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Interpopulation Variation in Growth and Life-History Traits of the Non-Native Juvenile Pumpkinseed *Lepomis gibbosus* (L., 1758), in Cooling Water of a Power Plant in the Lower Stretch of the Oder River, Poland

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1. Introduction

Invasions of expansive species is a serious global issue and, according to the International Union for Conservation of Nature, and are one of the most significant threats to biodiversity due to unforeseeable effects that are caused by the appearance of a new species in the given area. One of the invasive foreign species is the North American pumpkinseed *Leppomis gibbosus* (L. 1758) (Casal 2006) introduced in European waters as a sporting and decorative fish (de Groot 1985) from where he reached natural conditions (Welcomme 1988, Copp & Fox 2007). Currently, populations of the pumpkinseed are typical of the water of Central and Western Europe (de Groot 1985, Welcomme 1992) and the Iberian Peninsula (Sostoa *et al.*, 1987) as well as the Black Sea in the south (Economidis *et al.*, 1981). The species predominantly occurs in stagnant waters, but also in lenitic segments of watercourses in which it feeds on available invertebrates and fish (Van Kleef *et al.*, 2008). It normally reaches puberty at the age of three years (Copp & Fox 2007) and seldom reaches the age of ten years (Copp *et al.,* 2004). The presence of the pumpkinseed in some European waters caused a clear decrease in the water quality, zooplankton biomass (Angeler *et al.*, 2002), benthos organisms (Osenberg 1992) and most importantly a change in the structure of local fish, mainly due to feeding on the spawn and young fish and interspecific competition (Holcik 1991). For instance, in a Spanish lake of Albufera, *Mugil cephalus* was a dominant species until 2000. The introduction of the pumpkinseed caused elimination of the aforementioned species and more than a twofold increase in the number of the pumpkinseed (Blanco *et al.*, 2003). Moreover, in some Portugal rivers, the pumpkinseed not only reduced populations of local fish, but also became the dominant species (Godinho *et al.*, 1997). Another example of food competition between local fish species (the silver bream *Blicca bjoerkna*, the eel *Anguilla anguilla* and the pope *Gymnocephalus cernuus*) and the introduced pumpkinseed was observed in an Austrian lake of Neusiedler (Tomeček *et al.*, 2007) and the non-local Prussian carp (Guti *et al.*, 1991). Although the pumpkinseed is a typical generalist with high adaptability and tolerance of environmental conditions different from its natural habitat, it is not an invasive species everywhere in Europe and then its influence on the environment is slight due to its small populations (Copp *et al.*, 2002).

The pumpkinseed was first observed in the Polish waters in 1927 (Grabowska *et al.*, 2010) and currently, except for populations residing in warm waters with higher temperatures, single specimens of this species are caught sporadically in natural waters. The biggest population of the pumpkinseed occurs in warm waters of the Dolna Odra power plant (North-West of Poland) and, in comparison to other European populations, it is distinguished by significant populations, a rapid growth rate at each stage of life (Domagała *et al.*, 2016) and a long portion spawning season (Domagała *et al.*, 2014). However, little is known about seasonal changes in the increase in the length, mass and condition of young pumpkinseeds in these waters. The data obtained for this foreign species occurring in water with increased thermal conditions is important especially in connection with the global warming and may indicate possible expansion of this fish to natural surface waters in the future. The aim of the present paper is to assess the effect of increased thermal water conditions on the size of seasonal changes in the length, mass and condition and a detailed analysis of scales for the number of sclerites in each month of their lives and the time of development of annual growth rings in the population of young pumpkinseeds caught out in warm waters.

2. Material and Methods

The research material included 341 pumpkinseed individuals in age 0+ (305 ind.) and 1+ (36 ind.) caught during monthly catches (electrofishing) (Penczak 1967) in the waters of the lower Oder River. The site of the catch were the waters of the Warm Canal that cool the generators of the Dolna Odra power plant near Gryfino (Northwestern Poland). These waters characterized by an increased temperature with compared to natural waters Domagała et al. 2015), with similar values of other physical and chemical parameters of water (Domagała & Kondratowicz 2006, Domagała & Pilecka-Rapacz 2007).

Fig. 1. Location of the juvenile pumpkinseed catch site: (A) Odra River, from which water is supplied to the power plant 'Dolna Odra' (PDO), the canal receiving heated effluents (W) discharged in the cooling water, and Dąbie Lake
Rys. 1. Lokalizacja miejsc połowu młodocianego bassa słonecznego: (A) rzeka Odra, z której woda jest dostarczana do elektrowni "Dolna Odra" (PDO), kanał ciepły otrzymuje i odprowadza podgrzaną wodę pochłodniczą z elektrowni (W) i jezioro Dąbie

