

# Absolute fecundity of two populations of signal crayfish, *Pacifastacus leniusculus* (Dana)

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**Abstract.** The subject of the study was two populations of signal crayfish, *Pacifastacus leniusculus* (Dana), from Lake Poblędzie and the Naryjska Struga River. Individual female absolute fecundity was studied. The mean individual fecundity of females from Lake Poblędzie was 361 eggs, while that of females from the Naryjska Struga River was 371 eggs. The average absolute fecundity of signal crayfish in Poland was higher than that of noble crayfish, similar to that of narrow-clawed crayfish, and lower than that of spiny-cheek crayfish.

**Keywords:** Lake Poblędzie, Naryjska Struga River, signal crayfish, absolute fecundity

## Introduction

The signal crayfish, *Pacifastacus leniusculus* (Dana), alien species to European fauna, was introduced from North America in 1959, and was stocked into Swedish open waters in 1960 (Abrahamsson 1971, Fürst 1977, Ahlmer and Karlsson 1980, Brinck 1983). The signal crayfish was brought to Poland in the 1972-1979 and 1990-1991 periods (Kossakowski et al. 1978, 1983, Gondko and Girsztowt 1987, Krzywosz 1994), and

has been documented at 18 sites in inland flowing waters in Poland (Jażdżewski and Konopacka 1993, 1995, Krzywosz et al. 1995, Śmietana and Krzywosz 2006). In addition to the signal crayfish, three other species of crayfish occur in Polish waters; two are endemic – the noble crayfish, *Astacus astacus* (L.), and the narrow-clawed crayfish, *Astacus leptodactylus* Esch, while the third, the spiny-cheek crayfish, *Orconectes limosus* (Raf.), is also a North American species (Kulmatycki 1935, Kossakowski 1973, Jażdżewski and Konopacka 1993, 1995, Strużyński and Śmietana 1998, Śmietana and Strużyński 1999). Signal crayfish were released in 1992 into Lake Poblędzie (Krzywosz 1994, Krzywosz et al. 1995), and in 2000 Krzywosz confirmed the occurrence of signal crayfish in the Naryjska Struga River (Krzywosz and Krzywosz 2001).

The absolute fecundity of noble, narrow-clawed, and spiny-cheek crayfish in Poland has already been described (Leńkowa 1962, Kossakowski 1966, Stypińska 1972, 1973, 1978, Orzechowski 1984, Schulz and Smietana 2001, Chybowski 2007); however, it has yet to be studied in the signal crayfish in natural waters in Poland. Only Krzywosz (1994) described the number of pleopodal by females in ponds (Krzywosz 1994).

The aim of the present study was to examine the individual absolute fecundity of signal crayfish from two populations inhabiting different habitats. The

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subject of the study was signal crayfish populations from Lake Poblędzie and the Naryjska Struga River.

## Materials and methods

Lake Poblędzie is located in the northeast of Poland. The lake surface area is 57.6 ha, with a maximum depth of 15.4 m, and a mean depth of 5.9 m. The lake develops distinct thermal stratification during summer. The lake is eutrophic, and, according to fisheries classification, it is a bream lake (Krzywosz and Krzywosz 2002). The Naryjska Struga River is located in northern Poland, and is classified as a submontane river (Krzywosz 2006). The mean width of the river is about 5 m, the bottom is hard, rocky, and gravelly, and its gradient is 3.6‰. The river links lakes Narie and Mildzie (Krzywosz 2006).

The study material was collected in the 2006-2008 period. Evo traps were used to catch the crayfish. The female crayfish caught were weighed and measured. The crayfish body wet weight (BW) was determined by weighing the crayfish to the nearest 0.1 g. Total body length (TL) was measured from the tip of the rostrum to the end of the abdomen to the nearest 1 mm, and cephalothorax length (CL) was measured from the tip of the rostrum to the end of the cephalothorax to the nearest 0.1 mm. The crayfish were preserved in a 4% formalin solution. Female absolute fecundity was determined by counting all of the mature eggs in the gonads (Smart 1962, Prins 1968, Stypińska 1972, 1973, 1978, Orzechowski 1984). Calculations and statistical analyses were performed with Statgraphics Centurion XVI. The fit of the model was evaluated statistically based on standard error (SE), the coefficient of determination ( $R^2$ ), and probability values (P).

## Results and discussion

The total body length (TL) of the female signal crayfish ranged from 80.0 to 138.0 mm, cephalothorax length (CL) was from 37.2 to 70.2 mm, and body weight

(BW) was from 14.4 to 79.3 g (Table 1). The mean body and cephalothorax lengths of females from Lake Poblędzie were higher (test  $t$ ,  $P \leq 0.05$ ) than those of females from the Naryjska Struga River (Table 1). No statistically significant differences in mean body weights were found between the females from the two populations (test  $t$ ,  $P > 0.05$ ) (Table 1).

