

## Threatened lamprey (*Lampetra planeri*) populations of the Danube Basin within Baden-Württemberg, Germany

by

B. Kappus, W. Jansen, P. Fok, and H. Rahmann

(Received March 22, 1995)

**Abstract:** The brook lamprey (*Lampetra planeri*) populations of the upper Danube Basin within Baden-Württemberg (Germany) were studied between 1989 and 1994. Ten recently extinct and 40 currently existing populations were documented and major factors threatening their existence were identified. Among these factors, physical obstacles forming effective migration barriers often confine populations to isolated reaches of a river without the possibility of (genetic) exchange with other populations further downstream or within the Danube itself. Further physical disturbances adversely affecting lamprey habitat include river channelization, river bank reconstruction and sediment removal. As evidenced in the Lauchert River, sediment removal was the direct cause of mortality for substantial numbers of lampreys. The contamination of waters with organic wastes from agricultural use, input of nutrients from diffuse run-off or point sources, such as water treatment plants, and accidental toxic spills are generally of less importance, nevertheless represent significant threats for individual lamprey populations. Finally, heavy stocking of catchable size salmonids, particularly in unsuitable rivers, can lead to increased predation pressure on adult lampreys and, therefore, reduced population fecundity. The relative importance of the different factors that put lamprey populations at risk are quantified and discussed in the context of feasible conservation measures.

**Key words:** brook lamprey, *Lampetra planeri*, habitat alteration, water quality, population extinction, upper Danube Basin

### Introduction

Lampreys are sediment dwellers. The larvae, usually termed ammocoetes, spend 6 to 8 years hidden in the sediments of running waters where they filter organic particles (Hardisty & Potter 1971). Unlike the predatory, marine species, as for example the sea lamprey (*Petromyzon marinus*) and the river lamprey (*Lampetra fluviatilis*), which can migrate considerable distances back to the ocean after metamorphosis, the limnetic forms are stationary and complete their whole life-cycle in their native area (Holcik 1986). Among these latter species are the brook lamprey (*Lampetra planeri*), the Danube brook lamprey (*Eudontomyzon mariae*) and the Danube lamprey (*Eudontomyzon danfordi*), which is also predatory. As their names indicate, the centre of distribution of the two latter species is the Danube Basin, where *E. danfordi* is particularly limited to the Hungarian Tisza area (Banarescu 1969, Renaud 1982).

All of the lamprey species occurring in Central Europe, both anadromous and stationary, are considered threatened and have been included in the "Red List" of endangered animal species in Europe (Lelek 1987). The brook lamprey (*L. planeri*) has been classified as "strongly endangered" throughout its European range and is listed as a "protected species" in the species protection agreements of the European Council (ER 1988). Within Germany, *L.*

*planeri* is considered "endangered" (class 3 on the "Red List"; Bless & Lelek 1984). Table 1 summarizes the status of *L. planeri* according to the provincial "Red Lists". The median score of 2 designates the brook lamprey as "strongly endangered" and in Thüringen and Bayern the species is threatened by extinction (score of 1).

Table 1. Status of the brook lamprey (*L. planeri*) according to the "Red List" for different "Bundesländer" of the Federal Republic of Germany. Categories are: 1 = threatened by extinction; 2 = strongly endangered; 3 = endangered

Province	Status	Source
Niedersachsen	2	Gaumert & Kämmerit (1993)
Schleswig-Holstein	2	Dehus (1990)
Mecklenburg-Vorpommern	3	Winkler <i>et al.</i> (1991)
Thüringen	1	Brettfeld <i>et al.</i> (1993)
Nordrhein-Westfalen	3	Borchard <i>et al.</i> (1986)
Hessen	2	Meinel <i>et al.</i> (1986)
Bayern	1	Bohl (1992)
Baden-Württemberg	2	Berg <i>et al.</i> (1989)
	2	Bauer & Strubelt (1993)

In light of the poor population status throughout its range, the aim of the present paper is to highlight and to evaluate the specific threats to *L. planeri* populations in the upper Danube area of Baden-Württemberg. There, a unique situation exists in that a) a faunal element originating from the Rhine River system occurs naturally in the Danube River system (Kappus & Rahmann 1994a) and b) *L. planeri* shows, in addition to typical brook lamprey characteristics, some taxonomic features closely resembling those of *Eudontomyzon* species (Kappus *et al.* in press). Therefore, a specific protection scheme is strongly needed.

### Material and methods

The study area encompassed the Danube River system within Baden-Württemberg (47°56'-49°09' N and 8°13'-9°62' E), beginning from headwaters of the rivers Brigach and Breg all the way to the city of Ulm (Fig. 1). Potential lamprey habitats and previously known lamprey populations of the Danube and its tributaries were surveyed regarding the presence or absence of lampreys, their population size and key habitat features (for details see Kappus & Rahmann in press). Of the 50 populations documented in the study area, 10 have not been confirmed within the last 20 years and hence must be considered extinct. The potential threats to the remaining 40 populations were documented through numerous visits to the sites from May 1989 to August 1993. For each site, the relevant biotic and abiotic information were gathered including the degree of morphometrical disturbance, frequency and nature of maintenance measures, presence of horizontal barriers, sewer lines, land use practices, associated fish fauna, and ongoing fisheries management (i.e. stocking) practices. For most sites, questionnaires were distributed to prospective river users, mainly sportfishing clubs.

