



A Study on Some Biological Parameters of Crayfish (*Astacus leptodactylus* Eschscholtz, 1823) in Ulugöl, Samsun, Turkey

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ABSTRACT

The study aimed to investigate some morphometric traits, length-weight relationship, meat yield, fecundity and some biochemical compositions of *Astacus leptodactylus*, in one of the Bafra Fish Lakes named Ulugöl, Samsun, Turkey. A total of 378 *A. leptodactylus* (198 female and 180 male) were examined. The average carapace length was 50.96±0.46 mm for females, 51.31±0.66 mm for males and 51.13±0.40 mm for all sampled crayfish. Abdomen length was 52.36±0.49 mm for females, 49.26±0.62 mm for males and 50.87±0.40 mm for all sampled crayfish. Live weight was between 14.38 g and 105.03 g with an average of 38.26±0.73 g. The average weight of females was less than that of males. There was a strong relationship between length and weight. The weight of crayfish with pleopodal eggs ranged from 28.24 g, to 59.50 g with an average of 41.73±1.09g. The average number of eggs per individuals was 192.90±9.94 with an average number of 4.62±0.21 per unit of live weight. The average total egg weight was 3.35±0.19 g while the average egg diameter was 2.17±0.03 mm. Abdomen meat was lower for males comparing with females. Average moisture, crude ash, crude oil and crude protein of abdomen meat were 81.27%, 1.47%, 0.81% and 16.45%, respectively.

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Introduction

Crayfish are ecological, economically and socially important species. Generally, they are traditionally consumed as a luxury food as well as consumed at special occasions in some countries (Hogger, 1988; Momot, 1995; Harlıoğlu and Holdich, 2001). On the other hand, they are a source of protein with low calories and rich for vitamin B, sodium, potassium, calcium and magnesium (Goddard, 1988). Also, crayfish meat has higher content of vitamin C and carotene than many commercial fish species (Harlıoğlu and Köprücü, 2000).

Astacus leptodactylus belonging to Astacidae family naturally exist in Turkey (Holthius, 1961; Geldiay and Kocataş, 1970; Balık et al., 2005). Distribution of two subspecies which generally can be recognizable with the appearance of carapace and chelae (*Astacus leptodactylus leptodactylus* and *Astacus leptodactylus salinus*) is reported in Turkey (Geldiay and Kocataş, 1970). This species has also been stocked to harvest from natural or artificially created environment in a number of countries

(Poland, Italy, Germany, England, Spain and France). In some areas of stocked countries, they formed big population (Köksal, 1988).

Although there are 33 water sources where fishing of crayfish can be done, there is a need for culturing this species under controlled conditions in Turkey (Harlıoğlu, 2004). Crayfish production reached 5000 tons in the 1980's. After that date, the production has been dramatically decreased because of a kind of fungal (*Aphanomyces astaci*) shellfish disease called crayfish plague (Bolat, 2001). Production was 696 tons in 2019 (TÜİK, 2020).

After crayfish plague occurrence in many European countries, studies started to render natural water resources efficiently again by making an attempt to boost the population of Europe's native crayfish species. Therefore, *A. astacus* and *A. leptodactylus* known as "Turkish crayfish" became the most important shellfish species used in stocking since *A. leptodactylus* is more resistant than

other crayfish species in Europe against the crayfish plague. Besides, the features like high growth rate and reproductive capacity, adapting quickly to the environmental conditions and the similar flavor to *A. astacus*, which is very popular in Europe, have led *A. leptodactylus* to use for stocking (Ingle and Clarke, 1989; Köksal et al., 1992; Harlıoğlu, 2000).

Crayfish stock in Ulugöl, one of the Bafra Fish Lakes, Turkey, is natural and the commercial fishing is based on renting of lakes by commercial enterprises. Since there is no study done in that area before, it is aimed to determine the size of populations, length and weight compositions according to the sex ratio, length-weight relationship, reproduction periods, fecundity, meat yield and biochemical compositions of crayfish, *Astacus leptodactylus* in this study.

