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Growth Rate, Age and Size Structure of the Alien Pumpkinseed, *Lepomis gibbosus* (L., 1758) Population from a Heated-water Discharge Canal of a Power Plant in the Lower Stretch of the Oder River, Poland

Józef Domagała[*], *Przemysław Czerniejewski*[**],
Małgorzata Pilecka-Rapacz[*]
[*]*University of Szczecin, Poland*
[**]*West Pomeranian University of Technology, Szczecin, Poland*

1. Introduction

One of the sites of natural occurrence of the pumpkinseed (*Lepomis gibbosus*, Linnaeus, 1758) are the waters of eastern North America in which it has been present since the Miocene (Scott & Crossman 1973). In the 19th century, the species was imported to Europe as a sport and ornamental species (Groot 1985) and there it made its way to the natural environments (Copp & Fox 2007, Welcomme 1992). Currently, the pumpkinseed populations are present in the waters of Central and Western Europe (Groot 1985, Welcomme 1992), reaching the Iberian Peninsula (Sostoa et al. 1987) and the Black Sea in the south (Economidis et al. 1981). Even though the species is widespread in Europe, its populations occur in spots and are limited only to waters offering environmental conditions favourable for this species. However, an increase in the pumpkinseed population in these areas can lead to adverse changes in biocenoses and a progressive elimination of indigenous species (Almeida et al. 2014, Godinho 2004). Therefore, multiple studies of populations of the species inhabiting Western and Southern Europe were conducted in the last decades (Crivelli & Mestre 1988, Fox & Crivelli 2001, Papadopol & Ignat

1967, Tandon 1977a,b, Uzunova et al. 2008, Zięba et al. 2015). The obtained results indicated large differences between the European populations of this species, probably because of the large variability of the environments in which the fish occur. However, little information of the populations inhabiting Northern and Eastern Europe is available (Copp et al. 2002). Also in Poland, although the species was observed for the first time in 1927 (Grabowska et al. 2010), apart from the report by Heese & Przybyszewski (Heese & Przybyszewski 1985) and a valuable study of the pumpkinseed reproduction (Domagała et al. 2014), there are no scientific publications regarding the population structure and the growth rate of the only Polish population of the pumpkinseed inhabiting the heated waters of the lower Oder River.

In view of the above, it seems necessary to identify and update the data on the population structure, condition and growth rate of the pumpkinseed in a heated-water discharge canal of a power plant in the lower stretch of the Oder river and compare this data with that from other regions of Europe. The obtained results will also be useful for assessing the results of studies of the potential impact of the species on the native species of fish and aquatic invertebrates.

2. Material and methods

The research material included 1077 pumpkinseed individuals caught during monthly catches (electrofishing) in the waters of the lower Oder River between 2010 and 2013. 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) (Figure 1), characterized by an increased temperature compared to natural waters (Domagała & Kondratowicz 2006, Domagała & Pilecka-Rapacz 2007).

After the catch, all fish were measured with 0.1 mm accuracy using a Helios electronic calliper connected to a PC, and then weighed with 0.1 g accuracy using an Axis 2000 scale. The length-weight relationship was estimated using the equation: $W = a L^{b}$, where W is total weight (g), L is total length (cm), a is intercept, and b is slope (Ricker 1975). Fish condition, age, as well as growth rate in body length and mass were also assessed. Fish condition was determined using Fulton ($K = 100 \cdot W \cdot L^{-3}$, where W – individual weight in grams, L – total length in mm) and Le Cren ($C = 100 \cdot W \cdot L^{-n}$, where W – individual weight in grams, L – total length in mm, n – the allometry coefficient related to the form of the individuals' growth, calculated from the length-weight relationship) formulas (Bolger & Connolly 1989, Ritterbusch-Nauwerck 1995). Fulton formula is the most popular in literature to determine the condition of fish, but when fish increase less in weight than predicted by increase in length or vice versa (3 < n < 3) we should use the Le Cren formula (Ricker 1975). Fish age and growth rate in body length and mass were determined based on the assessment of scales. Scales were collected in accordance with the methodology specified by Uzunova et al. (Uzunova et al. 2008), under the dorsal fin, cleaned of the remaining mucus in an aqueous solution of ammonia, and used for the preparation of specimens. The age was determined from the number of annual rings seen on a Zeiss Stereo Discovery V12 microscope at various magnifications. Every reading of fish age was repeated using 3-4 scales per fish. Annual rings on scales were measured using a computer with special image analysis software "MultiScan" (with 0.001 mm accuracy).