## Results

### Distribution of lamprey populations within the Danube basin of Baden-Württemberg

A total of 50 lamprey populations within the upper Danube system were detected in the field or known to have existed based on reliable historic records. Of these, 40 populations have been confirmed to exist during the last 20 years. A minimum of 10 brook lamprey populations have become extinct since 1820, while a much higher number must realistically be assumed to have disappeared without ever being recorded (Kappus *et al.* 1994). The 50 confirmed populations can be separated into two centres of distribution: one group of 26 populations are clustered within the "Schwäbische Alb" area in the vicinity of the cities of Ulm and Sigmaringen, the other group of 22 populations is centred in the headwaters region of the Danube in the area of the rivers Brigach and Breg (Fig. 1). The relatively low number of populations ( $n=4$ ) in those tributaries entering the Danube from the south is most likely caused by glaciation effects, as this southern area was largely covered by ice during the last Riss-glaciation.

### Hazards to lamprey populations of the Danube basin of Baden-Württemberg

In the following section the specific hazards affecting each of the presently known 40 lamprey populations found in the study area are described. The number of different threats for each population can range between 0 and 7 (Table 2). Generally, the populations in the "Schwäbische Alb" area face an average of 3.3 identifiable threats, whereas this number is only 2.5 for the populations in the Danube headwaters area. If the different hazards are ranked according to their number of occurrences, with 32 listings, in-stream migration barriers must be considered the number one threat to lamprey populations, followed by the sealing of river banks through deployment of large and flat rocks and, thirdly, the input of organic nutrients (Table 3). Other hazards, which occurred less frequently, may nevertheless pose a major threat to an individual population, were river channelization, minimal low flow conditions, removal of sediments, toxicants, and fish stocking practices.

### Physical disturbances of river integrity

Morphometrical changes due to construction measures represent the major threat to lamprey populations of the upper Danube Basin. Eighty percent of all rivers with known lamprey populations were affected by one or more horizontal barriers (Fig. 2), forming effective obstacles to upstream (and downstream) movement of lampreys (and other fish). A total of 102 barriers have been identified in the rivers with known lamprey populations. As the mean number of 5.3 barriers indicates, the affected rivers have been dammed several times and an unbroken sequence of "impoundments" continues for a major section of the river or follows each other with only minor distances in between. Such conditions destroy the former continuum of suitable lamprey habitat and render potential survivors to small groups of animals with no hope for long-term survival.

In addition to migration barriers, river channelization may be equally destructive to lamprey habitat. In this case, flow conditions are often altered in such a way, that the fine particulate sediments, necessary as ammocete (feeding) habitat, have been washed away and cannot be re-established. A third factor negatively affecting lamprey populations by disturbing the river

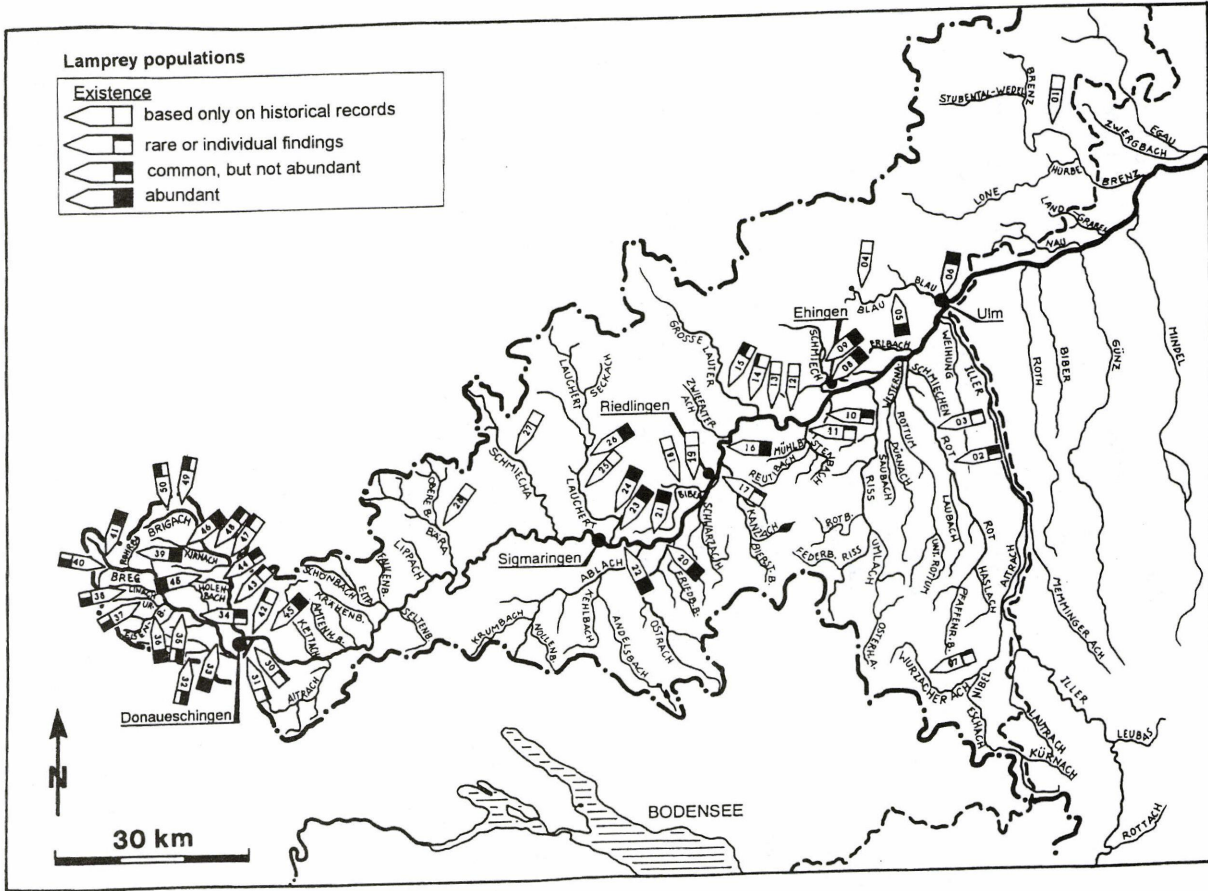


Fig. 1. Historical and recent records of brook lamprey (*Lampetra planeri*) populations within the Danube River basin in Baden-Württemberg (from Kappus & Rahmann, in press)

