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Relative Efficiencies of Live, Dry and Mixed Food Diets for Larval Rearing of Tigris Scraper (*Capoeta umbla*) and the Influence of Stocking Density on Fry Growth Characteristics

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Abstract

In this research, larval growth features by applying different diets and growth characteristics of fry at different stocking densities were studied under controlled conditions for the Tigris scraper (*Capoeta umbla*). In the first experiment, the growth and survival rates of Tigris scraper postlarvae were evaluated under three different diet regimes over 21 days. The highest mean total length was 24.04±0.27 mm in the group L1 fed solely *Artemia* nauplii, and the lowest mean total length was 17.89±0.16 mm in the group L2 fed only dry feed. The highest mean specific growth rate was in the L1, and the lowest mean specific growth rate was in the L2. In the second experiment in which the growth characteristics of fry were investigated at different stocking densities for 98 days, the highest mean live weight was found in S1 with 2.819±0.157 g and the lowest mean live weight was determined as 0.859±0.073 g in S5. The highest mean specific growth rate was in S1, while the lowest rate was in S5. High stocking densities were found to be disadvantageous for growth of *C. umbla* fry. The findings suggest that successful rearing of Tigris scraper postlarvae and fry is feasible under controlled conditions.

Introduction

Sustainable aquaculture plays a crucial role in actively protecting endangered fish species. Raising larvae under controlled conditions is one of the most effective methods for stock enhancement which is directly dependent on the release of appropriate-sized and good quality fry into the environment at a suitable time (Cowx, 1994; Sarkar et al., 2006; Ross et al., 2008; Zarski et al., 2011). Apart from fish and other aquatic products that are produced mainly as seafood, there are also conservation aquaculture practices developed for non-commercial fish species (Turkowski et al., 2008; Ciesla et al., 2014; Nowosad et al., 2016; Kucharczyk et al., 2019). Fish or invertebrates are produced through such aquaculture activities for rivers, lakes, seas and oceans. (Kucharczyk et al., 2020). One of these species in Türkiye is the Tigris scraper (*Capoeta umbla*). It is an economic species that has an important place in the inland fisheries of Eastern Anatolia. The decrease in Tigris scraper production through fisheries in recent years shows that the natural stocks of this species should be supported by stock enhancement.

Factors such as feed type have a direct impact on growth and can vary significantly among various species (Zarski et al., 2011). Formulated microfeeds have been tested with variable success as starter feeds for larvae (Lahnsteiner et al., 2012). Microfeeding significantly reduces rearing costs and saves feeding time. Larvae of some freshwater fish species can be fed mixed feed from day one without significant impact on their survival, but other freshwater species need to receive

digestive enzymes through live food (Kujawa, 2004; Wolnicki, 2005; Zarski et al., 2011). Most cyprinid larvae require live food during the first few days of exogenous feeding (Wolnicki and Gorny, 1995; Kujawa, 2004; Wolnicki, 2005). This situation is associated with an incompletely formed digestive tube that is dependent on exogenous enzyme digestion. Cyprinid larvae belong to the third group, characterized by short and insufficient developed digestive tracts with poor enzyme composition (Dabrowski, 1984). It has been reported that feeding larvae only starter food results in mortality in most cases due to loss of appetite, growth stall and a significant reduction in disease resistance (Grudniewski, 1980; Kujawa, 2004).

In recent years, great progress has been observed in fish larvae-rearing techniques. However, different methods still need to be developed for many fish species (Kujawa et al., 1999). It has been proven that fish larvae are sensitive to feed, especially at the beginning of exogenous feeding, and feeding based solely on dry feed reduces the condition of the larvae and increases mortality (Zarski et al., 2011). The combination of live food and formulated commercial feeds has been used successfully in feeding larvae (Lahnsteiner et al., 2012).

