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# Ichthyofauna in the upper Rhine River close to the city of Karlsruhe as determined by the analysis of fish impingement by cooling-water intakes of a power plant

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## Abstract

The fish fauna in the northern part of the upper river Rhine close to the city of Karlsruhe (Germany) was analyzed by collecting fish from the cooling-water intake of a power plant (impingement method) between 1989 and 2001. With this method a total of 36 fish species were recorded. The results were compared between the years as well as with other studies on the fish fauna in this area. Particularly with regard to the physical structure of the river bed and banks, the pre-technical situation of the river Rhine has not been restored. However, the number of fish species has been augmented since the 1970s mainly due to improvements in the water quality and almost all autochthonous fish species are present again. Altogether only three introduced fish species (*Sander lucioperca* L., *Lepomis gibbosus* L., and *Carassius auratus gibelio* were found in this study. Among the long-distance migrating species three freshwater spawners (*Lampetra fluviatilis*, *Petromyzon marinus* and *Salmo trutta trutta*) were detected in addition to the catadromous eel. The eudominant fish species varied between years, i.e. the European eel, *Anguilla anguilla*, was the eudominant species 1989, whereas this species occurred in much lower numbers during the subsequent sampling campaigns. This clearly indicates that the high dominance of eels is mainly caused by stocking activities in the upper Rhine. In the following years roach, *Rutilus rutilus* was the eudominant fish species. Overall a positive development of the fish fauna in the upper Rhine over the last 15 years could be observed in terms of fish populations as well as in terms of species richness.


***Keywords:*** Fish fauna; Upper river Rhine; Fish impingement; Power plant

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## Introduction

The River Rhine has its source in the Swiss Alps and flows into the North Sea (Fig. 1). With a total length of 1236 km and a catchment area of 189,510 km$^2$ it is one of Europe's largest river systems (Tittizer & Krebs 1996). Its appearance has changed dramatically over the last 200 years due to anthropogenic influences resulting in ecological degradation (Köhler & Lelek 1992; Tittizer & Krebs 1996). Especially the straightening of the river by the civil engineer Tulla in the 19th century changed the natural flow of the river completely (Lelek 1989). This led to a loss of most of the ecologically valuable flood plains around the southern part of the river. Due to the changes in the physical structure of the river bed and banks, and the massive inflow of rural and industrial waste water, the diversity of the fish fauna in the River Rhine hit rock bottom in the early 1970s. Of the 45 species described for the upper Rhine, only 23 species were left (Lelek 1976). In particular, anadromous fish species and the cyclostomata were negatively affected (Lelek & Köhler 1989; Roth 1988). Environmental requirements enforced on industry and the building of several sewage treatment plants initiated an ecological recovery for the river system. This ecological recovery was set back in 1986 when toxic fire runoff water ran into the river after an accident at the Sandoz chemical plant in Switzerland. The macrozoobenthos was eliminated over large stretches of the upper River Rhine (Marten 1990). Accordingly, expert groups worried about the fish fauna at that time. This was the reason why the International Commission for the Protection of the River Rhine (ICPR) was founded, aiming at a sustainable development of the entire Rhine River ecosystem. Since 1986, several investigations have been carried out to assess the ichthyofauna in the northern part of the upper Rhine (Berg, Blank, & Strubelt 1989; Hoffmann 1995; IKSR 1997, 2002; Köhler & Lelek 1992; Korte 1999, 2001). The most common method used for analyzing the fish fauna in large river systems is electric-fishing (Korte 1999; IKSR 2002; Meador 2003, 2005). However, with this method only fish from the banks and areas with low current speeds are accessible. An alternative method to gain information on the fish fauna in a large river is to investigate the fish impingement at cooling-water intakes of big power plants. Data on the fish fauna in the Rhine obtained with this method are available from Hadderingh, Van Aerssen, Groeneveld, Jenner, & Van der Stoep (1983) who analyzed fish impingement at power stations along the lower Rhine in the Netherlands.

The aim of the present study was to gain qualitative and, as far as possible, quantitative data on the fish fauna in the northern upper Rhine with the impingement method. Therefore the fish fauna was analyzed three times with this method during the last 13 years at the cooling-water inlet of the Rheinhafendampfkraftwerk Karlsruhe (RDK). The results between the different years are presented and compared with other investigations on the ichthyofauna in the same area. Furthermore, the differences obtained with a shorter sampling period during the last survey are discussed as well as advantages and disadvantages of the applied method.

