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Comparison of Juvenile *Astacus leptodactylus* Growth Raised in Cages in Rice Fields to other Crayfish Juvenile Growth Studies

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Abstract

The objective of this study was to determine whether the freshwater crayfish (*Astacus leptodactylus* Eschscholtz, 1823) rearing can be economically achieved in the rice fields using meta-analysis. For this purpose, 100 juvenile freshwater crayfishes were settled in each of three cages in the rice field and the survival and growth characteristics of juvenile freshwater crayfishes in the rice fields were evaluated for 68 days. The meta-analysis was performed to the present study and nineteen studies where researchers evaluated the survival and growth characteristics of juvenile freshwater crayfish. As a result, initial average length and weight of the individuals were 11.08±0.097 mm and 0.04±0.003 g, respectively. They reached to a total of 37.46±0.872 mm length and an average of 1.46±0.095 g weight after 68 days. During this period, the survival rate of the juvenile individuals was also determined as 64.67%. The meta-analysis showed that growth in length at a significant rate on the contrary growth in weight. In conclusion, it is suggested that freshwater crayfish rearing in rice fields is a new and applicable alternative method for growth of freshwater crayfish in Turkey.

Keywords: *Astacus leptodactylus*, survival, growth, rice, meta-analysis.

Introduction

As being one of the biggest forms of decapods crustaceans living in inland waters, freshwater crayfishes, or crayfishes, are represented by almost 640 species and subspecies in the world (Crandall & Buhay, 2008). Although the number of species is high, it is known that they are produced only as 3 families through fishing and aquaculture, which are economically important. Among these, Cambaridae shows natural distribution in North America and Far Eastern Asia; Parastacidae in Southern Hemisphere; and Astacidae in North America and Eurasia (Hobbs, 1988; Momot, 1995).

Production of the crayfish in the world is practiced through fishing and aquaculture. Since 2013, the total amount of production has been 668517 tons; 15878 tons from fishing (except China) and 625639 tons from aquaculture. The mostly produced freshwater crayfish species both from fishing and aquaculture is *Procambarus clarkii* (FAO, 2013). Freshwater crayfish production has increased up to 8000 tons in Turkey and has become dominant in the world freshwater crayfish market with comprising approximately 70% of the market. However, in the following

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years, the amount has significantly decreased due to the freshwater crayfish plague, extreme fishing rates, and water pollution and has decreased down to 532 tons since 2013 (FAO, 2013). Production of crayfish dramatically reduced gradually in Turkey and in the world year by year. Therefore, it is attempted to increase the production of crayfish through rearing to meet the demands.

Apart from fishing, freshwater crayfish production is also practiced with freshwater crayfish aquaculture methods in the world. Although these methods can vary from species to species, they can be ranked as monoculture, alternate, extensive, and intensive. Depending on the species and rearing method, the production amount can increase up to 3000 kg per hectare. One of the freshwater crayfish rearing methods is the rice-crayfish alternate culture system. Meeting of rice and crayfishes began with the invasion of the crayfishes to rice fields through the destroyed banks of rice fields as a result of a flood. Initially, the relationship between rice and freshwater crayfish was evaluated as a negative one because of such reasons that crayfishes fed from rice sprouts; they increased the turbidity because of their bioturbation feature and damaged the rice roots because they were able to nest in very deep places. Despite all these, methods that can integrate both rice and crayfishes into the same field were studied. In the successive periods, cultivation and rearing of both stocked products was achieved. In the present day, it is not possible to stock *Astacus leptodactylus*, native species of Turkey, in the fields where rice production is practiced. However, since this species can nest from the ground of the water to the depths of ground, it has a significant advantage with regard to rice and polyculture (Berber, Yıldız, & Türel, 2011). Regarding the rice cultivation and the utilized fields, according to Turkish Statistical Institute's records, by the year 2015, 1158561 da fields have been used for rice cultivation in all around Turkey; and, 110519 da fields have been used in Çanakkale (TÜİK, 2016). Considering that 1-2 ton ha^{-1} crayfish production can be achieved through rice-crayfish rotation in the world, there is a significant potential in Çanakkale and Turkey.

Some aspects of *A. leptodactylus* such as biological, morphometric, population characteristics were investigated in Turkey. Köksal (1980) investigated the population characteristics of *A. leptodactylus*. Balık, Özkök, and Özkök (2002) investigated the length composition and stocking density. Harlıoğlu and Harlıoğlu (2005) and Büyükçapar, Alp, Kaya, and Çiçek (2006) investigated meat yields and morphometric characteristics of *A. leptodactylus*. Berber and Balık (2006) investigated growth and morphometric characteristics of *A. leptodactylus*. Balık, Ustaoğlu, Sarı, and Berber (2006) and Berber and Mazlum (2009) investigated spawning efficiency. Deniz (Bök), Harlıoğlu, and Deval (2010) and Deniz (Bök), Aydın, and Ateş (2013) investigated morphological characteristics of *A. leptodactylus*. Aydin, Harlıoğlu, and Deniz (2015) investigated biological and population characteristics of *A. leptodactylus*. However, there is no direct study on rice.

