Growth rate of nase, *Chondrostoma nasus* (L.), in the Dobczyce Reservoir and in the River Raba above the Reservoir*

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Abstract – The age and growth rate of individuals from the Dobczyce Reservoir (n = 46) and from the River Raba above it (n = 61) were determined using the E. Lea method of retrospective calculation, corrected by R. Lee (a = 30 mm). The multifactor analysis of variance showed that no significant differences occurred between the growth rate of individuals from the reservoir and the river (F = 1.436, P = 0.2337) or between females and males (F = 0.072, P = 0.7919). Significant differences in the growth rate (F = 22.703, P <0.001) were found between the cohorts. Probably the two samples belong to one population migrating for food and reproduction between the reservoir and the river. The current growth rate is faster than that recorded in the Raba in sectors now included in the reservoir, before creation of the reservoir.

Key words: nase, *Chondrostoma nasus*, growth rate, the River Raba, Dobczyce Reservoir, dam reservoir.

1. Introduction

Nase, *Chondrostoma nasus* (L.), is a poorly known species and each year investigation on this fish becomes more and more difficult owing to its rapid extinction in the former area of occurrence. In the past nase was one of the most abundantly occurring species in the upper and middle course of Polish rivers. The unpublished data of the Fishery Inspectorate of the Province of Cracow show that nase constituted 70% of weight of all the fish caught in 1962 (Prawocheński 1963*b*). From the 1970s the studies show the decline of nase in the rivers of Poland, Czech Republic, and Slovakia (Wajdowicz 1958, Kołder 1964, Olewski 1967, Kołder et al. 1974, Starmach 1985, Jelonek and Starmach 1988, Starmach et al. 1988, Skóra et al. 1994, Lusk 1995*a*, 1995*b*, Lusk and Halacka 1995). This decline can be attributed among other factors to the hydraulic engineering and river regulation works. The changing growth rate of individuals and the numbers of populations

manifest the response of this species to the changing environment. How the construction of a large dam reservoir on the river sector, where the numbers of nase were high, affects the population of this species has not been definitely recognised. A good subject for studying this problem is the River Raba, since in the years 1968–1971 nase constituted as much as 90% of commercial catches (Klim-czyk-Janikowska 1973). The Dobczyce Reservoir constructed on the 60th kilometre of the Raba was filled with water and turned into exploitation in 1987. In the reach of the Raba covered by it the greatest density of nase had previously been recorded (Starmach 1956, Klimczyk Janikowska 1973, Kołder et al. 1974, Jelonek and Star-mach 1988, Starmach et al. 1988).

Data concerning the biology of nase in Polish waters are scarce. Prawocheński (1963*b*) presented the growth rate of nase in the upper and middle course of the Vistula, in the upper course of the Rivers San and Dunajec, and conducted aquarium experiments on early stages of nase development (Prawocheński 1963*a*). Gąsowska (1960) described the morphology of nase from the Vistula, San, and Łososina stream. Iwaszkiewicz (1969) investigated this species in the River Warta catchment. Two works deal with the growth rate of this species in the Raba: Chitravadivelu (1971) investigated the growth rate of nase in this river on the basis of samples caught in 1961, while Klimczyk-Janikowska (1973) carried out complex studies on nase in the Raba in 1968–1969. Besides, Starmach (1956) elaborated the fishery and biological characteristics of this river while Kołder et al. (1974) investigated the ichthyofauna of the Raba and its tributaries. The condition of the ichthyofauna and the production capacity of the Raba catchment basin were investigated immediately before the construction of the Dobczyce Reservoir (Jelonek and Starmach 1988, Starmach et al. 1988).

