Int. Revue ges. Hydrobiol.	75	1990	5	619–638

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Results to the Ecology of Endangered Species of Fish and Cyclostomes from Three Streams of Northern and Central Germany

key words: streams conservation, ecology, endangered cyclostomes and fish

Abstract

Research into endangered species of fish and cyclostomes, as well as their living environment, are prerequisite to determining species protection measures.

Relevant ecological research was carried out in three streams in the trout and grayling region; the environmental conditions were recorded, and the populations characterised.

Consequently the following suggestions for the protection of the streams dealt with in this research can be made.

Contents

1. Introduction

Streams within their natural state are of increasing interest in nature conservation. This is true for the living environment for the majority of protected fish and cyclostomes, as well as for further animal and plant species. This is equally applicable to the conservation of individual species as to that of the ecosystem.

Studying the list of conservation reserves in the former G.D.R., one sees that streams run through 17 % of them. There are springs, short stretches of streams, old arms. Long sections are protected in only a few cases. It is especially evident in the north of the former G.D.R., that many waterways, in which endangered and protected species live, are not in conservation reserves.

To determine species conservation programmes for the freshwater stream species minnow *(Phoxinus phoxinus)*, bullhead *(Cottus gobio)*, stone loach *(Noemacheilus barbatulus)*, brook lamprey *(Lampetra planeri)*, river lamprey *(Lampetra fluviatilis)* and *Alburnoides bipuncatutus*, comprehensive ecological research is necessary. Staff of the biological station at Serrahn have undertaken research since 1986, with the following objectives.

- Identification of selected population ecology parameters.
- Recordings of important environment conditions for the species.
- Observation of the development of stocks in specified streams, and also observation of the development of the stream sections themselves.
- Derivation of protection measures for species and waterways.

In this contribution, the investigation of 3 streams is presented, and early results are discussed. Two streams in the northern plain (the Nebel, in the Güstrow district, and the Dömnitz, in the Pritzwalk district) and one from the central mountain region (the Ulster, in the Bad Salzungen district) are dealt with.

2. Subjects of Investigation

The selection of streams for the enquiry was made with regard to the fish fauna, especially where endangered or protected species existed. In these waterways, sections were selected which represent typical stretches, e.g. close to natural conditions, and a section that has been drastically rechannelled.

2.1. The Nebel

The Nebel has its source south of the Malkwitzer See (Lake) in the Waren district, and flows into the Krakower See near the village of Dobbin (Fig. 1). The flow is extensively regulated.

Near the township of Serrahn, the Nebel flows out from this local lake, cuts through the end moraine in a close to natural course, before running into the Warnow near the town of Bützow. (The Warnow has its mouth in the Baltic sea near Rostock.) In the upper reaches, it changes from extensive gravel and pebble stretches with sharp a fall, to stretches whose character is dominated by meadows. In short stretches scattered forestation has formed. Meandering sections alternate with sections that were long ago straightened. Since the water comes largely from the Krakower See, there are relatively high temperatures in summer (18 °C/64 °F) and whilst in winter it is relativly cool.

The Nebel ist roughly 70 km long. The waterflow is regulated by a barrage at the point of discharge from the Krakower See.

The research section I is downstream from the Kuchelmiss roadbridge, and begins after a section with pebbles, which runs into a near-to-natural section, with a meadow dominated character. The water surface area amounts to 787 m^2. The degree of shading during the time of foliation (Black Alder, *Alnus glutinosa*; Red Beech, *Fagus silvatica*) is approximately 40 %. Until summer, a large quantity of *Elodea canadensis*, *Potamogeton crispus*, *Sparganium erectum* and *Nuphar lutea* develop in the water, and occupy approximately 55 % of the area.

The research section II lies upstream from the Ahrenshagen/Koppelow roadbridge, and is dominantly consisting of meadows as it flows from a wooded section.

The surface area amounts to 397 m^2. The banks are strongly wooded with alders, and the shading amounts to around 75 %, with the submerged macrophytic growth covering about 10 %.

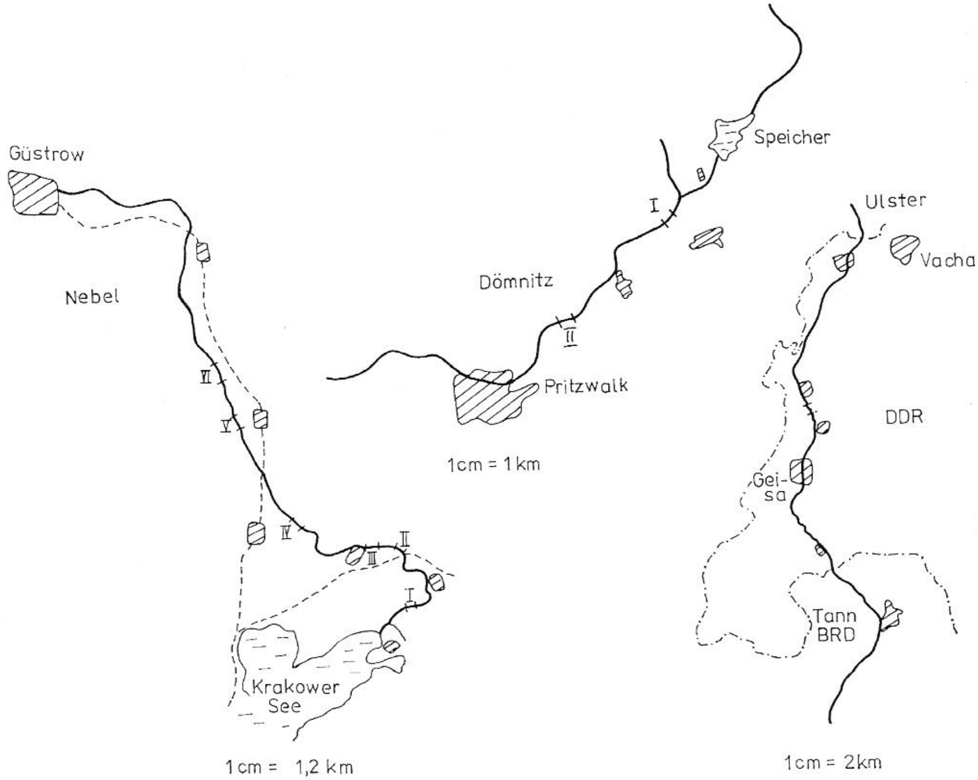

Figure 1. Maps of the streams under investigation.