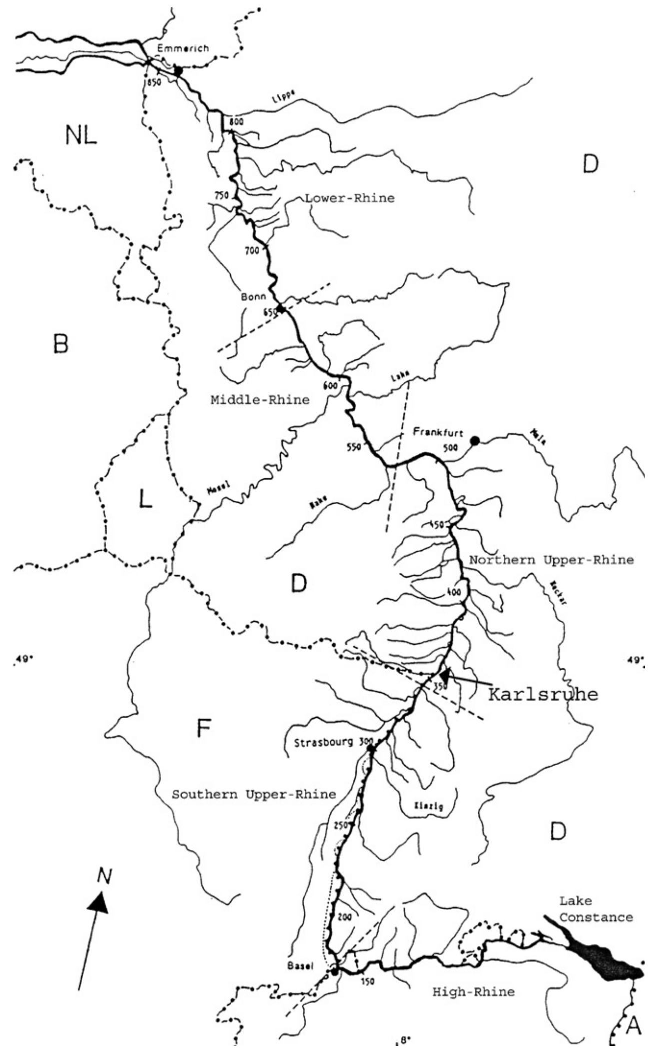


**Fig. 1.** Map of the river Rhine and location of the sampling site Karlsruhe.

## Methods

The RDK is a power plant operating with fossil energy reserves (coal, petroleum) and has a total power of 950 MW. Located close to the river Rhine, at river km 359.4 (Fig. 1), it uses 12.4 m$^3$/s cooling water in normal operating mode. Two water pipelines with a diameter of

2.5 m pipe the water from the Rhine to the plant. The intake is 4.8 m under the mean water level and is protected by a trash rack, consisting of fixed bars, to prevent large debris from entering the system and to protect the power plant equipment such as pumps and condenser from damage or clogging. The water reaches a second and third grid where the distance between the bars measures 40 and 12 mm, respectively. The third grid is cleaned automatically as a function of the dynamic pressure. The restrained waste which also contains fish falls onto a conveyer band from where the fish can be collected.

A first survey was conducted from June 1989 until June 1990. The fish were collected during 24 h whereas the second grid, containing only sporadically fish, was only checked once a day. The third grid was cleaned every 2 h and the fish falling onto the conveyer band were collected by the maintenance staff of the power plant, labeled and frozen. Afterwards the fish were identified to species level in the laboratory.

The second survey lasted from March 1995 to February1996. The fish were collected every day by the maintenance staff between 14:00 and 20:00 h. Additionally, all rare species, for instance cyclostomata, were collected during the whole day. Again most of the fish were frozen and determined later to species level in the laboratory. Due to maintenance works no sampling was possible between 18.05.1995 and 30.09.1995.

In 2001 the water inlet of the power plant was sampled for 24 h during 6 weeks from the beginning of November to mid-December. Again like in the first survey the third grid was cleaned every 2 h and the fish were collected by the maintenance staff. Live fish were placed into an aerated plastic tank containing Rhine-water. Every day all dead and live fish were brought to the laboratory, identified to species and counted.

Due to identification problems of bream (*Abramis brama* L.) and white bream (*Blicca bjoerkna* L.) in 2001 both species are referred to as bream during the three surveys.

Soerensen's Index (Soerensen 1948) was used to compare the species composition between the different years and between the months November and December for all 3 years. Dominance structure in the community was described according to the logarithmic classification of Engelmann (1978).

As the sampling method varied between the different years, the frequency of all fish species in the different years is always expressed in percent (see Tables 1 and 4). However the absolute numbers of the respective fish species are also given. To compare the impingement rate between the years, the total number of fish caught in the respective year was divided by the total sampling time (in hours) in that year. The result is expressed as average impingement rate in: fish/h.

