14-28°C	BUNZEL-DRÜKE 2011, MKUNLV 2010, several in TISSON & SOUCHON 2010
Alburnoides bipunctatus	Sprilin	Regression		Due to a presumably restricted extension of the grayling region Spawn 16.3-19.3°C Larvae 12-24°C Adult 1.9-23.9°C Spawning period 12-25°C	BUNZEL-DRÜKE 2011, several in TISSON & SOUCHON 2010
Alosa alosa	Allice shad	Increase	Habitats Directive, annex II & V	Due to the reintroduction project, not due to climate change	BUNZEL-DRÜKE 2011

Fish species Scientific Name	**Fish species English name**	**Prognosis**	**State of protection, origin**	**Remarks Tolerated temperatures / extreme values (and optimum)**	**Source**
Anguilla anguilla	Eel	Regression	CITES Annex II, EU Eel regulation	Juvenile (glass eel): > 15°C Adults: > 0/ 8°C, < 30 / 39°C (8-29°C / 22-23°C) At risk of stress and illness during hot spells; Enteric Redmouth Disease is being enhanced	Küttel et al. 2002, ICPR 2004
				Unchanged	Bunzel-Drüke 2011
Aspius aspius	Asp	Increase	Habitats Directive, annex II & V		Bunzel-Drüke 2011
Barbus barbus	Barbel	Regression	Habitats Directive, annex V	At a temperature rise of 2°C	Pont 2003
		Increase		Spawn 12.1-21°C (16-19°C) Larvae 14.8-18.9°C (18.5°C) Juvenile 7-27°C Adult 7-30°C Spawning period 8- 20 °C / 29°C Extension of the habitat in rivers of the midlands and the Alps	Küttel et al. 2002
Barbatula barbatula	Loach	Increase		Tolerates water temperatures > 20°C	MKUNLV 2010, Bunzel-Drüke 2011
		Regression		Regression predicted in French rivers at a temperature rise of 2°C	Pont 2003
Blicca bjoerkna	Silver bream	Increase		Spawn 15-20°C Adult 15-25°C Spawning period 9.6-29°C	Bunzel-Drüke 2011, several in Tisson & Souchon 2010
Carassius carassius	Crucian carp	Regression		Due to desiccation of smaller standing waters and ditches	Bunzel-Drüke 2011
Chondrostoma nasus	Nase	Regression		Spawn: 8.6-19°C Larvae 10-28°C (15°C) Juvenile 7-27°C Adult 4-24°C Spawning period 6-16.2°C	Küttel et al. 2002, Pont 2003, several in Tisson & Souchon 2010

Fish species Scientific Name	**Fish species English name**	**Prognosis**	**State of protection, origin**	**Remarks** **Tolerated temperatures / extreme values (and optimum)**	**Source**
Cottus gobio	Bullhead	Regression	Habitats Directive, annex II	Juvenile <28°C (5-27°C) Adult <16 / 20°C (10-15°C) Spawning period 7-14°C	BUNZEL-DRÜKE 2011, KÜTTEL et al. 2002, PONT 2003
Cyprinus carpio	Carp	Increase	Widespread due to stocking measures	Spawning period: > 17°C, Juvenile: 16-25°C. Great reproduction success after flooding of terrestrial vegetation in Mai/June	BALON 1995, STEFFENS 2008 among others in BUNZEL-DRÜKE 2011
Esox lucius	Pike			Spawn 2-23°C (8-15°C) Larvae 12.3-21°C Juvenile 9-28°C (26°C) Adult 10-30 / 34°C (20-26°C) Spawning period 0-20°C (7-17°C)	EUROLIMPACS; KÜTTEL et al. 2002, several in TISSON & SOUCHON 2010
Gasterosteus aculeatus	Three-spined stickleback	(Regression)		Highly adaptable pioneer species which might profit from periodical drying out of waters, but little concurrence; avoids temperatures above 20°C	BUNZEL-DRÜKE 2011, KÜTTEL et al. 2002
Gobio gobio	Goby			Spawn 16-20°C Larvae 20.5°C Juvenile 7-27°C Adult 5-30.9 / 37°C (15-27°C) Spawning period 12-17°C	KÜTTEL et al. 2002, several in TISSON & SOUCHON 2010
Gymnocephalus cernuus	Ruffe	Regression		Spawn 9-21°C Larvae 16.5-30°C Juvenile 7-24.8°C Spawning period 2-18°C	Bunzel-Drüke 2011, several in TISSON & SOUCHON 2010
Lampetra planeri	River lamprey	Regression	Habitats Directive, annex II	Regression predicted in French rivers at a temperature rise of 2°C	Bunzel-Drüke 2011, Pont 2003
Lepomis gibbosus	Sunfish	Regression		Allochtone species Spawn 22.5°C Larvae 20.4-23.5°C Juvenile 13-28°C (31.5°C) Adult 11.9-40°C (24.2-30°C) Spawning period 20-25°C (22.5°C)	Pont 2003, several in TISSON & SOUCHON 2010