In this study, the first experiment was carried out with regard to the applicability of the rice-crayfish alternate rearing methods, which have been successfully practiced all around the world for nourishing juveniles. Long hatching period (3 summers) of *A. leptodactylus*, one of native species of Turkey with a commercial potential was considered as a crucial factor preventing investment. In addition to this, since the potential of Turkey's inland water sources is high, as a worldwide-accepted method of producing freshwater crayfish, aquaculture method, which is practiced through juvenile production in the controlled environment and vaccination to natural or artificial reservoirs when they reach a specific size, is practicable for Turkey. In this study, the acquired data were compared with the results of previous studies related to crayfish rearing; and its practicability as a new method for Turkey was evaluated.

RESEARCH PAPER
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Materials and Methods

In this study, freshwater crayfish (*A. leptodactylus* Eschscholtz, 1823) taken from Porsuk Dam Lake, their spawner and juvenile individuals obtained from them were used. Fyke nets with 5 hoops, which were used to catch freshwater crayfish samples, and a net was placed between two fyke nets; the width of mesh size was 34 mm. Fyke nets were placed in different locations of the pond at the beginning of May, and 3 days later, they were taken and controlled; and, female freshwater crayfishes with spawns were detected for transfer. Approximately 74 spawner crayfishes were taken to Çanakkale Onsekiz Mart University, Faculty of Marine Sciences and Technology, Dardanos Marine Species Research and Application Centre via 10 liters styrofoam boxes, which had wet sponges and ice bags on their bottom.

Porsuk Dam where freshwater crayfish individuals were hunted is a dam, which was built in Porsuk Brook in Eskişehir between 1966 and 1972 with the aim of irrigation, flood control, and potable water supply. It is formed by the springs, which come out from the Northeast of Murat Mount and join in the North of Altıntaş. It joins with Felent Brook when it passes through Northeast of Kütahya Plain. Porsuk Dam was built at the point where Porsuk Brook exceeds the city border. The dam itself is situated in Eskişehir while the lake is within the borders of Kütahya. Within the dam lake, the existence of freshwater crayfish (*A. leptodactylus*), common carp (*Cyprinus carpio*), roach (*Rutilus rutilus*), and barbus (*Barbus plebejus*) was reported (Çiçek & Koparal, 2001; Emiroğlu, Yetim, & Kuyumcu, 2001). Fishery activities and acquisition rights of the pond have been carried out by S.S. Sofca, Sobran, Sabuncupınar, İncesu, Kalburcu Farm Water Products Cooperative.

Following transport from Porsuk Dam Lake in May of 2013, freshwater crayfish spawners with spawn were placed into circular tanks, which were 1 m depth, 1.5 m diameter, and 140 l capacity with 5 spawners for each tank while water depth was 40 cm. In the first week of June, eggs began to crack and juvenile freshwater crayfish individuals began to hatch. After juveniles hatched from the spawners, they were put into 12 glass fish tanks, which had 0.5 m^2 surface area and 100×50×100 cm (height, width, length) sizes. Spawners, all pleopodal eggs of which were cracked, were taken out of the cage to prevent cannibalism. Approximately 10 days later, juvenile freshwater crayfish individuals were measured for length and weight and placed into aquariums. Size measurement of both freshwater crayfish spawner and juvenile individuals was carried out with Minalto calliper with a sensitivity of 0.01 mm. In this measurement, the length from rostrum point to the telson point was taken as a basis. Weights of the freshwater crayfish spawner were measured by a 0.01 g-sensitive weighing scale; and, weights of the juvenile individuals were measured with a Schimadzu, 0.0001 g-sensitive weighing scale (Bromage & Robert, 1995; Holdich, 2002). Juvenile freshwater crayfishes, which had been kept in aquariums until they were placed into the rice field, were fed with a powdered trout feed during this process. After rice field was disinfected with various pesticides against weed and harmful insects resulting in a harmless environment for juvenile individuals (around 15 days later), they were placed into the rice fields, which were full of water. Juvenile individuals were randomly placed into same quality of 3 boxes, each of which contained 50 individuals. Juvenile individuals, which stayed in rice fields for about 2 months, were removed from the cages 1-2 days before the rice harvest, and their lengths and weights were determined.

