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AGE AND GROWTH-RATE OF GRAYLING *THYMALLUS THYMALLUS* (L.) IN THE RIVERS OF POMERANIA (NW POLAND)

WIEK I TEMPO WZROSTU LIPIENIA *THYMALLUS THYMALLUS* (L.) W RZEKACH POMORZA

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The studies were carried out on the material of 308 individuals from 18 upland rivers of moraine character, in north-western Poland. The growth rate, growth intensity, condition factor and the dependence between body weight and total length were estimated. It has been found that the graylings from north-western Poland live longer and grow quicker than those from mountain rivers in southern regions of the country, and also in other parts of Europe.

INTRODUCTION

The European grayling *Thymallus thymallus* (L.) is among fishes of high habitat requirements. It is regarded as species indicative of pure water, since it is little resistant to even slight pollution (Witkowski et al. 1984). Besides, it does not tolerate higher water temperatures (over 20°C), both during its embryogenesis and other periods of life (Humpesch 1985, Kokurewicz et al. 1980). Because of this it lives in pure, cold and very well oxygenated waters, being confined to submontane and partly mountain rivers (grayling zone).

For the reasone just named, the occurrence of the species in Poland is limited to two areas: southern, including some Carpathian and Sudetic rivers, and northern, where it is found in most rivers of Pomerania. On account of its high angling importance it has been recently introduced to many rivers in which it either did not occur originally, or was extinct earlier (Witkowski et al. 1984).

The growth-rate of grayling in Poland has been comparatively poorly studied. Only a few populations from the south of Poland have been studied in this respect: from the river Dunajec and its tributaries, from Soła, Nysa Kłodzka and Kaczawa (Błachuta 1987, Gertychowa 1976, Krajewski 1986, Solewski 1960, 1963, Witkowski 1975). The information on grayling from Pomeranian rivers is still scarcer. Only Penczak et al. (1986) studied the growth of this species in two rivers of the Gwda basin, and Iwaszkiewicz (1962) attempted an estimate of the fertility and age of graylings from several rivers of that region. The objective of this study was to ascertain the growth-rate and age of grayling in most rivers of that area which, besides its scientific value, may also be of practical importance, as it allows a rational management of the species. Apart from this, it enables an estimate of the environment pressure, and a detailed description of habitats to which grayling is best adapted (Błachuta 1987).

MATERIAL AND METHODS

For the analysis of the growth-rate and estimate of age, 308 graylings were used, caught in 18 Pomeranian rivers in 1958-1987. The localization of the rivers is presented in fig. 1. More detailed data on the origin, number and length of fish are summarized in tab. 1.

The fish were caught using angling rod. Their total length (Tl) was measured to the nearest 1 mm, and they were weighed with an accuracy of 1 g. Of each specimen several scales were taken from the first two rows abowe the lateral line, between the dorsal and the adipose fin. This is the place where first scales are formed, and their size is the most correlated with the gryling length (Błachuta et al. 1986). Like in the studies of Błachuta (1987) the radius of annual rings and that of scales were measured in latero-dorsal line of the scales.

The body length for particular years of life was calculated using the methods of back calculation of E. Lea. In order to ascertain the size of increment in consecutive years, the following formula was used: $dTl = Tl_n - Tl_{n-1}$, where Tl_n – length in the nth year of life, Tl_{n-1} – length in the preceding year. In the comparative analysis of growth, the method proposed by Beverton and Holt (1957) was applied, according to von Bertalanffy's formula: $Lt_t = Lt\ (1-e^{-k/t-t_o})$, where Lt_t – total length attained at t age, Lt – hypothetical ultimate length, e – base of natural logarithm, t – fish age, t_0 – hypothetical value of the origin of growth curve, k – power parameter. Changes in the intensity of growth were estimated using the coefficient of growth characteristics:

