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IMPACT OF FOOD SUPPLY FREQUENCY AND THE NUMBER OF SHELTERS ON THE GROWTH AND SURVIVAL OF JUVENILE NARROW-CLAWED CRAYFISH (*ASTACUS LEPTODACTYLUS* ESCH.)

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ABSTRACT. The aim of the research was to study the impact food supply frequency and the number of shelters has on the growth and survival of juvenile narrow-clawed crayfish, *Astacus leptodactylus* Esch., fed formulated feed and to determine the dependence of total body length (LT) on the carapace length (LC). In the first experiment, four food supply frequencies were tested for 28 days at a crayfish stocking density of 300 indiv. m^{-2}. Feed was delivered at intervals of 12 h (08:00 and 20:00), 24 h (20:00), 48 h (20:00) and 96 h (20:00). In the second experiment four different numbers of shelters in the tanks were tested for 30 days at a crayfish stocking density of 1500 indiv. m^{-2} (0, 60, 150, and 300 shelters m^{-2}). Feeding frequency had a significant impact on crayfish body weight, specific growth rate (SGR), and relative growth rate (RGR) ($P < 0.05$). The highest values of these parameters were obtained at food supply rates of 12 and 24 h (82.9 mg, 3.6% day^{-1}, 274% and 85.2 mg, 3.7% day^{-1}, 282%), while the lowest values were noted for the longest food supply interval of 96 h (63.6 mg, 2.7 % day^{-1}, 211%). The impact of various food supply frequencies on the survival of the stock was insignificant ($P > 0.05$). The number of shelters had a highly significant impact on survival and stock biomass ($P < 0.05$). The highest survival rate and stock biomass (31.5% and 57.9 g m^{-2}, respectively) was noted in the variant with the most shelters (300 shelters m^{-2}), while the lowest values (16.4% and 25.2 g m^{-2}) were noted in the control variant (tank without shelters). The impact of the various numbers of shelters on crayfish growth and cheliped injury was not statistically significant ($P > 0.05$). The mean value of the proportion between total body length (LT) and the carapace length (LC) was 1.82 (variation coefficient V = 4.56%). There was a highly significant linear dependence among the morphometric indicators mentioned previously ($P < 0.001$, $r = 0.9209$), which was described by the following equation: $LT = 1.6009\ LC + 1.8662$.

Key words: NARROW-CLAWED CRAYFISH (*ASTACUS LEPTODACTYLUS*), REARING, SHELTER, FEEDING FREQUENCY, GROWTH, SURVIVAL

INTRODUCTION

In Poland the range of occurrence and abundance of indigenous crayfish species, the noble, *Astacus astacus* Linnaeus, and the narrow-clawed, *Astacus leptodactylus* Eschscholtz, has declined drastically over the past three decades (Krzywosz 1994,

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Białokoz et al. 1996, Mastyński and Andrzejewski 2001). The fundamental causes of this are the degradation and pollution of the natural environment, as well as repeated episodes of the epizootic of "crayfish plague" caused by the fungus *Aphanomyces astaci* as well as the expansion of the plague-resistant American spiny-cheek crayfish, *Orconectes limosus* (Rafinesque). There is currently a total ban in force on all catches of indigenous crayfish species and the habitats in which they occur are protected by law. Unfortunately, these regulations limit substantially the possibilities of obtaining the necessary stocking material for restoration programs from existing wild populations. Indeed, this is one of the simplest and least expensive methods for actively protecting species threatened by extinction (Cukerzis 1989, Holdich 1993). This is also why the cultivation of indigenous crayfish species under aquaculture conditions is of significant importance for restoration programs and the enrichment of the biodiversity of the natural environment (Ackefors and Lindqvist 1994, Ackefors 1998, Mastyński and Andrzejewski 2001, Skurdal and Taugbøl 2002).

Various methods are applied for the production of crayfish stocking material (Holdich 1993, 2002). One of them is to incubate eggs and rear juvenile crayfish under controlled conditions (Cukerzis 1989, Holdich 1993, Ackefors and Lindqvist 1994, Ackefors 1998). The principle advantages of this method include the possibility of obtaining a large quantity of crayfish stocking material earlier than is possible under natural conditions (Cukerzis 1989, Mackieviciene et al. 1996). Thanks to this, the juvenile crayfish profit more from their first growth season, and their initial rearing under controlled conditions increases their chances for survival in the natural environment. Such initial rearing is of particular significance in the first months of juvenile crayfish independent living when mortality rates are the highest (Celada et al. 1989, Gydemo and Westin 1989, Saez-Royuela et al. 1995).

Juvenile crayfish usually begin exogenous feeding after they have undergone the initial molt; this is known as juvenile stage II (Holdich 2002). Various types of diets have been tested in the rearing of juvenile crayfish (Ackefors 1998, Celada et al. 1989, 1993, Verhof et al. 1998, Ulikowski 2003). Regardless of the type of diet applied, other factors impact the survival and growth of crayfish including physicochemical water parameters, photoperiod, stocking density, food supply frequency, and the number of shelters. The present authors' previous research describes the impact of photoperiod and stocking density of juvenile *A. leptodactylus* (Ulikowski and Krzywosz 2004a).

