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Characteristics of the remnant *Vimba vimba* population in the upper part of the Dyje River

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A b s t r a c t . The population and genetic profiles of a remnant *Vimba vimba* population in the upper course of the River Dyje (N=48°53´18´´/ E=15°39´29´´) was carried out to provide a basis for conservation measures. This population is an isolated fragment of a more widespread population in this river system and is now declining. It came into being 60 years ago as a consequence of the construction of the Vranov dam in the middle section of the River Dyje. Over those 60 years *V. vimba* disappeared from the other localities of the River Dyje basin. In the population under study, vimba is a single-batch spawner involving two age groups of fishes (4 to 5 years of the age). Individuals over six years of age are rare and sporadically occurring fishes of 8 to 10 years are exclusively females. The size of the adult part of population is less than one thousand individuals. The length growth rate is relatively high as compared with other studied populations in the Czech Republic, fishes of five years attain 200 mm of Sl. A very low genetic variability was evidenced in the population (mean number of alleles per locus = 1.30 ± 0.1; percentage of polymorphic loci = 16.7 %; mean observed heterozygosity = 0.022 ± 0.011).

Key words: small population, genetic and population characteristics

Introduction

Cyprinid species *Vimba vimba* (Linnaeus, 1758) is classified in the Czech Republic as "vulnerable" to "critically endangered" depending on the sea basin (L u s k et al. 2002, 2004). This species once constituted an important component of fish communities in the "barbel" section of Czech streams (L u s k 1995). It is now disappearing and most populations have declined in abundance. The situation seems to be similar in other countries (L e l e k 1987).

The negative influence of dams, weirs and locks on migrations of anadromous fish species is well known. Now it appears that fragmentation of rivers by such river engineering can be a serious devastation factor that affects the populations of autochthonous river fish species (L u s k 1995). *V. vimba* occurred originally in the whole hydrological system of the Czech Republic pertaining to the three sea basins (Black Sea, Baltic Sea, and North Sea). Notwithstanding its past economic importance (J e i t t e l e s 1863, K i t t 1905) and partially also at present, knowledge of its biology and population characteristics is scanty (B a r u š & O l i v a 1995). Actual status of *V. vimba* in rivers of different sea basins in the Czech Republic shows very marked differences (L u s k et al. 1996), and this has affected assessment of the threat to this species in the Red List of Fishes in the Czech Republic (L u s k et al. 2004). Knowledge indicates that fragmented so-called "micropopulations" represent the disappearing of populations from a river system, possibly to extinction.

In this study we evaluated the basic characteristics of a small population of *V. vimba*, the last one we have found in the system of the River Dyje that seems to be in a good state to survive and reproduce. Using the facts we discuss ways to stabilize and preserve the population using different supporting activities (artificial reproduction, stocking).

Study Area

The study was performed in the River Dyje (tributary of the Morava River, Danube basin) situated upstream of the Vranov reservoir near the village Podhradí (65 km south of Brno), Fig. 1. The section is limited by r. km 204.05 (weir) and r. km 209.35 (boundary with Austria). The headwater weir caused by is 2.5 km long and reaches r. km 206.5. Further upstream, up to r. km 207.6, is a typical "barbel" section (epipotamon) with free-flowing parts alternating with pools and riffles, and containing gravel bars. The next upstream section is a uniform flowing stream with relatively uniform bottom and river banks. *V. vimba* inhabits the upper part of the reservoir and upstream to the river km 207.6, where a broken-down weir is situated. Spawning occurs only on the riffle at r. km 207.2 (N=48°53´18.4´´ / E=15°39´28.7´´). The rapid width is 16.5 m; its length is between 6 and 14 m with the maximum in the middle of the river bed.

In the area studied the River Dyje is mostly unmodified. The mean annual discharge is 9.21 $m^3.s^{-1}$; Q_{355} = 0.96 $m^3.s^{-1}$, Q_{330} = 1.38 $m^3.s^{-1}$, Q_{270} = 2.68 $m^3.s^{-1}$. Q_{180} = 4.79 $m^3.s^{-1}$. The discharge under 3 $m^3.s^{-1}$ fluctuates during the day from 1 to 1.5 $m^3.s^{-1}$ due to the operation of Austrian hydropower stations.

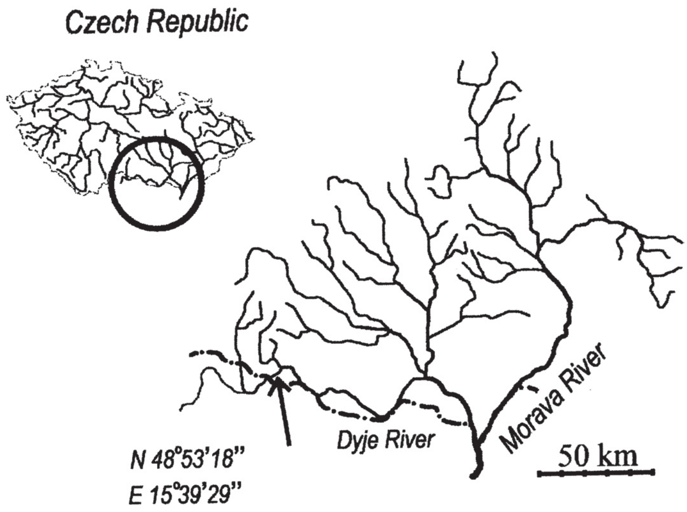

Fig. 1. Localization of study site in the Dyje River.

Material and Methods

The study was conducted during years 1993 to 1997 and 1999 (end of May to mid June – see Table 6). Fishes were captured by electrofishing. On four dates (13 June 1993, 13 June 1995, 17 June 1997 and 15 June 1999) the same sections of 180 m length and 2,880 m^2 stretch (in 1997 230 m and 3,680 m^2, respectively) were fished to provide quantitative estimates, based on two repeated fishings (S e b e r & L e C r e n 1967). Nets (20 mm mesh) were placed at both ends of the section to prevent fish escaping. The standard length (Sl) was measured and scales for age and growth rate determination were taken at the level of the anal fin beginning from the scale row below the lateral line. The back-calculation of growth rate was according to R. L e e (1912) with the correction of 18 mm for scale base (linear relationship between scale ventro-lateral radius and Sl). Morphometric data were determined in fishes fixed in 4% formalin after H o l č í k (1989); measurements were by sliding scale to the nearest 0.1 mm. The fecundity and gonadosomatic index (GSI) were determined after morphometric measurements in formalin-fixed fishes sampled on June 3, 1994. Fecundity was determined using the gravimetric method, and GSI was calculated (H o l č í k & H e n s e l 1972). The development stage of oocytes was classified using the scale by M e i e n (1939) (see H a l a č k a et al. 2000). Shannon-Wiener diversity (H´) was calculated using the two base logarithms.