Individual signal crayfish females from Lake Poblędzie reach sexual maturity at a total length (TL) of 80.0 mm, and in the Naryjska Struga River at 81.0 mm. Śmietana and Krzywosz (2006) studied the growth rates of signal crayfish in Lake Poblędzie, and they conclude that female signal crayfish at age 1+ (second year of life) reach total body lengths (TL) of 79 to 92 mm, thus the female signal crayfish in Lake Poblędzie and in the Naryjska Struga River achieve sexual maturity in the second year of life. Other authors report that female signal crayfish reach sexual maturity in the second or third years of life at total body lengths (TL) of 60-90 mm (Flint 1975, McGriff 1983, Lewis 2002, Souty-Grosset et al. 2006). However, these and other authors also report that female signal crayfish can reach sexual maturity earlier in the first year of life (Abrahamsson 1971, McGriff 1983, Lewis 2002, Souty-Grosset et al. 2006). Among the four crayfish species occurring in Polish waters, the spiny-cheek crayfish achieves sexual maturity the earliest, even in the first year of life (Leńkowa 1962, Kossakowski 1966, Stypińska 1973, Schulz and Smietana 2001), followed by the signal crayfish in the second or third years of life (Krzywosz 1994, present study), while the endemic noble and narrow-clawed crayfish species do so later in the third or fourth years of life (Kossakowski 1966).

The mean individual absolute fecundity ( $F_a$ , eggs female<sup>-1</sup>) of signal crayfish from Lake Poblędzie in females with a mean total body length (TL) of 105.6 mm and mean body weight (BW) of 37.1 g was 361 eggs, while that of females from the Naryjska Struga River (mean TL and BW of 102.8 mm and 35.7 g, respectively) was 371 eggs. No statistically significant differences were noted between the means (test  $t$ ,  $P > 0.05$ ). Savolainen et al. (1996) report that the mean individual fecundity of signal crayfish fluctuates

**Table 1**

General characters of the measured signal crayfish (*Pacifastacus leniusculus*) females from Lake Poblędzie and Naryjska Struga River. Data are mean  $\pm$  95% confidence interval and range (min-max). TL – total length (mm), CL – cephalothorax length (mm), BW – body weight (g). Values marked with different letter indexes in the same row differ significantly statistically (test t,  $P \leq 0.05$ )

Parameter	Lake Poblędzie		Naryjska Struga River	
	mean	range	mean	range
TL	105.6 $\pm$ 1.2 <sup>a</sup>	80.0-138.0	102.8 $\pm$ 1.1 <sup>b</sup>	81.0-121.0
CL	52.0 $\pm$ 0.6 <sup>a</sup>	38.9-70.2	49.7 $\pm$ 0.6 <sup>b</sup>	37.2-58.7
BW	37.1 $\pm$ 1.3 <sup>a</sup>	14.4-79.3	35.7 $\pm$ 1.1 <sup>a</sup>	18.4-61.1

**Table 2**

The number of females (n), and absolute fecundity (Fa, eggs female<sup>-1</sup>) of the signal crayfish (*Pacifastacus leniusculus*) from Lake Poblędzie and Naryjska Struga River. Data are mean  $\pm$  95% confidence interval and fecundity range (min-max). Values marked with different letter indexes in the same row (test t,  $P \leq 0.05$ ) and different number indexes in the same column differ significantly statistically (Fisher test,  $P \leq 0.05$ )

Total length class (mm)	Lake Poblędzie			Naryjska Struga River		
	n	mean (eggs)	range (eggs)	n	mean (eggs)	range (eggs)
71-80	1	214				
81-90	17	2431 $\pm$ 23 <sup>a</sup>	130-285	19	2071 $\pm$ 23 <sup>b</sup>	91-266
91-100	98	3082 $\pm$ 11 <sup>a</sup>	103-448	64	3202 $\pm$ 23 <sup>a</sup>	83-566
101-110	125	3583 $\pm$ 12 <sup>a</sup>	217-520	102	3963 $\pm$ 18 <sup>b</sup>	206-695
111-120	60	4234 $\pm$ 21 <sup>a</sup>	265-724	32	4874 $\pm$ 32 <sup>b</sup>	289-671
121-130	26	4414 $\pm$ 34 <sup>a</sup>	263-566	2	4953,4 $\pm$ 718 <sup>a</sup>	438-551
131-140	10	5325 $\pm$ 65	334-655			