In studies of crayfish, the most frequently applied measurements are of total body length (*longitudo totalis* = LT) from the beginning of the rostrum to the end of the telson and the carapace length (*longitudo carapax* = LC) from the beginning of the rostrum to the end of the spinal section of the cephalathorax carapace. These body length measurements permit comparing the growth of different crayfish populations. In the case of the *A. leptodactylus* occurring in Poland, the LT to LC ratio is approximately 2 : 1, and there is a linear dependence between these parameters (Kossakowski 1962, Stypińska et al. 1978, Śmietana 1998, Andrzejewski et al. 2001). As the material studied by the authors mentioned above was comprised nearly exclusively of adult specimens, it remains to be discovered what the dependence is between these morphometric parameters in juvenile specimens.

The aim of the present research was to study the impact of food supply frequency and the number of shelters on the growth and survival of juvenile *A. leptodactylus* and to determine the dependence of total body length (LT) on carapace length (LC) in one-month-old specimens.

MATERIALS AND METHODS

The study material was comprised of juvenile specimens of *A. leptodactylus* which had undergone the first molt (stage II). They were obtained from females cultivated in ponds at the Dgał Experimental Hatchery of the Inland Fisheries Institute in Olsztyn (Poland) after egg incubation conducted according to a method developed previously (Ulikowski and Krzywosz 2005). The crayfish were reared in a recirculating system equipped with a water treatment system, thermoregulation, and 12 rotation tanks for rearing (each was 50 dm^3, with a bottom surface area of 0.167 m^2). The tanks were lit continuously (100 lx, photoperoid 24L:0D) in accordance with the general recommendations for this species (Ulikowski and Krzywosz 2004a).

The crayfish were fed Perla Larva 3.0 formulated feed for marine fish (Nutreco Company, Italy; chemical composition according to manufacturer's data: protein 62%, fat 11%, fiber 0.8%, ash 1.0%). The feed was supplied *ad libitum*, and the tanks were cleaned once a week.

The water temperature and oxygen contents were measured daily using an OxyGuard electronic instrument. Every two to three days water samples were collected and the following were determined: pH with a PM 600 electronic probe, ammonia nitrogen $N\text{-}NH_4$ (Nessler method), and nitrate nitrogen $N\text{-}NO_2$ (sulfonyl method) colormetrically (Spekol 11 spectrophotometer). Oxygenation at the water inflow was maintained at a level above 6 mg O_2 dm^{-3}. During both experiments the contents of the following did not exceed the values given: ammonia nitrogen N-NH_4 – 0.3 mg dm^{-3}; nitrate nitrogen N-NO_2 – 0.1 mg dm^{-3}; pH – 8.0-8.3.

EXPERIMENT 1

This experiment studied the impact of the frequency of formulated feed supply on crayfish growth and survival. A total of 600 juvenile specimens were stocked into 12 tanks (50 indiv. tank^{-1} or 300 indiv. m^{-2}). At the beginning of the experiment the average body weight was 30.2 ± 4.2 mg and the mean total body length was 9.8 ± 0.4 mm. There were no shelters for the crayfish in the tanks. Four food supply regimes were applied (each in three replicates): A – feed supplied at intervals of 12 h (08:00 and 20:00), B – 24 h (20:00), C – 48 h (20:00) and D – 96 h (20:00). The stock abundance was monitored every seven days. Rearing was continued for 28 days, and the mean water temperature was 20.2 ± 0.2°C.

EXPERIMENT 2

This experiment studied the impact different numbers of shelters had on the growth and survival of crayfish. A total of 3000 juvenile specimens were stocked into 12 tanks (250 indiv. tank^{-1} or 1500 indiv. m^{-2}). At the beginning of the experiment the mean body weight was 35.2 ± 3.9 mg and the mean total body length was 9.9 ± 0.5 mm. Four different numbers of shelters were deployed in the tanks, as follows: (A (control) – no shelters; B – 10 shelters tank^{-1} = 60 shelters m^{-2}; C – 25 shelters tank^{-1} = 150 shelters m^{-2}; D – 50 shelters tank^{-1} = 300 shelters m^{-2}). All of the variants were tested in three replicates. The shelters were made of sections of PVC garden hose (internal diameter – 16 mm) cut into segments approximately 3 cm long. The crayfish were fed twice daily (08.00 and 20.00). The abundance of the stock was monitored every 15 days. Rearing was conducted for 30 days, and the mean water temperature was 24.0 ± 0.1°C. After this experiment was completed, photographs were taken of each of the crayfish from each tank, and then individual measurements were taken of the crayfish body length. The total body length (LT – from the tip of the rostrum to the end of the telson) and the carapace length (LC – from the tip of the rostrum to the posterior edge of the carapace). The measurements were performed on the photographs of the individuals with the MultiScan 8.1 program (to the nearest 0.1 mm). This is how measurements of 322 individuals from all the experiment variants (the number of crayfish in variants of A, B, C, D was 68, 91, 85, and 78 individuals). Additionally, the number of individuals with complete sets of chelipeds or with the loss of one or both was noted.