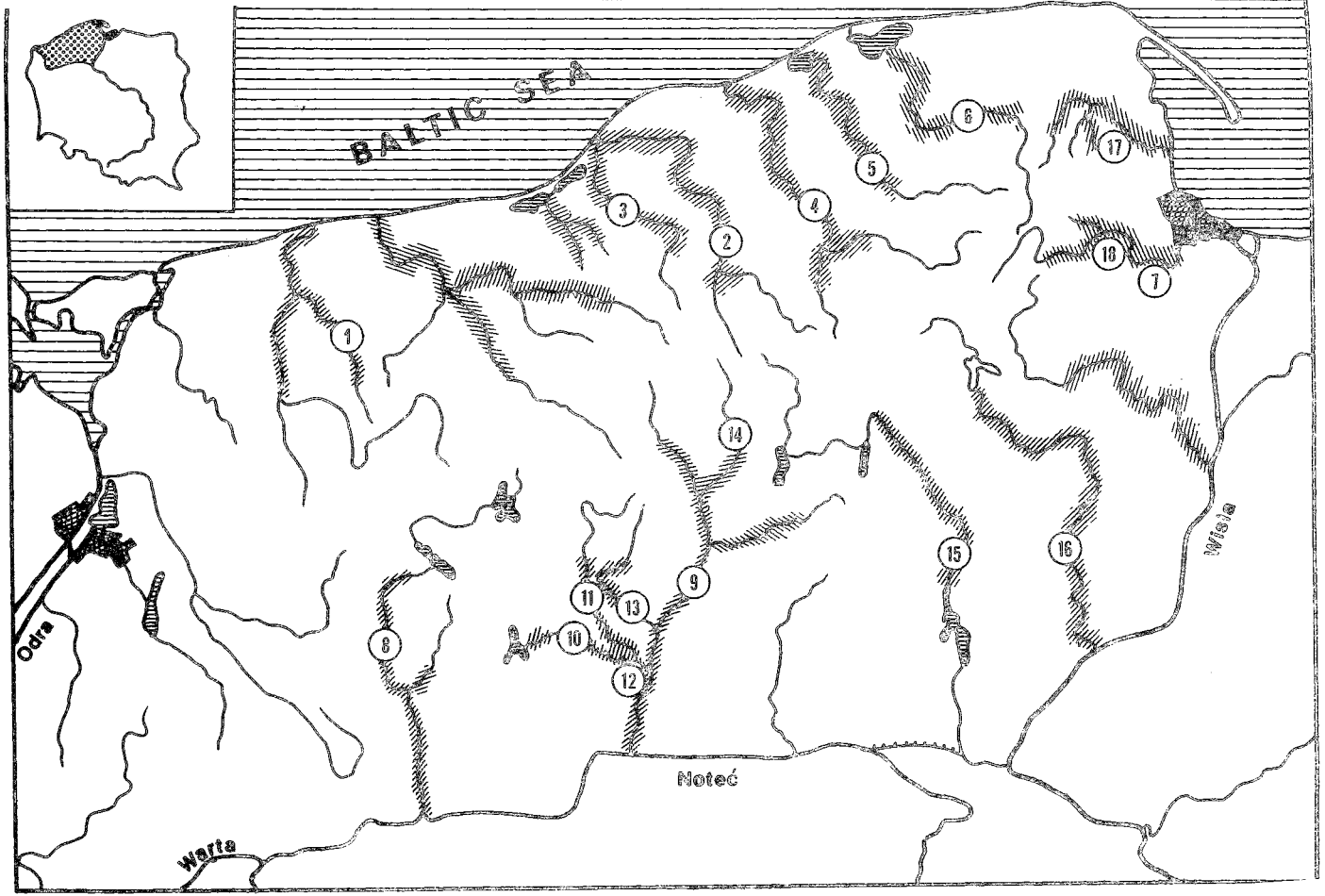

Fig. 1. Grayling rivers of Pomerania. Rivers numbered 1–18 are those from which the material came, detailed data in tab. 1.

Table 1

List of the grayling material from Pomeranian rivers used for the studies

No	River	n	Tl (mm)	Sampling data
1	Mołstowa	3	290 – 350	1966
2	Wieprza	9	330 – 380	1977
3	Grabowa	35	232 – 405	1958
4	Słupia	3	300 – 410	1977
5	Łupawa	6	188 – 345	1976, 1977
6	Łeba	11	220 – 340	1974, 1976, 1977, 1983
7	Radunia	47	290 – 400	1974, 1976, 1977, 1984
8	Drawa	6	310 – 390	1977, 1985, 1986
9	Gwda	27	310 – 440	1983, 1984
10	Dobrzyca	25	238 – 485	1977, 1986, 1987
11	Piława	5	300 – 360	1986
12	Połączone	35	300 – 480	1986, 1987
13	Płytnica	1	315	?
14	Czernica	36	202 – 410	1986, 1987
15	Brda	24	213 – 440	1986, 1987
16	Wda	30	252 – 460	1977, 1985, 1987
17	Gościnka	1	315	1976
18	Supina	4	300 – 350	1974

$C = \lg Tl_n - \lg Tl_{n-1}/0.4343\ Tl_n$, where lg Tl and $\lg Tl_{n-1}$, – common logarithm of fish length attained in a given and preceding year of life. Values condition coefficient (K) were calculated from the equation: $K = w\ 100/Tl^3$, where w – fish weight in g, Tl – total length in cm. The dependence between the weight changes (w) and the fish length (Tl) was calculated according to the formula $w = a\ Tl^b$, using its logarithmic form: $\lg w = \lg a + b \lg Tl$, where a and b – constant values calculated from empirical data.