Stocking density has a direct impact on aquaculture and there may be significant differences among fish species (Huang and Chiu, 1997; El-Sayed, 2002; Wolnicki, 2005; Merino et al., 2007; Zarski et al., 2008; Zarski et al., 2011; Niazie et al., 2013; Usandi et al., 2019; Santana et al., 2020). Survival, growth and water quality are affected by stocking density (Imanpoor et al., 2009). Studies have been conducted on the effects of stocking density on many different fish species (El-Sayed, 2002; Sahoo et al., 2004; Kupren et al., 2011; Zarski et al., 2011; Niazie et al., 2013; Usandi et al., 2019; Santana et al., 2020). High stocking density can have negative effects on growth indices and survival in some fish species (Imanpoor et al., 2009; Usandi et al. 2019) and decreases in growth and survival rates have been reported to be largely dependent on stock density (El-Sayed, 2002; Alvarez-Gonzalez et al., 2001; Sahoo et al., 2004; Kujawa, 2004; Zarski et al., 2008; Zarski et al., 2011; Usandi et al. 2019). According to some studies, stocking density does not have any significant effect on survival (Kupren et al., 2011; Zarski et al., 2011; Niazie et al., 2013; Arifin et al., 2019). In general, it is noted that there is a negative correlation between growth and stocking density (Alvarez-Gonzales et al., 2001; El-Sayed, 2002; Zarski et al., 2008; Kupren et al., 2011; Usandi et al. 2019). Studies show that each fish species needs to be examined within its rearing conditions and biological characteristics and the optimal stocking density to be determined on a species-specific basis.

The data recorded in this study is the first and provides preliminary results for *C. umbla* larvae and fry culture. This study aimed to determine the growth characteristics of larvae subjected to different dietary treatments and to determine the growth performance of fry at different stocking densities in Tigris scraper.

Materials and Methods

Experimental Area and Ethical Statement

This study was carried out in the R&D facility of the Elazig Fisheries Research Institute, which is affiliated with the Republic of Türkiye Ministry of Agriculture and Forestry, General Directorate of Agricultural Research and Policies. This research was carried out in accordance with the permission of Elazığ Veterinary Control Institute Animal Experiments Local Ethics Committee numbered 2017/04-07 and the ethical values determined for animal experiments. A semi-recirculating system consisting of a total of 30 glass aquariums (40 liters) was used. Submersible pumps (RTRMAX, 400 W) are set to work for 15 minutes and rest for 15 minutes with a timer. Water flow rate was 40 lt/15 min. A daily natural light regime was applied.

Experiment 1. Growth and Survival Characteristics of Tigris Scraper Postlarvae in Different Diets

Larvae and Experimental Design

7-day-old larvae with a total length of 11.95–12.10 mm, with most of the yolk-sac consumed and swim bladder inflated, were used. Postlarvae were reared with freshly-hatched *Artemia* nauplii and dry feed in 7 different diets for 21 days. 300 individuals per aquarium were stocked and 7 different trial groups (L1, L2, L3, L4, L5, L6 and L7) were prepared with 3 replications with a total of 21 glass aquariums. Larvae were exposed to a natural photoperiod and fed six times per day *ad libitum*. Ten sampled larvae were observed under a microscope, and scaled photographs were taken to detect the presence of feed in the stomach of larvae. Survival rates and growth data were recorded by counting larvae and measuring their total lengths at the beginning and end of the experiment. Different diets for the trial groups were formed as follows:

Group L1: 5-10 *Artemia* nauplii·ml^{-1} for 21 days

Group L2: 300-500 µm dry feed (45% HP) for 21 days

Group L3: *Artemia* nauplii until the 5th day, then 300-500 µm dry feed (45% HP) for 16 days

Group L4: *Artemia* nauplii until the 10th day, then 300-500 µm dry feed (45% HP) for 11 days

Group L5: 300-500 µm dry feed (55% HP) for 21 days

Group L6: *Artemia* nauplii until the 5th day, then 300-500 µm dry feed (55% HP) for 16 days

Group L7: *Artemia* nauplii until the 10th day, then 300-500 µm dry feed (55% HP) for 11 days

Artemia cysts were obtained from a commercial company (Artemia Cysts Koral). Nutritional contents are as follows; moisture 8.0%, protein 53.0%, lipid 13.0%, ash 6.0%, fibre 13.0, DHA 2.31% and EPA 8.96%. 300-500 µm dry feeds with 45% HP and 55% HP ratios were

obtained from a commercial company (Hem-Yem). Nutritional contents are given in Table 1.