The weight and total body length (LT) of individual crayfish (N = 20) were determined at the beginning of each experiment. After rearing was completed, all of the crayfish were caught, counted, and weighed to the nearest 0.1 g. The percentage of individuals from the final stock with complete sets of chelipeds or with single or double cheliped injury was calculated. Two crayfish growth indices were calculated – specific growth rate ($SGR = 100 \times (\ln (w_f)-\ln (w_i))\ t^{-1}$) and relative growth rate ($RGR = 100 \times (w_f - w_i)\ w_i^{-1}$, where: w_i – initial body weight (mg), w_f – final body weight (mg), t – duration of rearing (days).

The data obtained was subjected to statistical analysis using Statistica 7.1. The survival data and the percentages were subjected to *arcsin* function transformation prior to analysis (Zar 1984). One-way variance analysis (ANOVA) was applied, and, when significant differences were determined, this was followed by comparison with mean post-hoc using the Tukey test. The Kruskal-Wallis test was used to compare the mean body length (LT and LC). All of the analyses were conducted at a level of significance of $P = 0.05$. Data from the measurements of crayfish body length (LT and LC) in all of the variants of the second experiment (N = 322) were used to determine the dependence between these parameters as the ratio of LT to LC as well as linear regression and the equation that describes it. The strength of the relation was determined with a correlation coefficient (r).

RESULTS

EXPERIMENT 1 – IMPACT OF FOOD SUPPLY FREQUENCY

The statistical analysis conducted indicated that food supply frequency has a significant impact on the growth of juvenile *A. leptodactylus* ($P < 0.05$). The specific growth rate (SGR) decreased as the food supply frequency decreased. Similar dependencies were noted with regard to mean body weight and relative growth rate (RGR). The values of these parameters in experiment variants A and B were significantly statistically higher than in variant D ($P < 0.05$; Table 1). The mean stock biomass in variant C was 8.5 ± 2.5 g m^{-2} and was nearly two-fold higher than in variant D (4.4 ± 3.4 g m^{-2}).

TABLE 1

Impact of feeding frequency with formulated feed (A – 12 h, B – 24 h, C – 48 h, D – 96 h) on body weight, specific growth rate (SGR), relative growth rate (RGR), biomass, and survival of juvenile *A. leptodactylus* after 28 days of rearing (mean ± SD)

	Variant			
	A	B	C	D
Body weight (mg)	82.9 ± 2.1	85.2 ± 4.2	70.2 ± 12.0	63.6 ± 5.3
SGR (% day^{-1})	3.60^{b} ± 0.09	3.70^{b} ± 0.18	2.98^{ab} ± 0.61	2.65^{a} ± 0.30
RGR (%)	274^{b} ± 7	282^{b} ± 14	232^{ab} ± 40	211^{a} ± 18
Biomass (g m^{-2})	6.1 ± 0.9	5.7 ± 1.8	8.5 ± 2.5	4.4 ± 3.4
Survival (%)	24.7 ± 3.1	22.0 ± 6.0	40.0 ± 6.0	22.0 ± 16.0

Values with different letter in the same row indices differ significantly statistically (P < 0.05)

Food supply frequency was not found to have a statistically significant impact on stock survival or final biomass (P > 0.05; Table 1). The highest survival was obtained in variant C (40%), and the lowest in variants B and D (22% in each). Mortality patterns were similar in all of the variants (Fig. 1). The highest increase in mortality occurred in the second week of rearing, during which the crayfish molted for the first time.