2.2. The Dömnitz

This brook is formed by the combination of three smaller flows in the neighbourhood of the village of Kuckuck. It flows into the Stepenitz at Wolfshagen (Fig. 1). The flow is accompanied mainly by agricultural land (fields and meadows). In the upper reaches near Kuckuck there is a reservoir for agricultural purposes, in service since 1987, which contributes to some changes in water parameters. Large sections of the Dömnitz have already been rechannelled. Approximately as far as Pritzwalk, the water quality is such that protected species still live there and can propagate themselves.

The enquiry was carried out over two sections.

Research section I is located near the village of Sadenbeck, downstream from a weir that makes fish movement to the upper flow impossible. The length amounts to 100 m. Apart from remains of fascines, there are no pools or cover. This part of the brook was rechannelled 10 years ago, and set about 1.5 m below the meadow landscape. Alder trees have been planted on the eastern bank, but are so far from the centre line of the water that they contribute neither to the strengthening of the banks, nor to the formation of funk holes for fish. The shading amounts to 20 %. As a result of the strong current there is only a meagre plant population. This varies between 0–30 % growth (mainly *Berula erecta* and *Fontinalis* spec.).

Research section II is located in Hainholz, about 5 km north of the city of Pritzwalk.

Here, the Dömnitz flows naturally, with strong meanders, through riverbank forestation roughly 50 m wide. Riparian vegetation consists of alders, ash *(Fraxinus excelsior)* and willows *(Salix)*. This riverbank area itself is set about 2 m below the level of the surrounding countryside.

Older alders stand on both banks, and form cover for fish. As a result of the high degree of shadowing (70 %) there is no water-plant population. The research section is 100 m long.

2.3. The Ulster

The Ulster is a tributary of the River Werra. Its source is at Heidelstein (920 m above sea-level) near Wüstensachen, when after about 23 km it reaches the former border of the G.D.R. at Motzler. After a further 24 km course through the former G.D.R., the river flows at Philippsthal into the Werra (Fig. 1).

Several brooks are tributaries of the river, e.g. the Brandbach, Schoppenbach, and Taft, and the Apfelbach, Geisa, Kohlbach and Bernbach. On its course the river has cut through basalt, limestone and red sandstone. The quantity of water carried changes dramatically in proportion to rainfall. As a result of high water at the time of our investigation, a quantitative enquiry of fish fauna was necessarily limited. In the section within the former G.D.R., stretches alternate with some that exhibit a relatively natural state, and others that have been heavily rechannelled. The process of straightening went as far as shifting the river bed and filling in bends. Because of the relatively great width, and the velocity of the current, only one test section was worked on, this was the section between Buttler and Borsch, situated in a stretch rechannelled a few years ago. An old arm of the river, on the right hand side, is still directly connected with it. Both sides are bounded by meadows and fields; the river itself is about 2,50 m below the land level. Alders and willows *(Salix)* grow on about 20 % of the bank area. The research section is about 65 m long, and the surface area amounts to 1200 m². The river bed has no plant population, but some plants on the bank hang into the water.

3. Methods

The fish stock survey took place with the help of D.C. electro-fishing gear. This process had technologically some limitations and consequently quantitatively significant recordings could not be obtained for all species especially for the case of those in the years of life 0^+ an 1^+. As a rule, two samplings of fish were taken close after each other. The fish were held, measured and weighed, and after the recording of their species had been completed, replaced in the area from which they were taken.

The fish quantity caculation was made by application of the formula proposed by Zippin (1956)

$$C = \frac{C_1^2}{C_1 - C_2}$$

C = total fish quantity

C_1 = quantity in first sample

C_2 = quantity in second sample

The total length (Lt) was measured accurately to the nearest 0.5 cm, and the mass of each fish to the nearest 0.1 g. To ensure comparability of values the investigations in each case were done at the same time of year (August/September).

To evaluate the ecological importance, the following parameters of the section that had been researched were qualified in breadth, depth, flow velocity, sediment composition, temperature, proportion in skade, growth of underwater vegetation, pools, O_2 content. The flow velocities were measured with a water flow-meter type G_1RSS, $V_0 = 0.07$ m/s, $d = 6.5$ cm. Determination of propellor blade revolutions per second 10 cm above the bed and 10 cm below the top surface.

In the morphometric survey of the sections, the following procedure was used.

- Marking and mapping out of the cross-section (5 m intervals) upstream (so that the stirred-up sediment could not lead to inaccuracies in measurement). First the vertical measurements were set at 0.5 m, then again, in the upstream direction going towards the left.
- Breadths corresponding to the current water level were measured with a tape.
- Sediment (in every vertical measurement)

Sediments were evaluated with the help of a 6 step scale.

1. = Clay, fine and medium silt.	$d < 0.02$ mm.
2. = Coarse silt and fine sand.	$0.07 > d < 0.2$ mm.
3. = Medium and coarse sand.	$0.2 > d < 2$ mm.
4. = Fine and medium gravel.	$2 > d < 20$ mm.
5. = Coarse gravel.	$20 > d < 63$ mm.
6. = Rubble and Boulders.	$d > 63$ mm.

The waterplants were recorded according to species and their degree of cover, as well as the proportion of shadow due to trees on banks; this was evaluated on a percentage basis. We counted pools and cover during the fish removal process. Sediment samples were removed, dried in a drying cupboard, and separated into separate grain-size samples with graded sieves.

An analysis of primary statistics was prepared for every stream section.

Against the mean values we also tabulated minimum, maximum and standard deviation, since the distributions of depth, width and flow velocity are characteristic values bound to the mean.

4. Results

Table 1 gives an overview of the flow relationships, flow velocity, waterway depth, and width of the three waterways. It will already be apparent from these parameters that three very different streams are being dealt with, from which direct comparisons are not immediately possible. The analysis of these results shows that the mean value of flow velocity ($\bar{x}$) is not a reliable indicator, but only the extent of the diversity. Therefore the standard deviatation (s) has been arrived at.

The species in the waterways are listed in Table 2.

