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RESEARCH ARTICLE

Lake Hańcza – a new site for signal crayfish (*Pacifastacus leniusculus* Dana) occurrence in Poland

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Abstract. Crayfish catches were conducted using traps in Lake Hańcza, which is the deepest lake in Poland. Two crayfish populations were found to co-exist in the lake: spiny-cheek crayfish (*Orconectes limosus* Raf.) and signal crayfish (*Pacifastacus leniusculus* Dana), which is a new species for this lake. Signal crayfish dominated the samples at 98.5% of the specimens caught. The crayfish occurred at depths of 1-10 m. The mean total body length of the male and female signal crayfish (TL) was 99.5 ± 17.8 mm and 96.5 ± 11.7 mm, respectively, while the average body weight (BW) was 38.7 ± 24.9 g and 26.8 ± 9.5, respectively. Chelae were damaged in 4.5% of the individuals. Fishing efficiency (catch per unit effort – CPUE) was 0.96 crayfish trap^{-1} night^{-1}. Selected characteristics of the population and of individual signal crayfish from Lake Hańcza were compared with those of the two closest neighboring populations of this species in lakes Mauda and Pobłędzie. The confirmed occurrence of the relatively large signal crayfish population in Lake Hańcza excludes this lake as a possible site for native noble crayfish (*Astacus astacus* L.) restoration.

Keywords: crayfish, *Pacifastacus leniusculus*, Lake Hańcza, *Orconectes limosus*, co-existence

Signal crayfish (*Pacifastacus leniusculus* Dana) is an alien species native to North America that was introduced to European waters in the 1960s and 1970s (Souty-Grosset et al. 2006). In 1972-1973, 1975-1977, 1979, and 1991-1992 a total of 50,200 specimens of this species was imported to Poland (Krzywosz 1994, 1995). All crayfish lots originated from a culture facility in Sweden. These crayfish were stocked into ponds and recirculating system tanks in the Inland Fisheries Institute experimental facility in Pieczarki near Giżycko and a trout facility in Gawrych Ruda near Suwałki. Following successful breeding, the crayfish progeny were stocked into selected closed water basins in northeastern Poland (Krzywosz 1994). Signal crayfish were released into lakes Pobłędzie and Mauda in 1992. A part of the stock was sent to a culture facility located in Pomerania (Mastyński and Andrzejewski 2005). The success of the introduction was low; until last year only the sites where this species occurred were known in northeastern Poland including two in lakes Pobłędzie and Mauda and a river site in the Naryjska Struga stream (Krzywosz and Krzywosz 2001, Krzywosz 2006a). At each of these sites signal crayfish populations were confirmed to co-exist with spiny-cheek crayfish (*Orconectes limosus* Raf.). Sporadically, single specimens of signal crayfish were caught in other lakes but they did not form breeding populations. One example of this could be Lake Hańcza.

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Lake Hańcza (54°15.8' N, 22°48.7' E) is located in the Suwałki Landscape Park, and it has been a part of the landscape preserve since 1963 (Zdanowski et al. 2008). This is the deepest lake in Poland with a surface area of 311.4 ha, a maximum depth of 108.5 m, an average width of 38.7 m, and a shoreline length of 11,750 m (Rühle 1932, Bajkiewicz-Grabowska 2008).

The history of the composition of the Lake Hańcza crayfish in the twentieth century is characterized by highly dynamic change. At the beginning of the century, a noble crayfish (*Astacus astacus* L.) population inhabited the lake, and it was exploited commercially. However, this population died out in 1926 because of a crayfish plague (*Pestis astacorum*) epizooitc (Mackiewicz 1929). Following this, the noble crayfish was successfully introduced into the lake and was commercially fished sporadically until 1972, when 11 kg of crayfish was obtained. By the mid-1990s, the noble crayfish had been extirpated and supplanted by the spiny-cheek crayfish (Krzywosz et al. 2008). In the 1995-1996 period, the highest spiny-cheek crayfish catch per unit effort (CPUE) was noted at an average of 1.74 crayfish trap^{-1} night^{-1} (Krzywosz et al. 1995). Since 2002, a significant decrease in spiny-cheek crayfish populations has been observed in many lakes in Poland, including Lake Hańcza, but the cause has yet to be determined (Krzywosz 2004). Catches were conducted in 2005 in Lake Hańcza with 70 traps, and no crayfish was caught. Subsequently, the CPUE of fishing spiny-cheek crayfish in 2006 was 0.28 and in 2007 0.60 crayfish trap^{-1} night^{-1}. The first signal crayfish caught in 1996 was a male with a total body length (TL) of 116 mm. It was probably introduced from the nearby lakes Mauda or Pobłędzie through human activity, because there is no natural connection with Lake Hańcza, and these lakes are in another catchment area. This species was not found in subsequent catches conducted with signal crayfish traps (Krzywosz et al. 2008). However, all previous crayfish monitoring was done only in the southern part of Lake Hańcza, which is why crayfish monitoring in 2017 was conducted in the northern part of the lake.