Table 2. Specific hazards endangering brook lamprey (*L. planeri*) populations within the upper Danube Basin of Baden-Württemberg. 1 = migration barriers (the number of barriers in the vicinity of a known population is given); 2 = diverted river section with minimal flow regulation; 3 = input of organic nutrients; 4 = toxic spill; 5 = water removal; 6 = stocking with brown trout and/or eel; 7 = channelization; 8 = armoring of river banks with stone blocks; 9 = mowing of macrophytes; 10 = predation by heron (*Ardea cinerea*); 11 = sediment removal; 12 = trampling by livestock; 13 = water acidification; n = total number of hazards affecting each population

River / nearest town	Threat													n
	1	2	3	4	5	6	7	8	9	10	11	12	13	
<b>A) Danube River and its tributaries within the "Schwäbische Alb"</b>														
Rot / Schwendi	3	x	x				x	x						5
Rot / Bußmannshausen	2	x	x			x	x	x						6
Blau / Arnegg	2								x					2
Blau / Ulm	5		x						x					3
Schmiech / Ehingen	5		x			x		x	x	x	x			7
Schmiech / Allmendingen			x				x				x			3
Donau / Dettingen	2							x						2
Stehbach / Rottenacker	2						x	x						3
Große Lauter / Lauterach	5						x	x						3
Große Lauter / Anhausen	3													1
Donau / Zell								x						1
Donau / Riedlingen	2							x						2
Donau / Hundertsingen	1							x						2
Heudorferbach / Blochingen	4			x	x			x						4
Donau / Scheer	3	x						x						3
Lauchert / Lauchertthal	4							x			x			3
Lauchert / Bingen	5	x						x			x			4
Lauchert / Hermentingen								x						1
Donau / Donaueschingen	2		x					x	x					4
<b>B) Danube River headwaters</b>														
Breg / Donaueschingen		x					x	x						3
Breg / Hüfingen	1	x					x							3
Brändbach / Unterbränd	2													1
Breg / Bruggen														0
Breg / Wolterdingen	5													1
Breg / Krumpenhof	1													1
Eisenbach / Hammereisenbach	5	x										x		3
Urach / Urach	3													1
Linach / Fuchsloch	3													1
Rohrbach / Schönenbach	4	x	x								x			4
Breg / Furtwangen	3		x					x						3
Breg / Gabrielenhof	4													1
Brigach / Donaueschingen			x				x	x						3
Brigach / Klengen			x											1
Wolfbach / Rietheim			x	x			x	x						4
Warenbach / Villingen	3				x					x		x	x	5
Kirnach / Unterkirnach	6	x												2
Brigach / Villingen	4	x	x	x				x						5
Brigach / Peterzell	1		x	x			x	x						5
Harzlochbach	3													1
Brigach / St. Georgen	4		x				x	x						4

Table 3. Ranking (according to number of occurrences) of hazards endangering brook lamprey populations within the upper Danube Basin of Baden-Württemberg

Rank	Hazard	n	%
1	Migration barriers	32	80,0
2	Armoring of river banks with stone blocks	22	55,0
3	Input of organic nutrients	17	42,5
4	Channelization	12	30,0
5	Diverted river section with minimal flow regulation	10	25,0
6	Sediment removal	7	17,5
7	Toxic spill	4	10,0
8	Stocking	4	10,0
	Others	8	20,0

continuum, is the construction of in-stream rainwater retention ponds. The Danube headwaters are particularly affected, with several of these types of impoundments located on the rivers Kirnach, Linach and Brändbach.

#### River maintenance

River bank reconstruction and "stabilization", which affect approximately 2/3 of all rivers within the "Alb" region and 1/3 of the Danube headwaters, threaten 55% of all lamprey