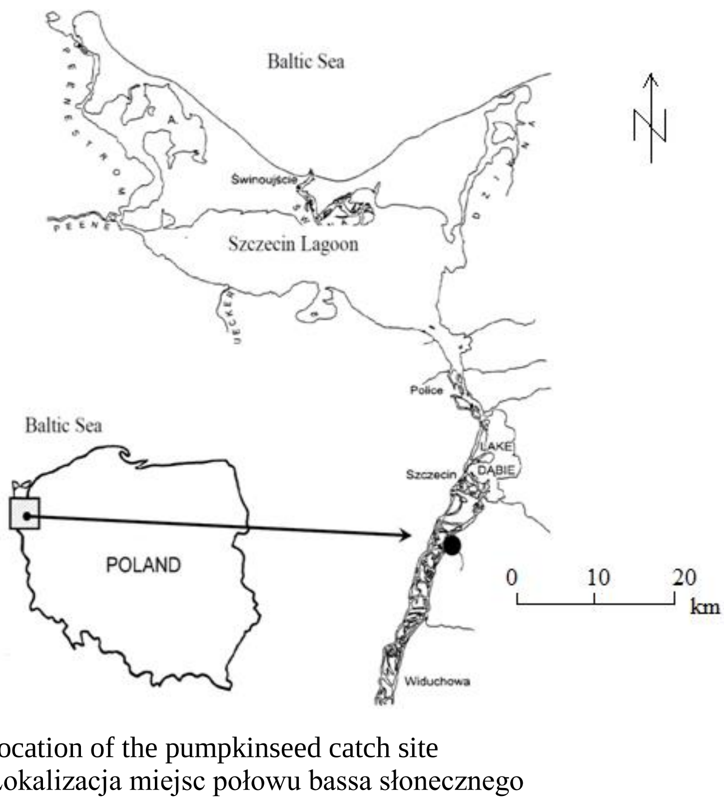

Fig. 1. Location of the pumpkinseed catch site
Rys. 1. Lokalizacja miejsc połowu bassa słonecznego

In view of the linear R-L correlation, reverse readings were performed in the Dahl-Lea variant, as proposed by Heese (Heese 1992). Thus obtained empirical data was used according to Chen et al. (Chen et al. 1992) to present the theoretical increase in fish length using von Bertalanffy formula (Chen et al. 1992, Ricker 1975).

Moreover, the structure of age, size and change in the condition of the pumpkinseed was assessed in each month of the year.

In addition to the tests involving fish, the physico-chemical characteristics of water (oxygen content, temperature and pH) were determined using a CX-410 multimeter and appropriate electrodes. Organic matter content was measured by determining 5-day Biochemical Oxygen Demand (using the direct method). Nitrogen and phosphorus compounds were determined using a Hach DR-890 photometer. The measurements were made once a month for the entire period of the study. The obtained measurement results were processed using statistical methods (in Microsoft Excel and Statistica 6.0 software) to calculate arithmetic means ($\bar{x}$) 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

The pH of water in the Warm Canal in the study period was slightly alkaline. Its mean value ranged from 7.5 to 8.6. In most months, it was generally below 8. However, in extreme cases, it reached 9.8. The average BOD5 was 3.6-4.3 mg O_2 dm^{-3}. The usual range was 3.5-4.5. The content of dissolved oxygen ranged from 289 to 360 mg O_2 dm^{-3}. Nitrogen and phosphorus compounds occurred at quantities typical of these waters. The mean content of total nitrogen was 3.6 mg N dm^{-3}. Total phosphorus was 0.22 mg P dm^{-3} . Conductivity was in the range of 590-630 μS cm^{-1}. The examined waters were characterized by an elevated trophic level, which was reflected in the significant variability of oxygen content, as well as in the concentrations of biogenic compounds and organic matter. However, these parameters were no different from the environmental conditions of the Oder River. The mean oxygen content in the Warm Canal is 7.9 mg O_2 dm^{-3} , while in the Oder River it was usually higher, within the range of 8.2-8.8 mg O_2 dm^{-3}. The only parameter distinguishing the waters of the Warm Canal from the freely flowing waters of the lower Oder River was water temperature. In the Warm Canal, water temperature depends on anthropogenic factors, mainly on specific energy demand. It may vary significantly throughout the day. The highest temperatures were recorded in the summer, while the lowest were recorded in the winter, from November to March. The mean monthly water temperature in the Warm Canal ranged from 11.7°C in January to 29.4°C in July. These temperatures were usually higher than those of the naturally flowing waters of the lower Oder River by 7-8°C throughout the year. The greatest difference between water temperature in the Warm Canal and in natural waters was observed in the winter. In extreme cases, it exceeded 10°C (December to February).

The total number of the pumpkinseed individuals caught was 1077, among which the most individuals were caught from April to October (Table 1). Fish caught in November were characterized by the greatest length (TL and SL) and body mass per individual. The highest condition value was reached by the fish caught in November ($K = 2.10$), when water temperature was still above 13°C. It should be noted that this mean water temperature in the Warm Canal refers to daily measurements, and the changes in water temperature over the day in the winter period are high, reaching a few degrees Celsius. This is associated with an increased demand of electricity in the evening. Therefore, water temperatures in certain periods of the day in the winter may be higher than 13°C, and the fish can grow, as can be concluded from the data in Table 1. Perhaps this is a reflection of their high capacity of adapting to high temperature fluctuations over the day.

Moreover, high condition values were also established in the fish caught in the summer (May to August) ($K \geq 2.0$), and Le Cren coefficient (C) reached the highest values in the fish caught between June and August. On the one hand, this may be due to the optimum temperature for feeding, and on the other hand, due to the reproductive season and filling of the body cavity with developed gonads.