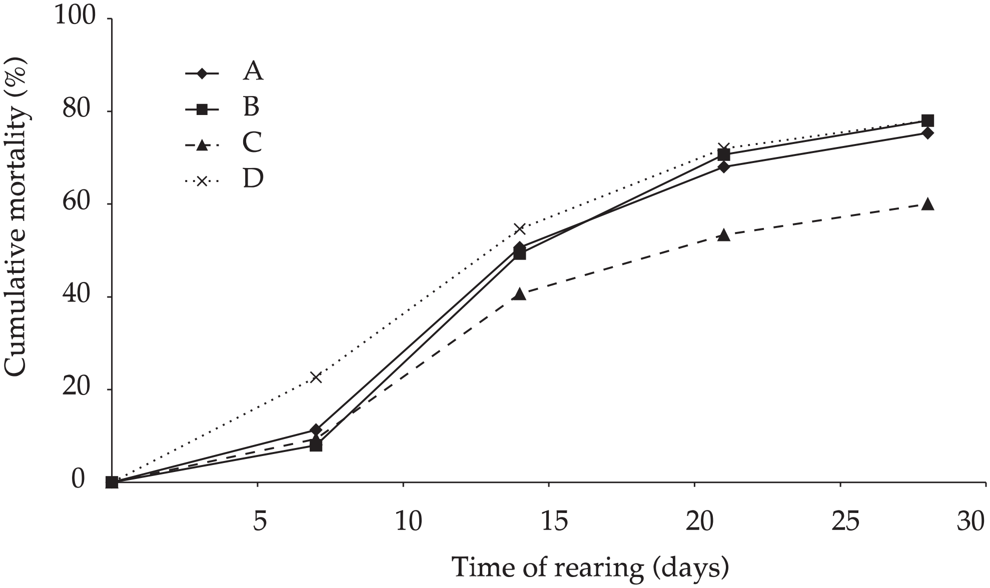

Fig. 1. Cumulative mortality of juvenile *A. leptodactylus* over a 28-day rearing period with various food supply frequencies (A – 12 h, B – 24 h, C – 48 h, D – 96 h).

EXPERIMENT 2 – IMPACT OF THE NUMBER OF SHELTERS

The number of shelters was not noted to have a significant impact on the SGR or RGR indices ($P > 0.05$) (Table 2). However, both body lengths (LT and LC) were subjected to the Kruskal-Wallis test, which indicated that there were significant differences between variant D and control variant A ($P < 0.05$) (Table 2). The stock biomass in variants A (25.2 ± 6.4 g m^{-2}), B (40.5 ± 6.1 g m^{-2}), and C (38.8 ± 8.9 g m^{-2}) was significantly lower than in variant D (57.9 ± 3.5 g m^{-2}) ($P < 0.05$).

TABLE 2

Impact of the number of shelters (A – control – no shelter; B – 60 shelters m^{-2}; C – 150 shelters m^{-2}; D – 300 shelters m^{-2}) on mean body weight and body length (LT – total, LC – carapace), specific growth rate (SGR), relative growth rate (RGR), stock biomass, and the survival of juvenile *A. leptodactylus* and the percentage share of specimens with incomplete sets of chelipeds after 30 days of rearing (mean ± SD)

	Variant			
	A	B	C	D
Body weight (mg)	102.1 ± 22.3	114.1 ± 9.3	107.7 ± 28.6	123.1 ± 12.1
LT (mm)	15.0^{b} ± 1.6	15.6^{ab} ± 1.8	15.1^{b} ± 2.0	15.9^{a} ± 1.4
LC (mm)	8.2^{b} ± 1.0	8.6^{a} ± 1.0	8.4^{a} ± 1.1	8.7^{a} ± 0.8
SGR (% day^{-1})	3.49 ± 0.72	3.91 ± 0.27	3.64 ± 0.96	4.16 ± 0.33
RGR (%)	290 ± 63	324 ± 26	306 ± 81	350 ± 34
Stock biomass (g m^{-2})	25.2^{a} ± 6.4	40.5^{a} ± 6.1	38.8^{a} ± 8.9	57.9^{b} ± 3.5
Share of specimens with incomplete sets of chelipeds (%)	69.5 ± 7.6	68.7 ± 5.9	58.4 ± 8.7	55.7 ± 4.3
Survival (%)	16.4^{a} ± 1.1	23.6^{b} ± 1.8	24.3^{b} ± 1.6	31.5^{c} ± 1.3

Values with different letter indices in the same row differ statistically significantly (Kruskal-Wallis test, $P < 0.05$)

The number of shelters had a significant impact on the final stock survival and biomass of the juvenile *A. leptodactylus* ($P < 0.05$). The values of these parameters were higher in the variants with more shelters (Table 2). The final survival of the stock in the control variant (A) was 16.4 ± 1.1% and was significantly lower than that in variants B and C (23.6 ± 1.8% and 24.3 ± 1.6%, respectively) ($P < 0.05$). However, the final survival of the stock in variants B and C was significantly lower than in variant D (31.5 ± 1.3%) ($P < 0.05$). During the first 15 days of rearing, mortality in all of the variants was similar (58.0-62.5%). In the subsequent rearing period (days 16-30), the mortality noted was significantly lower than during the period of the first fifteen days ($P < 0.05$) (Fig. 2).

