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Research Article

MORPHOMETRIC CHARACTERS OF THE FRESHWATER AMERICAN CRAYFISH, *ORCONECTES LIMOSUS* RAF., FROM THE VISTULA LAGOON (POLAND)

ANNA SZANIAWSKA[1], MONIKA NORMANT, MONIKA MICHAŁOWSKA AND AGNIESZKA KAMIŃSKA

Institute of Oceanography, University of Gdańsk
Al. Marszałka Piłsudskiego 46, 81-378 Gdynia, Poland

[1]corresponding author: Tel. +48-58-6601619; fax +48-58-6601678;
e-mail address: oceasz@univ.gda.pl

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Abstract

The aim of the present study was to perform an initial characterization of the morphometric parameters of the American crayfish, *Orconectes limosus,* that occur in the brackish waters of the Polish coastal zone, as well as to present its range of occurrence and rate of expansion in Polish waters. The size of *O. limosus* occurring in the Vistula Lagoon (2-4 psu) varied from 77.0 mm to 118.0 mm (mean 95.0 ± 8.0 mm). The most numerous class was comprised of specimens measuring from 90.1 to 95.0 mm; this class represented 23% of animals collected. Males and females had similar dimensions and body ratios, while the abdomen width (23.6 ± 2.7 mm) of females was wider than that of males (20.3 ± 2.0 mm). The males had longer and higher chelae that did females of comparable length. Individuals from Vistula Lagoon (4 psu) exhibited a larger maximum body length in comparison with those caught in the freshwater habitats (Lake Wdzydze). The relationship between carapace length and specimen dry weight is represented by the following formula: $DW = 0.0072L^{3.05}$ ($r = 0.69$).

INTRODUCTION

During the last fifty years invasions of non-native species into freshwaters has increased in many regions worldwide (Carlton 1999), including the Baltic Sea region. Approximately one hundred introduced animal species have been reported in the Baltic Sea (Leppäkoski and Olenin 2000). Of these, about seventy have been able to establish reproductive populations (Leppäkoski 1984, Leppäkoski 2002, Telesh and Ojaveer 2002, Szaniawska *et al.* 2003). Due to the wide salinity range, the Baltic Sea provides ecological niches for marine, brackish, and freshwater species (Gollasch and Leppäkoski 1999).

While non-native crayfish species have become more common and numerous inhabitants of Polish waters, populations of the native species *Astacus astacus* and *Astacus leptodactylus* have been weakened by the fungal disease caused by *Aphanomyces astaci*. One species that is still expanding is the American crayfish, *Orconectes limosus* Raf. (Śmietana and Strużyński 1999). This species was the first crustacean introduced to Polish waters (Jażdżewski 1970, Jażdżewski and Konopacka 1993). Approximately one hundred specimens from North America were imported to Europe in 1881 by the German breeder Max von der Borne. They were introduced into fish ponds located near Dębno Lubuskie (northwest Poland) (Hobbos *et al.* 1989, Mastyński 1991, Śmietana and Strużyński 1999). *O. limosus* began expanding immediately, and today it is the dominant crayfish species in Poland. In the 1950s *O. limosus* enlarged its territory to the western and northern regions of Poland (Jażdżewski and Konopacka 2000). During the 1990s this species expanded rapidly to almost all Polish inland waters, both oligotrophic and eutrophic (Strużyński and Śmietana 1999, Śmietana and Strużyński 1999). According to the most recent studies, *O. limosus* has also appeared in the Polish coastal zone, and has lately been recorded in the Szczecin Lagoon (4 psu) and Pomeranian Bay (7 psu) (Leppäkoski 1984, Gruszka 1999). One specimen was found in the coastal zone of the Baltic Sea, near Władysławowo (8 psu) in 2000 (K. Skóra, pers. comm.) (Fig.1).

