FISHERIES & AQUATIC LIFE (2024) 32: 166 - 174
Archives of Polish Fisheries
DOI 10.2478/aopf-2024-0015

sciendo

RESEARCH ARTICLE

An investigation on the population parameters of freshwater crayfish (*Pontastacus leptodactylus* Eschscholtz, 1823) in Lake Yeniçağa (Bolu)

İrem Gençay, Bura Uğur Sorguç, Yasemin Saygı

Received – 25 July 2024/Accepted – 04 September 2024. Published online: 30 September 2024;
Citation: Gençay, İ., Sorguç, B. U., Saygı, Y. (2024). An investigation on the population parameters of freshwater crayfish (*Pontastacus leptodactylus* Eschscholtz, 1823) in Lake Yeniçağa (Bolu). Fisheries & Aquatic Life 32, 166-174

Abstract. This study examines the monthly population parameters of *Pontastacus leptodactylus* in Lake Yeniçağa, including sex, length, and weight compositions, length-weight relationship, fecundity, morphometry, meat yield, and crayfish plague ratio. For this purpose, 641 crayfish were collected using fyke nets with a 34 mm mesh size. The females carrying eggs were observed between February and May. The female specimens carried between 103 and 841 eggs each, with a diameter ranging from 2.03 to 2.82 mm. The research revealed a size range of 80–168 mm and weight range of 15–133 g for crayfish specimens. As a result of regression analyses, the length-weight relationship was calculated as $W = 0.0392L^{2.9148}$ for males and $W = 0.0701L^{2.6139}$ for females. The population exhibited negative allometric growth based on the length and weight data. The evaluation of meat yield was based on the total meat yield, which comprises cheliped meat yield and abdomen meat yield. The study found that 14.35% of the *P. leptodactylus* population in Yeniçağa Lake was affected by crayfish disease. The results indicate that the *P. leptodactylus* population in Lake Yeniçağa has an overall healthy population structure, with a size suitable for fishing, and should be considered from an economic standpoint.

Keywords: *Pontastacus leptodactylus*, narrow-clawed crayfish, population characteristics, morphometry, meat yield, spawning characteristics

İ. Gençay, B.U. Sorguç, Y. Saygı [✉]
Biology Department, Faculty of Science, Hacettepe University, 06800 Ankara, Türkiye
E-mail: basbug@hacettepe.edu.tr

Y. Saygı
Hacettepe University, Biological Diversity Advanced Research Center (HUBIOM) 06800, Ankara, Türkiye

Introduction

Pontastacus leptodactylus, also known as the narrow-clawed crayfish or Turkish crayfish, is a species in the family Astacidae, and is classified in the genus *Pontastacus* (Crandall and De Grave 2017). *P. leptodactylus* has been identified in a wide geographical range including Europe and Asia (Skurdal and Taugbøl 2002). Although it is most abundant in Eastern Europe and the Middle East, it has been introduced into several countries by humans and has been found in 32 territories in Europe (Kouba et al. 2014).

P. leptodactylus is an economically valuable species thanks to its cultivation and harvesting. The practice of crayfish fishing was first initiated in Turkey in 1961, and since 1968, these organisms have been exported primarily to European countries. Turkey became the leading supplier of *P. leptodactylus*

in the world through exports of crayfish from 1970 to 1986 (Köksal 1988, Harlıoğlu and Harlıoğlu 2009). However, the crayfish plague (*Aphanomyces astaci*), which was detected widely in Turkish inland waters after 1985, affected numerous crayfish populations. In numerous lakes and ponds, including Lake Yeniçağa, the subject of this study, crayfish populations were significantly impacted by the disease, resulting in substantial declines in catch rates (Köksal 1988). This is reflected in Turkey's crayfish production, which declined from 7,936 tons in 1984 to 1,565 tons in 1987 and further to 320 tons in 1991. Nevertheless, the production of *P. leptodactylus* has demonstrated a recovery, reaching 1,233 tons by 2020 (Cilbiz et al. 2020).