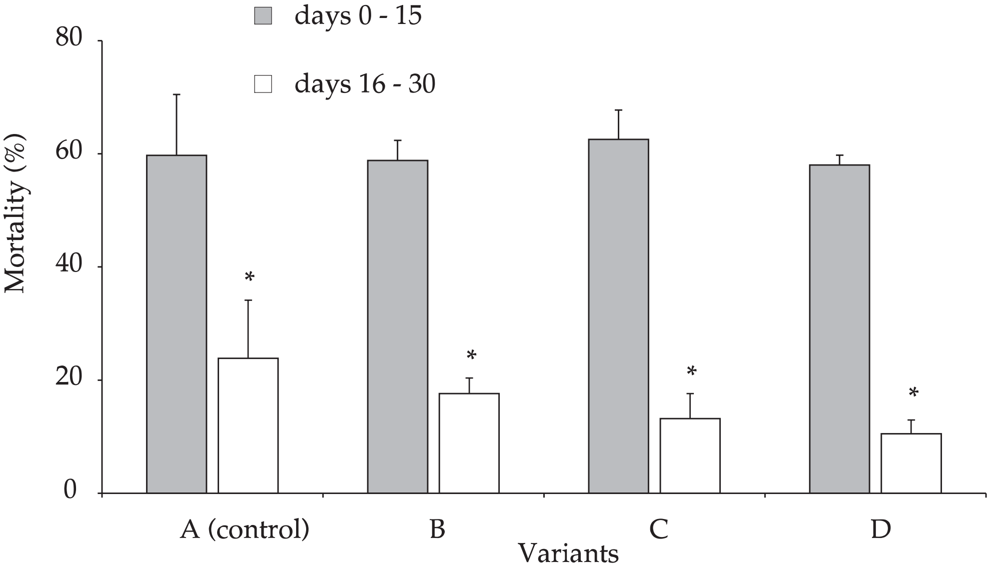

Fig. 2. Comparison of stock mortality during two juvenile rearing periods (days 0-15 and 16-30) with different numbers of shelters in the tanks (A – control – no shelter; B – 60 shelters m^{-2}; C – 150 shelters m^{-2}; D – 300 shelters m^{-2}). Stars indicate statistically significant differences (P < 0.05).

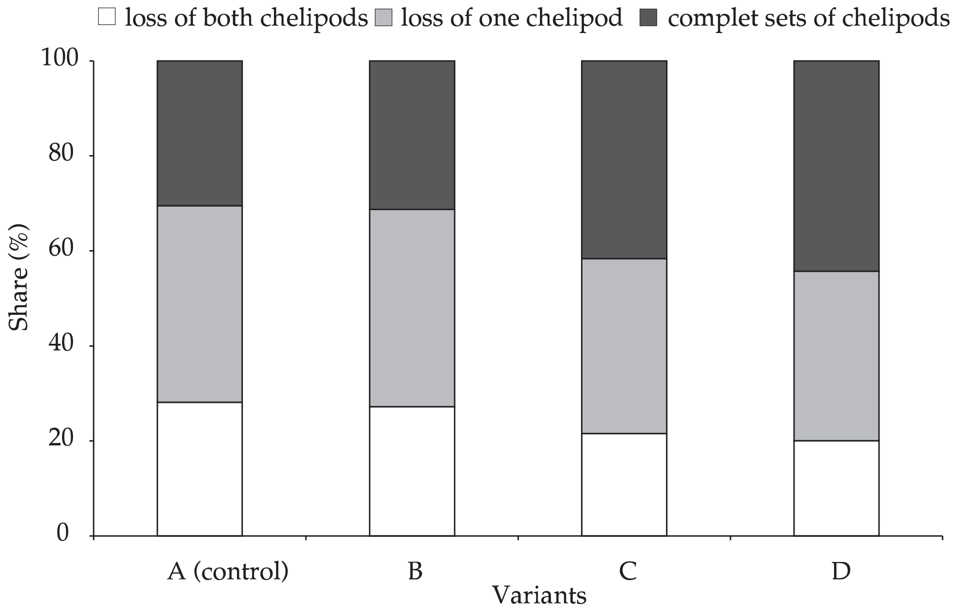

Fig. 3. Impact of various numbers of shelters (A – control – no shelters; B – 60 shelters m^{-2}; C – 150 shelters m^{-2}; D – 300 shelters m^{-2}) on cheliped injury in *A. leptodactylus* after 30 days of rearing.

The percentage of individuals without complete sets of chelipeds (loss of one or both) was the highest in control variant A (69.5 ± 7.6%), and the lowest in variant D (55.7 ± 4.3%). As the number of shelters increased, the percentage of individuals with cheliped injury decreased while that of those with full sets increased (Fig. 3). The differences noted among the variants were statistically insignificant ($P > 0.05$).

The total body length (LT) range of the studied one-month-old *A. leptodactylus* was 11.4-19.2 mm, and the length of the carapace (LC) was 6.0-11.0 mm. The mean value of the proportion between crayfish total body length (LT) and carapace length (LC) was 1.82, and the variation coefficient was $V = 4.56\%$ (Table 3). There was a linear dependence between crayfish total body length (LT) and carapace length (LC) (Fig. 4), and the equation that describes it is a follows: $LT = 1.6009\ LC + 1.8662$. The correlation coefficient that was calculated ($r = 0.9209$, $P < 0.001$) indicates that the dependence is highly significant statistically.