STUDY AREA

Pomerania, called also Pomeranian Lake District, is situated in the north-western part of Poland. In the north it is bordered by the Baltic Sea, in the east by the Vistula river, in the south – the lower section of the river Brda, the Noteć and the lower Warta, in the west – the river Odra. The area is 48 000 km^2. It lies within the limits of the last glaciation. The latter resulted in a typically moraine landscape. Lakes occupy c. 700 km^2, the river system is also exceptionally dense, its characteristic feature being large slopes which gives the rivers a submontane character (Kondracki 1980). Both lakes and rivers still have water of the highest quality class which enables existence of many rare fish and lamprey species (e.g. *Lampetra fluviatilis, L. planeri, Salmo salar, S. trutta trutta, S. trutta*

fario, S. trutta lacustris, Coregonus albula, C. lavaretus, Phoxinus phoxinus, Moroco percnurus, Cottus gobio (Rembiszewski, Rolik 1975). The grayling is common and abundant in most rivers. According to Witkowski et al. (1984) the area of Pomerania constitutes its main distribution centre, as the species inhabits 1 745 km of the rivers which accounts for 64.5% its distribution area in Poland.

RESULTS

The age of studied graylings ranged from 1^+ to 6^+ years. Of the age groups fish three (2^+) and four (3^+) years old were the most numerous, constituting 44.48 and 29.22%, respectively. With increasing age, the number of individuals per age class decreased. The oldest, seven years old (6^+) fish was recorded in the material from (rivers Piława and Dobrzyca), but it constituted only 0.32% of all studied individuals. The percentage of fish in particular age classes for each population is presented in tab.2,

Table 2

Age structure of grayling from Pomeranian rivers

No	River	n	Age					
			1^+	2^+	3^+	4^+	5^+	6^+
1	Mołstowa	3			3			
2	Wieprza	9		4	1	4		
3	Grabowa	35	3	19	9	3	1	
4	Słupia	3		3				
5	Łupawa	6	1	5				
6	Łeba	11	2	8	1			
7	Radunia	47	2	31	10	2	2	
8	Drawa	6		2	2	2		
9	Gwda	27		8	11	6	2	
10	Dobrzyca	25	1	10	9	4	1	
11	Piława	5			5			
12	Połączone	35	5	11	10	3	5	1
13	Płytnica	1			1			
14	Czernica	36	10	16	8	2		
15	Brda	24	3	14	1	2	4	
16	Wda	30	1	4	16	7	2	
17	Gościnka	1		1				
18	Supina	4		3	1			
Σ		308	28	139	88	35	17	1
%		100.0	9.1	45.1	28.6	11.4	5.5	0.3

Table 3

Length Tl (mm) reached by grayling from Pomeranian rivers in consecutive years of life. Numerator represents mean value, denominator – range

No	Length / River	Tl_1	Tl_2	Tl_3	Tl_4	Tl_5	Tl_6
1	Mołstowa	226 / 225 – 229	295 / 225 – 311	295 / 225 – 311			
2	Wieprza	127 / 94 – 164	266 / 188 – 327	310 / 279 – 320	346 / 316 – 356		
3	Grabowa	120 / 91 – 158	238 / 180 – 277	311 / 290 – 366	352 / 325 – 371	376	
4	Słupia	129 / 117 – 137	246 / 222 – 268	354 / 326 – 383			
5	Łupawa	129 / 111 – 152	248 / 223 – 279				
6	Łeba	121 / 112 – 137	234 / 212 – 257	278			
7	Radunia	122 / 95 – 171	228 / 190 – 286	294 / 276 – 327	333 / 314 – 364	371 / 360 – 382	
8	Drawa	137 / 124 – 159	255 / 225 – 293	305 / 280 – 323	375 / 363 – 367		
9	Gwda	135 / 97 – 195	240 / 168 – 303	312 / 241 – 375	349 / 290 – 394	402 / 383 – 421	
10	Dobrzyca	142 / 122 – 179	257 / 197 – 300	322 / 261 – 354	388 / 357 – 416	443	
11	Piława	139 / 111 – 186	199 / 154 – 248	287 / 251 – 322			
12	Połączone	159 / 98 – 200	273 / 182 – 328	346 / 296 – 387	399 / 353 – 408	452 / 391 – 463	419
13	Płytnica	108	176	243			
14	Czernica	159 / 110 – 189	286 / 230 – 346	351 / 297 – 385	354 / 332 – 375		
15	Brda	129 / 80 – 173	243 / 173 – 288	313 / 273 – 347	365 / 323 – 393	402 / 379 – 426	
16	Wda	143 / 106 – 203	243 / 201 – 310	304 / 264 – 379	369 / 329 – 414	419 / 393 – 445	
17	Gościnka	105	197				
18	Supina	122	231	303			

Growth rate

The growth rate of grayling in the studied rivers is presented in tabs 3 and 4, and in figs 2 and 3.

Mean total lengths (Tl) attained in consecutive years of life in all the studied populations are as follows: 1st year – 131, 2nd year – 238, 3rd year – 308, 4th year – 363, 5th year – 409, and 6th year – 419. The best increments are reached in the first two years of life and amount to 131 and 107 mm, respectively. In subsequent years they range from 68 to 44 mm. Populations from Połączone (Piława + Dobrzyca), Dobrzyca, Czernica and Drawa are characterized by decidedly quickest growth. Those from the smallest rivers of the studied area – Płytnica, Gościnka and Supina – have the lowest growth rate.

