Folia Zool. – 52(4): 441–448 (2003)

Temporal changes in the abundance of barbel, *Barbus barbus* in the Jihlava River, Czech Republic

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Received 10 March 2003; Accepted 18 November 2003

A b s t r a c t . A four-year experiment with a total of 993 individually-tagged barbel, *Barbus barbus*, resulted in the assessment of survival and abundance. The mean annual survival rate was 0.862, but the partial values assessed separately for seasons (spring – autumn and autumn – spring) differed considerably and the possible reasons for this phenomenon are discussed. On the basis of known survival rate, the abundance was subsequently estimated (for the entire studied stretch and per hectare) using the Petersen capture-recapture method for the period spring 1999 to autumn 2002, and the mean value reached 303 ± 110 ind.ha^{-1} (minimum 195, maximum 498 ind.ha^{-1}). The Jolly-Seber method was also used to estimate abundance from autumn 1999 to spring 2001 and gave a mean 425 ± 120 ind.ha^{-1} and a range 233–563 ind.ha^{1}. These results were in autumn 2001 supported by another simultaneously conducted census following the removal method by Zippin (316 ind.ha^{-1}). The abundance showed a significant tendency to increase during the four-year survey, which is in an accordance with the long-term changes observed in the dynamics of the fish community in this stream.

Key words: capture-recapture, electrofishing, survival, tagging

Introduction

Despite being only rarely included in the lists of endangered fish species, either within the European or the Czech national legislation, most barbel, *Barbus barbus* Linnaeus, 1758 populations exhibit a considerable and widely observed decline in their abundance and fishery yields for many years. Given their vulnerable status, barbel populations are worthy of conservation efforts (L e l e k 1987, P h i l i p p a r t 1987, L u s k 1996a,b, L u s k & H a n e l 2000). However, barbel in the Jihlava River represents a rather exceptional case of a prosperous population, with continuously increasing abundance and proportion in local fish community over a longer period. This can be attributed to a complex array of favourable changes in environmental conditions (improved physical and chemical water conditions due to water accumulation in the two upstream reservoirs) and in fishery management practices with changed fishing rules from those for the non-salmonid towards the salmonid streams. These changes have been accompanied by reduced fishing pressure on barbel, as well as, in recent years, a reduction in the stocking of trout and other salmonids and thus reduced competition for available resources (P e ň á z & W o h l g e m u t h 1990, P e ň á z et al. 1999).

The study of mortality and abundance of barbel became thus an essential, interesting and practically applicable problem within a widely conceptualised research project conducted on

the middle course of the Jihlava River and focused on diverse aspects of population biology of barbel (P e ň á z et al. 2002a, 2002b, P e ň á z et al., in press). During a previous study (P e ň á z et al. 2002a), we found that the barbel population under study is highly sedentary (70.47 %), with apparently low immigration and emigration rates. The fish we denominated as "resident" were always recaptured within a certain one of seven particular restricted stream sections (250–780 m long) in which they had been initially captured, tagged and released. In contrast, the remaining fish, despite being classed as "mobile", were recaptured in stream sections in close vicinity to the section in which they had been released after tagging. The recorded distance of their movement reached a maximum of 1680 m downstream and 2080 m upstream from the centres of their home sections. A similary high sedentary character was also observed in the Berounka River near Radnice (Czech Republic) during another investigation conducted in 1998–2002. From 820 tagged fish on four different localities located 3–4 km each of other, only two barbel were captured on another place than tagged (P i v n i č k a , unpublished data). These facts much facilitated the analysis of the temporal changes in survival and abundance rates.

The aim of our research was thus to elucidate the course and reasons of interesting population development and to test whether the Petersen method could be used for a population of primarily sedentary barbel.

Study Area

A long-term stationary research has been conducted on a 3.1 km stretch (6.47 hectares) of the Jihlava River (tributary to the Dyje River, Danube basin) at Hrubšice (RK 46.0 - 49.1) divided into seven sections, demarcated naturally by riffles or weirs (Fig. 1). The long-term average discharge Q_a was 6.05 $m^3.s^{-1}$, the width of river bed varied under normal discharge conditions from 9 to 24 m, depth 20–180 cm and current speed 0–1.7 $m.s^{-1}$ (P e ň á z et al. 2002a). The studied stretch of Jihlava River was characterised by an extraordinary physical heterogeneity of fluvial habitats which fully correspond to the barbel's ecological requirements. However, the presence of impassable weirs and a reservoir dam, and the absence of tributaries limits the possibilities for long-distance migrations. The river stretch was well suited for efficient electro-fishing, although fish catchability in deeper sites and pools was limited despite the water discharge in the river stretch studied (located below the dam of Dalešice reservoir), after an agreement with the water authority, being usually reduced to 2 $m^3.s^{-1}$ during the time of fishing.