In order to protect the population and ensure sustainable fishing, it is important to know the characteristics of the crayfish and the size of the population. Biological research on this subject is crucial in providing valuable results on crayfish populations, and is also valuable in terms of commercial management and for determining harvesting bans. In Yeniçağa Lake, there has been no research on the population parameters of *P. leptodactylus*. For this reason, some biological parameters of the *P. leptodactylus* population (length and weight distribution of male and female specimens, length-weight ratio, fecundity, morphological characteristics, meat yield, and the rate of crayfish plague in the population) were determined within the framework of this research for a period of one year.

Materials and methods

This study was conducted in Lake Yeniçağa (40°47'N, 32°01'E), which is a tectonic, eutrophic, shallow lake in the northwestern Black Sea region and is recognized as one of Turkey's important wetlands (Saygı and Demirkalp 2004). *P. leptodactylus* was one of the commercially harvested species in Lake Yeniçağa until 1986. After the occurrence of crayfish plague in Turkish inland waters, crayfish stocks in Lake Yeniçağa were also negatively affected, and commercial crayfish harvesting could not be conducted in the lake for a long time. The effects of crayfish plague gradually decreased when harvesting was halted (personal communication).

Monthly crayfish sampling was conducted using fyke nets with a 34 mm mesh size between May 2017 and April 2018. Fyke nets were cast into the water at three different stations. A total of 641 crayfish samples were obtained and fixed in 70% ethyl alcohol. After washing the crayfish with water to remove the ethyl alcohol, they were separated by sex. Male specimens were identified by their gonopods. Any specimens displaying symptoms of crayfish plague, the presence of brown spots on the carapace of the organisms, were isolated from the healthy population and counted separately.

Each specimen was weighed with a Radwag AS220X2 digital scale (0.1 g sensitivity), and their total lengths and body measurements (carapace length, carapace width, abdominal length, abdominal width, cheliped length, and cheliped width) were measured with an AGT-00121 digital caliper (to the nearest 0.1 mm) (Rhodes and Holdich 1984). The Le Cren (1951) equation was used to determine the relationship between length and weight – $W = aL^b$. In this equation, W is the total weight (g), L is the total length (mm), and a and b are regression parameters. Egg diameters were determined by measuring 50 randomly selected eggs from each of 38 egg-bearing females using a digital caliper. A total of 152 specimens were selected from healthy crayfish and subjected to a meat yield examination. The crayfish were boiled for 5 minutes and then allowed to cool at room temperature (Huner et al. 1995). The meat in the abdominal and cheliped parts of each specimen was separated using a scalpel and weighed with the digital scale. To determine the statistical significance of the differences between the sexes, the length, weight, morphometric characteristics, and meat yield of male and female specimens were analyzed using a t-test. Statistical analysis was performed with the SPSS 20.0 program.

Table 1
Total weight, total length, and morphometric characteristics of *Pontastacus leptodactylus* in Lake Yeniçağa

	Female				Male				
Parameters	Min	Max	Avg	SD	Min	Max	Avg	SD	P value
Total weight (g)	15.00	112.00	45.86	17.25	16.00	133.00	54.21	24.04	P < 0.05
Total length (mm)	86.00	168.21	117.45	17.46	80.00	162.20	116.94	18.09	P > 0.05
Carapace length (mm)	41.00	76.00	58.52	7.96	36.80	84.20	60.50	9.46	P < 0.05
Carapace width (mm)	20.00	42.31	30.70	4.69	20.00	45.00	31.92	5.64	P < 0.05
Abdominal length (mm)	39.80	76.96	59.25	9.10	37.10	77.20	56.23	8.54	P > 0.05
Abdominal width (mm)	18.00	46.45	30.96	6.29	16.00	35.55	25.87	4.31	P < 0.05
Cheliped length (mm)	24.26	56.96	39.12	6.91	24.14	87.27	50.39	13.26	P < 0.05
Cheliped width (mm)	8.04	22.44	15.50	2.87	8.99	30.72	17.45	4.26	P < 0.05