Materials and Methods

The study was carried out in one of the Bafra Fish Lakes named Ulugöl located in Bafra, Samsun, Turkey. Ulugöl is located in Kızılırmak Delta and coordinated with 41° 36' N; 36° 04' E showing a lagoon character with 1389 ha area (Figure 1). Ulugöl, having prime importance for fishing, has an average depth of 1.5 m.

The *A. leptodactylus* samples used in this study were chosen randomly among healthy population, caught with pinter nets by fishermen monthly between July 2010 and July 2011. A total of 378 crayfishes (f:m 1:0,91) were used in the study.

The samples were brought to a laboratuar in Faculty of Aquaculture, University of Sinop with a humidified styropor container. Morphometric measurements were done according to Rhodes and Holdich (1984). After sexing of the samples, total length, carapace length, carapace width, abdomen length, abdomen width, chelae length and chelae width were measured with a digital caliper to the nearest 0.1 mm whereas their weights were measured with a sensitive scale to the nearest 0.001 g (Figure 2). In order to determine the abdomen meat yield, the whole samples were boiled for 10 minutes in water, their abdomens were cut and fleshs were taken with a clip and then they were weighed with the sensitive scale.

In order to determine the biochemical composition, abdomens of the crayfish were removed and stored - 80°C. Crude protein analyze was done according to Kjeldahl method (AOAC, 1980), crude oil analyze was done according to Soksaleet method by using Gerhard brand device and moisture, ash and dry matter analyses were done according to AOAC, 1990 with three paralels.

Eggs adhered to pleopods of crayfish were taken out without giving any damage by a clip and weighthed in a tared container with the sensitive scale for determination of the fecundity. After completion of the weighing operation, the whole eggs taken from each female were counted in a separate container and their diameters were measured with a sensitive electronical caliper to the nearest 0.01 mm.

Regression analyses were performed for the relationships between morphometric parameters. Relations between parameters related to fecundity were evaluated by correlation analysis. Microsoft Office Excel 2003 and Minitab 13.1 software programs were used for the statistical analysis.

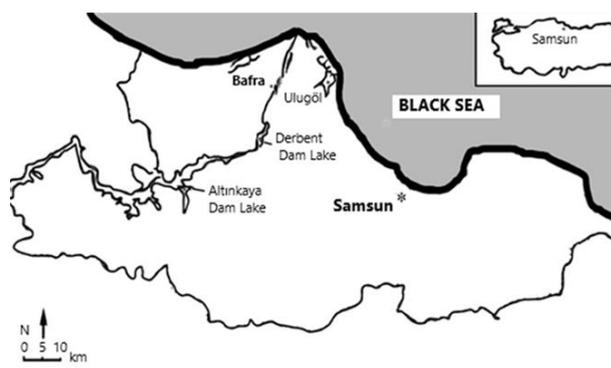


Figure 1. Research area

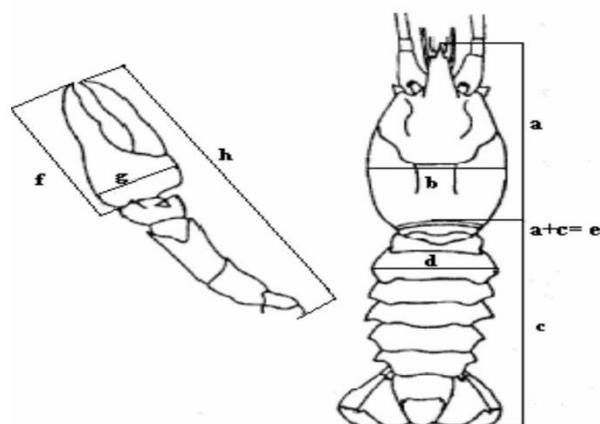


Figure 2. Particular measurements relating to the body portion of crayfish (Rhodes and Holdich, 1984).

a) carapace length b) carapace width c) abdomen length d) abdomen width e) total length f) chelae length g) chelae width and h) chelae foot length.

Results

A total of 378 *A. leptodactylus* (198 female and 180 male) were examined and there were no significant differences in sex ratio according to the months ($P>0.05$).