Material and Methods

The fish were collected by means of the gasoline powered electro-shocker (DC 250 V, 1.5–2 A, 50 Hz) during 25 excursion-days, every late spring and early autumn over four years (1999–2002). Only barbel >120 mm (SL) were handled and both the tagged and recaptured fish were measured, weighed, examined for sex according to external features, and the exact site of their capture (and/or recapture) was recorded. Tagging of barbel was made by means of anchor full plastic tags (Floy Tag - type FD-94), which were fixed on the left body side into the dorsal musculature, near the insertion of dorsal fin. Different colours of tags were applied in consecutive years (yellow: 1999; white: 2000; red: 2001). Both the newly tagged and controlled recaptured fish were always released where they were captured, i.e. in centres of particular seven

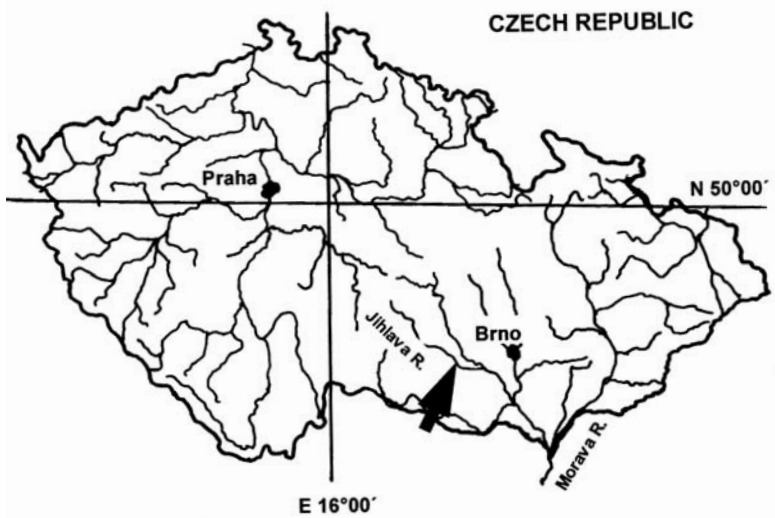

Fig. 1. Study area; arrow indicates the location of stream section studied.

sections in which the entire studied river stretch was divided. The last tagging was conducted in spring 2001, however the control and recapture of tagged fish continued until autumn 2002. We tagged a total of 993 barbel during the period from spring 1999 to spring 2001.

The calculation of survival rate became the first important step foregoing the subsequent abundance assessments of the barbel population by means of the Petersen method and this was enabled by sufficiently long periods of tagging and recapturing the fish. In all cases, the survival rate was estimated using the ratio between the number of recaptured tagged barbel per 100 captured and tagged fish in two or more successive seasons. In tagged barbel, starting in spring 1999 and ending in spring 2001 it was possible to assess values of survival rate (Table 2), both for the partial periods (spring – autumn, autumn – spring) and also for the whole year (spring – spring or autumn – autumn). When doing this, we have took into consideration the growth in length of tagged fish, and we have assumed that 2/3 of approximate annual increment in SL (3 cm) was achieved during the season spring – autumn, whereas 1/3 occurred during the period of autumn – spring.

For autumn 2001 and 2002 data, the Petersen capture – recapture method had to be used, as tagging finished in spring 2001. The same method was then conducted for all periods with the modification suggested by C h a p m a n (1951) and described also by R i c k e r (1975) and S e b e r (1982). For the period autumn 1999 – spring 2001 we have used the Jolly–Seber method, which is more realistic for open populations (Program JOLLY, Version 5.1; K r e b s 1999). We used this method for the whole season and for individual days of tagging. In the second case we had not taken the first two values from spring 1999 into account (4389 and 4806) as the proportion of tagged fish was still very low. The computation procedures, both for the Jolly–Seber and the Petersen methods, including also the 95 % confidence limits, followed programs by K r e b s (1999).