Results

A total of 641 crayfish (245 females and 396 males) were caught during the annual sampling period from Lake Yeniçağa. The total length of the specimens ranged from 80 to 168 mm. The size distributions of males (80–162 mm) and females (81–168 mm) were similar. The weight of the crayfish ranged from 15 to 133 grams (Table 1). The relationship between the length and weight of the crayfish population in Lake Yeniçağa was analyzed using all 641 crayfish specimens (Fig. 1). The b values for the male and female crayfish in the Lake Yeniçağa crayfish population were 2.914 and 2.613, respectively. Length-weight relationship equations were calculated for males and females at $W = 0.0392L^{2.9148}$ and $W = 0.0701L^{2.6139}$, respectively. The results indicated that the population of *P. leptodactylus* in Lake Yeniçağa showed negative allometric growth, which meant that the crayfish become slenderer as weight increased. The determination coefficient (r^2) between the length and weight of the freshwater crayfish samples was 0.9944 and 0.9917 for male and female crayfish, respectively. These values, which are close to 1, determined that there was a positive relationship between length and weight. A comprehensive examination was conducted on 38 egg-bearing female crayfish. The first observation of female specimens carrying eggs was made in February. Subsequent monthly observations revealed that no female specimens were observed carrying eggs after May. During the breeding period, female crayfish were observed to carry between 103 and 841 eggs each, with an average of 270 to 422 eggs per specimen. The diameter range of the eggs was 2.03–2.82 mm, with an average diameter of 2.45 mm (Table 2).

The morphometric measurements (carapace length, carapace width, abdomen length, abdomen width, cheliped length, and cheliped width) of 641 crayfish revealed significant sexual dimorphism (Table 1). The male crayfish exhibited significantly larger carapace length, carapace width, cheliped

Table 2
Number of eggs carried by female crayfish and egg diameter (mm) during the reproductive period

	Number of Eggs				Egg Diameter (mm)			
Month	Number of Individuals	Min	Max	Avg ± SD	n	Min	Max	Avg ± SD
February	4	103	469	347 ± 82.67	200	2.1	2.82	2.45±0.09
March	13	104	608	338 ± 46.60	650	2.2	2.73	2.45±0.03
April	18	124	841	422 ± 44.55	900	2.1	2.77	2.46±0.04
May	3	160	444	270 ± 87.88	150	2.0	2.66	2.43±0.04