The aim of the study was to monitor the current state of the crayfish population in Lake Hańcza. The research area was the northern bay of Lake Hańcza (Fig. 1). Crayfish catches were conducted on September

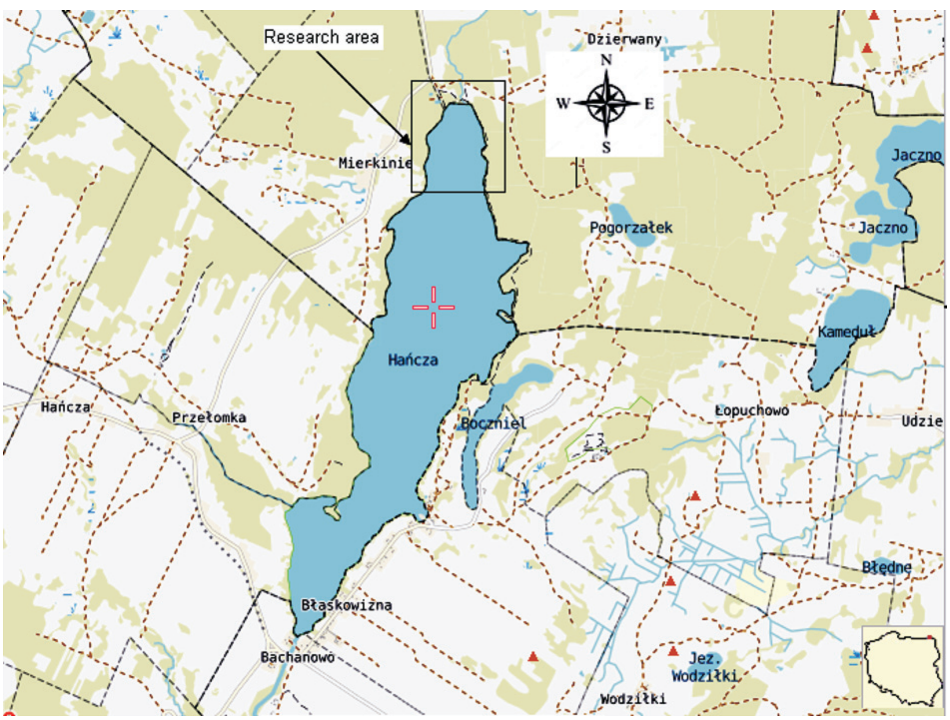

Figure 1. Study area map (the base map from the www.mapszukacz.pl website).

24-25, 2017. At a depth of 1 m the water temperature was 14.5°C, oxygenation was 7.3 mg O_2 l^{-1}, and Secchi disc visibility was 7.5 m. Seventy traps of two different types were used: 30 Evo and 40 Vulkan traps (Ulikowski et al. 2017). Frozen cyprinids were used as bait. The size of the catch was compared to the results of catches performed one to two days earlier with the same number of traps in lakes Mauda and Pobłędzie located 6-7 km northwest of Lake Hańcza. Sixty of the traps in Lake Hańcza were set along the shoreline at depths of 1-10 m, while 10 Evo traps were set in the middle of the bay at depths of 15-25 m. Similarly, crayfish were caught in lakes Mauda and Pobłędzie, where in each lake 10 Evo traps were set at depths in excess of 10 m. After removing the crayfish from the traps, the species and sexes were determined and the number of individuals caught was counted. All of the crayfish caught underwent the same examination procedure to determine species, sex, chela intactness, body weight (BW), and total body length measured from the end of the rostrum to the end of the telson (TL). Selected morphometric features of the crayfish bodies were also measured according to the diagram in Fig. 2. The average values and standard deviations (SD) of body weight and total body length of female and male signal crayfish from lakes Hańcza, Mauda, and Pobłędzie were calculated. The statistical significance of differences among averages was tested with the Kruskal-Wallis test at $P < 0.05$. Additionally, the percentage share of each species in the total crayfish population was calculated, as were male:female sex ratios, individuals with damaged chelae, and the CPUE for each of the lakes monitored. The morphometric characters of the crayfish from Lake Hańcza were compared with those of crayfish from lakes Mauda and Pobłędzie. The morphometric characters were also evaluated by analyzing all the variables simultaneously with discriminant analysis. Stepwise, progressive discriminant analysis was applied. The analysis was performed separately for males and females. All statistical analyzes were performed with Statistica 8.1 (Statsoft, Poland).