## Results

In 1989/90 a total of 32,850 fish belonging to 36 species were collected at the water inlet of the RDK (Table 1). Eel (*Anguilla anguilla*) was the only eudominant fish species with a proportion of 41.6%. Dominant species were perch (*Perca fluviatilis*, 13.7%), roach (*Rutilus rutilus*, 13.2%) and bream (*A. brama*, *B. bjoerkna*, together 20.5%). With a proportion of 3.9% ruffe (*Gymnocephalus cernuus*) was the only subdominant fish species. All other fish species were present with a proportion of less than 3.2% (see Table 1). Most of the fish species (25) were only sporadically present (Tables 1 and 2). Four long distance migrating species were detected during this first survey. The catadromous eel and three freshwater spawners (*Lampetra fluviatilis*, *Petromyzon marinus* and *Salmo trutta trutta*). Except for the eel with 13,677 individuals all other three migrating species were only present with few individuals (Table 1). The average impingement rate turned out to reach 3.5 fish per hour regarding the whole year. Regarding only the months November and December a total of 26 fish species were observed (Table 4) being collected with an average impingement rate of 2.8 fish/h. The proportion of the fish species observed during the whole year and during the months of November and December revealed only slight differences. For instance the proportion of eels was with 28% lower during the winter months as compared to the whole year (41%). The high similarity in the composition of the fish community between the whole year 1989/90 and the months November/December 1989 is also reflected by the high Soerensen Index reaching 81% (see Table 3), 100% indicates complete similarity.

In the second sampling period in 1995/96, 2107 fish were collected belonging to 27 species (Table 1). The much lower total number of fish compared to 1989/90 can partly be explained by the different sampling method. In 1995/96 fish were only sampled 6 h a day, compared to 24 h a day in 1989/90. However the calculation of the average fish impingement per hour revealed only a rate of 1.1 for 1995/96. The only eudominant species was roach (35.5%) followed by perch (22.2%) and bream (*A. brama*, *B. bjoerkna*, together 14%) as dominant species. The absolute number and the proportion of all other species are listed in Table 1. Among the migrating species again the two cyclostomata and the eel, although in much lower numbers, were present whereas *S. trutta trutta* was not observed. Considering only the months November and December in 1995 a total of 18 species were observed (Table 4). Like in the first survey also in 1995/96, there were only slight differences between the whole year and the months November/December. The similarity of the fish fauna between the whole year 1995/96 and November/December 1995 was calculated to be

**Table 1.** Number and proportion of fish species as determined by fish impingement in the Rheinhafendampfkraftwerk Karlsruhe (RDK) during the years 1989/90, 1996/96 and 2001