The length attained by graylings in the first year of life are very similar in most populations. They range from 120 to 130 mm. Only fish from Dobrzyca and Czernica are distinctly larger (159 mm Tl), and those from Płytnica and Gościnka – smaller (108 and 105 mm, respectively). In the second year of life, and especially in the third, the growth in the Pomeranian populations is more diversified. In subsequent years (4th and 5th) the differences are smaller, though this results probably from the scarcity of material, as the fish of those age classes were few. The growth curves (von Bertalanffy's equation) enabled

Table 4

Increase in total length (Tl) as % length in the first year

No	River	Tl_1	Tl_2	Tl_3	Tl_4	Tl_5
1	Mołstowa	100.0	69.9	51.8		
2	Wieprza	100.0	109.4	34.6	28.3	
3	Grabowa	100.0	98.3	60.8	34.1	20.0
4	Słupia	100.0	90.6	83.7		
5	Łupawa	100.0	92.2			
6	Łeba	100.0	93.3	36.3		
7	Radunia	100.0	86.8	54.1	32.0	31.1
8	Drawa	100.0	86.1	36.4	51.1	
9	Gwda	100.0	77.7	53.3	27.4	39.2
10	Dobrzyca	100.0	80.1	45.7	46.4	38.7
11	Piława	100.0	43.1	63.3		
12	Połączone	100.0	71.7	45.9	33.3	33.3
13	Płytnica	100.0	62.9	62.0		
14	Czernica	100.0	79.8	40.8	1.8	
15	Brda	100.0	88.3	54.2	40.3	28.6
16	Wda	100.0	69.9	42.6	45.4	34.9
17	Gościnka	100.0	87.6			
18	Supina	100.0	89.3	59.0		

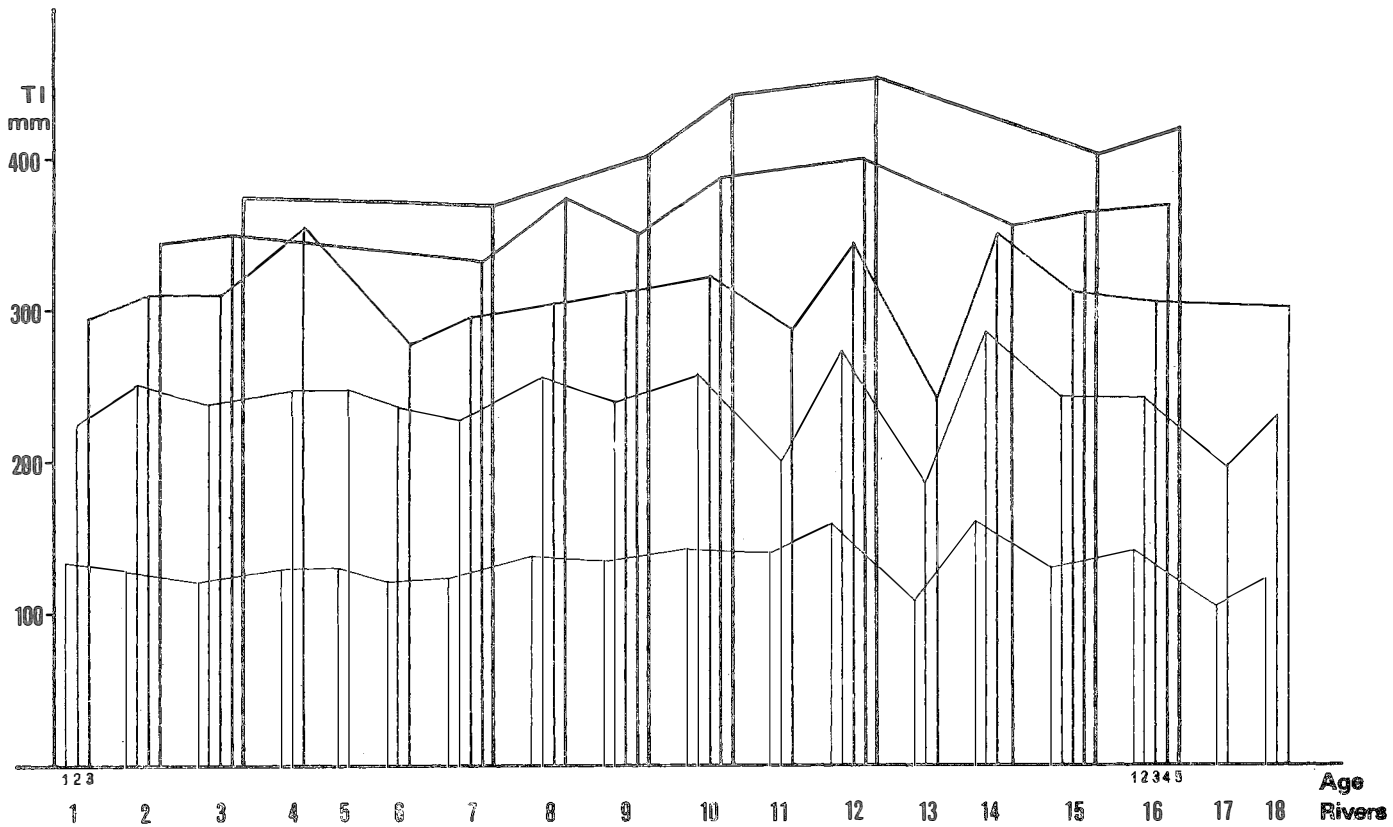

Fig. 2. Growth rate of grayling in Pomeranian rivers. Rivers numbered as in fig. 1.