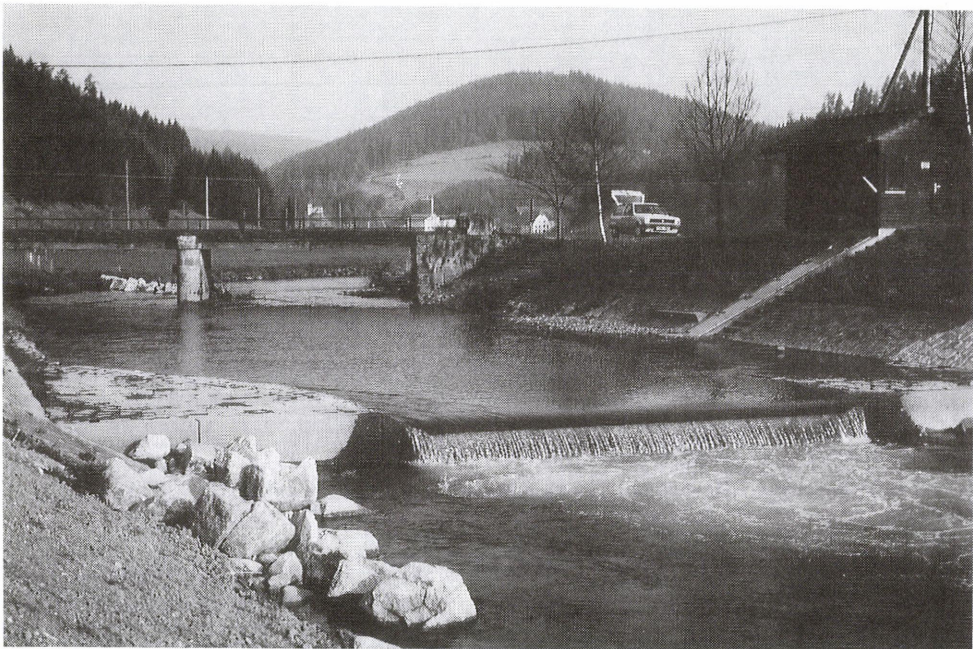


Fig. 2. Gauging station at the Breg River, an example of an impassable migration barrier

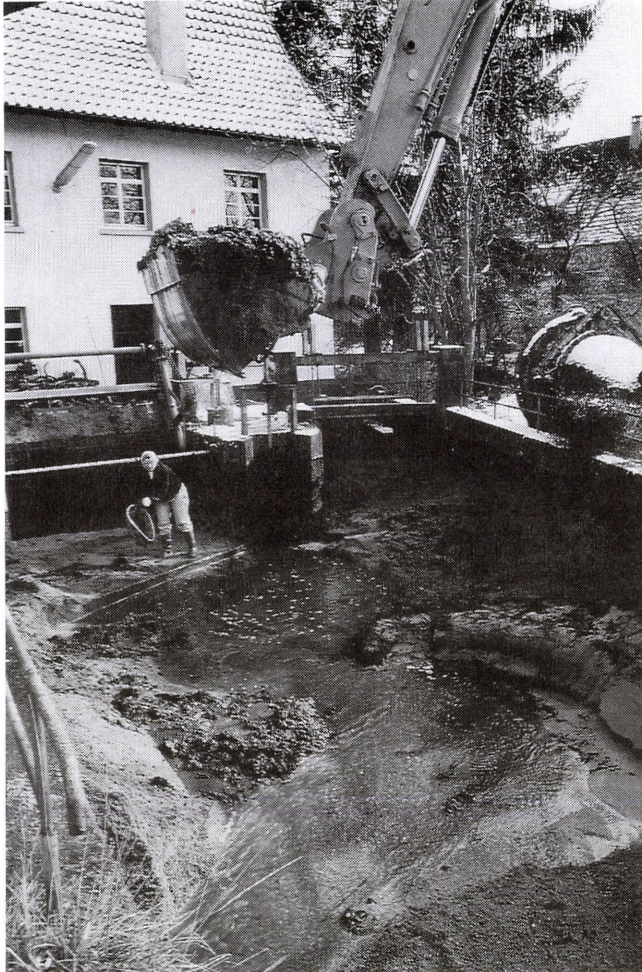


Fig. 3. Sediment removal in the Lauchert River at Bingen on January 26, 1993

populations within the study area. A further maintenance measure, the periodic removal of sediments, has been documented for 18% of the rivers supporting lampreys. Due to impoundment and channelization, flow dynamics are changed resulting in local accumulation of fine sediments. This silting-up is considered detrimental to flow conditions when rivers are heavily used for electric power generation or for irrigation purposes. Thus, sediments are often completely removed, sometimes destroying many generations of ammocoetes. The drastic consequences of such measures have been frequently observed during the 4-year study period, affecting the lamprey populations of the Schmiech at Eningen, the Rohrbach at Furtwangen, the Eisenbach at Hammereisenbach and of the Lauchert at Bingen. An incident occurred on the Lauchert River which provided a drastic example of losses that can occur to a lamprey population. On January 26, 1993 a dredge was seen to remove sediments over a 40 m long section of the Lauchert just upstream of the mill-race in Bingen (Fig. 3). Approximately 15

truckloads full of sediments (80% sand, 20% organic compounds) were deposited 500 m away from the removal site. Inspection of the sediments, both on the trucks and at the dump site revealed a total of approximately 700 animals, mainly ammocoetes, which were effectively removed from their habitat and killed. Most of the larvae were found in the organic laden sediments, less so in the sediments consisting of almost pure sands. Considering that the young larvae (ca. 30 mm) were very difficult to detect within the sediments, the total loss of lampreys was estimated to be at least 1500 animals. The remaining sediments left in the river were also inspected and approximately 100 lampreys were found within half an hour of searching. Among these, 20 subadult "macrophthalmia" (i.e. animals that will spawn in spring) were identified, readily distinguishable by their prominent eyes.

#### Input of toxicants and nutrients

Unfortunately, the accidental introduction of toxicants into rivers occasionally still occurs. Two such "accidents" were recorded during the present study and had severe effects on the lamprey populations. In August of 1991, cyanide from the water treatment plant at Peterzell resulted in a massive fish kill which affected a 15 km long section of the Brigach River. Although no dead or dying lampreys were reported by local fishermen who were mainly observing the moribund salmonids and cyprinids, there was indirect evidence that lampreys were also affected by the cyanide. One day after the spill, an electro-fishing survey showed the complete absence of lampreys in the affected area, while immediately upstream, within the city limits of St. Georgen, lampreys were present. A second case of river pollution was documented in 1989 when mineral oil entered the Wolfbach at Rietheim, which was certain to have adverse effects on the lamprey population.