Morphometric Measurements and Growth Parameters

The length measurements of the larvae were taken from all groups by random sampling method that was performed on the 7th, 14th and 21st days (n=20). Weight measurements were also made at the end of the study. Measurements were taken before the first feeding in the morning. 600 µl·L^{-1} 2-phenoxyethanol was applied to the larvae for anesthesia. The live weights of the larvae at the end of the trial were weighed using a digital scale with a precision of 0.0001 g. Each larva was dewatered using a paper towel before weighing. A digital calliper was used for total length measurements in mm. The following formulas were used to calculate growth parameters (Lugert et al., 2016).

$$\text{Absolute Growth in Length (AGL)} = L_t - L_i$$

$$\text{AGRL} = [(L_t - L_i)/ L_i] \times 100$$

Where; AGRL: Absolute Growth Rate in Length, L_t: Final total length (mm), L_i: Initial total length (mm)

$$\text{Specific Growth Rate in Length (SGRL)} = [(\ln L_t - \ln L_i) / t] \times 100$$

Where; L_t: Final total length (mm), L_i: Initial total length (mm), t: Period (day)

Experiment 2. Growth and Survival Characteristics of Tigris Scraper Fry in Different Stocking Densities

Experimental Design for Fry Rearing and Feeding Protocol

Growth and survival characteristics of Tigris scraper fry at different stocking densities were examined for 98 days (June-September). The initial live weight of fry that completed the postlarval phase used in the experiment was determined as 0.099-0.107 g.

Experimental groups were prepared at 5 different stocking densities. It was determined as 40, 80, 120, 160 and 200 fry fish·40 L^{-1}. Each group consisted of 3 replicates and a total of 15 aquariums were used. 300 – 500 µm and 500 – 800 µm feeds with 45% HP were given to the fry (Table 1). *Ad libitum* feeding was applied 4 times a day.

Morphometric Measurements and Growth Parameters

At least 10 fries were sampled from each experimental group by random sampling method for live weight and total length measurements. Weekly live weight measurements were made with an electronic scale with 0.0001 g precision. 600 µl·L^{-1} 2-phenoxyethanol was applied to the fry for anesthesia. A digital caliper was used for total length measurements. The following formulas were used to calculate growth parameters (Korkut et al., 2007; Lugert et al., 2016).

$$\text{Absolute Growth (AG)} = W_t - W_i$$

$$\text{Relative Growth Rate (RGR)} = [(W_t - W_i)/ W_i] \times 100$$

Where; W_t: Final live weight (g), W_i: Initial live weight (g),

$$\text{Specific Growth Rate (SGR)} = [(\ln W_t - \ln W_i) / t] \times 100$$

Where; W_t: Final live weight (g), W_i: Initial live weight (g), t: Period (day)

$$\text{Condition Factor (KF)} = (W / L^3) \times 100$$

Where; W: Weight (g), L: Total length (cm)

Feed Conversion Ratio (FCR) = Amount of feed consumed (g) / Live weight gain (g)

Water Parameters Measurements

Water temperature, dissolved oxygen and pH values were measured twice a day with a YSI 55 Model device.

Table 1. Contents of the feeds used in the experiments

Feed Components	45% HP	55% HP
Total Protein	45.00	55.00
Total Lipid	17.00	17.00
Total Cellulose	2.31	1.94
Total Calcium	2.10	2.21
Total Phosphor	0.83	0.59
Lysine	2.39	3.25
Methionine	1.15	1.52
Total Energy kcal·kg^{-1}	4970.30	4943.30
Metabolic Energy kcal·kg^{-1}	3461.63	3602.60
Ash	8.21	13.07
Histidine	1.01	1.17
Leucine	3.70	3.89
Valine	2.09	2.51
Arginine	2.54	2.77
Tryptophan	0.47	0.57
Sodium	0.35	0.58

Statistical Analysis

SPSS statistical program (14.0) and Excel program were used to evaluate the data. Results are given as mean ± standard error. Normality and homogeneity of data were checked to comply with ANOVA assumptions. In cases where the data did not show a normal distribution and the variations were not homogeneous, Kruskal-Wallis, a non-parametric test, was applied. Evaluation of the data was tested at the $P<0.05$ significance level. One-way analysis of variance (one-way ANOVA) was used to analyze the differences, and the Duncan test was used to determine the differences between the means. Relationships between parameters are shown with regression-correlation graphs (Excel program).

Results

Experiment 1.

The average water temperature was recorded as 18.51±0.22°C and dissolved O_2 6.67±0.02 ppm. During the trial period, average O_2 saturation was measured as 69.11±0.050%, pH 8.14±0.011 and electrical conductivity 266.87±1.382 µS.