Samples for genetic analyses were taken from fishes killed by overdosing with anaesthetic 2-phenoxy-ethanol. Sampled tissues (muscle and hepatopancreas) were stored at -85 °C prior to being analysed. Tissues were extracted by homogenization with the adequate amount of 0.1 mol.l^{-1} Tris-HCl, pH 8.0 buffer in the ice bath (V a l e n t a et al. 1971). After centrifugation of the

Table 1. Protein systems analysed in *Vimba vimba* in the Dyje River, locality Podhradí.

Protein	Locus	Tissue analysed *	Buffer **	Mobility of alleles
6-phosphogluconate dehydrogenase	*6Pgd**	L	V	100, 120
Alcohol dehydrogenase	*Adh**	L	V	100, 124
Adenylate kinase	*Ak-1**	M	V	100
	*Aj-2**	M	V	100
Aspartate aminotransferase	*sAat-1**	M	V	100
	*sAat-2**	L	V	100
	*mAat**	M	V	100
Creatine kinase	*Ck-1**	M	PH	100
Glucosephosphate isomerase	*Gpi-1**	M	V	100
	*Gpi-2**	M	V	100, 300
GlycetoL-3-phosphate dehydrogenase	*G3pd-1**	M	V	100
	*G3pd-2**	M	V	100
Isocitrate dehydrogenase	*sIdhP-1**	L	PH	100
	*sIdhP-2**	L	PH	100
	*mIdhP**	M	PH	100
Lactate dehydrogenase	*Ldh-1(A)**	M	V	100
	*Ldh-2(B)**	M	V	100
	*Ldh-3(C)**	L	F	100
Malate dehydrogenase	*sMdh-1**	L	PH	100
	*sMdh-2**	M	PH	100
	*mMdh**	M	PH	100
Malate dehydrogenase (NADP)	*sMdhP**	M	PH	100
Phosphoglucomutase	*Pgm-1**	M	V	100
	*Pgm-2**	L	V	95, 100, 102, 105
Superoxide dismutase	*Sod**	L	V	100

* M – muscle, L – liver

** V – V a l e n t a et al. (1971), PH – P h i l i p p et al. (1979), F – F e r g u s o n & W a l l a c e (1961) homogenate (for 30 min. at 20 000 x G at 4°C) the supernatant was analysed immediately and the rest stored at -85° C for the repeat analyses. Supernatants were analysed using horizontal refrigerated electrophoresis at 12% starch gel using the buffer systems listed in Table 1, following staining for general proteins or specific enzymes (L u s k o v á et al. 1995, 1997). The nomenclature of loci and alleles followed that recommended by S h a k l e e et al. (1990). Statistical evaluation of genetic data was performed using the BIOSYS-1 software (S w o f f o r d & S e l a n d e r 1981). Due to the low abundance of the studied *V. vimba* population only 42 individuals were analyzed.

Results and Discussion

F i s h c o m m u n i t y

During four quantitative fishings in 1993, 1995, 1997 and 1999 in the section with the *V. vimba* spawning place, eighteen fish species were found in total. Of those, *Salmo trutta*, *Scardinius erythrophthalmus, Abramis brama* and *Proterorhinus marmoratus* occurred in one case only. Based on these findings the community can be described as a typical *Barbus-Chondrostoma* community with the key-species *Barbus barbus, Chondrostoma nasus, Leu-*

Table 2. Characterization of fish communities – species richness, abundace (N.ha^{-1}) and biomass (kg.ha^{-1}) in the section of the Dyje River in different years.

Species	13 July 1993 N – kg	13 July 1995 N – kg	17 July 1997 N – kg	15 July 1999 N – kg
Salmo trutta	7 – 4.18	0 – 0	0 – 0	0 – 0
Rutilus rutilus	611 – 13.20	312 – 11.13	253 – 5.75	536 – 14.98
Leuciscus leuciscus	117 – 2.84	85 – 2.22	63 – 1.88	98 – 2.39
Leuciscus cephalus	857 – 137.98	714 – 102.25	458 – 57.14	699 – 92.53
Scardinius erythrophthalmus	0 – 0	0 – 0	4 – 0.35	0 – 0
Chondrostoma nasus	189 – 37.56	203 – 54.00	190 – 42.34	228 – 56.45
Gobio gobio	1,640 – 15.36	585 – 8.40	646 – 9.67	618 – 8.06
Gobio albipinnatus	0 – 0	43 – 0.43	43 – 0.29	47 – 0.34
Barbus barbus	266 – 78.41	307 – 60.23	376 – 61.97	345 – 59.59
Alburnus alburnus	449 – 5.34	505 – 6.00	498 – 5.47	311 – 2.86
Alburnoides bipunctatus	2,087 – 16.93	1,050 – 11.25	1,038 – 7.17	557 – 4.23
Abramis brama	0 – 0	0 – 0	7 – 2.15	0 – 0
Vimba vimba	386 – 37.11	705 – 48.99	337 – 28.13	550 – 42.33
Rhodeus sericeus	78 – 0.29	60 – 0.29	91 – 0.31	76 – 0.31
Barbatula barbatula	100 – 0.69	191 – 1.56	85 – 0.56	182 – 0.98
Anguilla anguilla	3 – 3.47	14 – 7.16	7 – 4.34	3 – 3.13
Perca fluviatilis	10 – 1.04	44 – 0.78	56 – 0.99	28 – 0,58
Proterorhinus marmoratus	0 – 0	0 – 0	0 – 0	22 – 0.16
T o t a l	6,801 – 354.41	4,818 – 314.71	4,152 – 228,50	4,298 – 288.89
Number of species	14	14	16	15
Index diversity (H´)	2.822	3.218	3.211	3.340
Equitability (E)	0.74	0.84	0.80	0.85

ciscus cephalus, Leuciscus leuciscus, Gobio gobio, Alburnoides bipunctatus and *V. vimba*. These species constituted the major part (76.7%) of the mean abundance and also of the mean ichthyomass (88.1%). Other species occurring with relatively high frequency included *Rutilus rutilus* and *Alburnus alburnus*, which migrated up during higher water discharge from the Vranov water reservoir. *P. marmoratus* was caught for the first time during orientation sampling in September 1997 (L u s k et al. 2000). Details of the species composition are presented in Table 2.