A total of 68 crayfish were caught in Lake Hańcza (67 signal crayfish and 1 female spiny-cheek crayfish). All the crayfish were caught in the traps set at a depth of 1-10 m, while the traps set at depths greater than 10 m were empty in all the lakes. In total, 50% of the traps in Lake Hańcza were empty compared to 69% in Lake Mauda and 30% in Lake Pobłędzie. These results indicate the co-existence in Lake Hańcza of signal and spiny-cheek crayfish, which is similar to the crayfish populations in nearby lakes Mauda and Pobłędzie. In Lake Hańcza, the area studied was dominated decisively by signal crayfish, which constituted 98.5% of the crayfish population. In contrast, the signal crayfish accounted for 66.7% and 68.5% of the crayfish populations in lakes Mauda and Pobłędzie, respectively (Table 1). Changes in the proportion of crayfish species can be

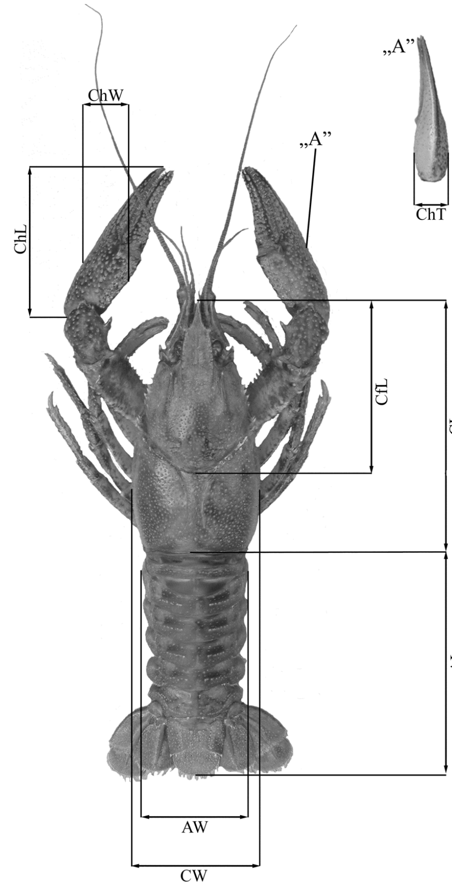

Figure 2. Diagram of morphometric measurements of crayfish bodies: CL - cephalothorax length (mm), AL - abdomen length (mm), CfL - cephalothorax length to the cephalic groove (mm), ChL - chela length (mm), CW - cephalothorax width (mm), AW - width of the first abdominal segment (mm), ChW - chela width (mm), and ChT - chela thickness (mm).

Table 1
Comparison of selected parameters of crayfish populations from Lake Hańcza and from the nearby lakes Mauda and Pobłędzie

Lake	Species	N	Percentage share of both species	Sex ratio male:female	Percentage of specimens with damaged chelae	CPUE (crayfish trap^{-1} night^{-1})
Hańcza	*Pacifastacus leniusculus*	67	98.5	1.7 : 1	4.5	0.96
	Orconectes limosus	1	1.5	0.0 : 1	0.0	0.01
Mauda	*Pacifastacus leniusculus*	26	66.7	2.3 : 1	7.7	0.37
	Orconectes limosus	13	33.3	1.2 : 1	7.7	0.18
Pobłędzie	*Pacifastacus leniusculus*	61	68.5	0.6 : 1	9.8	0.87
	Orconectes limosus	28	31.5	2.5 : 1	0.0	0.4

very dynamic, as Krzywosz (2006b) reports in a study conducted in Lake Pobłędzie. The smallest (4.5%) signal crayfish individuals with damaged chelae were found in Lake Hańcza, while the most (9.8%) were noted in Lake Pobłędzie (Table 1). Male signal crayfish prevailed in lakes Hańcza and Mauda, while females did so in Lake Pobłędzie (Table 1). Male spiny-cheek crayfish dominated in lakes Mauda and Pobłędzie, but Lake Hańcza was not taken into consideration since only one specimen of this species was caught. The prevalence of males in catches made with traps is characteristic of spiny-cheek crayfish catches, and when using non-selective tools (e.g., trawls) the gender proportions of the catches are similar (Chybowski 2007, Krzywosz et al. 2008). The CPUE of signal crayfish in the lakes Hańcza and Pobłędzie was correspondingly similar and higher than that in Lake Mauda (Table 1). The signal crayfish CPUE from the northern part of Lake Hańcza was higher than that of crayfish spiny-cheek obtained in 2005–2007 in the southern part of the lake, when the last crayfish catches were made using traps (Krzywosz et al. 2008).