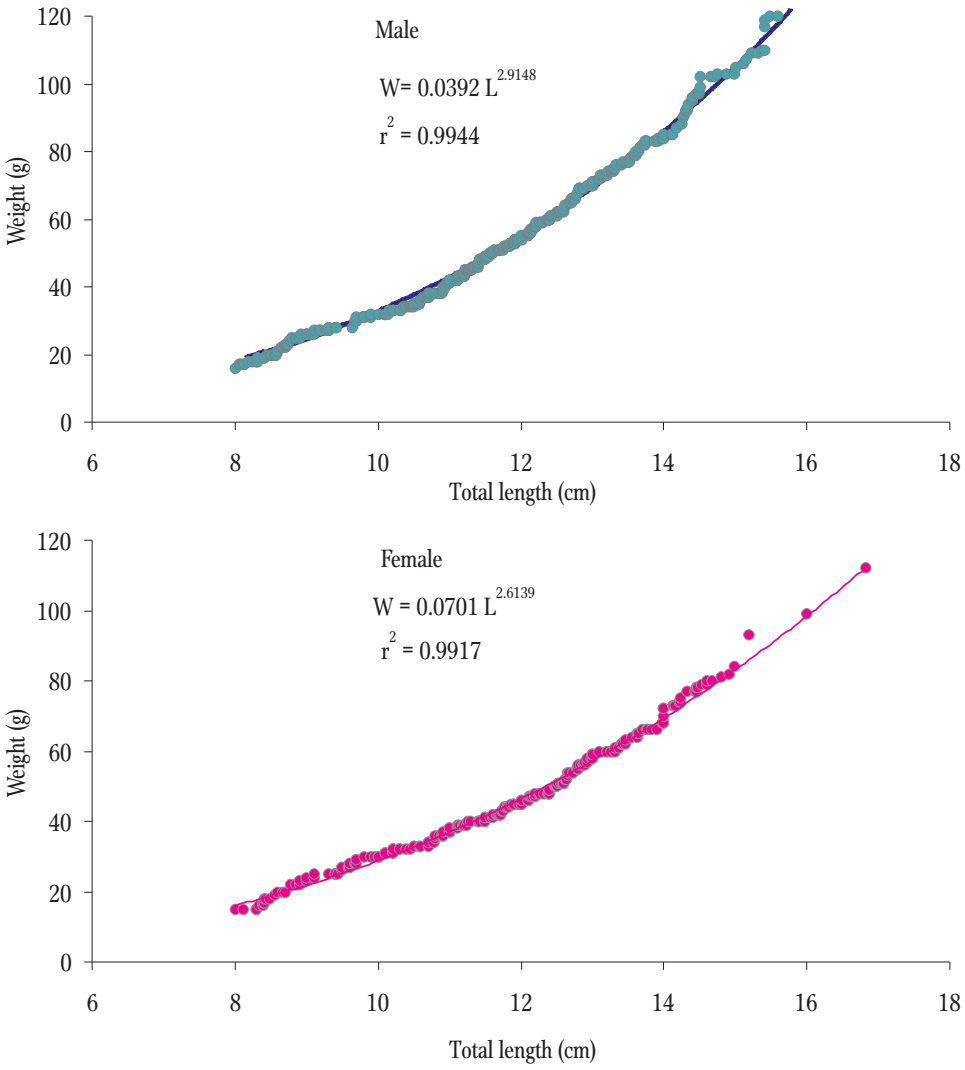

Figure 1. Length-weight relationship of male and female crayfish in Lake Yeniçağa.

length, and cheliped width compared to the female crayfish ($P < 0.05$). The female crayfish exhibited greater abdominal length and abdominal width compared to the males. However, no significant differences in abdominal length were observed ($P > 0.05$). A total of 152 crayfish samples were randomly selected for the meat yield examination, which was divided into three groups: abdominal meat, cheliped meat, and total meat yield. The mean abdominal meat yield was 3.39 g for males and 3.77 g for females. However, no significant difference was observed between the sexes ($P > 0.05$). The average cheliped meat yield was 1.55 g in males and 0.90 g in females, indicating a statistically significant difference between the sexes ($P < 0.05$). The total meat yield, obtained by combining the abdominal and cheliped meat yields, averaged 4.94 g for males and 4.70 g for females, which also did not indicate a statistically significant difference between the sexes ($P > 0.05$) (Table 3). Crayfish plague was detected in male specimens in all months except March, June, and August, with an average prevalence of 13.88% in the male population. Female specimens exhibited signs of crayfish plague in the majority of sampling months, with an average of 15.10% affected. The overall prevalence of the disease in the crayfish population was 14.35%.

Table 3
Meat yield of *Pontastacus leptodactylus* in Lake Yeniçağa

		Male		Female		
Parameters	Length (mm)	n	Avg ± SD	n	Avg ± SD	P value
Abdominal meat (g)	40-49	15	1.69±0.48	8	1.24±0.56	P < 0.05
	50-59	34	3.3±1.01	20	3.46±1.18	P > 0.05
	60-69	43	4.05±1.26	32	4.60±1.47	P > 0.05
Average	58.18	92	3.39±1.34	60	3.77±1.69	P > 0.05
Cheliped meat (g)	40-49	15	0.46±0.20	8	0.28±0.11	P > 0.05
	50-59	34	1.42±0.61	20	0.81±0.28	P < 0.05
	60-69	43	2.03±0.99	32	1.15±0.51	P < 0.05
Average	58.18	92	1.55±0.95	60	0.92±0.50	P < 0.05
Total meat (g)	40-49	15	2.16±0.66	8	1.52±0.65	P < 0.05
	50-59	34	4.72±1.49	20	4.27±1.36	P > 0.05
	60-69	43	6.09±2.04	32	5.76±1.84	P > 0.05
Average	58.18	92	4.94±2.16	60	4.70±2.09	P > 0.05

Discussion

The findings from this study, aimed at understanding the *P. leptodactylus* population in Lake Yeniçağa, were compared with other studies in the literature, and the biological characteristics of the species were evaluated.