The abundance ($n.ha^{-1}$) and biomass ($kg.ha^{-1}$) of *V. vimba* were in 1993: 386 and 37.1 respectively; 1995: 705 and 49 respectively; 1997: 337 and 28.1 and 1999: 550 and 26.4, mean values per all years 494 ind. (9.86% of total numbers) and 39.1 kg (13.2 % of total biomass) per ha, respectively. Species composition of the community was stable with 14 species in each fishing. The diversity index H´ varied between 2.82 and 3.34 (mean 3.15). Equitability value also possessed low mean variability of 0.78 (0.76–0.83).

C h a r a c t e r i z a t i o n o f t h e *Vimba vimba* p o p u l a t i o n

The mean population size inhabiting the 2–3 km of the River Dyje is estimated as 500–800 adults according to spawning shoal sizes and repeated catches during the study years mentioned. This population emerged as a fragment by segregation from the original, larger population in 1934, when the Vranov dam was constructed (r. km 175.5) and the reservoir flooded the upstream part of the River Dyje up to r. km 203.2 (L u s k 1995). Even in 1951 R o m a n o v s k ý (1952) found *V. vimba* under the Vranov reservoir but now – after the construction of another dam in Znojmo (r. km 132.6), this species disappeared there (L u s k et al. 1997).

M e r i s t i c a n d p l a s t i c p a r a m e t e r s

A total of 42 individuals were measured (34 males, 8 females) and the data (mean, SD, maximum and minimum values) are presented in Tables 3 and 4. These data could be used for comparison with any further studies as there are different speculations on the systematic position of *Vimba vimba* (B ă n ă r e s c u et al. 1963, 1970, B a l o n et al. 1987).

G e n e t i c c h a r a c t e r i z a t i o n

Genetic variability was estimated in 41 individuals, fished during 1995 and 1997, by analysis of the products of 23 loci representing 15 protein systems (Table 1). Polymorphic alleles were detected at four loci with the frequencies: *ADH** = 6%, *6PGDH** = 3%, *GPI-2** = 9% and *PGM-2** = 27%. Products of the remaining loci were monomorphic (Table 5). The values of genetic parameters (mean number of alleles per locus = 1.30 ± 0.1; percentage of polymorphic loci = 16.7%; mean observed heterozygosity = 0.022 ± 0.011) were evidence of a very low genetic variability in the population. The influence of isolation on this low variability could be evaluated after performing similar analyses of other *V. vimba* populations.

According to the results in Table 6, the population is in the equilibrium as to the homozygote / heterozygote ratio (Hardy-Weinberg equilibrium) except the *PGM-2** locus where an excess of homozygotes was observed. Considering the presence of four alleles (and so ten phenotypes) and relatively low number of individuals analyzed (N = 31), this discrepancy could be due to random sampling error.

Table 3. Counts of *Vimba vimba* from Dyje River, locality Podhradí.

Parameter	Total				Males (N=34)				Females (N=8)			
	Min	Max	Ave	SD	Min	Max	Ave	SD	Min	Max	Ave	SD
radii D – unramified	3	3	3.00	0.00	3	3	3.00	0.00	3	3	3.00	0.00
radii D – ramified	7	9	8.07	0.34	7	9	8.03	0.30	8	9	8.25	0.43
radii A – unramified	3	3	3.00	0.00	3	3	3.00	0.00	3	3	3.00	0.00
radii A – ramified	17	22	19.55	1.07	17	22	19.59	1.11	18	21	19.38	0.86
radii C – unramified	4	4	4.00	0.00	4	4	4.00	0.00	4	4	4.00	0.00
radii C – ramified	16	18	16.98	0.41	16	18	17.03	0.38	16	17	16.75	0.43
radii P – unramified	1	1	1.00	0.00	1	1	1.00	0.00	1	1	1.00	0.00
radii P – ramified	14	18	15.90	0.97	14	18	15.97	0.95	14	17	15.63	0.99
radii V – unramified	2	3	2.05	0.21	2	3	2.06	0.24	2	2	2.00	0.00
radii V – ramified	8	10	8.95	0.30	8	10	8.97	0.30	8	9	8.88	0.33
squamae linea lateralis	54	63	57.07	2.10	54	63	57.12	2.11	54	59	56.88	2.03
squamae linea transversalis (1)	9	11	10.00	0.49	9	11	10.09	0.45	9	10	9.63	0.48
squamae linea transversalis (2)	5	7	5.55	0.54	5	7	5.53	0.55	5	6	5.63	0.48
num.spin.branchialium	14	18	15.95	1.00	14	18	15.82	0.98	15	18	16.50	0.87

Age and length – growth rate

The oldest individual found in our study was a female of 10 years and 300 mm Sl. One aged 9 years and three aged 8 years were also females. The oldest males (n=6) were 7 years old and there were 8 females of this age. Individuals aged 7 years or more were found only exceptionally in the population studied; their proportion in samples in two spawning shoals was 0.19% (15 ind.), Fig. 2.

Using scale analysis we back-calculated lengths at earlier ages (Table 7). Variance analysis (ANOVA) of length values in males and females in the most numerous IV age group indicated that there is no statistically significant difference in individual life years between sexes ($P < 0.05$) and so we pooled data from the back calculations in males and females together. There are only single data on *V.vimba* growth rate from water bodies of the Czech Republic. Bontemps (1963) assessed the growth rate in 33 specimens from several streams in the River Vltava drainage area without differentiating them, and he found the following Sl values at ages of 1–6 years: 53 – 88 – 120 – 154 – 184 and 216 mm respectively. In a similar way, he examined 20 vimba growth rates from several streams in the Danube drainage basin, including four specimens from the River Dyje with the following Sl values: 60 – 99 – 131 – 166 and 198 mm respectively. Our data of *V. vimba* growth rate from the River Dyje are higher (Table 7), but as regards non-homogeneous and less numerous material of Bontemps (1963), these differences cannot be assessed. *V. vimba* growth rates in the Slapy valley reservoir on the River Vltava (Čihař 1961) and in the Orava walley reservoir on the River Orava (Balon 1967) were markedly higher.