After catching all specimens were examined biologically: total length (TL) with the accuracy of 1 mm was established, individual weight (W) estimated on the electronic balance (type AXIS), with the accuracy of 0.1 g. The length-weight relationships were estimated using the equation W = aSLb , where W is total weight (g), SL - standard length (cm), a intercept, and b slope (Ricker 1975). Condition of fish was estimated on the basis of Fulton condition coefficient according to the formula: K = (W/SL3) * 100 (Bolger & Connolly 1989). Increases in length (Δ SL), weight (Δ W) and condition (Δ K) in each months of the year were estimated starting from June (May is the beginning of the breeding of pumpkinseed in the Warm Canal - Domagala et al. 2014) to May next year and expressed as the function of the size of fish at the start of the year's growth stanza (i. e. Wx, SLx) (Osenberg et al. 1988):

$$\Delta W = Wx+1 - Wx$$
$$\Delta SL = SL_{x+1} - SL_x$$

The scales were sampled following Uzunova et al. (2008) under the dorsal fin, next they were cleaned from of mucus in ammonia water and prepared for examination. On a Zeiss Stereo Discovery V12 microscope at various magnifications connected to PC using a special image analysis software “MultiScan” the age, number of sclerites (S) and the length of oral radius of scales (Po) from the center to the edge of scales in each month were determinated. It allowed indication of the time of setting up the annual ring on the scales of pumpkinseed, and calculation of SL_0 ie. the length at which in this species the scales start forming (Creaser 1926, Osenberg et al., 1988, Uzunova et al. 2008). This value was determined by the graphical method, by plotting the relationship between the standard length of fish (SL) and the scale radius (Po) (Fox & Crivelli 2001 Uzunova et al. 2008).

The obtained measurement results were processed using statistical methods (in Microsoft Excel and Statistica 6.0 software) to calculate arithmetic means ($\overline{x}$) and standard deviation (SD). Before the hypothesis of equal means was verified, the normality of distribution of the analysed characteristic was assessed (using the Shapiro–Wilk test and Levene's test of homogeneity of variance). The significance of differences was determined using Scheffe's test ($P < 0.05$) and analysis of variance (for multiple samples) (Stanisz 1998). To study correlations between variables, regression analysis was used. The degree of match between function and empirical data was determined by calculating coefficients of correlation (R) and determination (R^2). The significance of correlation coefficient was established using t - test (Sokal & Rohlf 1995).

3. Results

Mean lengths (TL and SL) of young pumpkinseeds from the waters were 5.37 cm and 4.30 cm, respectively, and the lower standard deviation indicating smaller sample variation and the higher measurement accuracy were observed for SL (1.21) whereas for T1 the value was 1.52. Therefore, all the analyses and result discussion were conducted on the basis of SL. A statistically significant linear correlation was observed between TL and SL $TL = 1.2451\ SL + 0.012$ ($R = 0.9945$ with $p<0.001$). The mean individual weight (W) of the caught fish was 3.20 g (±2.38). The lowest values SL and W were observed in the fish caught in June, which indicates that strong recruitment caused by intensive feeding of the youngest fish occurs in this period. The highest statistically significant increases in the standard length (Δ SL) (over 0.5 cm/month) and the individual weight (Δ W) (over 0.7 g/month) were observed in months with the highest water temperature (July, August) (ANOVA, $p<0.001$) (Fig. 2, 3). A statistically significant decrease in Δ SL and Δ W in comparison to the previous month was observed in September and October (ANOVA, $p<0.001$) and in the weight additionally in November and May. It seems it was caused by the autumn catch of fish which hatched at the end of August and at the beginning of September which lowered the mean SL and W values. A wide range of these parameters in the fish caught from September to November, 2.30-6.40 cm and 0.35-8.79g, relatively, indicates this phenomenon.

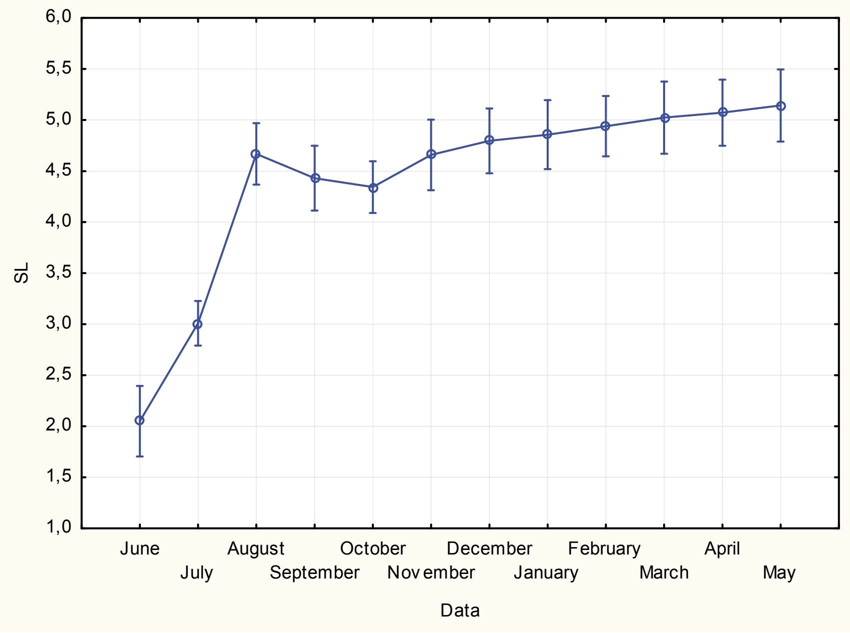

Fig. 2. Changes in standard length (SL) of the juvenile pumpkinseed in warm water
Rys. 2. Zmiany długości (SL) młodocianego bassa słonecznego w wodach pochłodniczych

The standard length (SL) and the individual weight in a young pumpkinseed from warm waters are significantly statistically correlated (R = 0.9927, p<0.001) and the equation looks as follows: $W = 0{,}0222SL^{3{,}2375}$. The high value of parameter b indicates the allometric increase in the weight in comparison to the increase in the body length of the fish.