In order to compare the assessed abundance data, we carried out a special quantitative electro-fishing survey along the entire river stretch studied on 30 Oct. – 7 Nov. 2001, with two electrofishing depletions carried out separately in each of the seven partial stream sections, with the removal of all fish from the first fishing runs. The resulting estimate of

abundance was then obtained using the method proposed by Z i p p i n (1958) and modified by S e b e r & L e C r e n (1967). Survival values were used for calculating the number of tagged fish in individual periods. We have always made one estimate of abundance for all tagged fish caught in the given season, the fish tagged in a certain season were not considered in calculation for this particular season. The exception was spring 1999 when we have to use tags from the same season.

Results and Discussion

In total, 507 tag recaptures were made, representing 343 individuals: 221 were recaptured once, 86 twice, 31 three times, 4 four times and 1 five times. All important conditions assumed by the used census mark-recapture technique were fulfilled: tags were durable and well identifiable over the course of the entire survey (up to almost four years since the first tagging in 1999); tagging procedure has neither increased the mortality nor influenced the behaviour of tagged fish. These results served as the basis for the survival rate and abundance assessments. The overall statistical data of tagging experiment conducted are presented in Table 1.

Table 1. Summary of tagging experiment with barbel, *Barbus barbus* conducted on a stretch of the Jihlava River at Hrubšice. C, number of all barbel caught; M_1, no of specimens tagged during particular period; M_2, cumulated number of tagged fish; R, number of recaptured fish.

Period	C	M_1	M_2	R	Recaptured fish were tagged during				
					spring 99	autumn 99	spring 00	autumn 00	spring 01
Spring 99	349	320	320	22	22				
Autumn 99	163	68	388	20	20				
Spring 00	261	184	572	71	52	6	13		
Autumn 00	273	132	704	53	25	6	22		
Spring 01	501	289	993	117	46	7	31	11	22
Autumn 01	391	0	993	69	17	5	11	8	28
Spring 02	344	0	993	98	29	2	24	5	38
Autumn 02	377	0	993	57	15	4	12	5	21
Total	2659	993	993	507	226	30	113	29	109

S u r v i v a l

The mean value of survival rate for the period spring – autumn was approximately half of that observed in the period autumn-spring (both computations based on six partial independent values; Table 2). The annual survival rate for the periods spring-spring and autumn-autumn (five partial values) seems to be realistic also with the respect of barbel's long life span which amounts up to 17 years in the population studied. At first sight, the apparent disproportion in survival rate in barbel calculated for the entire year (0.862) and parts thereof may be the result of movements by some portion of the population, which leave the river stretch studied and are replaced with another fish from neighbouring areas. These migrations dilute the ratio R/C, and the calculated survival rate for the period spring-autumn decreases. A similar phenomenon, with the same explanation, was reported for the pike in two rivers of Dorset (England) by M a n n (1980).

Table 2. Final values of survival rate for the whole year (SS and AA) and partial survival values for periods "spring – autumn" (S-A) and "autumn – spring" (A-S).

Period	Year		S-A	A-S
	S-S	A-A		
1999			0.452	
	0.896	0.898		1.000
2000			0.493	
	1.000	0.750		0.851; 0.785
2001	-		0.558; 0.467	
		0.767		1.0; 1.0; 0.998
2002			0.421; 0.429	
Mean ± S.D.	0.862 ± 0.093		0.470 ± 0.046	0.939 ± 0.094

Abundance

Estimated values of abundance, based on the eight Petersen censuses averaged 1960 fish for the entire river stretch studied (6.47 hectares) and 303 fish.ha^{-1}, respectively. The abundance assessment by the Jolly–Seber method (Table 4A) resulted into a mean value of 2757 individuals for the entire river stretch, i.e. 425 ind.ha^{-1}, respectively. The particular results, ranges and confidence limits subsequent seasons and years are presented in Tables 3 and 4A, B.

When comparing the abundance estimates obtained by the Petersen method (Table 3) and those obtained by the Jolly-Seber method for the whole seasons (Table 4A, numbers in italics), the means for the entire data set are very similar and the same can be said about the mean value of abundance assessed for individual days of tagging. A small extent of movements on long distance of rather sedentary barbel (Peňáz et al. 2002a) seems to be responsible for it.