Some prerequisites justify investigation on the growth rate of nase in the River Raba and Dobczyce Reservoir. The construction of dam reservoirs is usually followed by a decrease in the abundance of nase in their area (Wajdowicz 1958). In the Dobczyce Reservoir this observation is confirmed by the statistics of catches recorded by the Regional Directorate of Water Management (ODGW) in Cracow: in the years 1987–1991 the share of nase in the catches varied in the range 0.26–2.55%, and in 1992–1995 – 0.22–0.49 (M. Jelonek, unpubl.). It would be interesting to know whether the decreasing numbers of nase in the reservoir are accompanied by changes in its growth rate. The upper limit of nase occurrence was shifted from the 31st kilometre of the Raba (Starmach 1956) to the region of Myślenice, i.e. the 56th kilometre (Kołder et al. 1974, Starmach et al. 1988). On account of the withdrawal of this fish from the upper sectors of the Raba it seemed worth while to compare the current growth rate of this species with the data obtained by Chitravadivelu (1971) and Klimczyk-Janikowska (1973) before the construction of the reservoir.

The aim of this study was to characterize the growth of nase in the River Raba in the region of the Dobczyce Reservoir. An attempt was made to answer the following questions: (1) Are there any differences in the growth of nase caught in the reservoir and in the Raba?; (2) Are there any differences in the growth rate of males and females?; and (3) Did the construction of the reservoir effect changes in the growth rate of nase from the Raba in comparison with data from previous years?

2. Study area

The investigation was conducted in the Dobczyce Reservoir (49°52' N, 20°03' E, alt. 270 m) and in a reach of the River Raba about 300 m in length, one kilometre above the backwaters of the reservoir. The Dobczyce Reservoir lies about 20 km south of Cracow in the area of the Pogórze Wielickie and Pogórze Wiśnickie foothills, between the towns of Dobczyce and Myślenice. The dam, 32 m in height and 710 m in length, built on the 60th kilometre of the river course, closes the catchment basin of 736 km^2. With the normal level of damming (alt. 269.9 m) the area of the reservoir reaches 928 ha, the capacity 99.2 10^6 m^3, and the mean depth 11.1 m. The main tributary of the reservoir is the Raba, supplying 88.6% of inflowing water. The water residence time amounts to about 1/3 year on the average. The reservoir was constructed for water supply to the city of Cracow. From the very beginning of its exploitation water sports, recreation, and angling have been prohibited. The main aim of fishery management is to control planktivorous fish populations according to the biomanipulation concept (data from the Biology and Fisheries Station of the Karol Starmach Institute of Freshwater Biology at Brzączowice). The reach of the Raba where the samples were taken has a non-regulated riverbed about 40 m in width, with gradient 3–4‰, and maximum depth of 0.8–1.4 m. The banks are overgrown by willows, the bottom of gravel and small stones is 25–50% covered with algae, chiefly of the genus *Cladophora*.

3. Material and methods

In the Dobczyce Reservoir nase were caught from March to November 1997 during the entire season of commercial catches carried out by the Fishery Farm of the Regional Directorate of Water Management (ODGW) in Cracow. In order to ensure the random character of the sample the measurements were made on all the individuals found in the nets on the days of sampling. Chiefly, 35 x 1.5 m gill nets with mesh size not exceeding 55 mm were used. The sample from the Raba was taken early in March 1998, using the same fishing gear as in the catches in the reservoir. The total length (*LT*) and body length (*LC*) were measured exact to 1 mm, the weight of fish being determined exact to 5 g (*W*). Gender was identified on the basis of gonads. Annual increments of previous years were determined using the modified Lea method with Lee phenomenon correction (Chugunova 1959). The value for the correction (*a* = 30 mm) was accepted according to Prawocheński (1963*a*), who carried out studies on the development of nase. From each fish caught several scales were taken from the left side of the body, below the beginning of the dorsal fin and above the lateral line. Three scales were used for back-calculation of growth, the arithmetical mean being drawn from the obtained results. The readings were made in the lateral part of the scale. In nase the determination of age on the basis of scales requires considerable skill, since in some individuals serious difficulties are encountered because of the occurrence of additional rings, fry rings and spawning rings (Chugunova 1959, Prawocheński 1963*b*, Chitravadi-velu 1971). Therefore, control determinations of age were carried out using the left operculum. A Carl Zeiss, Germany microfilm reader was used in the observation of scales (magnification 17.5x) and opercular bones (9 and 13x). The results were compared with earlier investigations on the age and growth of nase in Polish waters (Rychlicki 1933, Prawocheński 1963*b*, Klimczyk-Janikowska 1973, Kopiejew-ska 1986).