The aim of this study was to describe the morphometric characters (nine size parameters) of the *O. limosus* occurring in the Vistula Lagoon (2-4 psu). It was also interesting to determine the dependence between the analyzed parameters for male and female American crayfish, as well as to compare them with those of American crayfish inhabiting Polish freshwater habitats. Another important aspect of this study was use the most recent data to identify the range of occurrence of *O. limosus* in Polish waters.

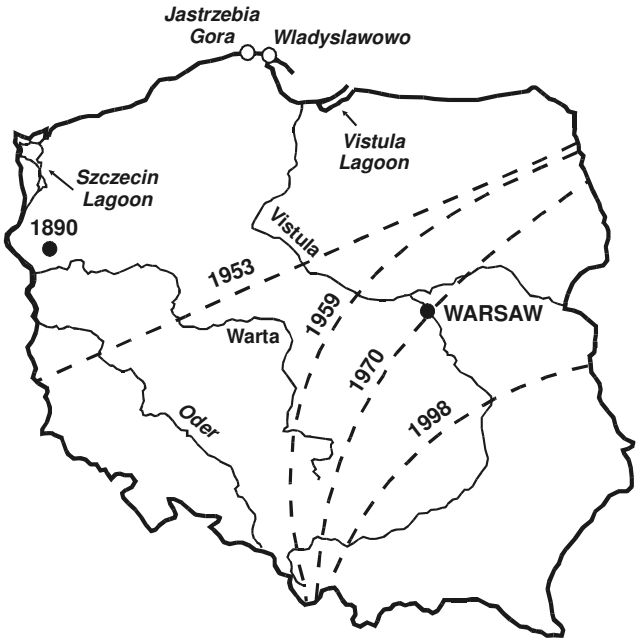

Fig. 1. Distribution of *O. limosus* in Polish waters after Jażdżewski and Konopacka (2000: 56, Fig. 1); • - first occurrence, ------ - southern limit of occurrence.

MATERIALS AND METHODS

O. limosus specimens were collected from the western part of the Vistula Lagoon, an area that extends from the Wisła Królewiecka estuary to the Nogat estuary, at monthly intervals from August to October 2001 (Fig. 1). The specimens were collected randomly from fyke-nets with a circumference of 100-140 cm and a mesh size of 16-20 mm. The fyke-nets were deployed at depths of 1.2-2 m in areas with submerged vegetation dominated by reeds. The bottom was sandy and muddy. In the laboratory, nine crayfish size parameters were measured (according to Kossakowski, 1962) (Fig. 2) with a digital slide caliper (± 0.1 mm). Nine length classes were established at 5.0 mm intervals. Length class 1 included specimens measuring 75.1-80.0 mm, while length class 9 included those from 115.1 to 120.0 mm. Sex was then determined based on the structure of the first pair of swimmerets (Holdich and Reeve 1988, Stańczykowska 1986). The animals were weighed wet (± 0.1 g) and then dried at a temperature of 60 ^{o}C in order to obtain the constant weight. Ten ratios were described among the measured parameters. The values obtained were expressed

as means with standard deviation (± SD). Linear (y = ax + b) and power regressions ($y = ax^b$) with correlation coefficients (r) were used to determine the relationship between the investigated parameters. The significance criterion was $p < 0.05$.