Table 1. Discharges, velocity of flow stream, depth and width in research sections

		Nebel		Dömnitz		Ulster
		Kuchelmiß 3.6.87	Ahrenshagen 3.6.87	Sadenbeck 2.6.87	Hainholz 2.6.87	Buttlar 18.9.87
discharge (m^3/s)	$\bar{x}$	0.87	0.95	0.14	0.20	2.15
velocity below level (m/s)	$\bar{x}$	0.31	0.24	0.31	0.31	0.56
	s	0.21	0.14	0.21	0.16	0.34
	n	172	87	86	139	62
depth (cm)	$\bar{x}$	19.6	45.0	19.7	19.3	22.4
	s	16.7	15.9	8.2	9.5	12.3
	n	167	87	86	139	62
width (m)	$\bar{x}$	14.23	7.98	2.48	3.18	14.86
	s	2.79	1.41	0.25	0.48	1.83
	n	12	11	17	21	8
section distance (m)		55	50	80	100	80
area (m^2)		787	397	198	330	1200

Table 2. The species list and population densities of the species (Ind./100 m²) of the research sections.
*information received from the German Anglers Association

stream / species	Nebel: list of species Nebel	Nebel: Kuchelmiß 20. 8. 87	Nebel: Ahrenshagen 21. 8. 87	Dömnitz: list of species Dömnitz	Dömnitz: Sadenbeck 13. 8. 87	Dömnitz: Hainholz 13. 8. 87	Ulster: list of species Ulster	Ulster: Buttlar 18. 9. 87
Lampetra planeri juv.	+	6.4	0.5	+	5.1	30.3	+*	
ad.						3.9		
Salmo trutta fario	+	0.3	5.0	+	5.6	0.6	+	0.25
Salmo gairdneri	+	0.1	0.3	–			+	
Salvelinus fontinalis	–			–			+*	
Thymallus thymallus	+	0.5		–			+	0.4
Anguilla anguilla	+	3.2	1.3	+		0.6	+*	
Esox lucius	+			–			–	
Phoxinus phoxinus	+	22.2	16.6	+	10.1	24.8	+	25.0
Gobio gobio	+	2.5	14.1	–			+	2.5
Tinca tinca	+	0.3		+			–	
Leuciscus cephalus	+	3.0	6.0	–			+	0.2
Leuciscus leuciscus	–			–			+	0.8
Leuciscus idus	+*			–			–	
Barbus barbus	–			–			+	
Alburnoides bipunctatus	–			–			+	
Rutilus rutilus	+*			–			–	
Noemacheilus barbatulus	+	1.5	1.3	+	5.1	6.1	+	2.5
Cobitis taenia	+			–			–	
Perca fluviatilis	+	0.1	2.5	–			–	
Gymnocephalus cernua	+*			–			–	
Cottus gobio	–			+	47.4	27.3	+	75.0
Gasterosteus aculeatus	+			+	24.7	5.5	–	
Pungitus pungitus	+	0.1	0.3	+	3.5	2.4	–	
Alburnus alburnus	+*							
species total	19			9			14	
total population density		40.2	47.9		101.5	101.5		97.5

4.1. Morphology, hydrology and fish stocks of the Nebel

Comparison of the two sections, both are in an almost natural state, shows a marked variation of form. This is evident from Figures 2 and 3, which show the cross-section profiles, as well as from Figures 4 and 5, which represent the sediment distributions.

The depth of water varies constantly, a result of the effect of the heterogeneous sediment which had been deposited. This gives a richly varied profile of the waterway and guarantees good living condition for many species of fish.

Depending on the shading the extent of distribution of underwater macrophytes is very variable. During the early part of the year, there is only a slight growth, but this becomes relatively thick and by summer covers a large area.

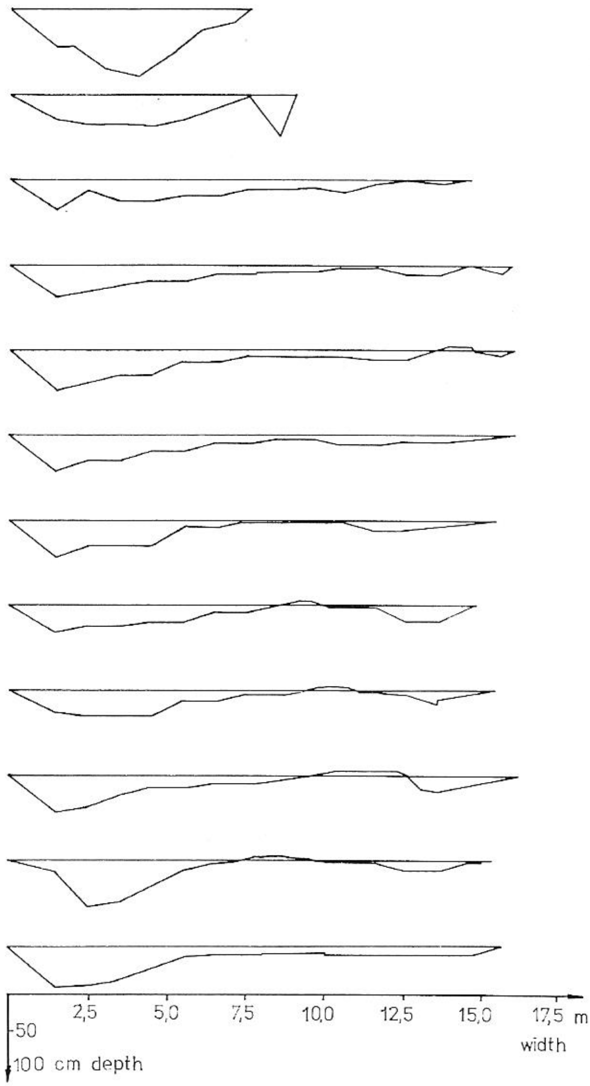

Figure 2. Cross-section profiles Nebel section I.

The ichthyofauna of the Nebel comprises altogether 19 species (SPIESS and WATERSTRAAT, 1988) of which 12 could be authenticated in the test area during the time we had available (Table 2).

Further species, such as the pike *(Esox lucius)* and the tench *(Tinca tinca)* apparently come down from the Krakower See or escape regularly from fish breeding centres (rainbow trout, *Salmo gairdneri)*. The grayling *(Thymallus thymallus)* has been released in the Nebel in recent decades. The Nebel contains even without these above mentioned fish a great variety of species.