Table 1. Seasonal variability in basic biological characteristics of the pumpkinseed inhabiting the waters of the Warm Canal of the lower Oder River in 2010-2013
Tabela 1. Sezonowa zmienność podstawowych cech biologicznych bassa słonecznego występującego w Kanale Ciepłym dolnej Odry w latach 2010-2013

Month	n*	TL. (cm) ±SD	SL (cm) ±SD	Weight (g) ±SD	Fulton coeffi-cient (K) ±SD	Le Cren coefficient (C) ±SD
January	45	12.42 ±1.71	10.3 4± 1.48	38.65 ± 15.10	1.89 ± 0.17	1.08 ± 0.09
February	65	12.25 ±3.14	10.28 ± 2.74	42.77 ± 24.95	1.92 ± 0.21	1.10 ± 0.11
March	64	12.26 ±2.59	10.22 ± 2.26	41.64 ± 21.09	1.97 ± 0.23	1.13 ± 0.11
April	102	11.58± 3.53	9.64 ± 3.02	40.18 ± 30.04	1.94 ± 0.25	1.13 ± 0.11
May	103	12.10 ±3.19	10.07 ± 2.74	44.40 ± 26.98	2.00 ± 0.28	1.15 ± 0.11
June	124	11.83 ±2.57	9.78 ± 2.24	40.08 ± 26.25	2.05 ± 0.28	1.18 ± 0.15
July	198	11.11 ±3.85	9.22 ± 3.29	39.33 ± 29.99	2.06 ± 0.28	1.22 ± 0.13
August	122	10.82 ±3.37	9.03 ± 2.92	33.91 ± 24.22	2.00 ± 0.27	1.18 ± 0.13
September	69	11.46± 2.32	9.50 ± 2.01	32.98 ± 18.59	1.91 ± 0.22	1.11 ± 0.12
October	121	11.48 ±2.78	9.46 ± 2.40	35.81 ± 20.68	1.98 ± 0.30	1.15 ± 0.16
November	54	13.77 ±1.65	11.53 ± 1.48	56.40 ± 17.33	2.10 ± 0.21	1.17 ± 0.13
December	10	12.37 ±1.53	10.31 ± 1.39	40.74 ± 16.95	2.03 ± 0.25	1.15 ± 0.13

* Among the 1077 individuals, 310 were caught in 2010, 272 in 2011, 241 in 2012, and 254 in 2013

In the sex structure of the population, males prevailed over females, constituting 57.38% and 33.43%, respectively, while individuals of unspecified sex constituted 9.19% (including 3.9% of juvenile individuals). The high number of males among the caught fish is due to the fact that males guard nests and dwell at smaller depths, closer to the shore, while females remain at greater depths, which makes them more difficult to catch using an electric pulse device.

As for the age structure of the fish, it was found that most individuals were in the 3+ and 4+ age groups, constituting a total of 58.31% of all fish (Table 2). The least represented age group was 5+ (2.60%). The mean body mass per individual was 41.65 g (SD = 24.81), with a total length of 11.98 cm (SD = 2.97). Slight differences in the mean body mass and total length between males and females were found. However, no statistically significant differences in these parameters were observed between juvenile and adult individuals (Table 2).

Table 2. The structure of sex, age and total length (T.L., cm), as well as body mass per individual (g) of the pumpkinseed inhabiting the waters of the Warm Canal of the lower Oder River
Tabela 2. Struktura płci, wieku, długości całkowitej (TL., cm) i masy jednostkowej (g) bassa słonecznego występującego w Kanale Ciepłym dolnej Odry

		Age						T.L.	Weight
	n	0+	1+	2+	3+	4+	5+	(cm)±SD	(g)±SD
Male	618	23	48	110	267	150	20	12.54±2.45	45.08±22.92
Female	360	31	50	60	153	58	8	11.85±2.85	40.38±25.28
Unspecified sex and juvenile individuals	99	42	57	–	–	–	–	4.83±0.32	2.02±0.45
Total	1077	153	97	171	420	208	28	11.98±2.97	41.65±24.81

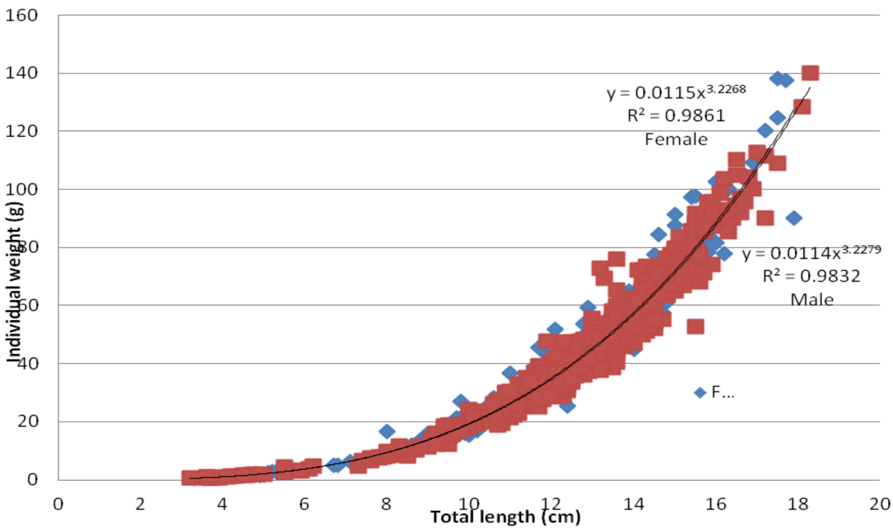

Fig. 2. Correlation between the total length and body mass per individual of the pumpkinseed inhabiting the Warm Canal by sexes.
Rys 2. Zależność pomiędzy długością całkowitą a masą jednostkową samic i samców bassa słonecznego z wód kanału ciepłego

The correlation between the total length and body mass per individual of the pumpkinseed inhabiting the Warm Canal of the lower Oder River is characterized by the following formula: $W = 0.0115\ L^{3.2248}$, with $R^2 = 0.9847$, and no statistically significant differences between the growth rate of males and females were observed (Figure 2). The above formulas and the statistically significant values of determination coefficients R^2 ranging between 0.9832 and 0.9843 (at $P < 0.05$) indicate a good match between the data points and the regression line.