Total length and carapace length of crayfishes were ranged between 80-156 mm and 22-83 mm, respectively. Average carapace length in females, in males and in all samples were 50.96 ± 0.46 mm (min: 30.66 mm, max: 82.03 mm), 51.31 ± 0.66 mm (min: 22.17 mm, max: 78.28 mm) and 51.13 ± 0.40 mm, respectively. The average length of the abdomen of females was 52.36 ± 0.49 mm, whereas it was 49.26 ± 0.62 mm in males with an average of 50.87 ± 0.40 mm for all specimens. The abdomen length of females (24.00 ± 0.23 mm) was significantly higher that of males (20.48 ± 0.23 mm, $P<0.001$).

In addition, carapace length, chelae length and width of males were significantly higher when compared with females ($P<0.001$). The weight of crayfish samples changed between 14.38 - 105.03 g and the average weight was 38.26 ± 0.73 g. The average weight of females (35.63 ± 0.73 g) was less than that of males (41.12 ± 1.27 g) ($P<0.05$).

Length-weight relationship (r) was 0.91 for all individuals whereas it was 0.93 for only females and males (Figure 3).

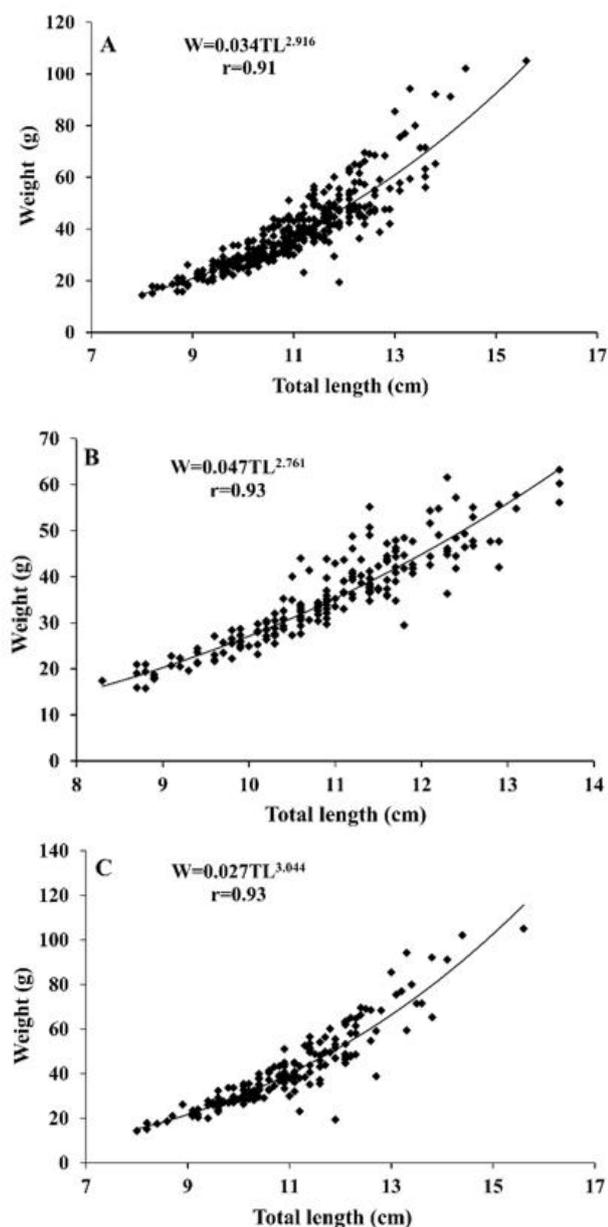


Figure 3. Total length-weight relationship of female+male *A. leptodactylus* (A), females (B) and males (C).

The average weights of abdomen meat were 3.59 ± 0.13 and 3.49 ± 0.14 g for females and males, respectively and there was no significant difference between them ($P > 0.05$). The average abdomen meat yields were $9.43 \pm 0.79\%$ in females and $9.57 \pm 0.95\%$ in males. The difference was not significant in terms of abdomen meat yield between male and female crayfish ($P > 0.05$).

Table 1. shows the correlation values and regression equations of total weight, total egg weight, the number of eggs per unit of live weight in crayfish.