To determine the growth, specific growth rate (SGR) was used in this study. In order to compare the growth rates, average weights of crayfishes were used. At the end of the experiment, SGR values for all groups were calculated through the following formula (Holdich, 2002).

$$\mathbf{SGR}=\frac{\ln W_t-\ln W_i}{t}\times 100$$

W_t= Final average crayfish weight (g), W_i= First average crayfish weight (g), t= the number of experiment days.

At the end of the experiment, survival rate (SR) in the groups was determined through the following formula (Ravi *et al.*, 1999).

$$\mathbf{SR}=\frac{\text{The number of crayfish that can survive during the experiment}}{\text{The number of crayfish in the beginning of the experiment}}\times 100$$

Juvenile freshwater crayfish individuals were placed in 3 cages, each of which contained 100 individuals, which were specially designed as cubes having one 1×1×1 m sized side was open; and these cages were placed to a 10 × 50 m sized rice field near Pınarbaşı Village, which was determined before (Figure 1). After rice field was disinfected against weed and harmful insects, the cages were placed into the fields on 11.VII.2013 and were taken out on 16.IX.2013 before the rice harvest.

Physico-chemical parameters of rice field's water (pH, dissolved oxygen, conductivity, and temperature) were measured in situ during the field survey, via YSI Pro 2030 and WTW 3110 devices.

In the study, the growth values in terms of length and weight of freshwater crayfishes during the experiment were compared with the results of previous juvenile rearing experiments through using meta-analysis (CMA, Comprehensive Meta-Analysis) (Borenstein, Hedges, Higgins, & Rothstein, 2009). Studies about the comparison of two groups with regard to freshwater crayfish rearing were chosen from the literature. Through Comprehensive Meta-Analysis (CMA) program by using arithmetic average, variance and sample size values of 12 studies, which were deemed appropriate to be included in the analysis, meta-analysis was carried out. The results of the analysis were discussed by taking sample size as 0.5.

The effect size indicates the differences between the new and old methods, which are determined by using previous studies, related to the topic and is calculated depending on standard deviation. Since this is a statistical analysis, it can give various results in accordance with different sample numbers, average, and standard deviation values; therefore, lower and upper limits should be specified. In the graphic, the middle point of the lines indicates standard difference; starting point indicates the lower limit; whereas endpoint indicates the upper limit. If there is no study related to the research subject, the effect size is calculated with a pilot study. Generally Cohen's d (one of the effect size formulas) is used. If d value is lower than 0.2, it means that effect size is weak; if d value is 0.5, it means that effect size is at a medium level; and, if d value is higher than 0.8, it means that effect size is powerful (Çarkungöz, 2009).

Since in studies, including biological based ones, results taken from only one analysis cannot lead the researchers to a healthy and reliable evaluation, this analysis is considered as a re-analysing method (Mosteller & Colditz, 1996). When the essential point for all traditional methods is significance test, in the general concept of meta-analysis, essential points are the specification of the effect size used in researches, of their effects, and of the effect direction (Lipson & Wilson, 2001). It means that aims of meta-analysis are to combine the results acquired from different studies, conducted on the same topic in different places and times, to reveal reliable information; to increase the statistical significance level; to provide the same level in sub-samples, which diverge extreme points, to search contradictions between the results, if there is any, and to search them with their reasons; and, to determine the criterion of effect size and parameter estimations with their confidence intervals (Çağatay, 1994; Akçil, 1995).

www.trjfas.org
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Results

Physico-Chemical Characteristics of Rice Field's Water

Before juvenile freshwater crayfish individuals were placed into the cages in rice field and taken out after, temperature, dissolved oxygen, salinity, and pH values of the environment were determined in situ (Table 1). Measurements were carried out in two different points and in cage, and through the waterway that brings water to the field. The stations were not significantly different from each other with regard to the results of the mentioned parameters ($P > 0.05$).

Growth in Freshwater Crayfishes

Average total lengths and total weights of the spawner freshwater crayfishes were calculated as 104.33 mm ± 1.55 and 39.01 g ± 1.681, respectively. Total lengths of the spawner ranged from 79.77 mm to 138.5 mm; and their total weights varied between 15.59 g and 87.12 g. The number of the pleopodal eggs, which were incubated by female freshwater crayfish spawner, showed variation between 30 and 450 with an average number of eggs of 136. Average total lengths and weights of the juvenile freshwater crayfishes were determined as 11.08 ± 0.122 mm and 0.04 ± 0.004 g, respectively. Average total lengths and total weights of the juvenile individuals were calculated as 37.46 ± 0.863 mm and 1.46 ± 0.094 g, respectively (Figure 2). Survival rate of the juvenile individuals taken from the cages was found as 64.67%.