Regression analysis demonstrated that the values of regression line coefficient (a) in the males and females of the pumpkinseed differ significantly from 1, which indicates an allometric correlation between the body mass per individual of these fish and their body length.

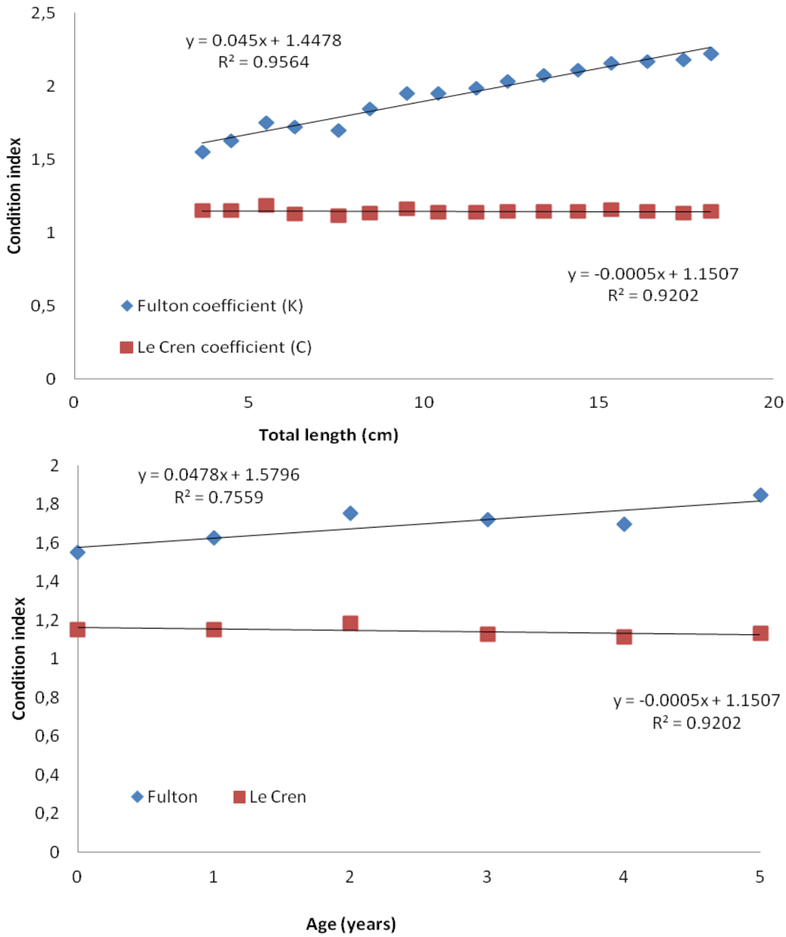

Fig. 3. Correlation between Fulton and Le Cren condition coefficients and fish total length (A) and age (B).
Rys. 3. Zależność pomiędzy wartością współczynnika Fultona i LeCrena a długością całkowitą ryb (A) oraz wiekiem ryb (B)

The mean value of Fulton's factor (K) for the pumpkinseed inhabiting the Warm Canal of the lower Oder River was 2.012 (SD = 0.26), and did not differ in a statistically significant manner (with $P > 0.05$) between males and females (2.02 ± 0.24 and 2.02 ± 0.28, respectively). However, it was significantly lower for juvenile individuals (1.76 ± 0.14). The value of this parameter increases proportionally with fish body length and age (Figure 3), which is caused by the allometric increase in the body mass of the fish in relation to their body length and age. Also in the case of Le Cren coefficient (C), no statistically significant differences were found between individuals of different sexes: the value of this parameter was 1.15 for females and 1.14 for males (mean C = 1.16 ± 0.13). This value is more reliable than Fulton coefficient in the assessment of condition among populations with different fish body length and age, since it does not change along with the increase in body length and age.

Table 3 shows the growth rate in standard length (SL) of the investigated pumpkinseed individuals in each year of life, as determined by reverse readings. Statistical analysis revealed no statistically significant differences between the growth rate of males and females (ANOVA, $P < 0.05$). Therefore, a more detailed analysis was performed in each age group, involving all fish regardless of their sex. In the analysis, growth rates that were lower in a statistically significant manner were observed in the first year of life in age group II (ANOVA, $P < 0.05$). In the other age groups, the annual increments in body length did not differ in a statistically significant manner.

In the investigated fish, the nature of the growth rates was typical of fast-growing, short-lived species. The highest growth rate was obtained by the pumpkinseed in the first year of life (5.87 cm). In subsequent years, the increments were nearly 3 times lower (ranging between 2.93 and 2.17 cm).

Interesting was the large range of growth rate variations in each year of life of the pumpkinseed, expressed as standard deviation (SD). Probably, the variability of the body length of these fish, particularly in the first year of life, was due to their long spawning period in the waters of the Warm Canal of the lower Oder River, in which the differences in the pumpkinseed hatching period may even reach a few months. This phenomenon was maintained in the following years of life, as indicated by the high values of standard deviation.