Fish species Scientific Name	**Fish species English name**	**Prognosis**	**State of protection, origin**	**Remarks Tolerated temperatures / extreme values (and optimum)**	**Source**
Leucaspius delineatus	Moderlieschen	Regression		Due to drying-out of smaller standing waters and ditches	Bunzel-Drüke 2011
Leuciscus (Squalius) cephalus	Chub	Increase		Spawn 12.3-30°C (17-23°C) Larvae 14-25°C (17.5-25°C) Juvenile 7-24°C Adult 7-27°C / 34°C (8-25°C) Spawning period 14-20°C Upstream extension	Bunzel-Drüke 2011, Küttel et al. 2002, Pont 2003, several in Tisson & Souchon 2010
Leuciscus leuciscus	Dace	Regression		Spawn 4-23°C (6-15°C) Larvae 16-25°C (12.3-17.5°C) Juvenile & Adult 10-20°C Spawning period 5-16.5°C (8-9°C)	Küttel et al. 2002, Pont 2003, several in Tisson & Souchon 2010
Lota lota	Burbot	Regression		Considerable regression expected, among others in Lake IJssel due to periodic lack of oxygen	Bunzel-Drüke 2011, Lammens 2012, orally
Misgurnus fossilis	Weather fish	Regression	Habitats Directive, annex II	Due to drying-out of smaller standing waters and ditches	Bunzel-Drüke 2011
Neogobio kessleri	Bighead Goby	Increase	Alien species	From the Black Sea region 25°C-30°C, concurrent and predator for indigenous species and their spawn, including salmon	KLIWA 2010
Neogobio melanostomus	Round goby	Increase	Alien species	See bighead goby	KLIWA 2010
Neogobio fluviatilis	Monkey goby	./.	Alien species	Due to its comparatively low temperature tolerance (4°C to 20°C) it is expected to profit less from climate change than other goby species	KLIWA 2010
Oncorhynchus mykiss	Rainbow trout	Increase	Species introduced for purposes of use	Spawn < 20 / 18°C (8-11°C) Juvenile 26°C (17°C) Adult < 26°C (16-19°C) Species introduced for commercial purposes; more tolerant to higher water temperatures than brook trout; may crowd out brook trout	Bunzel-Drüke 2011, KLIWA 2010

Fish species Scientific Name	**Fish species English name**	**Prognosis**	**State of protection, origin**	**Remarks** Tolerated temperatures / extreme values (and optimum)	**Source**
Osperus eperlanus	Smelt	Regression		A lack of oxygen in lakes (e.g. Lake IJssel) might be lethal for smelt.	Lammens 2012, orally
		./.		No change in stock forecast for NRW	Bunzel-Drüke 2011
Perca fluviatilis	Perch	Increase?		Spawn 5-21°C Larvae 5-30°C (11-15.5°C) Juvenile > 8°C / < 36°C (25°C) Adult 10-31°C / 36.2°C Spawning period 5-19°C	several in Tisson & Souchon 2010
Phoxinus phoxinus	Minnow	Regression		Due to a presumably restricted extension of the grayling region	Bunzel-Drüke 2011
Pseudorasbora parva	Stone moroko	Regression	Alien species	Due to drying-out of smaller standing waters and ditches	Bunzel-Drüke 2011
Pungitius pungitius	Ninespine stickleback	Regression		Due to drying-out of smaller standing waters and ditches	Bunzel-Drüke 2011
Rhodeus amarus	Bitterling	Increase	Habitats Directive, annex II	Adult 12-30°C / 37°C (2325°C) Spawning period 12-22°C	Bunzel-Drüke 2011, several in Tisson & Souchon 2010
Rutilus rutilus	Roach			Spawn 5-27°C (12-20°C) Larvae 17.5°C Juvenile 7-21°C Adult 12-30°C / 36°C (20-25°C) Spawning period 5-22°C (8-19°C)	Küttel et al. 2002, several in Tisson & Souchon 2010
Salmo trutta fario (& Salmo trutta trutta)	Brook trout (& Sea trout)	Regression		Spawn 0-13°C (7-12°C) Juvenile < 23 / 28°C (6-14°C / 8-13°C) Adult < 25 / 28°C (4-19°C / 14-17°C) Spawning period 1-10°C (6°C) Regression at least probable in southern Europe. Further north eventual advantages due to survival of the spawn during mild winters. Might die out in places where no migration to higher regions is possible.	Bunzel-Drüke 2011, Eurolimpacs, MKUNLV 2010, Notter & Staub 2009, Pont 2003, Webb & Walsh 2004 in WWF 2009
Salmo trutta lacustris	Lake trout			Adult <25 / 30°C (16-23°C) Spawning period 1-9°C	Küttel et al. 2002