from 377 to 456 eggs, and Souty-Grosset et al. (2006) report that fecundity ranges from 200 to 400 eggs, while large females can produce in excess of 500 eggs. According to Stypińska (1978), the mean absolute fecundity of crayfish occurring in Polish waters in the Mazurian Lake District is 242 eggs for noble crayfish, 379 eggs for narrow-clawed crayfish, and 447 eggs for spiny-cheek crayfish. The mean absolute fecundity of female signal crayfish from Lake Poblędzie and the Naryjska Struga River was higher (361 and 371 eggs) than that of female noble crayfish, similar to that of narrow-clawed crayfish, and lower than that of spiny-cheek crayfish.

The range of mean individual absolute fecundity in the total body length (TL) classes analyzed was considerable. It was from 243 to 532 eggs in female signal crayfish from Lake Poblędzie, and from 207 to

495 eggs in females from the Naryjska Struga River (Table 2). In both Lake Poblędzie and Naryjska Struga River, the mean absolute fecundity increased with longer total body and cephalothorax lengths (Fisher's test,  $P \leq 0.05$ ; Tables 2 and 3). The mean absolute fecundity of females with total body lengths from 91 to 100 mm and 121-130 mm from both populations did not differ statistically significantly, but in the other length classes the mean absolute fecundity of females from the Naryjska Struga River was higher than that of the females from Lake Poblędzie (test t,  $P \leq 0.05$ ; Table 2). McGriff (1983) compared female absolute fecundity of signal crayfish with mean body lengths (TL) of 80-90 mm from Lake Tahoe, Berry Creek, and the Sacramento and San Joaquin river deltas. The mean absolute fecundity values from the sites compared were 144.5 (110-175) eggs, 175.4

**Table 3**

The number of females (n), and absolute fecundity (Fa, eggs female<sup>-1</sup>) of the signal crayfish (*Pacifastacus leniusculus*) for seven size cephalothorax length classes from Lake Poblędzie and Naryjska Struga River. Data are mean ± 95% confidence interval and fecundity range (min-max). Values marked with different letter indexes in the same row (test t, P ≤ 0.05) and different number indexes in the same column differ significantly statistically (Fisher test, P ≤ 0.05)

Cephalothorax length class (mm)	Lake Poblędzie			Naryjska Struga River		
	n	mean (eggs)	range (eggs)	n	mean (eggs)	range (eggs)
35.1-40.0	2	1851 ± 368 <sup>a</sup>	156-214	6	2081 ± 44 <sup>a</sup>	148-252
40.1-45.0	27	2561 ± 15 <sup>a</sup>	130-322	21	2261 ± 32 <sup>a</sup>	91-384
45.1-50.0	107	3182 ± 12 <sup>a</sup>	103-469	90	3392 ± 17 <sup>b</sup>	83-541
50.1-55.0	110	3643 ± 12 <sup>a</sup>	217-520	75	4183 ± 22 <sup>b</sup>	221-695
55.1-60.0	58	4224 ± 21 <sup>a</sup>	265-724	27	4984 ± 33 <sup>b</sup>	289-671
60.1-65.0	32	4715 ± 30	263-566			
65.1-70.0						
70.1-75.0	1	655				

**Table 4**

Parameters of the regression equations that best explains the dependence of absolute fecundity (Fa) and total length (TL), and cephalothorax length (CL), and body weight (BW) of the signal crayfish (*Pacifastacus leniusculus*). a – power equation (Fa = b<sub>0</sub> x<sup>b<sub>1</sub></sup>), b – linear equation (Fa = b<sub>0</sub> + b<sub>1</sub>x), n – number of females, b<sub>0</sub>, b<sub>1</sub> – regression coefficient, SE – standard error, R<sup>2</sup> – determination coefficient, P < 0.0001

y – x	Lake/River	n	Equation	b <sub>0</sub>	b <sub>1</sub>	SE	R <sup>2</sup> (%)
Fa – TL	Lake Poblędzie	337	b	-247.14	5.75	65.6	47.6
	Naryjska Struga River	219	b	-595.73	9.41	86.5	43.6
Fa – CL	Lake Poblędzie	337	b	-192.15	10.63	65.6	47.5
	Naryjska Struga River	219	b	-528.24	18.08	82.3	48.8
Fa – BW	Lake Poblędzie	337	a	42.37	0.59	1.19	50.4
	Naryjska Struga River	219	a	10.41	0.99	1.29	47.6

(140-218) eggs, and 161.2 (88-239), respectively. In the populations examined in the current study, the mean absolute fecundity (Fa) and range of females measuring 81-90 mm total body length (TL) was higher at 243 (130-285) eggs for the crayfish from Lake Poblędzie and 207 (91-266) eggs for those from Naryjska Struga River (Table 2).