Age structure of the spawning shoal

Analysis of the age structure of the spawning shoals sampled on 3 June, 1993 and 2 June, 1995 showed that they comprised mainly 4 to 6 year old fish, with a predominance in two year classes: four – and five-year old males comprising 91.97 % of 83 individuals in 1993 and 82.30 % 96 individuals in 1995, whereas females consisted mainly of fishes in the age of five to six years in 1993 (= 74.19 % from 31 ind.) and four to six years in 1995 (= 82.30 % of 39 ind.) – see Fig. 2.

The mean age of males declined from 4.83 to 4.39 which is a strong decrease as regards the age structure of the population. A similar decrease in mean age in females from 5.65 to 4.95 was also observed; the abundance of four-year-old fishes increased from 6.45 to 53.85 % and that of five-year-old females decreased from 54.84 to 20.51 %. The oldest males were aged seven years, but we occasionally found females aged 8 to 10 years (see Fig. 2). The studied population of *V. vimba* can be classified rather as short-living regarding its age structure. Because a substantial part of the reproduction of this small population is composed of two age groups and older groups participate only sporadically, we must consider this population as vulnerable and unstable as regards its future survival.

Maturity

The youngest mature males in the spawning shoal in 1993 were four years old – 14 males and only one female (year class 1990). In 1995 seven mature males aged 3 years (year class 1992) and four mature females 4 years old (year class 1992) were found. Males generally matured one year-earlier than females.

Fecundity

The number of eggs was determined in eight females caught when they were spawning. Two size groups of eggs were found in gonads, the first of size 1.15–1.63 mm in stage "E",

Table 4. Measurements of *Vimba vimba* (N = 42) from the Dyje River, locality Podhradí.

	Parameter	Total (N=42)				Males (N=34)				Females (N=8)			
		Min	Max	Ave	SD	Min	Max	Ave	SD	Min	Max	Ave	SD
1.	standard length	153	356	191	27.9	153	356	190	30.75	187	208	195	6.70
2.	weight [g]	64	175	115	23.0	64	145	108	17.8	126	175	144	17.2
	in % standard length												
3.	total length	120	128	124	1.59	120	125	123	1.40	122	128	124	1.81
4.	head length	22.4	26.3	25.0	0.85	22.4	26.3	25.0	0.87	23.3	25.8	25.0	0.75
5.	praeorbital distance	7.1	9.3	8.50	0.51	7.1	9.3	8.5	0.51	7.3	8.9	8.4	0.50
6.	diameter of the eye	4.2	6.6	5.67	0.45	4.2	6.6	5.7	0.45	4.8	6.0	5.5	0.37
7.	distance between nostrils	3.4	4.8	4.1	0.34	3.4	4.8	4.1	0.35	3.6	4.5	4.1	0.28
8.	interorbital distance	6.8	8.2	7.4	0.31	6.8	8.2	7.4	0.32	7.4	8.0	7.6	0.21
9.	postorbital distance	9.8	12.0	10.8	0.56	9.8	12.0	10.8	0.54	9.8	11.6	10.9	0.63
10.	head depth	15.2	20.0	17.7	0.81	15.2	20.0	17.6	0.87	17.6	18.5	18.1	0.29
11.	head width	11.0	13.4	12.1	0.52	11.0	13.4	12.0	0.54	12.0	12.9	12.4	0.27
12.	praedorsal distance	49.9	55.6	52.8	1.36	49.9	54.8	52.7	1.36	52.0	55.6	53.5	1.07
13.	praeventral distance	44.8	50.6	47.3	1.15	44.8	49.1	47.1	0.99	46.0	50.6	48.3	1.30
14.	praeanal distance	64.5	70.3	67.1	1.39	64.5	69.3	66.6	1.10	67.8	70.3	69.0	0.80
15.	body depth	25.6	30.8	28.5	1.24	25.6	30.8	28.3	1.29	28.1	30.0	29.1	0.63
16.	body width	9.5	14.4	12.0	0.97	9.5	13.8	11.8	0.85	12.4	14.4	13.1	0.65
17.	lenght of the caudal peduncle	13.0	18.3	16.1	0.94	14.3	17.3	16.2	0.73	13.0	18.3	15.9	1.50
18.	caudal peduncle depth	9.5	11.6	10.7	0.53	9.5	11.6	10.7	0.51	9.8	11.4	10.6	0.61
19.	caudal peduncle width	3.9	6.0	4.9	0.47	3.9	6.0	4.9	0.50	4.3	5.2	4.7	0.27
20.	minimum body depth	8.4	10.5	9.5	0.51	8.4	10.5	9.5	0.51	8.5	10.0	9.5	0.47
21.	distance P-V	21.4	26.8	23.7	1.40	21.4	25.7	23.3	1.11	22.9	26.8	25.3	1.27
22.	distance V-A	15.9	24.3	21.5	1.61	15.9	24.1	21.1	1.44	20.9	24.3	23.2	1.14
23.	lenght of the dorsal fin	8.7	12.6	10.8	0.78	8.7	12.6	10.9	0.81	10.0	11.5	10.5	0.49
24.	lenght of the anal fin	16.5	24.5	20.0	1.40	16.5	24.5	20.3	1.41	17.9	20.2	19.0	0.76