With the existence of approximately 20 individuals/100 m^2, the minnow *(Phoxinus phoxinus)* is the most populous species in the Nebel's upper reaches, with the exception of the pebble section. The gudgeon *(Gobio gobio)* with 2.5–14.1 individuals/100 m^2 and the chub *(Leuciscus cephalus)* with 3–6 individuals/100 m^2 are also frequently

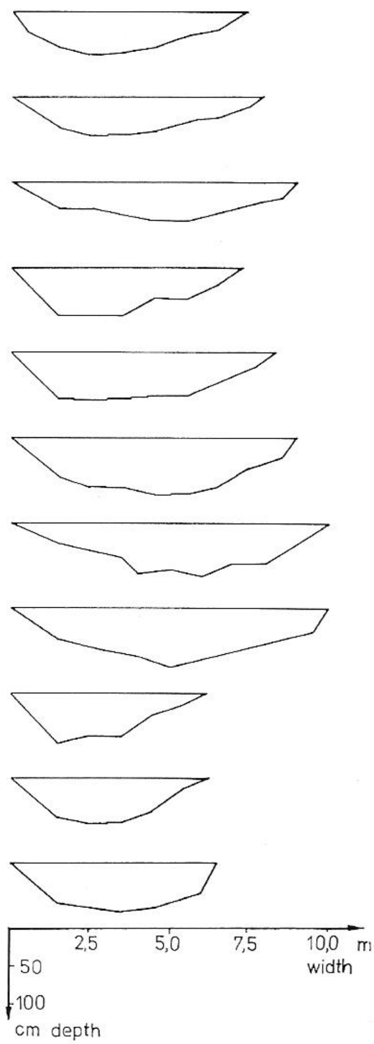

Figure 3. Cross-section profiles Nebel section II.

found. The availability of cover allows the larger brown throut (*Salmo trutta* f. *fario*) to be widely distributed, while the influence of angling on the abatement of biological quantities can also be conjectured. In the research section II a large number of juvenile brown trout, that had resulted from natural reproduction, was recorded. The small number of individuals of the species grayling doesn't reflect their true number; this was probably due to the large extent with which some fish fled the test area, without being restrained by net barricades. At least in the boulder section directly above the research section I the population density is nearly as great as for brown trout. This was confirmed when in 1988 a number of fish were found poisoned in this part of the Nebel. The greater presence of juvenile *Lampetra planeri* (brook lamprey) in the research section I credited to the existence of suitable spawning places in this area. At the end of May 1988, about 50 m downstream from the test-stretch at Kuchelmiss, numerous spawning places occupied by adult brook lampreys could be found.

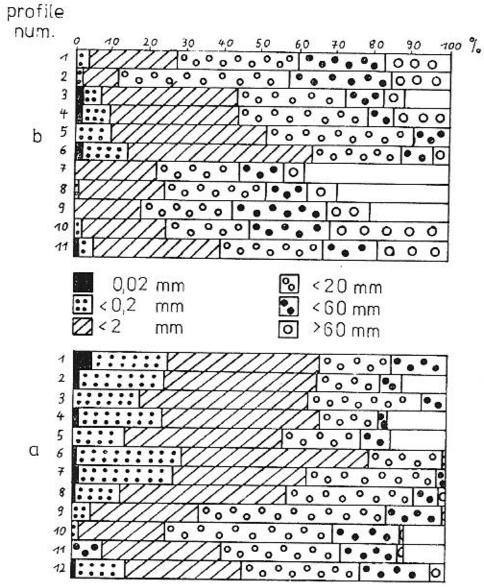

Figure 4. The sediment distributions of the cross-section profiles Nebel section I (*a*) and section profiles Nebel section II (*b*), 3. 6. 1987.

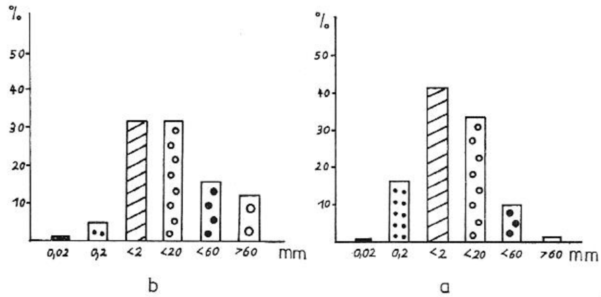

Figure 5. The sediment composition of test section I (*a*) and II (*b*) of the Nebel, 3. 6. 1987.

Seasonal differences in the occurrence of fish fauna in the individual sections of the Nebel have been described by Spiess and Waterstraat (1988). The vegetation on the banks plays an important role by its changing degree of shading. Due to heavy shading by *Alnus glutinosa* in summer, only patchy macrophytic growth develop. This is especially characteristic of section II. These locations are better suited for habitation by young fish (*Salmo trutta* f. *fario*; *Phoxinus phoxinus*, *Gobio gobio*) than the thick macrophytic growths in the river section near Ahrenshagen.

As only a small number of young fish in the 0^+ year of life were caught, the length distributions for minnows, as shown on Figure 6, is predominantly from 2–3 year old specimens. Following the Tack method of 1941, the age was accordingly determined by the sampling of scales.

The absence of larger minnows, in comparison with other streams, is conspicuous. This has also been confirmed in other investigations along this stream.

The population has a noticeably low *K*-factor (Fulton's coefficient) (Table 3).

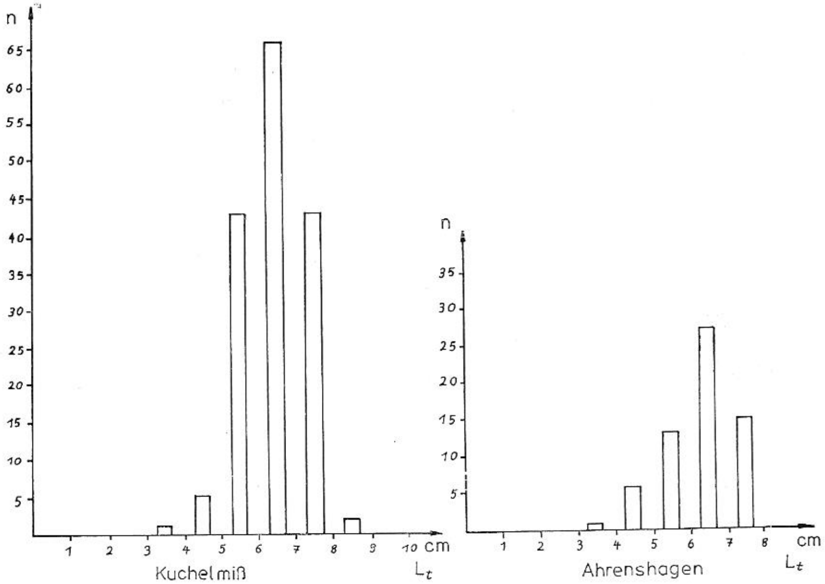

Figure 6. The length distributions of minnows of the Nebel.