In addition to these known toxic spills, and nutrient input from point sources such as sewer outfalls or water treatment plants, organic wastes from agricultural sources may enter the rivers as diffuse run-off from fields. Occasionally, larger amounts of raw sewage are illegally "disposed of" by directly emptying containers onto frozen fields close to rivers. Such an incidence where large amounts of raw sewage entered the Wolfbach at Rietheim, was witnessed in February 1992.

Water acidification must be considered as another source of chemical "contamination" of lamprey habitats. During this study it was found that the creeks flowing through the red sandstone bedrock at Villingen-Schwenningen had increased water acidity with yearly mean pH values of 6,6 (Warenbach/Wieselsbach). As evidenced by the relatively large and stable population of the Warenbach, this depression in water pH does not, as yet, seem to be critical for the successful reproduction of the brook lamprey.

#### Fisheries practices

The intensive management of many rivers for sport fishing purposes represents a further, although limited, threat to lamprey populations. Of the 33 river sections with known lamprey populations that were managed for sport fishing purposes, only 12% were intensively stocked, i.e. adult size salmonids were introduced into the river several times a year. Forty five percent of these sites were stocked at low intensity and 42% were not stocked at all. Low intensity stocking represents introduction of fry and fingerlings once a year. Although just one case could be established in which high lamprey population density occurred concomitant with high stocking intensity, there was no general negative correlation between the number of salmonids

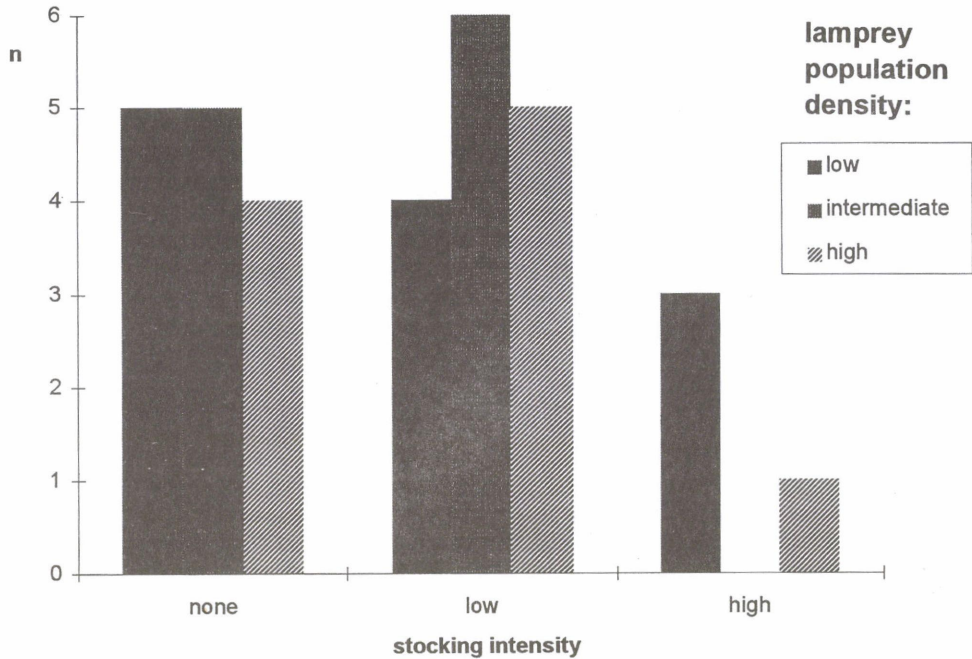


Fig. 4. Absolute number (n) of different combinations in the level of stocking intensity (high = introduction of adult sized trout several times a year; low = introduction of fry or fingerlings once a year; none = no stocking) and lamprey population density (levels of low, intermediate, and high densities were assigned subjectively base on sampling by electro-fishing, nets, and observations at the site). A total of 33 lamprey populations were considered

stocked and lamprey population size (Fig. 4). However, the lack of a general relationship must be considered with caution, because stocking practices differed with regard to the size of the fish stocked. Whereas fingerling trout do not put lampreys at risk, stocking of adult size trout can exert an adverse effect on lamprey populations. For example, direct observations of lamprey-salmonid interactions during each of the reproductive seasons 1991-1993 at the River Schmiech confirmed that trout (*Salmo trutta* and *Oncorhynchus mykiss*) aggregated in the vicinity of lamprey spawning sites and frequently preyed upon mature individuals. Therefore, intensive stocking with adult-size salmonids (*S. trutta*, *O. mykiss* and *Salvelinus fontinalis*), particularly into unsuitable water bodies, may contribute to the reduction of lamprey populations (and of other endemic small fish species).

Not only stocking with adult size salmonids, but also with fry may be harmful to lamprey populations. Frequently salmonid fry are stocked into very small creeks only to be recaptured months later as fingerlings by electro-fishing. If a lamprey population is present in such a habitat, this method of capture, if not carried out carefully, may harm or even kill ammocoetes.

Finally, the large scale stocking of eels (*Anguilla anguilla*) must be considered detrimental to the autochthonous lamprey populations, because lampreys of unknown origin and species are frequently found with the introduced eels. In order to obtain an estimate of the numbers involved, authorities at the German Fisheries Association (Deutscher Fischerei Verband), responsible for the shipping of eels used for stocking, were approached. The information obtained indicated that among the eels, river lampreys (*L. fluviatilis*) are found in quantities of "less than 1%" and that the "percentage has been declining in recent years".