On the basis of body measurements of collected individuals, the length-weight relationship ($W = a \, LC^b$) and the Fulton's condition factor ($CF = 100 \, W/LT^3$) were calculated (Opuszyński 1979). Absolute length increments were calculated as $I_a = LC_t - LC_{t-1}$. Next, the multifactor analysis of variance was carried out in order to verify the statistical significance of differences in growth rate between separated groups (collected from the river and the reservoir, males and females, and particular cohorts). For this the relative length increments were calculated for each age class as $I_r = 100 \, I_a \, /LC_t$. The I_r values were changed into decimal logarithms. Since after such transformation the log I_r dependence upon time is linear, the b coefficient of linear regression was calculated. The b coefficients were statistics subjected to analysis of variance. The homogeneity of variance within groups was checked with the Bartelet test. Computations were carried out using Statgraphics 5.0 software.

4. Results and discussion

Both in the reservoir and river larger numbers of females were caught, the samples differing by their age structure (Table I). The back-calculated body lengths

Table I. Numbers of collected specimens of nase, *Chondrostoma nasus* (L.).

Age groups (years)	Dobczyce Reservoir (March–November 1997)			River Raba (March 1998)		
	Males	Females	Total	Males	Females	Total
6	1	2	3	6	4	10
7		5	5	10	16	26
8	3		3	3	6	9
9	6	5	11	2	3	5
10	7	8	15		5	5
11	2	7	9	4	2	6
Total	19	27	46	25	36	61

are characterized by a poor variability in the samples, manifested by the low variance in spite of small numbers. The most rapid growth is characteristic of individuals 6 and 9 years of age, the slowest growth being found for the 11-year old cohort. In older age groups the growth rate is lower in the first three years of life (the Lee phenomenon). This may be explained by an effect of selective mortality caused by fishery exploitation. Individuals growing slowly in the first years of life attain harvestable size later, hence they have a greater chance of reaching older age than the rapidly growing individuals of the same generation. The growth rate decreases with age. The greatest decrease occurs after the 4th year of life, while in the 7th, 8th, and 9th years the growth rate is maintained at an even level, much lower than in the juvenile period (Fig. 1). The exponent b in the length-weight relationship approximates the value of 3, suggesting isometric growth (Fig. 2).

It was found on the basis of the multifactor analysis of variance that: (1) differences in log-transformed relative length increments between males and females are not significant ($F = 0.072$, $P = 0.7919$); (2) differences in log I_r between
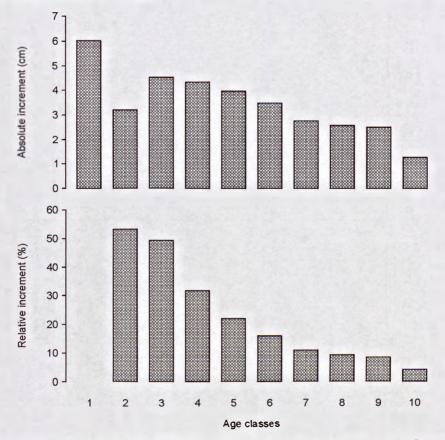
Fig. 1. Mean increments in body length of nase, *Chondrostoma nasus* (L.), in the Dobczyce Reservoir (March–November 1997) and the River Raba (March 1998) on the basis of back-calculations ($n = 107$).

individuals from the Raba and the Dobczyce Reservoir are not significant ($F = 1.436$, $P = 0.2337$); and (3) differences in log l_r between cohorts are statistically significant ($F = 22.703$, $P < 0.001$).