Table 3. k-Factor $\left(\text{Fulton's coefficient } k = \frac{100 \cdot M}{L^2}\right)$ of minnows in the three research streams

Age / site		Nebel		Dömnitz		Ulster	
		Kuchelmiß	Ahrenshagen	Sadenbeck	Hainholz	Buttlar	
						7 cm	7 cm
1+	$\bar{x}$	0.80	0.73	0.96	0.96	0.70	0.96
	s	0.14	0.12	0.13	0.13	0.03	0.18
	n	160	61	12	58	76	33

4.2. Morphology, hydrology and fish stocks of the Dömnitz

Both research sections show very different circumstances and conditions. This is illustrated by Figures 7 and 8 as well as Figures 9 and 10, with regard to sediments, especially in the sediment analysis. While coarse material strongly dominates in section I fine sediments make up the greatest proportion in test section II.

But the flow velocities are also very different. No pools or funk-holes existed in section I, however the second section was enriched by both these important structural elements. The stream in this section meanders very strongly.

These differences in abiotic conditions are reflected back in the results for fish fauna, especially in the population structures of various species.

The actual fish fauna of the Dömnitz comprises 8 species (see Table 2). Occasional catches of other types, such as the tench *(Tinca tinca)* are the result of escapes by fish from water reservoirs in the upper reaches. The existence of the bullhead *(Cottus gobio)* is especially to be emphasized. Other protected species, such as *Ph. phoxinus*, *N. barbalatus* and *L. planeri* still find suitable conditions here.

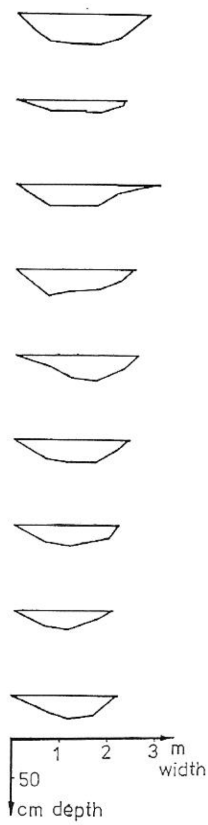

Figure 7. Cross-section profiles Dömnitz section I (Sadenbeck).

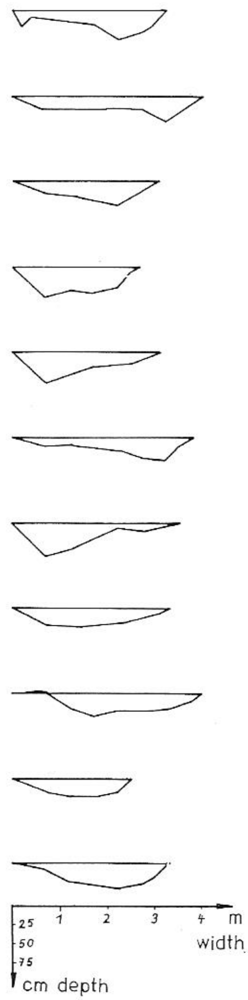

Figure 8. Cross-section profiles Dömnitz section II (Hainholz).

Considerable differences in the population structure between the test sections can also be found during the course of the year. This is caused by effects not described here. This applies for stickleback types, which are underrepresented in the catch, as well as for bullheads, minnows and lampreys. Larvae of the brook lamprey could be found predominantly in the natural course of the stream in the wooded section, while the younger brown trout were found especially in the coarse sand and rubble of the upper test section. Considerable differences also occur with minnows (Fig. 11). Young fish were exclusively present in the meandering section of the brook, in the wooded part of Hainholz, while older specimens of 8 cm and longer dominated at Sadenbeck. A similar population structure could be observed for *C. gobio* at the time of the investigation. In the wooded Hainholz section, all age groups were represented. This can be seen as the result of undisturbed reproduction. In comparison, the reproduction in the upper section near Sadenbeck was practically non-existent in 1987, although our investigation in 1986 had established a high reproduction rate in this part.

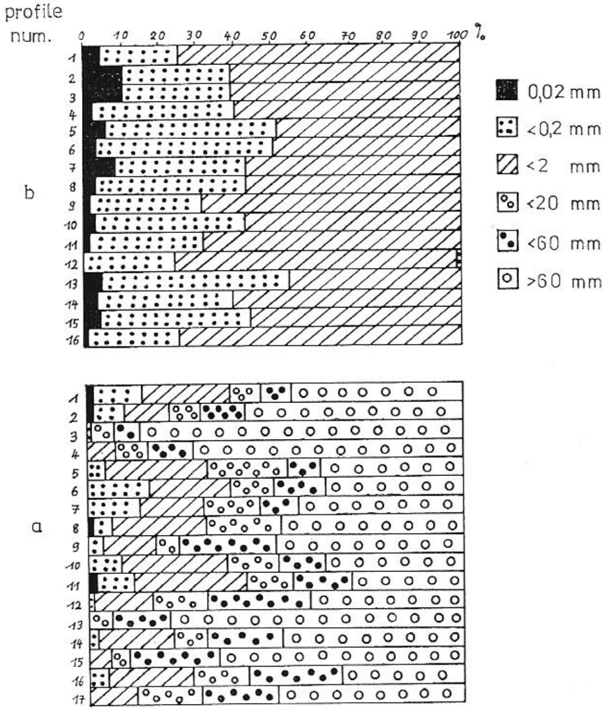

Figure 9. The sediment distributions of the Dömnitz sections I (*a*) and II (*b*), 2. 6. 1987.

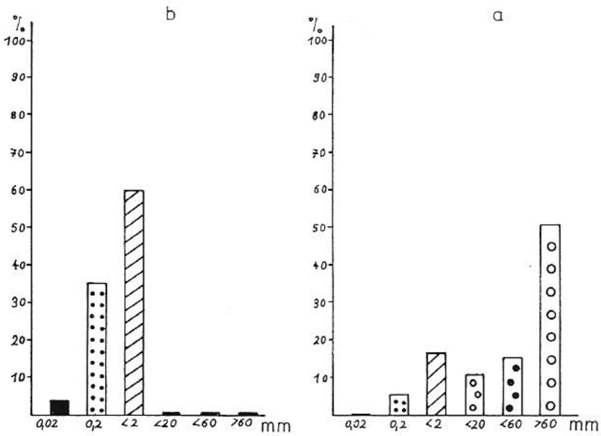

Figure 10. The sediment composition of test section I (*a*) and section II (*b*).