The female-to-male ratio of all specimens caught during the study was 0.62:1.00. While the sex ratio of female to male is close to 1:1 in Astacidae species, there are known variations (Reynolds et al. 1992). These differences in sex ratio are believed to arise from seasonal differences between male and female crayfish (Aydın et al. 2015). Several studies on *P. leptodactylus* have demonstrated a higher probability of capturing male specimens during the breeding season compared to females (Berber and Balık 2009, Dartay and Ateşşahin 2013, Aydın et al. 2015). The female-to-male sex ratio observed in our study at Lake Yeniçağa is consistent with findings from similar research conducted across Turkey.

The study found that female *P. leptodactylus* in Lake Yenicağa had a slightly higher average total length than males, but the difference was not statistically significant (P > 0.05) (Table 1). The weight distribution of *P. leptodactylus* in Lake Yeniçağa varied considerably, with males significantly heavier than females (P < 0.05) (Table 1). This pattern is consistent with observations in other crayfish populations, where males are typically heavier than females (Dartay and Ateşşahin 2013, Vasileva et al. 2017). This is attributed to the larger size of their chelipeds and walking legs. Additionally, crayfish in Lake Yeniçağa exhibited a higher average weight compared to other populations, likely due to the absence of active harvesting, which allows specimens to grow larger.

The b values acquired at the end of the regression analyses indicate that the *P. leptodactylus* population in Lake Yeniçağa exhibited negative allometric growth for both male and female specimens (Fig. 1). Comparative studies revealed that the b value indicated negative allometric growth in both male and female crayfish in Gaga Lake (Yılmaz et al. 2011). Isometric growth was observed in females and positive allometric growth in males in Lake Iznik and Demirköprü Dam Lake (Balık et al. 2005, Aydın et al. 2015). In Mamasın Dam Lake and Keban Dam Lake, females exhibited negative allometric growth, while males demonstrated positive allometric growth (Büyükçapar et al. 2006, Dartay and Ateşşahin 2013). In Lake Apolyont, females showed negative

Table 4
Growth types of different *Pontastacus leptodactylus* populations

Location	n	b	Growth Type	Literature
Iznik Lake				
Female	896	3.011	Isometric	Aydın et al. 2015
Male	1001	3.301	Positive Allometric	
Mamasın Dam Lake				
Female	194	2.754	Negative Allometric	Büyükçapar et al. 2006
Male	356	3.104	Positive Allometric	
Keban Dam Lake				
Female	27	2.338	Negative Allometric	Dartay and Ateşşahin 2013
Male	63	3.018	Positive Allometric	
Gaga Lake				
Female	129	2.490	Negative Allometric	Yılmaz et al. 2011
Male	131	2.550	Negative Allometric	
Apolyont Lake				
Female	573	2.955	Negative Allometric	Berber and Balık 2009
Male	843	3.025	Isometric	
Demirköprü Dam Lake				
Female	113	3.054	Isometric	Balık et al. 2005
Male	233	3.266	Positive Allometric	
Yeniçağa Lake				
Female	245	2.613	Negative Allometric	This study
Male	396	2.914	Negative Allometric	

allometric growth, whereas males exhibited isometric growth (Berber and Balık 2009) (Table 4). Vasileva et al. (2017) examined the length-weight relationship in three distinct age groups and observed negative allometric growth in two-summer-old female crayfish groups. Conversely, they found positive allometric growth in one-year-old and one-summer-old female and male crayfish and two-summer-old male crayfish. A strong correlation exists between growth and shell change in crayfish, particularly in younger specimens that experience rapid growth and frequent molting during their initial years. After reaching reproductive maturity, crayfish shells begin to thicken during the growth period. In some species, weight gain from shell changes can exceed three times the length increase. Male crayfish often show increased cheliped weight during molting, while females typically exhibit negative allometric or isometric growth (Harlıoğlu 1999). Differences in the length-weight relationship observed in this study compared to others may be due to factors such as trophic level, population density, food competition, human influences, and environmental physicochemical parameters.