The maximum total length was recorded in the L1 group with an average of 24.04±0.27 mm, and the lowest total length was recorded in the L2 group with an average of 17.89±0.16 mm at the end of 21 days ($P<0.05$) (Figure 1, Table 2).

The highest live weight and biomass values were found in the L1 group and the lowest in the L5 group ($P<0.05$). The highest absolute growth, relative growth rate and specific growth rate were calculated in the L1 group, and the lowest in the L2 group ($P<0.05$). The highest mortality was recorded in the L5 group and the lowest mortality was recorded in the L4 group ($P<0.05$).

Experiment 2.

The average water temperature was recorded as 23.69±0.18°C. dissolved O_2 was determined as 5.98±0.02 ppm, O_2 saturation as 65.47±0.13%, pH as 7.66±0.01 and electrical conductivity as 294.48±1.196 µS during the trial period.

At the end of 98 days, the highest live weight was recorded in the S1 trial group, followed by the S2, S3, S4 and S5 groups (Table 3, Figure 2) ($P<0.05$). The highest final total length and final live weight were in the S1 group, and the lowest was 44.91±1.21 in the S5 group ($P<0.05$). There is no significant difference in terms of condition factors among trial groups ($P>0.05$).

The highest absolute growth, relative growth rate, and specific growth rate were recorded in the S1 group, and the lowest in the S5 group (Table 3) ($P<0.05$). The highest FCR was calculated in the S5 group, and the lowest FCR was calculated in the S1 group ($P<0.05$). The highest survival rate was recorded in the S2 group, while the lowest rates were observed in the S1, S4, and S5 groups ($P<0.05$). It was determined that the most biomass was in the S5 group and the least biomass was in the S1 group (Table 3) ($P<0.05$).

Discussion

The initial total length of the Tigris scraper postlarvae ranged from 11.95 to 12.10 mm, which is considered among the largest sizes reported for cyprinid species. According to research on cyprinid larvae, the total initial length of *Leuciscus cephalus*, *L. idus*, and *L. leuciscus* larvae is 7.86-9.12 mm (Kwiatkowski et al., 2008), *C. carassius* larvae is 5.49 mm (Zarski et al., 2011), and *C. carpio* larva is reported to be 5.3-6.8 mm (Kucharczyk et al., 2008). The larger size of the larva, depending on the egg size, allows the larva to pass directly to the dry feed. Additionally, it can provide the

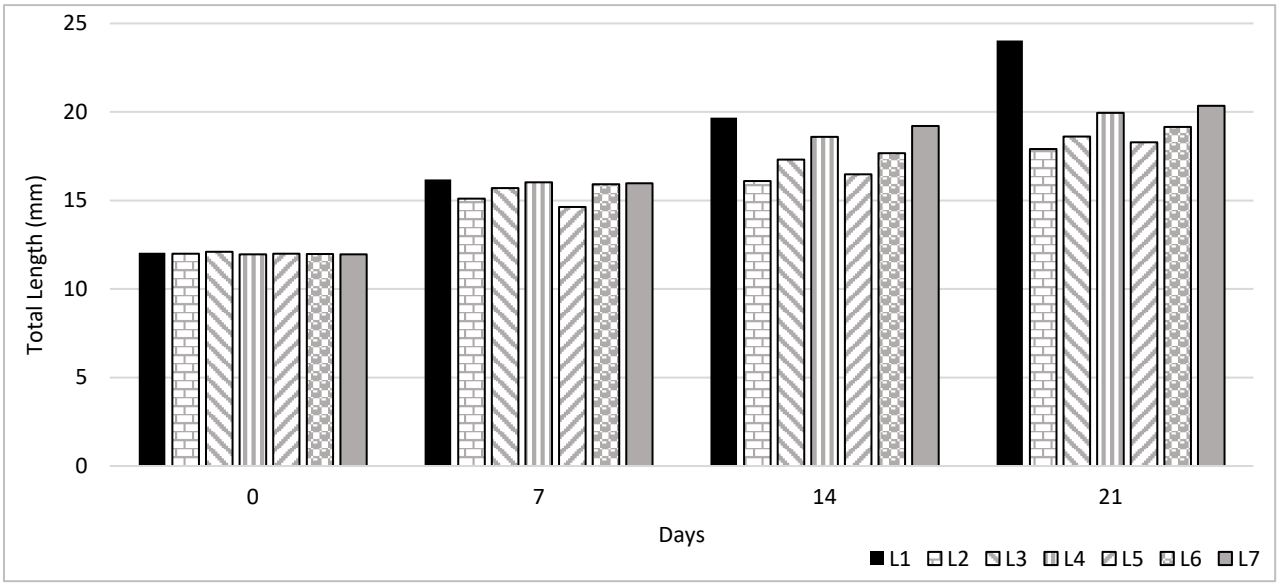

Figure 1. Total lengths of *C. umbla* postlarvae over a 21-day period.