Meta-Analysis Results

Meta-analysis was conducted for both length and weight by using arithmetic average, standard deviation and sample number of the data determined from literature search results. Standard errors, standard deviations, variances, minimum and maximum limits, and P and Z values were calculated for mean values in meta-analysis and were given in Table 2 and Table 3. Effect sizes of the experiments which were calculated to have 95% reliability were given for average lengths in Figure 3 and for average weights in Figure 4. Effect size is a statistic, which shows how the experimental group shows differences compared to the previous studies; and is calculated based on standard deviation. Effect size requires minimum and maximum limits due to it can give various results in accordance with different sample numbers, average, and standard deviation values offered for the same experiment. In the Figure 3 and Figure 4, starting point indicates the minimum limit and endpoint indicates the maximum limit whereas the middle point of the lines indicates the standard deviation of the mean. In this regard, the studies, which had the effect size placed within minimum and maximum limit, were presented in Figure 3 and Figure 4. In terms of average lengths, the results of Berber (1999) and present study were statistically different from other studies. Both studies, also, showed differences compared to other studies with regard to effect size. In this regard, since the standard deviations of the effect size in the other studies were so low, the effect size was not presented in Figure 3. In terms of average weights, data acquired from Mazlum (2007), Kulesh and Alekhnovich (2010), Mazlum and Uzun (2008), Berber (1999) and present study were found statistically different. With regard to effect size, it was also found that they had higher values compared to other studies (Figure 4).

www.trjfas.org
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Discussion

Studies regarding crayfish rearing started around 1930s, and their mass production dates back to 1970s. Freshwater crayfish rearing in Europe dates back to 1850s-1900s and their mass production rates increased after *Pacifastacus leniusculus* species were transferred to the area in Eastern Europe, Germany and France. Although the freshwater crayfish rearing had been practiced through rudimentary methods initially, as a result of the developments in recent years, the freshwater crayfish has become a product, which is continuously under production. Within these experiments, the crayfishes were aimed to be reproduced in the lakes. Although numerous extensive production methods have been developed for the freshwater crayfish production, extensive and semi-extensive production types are preferred due to both high cannibalism and high costs of the system. Within these production methods, the juvenile individuals were aimed to be stocked in natural and unnatural reservoirs with different sizes or the natural stocks were aimed to be enriched (Nyström, 2002; Diler, 2013).

Another extensive production method for freshwater crayfish is the polyculture, which is performed with various economical plants. Rice is the most important one among these economical plants. Freshwater crayfish was first begun to be produced with rice in Texas and Louisiana states of America. After these studies were brought to a certain level, main control strategies related with the freshwater crayfish farming in rice fields were determined and this constituted the basis for the applications in use today (Thomas, 1965; Viosca, 1966; LaCaze, 1981). First scientific findings about the growth and production of freshwater crayfish in the rice fields were presented by Thomas (1965). Feeding characteristic of the crayfish underlies the production of freshwater crayfish and rice alternately. Freshwater crayfishes are described as herbivore, detritivore, omnivore and sometimes carnivore (Momot, 1995). A large group such as living and blighted plants, cereals, algae, and from small invertebrates to the vertebrates such as small fish species is known to be in their nutrition regimen. In order to increase growth to the highest level in recent years as an addition to the nutritional sources given above, it is also known that they also need to be fed with nutritional sources with high protein levels (McClain, Neill, & Gatlin, 1992; Momot, 1995). It is known that although the crayfishes need baits which are rich in protein, the can also keep living with completely or half blighted plant sources and bottom sediments which are the last products of the organic destruction. In the ponds where the mass production is performed, enough number of invertebrates is needed to deplete the continuous detritus inflow. Putrefaction of the plant organisms must be perpetual and continuous during the production season.

Large amount of dissolved herbal materials, which are not totally consumed, are decomposed. Excessive amount of blighted material also negatively affects water quality characteristics. However, lack of this material results in a decrease of the nutrition sources for crayfishes and other organisms. In the alternately production of freshwater crayfish with rice plant, plant material left after rice harvest and stooling contributes to the nourishment of the freshwater crayfishes. When immature rice plant is left under water, its older leaves die and fall in the water slowly. Thus, the plant contributes to the detritus while growing up and ripening. As the parts left above the water die in the winter, more contribution is made to the detritus. On the contrary, mature rice drops its leaves in a short time after the rise in the water level. This helps to prevent a faster disintegration and possible scarcity of food (McClain & Dunand, 1994). The most important advantage of this method is the effective use of the field, work force and equipment. Besides, seasonal products and two different harvests each year can be given as other advantages. In this production type, generally crayfish production and harvest following the rice harvest is performed.