## Discussion

The general situation of the brook lamprey within the upper Danube Basin is well illustrated by a comparison of the historic and recent existence of populations. At least 20% of the populations have disappeared and the size of remaining populations has generally been reduced. These developments were paralleled over the last 200 years by structural changes of rivers and creeks, and biotic disturbances. Among the latter disturbances, stocking practices are of major importance in affecting lamprey populations. The present study clearly demonstrates that stocked salmonids kill or injure adult lampreys during spawning time. Similar results were obtained by Bohl (1993) and Kirchhofer (in press). Our findings confirm those of Bohl (1993) who reported that the conspicuous spawning behaviour makes them vulnerable to predation by salmonids and also by burbot (*Lota lota*), pike (*Esox lucius*), and eel (*A. anguilla*), particularly if predator densities have been artificially increased by stocking. Since our electro-fishing surveys indicate that eels frequently occur within accumulations of detritus, sand or gravel, these fish may not only prey on adult lampreys, but also potentially eat eggs and larvae.

The stocking of eels, which until recently, has been financially supported by state authorities, is also important from a different aspect. The apparently consistent presence of lampreys among the eel-batches used for stocking had, and still have, a number of noteworthy consequences. There is the chance that species of lampreys have been introduced into water bodies, which they could not have reached otherwise (i.e. ponds and lakes without inlets or outlets), or into lotic systems in which they did not occur naturally (also see Kappus & Rahmann 1994b). Although the first record of river lampreys (*L. fluviatilis*) from the Danube River dates before the first (known) stocking of eels in 1881 (Hack 1881), this species has most likely been introduced into the Danube system via this route. A total of 2.4 million eels have been introduced into water bodies within the area of what is now Baden-Württemberg between 1893 and 1906 (Sieglin 1892). Assuming that 30% of these fish have gone into the Danube system, and that the proportion of lampreys mixed in with the eels was 0.5 %, then approximately 4000 lampreys have been accidentally introduced into this river system within 13 years. A further 1000 lampreys can be estimated to have entered the Danube in the vicinity of the city of Ulm, where eels were stocked at the beginning of the 20th century (Fischereiverein Ulm 1905). According to Holcik (1986), *L. fluviatilis*, *L. planeri* and also *P. marinus* were among those accidentally stocked. Little is known about the fate of these fish, but it is likely that some exchange of genetic material information occurred between the *L. planeri* of unknown origin and the autochthonous stocks already present. This gene flow must be considered detrimental, because the evolutionary history of the introduced lampreys took place outside their "new" habitat and these animals were not adapted to the specific local conditions.

Among the structural changes detrimental to lampreys, the removal of stream meanders and large scale channelization has notably resulted in a considerable loss of suitable lamprey habitat. Although these measures, which affect the whole river profile, now have to be officially authorized, regular river "maintenance" does not. Therefore, it is still common practice and indirectly encouraged by the regulations of the Ministry for Rural Affairs (MLR 1980) to invest considerable financial resources into measures, which do not consider species and habitat protection requirements (see also Berg *et al.* 1989). In the case of lampreys, the armoring of river banks often completely destroys actual or potential larval habitats within the lenitic, sediment covered nearshore areas (Schadt 1994). A further "maintenance" measure, which negatively affects lamprey populations, is the frequent cutting of shoreline vegetation.

This may start a cycle of radiation mediated increase in macrophyte and algal growth, which is additionally enhanced by nutrient input. While the higher plant growth leads to increased sedimentation (and the perceived necessity for its removal), decaying algal material often results in anoxic sediment layers preventing ammocoete settlement.

All these physical disturbances change flow dynamics, prevent the formation of pool and riffle sequences, and disrupt the frequent, but locally distributed accumulation of finer sediments. These altered rivers also frequently lack fast flowing, shallow reaches with gravel-sized sediments (Waterstraat 1989). Apart from the "regulation" of rivers, many of the very small water bodies have also been heavily degraded by their partial transformation into completely lined channels or culverts. Thus, both larval habitats and adult spawning sites have largely disappeared. If these habitats are present, they are often spatially separated and do not provide functional units in terms of lamprey reproduction. Prime examples for these negative developments are found at the Rot River in the vicinity of Bussmannshausen, the lower reaches of the Lauchert, the Stehbach at Rottenacker and over most of the course of the Danube.

Hand in hand with the loss of suitable lamprey habitat, migration barriers have separated the remaining habitats into isolated patches, with limited biotic exchange. Ammocoetes carried downstream during periods of flooding are potentially able to bypass barriers and become newly established on sediments downstream. However, after metamorphosis, the adults are unable to return to their native spawning grounds and spawning must take place under less favourable conditions or may completely fail. As a consequence, local extinction of populations occurs (Kirchhofer in press, Bohl 1993, Schadt 1991). Such a scenario provides a reasonable explanation for the present disjunct distribution of the lamprey populations of the upper Danube Basin. The once interconnected populations of the corresponding creeks and rivers have often been reduced to isolated, small units which dynamics largely follow the metapopulation concept (Hanski & Gilpin 1991; Fig. 5). Thus, locally high population densities at some of the sites cannot hide the fact that the brook lamprey of the upper Danube Basin must be considered strongly endangered. Despite dealing with quite different types of waters, Dehus (1990) arrives at similar conclusions analyzing the status of lamprey populations in Northern Germany (Schleswig-Holstein). Obviously, efficient conservation measures have to be defined and implemented to guarantee the long-term survival of the brook lamprey (*L. planeri*) throughout its Central European range. One such concept has been proposed by Kappus & Rahmann (1994b), in which all interventions into known or potential lamprey habitats should be assessed with regard to their compatibility with the existence of a self-sustaining, reproducing lamprey population, prior to their actual implementation.