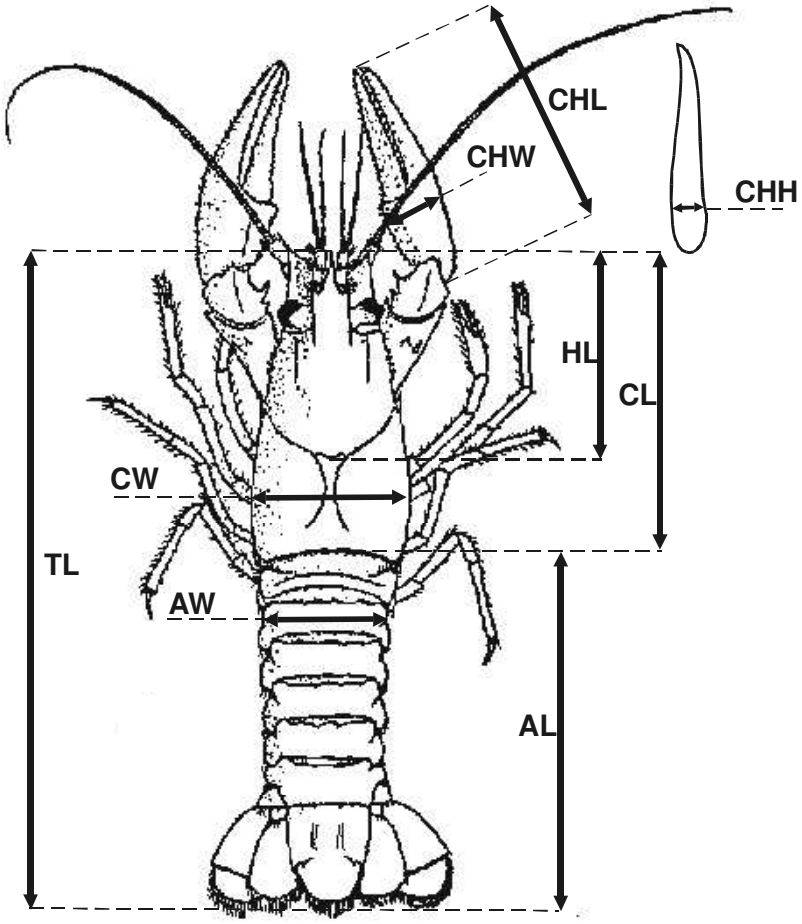

Fig. 2. Scheme of measurements taken from investigated crayfish: TL- total body length, AL- abdomen length, CL- cephalothorax length, HL- cephalothorax length from the tip of the rostrum to cervical croove, CHL- chela length, CW- cephalothorax width, AW- abdomen width, CHW chela width, CHH- chela height.

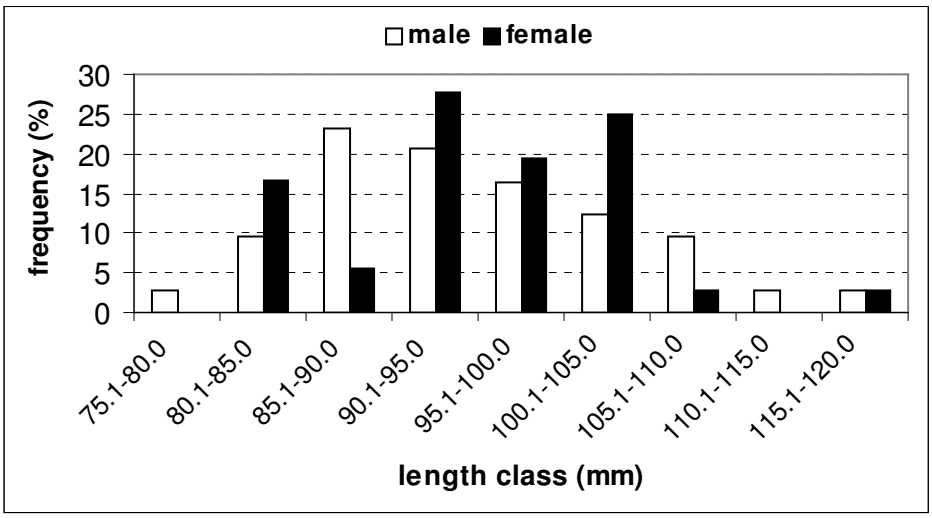

Fig. 3. Frequencies of males and females of *O. limosus* collected from the Vistula Lagoon in consecutive length classes.

Table 1

Minimal, mean, and maximal values of the measured body parameters of *O. limosus* from the Vistula Lagoon.