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This study is the first research applied in Turkey in terms of joint production method for rice and crayfish. In the determination of the project as a concept, the facts that many localities within the Turkey's inland waters are suitable for the freshwater crayfish in terms of ecological conditions and particularly stocking these water sources with juveniles is seen as an ideal production method have been effective. Temperature, pH and dissolved oxygen values measured at rice field at the beginning and the end of the research are known as highly effective ecological factors for the lifecycles of the freshwater crayfishes. Freshwater crayfishes can easily keep on living in lakes, ponds, dams and rivers that are the fresh water habitats under the effect of various environmental factors. Geographical and environmental factors affect the population density and growth as well as lifecycles of various species. They also affect the population diversity of some species (Momot, Gowing, & Jones, 1978). Physico-chemical factors at certain levels play an important role for the freshwater crayfishes in the physiological adaptation (Hill & Lodge, 1994). Temperature is an essential factor for living organisms. It has an important effect in survivability of the creatures and their behaviours, nourishments, growth, metabolisms, reproduction, local and geographical distributions (Ramirez, Herrera, Sandoval, Sevilla, & Rodriguez, 1994; Whitledge & Rabeni, 2003; Begon, Townsend, & Harper, 2006). The species is able to tolerate the wide range temperature values (4-32 °C) (Köksal, 1988). In an experiment performed on the second period young freshwater crayfish juveniles, lethal temperature average was found to be 36.4 °C (Firkins, 1993). Optimal temperature level in which the growth activity of the creature is observed to be best was determined as 21.8 °C (Nyström, 2002). Optimal water temperature value for the rearing of the *A. leptodactylus* species under the culture conditions was determined to be between 20-25 °C (Köksal, 1988). For the temperature values, it was found out that water characteristics of the rice field are not at a level to constitute a risk for the freshwater crayfishes. Besides, optimal water temperature level specified within the scope of the literature was found out to be between 20-25 °C.

As many abiotic factors affect the life of the creatures, pH level of water is highly effective on the distribution and density of some aquatic creatures (Bradford, Cooper, Jenkins, Krantz, Sarnelle, & Brown, 1998). It is stated that in some rivers and lakes where the pH level is under 6 some fish species cannot be found. Low pH level means activation of toxic compounds. This results in the formation of habitats, which are not appropriate for the species. The factors, which have the most effective chemical stress on the fishes and some other aquatic invertebrates (chemical stressors), are the low pH values and high aluminium contents resulting from the acidifications occurring after the human activities (Nyström, 2002). pH affects the population density of the freshwater crayfishes in the lotic habitats in two ways. Acidification, while showing a negative effect on the individual growth of the crayfishes, shows a positive effect on the population growth. The number of living organisms in the waters with low pH values is lower than the usual. Therefore, important changes occur in the food chain interactions. Specially, the decrease in the number of the fishes living in the same environment decreases the predation stress on the freshwater crayfishes (Seiler & Turner, 2004). The factors for the extinction of *Orconectes virilis* species in the Plastic Lake (USA) can be explained as high acidity on the hatchery process of this species, deterioration of re-calcification and the prevalence of infectious microorganisms in the environment (France & Collins, 1993). Acidification can also cause an increase in the receiving of trace elements such as mercury (Hg) and manganese (Mn). Therefore, this may have a toxic effect by interacting with other elements in the freshwater crayfishes (France, 1987). Optimal pH levels for the freshwater crayfishes have been noted between 6.5 and 8.5, can go down to a minimum level of 6 (James & Huner, 1985; Alderman & Wickins, 1996). Optimal pH level was found between

www.trjfas.org
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6.5 and 8 for *A. leptodactylus,* which could even survive between 3 and 12 pH levels (Köksal, 1988). Köksal, Aydın, and Seçer (1998) pointed out that the tolerance of *A. leptodactylus* freshwater crayfish to pH increased and noted lifetime of the mature individuals 10.5 h at a pH 1.5, 14 days at a pH 5, consistent to be at pH levels between 6.7 and 8.5. The pH measurement values recorded during the research were within tolerable levels for the freshwater crayfish juvenile individuals, which were subject to the experiment.