The minimum, maximum and the average weight of crayfishes with pleopodal eggs were 28.24, 59.50 and 41.73 ± 1.09 g, respectively. The average egg number of individual crayfish was 192.90 ± 9.94 (maximum 368, minimum 50 eggs). The number of eggs for per unit of live weight was 4.62 ± 0.21 . The average total egg weight was 3.35 ± 0.19 g. The average diameter of 9645 eggs was 2.17 ± 0.03 mm.

Significant relationships between total weight-total egg weight ($r=0.74$) and total weight- total egg number ($r=0.50$), total egg weight-total egg number ($r=0.72$), total egg number-the number of eggs for per unit of live weight ($r=0.86$) were determined ($P < 0.05$) (Figure 4).

Positively, but non-significant relationships between total weight-the number of eggs for per unit of live weight ($r=0.01$) and total weight-egg diameter ($r=0.21$), total egg weight-the number of eggs for per unit of live weight ($r=0.43$) and total egg weight-egg diameter ($r=0.27$), total egg number-egg diameter ($r=0.20$) and egg diameter-the number of eggs for per unit of live weight ($r=0.14$) were detected.

Average moisture, crude ash, crude oil and crude protein were $81.27 \pm 0.36\%$, $1.47 \pm 0.14\%$, $0.81 \pm 0.04\%$, $16.45 \pm 0.36\%$ respectively (Table 2).

Discussion

In studies comparing of different lengths and weights of body parts of male and female crayfish species, it was reported that generally body weight of males is higher than that of females and abdomens of females are longer and wider than males whereas chelae and chelae feet of males are longer and chelae of males also are wider than that of females (Stein, 1976; Rhodes and Holdich, 1979; Lindqvist and Lahti, 1983; Huner et al., 1991; Harlıoğlu, 2000). In the present study, male *A. leptodactylus* was heavier than females, chelae length and width were longer than females but abdomens of females were wider and longer with a similarity of previous studies. Balık et al. (2005) reported that the highest ratio value of 22.25% was between 18.5-23.4 g weight ranges of *A. leptodactylus* population at Demirköprü Reservoir. Female individuals with 28.32% ratio were in 23.5-28.4 g weight group while males with 19.74% ratio was in 18.5-23.4 g as the highest density. Güner (2006) determined that the average weight and average length of *A. leptodactylus* in Terkos Lake were 52.25 g and 121.33 mm, respectively.

Dartay and Ateşşahin (2013) reported that the average length and weight of male and female *A. leptodactylus* were 112.93 mm and 50.32 ± 4.34 g and 100.38 mm and 35.82 ± 5.76 g, respectively. Considering the average length and weight values of crayfish, this study showed a similarity and also differences with the findings of other researchers. When all studies were analysed, there are differences between the values obtained by several researchers of the same lake in length and weight distribution. Similarly, differences were observed between the values that the same researcher obtained in different lakes or in the same lake with different times. The reasons for these differences might be the occurrence of crayfish with different lengths at different depths and at different base structures in different seasons, the different hunting methods and the effect of hunting pressure in some lakes.

There were no significant differences in sex ratio of *A. leptodactylus* in the present study. The sex ratio of *A. leptodactylus* was 47% male and 53% female in Eğirdir Lake and 48% male and 52% female in Terkos Lake (Köksal, 1980). 54% female and 46% male of *A. leptodactylus* in Apa Dam Lake and 61% female and 39% male of *A. leptodactylus* in Eğirdir Lake were reported by Erdemli (1983).

Table 1. Correlation values and regression equations of total weight, total egg weight, the number of eggs per unit of live weight in *A. leptodactylus* (TW: Total-weight, TWE: Total weight of eggs, TNE: Total number of eggs, ED: Egg diameter, NEPULW: The number of eggs for per unit of live weight).

Correlation value and regression equations					
	TW	TWE	TNE	ED	NEPULW
TW		$y=0.127x-1.951$	$y=4.647x-1.063$	$y=-0.038x+3.983$	$y=0.004x+4.442$
TWE	0.74		$y=38.76x+63.15$	$y=-0.287x+3.333$	$y=0.497x+2.950$
TNE	0.50	0.72		$y=-0.004x+3.145$	$y=0.018x+1.052$
ED	0.21	0.27	0.20		$y=0.153x+4.980$
NEPULW	0.01	0.43	0.86	0.14	

Table 2. Monthly distribution of average moisture, crude ash, crude oil and crude protein during experimental period in *A. leptodactylus*.