25.	lenght of the upper caudal tip	22.7	29.5	25.8	1.22	22.7	29.5	25.8	1.31	24.7	26.9	25.8	0.80
26.	lenght of the lower caudal tip	24.2	29.8	26.8	1.09	24.2	29.8	26.7	1.08	25.1	28.9	26.9	1.11
27.	lenght of the pectoral fin	17.4	21.5	19.8	0.81	17.4	21.5	19.9	0.80	18.0	20.7	19.5	0.79
28.	lenght of the ventral fin	15.5	19.2	17.8	0.77	15.5	19.2	18.0	0.76	16.5	17.9	17.2	0.46
29.	depth of the dorsal fin	19.3	27.4	23.7	1.36	19.3	27.4	23.7	1.48	22.5	24.5	23.6	0.71
30.	depth of the anal fin	13.1	19.8	14.8	1.25	13.1	19.1	14.8	0.97	13.1	19.8	14.8	2.04
31.	upper jaw lenght	6.6	10.1	8.7	0.66	6.6	10.1	8.7	0.66	7.3	9.6	8.8	0.68
32.	postdorsal distance	33.0	38.2	35.5	1.36	33.0	38.2	35.5	1.33	33.1	37.5	35.4	1.50
	in % head length												
33.	praeorbital distance	31.2	37.3	34.0	1.38	31.2	37.3	34.1	1.41	31.4	34.9	33.8	1.17
34.	diameter of the eye	18.6	26.2	22.7	1.70	18.6	26.2	22.9	1.67	19.7	24.2	21.9	1.53
35.	distance between nostrils	14.0	19.7	16.3	1.31	14.0	19.7	16.3	1.36	14.1	17.6	16.4	1.05
36.	interorbital distance	26.8	32.1	29.7	1.10	26.8	31.5	29.5	1.03	28.6	32.1	30.4	1.09
37.	postorbital distance	39.4	49.1	43.2	2.10	39.4	49.1	43.1	1.87	39.4	48.9	43.6	2.83
38.	head depth	62.4	83.2	71.10	4.34	62.4	83.2	70.7	4.68	71.2	76.8	72.6	1.75
39.	head width	44.7	52.1	48.4	1.85	44.7	52.1	48.1	1.80	46.8	51.6	49.7	1.50
40.	upper jaw lenght	29.0	42.4	34.9	2.42	29.0	42.4	34.8	2.44	31.2	38.8	35.3	2.29

Table 5. Allele frequencies and genetic variability in *Vimba vimba* in the Dyje River, locality Podhradí.

Locus	Sample size	Allele A	B	C	D	E	H	H(unb)	H(D.C.)
*AAT**	33	1	0	0	0	0	0	0	0
*mAAT**	33	1	0	0	0	0	0	0	0
*ADH**	25	0.94	0	0	0	0	0.113	0.115	0.12
*AK**	25	1	0	0	0	0	0	0	0
*MPI**	25	1	0	0	0	0	0	0	0
*CK-A**	33	1	0	0	0	0	0	0	0
*GPI 1**	33	1	0	0	0	0	0	0	0
*GPI 2**	33	0.909	0	0	0	0.091	0.165	0.168	0.182
*G3PDH-1**	33	1	0	0	0	0	0	0	0
*G3PDH-2**	25	1	0	0	0	0	0	0	0
*sIDHP-1**	33	1	0	0	0	0	0	0	0
*sIDP-H2**	33	1	0	0	0	0	0	0	0
*mIDHP**	33	1	0	0	0	0	0	0	0
*LDH-A**	33	1	0	0	0	0	0	0	0
*LDH-B**	33	1	0	0	0	0	0	0	0
*LDH-C**	33	1	0	0	0	0	0	0	0
*sMDH-A**	33	1	0	0	0	0	0	0	0
*sMDH-B**	33	1	0	0	0	0	0	0	0
*mMDH**	33	1	0	0	0	0	0	0	0
*ME**	25	1	0	0	0	0	0	0	0
*6PGDH**	33	0.97	0	0	0.03	0	0.059	0.06	0.061
*PGM-1**	33	1	0	0	0	0	0	0	0
*PGM-2**	31	0.726	0.113	0.065	0.097	0	0.447	0.454	0.161
*SOD**	33	1	0	0	0	0	0	0	0

Mean heterozygosity per locus (biased estimate) = 0.033 (S.E. 0.020)
Mean heterozygosity per locus (unbiased estimate) = 0.033 (S.E. 0.020)
Mean heterozygosity per locus (direct-count estimate) = 0.022 (S.E. 0.011)
Mean number of alleles per locus = 1.25 (S.E. 0.14)

the second with size 0.4–0.6 mm in stage “C”. According to our examination vimba had a single spawning per season in the studied population and hence only eggs in stage “E” were taken into consideration for the fecundity determination. In eight females with mean SL = 196.7 mm (188–213 mm) and mean weight 149.1 g (126–175 g), the absolute fecundity varied between 15,600 and 23,100 eggs (mean = 19,300 eggs), the relative fecundity was 133,000 to 155,000 eggs per kg of female weight (mean = 133,000 eggs.kg^{-1}). The mean egg size was 1.33 mm (1.26–1.41 mm). The mean gonadosomatic index GSI in eight examined females amounted to 13.9 % (12.1–17.3 %). Mean GSI in 14 males was 2.48 % (1.68–3.38 %). We are aware of the low number of females studied for the fecundity parameters but the size of this population was too small to sacrifice more individuals. Thus our data should be taken with caution but will serve as a useful reference point with respect to artificial reproduction.

Table 6. Chi-square test for deviation from Hardy-Weinberg equilibrium in *Vimba vimba* in the Dyje River, locality Podhradí.

Locus	Class	Observed frequency	Expected frequency	Chi – square	df	P
*ADH**	A-A	22	22.061			
	A-B	3	2.878			
	A-B	0	0.601			
				0.067	1	0.796
*GPI-2**	A-A	27	27.231			
	A-E	6	5.538			
	E-E	0	0.231			
				0.271	1	0.603
*6PGDH**	A-A	31	31.015			
	A-D	2	1.969			
	D-D	0	0.015			
				0.016	1	0.9
*PMG-2**	A-A	20	16.230			
	A-B	3	5.164			
	A-C	0	2.951			
	A-D	2	4.426			
	B-B	2	0.344			
	B-C	0	0.459			
	B-D	0	0.689			
	C-C	2	0.098			
	C-D	0	0.393			
	D-D	2	0.246			
				64.845	6	0

In their review paper on *V. vimba* fecundity M o r o z et al. (1970) indicated a finding of three size categories of eggs. Their first and third categories corresponded in size with our classes but the second category was missing in our samples. According to that report, *V. vimba* in the basins of the Baltic and Black seas is a repeat spawner (2–3 batches) and it is therefore impossible to compare those results with ours.

S p a w n i n g

The spawning of *V. vimba* in the studied locality occurred once each year according to our observations and lasted 2–3 days; no other spawning sites were found in this part of the River Dyje. Among the parameters measured during the spawning, water temperature (measured in the midday) was nearly constant but higher water discharges occurred in 1997 (Table 8).