P. leptodactylus is one of the most productive European crayfish species, with a female egg yield of between 200 and 400 (Harlıoğlu and Harlıoğlu 2009). In Lake Yeniçağa, females carried an average of 270 to 422 eggs, with an average egg diameter of 2.45 mm. In studies conducted in different regions of Turkey, the average number of eggs carried by *P. leptodactylus* specimens was 170 in Lake Eğirdir, 156 in Lake Beyşehir, 161 in Lake Eber, and 161 in Lake Akşehir. Egg diameter was between 2.44 and 2.49 mm in crayfish populations in Lake Eğirdir, Lake Akşehir, and Lake Eber (Erdemli 1982). It was

found that the egg productivity in the Lake Yeniçağa crayfish population was higher than in other populations. The size of crayfish eggs is influenced by several environmental factors, including parasitism, predator pressure, water quality, and nutrition. The high number of eggs obtained per female in Lake Yeniçağa relative to other lakes can be attributed to the absence of crayfish harvesting and the region's ecological conditions.

In this study, the male crayfish exhibited significantly larger carapace length, carapace width, cheliped length, and cheliped width compared to the female crayfish ($P < 0.05$), and females exhibited a significantly wider abdomen than males ($P < 0.05$). In Manyas Lake, male crayfish exhibited greater cheliped length and width than females, while females demonstrated higher values for total length, carapace length and width, and abdominal length and width (Berber and Balık 2009). Similarly, in Iznik Lake, females generally exhibited larger sizes than males. (Aydın et al. 2015). Vasileva et al. (2017) conducted a study in Bulgaria that showed males had greater carapace and cheliped length and width, while females had greater abdominal length and width. Aksu and Kaya (2017) found that male crayfish in Ardahan Aktaş Lake had larger carapaces than females, while females exhibited larger abdomen width. Dartay and Ateşşahin (2013) observed that males in the Pertek Region of Keban Dam Lake surpassed females in total length, carapace width, and cheliped size, while females had a greater abdominal length and width. In contrast, in the Vrbas River, male crayfish had a greater abdominal length (Roljić et al. 2019). The morphometric analyses suggest that the crayfish from Lake Yeniçağa have similar body morphometry to other naturally occurring populations, which is consistent with the literature. The larger body length of males may be due to more frequent molting, while the wider abdomen measurements in females may be linked to their use of the abdomen for carrying eggs.

The edible meat of freshwater crayfish is primarily derived from the abdominal meat, although total meat yield calculations also include cheliped meat (Berber 2005). In this study, females had a higher abdominal meat yield compared to males, while males demonstrated greater cheliped and total meat yields. However, only differences in the cheliped meat yield was statistically significant ($P < 0.05$) (Table 3). Females typically show an increase in abdominal meat yield only during the breeding period, whereas males generally exhibit higher yields in both cheliped and abdominal meat (Harlıoğlu and Holdich 2001). The meat yield values noted in the present study were similar to those of crayfish in Ardahan Aktaş Lake, where males were more productive than females in terms of abdominal, cheliped, and total meat yield (Aksu and Kaya 2017). This is consistent with findings from Gaga Lake, where males had significantly higher meat yields (Yılmaz et al. 2011). Conversely, in Apolyont Lake, males exhibited a lower abdominal meat yield than females, while no differences in total meat yield were noted. (Berber and Balık 2009). The findings from Lake Yeniçağa align with those of other populations. The higher meat yield in males may be attributed to their more active feeding habits and frequent molting, resulting in greater meat yield, particularly in the chelipeds.