Monthly	Moisture (%)	Crude ash (%)	Crude oil (%)	Crude protein (%)
July	81.98±0.58	1.37±0.11	0.41±0.02	16.24±0.34
August	82.68±0.39	1.56±0.13	0.46±0.03	15.28±0.51
September	83.17±0.18	1.62±0.09	0.54±0.07	14.66±0.06
October	82.96±0.17	1.56±0.20	0.60±0.02	14.87±0.44
November	83.33±0.05	1.51±0.27	0.51±0.00	14.64±0.47
December	81.90±0.37	1.42±0.15	0.41±0.02	16.27±0.11
January	78.82±0.54	1.21±0.27	1.58±0.09	18.38±1.10
February	79.63±0.20	1.27±0.02	1.54±0.03	17.56±0.24
March	82.93±0.15	1.18±0.07	0.44±0.02	15.44±0.22
April	79.19±0.39	1.54±0.02	1.49±0.04	17.79±0.09
May	79.35±0.41	1.99±0.16	0.42±0.04	18.24±0.51
June	78.12±0.36	1.31±0.02	1.75±0.03	18.82±0.14
July	82.25±0.53	1.57±0.13	0.45±0.02	15.73±0.08
Average	81.27±0.36	1.47±0.14	0.81±0.04	16.45±0.36