Statistically significant correlations were noted between absolute fecundity and total body length, cephalothorax length, and body weight. Correlations between absolute fecundity and total body length and cephalothorax length were described with a linear equation, while that between fecundity and weight with a power equation (Table 4). Individual

absolute fecundity (Fa) in crayfish is correlated with basic linear measurements: total length and cephalothorax length and with body weight. According to other authors, these correlations in crayfish are most frequently described with either linear or power equations (Kossakowski 1966, Stypińska 1973, 1978, Kozák and Policar 2001, Lewis 2002, Chybowski 2007). In the present study of signal crayfish, linear equations best described the correlations between fecundity and total length (TL) and cephalothorax length (CL), while the correlation between fecundity and body weight (BW) was best described by a power equation (Table 4). These equations were highly statistically significant (P <



0.0001), they fit the empirical data fairly well (Table 4), and they can be used to estimate individual absolute fecundity using total body length, cephalothorax length, or body weight data.

Female signal crayfish in Lake Poblędzie and the Naryjska Struga River usually mature at age 2+ (third year of life). Thus, they reach sexual maturity at the same age as do the majority of signal crayfish populations in the world (Flint 1975, McGriff 1983, Lewis 2002, Souty-Grosset et al. 2006). The mean absolute fecundity (Fa) of the females studied (361 and 371 eggs, respectively at the two study sites) did not differ substantially from that of female signal crayfish from other waters (Savolainen et al. 1996, Souty-Grosset et al. 2006). Thus, it can be concluded that the environmental conditions the signal crayfish inhabit in Poland are appropriate for this species and did not cause significant changes in the elements of their biology that were analyzed.

## References

- Abrahamsson S.A.A. 1971 – Density, growth and reproduction in populations of *Astacus astacus* and *Pacifastacus leniusculus* in an isolated pond – *Oikos* 22: 373-380.
- Ahlmer B., Karlsson A.S. 1980 – Der Signalkrebs im Regierungsbezirk – Jönköping. Mimeo, Sweden, 18 p.
- Brinck P. 1983 – Sture Abrahamsson Memorial Lecture: An ecologist's approach to dealing with the loss of *Astacus astacus* – *Freshw. Crayfish* 5: 21-37.
- Chybowski Ł. 2007 – Morphometrics, fecundity, density, and feeding intensity of the spinycheek crayfish, *Orconectes limosus* (Raf.) in natural conditions – *Arch. Pol. Fish.* 15: 175-241.
- Flint R.W. 1975 – Growth in a population of the crayfish *Pacifastacus leniusculus* from a subalpine lacustrine environment – *J. Fish. Res. Bd Can.* 32: 2433-2440.
- Fürst M. 1977 – Introduction of *Pacifastacus leniusculus* (Dana) into Sweden: methods, results, and management – *Freshw. Crayfish* 3: 229-247.
- Gondko R., Girsztowt Z. 1987 – A new crayfish species *Pacifastacus leniusculus* Dana inhabits Polish waters – *Kieleckie Studia Biologiczne* 4: 133-143 (in Polish).
- Jażdżewski K., Konopacka A. 1993 – Survey and distribution of Crustacea Malacostraca in Poland – *Crustaceana* 65: 176-191.
- Jażdżewski K., Konopacka A. 1995 – *Malacostraca* except *Oniscoidea* – Katalog Fauny Polski Vol. XIII, Wyd. MiZ PAN, Warszawa: 84-96 (in Polish).
- Kossakowski J. 1966 – Crayfish – PWRiL, Warszawa, 292 p. (in Polish).
- Kossakowski J. 1973 – The freshwater crayfish in Poland – *Freshw. Crayfish* 1: 15-24.
- Kossakowski J., Mnich M., Kossakowski G. 1978 – The first introduction of the crayfish *Pacifastacus leniusculus* Dana into Polish waters – *Freshw. Crayfish* 4: 195.
- Kossakowski J., Mnich M., Kossakowski G. 1983 – An attempt to raise juvenile crayfish *Pacifastacus leniusculus* Dana – *Freshw. Crayfish* 5: 555-556.
- Kozák P., Polícar T. 2001 – Meat yields in the introduced signal crayfish *Pacifastacus leniusculus* (Dana) – *Bull. VÚRH Vodňany* 37: 109-115.
- Krzywosz T. 1994 – The introduction of the signal crayfish, *Pacifastacus leniusculus* Dana, to Polish waters – *Rocz. Nauk. PZW* 7: 81-93 (in Polish).
- Krzywosz T. 2006 – Co-occurrence of the signal crayfish *Pacifastacus leniusculus* (Dana) and the spiny-cheek crayfish (*Orconectes limosus* (Raf.)) in a foothill-like river (Northern Poland) – *Arch. Pol. Fish.* 14: 309-316.
- Krzywosz T., Chybowski Ł., Ulikowski D. 1995 – Signal crayfish in Poland: their history, current state, and perspectives – *Komun. Ryb.* 1: 5-8 (in Polish).
- Krzywosz T., Krzywosz W. 2001 – Preliminary observations of an American crayfish *Pacifastacus leniusculus* (Dana) population at a new site in the Mazurian Lake District – *Arch. Pol. Fish.* 9: 273-278.
- Krzywosz T., Krzywosz W. 2002. Observations of the signal crayfish *Pacifastacus leniusculus* (Dana) in a lake in the eastern Suwałki Lake District – *Arch. Pol. Fish.* 10: 255-267.
- Kulmatycki W. 1935 – *Cambarus affinis* Say – American crayfish – a new resident of Pomeranian and Wielkopolska waters – *Przegl. Ryb.* 10/11: 1-16 (in Polish).
- Leńkowa A. 1962 – Studies of the causes of the disappearance, conservation methods, and restoration of the noble crayfish, *Astacus astacus* (L.), in light of the growing distribution of the American crayfish *Cambarus affinis* Say. – *Ochr. Przyr.* PAN 28: 1-37 (in Polish).
- Lewis S.D. 2002 – *Pacifastacus* – In: *Biology of Freshwater Crayfish* (Ed.) D.M. Holdich, Blackwell Science Ltd.: 511-540.
- McGriff D. 1983 – Growth, maturity, and fecundity of the crayfish, *Pacifastacus leniusculus*, from the Sacramento-San Joaquin Delta – *Calif. Fish Game* 69: 227-242.
- Orzechowski B. 1984 – Productivity of the freshwater crayfish *Orconectes limosus* Raf. (*Cambarus affinis* Say.) in Koronowo Basin – *Acta Univ. Nicolai Copernici* 57: 3-35.
- Prins R. 1968 – Comparative ecology of the crayfishes *Orconectes rusticus* and *Cambarus tenebrosus* in Doe