The body weight and total length of the signal crayfish from the three lakes studied were similar ($P > 0.05$) with the exception of the males from Lake Mauda, which were statistically significantly ($P < 0.05$) larger than the males from lakes Hańcza and Pobłędzie (Table 2). The signal crayfish catches from Lake Hańcza contained more specimens with total body lengths (TL) in the 80-89 mm and 100-109 mm ranges, and the distribution of the number of specimens in the different body length ranges indicated the multigenerational composition of the sample (Fig. 3).

The results of discriminant analysis identified six features that best discriminated the females and four features that best discriminated the males of the populations studied. Two discriminatory functions were created for females and males. With females, the two functions were statistically significant, and with males, only the first function was statistically significant. Further analysis was based on statistically significant functions. In females, the most

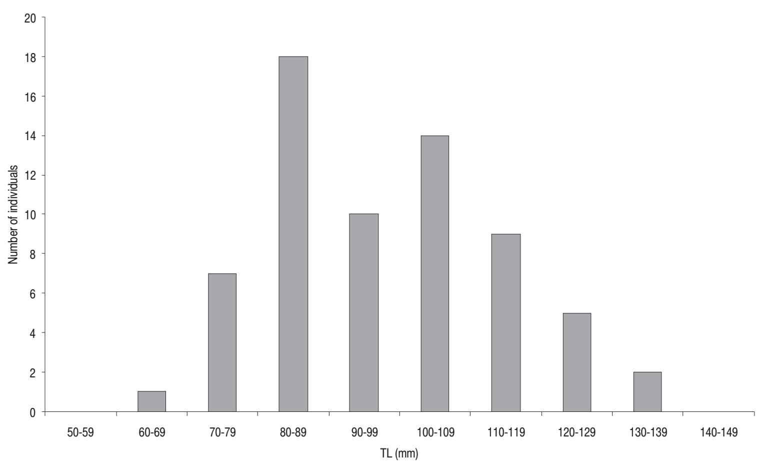

Figure. 3. Abundance distribution of signal crayfish (*P. leniusculus*) in different total body length (TL) ranges.

Table 2
Comparison of the weight (BW) and total length (TL) of signal crayfish (*P. leniusculus*) from Lake Hańcza and from the two nearby lakes Mauda and Pobłędzie. Mean values in columns with a different letter index differ significantly (Kruskal-Wallis test, P < 0.05)

			BW (g)			TL (mm)		
Lake	Sex	N	Mean	SD	Min-max	Mean	SD	Min-max
Hańcza	males	42	38.7[a]	24.9	7-101	99.5[a]	17.8	65-135
	females	25	26.8[a]	9.5	14-45	96.5[a]	11.7	79-120
Mauda	males	18	62.2[b]	18.3	36-94	117.4[b]	9.2	99-135
	females	8	38.7[ab]	7.5	29-49	109.3[ab]	6.0	100-117
Pobłędzie	males	23	40.2[ab]	14.5	19-73	104.2[ab]	11.7	83-120
	females	38	33.5[a]	14.1	12-67	103.2[a]	15.8	76-138

Table 3
Coefficients of discriminatory functions for females of signal crayfish (*P. leniusculus*). Designations as in Fig. 2

	Coefficients of discriminatory functions			
	Function 1		Function 2	
	Raw	Standardized	Raw	Standardized
Constant	7.55		-8.24	
AL	-0.28	-2.12	0.19	1.44
ChL	0.17	1.10	0.14	0.93
AW	0.31	1.62	-0.40	-2.09
CL	-0.28	-1.71	0.62	3.82
CW	-0.36	-1.31	-1.02	-3.76
CfL	0.46	2.10	-0.01	-0.03
Percentage of variance explained	67.70		32.30	

discriminating features of the populations studied were abdominal length (AL), chela length (ChL), abdomen width (AW), cephalothorax length (CL), cephalothorax width (CW), and cephalothorax length to the cephalic groove (CfL) (Table 3), while in males they were abdomen length (AL), chela length (CHL), cephalothorax length (CL), and abdomen width (AW) (Table 4). The first discriminatory function in females was responsible for 67.70% of the variance explained, while AL, CfL, and CL had the greatest effect on the morphometric diversity of the populations studied. The second discriminatory function explained 32.30% of variance, and CL and CW were the features that most significantly affected morphometric diversity (Table 3). In males, the first discriminatory function was responsible for 85.00% of the variance explained, and AL, AW, and CL were the features that had the greatest effect on