| | 1989/90 | | 1995/96 | | 2001 | |
|---|---|---|---|---|---|---|
| | Number | Proportion | Number | Proportion | Number | Proportion |
| *Abramis brama/Blicca bjoerkna* | 6739 | 20.51 | 295 | 14.00 | 529 | 19.19 |
| *Alburnus alburnus* | 590 | 1.80 | 20 | 0.95 | 210 | 7.62 |
| *Anguilla anguilla* | 13677 | 41.63 | 43 | 2.04 | 19 | 0.69 |
| *Aspius aspius* | 11 | 0.03 | 2 | 0.09 | 1 | 0.04 |
| *Barbartula barbartula* | 3 | 0.01 | 8 | 0.38 | | |
| *Barbus barbus* | 466 | 1.42 | 102 | 4.84 | 10 | 0.36 |
| *Carassius gibelio* | 9 | 0.03 | 3 | 0.14 | | |
| *Chondrostoma nasus* | 49 | 0.15 | 19 | 0.90 | | |
| *Cobitis taenia* | 5 | 0.02 | 3 | 0.14 | | |
| *Coregonus spp.* | 6 | 0.02 | | | | |
| *Cottus gobio* | 1 | 0.00 | | | 56 | 2.03 |
| *Ctenopharyngodon idella* | 5 | 0.02 | 1 | 0.05 | | |
| *Cyprinus carpio* | 16 | 0.05 | | | 1 | 0.04 |
| *Esox lucius* | 55 | 0.17 | 12 | 0.57 | 6 | 0.22 |
| *Gasterosteus aculeatus* | 1 | 0.00 | 1 | 0.05 | 9 | 0.33 |
| *Gobio gobio* | 171 | 0.52 | 13 | 0.62 | 29 | 1.05 |
| *Gymnocephalus cernuus* | 1269 | 3.86 | 205 | 9.73 | 148 | 5.37 |
| *Lampetra fluviatilis* | 2 | 0.01 | 75 | 3.56 | 5 | 0.18 |
| *Lampetra planeri* | 8 | 0.02 | 7 | 0.33 | 19 | 0.69 |
| *Lepomis gibbosus* | 261 | 0.79 | 3 | 0.14 | 3 | 0.11 |
| *Leuciscus cephalus* | 37 | 0.11 | 6 | 0.28 | 23 | 0.83 |
| *Leuciscus idus* | 1 | 0.00 | | | | |
| *Leuciscus leuciscus* | 47 | 0.14 | 8 | 0.38 | 2 | 0.07 |
| *Lota lota* | 71 | 0.22 | 24 | 1.14 | 4 | 0.15 |
| *Misgurnus fossilis* | 1 | 0.00 | | | | |
| *Perca fluviatilis* | 4493 | 13.68 | 467 | 22.16 | 365 | 13.24 |
| *Petromyzon marinus* | 6 | 0.02 | 4 | 0.19 | 1 | 0.04 |
| *Rutilus rutilus* | 4333 | 13.19 | 748 | 35.50 | 1308 | 47.44 |
| *Salmo trutta f. fario* | 7 | 0.02 | 3 | 0.14 | | |
| *Salmo trutta trutta* | 3 | 0.01 | | | | |
| *Scardinius erythrophthalmus* | 5 | 0.02 | | | 1 | 0.04 |
| *Siluris glanis* | 1 | 0.00 | 7 | 0.33 | 1 | 0.04 |
| *Sander lucioperca* | 430 | 1.31 | 28 | 1.33 | 6 | 0.22 |
| *Thymalus thymalus* | 1 | 0.00 | | | | |
| *Tinca tinca* | 70 | 0.21 | | | 1 | 0.04 |
| Total | 32,850 | 100 | 2107 | 100 | 2757 | 100 |
| Number of species | 36 | | 27 | | 25 | |

**Table 2.** Dominance classes of fish sampled during the whole year 1989/90 and 1995/96 and during the months November and December for all three surveys

| Dominance classes | 1989/90 | | 1995/96 | | 2001 |
|---|---|---|---|---|---|
| | Whole year | Nov./Dec. 1989 | Whole year | Nov./Dec. 1995 | Nov./Dec. 2001 |
| Eudominant (>32%) | 1 | 0 | 1 | 1 | 1 |
| Dominant (10.0–31.9%) | 3 | 4 | 2 | 1 | 2 |
| Subdominant (3.2–9.9%) | 1 | 3 | 3 | 4 | 2 |
| Recedent (1–3.1%) | 3 | 1 | 3 | 2 | 2 |
| Subrecedent (0.32–0.99) | 2 | 5 | 8 | 5 | 5 |
| Sporadic (<0.32%) | 25 | 12 | 9 | 4 | 12 |
| Total species number | 36 | 26 | 27 | 18 | 25 |

**Table 3.** Percentage of species similarity expressed as Soerenson Index between the different years

| Similarity between | Soerensen Index (%) |
|---|---|
| 1989/90–1995/96 | 86 |
| 1989/90–Nov./Dec. '01 | 82 |
| 1995/96–Nov./Dec. '01 | 81 |
| Nov./Dec. '89–Nov./Dec. '95 | 77 |
| Nov./Dec. '89–Nov./Dec. '01 | 71 |
| Nov./Dec. '95–Nov./Dec. '01 | 74 |
| 1989/90–Nov./Dec. '89 | 81 |
| 1995/96–Nov./Dec. '95 | 76 |

76% (Soerensen Index). The mean impingement rate during the winter months in 1995 was calculated to be 1.7 fish/h.

A total of 2757 fish belonging to 25 species were collected at the power station during the 6-week sampling period in 2001 (Table 1). The eudominant species was, as in 1995/96, roach (*R. rutilus*) which represent 47.4% of all fish. Bream were also present in high numbers (*A. brama*, *B. bjoerkna*, together 19.2%) and were the dominant fish species together with perch (*P. fluviatilis*, 13.3%). The migrating species observed were the same as in 1995/96 (*A. anguilla*, *L. fluviatilis*