Low dissolved oxygen concentration with its rapid fluctuation is one of the main problems in natural and unnatural environments where crayfish rearing is performed (Huner, 1988). Oxygen content is a limiting factor for the growth of the freshwater crayfishes. Deceleration in growth and nourishment generally occur in the crayfishes, which are continuously exposed to low oxygen concentrations (Chien & Avault, 1983). It has been noted that freshwater crayfishes get under stress while oxygen level is below 3 mg L^{-1} in rearing units. It has been found that freshwater crayfishes come up to the water surface for using atmospheric oxygen in the waters below 2 mg L^{-1} (Huner & Barr, 1991). It has been determined that *A. leptodactylus* species, which shows natural distribution also in our country, can tolerate a minimum concentration of 3.97 mg L^{-1} and needs an optimal oxygen concentration above 6 mg L^{-1} (Huner & Barr, 1991; Merrick & Lambert, 1991; Ackefors & Lindqvist, 1994; Wingfield, 1998; Nyström, 2002). Dissolved oxygen values specified within the study carried out during the summer season range from 1.66 mg L^{-1} and 2.4 mg L^{-1}. According to the literature information on *A. leptodactylus* freshwater crayfishes, they can keep on living at an oxygen concentration 3.97 mg L^{-1} with an optimal level above 6 mg L^{-1}. Dissolved oxygen levels that were determined through our research are quite low compared with the mentioned values above. Although it is known that low dissolved oxygen values are limiting factors for the freshwater crayfishes and even cause slower growth and decreased nourishment, when the growth values obtained through our study are compared with the other literatures, no significant difference was found. Besides, low oxygen level is thought to cause a decrease in the survival rate of the freshwater crayfishes (51.33%).

In the research, initial average total heights and weights of the juvenile freshwater crayfishes, which were kept in the cages placed in the rice field, were determined as 11.08 ± 0.122 mm and 0.04 ± 0.004 g, respectively. Average heights and weights when the juvenile freshwater crayfishes were taken out of the field just before the rice harvest were relatively 37.46 ± 0.863 mm and 1.46 ± 0.094 g. Specific growth rate (SGR) for weight and height were found as 2.87 and 1.35, respectively. Uzun (2007) tried three different stock densities (10-50-100 individuals per m^2) in a study for 120 days and calculated the SGR as 1.16, 0.95 and 0.89, respectively. Köksal (1982) stated that the second period *A. leptodactylus* juveniles, whose initial average weight and stock density were 39.27 mg and 130 juveniles per m^2, respectively, were fed with salmon pellet baits and filamentous green algae reached the weight of 430.84 – 476.16 mg and total height of 25.03 – 26.32 mm after 90 days with a survival rate of 44.23%. It is seen that quite different results are obtained when analysing the studies carried out in our country and worldwide on *A. leptodactylus*. In these studies, the influence of exposing the juvenile freshwater crayfishes to different temperatures, feeding with baits with different protein levels and rearing at different stock rates on growth and development levels are presented in Table 4.

Survival rate of the juvenile individuals removed from the cages was determined as 64.67%. It is thought that the survival rate of the juvenile individuals is influenced by the difficulty of catching the juvenile individuals during harvesting.

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It is possible to find various studies performed on the same topic and by different researchers at different places and time. Although similar results are generally obtained from these studies, it is sometimes also possible to get rather different results in the literature depending on characteristics analysed. Abramson and Abramson (2001) stated that validity of the individual studies using similar characteristics with meta-analysis could be tested and strengthened in a sense, and it was possible to determine the source of the differences in those with different findings. Meta-analysis was performed to evaluate the results of the studies carried out until nowadays on the rearing of juvenile crayfish and the results of the present study, especially for height and weight after the experiments. Studies having the similar characteristics with our study were specified within those to be included in the meta-analysis. Especially those with close height and weight values and experiment durations were assessed. Results of our study and Berber (1999) were found to be statistically different from others in terms of average heights. Likewise, these two studies also differ from others in terms of effect size. Differences between these two studies and others can be due to the facts that relatively unnatural environments were used in the rearing processes and environmental characteristics were used without any external feeding. Thus, if the nutritional composition of the environment is at an adequate level for the crayfishes, a significant difference may appear in the growth. In terms of average weights; the data obtained from the studies of Mazlum (2007), Kulesh and Alekhnovich (2010), Mazlum and Uzun (2008), Berber (1999) and this study were found to be statistically quite different. The size effect values of these studies are close to each other but are greater than those of other studies (Table 4). The different findings can be attributed to no use of external feeding in the study of Berber (1999) and the present study and the use of high protein diets and water rich in calcium in other similar studies.

The reasons for the lack of the size effect of the studies, which were not presented in Table 3 and can be small standard deviations, body size of individuals, feed materials, water sources and differences in the duration of the studies. However, the increase in the number of crayfish studies will provide more comprehensible results from meta-analysis studies.