### Acknowledgements

We thank the Government of Baden-Württemberg, Ministerium für Ländlichen Raum, Ernährung, Landwirtschaft und Forsten, for the financial support of this study (Staatshaushaltsplan 1990, Kap. 0802 Tit.Gr. 74, Projekt Nr. 27-90.35).

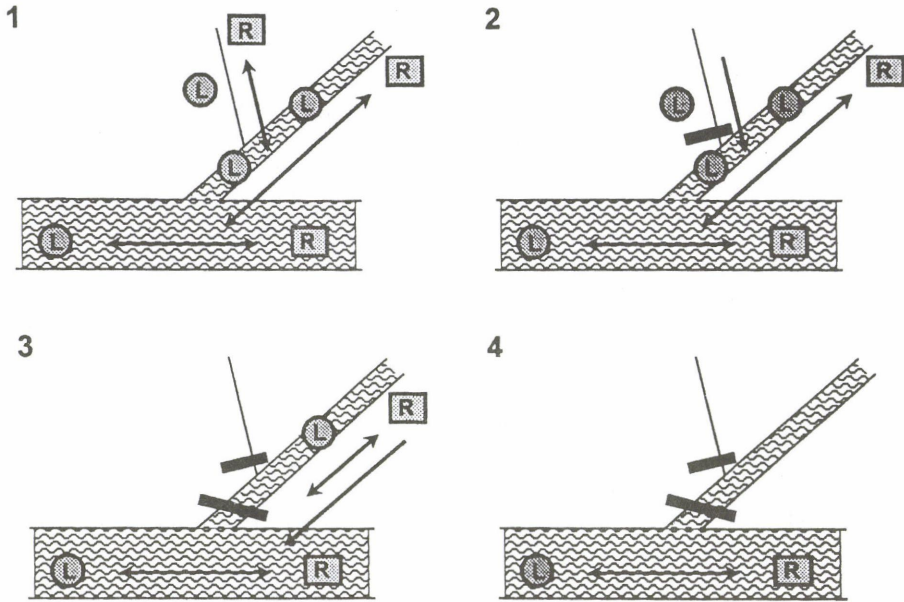


Fig. 5. Hypothetical process of extinction of a lamprey metapopulation in a lotic system (from Kirchhofer, in press). 1 = free exchange between members of metapopulations; 2, 3 = barriers disrupt the free exchange, i.e. only downstream drift of larvae is possible and metapopulations become isolated; 4 = extinction of a metapopulation. → passive drift of lamprey larvae; ↔ active spawning migrations

## References

- Banarescu, P. (1969): Cyclostomata si Chondrychthyes (cyclostomi si selacieni). – *Fauna Rep. Soc. Rom.* **12**: 5-54.
- Bauer, S. & Strubelt, T. (1993): Gefährdete Fischarten in Baden-Württemberg "Rote Liste" (1. Fassung, Stand: 31.7.1977). – In: Landesanstalt für Umweltschutz Baden-Württemberg (Hrsg.) (*Arten- und Biotopschutzprogramm Baden-Württemberg*, Band 1- 2, Ergänzungslieferung: III A/6-III A/7., Karlsruhe
- Berg, R., Blank, S. & Strubelt, T. (1989): Fische in Baden-Württemberg – Ergebnisse einer landesweiten Fischartenkartierung und Bestandsuntersuchung. – Information des Ministeriums für den Ländlichen Raum, Landwirtschaft und Forsten Baden-Württemberg, Stuttgart, 156 pp.
- Bless, R. & Lelek, A. (1984): Rote Liste der Fische und Rundmäuler. Pisces et Cyclostomata. – In: Blab, J., Novak, E., Trautmann, W. & H. Sukopp (Hrsg): *Rote Liste der gefährdeten Tiere und Pflanzen in der Bundesrepublik Deutschland*. Greven (Kilda-Verlag), pp. 30-32.
- Bohl, E. (1992): Fische (Pisces). – *Schriftenreihe des Bayerischen Landesamtes für Umweltschutz* (Beiträge zum Artenschutz 15 – Rote Liste gefährdeter Tiere Bayerns) **111**: 42-46.