The densities of barbel in the middle Severn River (a stream with much greater size and discharge in England), studied in a similar way by the capture/recapture method, were estimated to range from 240 to 2020 ind.ha^{-1} (Hunt & Jones 1974). The preliminary data about barbel abundance in the Berounka River near the town Radnice (SW of the

Table 3. Dynamics of abundance of barbel, *Barbus barbus* in the Jihlava River during 1999–2002. C, number of the fish caught; Ms, hypothetical number of all tagged fish surviving to the period; R*, number of recaptured tagged fish after subtraction of those specimens tagged during the same estimated period; N, estimated abundance.

Period	C	M_s	R*	N	N.ha^{-1}	Confidence limits	
Spring 99	120	225	21	1242	192	896	1963
Autumn 99	163	152	20	1194	184	850	1909
Spring 00	261	341	58	1518	235	1262	1957
Autumn 00	273	249	53	1268	196	1047	1653
Spring 01	441	578	76	3223	498	2801	4279
Autumn 01	391	412	69	2312	357	1941	2929
Spring 02	344	747	98	2606	403	2258	3128
Autumn 02	377	355	57	2319	358	1912	3042
Total	2370						
Mean ± S.D.				1960±711	303±110		

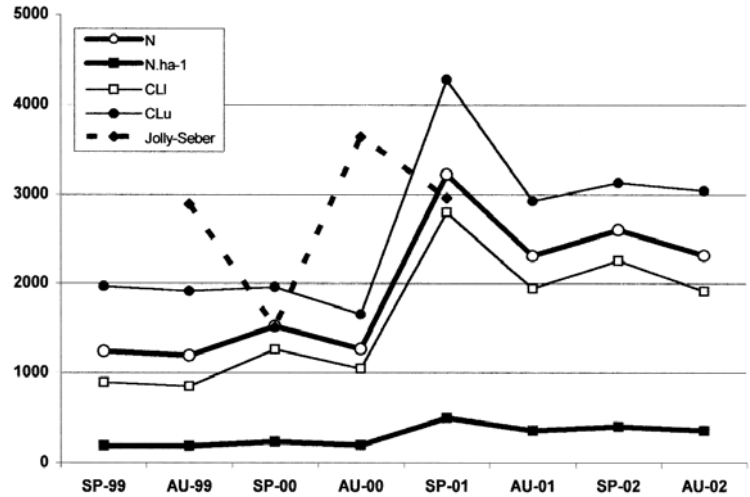

Fig. 2. Abundance dynamics of barbel, *Barbus barbus* in the stretch of Jihlava River near Hrubšice in 1999–2002 assessed using the Petersen and Jolly-Seber methods. (SP-99 to AU-02). N – abundance per whole river stretch; CLl – lower confidence limits; CLu – upper confidence limits.

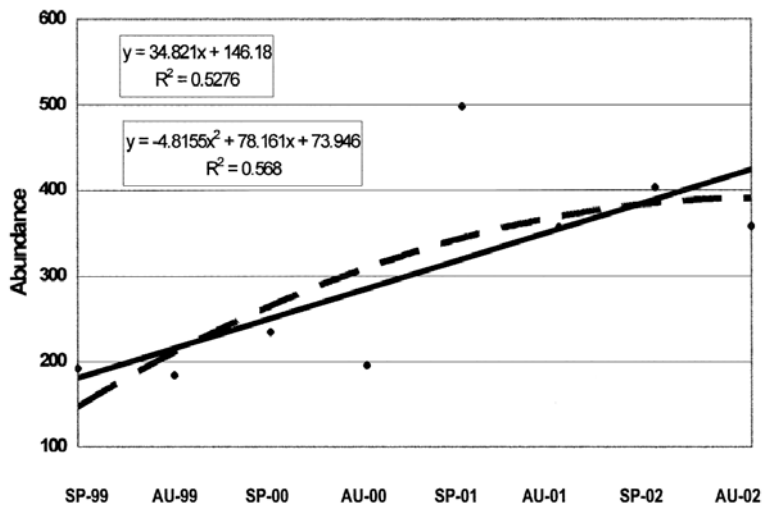

Fig. 3. The regression analysis of the abundance dependence upon the time in the barbel population from the studied stretch of Jihlava River. Period from spring 1999 to autumn 2002 (SP-99 – AU-02). (Petersen procedure).