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Table 1. Parameters determined at the beginning and at the end of the study

Parameters	Initial (11.VII.2013)	Final (16.IX.2013)
Temperature (°C)	25.6	20.5
Dissolved Oxygen (mg L^{-1})	1.83	2.25
pH	8.2	8.1
Salinity (ppt)	2	2

Table 2. Meta-analysis results for average lengths

References	Standard Deviation	Standard Error	Variance	Lower Limit	Upper Limit	Z	P
Erkebay, 2004	-2.739	0.359	0.129	-3.444	-2.035	-7.621	0.000
Uzun, 2007	-24.835	1.707	2.914	-28.181	-21.490	-14.550	0.000
Mazlum,2007	-8.527	0.413	0.170	-9.337	-7.718	-20.656	0.000
Güner and Mazlum, 2010	-4.417	0.276	0.076	-4.959	-3.875	-15.979	0.000
Şirin, 2010	-11.409	0.831	0.691	-13.039	-9.780	-13.727	0.000
Köksal, 1985	-19.924	1.837	3.375	-23.525	-16.324	-10.846	0.000
Kulesh and Alekhnovich, 2010	-36.380	2.181	4.755	-40.654	-32.106	-16.683	0.000
Mazlum *et al.*, 2011	-11.108	0.740	0.547	-12.558	-9.658	-15.013	0.000
Koca *et al.*, 2011	-17.621	1.152	1.327	-19.879	-15.363	-15.296	0.000
Mazlum and Uzun, 2008	-36.219	2.872	8.249	-41.848	-30.590	-12.611	0.000
Berber, 1999	0.000	0.200	0.040	-0.392	0.392	0.000	1.000
Present Study	-0.177	0.259	0.067	-0.686	0.331	-0.684	0.494

RESEARCH PAPER
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ISSN 1303-2712
Turkish Journal of Fisheries and Aquatic Sciences
DOI: 10.4194/1303-2712-v18_2_12

Table 3. Meta-analysis results for average weights

References	Standard Deviation	Standard Error	Variance	Lower Limit	Upper Limit	Z	P
Erkebay, 2004	-2.177	0.323	0.104	-2.749	-1.485	-6.654	0.000
Uzun, 2007	-1.690	0.351	0.123	-2.378	-1.003	-4.820	0.000
Mazlum,2007	-1.217	0.167	0.028	-1.545	-0.889	-7.279	0.000
Güner and Mazlum, 2010	-2.263	0.191	0.036	-2.637	-1.889	-11.853	0.000
Şirin, 2010	-2.273	0.261	0.068	-2.885	-1.862	-9.091	0.000
Köksal, 1985	-21.981	2.023	4.093	-25.947	-18.016	-10.865	0.000
Kulesh and Alekhnovich, 2010	-0.423	0.171	0.029	-0.758	-0.088	-2.475	0.013
Mazlum *et al.*, 2011	-3.988	0.316	0.100	-4.607	-3.370	-12.637	0.000
Koca *et al.*, 2011	-1.473	0.206	0.042	-1.876	-1.069	-7.154	0.000
Mazlum and Uzun, 2008	-0.547	0.228	0.052	-0.993	-0.100	-2.400	0.016
Berber, 1999	-0.223	0.201	0.040	-0.617	0.170	-1.114	0.265
Present Study	-0.021	0.259	0.067	-0.528	0.487	-0.080	0.937

RESEARCH PAPER

Turkish Journal of Fisheries and Aquatic Sciences

www.trjfas.org
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Table 4. Rearing studies on *A. leptodactylus* freshwater crayfish

References	Initial		Finish		Duration (day)
	Length (mm)	*Weight (g)*	*Length (mm)*	*Weight (g)*	
Köksal, 1982		0.039	25.03-26.32	0.43-0.48	90
Balık and Ustaoğlu, 1983	8.8	0.03	32	0.99	83
Köksal, 1985	11.3	0.041	20.78	0.2	45
			20.64	0.198	
			20.6	0.2	
			20.8	0.21	
			20.73	0.21	
	21.1	0.22	34.88	1.08	60
			34.96	0.96	
			37.41	1.22	
			30.46	0.7	
	11.22	-	26.32	0.48	90
		-	30.37	0.87	
	21.1	0.22	43.7	2.1	120
			47.82	3.3	
Köksal, 1988			29.17-36.31	0.6-1.2	60
Köksal *et al.*, 1992	16	0.07	25.6	0.56	120
			30.1	0.91	
			30.7	0.98	
			33.8	1.22	
Erdem, 1993	8.3	0.03	26	0.4	90
Kalma, 1996			45	2.7	330
Köksal *et al.*, 1998	11.2	0.067		0.68	90
Berber, 1999	11,98	0.04	32.34 (♂)	0.84	90
			31.19 (♀)	0.77	
			35.8 (♂)	1.25	
			34.1 (♀)	0.98	
Erkebay, 2004	14.89	0.073	24.21	0.33	90
	14.89	0.072	23.65	0.30	
	14.84	0.073	22.40	0.25	
	14.87	0.075	27.45	0.48	
Ulikowski *et al.*, 2006	12	0.029	29.2	0.799	92
Uzun, 2007	12	0.02	48.3	2.27	120
			37.33	1.4	
			35.1	1.08	
Mazlum, 2007	11,4	0.02	36.05	1.26	120
			35.5	1.16	
			33.3	0.91	
Mazlum and Uzun, 2008	14	0.025	31.3	0.85	90
			35.4	0.97	
			41.7	1.3	
Aydin, 2010	10.1	0.067	36.6	0.648	120
Güner and Mazlum, 2010	10.8	0.045	29.4	0.38	90
			27.4	0.3	
			27.9	0.32	
			24.6	0.23	
Kulesh and Alekhnovich, 2010	10.1	0.028	43.6	2.69	108
			46.2	3.34	
Mazlum *et al.*, 2011	10.8	0.045	23.44	0.86	90
			28.4	1.02	
			21.93	0.62	
			21.22	0.5	
Türel, 2012	11.08	0.04	28.29	0.343	90
	10.74	0.045	31.51	0.395	
	11.09	0.040	29.93	0.380	
	11.06	0.040	27.57	0.367	
Present Study	11.08	0.04	37.46	1.46	68