Table 2. Growth parameters and mortalities of *C. umbla* postlarvae fed with different diets for 21 days (mean±s.e.)

Trial Groups	Day 0 Total Length (mm)	Day 21 Total Length(mm)	Day 21 Live Weight (g)	Day 21 Biomass (g)	Agl (mm)	Agrl (%)	Sgrl (%)	Mortality (%)
L1	12.05±0.065	24.04±0.27^{e}	0.122±0.0031^{d}	35.97±0.32^{e}	11.99±0.03^{g}	99.56±0.25^{g}	3.29±0.006^{g}	2.42±0.40^{b}
L2	11.99±0.132	17.89±0.16^{a}	0.048±0.0046^{a}	14.22±0.04^{b}	5.90±0.03^{a}	49.22±0.23^{a}	1.91±0.007^{a}	1.97±0.15^{b}
L3	12.10±0.115	18.58±0.12^{b}	0.047±0.0019^{a}	13.79±0.08^{b}	6.51±0.04^{c}	53.75±0.35^{c}	2.05±0.011^{c}	2.27±0.26^{b}
L4	11.95±0.095	19.95±0.15^{d}	0.058±0.0018^{b}	17.08±0.12^{c}	7.99±0.07^{e}	66.88±0.57^{e}	2.44±0.016^{e}	1.81±0.26^{b}
L5	11.99±0.157	18.29±0.14^{ab}	0.041±0.0019^{a}	11.86±0.09^{a}	6.29±0.01^{b}	52.54±0.07^{b}	2.01±0.002^{b}	3.64±0.26^{a}
L6	11.97±0.080	19.15±0.13^{c}	0.057±0.0019^{b}	16.73±0.22^{c}	7.17±0.05^{d}	59.92±0.38^{d}	2.24±0.011^{d}	2.42±0.15^{b}
L7	11.96±0.194	20.35±0.14^{d}	0.066±0.0022^{c}	19.58±0.50^{d}	8.39±0.04^{f}	70.11±0.29^{f}	2.53±0.008^{f}	2.27±0.26^{b}

*Statistical differences between values with different superscripts within the same column are significant (P<0.05).

Table 3. Growth parameters, feed conversion ratio and survival rates of *C. umbla* fry raised at different stocking densities for 98 days (mean ± s.e.)

		Experimental Groups				
		S1	S2	S3	S4	S5
Parameters	Initial Total Length (mm)	22.86±0.34	22.88±0.35	23.42±0.46	22.74±0.66	23.30±0.65
	Final Total Length (mm)	67.07±1.13^{d}	59.05±1.79^{c}	51.56±1.14^{b}	47.96±1.40^{ab}	44.91±1.21^{a}
	Initial Live Weight (g)	0.099±0.006	0.103±0.006	0.104±0.006	0.100±0.010	0.107±0.009
	Final Live Weight (g)	2.819±0.157^{d}	1.956±0.161^{c}	1.418±0.144^{b}	0.989±0.087^{a}	0.859±0.073^{a}
	Condition Factor	0.927±0.018^{ab}	0.93±0.010^{ab}	1.019±0.079^{b}	0.879±0.016^{a}	0.928±0.021^{ab}
	Absolute Growth (g)	2.721±0.012^{e}	1.853±0.012^{d}	1.314±0.009^{c}	0.889±0.006^{b}	0.753±0.013^{a}
	Relative Growth RATE (%)	2751.48±11.97^{e}	1799.18±12.19^{d}	1263.00±8.60^{c}	889.01±5.77^{b}	703.74±11.90^{a}
	Specific Growth RATE (%)	3.419±0.004^{e}	3.004±0.006^{d}	2.666 ± 0.007^{c}	2.338±0.006^{b}	2.127±0.015^{a}
	Fcr	4.55±0.03^{a}	4.63±0.02^{a}	5.65±0.02^{b}	7.54±0.04^{c}	8.56±0.14^{d}
	Survival (%)	97.5±1.44	98.75±0.72	98.33±0.48	97.5±0.36	97.5±0.29
	Final Biomass (g)	109.98±2.09^{a}	154.52±0.14^{b}	167.28±1.88^{c}	154.29±1.47^{b}	167.69±1.99^{c}