Table 3. Increase in the standard length (SL) of the pumpkinseed inhabiting the Warm Canal of the lower Oder River
Tabela 3. Wzrost długości ciała (SL) bassa słonecznego występującego w Kanale Ciepłym dolnej Odry

	Standard length (cm) ±SD in individual years of life				
	L1	L2	L3	L4	L5
			Sex		
Male	5.81^{a}±0.76	8.80 ^{a}±0.61	10.94 ^{a}±0,67	12.97 ^{a}±0.64	15.35 ^{a}±0.58
Female	5.90±0.74	8.63 ^{a}±0.67	10.96 ^{a}±0.83	13.21 ^{a}±0.69	15.43 ^{a}±0.59
			Age groups		
I	5.92^{a}±0.93				
II	5.71^{b}±0.75	8.65^{a}±0.66			
III	5.86^{a}±0.58	8.74^{a}±0.54	10.9^{a}±0.73		
IV	5.93^{a}±0.68	8.78^{a}±0.77	10.96^{a}±0.77	13.12^{a}±0.73	
V	5.97^{a}±0.75	8.81^{a}±0.54	10.97^{a}±0.47	13.21^{a}±0.44	15.41±0.58
Mean	5.87±0.75	8.79±0.65	10.96±0.75	13.21±0.67	15.41±0.58
Increment	5.87	2.92	2.17	2.25	2.20
		Mathematical growth model according von Bertalanffy			
Theoretical length	5.24	8.69	11.25	13.15	14.56

Values marked with the same latter superscript in the same column indicates a lack of statistically significant differences among age groups studied (ANOVA, P < 0.05)

Due to the lack of statistically significant differences in the body length between males and females in each year, the parameters for von Bertalanffy formula were based on empirical data. According to this model, the asymptotic length L_∞ for the investigated population of the pumpkinseed was 18.63 cm, while the t_0 and K values were – 0.11 and 0.2979, respectively. The equation for the investigated fish is as follows:

$$SL(t) = 18.63 * [1 - \exp(-0.2979 * (t + 0.11))]$$

4. Discussion

In the population of the pumpkinseed inhabiting the waters of the Warm Canal, fish of the 3+ and 4+ age groups prevailed (58.31% of all fish). The oldest age group, estimated at 5+, constituted only 2.60%. The age structure and maximum age differ from those of other European populations of this species, which may be caused by a various degree of adaptation of the fish to new environmental conditions. As reported by Gutierrez-Estrada et al. (Gutierrez-Estrada et al. 2000) for the waters of Spain, Villeneuve et al. (Villeneuve et al. 2005) for the waters of England, Uzunova et al. (Uzunova et al. 2008) for the waters of Bulgaria, Konečná et al. (Konečná et al. 2015) for the waters of Czech Republic individuals of the younger age groups (1+ and 2+) prevailed among the caught fish, with the maximum age reported for the European populations being 8 years, and in the case of the waters of natural occurrence of this species, even 10 years (Copp et al. 2004). Due to the prevalence of the younger groups in the European populations, also the mean and maximum body lengths ($L\infty$) are much smaller compared to the values obtained by the fish in the American waters. For example, as reported by Copp et al. (Copp et al. 2004), the maximum theoretical body length for the European populations is 12.81 cm, while that in the waters of natural occurrence is 16.86 cm, although in certain water bodies in the USA it exceeded 20.0 cm (Carlander 1977, Parker 1958). The data collected from the population inhabiting the Warm Canal of the Dolna Odra power plant differs from the above mentioned data from other European populations, with its $L\infty$ estimated at 18.63 cm, mean body mass per individual of 41.65 g (SD = 24.81), and mean total length of 11.98 cm (SD = 2.97). Also the growth rate in this water body is higher than that observed in other European waters, and is similar to that of the native populations (Carlander 1977, Copp et al. 2004). Probably due to higher temperature compare to natural waters in this area, and large food supplies (Domagała & Kondratowicz 2006, Domagała & Pilecka-Rapacz 2007). According to the report by Copp et al. (Copp et al. 2004), the mean body length obtained in each year of life of this species in the natural European waters is approx. 30% lower than in the native populations, and in the heated-water discharge canal of a power plant in the lower stretch of the Oder river. MacArthur & Wilson (Macarthur & Wilson 1967) and Klaar et al. (Klaar et al. 2004) concluded that this phenomenon is caused by the higher density of fish population and competition in the colonization of new environmental niches, as well as trophic competition (territorialism). Holtan (Holtan 1998) explained the different growth of this fish also provides water quality, and presence of other fish (predatory fish). The aforementioned explanations for the smaller size of acclimatised European pumpkinseed populations seems more plausible than that proposed by Crivelli & Mestre (Crivelli & Mestre 1988), who indicated that the reason for the slower growth of the European populations may be the fact that the pumpkinseed was introduced in Europe to be kept in aquariums, thus the individuals selected for transport were probably the smallest ones with the slowest growth.