**Table 4.** Number and proportion of fish species as determined by fish impingement in the Rheinhafendampfkraftwerk Karlsruhe (RDK) during the months of November and December in the years 1989, 1995 and 2001

| | Nov./Dec. 1989 | | Nov./Dec. 1995 | | Nov./Dec. 2001 | |
|---|---|---|---|---|---|---|
| | Number | Proportion | Number | Proportion | Number | Proportion |
| *Abramis brama/Blicca bjoerkna* | 1021 | 24.23 | 60 | 7.33 | 529 | 19.19 |
| *Alburnus alburnus* | 191 | 4.53 | 7 | 0.86 | 210 | 7.62 |
| *Anguilla anguilla* | 1198 | 28.44 | 27 | 3.30 | 19 | 0.69 |
| *Aspius aspius* | 1 | 0.02 | 1 | 0.12 | 1 | 0.04 |
| *Barbartula barbartula* | | | | | | |
| *Barbus barbus* | 139 | 3.30 | 38 | 4.65 | 10 | 0.36 |
| *Carassius gibelio* | | | | | | |
| *Chondrostoma nasus* | 29 | 0.69 | 3 | 0.37 | | |
| *Cobitis taenia* | 1 | 0.02 | | | | |
| *Coregonus spp.* | 3 | 0.07 | | | | |
| *Cottus gobio* | | | | | 56 | 2.03 |
| *Ctenopharyngodon idella* | 1 | 0.02 | | | | |
| *Cyprinus carpio* | 6 | 0.14 | | | 0 | 0.04 |
| *Esox lucius* | 13 | 0.31 | 2 | 0.24 | 6 | 0.22 |
| *Gasterosteus aculeatus* | | | | | 9 | 0.33 |
| *Gobio gobio* | 9 | 0.21 | | | 29 | 1.05 |
| *Gymnocephalus cernuus* | 178 | 4.23 | 78 | 9.54 | 148 | 5.37 |
| *Lampetra fluviatilis* | 2 | 0.05 | 16 | 1.96 | 5 | 0.18 |
| *Lampetra planeri* | 2 | 0.05 | | | 19 | 0.69 |
| *Lepomis gibbosus* | 1 | 0.02 | | | 3 | 0.11 |
| *Leuciscus cephalus* | 15 | 0.36 | 1 | 0.12 | 23 | 0.83 |
| *Leuciscus idus* | | | | | | |
| *Leuciscus leuciscus* | 26 | 0.62 | 3 | 0.37 | 2 | 0.07 |
| *Lota lota* | 20 | 0.47 | 7 | 0.86 | 4 | 0.15 |
| *Misgurnus fossilis* | | | | | | |
| *Perca fluviatilis* | 617 | 14.65 | 245 | 29.95 | 365 | 13.24 |
| *Petromyzon marinus* | | | 2 | 0.24 | 1 | 0.04 |
| *Rutilus rutilus* | 631 | 14.98 | 309 | 37.78 | 1308 | 47.44 |
| *Salmo trutta f. fario* | | | | | | |
| *Salmo trutta trutta* | 1 | 0.02 | | | | |
| *Scardinius erythrophthalmus* | | | | | 1 | 0.04 |
| *Siluris glanis* | | | 3 | 0.37 | 1 | 0.04 |
| *Sander lucioperca* | 77 | 1.83 | 16 | 1.96 | 6 | 0.22 |
| *Thymalus thymalus* | 1 | 0.02 | | | | |
| *Tinca tinca* | 30 | 0.71 | | | 1 | 0.04 |
| Total | 4213 | 100 | 818 | 100 | 2757 | 100 |
| Number of species | 26 | | 18 | | 25 | |

and *P. marinus*). In average 2.55 fish were collected per hour in the 6-week sampling period in winter 2001.

Most of the fish species identified during the three sampling periods belonged to the subrecendent and sporadic dominance classes (Table 3). For every year around two-third of all fish species fell into these two classes. Only a few species were abundant and belonged to the eudominant or dominant class (Table 3).

The similarity of the ichthyofauna between the years and between the months November/December of the different years is shown as Soerensen Index in Table 4. Overall a high similarity was observed between the years and the months November/December with the highest similarity (86%) between the whole years of 1989/90 and 1995/96 and the lowest similarity between November/December 1989 and the same months in 2001 (71%).

## Discussion

The fish fauna in the northern part of the upper Rhine close to the city of Karlsruhe was determined by collecting fish from the cooling-water intake of a power plant. With the impingement method information of the fish fauna of large rivers can be easily and cheaply obtained. Large water bodies can be analyzed as power plants usually use huge amounts of cooling water (Hadderingh et al. 1983). In particular, information from the deeper part of the water body which cannot be easily assessed using other methods can be gathered (Korte 1999). The sampling is not depending on weather conditions and the permanent cooling-water intake and the 24 h presence of the maintenance staff makes continuous sampling possible (Korte 1999; Maes, Taillieu, Van Damme, Cottenie, & Ollevier 1998). Due to the well-known inflow per time a quantification of the fish fauna is also possible (Hadderingh et al. 1983). Continuous sampling during a long period makes seasonal differences visible (see Hadderingh et al. 1983; Korte 1999; Maes et al. 1998). For example, rheophilic fish species move to deeper parts of the river and are therefore more vulnerable to entering the water intake. This method was applied three times during a time period of 13 years, from 1989 to 2001. An overall of 36 species was detected.