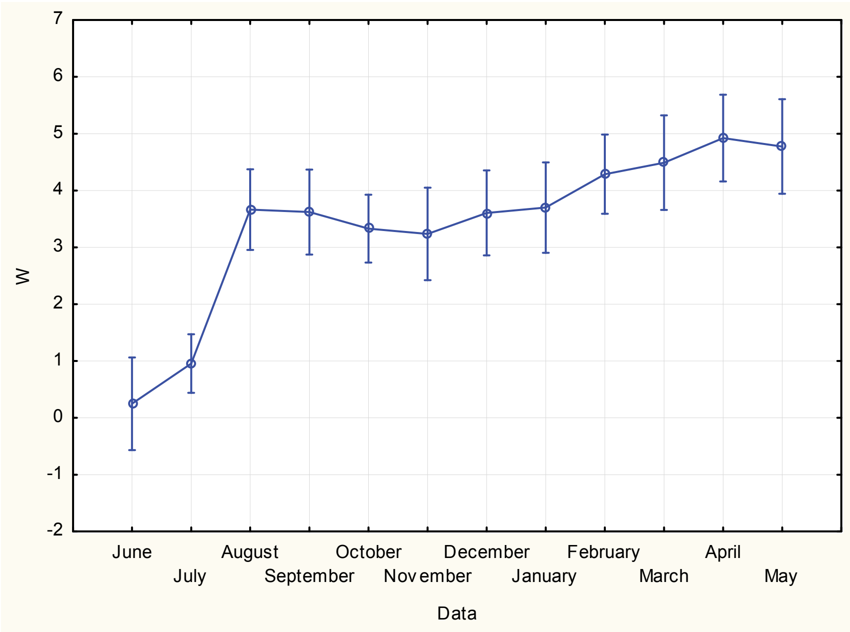

Fig. 3. Changes in individual weight (W) of the juvenile pumpkinseed in warm water
Rys. 3. Zmiany masy jednostkowej (W) młodocianego bassa słonecznego w wodach pochłodniczych

The mean value of the condition coefficient (K) of the caught fish was 3.14 ± 0.45. In the annual cycle, the highest mean K value belonged to the fish caught in April (K=3.60) whereas the significantly statistically lowest value of this parameter (K<3.0) in comparison to other months was observed in June and from November to December (ANOVA, p<0.05) (Fig. 4). The lowest values of condition coefficients in months with the lowest water temperature are typical of this thermophilic species.

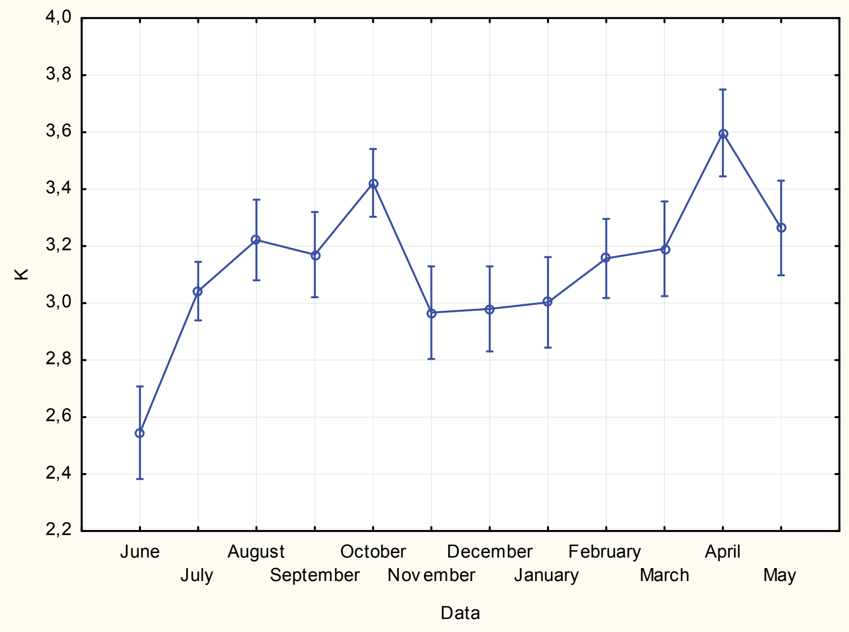

Fig. 4. Changes in condition coefficient (K) of the juvenile pumpkinseed in warm water
Rys. 4. Zmiany wartości współczynnika kondycji (K) młodocianego bassa słonecznego w wodach pochłodniczych

The age of the caught fish was estimated at 0+ (89.44%) and 1+ (10.56%). The fish aged 1+ were only caught in April and May. During the first year of life, the number of sclerites in a scale was on average 20.73 ±5.24 whereas the mean value for the oral ring was 0.892mm±0.241. The number of sclerites on a scale of the pumpkinseed grows proportionally to the increase in the length of this species according to the following formula: S = -0.8441 + 5.0880*SL (R = 0.95682, p<0.001). Also, the statistically significant increase in the length of the oral ring of the scale proved to be proportional to the length (SL) of the studied fish (ANOVA, p<0.001) (Fig. 5) and the length at which it is assumed that the scale in this species is 1.58 cm.