Parameter	Size (mm)		
	min	**mean**	**max**
TL	77.0	94.4	118.0
AL	41.6	51.1	63.1
CL	31.3	44.9	56.5
HL	23.8	29.5	37.3
CHL	21.1	31.9	49.9
CW	17.7	23.2	33.7
AW	15.8	20.9	29.6
CHW	8.1	12.4	19.8
CHH	4.0	7.3	11.4

RESULTS

Of the 109 specimens collected from August to October in the Vistula Lagoon, 67% were males and 33% were females. The body length of the individuals varied from 77.0 mm to 118.0 mm, with a mean of 95.1 ± 8.0 mm (Tab. 1, Fig. 3). The maximum male body length was 117.0 mm and that of the females was similar at 118.0 mm. The highest frequency (23%) was observed in

the 90.0-95.0 mm length class. The smallest specimens from the 75.1-80.0 mm length class and the largest from the 115.1-120.0 mm length class constituted a small percentage of the whole sample at 2 and 3%, respectively. The mean total length of the females was 97.4 ± 5.9 mm, and of males - 95.0 ± 8.9 mm. (Tab. 2). However, the mean abdomen length of the females was 2.0 mm higher ($p > 0.05$) than that of the males at 51.6 ± 3.1 mm and 49.6 ± 4.3 mm, respectively. The males had a slightly longer ($p > 0.05$) cephalothorax (mean 46.7 ± 4.6 mm) than did the females (mean 45.3 ± 4.5 mm). The length of the cephalothorax measured from the cervical groove was almost of identical length in both females and males at 30.3 ± 1.8 mm and 29.9 ± 2.8 mm, respectively. The width of the cephalothorax in both sexes was nearly identical – females 23.8 ± 2.9 mm (mean) and males 23.2 ± 1.8 mm (mean). The abdomen of the females (average 23.6 ± 2.7mm) was wider than in males (mean 20.3 ± 2.0 mm). Although statistically insignificant, there was a clear difference in chela length between the two sexes. The mean chela length of males was 8.6 mm longer at 35.4 ± 7.6 mm, while that of females was 26.8 ± 3.1 mm. The males also had heigher chelae (mean 8.0 ± 1.6 mm) than did females (mean 6.8 ± 0.7mm). The female chelae (average 13.2 ± 2.9 mm) were slightly wider than those of the males (mean 11.5 ± 1.4 mm). The mean size parameters of all the analyzed specimens are presented in Figure 4.

Table 2

Mean values (± SD) of the measured body parameters of *O. limosus* females and males collected from the Vistula Lagoon.

Parameter	Size (mm)	
	females	**males**
TL	97.4 ± 5.9	95.0 ± 8.9
AL	51.6 ± 3.1	49.6 ± 4.3
CL	45.3 ± 4.5	46.7 ± 4.6
HL	30.3 ± 1.8	29.9 ± 2.8
CHL	26.8 ± 3.1	35.4 ± 7.6
CW	23.8 ± 2.9	23.2 ± 1.8
AW	23.6 ± 2.7	20.3 ± 2.0
CHW	13.2 ± 2.9	11.5 ± 1.4
CHH	6.8 ± 0.7	8.0 ± 1.6

In females and males, the ratio of total length to abdomen length was 1.9 ± 0.0 and of total length to cephalothorax length was 2.1 ± 0.0. This indicates that the *O. limosus* abdomen and cephalothorax lengths are almost the same (Tab. 3). Total length to cephalothorax length measured to the cervical groove of females and males was the same at 3.2 ± 0.1 mm. Males were characterized by