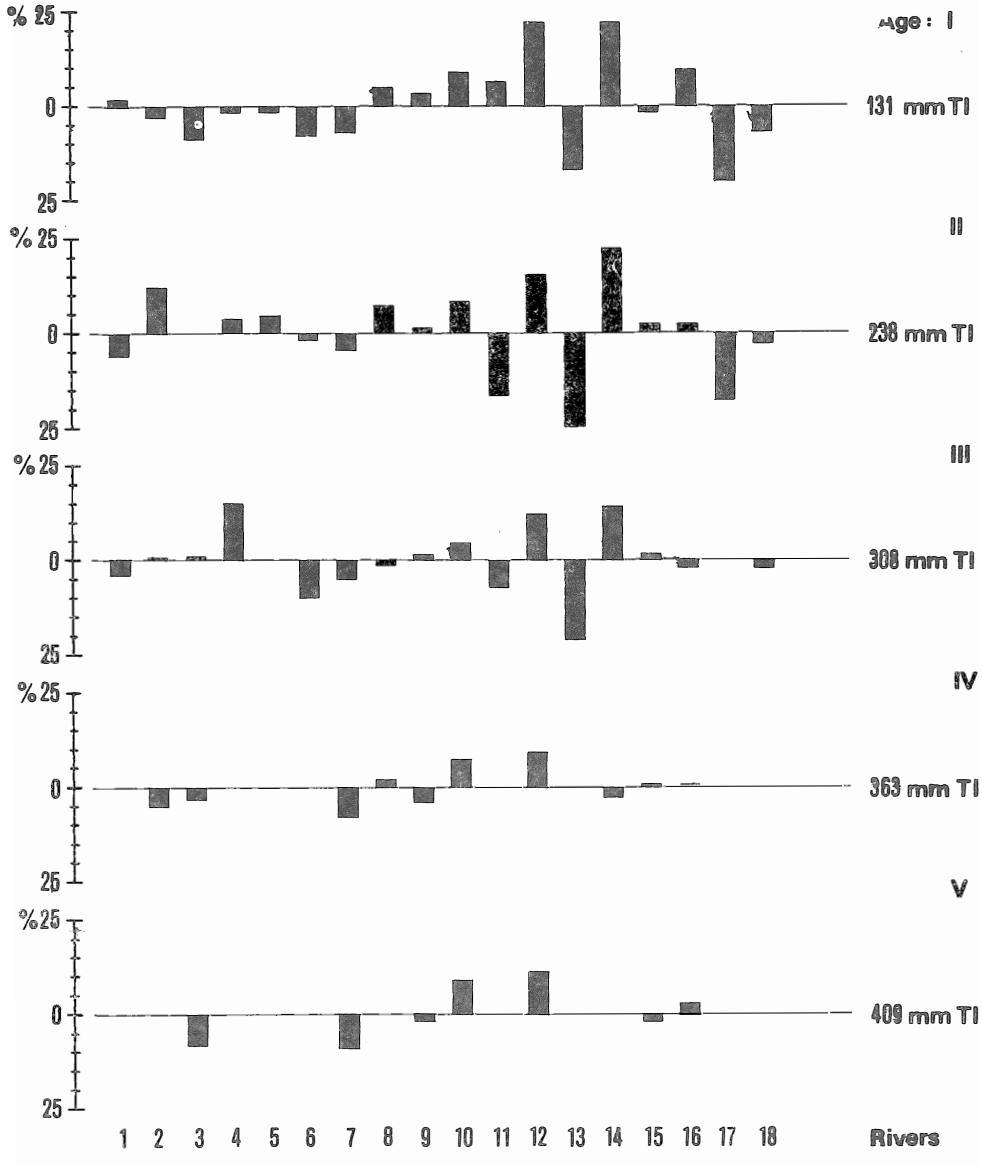

Fig. 3. Deviation (%) from mean growth rate for particular age classes in the studied grayling populations. Rivers numbered as in fig. 1 and tab. 1.