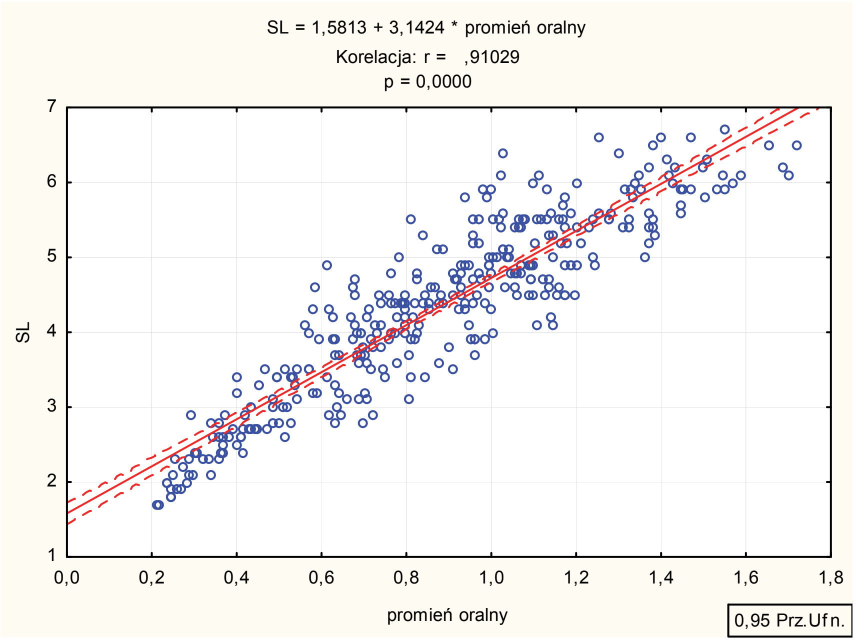

Fig. 5. Correlation between standard length (SL) and the scale radius (Po) of the juvenile pumpkinseed in warm water
Rys. 5. Korelacja prostoliniowa pomiędzy długością (SL) a długością promienia oralnego łuski młodocianego bassa słonecznego z wód pochłodniczych

It was observed that the number of sclerites (S) in an annual cycle increased in all the caught fish from 8,20 ±0.78 (in June) to 27.37 ±5.18 (in May). However, in 27.3 of the fish caught in April and in 56.7% in May the annual ring was already observed and on average 1.38 ±0.55 and 3.40 ±1.02 sclerites of the second year of life, respectively (Table 1). The fact indicates that the annual ring develops in the pumpkinseed in warm waters in this period. The highest statistically significant increases in the number of sclerities and the oral ring of the scale (respectively over 5 items and 0.3 mm) was observed on the scales of the fish caught from June to August (ANOVA, $p<0.05$) (Table 1). A statistically insignificant decrease in the number of sclerties and the lengths of oral rings of the scale in comparison to the previous month was observed in September as well as in January and February (ANOVA, $p<0.05$).

Table 1. Number of sclerites and the scale radius (Po) of the juvenile pumpkinseed in warm water
Tabela 1. Liczba sklerytów (szt.) i długości promienia oralnego łuski (mm) młodocianego bassa słonecznego z wód pochłodniczych

Month	Number of sclerites (pcs.)		The scale oral radius (mm)	
	Mean	SD	Mean	SD
June	8.20	0.78	0.261	0.039
July	14.32	3.26	0.601	0.239
August	22.18	4.59	0.931	0.665
September	21.08	5.88	0.715	0.295
October	21.31	4.74	0.747	0.197
November	23.21	3.79	0.946	0.240
December	24.69	4.41	1.036	0.262
January	24.41	3.92	1.019	0.239
February	22.88	5.14	0.913	0.324
March	25.02	4.46	1.133	0.290
April	25.89	4.56	1.118	0.251
May	27.37	5.18	1.279	0.241

In each month, the relative number of sclerties (S) crossing the oral ring in the pumpkinseed at 1 mm of the length of the oral ring decreases statistically insignificantly with the length SL according to the formula $S + 35.181 - 2.2 * SL$ ($R = -0.5523$ with $p<0.01$) and its annual average is 25.64 with small SD = 3.04.

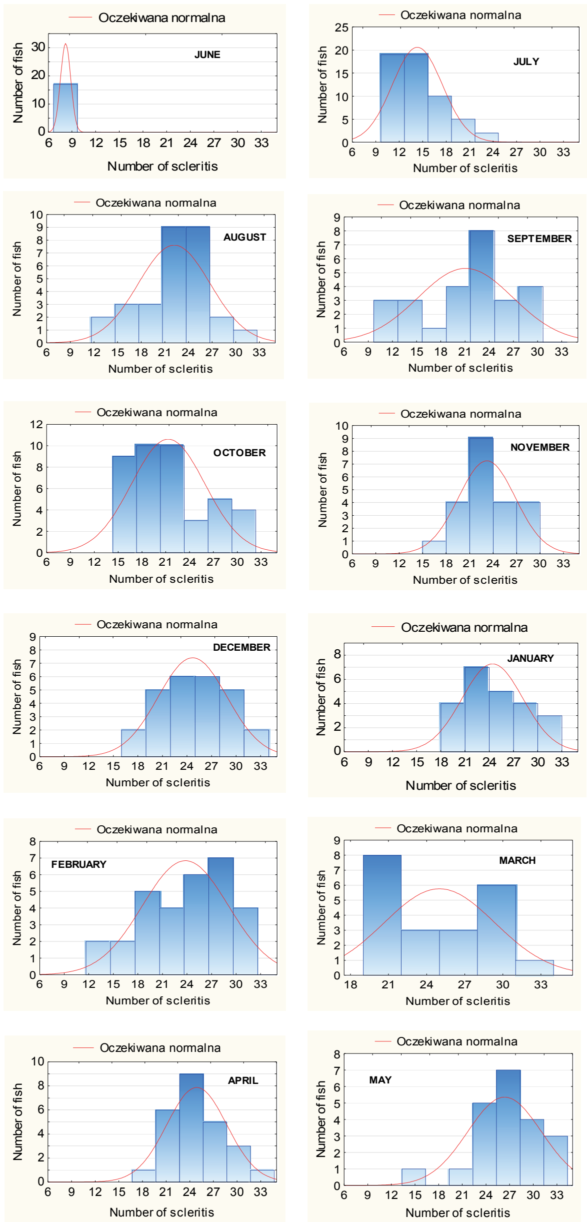

Fig. 6. Distribution of sclerites of pumpkinseed in warm water in annual cycle
Rys. 6. Rozkład liczby sklerytów bassa słonecznego z wód pochłodniczych w cyklu rocznym