However there were remarkable differences in the number of individuals collected between the years 1989/90 and 1995/96. This was mainly due to a different sampling regime in the second survey. In 1989/90 and 2001 fish were collected for 24 h a day whereas collection lasted only 6 h a day in 1995/96. Furthermore the sampling in 1995/96 occurred only between 14:00 and 20:00 h and fish species (for instance eels) showing a nocturnal feeding were less vulnerable to enter the water inlet as the dark period was much shorter. But also many other fish species for instance *Cobitis taenia* or *Cyprinus carpio* show a crepuscular or nocturnal feeding behavior and were missing in 1995. The lower number of fish species during the winter months in 1995, with only 4 species in the sporadic dominance class, as well as the lower average impingement rate, may hence be the result of the shorter sampling period per day (Table 2).

The distribution of the most abundant fish species in the years 1989/90, 1995/96 and 2001 is illustrated in Fig. 2. In 1989/90 the eel was by far the eudominant fish species whereas in 1995/96 and 2001 roach became the eudominant species. Also, Lelek and Köhler (1989) and IKSR (2002) found roach as the eudominant fish species in the northern part of the upper Rhine. The high abundance of eel in 1989/90 can probably be attributed to the massive stocking of eels in the upper Rhine after the Sandoz accident (Pedroli 1987). This is also supported by the fact that almost all eels (98.2%) caught in 1989/90 were below 40 cm in length (Weibel 1990). The eel was therefore responsible for the generally higher impingement rate during the first survey compared to the second and third monitoring. If the eel is not considered in 1989/90 when calculating the average impingement rate, the rate drops from 3.47 to 2.1 and thus being similar to that of 2001 (2.5 fish/h). However the rates in 1989/90 and 2001 are still higher as in 1995/96 for the reasons discussed above. As a bottom orientated fish species the eel is also more vulnerable entering the cooling-water inlet located at the river bed. For instance the analysis of the ichthyofauna in the area of the water inlet in September 1989 with electric-fishing revealed a proportion of only 2% for eels among the fish caught whereas at the same day the proportion of eel in the RDK was 90% (Weibel 1990). Despite the differences in individual numbers the similarity of the species composition between the first and second investigation was the highest observed (Soerensen Index 86%).

Comparison of fish species in the same months (November and December) for all investigations revealed 27 species during the first sampling period, 18 species during the second collection and 25 species during the last sampling period. The average fish impingement rate of the latest survey in 2001was calculated to be 2.5 fish/h. In 1989/90 and 1995/96 this rate for the months December and November turned out to be 2.8 and 1.7 fish/h, respectively. Accordingly, between 70% and 75% of all fish species were detected during the winter sampling periods in the surveys of 1989/90 and 1995/96. Comparing the species composition in 2001 with the former collections, a high degree of similarity can be observed (Table 3). Never the less the population development of some fish species changed remarkably between 1989 and 2001. *Cottus gobio* was missing in 1989/90 and 1995/96 but could be found in the recedent dominance class in 2001. Although this