- Bohl, E. (1993): Rundmäuler und Fische im Sediment. Ökologische Untersuchungen an Bachneunauge, Schlammpeitzger und Steinbeisser. – *Berichte der Bayerischen Landesanstalt für Wasserforschung* **22**: 1–123.
- Borchard, B., Brenner, T. & Steinberg, L. (1986): Fische in Nordrhein-Westfalen. – Der Minister für Umwelt, Raumordnung und Landwirtschaft des Landes Nordrhein-Westfalen, Düsseldorf, (Hrsg), 127 pp.
- Brettfeld, R., Bock, K.-H., Klemm, W., Müller, R. & Müller, U. (1993): Rote Liste der Fische und Rundmäuler (Pisces et Cyclostomata) Thüringens. 1. Fassung, Stand 1992. – Thüringer Landesanstalt für Umweltschutz (Hrsg), Naturschutzreport **5**: 31-34.
- Dehus, P. (1990): Rote Liste der in Schleswig-Holstein gefährdeten Süßwasserfische und Neunaugen. 2. Fassung, Stand: 1. Januar 1990. – Landesamt für Naturschutz und Landschaftspflege Schleswig-Holstein, Kiel, (Hrsg), 20 pp.
- ER, Europarat (1988): Übereinkommen über die Erhaltung der europäischen wildlebenden Pflanzen und Tiere und ihrer natürlichen Lebensräume. – SR 0.455 Rechtssammlung Schweiz.
- Fischereiverein Ulm/Neu-Ulm e.V. (1905): Festschrift zur Feier seines 25-jährigen Bestehens. – Ebner Verlag, Ulm.
- Gaumert, D. & Kämmereit, M. (1993): Süßwasserfische in Niedersachsen. – Niedersächsisches Landesamt für Ökologie (Hrsg.), Hildesheim, 161 pp.
- Hack, H. (1881): Bericht über die erste grössere Aussetzung von Aalen in das Gebiet der Donau. – *Circulare des Deutschen Fischerei Vereins (Berlin)*: 123-125.
- Hanski, I. & Gilpin, M. (1991): Metapopulation dynamics: brief history and conceptual domain. – *Biol. J. Linn. Soc.* **42**: 3-16.
- Hardisty, M.W. & Potter, I.C. (1971): The behaviour, ecology and growth of larval lampreys. – In: Hardisty, M.W. & Potter, I.C. (eds): *The Biology of Lampreys*, Vol. 1. Academic Press, London – New York, pp. 85-125.
- Holcik, J. (ed.) (1986): *Petromyzontiformes*. – In: *The freshwater fishes of Europe, Vol. 1*. Aula Verlag, Wiesbaden, 313 pp.
- Kappus, B. & Rahmann, H. (1994a): Neunaugen im Ökosystem Donau – Vorkommen, Habitatansprüche, Taxonomie und Gefährdungsstatus. – *Beiträge der Akademie für Natur- und Umweltschutz Baden-Württemberg (Lebensraum Donau – Europäisches Ökosystem)* **17**: 204-214.
- Kappus, B. & Rahmann, H. (1994b): Donau-Neunaugen – Fischereibiologische Grundlagenuntersuchungen zu ihrem Schutz.– Abschlussbericht des Instituts für Zoologie an das Ministerium für den Ländlichen Raum, Ernährung, Landwirtschaft und Forsten Baden-Württemberg, Stuttgart, 270 pp. (unpublished)
- Kappus, B. & Rahmann, H. (in press): Neunaugenvorkommen im südlichen Baden-Württemberg (Donaugebiet).– *Fischökologie* .
- Kappus, B., Zintz, K. & Rahmann, H. (1994): Sedimente der Donau und ihrer Nebengewässer als Lebensraum für Neunaugen. – *Wissenschaftliche Mitteilungen aus dem Niederösterreichischen Landesmuseum*, Sonderheft Symposium "Fluss-Ufer-Ökologie" vom 10.-13.9.92 in Krems (Wien) **8**: 33-43.
- Kappus, B., Salewski, V. & Holcik, J. (in press): Taxonomie der Neunaugen der Oberen Donau in Baden-Württemberg. – *Fischökologie*..
- Kirchhofer, A. (in press): Schutzkonzept für Neunaugen (*Lampetra planeri*) in der Schweiz.– *Fischökologie*.
- Lelek, A. (1987): *Threatened Fishes of Europe*. – In: *The Freshwater Fishes of Europe, Vol. 9*. Aula Verlag, Wiesbaden, 343 pp.
- Meinel, W., Pieper, H.-G., Lelek, A. & Pelz, G.R. (1986): Das Vorkommen der Fische in Fließgewässern des Landes Hessen. – Der Hessische Minister für Landwirtschaft und Forsten, Wiesbaden (Hrsg), Wiesbaden, 72 pp.
- MLR – Ministerium für Ernährung, Landwirtschaft, Umwelt und Forsten (1980): Berücksichtigung der Belange von Naturschutz, Landschaftspflege, Erholungsvorsorge und Fischerei bei wasserbaulichen Massnahmen an oberirdischen Gewässern (Wasserbaumerkblatt). Erläss vom 30. Juni 1980.

- Renaud, C.B. (1982): Revision of the lamprey genus *Eudontomyzon* Regan, 1911. – M. Sc. Thesis, University of Ottawa, Ottawa, 146 pp.
- Schadt, J. (1991): Das Bachneunauge. – *Der Angler und Naturfreund* **3**: 17-19.
- Schadt, J. (1994): Fische, Neunaugen, Krebse und Muscheln in Oberfranken – Atlas der Arten – Vorkommen und Verbreitung als Grundlage für den Fischartenschutz. – Fachberatung für Fischerei des Bezirks Oberfranken (Hrsg.), Bayreuth, Gürtler-Druck, Forchheim, 136 pp.
- Sieglin, H. (1892): Die Fischerei-Verhältnisse in Württemberg. – *Württ. Jb. Statistik Landeskunde*, **2**: 65-271.
- Waterstraat, A. (1989): Einfluss eines Gewässerausbaus auf eine Population des Bachneunauges *Lampetra planeri* (Bloch, 1784) in einem Flachlandbach im Norden der DDR. – *Fischökologie* **1**: 29-44.
- Winkler, H.M., Hamann, N. & Waterstraat, A. (1991): Rote Liste der gefährdeten Rundmäuler, Süßwasser- und Wanderfischarten Mecklenburg-Vorpommerns. 1. Fassung. – Umweltministerium des Landes Mecklenburg-Vorpommern, 28 pp.

**Authors' address:** Berthold Kappus  
Wolfgang Jansen  
Pearl Fok  
H. Rahmann  
Institute for Zoology  
University of Hohenheim  
Garbenstrasse 30  
D-70593 Stuttgart, Germany