Figure 6 presents the distribution of the number of sclerites in young pumpkinseeds in each month. It was assumed that in June the number of sclerites in the scale amounting to less than 14 corresponds to younger fish hatched in May although the pumpkinseed is a portion-spawning fish. From July, the fish were divided into groups in each month according to the number of sclerites. The younger ones from the June hatch were assumed to have up to 14 sclerites whereas the older ones from the May hatch were assumed to have over 14 sclerites. In June, the mean length (SL) of this fish in each group was 2.66 cm and 3.49 cm whereas the weight was 1.51 g and 1.69 g and differed statistically (ANOVA, $p<0.05$). In August, there were probably three age groups coming from the May, June and July hatches. Taking into account the distribution of sclerites in the fish from the catch from this month, it was assumed that we only caught two fishes with scales containing up to 14 sclerites (probably coming from the July hatch, the mean length SL was 3.25 cm and the weight was 0.90 g). Eight fishes featured from 14 to 22 sclerites (from the June hatch, SL = 4.06 cm and W = 2.26) whereas the other fish with the number of sclerites exceeding 22 belonged to the May hatch (SL = 5.26 cm and W = 4.97 g). In September, there were at least four groups differing in hatch season. However, only three groups were distinguished on the basis of the distribution of sclerites. Group I from the August hatch with the smallest number of sclerites (up to 14 sclerites) – 6 individuals (SL = 2.72 cm, W = 0.53 g), group II (July) which had from 14 to 22 sclerites – 8 individuals (SL = 4.31 cm, 2.85 g) and group III – older fish probably from the May and June hatches, over 22 sclerites (SL = 5.58 cm, W = 6.35 g). In October, the group from the September hatch was not caught, which is indicated by the lack of fish with the number of sclerites lower than 14. However, a large group of fish was caught probably from the August hatch which was characterised by up to 22 sclerites (SL = 3.77 cm, W = 1.65 g) and another group which consisted of older individuals (>22 sclerites, SL = 5.44 cm, W = 6.37 g). In November, the pumpkinseeds can only be divided into two groups according to the number of sclerites: up to 22 sclerites with the mean length of 4.01 cm and weight of 1.83 g and over 22 sclerites with SL = 5.29 cm and W = 4.35 g. In December and January, also two groups differing in the number of sclerites (group I <22, group II >22 sclerites) and in mean lengths (TL, SL), weights (W) and condition (K) were distinguished (Table 2) whereas in February unexpectedly two fished with sclerites of up to 14 were caught, which may be caused by the catch of a small group of fish (2 individuals) coming from the September hatch. This group of fish featured low condition (K = 2.85), weight (W = 0.68 g) and length (TL = 3.61 cm and SL = 2.85 cm), which indicates that they encountered unfavourable environmental conditions after the hatch. In March, April and May two groups in each were observed with less than or more than 22 sclerites differing in lengths (TL and SL), weight (W) and condition (Table 2).

Table 2. The division of pumpkinseed from warm water into groups according to number of sclerites with mean lengths (SL and TL, mm), individual weight (W) and condition factor (K)
Tabela 2. Podział bassów na grupy według ilości sklerytów na łusce bassa słonecznego z wód pochłodniczych wraz z ich średnimi długościami (SL i TL, mm), masą (W) oraz współczynnikiem kondycji (K)

Month	Groups by numer of sclerites	Mean value of length (TL, SL, cm), individual weight (W, g) and condition (K) with standard deviation (SD)			
		TL±SD	SL±SD	W±SD	K±SD
June	<14	2.51±0.47	2.05±0.38	0.25±0.16	2.55±0.30
July	<14	3.28±0.37	2.66±0.22	1.51±0.18	2.83±0.42
	>14	4.38±0.51	3.49±0.43	1.69±0.22	3.34±0.31
August	<14	3.85±0.35	3.25±0.35	0.90±0.15	2.62±0.42
	14-22	5.09±0.55	4.06±0.50	2.26±1.01	3.18±0.59
	>22	6.54±0.52	5.26±0.36	4.97±1.44	3.33±0.40
September	<14	3.22±0.26	2.72±0.23	0.53±0.12	2.64±0.28
	14-22	5.37±0.90	4.31±0.75	2.85±1.69	3.15±0.41
	>22	7.09±0.64	5.58±0.44	6.35±1.74	3.56±0.32
October	<22	4.41±0.66	3.77±0.51	1.65±0.18	3.14±0.33
	>22	6.93±0.75	5.44±2.13	6.37±2.13	3.80±0.34
November	<22	5.01±0.57	4.01±0.51	1.83±0.65	2.72±0.24
	>22	6.53±0.60	5.29±0.45	4.35±0.15	2.87±0.35