It is difficult to select properly the value for correction of the Lee phenomenon, i.e. the length of fish at the time when scales are first developed (Chugunova 1959). Prawocheński (1963b) did not use any correction. Other authors rely on the work by Lusk (1967) who determined the correction value a from the linear regression $Y = bX + a$, where Y is the fish length, and X – the scale radius. On the basis of measurements conducted on 692 individuals from the River Rokytna, he obtained the value of $a = 16$ mm. In the present work, however, the correction $a = 30$ mm was used on the basis of the Prawocheński's (1963a) results. The latter author found in aquarium experiments that at the time when the scales develop along the lateral line the total length of nase reaches 30–32.5 mm. The linear regression used by Lusk can be a source of error, especially with a small number of individuals in the sample.

The comparison of the growth rate of nase by calculating the slope coefficient of linear regression of relative annual increment logarithms on time for each
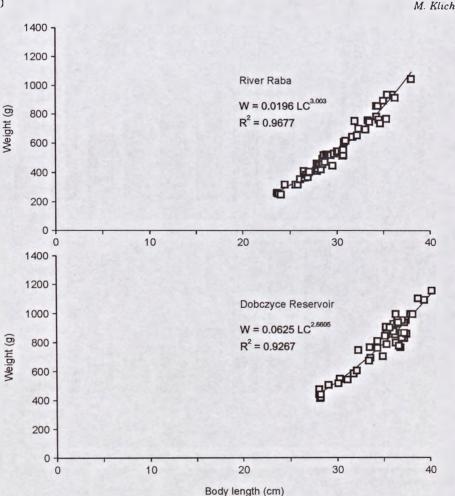
Fig. 2. Length-weight relationship of nase, *Chondrostoma nasus* (L.), in the Dobczyce Reservoir (March–November 1997, $n = 47$) and the River Raba (March 1998, $n = 62$).

individual was found to be a very useful method. For each fish the slope coefficient (statistics *b*) was obtained which describes the dynamics of growth of an individual throughout its life. The merit of coefficient *b* is that it is determined for the regression of a very high coefficient of determination (for 107 investigated individuals r^2 value reaches 0.89–0.99). The coefficient *b* meets the requirement of the normal distribution. In the investigated groups (sexes, cohorts, environment – reservoir or river) the variance is homogeneous. Thus the test of the multivariate analysis of variance is justified. The test conducted on statistics *b* is a simple method in investigating the differences between the growth rate of different groups of individuals. This is a parametric test of great power.

There are no differences in the growth rate of the sexes, suggesting that both sexes are encumbered with the same costs of reproduction. Then the absence of differences between the fish from the reservoir and the river may suggest that the

nase is fairly insensitive to changes in the environment while its growth chiefly depends on genetic factors. An alternative hypothesis, regarded by the present author as much more reliable, is the postulate that nase individuals caught in the reservoir and in the River Raba above it belong to the same populations. Interviews with fishermen showed that after the construction of the reservoir the greatest numbers of nase were caught in the backwaters of the reservoir. Currently this species is caught in the entire area of the reservoir, yet with distance from backwaters the number of nase in catches decreases. In the annual cycle nase can undertake small-distance migrations for feeding and spawning (Balon 1964). The eutrophicating reservoir offers good feeding conditions while the shallow and well-oxygenated river ensures better prospects for successful spawning.