In the year 1988 the tendency in the population development of the bullhead in the upper reaches declined (Fig. 12). On the other hand, the increase of important fish species appears to be similar in both sections. The *K*-factor (Fulton's coefficient) taken as a function of the feeding conditions, is around 0.96 for minnows in both sections of the brook (Table 4). This is a relativly high value in comparison to other waterways. A higher *K*-factor can also be reported for *C. gobio,* than in other waterways (WATERSTRAAT, in preparation).

The population count for bullheads was between 27 an 47 ind./100 m^2.

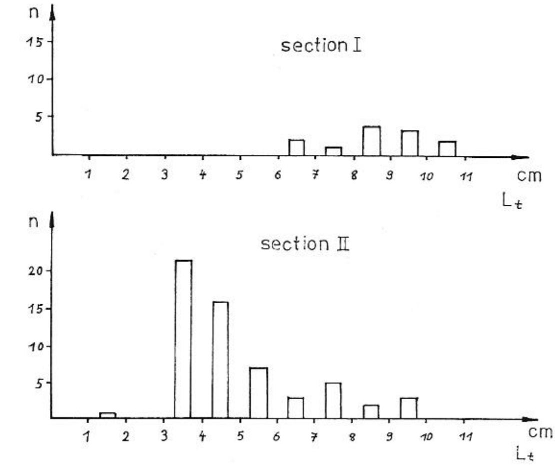

Figure 11. Length distribution of minnows of the Dömnitz test sections I and II.

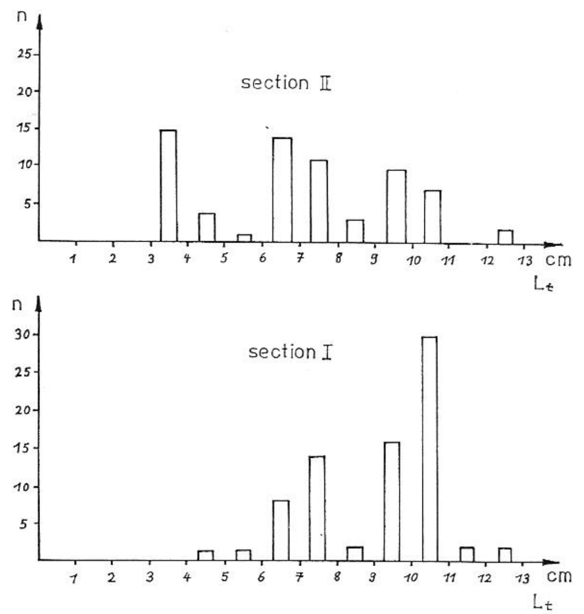

Figure 12. Length distribution of *Cottus gobio* of the Dömnitz.

Table 4. *k*-Factor (Fulton's coefficient) of *Cottus gobio*

Age / site		Dömnitz Sadenbeck	Dömnitz Hainholz	Ulster Buttlar
0^+	$\bar{x}$	–	1.14	1.23
	s		0.21	0.23
	n		11	5
	$\bar{x}$	1.21	1.18	1.24
1^+	s	0.16	0.18	0.17
	n	79	26	43

4.3. Results of Investigation in the Ulster

Because of the width of this stream, and its limited capacity for measurement, research of fish fauna could only be undertaken for one section.

The cross-section of the part (Fig. 13) shows that at this stretch the river is relatively wide and has minimal depth; these are similar to the more level sections. In other sections, especially rechannelled or otherwise reconstructed, fundamentally different conditions exist. After heavy rainfall, or during the melting of snow, the water-level is noticeably higher than at the time of the investigation. The sections have been stabilised with stone materials following rechannelling.

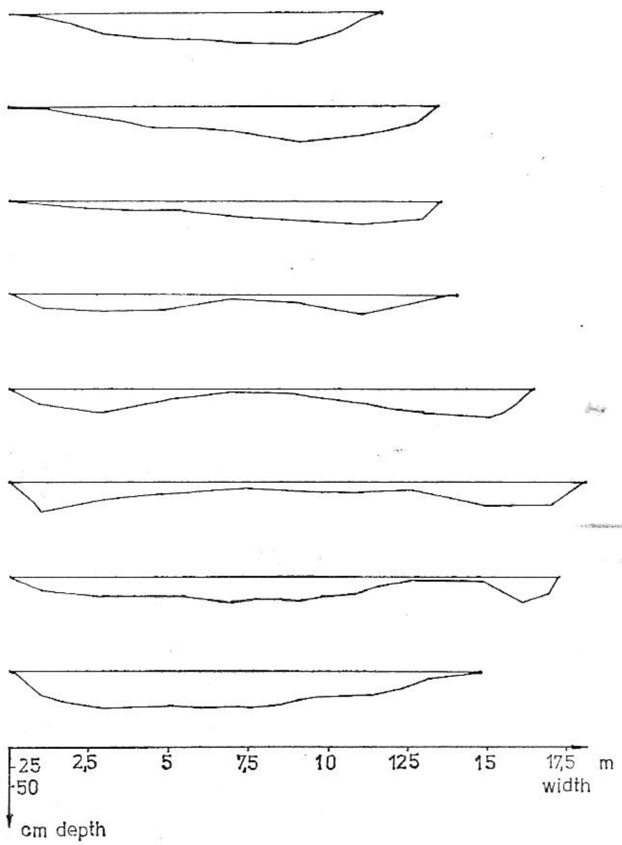

Figure 13. Cross sections profiles Ulster.

Figures 14 and 15 show a preponderance of larger particles in the sediment; the distribution is relatively similar within the research section. Pools were not recorded in the research section, but it must be pointed out that very deep pools (up to 2 m) exist in other stretches of the waterway. In one such pool, an adult example of *Alburnoides bipunctatus* was caught, thus confirming the information from Klemm (1985).

In the course of our research we were able to confirm the existence of 12 species of fish in the course of the Ulster (Table 2). However, evidence of the *Alburnoides bipunctatus*, the barbel *(Barbus barbus)*, the rainbow trout *(Salmo gairdneri)* and the eel *(Anguilla anguilla)* was only possible outside the test section, and the information on

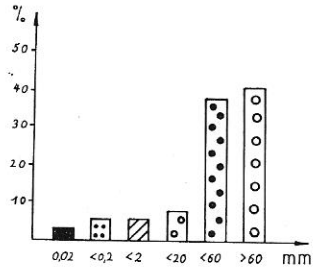

Figure 14. The sediment composition of the Ulster (test section).