RESEARCH PAPER

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Figure 1. Rice field and cages (a: rice field; b: freshwater crayfish cages placed in the rice field)

Figure 2. Freshwater crayfish individuals (a: individuals in the cages; b: individuals taken from the cages)

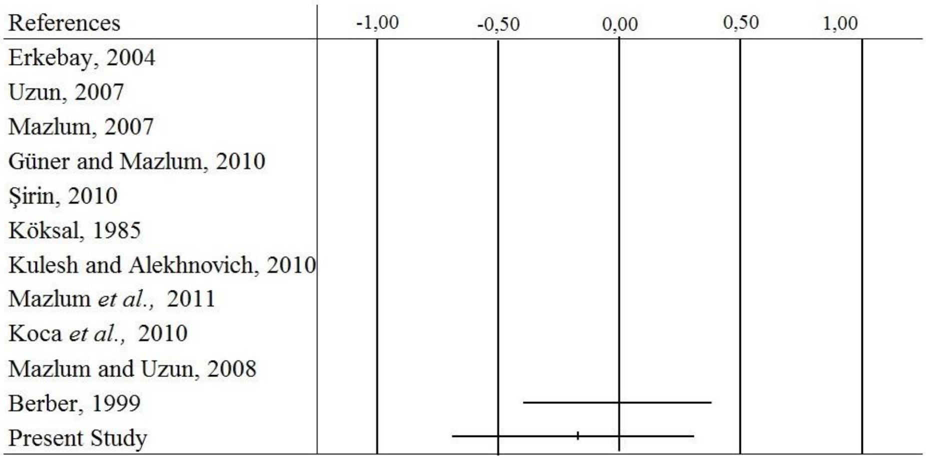

Figure 3. Effect size of the studies with regard to average lengths

RESEARCH PAPER
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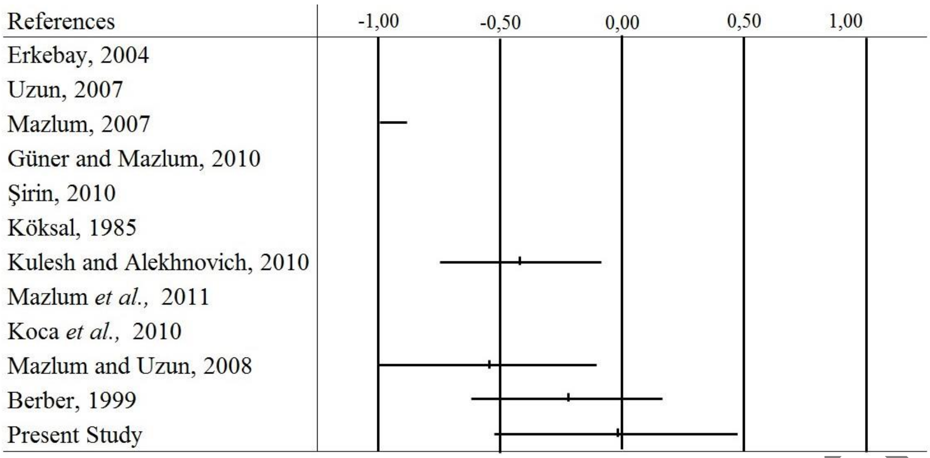

Figure 4. Effect size of the studies with regard to average weights