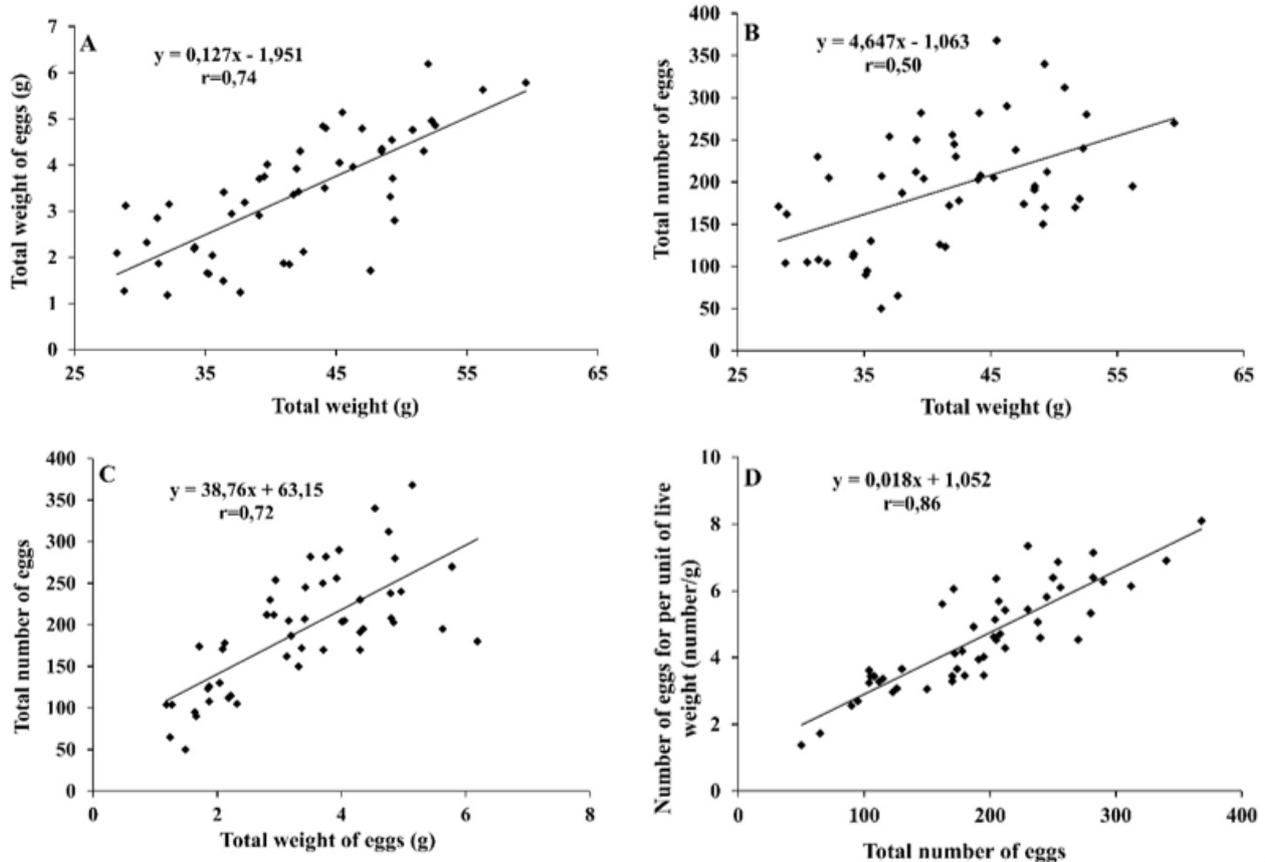


Figure 4. Total weight-total weight of eggs (A), Total weight-total number of eggs (B), Total weight of eggs-total number of eggs (C), Total number of eggs-number of eggs for per unit of live weight (D) in *A. leptodactylus*.

The average female and male *A. leptodactylus* ratio were 47% and 53%, respectively from seven inland waters: Avşar Dam Lake, Çıldır Lake, Eğirdir Lake, Hirfanlı Dam Lake, Keban Dam Lake, Porsuk Dam Lake and Karpuzlu Pond (Bök et al., 2013). Dartay and Ateşşahin (2013) reported that 42% female and 58% male *A. leptodactylus* in Keban Dam Lake, Pertek region. Maguire and Dakic (2011) found 41% female and 59% male *A. leptodactylus* in Croatia and Armenia. Results obtained from the present study showed similarity with the study of Köksal (1980) for Terkos Lake and Erdemli (1983) for Eğirdir Lake. The values obtained from the other studies are very different. The reason of this difference could be resulted from that because females in spawning period carry eggs under abdomens, they cannot be active as male crayfish and they may not show interest to eel-buck as much as male crayfishes. So, it is thought that the hunting season and even the different hours of day of catching time might have an effect on sex ratio of caught individuals.

In this research, a strong linear relationship between length and weight was found. A negative allometric growth was detected in female and in male + female *A. leptodactylus* (b values for female and male + female crayfish were 2.76, 2.92, respectively). There was a positive allometric growth in male crayfish (b value was 3.04). A negative allometric growth in male and female *A. leptodactylus* was reported by Harlıoğlu (1999) in Keban Dam Lake and Bolat (2001) in Eğirdir Lake. A positive allometric growth in male *A. leptodactylus* in Demirköprü Dam Lake (Balık et al., 2005) and in Sera Lake (Erkebay, 2004) was also reported. A positive allometric growth in male (b value was 3.01) and a negative allometric growth in female (b value was 2.33) were detected in *A. leptodactylus* from Keban Dam Lake by Dartay and Ateşşahin (2013). Despite the livings grow in length during development, weight growth rate is influenced by genetic structures and ecological factors which have great effect on food quality and quantity. So, in the present study, growth characteristics and regression equations obtained in the length-weight relationship are the natural results and they could be similar or different according to region and period which data was obtained.

In the present study, the average abdomen meat amount was 3.49 ± 0.14 g in male and 3.59 ± 0.13 g in female *A. leptodactylus* and it was not differed significantly between both sexes ($P > 0.05$). Yıldırım et al. (1995) found this value as 3.0 ± 0.5 g for boiled male and female *A. leptodactylus* in the length group of 90 to 100 mm caught from Lake Eğirdir. Harlıoğlu (1999) reported that the abdomen meat amount of male and female *A. leptodactylus* obtained from Keban Dam Lake after cooked for 10 minutes were 3.72 ± 0.75 g ve 3.47 ± 0.55 g, respectively in 46-58 mm carapace length-group and there were no significant differences between the sexes in terms of abdomen meat yield. The abdomen meat amounts of female and male *A. leptodactylus* were ranged between 8.97-10.23% and 7.34-8.67%, respectively in Kardshali Lake (Bulgaria) (Hubenova et al., 2004). The findings of the present study related to abdomen meat amount show similarity to the findings of the above researches.