Currently, there is no doubt that in natural conditions, the growth of the pumpkinseed is also affected by water body location (geographical latitude) (Copp & Fox 2007, Copp et al. 2002, Copp et al. 2004) which determines water temperature, as well as the length of the period of intensive feeding. A study by Fox & Crivelli (Fox & Crivelli 2001) demonstrated that the growth rate of fish of the *Centrarchidae* family is higher in waters of higher temperature. The optimum water temperature for this species is 21-32°C (Holtan 1998, Wang 1996), while below 13°C, the fish cease to grow (Wismer & Christie 1987). Therefore, in the waters of Northern and Central Europe, the period of intensive feeding is usually shorter than in the water bodies located in Southern Europe. However, in the waters of the Warm Canal of the lower Oder River, the temperature conditions are optimal for growth from May to September, with the temperature remaining above 13°C for 10 months (Domagała & Pilecka-Rapacz 2007), and even in December and January, water temperature may exceed this value with daily fluctuations. Sadowski (Sadowski 2013) confirmed that the oxygen level in the Warm Canal depended on its content in the natural waters of the Regalica River. With the mean content of 7-8 mg O_2 dm^{-3} in the summer, the difference in oxygen content between consumed and discharged water was, in principle, small and did not exceed 0.2-0.3 mg O_2 dm^{-3}. Only in the periods in which the water level in the Regalica River decreased, oxygen content in the water of the Warm Canal decreased as well (Sadowski 2013). Other chemical parameters of water and sediment at the bottom of the Oder (Gosińska & Siepak 2007) does not adversely affect the growth of this species. The confirmation of conditions favourable for the growth of this species in the waters of the Warm Canal of the lower Oder River is the high growth rate, similar to that obtained by the fast-growing American populations (Carlander 1977), and achieving an asymptotic length ($L\infty$) greatly exceeding the mean value of this parameter established in other European populations (Copp et al. 2002, Tandon 1977a). It should be noted that the

$L\infty$ value for the pumpkinseed individuals originating from the investigated waters is slightly higher compared to the length established in the populations from the waters of natural occurrence (Copp et al. 2004).

The pumpkinseed is one of the short-lived species with a typical high growth rate in the first years of life (Carlander 1977, Copp et al. 2002). However, in contrast to the pumpkinseed from other non-indigenous European populations, the fish from the Warm Canal of the lower Oder River demonstrate increments in body length in the subsequent years of life at 2.17-2.93 cm per year. This could indicate a good adaptation of the fish to specific environmental conditions, in which a temperature optimal for growth and abundance of nutrients are maintained for most of the year, and constitute determinants for the fast growth of the fish. The successful, although not deliberate introduction of the species by humans, and adaptation of the fish to the new environmental conditions are also indicated by the high density of the population, good condition of the fish, and age structure with a clear prevalence of the younger age groups (3+ and 4+). It should also be emphasized that the increased water temperature in the Warm Canal does not cause a significant increase in the temperature of the Oder River, and therefore only single individuals of this species are found in natural waters. In light of the above, it appears that further expansion of the pumpkinseed into the waters of the Oder River may only be incidental, however, it should be regularly monitored.

In conclusion, this study indicate that condition, the growth rate and the maximum theoretical body length of pumpkinseed population from a heated-water discharge canal of a power plant in the lower stretch of the Oder river (Poland) is higher than other European populations and similar to that obtained by the fast-growing American populations. This phenomenon is due to higher water temperature compared to the natural surface waters which determines the length of the period of intensive feeding. Rapid growth provides many advantages for pumpkinseed including decreased vulnerability to predators, increased overwinter survival, size advantages over both inter- and intraspecific competitors, and rapid passage through competitive size classes. Among the caught fish in heated waters, males represented 70.07% and females represented 29.93%. As regards the age structure, most individuals belonged to the groups aged 3+ and 4+, which together constituted 58.31% of the fish, and compared to other populations of European waters were recorded individuals in older age groups. This is probably the result of a small amount of enemies of pumpkinseed in a heated-water discharge canal of a power plant in the lower stretch of the Oder river.

References

Almeida, D., Vilizzi, L., Copp, G.H. (2014). Interspecific aggressive behaviour of invasive pumpkinseed *Lepomis gibbosus* in Iberian fresh waters. *PLoS ONE, 9(2)*: e88038, doi:10.1371/journal.pone.0088038.

Bolger, T., Connolly, P. L. (1989). The selection of suitable indices for the measurement and analysis of fish condition. *Journal of Fish Biology, 34,* 171-182.

Carlander, K.D. (1977). *Handbook of Freshwater Biology*. Vol. 2. The Iowa State Press, Ames.

Chen, Y.D., Jackson, A., Harvey, H.H. (1992). A comparison of von Bertalanffy and polynomial functions in modeling fish growth data. *Canadian Journal of Fisheries and Aquatic Science, 49*, 1228-1235.

Copp, C., Fox, G. (2007). Growth and life history traits of introduced pumpkinseed (*Lepomis gibbosus*) in Europe, and the relevance to its potential invasiveness. In: Francesca Gherardi (Editor). *Biological invaders in inland waters: profiles, distribution, and threats,* 289-306.

Copp, G.H., Fox, M.G., Kováč, V. (2002). Growth, morphology and life history traits of a coolwater European population of pumpkinseed *Lepomis gibbosus*. *Archiv fur Hydrobiologie, 155*, 585-614.

Copp, H.G., Fox, M.G., Przybylski, M., Godinho, N., Vila-Gispert, A.(2004). Life-time growth patterns of pumpkinseed *Lepomis gibbosus* introduced to Europe, relative to native North American populations. *Folia Zoologica, 53*, 237-254.

Crivelli, A.J., Mestre, D. (1988). Life history traits of pumpkinseed *Lepomis gibbosus* introduced into the Camargue, a Mediterranean wetland. *Archiv fur Hydrobiologie, 111*, 449-466.

Domagała, J., Kirczuk, L., Dziewulska, K., Pilecka-Rapacz, M. (2014). Annual development of gonads of pumpkinseed, *Lepomis gibbosus (Actinopterygii: Perciformes: Centrarchidae)* from a heated-water discharge canal of a power plant in the lower stretch of the Oder River, Poland. *Acta Ichthyologica et Piscatoria, 44,* 131-143.