The spawning behaviour and the course of spawning are similar to those of the nase carp *Ch. nasus* (L e l e k & P e ň á z 1963, L u s k 1967). The spawning ground was occupied by the shoal consisting of males, whereas females stayed downstream of the place. Ripe females came individually to the spawning site where the group of males joined them. The

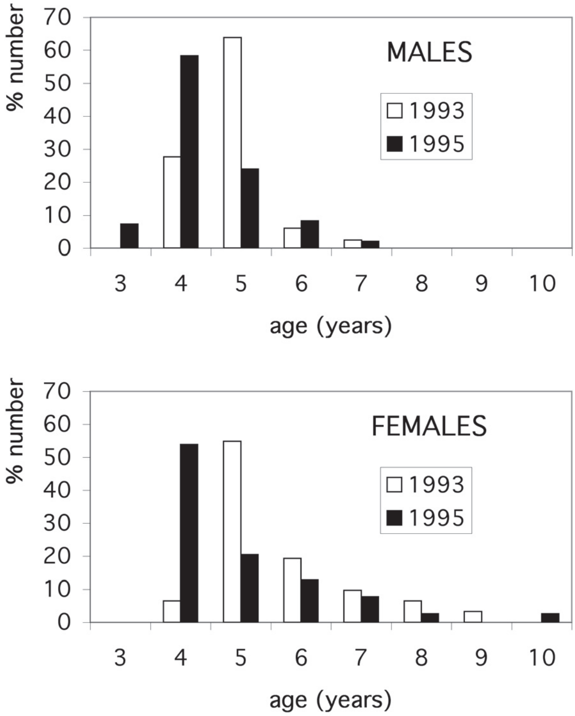

Fig. 2. Age structure of spawning shoals in June 1993 and June 1995.

whole group of one female and several males moved upstream with simultaneous releasing of gametes. Males were found only sporadically away from the spawning place. A sample of the male spawning shoal estimated to one fourth (83 individuals) was fished on 3 June, 1993 and so we estimated maximum number of males at the spawning place as 250. Females were obtained out of spawning ground. The next sample of spawning shoal was obtained in 1995 (28 May), when by estimate half of the shoal (96 ind.) was caught. In 1997 a detailed study was impossible due to high water discharge.

Artificial spawning and hatching

Two mature females were obtained on 3 June, 1994 and transported, together with five males to the laboratory, where they were stripped the same day. We obtained 9,500 eggs (mean diameter 1.51 mm) from the female with Sl = 213 mm (age 5 years) and 7,400 eggs (mean diameter 1.46 mm) from the female with Sl = 188 mm (age 4 years). Fertilized eggs were separated using water-diluted milk and placed in 1.5 litre hatching jars. Water flowing through the apparatus had a temperature of 15–16 °C, rising at the end of incubation to 17 °C. The mean egg size on the 3rd day of incubation reached 1.95 mm (1.90–2.05 mm). Hatching occurred on the 5th day within 6 hours after reaching 80–90 degree-days. Larvae hatched in the VIIth developmental stage at a mean length of 4.7 mm, eyes without pigmentation and pectoral fins just beginning to form. After hatching the fish larvae were transferred to a nursery tank where they grew to 42–61 mm of Sl by the end of September. From this 2,500 individuals were stocked in the monitored part of the River Dyje .

Table 7. Length growth (Sl, mm) of *Vimba vimba* in Dyje River, locality Podhradí (combined data from years 1993 and 1995).

Age g group	Sex	N		Back calculated Sl									
				Sl_1	Sl_2	Sl_3	Sl_4	Sl_5	Sl_6	Sl_7	Sl_8	Sl_9	Sl_{10}
III	m	7	Ave	70.7	117.4	152.4							
			S.D	5.41	8.70	8.22							
IV	m	41	Ave	73.4	117.3	149.3	178.6						
			S.D	4.61	6.71	5.52	4.97						
	f	17	Ave	71.8	117.3	147.1	178.6						
			S.D	5.08	5.68	4.51	3.79						
V	m	15	Ave	67.2	110.0	145.9	176.7	200.7					
			S.D	5.65	8.04	9.89	8.77	7.88					
	f	4	Ave	65.5	107.0	140.5	171.2	197.5					
			S.D	4.51	5.47	11.73	11.30	7.72					
VI	m	2	Ave	75.0	113.5	152.0	185.0	212.0	238.5				
	f	1	Ave	69.0	115.0	145.0	178.0	209.0	240.0				
VII	m	2	Ave	72.0	125.5	159.5	184.0	212.0	236.5	260.5			
	f	4	Ave	66.8	112.2	143.5	173.2	203.0	229.2	251.8			
			S.D	4.50	1.71	9.75	4.72	4.24	6.90	3.78			
VIII	f	1	Ave	64.0	110.0	143.0	172.0	206.0	239.0	257.0	280.0		
X	f	1	Ave	62.0	103.0	130.0	168.0	203.0	230.0	250.0	267.0	285.0	300.0
Total			Ave	71.0	115.4	148.0	177.8	201.6	234.2	254.4	273.5	285.0	300.0
			S.D	5.53	7.47	7.54	6.38	8.58	6.23	5.13			
			Min	59	97	130	162	184	228	229	267		
			Max	85	129	166	194	217	242	257	280		
			N	95	95	95	88	30	11	8	2	1	1

Table 8. Conditions during the spawning of *Vimba vimba* in the Dyje River, locality Podhradí.

Date	Water temperature (°C)	Discharge ($m^3.s^{-1}$)	Stream velocity ($m.s^{-1}$)	Weather
1–3 June 1993	19.1–20.0	2.8–3.6	0.4–0.8	somewhat cloudy
2–3 June 1994	19.3–19.8	3.1–3.6	–	sunshine
28–30 May 1995	19.0–20.2	3.8–4.6	0.6–0.9	overcast
1–2 June 1996	19.8	4.3–5.6	–	overcast
3–4 June 1997	20.2	6.2–7.0	1.4	somewhat cloudy

This experiment with the artificial spawning and fry nursing demonstrated its efficiency in supporting and rehabilitating *V. vimba* remnant populations.