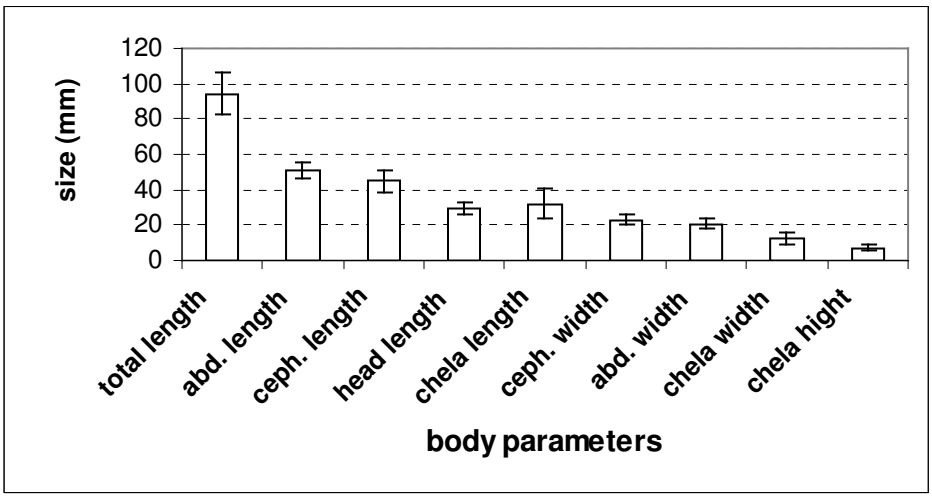

Fig. 3. Frequencies of males and females of *O. limosus* collected from the Vistula Lagoon in consecutive length classes.

Table 3

Regression coefficients for the relationship (y = ax + b) between the studied parameters of females and males of *O. limosus* (r – correlation coefficient ,* - significant at $p < 0.05$).

parameters		female (n=36)			male (n=76)		
x	y	a	b	r	a	b	r
TL	AL	0.521	1.166	0.97*	0.466	5.441	0.97*
TL	CL	0.499	-2.760	0.98*	0.506	-2.437	0.99*
TL	HL	0.340	-2.920	0.98*	0.296	1.628	0.97*
TL	CHL	0.448	-17.373	0.83*	0.809	-40.953	0.88*
TL	CW	0.266	-2.529	0.93*	0.292	-4.093	0.96*
CL	CW	0.535	-1.130	0.95*	0.571	-2.378	0.96*

longer chelae than females. The mean values of total length to chelae length were 2.8 ± 0.5 mm for males and 3.8 ± 0.5 mm for females. Standard deviation indicates that there was a wide range of chela size. The correlation coefficient between body length and the value of the total length/chela length ratio was inversely proportional. Thus, it can be assumed that in *O. limosus* individuals the growth of chela length is faster than that of body length. The ratio of total length to the width of the cephalothorax was 4.2 ± 0.2 mm in females and 4.0 ± 0.2 mm in males. The ratio of total length to chela width in females was 9.0 ± 1.4 mm, and in males it was 7.5 ± 1.5 mm. The ratio of abdomen length to

width in females was 2.3 ± 0.2 mm, an in males it was 2.5 ± 0.1 mm; this indicates that females have a wider abdomen than males do. The ratio of cephalothorax length to width in females was, on average, 2.0 ± 0.3 mm and in males - 1.9 ± 0.1 mm. The relationship between the studied parameters of *O. limosus* females and males was statistically significant in all cases (Tab. 4).

Table 4

Mean values of the ratios of the investigated parameters (Fig.2) of female and male *O. limosus* from the Vistula Lagoon and Lake Wdzydze (after Kossakowski 1962).

Parameter ratio	Vistula Lagoon		Lake Wdzydze	
	female (n=36)	male (n=76)	female (n=33)	male (n=33)
TL : AL	1.9 ± 0.0	1.9 ± 0.0	1.9	1.9
TL : CL	2.1 ± 0.0	2.1 ± 0.0	2.0	2.0
TL : HL	3.2 ± 0.1	3.2 ± 0.1	3.2	3.2
TL : CHL	3.8 ± 0.5	2.8 ± 0.5	3.8	2.8
TL : CW	4.2 ± 0.2	4.0 ± 0.2	3.9	3.9
TL : CHW	9.0 ± 1.4	7.5 ± 1.5	8.5	7.2
AL : AW	2.3 ± 0.2	2.5 ± 0.1	2.0	2.3
CL : CW	2.0 ± 0.3	1.9 ± 0.1	1.9	1.9
CHL : CHW	2.4 ± 0.1	2.7 ± 0.2	2.2	2.6
CHL : CHH	4.1 ± 0.3	4.3 ± 0.8	3.9	4.1