Domagała, J., Kondratowicz, A. (2006). Environmental Conditions of Waters of Cold and Warm Canals of "Dolna Odra" Power Station in the Second Half of the Nineties. *Rocznik Ochrona Środowiska, 22*, 355-360.

Domagała, J., Pilecka-Rapacz, M. (2007). Charakterystyka wód pochłodniczych Elektrowni Dolna Odra w latach 2004-2006. *Zeszyty Naukowe Wydziału Budownictwa i Inżynierii Środowiska, 23,* 751-760.

Economidis, P.S., Kattoulas, M., Stephanidis, E. (1981). Fish fauna of the Aliakmon Rriver and the adjacent waters (Macedonia, Greece). *Cybium, 5,* 89-95.

Fox, M.G., Crivelli, A.J. (2001). Life history traits of pumpkinseed (*Lepomis gibbosus*) populations introduced into warm thermal environments. *Archiv fur Hydrobiologie, 150,* 561-580.

Godinho, F.N. (2004). *The ecology of largemouth bass Micropterus salmoides, and pumpkinseed sunfish Lepomis gibbosus, in the lower Guadiana basin: the environmental mediation of biotic interactions*. Universidad Téchnica de Lisboa, Portugal.

Gosińska, G., Siepak, J. (2007). Zanieczyszczenie środkowej i dolnej Odry wybranymi metalami ciężkimi w latach 1991÷2005 na podstawie wyników monitoringu geochemicznego osadów dennych. *Rocznik Ochrona Środowiska, 9,* 167-181.

Grabowska, J., Kotusz, J., Witkowski, A. (2010). Alien invasive fish species in Polish waters: an overview. *Folia Zoologica, 59,* 73-85.

Groot de, S.J. (1985). Introductions of non-indigenous fish species for release and culture in the Netherlands. *Aquaculture, 46,* 237-257.

Gutierrez-Estrada, J.C., Pulido-Calvo, I., Fernandez-Delgado, C. (2000). Age-structure, growth and reproduction of the introduced pumpkinseed *(Lepomis gibbossus,* L. 1758*)* in a tributary of the Guadalquivir River (Southern Spain). *Limnetica, 19,* 21-29.

Heese, T., Przybyszewski, C. (1985). Pumpkinseed sunfish *Lepomis gibbosus (L., 1758) (Pisces, Centrarchidae*) in the Lower Oder. *Przegląd Zoologiczny, 29,* 515-519.

Heese, T. (1992). *Optimalisation of fish growth rate estimation using the back-calculation method.* Koszalin: WSI.

Holtan, P. (1998). *Pumpkinseed (Lepomis gibbosus).* Wisconsin: Wisconsin Department of Natural Resources, Bureau of Fisheries Management.

Klaar, M., Copp, G.H., Horsfield, R. (2004). Autumnal habitat use of non-native pumpkinseed *Lepomis gibbosus* and associations with native fish species in small English streams. *Folia Zoologica, 53,* 189-202.

Konečná, M., Janáč, M., Roche, K., Jurajda, P. (2015). Variation in life-history traits between a newly established and long-established population of non-native pumpkinseed, *Lepomis gibbosus* (*Actinopterygii: Perciformes: Centrarchidae*). *Acta Ichthyologica et Piscatoria, 45,* 385-392.

Macarthur, R.H., Wilson, E.O. (1967). *Theory of Island Biogeography*. Princeton: Princeton University Press.

Papadopol, M., Ignat, G.H. (1967). Contribution to the study of the reproduction biology and growth of the American sun-fish *(Lepomis gibbosus (L.))* in the Lower Danube (flooded zone). *Buletinul Instutului de Cercetari i Projectari Piscicole, 26*, 55-68.

Parker, R.A. (1958). Some effects of thinning on a population of fishes. *Ecology, 39,* 304-317.

Ricker, W.E. (1975). Computation and interpretation of biological statistics of fish populations. *Bulletin Fisheries Research Board of Canada, 191,* 1-382.

Ritterbusch-Nauwerck, B. (1995). Condition or corpulence, fitness or fatness: a discussion of terms. *Archiv fur Hydrobiologie, 46,* 109-112.

Sadowski, J. (2013). *Technologie chowu i żywienia ryb w wodach podgrzanych*. W: *Stan rybactwa śródlądowego w Polsce*. Materiały Szkoleniowe In: State of inland fisheries in Poland. Conference material. Poznań: P.T.Ryb.

Scott, W.B., Crossman, E.J. (1973). Freshwater fishes of Canada. *Bulletin Fisheries Research Board of Canada, 184,* 1-966.

Sokal, R.R., Rohlf, F.J. (1995). *Biometry: the principles and practice of statistics in biological research*. New York: Third Edition, H. Freeman and Company.

Sostoa, A., Lobon-Cervia, J., Fernandez-Colome, V., Sostoa, F.J. (1987). La distribucion del pez sol *(Lepomis gibbosus L.)* en la Peninsula Iberica. *Acta Vertebrata, 14,* 121-123.

Stanisz, A. (1998). *Przystępny kurs statystyki*. Kraków: StatSoft Poland. (in Polish).

Tandon, K.K. (1977a). Age and growth of pumpkinseed (*Lepomis gibbosus* (*Perciforms, Centrarhidae*)) from Hungary. *Vestnik Ceskoslovenske Spolectosti Zoologicke, 16,* 74-79.