Supportive breeding and population enhancement

Based on the evaluation of parameters of the *V. vimba* small population and on our experience with the extinction of sub-populations in the Dyje River system within last 60–70 years (Lusk 1995, Lusk et al. 1998), the crucial question "What is the future of this small population ?" arose as well as connected questions, *i. e.* "Is it possible to save it effectively ?" and "What are the best ways to do it ?".

It is true that the greatest attention as regards the species / population / stock conservation, sustaining and management has been (and still is) paid to salmonids due to their economic importance (Olver et al. 1995). Developments have shown that apart from fishery practices (artificial spawning, breeding, and stocking), ecological and protective aspects should also be respected (Laikre & Ryman 1996). Genetic problems connected with the long-term population conservation policy have become a part of basic protective management (Meffe 1986, Leberg 1990, Jorde & Ryman 1996). In some species (*B. barbus*, *Ch. nasus)* supportive breeding in the Czech Republic, evoked by interests of anglers, caused the wiping out of interpopulation differences in genetic variability (Lusková et al. 1995,1997, Šlechtová et al. 1998).

In Poland, *V. vimba* was previously an important fishery subject. At present, this species is, of course, critically endangered. The critical state of *V.vimba* is the consequence especially of river pollution, damming rivers and over fishing in the past. Improvements of this state would be achieved, besides protection measures, by rehabilitation projects (Sych 1996).Within the Odra River system, attempts are undertaken to rehabilitate *V. vimba* populations using using artificial spawning (stripping) and nursing (Witkowski et al. 2001). Backiel & Bontemps (1996) tried to reinforce the population of nase divided by a dam by transfer of adult fish over the dam but their results were not convincing. Nevertheless, we believe that small, geographically-limited stocks can guarantee species genetic diversity, and therefore effort should be aimed at preserving them. Considering all the available characteristics of the *V. vimba* small population in the upstream part of the River Dyje and utilising knowledge and experience with the artificial propagation and rearing of this species, we elaborated two variants for its active protection.

1. Capture and artificial reproduction of 5 – 10 females and 3 – 4 males yearly (by the method of fertilisation of mixed eggs by pooled sperm); hatching of larvae and rearing of juveniles up to one year of age; stocking 5 to 10 thousand juveniles in the original locality. Parental fishes to be released back to the river. Genetic parameters to be determined at five-year intervals.

2. Another strong population of *V. vimba* exists in the River Bečva (River Morava / Dyje basin). Its genetic characteristics are presently being studied and after their evaluation, the possibility of enhancement of the above-mentioned population by fish from Bečva will be examined.

The evaluated small population was isolated more than 60 years ago (1935) by erecting the dam at Vranov. Unfortunately we do not know the population parameters before this event. Nevertheless, we consider the actual state of this population to be critical due to low total abundance and especially low abundance of age groups involved in reproduction. This has led us to the idea of enhancing the population by the artificial propagation, breeding and stocking of yearlings. We assess that the present unfavourable situation was caused mainly by fragmentation of the river channel (L u s k 1995). We also took into account the possible negative effects of supporting the population by stocking artificially reared fish (M e f f e 1992), but in the actual situation we consider our resolution to be practical and expadient.

A c k n o w l e d g e m e n t s

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LITERATURE

BACKIEL T. & BONTEMPS S. 1996: The recruitment succes of *Vimba vimba* transfered over a dam. *J. Fish Biol. 48: 992–995.*

BALON E. K. 1967: Influence of life environment on the growth of fishes in the Orava dam lake. *Biologické práce SAV, Bratislava 13 (1): 123–175.*

BALON E. K., CRAWFORD S. S. & LELEK A. 1987: Are there sympatric forms of *Vimba* Fitzinger 1873 in the Danube near the future connection to the Main River? *Senckenbergiana Biol. 67 (4/6): 231–248.*

BĂNĂRESCU P., PAPADOPOL M. & MÜLLER G. 1963: Le genre *Vimba* (Pisces, Cyprinidae) dans le basin du Danube. *Trans. Mus. Hist. Nat. "Gr. Antipa" 4: 381–400.*

BĂNĂRESCU P., PAPADOPOL M. & MIKHAILOVA L. 1970: Systematics. In: Zayanchkauskas P. et al. (eds), Biology and fisheries of *Vimba* in Europe. *Vilnius: 23–70.*

BARUŠ V. & OLIVA O. (eds) 1995: Mihulovci a ryby (2). (Lampreys and Fishes). Fauna ČR a SR, sv. 28. *Academia Praha, 698 pp. (in Czech with English summary).*

BONTEMPS S. 1963: The growth of east-European bream, *Vimba vimba* (Linnaeus) in the Labe and Danube river drainages. *Věst. Čs. spol. zool. 27 (2): 125–129.*

ČIHAŘ J. 1961: Růst ryb ve Slapské údolní nádrži v r. 1959 [Growth of fishes in dam reservoir Slapy in 1959]. *Sb. ČSAZV Živočišná výroba 6 (4): 295–302 (in Czech).*

FERGUSON K.A. & WALLACE L.C. 1961: Starch gel electrophoresis of anterior pituitary hormones. *Nature 190: 629–630.*

HALAČKA K., LUSKOVÁ V. & LUSK S. 2000: Fecundity of *Cobitis elongatoides* in the Nová Říše Reservoir. *Folia Zool. 49 (Suppl. 1): 141–150.*

HOLČÍK J. (ed.) 1989: General introduction to fishes, Acipenseriformes. The freshwater fishes of Europe. Vol. 1, Part II. *AULA-Verlag GmbH, Wiesbaden, 469 pp.*

HOLČÍK J. & HENSEL K. 1972: Ichtyologická príručka [Ichthyological Handbook.] *Obzor, Bratislava, 217 pp. (in Slovak).*

JEITTELES L. H. 1863: Die Fische der March bei Olmütz. I. *Abth. Jahres-Bericht über das kaiserl.-königl. Gymnasium in Olmütz während des Schuljahres 1863: 3–33.*

JORDE P. E. & RYMAN N. 1996: Demographic genetics of brown trout (*Salmo trutta*) and estimation of effective population size from temporal change of allele frequencies. *Genetics 143: 1369–1381.*

KITT M. 1905: Die Fische der March bei Olmütz. I. *Bericht Naturwissenschaftlichen Sektion des Vereins "Botanischer Garten" in Olmütz : 29–43.*