Table 5

Parameters of the von Bertalanffy equation characterizing linear growth and hypothetical total lenght at age 3 years (Lt_3) of graylings from Pomeranian rivers

No	River	L	K (−ln k)	t^o	Lt_3
1	Mołstowa	525	0.269	−0.20	303
2	Wieprza	445	0.397	0.13	302
3	Grabowa	430	0.468	0.18	315
4	Słupia	593	0.312	0.30	338
5	Łupawa	773	0.204	0.10	345
6	Łeba	400	0.481	0.30	291
7	Radunia	444	0.378	0.06	298
8	Drawa	428	0.502	0.40	312
9	Gwda	525	0.294	−0.11	314
10	Dobrzyca	619	0.252	−0.07	333
12	Połączone	556	0.321	−0.03	346
14	Czernica	413	0.695	−0.15	367
15	Brda	505	0.341	0.01	323
16	Wda	614	0.219	−0.23	311
18	Supina	441	0.418	0.22	303

a comparison of the length attained by the graylings of the Pomeranian rivers at a given age. For practical reasons the length in the third year of life was compared (tab. 5), since at that age most Central European populations reach sexual maturity. It follows from the comparison that most Pomeranian graylings start their first spawning after having attained the legal size which in Poland amounts to 300 mm Tl.

Growth intensity

The growth of grayling expressed as coefficient of growth characteristics (C) shows marked differences between particular age groups. The highest mean values (4.92–9.93) were recorded among fish aged 1–3. In subsequent years the values decrease gradually and are the lowest in the oldest individuals – 5 and 6 years old (2.70). Probably the variation in the coefficient, like in other fish species, is associated with the grayling life cycle. Until reaching sexual maturity (3rd year) the growth of fish is very quick. In the 3rd year it is distinctly lower and more stabilized. In senile period (over 4 years) it is decidedly the lowest. Mean values of the growth intensity coefficient for all the studied populations are presented in tab. 6.

Condition coefficient

Mean values of condition coefficient (K) ranged from 0.7 to 1.14. They were decidedly the highest (above 1.0) in the population of the Gwda basin (Dobrzyca,

Table 6

Growth characteristics (C) in grayling from Pomeranian rivers

No	River	C_1/C_2	C_2/C_3	C_3/C_4	C_4/C_5	C_5/C_6
1	Mołstowa	7.01	6.02			
2	Wieprza	9.33	7.29	3.58		
3	Grabowa	8.20	6.26	3.83	4.74	
4	Słupia	8.33	7.88			
5	Łupawa	8.33				
6	Łeba	8.04	5.38			
7	Radunia	7.62	6.36	3.37	2.18	
8	Drawa	8.52	5.38	4.12		
9	Gwda	7.66	6.32	4.82	2.83	
10	Dobrzyca	8.38	6.16	4.75	5.58	
11	Piława	4.92	5.82			
12	Połączone	8.54	7.11	5.15	3.04	2.70
13	Płytnica	5.27	5.08			
14	Czernica	8.06	5.79	3.18		
15	Brda	9.12	7.59	2.88	1.99	
16	Wda	7.53	5.82	4.49	2.84	
17	Gościnka	6.61				
18	Supina	8.30	6.41			
$\bar{x}$		7.76	6.33	4.01	3.31	2.70

Płytnica, Połączone, Czernica), and the lowest (below 0.8) in the graylings from Gościnka, Słupia, Wieprza and Radunia (tab. 7). Because the material was collected mainly in autumn and early winter seasonal changes of that coefficient could not be traced.

Dependence between body weight and total length

The dependence between body weight (w) and length (Tl) in graylings was calculated only for the most numerous samples obtained from the rivers: Wda, Dobrzyca, Grabowa and Radunia. The equations describing it are presented in fig. 4. It follows from the figure that the highest weight increments were attained by the graylings from Wda and Radunia.

DISCUSSION

The European grayling is a short-lived species. In Central and South Europe most individuals reach the age of 3–4 years (Błachuta 1987, Gertychowa 1976, Persat 1976, Solewski 1960, 1963), and only a small fraction lives 5–8 years (Aganović 1965, Balon