Tandon, K.K. (1977b). Morphometric and growth study of *Lepomis gibbosus (Osteichthyes, Percidae*) from Italy. *Vestnik Ceskoslovenske Spolectosti Zoologicke, 16,* 211-217.

Uzunova, E.B., Velkov, S., Studenkov, M., Georgieva, M., Nikolova, L., Pehlivanov, D., Parvanov, D. (2008). Growth, age and size structure of the introduced pumpkinseed (*Lepomis gibbosus* L.) population from small ponds along the Vit River (Bulgaria). *Bulgarian Journal of Agricultural Sciences, 14*, 227-234.

Villeneuve, F., Copp, G.H., Fox, M.G., Stakėnas, S. (2005). Interpopulation variation in growth and life-history traits of the introduced sunfish, pumpkinseed *Lepomis gibbosus,* in southern England. *Journal of Applied Ichthyology, 21*,275-281.

Wang, J. (1996). *Fishes of the Sacramenti-San Joaquin Estuary and Adjacent Waters, California: A Guide to the Early Life Histories*. Berkeley Digital Library Project. http://elib.cs.berkeley.edu/kopec/tr9/html/sp-pumpkinseed.html.

Welcomme, R.L. (1992). A history of international introductions of inland aquatic species. *ICES Marine Science*, *194*, 3-14.

Wismer, D.A., Christie, A.E. (1987). Temperature Relationships of Great Lakes Fishes: A Data Compilation. *Great Lakes Fishery Commission Special Publication*, *87*, 1-165.

Zięba, G., Fox, M.G., Copp, G.H. (2015). How will climate change affect non-native pumpkinseed *Lepomis gibbosus* in the U.K.? *PLoS Biology*, *10*, e0135482.

Tempo wzrostu, wiek i struktura populacji nierodzimego bassa słonecznego, *Lepomis gibbosus* (L., 1758) z wód pochłodniczych dolnej Odry, Polska

Streszczenie

Bass słoneczny jest gatunkiem obcym w wodach Europy, a występowanie populacji jest punktowe i ograniczone tylko do wód o korzystnych warunkach środowiskowych dla tego gatunku. W Polsce rozsiedlony jest w wodach kanału ciepłego elektrowni Dolna Odra, o termice wody znacznie wyższej niż w wodach naturalnych. W latach 2010-2013, przy pomocy elektrycznego urządzenia impulsowego, do badań złowiono 1077 bassów słonecznych, które poddano badaniom populacyjnym określając struktury płci, długości i wieku oraz biologicznych, oceniając tempo wzrostu długości i kondycję ryb. Ponadto wskazano sezonowe zmiany tych parametrów w cyklu rocznym. W strukturze płci dominowały samce, stanowiące 57,38%, samice stanowiły 33,43%, natomiast osobniki z nieoznaczoną płcią 9,19%, w tym osobniki juwenilne 3,9 %. Średnia długość całkowita (TL) złowionych ryb wyniosła 162,62 mm, przy średniej masie jednostkowej 83,21 g. Wśród złowionych ryb dominowały samce stanowiące 70,07% ryb, samice stanowiły 29,93%, W strukturze wieku ryb najwięcej osobników stwierdzono w grupach wieku 3+ i 4+, które stanowiły łącznie 58,31% ryb. Średnia masa jednostkowa złowionych bassów wyniosła 41,65 g (SD = 24,81), przy długości całkowitej 11,98 cm (SD = 2,97). Największe roczne przyrosty długości u badanych ryb zanotowano w pierwszym roku życia (5,87cm), podczas gdy w kolejnych przyrosty były blisko 3 krotnie niższe. Tempo wzrostu długości bassów słonecznych było zdecydowanie wyższe w porównaniu do populacji zamieszkujących inne wody Europy i zbliżone do szybkorosnących populacji występujących w naturalnym zasięgu występowania. Prawdopodobnie czynnikiem warunkującym szybki wzrost bassów z wód kanału ciepłego jest woda o podwyższonej termice w stosunku do wód naturalnych.

Abstract

In 2010-2013, 1077 pumpkinseed individuals were caught using an electric pulse device and subjected to population studies aimed to determine their sex, length and age structure, as well as biological studies assessing fish growth rate and condition. Moreover, an annual cycle of seasonal changes in these parameters was demonstrated. In the sex structure of the population, males prevailed over females, constituting 57.38% and 33.43%, respectively, while individuals of unspecified sex were 9.19% (including 3.9% of juvenile individuals). The mean total length (TL) of the caught fish was 162.62 mm, with the mean weight per individual of 83.21 g. Among the caught fish, males represented 70.07% and females represented 29.93%. As regards the age structure, most individuals belonged to the groups aged 3+ and 4+, which together constituted 58.31% of the fish. The mean weight per individual of the caught pumpkinseed was 41.65 g (SD = 24.81), with a total length of 11.98 cm (SD = 2.97). The largest annual increments in the length of the investigated fish were observed in the first year of life (5.87 cm), with increments nearly 3 times lower in the following years. The growth rate of the pumpkinseed was significantly higher in comparison to the populations inhabiting other European waters and was similar to the fast-growing populations occurring in the natural range of occurrence. The probable factor allowing the higher growth rate of the pumpkinseed in the Warm Canal is water temperature much higher than that in natural waters.

Słowa kluczowe:
ryby nierodzime, bass słoneczny, struktura populacji, tempo wzrostu, rzeka Odra

Keywords:
non-native fish, pumpkinseed, population structure, growth rate, Odra river