Crayfish plague (*A. astaci*), a fungal-like disease, has caused a significant decline in native European freshwater crayfish populations since the 1860s. The populations in Turkey were also affected by this disease, but they have recently begun to recover (Harlıoğlu and Harlıoğlu 2009). In this study, we assessed the prevalence of crayfish plague in the *P. leptodactylus* population in Lake Yeniçağa. On average, 15.10% of female and 13.88% of male specimens were found to have the disease. In a healthy population, the prevalence of crayfish plague is typically around 20%. If this threshold is exceeded in Lake Yeniçağa, this could potentially threaten the stability of the population and lead to a decline in the crayfish stock in the lake (Köksal 1988). However, the current prevalence of crayfish plague is below the level that could threaten the future stability of the crayfish population in the lake. Nevertheless, regular monitoring is very important due to the presence of disease symptoms.

The collection and analysis of data on the biological characteristics of crayfish populations are crucial for the maintenance of ecosystem balance and the potential development of practical cultivation strategies. The comprehensive results demonstrate that the *P. leptodactylus* population in Lake Yeniçağa exhibits a healthy population structure, with an optimal size for fishing, and should be considered from an economic standpoint. It is recommended that crayfish fishing in Lake Yeniçağa, where it is currently not practiced, be initiated in compliance with relevant legislation, and comprehensive information on the regulations should be communicated to fishers.

Acknowledgments. The authors would like to thank İbrahim Arslan and Nedim Bozoğlu for their help with field work.

Author Contributions: İ.G. Sampling, Laboratory works, Investigation, Data analyses, Writing-original draft; B.U.S. Investigation, Writing-original draft; Y.S. Sampling, Laboratory work, Investigation, Data analyses, Writing-original draft, Supervision.

Conflict of Interest: The authors declare no competing interests.

Funding Information: This study conducted with the financial support of Hacettepe University Scientific Research Project Commission (Project no: FHD-2017-13750).

ORCID iD

İrem Gençay https://orcid.org/0009-0006-1548-3369

Bura Uğur Sorguç https://orcid.org/0000-0001-9995-0441

Yasemin Saygı https://orcid.org/0000-0001-8007-9158

References

Aksu, Ö., Kaya, G. K. (2017). The relationships between length-weight, and meat yield of freshwater crayfish (*Astacus leptodactylus* Eschscholtz, 1823) of Aktaş Lake. Balıkesir Üniversitesi Fen Bilimleri Enstitüsü Dergisi, 19(2), 283-295 (in Turkish).

Aydın, H., Harlıoğlu, M. M., Deniz, T. (2015). An investigation on the population parameters of freshwater crayfish (*Astacus leptodactylus* Esch., 1823) in Lake İznik (Bursa). Turkish Journal of Zoology, 39(4), 660-668.

Balık, S., Ustaoğlu, M. R., Berber, S. (2005). Determination of traits some growth and morphometric of crayfish (*Astacus leptodactylus* Eschscholtz, 1823) at Demirköprü Dam Lake (Manisa). Ege Journal of Fisheries and Aquatic Sciences, 22(1), 83-89 (in Turkish).

Berber, S., Balık, S. (2009). The lenght-weight relationships, and meat yield of crayfish (*Astacus leptodactylus* Eschcholtz, 1823) population in Apolyont Lake (Bursa, Turkey). Journal of FisheriesSciences.com, 3(2), 86 (in Turkish).

Berber, S. (2005). Comparison of investigation of bio-ecological, morphometry characteristics and disease status of crayfish (*Astacus leptodactylus* Eschscholtz, 1823) populations in Manyas, Apolyont and Iznik Lakes. Doctoral dissertation, Ege University (in Turkish).

Büyükçapar, H. M., Alp, A., Kaya, M., Çiçek, Y. (2006). The length-weight relationships, and meat yield of crayfish (*Astacus leptodactylus* Eschscholtz, 1823) in the Mamasın Reservoir (Aksaray, Turkey). Ege Journal of Fisheries and Aquatic Sciences, 23(1), 21-25 (in Turkish).

Cilbiz, M. (2020). Pleopodal fecundity of narrow-clawed crayfish (*Pontastacus leptodactylus* Eschscholtz, 1823). Invertebrate Reproduction & Development, 64(3), 208-218.