TABLE 3

Comparison of the proportions between total body length (LT) and carapace length (LC) and the variation coefficients (V) of adult *A. leptodactylus* specimens from various Polish lakes and one-month-old individuals from the present study

Origin of the study material	Sex or age	LT/LC	V (%)	Authors
Mazurian lakes	male	1.9	1.1	Kossakowski (1962)
	female	2.0	2.5	
Mazurian lakes	male	1.86	3.67	Śmietana (1998)
	female	2.0	2.5	
Lake Bylice Małe	male	1.95	3.31	
	female	2.01	2.48	
Lake Rzeplino	male	1.90	2.63	
	female	2.02	1.99	
Lake Sumin	male	1.91	1.52	
	female	2.04	6.68	
Lake Cerkiew Nowa	male	1.91	2.41	
	female	1.92	2.83	
Lake Gaj	male	1.90	4.60	Andrzejewski et al. (2001)
	female	2.05	2.57	
Recirculating system	0+ (one-month specimens)	1.82	4.56	this study

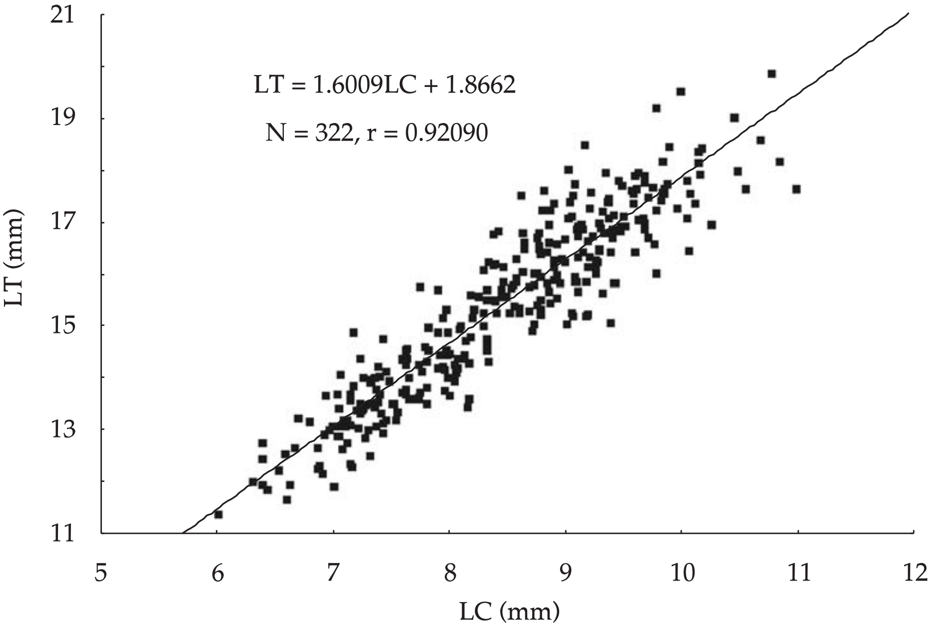

Fig. 4. Dependence between total body length (LT) and carapace length (LC) of one-month-old *A. leptodactylus.*

DISCUSSION

The current study indicated that over the course of 28 days of rearing the higher food supply frequency had a positive impact on the growth of juvenile *A. leptodactylus*. However, the food supply frequencies applied did not impact stock survival during this period. Saez-Royuela et al. (2001), in an 80-day rearing period, obtained decidedly higher survival rates with juvenile crayfish, *Austropotamobius pallipes* (Lereboullet), that were fed twice daily (60.5%) than with those that were fed once daily (38.0%). These frequencies did not have a significant impact on the growth of juvenile *A. pallipes* ($P > 0.05$). However, as in the current study, food supply frequency was found to have an impact on the growth of Australian redclaw crayfish *Cherax quadricarinatus* (von Martens) (Barki et al. 1997, Cortes et al. 2003) and the yabby, *Cherax destructor* Clark (Mills and McCloud 1983). According to Aiken and Waddy (1992), food supply frequency impacts crayfish growth mainly by regulating molting frequency. As the food supply frequency was increased, the frequency of their molting increased (Barki et al. 1997, Saez-Royuela et al. 2001).

The impact of feeding frequency on the survival of the juvenile crayfish has not been determined unequivocally. During a 60-day rearing period of juvenile *C. quadricarinatus* higher feeding frequency (at intervals of 3-24 h) had a positive influence on their survival (Cortes et al. 2003). However, contrary results were obtained after 27 days of rearing juvenile crayfish of the same species at feeding intervals of once per day or once every four days (Barki et al. 1997). Furthermore, Barki et al. (1997) confirmed a significantly higher number of aggressive interactions among juvenile crayfish immediately following the delivery of feed than either before or after the tanks were cleaned ($P < 0.001$). Crayfish mortality increased primarily during molting periods due to cannibalism (Holdich 2002). This is why Barki et al. (1997) hypothesized that crayfish cannibalism was the main factor that contributed to the lower survival among the stocks fed once daily than in those fed once every four days.