Table 4
Coefficients of discriminatory functions for males of signal crayfish (*P. leniusculus*). Designations as in Fig. 2

	Coefficients of discriminatory functions	
	Function 1	
	Raw	Standardized
Constant	-7.20	
AL.	0.22	1.46
ChL	0.01	0.09
CL	-0.14	-1.12
AW	0.11	0.51
Percentage of variance explained	85.00	

the results (Figs. 4 and 5). Table 5 presents the accuracy matrix of the classification of female and male signal crayfish to particular populations. The best fit, with 87.5% accuracy, classified only males from Lake Hańcza, while the classification of the other crayfish specimens was not as precise.

Chybowski (2014) studied the morphometric characteristics of signal crayfish from three lakes (including lakes Pobłędzie and Mauda) and from the Naryjska Struga stream, and he concluded that clear differentiation in morphometric features occurred only between signal crayfish from lentic and lotic waters. The results of the present study indicated that the signal crayfish populations from the lakes studied did not differ significantly. This is why it was difficult to determine unequivocally the origin of the crayfish introduced to Lake Hańcza based on the comparisons made in this study.

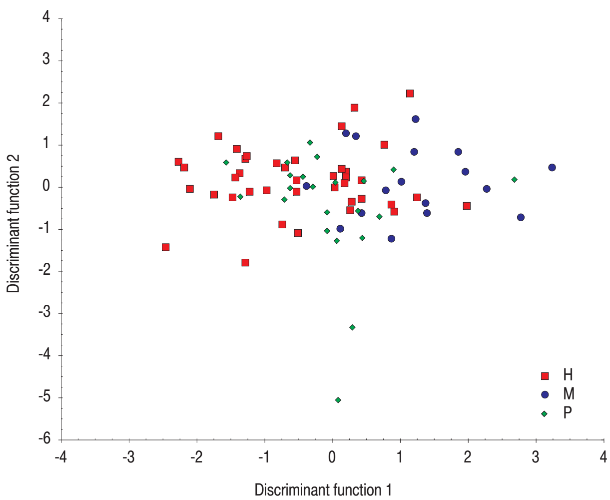

Fig. 4. Scatter plot of canonical variables of signal crayfish (*P. leniusculus*) females determined by the first two discriminant functions: H – Hańcza, M – Mauda, P – Pobłędzie.

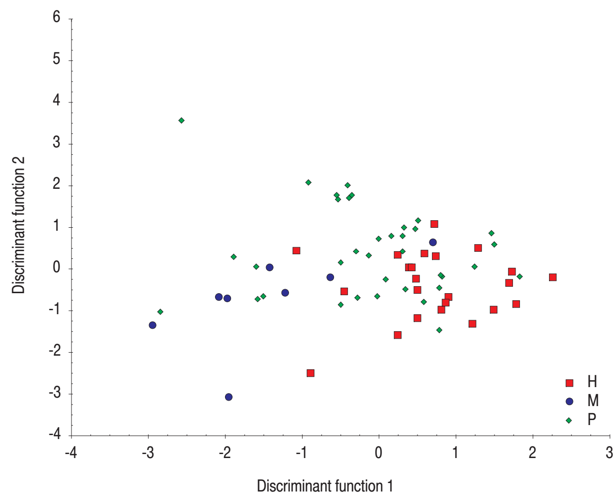

Fig. 5. Scatter plot of canonical variables of signal crayfish (*P. leniusculus*) males determined by the first two discriminant functions: H – Hańcza, M – Mauda, P – Pobłędzie.

morphometric diversity (Table 4). The features that best discriminated females were those associated with the cephalothorax (CL, CfL) and abdomen length (AL), and in males they were the abdominal features (AL and AW) and cephalothorax length. These features did not permit making clear distinctions among the crayfish from the different lakes. This was confirmed by the graphic interpretation of

The confirmation of the existence of a relatively large signal crayfish population in Lake Hańcza excludes it as a possible site for the restitution of the native noble crayfish.

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Author contributions. D.U. and Ł.U designed and performed the research, analyzed the data and wrote the paper.

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