- Run Lake – Kentucky. Int. Rev. Ges. Hydrobiol. 53: 667-714.
- Savolainen R., Westman K., Pursiainen M. 1996 – Fecundity of Finnish noble crayfish, *Astacus astacus* L., and signal crayfish, *Pacifastacus leniusculus*, in various natural habitats and in culture – Freshw. Crayfish 11: 319-338.
- Schulz R., Smetana P. 2001 – Occurrence of native and introduced crayfish in northeastern Germany and Northwestern Poland – Bull. Fr. Pêche Piscic. 361: 629-641.
- Smart G. 1962 – The life history of the crayfish *Cambarus longulus longulus* – Am. Midl. Nat. 68: 83-94.
- Souty-Grosset C., Holdich D. M., Noël P. Y., Reynolds J. D., Haffner P. 2006 – Atlas of crayfish in Europe – Muséum national d'Histoire naturelle Paris, 188 p.
- Strużyński, W., Śmietana P. 1998 – Protecting endemic crayfish species from threats by the growing distribution of alien species – Prz. Ryb. 6: 29-31 (in Polish).
- Stypińska M. 1972 – Fluctuations in the fecundity of spiny-cheek crayfish (*Orconectes limosus* Rafinesque 1817) in Lake Wdzydze – Roczn. Nauk Rol. 94-H-3: 73-82 (in Polish).
- Stypińska M. 1973 – Fecundity of three crayfish species occurring in Polish waters – Roczn. Nauk Rol. 95-H-1: 147-156 (in Polish).
- Stypińska M. 1978 – Fluctuations in the absolute fecundity of crayfish occurring in the waters of the Mazurian Lake District – Roczn. Nauk Rol. 98-H-3: 177-203 (in Polish).
- Śmietana P., Krzywosz T. 2006 – Determination of the rate of growth of *Pacifastacus leniusculus* in Lake Poblędzie, using polymodal length frequency distribution – Bull. Fr. Pêche Piscic. 380-381: 1229-1243.
- Śmietana P., Strużyński W. 1999 – Crayfish – a review of their situation in Poland – Mag. Przem. Ryb. 2 (10): 80-82 (in Polish).