Crandall, K. A., De Grave, S. (2017). An updated classification of the freshwater crayfishes (Decapoda: Astacidea) of the world, with a complete species list. Journal of Crustacean Biology, 37(5), 615-653.

Dartay, M., Ateşşahin, T. (2013). A study on catching freshwater crayfish, *Astacus leptodactylus* Eschscholtz 1823, and its some population characteristics. Turkish Journal of Science & Technology, 8(2), 125-130.

Erdemli, A. Ü. (1982). A research on the freshwater crayfish (*Astacus leptodactylus*, Esch., 1823) populations of Beyşehir, Eğridir, Akşehir, Eber Lakes and Apa Dam Lake. Doğa Bilim Dergisi: Veterinerlik ve Hayvancılık, 7(2), 313-318.

Harlıoğlu, M. M. (1999). The relationships between length-weight, and meat yield of freshwater crayfish, *Astacus leptodactylus* Eschscholtz, in the Ağın Region of Keban Dam Lake. Turkish Journal of Zoology, 23(7), 949-958.

Harlıoğlu, M. M., Holdich, D. M. (2001). Meat yields in the introduced freshwater crayfish, *Pacifastacus leniusculus* (Dana) and *Astacus leptodactylus* Eschscholtz, from British waters. Aquaculture Research, 32(5), 411-417.

Harlıoğlu, A. G., Harlıoğlu, M. M. (2009). The status of freshwater crayfish (*Astacus leptodactylus* Eschscholtz) fisheries in Turkey. Reviews in Fisheries Science, 17(2), 187-189.

Huner, J. V., Lindqvist, O. V., Könönen, H. (1995). Sexual dimorphism and yield of edible products from a stunted, by commercial standards, population of noble crayfish (*Astacus astacus* Linne') in central Finland. Freshwater Crayfish, 8, 668-679.

Kouba, A., Petrusek, A., Kozák, P. (2014). Continental-wide distribution of crayfish species in Europe: update and maps. Knowledge and Management of Aquatic Ecosystems, 05.

Köksal, G. (1988). *Astacus leptodactylus* in Europe. Freshwater crayfish: biology, management and exploitation. 365-400.

Le Cren, E. D. (1951). The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). Journal of Animal Ecology, 201-219.

Reynolds, J. D., Celada, J. D., Carral, J. M., Matthews, M. A. (1992). Reproduction of astacid crayfish in captivity—current developments and implications for culture, with special reference to Ireland and Spain. Invertebrate Reproduction & Development, 22(1-3), 253-265.

Rhodes, C. P., Holdich, D. M. (1984). Length-weight relationship, muscle production and proximate composition of the freshwater crayfish *Austropotamobius pallipes* (Lereboullet). Aquaculture, 37(2), 107-123.

Roljić, R., Nikolić, V., Savić, N. (2019). Morphological variability and sexual dimorphism of Danube crayfish *Pontastacus leptodactylus* Eschscholtz, 1823 from the Vrbas River. Water Research and Management, 9(2), 27-32.

Saygı, Y., Demirkalp, F. Y. (2004). Trophic status of shallow Yeniçağa Lake (Bolu, Turkey) in relation to physical and chemical environment. Fresenius Environmental Bulletin, 13, 358-393.

Skurdal, J., Taugbøl, T. (2002). *Astacus*. Biology of freshwater crayfish, 467-510.

Vasileva, P. L., Hubenova, T. A., Zaikov, A. N., Stoyanov, I. Y. (2017). Morphometric variability, allometric growth and sexual dimorphism in narrow-clawed crayfish, *Astacus leptodactylus* Eschscholtz, 1823 (Crustacea: Decapoda) during the ontogenesis. Acta Zoologica Bulgarica, 8, 99-106.

Yılmaz, E., Harlıoğlu, A. G., Yımaz, A. (2011). The relationships between length-weight, and meat content of freshwater crayfish (*Astacus leptodactylus* Eschscholtz, 1823) caught from Gaga Lake (Ordu-Turkey). Su Ürünleri Dergisi, 28(3), 75-80 (in Turkish).