*Statistical differences between values with different superscripts within the same column are significant (P<0.05).

opportunity to start feeding with *Artemia* nauplii without the need for small-sized live food such as *Rotifer*.

According to some researchers, Cyprinid larvae should be fed with live food in the first days of exogenous feeding, so that they can digest dry feed afterwards effectively (Grudniewski, 1980; Dabrowski and Poczyczynski, 1988; Kwiatkowski et al., 2008). It is seen that the growth and growth parameters in the L1 group fed with *Artemia* nauplii for 21 days are significantly superior to the other trial groups (P<0.05). Similar results are reported on the feeding of larvae with live food in some cyprinid species (Kujawa, 2004; Zarski et al., 2011; Demeny et al., 2012; Lahnsteiner et al., 2012). Larval growth was low in feeding diets that included dry feeds (P<0.05). Kujawa et al. (1999) achieved the best growth in *L. lota* larvae with *Artemia* nauplii. Reduced growth rates were also found in most other cyprinid larvae reared solely on dry feed (Mamcarz et al., 2011; Demeny et al., 2012). In another study (Lahnsteiner et al., 2012), artificial microdiets were used in the first feeding of *L. lota* larvae, but the experiments failed and 100% mortality was recorded. These results show that the characteristics of the feed to be given in the first feeding of the larvae are vital in terms of larval growth and survival rate. The selection of starter feed is seen as one of the most critical points in intensive larval rearing (Demeny et al., 2012). The trial groups with the lowest growth and growth parameters in Tigris scraper larvae were the L2 and L5, which were fed only with dry feed during the 21 days. Although there was no significant difference between L2 and L5 (P>0.05), L5 group larvae fed with 55% HP content grew better than L2 group larvae (P>0.05). However, the survival rate was found to be lower (P<0.05) (Table 2). Wolnicki and Gorny (1995) also reported lower larval growth and higher mortality, although it is possible to use microfeed as a starter feed for larvae. Zarski et al. (2011) reported that feeding dry feed as the only food for *C. carassius* larvae caused a decrease in all parameters compared to the group fed only with *Artemia*, and that commercial feeds could not compete with live food in terms of survival rates, and larval mortality due to not receiving feed occurred in this period. It has been stated that a similar sensitivity is observed in some cyprinid larvae (Wolnicki and Gorny 1995; Zarski et al., 2011; Demeny et al., 2012). However, Mamcarz et al. (2011) report that it is possible to successfully raise *T. tinca* larvae only with dry feed, without having a negative impact on survival rates. As a matter of fact, in the present study, the mortality rates (Table 2) in L2 and L5 group Tigris scraper larvae fed only with dry feed were recorded to be very low, confirming this situation.

Mortality rates in this study remained at a very reasonable level for all groups (Table 2), with survival rates above approximately 96%, higher than the findings reported for cyprinid larvae in many researches. Survival rates of larvae of other fish species as a result of feeding *Artemia* nauplii vary between 87.5-99% (Wolnicki and Gorny, 1995; Zarski et al., 2011; Demeny et al., 2012; Lahnsteiner et al., 2012). A survival rate of 79.6-99.1% is reported in *Leuciscus* sp. larvae fed with *Artemia* for 21 days, and a survival rate of 85.1-96.1% in mixed feed groups (Kwiatkowski et al., 2008). Variations in survival rates can be attributed to species differences, larval origin (improved breed), feed type, feed size, nutritional and energy content of the feed, diet and feeding time, in line with the relevant literature.