Differences noted in the growth rate in various cohorts show that the year of birth affects the growth rate. Since the differences observed are distinct (Table II), it seems justified to seek for their reasons. Attempts can be undertaken to draw conclusions based on the slow growth of the 11- and 10-year-old cohorts and the fastest growth of the 6-year-olds. It may be conjectured that in the period of filling the reservoir (the normal damming level was reached in 1987) and in the first years of its existence, unstable conditions and the oligotrophy of the newly originated water body unfavourably affected the population of nase. Younger cohorts based their life history on fairly stabilised habitat conditions, where from year to year the feeding relations improved with the increasing eutrophication. The rapid growth of the 9-year-old cohort is rather difficult to explain. It may be effected by the length of the vegetation season in a given year (especially in the year of hatch), stability of water flow, or the trophic condition of the reservoir changing in the course of succession. However, it is not possible to select a decisive factor on the basis of the obtained results.

Differences observed between samples taken from the Raba and Dobczyce Reservoir (Fig. 2) in the dependence between body length and weight are due to the date of sampling. Nase from the Raba were caught in March, i.e. in the period preceding spawning, when the weight of fish with mature gonads was greater. The gonads can constitute up to 20% of the body weight of mature individuals (Opuszyński 1979). Also this was why the mean coefficients of nase condition calculated on the basis of direct measurements are higher in the Raba than in the reservoir (Table III). Before spawning the condition coefficient is higher in females than in males. In the remaining part of the year the condition of females and males is similar. In the cohorts the condition of fish differs to a small degree. It is interesting that the poorest condition is found in the 9-year-old cohort which grows fairly rapidly (Tables II and III).

The construction of the Dobczyce Reservoir effected an increase in the growth rate of nase in comparison with the data previously obtained in the Raba, in the region now included in the reservoir (Tables II and IV). The results obtained by Chitravadivelu (1971) show that to the 4th year of life the growth of fish was faster than it is now, while from the 5th year of life it was slower than now. Owing to the much greater numbers in the sample, the results obtained by Klimczyk- -Janikowska (1973) are more precise. The length of nase individuals investigated from the 5th year of life by the latter author approximated to that determined in the present work for fish younger by one year. In the same investigation, Klimczyk- -Janikowska (1973) found that in the River Raba nase attains sexual maturity in the 4th year of life. This explains the reduced growth rate of nase after the fourth year.

Table II. Mean back-calculated body lengths (mean ±SD) of nase, *Chondrostoma nasus* (L.), at each age in the Dobczyce Reservoir (March–November 1997) and the River Raba (March 1998).

Age (years)	n	LC (cm)									
		1	2	3	4	5	6	7	8	9	10
6	13	6.0 ±0.91	10.0 ±1.85	15.3 ±2.32	20.6 ±2.32	24.2 ±2.39					
7	31	6.2 ±0.59	8.9 ±1.21	14.3 ±1.73	18.7 ±1.65	22.6 ±1.56	25.9 ±1.18				
8	12	6.1 ±0.53	9.3 ±1.02	13.8 ±1.47	17.6 ±1.66	21.5 ±1.88	25.3 ±1.90	28.3 ±2.12			
9	16	5.8 ±0.65	9.2 ±0.91	13.6 ±1.32	18.8 ±1.76	23.5 ±1.52	27.5 ±1.44	30.4 ±1.33	32.9 ±1.31		
10	20	6.2 ±0.72	9.7 ±1.46	13.5 ±1.73	17.5 ±2.27	21.2 ±2.46	24.9 ±2.80	28.2 ±2.52	31.0 ±2.64	33.4 ±2.66	
11	15	5.7 ±0.67	8.5 ±1.08	11.7 ±1.05	15.2 ±1.44	18.9 ±1.65	22.4 ±1.67	25.5 ±1.69	28.5 ±1.64	31.1 ±1.59	33.4 ±1.59
Mean		6.0 ±0.67	9.2 ±1.32	13.7 ±1.91	18.1 ±2.3	22.0 ±2.46	25.5 ±2.45	28.3 ±2.27	30.8 ±2.56	33.3 ±2.62	33.4 ±2.46

Table III Mean values of condition factors (mean ±SD) of nase, *Chondrostoma nasus* (L), in the Dobczyce Reservoir (March–November 1997; *n*=46) and the River Raba (March 1998; *n*=61).