**Table 5.** Fish species present in the northern part of the upper Rhine from 1975 to 2005

| Species | 1975[a] | 1989/1990[b] | 1995/1996[b] | 2000[c] | 2001[b] | 2005[d] |
|---|---|---|---|---|---|---|
| Petromyzonidae | | | | | | |
| *Lampetra fluviatilis* | – | + | + | – | + | – |
| *Lampetra planeri* | + | + | + | – | + | – |
| *Petromyzon marinus* | – | + | + | – | + | + |
| Salmonidae | | | | | | |
| *Oncorhynchus mykiss* | + | – | – | – | – | + |
| *Salmo salar* | – | – | – | – | – | + |
| *Salmo trutta trutta* | – | + | – | – | – | + |
| *Salmo trutta f. fario* | + | + | + | – | – | + |
| *Salvelinus fontinalis* | – | – | – | – | – | – |
| Coregonidae | | | | | | |
| *Coregonus lavaretus* | – | + | – | – | – | – |
| Thymallidae | | | | | | |
| *Thymallus thymallus* | + | + | – | – | – | – |
| Cyprinidae | | | | | | |
| *Barbus barbus* | – | + | + | + | + | + |
| *Gobio gobio* | + | + | + | + | + | + |
| *Leuciscus idus* | – | + | – | + | – | – |
| *Leuciscus cephalus* | + | + | + | + | + | + |
| *Leuciscus leuciscus* | + | + | + | + | + | – |
| *Rutilus rutilus* | + | + | + | + | + | + |
| *Scardinius erythrophthalmus* | + | + | + | + | + | – |
| *Alburnus alburnus* | + | + | + | + | + | + |
| *Blicca bjoerkna* | + | + | + | + | + | + |
| *Abramis brama* | + | + | + | + | + | + |
| *Abramis sapa* | – | – | – | – | – | + |
| *Aspius aspius* | – | + | + | + | + | + |
| *Chondrostoma nasus* | + | + | + | + | – | + |
| *Tinca tinca* | + | + | – | – | + | + |
| *Carassiuso auratus gibelio* | + | + | + | – | – | – |
| *Carassius carassius* | – | – | – | – | – | + |
| *Cyprinus carpio* | + | + | – | + | + | + |
| *Ctenopharyngodon idella* | – | + | + | – | – | + |
| *Vimba vimba* | – | – | – | – | – | + |
| Cobitidae | | | | | | |
| *Misgurnus fossilis* | – | + | – | – | – | – |
| *Cobitis taenia* | – | + | + | – | – | – |
| *Barbatula barbatula* | – | + | + | – | – | – |
| Gadidae | | | | | | |
| *Lota lota* | + | + | + | + | + | – |
| Siluridae | | | | | | |
| *Silurus glanis* | + | + | + | + | + | + |
| Anguillidae | | | | | | |
| *Anguilla anguilla* | + | + | + | + | + | + |
| Esocidae | | | | | | |
| *Esox lucius* | + | + | + | + | + | – |
| Gasterosteidae | | | | | | |
| *Gasterosteus aculeatus* | + | + | + | – | + | – |
| Percidae | | | | | | |
| *Perca fluviatilis* | + | + | + | + | + | + |
| *Sander lucioperca* | + | + | + | + | + | + |

**Table 5.** (*continued*)

| Species | 1975[a] | 1989/1990[b] | 1995/1996[b] | 2000[c] | 2001[b] | 2005[d] |
|---|---|---|---|---|---|---|
| *Gymnocephalus cernuus* | + | + | + | + | + | – |
| Cottidae | | | | | | |
| *Cottus gobio* | – | + | – | + | + | – |
| Gobiidae | | | | | | |
| *Proterorhinus marmoratus* | – | – | – | + | – | – |
| Centrarchidae | | | | | | |
| *Lepomis gibbosus* | – | + | + | – | + | – |
| Clupeidae | | | | | | |
| *Alosa alosa* | – | – | – | – | – | + |
| Number of species | 24 | 36 | 27 | 22 | 25 | 25 |

[a]Lelek (1976).
[b]Own data.
[c]IKSR (2002).
[d]LFV Baden (2006).

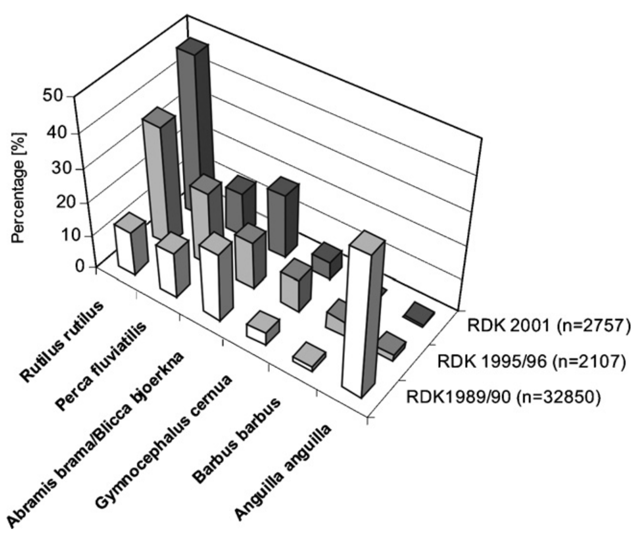


**Fig. 2.** Comparison of the most abundant fish species in the RDK (Rheinhafendampfkraftwerk Karlsruhe) during the last 13 years.