Kujawa (2004) recommends that the feeding period of live food should be between 8-12 days. After this period, it is possible to use commercial feeds without any negative effects on larval survival. There are 4 trial groups in the study where mixed diets are applied. L3 and L6 groups are fed *Artemia* nauplii for the first 5 days followed by dry feed, while L4 and L7 groups are fed *Artemia* nauplii for the first 10 days followed by dry feed. L4 and L7 groups showed better results in terms of growth compared to other mixed feed groups (P<0.05)

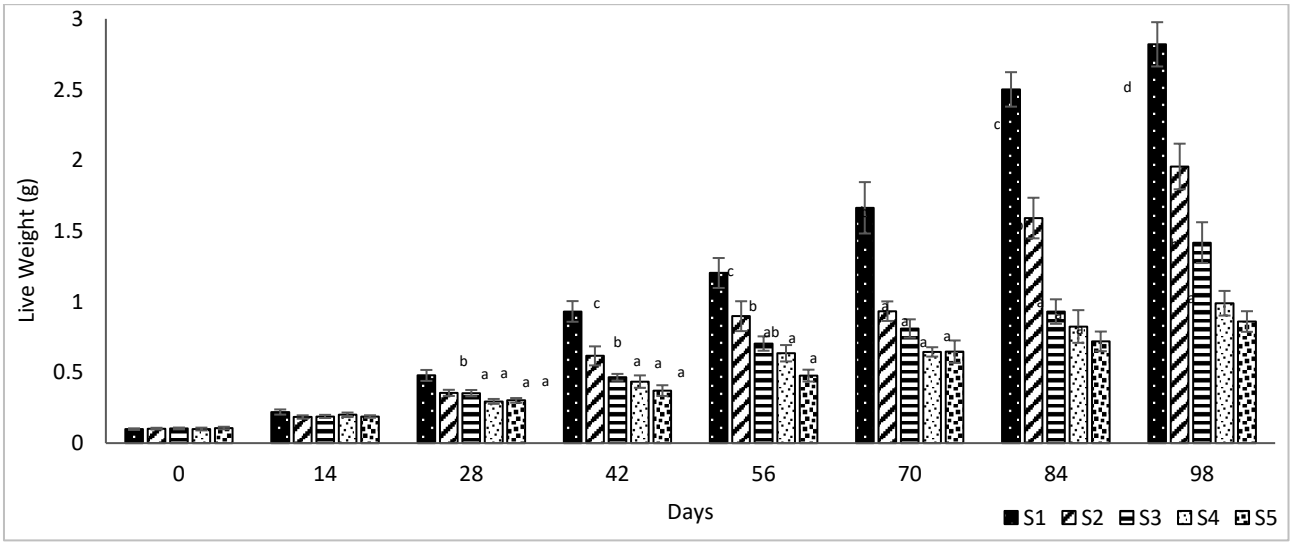

Figure 2. Live weights of *C. umbla* fry raised at different stocking densities for 98 days.

(Table 2). There is no significant difference in mortality rates (P>0.05). Kwiatkowski et al. (2008) aimed in their study to limit the negative impact of commercial feed on growing parameters with a very long transition period. Mixed diets have been tested in several cyprinid species and, although they have been found to perform better than those with solely dry feed diet, they are never reported to be as effective as a live food diet, especially in terms of growth rates (Wolnicki and Gorny, 1995; Kaiser et al., 2003; Mamcarz et al., 2011; Demeny et al., 2012). As an exception, it has been reported that the mixed diet gives better results in terms of growth parameters in some *Leuciscus* sp. larvae than the control group *Artemia* (Kwiatkowski et al., 2008). Kujawa et al. (2010) indicate that supplementing with dry diets, which was done as early as in the first week of larval exogenous feeding, has a positive influence on the fish.

Although it is possible to increase the growth rates of larvae with mixed diets (L3, L4, L6 and L7), these groups are still below the live food diet in terms of growth (Table 3). However, positive effects of the mixed diet are reported in some cyprinid species (Kaiser et al., 2003; Kwiatkowski et al., 2008). In the present study, the best results in terms of growth parameters among the mixed diets were obtained in the mixed feed trial groups (L4 and L7) where the live food diet period was kept the longest (*Artemia* nauplii for 10 days + dry feed for 11 days) (P<0.05). It is assumed that the best possible diet would be a 5-15 day live food period followed by a gradual transition to dry feed (Demeny et al., 2012).