The current study indicated that the higher number of shelters has a positive impact on the final stock survival and biomass of the juvenile *A. leptodactylus*. However, the number of shelters tested in the current study did not have a significant impact on the growth of this species or on the number of individuals with cheliped injury ($P > 0.05$). The number of shelters was also confirmed to have had a similarly advantageous impact on stock survival in the case of juvenile *Pacifastacus leniusculus* (Dana) (Westman 1973, Mason 1977, Savolainen et al. 2003) and on that of the shrimp *Macrobrachium nobilii* (Henderson and Matthai) (Mariappan and Balasundaram 2004). However, other studies did not confirm this with regard to juvenile *P. leniusculus* (Saez-Rouyela et al. 1995), *C. quadricarinatus* (Karplus et al. 1995), or *C. destructor* (Verhoef and Austin 1999). Only Karplus et al. (1995) confirmed the advantageous impact of more numerous shelters on the growth of juvenile *C. quadricarinatus*. Some of the shelters employed had a negative impact on crayfish survival and growth (Du Boulay et al. 1993, Blake et al. 1994, Fellows 1995, Jones 1995). Such disparate results obtained by different authors could have resulted from varied rearing conditions, different types of shelters, and the diverse preferences of the studied crayfish species. According to Westin and Gydemo (1988), the daily locomotor activity of juvenile *A. astacus* changes as follows: in summer and early fall they exhibit higher locomotor activity patterns at night than during the day, while the opposite is observed in late fall and during winter. However, the higher availability of shelters in comparison to their absence increased decisively the differences noted in the daily locomotor patterns exhibited by individuals of this species. It was confirmed in the case of juvenile *P. leniusculus* that the number of shelters occupied by crayfish increased to 50% along with increased numbers of crayfish and shelters (Ranta and Lindström 1992). When the number of crayfish was doubled with regard to the number of shelters, the level of hiding place occupancy rose to 75%. According to Ranta and Lindström (1992), *P. leniusculus* occupied the shelters located closest to the location where high-protein feed was delivered, and it was in these places that the crayfish attained the largest body sizes. Verhoef and Austin (1999) reported that the stocking density has a greater impact on the rearing results of juvenile *C. destructor* than did the number or type of shelter. However, in the case of juvenile *P. leniusculus* tank bottom type had a greater impact on this than did the availability of shelters (Savolainen et al. 2003). Shelter preferences differ among various crayfish species. For example, the stone crayfish, *Austropotamobius torrentium* (Schrank), occupies shelters more often than does *P. leniusculus* (Vorburger and Ribi 1999), although *A. leptodactylus* occupied shelters less frequently than did *P. leniusculus* (Ulikowski and Krzywosz 2004b).

The results obtained in the current research indicate that the presence and number of shelters (in the range applied in the present experiment) did not have a significant impact on the number of crayfish with cheliped injury stemming from aggressive interactions. Similar results were obtained by other authors (Figiel and Miller 1995, Savolainen et al. 2003). For example, according to Savolainen et al. (2003) following an 84-day rearing period of juvenile *P. leniusculus* the percentage of individuals with cheliped injury in the variant with shelters (59.5%) was only slightly higher than in the variant without shelters (55.0%). Additionally, Figiel and Miller (1995) reported that cheliped loss has a negative impact on the growth of 1+ *Procambarus clarkii* (Girard) individuals. According to various authors (Figiel and Miller 1995, Taugbøl and Skurdal 1995, Verhoef and Austin 1999, Savolainen et al. 2003, 2004), there is a positive correlation between survival and the degree of cheliped injury and molting frequency. Aggressive interactions and cannibalism are major problems in the rearing of juvenile crayfish.

The mean values of the proportion between total body length (LT) and carapace length (LC) of one-month *A. leptodactylus* individuals was 1.82 (V = 4.56%) and was lower than that obtained by other authors for adult specimens of this species from various Polish lakes (Kossakowski 1962, Śmietana 1998, Andrzejewski et al. 2001). In the current study, the dependence determined between the total body length (LT) and carapace length (LC) of one-month *A. leptodactylus* individuals (N = 322, r = 0.9209), described by the formula: LT = 1.6009 LC + 1.8662, differs from that obtained for adult specimens of this species from Mazurian lakes (Stypińska et al. 1978). According to Stypińska et al. (1978), this dependence in males (N = 50, r = 0.9930) is described by the formula: LT = 1.9078 LC – 0.0194, while in females (N = 150, r = 0.9874) by the formula: LT = 1.8773 LC + 0.7506. As a rule the share of carapace length in total body length is higher in male than in female crayfish (Kossakowski 1962, Stypińska et al. 1978, Śmietana 1998, Andrzejewski et al. 2001). The results obtained in the current study indicate that the share of carapace length (LC) in total body length (LT) of crayfish was higher in one-month-old individuals than it was in adult specimens. However, these differences could stem partially from the different methods of measuring the body length of crayfish. The computerized method based on photographs employed in the current study eliminated error that can occur during manual measurements due to the curve, stretching, and flattening of the abdominal sections (Stypińska et al. 1978). This method also eliminates the stress that the crayfish would be subjected to during the manipulation of traditional manual measurement methods. This method also contributes to the crayfish study methodology since the carapace length only need be determined and then the total body length can be calculated with the dependence formula of these two lengths. Doing such calculations allows comparing the various data available in the literature.