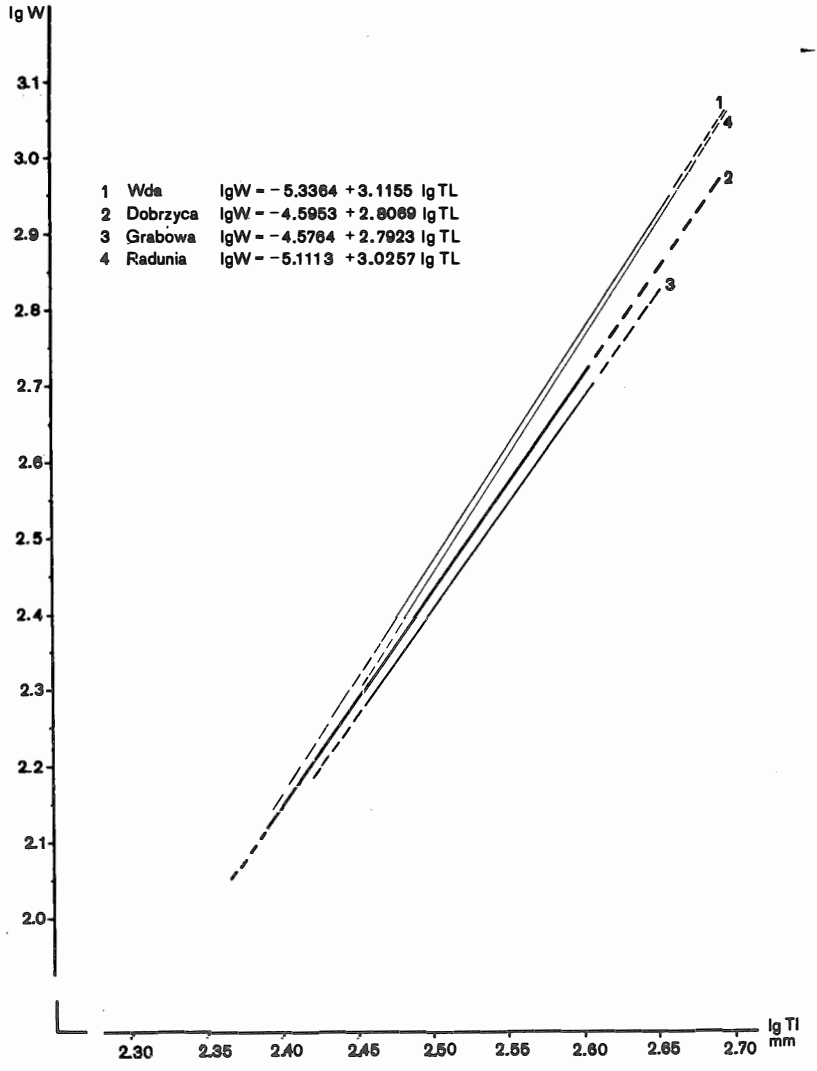

Fig. 4. Dependence between weight (w) and length (Tl) of grayling from Pemeranian rivers. Calculations were made only for the most numerous samples.

1962, Lusk 1975, Woolland, Jones 1975). As a rule, long-lived populations are found at higher geographic latidudes – in Scandinavia and Karelia – which is associated with later attainement of sexual maturity. In those areas the graylings may reach even the age of 13–15 years (Müller 1961, Peterson 1968, Vladimirskaya 1957). No fish that old has been found in the material examined. The age structure of graylings from the Pomeranian rivers is similar to that of many populations from Central Europe. The oldest individual was seven years old (6^+). Fish at the age of 2^+ and 3^+ constituted the highest percentage. Compared to other Polish populations the Pomeranian graylings live semewhat longer. It follows from the data of Penczak et al. (1986) that fish aged 5^+ constitute as much as 10.2% studied populations (Piława + Dobrzyca). In the studied material the percentage of fish at the age of six (5^+) and seven (6^+) years was also distinctly higher than in the basins of Dunajec, Nysa Kłodzka, Kaczawa and Soła (Błachuta 1987, Gertychowa 1976, Krajewski 1986, Solewski 1960, Witkowski 1975). This results probably from two facts: a higher geographic latitude and an angling pressure lower than in the south of Poland.

The growth rats in grayling depends on various environment factors, both biotic and abiotic. Błachuta (1987), Persat, Patte (1981) are of opinion that beside the water temperature, the growth rate is significantly influenced by the size of the river. In small rivers the graylings attain as a rule a much smaller size than in larger. According to

Table 7

Values of condition coefficient (K) in grayling from Pomeranian rivers

No	River	K	$K_{min.} - K_{max.}$
1	Mołstowa	0.85	0.83 – 0.86
2	Wieprza	0.78	0.75 – 1.02
3	Grabowa	0.93	0.55 – 1.29
4	Słupia	0.77	0.73 – 0.85
5	Łupawa	0.80	0.75 – 0.87
6	Łeba	0.80	0.66 – 1.04
7	Radunia	0.79	0.63 – 1.00
8	Drawa	0.97	0.93 – 1.00
9	Gwda	0.91	0.79 – 1.10
10	Dobrzyca	0.82	0.81 – 1.04
11	Piława	1.14	1.08 – 1.20
12	Połączone	1.10	0.84 – 1.30
13	Płytnica	1.11	1.11
14	Czernica	1.07	0.93 – 1.20
15	Brda	0.80	0.80
16	Wda	0.92	0.73 – 1.22
17	Gościnka	0.70	0.70
18	Supina	0.86	0.81 – 0.89

Table 8

Growth rate (Tl in mm) of the european grayling in various rivers/lakes of Europe