Unfavorable stocking density can lead to dominant behavior that impairs nutrition, leading to stress, heterogeneous stocks and low productivity in fish larval culture (Santana et al., 2020). Sahoo et al. (2004) report that optimal use of the rearing environment can optimize larval production in the hatchery. Stocking density is an important factor affecting growth, nutrient supply, environmental conditions and genetic character. It was observed that stocking density had a significant negative effect on growth parameters and FCR in Tigris scraper fry (P<0.05) (Table 3). As the stocking density increased, growth rates decreased and FCR values increased. The highest SGR (3.419%) and lowest FCR (4.55) were obtained at minimum stocking density, while the lowest SGR (2.127%) and highest FCR (8.56) were recorded at maximum stocking density (P<0.05). It seems that the lowest stocking density (1 individual·L^{-1}) is optimal in terms of growth parameters. Stocking density studies conducted on larvae and fry of different fish species also show that low stocking density has positive effects on growth (El-Sayed, 2002; Kupren et al., 2011; Zarski et al., 2011; Arifin et al., 2019; Usandi et al. 2019).

It appears that stocking density does not have a significant effect on the survival rate of Tigris scraper fry. According to stocking studies conducted with different species, fish density does not affect survival rate (Kupren et al., 2011; Zarski et al., 2011; Niazie et al., 2013; Arifin et al., 2019). However, stocking density may have a limited effect on larval survival rates (El-Sayed, 2002). Zarski et al. (2011) obtained the highest survival rates at the lowest stocking density and reported that the differences in survival rates (88-91%) were insignificant. The highest survival rates in Tigris scraper fry occurred in medium density groups, and the differences among the rates were found to be not significant (P>0.05).

In the present study, there were differences between the groups in terms of condition factors (P<0.05). Niazie et al. (2013) reported that increasing stocking density in goldfish fry caused significant differences in growth parameters and FCR, but no differences occurred in the condition factor. This shows that the condition factor may vary depending on the species under the influence of stocking density.

The negative correlation between growth and stocking density in larvae and fry is reported in many studies, and especially the negative effect of stocking density on growth has been revealed in many studies. This effect may be influenced by water quality changes due to high stocking density, as well as social interactions and cannibalism (Alvarez-Gonzalez et al., 2001; Zarski et al., 2008; Zarski et al., 2011). Cannibalism was not observed in Tigris scraper fry throughout the study, while it has been reported at the larval and fry stages in some fish species (Baras et al., 2003).

Kupren et al. (2011) stated that although high stocking density has negative effects on the growth rates of rheophilic cyprinid larvae, it does not have a significant effect on the survival rate, therefore high-density aquaculture may be suitable for the production of these rheophilic species. Since high stocking densities do not have a negative effect on the survival rate of Tigris scraper fry, a large number of fry can be stocked when necessary. Zarski et al. (2011) point out that a significantly larger biomass is obtained with a high stocking density. Although increasing stocking density has negative effects on growth in Tigris scraper, it is possible to grow and stock more fry per unit area or volume. Final biomass data confirms this situation (Table 3).

Conclusion

C. umbla larvae can easily adapt to dry feed. In this way, larval rearing operations become easier and more economical. Besides this, the survivals of larvae fed with micro feed can remain at optimal rates. Although their growth is slower compared to larvae fed live food, future researches such as the preparation of species-specific feed rations and the production of culture breeds with high feed utilization can eliminate this disadvantage. Apart from these, studies on digestive enzymes are also needed.

The results of stocking density can be evaluated from two different perspectives. Better growth at low stocking density allows individuals to be released into the wild at larger sizes at an earlier time for stock

enhancement. On the other hand, although stocking fry at high densities seems to be disadvantageous in terms of growth, it provides the opportunity to stock and raise a larger number of fry per unit area or volume which ensures maximum final biomass. Therefore, it would be better to determine the ideal stocking density for Tigris scraper fry according to the needs in line with the raising purposes. Stocking density studies in larger volume tanks should be attempted in the future studies.

Ethical Statement

This research was carried out in accordance with the permission of Elazığ Veterinary Control Institute Animal Experiments Local Ethics Committee numbered 2017/04-07 and the ethical values determined for animal experiments.

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Author Contribution

Abdulselam GÜN: Conceptualization, funding acquisition, project administration, methodology, formal analysis, visualization, investigation, writing-review & editing. Volkan KIZAK: Conceptualization, supervision, formal analysis, investigation, writing-original draft, writing-review & editing. Fatih GÜNDÜZ: Formal analysis, investigation, writing-review & editing.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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