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Month	Groups by numer of sclerites	Mean value of length (TL, SL, cm), individual weight (W, g) and condition (K) with standard deviation (SD)			
		TL±SD	SL±SD	W±SD	K±SD
December	<22	5.01±0.71	4.03±0.57	1.94±0.83	2.79±0.13
	>22	6.40±0.64	5.20±0.59	4.49±1.71	3.08±0.29
January	<22	5.08±0.45	3.94±0.32	2.09±0.49	3.39±0.44
	>22	6.46±0.82	5.06±0.68	4.56±1.67	3.40±0.28
February	<14	3.61±0.57	2.85±0.49	0.68±0.29	2.85±0.23
	14-22	5.11±0.36	4.08±0.26	2.23±0.53	3.19±0.33
	>22	6.86±0.59	5.64±0.59	6.19±2.03	3.34±0.35
March	<22	5.21±0.23	4.19±0.22	2.13±0.21	2.92±0.35
	>22	6.78±0.76	5.49±0.65	5.85±2.19	3.37±0.37
April	<22	5.56±0.30	4.34±0.24	2.93±0.63	3.55±0.43
	>22	6.87±0.64	5.42±0.57	5.86±1.61	3.62±0.28
May	<22	5.50±0.42	4.35±0.31	2.61±0.66	3.12±0.31
	>22	6.81±0.83	5.33±0.67	5.29±2.15	3.30±0.25

4. Discussion

In 1880 the pumpkinseed was brought into European waters and currently it is one of the six species of the *Centrarchidae* family present in these waters (Tomeček *et al.*, 2007). In Europe it resides in reservoirs with various trophy and hydrology so the growth of this species (especially of the young ones) more depends on the environmental conditions than on their genetics (Heath & Roff 1987). However, as demonstrated by Copp *et al.*, (2004) growth of adult pumpkinseeds is generally lower in non-native European populations than in native American populations, probably due to the greater effect of reproduction and, therefore, greater populations of the fish in the first ones. However, as shown by the studies conducted in warm waters, growth of adult pumpkinseeds is greater than in natural waters of Europe (Dembski 2006, Domagała *et al.*, 2016) which might be caused by higher water temperatures (Domagała & Kondratowicz 2006, Domagała & Pilecka-Rapacz 2007). For instance, in warm waters of the Dolna Odra power plant, thermal conditions optimal for their growth remain from May to September, but the temperature of over 13ºC remains for 10 months (Domagała *et al.*, 2015). A confirmation of the conditions conducive to the growth of adult pumpkinseeds in warm waters of the Lower Oder (Domagała *et al.*, 2016) is a high, similar to the fast-growing populations of American waters, rate of the increase in the lengths of adult pumpkinseeds (Carlander 1977) and reaching the asymptotic length (L_{∞}) significantly exceeding the mean value of this parameter in European populations (Copp *et al.*, 2002, Godinho 2004, Domagała *et al.*, 2016). Also, the growth of young (0+) individuals in warmed waters is higher than in natural waters (Dembski *et al.*, 2006, own studies). In European reservoirs young individuals reach the mean length (SL) of 40 mm in the first year of life (Copp *et al.*, 2004) whereas in waters with temperatures higher by 3.7ºC their length is 46.9 mm (Mirgenbach Reservoir, France) (Dembski *et al.*, 2006) whereas in warm waters of the Dolna Odra power plant it is as much as 51.4 cm (own data). Their rapid growth provides numerous benefits for the pumpkinseed, including reduced exposure to predator attacks, increased survival rate in winter, reduced interspecific and intraspecific competition as well as rapid transition to size classes (Arendt & Wilson 1999). However, rapid growth of the pumpkinseed may be caused by earlier puberty than in natural waters although an important role is played by higher water temperatures (Zapata & Granadolorencio 1993, Dembski *et al.*, 2006, Domagała *et al.,* 2016). However, as demonstrated by Copp *et al.*, (2002), the pumpkinseed matures in the waters of Southern Europe at the age of two years and in the waters to the north even at the age of four whereas in warmed waters of the Mirgenbach Reservoir (France) at the age of one with the length of 56.8 mm (females) and 34.4 mm (males). Also, in the warm canal of the Lower Oder, part of the fish matures at the age of 1+ as early as in mid-May; females at the length of 57 mm and males at the length of over 54 mm, which was observed on the basis of the detailed analysis of gonads.

While assessing the growth of the fish through back-reading, it is important to collect the fish soon after the development of the annual ring and use the SL_0 value, i.e. when the scale develops in fish of a given species, to calculate the growth on the basis of back-reading (Osenberg *et al.*, 1988). The present studies demonstrated that the annual ring in the pumpkinseed develops at the turn of March and April. In this period, the biggest number of sclerites and the greatest edge increase on the scale (March) and a statistically significant decrease in the number of sclerites (ANOVA, $p<0.001$) after the development of the annual ring in April were observed in the analysed group of fish aged 0+. This is confirmed by the fact that part of the fish caught in April (27.3%) and May (56.7%) already had the first annual ring and a small number of sclerities of the new year of life (respectively 1.38 ±0.55 and 3.40 ±1.02). The length of the fish (SL) at which the scale develops in populations from warm waters is 1.58 cm and is slightly lower than in the waters of Southern Europe (1.71 cm) and Northern Europe (SL = 1.82 cm) (Uzunova *et al.*, 2008, Fox & Crivelli 2001), but in some populations of native waters of the USA this length for pumpkinseed is from 1.19 to 1.50 cm (Creaser 1926, Osenberg *et al.*, 1988).