Praha) vary round 1206 ± 464 ind.ha^{-1} and are valid for 1998–2002 and two localities with the mean annual discharge of 30.1 m^3.s^{-1} (P i v n i č k a , unpubl. data).

The mean abundance represents, however, only a static view on the fish numbers. The dynamics are better defined by the 95 % confidence limits of average abundance that lie between 566 and 3354 individuals per whole river stretch in 1999–2002 (Table 3).

The subsequent regression analysis revealed that barbel abundance in the Jihlava River clearly increased during the four-year research (Fig. 2), which is in accordance with the long-termed tendency observed in the dynamics of most fish species here. These patterns

Table 4. Jolly's stochastic method of population estimation
A. Abundance calculated for all tagged fish for the given season (spring, autumn)

Time	Proportion marked	Abundance N ± S.E.		No. caught	No. released	Total number (N) Petersen
Spring 1999				349	320	1242
Autumn 1999	0.128	*2894*	765	163	68	*1194*
Spring 2000	0.225	*1510*	233	261	184	*1518*
Autumn 2000	0.197	*3643*	894	273	132	*1268*
Spring 2001	0.179	*2960*	694	441	252	*3222*
Autumn 2001	0.163			391	5	2312
Spring 2002						2606
Autumn 2002						2319
Mean		2752	775			

B. Abundance calculated for individual days of tagging

Time	Proportion marked	Total number (N)	S.E. (N)	No. caught	No. released
10.05.99				34	32
24.05.99	0.007	4389	13650	137	136
02.06.99	0.034	4806	4779	58	57
21.06.99	0.182	925	208	120	95
10.11.99	0.139	2758	993	78	68
17.05.00	0.169	2254	725	82	67
31.05.00	0.234	2060	982	36	28
08.06.00	0.330	792	172	90	57
22.06.00	0.407	845	274	53	32
23.10.00	0.170	6606	4287	52	44
31.10.00	0.156	4116	1492	121	88
24.04.01	0.292	1119	624	23	17
26.04.01	0.269	2326	1102	66	47
12.06.01	0.254	1500	473	125	90
14.06.01	0.201	2656	1183	133	98
30.10.01	0.247			173	5

can be attributed to prosperous environmental change caused by water retention in the upstream located Dalešice reservoirs and to changes in the fishery management practices, which have resulted in a reduced trout stock (P e ň á z et al. 1999, P e ň á z et al. 2002b). This temporally conditioned relationship is statistically significant both for the linear (y = 34.82 x + 146.18; R^2 = 0.528; P = 0.04) and the polynomial functions (y = -8.82 x^2 + 78.16 x + 73.95; R^2 = 0.568; P = 0.04) (Fig. 3).

During a special quantitative electro-fishing survey along the entire river stretch studied in autumn 2001, we captured a total of 1082 barbel during the first run and 509 barbel during the second depletion. The resulting estimate of abundance using the methods by (Zippin / Seber & LeCren estimates: N = 2042, i.e., 316 inds.ha^{-1}; P = 0.53). When comparing results obtained by both methodological approaches, it could be concluded that the abundance estimate obtained by the removal method amounts to 88.4 % of the corresponding estimate obtained by Petersen capture-recapture method for a particular year and period (e.g. autumn 2001), and corresponds to 104.2 % of the mean abundance value computed for the entire period of 1999–2002 (Table 3). Such a coincidence of the

abundance estimates obtained for autumn 2001 by the two different methods seems again to support the afore-expressed hypothesis on partial fish exchange associated with the wintering of barbel and low survival values between spring and autumn.

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

We are much indebted to J. M e l k u s , K. B u r e š , and M. C h l e b o u n (Moravian Angling Association) for a kind permission to conduct investigations in their fishing grounds and for their efficient assistance afforded during field works as well as to R.H.K. M a n n and G.H. C o p p for their advice concerning the interpretation of the results and improvement of English. We much appreciated also comments and recommendations by anonymous referees. The research was funded partly by the Grant Agency of the Czech Republic, Project No. 206/01/0586 and by the Grant Agency of the Academy of Sciences of the Czech Republic, Projects Nos AV 026093917, IAA 6093105 and KSK 6005114.

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