Country	River/lake	Age							Author
		1	2	3	4	5	6	7	
Soviet Union	Mesna	81	138	196	242	273	–	–	Svetovidov (1936)
	Čunozero	87	143	202	262	297	338	361	Vladymirskaya (1957)
	Éljavr	92	167	246	301	335	370	405	"
	Garjušnoje	85	138	196	250	305	350	375	"
	Kama	120	170	230	280	330	390	–	Zinovev (1962)
Norway	various rivers	50	127	199	292	312	–	–	Bauch (1970)
Sweden	Indasälven	94	172	239	296	349	386	408	Peterson (1968)
	Pasvigsän	70	149	233	305	–	–	–	"
	Storsjö	84	159	232	286	317	–	–	Gustafson (1949)
Great Britain	Llyn Tegid	120	225	298	358	379	399	–	Woolland, Jones (1975)
	Dee	125	238	303	344	–	–	–	"
	Test	159	286	335	387	413	432	–	Hutton (1923)
France	Ain	150	294	358	402	–	–	–	Persat (1976)
	Loue	144	273	319	360	–	–	–	"
	Ance	120	238	316	356	–	–	–	"
Belgium	Ourthe	145	235	295	–	–	–	–	Micha (1971)
GFR	Iser	90	180	270	350	–	–	–	Bauch (1970)
	Iller	98	202	290	363	–	–	–	"
GDR	Polenz	180	250	280	300	340	350	–	Bauch (1970)
Poland	Kaczawa	120	180	215	261	–	–	–	Błachuta (1987)
	Nysa Kłodzka	139	212	267	304	–	–	–	"
	Soła	112	216	262	302	–	–	–	Solewski (1960)
	Dunajec	129	241	306	351	361	–	–	Błachuta (1987)
	Rogoźnik	104	190	246	–	–	–	–	Solewski (1963)
	Pomeranian rivers	131	238	303	363	409	–	–	authors
	Piława + Dobrzyca	119	212	282	336	391	–	–	Penczak et al. (1986)
Czechoslovakia	Orava	134	252	330	381	408	–	–	Lusk, Skacel (1978)
	Hornad	117	206	258	–	–	–	–	Jedral (1965)
	Turiec	134	203	256	307	395	–	–	Nieslanik (1963)
	Poprad	129	204	261	–	–	–	–	Kirka (1975)
	Loučka	142	228	280	317	373	385	–	Lusk (1975)
	Svratka	137	242	300	337	355	358	–	"
	Divoka Orlice	150	238	300	342	–	–	–	Hochman (1964)
	Vltava	142	200	246	282	–	–	–	Naiksatam (1974)
Yugoslavia	Bosna	160	242	293	324	352	372	385	Aganovič (1965)
	Pliva	163	234	288	316	344	364	380	"
Austria	Kleine Erlauf	124	240	318	–	–	–	–	Jungwirth et al. (1980)
	Pielach	121	243	320	–	–	–	–	"

Witkowski et al. (1984) the growth rate of European populations of grayling is very diversified. In tab. 8 the growth of this species at various geographic latittudes is presented. At higher latitudes (Scandinavia, Karelia) the fish grow slower which is associated with the shorter vegetation season. Populations from Central and Western Europe (France, Belgium, Great Britain, some rivers of Czechoslovakia and Yugoslavia), however, are characterized by a very high growth rate. Those from Eastern Europe (Ural) grow distinctly slower (tab. 8).

According to the criteria of the estimate of growth rate accepted for grayling (Witkowski et al. 1984), the growth of the fish in the Pomeranian rivers can be desribed as follows. Populations from Wieprza, Grabowa, Drawa, Gwda, Dobrzyca, Czernica, Brda and Wda are characterized by a very rapid growth, those from Mołstowa, Słupia, Łeba, Łupawa, Radunia, Piława and Supina – by a quick growth, those from Płytnica and Gościnka – by a slow one.

Compared to populations from the south of Poland – Nysa Kłodzka, Kaczawa, Soła and Rogoźnik (Błachuta 1987, Krajewski 1986, Solewski 1960, 1963, Witkowski 1975) – the graylings from the Pomeranian rivers show a distinctly higher growth rate. Only in the rivers Dunajec and San the growth is similar to that observed in Pomerania (Błachuta 1987, Błachuta Witkowski unpubl. data, Gertychowa 1976).

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WIEK I TEMPO WZROSTU LIPIENIA *THYMALLUS THYMALLUS* (L.) W RZEKACH POMORZA

STRESZCZENIE

W oparciu o materiały liczące 308 osobników lipieni złowionych w 18 rzekach Pomorza przeprowadzono analizę ich wieku oraz dokonano oceny tempa wzrostu.

Z przeprowadzonych badań wynika, że populacje lipieni w tym regionie żyją dłużej oraz rosną szybciej niż w rzekach o podgórskim i górskim charakterze z południa Polski. Wzrost większości badanych populacji można ocenić jako bardzo szybki i szybki (wg kryteriów ustalonych przez Witkowskiego et al. 1984). Intensywność wzrostu wyrażona wskaźnikiem charakterystyki wzrostu jest największa w okresie juwenilnym (do momentu osiągnięcia dojrzałości płciowej). W późniejszych okresach (adult, senectiv) wyraźnie maleje. Największe wartości współczynnika kondycji obserwuje się u populacji najszybciej rosnących (dorzecze Gwdy), co wskazuje, że w rzekach tego systemu lipień znajduje optymalny układ czynników abiotyczno-biotycznych.

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