Specimen wet weight ranged from 13.0 to 47.4 g (mean 25.2 ± 8.1 g) and dry weight from 1.5 to 18.1 g (mean 7.76 ± 2.7 g). The average wet weight of all the studied females was lower than that of the males by 1.9 g at 24.7 ± 8.8 g and 26.3 ± 6.2 g, respectively. The mean dry weight was lower by 0.8 g at 7.2 ± 2.3 g and 8.0 ± 3.1 g, respectively. The carapace length (L)/specimen wet (WW) and dry (DW) weight ratios for *O. limosus* are represented by the formulae $WW = 0.00001L^{3.17}$ ($r = 0.91$) and $DW = 0.0072L^{3.05}$ ($r = 0.69$), respectively.

DISCUSSION

To date, interest in Baltic Sea invasive species has been limited to marine species, and little has been reported regarding species that originate from freshwater environments. The only exception are species whose invasion has become troublesome for humans, such as the bivalve, *Dreisena polymorpha*, that is found, for example, in the Great Lakes of North America (Strayer and Smith 1996). Żmudziński (1961) was the first to report the occurrence of the American crayfish in the coastal brackish waters of the Baltic Sea. He presented a brief description of the species, which was then identified as *Cambarus limosus*. According to this same author, the American crayfish occurred only in

waters with a salinity not exceeding 1-2 psu. In Poland, practically the only region that has not yet to be inhabited by *O. limosus* is the southeast. Estimates indicate that in the twentieth century this species came to inhabit three-quarters of Poland. Białe Lake, located near Włodawa, is probably the southern-most Polish basin inhabited by the American crayfish (Strużyński and Śmietana 1998). Available data regarding the dispersion and spread of this species refers only to freshwater environments. The salinity threshold for this species is approximately 8-9 psu. In May 2002, six crayfish measuring from 50.0 to 70.0 mm were collected on a beach near Jastrzębia Góra. The water salinity in this area was 8-9 psu.

Fyke-nets are size-selective depending on mesh size, which might explain why small individuals were seldom caught. However, the collection method had no influence on the morphometric parameters or the size ratios among the animals. Nor did it have an impact on the values of the various parameters or on the maximum size of the crayfish caught. Individuals from the Vistula Lagoon are larger than those from the fresh waters of Lake Wdzydze in the Pomeranian Region. Males dominated in the Vistula Lagoon from August to October. However, the use of fyke-nets could have affected the samples because the males were more active (Anwand 1993, Krzywosz *et al.* 1995). Crayfish activity, and thus catchability, varies widely in response to season, moulting, and reproductive status. Males constituted 68% of the samples collected. They are aggressive towards females, which are either of the same size or smaller (Krzywosz *et al.* 1995, Chybowski *et al.* 2000). Thus, the high disproportion between the sexes in the current study does not reflect the actual state of the population. The results of research conducted in Okrągłe Lake using the trawl method prove this hypothesis. The percentage of females caught by the trapping method did not exceed 2%, whereas with the trawl, females comprised 40% of the population. Thus, it can be assumed that the male to female ratio of American crayfish in most lakes is 1 : 1 (Orzechowski 1984, Anwand 1993).

The maximum length of the Vistula Lagoon males was similar to that reported by Anwand (1993). The same author reported a maximum female length of 126.0 mm. However, such long females were observed only in one of the nine German lakes studied; in all of the remaining lakes they measured less than 100.0 mm. Krzywosz *et al.* (1995) reported the maximum lengths for female and male crayfish inhabiting Suwalskie Province at 120.0 and 116.0 mm, respectively. These authors also stated that specimens of this size were only observed in lakes that had recently been inhabited by the American crayfish and in which the population was still relatively small. Young populations are characterized by a large proportion of specimens with high parameter values. Furthermore, the size of a crayfish population is limited in

reservoirs inhabited by large numbers of eel so the specimens attain larger sizes (Draganik 1962). On the other hand, specimen length does not exceed 100 mm in lakes with large populations. Kossakowski (1962), who studied the crayfish in Pomerania region lakes, reported that the maximum length of the crayfish there was 100 mm.