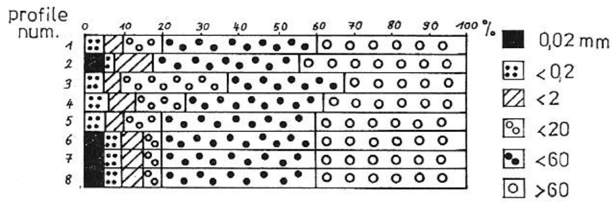

Figure 15. The sediment distributions of the cross-section profiles of the Ulster (test section 20. 9. 1987).

the brook lamprey *(Lampetra planeri)* and the brook trout *(Salvelinus fontinalis)* was obtained from the D.A.V. of the DDR (German Anglers Society).

At the time of the investigation, only a single recording could be conducted and the estimations of stocks were assessed from catches made in streams with comparable conditions. Dominating species in the research section at Buttler are *C. gobio* and *Ph. phoxinus*. It was conspicuous that *Cottus* was especially found where water streamed over gravel and pebble areas, while *Phoxinus* preferred deep water and the regions near banks. Both species could be observed in the whole Ulster region of the Bad Salzungen district above the potash works at Unterbreizbach. This also applies for a majority of the other species of the Ulster, of which grayling and barbel were especially found in stretches with a strong flow velocity and a stony bed, as for example in the main current of the waterway. A rechannelled section with flow-velocities from 0.6–1.4 m/sec, for example, gave population densities of 3.3 ind/100 m^2 for *T. thymallus* and 0.4 ind./100 m^2 for *B. barbus*, which lay fundamentally above the densities for other test sections. A more exakt analysis of the minnow population brought up

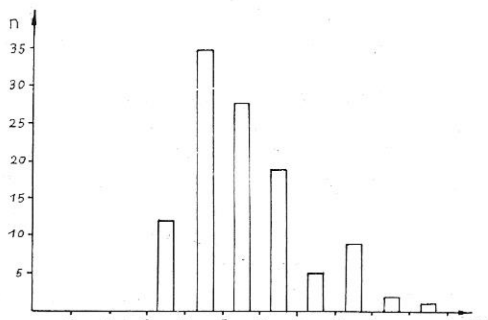

Figure 16. Length distribution of minnows of the Ulster.

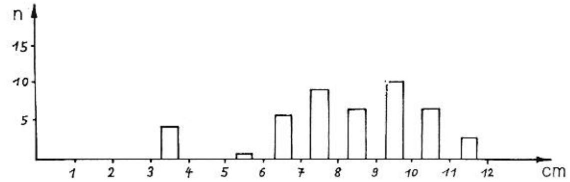

Figure 17. Length distribution of *Cottus gobio* of the Ulster.

consistently individuals larger than 9 cm (Fig. 16). The *K*-factor (Fulton's coefficient) also notably demonstrates good feeding conditions for the older specimens. The results taken for *C. gobio* demonstrate an undisturbed population development in the enquiry section (Fig. 17). When it is taken into account that, through methodological requirements (especially with high stream velocity) the 0^+ generation can only be very inadequately recorded, and thereby the estimated individual density of 12.5 ind./100 m^2 can probably be accepted as basically too low, it is apparent that the optimum conditions for *C. gobio* lie at hand. The *K*-factor (Fulton's coefficient) reflects this as well.

5. Discussion

The drastic decline of natural-state streams in middle Europe, and the accompanying endangering of natural communities in this living environment is significantly reflected in the Red Data Lists (Blab, 1984).

Essential protective measures have made it necessary to discuss more intensively the ecological potency of endangered species, as well as the effects of various decisive environmental factors. Indeed, in Ecology there are numerous findings which show that as the complexity of the living space diminishes, there is also a noticeable reduction in the diversity of the living community. In fact, quantitative research on this for fish fauna in streams is very scarce. As a first step Gorman and Karr (1978) showed the general relationship between the complexity of the stream environment and the diversity of the fish species, inhabiting subtropical regions of North America. Jungwirth *et al.* (1981, 1984) did the same for alpine and subalpine rivers in Austria. Both pieces of research, however, because of the specific conditions of their waterways, cannot necessarily be applied to the situation of our streams. An increasing amount of research is undertaken with the quantitative correlation between the fish population of small streams and other important environmental factors; in these, however, it is mostly only the habitat requirements of the Salmonides which are taken into account (Bowly and Roff, 1986; Nielsen, 1986; Kainz *et al.*, 1984). A study concentrating on the protection of especially endangered small fish was undertaken by Bless (1981, 1985).

Our research confirms the high diversity and, to some extent, great abundance of rheophile species in natural-state waterways, but also that some principal differences can be established in consideration of particular streams. In the research sections of the Nebel, the abundance and diversity of the fish fauna is significant and reflects structural diversity of the abiotic factors. When ecological classification based on spawn appearance (after Balons, 1965) is followed, the psammophilian species pedominate strongly in both sections: *Phoxinus phoxinus, Gobio gobio, Noemacheilus barbatulus,* and lithophiles: *Salmo trutta* f. *fario, Thymallus thymallus, Leuciscus cephalus, Lampetra planeri*. This is an secure effect of spawning places for these species. At the same time, the composition of the fish fauna also reflects the transitional character of the waterways.

Alongside of typical species of the Rhitrals such as *S. trutto* f. *fario, L. planeri* and *Ph. phoxinus* one can meet representatives of the Potamals, auch as *L. cephalus, G. gobio* and other Cyprinides. Important reasons for these relationships are represented in the typically high temperatures of the discharge from the lakes in the summer (Böttger, 1983), the good supply of foodstuffs from the resulting macrophyting stands, and the far-reaching absence of extreme high waters, which would otherwise limit the appearance of the limnophilic species of the rhithrals. Early research into a uniform rechannelled section in the middle part of the Nebel's course, with the same depth and flow velocity and without its meandering course and vegetation on the banks has already let us recognise that brown trout and chub, especially, cannot adapt to this living space, whilst other species, such as the sticklebacks *Gasterosteus aculeatus* and *Pungitius pungitius* appear with considerable abundance.