The pumpkinseed population from warm waters is characterised by high variability of mean lengths and individual weights of the fish in each month. This probably results from the significantly longer reproduction cycle of this fish than in natural waters. Generally, the pumpkinseed spawns in portions. One female can lay spawn many times and the male milts the spawn of several females many times (Morris & Mischke 2000). For instance, in Lake Opinicon (Canada) females of the species lay spawn on average 2.1 times (1-6 times) (Fox & Crivelli 1998). Also Kestemont & Philippart (1991) and Deacon & Keast (1987) indicate that the pumpkinseed females lay spawn at least three times every 20-30 days. The reproduction period of the native pumpkinseed populations normally begins in May or at the beginning of June (Bertschy & Fox 1999) and, depending on water temperature, lasts until the end of July or even the beginning of August (Forbes 1989, Vila-Gispert & Moreno-Amich 1998). Water temperature in this time should be 16-26ºC (Forbes 1989). Also a similar reproduction period for non-native populations occurring in Slovakian waters is reported by Holčik (1995), for Greek waters by Neophitou & Giapis (1994) and for Spain by Vila-Gispert & Moreno-Amich (1998). A significantly longer reproduction period is reported by Domagała *et al.* (2014) for the pumpkinseed population in warm waters of the Dolna Odra power plant (from May even to September). This is probably caused by higher water temperatures in comparison to natural waters (annually on average by 6-8ºC) remaining on the optimal level for this species until September (Fig. 7) (Domagała & Kondratowicz 2006). A similarly long reproduction period was observed in warm waters of the Mirgenbach Reservoir power plant in the south-east of France where the average annual water temperature is on average higher than in natural waters by 3.7ºC (Dembski *et al.*, 2006).

An effect of the variation of body lengths of the pumpkinseed may also be high food competition caused by large populations of the fish and cannibalism (Osenberg *et al.*, 1988), especially that individuals born in May are not only older by 5 months from the ones hatched in the last litter (September), but also encounter the most favourable thermal conditions as for the growth of this species (21-32ºC, as cited in Holtan 1989). However, individuals which hatched in September grow much more slowly only for 2-3 months (until November) and then the water temperature drops to 13ºC and remains below this level until mid-April (Fig. 7). Below this value, the pumpkinseed stops growing (Griffits 1978, as cited in Wismer & Christie 1987). This phenomenon was also observed in populations from warm waters of the Dolna Odra power plant, indicating that it is possible to determine fish groups from different hatch period on the basis of the number of sclerites on scales. Although the borders between the groups disappear, the groups differ in length increases (TL and SL), individual weights (W) and condition (K) and probably in mortality in each month. Continuation of the studies of this issue will allow us to take a closer look at the population condition, including recruitment, population sizes and the number of the pumpkinseed in the largest population in Poland.

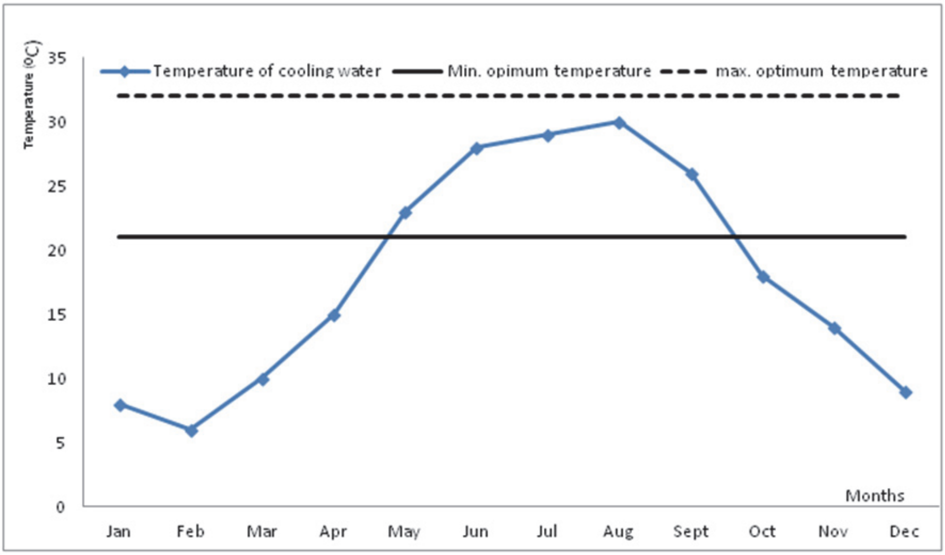

Fig. 7. Average monthly temperature of cooling water in 2009-2010, with an indication of the thermal optimum for the growth of the pumpikinseed (Domagala *et al.* 2015, modificated)
Rys. 7. Średniomiesięczne temperatury wód pochłodniczych w latach 2009-2010 wraz z zaznaczeniem optimum termicznego dla wzrostu bassa słonecznego (Domagała *et al.* 2015, zmienione)

4. Conclusions

An increase in the length and weight of a young pumpkinseed depends on water temperature. In warm waters of the Dolna Odra power plant with higher water temperatures than in natural waters, the fish is characterised by larger increases in lengths and weights in comparison to natural waters in Europe. This results from a longer period of optimal water temperature for the pumpkinseed to feed (Domagała *et al.*, 2015, Domagała *et al.,* 2016). This fact and richer food base in the warm canal explains why young pumpkinseeds do not leave the warm canal, excluding extreme situations. Also, the largest increases in lengths (Δ SL) (over 0.5 cm/month) and individual weights (Δ W) (over 0.7 g/month) which were observed in July and August are correlated with water temperature (over 26ºC). In successive months (autumn and winter), growth and values of the condition coefficient decrease despite temperatures higher by 5-8ºC in the warm canal than in neighbouring waters (Domagała & Kondratowicz 2006, Domagała & Pilecka-Rapacz 2007).