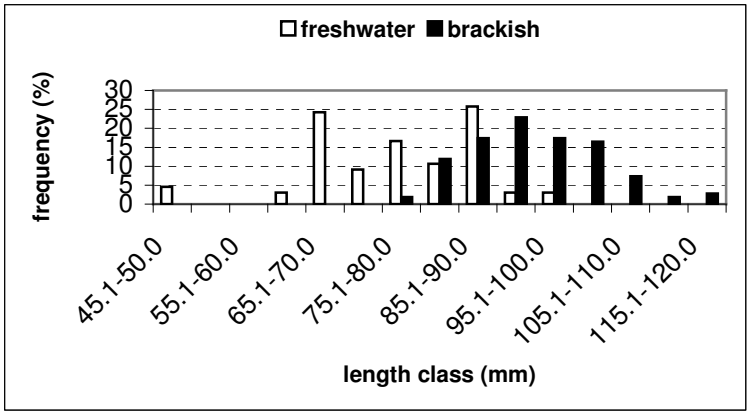

Fig. 5. Comparison of the frequencies of freshwater (Wdzydze Lake; after Kossakowski 1962) and brackish water (Vistula Lagoon) *O. limosus* in consecutive length classes.

Crayfish are bigger in fall than in early summer. No young specimens were noted in the Vistula Lagoon. The smallest female was 81.0 mm long and the smallest male – 77.0 mm. Krzywosz *et al.* (1995) found female and male specimens of a minimal length of 41.0 and 44.0 mm, respectively, in water reservoirs in the Suwalskie Province. Conversely, Anwand (1993) reported that in German waters the smallest females were 62.0 mm long and males - 60.0 mm long. The average length of the Vistula Lagoon specimens was similar to that reported by Anwand (1993). In five freshwater reservoirs, he observed crayfish of an average length that exceeded 90 mm. On the contrary, Krzywosz *et al.* (1995) reported that the average crayfish length from 15 lakes in the Suwałki Lake District was 82 mm. However, in lakes that had recently been inhabited by American crayfish the average length was 96 mm. In other reservoirs in this same region, where populations were stable, the average lengths were 75 ± 6 mm and 82 ± 9 mm, respectively. The specimens in the Vistula Lagoon were represented by three and four year-old crayfish and constituted 94% of all the studied individuals. There were only a few two and five year-olds. Conversely, according to Kossakowski (1962), the dominant length classes in Lake Wdzydze were 66.0 – 70.0 mm and 86.0 - 90.0 mm, which constituted 24% and 26%, of the sample, respectively (Fig. 5, Tab. 3).

This population was represented by two and three year-olds, with a few one and four year-olds. Anwand (1993) found that the dominant length class in German waters was 75.0-105.0 mm. He compared his results with earlier data for the same lakes, where the dominant length class was 62.0-82.0 mm (Pieplow 1938).

One explanation, namely that today's crayfish are just bigger, does not appear to be correct. However, the crayfish that occurred in the Vistula Lagoon, where water salinity is low (2 – 4 psu), were characterized by larger body parameters. It can be assumed that it is the salinity which influences specimen size. The phenomenon of the positive influence salinity has on size is well known (Hällfors *et al.* 1981). The tendency of greater growth being accompanied by increasing environmental salinity has been observed in may species. Salinity has a positive effect on both the growth and size of specimens. Since individuals of American crayfish have been living in the brackish waters of the Vistula Lagoon for some time now, it might be possible that this factor has a positive influence on size. However, it should be borne in mind that although the maximum sizes of American crayfish occurring in fresh waters, lakes, and the Vistula Lagoon were similar, the dominant classes differed. Larger specimens dominate in the brackish waters of the lagoon. The combination of a majority of males and the larger size of all specimens might indicate that stronger specimens colonize new territories, in this case a habitat with several psu.

ACKNOWLEDGEMENTS

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