species is threatened in the River Rhine (Dußling & Berg 2001), it could be found in high numbers, at least during the winter months, in 2001. The fish fauna in the upper Rhine is dominated by only a few euryoecious fish species which are generalists in respect to their reproductive biology (roach, perch, bream/white bream) (Dußling & Berg 2001). Most of the species were only found sporadically and in low numbers. In 1989/90 the eel reached its eudominant level only due to massive stocking (Lelek & Köhler 1989). Since then the proportion of eels decreased markedly. Being 2% in 1995 the proportion of eels dropped down to 0.7% in 2001. This reflects the overall trend of the development of eel populations throughout Europe (Dekker et al. 2003). The causes for this decline are not completely clear (Stone 2003) but it seems to be an assemblage of different causes like climate change (Wirth & Bernatchez 2003), environmental pollution (Palstra, van Ginneken, Murk, & van den Thillart 2006), overfishing (Dekker et al. 2003) and the introduction of neozoic parasites (Sures & Knopf 2004).

In order to determine the composition of the ichthyofauna in a large river the impingement method alone is not sufficient and should be used together with other methods (electric-fishing, netting) (Korte 1999, 2001). However, at least for the RDK, a short sampling at the power plant during the winter months provides a cheap and quick method to get an overview of the fish species present. Furthermore catadromous fish species are migrating during this period (Dußling & Berg 2001) and might be missed during the late spring and summer months.

On the other site, fish sampling with the impingement method also has a negative impact on fish communities as in most cases all fish caught in the cooling-water inlet are killed. As the impingement rate is strongly dependent on the structure and the position of the water intake a direct comparison between different power plants is difficult as is a comparison with other methods (Korte 1999). Fish species preferring the surface part of the water body might be underrepresented. The aim of the companies operating power stations using the once through water cooling technology should, however, be to minimize the impact of impingement on the fish fauna as much as possible (Perry, Seegert, Vondruska, Lohner, & Lewis 2002; Super & Gordon 2002; Veil, Puder, Littleton, & Johnson 2002) and the use of closed-cycle cooling or dry cooling would be more protective of the fish community.

The ichthyofauna in the northern part of the upper Rhine should also be observed in the future to follow its development especially with respect to endangered and migrating species. A new threat is the appearance of alien species (Lelek 1996). The connection of the two largest catchment systems in Europe, the Danube River and the Rhine River over the Main-Danube Canal, led to a tremendous change in the macrozoobenthos structure of the Rhine (Tittizer 1996; Tittizer & Banning 2000). The possible appearance of new fish parasites can also not be excluded (Sures & Knopf 2004; Sures & Streit 2001; Taraschewski, Moravec, Lamah, & Anders 1987) which might be a threat to the native fish fauna. Three introduced fish species (*Sander lucioperca* L., *Lepomis gibbosus* L., and *Carassius auratus gibelio* (Bloch, 1783) were found in this study. The recent detection of *Proterorhinus marmoratus* (Pallas, 1811), a fish species migrating from the Danube (IKSR 2002; Schadt 2000) and the finding of *Abramis sapa* (Pallas, 1811) in the water inlet of different power plants in 1995 (Hirt 1996) is a further sign of species interchange.

Overall a positive development of the fish fauna in the upper Rhine over the last 15 years could be observed in terms of fish populations as well as in terms of species richness. Except for the formerly autochthonous fish species *Acipenser sturio* L. and *Leuciscus souffia* (Risso, 1826) all autochthonous fish species were again present in the northern upper Rhine (Dußling & Berg 2001; IKSR 2002, this study; Korte 1999, 2001). This observation is confirmed by studies from other river systems in Germany. The number of autochthonous fish species in the upper Elbe increased from 19 to 36 between 1993 and 1999 (Gaumert 2000). This positive development in the fish fauna in larger rivers is undoubtedly due to improvements in water quality and by the removal of man-made obstructions such as dams, weirs and mills, or at least the making of these obstacles passable by building fish passes. Even though the northern upper Rhine is structurally highly altered, giving it the appearance of a canal, the improvement in water quality turned out to increase this anthropogenic system into a valuable secondary ecosystem. Especially the anthropogenic riprap regulating the discharge of the water body and serving as bank reinforcement are used by several fish species as secondary biotope, and enrich the physical structure in this part of the River Rhine. Due to the better water quality the surface of gravel and stones is less populated by protozoan-, bacterial- and fungal-species and therefore improved reproduction success of psammophilic and lithophilic spawners is observed (Weibel, Bernauer, & Hirt 1997). The constant detection of cyclostomata, or the increasing percentage of barbel between 1989 and 1995 are clear signs of this positive development. Even the efforts to reintroduce catadromous salmonid fish species into the northern upper Rhine show a positive development as the fish counts at the fishpass Iffezheim demonstrate (Table 5) (LFV Baden 2006).

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