By the example of varying development of macrophytic vegetation in both test sectons in the course of the year, it becomes significant how completely the influence of the environment affects the abundance of the individual species. Also to be taken into consideration is the variety of individual habitats in the Nebel, with characteristic features in each case, which simply could not be recorded in our research. This is especially the case for pebble sections. This variety of living spaces, and the seasonal alterations in them, appear to be prerequisite for high diversity of the ichthyofauna.

Due to the rechannelling process in the Dömnitz greater differences between the test sections had developed. This is reflected in the minnow population (Fig. 10) as well as in the reduction of density of lampreys in the rechanelled section.

On the other hand, more elaborate rechannelling measures, such as the inclusion of fascines, replanting with alders, and the regular laying-down of rubble sections in certain sections of the upper course of the Dömnitz, have over the course of at least a decade led to the formation of a variety of habitats for the fish fauna. This especially promotes the occurence (which is substrata dependent) of the bullhead, (Bless, 1983; Welton *et al.*, 1983) as well as the appearance, from time to time, of juvenile brown trout in the rubble-sections laid down near Sadenbeck while the high silt load promotes a mosaic distribution of areas of fine sand. As coarse sediment does not occur in natural locations in Hainholz, except for rare occasion as at bridges, *C. gobio* especially makes use of any existing structures in the microhabitat such as branches, tree-roots, overhanging grass, and peat sods as hiding places during the day (see also Feiler, 1986). Separate research confirms that creatures active at dawn and dusk (Mills and Mann, 1983) leave their hiding places at these times, whilst creatures in all age groups stay in the middle of the stream over fine-coarse sand. High density of fish stocks in such apparently unfavourable sediment conditions was also investigated by Zucchi and Goll (1981) and Späh and Beisenherz (1982, 1984). Späh and Beisenherz (1982) observed 30–100 ind./100 m^2 in similarly sandy streams in east Westphalia and the stocks in the river Tees (Crisp *et al.*, 1974) which lie in the same range. Both Andreasson (1973) in southern Swedish streams, and Mills and Mann (1983) in southern English streams, rich in food and lime, could report population densities even up to 1000 ind./100 m^2 for optimal biotopes, of which, however, 80 % belonged to the 0* age group. We did not record this for species-protection reasons. The research of Mills and Mann also shows that in the cold, low food supply streams of north England, the bullhead populations have a different living strategy, with small population densities, longer life-span, and delayed sexual maturity. We can note population densities of 0–58 ind./100 m^2 in streams of the Erzgebirge, depending on the degree of pollution in the water (Waterstraat, 1989). In this paper, populations of less than 10 ind./100 m^2 were taken as an indicator of damaging water pollution. A permanent peril for rheophilic fauna of the Dömnitz has been caused by barrages in the upper reaches of the Dömnitz, and has often been established, in the Sadenbeck area. The stream extent has been considerably reduced here and lenitic areas have been favoured.

A basic danger for the fauna of the Dömnitz results from the operation of a ca. 1.0 million m^3 shallow water reservoir operated on the through-flow principle, about 2.5 km upstream from the test section at Sadenbeck, built up for irrigation. The thermal pollution associated with this, as well as the eutrophication, or muddying of spawning places, is, after 1 year of operation of the reservoir, already judged to be the cause of the interrupted reproduction of *C. gobio*. More exact experiments about this question are being conducted at present.

Analysis of fish fauna in the Ulster brings up basic differences between this river and the preceding waterways. This occurs through appearance of such species as *B. barbus*, *A. bipunctatus* and *L. leuciscus*. In the main, this is caused by abiotic factors, such as higher stream velocities, and the predominance of sediment. Through the frequent occurrence of floods due to the melting of snow or heavy rains, only the rheophilic species can survive in the long term. Despite the rechannelling of some stretches, a multitude of habitats for the rheophilic fauna have been retained or newly formed in the Ulster, and these are frequently necessary for the survival of certain species of fish in certain stages of life. Thus adult *Alburnoides bipunctatus* need pools and deep river channels (Gebhardt, 1984), grayling and barbel fast flowing but adequately deep riffles, while old arms or other areas of weak current-flow represent ideal breeding areas for minnows.

A prerequisite for the high species diversity, compared with other waterways of the former G.D.R., is, naturally, the relatively low pollution and fouling. In addition, the possibility of migration is limited by only a few weirs.

Furthermore the self-reproducing population of *Barbus barbus*, the only evidence of *Alburnoides bipunctatus* in the G.D.R., is especially noteworthy. No mention of this fish was made by Pieper (Natur in Hessen, 1987) in the upper reaches of the Ulster in Hessen; only rivers that are tributaries of the Fulda have been cartographically recorded. Our results don't simply reflect the differences between the different water-way types. The research shows that there are also considerable fluctuations in the population densities of individual species in the course of the seasons. The customary single recordings (e.g. Jungwirth, 1985; Späh and Beisenherz, 1982) reflect the actual conditions or relationships very incompletely. In terms of species and biotope conservation, it is especially important to build up appropriate data for the different biotopes which determine the population (reproduction, growth development and winter-habitats). At the same time the cartographical productions on fish fauna of the G.D.R. (unpublished material) confirm that there are very few examples of the waterway types (and their natural communities) of the type presented here, in the G.D.R. Implementation of the conclusions from this research in conservation measures is thus urgently needed. Also proposed is the inclusion of all 3 waterways in the nature reserve/sanctuary system, as well as a whole complex of protection measures: The cleaning up of the waterways, protection of spawning biotopes, hydraulic engineering maintenance, and the restriction of use in agriculture or industry.

We consider stronger measures for the protection of waterways in the close-to-nature-state (Benndorf, 1986) and the realization of practical protection measures, to be made especially important.

6. Summary

The fish fauna of three waterways, the "Nebel" and "Dömnitz" in the northern plain of Germany, and the "Ulster" in the southern central mountain region, are herewith typified.

The population ecology of endangered fish and cyclostomes is discussed, and the fish stock densities, length distributions and *K*-factors (Fulton's coefficient) for *Cottus gobio* and *Phoxinus phoxinus* are stated.

The populations are discussed in connection with the abiotic parameters which were established for the waterways. The different hydrological situations in the three streams produce considerable differences in the fish fauna.

Anthropogenous influences such as rechannelling measures, the building of a reservoir, fishery cultivation and eutrophication lead to changing of the Ichthyocoenoses and to the endangering of species and their habitats.

7. Acknowledgement

We wish to thank the German Anglers Association (DAV der DDR) and the district councils for permitting ichthyological investigations. We also thank several voluntary co-workers for their support.

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Manuscript accepted: March 1st, 1990