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Wewnątrzpopulacyjne zróżnicowanie wzrostu i życia młodocianych basów słonecznych wprowadzonych do wód pochłodniczych dolnej Odry, Polska

Streszczenie

Bass słoneczny *Lepomis gibbosus,* Linnaeus (1758) jest gatunkiem nierodzimym, którego najliczniejsza populacja w Polsce zasiedla kanał ciepły elektrowni "Dolna Odra". Dotychczas na osobnikach dorosłych tego gatunku przeprowadzono analizy wzrostu długości i masy oraz zmian dojrzałości gonad. Celem niniejszej pracy była ocena wpływu podwyższonej termiki wody na wielkość sezonowych zmian długości, masy i kondycji oraz liczby sklerytów, ze szczególnym uwzględnieniem długości (S_0) przy której zakłada się łuska. Materiał do badań stanowiły osobniki młodociane w wieku 0+ (305 szt.) i 1+ (36 sztuk.) złowione podczas prowadzenia comiesięcznych elektropołowów. Ryby ważono (W, g) z dokładnością do 0,1g, zmierzono (TL, SL, mm) oraz określano ich kondycje za pomocą współczynnika Fultona (K). Ponadto na łuskach oszacowano liczbę sklerytów oraz termin zawiązywania się pierścienia rocznego.

Największe miesięczne przyrosty długości SL (powyżej 0,5cm/miesiąc) oraz masy jednostkowej W (powyżej 0,7 g/miesiąc) u badanych ryb zanotowano w miesiącach o najwyższej termice wody (lipiec, sierpień) (ANOVA, p<0,001). Spadek temperatury wody w kanale ciepłym, w miesiącach jesienno- zimowych, powodował zmniejszanie się przyrostów miesięcznych ryb. Analiza regresji pomiędzy długością (SL) a długością promienia oralnego łuski (Po) przybrała postać funkcji liniowej: SL = 1,5813 + 3,1424*Po (R = 0,91029, p = 0,0000) i wykazała, iż długość przy której zakłada sie łuska u tego gatunku wynosi 1,58cm. Liczba sklerytów (S) na łuskach młodocianego bassa slonecznego wzrastała w cyklu rocznym od 8,20 szt. ±0,78 (w czerwcu) do 27,37 szt. ±5,18 (w maju następnego roku). W kwietniu i w maju u ryb zanotowano założony już pierścień roczny i odpowiednio średnio 1,38 szt. ±0,55 oraz 3,40 szt. ±1,02 sklerytów drugiego roku życia. Ponadto stwierdzono, że liczba sklerytów (S) na łusce bassa słonecznego rośnie proporcjonalnie do wzrostu długości tego gatunku zgodnie ze wzorem: S = -0,8441 + 5,0880*SL (R = 0,95682, p<0,001).

Abstract

Pumpkinseed *Lepomis gibbosus*, Linnaeus (1758) is a non-native fish species, which the largest population in Poland inhabits warm canal of a “Dolna Odra” Power Plant. Until now, the growth in length and weight and changes the gonad’s maturity of adults individual of this species were carried out. The aim of this study was to evaluate the effect of high water temperature on the seasonal changes in the length, weight, condition, and the number of sclerites, with particular emphasis on length (S_0) at which in this species the scales start forming. The research material included 341 pumpkinseed individuals in age 0+ (305 ind.) and 1+ (36 ind.) caught during monthly catches (electrofishing). The fish was weighted (W, g) to the nearest 0.1 g, measured (TL, SL, mm) and their conditions was determined by the coefficient Fulton (K). In addition, number of sclerites (S) on scales and the time of setting up the annual ring were determinated. The biggest monthly increases in mean length - SL (more than 0.5 cm/month) and increases of mean weight W (above 0.7 g / month) in the fish were recorded in the months of highest thermals water (July, August) (ANOVA, p <0.001). The decrease of water temperature in the warm channel in the autumn and winter months, resulted in reduction of monthly growth of fish. Analysis of regression between length (SL) and the length of the scale radius (Po) took the form of a linear function: SL = 1.5813 + 3.1424 * Po (R = 0.91029, p = 0.0000) and showed that the length at which in this species the scales start forming is 1,58cm. Number of sclerites (S) on scales of juvenile pumpkinseed has grown at an annual cycle of 8.20 ± 0.78 (in June) to 27.37 ± 5.18 (in May of the following year). In April and May the fish were recorded already formed on scales a year ring and respectively 1.38 ± 0.55 and 3.40 ± 1.02 sclerites of the second year of life. Moreover, the number of sclerites (S) on pumpkinseed's scales proportionally increased to the length of this species according to the formula: S = -0.8441 + 5.0880 * SL (R = 0.95682, p <0.001).

Słowa kluczowe:
gatunek nierodzimy, młodociany bass słoneczny, wzrost, kondycja, sezonowa zmienność

Keywords:
non-native species, juvenile pumpkinseed, growth rate, condition, seasonal variability