Age (years)	River Raba		Dobczyce Reservoir	
	Females	Males	Females	Males
6	1 17 ±0.03	1.17 ±0.02	1.2 ±0.08	1.21
7	1 19 ±0.02	1.16 ±0.02	1.13 ±0.02	
8	1 22 ±0.04	1.12 ±0.08		1 12 ±0 07
9	1.07 ±0 02	1.14 ±0 01	1.07 ±0.01	1.08 ±0.01
10	1.25 ±0.04		1.13 ±0.02	1.14 ±0.03
11	1 21 ±0.02	1 14 ±0.04	1 07 ±0 04	1 16 ±0 09

Data reported by different authors show a great variability of the growth rate of nase in different environments (Table IV). The dependence can be observed here since the nase from lower river courses and from lowland rivers with the slower water flow grow faster. The natural habitat of this species are rivers of submontane regions and upper reaches of lowland rivers. Nevertheless, nase always appears in dam reservoirs, though its numbers are fairly small. Apart from the Dobczyce Reservoir, nase also occurs in the Rożnów, Czchów (unpublished data of the Tarnów Board of the Polish Angling Association), and Goczałkowice Reservoirs (Wajdowicz 1958). It may be concluded that nase successfully colonises lentic habitats of lowland rivers and dam reservoirs, finding there better growth conditions. The faster growth can be the result of the more advanced eutrophication of lowland rivers and dam reservoirs. Perhaps it is also important that in these environments fish need to utilize less energy in withstanding the water current.

In the aspect of the results of the present study it seems justified to undertake an investigation on the migration of nase between the Dobczyce Reservoir and the Raba, and to determine which habitat factors, and to what degree, affect differences in the growth rate of the particular cohorts.

Table IV. Growth rate of nase, *Chondrostoma nasus* (L.) (*LC*, cm) according to different authors.

River/Locality	Source	n	Age class (years)									
			1	2	3	4	5	6	7	8	9	10
Vistula basin												
Upper Vistula	Prawocheński (1963b)	48	6.4	11.8	17.1	23.0	26.3	30.1	33.1	35.8	38.3	
Vistula/Cracow	Rychlicki (1933)		5.8	11.6	17.4	20.9	24.7	32.1	40.3	50.7		
Vistula/Kazimierz – Puławy	Prawocheński (1963b)	198	7.2	14.5	21.7	27.6	32.0	37.7	39.6	40.7		
Vistula/Włocławek	Kopiejewska (1986)		11.8	17.1	21.7	25.1	28.1	30.7	33.1			
Raba	Klimczyk-Janikowska (1973)	186	5.45	8.93	12.55	15.59	18.74	21.72	24.22	26.33	27.49	29.42
Raba	Chitravadivelu (1971)	42	8.1	11.8	15.3	18.7	21.3	23.2	24.7	27.0		
Dunajec/Łopuszna	Prawocheński (1963b)	199	6.0	11.4	17.1	22.6	27.1	29.6	31.6	33.5	35.8	
Dunajec/Rożnów	Chitravadivelu (1971)	39	7.3	11.6	15.9	19.8	23.3	26.0	27.6	30.3		
Upper San	Prawocheński (1963b)	186	5.5	10.2	14.9	19.2	23.0	25.6	27.3	29.0	30.8	
Danube basin												
Czarna Orawa	Bałon (1964)[a]	206	8.8	12.63	17.2	21.0	24.1	26.4	28.4	29.9	29.8	29.9
Rokytna/Vemyslevice	Lusk (1967)	692	5.3	8.3	11.5	14.6	17.6	20.1	22.1	23.5	25.1	26.5
Rokytna/Kasparov Mlyn	Lusk (1967)	384	5.6	9.3	13.1	20.0	22.5	24.7	28.0	29.4	30.6	

[a] cited after Chitravadivelu (1971)

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