CONCLUSIONS

1. Increasing the food supply frequency (within the range of 12-96 h) of formulated feed to juvenile *A. leptodactylus* had a positive impact on individual growth, but not on stock survival. In the first month of life, these crayfish must be fed at least once a day.
2. An increased number of shelters (within the range of 0-300 shelters m^{-2}) has a positive impact on the final stock survival and biomass of juvenile *A. leptodactylus*, but it does not impact individual growth or the number of specimens with cheliped injury.

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STRESZCZENIE

WPŁYW CZĘSTOTLIWOŚCI KARMIENIA I LICZEBNOŚCI KRYJÓWEK NA WZROST I PRZEŻYWALNOŚĆ MŁODOCIANYCH RAKÓW BŁOTNYCH (*ASTACUS LEPTODACTYLUS* ESCH.)

Celem pracy było zbadanie wpływu częstotliwości karmienia i liczebności kryjówek na wzrost i przeżywalność młodocianych raków żywionych paszą sztuczną oraz określenie zależności długości całkowitej ciała (LT) od długości głowotułowia (LC) osobników jednomiesięcznych. Materiałem obsadowym były młodociane *A. leptodactylus* (stadium-II). W pierwszym doświadczeniu (obsada 300 szt. m^{-2}), przez 28 dni testowano 4 częstotliwości karmienia: 12 h (08.00 i 20.00), 24 h (20.00), 48 h (20.00) i 96 h (20.00). W drugim doświadczeniu (obsada 1500 szt. m^{-2}), przez 30 dni zastosowano 4 różne liczebności kryjówek w basenach (0, 60, 150 i 300 kryjówek m^{-2}). Wszystkie warianty w trzech powtórzeniach. Doświadczenia przeprowadzono w takim samym obiegu recyrkulacyjnym wody wyposażonym w12 rotacyjnych basenów (każdy 50 dm^3, 0,167 m^2). Stosowano ciągłe oświetlenie (100 lx, fotoperiod 24L:0D). Paszę sztuczną zadawano z nadmiarem.

Stwierdzono istotny wpływ częstotliwości karmienia na wzrost raków (tab. 1) (P < 0,05). Najwyższą wartość parametrów SGR i RGR uzyskano przy częstotliwości karmienia 12 h i 24 h (odpowiednio 82,9 mg, 3,6% dzień$^{-1}$, 274% i 85,2 mg, 3,7% dzień$^{-1}$, 282%), a najniższą przy częstotliwości 96 h (63,6 mg, 2,7% dzień$^{-1}$, 211%). Wartość tych parametrów malała wraz ze spadkiem częstotliwości karmienia.

Wpływ różnych częstotliwości karmienia na przeżywalność obsad był nieistotny (P > 0,05). Przebieg śmiertelności obsad w czasie podchowu był podobny we wszystkich wariantach (rys. 1).

Stwierdzono bardzo istotny wpływ liczebności kryjówek na przeżywalność i biomasę obsad (P < 0,05) (tab. 2). Najwyższą przeżywalność i biomasę obsad (odpowiednio 31,5% i 57,9 g m^{-2}) uzyskano w wariancie z najwyższą liczebnością kryjówek (300 kryjówek m^{-2}), a najniższą (16,4% i 25,2 g m^{-2}) w wariancie kontrolnym (baseny bez kryjówek). W czasie pierwszych 15 dni podchowu śmiertelność we wszystkich wariantach była podobna (58,0-62,5%). W kolejnych dniach podchowu (16-30 dnia) śmiertelność notowana we wszystkich wariantach była istotnie niższa niż w okresie pierwszych 15 dni (P < 0,05) (rys. 2).Wpływ różnej liczebności kryjówek na wzrost raków (tab. 2) i ubytki szczypiec (rys. 3) był nieistotny (P > 0,05).

Średnia wartość proporcji między długością całkowitą ciała (LT) a długością głowotułowia (LC) osobników jednomiesięcznych wynosiła 1,82 (V = 4,56%). Jest ona niższa niż u osobników dorosłych tego gatunku pochodzących z różnych jezior Polski (tab. 3). Między wymienionymi powyżej wskaźnikami morfometrycznymi istnieje wysoce istotna (P < 0,001, r = 0,9209) zależność liniowa opisana wzorem: LT = 1,6009 LC + 1,8662 (rys. 4).