LAIKRE L. & RYMAN N. 1996: Effects of intraspecific biodiversity from harvesting and enhancing natural populations. *Ambio 25: 504–509.*
LEBERG P. L. 1990: Influence of genetic variability on population growth: implications for conservation. *J. Fish Biol. 37 (Suppl. A): 193–195.*
LEE R. M. 1912: An investigation into the methods of growth determination in fishes by means of scales. *Publ. de Circ. Cons. Perman. Internat. Expl. de la Mer 63: 3–34.*
LELEK A. 1987: Threatened fishes of Europe. Vol. 9. The freshwater fishes of Europe. *AULA-Verlag GmbH, Wiesbaden, 343 pp..*
LELEK A. & PEŇÁZ M. 1963: Spawning of *Chondrostoma nasus* (L.) in the River Brumovka. *Zool. listy 12: 121–134.*
LUSK S. 1967: Population dynamics of *Chondrostoma nasus* (Linnaeus, 1758) in the Rokytná River. *Acta Sci. Nat. Brno 1 (12): 473–522.*
LUSK S. 1995: Influence of valley dams on the changes in fish communities inhabiting stream in the Dyje River drainage area. *Folia Zool. 44 (1): 45–56.*
LUSK S., HALAČKA K., JURAJDA P., LUSKOVÁ V. & PEŇÁZ M. 1997: Diversity of fish communities in the waters of the Podyjí National Park. *Živočišná výroba, 42 (6): 269–275.*
LUSK S., HANEL L. & LUSKOVÁ S. 2004: Red List of the ichthyofauna of the Czech Republic: Development and present status. *Folia Zool. 53: 215–226.*
LUSK S., LUSKOVÁ V. & HALAČKA K. 1996: Podoustev říční (*Vimba vimba*) – současný stav [*Vimba vimba* – actual status]. *Sb. ref. z II. české ichtyol. konf., Vodňany: 17–22 (in Czech).*
LUSK S., LUSKOVÁ V., HALAČKA K. & LOJKÁSEK B. 2000: Změny v druhové skladbě ichtyofauny na území České republiky po roce 2000 (Changes in the species composition of the ichthyofauna in the territory of the Czech Republic after 1990). *Biodiversity of fishes in the Czech Republic (III): 21–28 (in Czech with English summary).*
LUSK S., LUSKOVÁ V., HALAČKA K., ŠLECHTA V. & ŠLECHTOVÁ V. 2002: Status and protection of species and intraspecific diversity of the ichthyofauna in the Czech Republic. In: Collares-Pereira M.J., Coelho M.M. & Cowx I.G. (eds), Conservation of freshwater fishes: Options for the future. *Fishing News Books, Blackwell Science Ltd. Oxford: 23–33.*
LUSKOVÁ V., ŠLECHTOVÁ V., POVŽ M., ŠLECHTA V. & LUSK S. 1997: Genetic variability of *Chondrostoma nasus* populations in rivers of Black Sea and the Baltic Sea drainage systems. *Folia Zool. 46 (Suppl. 1): 27–36.*
LUSKOVÁ V., ŠLECHTOVÁ V., ŠLECHTA V. & LUSK S. 1995: The population genetic diversity of *Chondrostoma nasus* from Moravian and Slovak rivers. *Folia Zool. 44 (Suppl. 1): 91–98.*
MEFFE G. K. 1986: Conservation genetics and the management of endangered fishes. *Fisheries 11: 14–23.*
MEFFE G. K. 1992: Techno-arrogance and halfway technologies: salmon hatcheries on the Pacific coast of North America. *Conserv. Biol. 6: 350–354.*
MEIEN V.A. 1939: K voprosu o godovom cikle kostistykh ryb [On the question of the annual cycle of bony fishes]. *Izv. AN SSSR, seriya biol. 3: 389–420 (in Russian).*
MOROZ V. N., VOLSKIS R., ERM V., VLADIMIROV M. Z. & SUKHANOVA E. R. 1970: Fecundity. In: Zajankauckas P., Volskis R. (eds), Biology and fisheries of *Vimba* in Europe. *Vilnius: 135–154.*
OLVER C. H., SHUTER B. J. & MINNS C. K. 1995: Towards a definition of conservation principles for fisheries management. *Can. J. Fish. Aquat. Sci. 52: 1584–1594.*
PHILIPP D. P., CHILDERS W. F. & WHITT G.S. 1979: Evolution of patterns of differential gene expression: a comparison of the temporal and spatial patterns of isozyme locus expression in two closely related species (northern largemouth bass, *Micropterus salmoides*, and smallmouth bass, *Micropterus dolomieui*). *J. Exp. Zool. 210: 473–488.*
ROMANOVSKÝ A. 1952: Užitkové a plevelné druhy řeky Dyje [Utility and trash fish species in the river Dyje]. *Zool. a entomol. listy 1: 245–251 (in Czech).*
SEBER G. A. F. & LECREN E. D. 1967: Estimating population parameters from catches large relative population. *J. Anim. Ecol. 36: 631–643.*
SHAKLEE J. B., ALLENDORF F. W., MORIZOT D. C. & WHITT G. S. 1990: Gene nomenclature for protein-coding loci in fish. *Trans. Amer. Fish. Soc. 119: 2–15.*
SYCH R. 1996: About the project of migratory fish restoration in Poland. *Zoologica Poloniae 41 (Suppl.): 41–59.*
SWOFFORD D. L. & SELANDER R. B. 1981: BIOSYS-1: A FORTRAN program for the comprehensive analysis of electrophoretic data in population genetics and systematics. *J. Hered. 72 (4): 281–283.*
ŠLECHTOVÁ V., ŠLECHTA V., LUSKOVÁ V., LUSK S. & BERREBI P. 1998: Genetic variability of common barbel, *Barbus barbus* populations in the Czech Republic. *Folia Zool. 47 (Suppl. 1): 21–34.*
VALENTA M., HYLDGAARD-JENSEN J. & JENSEN E. S. 1971. Interaction of veronal, pyrophosphate, citrate and protein with lactate dehydrogenase isozyme determination and kinetics. *Acta Vet. Scand. 12: 15–35.*
WITKOWSKI A., BARTEL R. & KLESZCZ M. 2001: Successful fish restitutions in Poland. *Scientific annual of the Polish anglers association, Warszawa 14: 81–90.*