Fish species Scientific Name	**Fish species English name**	**Prognosis**	**State of protection, origin**	**Remarks** Tolerated temperatures / extreme values (and optimum)	**Source**
Salmo salar	Salmon	Regression	Habitats Directive annex II & annex V (in freshwater)	Spawn < 16°C (4-11°C) Juvenile < 17°C (< 10°C) Alevins < 23°C One summer old (2-3 months old) < 28.7-29.2°C Parr (0+ to 1+)< 27,4-32,8°C Downstream migrating smolt < 19°C (7-14.3°C) Adult < 28-32°C (9-17°C) Spawning period < 10°C (6-8°C) Interruption of migration at approx. 25°C A slight rise in temperature in winter has a positive effect on the development of spawn. Intermediate class of risk within an analysis of climate sensitivity	Bunzel-Drüke 2011, Küttel et al. 2002 Rabitsch et al. 2010
Salvelinus fontinalis	Brook trout	Regression		Lives in the epirhithral and the metarhithral	Bunzel-Drüke 2011
Sander (Stizostedion) lucioperca	Pikeperch	?		Spawn 3-24°C /25°C Larvae 13.1-26°C (13.1-15.5°C) Juvenile 27.3-30°C Adult < 33,3°C Spawning period 3-26°C	several in Tisson & Souchon 2010
Silurus glanis	Wels catfish	Increase		Spawn 22-25°C Juvenile > 13°C (24.5°C) Adult 7-33°C / 35°C (27°C) Spawning period 17-25°C	Bunzel-Drüke 2011, Stowa 2011, several in Tisson & Souchon 2010
Thymallus thymallus	Grayling	Regression	Habitats Directive, annex V	Spawn 6-13 / 14°C (9°C) Adult <18 / 24°C (15-17°C) Spawning period < 15°C (6-10°C) Requires cool waters of a certain width. If this is not available in higher altitude or if it cannot be reached, the species might disappear altogether. Intermediate class of risk within an analysis of climate sensitivity	Bunzel-Drüke 2011, Küttel et al. 2002, Pont 2003, Notter & Staub 2009; Rabitsch et al. 2010
Consideration of all fish species occurring		Increase 26%; Regression: 21%		All in all - and partly due to other aspects than climate change - about one third of the fish and cyclostomata occurring in the German Land North Rhine-Westphalia are detrimentally impacted.	MKUNLV 2010

Annex 2

Legend for Figure 2: Abiotic factors and groups of organisms in the lower section of a river liable to be impacted by climate change
Source: http://fliessgewaesserbiologie.kliwa.de

German	English
Klimawandel	**Climate change**
Direkte Einflüsse	**Direct impacts**
Strahlung	Radiation
Lufttemperatur	Air temperature
Niederschlag: Extreme, Saisonalität	Precipitation: Extreme, seasonal
Indirekte Einflüsse	**Indirect impacts**
Landnutzung	Land use
Auen	Floodplains
Grundwasser	Groundwater
Mineralisierung / Verwitterung	Mineralisation / Decay
Faktoren, die den Klimawandel imitieren	**Factors imitating climate change**
Gletscherwasserabfluss	Runoff from glaciers
Restwasser	Residual water
Wärmeeinleitungen	Thermal discharge
Abiotische Veränderungen	**Abiotic changes**
Hydrologie	**Hydrology**
Abflussregime	Runoff regime
Hochwasser-Abfluss (Q)	Flood runoff (Q)
Hochwasser-Zeitpunkt	Time of flood
Niedrigwasser-Abfluss (Q)	Low water runoff (Q)
Niedrigwasser-Zeitpunkt	Time of low water
Mittlerer Abfluss (Q) (Volumen)	Average runoff (Q) (volume)
Austrocknung	Drying-out
Verdunstung	Evaporation
Schneeschmelze / Schneedecke	Snow melt / snow cover
Morphologie	**Morphology**
Beschattung	Shading
Randstreifen	Green belts
Mesohabitate Aue	Mesohabitats floodplain
Mesohabitate Fließgewässer	Mesohabitats watercourse
Mikrohabitate Fließgewässer	Microhabitats watercourse
Interstitial	Interstitial space
Feinsedimenteintrag	Input of fine sediments
Geschiebetransport	Bedload discharge
Physiko-Chemie	**Physico-chemical**
Wassertemperatur	Water temperature
Delta Temperatur (= Amplitude)	Water temperature (= amplitude)
Sauerstoff	Oxygen
pH	pH
Chlorid	Chloride
Nährstoffe	Nutrients
Leitfähigkeit	Conductivity
Versauerung	Acidification
Saprobie	Saprobity
Toxische Substanzen	Toxic substances

German	English
Biologische Veränderungen	**Biological changes**
Organismen	**Organisms**
Phytoplankton	Phytoplankton
Phytobenthos / Makrophyten	Phytobenthos / Macrophytes
Makrozoobenthos	Macrozoobenthos
Fische	Fish
Andere Organismen	Other organisms
Neobiota	Invasive species
Bewertungsverfahren / Metrics	Assessment procedures / Metrics
Indikatorarten	Indicator species