Average abdomen meat yield was $9.43 \pm 0.79\%$ in females and $9.57 \pm 0.95\%$ in males in the present study. No notable difference was found between male and female

crayfish ($P > 0.05$) in terms of abdomen flesh yield. Similarly, there was no significant difference in abdomen meat weights of male and female *A. leptodactylus* in Keban Dam Lake, in Çemişgezek Location (Barım, 2007). The reason for findings of diverse results for the same species in meat yield studies might depend on the population, catching time, boiling time of the sample, the way of removing the flesh and length group of samples.

The average weight of crayfish with pleopodal eggs was 41.73 ± 1.09 g in this study. The average individual number of eggs of crayfish with eggs was 192.90 ± 9.94 while number of eggs for unit weight was 4.62 ± 0.21 . Total egg weight was 3.35 ± 0.19 g. The average egg diameter was 2.17 ± 0.03 mm. Average total weights of in *A. leptodactylus* with pleopodal eggs were 31.72 g in Işıklı Lake (Güner and Balık, 2002), 32.19 g in Mamasın Dam Lake (Büyükçapar et al., 2006) and 40.38 g in Terkos Lake (Güner, 2006). The findings of the present study show similarity with the values of the above studies.

The average numbers of eggs in *A. leptodactylus* were 154 in İznik Lake (Erdem et al., 2001), 216 in Işıklı Lake (Güner and Balık, 2002), 137 in Demirköprü Dam Lake (Balık et al., 2005), 200 in Eğirdir Lake (Mişe Yonar et al., 2017), 240 in Hirfanlı Dam Lake (Cilbiz, 2020), 314 in Dłuzek Lake (Polland) and 374 in Mazurian Lake (Polland) (Stypnski, 1979). The number of eggs varied from 50 to 368 with an average of 192.90 ± 9.94 in the present study and it was mostly similar with the others but might be higher than the values provided from other studies.

The average egg diameters of *A. leptodactylus* was 2.77 mm in Eğirdir Lake (Bolat, 2001), 2.15-2.99 mm in Işıklı Lake (Güner and Balık, 2002) and 2.72 mm in Demirköprü Barrage Lake (Balık et al., 2005). The average diameter of egg with 2.17 ± 0.03 mm in this study was lower than the other studies in different regions. It was reported that egg diameter is under the effect of a number of factors and it has a weak relationship with morphometric data in the studies about the crayfish (Harlıoğlu and Türkgülü, 2000; Güner and Balık, 2002; Demiroğlu et al., 2017; Cilbiz, 2020). It was pointed out that egg yield is controlled by genetic factors rather than ecological ones (Erdemli, 1985) or there are other factors which influence the productivity (Güner and Balık, 2002).

Chemical compositions of crayfish included $81.27 \pm 0.36\%$ moisture, $1.47 \pm 0.14\%$ crude ash, $0.81 \pm 0.04\%$ oil and $16.45 \pm 0.36\%$ crude protein in the present study. İlhan and Şahin (2006) reported that *A. leptodactylus* in Büyükçekmece Lake consisted of 83.01% moisture, 0.62% crude oil, 1.46% crude ash and 14.17% crude protein. A study was conducted by Bilgin et al. (2008) in order to determine some nutritional components of *A. leptodactylus* in Eğirdir Lake according to their length group and sex. The moisture, crude protein, crude oil and crude ash contents were 78.25 and 80.75%, 15.77 and 17.65%, 1.48 and 1.96% and 1.15 and 1.45%, respectively, in male and female in 8-13.9 cm length group. The findings obtained in this study showed similarity to the findings obtained from the other studies.

Conclusion

It could be concluded that there is a healthy catchable stock of *A. leptodactylus* in Ulugöl and it is thought that studies about morphologic characteristics of the

population, length-weight relationships between sexes, length and weight relationships, reproduction periods, fecundity, meat yield and biochemical composition could be useful to observe possible differences year by year and guide to be applied effective fishing strategies. Also, the evaluation of the population parameters of the freshwater lobster is of great importance in terms of maintaining the population balance in the ecosystem and providing outputs for growing it in culture conditions. It is thought that the data to be obtained from local studies on the current status of crayfish stocks will help to culture the crayfish.

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